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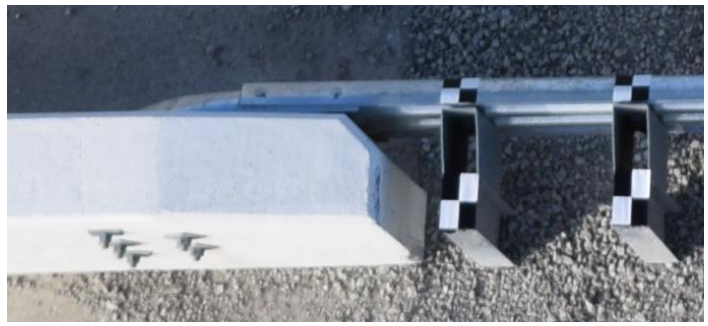
DEVELOPMENT OF A STANDARDIZED BUTTRESS FOR APPROACH GUARDRAIL TRANSITIONS

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Approach guardrail transitions (AGTs) incorporate increased post and rail sizes, reduced post spacings, specialized buttress end geometries, and other roadway features to smoothly transition from deformable W-beam guardrail to rigid barriers. This transition in barrier lateral stiffness requires specific combinations of these components to function properly. Changing components, or even the addition or removal of a curb below the rail, can negatively affect the safety performance of an otherwise crashworthy system. However, recent full-scale crash testing has indicated that a properly-designed buttress at the downstream end of an AGT may be utilized with multiple thrie-beam AGT systems. Thus, the objective of this project was to develop a standardized buttress to reduce vehicle snag and be compatible with a wide variety of previously-developed, 31-in. tall, thrie-beam AGT systems, either with or without a curb.
The standardized buttress was designed with a dual taper on its front upstream edge. A shallower lower taper was designed to mitigate tire snag below the rail, while a steeper upper taper was designed to prevent vehicle snag and limit the unsupported span length of the guardrail. This buttress design was evaluated in combination with a critical AGT (i.e., an AGT with lower stiffness than other crashworthy AGTs) without a curb, representing a worst-case scenario. The standardized buttress was successfully crash tested to the 2016 Manual for Assessing Safety Hardware (MASH) Test Level 3 (TL-3) safety criteria. Guidance was provided for both the attachment of the buttress to various crashworthy thrie-beam AGTs as well as how to transition the shape of the buttress to adjacent bridge rails or rigid parapets downstream from the AGT.</td></tr>
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UNCERTAINTY OF MEASUREMENT STATEMENT

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

INDEPENDENT APPROVING AUTHORITY

The Independent Approving Authority (IAA) for the data contained herein was Mr. Robert Bielenberg, Research Engineer.

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

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

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1 INTRODUCTION

1.1 Background

Approach guardrail transitions (AGTs) are utilized to attach deformable W-beam guardrail to various rigid barriers, including bridge rails and reinforced concrete parapets. To smoothly transition between barriers with different stiffness and prevent vehicle snag, AGTs typically incorporate thicker and/or nested guardrail segments, larger guardrail sections (i.e., thrie beam), increased post sizes, increased post embedment depths, and decreased post spacings. Additionally, the upstream end of the rigid barriers where the guardrails are attached are often modified to include various tapers, chamfers, and/or flares to reduce vehicle snag. Curbs have also been placed below the guardrail and adjacent to the rigid barrier to further reduce the likelihood of tire snag. AGTs require a specific combination of these components and roadside features in order to perform safely.

Over the last several decades, multiple AGTs have been developed to satisfy the safety performance criteria of the National Cooperative Highway Research Program (NCHRP) Report 350 [1], the American Association of State Highway and Transportation Officials (AASHTO) 2009 *Manual for Assessing Safety Hardware* (MASH) [2], or MASH 2016 [3]. However, full-scale crash testing has illustrated the sensitive nature of guardrail stiffness transitions. Changing only a single AGT component or feature can significantly alter its safety performance. For example, the addition or removal of a curb, altering the geometry of the rigid parapet, or altering the embedment depth of the transition posts can be the difference between a test failure or a successfully crash-tested AGT [4-12]. Due to the sensitivity of stiffness transitions, AGT components and features (e.g., curb usage and rigid barrier geometry) are not necessarily interchangeable between AGT systems.

The majority of failures observed during crash testing have been the result of excessive vehicle contact with the rigid parapet, especially for AGTs that did not utilize a curb beneath the guardrail. These tests indicated that the geometry of the rigid parapet was more critical than previously believed. Thus, the development of a concrete parapet end geometry was desired to minimize the risk of vehicle snag and to be crashworthy in combination with various thrie-beam AGTs.

1.2 Objective

The objective of this research project was to develop and evaluate a standardized buttress geometry for use with thrie-beam AGTs. The transition buttress was desired to be compatible with all of the previously-developed, thrie-beam AGT systems that were successfully crash tested to the Test Level 3 (TL-3) safety performance criteria of either MASH or NCHRP Report 350. Additionally, the buttress needed to safely transition from stiffened thrie beam to a variety of concrete parapets and bridge rail shapes. Finally, AGTs incorporating the standardized buttress needed to be crashworthy in both curbed and non-curbed configurations.

1.3 Research Plan

Development of the standardized concrete parapet end section began with a review of existing thrie-beam transitions to concrete parapets that were tested to either NCHRP Report 350 or MASH standards. Potential buttress geometries were reviewed, and a critical transition design was identified for use in the evaluation of the buttress. The new buttress geometry was based on the observed performance of the previous AGT crash test results and additional design and analysis. The proposed parapet configuration was then full-scale crash tested with a selected critical AGT that provided the greatest risk of vehicle snag. Testing was conducted in accordance with MASH 2016 TL-3 safety performance criteria.

2 BARRIER DESIGN

2.1 Preliminary Buttress Design

Development of the standardized transition buttress began with a review of previous full-scale crash testing on AGTs connected to concrete parapets. Since a limited number of AGTs had been evaluated to MASH standards, the review included both MASH and NCHRP Report 350 tested systems. Forty-two crash tests, which were conducted on 22 different transition systems, were reviewed in order to identify tendencies between the crashworthy systems and those that failed to meet the safety performance criteria [4-33]. Of these reviewed tests, eight were MASH tests and 34 were NCHRP Report 350 tests. Twenty-two tests were successful, while 20 tests failed to satisfy the safety performance criteria. The near 50 percent pass/fail rate was thought to provide valuable insight into the performance of various transition design characteristics, and knowledge gathered from this review was utilized to guide the design of the standardized buttress.

During the literature review, it was noted that nearly all AGTs were designed with the thrie-beam end connector mounted vertically to the face of the concrete parapet. If the parapet had a sloped face (e.g., New Jersey, F-shape, or single slope barriers), a wedge shaped connection plate was typically utilized between the thrie-beam end connector and the parapet, which allowed the rail to remain vertical as opposed to being twisted to match the slope of the parapet. At the time of time R&D for the buttress, only two tests had been conducted on thrie-beam AGTs with the rail twisted to match the sloped face of the parapet, and both of those NCHRP Report 350 tests resulted in vehicle rollovers [6, 17]. Thus, it was desired to keep the rail element vertical throughout the AGT. To keep the AGT design simple and avoid the additional components and costs associated with requiring a connection plate, the standardized buttress was designed with a vertical front face geometry. The vertical shape could then be transitioned into different parapet shapes downstream from the rail end connector.

Multiple AGTs had been designed with a rub rail placed below the rail to mitigate tire snag. However, six out of the nine tests conducted on AGTs incorporating rub rails were failures, and five of those failed tests involved vehicle rollovers [21-28]. These results indicate that tire interactions with rub rails may lead to vehicle instabilities during redirection. Therefore, a rub rail was not incorporated into the design of the standardized buttress.

Without a rub rail, the front upstream corner of the buttress needed to be tapered back to reduce snag on the buttress. Previous crash testing has shown that tapering the front corner 4 to 5 in. backward was sufficient to limit snag and often resulted in crashworthy designs [12-14]. Therefore, the lateral extent of the taper on the front corner of the standardized buttress was desired to be a minimum of 4 in.

The slope of the taper and the associated longitudinal extent of the taper affect the performance of the standardized buttress in opposing ways. A shallow slope over a long distance was desired to minimize vehicle and tire snag on the buttress. However, increasing the longitudinal length of the taper also increases the unsupported length of the thrie beam between the buttress and the adjacent transition post. Increasing the unsupported length of the rail would result in a reduction in stiffness, an increase in deflection, and increased potential for both pocketing and vehicle snag. Thus, a steeper taper over a shorter longitudinal distance was desired to maintain rail stiffness and prevent excessive barrier deflections.

To balance these two effects, a dual taper design was selected, as shown in Figure 1. The lower portion of the buttress below the thrie beam utilized a shallow taper to minimize tire snag, while the upper portion of the buttress behind the rail utilized a steep taper to limit the unsupported span length of the rail while still reducing vehicle snag. Previous MASH crash testing has demonstrated that a slope rate of 3:1 can prevent tire snag during vehicle impacts into AGTs [33]. Thus, the preliminary buttress design incorporated a lower taper with a 3:1 slope, resulting in a 12-in. long by 4-in. deep taper. The height of the lower taper on the preliminary design was 11 in. and extended to the bottom of the thrie beam. The upper taper on the preliminary design had a 1:1 slope, resulting in a 4-in. by 4-in. taper behind the rail.

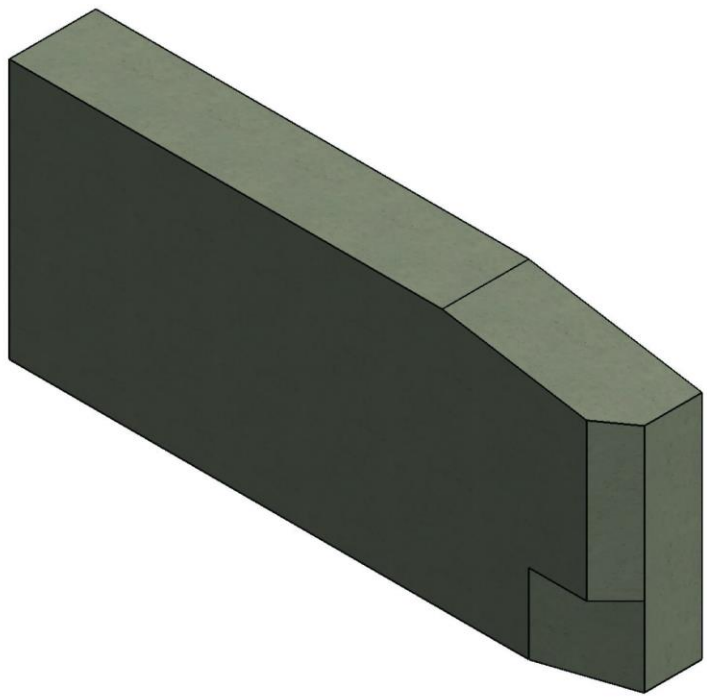


Figure 1. General Shape of Standardized Buttress Incorporating Dual Tapered Front Edge

To prevent vehicle snag on the buttress above the thrie beam, the upstream face of the standardized buttress was set at 32 in. tall, which would be 1 in. above the top of a 31-in. tall thrie beam. However, many concrete barriers and bridge rails are installed with a taller height to contain heavy trucks. For example, rigid barriers are typically designed with a minimum height of 36 in. to contain the 10000S single unit truck and satisfy MASH 2016 TL-4 criteria. Thus, a height transition was necessary to match the height of adjacent TL-4 and TL-5 bridge rails. Previous research and crash testing indicated that vertical slopes as steep as 5:1 may be crashworthy [34]. Being slightly conservative, the standardized buttress was designed with a 6:1 vertical slope beginning at the upstream end of the buttress. The system was tested with a buttress height of 36 in., so the 6:1 vertical slope was used to transition the 32-in. tall front face to the 36-in. nominal height over the first 2 ft of barrier length.

To be compatible with adjacent TL-4 bridge rails and concrete parapets, the capacity of the buttress was designed to withstand a TL-4 impact load of 80 kips [35]. The standardized buttress was tested with a 7-ft length to limit the length of the AGT system while still providing sufficient barrier length to resist impact loads. However, actual installation lengths may vary depending on strength requirements and the length required to safely transition to various bridge rail or rigid barrier shapes (see Chapter 9 for details). The selected test configuration was 12 in. wide and was reinforced with no. 4 longitudinal rebar placed along both the front and back faces of the buttress and no. 4 vertical rebar stirrups. Complete details for the preliminary buttress design are shown in Section 2.3.

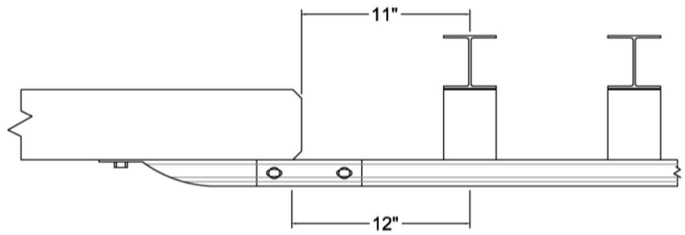
2.2 Selection of Critical Transition Configuration

The standardized buttress needed to be compatible with a wide variety of thrie-beam AGT systems, both with and without a curb. Therefore, the buttress had to be connected to a critical AGT creating a worst case scenario in order to properly evaluate the system and allow for other AGTs to be used without further crash testing. A review of existing AGTs successfully tested to TL-3 of MASH or NCHRP Report 350 was conducted to find the thrie-beam AGT with the lowest lateral stiffness (i.e., the most flexible system). This critical AGT would pose the greatest risk of vehicle snag on the rigid buttress. The system with the highest dynamic deflection was an AGT originally developed for the Iowa Department of Transportation (DOT) [4-5, 7]. This transition utilized the smallest transition posts (in terms of cross-section strength) and the shortest embedment depths of the reviewed systems. Thus, the Iowa AGT was identified as the critical AGT of those reviewed.

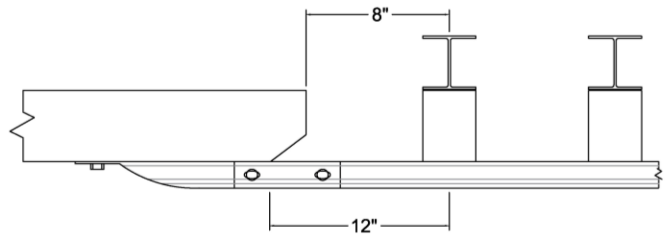
Further, the Iowa AGT was successfully tested to both MASH and NCHRP Report 350 TL-3 criteria when used in combination with a 4-in., triangular curb. However, similar AGTs evaluated without a curb failed to satisfy TL-3 criteria in either testing standard [6, 8]. These crash test results not only reinforced the notion that this system was susceptible to vehicle snag, but also indicated that testing without a curb was more critical as the vehicle tires could extend under the rail and snag on the buttress. Therefore, the AGT originally developed for the Iowa DOT, but without a curb, was selected as the critical AGT configuration for the evaluation of the standardized buttress.

To prevent altering the stiffness of the selected AGT, the rail segments and posts needed to be properly positioned relative to the buttress. The original AGT design had an 11-in. offset between the upstream face of the buttress and the centerline of the first transition post. A 1-in. chamfer was present on the corners of the buttress creating a 12-in. span length in which the rail was unsupported in the lateral direction. Since the new standardized buttress incorporated a 4-in. x 4-in. chamfer on the front corner behind the rail, the centerline of the first transition post was placed 8 in. upstream from the buttress to maintain the 12-in. unsupported span length. These dimensions are shown in Figure 2.

Finally, the upstream end of the original AGT design, which was untested and connected to 27-in. tall guardrail, was altered to incorporate the MASH TL-3 crashworthy MGS stiffness transition [36-37]. Both the original Iowa AGT and the critical configuration utilized to test the standardized buttress are shown in Figure 3.

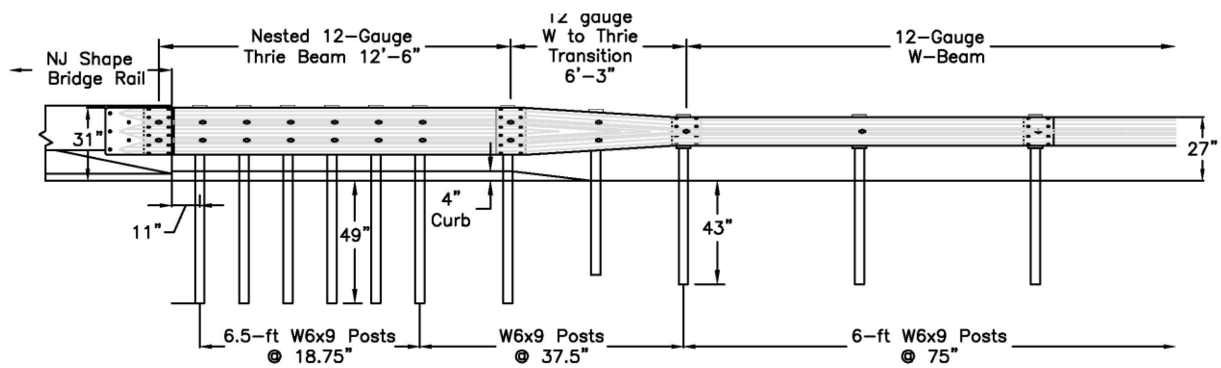


(a)



(b)

Figure 2. Buttress to Transition Offset: (a) Original As-tested AGT and (b) AGT in Combination with the Standardized Buttress



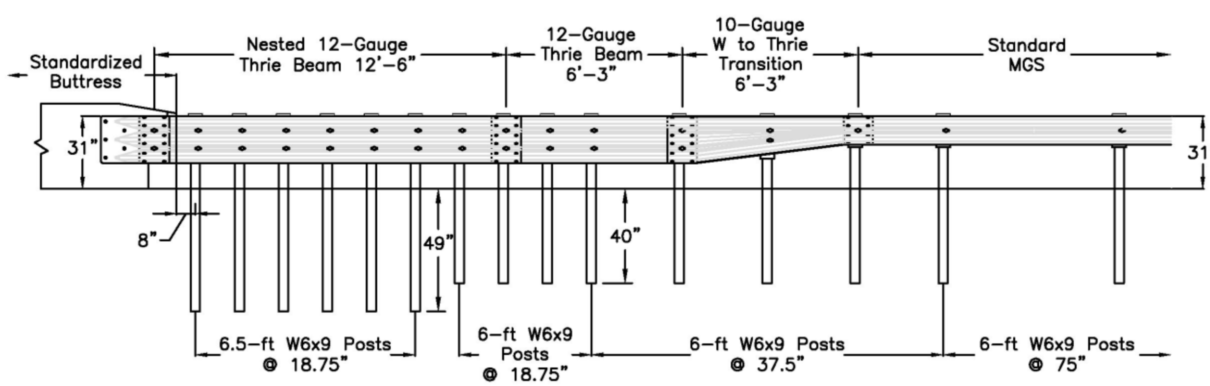


Figure 3. Selected AGT Design in its (a) Original, As-Tested Configuration and (b) Critical Configuration for Evaluating the Standardized Buttress

2.3 Preliminary Design Details, Test No. AGTB-1

The barrier system installation for test no. AGTB-1 was approximately 82 ft long and consisted of four main components: (1) a concrete transition buttress, (2) a thrie-beam AGT, (3) standard MGS, and (4) a guardrail anchorage system. Design details for test no. AGBT-1 are shown in Figures 4 through 26. To test a worse-case scenario and increase the risk of wheel snag, a curb was not installed. Photographs of the test installations are shown in Figure 27. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix A.

The downstream end of the installation consisted of the concrete buttress. The buttress was 7 ft long and 36 in. tall, corresponding to a typical height for MASH TL-4 concrete barriers. To prevent vehicle snag above the thrie beam rail, the upstream end of the buttress was 32 in. tall and incorporated a 4-in. tall by 24-in. long slope to bring the barrier height up to 36 in. The buttress utilized a dual-tapered, or dual-chamfer, design along its front edge, as detailed in Figure 17. The lower taper measured 4 in. deep by 12 in. long by 11 in. tall and was designed to reduce wheel snag on the parapet. The upper taper measured 4 in. x 4 in. and extended from the lower taper to the top of the buttress. The upper taper was designed to limit vehicle snag on the buttress, to prevent a rail from bending around a rigid corner, and to limit the unsupported span length of the rail upstream from the buttress.

The AGT and adjacent MGS consisted of 12.5 ft of nested, 12-gauge thrie beam; 6.25 ft of single-ply, 12-gauge thrie beam; a 6.25-ft long 10-gauge asymmetric W-to-thrie transition rail segment; and 50 ft of 12-gauge W-beam. All rail segments were mounted with a top height of 31 in. The first six posts adjacent to the buttress were 6.5-ft long W6x8.5 posts spaced at 18¾ in. on-center and embedded 49 in. into the soil. Note, the thrie beam rail extended above the tops of these transition posts with the use of chamfered blockouts, as shown in Figures 6 and 13. The remaining steel posts were 6-ft long W6x8.5 posts embedded 40 in. into the soil, utilized 12-in. deep wood blockouts, and were spaced at various intervals, as shown in Figures 4 through 6. All posts were placed within a compacted, crushed limestone soil which satisfied MASH soil standards.

Finally, a guardrail anchorage system typically utilized as a trailing-end terminal was utilized to anchor the upstream end of the test installation. The guardrail 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 system has been MASH TL-3 crash tested as a downstream, trailing-end terminal [38-41].

It should be noted that the thrie-beam terminal connector (part C1) obtained and used for test no. AGTB-1 had yield and tensile strengths below the minimums specified in AASHTO M-180 for beams and transition sections (50 ksi yield strength and 70 ksi tensile strength). Although the reduced strength component did not appear to negatively affect the performance of the AGT, it is recommended to use higher grade steel for all guardrail terminal connectors since they need to carry structural loads (both tensile and bending loads) in order for the system to function properly. The thrie-beam terminal connector used for test no. AGTB-2 satisfied the minimum strengths described above.

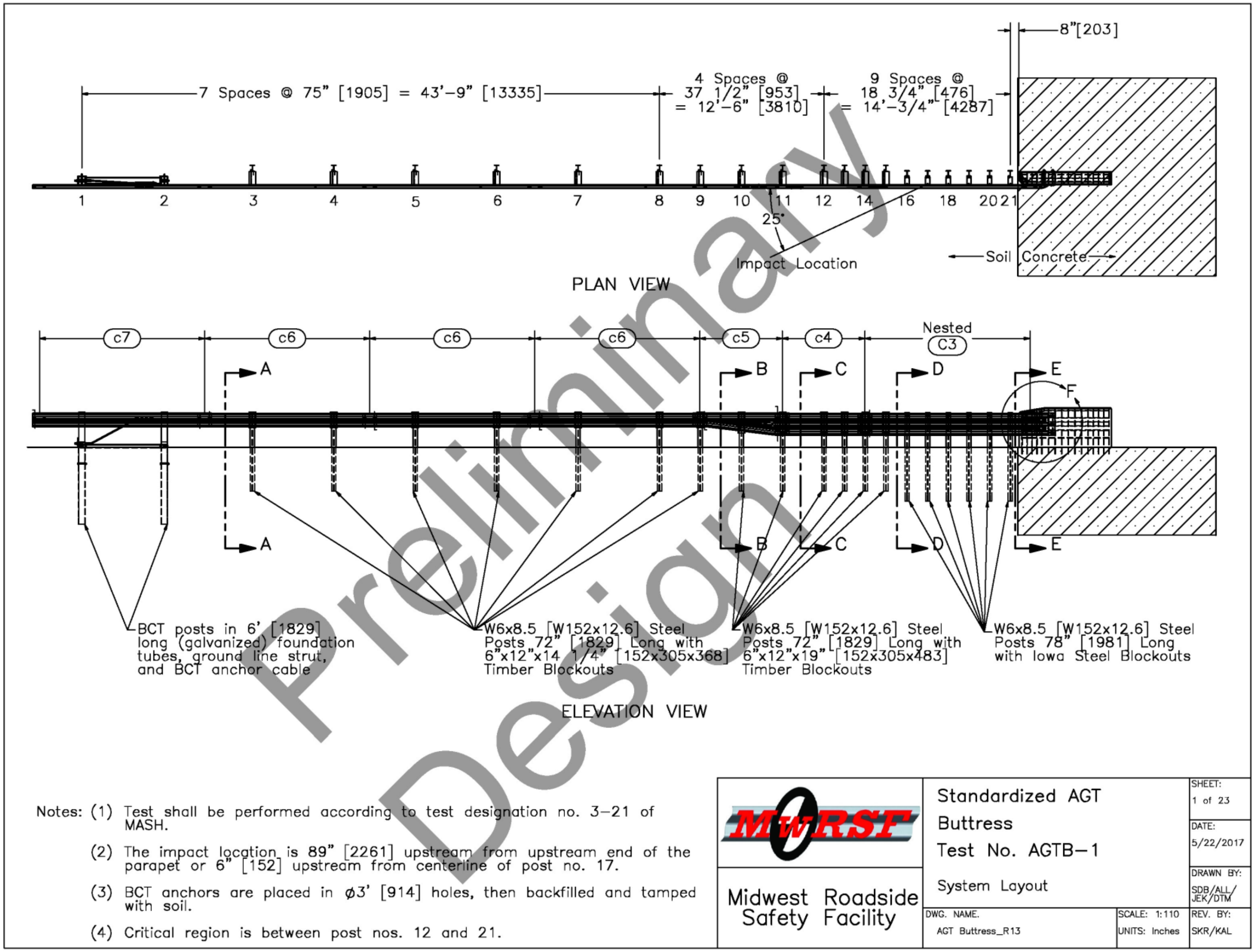


Figure 4. System Layout, Test No. AGTB-1

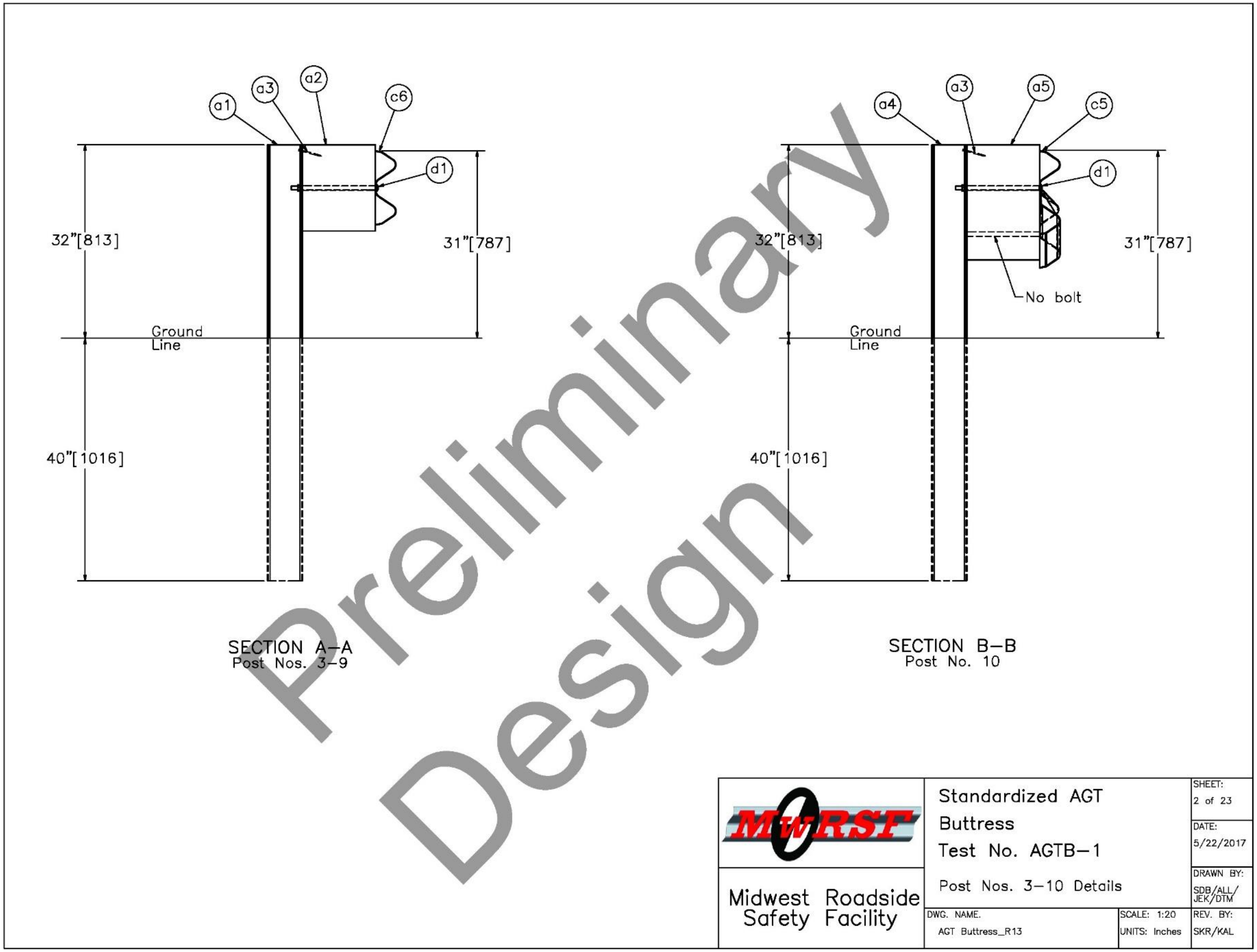


Figure 5. Post Nos. 3 through 10 Details with Rail, Test No. AGTB-1

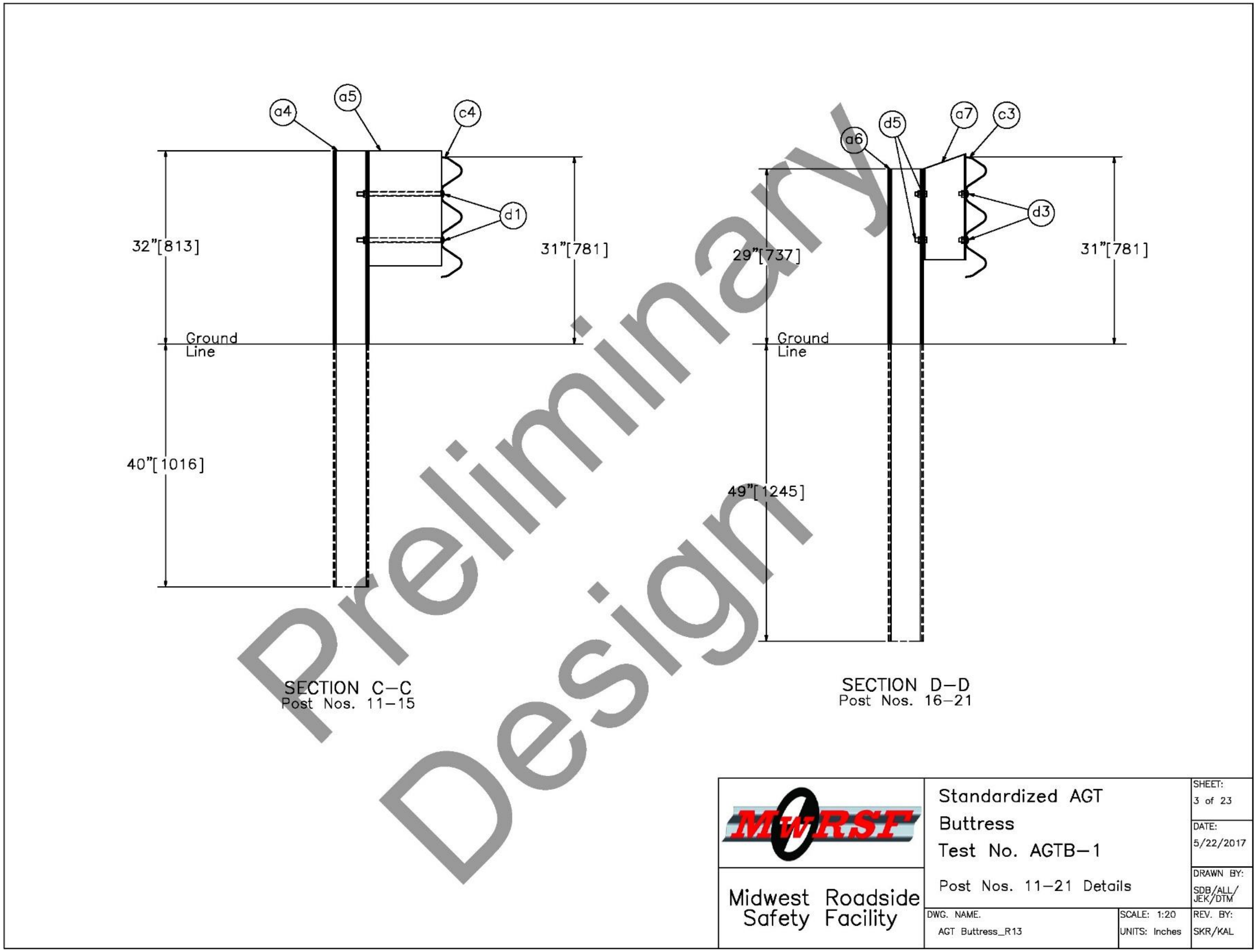


Figure 6. Post Nos. 11 through 21 Details with Rail, Test No. AGTB-1

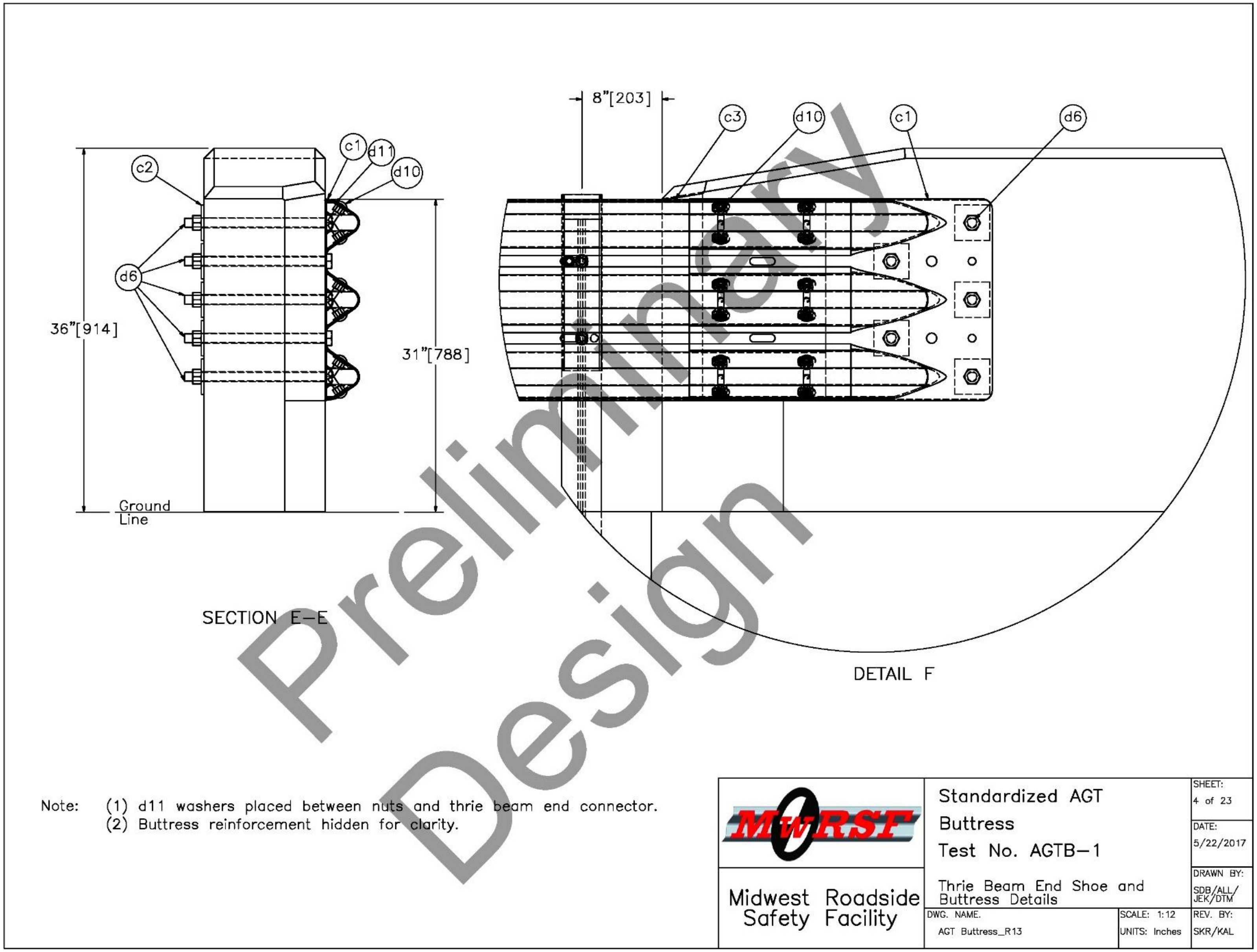


Figure 7. Thrie Beam Terminal Connector and Buttress Details, Test No. AGTB-1

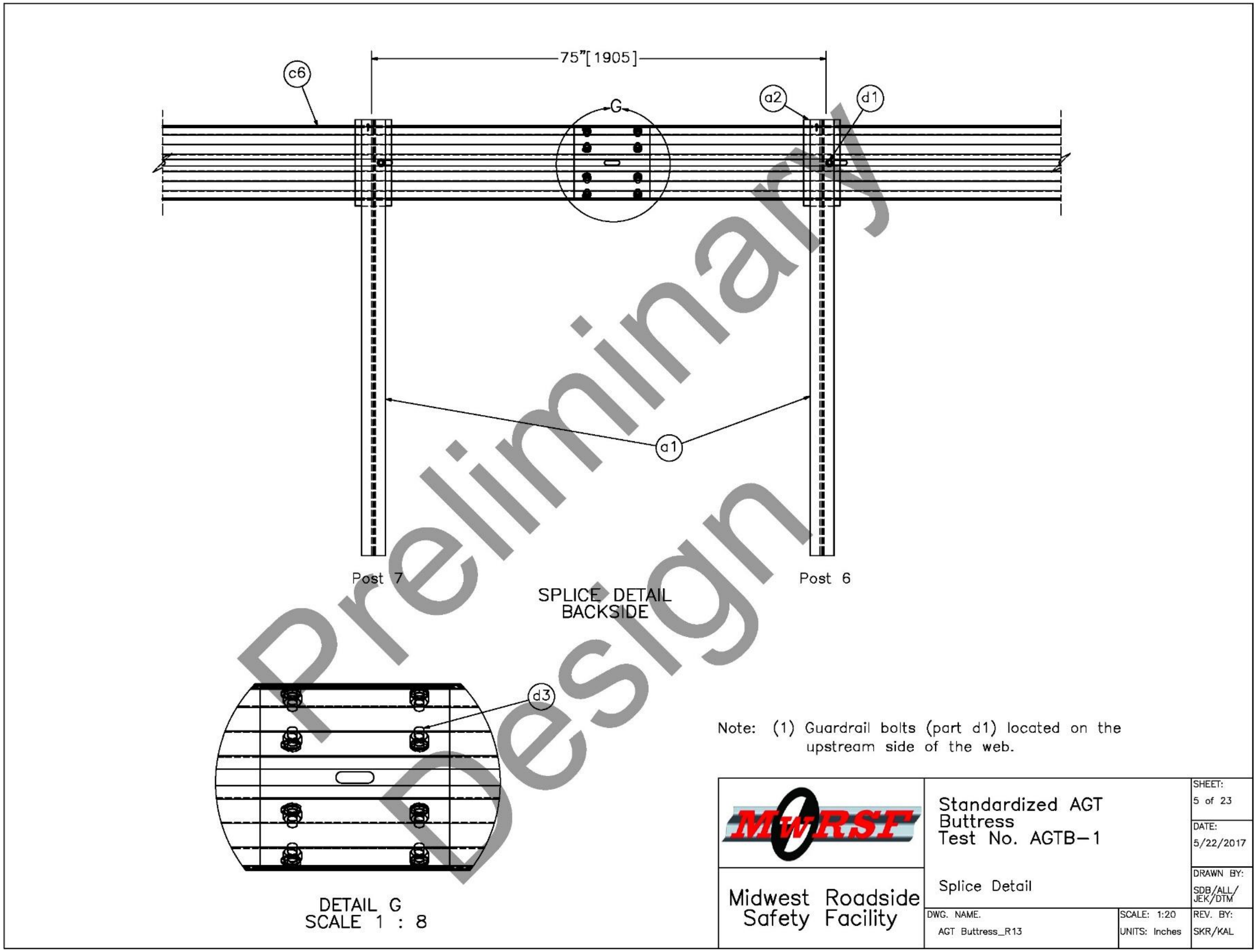


Figure 8. Splice Detail, Test No. AGTB-1

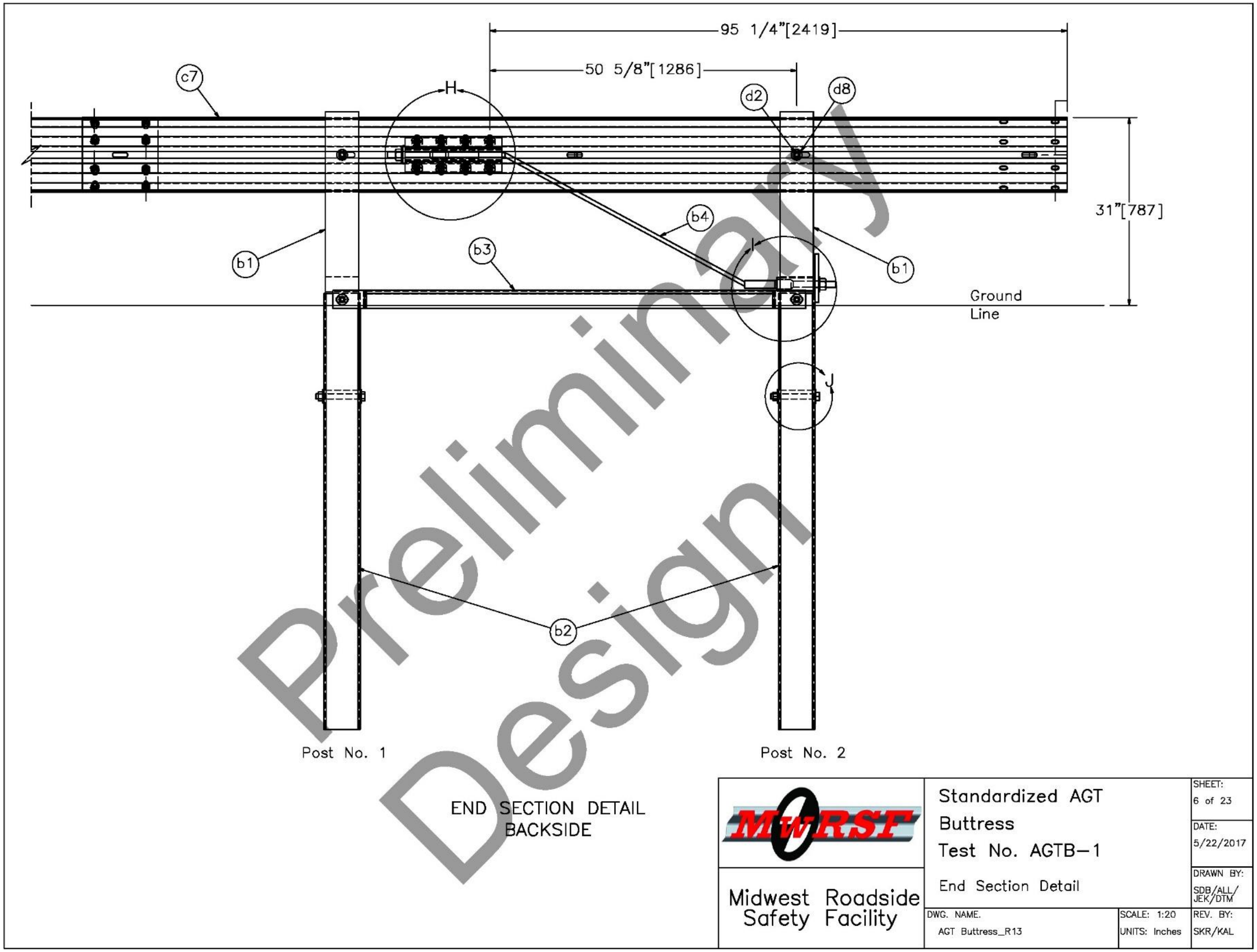


Figure 9. BCT Anchor Details, Test No. AGTB-1

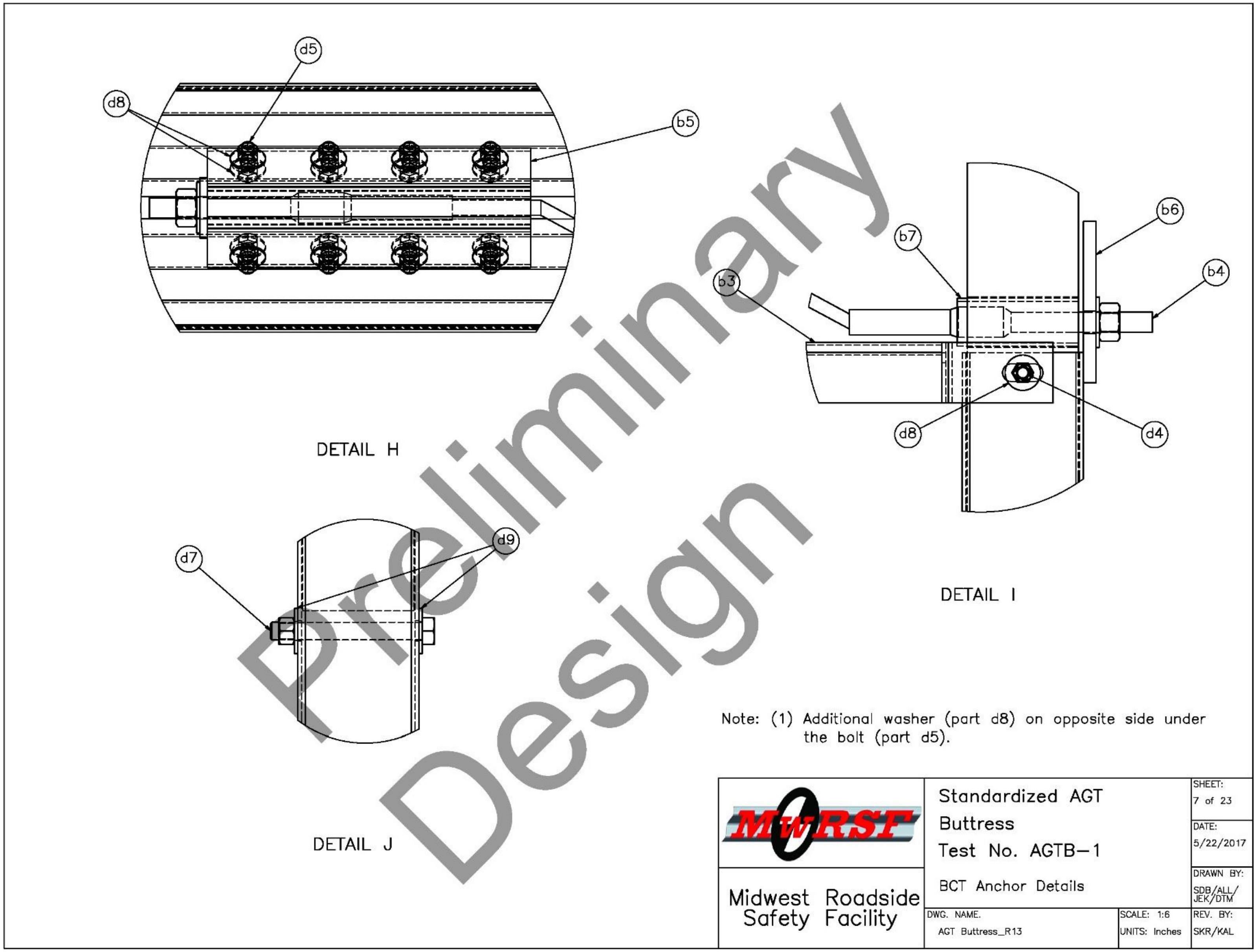


Figure 10. BCT Anchor Details, Test No. AGTB-1

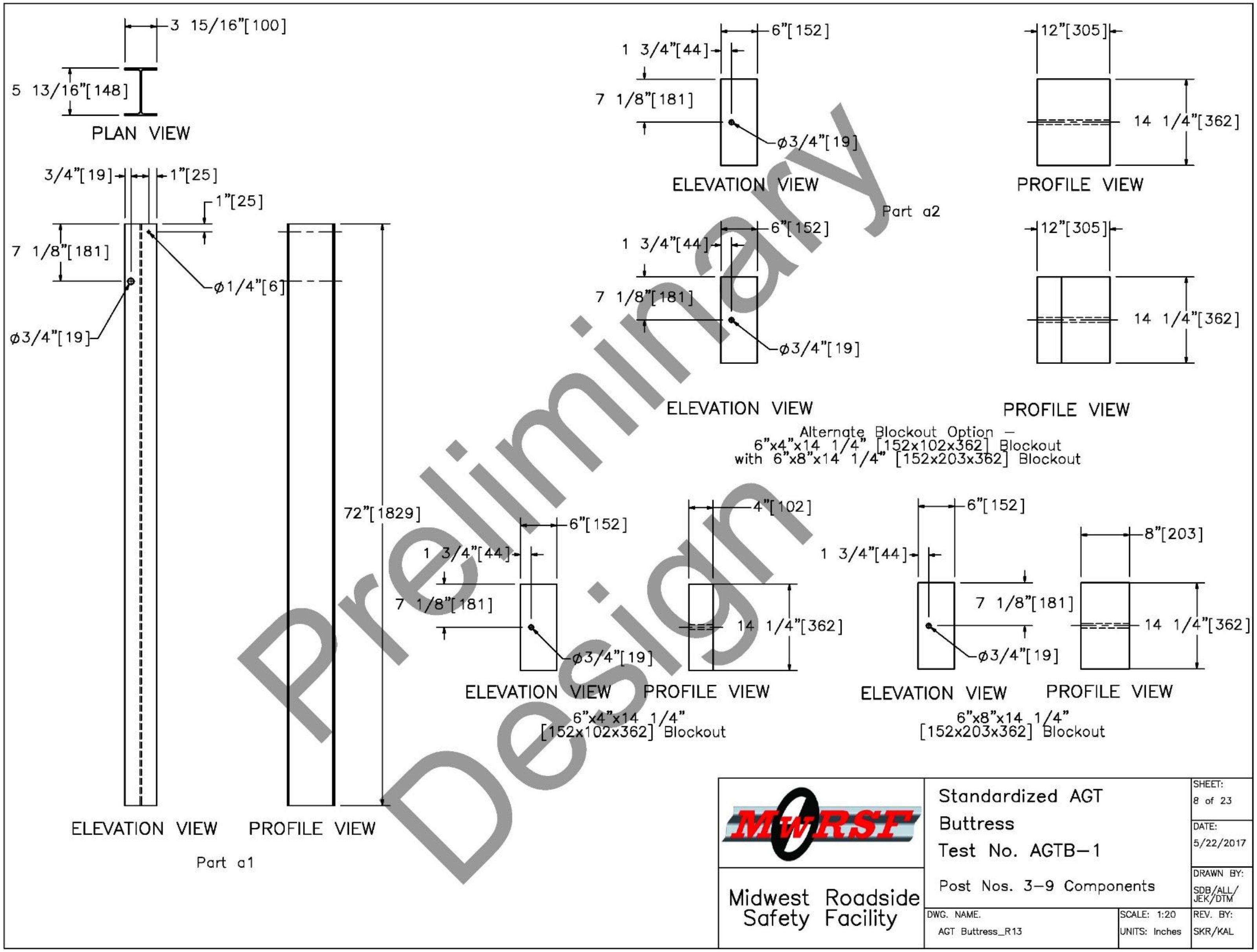


Figure 11. Post Nos. 3 through 9 Components, Test No. AGTB-1

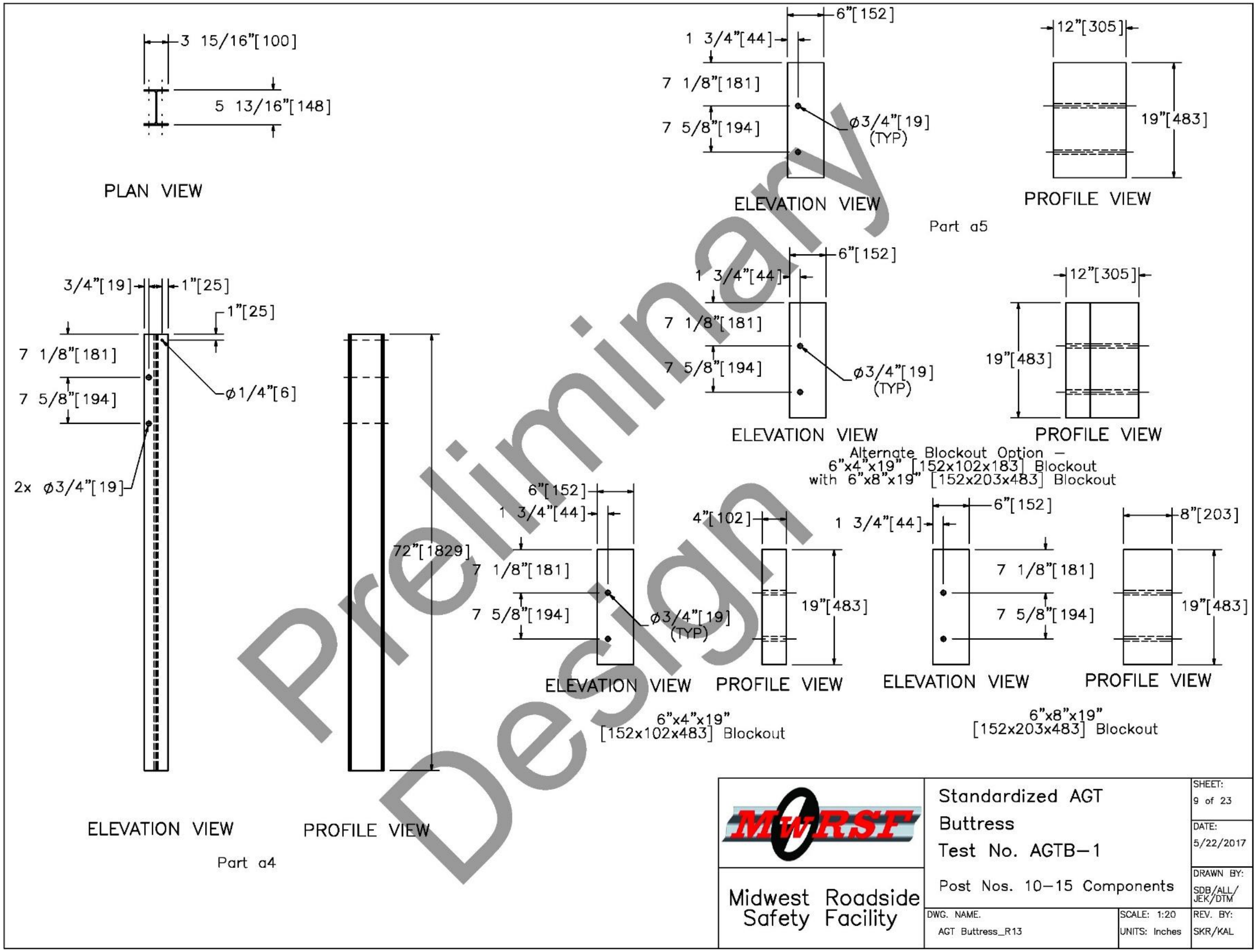


Figure 12. Post Nos. 10 through 15 Components, Test No. AGTB-1

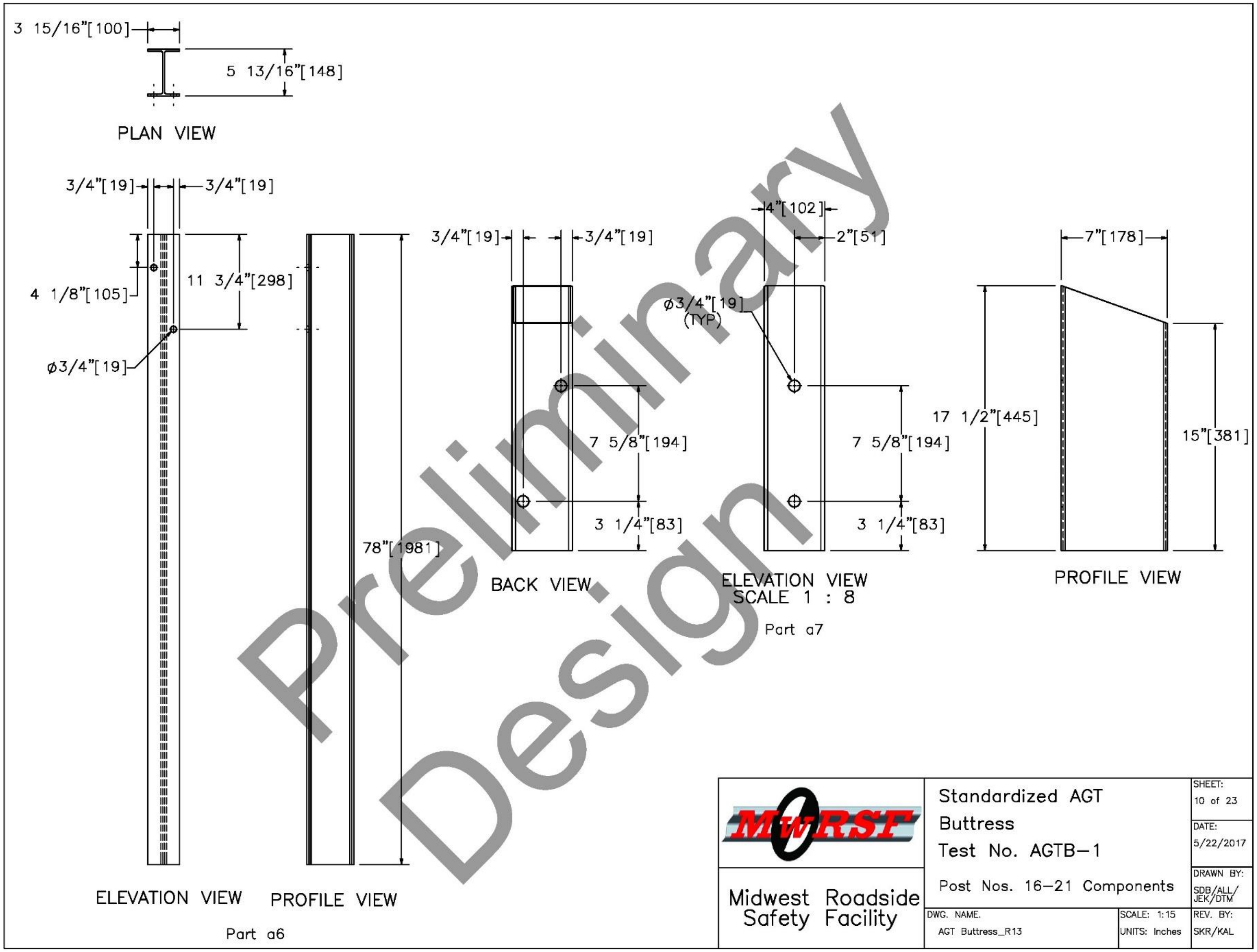


Figure 13. Post Nos. 16 through 21 Components, Test No. AGTB-1

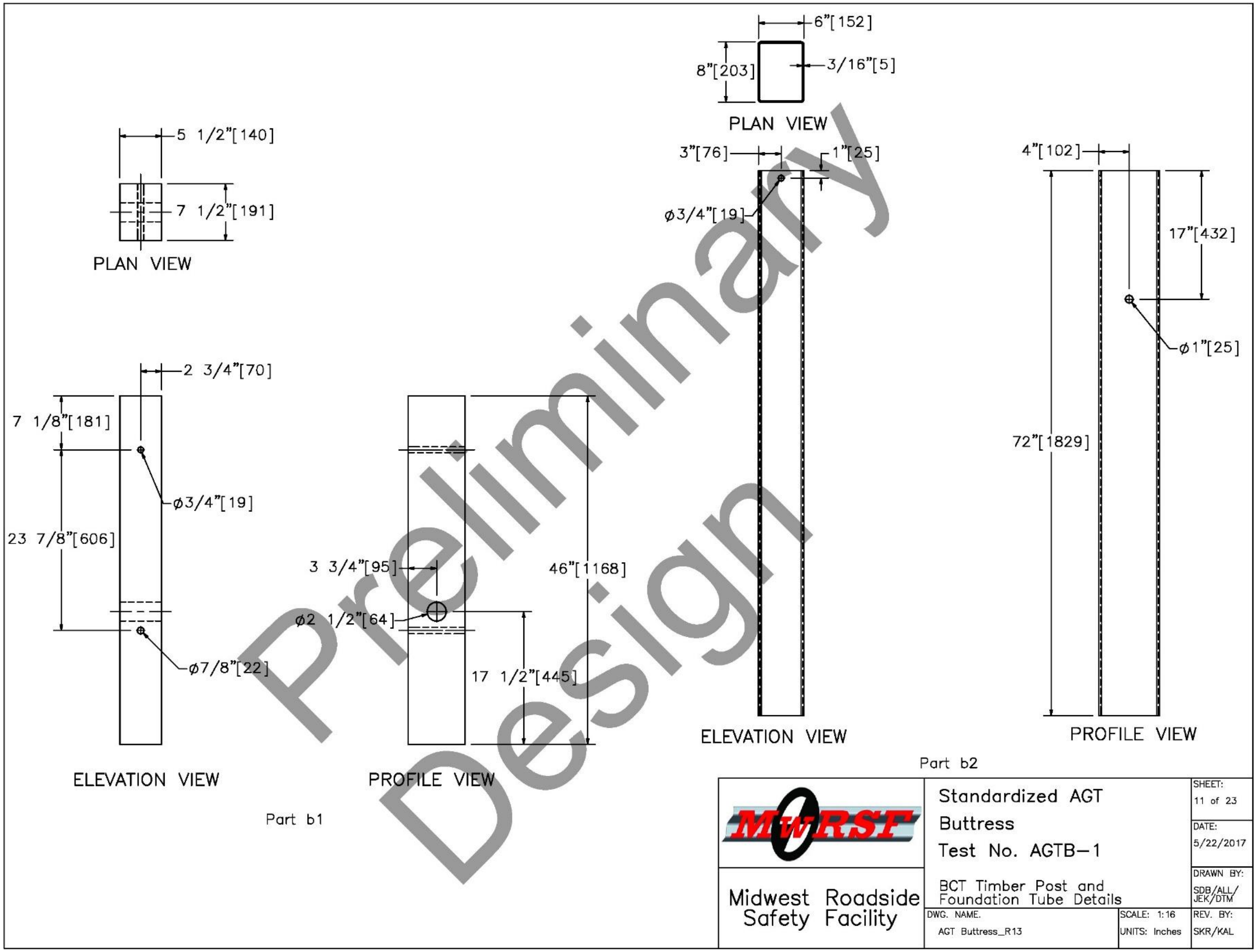


Figure 14. BCT Timber Post and Foundation Tube Details, Test No. AGTB-1

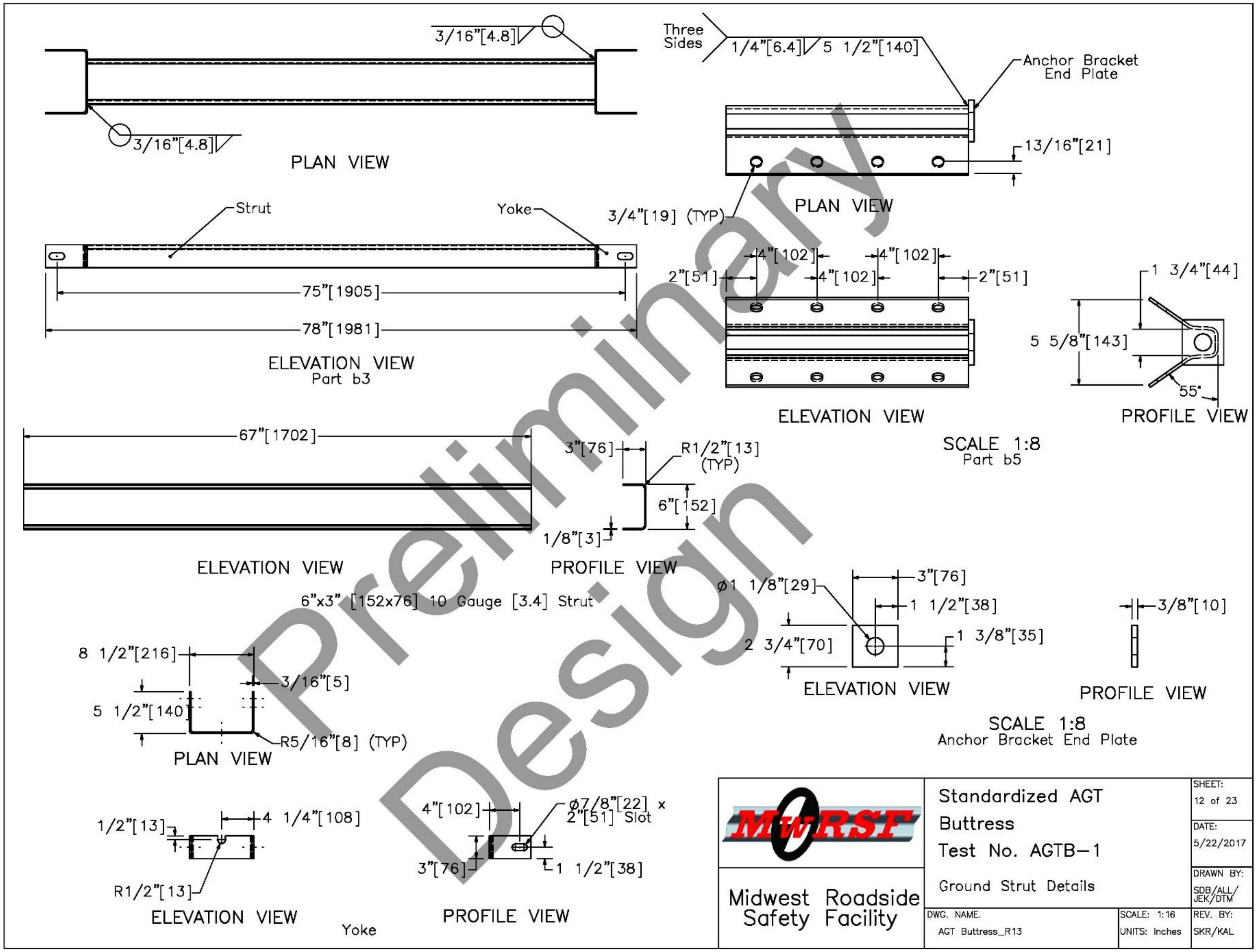


Figure 15. Ground Strut Details, Test No. AGTB-1

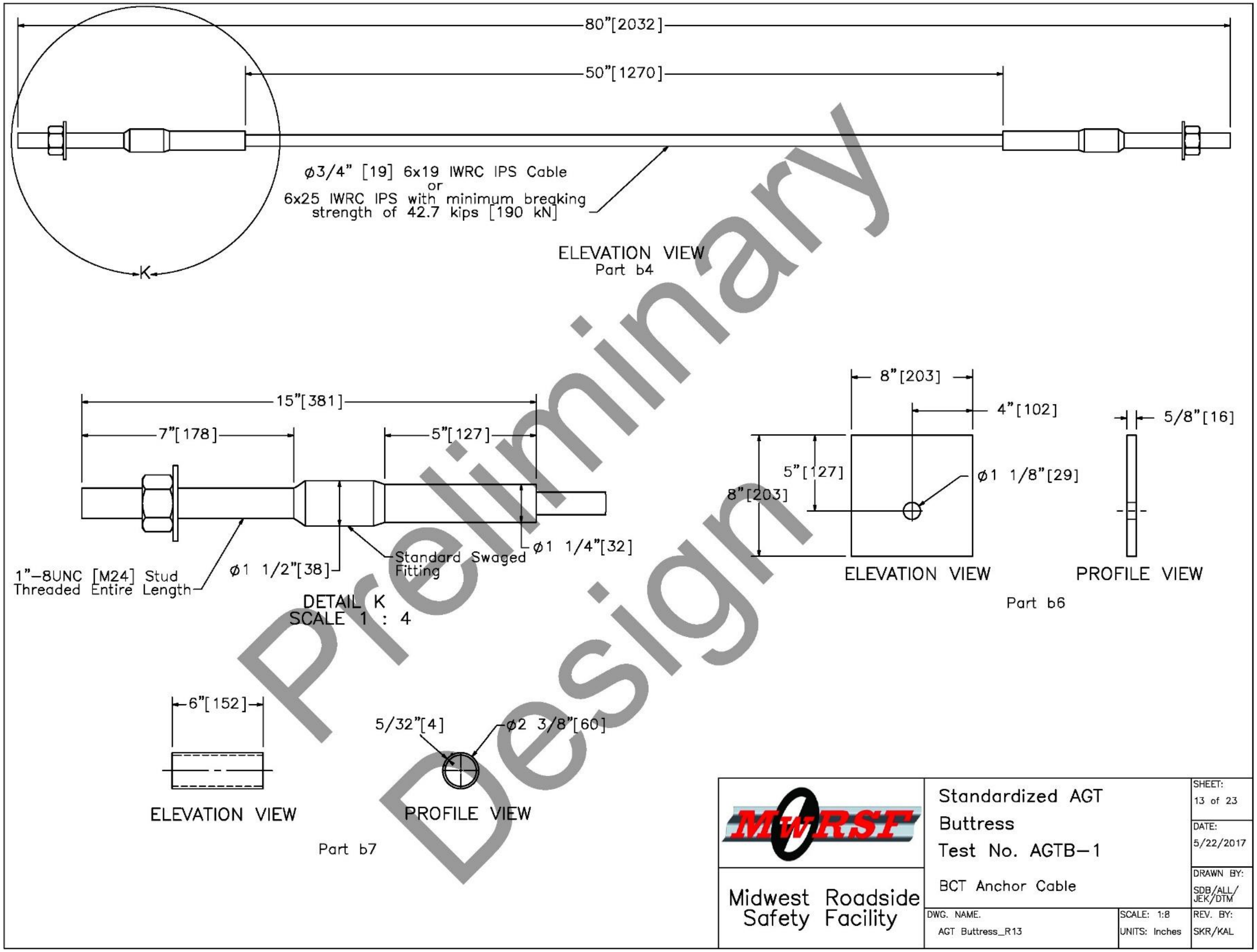


Figure 16. BCT Anchor Cable, Test No. AGTB-1

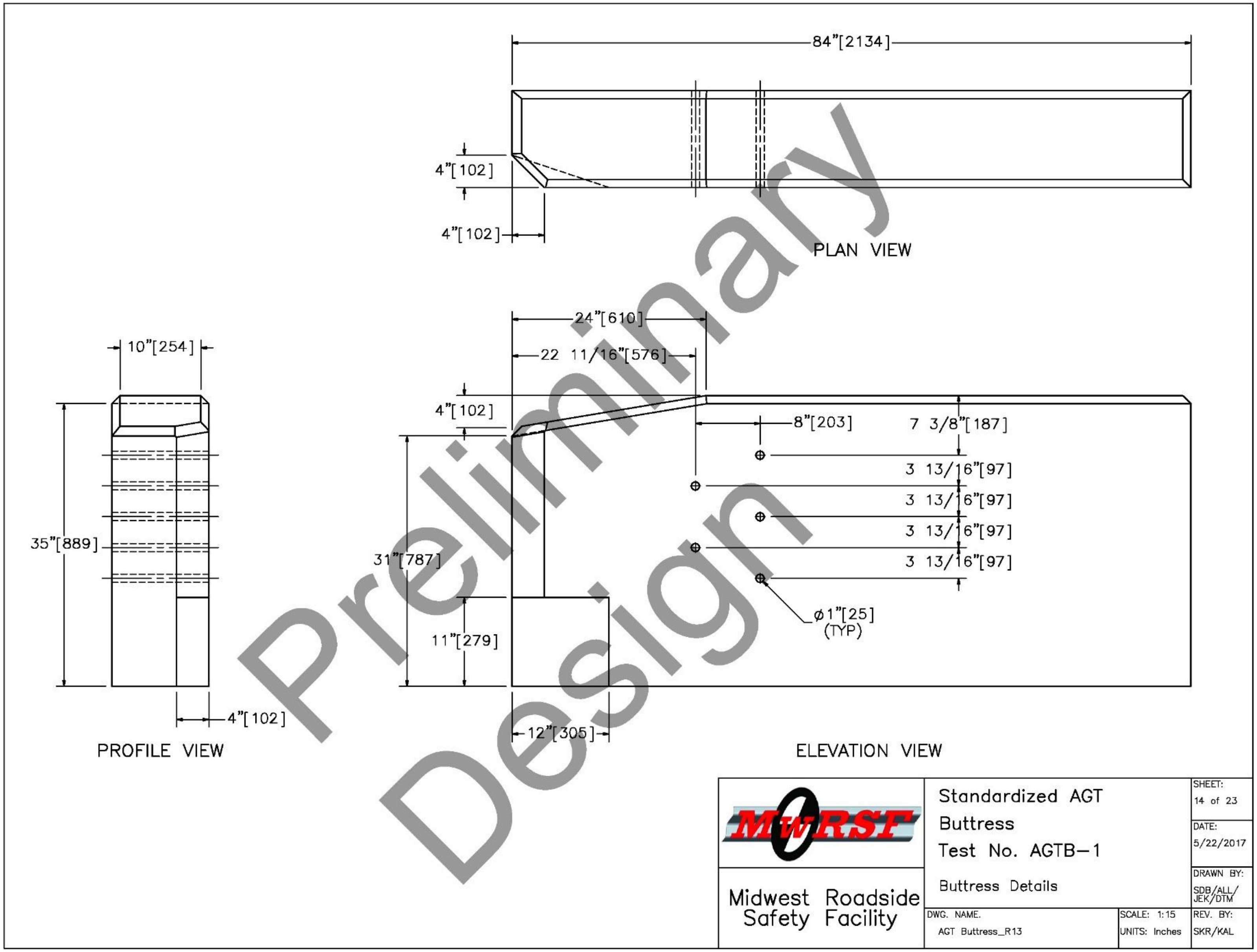


Figure 17. Buttress Details, Test No. AGTB-1

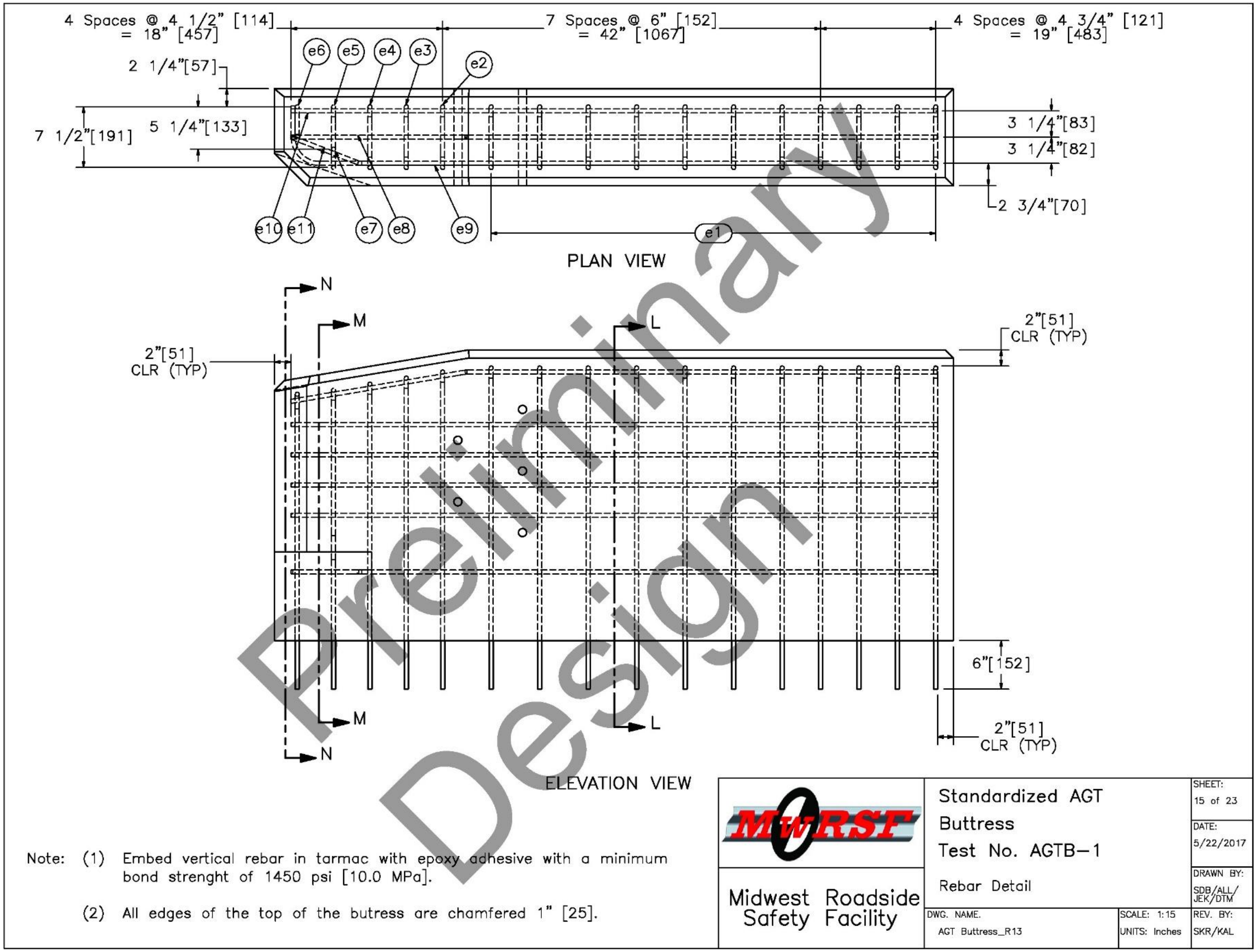


Figure 18. Buttress Rebar Details, Test No. AGTB-1

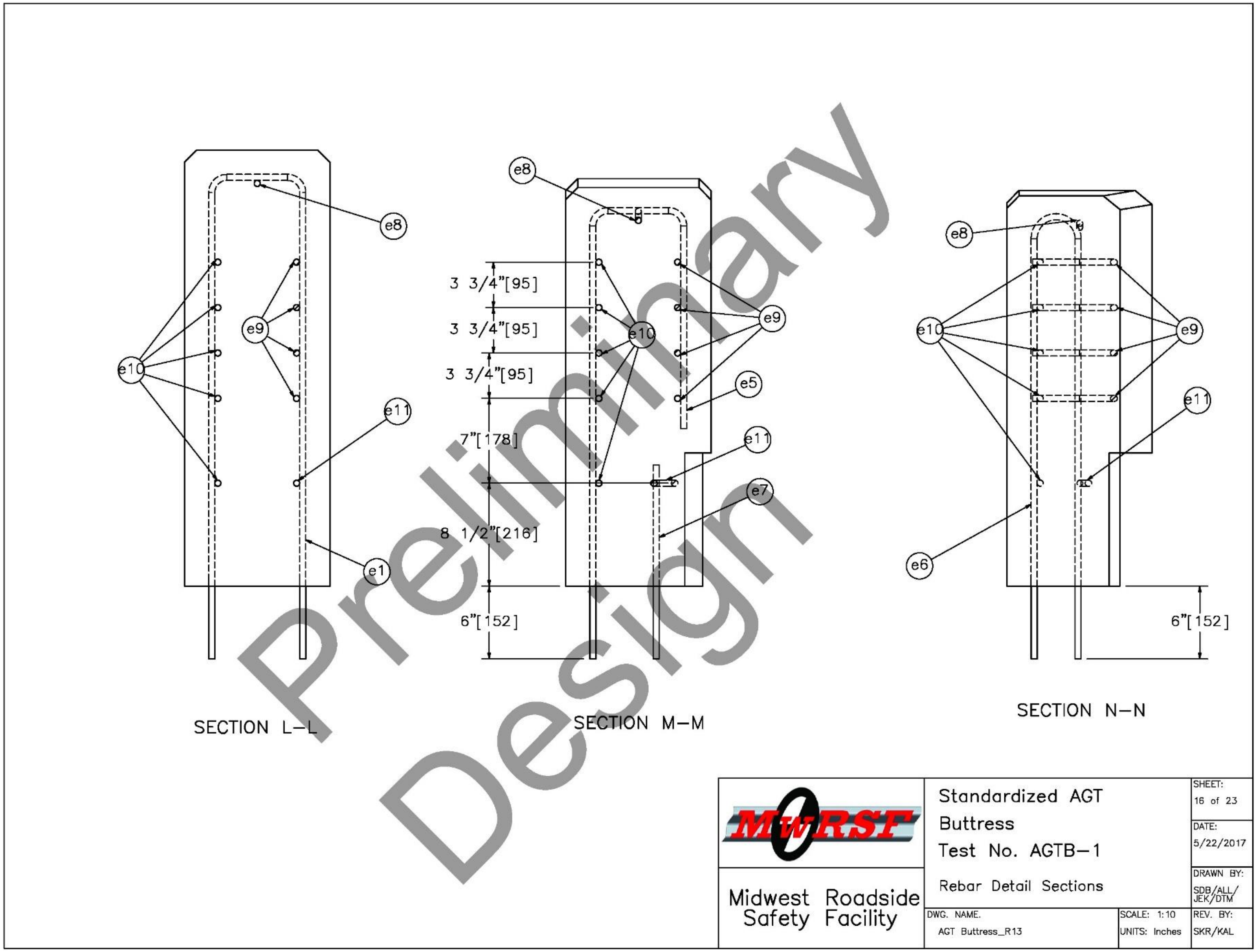
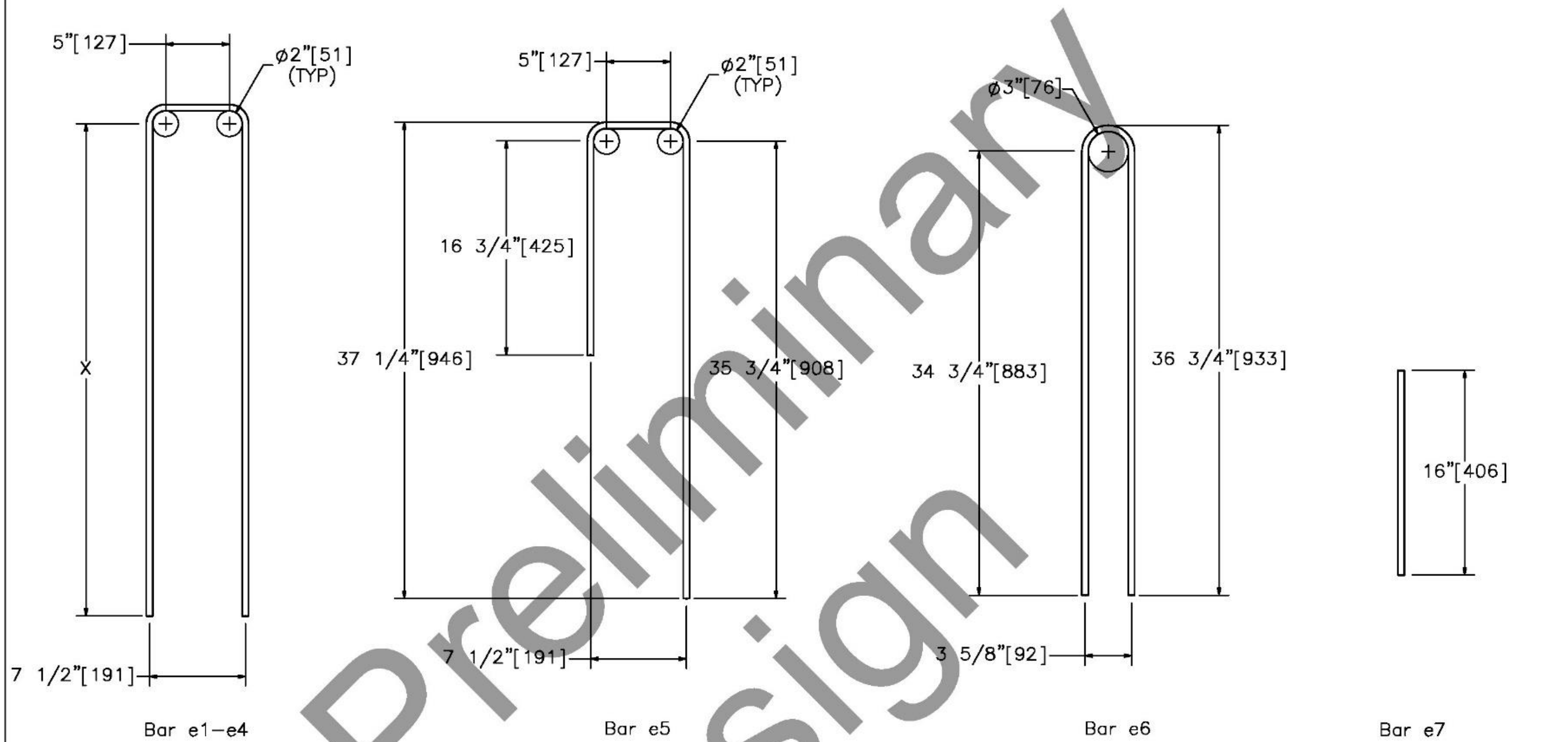


Figure 19. Buttress Cross Section Details, Test No. AGTB-1



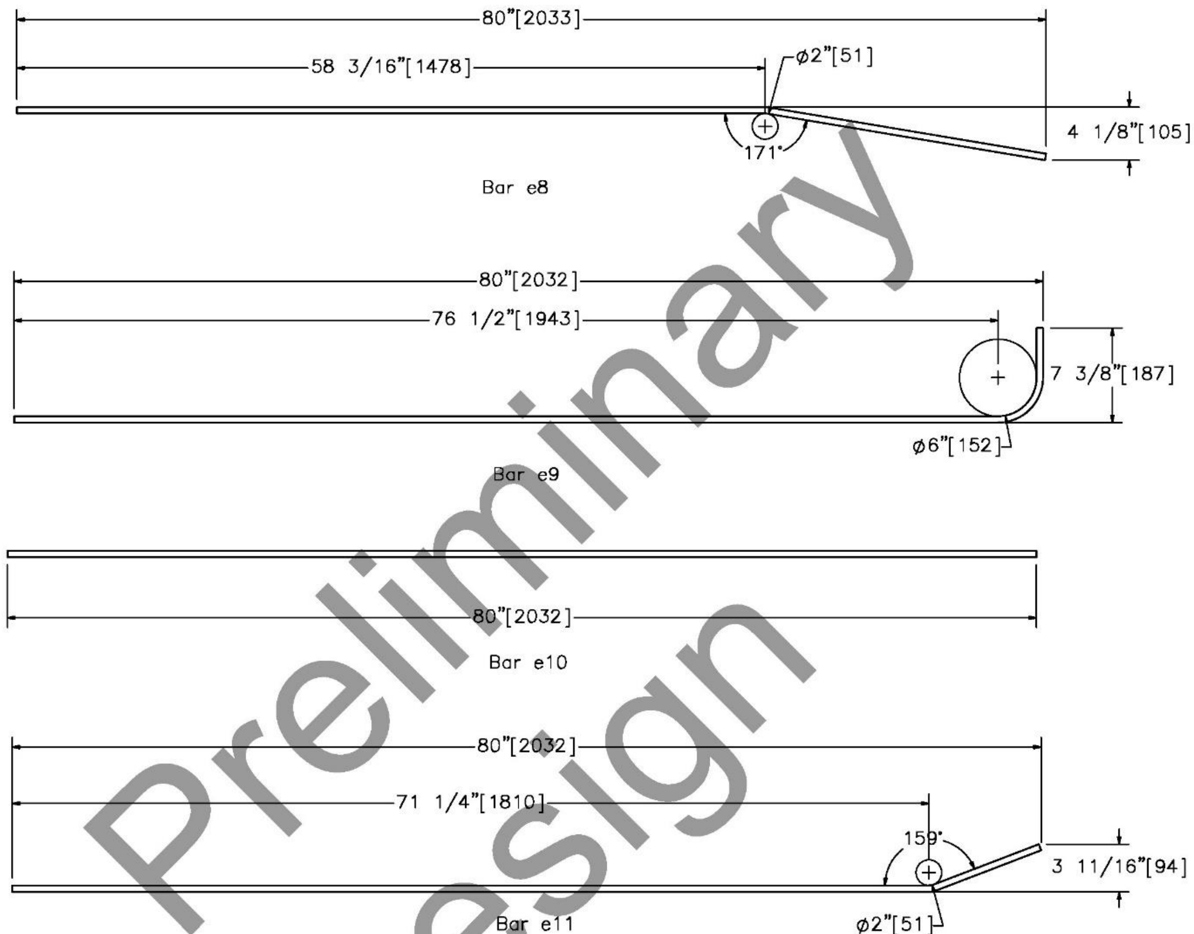
Bill of Bars					
Part No.	Bar No.	Qty.	Start of Bend (X)	Unbent Length	Material
e1	#4	11	38 1/2" [978]	86" [2184]	ASTM A615 Gr. 60
e2	#4	1	38" [965]	85" [2159]	ASTM A615 Gr. 60
e3	#4	1	37 1/4" [946]	83 1/2" [2121]	ASTM A615 Gr. 60
e4	#4	1	36 1/2" [927]	82" [2083]	ASTM A615 Gr. 60
e5	#4	1	–	61 1/2" [1562]	ASTM A615 Gr. 60
e6	#4	1	–	75 1/4" [1908]	ASTM A615 Gr. 60
e7	#4	1	–	16" [406]	ASTM A615 Gr. 60

MwRSF
Midwest Roadside Safety Facility

Standardized AGT Buttress
Test No. AGTB-1
Vertical Rebar Details

SHEET: 17 of 23
DATE: 5/22/2017
DRAWN BY: SDB/ALL/JEK/DTM
DWG. NAME. AGT Buttress_R13
SCALE: 1:12
UNITS: Inches
REV. BY: SKR/KAL

Figure 20. Buttress Vertical Rebar Details and Bill of Bars, Test No. AGTB-1



Bill of Bars

Part No.	Bar No.	Qty.	Unbent Length	Material
e8	#4	1	80 1/4" [2038]	ASTM A615 Gr. 60
e9	#4	4	85 1/2" [2172]	ASTM A615 Gr. 60
e10	#4	5	80" [2032]	ASTM A615 Gr. 60
e11	#4	1	80 1/2" [2045]	ASTM A615 Gr. 60

Midwest Roadside Safety Facility

Standardized AGT Buttress
Test No. AGTB-1

Horizontal Rebar Details

SHEET: 18 of 23
DATE: 5/22/2017
DRAWN BY: SDB/ALL/JEK/DTM
DWG. NAME. AGT Buttress_R13
SCALE: 1:12
UNITS: Inches
REV. BY: SKR/KAL

Figure 21. Buttress Horizontal Rebar Details and Bill of Bars, Test No. AGTB-1

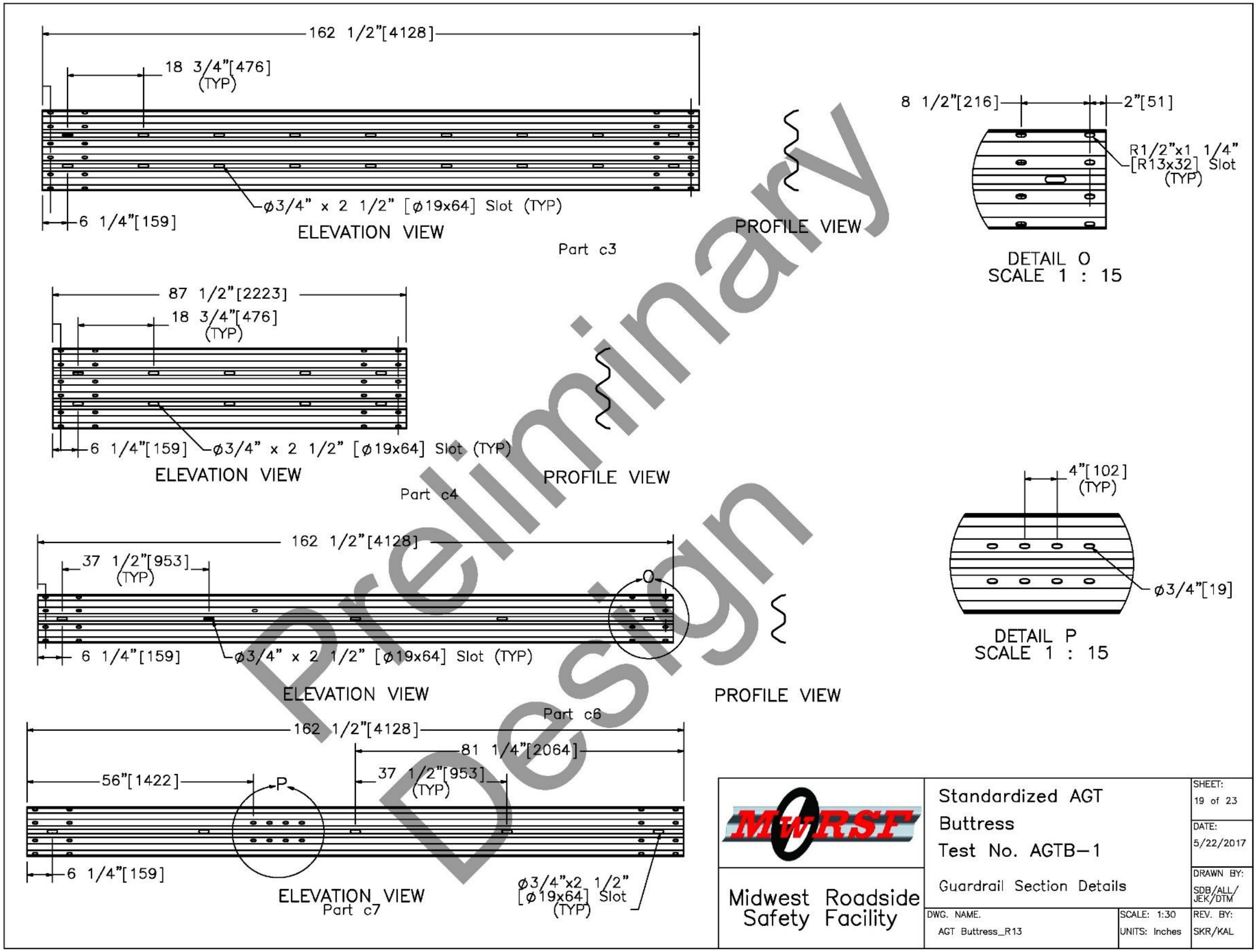


Figure 22. Rail Section Details, Test No. AGTB-1

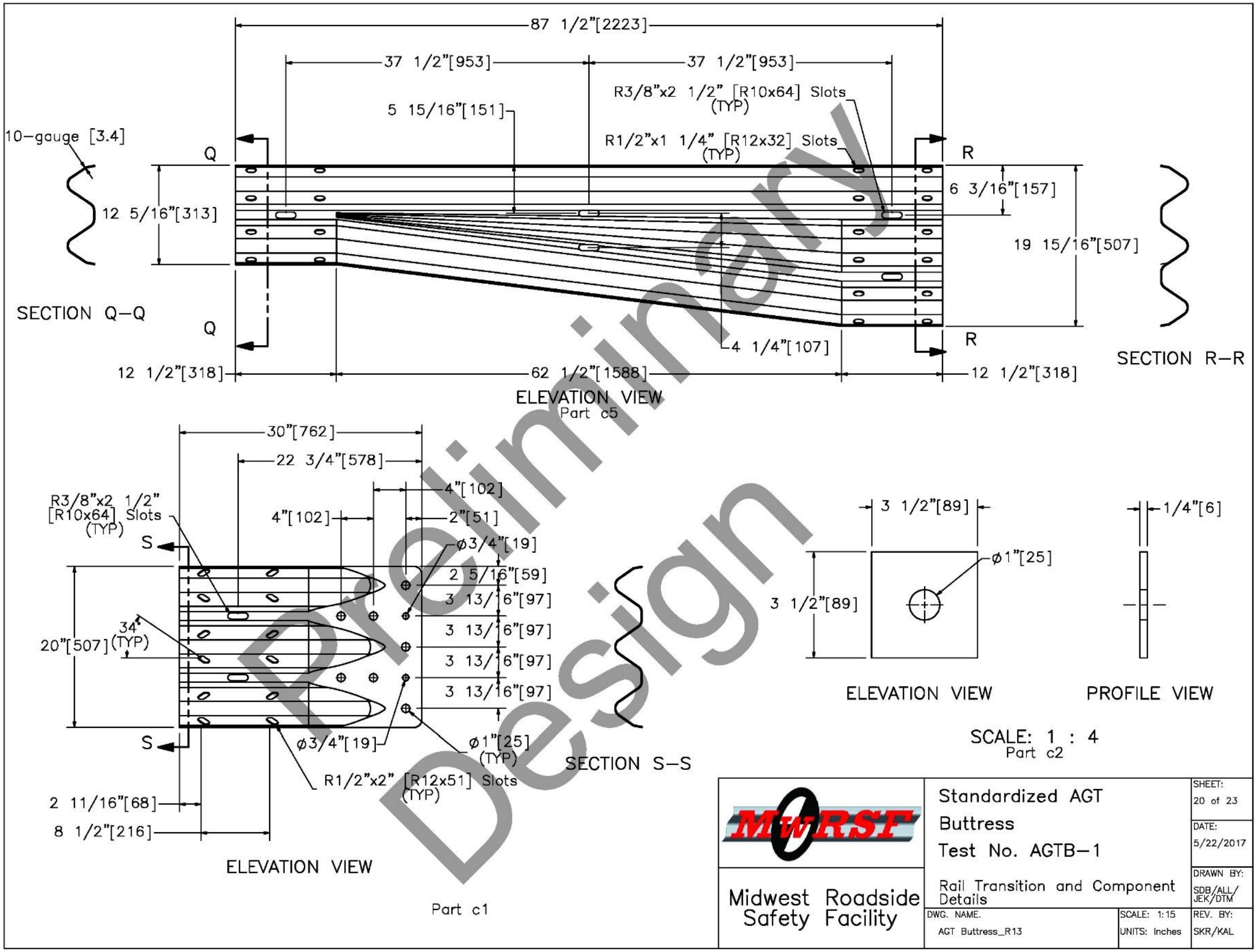


Figure 23. Rail Section Details, Test No. AGTB-1

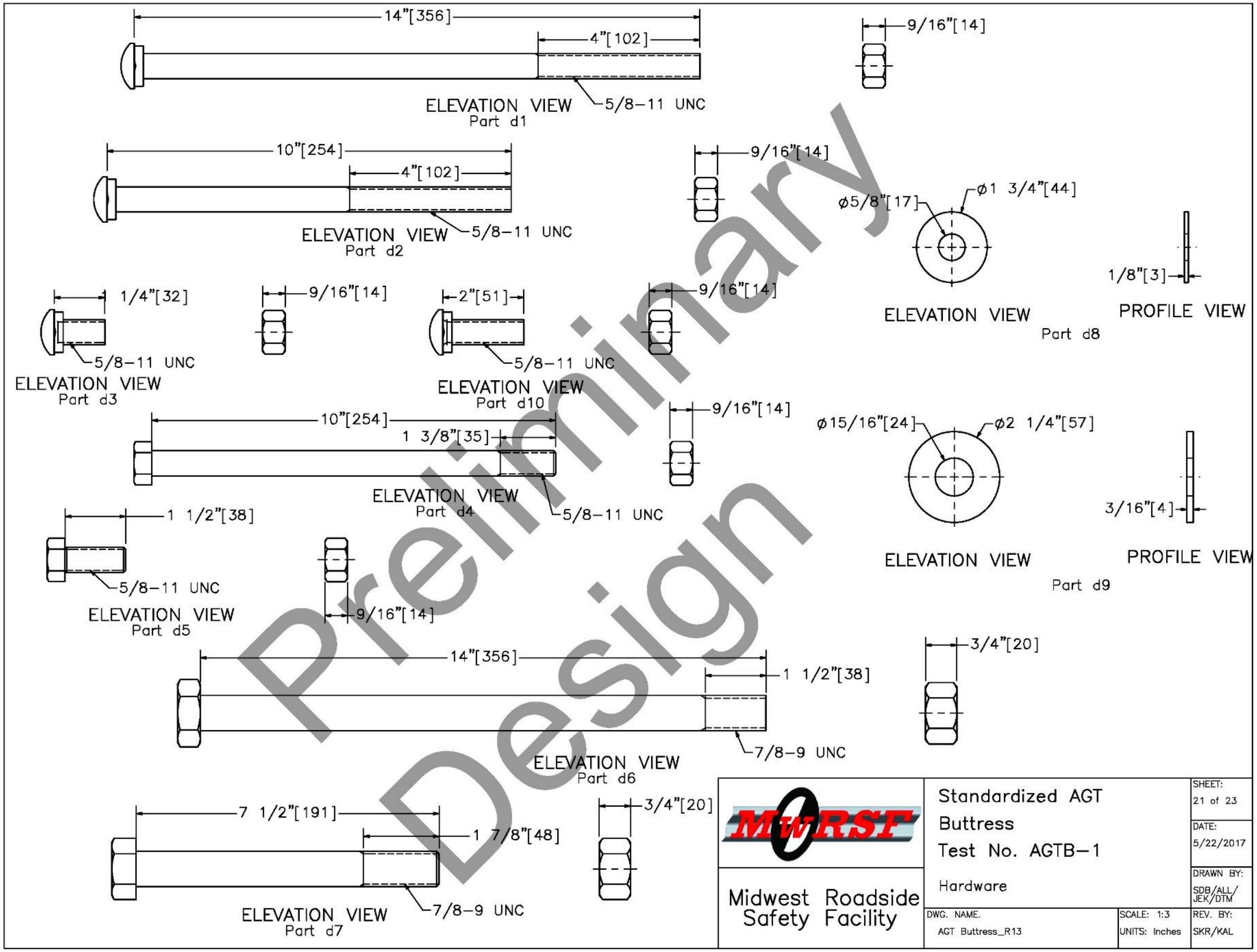


Figure 24. Fasteners Details, Test No. AGTB-1

Item No.	QTY.	Description	Material Spec	Galvanization Spec	Hardware Guide
a1	7	W6x8.5 [W152x12.6] 72" [1829] Long	ASTM A36	ASTM A123	PWE06
a2	7	6"x12"x14 1/4" [152x305x362] Blockout	SYP Grade No.1 or better	–	PDB10a
a3	8	16D Double Head Nail	–	–	–
a4	6	W6x8.5 [W152x12.6] 72" [1829] Long	ASTM A36	ASTM A123	–
a5	6	6"x12"x19" [152x305x483] Blockout	SYP Grade No.1 or better	–	–
a6	6	W6x8.5 [W152x12.6] 78" [1981] Long	ASTM A36	ASTM A123	PWE07
a7	6	17 1/2" Long [445] 7"x4"x3/16" [178x102x5] Iowa Steel Blockout	ASTM A500 Gr. B	ASTM A123	–
b1	2	BCT Timber Post – MGS Height	SYP Grade No. 1 or better (No knots, 18" [457] above or below ground tension face)	–	PDF01
b2	2	72" [1829] Long Foundation Tube	ASTM A500 Grade B	ASTM A123	PTE06
b3	1	Strut and Yoke Assembly	ASTM A36	ASTM A123	PFP02
b4	2	BCT Cable Anchor Assembly	ϕ3/4" [19] 6x19 IWRC IPS Wire Rope	ASTM A123	FCA01
b5	1	Anchor Bracket Assembly	ASTM A36	ASTM A123	FPA01
b6	1	8"x8"x5/8" [203x203x16] Anchor Bearing Plate	ASTM A36	ASTM A123	FPB01
b7	1	2 3/8" [60] O.D. x 6" Long [152] BCT Post Sleeve	ASTM A53 Grade B Schedule 40	ASTM A123	FMM02
c1	1	10–gauge [3.4] Thrie Beam Terminal Connector	AASHTO M180	ASTM A123 or A653	RTE01b
c2	5	3 1/2"x3 1/2"x1/4" [89x89x6] Washer Plate	ASTM A36	ASTM A123	–
c3	1	12'–6" [3,810] 12–gauge [2.7] Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM08a
c4	1	6'–3" [1,905] 12–gauge [2.7] Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM19a
c5	1	6'–3" [1,905] 10–gauge [3.4] W–Beam to Thrie–Beam Asymmetric Transition Section	AASHTO M180	ASTM A123 or A653	RWT02
c6	3	12'–6" [3,810] 12–gauge [2.7] W–Beam MGS Section	AASHTO M180	ASTM A123 or A653	RWM04a
c7	1	12'–6" [3810] 12–gauge [2.7] W–Beam MGS End Section	AASHTO M180	ASTM A123 or A653	RWM14a

Midwest Roadside Safety Facility	Standardized AGT Buttress Test No. AGTB–1		SHEET: 22 of 23
			DATE: 5/22/2017
	Bill of Materials		DRAWN BY: SDB/ALL/JEK/DTM
	DWG. NAME. AGT Buttress_R13	SCALE: 1:110 UNITS: Inches	REV. BY: SKR/KAL

Figure 25. Bill of Materials, Test No. AGTB-1

Item No.	QTY.	Description	Material Spec	Galvanization Spec	Hardware Guide
d1	19	5/8" [16] Dia. UNC, 14" [356] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB06
d2	2	5/8" [16] Dia. UNC, 10" [254] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB03
d3	56	5/8" [16] Dia. UNC, 1 1/4" [32] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB01
d4	2	5/8" [16] Dia. UNC, 10" [254] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBX16a
d5	20	5/8" [16] Dia. UNC, 1 1/2" [38] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBX16a
d6	5	7/8" [22] Dia. UNC, 14" [356] Long Heavy Hex Bolt and Nut	Bolt – ASTM F3125 Gr. 120 (A325) or A354 Gr. BC Nut – ASTM A563DH or A194 Gr. 2H	Bolt – ASTM A153 or B695 Class 55 or F1136 Gr. 3 or F2329 or F2833 Gr. 1 Nut – ASTM A153 or B633 or B695 Class 55 or F1941 or F2329	FBX22b
d7	2	7/8" [22] Dia. UNC, 7 1/2" [191] Long Heavy Hex Head Bolt and Nut	Bolt – ASTM F3125 Gr. 120 (A325) or A354 Gr. BC Nut – ASTM A563DH or A194 Gr. 2H	Bolt – ASTM A153 or B695 Class 55 or F1136 Gr. 3 or F2329 or F2833 Gr. 1 Nut – ASTM A153 or B633 or B695 Class 55 or F1941 or F2329	FBX22b
d8	22	5/8" [16] Dia. Plain Round Washer	ASTM A844	ASTM A123 or A153 or F2329	FWC16a
d9	4	7/8" [22] Dia. Plain Round Washer	ASTM A844	ASTM A123 or A153 or F2329	FWC22b
d10	24	5/8" [16] Dia. UNC, 2" [51] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB02
d11	24	5/8" [16] Dia. Plain Round Washer	ASTM A844	ASTM A123 or A153 or F2329	FWC16a
e1	11	1/2" [13] Dia., 86" [2,184] Long Bent Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)*	–
e2	1	1/2" [13] Dia., 85" [2,159] Long Bent Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)*	–
e3	1	1/2" [13] Dia., 83 1/2" [2,121] Long Bent Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)*	–
e4	1	1/2" [13] Dia., 82" [2,083] Long Bent Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)*	–
e5	1	1/2" [13] Dia., 61 1/2" [1,562] Long Bent Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)*	–
e6	1	1/2" [13] Dia., 75 1/8" [1,908] Long Bent Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)*	–
e7	1	1/2" [13] Dia., 16" [406] Long Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)*	–
e8	1	1/2" [13] Dia., 80 1/4" [2,038] Long Bent Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)*	–
e9	4	1/2" [13] Dia., 85 1/2" [2,172] Long Bent Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)*	–
e10	5	1/2" [13] Dia., 80" [2,032] Long Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)*	–
e11	1	1/2" [13] Dia., 80 1/2" [2,045] Long Bent Rebar	ASTM A615 Gr. 60	Epoxy Coated (ASTM A775 or A934)*	–
f1	1	Epoxy Adhesive	Min. Bond Strength = 1450 psi [10.0 MPa]	–	–
g1	1	Concrete	Min. f'c = 4000 psi [27.6 MPa]	–	–

*Rebar does not need to be epoxy–coated for testing purposes.

Midwest Roadside Safety Facility	Standardized AGT Buttress Test No. AGTB–1		SHEET: 23 of 23
			DATE: 5/22/2017
	Bill of Materials		DRAWN BY: SDB/ALL/JEK/DTM
	DWG. NAME. AGT Buttress_R13	SCALE: 1:110 UNITS: Inches	REV. BY: SKR/KAL

Figure 26. Bill of Materials Continued, Test No. AGTB-1

Figure 27. Test Installation Photographs, Test No. AGTB-1

3 TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 Test Requirements

Longitudinal barriers, such as approach guardrail transitions, must satisfy impact safety standards in order to be declared eligible for federal reimbursement by the Federal Highway Administration (FHWA) for use on the National Highway System (NHS). For new hardware, these safety standards consist of the guidelines and procedures published in MASH 2016 [3]. According to TL-3 of MASH 2016, it is recommended that longitudinal barrier transition systems be subjected to two full-scale vehicle crash tests, as summarized in Table 1. Note that there is no difference between MASH 2009 and MASH 2016 for transitions, 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 (deg.)	
Transition	3-20	1100C	2,425	62	25	A,D,F,H,I
	3-21	2270P	5,000	62	25	A,D,F,H,I

[1] Evaluation criteria explained in Table 2.

Although MASH 2016 requires two full-scale crash tests as described above, only MASH test designation no. 3-21 with the 2270P pickup truck was conducted and detailed herein. MASH test designation no. 3-20 with the small car was not considered critical since the lighter-weight vehicle would result in reduced rail deflections and a reduced risk of snag on the buttress. Additionally, a MASH test designation no. 3-20 test was previously conducted on a similar AGT system incorporating a slightly different version of the standardized buttress. This similar AGT utilized a top rail height of 34 in., or 3 in. higher than standard transitions. Thus, there was an increased risk of the small car extending under the rail and snagging on the buttress. The 34-in. tall transition was attached to a dual-tapered transition buttress very similar to the standardized buttress developed herein, except the buttress height and the height of the lower taper were each increased by 3 inches. The full-scale crash test results on the 34-in. tall AGT satisfied MASH test designation no. 3-20 evaluation criteria [42-43]. The lower rail height of standard 31-in. AGTs would better capture the front end of small cars and reduce the risk of the vehicle extending under the rail and snagging on the buttress. Therefore, conducting another MASH test designation no. 3-20 on the standardized buttress was not considered critical or necessary.

3.2 Evaluation Criteria

Evaluation criteria for full-scale vehicle crash testing are based on three appraisal areas: (1) structural adequacy; (2) occupant risk; and (3) vehicle trajectory after collision. Criteria for structural adequacy are intended to evaluate the ability of the transition barrier to contain and redirect impacting vehicles. In addition, controlled lateral deflection of the test article is acceptable. Occupant risk evaluates the degree of hazard to occupants in the impacting vehicle. Post-impact vehicle trajectory is a measure of the potential of the vehicle to result in a secondary collision with other vehicles and/or fixed objects, thereby increasing the risk of injury to the occupants of the impacting vehicle and/or other vehicles. These evaluation criteria are summarized in Table 2 and defined in greater detail in MASH. The first full-scale vehicle crash test was conducted and reported in accordance with the procedures provided in MASH 2009, while the second test was conducted and reported in accordance with 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.

Table 2. MASH 2016 Evaluation Criteria for Longitudinal Barrier Transitions

<table>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="3">Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td></tr>
<tr><td rowspan="9">Occupant Risk</td><td>D.</td><td colspan="3">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016.</td></tr>
<tr><td>F.</td><td colspan="3">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s</td><td>40 ft/s</td></tr>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH 2016 for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
</table>

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 are 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% of the static baseline test at deflections of 5, 10, and 15 inches. 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 transition system. A digital speedometer on the tow vehicle increased the accuracy of the test vehicle impact speed.

A vehicle guidance system developed by Hinch [44] was used to steer the test vehicle. A guide flag, attached to the front wheel (right-front wheel in test no. AGTB-1 and left-front wheel in test no. AGTB-2), 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. AGTB-1, a 2008 Dodge Ram 1500 was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,025 lb, 5,039 lb, and 5,199 lb, respectively. The test vehicle is shown in Figure 28, and vehicle dimensions are shown in Figure 29.

For test no. AGTB-2, a 2010 Dodge Ram 1500 was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,097 lb, 4,998 lb, and 5,160 lb, respectively. The test vehicle is shown in Figure 30, and vehicle dimensions are shown in Figure 31. Note, pre-test photographs of the vehicles' interior floorboards and undercarriages were not available for either test. Although the test vehicles were older than six model years on their respective test dates, both test vehicles were within the MASH-specified six-year window at the beginning of the project when the vehicles were purchased in anticipation of the tests. Thus, both test vehicles satisfy the age limit established in Section 4.2.1 of MASH 2016.

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [45] was used to determine the vertical component of the c.g. for the pickup trucks. 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 test no. AGTB-1 is shown in Figures 29 and 32. The location of the final c.g. for test no. AGTB-2 is shown in Figures 31 and 33. Data used to calculate the location of the c.g. and ballast information are shown in Appendix B.

Square, black- and white-checkered targets were placed on the vehicle for reference to be viewed from the high-speed digital video cameras and aid in the video analysis, as shown in Figures 32 and 33. 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' windshield wipers and was fired by a pressure tape switch mounted at the impact corner of the bumper. The flash bulb was fired upon initial impact with the test article to create a visual indicator of the precise time of impact on the high-speed videos. A remote-controlled brake system was installed in the test vehicle so the vehicle could be brought safely to a stop after the test.

Figure 28. Test Vehicle, Test No. AGTB-1

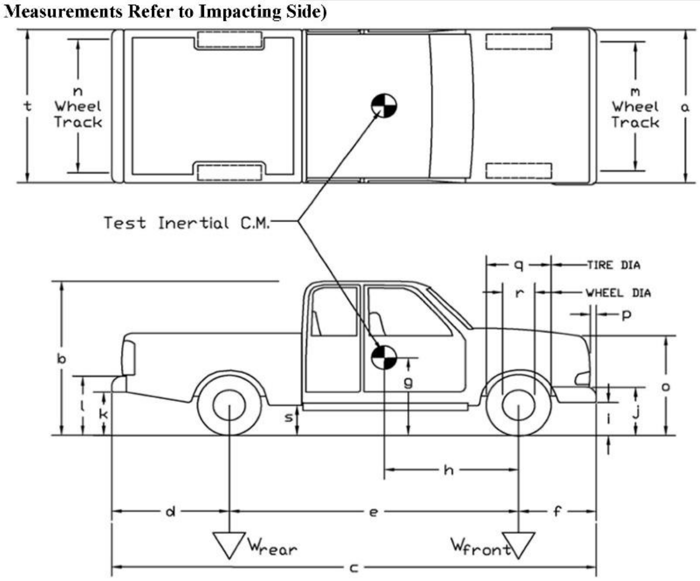
Date: 12/22/2015 **Test Number:** AGTB-1 **Model:** Ram 1500

Make: Dodge **Vehicle I.D.#:** id7ha18N08S514930

Tire Size: P275/60R20 **Year:** 2008 **Odometer:** 89934

Tire Inflation Pressure: 35

*(All Measurements Refer to Impacting Side)



Vehicle Geometry -- in. (mm)

a	77 1/4	(1962)	b	76 1/2	(1943)
c	227 3/8	(5775)	d	46 7/8	(1191)
e	140 1/2	(3569)	f	40	(1016)
g	29 1/3	(745)	h	61 3/5	(1564)
i	15 7/8	(403)	j	30	(762)
k	21 5/8	(549)	l	30 1/4	(768)
m	68 1/8	(1730)	n	68 1/8	(1730)
o	46 1/2	(1181)	p	3 1/8	(79)
q	33	(838)	r	21 5/8	(549)
s	17	(432)	t	75 1/2	(1918)

Wheel Center Height Front	15 1/4	(387)
Wheel Center Height Rear	15 3/4	(400)
Wheel Well Clearance (F)	36 1/4	(921)
Wheel Well Clearance (R)	39 1/4	(997)
Frame Height (F)	20	(508)
Frame Height (R)	27 1/4	(692)
Engine Type	Gasoline	
Engine Size	4.7L V8	
Transmission Type:	Automatic	
Drive Type:	RWD	

Mass Distribution lb (kg)

Gross Static	LF	1521 (690)	RF	1405 (637)
	LR	1132 (513)	RR	1141 (518)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2870 (1302)	2830 (1284)	2926 (1327)
W-rear	2155 (977)	2209 (1002)	2273 (1031)
W-total	5025 (2279)	5039 (2286)	5199 (2358)

GVWR Ratings

Front	3700 lb
Rear	3900 lb
Total	6700 lb

Dummy Data

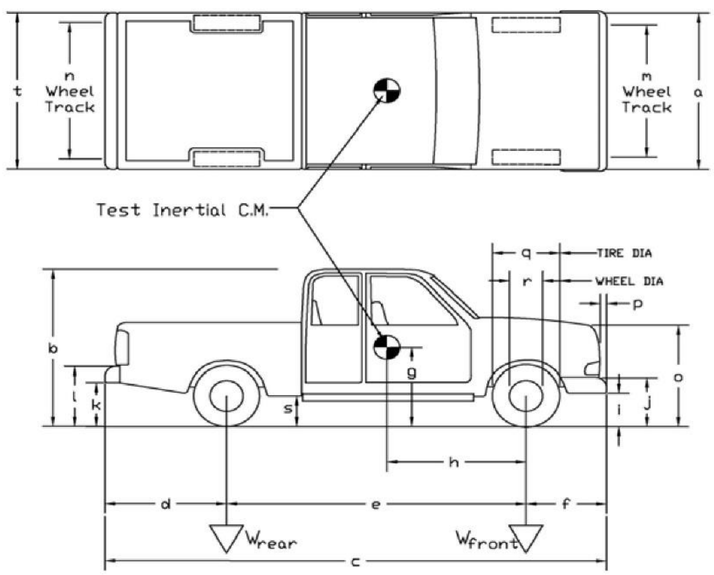
Type:	Hybrid II
Mass:	160 lb
Seat Position:	Driver

Note any damage prior to test: Bottom of the tailgate large dent, passenger side box side dent, rear bumper dents.

Figure 29. Vehicle Dimensions, Test No. AGTB-1

Figure 30. Test Vehicle, Test No. AGTB-2

Date:	5/24/2017	Test Name:	AGTB-2	VIN No:	1D7RB1CT0AS246796
Year:	2010	Make:	Dodge	Model:	Ram 1500 Hemi
Tire Size:	P265/70R17 113R	Tire Inflation Pressure:	40 Psi	Odometer:	159423



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

a:	77 3/8 (1965) 78±2 (1950±50)	b:	74 1/8 (1883)
c:	229 3/8 (5826) 237±13 (6020±325)	d:	48 1/4 (1226)
e:	140 3/8 (3566) 148±12 (3760±300)	f:	40 3/8 (1026) 39±3 (1000±75)
g:	28 3/8 (721) min: 28 (710)	h:	61 5/16 (1557) 63±4 (1575±100)
i:	7 1/2 (191)	j:	24 (611)
k:	20 3/8 (518)	l:	29 3/4 (756)
m:	68 (1727) 67±1.5 (1700±38)	n:	67 7/8 (1724) 67±1.5 (1700±38)
o:	46 1/2 (1181) 43±4 (1100±75)	p:	4 3/4 (121)
q:	33 (838)	r:	18 1/2 (470)
s:	15 (381)	t:	78 3/4 (2000)

Wheel Center Height (Front):	15 (381)
Wheel Center Height (Rear):	15 (381)
Wheel Well Clearance (Front):	34 3/4 (883)
Wheel Well Clearance (Rear):	38 (965)
Bottom Frame Height (Front):	13 5/8 (346)
Bottom Frame Height (Rear):	23 1/2 (597)
Engine Type:	Gasoline
Engine Size:	5.7L V8
Transmission Type:	Automatic
Drive Type:	RWD
Cab Style:	Crew Cab
Bed Length:	67"

Mass Distribution lb (kg)

Gross Static	LF	1429 (648)	RF	1487 (674)
	LR	1138 (516)	RR	1106 (502)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2827 (1282)	2816 (1277)	2916 (1323)
W-rear	2270 (1030)	2182 (990)	2244 (1018)
W-total	5097 (2312)	4998 (2267) 5000±110 (2270±50)	5160 (2341) 5165±110 (2343±50)

GVWR Ratings lb

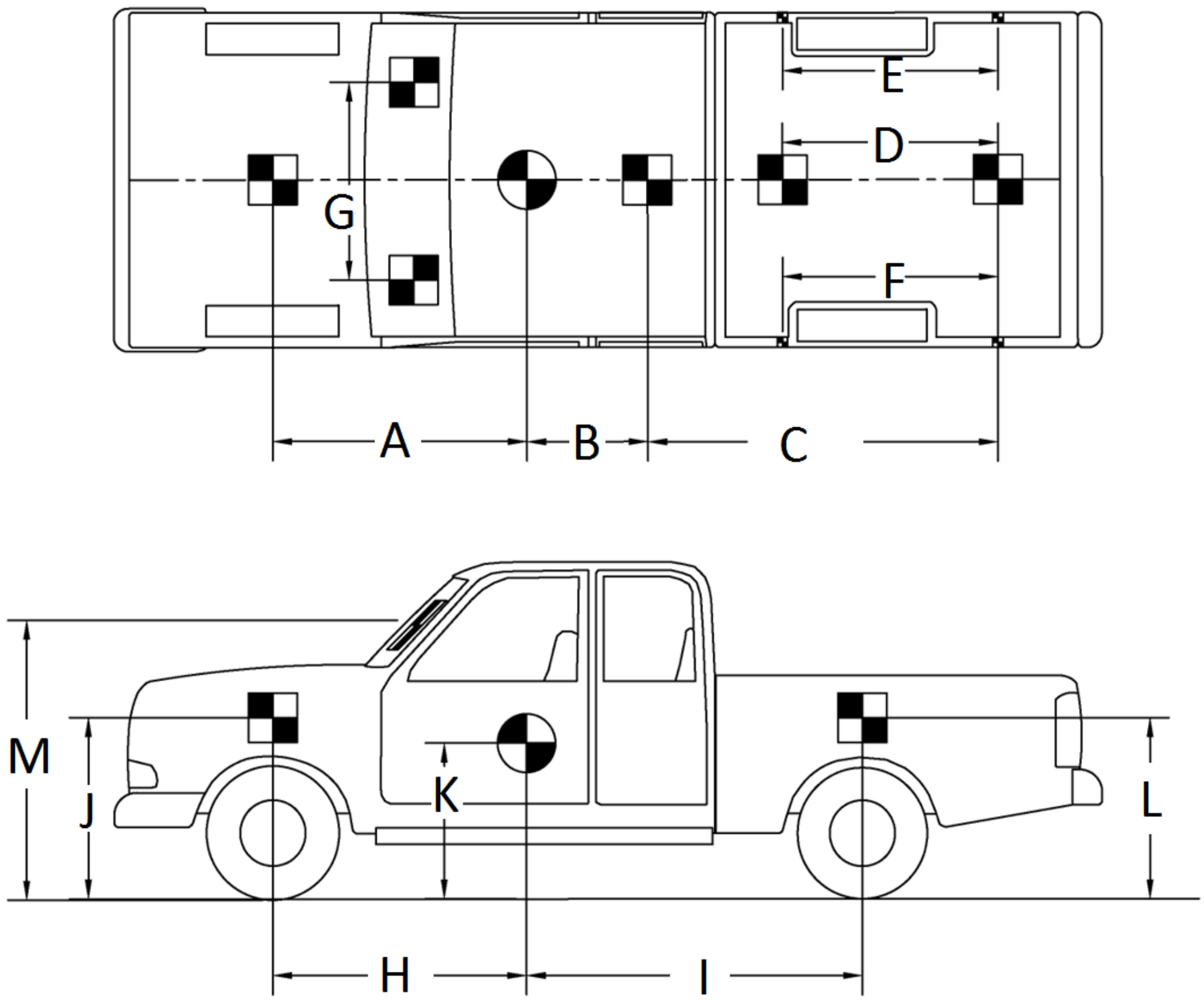
Front	3700
Rear	3900
Total	6700

Dummy Data

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

Note any damage prior to test: Minor denting on front and rear bumper.

Figure 31. Vehicle Dimensions, Test No. AGTB-2



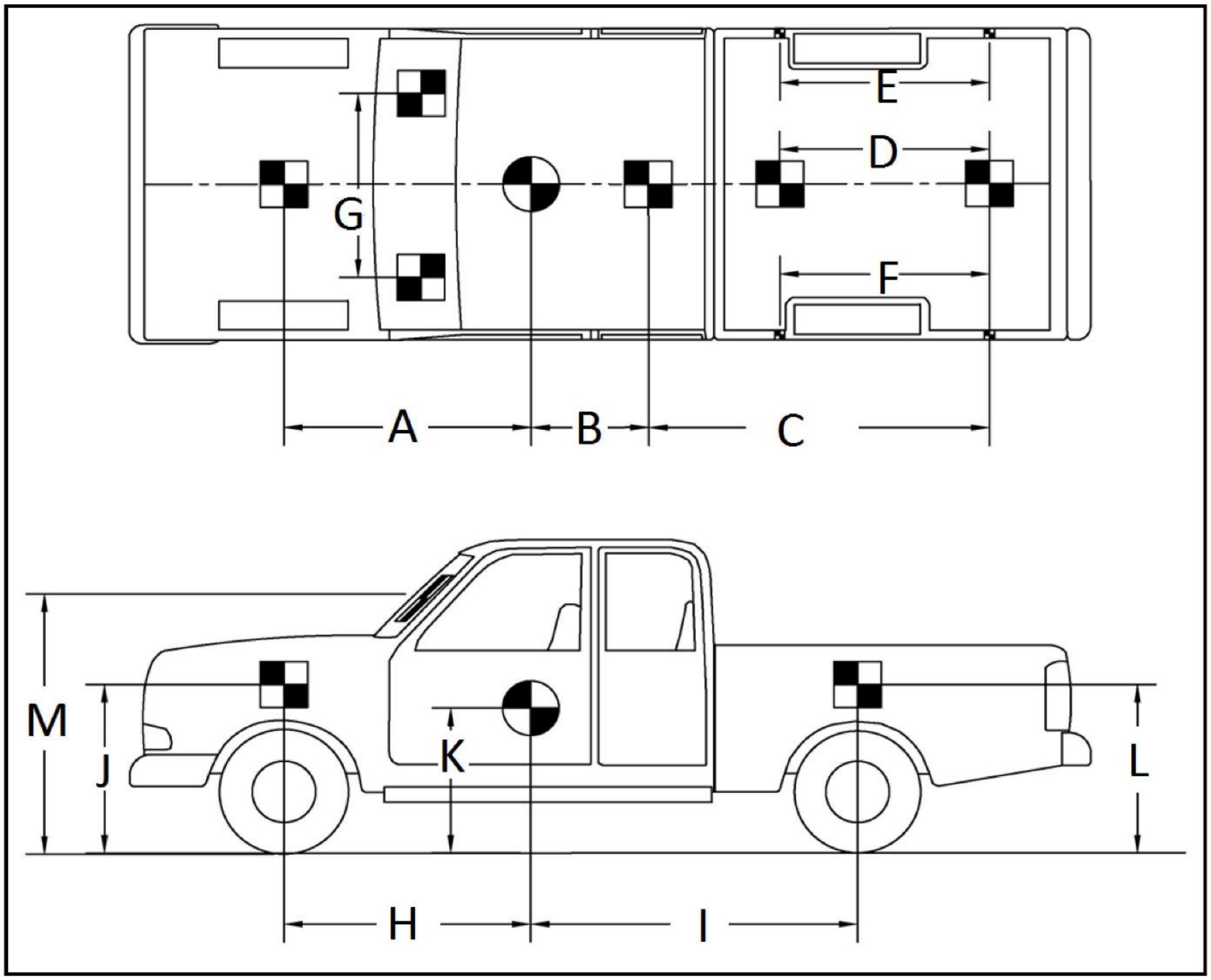
TEST #: AGTB-1

TARGET GEOMETRY-- in. (mm)

A	**74 3/4**	**(1899)**	**F**	**63 7/8**	**(1622)**	**K**	**29 3/8**	**(746)**
B	**25 1/2**	**(648)**	**G**	**35 3/4**	**(908)**	**L**	**43 1/2**	**(1105)**
C	**82 1/4**	**(2089)**	**H**	**61 3/5**	**(1564)**	**M**	**mwrsf**	**#VALUE!**
D	**48**	**(1219)**	**I**	**78 2/3**	**(1998)**			
E	**63 7/8**	**(1622)**	**J**	**40 1/4**	**(1022)**			

Figure 32. Target Geometry, Test No. AGTB-1

Date:	5/24/2017	Test Name:	AGTB-2	VIN:	1D7RB1CT0AS246796
Year:	2010	Make:	Dodge	Model:	Ram 1500 Hemi



TARGET GEOMETRY-- in. (mm)

A:	76 3/4	(1949)	E:	54 3/8	(1381)	J:	38 31/32	(990)
B:	36 13/16	(935)	F:	54 1/4	(1378)	K:	28 5/16	(719)
C:	72	(1829)	G:	30 3/8	(772)	L:	42 5/16	(1075)
D:	38 1/16	(967)	H:	61 1/8	(1553)	M:	64 13/16	(1646)
			I:	79 5/16	(2015)			

Figure 33. Target Geometry, Test No. AGTB-2

4.4 Simulated Occupant

For test nos. AGTB-1 and AGTB-2, a Hybrid II 50^{th}-Percentile, Adult Male Dummy equipped with footwear was placed in the front, impact-side seat of the test vehicles with the seat belt fastened. The simulated occupant had a final weight of 160 lb and 162 lb for test nos. AGTB-1 and AGTB-2, respectively. As recommended by MASH 2016, the simulant occupant weight was not included in calculating the c.g. location.

4.5 Data Acquisition Systems

4.5.1 Accelerometers

Two environmental shock and vibration sensor/recorder systems were used to measure the accelerations in the longitudinal, lateral, and vertical directions. Both accelerometer systems were mounted near the center of gravity of the test vehicles. The electronic accelerometer data obtained in dynamic testing was filtered using the SAE Class 60 and the SAE Class 180 Butterworth filter conforming to the SAE J211/1 specifications [46].

The two systems, the SLICE-1 and SLICE-2 units, were modular data acquisition systems manufactured by Diversified Technical Systems, Inc. (DTS) of Seal Beach, California. The SLICE-2 unit was designated as the primary system for both tests. 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

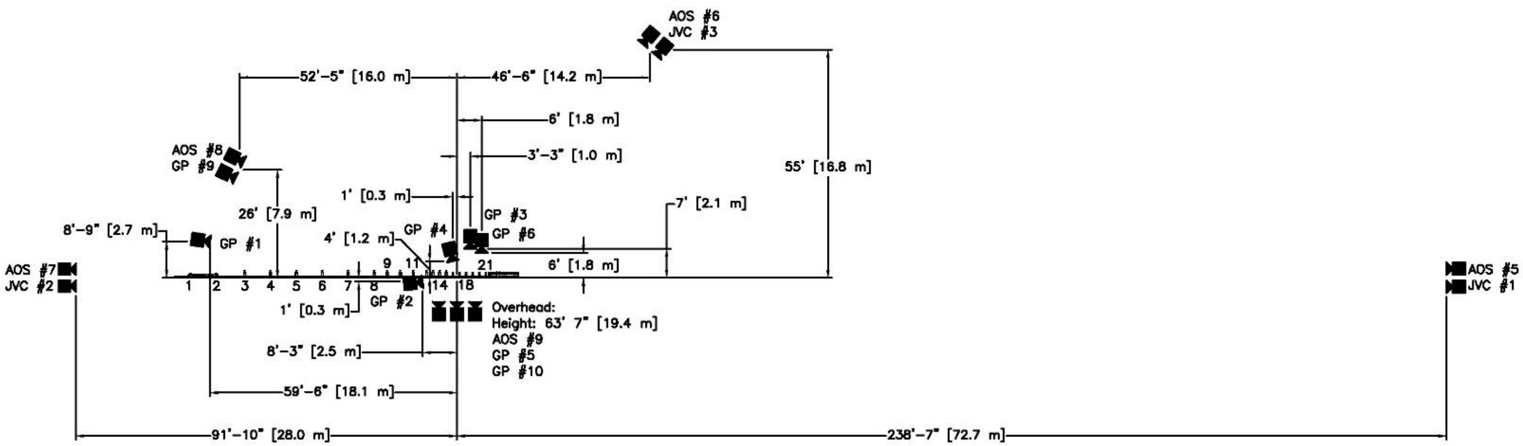
The retroreflective optic speed trap was used to determine the speed of the test vehicles before impact. Five retroreflective targets, spaced at approximately 18-in. intervals, were applied to the side of the vehicles. When the emitted beam of light was reflected by the targets and returned to the Emitter/Receiver, 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 only used as a backup in the event that vehicle speeds cannot be determined from the electronic data.

4.5.4 Digital Photography

Five AOS high-speed digital video cameras, eight GoPro digital video cameras, and three JVC digital video cameras were utilized to film test no. AGTB-1. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 34.

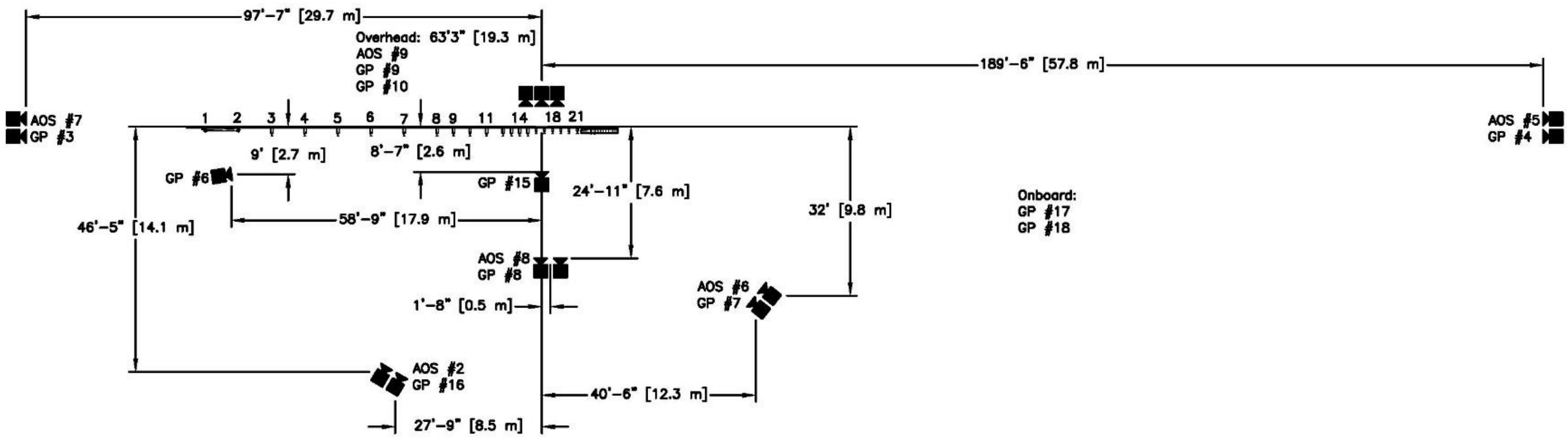
Six AOS high-speed digital video cameras and eleven GoPro digital video cameras were utilized to film test no. AGTB-2. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 35.

The high-speed videos were analyzed using ImageExpress MotionPlus 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 used to document pre- and post-test conditions for test nos. AGTB-1 and AGTB-2.



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-5	AOS X-PRI Gigabit	500	Vivitar 135mm Fixed	-
AOS-6	AOS X-PRI Gigabit	500	Sigma 28-70	-
AOS-7	AOS X-PRI Gigabit	500	Nikon 28mm Fixed	-
AOS-8	AOS S-VIT 1531	500	Sigma 28-70 DG	-
AOS-9	AOS TRI-VIT 2236	500	Kowa	-
GP-1	GoPro Hero 3+	120		
GP-2	GoPro Hero 3+	120		
GP-3	GoPro Hero 3+	120		
GP-4	GoPro Hero 3+	120		
GP-5	GoPro Hero 3+	120		
GP-6	GoPro Hero 3+	120		
GP-7	GoPro Hero 4	120		
GP-8	GoPro Hero 4	120		
GP-9	GoPro Hero 4	240		
GP-10	GoPro Hero 4	240		
JVC-1	JVC – GZ-MC500 (Everio)	29.97		
JVC-2	JVC – GZ-MG27u (Everio)	29.97		
JVC-3	JVC – GZ-MG27u (Everio)	29.97		

Figure 34. Camera Locations, Speeds, and Lens Settings, Test No. AGTB-1



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-2	AOS Vitcam	500	Nikon 28-70 DG (#1)	50
AOS-5	AOS X-PRI	500	Vivitar 135 mm Fixed	-
AOS-6	AOS X-PRI	500	Nikon 28-70 (#2)	28
AOS-7	AOS X-PRI	500	Fujinon 35mm Fixed	-
AOS-8	AOS S-VIT 1531	500	Kowa 25mm Fixed	-
AOS-9	AOS TRI-VIT 2236	1000	Kowa 12mm Fixed	-
GP-3	GoPro Hero 3+	120	Cosmicar – 12.5mm	
GP-4	GoPro Hero 3+	120	Computer – 12.5mm	
GP-6	GoPro Hero 3+	120		
GP-7	GoPro Hero 4	240		
GP-8	GoPro Hero 4	240		
GP-9	GoPro Hero 4	120		
GP-10	GoPro Hero 4	240		
GP-15	GoPro Hero 4	240		
GP-16	GoPro Hero 4	240		
GP-17	GoPro Hero 4	120		
GP-18	GoPro Hero 4	120		

Figure 35. Camera Locations, Speeds, and Lens Settings, Test No. AGTB-2

5 FULL-SCALE CRASH TEST NO. AGTB-1

5.1 Static Soil Test

Before full-scale crash test no. AGTB-1 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH 2009. 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. AGTB-1 was conducted on December 22, 2015 at approximately 12:30 pm. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 3.

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

Temperature	47°F
Humidity	59%
Wind Speed	22 mph
Wind Direction	180° from True North
Sky Conditions	Overcast
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0 in.
Previous 7-Day Precipitation	0 in.

5.3 Test Description

The critical impact point for test no. AGTB-1 was selected using the tables provided in Section 2.3.2.1 of MASH to maximize the potential for snag on the upstream face of the concrete buttress. The critical impact point was determined to be 89 in. upstream from the end of the concrete buttress, or 6 in. upstream from the centerline of post no. 17, as shown in Figure 36.

During the test, the 5,199-lb pickup truck impacted the thrie-beam AGT 80½ in. upstream from the concrete buttress at a speed of 61.9 mph and at an angle of 24.4 degrees. The vehicle was contained and redirected with an exit speed and angle of 41.3 mph and -4.1 degrees, respectively. The vehicle remained stable throughout the impact event with maximum roll and pitch angular displacements of only 27 degrees and 11 degrees, respectively. Moderate snagging of the front impact-side wheel on the concrete buttress was observed, which led to deformations of the vehicle toe pan, floorboard, and impact-side door. These deformations appeared to shift the front seats and the mounting brackets that were supporting the on-board transducers and resulted in what is believed to be abnormal and artificially high acceleration spikes. As a result, the calculated longitudinal occupant ridedown accelerations exceeded MASH limits. After exiting the system, the vehicle's brakes were applied, and the vehicle came to rest 199 ft downstream from the impact location.

A detailed description of the sequential impact events is contained in Table 4. Sequential photographs are shown in Figures 37 and 38. Documentary photographs of the crash test are shown in Figure 39. The vehicle trajectory and final position are shown in Figure 40.

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

TIME (sec)	EVENT
0.000	Vehicle’s left-front bumper contacted rail 80.5 in. upstream from the buttress, near post no. 17.
0.002	Vehicle’s left-front bumper deformed.
0.004	Post nos. 16 and 17 deflected backward.
0.008	Post nos. 18 and 19 deflected backward.
0.010	Vehicle’s left fender deformed.
0.012	Post nos. 14 and 15 deflected backward.
0.020	Post no. 13 twisted downstream, and soil heaves formed on backside of post nos. 17 and 18.
0.026	Soil heave formed on backside of post nos. 19 through 21.
0.028	Vehicle rolled toward barrier.
0.034	Vehicle yaw away from barrier
0.038	Upper part of left-front door separated from vehicle.
0.046	Vehicle’s left airbag deployed.
0.080	Vehicle’s left quad panel impacted concrete buttress above guardrail.
0.090	Vehicle’s left-front tire contacted concrete buttress below guardrail.
0.098	System reached maximum lateral deflection of 6.0 in. at post no. 19.
0.112	Vehicle’s right-front wheel became airborne.
0.128	Vehicle pitched downward.
0.134	Vehicle’s right-rear wheel became airborne.
0.180	Vehicle was parallel to system at a speed of 45.5 mph.
0.198	Vehicle’s left quad panel contacted rail between post nos. 17 and 18.
0.210	Rear of vehicle impacted guardrail, and left-front tire detached.
0.328	Vehicle exited system at a speed of 41.3 mph and an angle of -4.1 degrees.
0.422	Vehicle’s left-rear wheel was airborne.
0.594	Vehicle reached maximum pitch and pitched upward.
0.758	Vehicle’s left-rear wheel landed awkwardly on ground causing damage and eventually separating it from vehicle.
0.864	Vehicle reached maximum roll and rolled away from barrier.
1.110	Vehicle’s right-side wheels regained contact with ground.
6.400	Vehicle came to rest 199 ft downstream from impact, 26.5 ft in front of system.

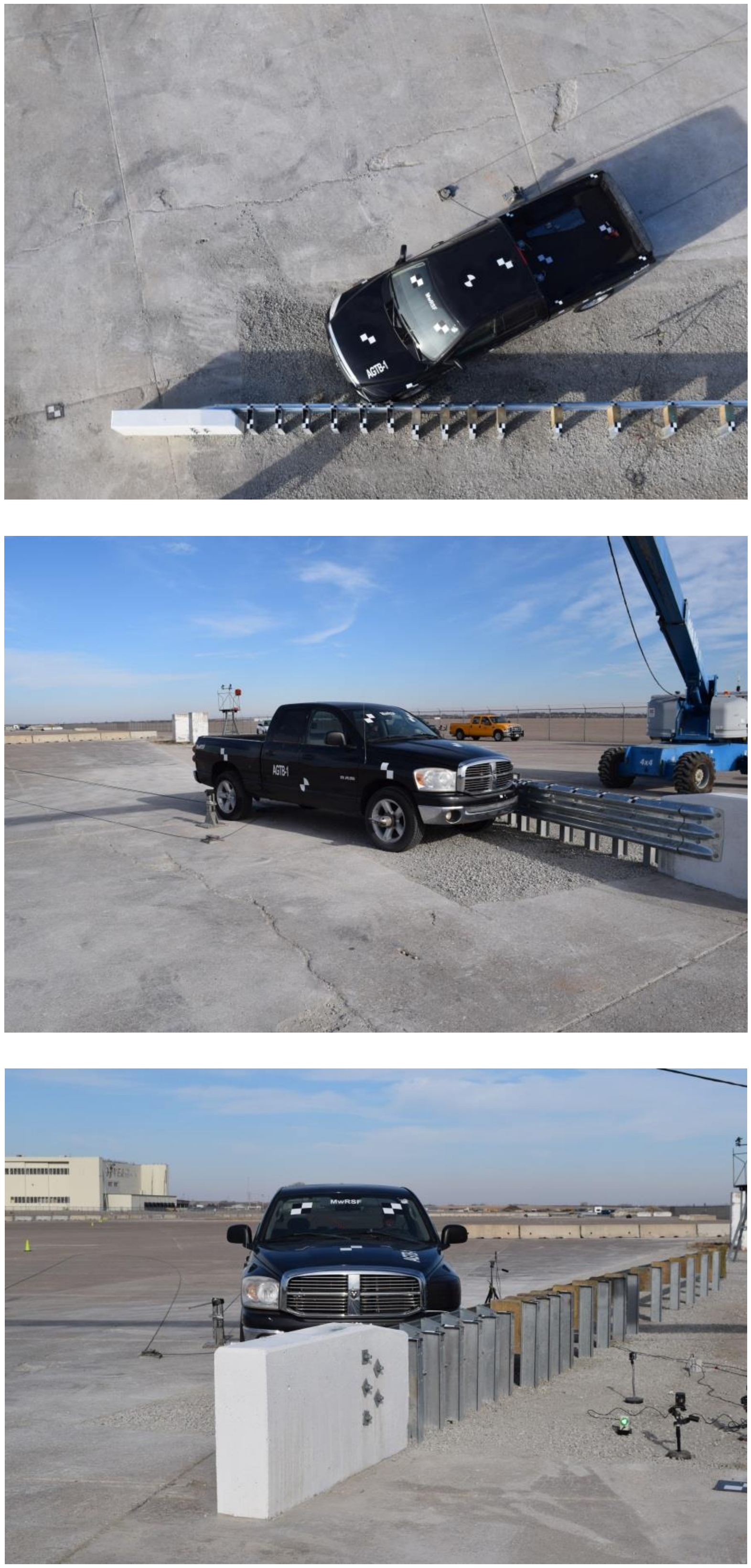


Figure 36. Impact Location, Test No. AGTB-1


0.000 sec


0.100 sec


0.200 sec


0.300 sec

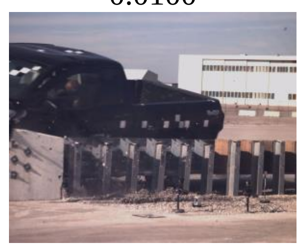

0.400 sec


0.500 sec


0.000 sec


0.050 sec


0.0100


0.150ec


0.200 sec


0.250 sec

Figure 37. Sequential Photographs, Test No. AGTB-1

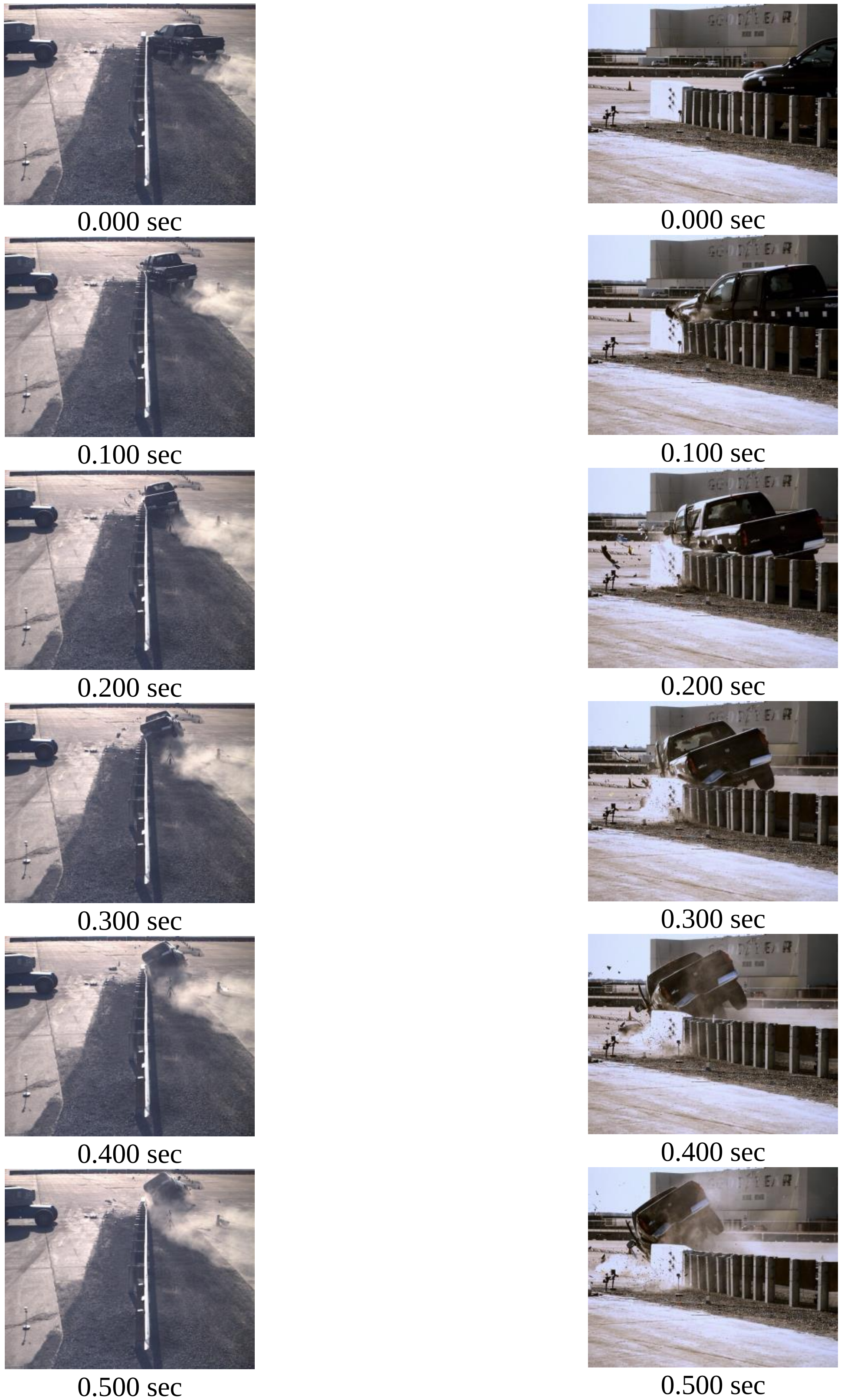


Figure 38. Additional Sequential Photographs, Test No. AGTB-1

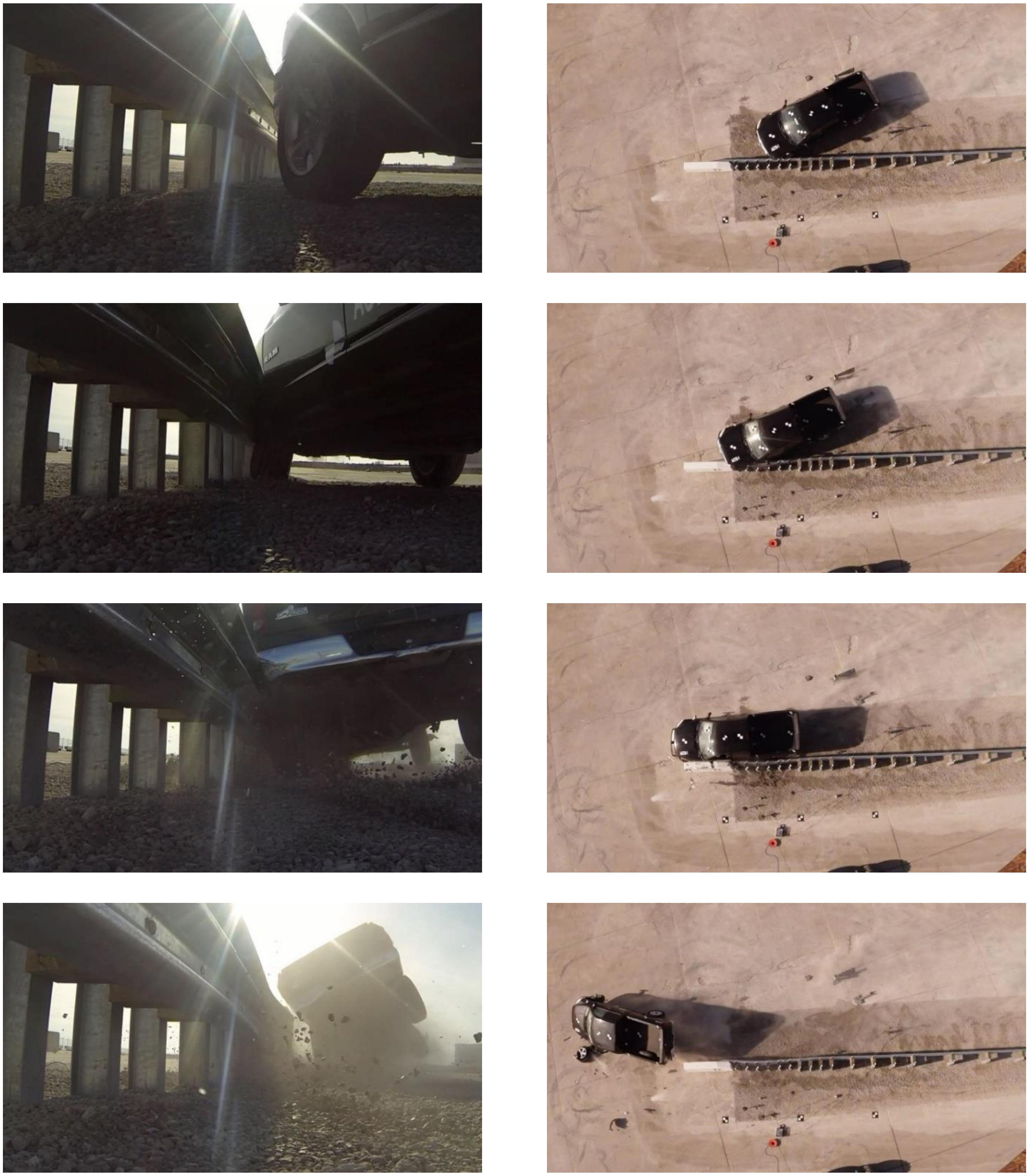


Figure 39. Documentary Photographs, Test No. AGTB-1

Figure 40. Vehicle Final Position and Trajectory Marks, Test No. AGTB-1

5.4 Barrier Damage

Damage to the barrier consisted of contact marks, rail deformations, and post deflections, as shown in Figures 41 through 42. The length of vehicle contact on the system was 10 ft – 10 in. with contact marks beginning 14½ in. upstream from post no. 17 and ending near the downstream end of the thrie-beam terminal connector. The nested thrie beam sustained various deformations, kinks, and buckling that spanned from post no. 17 to the terminal connector. Significant buckling was observed on the lower and middle humps of the guardrail around post no. 17 and on the lower hump of the guardrail extending from post no. 19 to post no. 21. The bottom of the thrie beam was folded upward between post nos. 18 and 21 and kinked at the upstream edge of the concrete buttress. The terminal connector was slightly kinked around the upstream anchor bolts.

At the splice between the thrie beam and the terminal connector, one of the upstream splice bolts on the lower guardrail hump was fractured, and the dome head was wedged between rail plies 5 in. downstream from its original location. As the fractured dome head was pushed downstream during impact, it tore a strip of the front thrie-beam rail from the original hole to its final location. Tire contact marks were found covering the lower taper of the concrete buttress below the guardrail and extending ¼-in. onto the upstream face of the buttress. Scraps and contact marks were also observed on top surface of the buttress along the vertical taper.

The maximum permanent set of the system was 5⅝ in., which occurred to the rail near post no. 19, as measured in the field. The maximum lateral dynamic deflection of the system was 6.0 in. measured on the rail at post no. 19, as determined from high-speed digital video analysis. The working width of the system was found to be 23.0 in. at post no. 19, also determined from high-speed digital video analysis. These system deflections are illustrated in Figure 43.

Figure 41. System Damage, Test No. AGTB-1

Figure 42. System Damage, Test No. AGTB-1

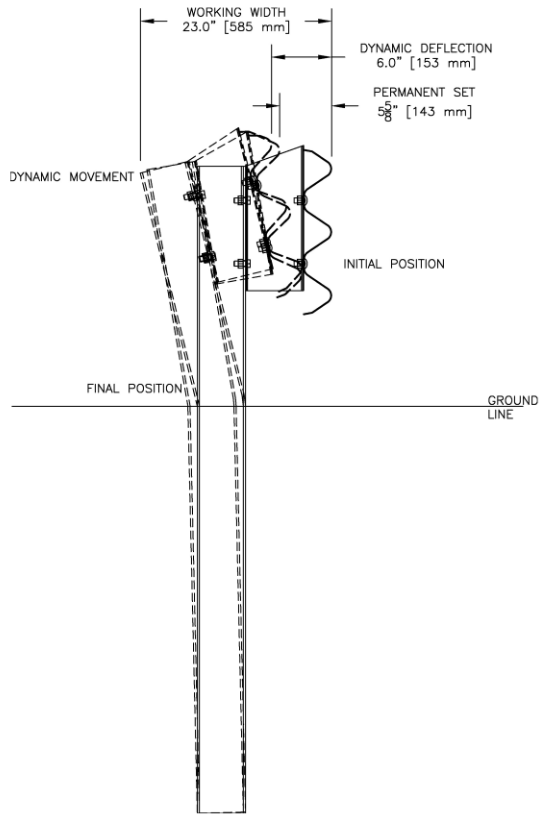


Figure 43. Maximum Dynamic Deflection and Working Width, Test No. AGTB-1

5.5 Vehicle Damage

The majority of damage was concentrated on the left-front corner and left side of the vehicle where the impact occurred, as shown in Figures 44 and 45. Both the left-front and left-rear wheels had disengaged. The left side of the bumper was crushed inward and back. The left-front fender was pushed upward near the door panel and was dented and gouged behind the left-front wheel. The right upper control arm, upright, and brake disk were deformed. The left-side headlight and foglight were disengaged from the vehicle. The left side of the radiator was pushed backward. Denting and scraping were observed on the entire left side. The left-front door was separated from the vehicle body approximately 9½ in. at the top, and the top of the left-rear door was separated by 1½ inches. Both doors remained latched. The left side of the rear bumper was dented, crushed downward, and scuffed. The lower-right side of the windshield had spider-web cracking extending 15 in. wide and 21 in. tall. The grille was cracked and had a maximum separation of 4 in. from the hood. The roof had some minor denting with the largest being ¼ in. deep.

There were significant deformations to the vehicle floorpan and side door. The floorpan was buckled behind the left-front tire and along the transmission tunnel. The maximum occupant compartment deformations are shown in Figure 46 and listed in Table 5 along with the deformation limits established in MASH 2009 for various areas of the occupant compartment. None of the MASH 2009 established deformation limits were violated. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix D. Note, the occupant compartment deformations in Appendix D are shown in local X, Y, and Z, components and not as resultant deformations or inward crush.

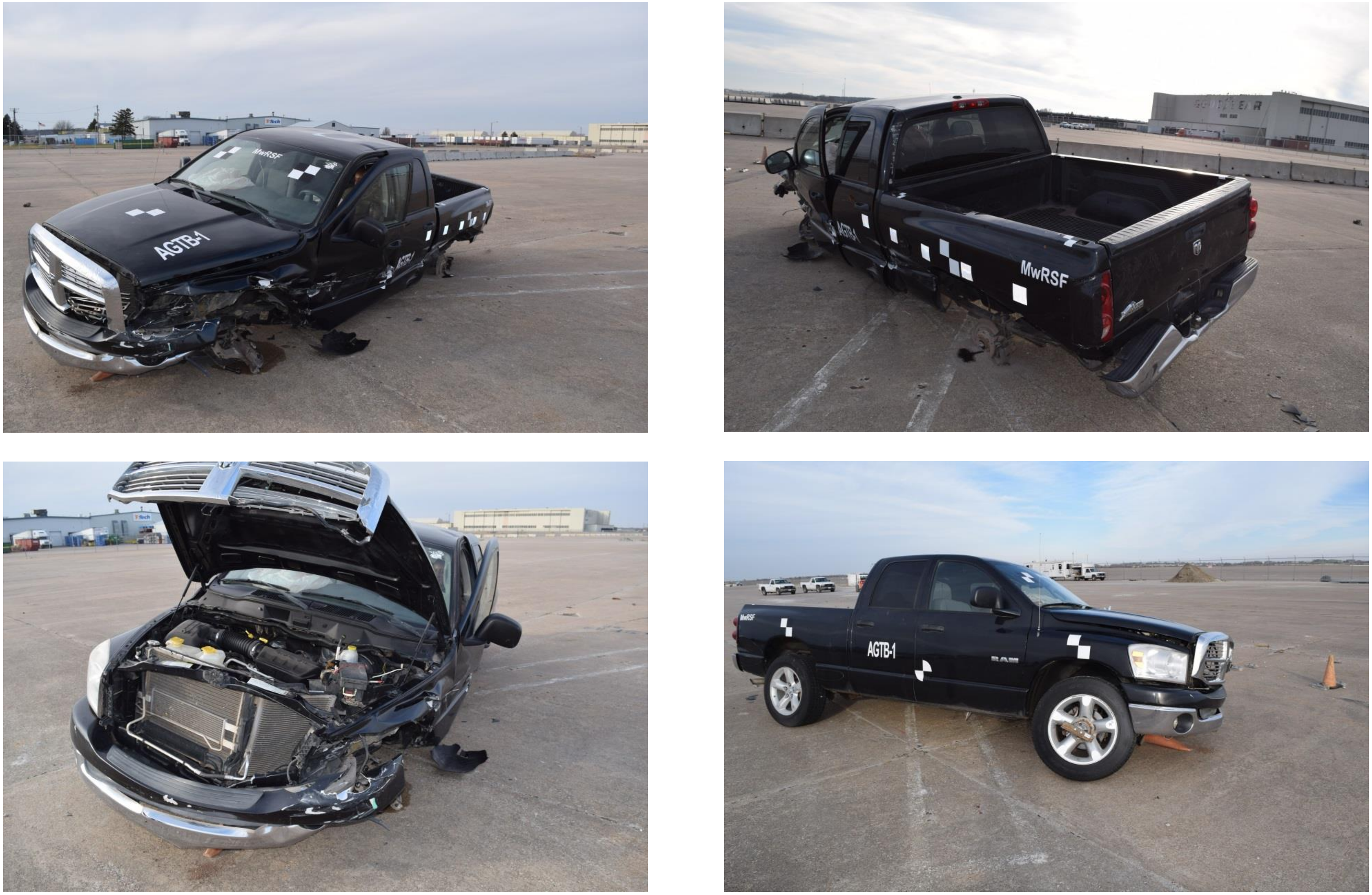


Figure 44. Vehicle Damage, Test No. AGTB-1

Figure 45. Vehicle Damage, Test No. AGTB-1

Figure 46. Vehicle Occupant Compartment Damage, Test No. AGTB-1

Table 5. Maximum Occupant Compartment Deformations by Location

LOCATION	MAXIMUM DEFORMATION in.	MASH ALLOWABLE DEFORMATION in.
Wheel Well & Toe Pan	4¼	≤ 9
Floor Pan & Transmission Tunnel	3⅜	≤ 12
Side Front Panel (in Front of A-Pillar)	3¾	≤ 12
Side Door (Above Seat)	3⅞	≤ 9
Side Door (Below Seat)	3	≤ 12
Roof	1	≤ 4
Windshield	0	≤ 3
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	⅜	N/A

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 are shown in Table 6. Note that the longitudinal ORA exceeded the MASH limit of 20.49 g. It was believed that deformations of the floorpan and mounting bracket that were supporting the accelerometers may have contributed to this unexpectedly high ORA value, as discussed in the following section. The calculated THIV, PHD, and ASI values are also shown in Table 6. Results of the occupant risk analysis are also summarized in Figure 47. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix E.

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

Evaluation Criteria		**Transducer**		**MASH 2009 Limits**
		SLICE-1	**SLICE-2 (primary)**	
OIV (ft/s)	Longitudinal	-22.83	-22.70	±40
	Lateral	28.87	27.68	±40
ORA (g's)	Longitudinal	-29.22	-30.03	±20.49
	Lateral	7.01	9.96	±20.49
MAXIMUM ANGULAR DISPLACEMENT (deg.)	Roll	-32.73	-27.27	±75
	Pitch	-7.20	-10.55	±75
	Yaw	58.46	58.62	not required
THIV (ft/s)		35.03	35.44	not required
PHD (g's)		29.42	30.34	not required
ASI		1.75	1.68	not required

5.7 Discussion

The analysis of the results for test no. AGTB-1 showed that the system adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix E, were deemed acceptable because they did not adversely influence occupant risk nor cause rollover. After impact, the vehicle exited the barrier at an angle of 4.1 degrees, and its trajectory did not violate the bounds of the exit box. While the OIVs fell within MASH acceptable ranges, the longitudinal ORA was -30.0 g's, which exceeded the 20.49 g MASH limit. Therefore, test no. AGTB-1 was determined to be unacceptable according to the MASH safety performance criteria for test designation no. 3-21.

The longitudinal ORA was surprisingly high, as longitudinal ORAs of this magnitude had not been previously observed in oblique-angle MASH crash tests, and there was no indication from the test videos, barrier damage, or vehicle damage that vehicle decelerations were excessive. While there was some vehicle and tire snag on the tapered portions of the buttress, it did not appear to be significant enough to cause accelerations of this magnitude. Review of the crash-tested vehicle revealed significant deformations to the floorpan and shifting of the seat frame. Unfortunately, the onboard data recorders were positioned on a mounting bracket which was attached to the seat frame. Thus, if the seat frame displaced during the test, the measured accelerations would apply only to the local acceleration of the seat frame and would not be representative of the vehicle as a whole. On-board video cameras showed significant and sudden movement of the seats, beginning approximately 100 ms into the impact event, which occurred at the same time as the large deceleration spike in the data. Additionally, there was a 17-g positive spike in the 10-ms average longitudinal acceleration following the -30-g spike, as shown in Appendix E, which corresponded to a 4.5-mph increase in vehicle velocity. Since the vehicle did not experience an increase in velocity during redirection, this provided further evidence that the acceleration data was compromised by the shifting seat frame and accelerometer mounting bracket. Thus, the accelerometer data was believed to be in error.

Although this large deceleration spike and resulting longitudinal ORA seemed unrealistic and was likely magnified by movement of the accelerometers relative to the vehicle, the actual ORA values for test no. AGTB-1 could not be obtained. Therefore, the test was determined to be a failure according to MASH evaluation criteria due to excessive longitudinal ORA.

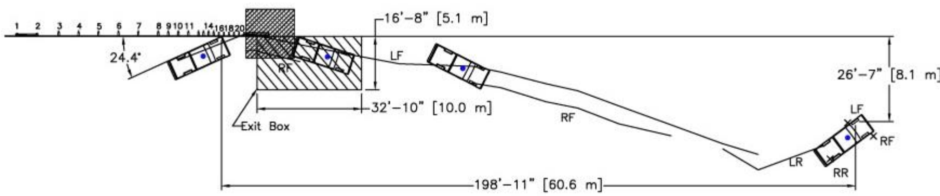
0.000 sec

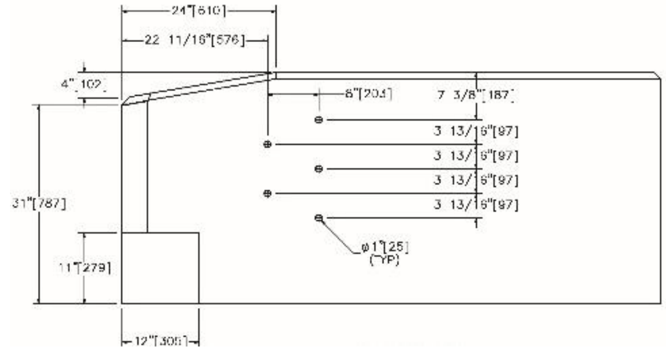
0.034 sec

0.148 sec

0.326 sec

0.526 sec





- Test Agency .... MwRSF
- Test Number AGTB-1
- Date 12/22/2015
- MASH Test Designation No. 3-21
- Test Article .... Standardized Buttress for AGT
- Total Length .... 980$^{5}/_{16}$ in.
- Key Components – Guardrail AGT
  - Nested Thrie beam .... 12 gauge
  - Asymmetric W-to-Thrie Transition Segment .... 10 gauge
  - Thrie Beam Terminal Connector .... 10 gauge
  - Concrete Buttress (*l* x *w* x *h*) .... 84 x 12 x 36 in.
- Soil Type .... Coarse Crushed Limestone
- Vehicle Make /Model .... 2008 Dodge Ram 1500
  - Curb .... 5,025 lb
  - Test Inertial .... 5,039 lb
  - Gross Static .... 5,199 lb
- Impact Conditions
  - Speed .... 61.9 mph
  - Angle .... 24.4 deg.
  - Impact Location .... 80½ in. upstream from the concrete buttress
- Impact Severity (IS) .... 110.4 kip-ft > 106 kip-ft Limit from MASH
- Exit Conditions
  - Speed .... 41.3 mph
  - Angle .... -4.1 deg.
- Exit Box Criterion .... Pass
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 198 ft – 11 in.
- Vehicle Damage .... Moderate
  - VDS [47] 11-LFQ-5
  - CDC [48] 11-LFME-3
  - Maximum Interior Deformation .... 4¼ in.
- Test Article Damage .... Minimal
- Maximum Test Article Deflections
  - Permanent Set .... 5⅝ in.
  - Dynamic .... 6.0 in.
  - Working Width .... 23.0 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH Limit
		SLICE-1	SLICE-2 (primary)	
OIV (ft/s)	Longitudinal	-22.83	-22.70	±40
	Lateral	28.87	27.68	±40
ORA (g's)	Longitudinal	-29.22	-30.03	±20.49
	Lateral	7.01	9.96	±20.49
MAXIMUM ANGULAR DISP. (deg.)	Roll	-32.73	-27.27	±75
	Pitch	-7.20	-10.55	±75
	Yaw	58.46	58.62	Not required
THIV (ft/s)		35.03	35.44	Not required
PHD (g's)		29.42	30.34	Not required
ASI		1.75	1.68	Not required

Figure 47. Summary of Test Results and Sequential Photographs, Test No. AGTB-1

6 FINAL DESIGN DETAILS

6.1 Buttress Redesign

Upon the failure experienced during test no. AGTB-1, the buttress was redesigned to reduce the amount of vehicle and tire snag. The dual-taper design and reinforcement pattern of the buttress was maintained, but small changes were made to the tapers on the front edge of the buttress. To reduce the severity of tire snag below the rail, the slope of the lower taper was reduced from a 3:1 slope to a 4:1 slope. Additionally, the lateral offset of the lower taper was increased by ½ in. to 4½ inches. The height of the lower taper increased to 14 in. to reduce the vehicle snag on the lower portion of the upper taper. The 14-in. height also corresponded to the height to the bottom of the transition blockouts. Thus, the lower taper measured 4½ in. deep x 18 in. long x 14 in. high.

High-speed video from test no. AGTB-1 showed that the pickup truck bumper and front corner were not at risk of impacting the front face of the buttress. However, a reduction to the slope of the upper taper may reduce snag on the taper itself. Thus, the lateral extent of the upper taper was reduced from 4 in. to 3 inches. The upper taper now measured 3 in. deep x 4 in. long x 18 in. tall.

6.2 Design Details for Test No. AGTB-2

The test installation for test no. AGTB-2 was nearly identical to the previous system evaluated during test no. AGTB-1. The only differences between the two barrier systems were the dimensions of the dual tapers located on the upstream edge of the concrete transition buttress. The lower taper had a 4:1 slope and measured 4½ in. deep x 18 in. long x 14 in. high, while the upper taper measured 3 in. deep x 4 in. long x 18 in. tall.

The test installation for test no. AGTB-2 was approximately 82 ft long and consisted of four main components: (1) a concrete transition buttress, (2) a thrie beam AGT, (3) standard MGS, and (4) a guardrail anchorage system. Design details for test no. AGBT-2 are shown in Figures 48 through 70. To test a worse-case scenario and increase the risk of wheel snag, a curb was not installed. Photographs of the test installations are shown in Figure 71. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix A.

The downstream end of the installation consisted of the standardized concrete buttress. The buttress was 7 ft long and 36 in. tall, corresponding to a typical height for MASH TL-4 concrete barriers. To prevent vehicle snag above the thrie beam rail, the upstream end of the buttress was 32 in. tall and incorporated a 4-in. tall by 24-in. long slope to bring the barrier height up to 36 in. The buttress utilized a dual-tapered, or dual-chamfer, design along its front edge, as detailed in Figure 61. The lower taper measured 4½ in. deep x 18 in. long x 14 in. tall and was designed to reduce wheel snagging on the parapet. The upper taper measured 3 in. x 4 in. and extended from the lower taper to the top of the buttress. The upper taper was designed to limit vehicle snag on the buttress, to prevent the rail from bending around a rigid corner, and to limit the unsupported span length of the rail upstream from the buttress.

The thrie beam AGT and adjacent MGS consisted of 12.5 ft of nested 12-ga. thrie beam, 6.25 ft of single ply 12-gauge thrie beam, a 6.25-ft long 10-gauge asymmetric W-to-thrie transition rail segment, and 50 ft of 12-gauge W-beam. All rail segments were mounted with a top height of

31 inches. The first six posts adjacent to the buttress were 6.5-ft long W6x8.5 posts spaced at 18¾ in. on-center and embedded 49 in. into the soil. Note, the thrie beam rail extended above the tops of these transition posts with the use of chamfered blockouts, as shown in Figures 50 and 57. The remaining steel posts were 6-ft long W6x8.5 posts embedded 40 in. into the soil, utilized 12-in. deep wood blockouts, and were spaced at various intervals, as shown in Figures 48 through 50. All posts were placed within a compacted, crushed limestone soil which satisfied MASH soil standards.

Finally, a guardrail anchorage system typically utilized as a trailing-end terminal was utilized to anchor the upstream end of the test installation. The guardrail 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 BCT system. The guardrail anchorage system has been MASH TL-3 crash tested as a downstream, trailing-end terminal [38-41].

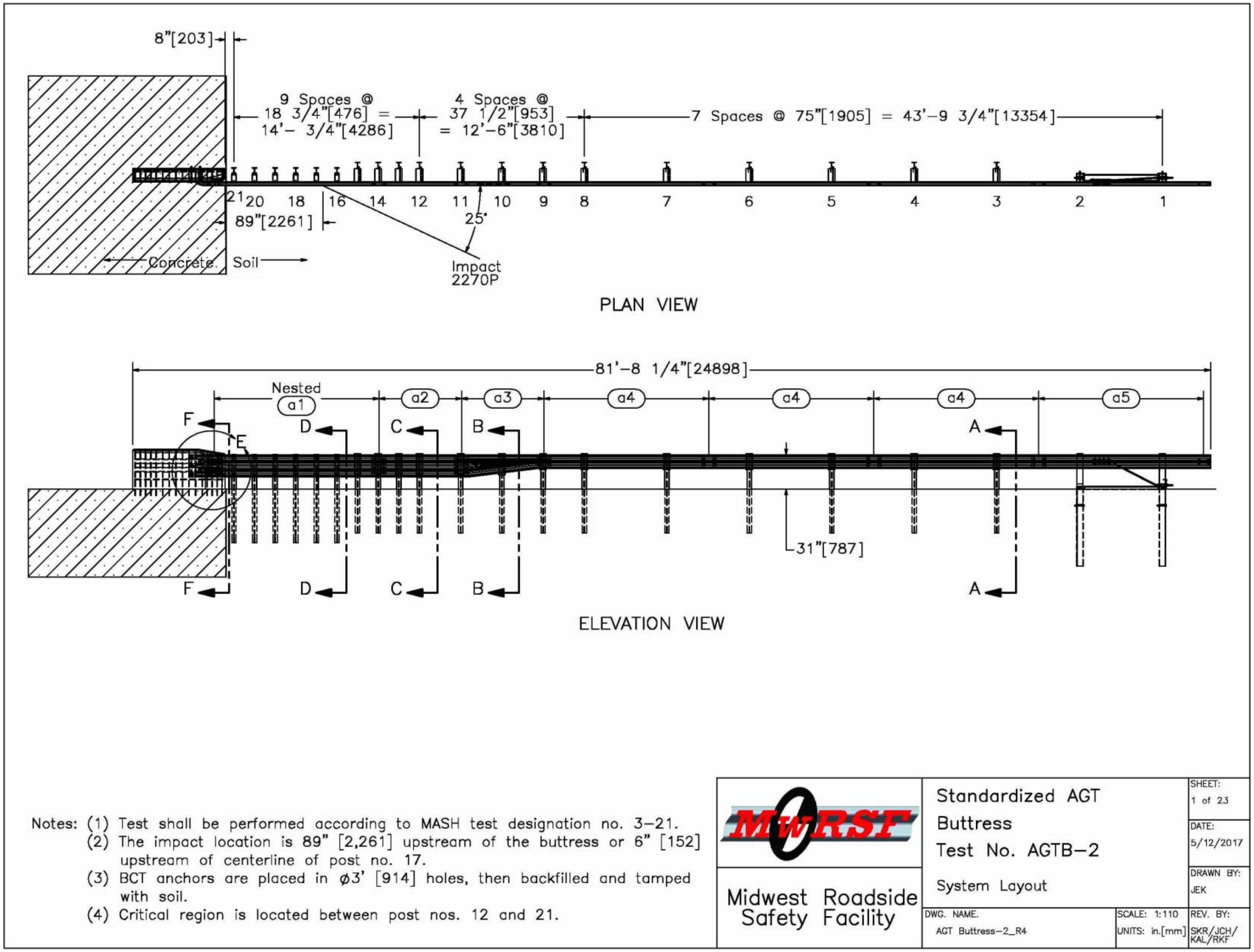


Figure 48. System Layout, Test No. AGTB-2

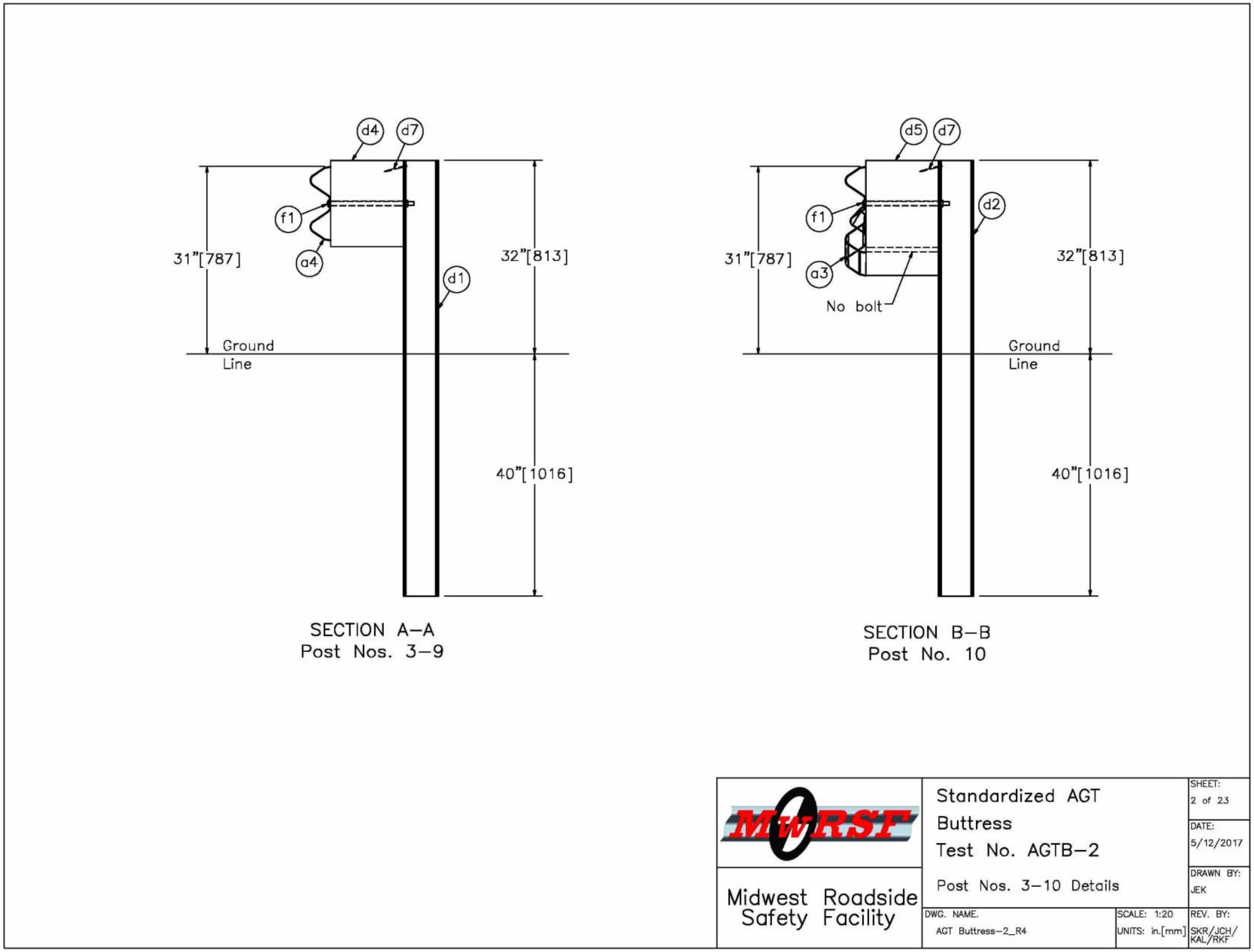


Figure 49. Post Nos. 3 through 10 Details, Test No. AGTB-2

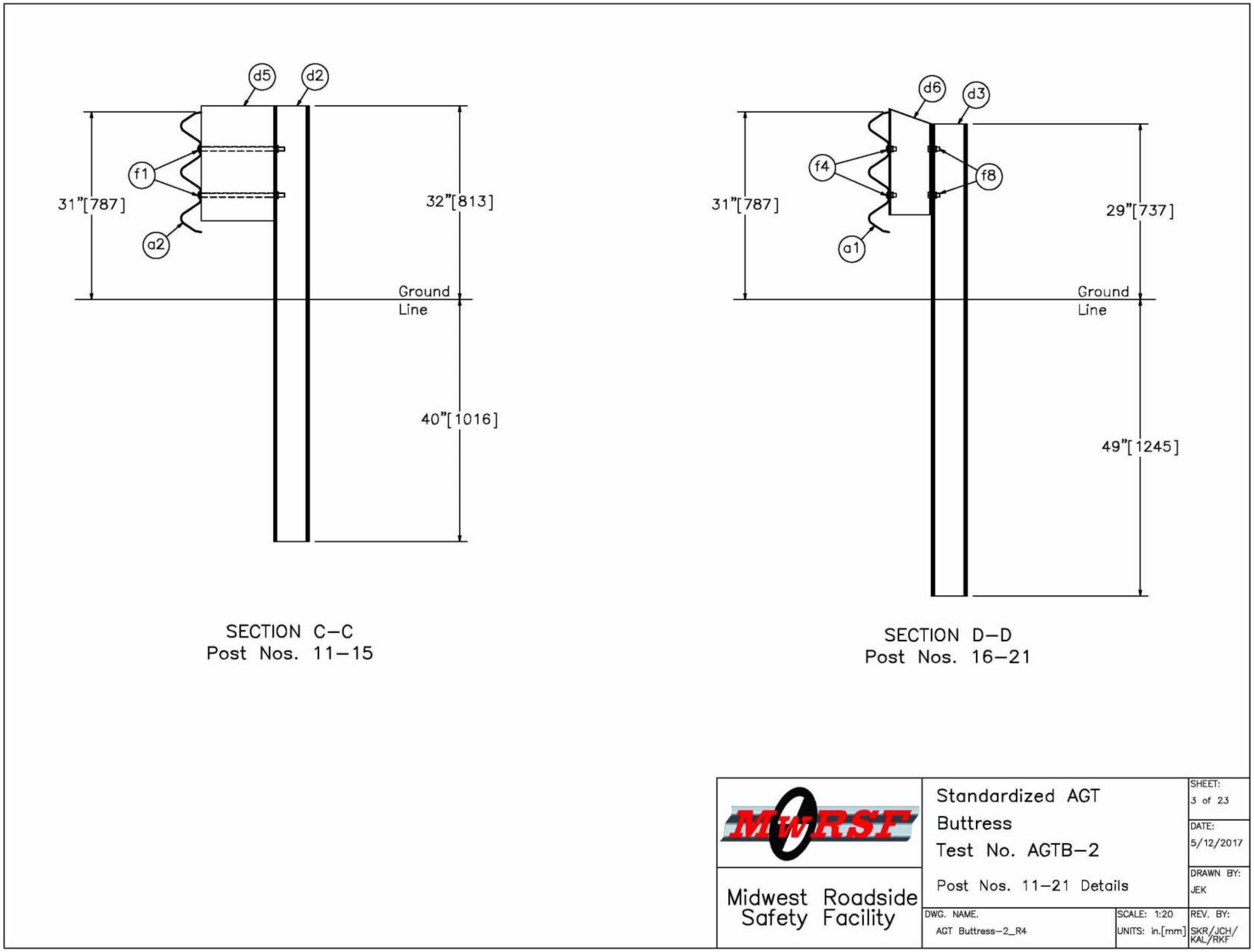
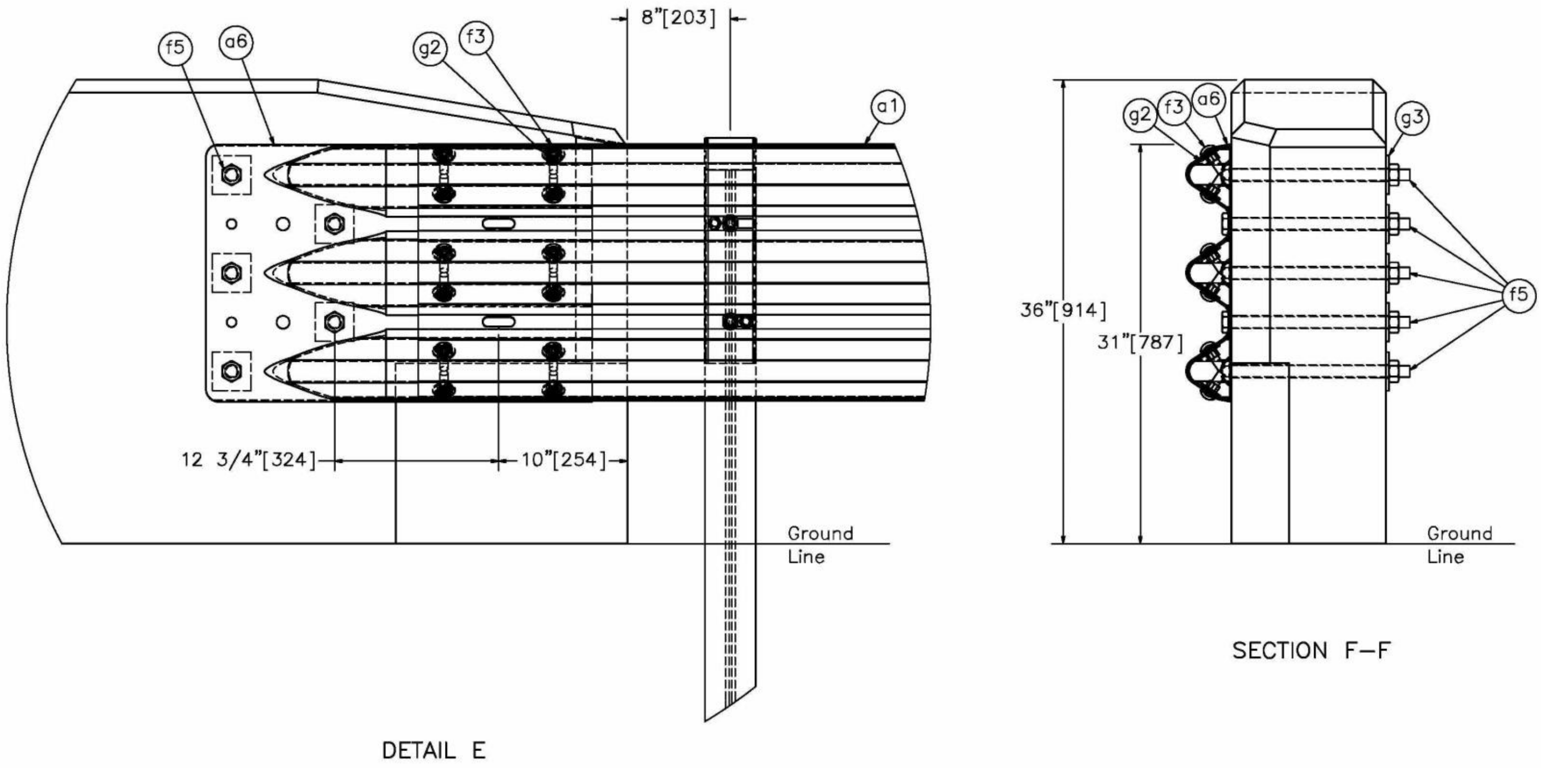


Figure 50. Post Nos. 11 through 21 Details, Test No. AGTB-2



Note: (1) g2 washers placed between nuts and thrie beam end connector.
(2) f4 guardrail bolts may be used in place of f3 guardrail bolts in nested thrie beam splices if the nut can be fully threaded (dependent on thickness of stacked guardrail layers).
(3) Buttress reinforcement hidden for clarity.

Midwest Roadside Safety Facility	Standardized AGT Buttress Test No. AGTB–2	SHEET: 4 of 23
		DATE: 5/12/2017
	Thrie Beam End Shoe and Buttress Details	DRAWN BY: JEK
	DWG. NAME. AGT Buttress–2_R4 / SCALE: 1:12 UNITS: in.[mm]	REV. BY: SKR/JCH/KAL/RKF

Figure 51. Thrie Beam Terminal Connector and Buttress Details, Test No. AGTB-2

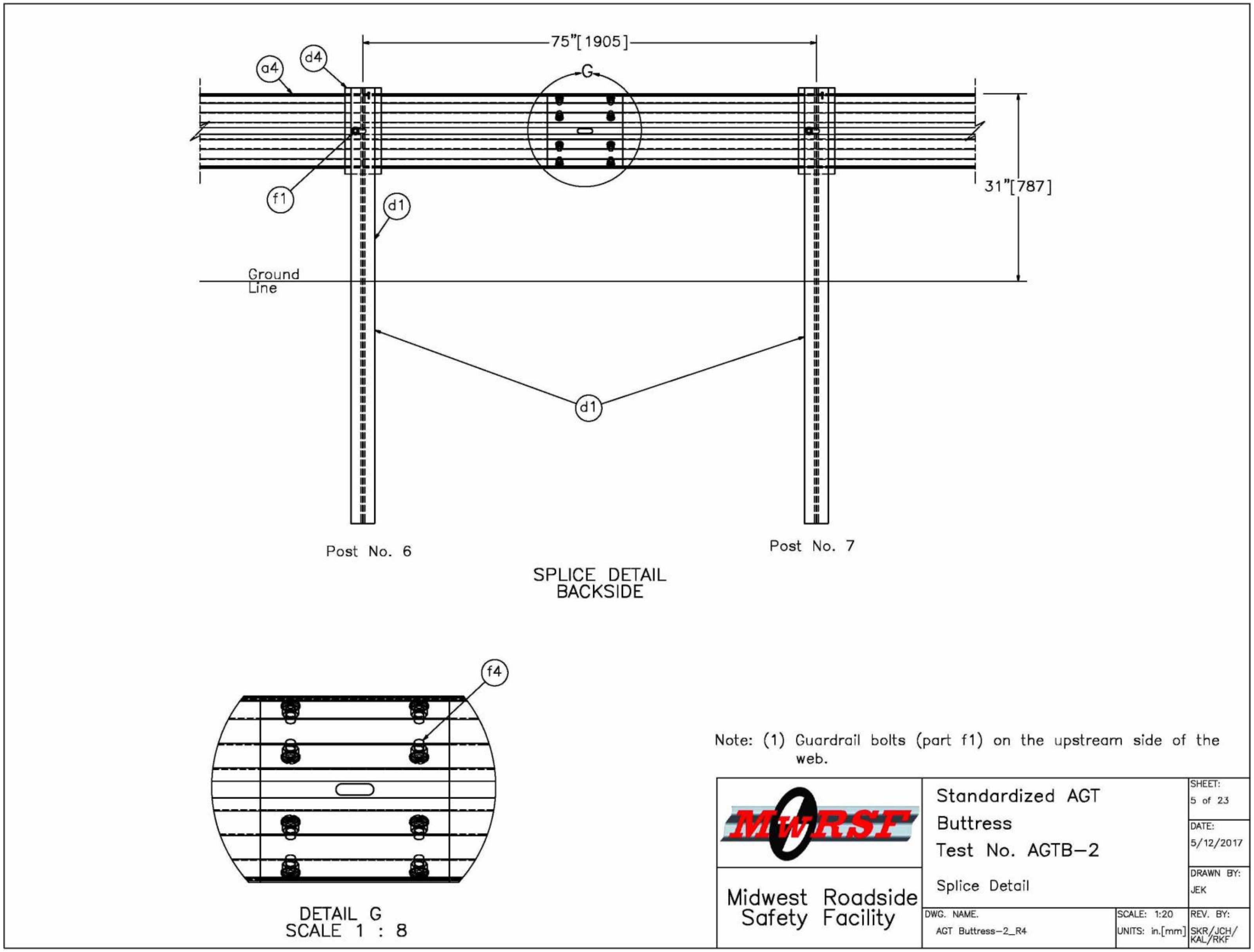


Figure 52. Splice Detail, Test No. AGTB-2

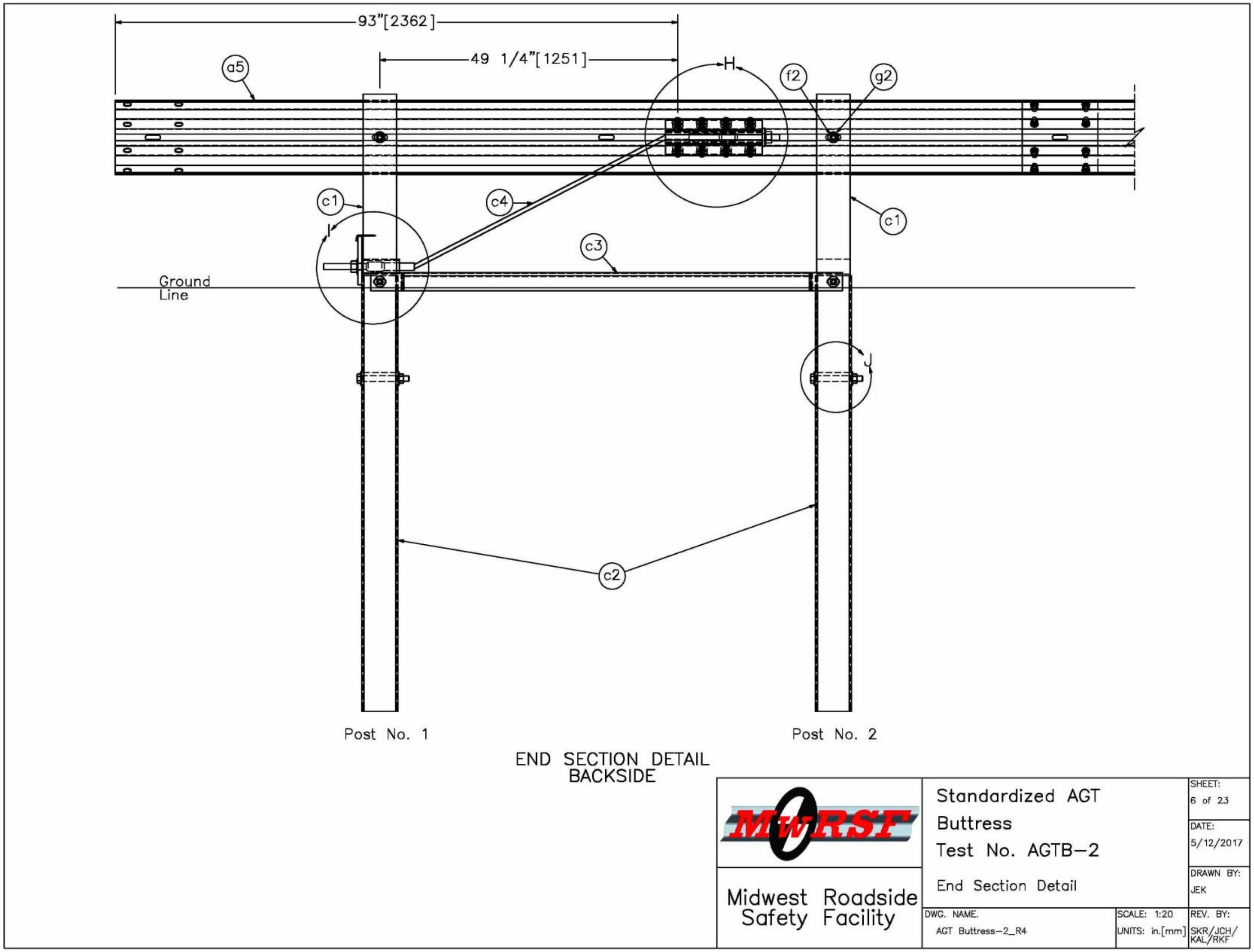


Figure 53. End Section Detail, Test No. AGTB-2

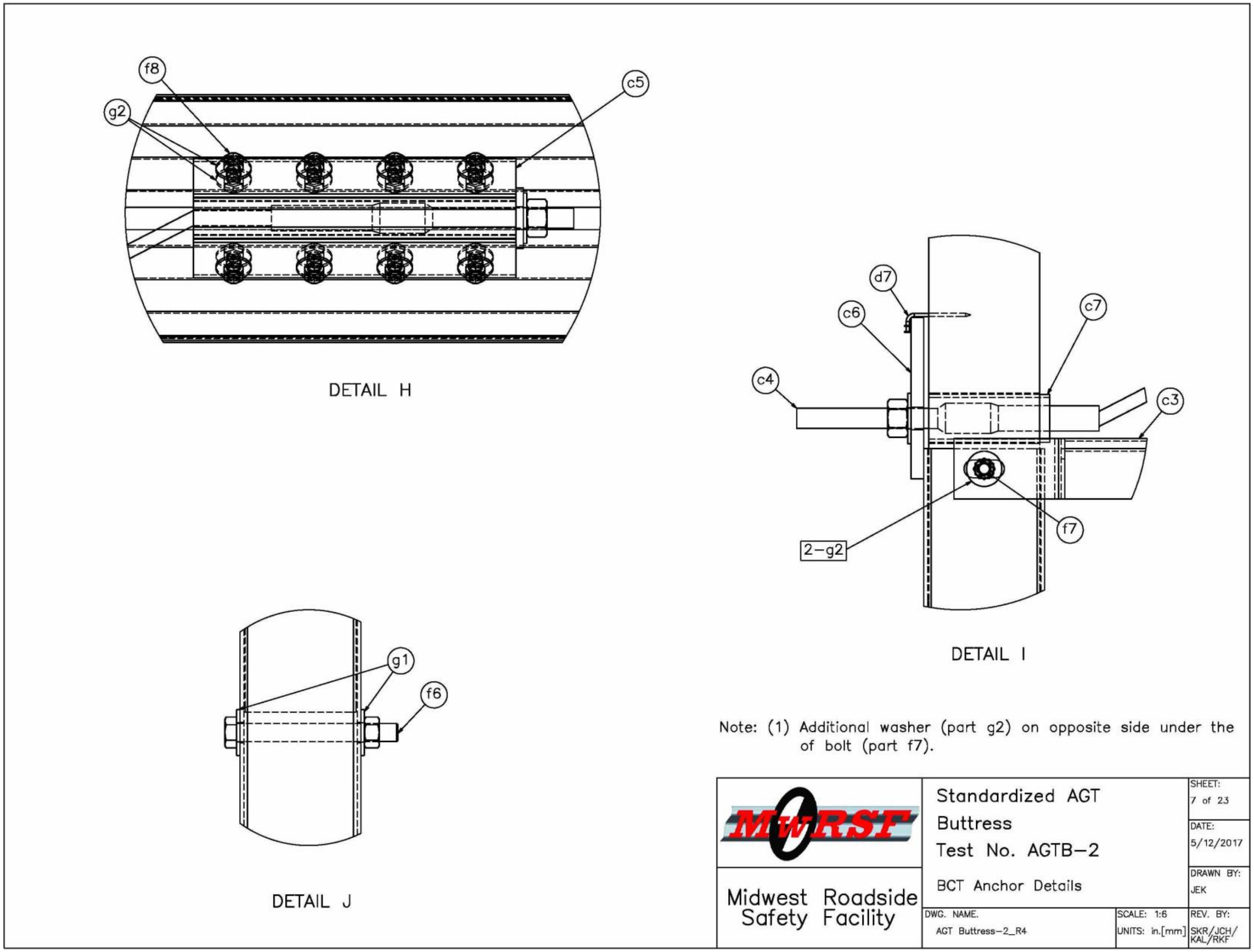


Figure 54. BCT Anchor Details, Test No. AGTB-2

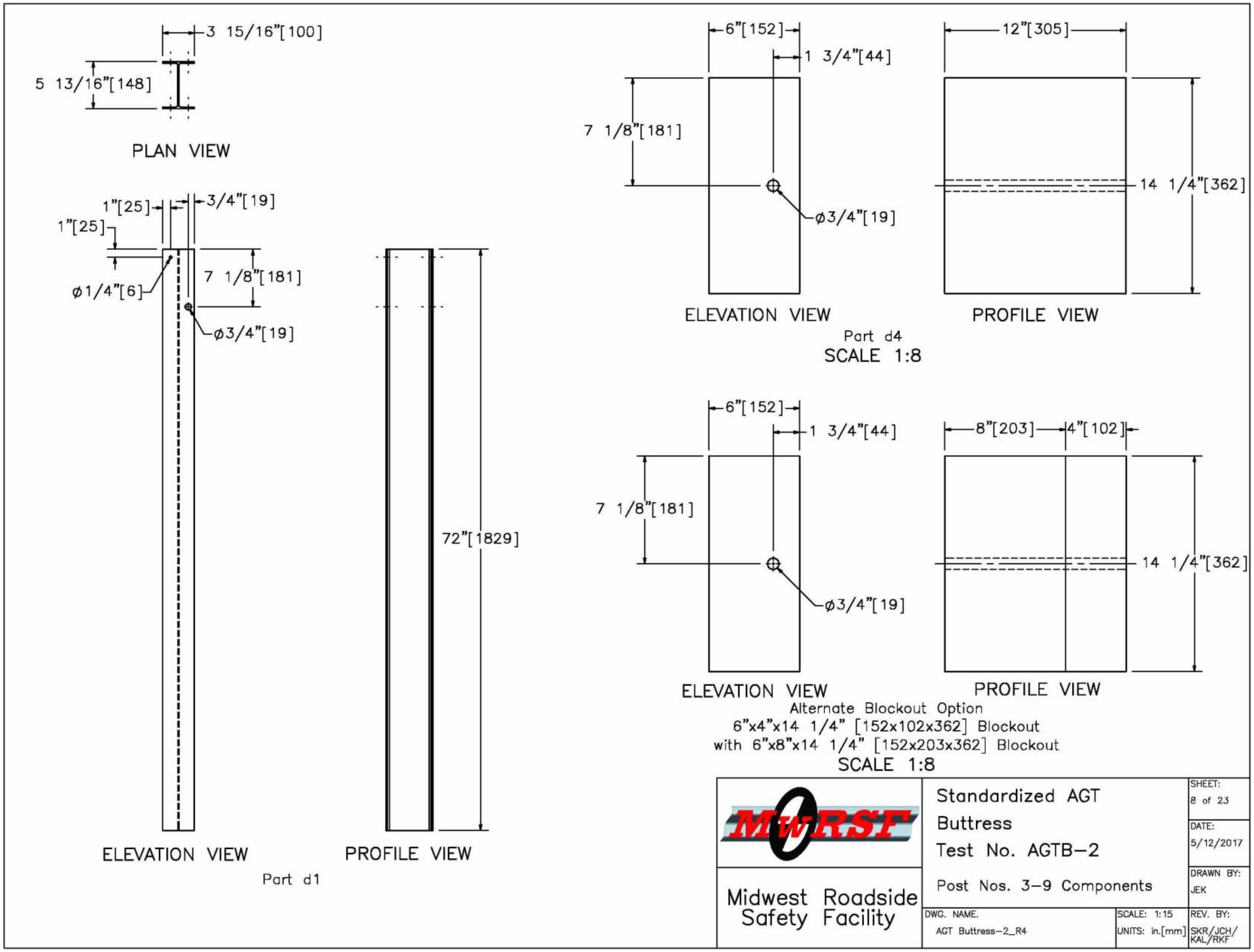


Figure 55. Post Nos. 3 through 9 Components, Test No. AGTB-2

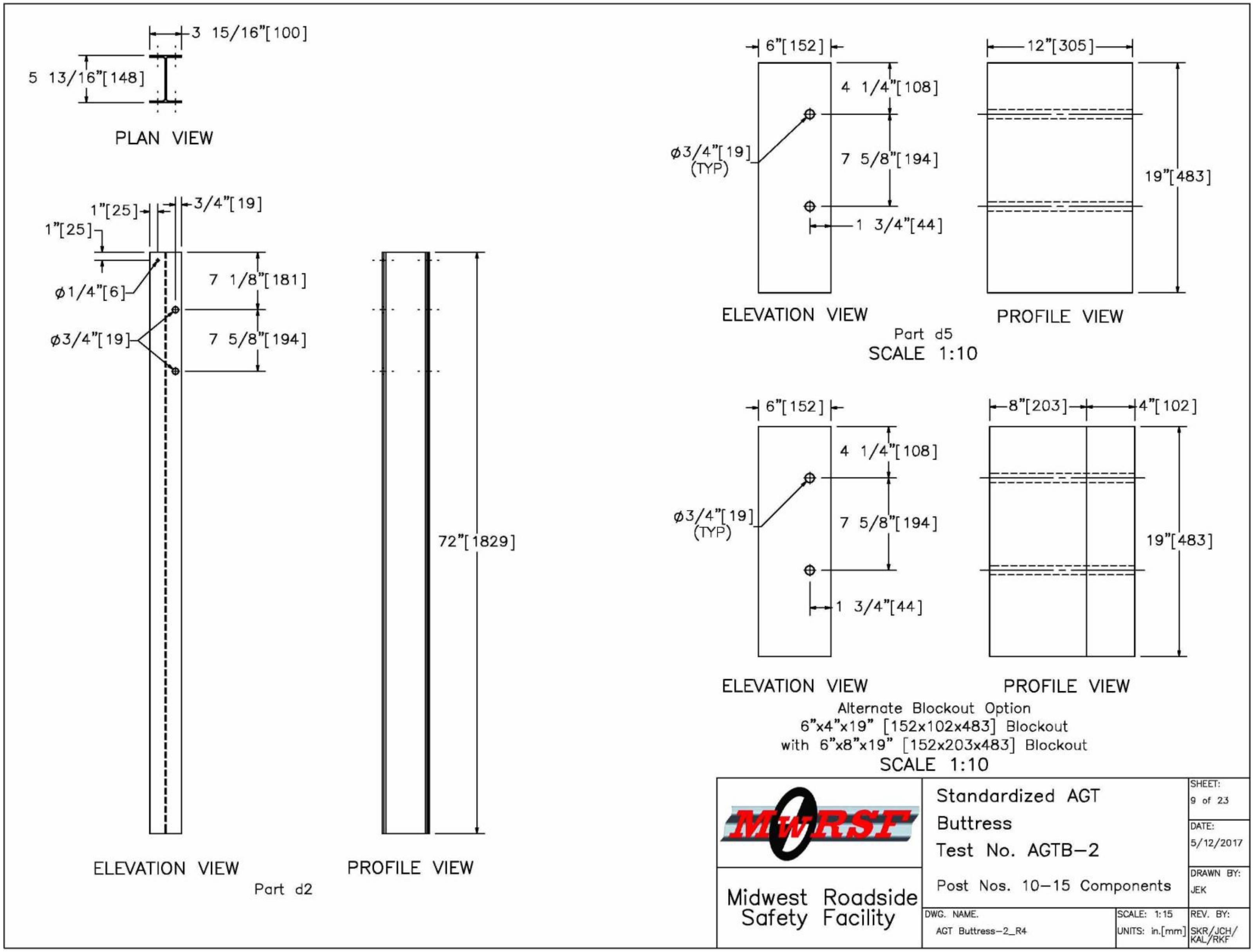


Figure 56. Post Nos. 10 through 15 Components, Test No. AGTB-2

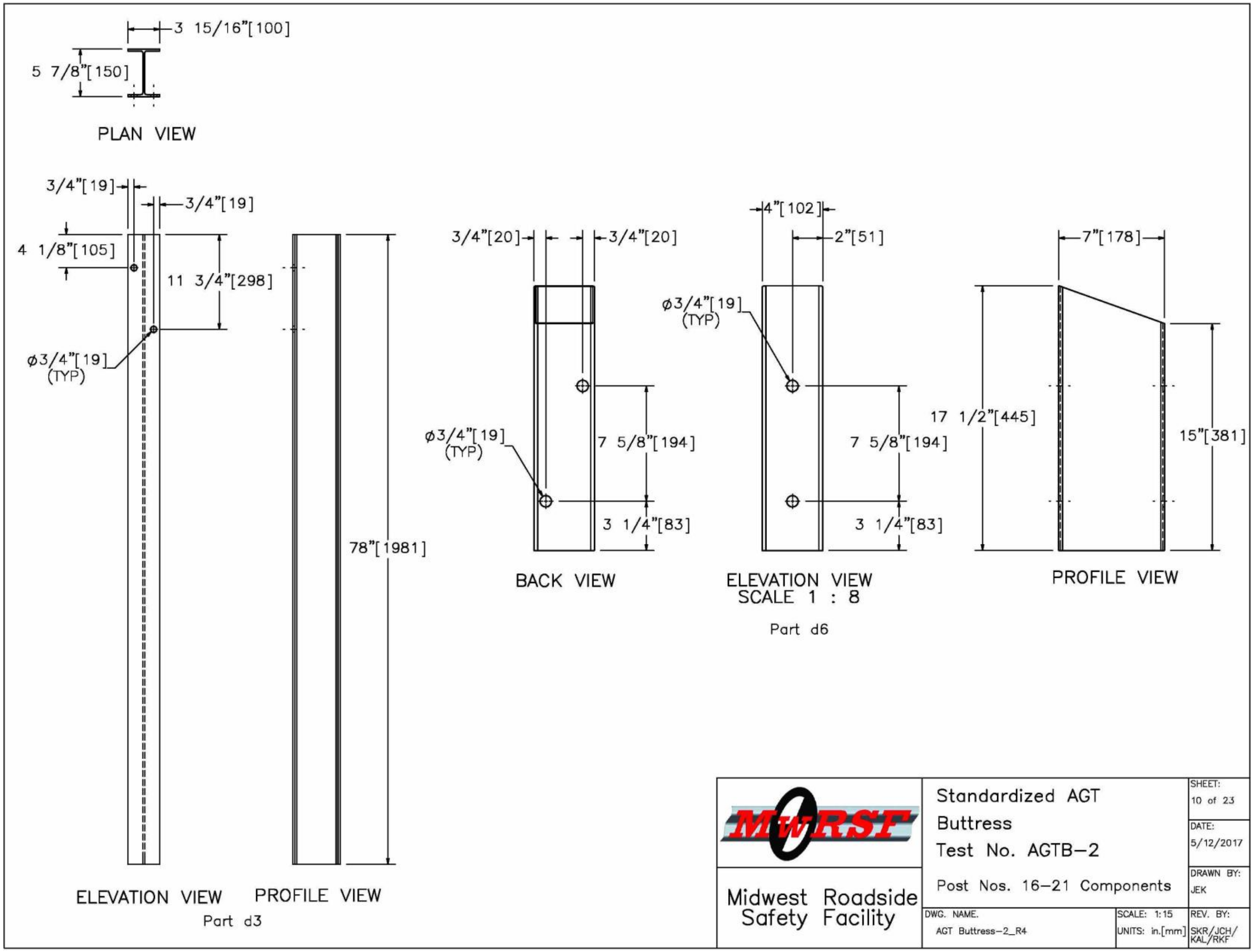


Figure 57. Post Nos. 16 through 21 Components, Test No. AGTB-2

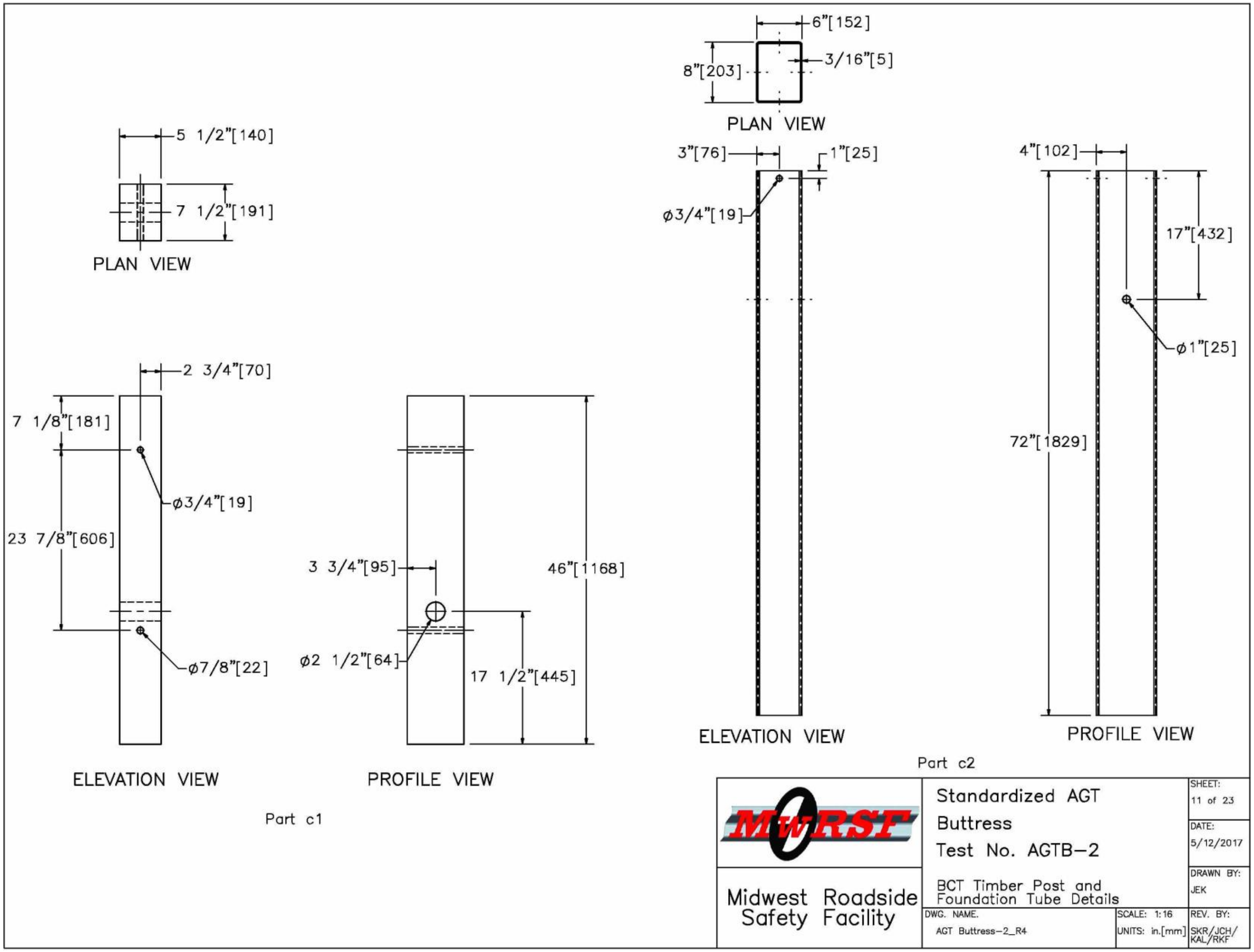


Figure 58. BCT Timber Post and Foundation Tube Details, Test No. AGTB-2

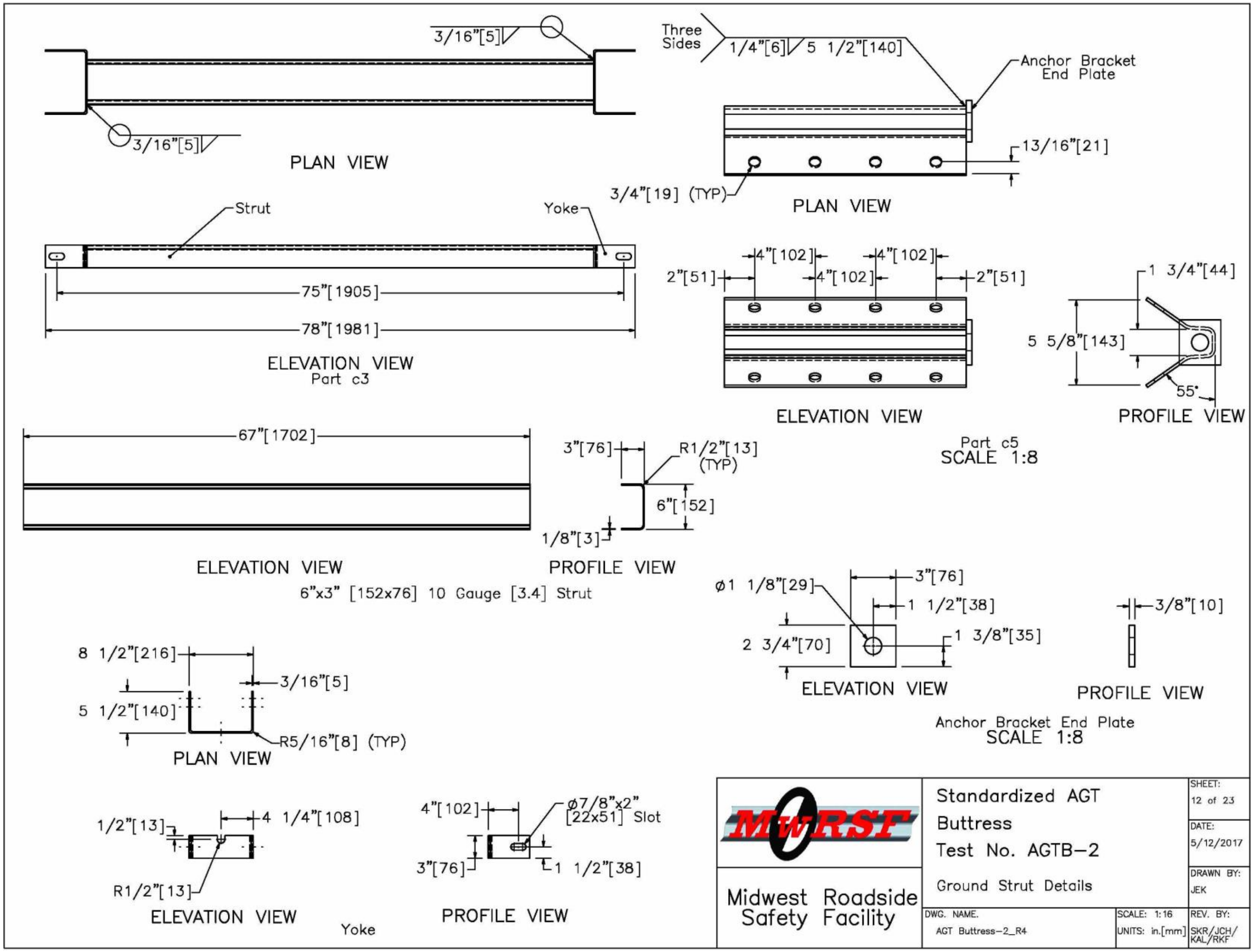


Figure 59. Ground Strut Details, Test No. AGTB-2

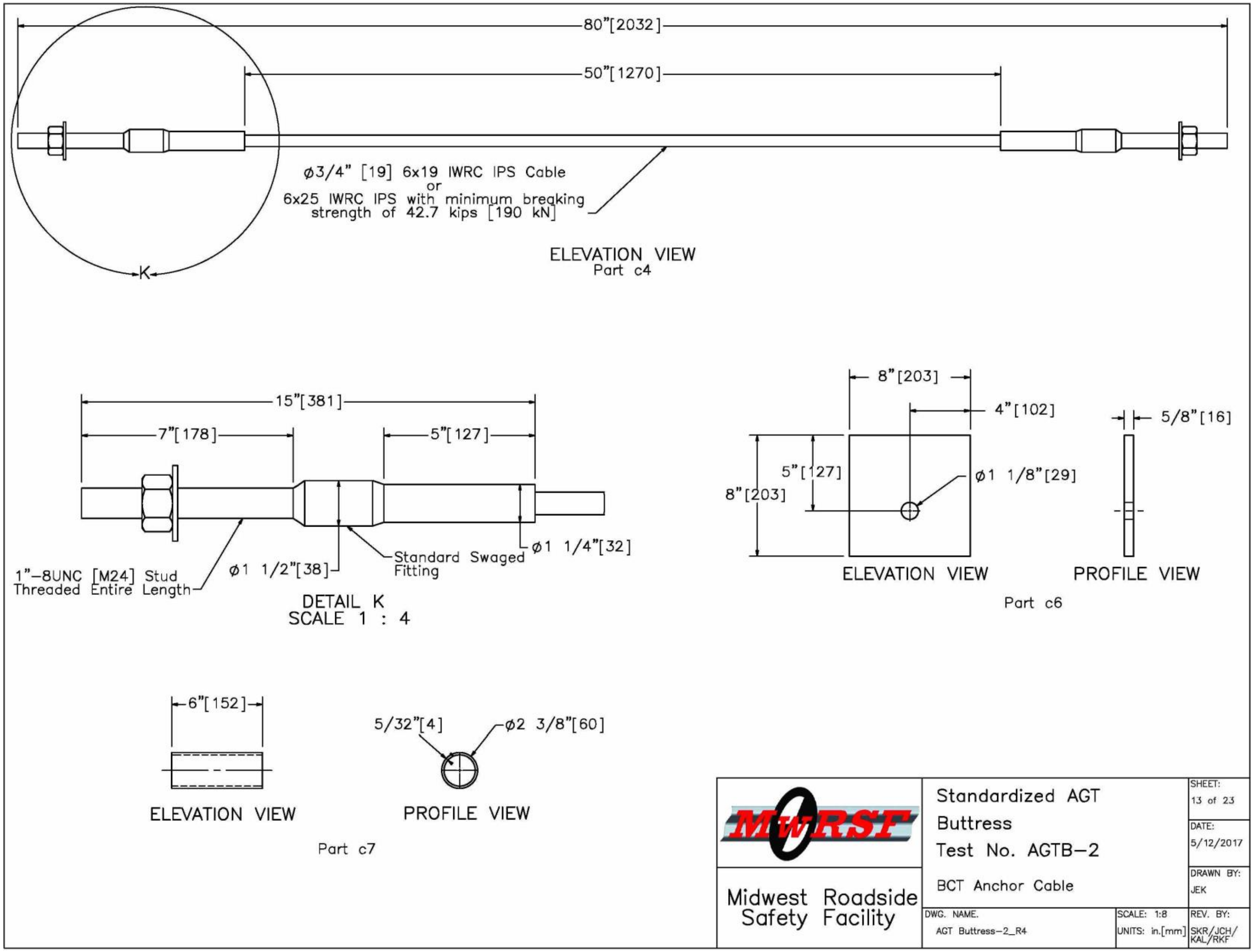
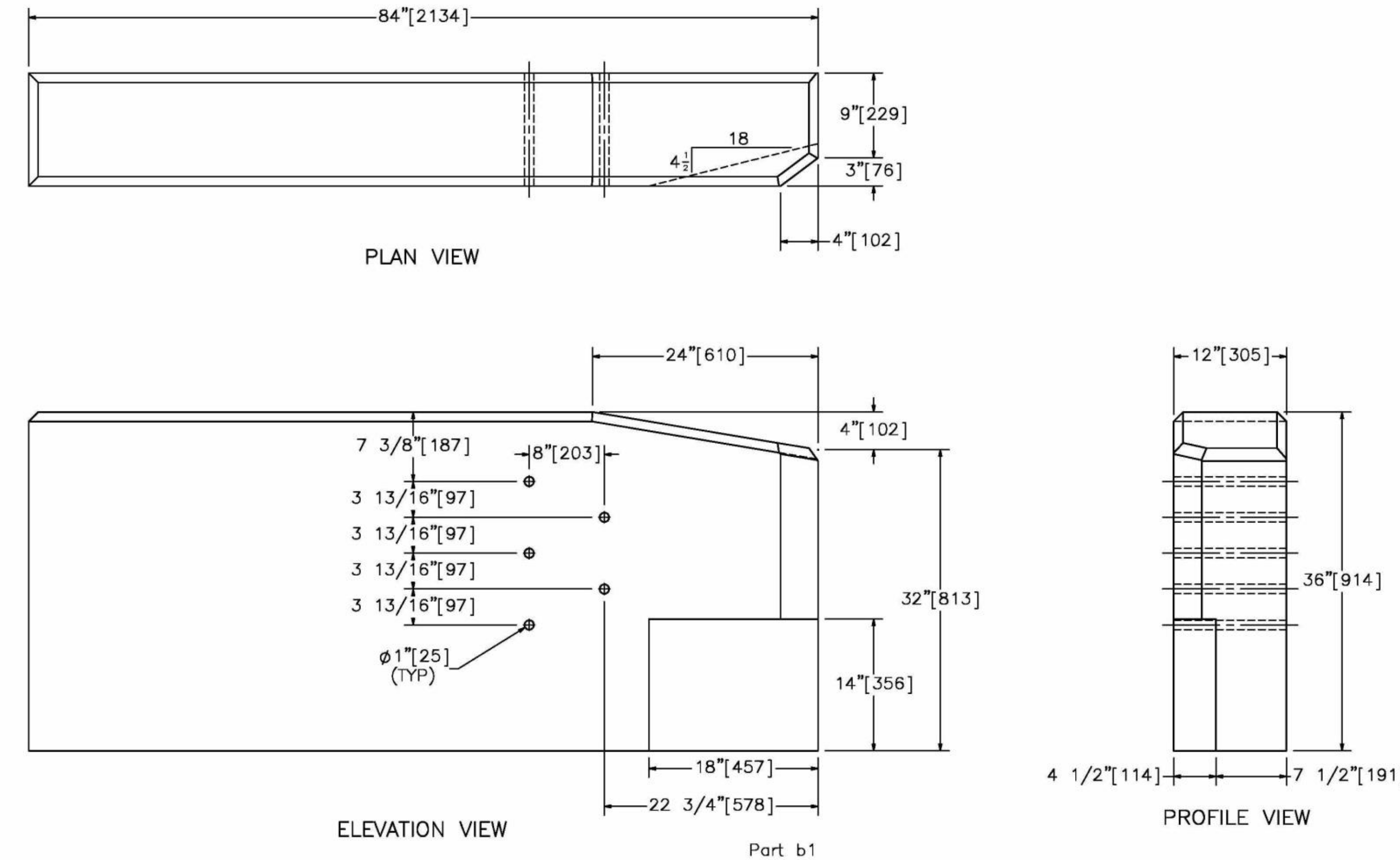


Figure 60. BCT Anchor Cable, Test No. AGTB-2



Note: (1) Lower setback has lateral flare of 1:4.
(2) Five 1" [25] diameter holes are required for placement of 7/8" [22] diameter bolts.
(3) All edges of the top of the buttress are chamfered 1" [25].

MwRSF Midwest Roadside Safety Facility	Standardized AGT Buttress Test No. AGTB-2	SHEET: 14 of 23 DATE: 5/12/2017
	Buttress Details	DRAWN BY: JEK
	DWG. NAME. AGT Buttress-2_R4 · SCALE: 1:15 · UNITS: in.[mm]	REV. BY: SKR/JCH/KAL/RKF

Figure 61. Buttress Details, Test No. AGTB-2

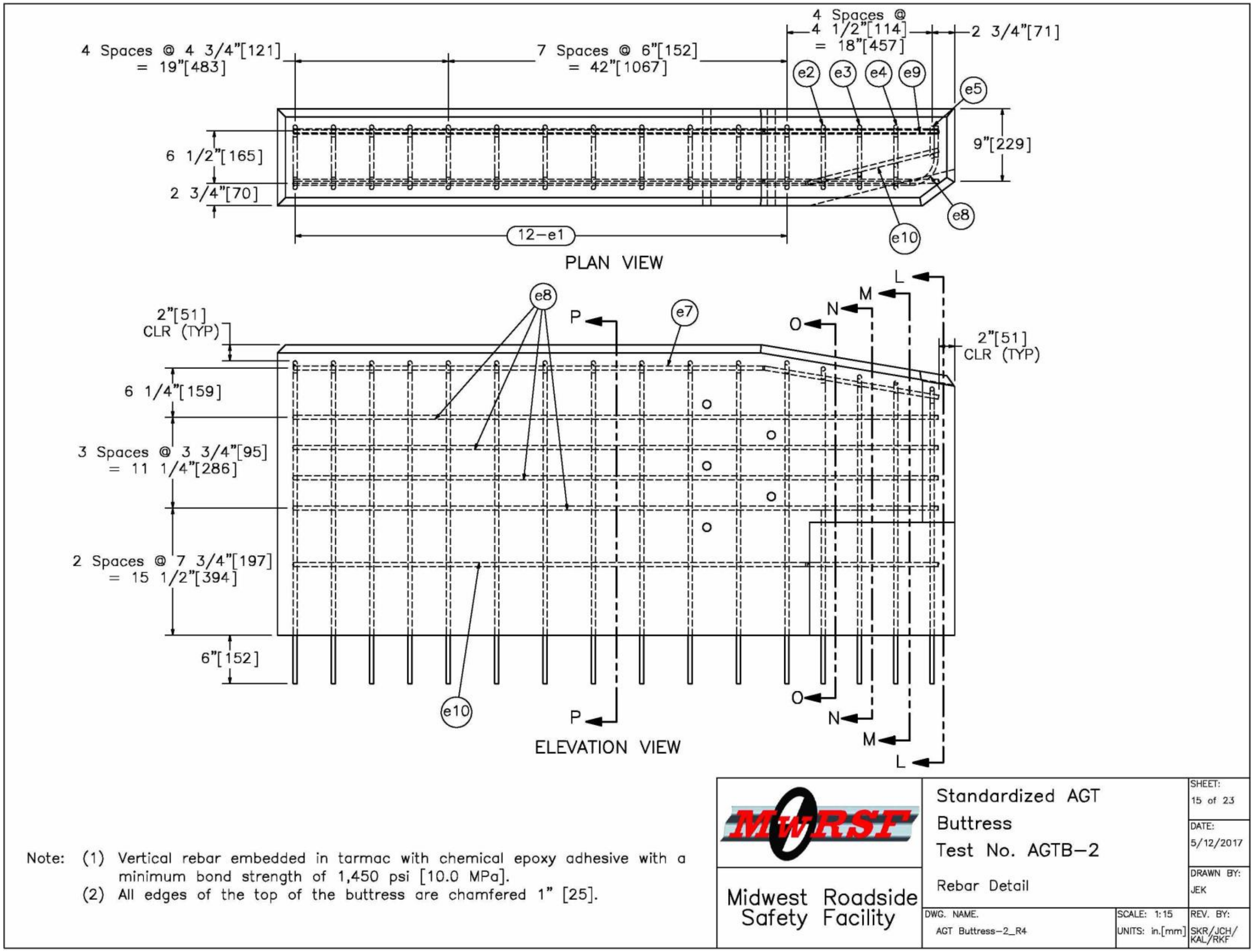


Figure 62. Rebar Detail, Test No. AGTB-2

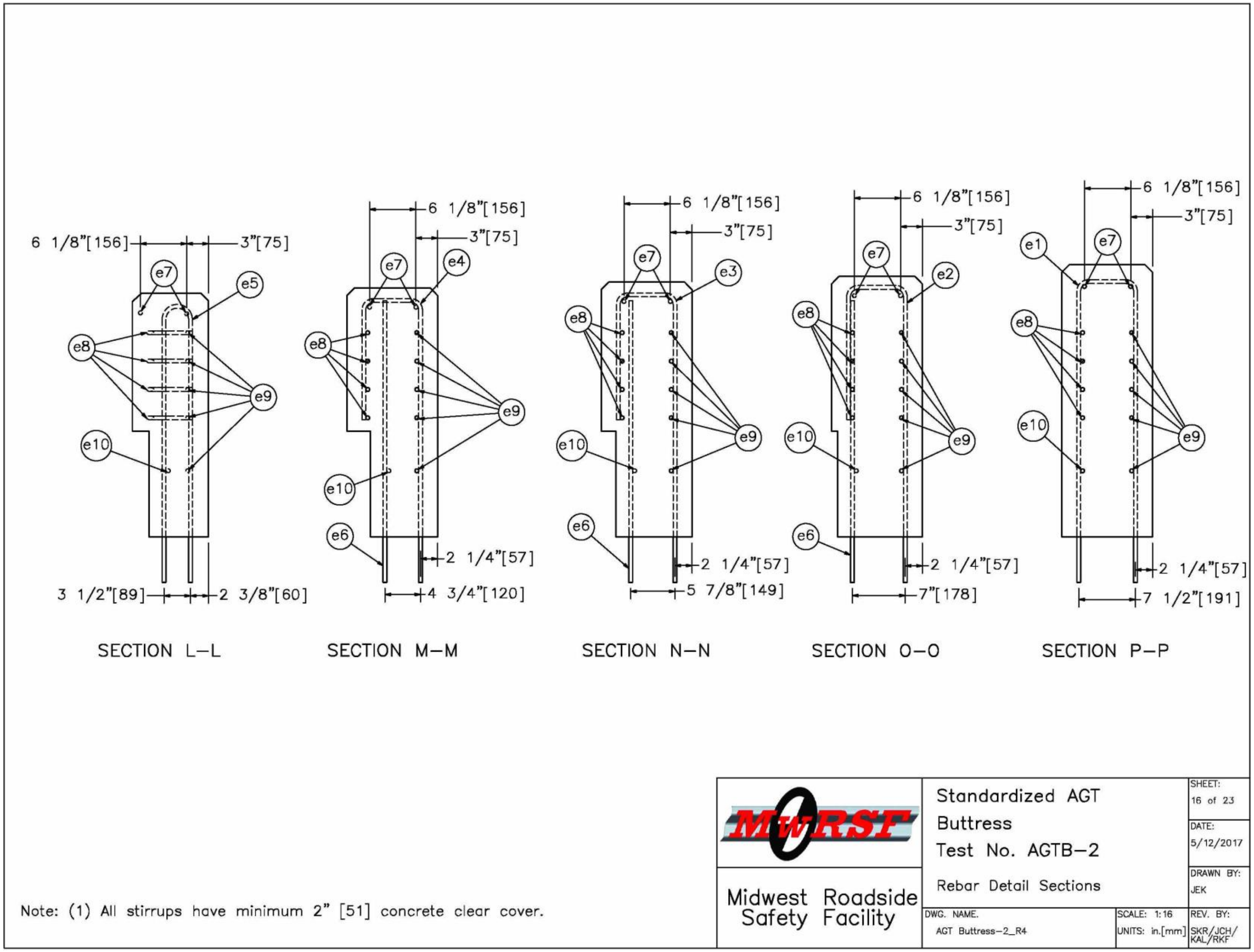
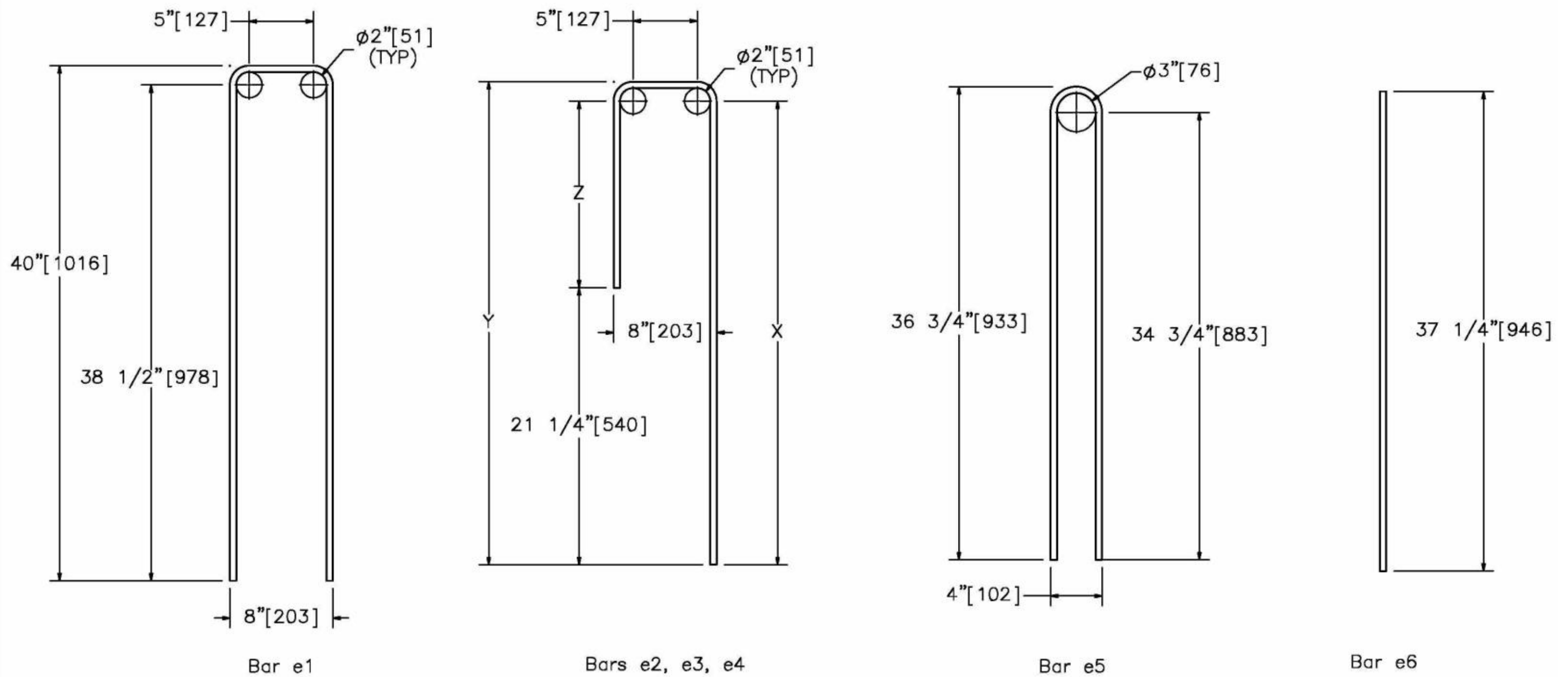


Figure 63. Rebar Detail Sections, Test No. AGTB-2



Bill of Bars

Bar No.	QTY	Size	X	Y	Z	Unbent Length
e1	12	#4	38 1/2" [978]	40" [1,016]	–	86" [2,184]
e2	1	#4	37 1/2" [953]	39" [991]	16 1/4" [413]	62 3/4" [1,594]
e3	1	#4	36 1/2" [927]	38" [965]	15 1/4" [387]	60 1/2" [1,537]
e4	1	#4	35 3/4" [908]	37 1/4" [946]	14 1/2" [368]	59 1/4" [1,505]
e5	1	#4	34 3/4" [883]	36 3/4" [933]	–	74 3/4" [1,899]
e6	3	#4	–	–	–	37 1/4" [946]

MwRSF

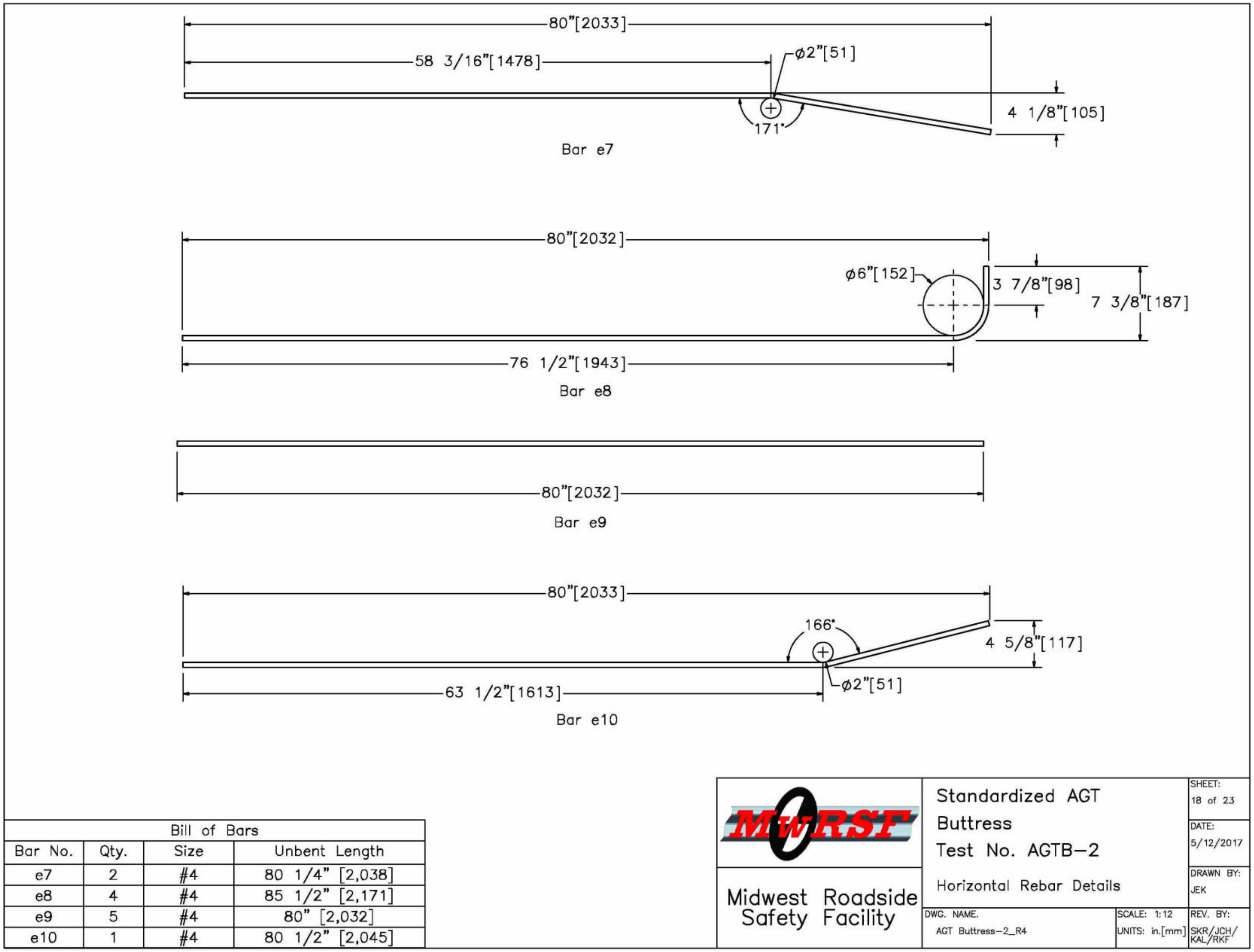
Midwest Roadside Safety Facility

Standardized AGT Buttress Test No. AGTB-2

Vertical Bar Details

SHEET:	17 of 23
DATE:	5/12/2017
DRAWN BY:	JEK
DWG. NAME.	AGT Buttress-2_R4
SCALE:	1:12
UNITS:	in.[mm]
REV. BY:	SKR/JCH/KAL/RKF

Figure 64. Vertical Bar Details, Test No. AGTB-2



Bill of Bars			
Bar No.	Qty.	Size	Unbent Length
e7	2	#4	80 1/4" [2,038]
e8	4	#4	85 1/2" [2,171]
e9	5	#4	80" [2,032]
e10	1	#4	80 1/2" [2,045]

Figure 65. Horizontal Rebar Details, Test No. AGTB-2

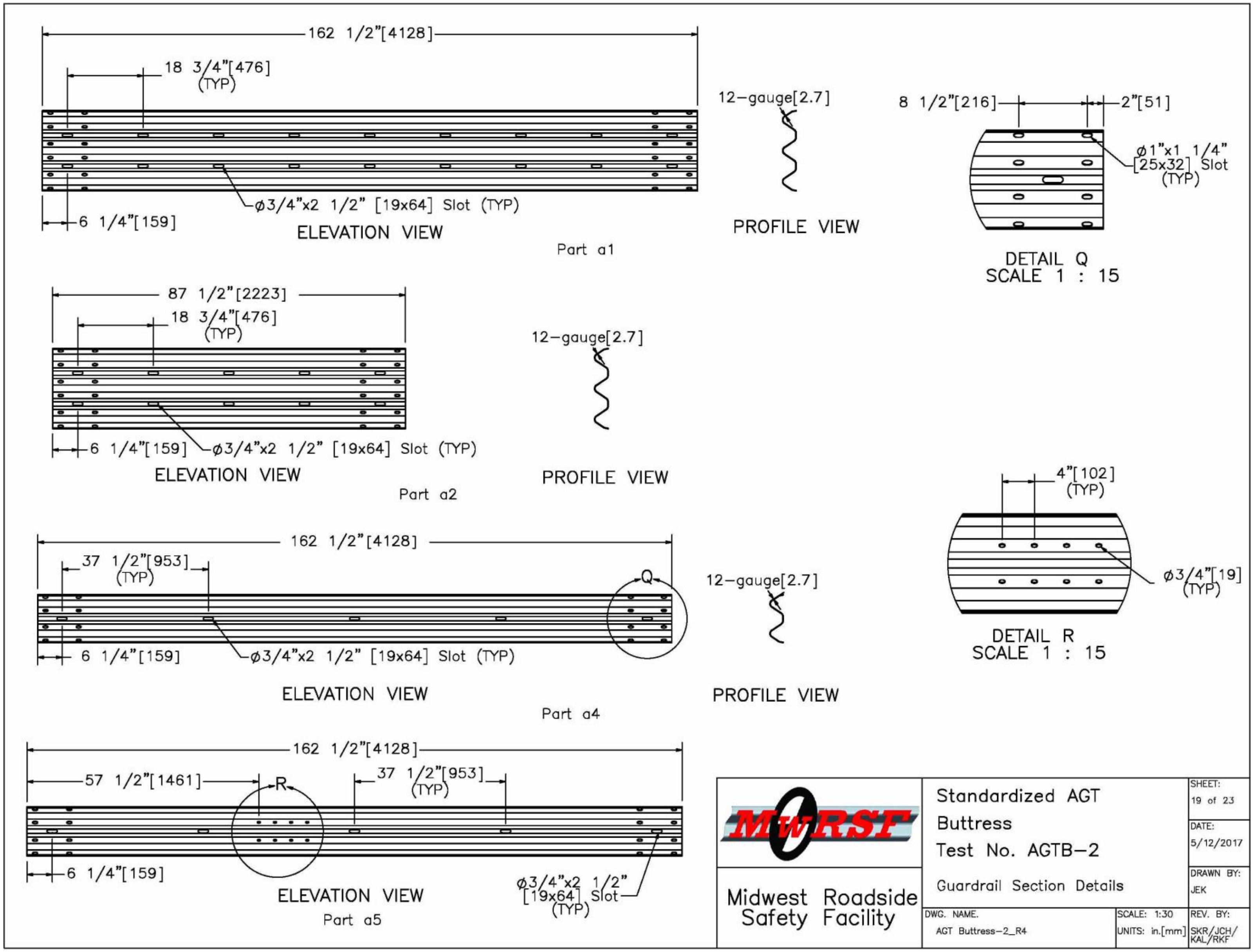


Figure 66. Guardrail Section Details, Test No. AGTB-2

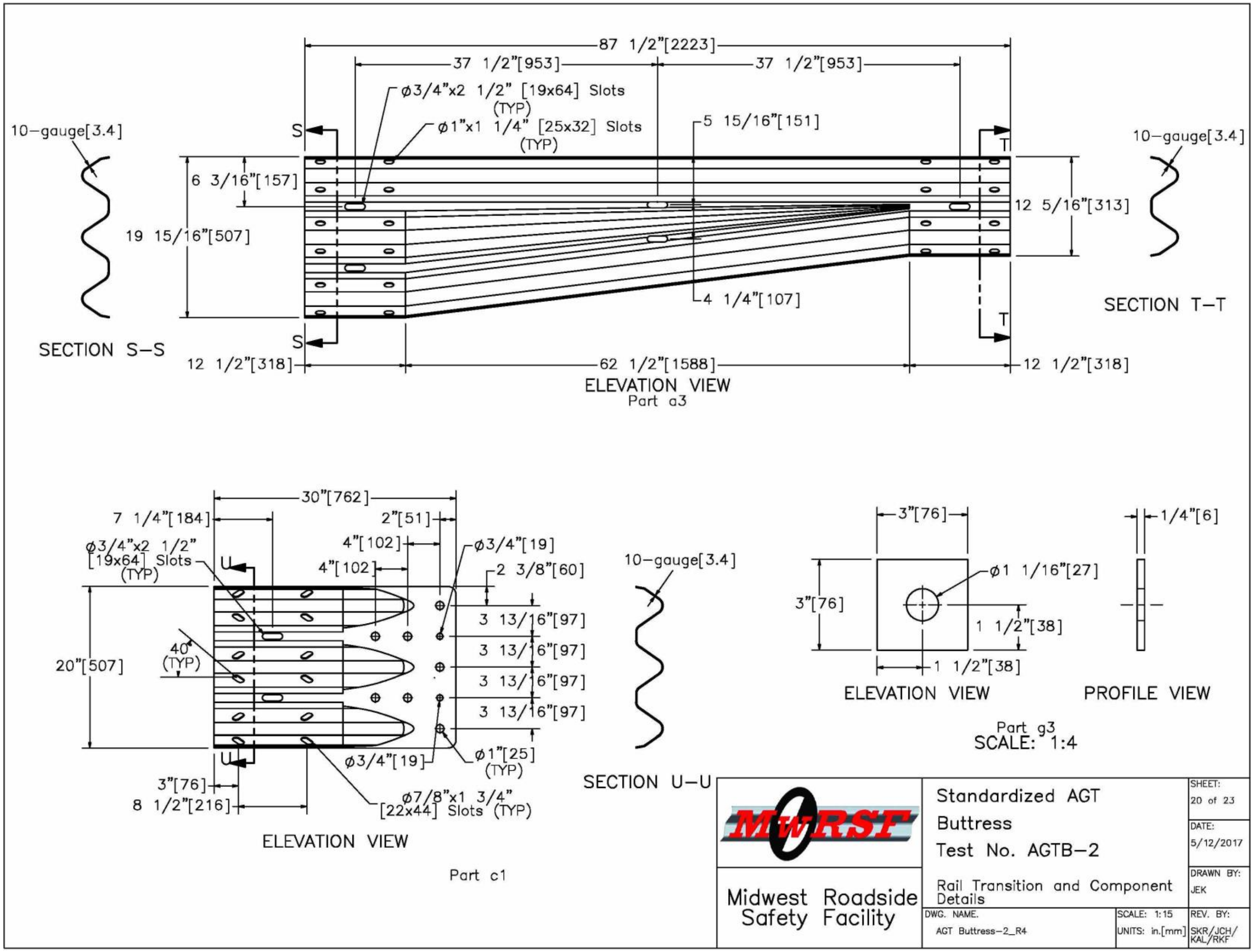


Figure 67. Rail Transition and Component Details, Test No. AGTB-2

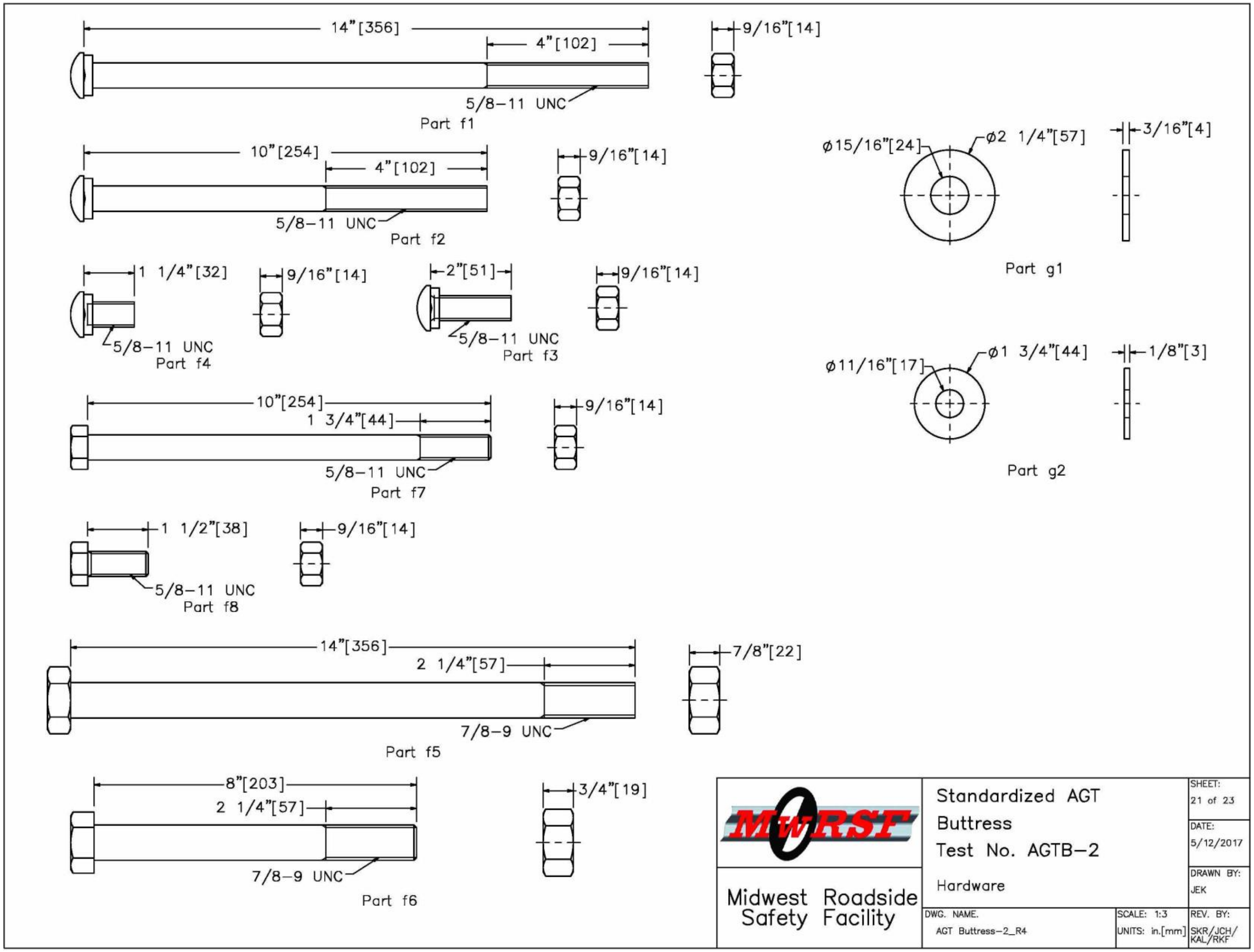


Figure 68. Hardware, Test No. AGTB-2

Item No.	QTY.	Description	Material Spec	Galvanization Spec	Hardware Guide
a1	2	12'-6" [3,810] 12-gauge [2.7] Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM08a
a2	1	6'-3" [1,905] 12-gauge [2.7] Thrie Beam Section	AASHTO M180	ASTM A123 or A653	RTM19a
a3	1	6'-3" [1905] 10-gauge [3.4] W-Beam to Thrie-Beam Asymetric Transition Section	AASHTO M180	ASTM A123 or A653	RWT02
a4	3	12'-6" [3,810] 12-gauge [2.7] W-Beam MGS Section	AASHTO M180	ASTM A123 or A653	RWM04a
a5	1	12'-6" [3,810] 12-gauge [2.7] W-Beam MGS End Section	AASHTO M180	ASTM A123 or A653	RWM14a
a6	1	10-gauge [3.4] Thrie Beam Terminal Connector	AASHTO M180 Min. yield strength = 50 ksi [345 MPa] Min. ultimate strength = 70 ksi [483 MPa]	ASTM A123 or A653	RTE01b
b1	1	Concrete – 21.9 cubic ft [0.62 cubic m]	Min. f'c = 4,000 psi [27.6 MPa]	–	–
c1	2	BCT Timber Post – MGS Height	SYP Grade No. 1 or better (No knots +/- 18" [457] from ground on tension face)	–	PDF01
c2	2	72" [1,829] Long Foundation Tube	ASTM A500 Gr. B	*ASTM A123	PTE06
c3	1	Ground Strut Assembly	ASTM A36	*ASTM A123	PFP02
c4	1	BCT Cable Anchor Assembly	–	–	FCA01
c5	1	Anchor Bracket Assembly	ASTM A36	*ASTM A123	FPA01
c6	1	8"x8"x5/8" [203x203x16] Anchor Bearing Plate	ASTM A36	*ASTM A123	FPB01
c7	1	2 3/8" [60] O.D. x 6" [152] Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	*ASTM A123	FMM02
d1	7	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 72" [1,829] Long Steel Post	ASTM A992	*ASTM A123	PWE06
d2	6	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 72" [1,829] Long Steel Post	ASTM A992	*ASTM A123	PWE06
d3	6	W6x8.5 [W152x12.6] or W6x9 [W152x13.4], 78" [1,981] Long Steel Post	ASTM A992	*ASTM A123	–
d4	7	6"x12"x14 1/4" [152x305x362] Timber Blockout	SYP Grade No.1 or better	–	PDB10a
d5	6	6"x12"x19" [152x305x483] Timber Blockout	SYP Grade No.1 or better	–	–
d6	6	17 1/2" [445] Long, 7"x4"x3/16" [178x102x5] Iowa Steel Blockout	ASTM A500 Gr. B	*ASTM A123	–
d7	9	16D Double Head Nail	–	–	–

* Component does not need to be galvanized for testing purposes.

Midwest Roadside Safety Facility

Standardized AGT Buttress Test No. AGTB-2

Bill of Materials

SHEET: 22 of 23

DATE: 5/12/2017

DRAWN BY: JEK

DWG. NAME. AGT Buttress-2_R4

SCALE: None

UNITS: in.[mm]

REV. BY: SKR/JCH/KAL/RKF

Figure 69. Bill of Materials, Test No. AGTB-2

Item No.	QTY.	Description	Material Spec	Galvanization Spec	Hardware Guide
e1	12	1/2" [13] Dia., 86" [2,184] Long Bent Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
e2	1	1/2" [13] Dia., 62 3/4" [1,594] Long Bent Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
e3	1	1/2" [13] Dia., 60 1/2" [1,537] Long Bent Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
e4	1	1/2" [13] Dia., 59 1/4" [1,505] Long Bent Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
e5	1	1/2" [13] Dia., 74 3/4" [1,899] Long Bent Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
e6	3	1/2" [13] Dia., 37 1/4" [946] Long Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
e7	2	1/2" [13] Dia., 80 1/4" [2,038] Long Bent Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
e8	4	1/2" [13] Dia., 85 1/2" [2,171] Long Bent Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
e9	5	1/2" [13] Dia., 80" [2,032] Long Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
e10	1	1/2" [13] Dia., 80 1/2" [2,045] Long Bent Rebar	ASTM A615 Gr. 60	**Epoxy Coated (ASTM A775 or A934)	–
f1	18	5/8" [16] Dia. UNC, 14" [356] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB06
f2	2	5/8" [16] Dia. UNC, 10" [254] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB03
f3	24	5/8" [16] Dia. UNC, 2" [51] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB02
f4	56	5/8" [16] Dia. UNC, 1 1/4" [32] Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBB01
f5	5	7/8 [22] Dia. UNC, 14 [356] Long Heavy Hex Head Bolt and Nut	Bolt – ASTM F3125 Gr. 120 (A325) or A354 Gr. BC Nut – ASTM A563DH or A194 Gr. 2H	Bolt – ASTM A153 or B695 Class 55 or F1136 Gr. 3 or F2329 or F2833 Gr. 1 Nut – ASTM A153 or B633 or B695 Class 55 or F1941 or F2329	FBX22b
f6	2	7/8" [22] Dia. UNC, 8" [203] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	–
f7	2	5/8" [16] Dia. UNC, 10" [254] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBX16a
f8	20	5/8" [16] Dia. UNC, 1 1/2" [38] Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	ASTM A153 or B695 Class 55 or F2329	FBX16a
g1	4	7/8" [22] Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	–
g2	46	5/8" [16] Dia. Plain Round Washer	ASTM F844	ASTM A123 or A153 or F2329	FWC16a
g3	5	3"x3"x1/4" [76x76x6] or 3 1/2"x3 1/2"x1/4" [89x89x6] Square Washer Plate	ASTM A572 Gr. 50	*ASTM A123	–

* Component does not need to be galvanized for testing purposes.

** Rebar does not need to be epoxy–coated for testing purposes.

Midwest Roadside Safety Facility	Standardized AGT Buttress Test No. AGTB–2
	Bill of Materials
SHEET: 23 of 23	DATE: 5/12/2017
DRAWN BY: JEK	DWG. NAME. AGT Buttress–2_R4
SCALE: None	UNITS: in.[mm]
REV. BY: SKR/JCH/KAL/RKF	

Figure 70. Bill of Materials Continued, Test No. AGTB-2

Figure 71. Test Installation Photographs, Test No. AGTB-2

7 FULL-SCALE CRASH TEST NO. AGTB-2

7.1 Static Soil Test

Before full-scale crash test no. AGTB-2 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH. The static test results, as shown in Appendix 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.

7.2 Weather Conditions

Test no. AGTB-2 was conducted on July 19, 2017 at approximately 12:45 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 7.

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

Temperature	90° F
Humidity	63%
Wind Speed	18 mph
Wind Direction	170° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.15 in.
Previous 7-Day Precipitation	2.34 in.

7.3 Test Description

The critical impact point for test no. AGTB-2 remained the same as test no. AGTB-1, which was selected using the tables provided in Section 2.3.2.1 of MASH to maximize the potential for snag on the upstream face of the concrete buttress. The critical impact point was determined to be 89 in. upstream from the end of the concrete buttress, or 6 in. upstream from the centerline of post no. 17, as shown in Figure 72.

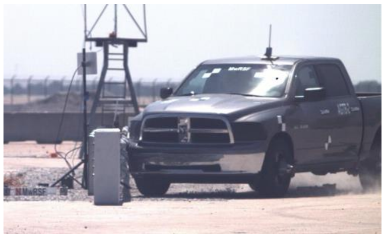
During test no. AGTB-2, the 5,160-lb pickup truck impacted the thrie-beam AGT 86 in. upstream from the concrete buttress at a speed of 62.6 mph and an angle of 25.4 degrees. The vehicle was contained and redirected with an exit speed and angle of 48.9 mph and -9.0 degrees, respectively. The vehicle remained stable throughout the impact event with maximum roll and pitch angular displacements of only 21 degrees and -6 degrees, respectively. The front-impact side wheel became disengaged and was pushed back toward the occupant compartment, which led to deformations of the vehicle toe pan, floorboard, and side front panel. However, these deformations were within MASH limits. With the wheel disengaged, the control arm extended under the guardrail and impacted the lower taper of concrete buttress, but it did not result in excessive decelerations. After exiting the system, the vehicle’s brakes were applied, and the vehicle slid into a row of temporary concrete containment barriers and came to rest 204 ft – 8 in. downstream from the impact location.

A detailed description of the sequential impact events is contained in Table 8. Sequential photographs are shown in Figures 73 and 74. The vehicle trajectory and final position are shown in Figure 75.

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

TIME (sec)	EVENT
0.000	Vehicle's front bumper contacted rail 86 in. upstream from the concrete buttress.
0.014	Post nos. 17 through 19 deflected backward.
0.018	Post nos. 16 and 20 deflected backward.
0.022	Rail buckled between post nos. 17 and 18.
0.034	Vehicle's right fender deformed, and vehicle yawed away from barrier and rolled toward barrier.
0.042	Rail buckled between post nos. 18 and 19, and vehicle's airbag deployed.
0.054	Vehicle's right-front wheel disengaged.
0.056	Vehicle's windshield cracked.
0.070	Vehicle's grille contacted sloped, top surface of concrete buttress.
0.090	Vehicle pitched downward.
0.098	Vehicle's right fender contacted sloped, top surface of concrete buttress.
0.108	Vehicle's right-front control arm impacted concrete buttress below guardrail.
0.112	Vehicle's right-front window shattered from contact with dummy's head.
0.116	Vehicle's left-rear tire became airborne.
0.126	Vehicle's left-front tire became airborne.
0.148	Dummy's head detached and passed through right-front window.
0.184	Vehicle's right-front door contacted concrete buttress, and vehicle's right quarter panel contacted rail.
0.196	Vehicle's rear bumper contacted rail.
0.212	Vehicle was parallel to system at a speed of 50.7 mph.
0.318	Vehicle exited system at a speed of and 48.9 mph and an angle of -9.0 degrees.
0.350	Vehicle's right-front control arm contacted ground.
0.464	Vehicle reached maximum pitch and began to pitch upward.
0.476	Vehicle reached maximum roll and began to roll away from barrier.
0.566	Vehicle's left-front tire regained contact with ground.
0.568	Vehicle's right-rear wheel returned to ground and disengaged from vehicle.
0.720	Vehicle's left-rear tire regained contact with ground.
3.350	Vehicle impacted temporary concrete containment barrier.
4.700	Vehicle came to rest.

Figure 72. Impact Location, Test No. AGTB-2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0.500 sec

Figure 73. Sequential Photographs, Test No. AGTB-2

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0.200 sec

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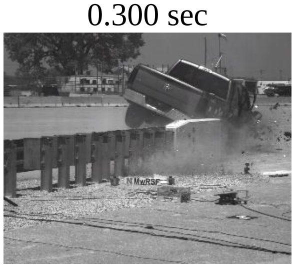

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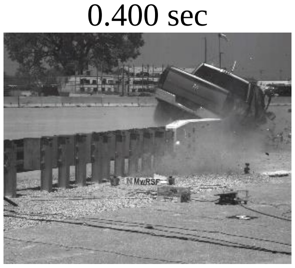

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Figure 74. Additional Sequential Photographs, Test No. AGTB-2

Figure 75. Vehicle Final Position and Trajectory Marks, Test No. AGTB-2

7.4 Barrier Damage

Damage to the barrier consisted of contact marks, rail deformations, and post deflections, as shown in Figures 76 through 78. Vehicle contact marks covered approximately 10 ft of the system spanning from 3 in. upstream from post no. 17 to the end of the thrie-beam terminal connector. The nested thrie beam sustained various deformations, kinks, and buckling that spanned from post no. 17 to the terminal connector. The middle corrugation of the thrie beam was deformed between post nos. 17 and 18, and the lower corrugation was deformed between post nos. 18 and 20. The bottom corrugation of the thrie beam was pushed upward from post no. 18 to the concrete buttress. Minor kinks were found on both the upper and lower edges of the rail from post no. 14 through the end of the rail.

Contact marks and scrapes were visible on the sloped top surface of the concrete buttress and on the lower taper of the buttress below the guardrail. A small section of concrete, measuring 1 in. tall and ¼ in. deep, was chipped from the upstream edge of the buttress about 7 in. from the ground where the vehicle’s control arm impacted the buttress. Tire tread marks on the lower taper of the buttress indicated that the tire was disengaged from the vehicle and lying flat when it contacted the buttress.

The permanent set of the barrier system was 2¾ in., which occurred at post no. 19, as measured in the field. The maximum lateral dynamic barrier deflection was 5.3 in. at the rail at post no. 19, as determined from high-speed digital video analysis. The working width of the system was found to be 26.0 in., also determined from high-speed digital video analysis.

Figure 76. System Damage, Test No. AGTB-2

Figure 77. System Damage, Test No. AGTB-2

Figure 78. System Damage, Test No. AGTB-2

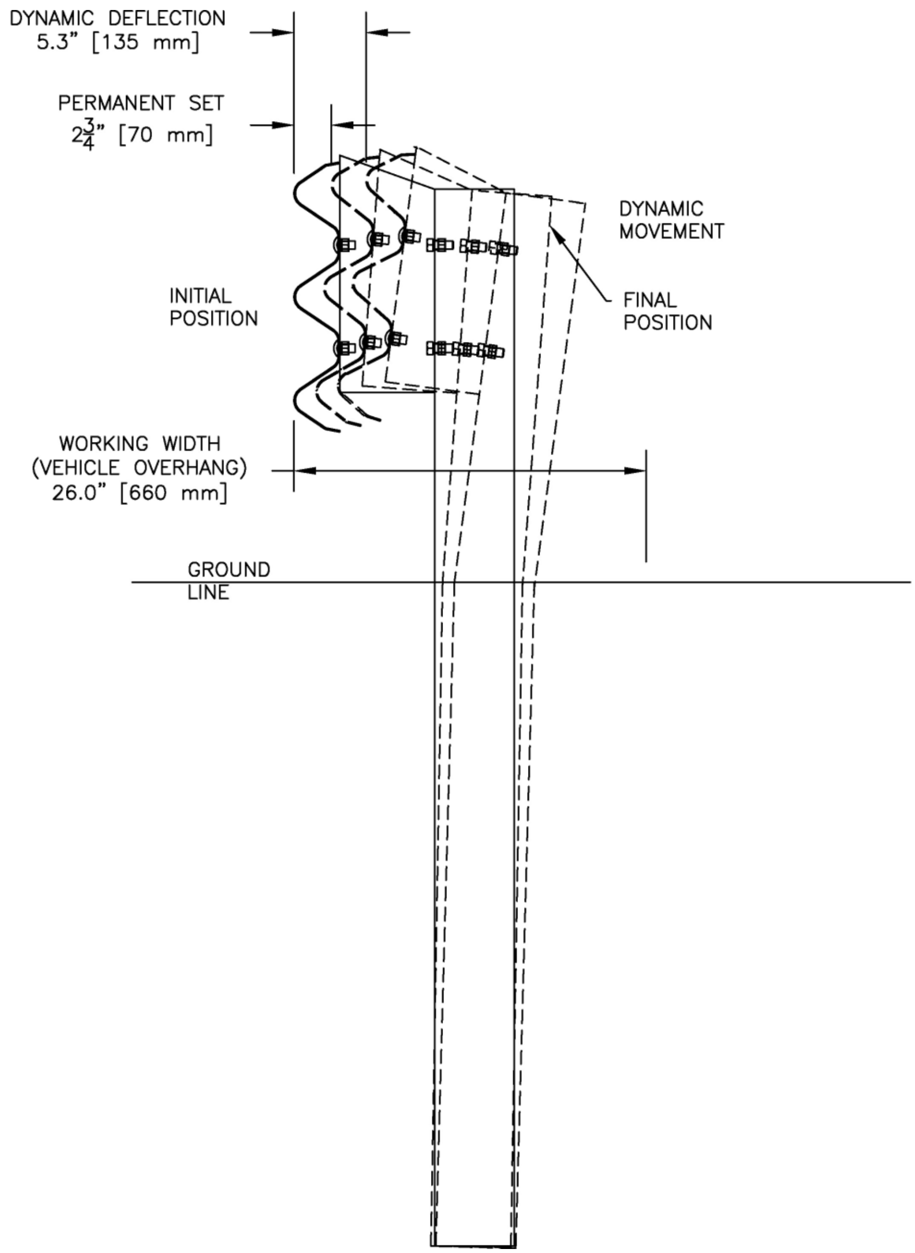

Figure 79. Permanent Set Deflection, Dynamic Deflection, and Working Width, Test No. AGTB-2

7.5 Vehicle Damage

The majority of the vehicle damage was concentrated on the right-front corner of the vehicle where the impact occurred, as shown in Figures 80 through Figure 82. Both of the right-side wheels had disengaged from the vehicle. The right-front lower shock mount was disengaged. The right-front and right-rear steering knuckle assemblies were disengaged. The right-front upper and lower control arms were bent and dented. The right-front tie rod was bent inward. The sway bar was bent backward toward the cab. The right side of the frame horn was kinked and dented. The left side of the frame horn was bent outward. The vehicle grille was fractured on the right end and was partially missing.

The entire right side of the vehicle contained various dents, kinks, gouges, and scrapes. Large indentions matching the corrugations of the guardrail stretched across both doors and the rear quarter panel. The right side of the bumper was bent backward and toward the centerline of the vehicle. The right-side fender was crushed inward. The top of the right-front door was separated from the body of the vehicle by 8 in. above the window, and the right-rear door was separated from the body of the vehicle by 2½ in. above the window. Both doors remained latched. Three small tears were found in the vehicle sheet metal located 6 in. behind the right-rear tire, directly in front of the right-rear wheel well, and 1 in. behind the right-rear door.

The right-front side window was shattered and disengaged due to contact with the dummy's head. The windshield was shattered and had significant deformations up to 4⅛ inches. However, high-speed video showed the windshield was damaged due to airbag deployment, not from interaction with the barrier. Thus, the windshield deformations were not considered as part of the MASH evaluation of the barrier system.

The maximum occupant compartment deformations are listed in Table 9 along with the deformation limits established in MASH for various areas of the occupant compartment. Note that none of the MASH established deformation limits were violated. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix D.

Figure 80. Vehicle Damage, Test No. AGTB-2

Figure 81. Vehicle Damage, Test No. AGTB-2

Figure 82. Vehicle Damage, Test No. AGTB-2

Table 9. Maximum Occupant Compartment Deformations by Location, Test No. AGTB-2

LOCATION	MAXIMUM DEFORMATION in.	MASH ALLOWABLE DEFORMATION in.
Wheel Well & Toe Pan	6⅜	≤ 9
Floor Pan & Transmission Tunnel	4	≤ 12
A-Pillar	1⅝	≤ 5
A-Pillar (Lateral)	1¼	≤ 3
B-Pillar	1½	≤ 5
B-Pillar (Lateral)	⅞	≤ 3
Side Front Panel (in Front of A-Pillar)	6¾	≤ 12
Side Door (Above Seat)	4¼	≤ 9
Side Door (Below Seat)	2⅛	≤ 12
Roof	1⅞	≤ 4
Windshield	0*	≤ 3
Side Window	N/A	No shattering resulting from contact with structural member of test article
Dash	1⅛	N/A

*Observed windshield damage was caused by airbag deployment, not contact with test article

7.6 Occupant Risk

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

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

Evaluation Criteria		Transducer		MASH Limits
		SLICE-1	SLICE-2 (primary)	
OIV (ft/s)	Longitudinal	-20.68	-20.28	±40
	Lateral	-23.08	-24.61	±40
ORA (g's)	Longitudinal	-6.95	-7.06	±20.49
	Lateral	-12.57	-10.40	±20.49
MAXIMUM ANGULAR DISPLACEMENT (deg.)	Roll	24.55	21.25	±75
	Pitch	-5.38	-6.30	±75
	Yaw	-39.19	-39.58	not required
THIV (ft/s)		30.46	30.95	not required
PHD (g's)		13.65	12.53	not required
ASI		1.30	1.37	not required

7.7 Discussion

Test no. AGTB-2 is summarized in Figure 83. Analysis of the test results showed that the AGT and standardized buttress adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix E, were deemed acceptable because they did not adversely influence occupant risk safety criteria nor cause rollover. The OIV and ORA values calculated as part of the occupant risk analysis were within the suggested MASH limits. After impact, the vehicle exited the barrier at an angle of -9.0 degrees and its trajectory did not violate the bounds of the exit box. Therefore, test no. AGTB-2 was determined to be acceptable according to the MASH safety performance criteria for test designation no. 3-21.

During the test, the windshield had shattered and deformed a maximum of 4⅛ inches. However, high-speed video showed the windshield was damaged due to airbag deployment, not from interaction with the barrier. Airbags have been shown to shatter and even tear windshields in previous oblique angle impacts [49]. Similar to the previous tests, the windshield was not considered in the evaluation of test no. AGTB-2 because the windshield damage was not due to interaction with the barrier system.


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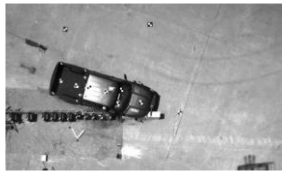
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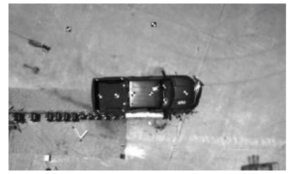
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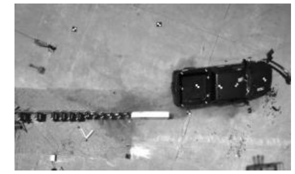
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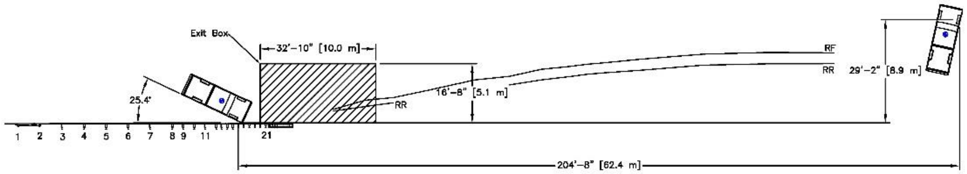
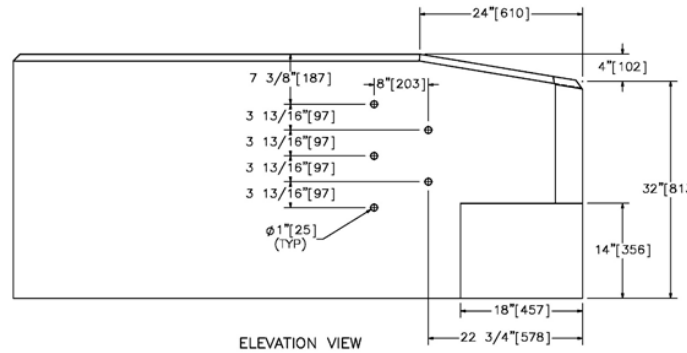




- Test Agency .... MwRSF
- Test Number............ AGTB-2
- Date............ 7/19/2017
- MASH Test Designation No. 3-21
- Test Article............ Standardized Buttress for AGT
- Total Length .... 81 ft - 8¼ in.
- Key Components – Guardrail AGT
  - Nested Thrie beam............ 12 gauge
  - Asymmetric W-to-Thrie Transition Segment............ 10 gauge
  - Thrie Beam Terminal Connector .... 10 gauge
  - Concrete Buttress (*l* x *w* x *h*) .... 84 x 12 x 36 in.
- Soil Type .... Coarse Crushed Limestone
- Vehicle Make /Model............ 2010 Dodge Ram 1500
  - Curb............ 5,097 lb
  - Test Inertial............ 4,998 lb
  - Gross Static............ 5,160 lb
- Impact Conditions
  - Speed .... 62.7 mph
  - Angle .... 25.4 deg
  - Impact Location............ 86 in. upstream from the end buttress
- Impact Severity (IS) .... 120.84 kip-ft > 106 kip-ft
- Exit Conditions
  - Speed .... 48.9 mph
  - Angle .... -9.0 deg
- Exit Box Criterion .... Pass
- Vehicle Stability............ Satisfactory
- Vehicle Stopping Distance .... 204 ft – 8 in.
- Vehicle Damage............ Moderate
  - VDS [47] 1-RFQ-5
  - CDC [48]............ 01-RFEE-4
  - Maximum Interior Deformation .... 6⅜ in.
- Test Article Damage .... Minimal
- Maximum Test Article Deflections
  - Permanent Set .... 2¾ in.
  - Dynamic............ 5.3 in.
  - Working Width............ 26.0 in.
- Transducer Data

Evaluation Criteria		Transducer		MASH Limit
		SLICE-1	SLICE-2 (primary)	
OIV (ft/s)	Longitudinal	-20.68	-20.28	±40
	Lateral	-23.08	-24.61	±40
ORA (g's)	Longitudinal	-6.95	-7.06	±20.49
	Lateral	-12.57	-10.40	±20.49
MAXIMUM ANGULAR DISP. (deg.)	Roll	24.56	21.25	±75
	Pitch	-5.38	-6.30	±75
	Yaw	-39.19	-39.58	Not required
THIV – (ft/s)		30.46	30.95	Not required
PHD – (g's)		13.65	12.53	Not required
ASI		1.30	1.37	Not required

Figure 83. Summary of Test Results and Sequential Photographs, Test No. AGTB-2

8 SUMMARY AND CONCLUSIONS

The objective of this research project was to develop a standardized concrete buttress compatible for use with previously-developed, thrie-beam AGTs that were successfully crash tested to the TL-3 criteria of either MASH or NCHRP Report 350. Additionally, AGTs incorporating the standardized buttress were to be crashworthy with or without a curb placed below the guardrail. Finally, the buttress geometry needed the ability to transition to match a variety of concrete parapets and bridge rail shapes.

The standardized buttress was designed with a dual taper on its upstream edge. The lower portion of the buttress below the thrie beam utilized a shallow taper to minimize tire snag, while the upper portion of the buttress behind the rail utilized a steeper taper to limit the unsupported span length of the rail and still reduce vehicle snag. To prevent vehicle snag on the buttress above the thrie beam, the upstream face of the standardized buttress was set at 32 in. tall, which would be 1 in. above the top of a 31-in. tall thrie beam. A 6:1 vertical slope located at the upstream end of the buttress was used to transition the height of the barrier to 36 in., corresponding to a common height for MASH TL-4 barriers.

The standardized buttress had to be evaluated in a critical, worst-case scenario to ensure it would be crashworthy in combination with various thrie-beam AGTs. A review of past NCHRP Report 350 and MASH crash-tested, thrie-beam AGTs was conducted, and a critical guardrail transition was identified. This critical guardrail transition had a reduced lateral stiffness compared to other thrie-beam AGTs, so it was more flexible and would pose an increased risk of vehicle snag on the rigid buttress.

Additionally, curbs placed below AGTs have been shown to help mitigate vehicle snag by limiting the lateral extent of tires under the guardrail. Testing without the presence of a curb would maximize the risk of snag on the buttress. Thus, the standardized buttress was full-scale crash tested in combination with a critical AGT without a curb.

Full-scale crash test no. AGTB-1 was conducted on the critical AGT according to MASH test designation no. 3-21. During the test, the pickup truck was contained and redirected. There were contact marks on the lower taper of the buttress below the guardrail indicating tire snag. Occupant compartment deformations to the vehicle’s floorboard and side panel were observed, but they did not violate MASH limits. Although the vehicle appeared to be smoothly redirected during the test, the longitudinal ORA was measured at 30 g’s, well above the MASH 20.49 g limit. Review of the vehicle damage and on-board video cameras revealed that the seat frame and the mounting brackets supporting the accelerometers had shifted during the impact event. This outcome likely introduced significant error to the acceleration data and resulted in the abnormally high ORA. Unfortunately, the ORAs could not be calculated from other analysis methods, so the test was determined to be a failure according to the MASH evaluation criteria.

Before the second full-scale crash test, small changes were made to the geometry of the standardized transition buttress to reduce the amount of vehicle and tire snag. To reduce the severity of tire snag below the rail, the angle of the lower taper was reduced to create a 4:1 slope. Additionally, the lateral offset of the lower taper was increased by ½ in. to 4½ inches. The height of the lower taper increased to 14 in. to reduce the vehicle snag on the lower portion of the upper taper. The 14-in. height also corresponded to the height to the bottom of the transition blockouts.

Thus, the lower taper measured 18 in. long, 4½ in. laterally, and 14 in. tall. Additionally, the slope of the upper taper was reduced to further mitigate vehicle snag. The final design for the upper taper measured 4 in. long, 3 in. laterally, and 18 in. tall.

After these modifications were implemented, test no. AGTB-2 was conducted on the standardized buttress and critical AGT according to MASH test designation no. 3-21. During the test, the vehicle was contained and smoothly redirected with minimal roll and pitch angular displacements. As expected, tire marks were again found on the lower taper of the buttress below the guardrail. However, contact with the buttress was not severe, and all occupant compartment deformations, OIVs, and ORAs satisfied MASH TL-3 criteria. Thus, test no. AGTB-2 satisfied all the requirements of MASH test designation no. 3-21. A summary of the safety performance results for both full-scale crash tests is shown in Table 11.

Although not detailed herein, a MASH test designation no. 3-20 test with the 1100C small car was conducted on a similar AGT system incorporating a slightly different version of the standardized buttress. That thrie beam AGT utilized a top rail height of 34 in., which is 3 in. higher than standard transitions, and was attached to the standardized buttress developed herein, except the buttress height and the height of the lower taper were each increased by 3 in. to match the increased height of the guardrail. The increased rail height was associated with an increased risk of the small car extending under the rail and snagging on the buttress. The 34-in. tall AGT was also tested without a curb. The full-scale crash test results on this 34-in. tall AGT satisfied MASH test designation no. 3-20 evaluation criteria [42-43]. By comparison, the lower rail height of standard 31-in. AGTs would better capture the front end of the small car and reduce the severity of vehicle snag on the buttress. Subsequently, the system evaluated in test no. AGTB-2 with the standardized transition buttress connected to a 31-in. tall thrie-beam AGTs is expected to satisfy all MASH test designation no. 3-20 criteria.

The standardized transition buttress was tested and evaluated in a worst-case scenario with a critical (i.e., more flexible) thrie-beam AGT configuration and without a curb below the guardrail. Therefore, the standardized transition buttress should be considered MASH TL-3 compliant when connected to other NCHRP Report 350 or MASH crash-tested, thrie-beam AGTs with equal or greater stiffness. Since curbs placed below AGTs help mitigate tire snag, the standardized transition buttress can be safely installed on roadways with or without curbs. Implementation guidance for attaching the buttress to various AGT configurations, incorporating curbs into an AGT, and transitioning the buttress to align with various common barrier shapes are provided in Chapter 9.

Table 11. Summary of Safety Performance Evaluation Results

<table>
<tr><th>Evaluation Factors</th><th colspan="4">Evaluation Criteria</th><th>Test No. AGTB-1</th><th>Test No. AGTB-2</th></tr>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="3">Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td><td>S</td><td>S</td></tr>
<tr><td rowspan="12">Occupant Risk</td><td rowspan="2">D.</td><td colspan="3">1. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.</td><td>S</td><td>S</td></tr>
<tr><td colspan="3">2. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016.</td><td>S</td><td>S</td></tr>
<tr><td>F.</td><td colspan="3">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td><td>S</td><td>S</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.2.2 of MASH for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</td><td rowspan="4">S</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s (9.1 m/s)</td><td>40 ft/s (12.2 m/s)</td></tr>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.2.2 of MASH for calculation procedure) should satisfy the following limits:</td><td rowspan="4">U</td><td rowspan="4">S</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
<tr><td colspan="5">MASH Test Designation</td><td>3-21</td><td>3-21</td></tr>
<tr><td colspan="5">Final Evaluation (Pass or Fail)</td><td>Fail</td><td>Pass</td></tr>
</table>

S – Satisfactory U – Unsatisfactory NA - Not Applicable

9 IMPLEMENTATION GUIDANCE

The standardized transition buttress was developed to be compatible with a variety of thrie-beam AGT systems, both with and without a curb. As part of the evaluation process, the standardized transition buttress was crash tested in combination with a critical guardrail transition (i.e., more flexible system) without a curb. This worst-case scenario posed the greatest risk for snag on the upstream end of the buttress. Since the buttress proved crashworthy in this critical configuration, the standardized buttress should remain crashworthy when utilized with other guardrail transition configurations as stiffer systems would only reduce vehicle snag. Therefore, the standardized transition buttress is considered crashworthy when in combination with any thrie beam AGT system that has previously been successfully tested to either NCHRP Report 350 or MASH safety performance criteria. These AGTs may either utilize ¼-post or ½-post spacings (i.e., 18¾-in. and 37½-in. post spacings) and may consist of a variety of post sections. Further, since the standardized transition buttress was tested without a curb, and curbs tend to reduce tire snag below the guardrail, the standardized transition buttress should be considered crashworthy with these various AGTs in either a curbed or non-curbed installation.

For the successful attachment of various AGTs to the standardized transition buttress, the same post, blockout, and rail components from the original as-tested AGT design should be utilized within the transition region. Thus, the post size, post embedment depth, post spacing, blockouts, rail thickness, rail height, and rail segment lengths should not be altered when the standardized buttress is utilized within other AGT designs. However, the offset between the buttress and the first transition post may vary. The unsupported span length of the rail, which is measured from the location where the rail is no longer laterally supported by the buttress to the centerline of the adjacent post, should remain the same as the original as-tested AGT so that the stiffness of the transition is not affected. Examples of this distance are shown in Figure 84. Because the unsupported span length varies with the flares, tapers, and post spacings utilized among various AGT designs, the offset distance from the standardized buttress to the first transition post will vary. Subsequently, the longitudinal location of the thrie-beam terminal connector attachment bolts within the buttress may also vary.

In the test installations evaluated herein, the thrie beam terminal connector was spliced to the back of the nested thrie beam rails. Some DOTs and guardrail installers prefer to install AGTs with the terminal connector sandwiched between the nested thrie beam rails to reduce the snag potential on the end of the thrie beams during reverse direction impacts. The two splice configurations have similar strengths and both are considered crashworthy. Thus, roadside designers may select either splice configuration for use on their roadways. However, MwRSF recommends using a sandwiched splice at these locations due to the potential safety benefits (i.e., snag mitigation) during reverse direction impacts.

Until recently, most AGTs were only evaluated and crash tested near the connection between the rail and the rigid parapet. However, more recent testing has highlighted the critical nature of the upstream stiffness transition between W-beam guardrail and the stiffened thrie-beam AGT. New AGT installations should utilize a crashworthy upstream stiffness transition even if they were not originally developed and tested with it. For installations transitioning from MGS to the standardized transition buttress, it is recommended to utilize the MGS stiffness transition on the upstream end of the AGT, as was incorporated herein with the Iowa AGT. Details on how to incorporate the MGS stiffness transition into a thrie beam AGT can be found in previous reports and papers [8-9, 36-37, 50].

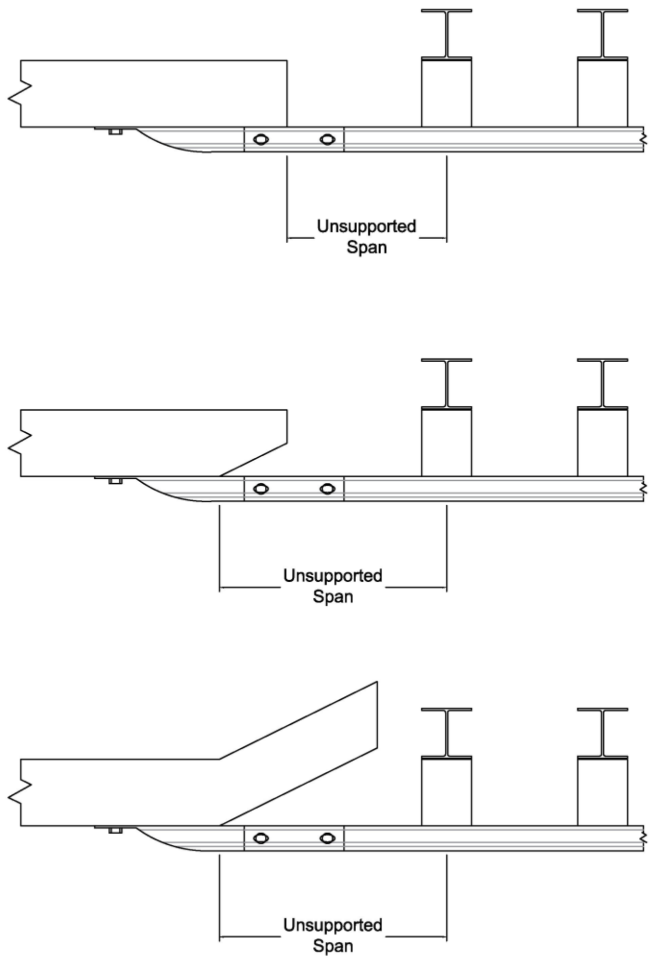
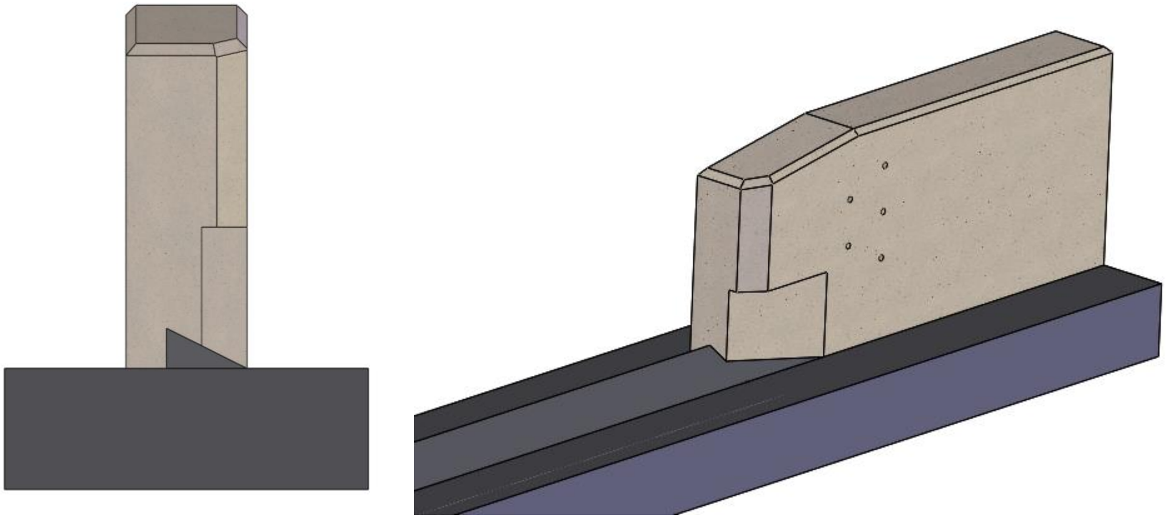
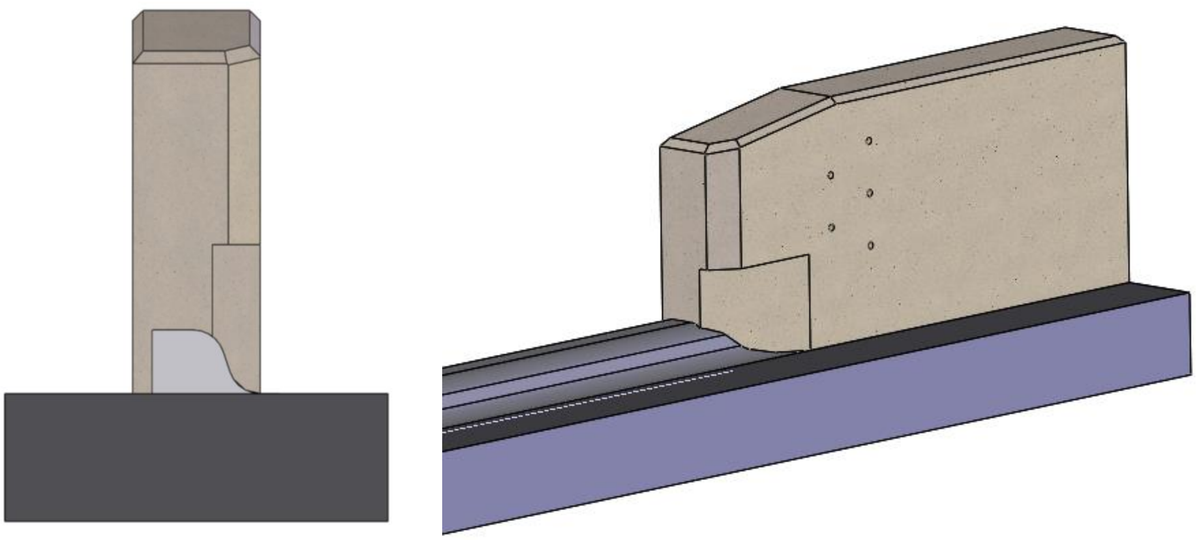


Figure 84. Examples of Unsupported Span Lengths for Various AGT Configurations

As described previously, the standardized buttress was tested in a critical configuration without a curb, but the addition of a curb would further mitigate the severity of tire snag on the buttress. Any curb added to an AGT system should be representative of those previously utilized and successfully crash tested with an AGT, which range from 4-in. tall wedge shaped curbs [4, 7] to 6-in. tall vertical curbs [51]. Curbs should be placed adjacent to the upstream face and lower taper of the standardized transition buttress, and it is recommended for the curb to hold a consistent flow line by extending into the slope of the lower taper, as shown in Figure 85. Note, if a curb is present under the upstream stiffness transition, 12.5 ft of nested W-beam should be placed adjacent to the W-to-thrie transition segment to prevent rail rupture [9]. To date, the upstream stiffness transition has only been evaluated with a 4-in. tall curb, and there are concerns that taller curbs may lead to premature rail rupture. Until further evaluation is conducted, taller curbs should be transitioned down to a 4 in. height for use below the upstream stiffness transition. Curb height and/or shape transitions should be located below thrie beam regions or upstream from the nested W-beam region of the guardrail.



(a) Triangular Curb



(b) AASHTO Type B Curb

Figure 85. Examples of Curb Placement Adjacent to Buttress with (a) Triangular and (b) Type B Curb Shapes

The standardized transition buttress was developed with a vertical face to optimize vehicle stability during impacts. However, the adjacent bridge rail or concrete parapet may not have the same geometry. Thus, the downstream end of the buttress should contain a shape transition to align with the adjacent bridge rail or concrete parapet. Shape transitions should be gradual to prevent vehicle instabilities. Based on previous simulation efforts, transitions to the face geometry of a rigid barrier incorporating lateral slopes steeper than 10:1 may cause stability issues [52]. Thus, it is recommended to utilize a maximum 10:1 lateral slope to transition the shape of the standardized buttress. Shape transitions should begin 6 in. downstream from the thrie beam terminal connector, or 8 in. downstream from the attachment bolts.

Height transitions will also be necessary for connecting to various height bridge rails and concrete parapets. The upstream end of the standardized transition buttress was successfully tested with a vertical taper of 4 in. over a 24-in. length, located at the upstream end of the buttress. For taller barriers, this 6:1 vertical slope may be continued upward until the desired height is reached. Note, this is a steeper slope than the previous 8:1 vertical slope guidance stemming from previous testing [53-54]. If the adjacent bridge rail or parapet is only 32 in. tall, the entire buttress can be installed with a constant 32-in. top height (i.e., no vertical taper would be present on the upstream end of the buttress).

Examples of various shape and height transitions utilizing the guidelines described above are shown in Figures 86 through 94. Note that the example shape transitions depict the shortest shape transitions possible following the recommended slopes/tapers. Longer shape transitions using shallower slopes would also be considered crashworthy. The transition examples were constructed with holding the top front corner of the barrier at the same lateral position. Thus, the lateral position of the bottom of the buttress changed along the shape transition. Shape transitions can also be constructed by holding the bottom of the buttress at the same lateral potions, creating a consistent water flow line and changing the lateral position of the top of the barrier. Both transition methods would be considered crashworthy.

It should be noted that the length and steel reinforcement within a buttress can change from the buttress configuration tested herein. The tested buttress had a 7-ft length, but this distance was only selected to represent a typical installation length. The final length for a transition buttress will be dependent upon the required length of the shape transition and ensuring the buttress has enough reinforcement and anchorage to prevent concrete fracture and barrier overturning (i.e., rocking backward). Figures 86 through 94 illustrate how shape transitions will require different minimum lengths depending on the desired barrier shape at the downstream end. Buttress reinforcement and anchorage should be sufficient to resist the resulting moment calculated by multiplying the design load by the effective height of the design load, both of which vary by desired test level. The most current MASH design load information is shown in Table 12. More detailed information can be found in the summary report from NCHRP Project 22-20(2) [35].

Table 12. NCHRP Project 22-20(2) Recommended MASH Design Loads [35]

Design Forces and Designations	TL-3	TL-4-1	TL-4-2	TL-5-1	TL-5-2
Rail Height, H (in.)	32	36	>36	42	>42
F_t Transverse (kips)	70	70	80	160	260
F_L Longitudinal (kips)	18	22	27	75	75
F_v Vertical (kips)	4.5	38	33	160	80
L_L (ft)	4	4	5	10	10
L_v (ft)	18	18	18	40	40
H_e (in.)	24	25	30	34	43

Finally, the standardized transition buttress may be constructed as part of the bridge rail or parapet (cast monolithically) or as an independent structure adjacent to the end of the bridge rail or parapet. When the buttress is constructed as an independent structure, the gap between the buttress and the adjacent barrier should be limited to a maximum of 4 in. to prevent excessive vehicle snag on the downstream side of the gap. This guidance is based on the gap distance between free-standing and anchored precast concrete barrier systems that have been successfully crash tested to MASH TL-3 [55-58].

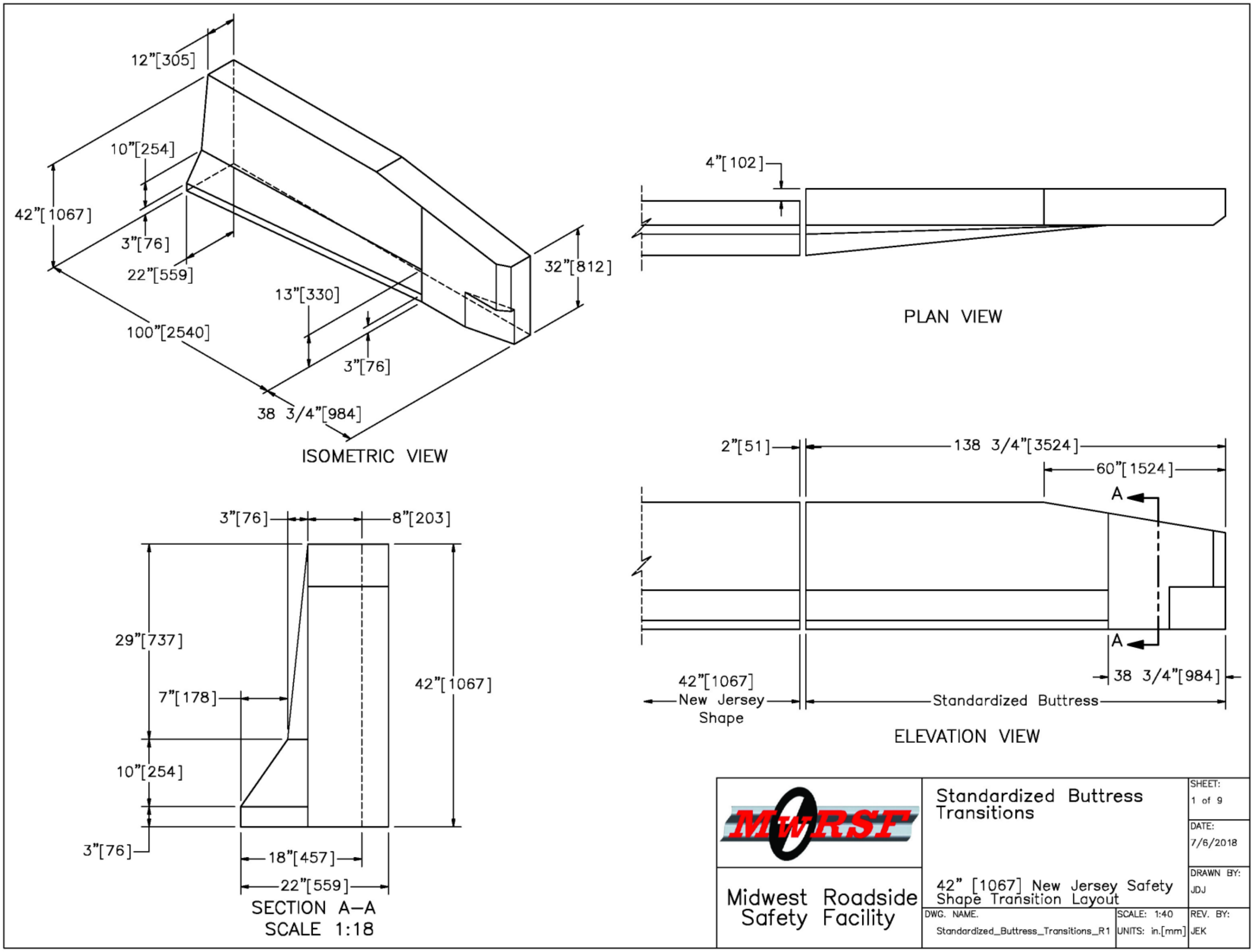


Figure 86. Buttress Shape Transition to 42-in. Tall NJ Shape Barrier

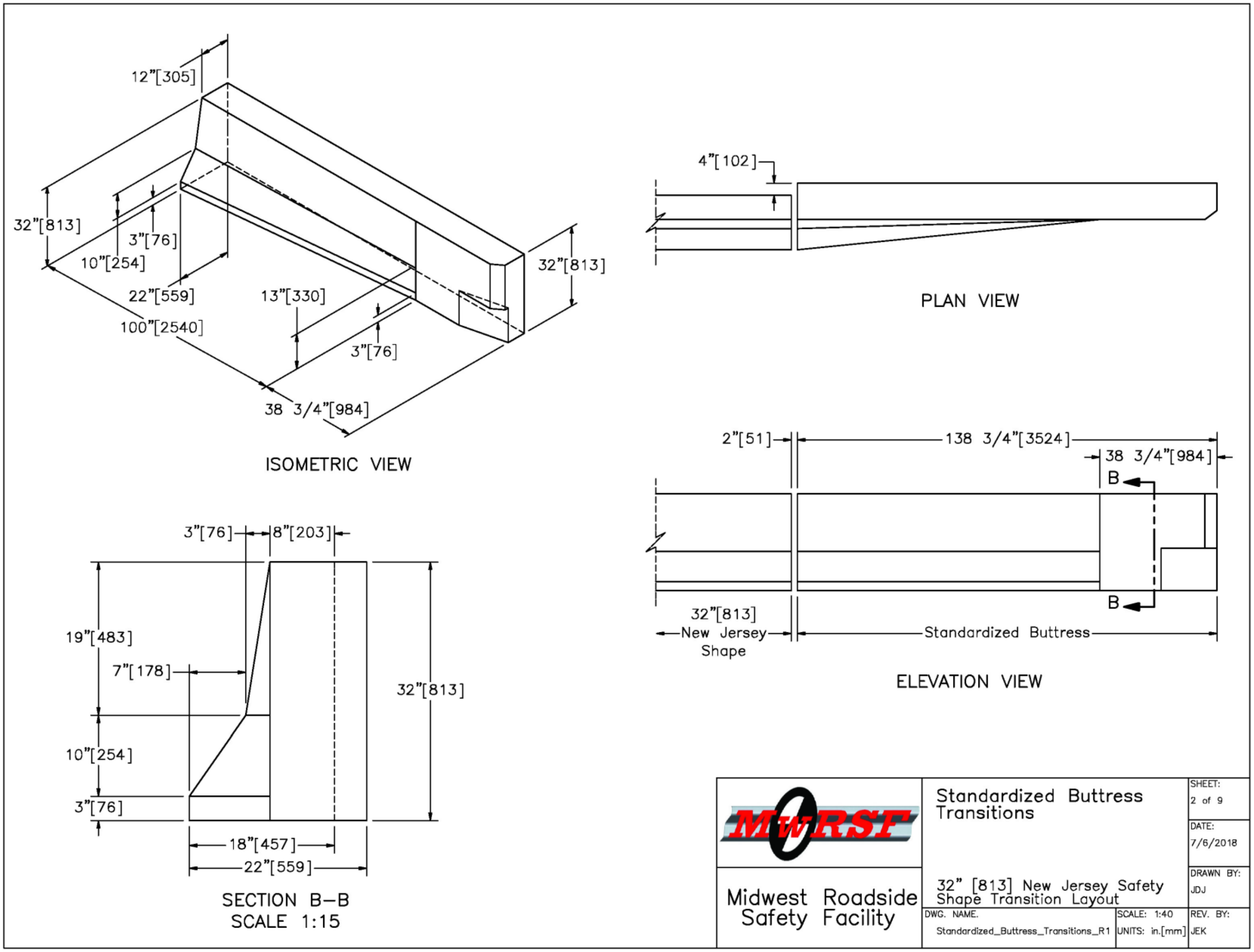


Figure 87. Buttress Shape Transition to 32-in. Tall NJ Shape Barrier

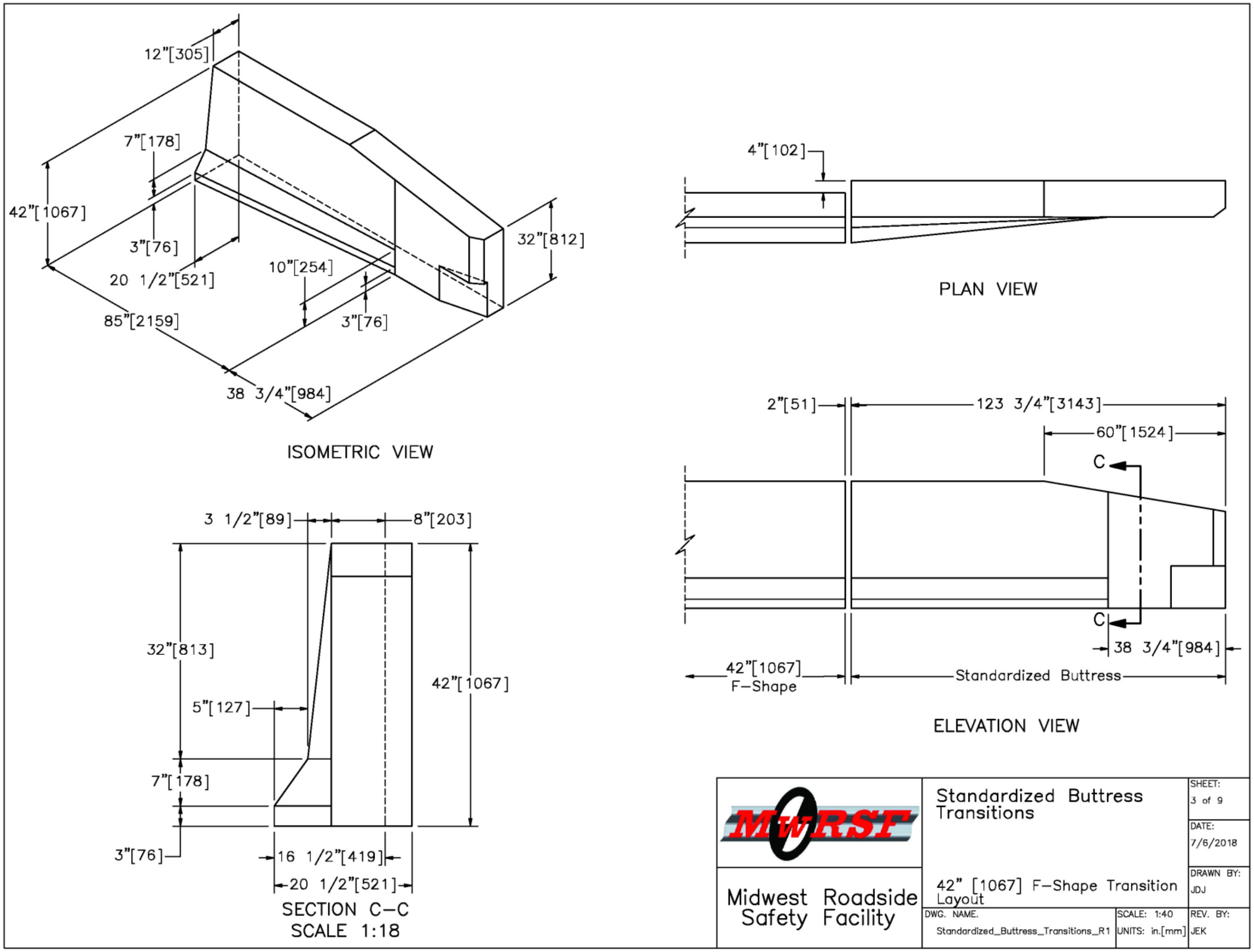


Figure 88. Buttress Shape Transition to 42-in. Tall F-Shape Barrier

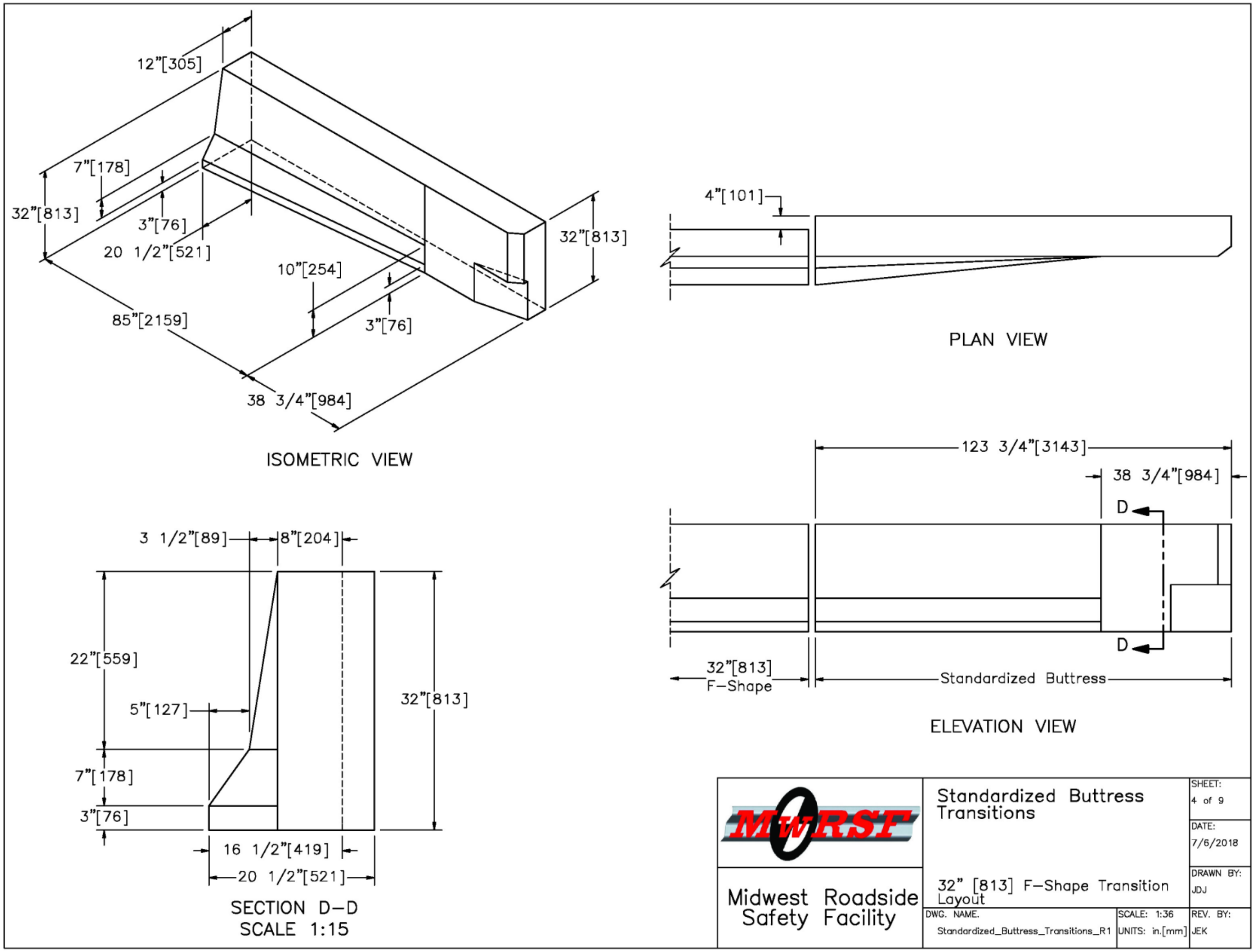


Figure 89. Buttress Shape Transition to 32-in. Tall F-Shape Barrier

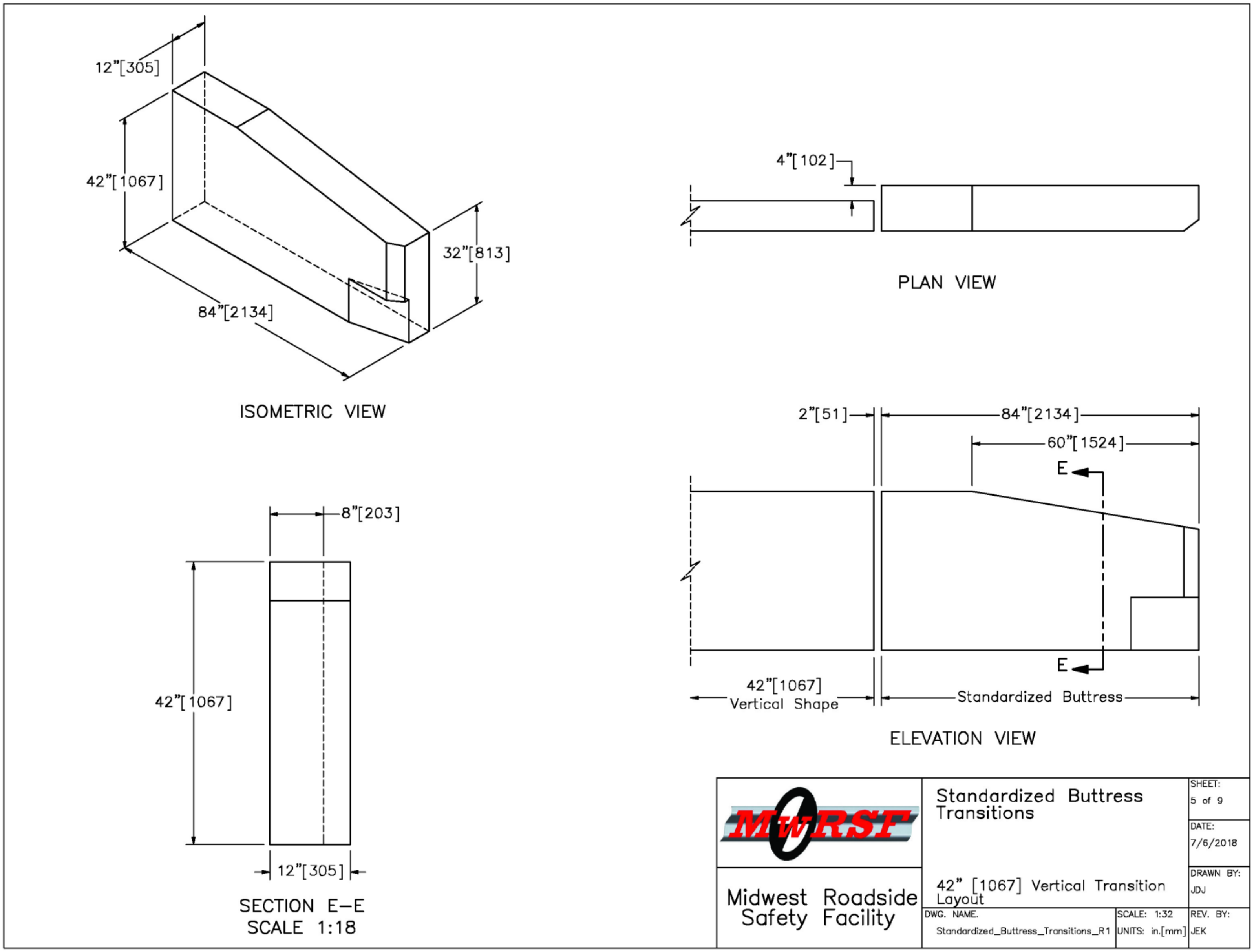


Figure 90. Buttress Shape Transition to 42-in. Tall Vertical Barrier

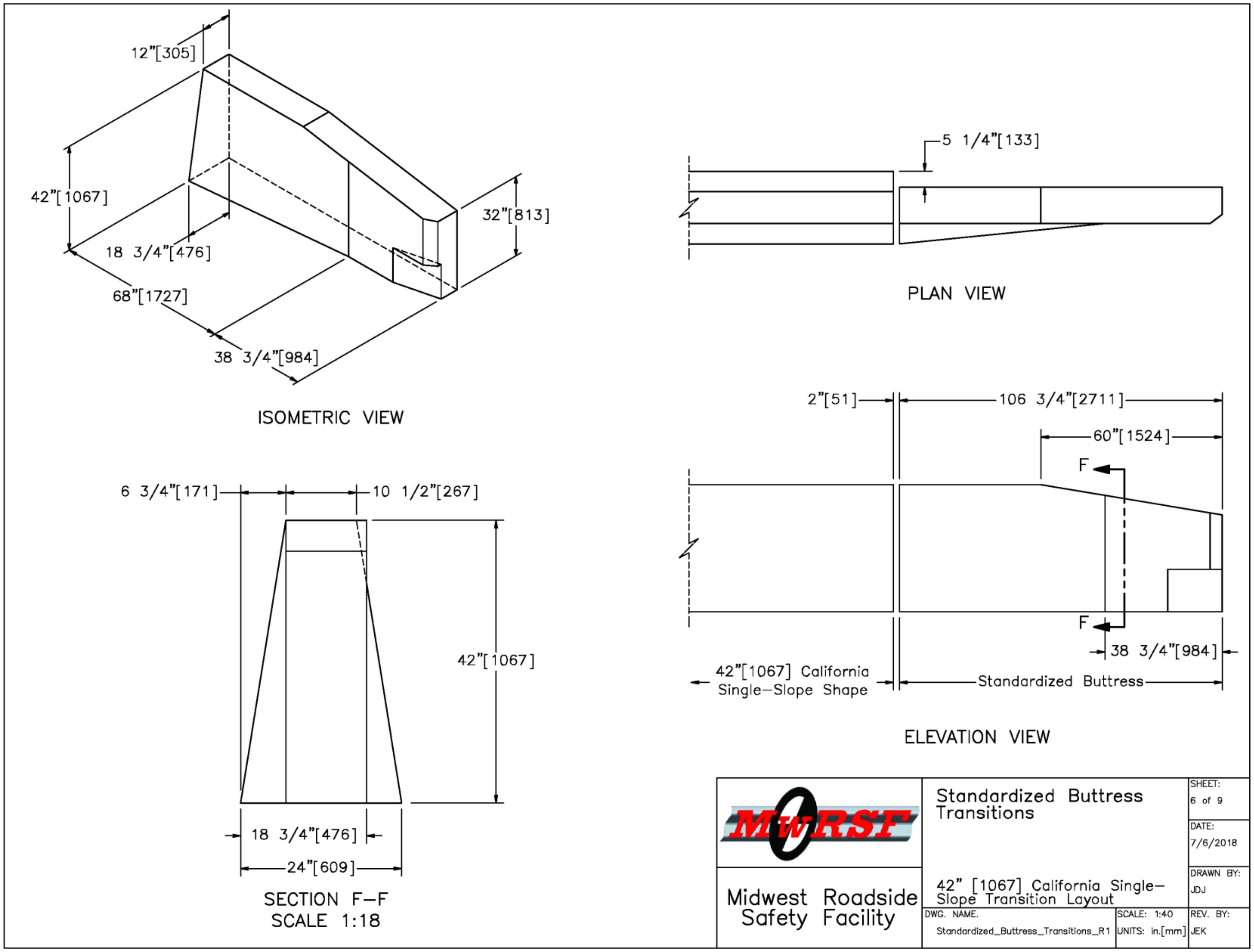


Figure 91. Buttress Shape Transition to 42-in. Tall California Single Slope Barrier

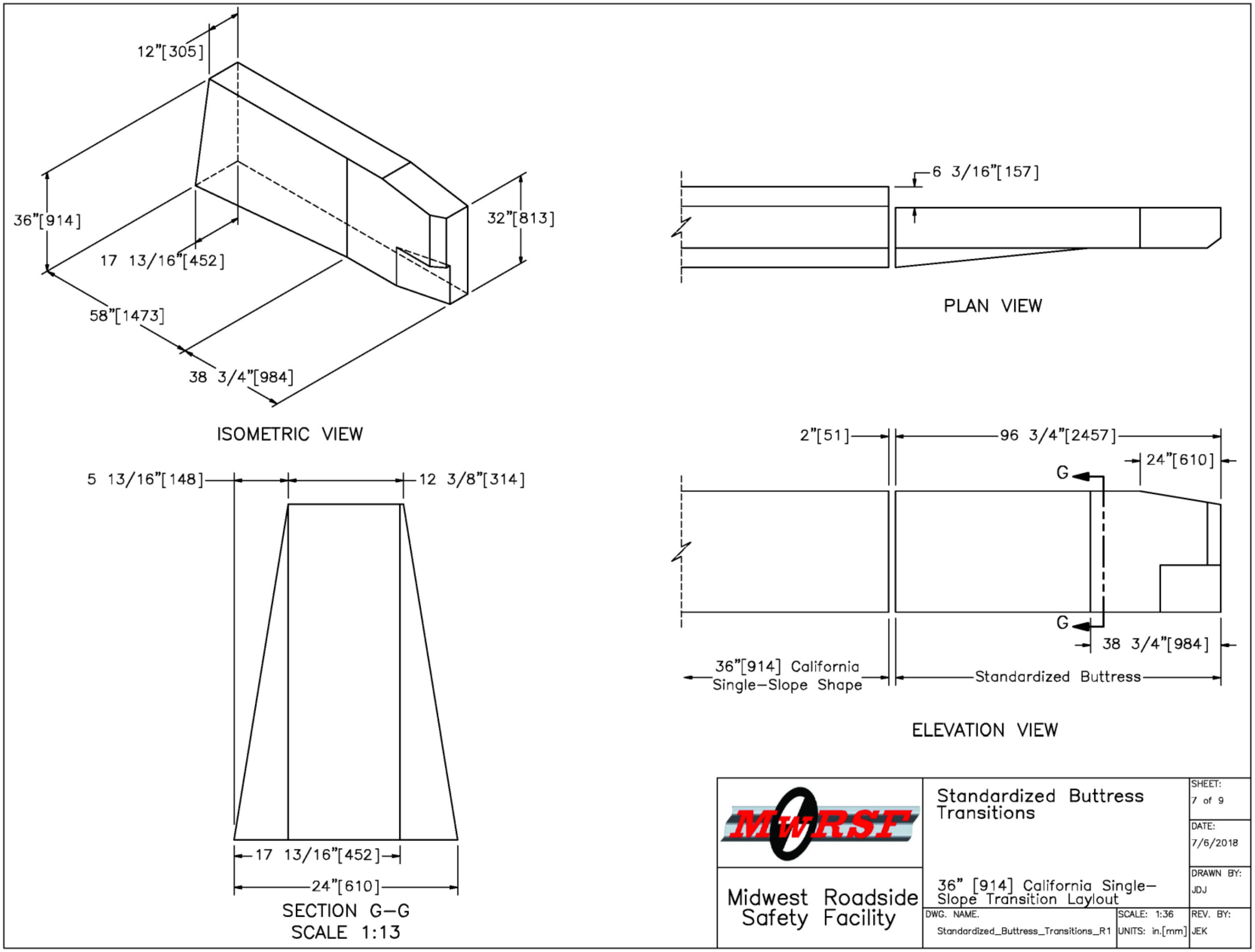


Figure 92. Buttress Shape Transition to 36-in. Tall California Single Slope Barrier

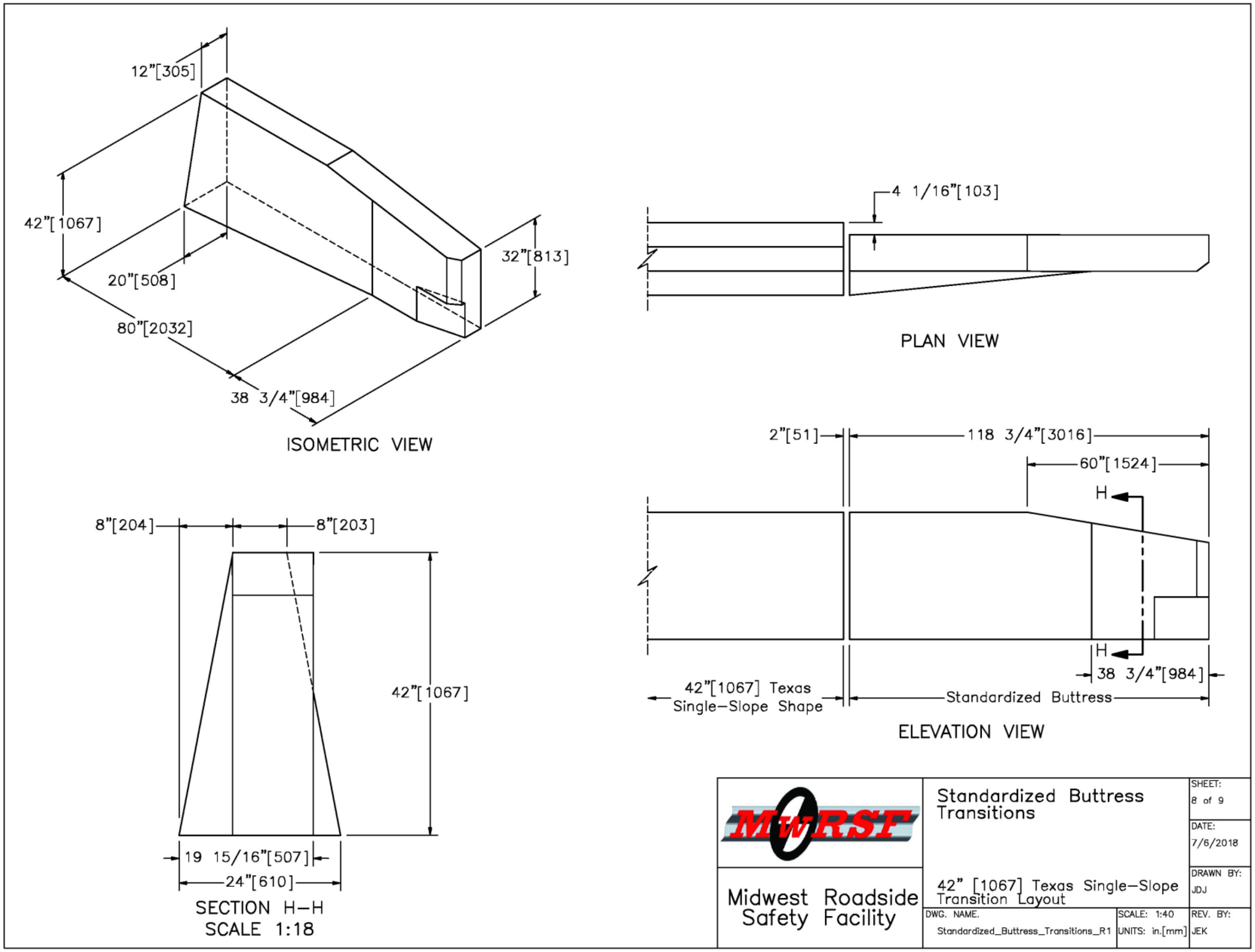


Figure 93. Buttress Shape Transition to 42-in. Tall Texas Single Slope Barrier

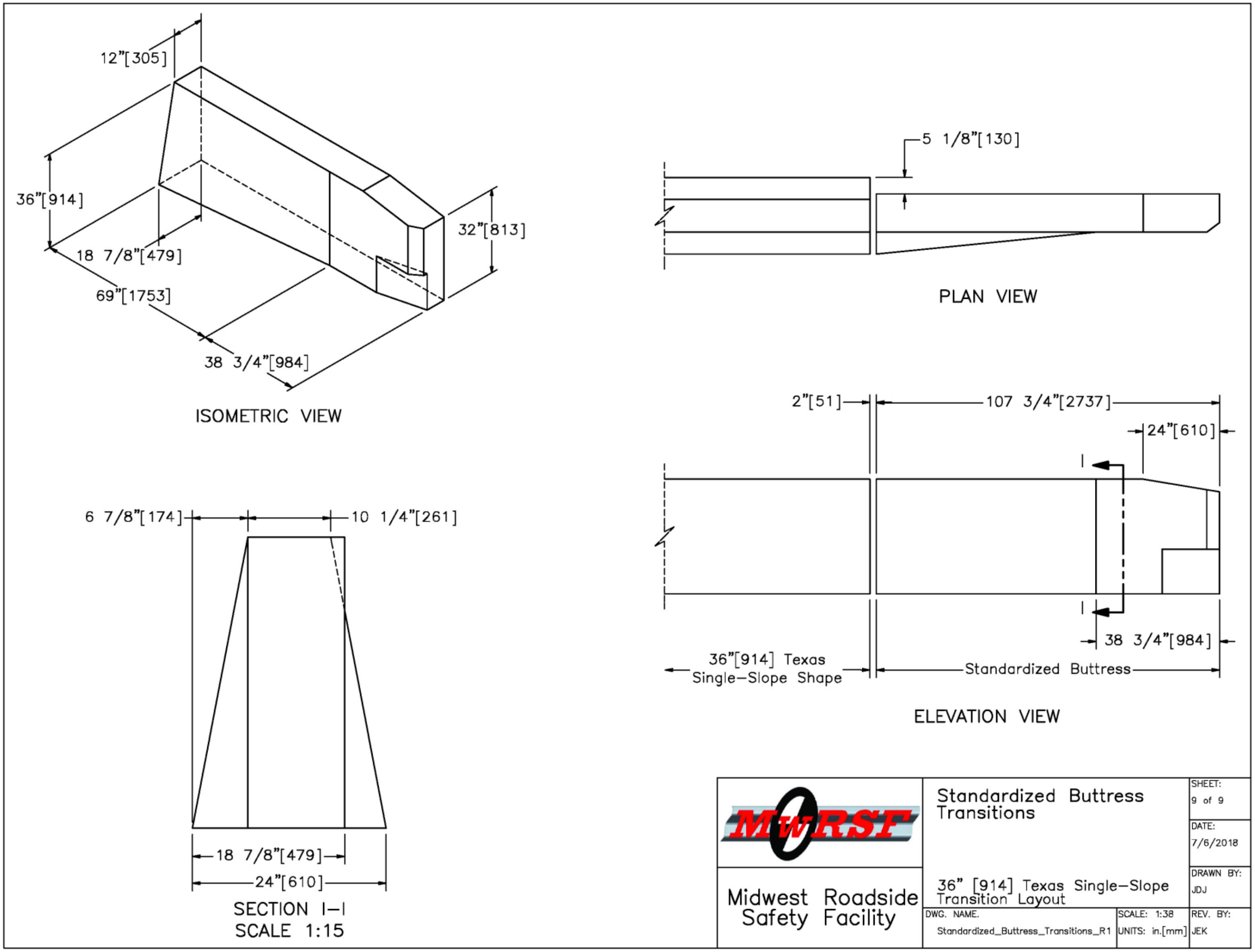


Figure 94. Buttress Shape Transition to 36-in. Tall Texas Single Slope Barrier

10 MASH EVALUATION

The standardized transition buttress was developed for use with a variety of thrie-beam, approach guardrail transitions (AGTs) either with or without a curb placed below the guardrail. The standardized transition buttress was designed with a dual taper on its upstream edge. The lower taper measured 4½ in. by 18 in. long and was 14 in. tall. The 4:1 slope of the lower taper was designed to mitigate the severity of tire snag on the buttress below the guardrail. The upper taper measured 3 in. by 4 in. longitudinally and was designed to prevent vehicle snag, to prevent sharp kinks from forming in the guardrail, and to limit the unsupported span length between the buttress and the first transition post. Additionally, the top of the buttress incorporated a 6:1 vertical slope at the upstream end to safely transition from 32 in. to the height of the adjacent bridge rail or rigid parapet.

Since the standardized buttress was intended for use in a variety of AGT and curb options, it was evaluated through crash testing in a worst-case scenario configuration. A literature review of previously-tested TL-3 AGTs was conducted to identify a critically flexible, thrie-beam, guardrail transition, which would allow large system deflections and maximize the risk snagging on the buttress. Additionally, curbs placed below AGTs have been shown to reduce snag by limiting the tires from extending under the guardrail. Thus, for testing purposes, the standardized transition buttress was attached to the critical AGT without a curb under the guardrail.

Test no. AGTB-2 was conducted on the test article described above in accordance with MASH test designation no. 3-21. The 2270P pickup truck impacted the system 86 in. upstream from the standardized transition buttress and was safely contained and redirected without excessive roll and pitch angular displacements. The front tire did contact the lower taper of the buttress, but the sloped faced prevented excessive decelerations to the vehicle. All OIV, ORA, and occupant crush values were within the MASH limits. Thus, test no. AGTB-2 satisfied all of the requirements for MASH test designation no. 3-21.

Although not detailed herein, a MASH test designation no. 3-20 test with the 1100C small car was conducted on a similar AGT system incorporating a slightly modified version of the standardized transition buttress. The AGT utilized a top rail height of 34 in., which is 3 in. higher than standard transitions, and the increased rail height was associated with an increased risk of the small car extending under the rail and snagging on the buttress. The AGT was connected to the standardized transition buttress with the height increased by 3 in. to match the height increase of the guardrail. The 34-in. tall AGT was also tested without a curb, thereby maximizing the potential for vehicle snag under the guardrail. The full scale crash test results on this 34-in. tall AGT satisfied MASH test designation no. 3-20 evaluation criteria [42-43].

The MASH test designation no. 3-20 test described above was considered a worst-case scenario since the increased rail height further increased the risk for excess vehicle snag on the buttress below the guardrail. Standard 31-in. tall AGTs would be expected to capture more of the vehicle during redirections and reduce the severity of vehicle snag on the buttress. Therefore, the standardized transition buttress has been successfully crash tested to both MASH tests designation nos. 3-20 and 3-21 in worst-case scenario configurations, and the buttress has been determined to be crashworthy to MASH TL-3 standards.

The standardized transition buttress was developed to be compatible with other crash-tested, thrie-beam, approach guardrail transitions. The use of the other crashworthy approach guardrail transitions would add stiffness and strength to the AGT and, thus, reduce snag on the buttress. Additionally, the use of a curb below the guardrail would limit tire extension into the rail and reduce vehicle snag on the buttress. Therefore, AGT systems can be considered MASH TL-3 crashworthy when standardized transition buttress is utilized with any previously crash-tested, thrie beam, approach guardrail transition installed either with or without a curb. Implementation guidance for AGT incorporating different guardrail configurations can be found in Chapter 9.

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12 APPENDICES

Appendix A. Material Specifications

Table A-1. Bill of Materials for Test No. AGTB-1

Item No.	Description	Material Specification	Reference
a1	W6x8.5, 72” Long Steel Post	ASTM A36 Steel Galv.	H#2413988
a2	6”x12”x14¼” Blockout	SYP Grade No. 1 or better	CNWP COC – 1/30/2015
a3	16D Double Head Nail	n/a	n/a
a4	W6x8.5, 72” Long Steel Post	ASTM A36 Steel Galv.	H#2413988
a5	6”x12”x19” Blockout	SYP Grade No. 1 or better	CNWP COC – 5/27/2015
a6	W6x8.5, 78” Long Steel Post	ASTM A36 Steel Galv.	LOT#5A19
a7	4”x7”x17½” Iowa Steel Blockout	n/a	H#E03090
b1	BCT Timber Post – MGS Height	SYP Grade No. 1 or better	ATS COC – 5/8/2015
b2	72” Long Foundation Tube	ASTM A500 Grade B Galv.	H#0173175
b3	Strut and Yoke Assembly	ASTM A36 Steel Galv.	THP COC – 6/30/2008
b4	BCT Cable Anchor Assembly	¾” 6x19 IWRC IPS Galv. Wire Rope	THP COC – 12/6/2013
b5	Anchor Bracket Assembly	ASTM A36 Steel Galv.	H#4153095
b6	8”x8”x⅝” Anchor Bearing Plate	ASTM A36 Steel Galv.	H#6106195
b7	2⅜” O.D. x 6” Long BCT Post Sleeve	A500 Grade B	H#E86298
c1	Thrie Beam Terminal Connector	10 gauge AASHTO M180	H#ND3831
c2	3½”x3½”x¼” Washer Plate	ASTM A36 Steel Plate Galv.	H#B505037
c3	12.5’ Thrie Beam Section	12 gauge AASHTO M180	H#L31815
c4	6’-3” Thrie Beam Section	12 gauge AASHTO M180	H#L31015
c5	6’-3” W-Beam to Thrie Beam Transition Section	12 gauge AASHTO M180	H#C71847
c6	12’-6” W-Beam MGS Section	12 gauge AASHTO M180	H#9411949
c7	12’-6” W-Beam MGS End Section	12 gauge AASHTO M180	H#9411949
d1	⅝” Dia. UNC, 14” Long Guardrail Bolt and Nut	Bolt – ASTM A307 Galv. Nut – ASTM A563 A Galv.	LOT#22191 & LOT#25512

Table A-2. Bill of Materials for Test No. AGTB-1, Cont.

Item No.	Description	Material Specification	Reference
d2	⅝" Dia. UNC, 10" Long Guardrail Bolt and Nut	Bolt – ASTM A307 Galv. Nut – ASTM A563 A Galv.	LOT#140530L H#20297970
d3	⅝" Dia. UNC, 1½" Long Guardrail Bolt and Nut	Bolt – ASTM A307 Galv. Nut – ASTM A563 A Galv.	Bolt: H#20337380 Nut: H#10351040
d4	⅝" Dia. UNC, 10" Long Hex Head Bolt and Nut	Bolt – ASTM A307 Galv. Nut – ASTM A563 A Galv.	LOT#08334-1 H#JK1110419701
d5	⅝" Dia. UNC, 1½" Long Hex Head Bolt and Nut	Bolt – ASTM A307 Galv. Nut – ASTM A563 A Galv.	Roll Form Group COC
d6	⅞" Dia. UNC, 14" Long Heavy Hex Bolt and Nut	Bolt – ASTM A325 Type 1 Galv. Nut – ASTM A563 A Galv.	Bolt: H#155540 Nut: H#155347
d7	⅞" Dia. UNC, 7½" Long Hex Head Bolt and Nut	Bolt – ASTM A325 Type 1 Galv. Nut – ASTM A563 A Galv.	Bolt: LOT#17071802 Nut: LOT#10011913
d8	⅝" Dia. Plain Round Washer	ASTM F844 Galv.	n/a
d9	⅞" Dia. Plain Round Washer	ASTM F844 Galv.	n/a
e1	#4 Bar – Stirrup – 86" Long	ASTM A615 Gr. 60	H#64050283
e2	#4 Bar – Stirrup – 85" Long	ASTM A615 Gr. 60	H#64050283
e3	#4 Bar – Stirrup – 83½" Long	ASTM A615 Gr. 60	H#64050283
e4	#4 Bar – Stirrup – 82" Long	ASTM A615 Gr. 60	H#64050283
e5	#4 Bar – Stirrup – 61½" Long	ASTM A615 Gr. 60	H#64050283
e6	#4 Bar – Stirrup – 75⅛" Long	ASTM A615 Gr. 60	H#64050283
e7	#4 Bar – Veritcal – 16" Long	ASTM A615 Gr. 60	H#579921
e8	#4 Bar – Bent Longitudinal – 80¼" Long	ASTM A615 Gr. 60	H#64050283
e9	#4 Bar – Bent Longitudinal – 85½" Long	ASTM A615 Gr. 60	H#64050283
e10	#4 Bar – Longitudinal – 80" Long	ASTM A615 Gr. 60	H#64050283
e11	#4 Bar – Bent Longitudinal – 80½"	ASTM A615 Gr. 60	H#64050283

Table A-3. Bill of Materials for Test No. AGTB-2

Item No.	Description	Material Specification	Reference
a1	12'-6" 12-gauge Thrie Beam Section	AASHTO M180	H#151877
a2	6'-3" 12-gauge Thrie Beam Section	AASHTO M180	H#L34816
a3	6'-3" 10-gauge W-Beam to Thrie Beam Asymmetric Transition Section	AASHTO M180	H#A81032
a4	12'-6" 12-gauge W-Beam MGS Section	AASHTO M180	H#9411949
a5	12'-6" 12-gauge W-Beam MGS End Section	AASHTO M180	H#9411949
a6	10-gauge Thrie Beam Terminal Connector	AASHTO M180	H#C79045
b1	Concrete – 21.9 cubic ft	Min. f'c = 4,000 psi	Benesch test 6/13/2017
c1	BCT Timber Post – MGS Height	SYP Grade No. 1 or better	CNWP COC 3/2/2017
c2	72" Long Foundation Tube	ASTM A500 Gr. B	H#A49248
c3	Ground Strut Assembly	ASTM A36	THP COC 6/30/2008
c4	BCT Cable Anchor Assembly	n/a	THP COC 7/6/2016
c5	Anchor Bracket Assembly	ASTM A36	H#JK16101488
c6	8"x8"x⅝" Anchor Bearing Plate	ASTM A36	H#DL15103543
c7	2⅜" O.D. x 6" Long BCT Post Sleeve	ASTM A53 Gr. B Schedule 40	H#A79999
d1	W6x8.5, 72" Long Steel Post	ASTM A992	H#55044258
d2	W6x8.5, 72" Long Steel Post	ASTM A992	H#55044258
d3	W6x8.5, 78" Long Steel Post	ASTM A992	H#55046653
d4	6"x12"x14¼" Timber Blockout	SYP Grade No. 1 or better	CNWP COC 7/26/2016
d5	6"x12"x19" Timber Blockout	SYP Grade No. 1 or better	CNWP COC 7/18/2016
d6	17½" Long, 7"x4"x$^3/_{16}$" Iowa Steel Blockout	ASTM A500 Gr. B	H#1828C4 H#E03090
d7	16D Double Head Nail	n/a	McMASTER-CARR COC PO E000357170
e1	½" Dia., 86" Long Bent Rebar	ASTM A615 Gr. 60	H#58028855

Table A-4. Bill of Materials for Test No. AGTB-2, Cont.

Item No.	Description	Material Specification	Reference
e2	½” Dia., 62¾” Long Bent Rebar	ASTM A615 Gr. 60	H#58028855
e3	½” Dia., 60½” Long Bent Rebar	ASTM A615 Gr. 60	H#58028855
e4	½” Dia., 59¼” Long Bent Rebar	ASTM A615 Gr. 60	H#58028855
e5	½” Dia., 74¾” Long Bent Rebar	ASTM A615 Gr. 60	H#58028855
e6	½” Dia., 37¼” Long Rebar	ASTM A615 Gr. 60	H#58028855
e7	½” Dia., 80¼” Long Bent Rebar	ASTM A615 Gr. 60	H#58028855
e8	½” Dia., 85½” Long Bent Rebar	ASTM A615 Gr. 60	H#58028855
e9	½” Dia., 80” Long Rebar	ASTM A615 Gr. 60	H#58028855
e10	½” Dia., 80½” Long Bent Rebar	ASTM A615 Gr. 60	H#58028855
f1	⅝” Dia. UNC, 14” Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	H#NF16100453
f2	⅝” Dia. UNC, 10” Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	H#20297970
f3	⅝” Dia. UNC, 2” Long Guardrail Bolt and Nut	1-1/4" Splice Bolts used	n/a
f4	⅝” Dia. UNC, 1¼” Long Guardrail Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – ASTM A563A	Bolts: H#20460760 Nuts: H#20479830
f5	⅞” Dia. UNC, 14” Long Heavy Hex Head Bolt and Nut	Bolt – ASTM F3125 Gr. A325 Nut – ASTM A563DH	Bolt: H#NF16102579 Nut: H#75066009
f6	⅞” Dia. UNC, 8” Long Hex Head Bolt and Nut	Bolt – ASTM A36 Nut – ASTM A563DH	Bolt: H#2038622 Nut: H#12101054
f7	⅝” Dia. UNC, 10” Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – SAE J995(99) – Gr. 2	H#DL15107048 COC 6/15/2016
f8	⅝” Dia. UNC, 1½” Long Hex Head Bolt and Nut	Bolt – ASTM A307 Gr. A Nut – SAE J995(99) – Gr. 2	Bolts: H#816070039 Nuts: C#210101523
g1	⅞” Dia. Plain Round Washer	ASTM F844	n/a
g2	⅝” Dia. Plain Round Washer	ASTM F844	n/a
g3	3”x3”x¼” Square Washer Plate	ASTM A572 Gr. 50	n/a

NUCOR STEEL BERKELEY
P.O. Box 2259
Mt. Pleasant, S.C. 29464
Phone: (843) 336-6000

CERTIFIED MILL TEST REPORT

12/22/14 18:46:36
100% MELTED AND MANUFACTURED IN THE USA
All beams produced by Nucor-Berkeley are cast and rolled to a fully killed and fine grain practice.
Mercury has not been used in the direct manufacturing of this material.

Sold To: HIGHWAY SAFETY CORP
PO BOX 358

GLASTONBURY, CI 06033

Ship To: HIGHWAY SAFETY CORP
473 WEST FAIRGROUND STREET

MARION, OH 43301

Customer #.: 352 - 3
Customer PO: 1627044
B.O.L. #...: 1110076
MOS: I

SPECIFICATIONS: Tested in accordance with ASTM specification A6/A6M-14 and A370. Quality Manual Rev #27.
ASTM : A572 5013a:A529-14-50 IB-B0600800

Description	Heat# / Grade(s) / Test/Heat JW	Yield/ Tensile Ratio	Yield (PSI) (MPa)	Tensile (PSI) (MPa)	Elong %	C / Cr / ******	Mn / Mo / Ti	P / Sn / ******	S / B / ******	Si / V / N	Cu / Nb / ******	Ni / ****** / CI	CE1 / CE2 / Pcm
W6X8.5	2413985	.83	57200	69300	25.54	.07	.84	.013	.039	.21	.20	.05	.25
042' 00.00"	A572 5013a		394	478		.06	.01	.0091	.0005	.005	.015		.2835
W150X12.6	A992-11	.82	56400	69100	26.69		.001			.0051		4.59	.1404
012.8016m	ANS		389	476	90 Pc(s) 32,130 lbs							Inv#:	0
W6X8.5	2413988	.83	58300	70600	26.70	.07	.86	.014	.034	.17	.23	.06	.25
042' 00.00"	A572 5013a		402	487		.06	.01	.0091	.0005	.004	.015		.2773
W150X12.6	A992-11	.82	57200	69800	28.55		.001			.0051		4.87	.1356
012.8016m	ANS		394	481	36 Pc(s) 12,852 lbs							Inv#:	0

2 Heat(s) for this MTR.

R#15-0515 H#2413988

W6x8.5x6'

April 2015 SMT

Elongation based on 8" (20.32cm) gauge length. 'No Weld Repair' was peformed.
CI = 26.01Cu+3.88Ni+1.20Cr+1.49Si+17.28P (7.29Cu*Ni) (9.10Ni*P) 33.39(Cu*Cu)
Pcm = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B
CE1 = C+(Mn/6)+((Cr+Mo+V)/5)+((Ni+Cu)/15)
CE2 = C+((Mn+Si)/6)+((Cr+Mo+V+Cb)/5)+((Ni+Cu)/15)

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

Bruce A. Work
Metallurgist

Figure A-1. W6x8.5 – 72-in. Long Steel Posts, Test No. AGTB-1

CENTRAL
NEBRASKA
WOOD PRESERVERS, INC.

P. O. Box 630 • Sutton, NE 68979
Pone 402-773-4319
FAX 402-773-4513

R#15-0515
6x12x14 OCD Wood Blockouts
Light Blue Paint

Date: 1/30/15

CERTIFICATE OF COMPLIANCE

Shipped TO: Midwest Machinery – Milford   BOL# 10050796

Customer PO# 3004 Thur 1   Preservative: CCA – C 0.60 pcf

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
GR6814 BLK	6x8-14" BLK Tapered	252	19877	.708 pcf
GR61214 BLK	6x12-14" BLK OCD	168	19815	.603 pcf
↓	↓	420	19814	.681 pcf
↓	↓	588	19809	.694 pcf

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

Kurt Andres, General Manager   1/30/15
Date

Figure A-2. 6-in. x 12-in. x 14¼-in. Blockouts, Test No. AGTB-1

CENTRAL NEBRASKA WOOD PRESERVERS, INC.

P. O. Box 630 • Sutton, NE 68979
Pone 402-773-4319
FAX 402-773-4513

6x12x19" Wood Blockouts
AGT Buttress
R#16-0008/9 Ch#20570

Date: 5/27/15

CERTIFICATE OF COMPLIANCE

Shipped TO: Midwest Machinery and Supply BOL# 10051538

Customer PO# 3065 Preservative: CCA – C 0.60 pcf AWPA UC4B

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
GR6823BLK	6x8x22" OCD Block	84	20570	.638
GR61219BLK	6x12x 19 OCD Tri Block	224	20570	.638
GR61214BLK	6x12x 14 OCD Block	252	20517	.629
GR61214BLK	6x12x14 OCD Block	84	20578	.652

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

VA: Central Nebraska 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

5/27/15
Date

Figure A-3. 6-in. x 12-in. x 19-in. Blockouts, Test No. AGTB-1

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

Customer:	GUARDRAIL SYSTEMS 8000 SERUM AVE RALSTON,NE,68127-4213	Test Report Ship Date: Customer P.O.: Shipped to: Project: GHP Order No:	 5/8/2015 VERBAL TRENT 4-13-2015 GUARDRAIL SYSTEMS STOCK 7844AA

HT # code	Lot #	C.	Mn.	P.	S.	Si.	Tensile	Yield	Elong.	Quanity	Class	Type	Description
L98864	5A19	0.09	0.9	0.014	0.021	0.18	63000	52000	20	400	#N/A	2	6INWF AT 8.5 X 6FT6IN GR POST
L98865	5A19	0.08	0.85	0.01	0.017	0.2	63000	50400	20	200	#N/A	2	6INWF AT 8.5 X 6FT6IN GR POST
L98866	5A19	0.08	0.88	0.01	0.016	0.21	69000	54400	25	200	#N/A	2	6INWF AT 8.5 X 6FT6IN GR POST

w6x8.5x6'6" QTY 6
R#16-0010 L#5A19
Heat number is not definitive
AGT Buttress July 2015 SMT

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 & Iowa 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 8 day of May, 2015

Notary Public, State of Ohio

Aubrey Patton
Notary Public, State of Ohio
My Commission Expires 02-02-2019

STATE OF OHIO

Figure A-4. W6x8.5 – 78-in. Long Steel Posts, Test No. AGTB-1

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

Atlas Tube JMC STEEL GROUP

Ref.B/L: 80664486
Date: 05.12.2015
Customer: 193

MATERIAL TEST REPORT

Sold to

Tubular Steel
1031 Executive Parkway
ST. LOUIS MO 63141
USA

AGT Buttress
Steel Blockout
R#16-0013 July 2015 SMT

Shipped to

Tubular Steel
7220 Polson Lane
HAZELWOOD MO 63042
USA

Material: 5.0x4.0x375x40'0"0(3x3). **Material No:** 500403754000 **Made in:** USA **Melted in:** USA

Sales order: 1001327 **Purchase Order:** PO-048483 **Cust Material #:** 012320

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
Y80316	0.200	0.820	0.014	0.009	0.024	0.044	0.040	0.006	0.005	0.020	0.040	0.001	0.001	0.000	0.005

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.35
M800554738	9	069347 Psi	079747 Psi	33 %	ASTM A500-13 GRADE B&C	

Material Note:
Sales Or.Note:

Material: 7.0x4.0x188x48'0"0(3x3). **Material No:** 700401884800 **Made in:** USA **Melted in:** USA

Sales order: 1001327 **Purchase Order:** PO-048483 **Cust Material #:** 012779

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
E03090	0.190	0.750	0.014	0.010	0.010	0.043	0.020	0.005	0.003	0.010	0.040	0.001	0.001	0.000	0.004

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.33
M800554401	9	062369 Psi	077410 Psi	28 %	ASTM A500-13 GRADE B&C	

Material Note:
Sales Or.Note:

Material: 7.0x4.0x188x48'0"0(3x3). **Material No:** 700401884800 **Made in:** USA **Melted in:** USA

Sales order: 1001327 **Purchase Order:** PO-048483 **Cust Material #:** 012779

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
E03090	0.190	0.750	0.014	0.010	0.010	0.043	0.020	0.005	0.003	0.010	0.040	0.001	0.001	0.000	0.004

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.33
M800554402	9	062369 Psi	077410 Psi	28 %	ASTM A500-13 GRADE B&C	

Material Note:
Sales Or.Note:

Marvin Phillips

Marvin Phillips

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 3

Metals Service Center Institute

Figure A-5. 6-in. x 7-in. x 17½-in. Iowa Steel Blockouts, Test No. AGTB-1

AMERICAN TIMBER AND STEEL

R#16-0010
BCT Wood Posts
12posts

This is to certify that the materials shipped, as indicated, conform to the State of Nebraska specifications.
Order Number: 158755
Project Number: N/A

QUANTITY	DESCRIPTION	CHARGE NO.	TREATMENT	TREATER
60	6X8-19" (2H) BLOCK	TX-3547	CCA	ATS-NAC
120	6X8-19" (2H) OS THRIE BLOCK	TX-3547	CCA	ATS-NAC
100	6X12-19" (2H) OS THRIE BLOCK	TX-3547	CCA	ATS-NAC
400	6X12-19" (2H) OS THRIE BLOCK	TX-3546	CCA	ATS-NAC
48	6X8-6' 2H THRIE POST	TX-2360	CCA	ATS-NAC
96	6X8-6' MGS CRT POST	TX-3547	CCA	ATS-NAC
40	5.5X7.5-45" BCT POST	TX-3227	CCA	ATS-NAC
40	5.5X7.5-46" BA POST	TX-3547	CCA	ATS-NAC

ATS – AMERICAN TIMBER AND STEEL, NORWALK, OH
MWT-OK - MIDWEST WOOD TREATING, INC., CHICKASHA, OK
ATS-NAC – AMERICAN TIMBER AND STEEL, NACADOCHES, TX
GAT- GREAT AMERICAN TREATING, TYLER,TX

Made & Treated in the USA. Meets AASHTO Specs M133 & M168.

AMERICAN TIMBER AND STEEL

By Derek Hoebing

Title Guardrail Salesman

Date May 8, 2015

NOTARIZED

Sworn to and subscribed before me

this 8 day of May 2015.

by Andrea L Bender

NOTARY PUBLIC STATE OF OHIO

ANDREA L. BENDER
Seneca County
NOTARY PUBLIC, STATE OF OHIO
My Commission Expires
March 26, 2020

American Timber And Steel Corp ★ 4832 Plank Rd / PO Box 767 ★ Norwalk, OH 44857 ★ Ph: 419.668.1610 ★ Fax: 419.663.1077

"THE TIMBER SPECIALISTS"

Figure A-6. BCT Timber Posts – MGS Height, Test No. AGTB-1

Certified Analysis

Trinity Highway Products, LLC
550 East Robb Ave.
Lima, OH 45801
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405
Project: STOCK

Order Number: 1215324 Prod Ln Grp: 9-End Terminals (Dom)
Customer PO: 2884
BOL Number: 80821 Ship Date:
Document #: 1
Shipped To: NE
Use State: KS

As of: 4/14/14

Foundation Tubes Green Paint
R#15-0157 September 2014 SMT

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
10	701A	.25X11.75X16 CAB ANC	A-36			A3V3361	48,600	69,000	29.1	0.180	0.410	0.010	0.005	0.040	0.270	0.000	0.070	0.001	4
	701A		A-36			JJ4744	50,500	71,900	30.0	0.150	1.060	0.010	0.035	0.240	0.270	0.002	0.090	0.021	4
12	729G	TS 8X6X3/16X8'-0" SLEEVE	A-500			0173175	55,871	74,495	31.0	0.160	0.610	0.012	0.009	0.010	0.030	0.000	0.030	0.000	4
15	736G	5'/TUBE SL/.188"X6"X8"FLA	A-500			0173175	55,871	74,495	31.0	0.160	0.610	0.012	0.009	0.010	0.030	0.000	0.030	0.000	4
12	749G	TS 8X6X3/16X6'-0" SLEEVE	A-500			0173175	55,871	74,495	31.0	0.160	0.610	0.012	0.009	0.010	0.030	0.000	0.030	0.000	4
5	783A	5/8X8X8 BEAR PL 3/16 STP	A-36			10903960	56,000	79,500	28.0	0.180	0.810	0.009	0.005	0.020	0.100	0.012	0.030	0.000	4
	783A		A-36			DL13106973	57,000	72,000	22.0	0.160	0.720	0.012	0.022	0.190	0.360	0.002	0.120	0.050	4
20	3000G	CBL 3/4X6'6/DBL	HW			99692													
25	4063B	WD 6'0 POST 6X8 CRT	HW			43360													
15	4147B	WD 3'9 POST 5.5"X7.5"	HW			2401													
20	15000G	6'0 SYT PST/8.5/31" GR HT	A-36			34940	46,000	66,000	25.3	0.130	0.640	0.012	0.043	0.220	0.310	0.001	0.100	0.002	4
10	19948G	.135(10Ga)X1.75X1.75	HW			P34744													
2	33795G	SYT-3"AN STRT 3-HL 6'6	A-36			JJ6421	53,600	73,400	31.3	0.140	1.050	0.009	0.028	0.210	0.280	0.000	0.100	0.022	4
4	34053A	SRT-31 TRM UP PST 2'6.625	A-36			JJ5463	56,300	77,700	31.3	0.170	1.070	0.009	0.016	0.240	0.220	0.002	0.080	0.020	4

1 of 3

Figure A-7. 72-in. Long Foundation Tubes, Test No. AGTB-1

425 E. O'Connor
Lima, OH

Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097

Sales Order: 1093497
Customer PO: 2030
BOL # 43073
Document # 1

Print Date: 6/30/08
Project: RESALE
Shipped To: NE
Use State: KS

Trinity Highway Products. LLC

Certificate Of Compliance For Trinity Industries, Inc. ** SLOTTED RAIL TERMINAL **

NCHRP Report 350 Compliant

Pieces	Description
64	5/8"X10" GR BOLT A307
192	5/8"X18" GR BOLT A307
32	1" ROUND WASHER F844
64	1" HEX NUT A563
192	WD 6'0 POST 6X8 CRT
192	WD BLK 6X8X14 DR
64	NAIL 16d SRT
64	WD 3'9 POST 5.5X7.5 BAND
32	STRUT & YOKE ASSY
128	SLOT GUARD '98
32	3/8 X 3 X 4 PL WASHER

MGSBR

Ground Strut

090453-8

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

05/04/2009 16:36 402-761-3288

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL OTHER GALVANIZED MATERIAL CONFORMS WITH ASTM-123.
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.
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 – 49100 LB
State of Ohio, County of Allen. Sworn and Subscribed before me this 30th day of June, 2008

Notary Public: [signature]
Commission Expires [illegible]

Trinity Highway Products, LLC
Certified By: [signature]

2 of 4

Figure A-8. Strut and Yoke Assembly, Test No. AGTB-1

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801

Customer: GUARDRAIL SYSTEMS, INC
8000 SERUM AVE.

RALSTON, NE 68127

Sales Order: 1210536
Customer PO: VERBAL TRENT
BOL # 79448
Document # 1

Print Date: 12/6/13
Project: RESALE
Shipped To: NE
Use State: NE

Trinity Highway Products, LLC

Certificate Of Compliance For Trinity Industries, Inc. ** SLOTTED RAIL TERMINAL **

NCHRP Report 350 Compliant

Pieces	Description	Part No
1	12/6"/FLANGE PROTECTOR	000007G
79	12/12'6/S SRT-1	000030G
79	12/12'6/S SRT-2	000039G
49	3/16X12.5X16 CAB ANC BRKT	000700A
49	12/BUFFER/ROLLED	000907G
49	CBL 3/4X6'6/DBL SWG/NOHWD	003000G
98	5/16" ROUND WASHER WIDE	003240G
98	5/16" HEX NUT A563	003245G
588	5/8" WASHER F844 A/W	003300G
3,283	5/8" GR HEX NUT	003340G
2,548	5/8"X1.25" GR BOLT	003360G
392	5/8"X1.5" HEX BOLT A307	003380G
98	5/8"X1.75" HEX BOLT A325	003391G
196	5/8"X2" GR BOLT	003400G
98	1" ROUND WASHER F844	003900G
98	1" HEX NUT A563	003910G
98	5/16"X1.75 HXBTA307 1-1/8	004211G
49	5/8"X1.75" SLTDCNTRSKBOLT	004419G
196	SLOT GUARD '98	009960G
49	12/9'4.5/3'1.5/S	010967G
245	6'0 SYT PST/8.5/31" GR HT	015000G
49	HBA-3"ANG STRUT 2-HL 6'6"	033875G
49	CASS-CBL BRKT FOR CRP PST	033909G
49	SRT-31/27 LOWER PST 6'4	034052A
49	SRT-31 TRM UP PST 2'6.625	034053A
49	W-BEAM GD RL SHELF ANGLE	034054G

R#15-0284 and R#15-0285
BCT Cables
purchased and some converted to
2part Cables at Omaha Slings
January 2015 SMT

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

1 of 2

Figure A-9. BCT Cable Anchor Assembly, Test No. AGTB-1

Certified Analysis

Trinity Highway Products, LLC
2548 N.E. 28th St.
Ft Worth, TX

Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097

Project: RESALE

Order Number: 1095199
Customer PO: 2841
BOL Number: 24481
Document #: 1
Shipped To: NE
Use State: KS

As of: 6/20/08

Qty	Part#	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
25	6G	12/6'3/S	M-180	A		84964	64,230	81,300	25.4	0.180	0.720	0.012	0.001	0.040	0.080	0.000	0.060	0.000	4
20	701A	.25X11.75X16 CAB ANC	A-36			4153095	44,900	60,800	34.0	0.240	0.750	0.012	0.003	0.020	0.030	0.000	0.040	0.002	4
10	742G	6'0 TUBE SL/.188X8X6	A-500			A8P1160	74,000	87,000	25.2	0.050	0.670	0.013	0.005	0.030	0.220	0.000	0.060	0.021	4
20	782G	5/8"X8"X8" BEAR PL/OF	A-36			6105195	46,700	69,900	23.5	0.180	0.830	0.010	0.005	0.020	0.230	0.000	0.070	0.006	4
40	907G	12/BUFFER/ROLLED	M-180	A		L0049	54,200	73,500	25.0	0.160	0.700	0.011	0.008	0.020	0.200	0.000	0.100	0.000	4

Upon delivery, all materials subject to Trinity Highway Products, LLC Storage Stain Policy No. LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL OTHER GALVANIZED MATERIAL CONFORMS WITH ASTM-123.
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.

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 – 49100 LB

State of Texas, County of Tarrant. Sworn and subscribed before me this 20th day of June, 2008

Notary Public:
Commission Expires

RACHEL R. MEDINA
Notary Public
State of Texas
My Commission Expires

Trinity Highway Products, LLC
Certified By:

Stefanie Onal.

Figure A-10. Anchor Bracket Assembly and Anchor Bearing Plate, Test No. AGTB-1

09Mar'15 13:22 TEST CERTIFICATE No: MAR 268339

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

P/O No 4500240795
Rel
S/O No MAR 280576-001
B/L No MAR 163860-003 Shp 09Mar'15
Inv No Inv

Sold To: (5016)
STEEL & PIPE SUPPLY
1003 FORT GIBSON ROAD
CATOOSA, OK 74015

Ship To: (1)
STEEL & PIPE SUPPLY
1003 FORT GIBSON ROAD
CATOOSA, OK 74015

Tel: 918-266-6325 Fax: 918 266-4652

CERTIFICATE of ANALYSIS and TESTS Cert. No: MAR 268339
05Mar'15

Part No 0010
ROUND A500 GRADE B(C)
2.375"OD (2"NPS) X SCH40 X 21'

		Pcs	Wgt
ROUND A500 GRADE B(C) 2.375"OD (2"NPS) X SCH40 X 21'		111	8,508
Heat Number	Tag No	Pcs	Wgt
E86298	927111 YLD=69600/TEN=79070/ELG=24.2	37	2,836
E86298	927113	37	2,836
E86298	927114	37	2,836

Heat Number *** Chemical Analysis ***
E86298 C=0.1700 Mn=0.5100 P=0.0100 S=0.0110 Si=0.0190 Al=0.0450
Cu=0.0300 Cr=0.0300 Mo=0.0030 V=0.0010 Ni=0.0100 Cb=0.0010
MELTED AND MANUFACTURED IN THE USA

R#15-0626 H#E86298
BCT Pipe Sleeves
June 2015 SMT

WE PROUDLY MANUFACTURE ALL OF OUR HSS IN THE USA.
INDEPENDENCE TUBE PRODUCT IS MANUFACTURED, TESTED,
AND INSPECTED IN ACCORDANCE WITH ASTM STANDARDS.

CURRENT STANDARDS:
................................A500/A500M-13
................................A513-12
................................A252-10
................................A847/A847M-12

MATERIAL IDENTIFIED AS A500 GRADE B(C) MEETS BOTH
ASTM A500 GRADE B AND A500 GRADE C SPECIFICATIONS.

Page: 1 .... Last

Figure A-11. 2⅜-in. O.D. x 6-in. Long BCT Post Sleeve, Test No. AGTB-1

Certified Analysis

Trinity Highway Products, LLC

'rinity Highway Products , LLC
50 East Robb Ave.
.ima, OH 45801
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405

Order Number: 1236801 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 3028
BOL Number: 86849
Document #: 1
Shipped To: NE
Use State: NE

As of: 3/13/15

Ship Date:
AGT Buttress
R#16-0008 Thrie Beam End Shoe
H#ND3831

Project: RESALE **TARP LOAD** **TARP LOAD** **TARP LOAD**

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
20	5G	12/6'3/3'1.5/S			2	L10915													
			M-180	A	2	186718	64,270	82,950	23.7	0.190	0.740	0.010	0.005	0.010	0.130	0.000	0.060	0.001	4
			M-180	A	2	186719	62,050	79,480	27.0	0.180	0.730	0.014	0.004	0.020	0.120	0.000	0.070	0.001	4
			M-180	A	2	186950	64,700	82,300	24.0	0.190	0.730	0.013	0.003	0.030	0.140	0.000	0.080	0.001	4
			M-180	A	2	186951	62,430	81,480	28.3	0.190	0.720	0.011	0.002	0.020	0.140	0.000	0.060	0.001	4
			M-180	A	2	187089	61,020	79,330	30.2	0.180	0.720	0.011	0.003	0.020	0.130	0.000	0.060	0.000	4
			M-180	A	2	187090	60,660	79,170	26.8	0.180	0.710	0.009	0.005	0.020	0.140	0.000	0.060	0.001	4
			M-180	A	2	187091	61,330	80,180	27.2	0.190	0.730	0.012	0.004	0.020	0.140	0.000	0.060	0.000	4
25	701A	.25X11.75X16 CAB ANC	A-36			JK0368	53,700	76,000	28.0	0.140	1.030	0.011	0.029	0.210	0.280	0.002	0.120	0.019	4
	701A		A-36			4118187	54,500	64,000	34.0	0.070	0.490	0.008	0.006	0.020	0.050	0.022	0.040	0.000	4
30	749G	TS 8X6X3/16X6'-0" SLEEVE	A-500			0177494	65,817	67,804	31.0	0.170	0.650	0.013	0.007	0.013	0.020	0.001	0.040	0.001	4
30	766G	.25"X 18"X 24"SOIL PL-3H	A-36			C70534	47,600	76,000	30.0	0.250	0.740	0.015	0.003	0.020	0.060	0.001	0.050	0.001	4
25	782G	5/8"X8"X8" BEAR PL/OF	A-36			1034124	55,400	74,100	25.0	0.150	0.760	0.014	0.028	0.190	0.300	0.001	0.160	0.000	4
30	980G	T10/END SHOE/SLANT	M-180	B	2	ND3831	42,300	55,100	36.5	0.040	0.190	0.009	0.005	0.023	0.140	0.003	0.040	0.001	4
4	1403G	12/12'6/3'1 1/2/S 40' CX			2	L10215													
			M-180	A	2	C72676	65,100	86,000	24.2	0.220	0.870	0.010	0.002	0.030	0.110	0.002	0.040	0.001	4
			M-180	A	2	C72677	59,200	77,600	20.1	0.210	0.880	0.012	0.002	0.030	0.150	0.003	0.050	0.001	4
3	1509G	12/12'6/3'1.5/S 50' CX			2	L10815													
			M-180	A	2	186718	64,270	82,950	23.7	0.190	0.740	0.010	0.005	0.010	0.130	0.000	0.060	0.001	4
			M-180	A	2	187089	61,020	79,330	30.2	0.180	0.720	0.011	0.003	0.020	0.130	0.000	0.060	0.000	4
			M-180	A	2	187090	60,660	79,170	26.8	0.180	0.710	0.009	0.005	0.020	0.140	0.000	0.060	0.001	4

1 of 7

Figure A-12. Thrie Beam Terminal Connector, Test No. AGTB-1

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 07/20/2015
TIME 17:59:11
USER MEHEULAL

SOLD TO
12355
Midwest Steel Works, Inc.
81096
Lincoln NE 68501

SHIP TO
12355
Midwest Steel Works, Inc.
737 N Street
Lincoln NE 68508

Order	Material No.	Description	Quantity	Weight	Customer Part	Customer PO	Ship Date
1864149-0010	70872120TM	1/4 72 X 120 A36 TEMPERPASS STPMLPL				47816	07/20/2015

Chemical Analysis

Heat No. B505037 Vendor STEEL DYNAMICS COLUMBUS DOMESTIC Mill STEEL DYNAMICS COLUMBUS Melted and Manufactured in the USA
Batch 0003988521 15 EA 9,189 LB Produced from Coil

Carbon	Manganese	Phosphorus	Sulphur	Silicon	Nickel	Chromium	Molybdenum	Boron	Copper	Aluminum	Titanium	Vanadium	Columbium	Nitrogen	Tin
0.2000	0.8200	0.0160	0.0030	0.0200	0.0500	0.0700	0.0100	0.0001	0.1100	0.0250	0.0010	0.0050	0.0010	0.0067	0.0060

Mechanical/ Physical Properties

Mill Coil No. B505037-02

Tensile	Yield	Elong	Rckwl	Grain	Charpy	Charpy Dr	Charpy Sz	Temperature	Olsen
79000.000	54500.000	25.40			0	NA			
77300.000	53900.000	27.80			0	NA			
76000.000	52800.000	30.50			0	NA			
73600.000	51600.000	27.80			0	NA			

AGT Buttress Square Washers
R#16-0015 H#B505037
July 2015 SMT

THE CHEMICAL, PHYSICAL, OR MECHANICAL TESTS REPORTED ABOVE ACCURATELY REFLECT INFORMATION AS CONTAINED IN THE RECORDS OF THE CORPORATION.

Figure A-13. 3½-in. x 3½-in. x ¼-in. Washer Plates, Test No. AGTB-1

Certified . .nalysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405
Project: RESALE

Order Number: 1240336
Customer PO: 3058
BOL Number: 87968
Document #: 1
Shipped To: NE
Use State: NE

Prod Ln Grp: 3-Guardrail (Dom)

Ship Date:

As of: 5/26/15

Thrie Beam 6'3" AGT Buttress
R#16-008 H#L31815
July 2015 SMT

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
250	4235G	3/16"X1.75"X3" WSHR	HW			C6086													
20	12173G	T12/6'3/4@1'6.75"/S			2	L31815													
			M-180	A	2	188030	63,750	82,190	25.0	0.190	0.740	0.016	0.000	0.020	0.130	0.000	0.080	0.001	4
			M-180	A	2	188035	61,840	79,850	26.9	0.200	0.740	0.012	0.003	0.020	0.130	0.000	0.060	0.001	4
			M-180	A	2	188036	60,720	79,620	28.0	0.190	0.730	0.013	0.004	0.020	0.150	0.000	0.060	0.001	4
			M-180	A	2	188037	62,940	81,950	24.3	0.190	0.720	0.015	0.003	0.020	0.140	0.000	0.070	0.001	4
			M-180	A	2	188038	62,380	81,480	25.6	0.190	0.740	0.014	0.003	0.020	0.150	0.000	0.070	0.001	4
			M-180	A	2	188039	60,270	79,080	25.1	0.200	0.740	0.012	0.005	0.010	0.130	0.000	0.060	0.000	4
			M-180	A	2	95742	58,010	76,770	29.1	0.180	0.710	0.016	0.001	0.020	0.110	0.000	0.090	0.001	4
43	12365G	T12/12'6/8@1'6.75/S			2	L31315													
			M-180	A	2	188036	60,720	79,620	28.0	0.190	0.730	0.013	0.004	0.020	0.150	0.000	0.060	0.001	4
			M-180	A	2	188037	62,940	81,950	24.3	0.190	0.720	0.015	0.003	0.020	0.140	0.000	0.070	0.001	4
			M-180	A	2	188038	62,380	81,480	25.6	0.190	0.740	0.014	0.003	0.020	0.150	0.000	0.070	0.001	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.
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"
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

4 of 5

Figure A-14. 12 ft – 6 in. Thrie Beam Section, Test No. AGTB-1

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: 1241616 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 3071
BOL Number: 88515 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 6/23/15

R#16-0008/R#16-0009
AGT Buttress June 2015 SMT
Thrie Beam 12'6" H#L31015

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
8	974G	T12/TRANS RAIL/6'3"/3'1.5	M-180	A	2	184354	64,550	83,590	22.1	0.190	0.730	0.010	0.003	0.020	0.100	0.000	0.050	0.000	4
40	980G	T10/END SHOE/SLANT	M-180	B	2	ND3831	42,300	55,100	36.5	0.040	0.190	0.009	0.005	0.023	0.140	0.003	0.040	0.001	4
20	10431G	12/12'6/8@1'6-3/4/S			2	L12415													
			M-180	A	2	190219	62,640	79,520	27.4	0.190	0.730	0.012	0.003	0.020	0.130	0.000	0.060	0.000	4
			M-180	A	2	191413	62,300	80,540	27.9	0.190	0.720	0.011	0.003	0.010	0.080	0.000	0.050	0.001	4
			M-180	A	2	191414	65,000	84,190	22.2	0.200	0.730	0.013	0.002	0.020	0.090	0.000	0.050	0.000	4
			M-180	A	2	191415	63,120	81,830	24.3	0.190	0.720	0.011	0.005	0.020	0.060	0.000	0.050	0.001	4
			M-180	A	2	A75083	58,700	80,200	22.3	0.210	0.860	0.013	0.002	0.030	0.110	0.002	0.050	0.001	4
20	10676G	12/25'/4@3'1.5:8@1'6.75/S			2	L12415													
			M-180	A	2	190219	62,640	79,520	27.4	0.190	0.730	0.012	0.003	0.020	0.130	0.000	0.060	0.000	4
			M-180	A	2	191413	62,300	80,540	27.9	0.190	0.720	0.011	0.003	0.010	0.080	0.000	0.050	0.001	4
			M-180	A	2	191414	65,000	84,190	22.2	0.200	0.730	0.013	0.002	0.020	0.090	0.000	0.050	0.000	4
			M-180	A	2	191415	63,120	81,830	24.3	0.190	0.720	0.011	0.005	0.020	0.060	0.000	0.050	0.001	4
			M-180	A	2	A75083	58,700	80,200	22.3	0.210	0.860	0.013	0.002	0.030	0.110	0.002	0.050	0.001	4
40	12173G	T12/6'3/4@1'6.75"/S			2	L32315													
			M-180	A	2	188030	63,750	82,190	25.0	0.190	0.740	0.016	0.000	0.020	0.130	0.000	0.080	0.001	4
			M-180	A	2	188035	61,840	79,850	26.9	0.200	0.740	0.012	0.003	0.020	0.130	0.000	0.060	0.001	4
			M-180	A	2	95742	58,010	76,770	29.1	0.180	0.710	0.016	0.001	0.020	0.110	0.000	0.090	0.001	4
40	12365G	T12/12'6/8@1'6.75/S			2	L31015													
			M-180	A	2	184176	60,470	79,010	26.4	0.180	0.710	0.013	0.004	0.010	0.011	0.000	0.060	0.007	4
			M-180	A	2	184177	59,660	78,450	27.8	0.190	0.720	0.011	0.002	0.020	0.120	0.000	0.050	0.001	4
			M-180	A	2	184354	64,550	83,590	22.1	0.190	0.730	0.010	0.003	0.020	0.100	0.000	0.050	0.000	4
	12365G				2	L32315													

Figure A-15. 6 ft – 3 in. Thrie Beam Section , Test No. AGTB-1

Ce‹tifiec Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801

Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405

Order Number: 1235734 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 3014 As of: 3/4/15
BOL Number: 86780 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

LH Asymmetrical WbeamThriebeam Transition
AGT Buttress R#16-0008 H#C71847
July 2015 SMT

Project: RESALE *TARP LOAD* *TARP LOAD* *TARP LOAD*

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	182998	60,310	78,910	25.4	0.200	0.730	0.012	0.006	0.010	0.140	0.000	0.050	0.001	4
			M-180	A	2	183930	63,240	81,490	26.1	0.180	0.720	0.011	0.003	0.020	0.100	0.000	0.060	0.001	4
			M-180	A	2	183931	59,180	80,750	27.9	0.170	0.720	0.013	0.003	0.020	0.120	0.000	0.070	0.000	4
			M-180	A	2	183932	63,930	82,010	26.7	0.190	0.730	0.012	0.004	0.020	0.110	0.000	0.070	0.001	4
			M-180	A	2	184860	63,890	82,450	25.3	0.190	0.750	0.012	0.005	0.010	0.110	0.000	0.060	0.001	4
1	22319G	12/6'-3"/S 11'CX			2	L14914													
			M-180	A	2	183934	63,290	81,350	26.9	0.190	0.730	0.011	0.005	0.010	0.100	0.000	0.060	0.001	4
			M-180	A	2	183937	63,580	80,650	27.7	0.180	0.730	0.012	0.004	0.020	0.130	0.000	0.060	0.000	4
			M-180	A	2	184177	59,660	78,450	27.8	0.190	0.720	0.011	0.002	0.020	0.120	0.000	0.050	0.001	4
			M-180	A	2	184179	60,260	79,190	25.8	0.190	0.730	0.011	0.006	0.010	0.120	0.000	0.040	0.001	4
			M-180	A	2	184355	62,180	79,660	24.6	0.190	0.710	0.010	0.002	0.020	0.110	0.000	0.060	0.001	4
					2	184356													4
			M-180	A	2	184357	62,230	80,930	25.6	0.190	0.720	0.010	0.020	0.020	0.100	0.000	0.060	0.001	4
			M-180	A	2	184358	59,680	78,200	26.4	0.190	0.740	0.014	0.005	0.020	0.110	0.000	0.070	0.000	4
30	32218G	T10/TRAN/TB:WB/ASYM/R	M-180	B	2	C71847	63,800	83,800	24.4	0.190	0.680	0.010	0.002	0.003	0.110	0.001	0.040	0.001	4
10	32219G	T10/TRAN/TB:WB/ASYM/LT	M-180	B	2	C71847	63,800	83,800	24.4	0.190	0.680	0.010	0.002	0.003	0.110	0.001	0.040	0.001	4
44	54936A	3'2 POST/W6X8.5#/.5X10X10	A-36			U3606	44,500	62,400	25.0	0.090	0.700	0.010	0.008	0.220	0.240	0.001	0.120	0.001	4
	54936A		HW			0806489398													
	54936A		A-36			28683	46,000	63,000	21.6	0.120	0.580	0.006	0.019	0.210	0.280	0.001	0.110	0.002	4
22	54937A	6'6 POST/W6X8.5#/.5X10X10	A-36			28683	46,000	63,000	21.6	0.120	0.580	0.006	0.019	0.210	0.280	0.001	0.110	0.002	4
	54937A		HW			0806489398													

Figure A-16. 6 ft – 3 in. W-to-Thrie Beam Transition Section, Test No. AGTB-1

Gregory Industries 13:54:11 Jun 24 2015 Page 1

HEAT MASTER LISTING

Heat No.	Mill#	Name	YR	Primary Grade	Secondary Grade	CODE	Original Heat Number
9411949	ARC03	ARCELOR MITTAL USA, LLC	15	1021		8534	

******* Chemistry *******

Cr	Si	P	C	Mn	S	Cu	Ni	Mo	Sn	Al	V	Cb	N	Ti
0.0400	0.0100	0.0100	0.2100	0.7500	0.0060	0.0200	0.0100	0.0100	0.0020	0.0580	0.0020	0.0020	0.0042	0.0020

Ca
0.0003

******* Mechanical Test *******

YIELD	TENSILE	ELONGATION	ROCKWELL
56527	75774	27.15	78

Guardrail W-Beam
20ct/25'
100ct/12'
10ct/25ft w/MGS Anchor Panel
July 2015 SMT

Figure A-17. 12 ft – 6 in. W-Beam MGS Sections and End Section, Test No. AGTB-1

3540G

INSPECTION CERTIFICATE

ROCKFORD BOLT & STEEL CO.
126 MILL STREET
ROCKFORD, IL 61101
815-968-0514 FAX# 815-968-3111

CUSTOMER NAME: TRINITY INDUSTRIES

CUSTOMER P.O.: 143227

INVOICE #: 946256 **DATE SHIPPED:** 6/20/11

LOT #: 22191

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

	SPECIFICATION	ACTUAL		
TENSILE RESULTS:	60,000 min.	81,460	70,642	76,898
		81,389	70,341	76,623
HARDNESS RESULTS:	100 MAX	80.63	83.90	84.00
		86.33	77.90	85.00

COATING: ASTM SPECIFICATION F2329 HOT DIP GALVANIZE

STEEL SUPPLIER: NUCOR, CHARTER, NUCOR

HEAT NO. NF11101335, 10132120, NF11101336

QUANTITY AND DESCRIPTION:

18,900 PCS 5/8" X 14" GUARD RAIL BOLT
P/N 3540G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE U.S.A.. WE FURTHER CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENTS PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS 21 DAY OF June 20 11
Diane Rasmussen

Linda Melones 6/21/11
APPROVED SIGNATORY DATE

OFFICIAL SEAL
DIANA RASMUSSEN
NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES:10/15/14

Figure A-18. ⅝-in. Dia. UNC, 14-in. Long Guardrail Bolts and Nuts, Test No. AGTB-1

5/8"x14" Post Bolts
Green Paint R#14-0554
July 2014 SMT

35406

CERTIFICATE OF COMPLIANCE

ROCKFORD BOLT & STEEL CO.
126 MILL STREET
ROCKFORD, IL 61101
815-968-0514 FAX# 815-968-3111

CUSTOMER NAME: TRINITY INDUSTRIES

CUSTOMER PO: 159892

SHIPPER#: 050883
DATE SHIPPED: 01/13/14

INVOICE #:

LOT#: 25512

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE: SPEC: 60,000 psi*min RESULTS: 78,318
78,539
78,075
78,380

HARDNESS: 100 max 86.80
86.76
86.00
90.10

*Pounds Per Square Inch.

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si	Cu	Ni	Cr	Mo
NUCOR	1010	NF13102751	13	.60	.009	.026	.18				

QUANTITY AND DESCRIPTION:

9,100 PCS 5/8" X 14" GUARD RAIL BOLT
P/N 3540G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL AT OUR FACILITY IN ROCKFORD, ILLINOIS, USA. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE USA. WE FURTHER CERIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENT PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS
14 DAY OF January 2014
Diana Rasmussen

OFFICIAL SEAL
DIANA RASMUSSEN
NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES:10/15/14

Deada Metomas
APPROVED SIGNATORY

1/14/14
DATE

Figure A-19. ⅝-in. Dia. UNC, 14-in. Long Guardrail Bolts and Nuts, Test No. AGTB-1

R#15-0627 H#20297970 L#140530L
5/8x10" Guardrail Bolt
June 2015 SMT

35006

TRINITY HIGHWAY PRODUCTS, LLC
425 East O'Connor Ave.
Lima, Ohio 45801
419-227-1296

7/31/14

MATERIAL CERTIFICATION

Customer: Stock **Date:** June 25,2014

Invoice Number:

Lot Number: 140530L

Part Number: 3500G **Quantity:** 17,173 Pcs.

Description: 5/8" x 10" G.R. Bolt **Heat Numbers:** 20297970 17,173

Specification: ASTM A307-A / A153 / F2329

MATERIAL CHEMISTRY

Heat	C	MN	P	S	SI	NI	CR	MO	CU	SN	V	AL	N	B	TI	NB
20297970	.09	.33	.006	.001	.06	.03	.04	.01	.08	.002	.001	.026	.008	.0001	.001	.002

PLATING OR PROTECTIVE COATING

HOT DIP GALVANIZED (Lot Ave.Thickness / Mils) 2.54 (2.0 Mils Minimum)

****THIS PRODUCT WAS MANUFACTURED IN THE UNITED STATES OF AMERICA****

THE MATERIAL USED IN THIS PRODUCT WAS MELTED AND MANUFACTURED IN THE U.S.A

WE HEREBY CERTIFY THAT TO THE BEST OF OUR KNOWLEDGE ALL INFORMATION CONTAINED HEREIN IS CORRECT.

TRINITY HIGHWAY PRODUCTS LLC

STATE OF OHIO, COUNTY OF ALLEN
SWORN AND SUBSCRIBED BEFORE ME THIS 11th day of July 2014

Sherri Braun NOTARY PUBLIC

425 E. O'CONNOR AVENUE LIMA, OHIO 45801 419-227-1296.

NOTARIAL SEAL STATE OF OHIO
SHERRI BRAUN
Notary Public, State of Ohio
My Commission Expires
April 20, 2019

RECEIVED
JUL 11 2014
Trinity Highway Products, LLC
Dallas, Texas. Plant 99

Figure A-20. ⅝-in. Dia. UNC, 10-in. Long Guardrail Bolts and Nuts, Test No. AGTB-1

R#15-0602 H#20337380
5/8x1-1/4" Guardrail Bolt
June 2015 SMT

Gregory

Silo Fasteners
1415 S Benham Road
Versailles IN 47042

Silo Fasteners

To: BENNETT BOLT WORKS, INC. P.O. BOX 922 12 ELBRIDGE STREET JORDAN, NEW YORK 13080	Date: 11/7/2014

We certify that all bolts are made and manufactured in the U.S.A.

P.O. #	6012018
Date Shipped	11/7/2014
Invoice #	827556
Manufacturer	SILO FASTENERS
ASTM Grade	307-A-10
Purchase Date	9/12/2014
Material Heat #	20337380
Lot#	0090480-KD
P/N	62C125BSP3
Galvanizer	
Galvanizer Date	
Qty & Description	224,113 PCS 5/8-11 x 1-1/4 GUARD RAIL BOLT A307 HDG-A153 CLASS C

Name	TERRY ELKINS
Signature	Terry Elkins
Title	QUALITY MANAGER
Date	10/7/2014

Figure A-21. ⅝-in. Dia. UNC, 1½-in. Long Guardrail Bolts, Test No. AGTB-1

R#15-0602 H#10351040
5/8" Splice Nuts
June 2015 SMT

Gregory

TFI
TELEFAST INDUSTRIES, INC.

MATERIAL CERTIFICATION

Customer: BENNETT BOLT WORKS C/O GREGORY INDUSTRIES 4100 13TH STREET SW CANTON OH 44710		Date: 4/1/2015
	Customer P.O. Number:	6013266
	Customer Part Number:	62CNDROH
	Invoice Number:	703231
	Lot Number:	0028970-87794
Description: NUT GUARDRAIL 5 8-11 -.031 HDG	Ship Quantity: 230000	Ship Date: 3/31/2015
	Material: 1018	Heat Number: 10351040
Specification:		

C	Mn	P	S	Si	Ni	Cr	Mo	Al
0.160	0.640	0.007	0.007	0.090	0.050	0.080	0.010	0.023

Hardness	B 94.4
Proof Load:	5
Plating	HOT DIP GALV. - Pass

We hereby certify that to our actual knowledge the information contained herein is correct. We also certify that all parts substantially conform to SAE, ASTM, or customer specifications as agreed upon. The product has been manufactured and tested in accordance with our Quality Assurance manual. The above data accurately represents values provided by our suppliers or values generated in the TELEFAST INDUSTRIES laboratory. Statistical process control data is on file. All manufacturing processes for these parts occurred in the United States of America.

This document may only be reproduced without alteration and only for the purpose of certifying the same or lesser quantity of the product specified here.

Frank Horvath
Director of Quality Assurance

Figure A-22. ⅝-in. Dia. UNC, 1½-in. Long Guardrail Bolt Nuts, Test No. AGTB-1

From: 281-391-2044 To: The Boulder Company Date: 5/24/2012 Time: 3:34:00 PM Page 2 of 2

May 24, 2012

K-T Bolt Manufacturing Company, Inc.® Date: May 24,2012
1150 Katy Fort-Bend Road
Katy, Texas 77494
Ph: 281-391-2196 Fax: 281-391-2673
shirley@k-tbolt.com

Original Mill Test Report

Company:	The Boulder Company
Part Description:	125 pcs ⅝ - 11X 9 ½"Finish Hex Bolts
Material Specification:	A307 A
Coating Specification	ASTM F2329-05
Purchase Order Number:	161005
Lot Number:	08334-1
Comments:	None
Material Heat Number:	JK1110419701
Testing Laboratory:	Nucor

Chemical Analysis – Weight Percent

C	Mn	P	S	Si	Cu	Cr	Ni	Mo	V	Cb	Sn	Al	B	Ti	Ca	Co	N
.13	.69	.018	.030	.20	.26	.12	.09	.020	.003	.002	-	-	-	-	-	-	-

100% Melted & Manufactured in the USA. Values reflect originating Steel Mill

Tensile and Hardness Test Results

Property	#1 psi
Tensile:	70.550
Proof/Yield:	52.360
Elongation:	27.5
ROA:	-
Hardness:	149 HBN

Comments
Test results meet mechanical requirements of specification.

Figure A-23. ⅝-in. Dia. UNC, 10-in. Long Hex Head Bolts Nuts, Test No. AGTB-1

FASTENERS & FITTINGS INC
901 STEELES AVENUE EAST MILTON, ONTARIO L9T 5H3
TEL: (905) 670-2503 FAX: (905) 670-2506 TOLL FREE: 1-800-613-4094

ISO 9001
REGISTERED COMPANY

TO: ROLL FORM GROUP

CERTIFICATE OF CONFORMANCE

WE HEREBY CERTIFY THAT THE FOLLOWING PRODUCT (S):
UNDER FF "PPS" # 191135 AND YOUR ORDER # 24825 CONFORMS TO THE FOLLOWING SPECIFIED STANDARD (S).

SIZE	DESCRIPTION	REFERENCED IFI or OTHER STANDARD	Made In	RoHS Compliant	
				Yes	No
⅝-11x 1½	UNC GR2 CAPSCREW H.D.G WITH NUTS	Bolt: ANSI B 18.2.1 (1981) Nut: ANSI B 18.2.2 (1986)	CHINA	X	

Figure A-24. ⅝-in. Dia. UNC, 1½-in. Long Hex Head Bolts Nuts, Test No. AGTB-1

AGT Buttress 7/8" Bolts and Nuts
R#16-0018 August 2015 SMT

GAFFNEY BOLT COMPANY
6100 MATERIAL AVENUE
ROCKFORD, IL 61111

FASTENER TEST REPORT

DATE SHIPPED:	August 4, 2015	**LOT NO:**	40274
CUSTOMER:	THE STRUCTURAL BOLT COMPANY		
P.O. NO:	17330	**QUANTITY:**	5
DESCRIPTION:	7/8-9 X 14 A449 HEX HDG	**HEAT NO:**	155540

CHEMICAL ANALYSIS ATTACHED

MATERIAL:	1045	**ROCKWELL:**	29-30
TENSILE:	62,370 LBS	**PROOFLOAD:**	39,250 LBS

PASSED VISUAL INSPECTION

ALL TEST ARE IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE SAE AND ASTM SPECIFICATIONS. PRODUCT MEETS ASME B18.2.1 DIMENSIONAL SPECIFICATION AND THREADS MEET ANSI B1.1 CLASS 2A. WE CERTIFY THAT THIS DATA IS TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.

THESE PARTS WERE MANUFACTURED BY GAFFNEY BOLT COMPANY FROM STEEL MELTED AND MANUFACTURED IN THE USA.

GAFFNEY BOLT COMPANY
Mary P Gaffney
MARY P. GAFFNEY
SECRETARY

Figure A-25. ⅞-in. Dia. UNC, 14-in. Long Heavy Hex Bolts, Test No. AGTB-1

UNYTITE INC.
INNOVATIVE FASTENING SYSTEMS

Unytite, Inc.
One Unytite Drive
Peru, IL 61354
Tel 815-224-2221
Fax 815-224-3434

INSPECTION CERTIFICATE

Job No: 20976 **Job Information** **Certified Date:** 6/8/15

Customer:
Customer PO No:
Lot Number: 20976-155347

Ship To:
Shipped Qty:

Part Information

Part No: A563 7/8-9 +0.022 DH HHN HDG BLUE DYE-0

Name: ASTM A563 HHN, Grade DH, Hot Dipped Galv, Blue Dye

Manufactured Quantity: 71,217

U
DH

Applicable Specifications

Specification	Amend	Specification	Amend
ASME B1.1	2008	ASME B18.2.2	2010
ASME B18.2.6	2010	ASTM A563	2007
ASTM F2329	2011	ASTM F606	2011
ASTM F812/F812M	2012		

Test Results
Test No: 8154 Test: A563 DH Mechanical Properties

Description	Hardness (HRC)	Tempering Temp (800 degree F Min)	Proof Load (Pass/Fail) (ASTM Min)	Shape & Dimension ASME B18.2.2	Thread Precision ASME B18.1.1	Visual ASTM F812
Sample Inspection	28.77	1,184	69,300	Pass	Pass	Pass

Certified Chemical Analysis

Heat No	Grade	Manufacturer	Origin	C	Mn	P	S	Si	Cr	Ni	Cu
155347	1045	Aton Steel Inc.	USA	0.4400	0.7300	0.006	0.030	0.2200	0.0900	0.0620	0.1800

Notes

All tests are in accordance with the latest revisions of the methods prescribed in the applicable SAE and ASTM Specifications.

The samples tested conform the specifications as described/listed above and were manufactured free of mercury contamination and there is no welding performed in the production of the products. No heats to which Bismuth, Selenium, Tellurium, or Lead was intentionally added have been used to produce products.
The steel was melted and manufactured in the U.S.A. and the product was manufactured and tested in the U.S.A.

We certify that this data is 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.

OFFICIAL SEAL
JEAN MARGHERIO
NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES:10/18/17

DSavage 6/8/15

Savage, Dan - Supervisor, Quality Date

Plex 6/8/15 9:10 AM dsavage Page 1

Figure A-26. ⅞-in. Dia. UNC, 14-in. Long Heavy Hex Bolt Nuts, Test No. AGTB-1

Figure A-27. ⅞-in. Dia. UNC, 7½-in. Long Hex Head Bolts, Test No. AGTB-1

Figure A-28. ⅞-in. Dia. UNC, 7½-in. Long Hex Head Bolt Nuts, Test No. AGTB-1

GERDAU

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

CERTIFIED MATERIAL TEST REPORT

Page 1/1

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	
NEBCO INC STEEL DIVISION HAVELOCK,NE 68529 USA	CONCRETE INDUSTRIES INC LINCOLN,NE 68529-0529 USA	60 (420)	Rebar / #4 (13MM)	
		LENGTH 60'00"	WEIGHT 139,395 LB	HEAT / BATCH 64050283/02
SALES ORDER 2046316/000010	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION ASTM A615/A615M-14		

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
111827	1332-0000027289	04/02/2015

AGT Buttress Rebar
R#16-0006 July 2015 SMT

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %
0.42	1.10	0.012	0.034	0.22	0.33	0.09	0.12	0.027	0.016

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
68000	469	105500	727	8.000	203.2

MECHANICAL PROPERTIES

Elong. %	BendTest
13.80	OK

GEOMETRIC CHARACTERISTICS

%Light %	Def Hgt Inch	Def Gap Inch	DefSpace Inch
-1.50	0.037	0.090	0.332

COMMENTS / NOTES

Material 100% melted and rolled in the USA. Manufacturing processes for this steel, which may include scrap melted in an electric arc furnace and hot rolling, has been performed at Gerdau St. Paul Mill, 1678 Red Rock Rd., St. Paul, Minnesota, USA. All products produced from strand cast billets. Silicon killed (deoxidized) steel. No weld repairment performed. Steel not exposed to mercury or any liquid alloy which is liquid at ambient temperatures during processing or while in Gerdau St. Paul Mill's possession. Any modification to this certification as provided by Gerdau St. Paul Mill without the expressed written consent of Gerdau St. Paul Mill negates the validity of this test report. This report shall not be reproduced except in full, without the expressed written consent of Gerdau St. Paul Mill. Gerdau St. Paul Mill is not responsible for the inability of this material to meet specific applications.
Roll batch 64050283/02 roll dtd 11/21/2014

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.

Bhaskar

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

ALEA BRANDENBURG
QUALITY ASSURANCE MGR.

Figure A-29. No. 4 Rebar – Stirrups, Longitudinal, and Bent Longitudinal, Test No. AGTB-1

EVRAZ ROCKY MOUNTAIN STEEL
A DIVISION OF EVRAZ INC. NA

2100 S. Freeway
Pueblo, CO 81004 USA

MATERIAL TEST REPORT

Date Printed: 23–JUN–15

Date Shipped: 23–JUN–15 **Product:** DEF #4 (1/2") **Specification:** ASTM A–706/A–615

FWIP: 52825704 **Customer:** CONCRETE INDUSTRIES INC **Cust. PO:** 113438

CHEMICAL ANALYSIS (In Weight %, uncertainty of measurement 0.005%) (Heat cast 05/21/15)

Heat Number	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al	V	B	Cb	Sn	N	Ti
579921	0.27	1.26	0.009	0.013	0.25	0.19	0.08	0.08	0.023	0.002	0.039	0.0004	0.000	0.010	0.0072	0.001

Carbon Equivalent = 0.492

Applies to item e7

MECHANICAL PROPERTIES (Tensiles test date 06/10/15)

Heat Number	Sample No.		Yield (Psi)	Ultimate (Psi)	Elongation (%)	Reduction (%)	Bend	Wt/ft
579921	01		64190	93060	16.4		ok	0.657
		(MPa)	442.6	641.6				
579921	02		63382	92490	16.1		ok	0.659
		(MPa)	437.0	637.7				

All melting and manufacturing processes of the material subject to this test certificate occurred in the United States of America.

ERMS also certifies this material to be free from Mercury contamination.

This material has been produced, tested and conforms to the requirements of the applicable specifications. We hereby certify that the above test results represent those contained in the records of the Company.

Methods used: ASTM A370. A510. A615. A706.

Valoree Varick
General Supervisor of Quality

FROM SHIPPING WEST (TUE)JUN 23 2015 9:42/ST. 9:41/No. 7527283678 P 1

Figure A-30. No. 4 Rebar – Vertical Bars, Test No. AGTB-1

Certified Analysis

Trinity Highway Products , LLC
550 East Robb Ave.
Lima, OH 45801
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 703

MILFORD, NE 68405
Project: RESALE

Order Number: 1164746
Customer PO: 2563
BOL Number: 69500
Document #: 1
Shipped To: NE
Use State: KS

As of: 5/16/12

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	515664	64,600	74,600	25.0	0.067	0.740	0.009	0.008	0.010	0.019	0.000	0.022	0.000	4
			M-180	A	2	515665	64,300	73,800	27.0	0.063	0.750	0.012	0.008	0.007	0.018	0.000	0.027	0.000	4
			M-180	A	2	515666	64,700	74,200	27.0	0.067	0.740	0.009	0.008	0.010	0.031	0.000	0.023	0.000	4
			M-180	A	2	515669	64,500	74,100	26.0	0.063	0.790	0.014	0.007	0.009	0.017	0.000	0.028	0.000	4
			M-180	A	2	515690	63,000	71,800	27.0	0.059	0.720	0.010	0.008	0.013	0.024	0.000	0.042	0.000	4
			M-180	A	2	515691	64,000	72,300	27.0	0.060	0.740	0.009	0.008	0.010	0.021	0.000	0.032	0.000	4
			M-180	A	2	515696	62,900	72,500	28.0	0.058	0.740	0.013	0.008	0.011	0.029	0.000	0.046	0.000	4
			M-180	A	2	515696	63,900	73,400	29.0	0.058	0.740	0.013	0.008	0.011	0.029	0.000	0.046	0.000	4
			M-180	A	2	515700	67,800	77,700	28.0	0.065	0.800	0.013	0.009	0.012	0.036	0.000	0.035	0.000	4
			M-180	A	2	515701	64,300	74,200	28.0	0.064	0.800	0.013	0.010	0.010	0.030	0.000	0.029	0.000	4
			M-180	A	2	515701	65,200	73,700	28.0	0.064	0.800	0.013	0.010	0.010	0.030	0.000	0.029	0.000	4
			M-180	A	2	521448	65,400	75,600	28.0	0.074	0.078	0.014	0.012	0.010	0.060	0.000	0.058	0.000	4
			M-180	A	2	616037	67,800	78,000	26.0	0.065	0.830	0.014	0.007	0.016	0.023	0.000	0.026	0.000	4
			M-180	A	2	616038	65,500	73,700	24.0	0.070	0.740	0.009	0.006	0.015	0.014	0.000	0.018	0.000	4
			M-180	A	2	616041	63,700	74,300	28.0	0.065	0.760	0.013	0.008	0.009	0.028	0.000	0.029	0.000	4
			M-180	A	2	616043	62,700	71,800	27.0	0.067	0.740	0.013	0.008	0.010	0.034	0.000	0.031	0.000	4
			M-180	A	2	616043	64,900	77,000	25.0	0.067	0.740	0.013	0.008	0.010	0.034	0.000	0.031	0.000	4
			M-180	A	2	616067	63,200	73,300	28.0	0.063	0.750	0.013	0.010	0.012	0.035	0.000	0.032	0.000	4
			M-180	A	2	616069	62,600	73,100	26.0	0.064	0.750	0.008	0.007	0.011	0.026	0.000	0.022	0.000	4
			M-180	A	2	616070	62,800	73,000	29.0	0.060	0.730	0.014	0.008	0.012	0.021	0.000	0.032	0.000	4
			M-180	A	2	616071	64,000	74,000	28.0	0.061	0.760	0.016	0.007	0.011	0.021	0.000	0.028	0.000	4
			M-180	A	2	616072	63,800	74,200	29.0	0.066	0.750	0.014	0.009	0.010	0.026	0.000	0.039	0.000	4
			M-180	A	2	616073	63,900	73,300	27.0	0.064	0.760	0.016	0.009	0.012	0.024	0.000	0.041	0.000	4
			M-180	A	2	616073	65,000	74,500	28.0	0.064	0.760	0.016	0.009	0.012	0.024	0.000	0.041	0.000	4
			M-180	A	2	621267	65,000	74,800	29.0	0.066	0.780	0.015	0.013	0.009	0.068	0.000	0.055	0.000	4
22	12365G	T12/12'6/8@1'6.75/S	M-180	A	2	151877	58,680	77,470	26.0	0.190	0.720	0.013	0.004	0.010	0.120	0.00	0.050	0.002	4

2 of 4

Figure A-31. 12 ft – 6 in. Long, 12-gauge Thrie Beam, Test No. AGTB-2

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: 1272514
Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 3376
BOL Number: 98293
Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 1/9/17

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
100	901G	12/FLARE/8 HOLE	M-180	A	2	193147	62,430	81,280	26.2	0.190	0.730	0.014	0.003	0.020	0.110	0.000	0.060	0.001	4
4	974G	T12/TRANS RAIL/6'3"/3'1.5	M-180	A	2	184354	64,550	83,590	22.1	0.190	0.730	0.010	0.003	0.020	0.100	0.000	0.050	0.000	4
10,000	3340G	5/8" GR HEX NUT	HW			0057933-117335													
6,000	3360G	5/8"X1.25" GR BOLT	HW			0049412-112338													
1,200	3400G	5/8"X2" GR BOLT	HW			1377346													
200	3480G	5/8"X8" GR BOLT A307	HW			29038-b													
675	3500G	5/8"X10" GR BOLT A307	HW			29366													
2,100	3540G	5/8"X14" GR BOLT A307	HW			29253													
10	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
	12173G				2	L34816													
			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
140	12365G	T12/12'6/8@1'6.75/S			2	L30117													
			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

2 of 4

Figure A-32. 6.25-ft long 12-gauge Thrie Beam, Test No. AGTB-2

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: 1270666 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 3360
BOL Number: 97906 Ship Date:
Document #: 1
Shipped To: NE
Use State: NE

As of: 12/6/16

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
82	12365G	T12/12'6/8@1'6.75/S			2	L34616													
			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	L32916													
			M-180	A	2	203660	58,830	76,800	26.7	0.190	0.720	0.013	0.005	0.010	0.120	0.000	0.070	0.000	4
			M-180	A	2	204522	62,180	80,590	25.5	0.190	0.720	0.014	0.003	0.020	0.120	0.000	0.060	0.000	4
4	29956A	10/90 DEGREES-O-CORNER			2	L14216													
			M-180	B	2	206986	58,850	79,050	25.4	0.190	0.730	0.011	0.005	0.010	0.110	0.000	0.060	0.000	4
			M-180	B	2	206987	59,260	79,010	25.8	0.190	0.720	0.010	0.004	0.020	0.110	0.000	0.050	0.000	4
23	32218G	T10/TRAN/TB:WB/ASYM/R	M-180	B	2	A81032	66,400	88,200	20.6	0.210	0.690	0.009	0.004	0.020	0.120	0.001	0.060	0.001	4
25	32219G	T10/TRAN/TB:WB/ASYM/LT	M-180	B	2	A80344	63,200	85,600	19.9	0.200	0.700	0.009	0.003	0.030	0.130	0.002	0.060	0.001	4
90	54043G	7'0 PST/6X15/DB:3HI	A-572			2612103	57,000	68,400	25.2	0.070	0.880	0.008	0.025	0.200	0.150	0.029	0.070	0.003	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

6 of 7

Figure A-33. 10-gauge Asymmetric W-to-Thrie beam Transition Rail, Test No. AGTB-2

Gregory Industries 13:54:11 Jun 24 2015 Page 1

H E A T M A S T E R L I S T I N G

Heat No.	Mill#	Name	YR	Primary Grade	Secondary Grade	CODE	Original Heat Number
9411949	ARC03	ARCELOR MITTAL USA, LLC	15	1021		8534	

******* Chemistry *******

Cr	Si	P	C	Mn	S	Cu	Ni	Mo	Sn	Al	V	Cb	N	Ti
0.0400	0.0100	0.0100	0.2100	0.7500	0.0060	0.0200	0.0100	0.0100	0.0020	0.0580	0.0020	0.0020	0.0042	0.0020

Ca
0.0003

******* Mechanical Test *******

YIELD	TENSILE	ELONGATION	ROCKWELL
56527	75774	27.15	78

Guardrail W-Beam
20ct/25'
100ct/12'
10ct/25ft w/MGS Anchor Panel
July 2015 SMT

Figure A-34. 12-gauge W-Beam Sections, Test No. AGTB-2

10 GA X 61.5 X 92.75 Buffer Steel

8-26-16

RCP R#17-684
H#C79045 QTY 6
END SHOES/TERMINAL CONNECTORS

TRIAMERICA STEEL RESOURCES LLC

1617 AKRON PENINSULA RD #103
AKRON, OH 44313
330-928-4400
Fax:330-928-4420

BL/SO/SS 407494

ROACO

Page# 1
SHIP DATE 8/24/16

SOLD TO: ROADWAY CONSTRUCTION PRODUCTS
A MID-PARK COMPANY
511 WEST MAIN STREET
CLARKSON, KY 42726

SHIP TO: ROADWAY CONSTRUCTION PRODUCTS
511 WEST MAIN STREET
CLARKSON, KY 42726

TAG#	SKIDS	PIECES	WEIGHT	TARE	GROSS	HEAT#	MASTER TAG#
PO# 70019754		PART# G10045BS				SO# 205970	01
50-YIELD				H50	10 GA	61.50	92.75
X159795A	1	22	4840		4840	C79045	X159795
		Tensile> 80			Yield> 68.7		Elong> 24
X159795B	1	22	4840		4840	C79045	X159795
		Tensile> 80			Yield> 68.7		Elong> 24
X159795C	1	22	4840		4840	C79045	X159795
		Tensile> 80			Yield> 68.7		Elong> 24
X159795D	1	22	4840		4840	C79045	X159795
		Tensile> 80			Yield> 68.7		Elong> 24
X159795E	1	22	4840		4840	C79045	X159795
		Tensile> 80			Yield> 68.7		Elong> 24
X159795F	1	12	2640		2640	C79045	X159795
		Tensile> 80			Yield> 68.7		Elong> 24
	6	122	26840		26840		

Heat#	C	Mn	P	S	Si	Ti	Cr	Al	Cb	V
C79045	.06	.83	.012	.003	.03	.002	.08	.023	.001	.075

TOTAL-> 6 122 26840 26840

Figure A-35. 10-gauge Thrie Beam Terminal Connector, Test No. AGTB-2

benesch
engineers · scientists · planners

LINCOLN OFFICE
825 "M" Street Suite 100
Lincoln, NE 68508
Phone: (402) 479-2200
Fax: (402) 479-2276

COMPRESSION TEST OF CYLINDRICAL CONCRETE SPECIMENS - 6x12

ASTM Designation: C 39

Client Name: Midwest Roadside Safety Facility
Date 13-Jun-17
Project Name: AGT Buttress-2
Placement Location: 5/23/17
Mix Designation: 4000
Required Strength: 4000

Laboratory Test Data

Laboratory Identification	Field Identification	Date Cast	Date Received	Date Tested	Days Cured in Field	Days Cured in Laboratory	Age of Test, Days	Length of Specimen, in.	Diameter of Specimen, in.	Cross-Sectional Area,sq.in.	Maximum Load, lbf	Compressive Strength, psi.	Required Strength, psi.	Type of Fracture	ASTM Practice for Capping Specimen
AGF- 1	A	5/23/2017	6/13/2017	6/13/2017	21	0	21	12	6.00	28.27	137,959	4,880		5	C 1231
AGF- 2	B	5/23/2017	6/13/2017	6/13/2017	21	0	21	12	5.99	28.18	135,692	4,820		5	C 1231

Remarks:

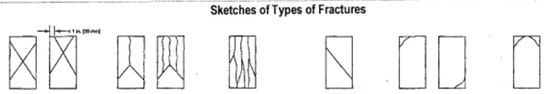
Concrete test specimens along with documentation and test data were submitted by Midwest Roadside Safety Facility.

Test results presented relate only to the concrete specimens as received from Midwest Roadside Safety

This report shall not be reproduced except in full, without the written approval of Alfred Benesch & Company.

Report Number 2147369222
Page 1

Sketches of Types of Fractures



Type 1 Reasonably well-formed cones on both ends, less than 1 in. [25 mm] of cracking through caps

Type 2 Well-formed cone on one end, vertical cracks running through caps, no well-defined cone on other end

Type 3 Columnar vertical cracking through both ends, no well-formed cones

Type 4 Diagonal fracture with no cracking through ends; tap with hammer to distinguish from Type 1

Type 5 Side fractures at top or bottom (occur commonly with unbonded caps)

Type 6 Similar to Type 5 but end of cylinder is pointed

ALFRED BENESCH & COMPANY
CONSTRUCTION MATERIALS LABORATORY

By____________________
Brant Wells, Field/Lab Operations Manager

Figure A-36. Concrete Breaking Strength, Test No. AGTB-2

CENTRAL NEBRASKA WOOD PRESERVERS, INC.

P. O. Box 630 • Sutton, NE 68979
Pone 402-773-4319
FAX 402-773-4513

R#17-505
BCT Posts
Orange Paint March 2017 SMT

Date: 3/2/17

CERTIFICATE OF COMPLIANCE

Shipped TO: Midwest Machinery + Supply BOL# 10056187

Customer PO# 3396 Preservative: CCA – C 0.60 pcf AWPA UC4B

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
656806.5PST	6x8-6.5 Rub Post	168	23489	.649
656806.5PST	6x8-6.5' Rub Post	42	23490	.724
656806.5PST	6x8.5-CRT PST	42	23490	.724
656846PST	6x8-46" BCT	42	23491	.651

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

VA: Central Nebraska 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

3/2/17
Date

Figure A-37. BCT Timber Posts, Test No. AGTB-2

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
Customer PO: 3346
BOL Number: 97457
Document #: 1
Shipped To: NE
Use State: NE

Prod Ln Grp: 3-Guardrail (Dom)
Ship Date:

As of: 11/7/16

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
	701A	Anchor Box	A-36			JK16101488	56,172	75,460	25.0	0.160	0.780	0.017	0.028	0.200	0.280	0.001	0.140	0.028	4
	701A		A-36			535133	43,300	68,500	33.0	0.019	0.460	0.013	0.016	0.013	0.090	0.001	0.090	0.002	4
4	729G	TS 8X6X3/16X8'-0" SLEEVE	A-500			A49248	64,818	78,412	32.0	0.200	0.810	0.014	0.002	0.040	0.020	0.000	0.040	0.001	4
20	738A	5'TUBE SL.188X6X8 1/4 /PL	A-36		2	4182184	45,000	67,900	31.0	0.210	0.760	0.012	0.008	0.010	0.050	0.001	0.030	0.002	4
	738A		A-500			A49248	64,818	78,412	32.0	0.200	0.810	0.014	0.002	0.040	0.020	0.000	0.040	0.001	4
6	749G	TS 8X6X3/16X6'-0" SLEEVE	A-500			A49248	64,818	78,412	32.0	0.200	0.810	0.014	0.002	0.040	0.020	0.000	0.040	0.001	4
6	782G	5/8"X8"X8" BEAR PL/OF	A-36			DL15103543	58,000	74,000	25.0	0.150	0.750	0.013	0.025	0.200	0.360	0.003	0.090	0.000	4
20	783A	5/8X8X8 BEAR PL 3/16 STP	A-36			PL14107973	48,167	69,811	25.0	0.160	0.740	0.012	0.041	0.190	0.370	0.000	0.220	0.002	4
	783A		A-36			DL15103543	58,000	74,000	25.0	0.150	0.750	0.013	0.025	0.200	0.360	0.003	0.090	0.000	4
45	3000G	CBL 3/4X6'6/DBL	HW			119048													
7,000	3340G	5/8" GR HEX NUT	HW			0055551-116146													
4,000	3360G	5/8"X1.25" GR BOLT	HW			0053777-115516													
450	3500G	5/8"X10" GR BOLT A307	HW			28971-B													
1,225	3540G	5/8"X14" GR BOLT A307	HW			29053-B													

Figure A-38. Foundation Tubes, Bracket Assembly, and Bearing Plate , Test AGTB-2

425 E. O'Connor
Lima, OH

Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097

Sales Order: 1093497
Customer PO: 2030
BOL # 43073
Document # 1

Print Date: 6/30/08
Project: RESALE
Shipped To: NE
Use State: KS

Trinity Highway Products. LLC
Certificate Of Compliance For Trinity Industries, Inc. ** SLOTTED RAIL TERMINAL **
NCHRP Report 350 Compliant

Pieces	Description
64	5/8"X10" GR BOLT A307
192	5/8"X18" GR BOLT A307
32	1" ROUND WASHER F844
64	1" HEX NUT A563
192	WD 6'0 POST 6X8 CRT
192	WD BLK 6X8X14 DR
64	NAIL 16d SRT
64	WD 3'9 POST 5.5X7.5 BAND
32	STRUT & YOKE ASSY
128	SLOT GUARD '98
32	3/8 X 3 X 4 PL WASHER

MGSBR

Ground Strut
090453-8

Jpon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

402-761-3288

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL OTHER GALVANIZED MATERIAL CONFORMS WITH ASTM-123.
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.
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 – 49100 LB
State of Ohio, County of Allen. Sworn and Subscribed before me this 30th day of June, 2008

Notary Public:
Commission Expires

Trinity Highway Products, LLC
Certified By:

2 of 4

05/04/2009 16:36

Figure A-39. Ground Strut Assembly, Test No. AGTB-2

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

Sales Order: 1261542
Customer PO: 3278
BOL # 95362
Document # 1

Print Date: 7/6/16
Project: RESALE
Shipped To: NE
Use State: NE

Trinity Highway Products, LLC

Certificate Of Compliance For Trinity Highway Products, LLC ** SLOTTED RAIL TERMINAL **

Pieces	Description	Part No
110	12/12'6/3'1.5/S	000011G
20	ET REF 18X18 YELLOW/BLACK	003177B
1,210	5/8" GR HEX NUT	003340G
880	5/8"X1.25" GR BOLT	003360G
330	5/8"X16" GR BOLT A307	003560G
330	6'-0" POST/W6X8.5/3-HI:DB	014416G
20	SRT-31SP 350 TL3 SS-616	500616B

R#16-692 3/4" BCT Cables and Nuts
Black Paint June2016 SMT

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 ASTM449 AASHTO M30, TYPE II BREAKING STRENGTH – 46000 LB

State of Ohio, County of Allen. Sworn and Subscribed before me this 6th day of July, 2016 .

Notary Public: Jamie A 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

Trinity Highway Products, LLC
Certified By:
Quality Assurance

1 of 1

Figure A-40. BCT Cable Anchor Assembly, Test AGTB-2

EXLTUBE

1000 BURLINGTON STREET, NORTH KANSAS CITY, MO 64116 1-816-474-8210 TOLL FREE 1-800-892-TUBE

STEEL VENTURES, LLC dba EXLTUBE

Certified Test Report

Customer: SPS - New Century 401 New Century Parkway NEW CENTURY KS 66031-1127	Size: 02.375	Customer Order No: 4500269918	Date: 07/26/2016
	Gauge: .154	Delivery No:82799116 Load No.3774661	
	Specification: ASTM A500-13 Gr.B/C, ASTM A53-12 Gr.B BNT*, ASME SA53 Gr.B BNT*		

Heat No	Yield KSI	Tensile KSI	Elongation % 2 Inch
A79999	63.2	67.3	31.00

R#17-175 H#A79999
BCT Post Sleeves QTY 8
Oct 2016 SMT

Heat No	C	MN	P	S	SI	CU	NI	CR	MO	V
A79999	0.0700	0.8400	0.0110	0.0040	0.0200	0.1500	0.0500	0.0600	0.0200	0.0010

This material was melted & manufactured in the U.S.A.
We hereby certify that all test results shown in this report are correct as contained in the records of our company. All testing and manufacturing is in accordance to A.S.T.M. parameters encompassed within the scope of the specifications denoted in the specification and grade tiles above. This product was manufactured in accordance with your purchase order requirements.
BNT=Grade B not pressure tested - meets tensile & chemical properties ONLY.

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

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

This material has passed NDE (eddy current, A309) testing. This material has passed flattening tests.

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

STEEL VENTURES, LLC dba EXLTUBE

Figure A-41. 6-in. Long BCT Post Sleeve, Test No. AGTB-2

GERDAU

CERTIFIED MATERIAL TEST REPORT Page 1/1

US-ML-CARTERSVILLE
384 OLD GRASSDALE ROAD NE
CARTERSVILLE, GA 30121
USA

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
HIGHWAY SAFETY CORP 473 W FAIRGROUND ST MARION,OH 43302-1701 USA	HIGHWAY SAFETY CORP GLASTONBURY,CT 06033-0358 USA	A992/A709-36	Wide Flange Beam / 6 X 8.5# / 150 X 13.0	0000000000

LENGTH	WEIGHT	HEAT / BATCH
42'00"	44,982 LB	55044258/02

SALES ORDER	CUSTOMER MATERIAL N°
3399484/000010	

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
0001677045 IB-B0600800	1323-0000067091	03/30/2016

SPECIFICATION / DATE or REVISION
ASTM A6-14
ASTM A709-13A
ASTM A992-11
CSA G40.21-13 345WM

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %
0.13	0.90	0.010	0.028	0.18	0.29	0.10	0.06	0.031	0.016	0.016	0.000

MECHANICAL PROPERTIES

YS 0.2% PSI	UTS PSI	YS MPa	UTS MPa	G/L Inch	Elong. %
52000	71200	359	491	8.000	20.50
51600	69800	356	481	8.000	23.40

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. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

Bhaskar — BHASKAR YALAMANCHILI, QUALITY DIRECTOR

YAN WANG, QUALITY ASSURANCE MGR.

Figure A-42. 6-ft Long W6x8.5 Posts, Test AGTB-2

GERDAU

CERTIFIED MATERIAL TEST REPORT Page 1/1

US-ML-CARTERSVILLE
384 OLD GRASSDALE ROAD NE
CARTERSVILLE, GA 30121
USA

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
HIGHWAY SAFETY CORP 473 W FAIRGROUND ST MARION,OH 43302-1701 USA	HIGHWAY SAFETY CORP GLASTONBURY,CT 06033-0358 USA	A992/A709-36	Wide Flange Beam / 6 X 8.5# / 150 X 13.0	0000000000

LENGTH	WEIGHT	HEAT / BATCH
39'00"	27,844 LB	55046653/04

SALES ORDER	CUSTOMER MATERIAL N°
4061537/000050	

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
0001698033 IB-B0600800	1323-0000076589	09/14/2016

SPECIFICATION / DATE or REVISION
ASTM A6-14
ASTM A709-15
ASTM A992-11 (2015)
CSA G40.21-13 345WM

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %
0.14	0.91	0.014	0.016	0.20	0.27	0.08	0.12	0.019	0.011	0.016	0.001

MECHANICAL PROPERTIES

YS 0.2% PSI	UTS PSI	YS MPa	UTS MPa	G/L Inch	Elong. %
56500	77800	390	536	8.000	22.90
57200	78500	394	541	8.000	23.20

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. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

Bhaskar — BHASKAR YALAMANCHILI, QUALITY DIRECTOR

YAN WANG, QUALITY ASSURANCE MGR.

Figure A-43. 6.5-ft Long W6x8.5 Posts, Test No. AGTB-2

CENTRAL
NEBRASKA
WOOD PRESERVERS, INC.

P. O. Box 630 • Sutton, NE 68979
Pone 402-773-4319
FAX 402-773-4513

Date: 7/26/16

CERTIFICATE OF COMPLIANCE

Shipped TO: Midwest Machinery + Supply BOL# 10054605

Customer PO# 3292 Preservative: CCA – C 0.60 pcf AWPA UC4B

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
40756	6x8-14" BLK	126	22416	.676
GR61214BLK	6x12-14" OCD BLK	84	21292	.623
		84	22397	.607
		.168	22421	.733

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

VA: Central Nebraska 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

7/26/16
Date

Figure A-44. 6-in. x 12-in. x 14¼-in. Timber Blockout, Test No. AGTB-2

CENTRAL
NEBRASKA
WOOD PRESERVERS, INC.

P. O. Box 630 • Sutton, NE 68979
Pone 402-773-4319
FAX 402-773-4513

Date: 7/18/16

CERTIFICATE OF COMPLIANCE

Shipped TO: Midwest Machinery + Supply BOL# 10054525

Customer PO#: 3289 Preservative: CCA – C 0.60 pcf AWPA UC4B

Part #	Physical Description	# of Pieces	Charge #	Tested Retention
GR6814BLK	6x8-14" BLK	126	22416	.623
GR6819BLK	6x8-19" BLK	84	22402	.676
GR61219BLK	6x12-19" BLK	168	22402	.676
GR61219BLK	6x12-19" BLK	168	22416	.623
GR61219BLK	6x12-19" BLK	56	22397	.607
GR61219BLK	6x12-19" BLK Trag	56	22402	.676

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

VA: Central Nebraska 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

7/18/16
Date

Figure A-45. 6-in. x 12-in. x 19-in. Timber Blockout, Test No. AGTB-2

CERTIFICATE OF TEST

Page 01 of 01

Certification Date
18-MAY-2017

CUSTOMER ORDER NUMBER
45171

CUSTOMER PART NUMBER
0001

EARLE M. JORGENSEN COMPANY
1800 N UNIVERSAL AVENUE
KANSAS CITY MO 64120

Invoice Number
S438576

SOLD TO: RIVERS METAL PRODUCTS
3100 N 38TH
LINCOLN NE 68504

SHIP TO: RIVERS METAL PRODUCTS
3100 NORTH 38TH
LINCOLN NE 68504

Description: ASTM A500 GR B
4 X 7 X .188 WALL X 24'
HEAT: 1828C4 ITEM: 121076

Line Total: 72 FT

Specifications:
ASTM A500 GR B 13

CHEMICAL ANALYSIS

C	MN	P	S	SI	AL	CU	MO
0.20	0.75	0.013	0.006	0.04	0.038	0.03	0.00

NI	CR	TI
0.01	0.03	0.002

RCPT: R104074
VENDOR: ATLAS TUBE

COUNTRY OF ORIGIN : CANADA

MECHANICAL PROPERTIES

DESCRIPTION	YLD STR PSI	ULT TEN PSI	%ELONG IN 02 IN	%RED IN AREA	HARDNESS
	56044.0	72862.0	31.0		

The above data were transcribed from the manufacturer's Certificate of Test after verification for completeness and specification requirements of the information on the certificate. All test results remain on file subject to examination.

We hereby certify that the material covered by this report will meet the applicable requirements described herein, including any specification forming a part of the description.

The willful recording of false, fictitious, or fraudulent statements in connection with test results may be punishable as a felony under federal statutes.

Material did not come in contact with mercury while in our possession.

LARRY BUSICK

Larry A. Busick

Manager, Quality Assurance

Figure A-46. Steel Tube Blockouts, Test No. AGTB-2

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

Atlas Tube JMC STEEL GROUP

Ref.B/L: 80664486
Date: 05.12.2015
Customer: 193

MATERIAL TEST REPORT

AGT Buttress
Steel Blockout
R#16-0013 July 2015 SMT

Sold to

Tubular Steel
1031 Executive Parkway
ST. LOUIS MO 63141
USA

Shipped to

Tubular Steel
7220 Polson Lane
HAZELWOOD MO 63042
USA

Material: 5.0x4.0x375x40'0"0(3x3). **Material No:** 500403754000 **Made in:** USA **Melted in:** USA

Sales order: 1001327 **Purchase Order:** PO-048483 **Cust Material #:** 012320

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
Y80316	0.200	0.820	0.014	0.009	0.024	0.044	0.040	0.006	0.005	0.020	0.040	0.001	0.001	0.000	0.005

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800554738	9	069347 Psi	079747 Psi	33 %	ASTM A500-13 GRADE B&C	0.35

Material Note:
Sales Or.Note:

Material: 7.0x4.0x188x48'0"0(3x3). **Material No:** 700401884800 **Made in:** USA **Melted in:** USA

Sales order: 1001327 **Purchase Order:** PO-048483 **Cust Material #:** 012779

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
E03090	0.190	0.750	0.014	0.010	0.010	0.043	0.020	0.005	0.003	0.010	0.040	0.001	0.001	0.000	0.004

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800554401	9	062369 Psi	077410 Psi	28 %	ASTM A500-13 GRADE B&C	0.33

Material Note:
Sales Or.Note:

Material: 7.0x4.0x188x48'0"0(3x3). **Material No:** 700401884800 **Made in:** USA **Melted in:** USA

Sales order: 1001327 **Purchase Order:** PO-048483 **Cust Material #:** 012779

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
E03090	0.190	0.750	0.014	0.010	0.010	0.043	0.020	0.005	0.003	0.010	0.040	0.001	0.001	0.000	0.004

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800554402	9	062369 Psi	077410 Psi	28 %	ASTM A500-13 GRADE B&C	0.33

Material Note:
Sales Or.Note:

Marvin Phillips

Marvin Phillips

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 3

Metals Service Center Institute

Figure A-47. Steel Tube Blockouts, Test No. AGTB-2

McMASTER-CARR

Certificate of Compliance

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

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

Purchase Order
E000357170

Order Placed By
Shaun M Tighe

McMaster-Carr Number
2098331-01

Page 1 of 1

Line		Product	Ordered	Shipped
1	**97812A109**	Steel Double-Headed Nail Size 16D, 3" Length, .16" Shank Diameter, 200 Pieces/Pack, Packs of 5	**5 Packs**	**5**

Certificate of compliance

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

Sarah Weinberg
Compliance Manager

Figure A-48. 16D Double Head Nails, Test AGTB-2

GERDAU

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

CERTIFIED MATERIAL TEST REPORT

Page 1/1

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
NEBCO INC STEEL DIVISION HAVELOCK,NE 68529 USA	CONCRETE INDUSTRIES INC LINCOLN,NE 68529-0529 USA	60 (420)	Rebar / #4 (13MM)	0000000000

LENGTH	WEIGHT	HEAT / BATCH
60'00"	131,664 LB	58028855/02

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
4777299/000010		ASTM A615/A615M-15 E1

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
123808	1327-0000226793	02/28/2017

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %	Al %
0.44	0.96	0.015	0.030	0.23	0.33	0.13	0.20	0.028	0.006	0.004	0.000	0.003

CHEMICAL COMPOSITION

CEqyA706 %
0.63

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
73269	505	113850	785	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
12.50	OK

COMMENTS / NOTES

AGT Standarized Buttress-2 Rebar
R#17-668 H#58028855

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.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 769-1014 Email: Bhaskar.Yalamanchili@gerdau.com

TOM HARRINGTON
QUALITY ASSURANCE MGR.
Phone: 972-779-1872 Email: Tommy.Harrington@gerdau.com

Figure A-49. No. 4 Rebar, Test No. AGTB-2

R#16-692 5/8"x14"GR Bolt
Orange Paint H#16100453 L#28667-B
June2016 SMT

CERTIFICATE OF COMPLIANCE

3540G

ROCKFORD BOLT & STEEL CO.
126 MILL STREET
ROCKFORD, IL 61101
815-968-0514 FAX# 815-968-3111

CUSTOMER NAME: TRINITY INDUSTRIES

CUSTOMER PO: 176703

SHIPPER #: 057716
DATE SHIPPED: 05/17/2016

LOT#: 28667-B

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE: SPEC: 60,000 psi*min RESULTS: 78,080 / 76,544

HARDNESS: 100 max 82.10 / 83.50

*Pounds Per Square Inch.

COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
ROGERS GALVANIZE: 28667-B

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si
NUCOR	1010	NF16100453	.12	.56	.006	.030	.19

QUANTITY AND DESCRIPTION:

5,950 PCS 5/8" X 14" GUARD RAIL BOLT
P/N 3540G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL AT OUR FACILITY IN ROCKFORD, ILLINOIS, USA. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE USA. WE FURTHER CERIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENT PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS
17th DAY OF May 2016

Merry F Shane

Linda Melomas
APPROVED SIGNATORY

5/17/16
DATE

OFFICIAL SEAL
MERRY F. SHANE
NOTARY PUBLIC – STATE OF ILLINOIS
MY COMMISSION EXPIRES OCTOBER 3, 2018

Figure A-50. ⅝-in. Dia. UNC, 14-in. Long Guardrail Bolts, Test No. AGTB-2

R#15-0627 H#20297970 L#140530L
5/8x10" Guardrail Bolt
June 2015 SMT White Paint

35006

TRINITY HIGHWAY PRODUCTS, LLC
425 East O'Connor Ave.
Lima, Ohio 45801
419-227-1296

7/31/14

MATERIAL CERTIFICATION

Customer: Stock

Date: June 25,2014

Invoice Number:

Lot Number: 140530L

Part Number: 3500G

Quantity: 17,173 Pcs.

Description: 5/8" x 10" G.R. Bolt

Heat Numbers: 20297970 17,173

Specification: ASTM A307-A / A153 / F2329

MATERIAL CHEMISTRY

Heat	C	MN	P	S	SI	NI	CR	MO	CU	SN	V	AL	N	B	TI	NB
20297970	.09	.33	.006	.001	.06	.03	.04	.01	.08	.002	.001	.026	.008	.0001	.001	.002

PLATING OR PROTECTIVE COATING

HOT DIP GALVANIZED (Lot Ave.Thickness / Mils) 2.54 (2.0 Mils Minimum)

****THIS PRODUCT WAS MANUFACTURED IN THE UNITED STATES OF AMERICA****

THE MATERIAL USED IN THIS PRODUCT WAS MELTED AND MANUFACTURED IN THE U.S.A

WE HEREBY CERTIFY THAT TO THE BEST OF OUR KNOWLEDGE ALL INFORMATION CONTAINED HEREIN IS CORRECT.

TRINITY HIGHWAY PRODUCTS LLC

STATE OF OHIO, COUNTY OF ALLEN
SWORN AND SUBSCRIBED BEFORE ME THIS 11th day of July 2014

Sherri Braun NOTARY PUBLIC

425 E. O'CONNOR AVENUE LIMA, OHIO 45801 419-227-1296.

NOTARIAL SEAL STATE OF OHIO
SHERRI BRAUN
Notary Public, State of Ohio
My Commission Expires
April 20, 2019

RECEIVED
JUL 11 2014
Trinity Highway Products, LLC
Dallas, Texas. Plant 99

Figure A-51. ⅝-in. Dia. UNC, 10-in. Long Guardrail Bolts, Test No. AGTB-2

CERTIFICATE OF COMPLIANCE

ROCKFORD BOLT & STEEL CO.
126 MILL STREET
ROCKFORD, IL 61101
815-968-0514 FAX# 815-968-3111

CUSTOMER NAME: GREGORY INDUSTRIES

CUSTOMER PO: 37464

SHIPPER#: 060204
DATE SHIPPED: 04/10/2017

LOT#: 29256-G

SPECIFICATION: ASTM A307, GRADE A MILD CARBON STEEL BOLTS

TENSILE:	SPEC:	60,000 psi*min	RESULTS:	66,593 67,960
HARDNESS:		100 max		70.40 70.30

*Pounds Per Square Inch.
COATING: ASTM SPECIFICATION F-2329 HOT DIP GALVANIZE
ROGERS GALVANIZE: 29256-G

CHEMICAL COMPOSITION

MILL	GRADE	HEAT#	C	Mn	P	S	Si
CHARTER	1010	20460760	.09	.33	.006	.003	.06

QUANTITY AND DESCRIPTION:

105,000 PCS 5/8" X 1.25" GUARD RAIL BOLT
P/N 1001G

WE HEREBY CERTIFY THE ABOVE BOLTS HAVE BEEN MANUFACTURED BY ROCKFORD BOLT AND STEEL AT OUR FACILITY IN ROCKFORD, ILLINOIS, USA. THE MATERIAL USED WAS MELTED AND MANUFACTURED IN THE USA. WE FURTHER CERIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIALS SUPPLIER, AND THAT OUR PROCEDURES FOR THE CONTROL OF PRODUCT QUALITY ASSURE THAT ALL ITEMS FURNISHED ON THIS ORDER MEET OR EXCEED ALL APPLICABLE TESTS, PROCESS, AND INSPECTION REQUIREMENT PER ABOVE SPECIFICATION.

STATE OF ILLINOIS
COUNTY OF WINNEBAGO
SIGNED BEFORE ME ON THIS

10th DAY OF April 2017 Linda McComas 4/10/17
APPROVED SIGNATORY DATE

Merry F Shane

OFFICIAL SEAL
MERRY F. SHANE
NOTARY PUBLIC – STATE OF ILLINOIS
MY COMMISSION EXPIRES OCTOBER 3, 2018

Figure A-52. ⅝-in. Dia. UNC, 1.25-in. Long Guardrail Bolts, Test No. AGTB-2

TFI
Telefast Industries
A Division of EFG

CERTIFICATION

DATE: 4/3/2017

CUSTOMER
Bennett Bolt Works, Inc.
12 Elbridge Street
Jordan, NY 13080
DESCRIPTION
Nut Guardrail 5/8-11 + .031
A563 GrA HDG
EFG PART NUMBER: T3400

CUSTOMER P.O.
6015438 BLANKET
LOT NUMBER
0068078-124590
MATERIAL
1018
CUSTOMER PART NUMBER
62CNDR0H

INVOICE
58432
SHIP DATE
4/3/2017
HEAT NUMBER
20479830
QUANTITY
36000

HARDNESS: B 85.4
PROOF LOAD: 5 samples passed at 75,000 psi min.
PLATING: Hot Dip Galvanized - Pass

All parts processed Mercury free and without Welds.

We hereby certify that to our actual knowledge the information contained herein is correct. We also certify that all parts substantially conform to SAE, ASTM, or customer specifications as agreed upon. The product has been manufactured and tested in accordance with our Quality Assurance manual. The above data accurately represents values provided by our suppliers or values generated in the EFG – Berea Plant laboratory. All manufacturing processes for these parts occurred in the United States of America.

This document may only be reproduced without alteration and only for the purpose of certifying the same or lesser quantity of the product specified here.

The recording of false, fictitious or fraudulent statements or entries on this document may be punishable as a felony under Federal Statutes.

Joe Kilpatrick

Joe Kilpatrick
Quality Assurance Technician

ENGINEERED FASTENING SOLUTIONS

Figure A-53. ⅝-in. Dia. UNC Nuts, Test No. AGTB-2

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: CASH SALE
PB Invoice#: 099709
Cust PO#: MIDWEST ROADSIDE
Date: 6/14/2017
Shipped: 6/14/2017

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 14 GALV ASTM F3125 GRADE A325 HEAVY HEX BOLT

Heat#:	NF16102579			**Base Steel:**	4140			**Diam:**	7/8		
Source:	KREHER STEEL CO LLC					**Proof Load:**	39,280 LBF				
C :	.420	**Mn:**	.930	**P :**	.013	**Hardness:**	263 HBN				
S :	.025	**Si:**	.250	**Ni:**	.080	**Tensile:**	58,660 LBF			**RA:**	.00%
Cr:	.910	**Mo:**	.180	**Cu:**	.190	**Yield:**	0			**Elon:**	.00%
Pb:	.000	**V :**	.009	**Cb:**	.000	**Sample Length:**	0				
N :	.000			**CE:**	.6702	**Charpy:**				**CVN Temp:**	

LOT#18455

Product:
ASTM A572G50 PLATES

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-54. ⅞-in. Dia. UNC, 14-in. Long Heavy Hex Bolts, Test No. AGTB-2

UNYTITE INC.
INNOVATIVE FASTENING SYSTEMS

Unytite, Inc.
One Unytite Drive
Peru, IL 61354
Tel 815-224-2221
Fax 815-224-3434

INSPECTION CERTIFICATE

Job No: 25506 **Job Information** **Certified Date:** 4/14/17

Customer:
Ship To:
Customer PO No:
Shipped Qty:
Lot Number: 25506-75066009

Part Information

Part No: A563 7/8-9 +0.022 DH HHN HDG BLUE DYE-0
Name: ASTM A563 HHN, Grade DH, Hot Dipped Galv, Blue Dye
Manufactured Quantity: 82,396

Applicable Specifications

Specification	Amend	Specification	Amend
ASME B1.1	2003	ASME B18.2.2	2015
ASME B18.2.6	2010	ASTM A563	2015
ASTM F2329	2013	ASTM F606/606M	2014
ASTM F812/F812M	2012		

Test Results
Test No: 14764 **Test:** A563 DH Mechanical Properties

Description	Hardness (HRC)	Tempering Temp (800 degree F Min)	Proof Load (Pass/Fail) (ASTM Min)	Shape & Dimension ASME B18.2.2	Thread Precision ASME B18.1.1	Visual ASTM F812
Sample Inspection	28.45	1,202	69,300	Pass	Pass	Pass

Certified Chemical Analysis

Heat No	Grade	Manufacturer	Origin	C	Mn	P	S	Si	Cr	Ni	Cu
75066009	1045	Gerdau Special Steel North America	USA	0.4400	0.7500	0.009	0.0340	0.2400	0.1800	0.1200	0.2200

Notes

All tests are in accordance with the latest revisions of the methods prescribed in the applicable SAE and ASTM Specifications.

The samples tested conform the specifications as described/listed above and were manufactured free of mercury contamination and there is no welding performed in the production of the products. No heats to which Bismuth, Selenium, Tellurium, or Lead was intentionally added have been used to produce products.
The steel was melted and manufactured in the U.S.A. and the product was manufactured and tested in the U.S.A.

We certify that this data is 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.

OFFICIAL SEAL
JEAN MARGHERIO
NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES:10/18/17

Sobkowiak, Bill - Supervisor, Quality 4/14/17
Date

Plex 4/14/17 7:59 AM bsobkowiak Page 1

30094-2

Figure A-55. ⅞-in. Dia. UNC, Heavy Hex Nuts, Test No. AGTB-2

Heat Number	Shipper No	Invoice No	Customer PO#	Customer Name
2038622	680907	701917	5-7-2015 MIKE	GAFFNEY BOLT CO.

CMC

1SERIES-BPS®

CMC STEEL SOUTH CAROLINA
310 New State Road
Cayce SC 29033-3704

CERTIFIED MILL TEST REPORT
For additional copies call
800-637-3227

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

Richard S. Ray

Richard S. Ray - CMC Steel SC
Quality Assurance Manager

HEAT NO.:2038622 SECTION: ROUND 7/8 x 40'0" A36/52950 GRADE: ASTM A36-12/A529-05 Gr 50 ROLL DATE: 09/09/2014 MELT DATE: 09/08/2014	SOLD TO: Infra-Metals - Mars 1601 Broadway St Marseilles IL US 61341-9326 8009875283	SHIP TO: Infra-Metals - Mars 1601 Broadway St Marseilles IL US 61341-9326 8009875283	Delivery#: 81471569 BOL#: 70533247 CUST PO#: CE-485729 CUST P/N: DLVRY LBS / HEAT: 9075.000 LB DLVRY PCS / HEAT: 111 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.16%	Elongation Gage Lgth test 1	8IN		
Mn	0.73%	Reduction of Area test 1	58%		
P	0.013%	Yield to tensile ratio test1	0.75		
S	0.021%	Yield Strength test 2	56.9ksi		
Si	0.22%	Tensile Strength test 2	76.5ksi		
Cu	0.32%	Elongation test 2	25%		
Cr	0.13%	Elongation Gage Lgth test 2	8IN		
Ni	0.10%	Reduction of Area test 2	57%		
Mo	0.027%	Yield to tensile ratio test2	0.74		
V	0.000%	C+(Mn/6)	0.28%		
Cb	0.026%				
Sn	0.010%				
Al	0.000%				
Ti	0.001%				
N	0.0084%				
Carbon Eq A529	0.38%				
Yield Strength test 1	57.1ksi				
Tensile Strength test 1	76.3ksi				
Elongation test 1	23%				

THIS MATERIAL IS FULLY KILLED, 100% MELTED AND MANUFACTURED IN THE USA, WITH NO WELD REPAIR OR MERCURY CONTAMINATION IN THE PROCESS.

REMARKS :

ALSO MEETS ASTM GRADE A36 REV-03A, A529 GR.50, A572-2013A GR.50, A709 GR.36, A709 GR.50, A992, AASHTO GRADE M270 GR.36, M270 GR.50, CSA G40.21-04 GRADE 44W, 50WASME SA-36 2008A ADDEND A.

03/18/2015 14:05:35
Page 1 OF 1

INSPECTION CERTIFICATE

Customer	Specification	Size	Lot No.	Date
	ASTM A-563 GRADE DH HEAVY HEX NUT	7/8- 9 UNC	WA651	Jun. 29, '12

UNYTITE, INC.
One Unytite Drive
Peru, Illinois 61354
815-224-2221 — FAX# 815-224-3434

Mechanical properties tested in accordance to ASTM F606/F606M, ASTM A370, ASTM E18

Chemical Composition (%)

Mill Maker	Material Size	Heat No. \ Spec.	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	
NUCOR	CARBON		0.20 0.55	-	MIN. 0.60	MAX. 0.040	MAX. 0.050	-	-	-	-	-
STEEL	STEEL	12101054	0.43	0.24	0.87	0.015	0.020	0.09	0.04	0.08	-	-

Shape & Dimension	
Inspection	ANSI B18.2.2 GOOD
Thread Precision Inspection	ANSI B1.1 CLASS 2B GOOD
Appearance Inspection	GOOD

Mechanical Property Inspection

Item	Proof Load	Cone stripping	Hardness	After Heat Treatment Hardness	Absorbed Energy	Heat Treatment
Spec.	80,850 lbf	- kN·kgf·lbf	24-38 HrC	HrB·HB	j·kgfm·ftlbf	T:MIN.800 F
Results	n 5 Results GOOD	n - Results -	29.4 28.9 29.7 29.7 29.5 29.4	5 Piece Average After Heat Treament Hardness Treatment After 24 Hr.X °F(°C)	at °F(°C)	Q:FORGING Q (W.Q.) T:1058 F/45M. (W.C. Q: Quenching T: Tempering ST: Solution Treatment

Jean Margherio
OFFICIAL SEAL
JEAN MARGHERIO
NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES 10/18/13
07-10-12

Remarks:

"DH U"

Production Quantity
22,391 pcs.

BCT Foundation Tube
Keeper Bolt Nuts
R#15-0600 June 2015 SMT

Material used for the nut was melted and manufactured in the USA. The nut was manufactured in the USA to the above specification.

Chief of Quality Assurance Section

We hereby certify that the material described has been manufactured and inspected satisfactorily with the requirement of the above specification.

Figure A-56. ⅞-in. Dia. UNC, 8-in. Long Hex Bolts and Nuts, Test No. AGTB-2

Birmingham Fastener Manufacturing

P.O. Box 10323
Birmingham, Alabama 35202
(205) 595-3512

Pg 1 of 1

Certificate of Compliance

Customer : Midwest Machinery & Supply
P.O. #: 3275
BFM # : 1338859
Date Shipped : 6/16/2016

	Quantity	Description	Lot#	Heat #	Specification	Finish
1	104	5/8"-11 x 8" HEX BOLT	208976	DL15107048	ASTM A307 Gr A	HDG
2	157	5/8"-11 x 10" HEX BOLT	208977	DL15107048	ASTM A307 Gr A	HDG
3	402	7/8"-9 x 16" Hex Bolt	208978	JK15100276	ASTM A307 Gr A	HDG
4	67	7/8"-9 X 26" Hex Bolt	208979	JK15100276	ASTM A307 Gr A	HDG

Birmingham Fastener Manufacturing. hereby certifies that the material furnished in reference to the above purchase order number will meet or exceed the above assigned specifications.

Signed: ***Date:*** ***06/15/2016***
Brian Hughes

Figure A-57. ⅝-in. Dia. UNC, 10-in. Hex Head Bolts, Test AGTB-2

CERTIFIED MATERIAL TEST REPORT
FOR ASTM A307, GRADE A - MACHINE BOLTS

FACTORY: NINGBO ECONOMIC & TECHNICAL DEVELOPMENT ZONE YONGGANG FASTENERS CO., LTD.
REPORT DATE:2016/12/29
R#17-507 H#816070039
ADDRESS: FuShan South Road No.17,BeiLun NingBo China
BCT Cable Bracket Bolts
MANUFACTURE DATE:2016/12/2
TEL#(852)25423366
CUSTOMER: FASTENAL
MFG LOT NUMBER:M-2016HT927-9
SAMPE SIZE: ACC.TO Dimension:ASME B18.18-11;Mechanical Properties:ASTM F1470-12
MANU QTY: 4800PCS
SHIPPED QTY: 4800PCS
SIZE: 5/8-11X1 1/2 HDG
HEADMARKS: 307A PLUS NY
PO NUMBER:220023115
PART NO:1191919

STEEL PROPERTIES:
MATERIAL TYPE:Q195
HEAT NUMBER: 816070039

CHEMISTRY SPEC:	C %*100	Mn%*100	P %*1000	S %*1000
Grade A ASTM A307-12	0.29max	1.20 max	0.04max	0.15max
TEST:	0.07	0.28	0.016	0.003

DIMENSIONAL INSPECTIONS Unit:inch SPECIFICATION: ASME B18.2.1 - 2012

CHARACTERISTICS	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
VISUAL	ASTM F788-2013	PASSED	22	0
THREAD	ASME B1.1-2003,3A GO,2A NOGO	PASSED	15	0
WIDTH FLATS	0.906-0.938	0.915-0.928	4	0
WIDTH A/C	1.033-1.083	1.048-1.057	4	0
HEAD HEIGHT	0.378-0.444	0.394-0.424	4	0
THREAD LENGTH	1.420-1.560	1.435-1.541	15	0
LENGTH	1.420-1.560	1.435-1.541	15	0

MECHANICAL PROPERTIES: SPECIFICATION: ASTM A307-2012 GR-A

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS :	ASTM F606-2014	69-100 HRB	76-79 HRB	4	0
WEDGE TENSILE:	ASTM F606-2014	Min 60 KSI	65-69 KSI	4	0

COATINGS OF ZINC: SPECIFIATION:ASTM F2329-2013

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
HOT DIP GALVANIZED	ASTM B568-98(2104)	Min 0.0017"	0.0017" -0.0018"	4	0

ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM SPECIFICATION. WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.

Maker's ISO# 00109Q16722R3M/3302

NINGBO ECONOMIC & TECHNICAL ... ZONE YONGGANG FASTENERS CO., LTD

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

Figure A-58. ⅝-in. Dia. UNC, 1½-in. Hex Head Bolts, Test No. AGTB-2

R#16-0217
BCT Hex Nuts
December 2015 SMT
Fastenal part#36713
Control# 210101523

STELFAST® INC.

22979 Stelfast Parkway
Strongsville, Ohio 44149

CERTIFICATE OF CONFORMANCE

DESCRIPTION OF MATERIAL AND SPECIFICATIONS

- Sales Order #: 129980
- Part No: AFH2G0625C
- Cust Part No: 36713
- Quantity (PCS): 1200
- Description: 5/8-11 Fin Hx Nut Gr2 HDG/TOS 0.020
- Specification: SAE J995(99) - GRADE 2 / ANSI B18.2.2
- Stelfast I.D. NO: 595689-O201087
- Customer PO: 210101523
- Warehouse: DAL

The data in this report is a true representation of the information provided by the material supplier certifying that the product meets the mechanical and material requirements of the listed specification. This certificate applies to the product shown on this document, as supplied by STELFAST INC. Alterations to the product by our customer or a third party shall render this certificate void.

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Stelfast certifies parts to the above description. The customer part number is only for reference purposes.

David Biss
Quality Manager

December 07, 2015

Page 1 of 1

Figure A-59. ⅝-in. Dia. UNC, Hex Nuts, Test No. AGTB-2

Appendix B. Vehicle Center of Gravity Determination

Test: AGTB-1 Vehicle: Ram 1500

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb.)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unbalasted Truck (Curb)	5025	29.53239	148400.25
+	Brake receivers/wires	5	53	265
+	Brake Frame	7	28	196
+	Brake Cylinder (Nitrogen)	22	28.25	621.5
+	Strobe/Brake Battery	5	33	165
+	Hub	19	15.5	294.5
+	CG Plate (EDRs)	8	34.5	276
-	Battery	-43	42	-1806
-	Oil	-6	19	-114
-	Interior	-84	28	-2352
-	Fuel	-167	21.5	-3590.5
-	Coolant	-16	37	-592
-	Washer fluid	0	0	0
	Water Ballast	226	21.5	4859
	Supplemental battery	14	28	392
	Misc.			0
				147014.75

Estimated Total Weight (lb.)	5015
Vertical CG Location (in.)	29.315

Wheel Base (in.) 140.5

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb.)	5000 ± 110	5039	39.0
Longitudinal CG (in.)	63 ± 4	61.59	-1.40752
Lateral CG (in.)	NA	-0.08788	NA
Vertical CG (in.)	28 or greater	29.32	1.31500

Note: Long. CG is measured from front axle of test vehicle
Note: Lateral CG measured from centerline - positive to vehicle right (passenger) side
Note: Cells highlighted in red do not meet target requirements

CURB WEIGHT (lb.)

	Left	Right
Front	1466	1404
Rear	1092	1063

FRONT	2870 lb.
REAR	2155 lb.
TOTAL	5025 lb.

TEST INERTIAL WEIGHT (lb.)
(from scales)

	Left	Right
Front	1439	1391
Rear	1087	1122

FRONT	2830 lb.
REAR	2209 lb.
TOTAL	5039 lb.

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

Date:	5/24/2017	Test Name:	AGTB-2	VIN:	1D7RB1CT0AS246796
Year:	2010	Make:	Dodge	Model:	Ram 1500 Hemi

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb.)	Vertical CG (in.)	Vertical M (lb.-in.)
+	Unballasted Truck (Curb)	5097	28 1/3	144308.81
+	Hub	19	15	285
+	Brake activation cylinder & frame	6	26	156
+	Pneumatic tank (Nitrogen)	27	27	729
+	Strobe/Brake Battery	5	25 1/2	127.5
+	Brake Receiver/Wires	5	53 1/2	267.5
+	CG Plate including DAS	50	29 7/8	1493.75
-	Battery	-39	40 3/8	-1574.625
-	Oil	-11	28 1/2	-313.5
-	Interior	-106	26 1/2	-2809
-	Fuel	-172	19 5/8	-3375.5
-	Coolant	-18	34	-612
-	Washer fluid	-9	38	-342
+	Water Ballast (In Fuel Tank)	39	14 1/2	565.5
+	Onboard Supplemental Battery	13	25 1/2	331.5
		0	0	0
Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle				139237.94

Estimated Total Weight (lb.)	4906
Vertical CG Location (in.)	28.3812

Vehicle Dimensions for C.G. Calculations

Wheel Base:	140 3/8 in.		Front Track Width:	68 in.
			Rear Track Width:	67 7/8 in.

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb.)	5000 ± 110	4998	-2.0
Longitudinal CG (in.)	63 ± 4	61.284164	-1.71584
Lateral CG (in.)	NA	-0.013593	NA
Vertical CG (in.)	28 or greater	28.38	0.38115

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	1481	1346
Rear	1141	1129

FRONT	2827	lb.
REAR	2270	lb.
TOTAL	5097	lb.

TEST INERTIAL WEIGHT (lb.)

	Left	Right
Front	1415	1401
Rear	1085	1097

FRONT	2816	lb.
REAR	2182	lb.
TOTAL	4998	lb.

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

Date:	**5/24/2017**	**Test Name:**	**AGTB-2**	**VIN:**	**1D7RB1CT0AS246796**
Year:	**2010**	**Make:**	**Dodge**	**Model:**	**Ram 1500 Hemi**

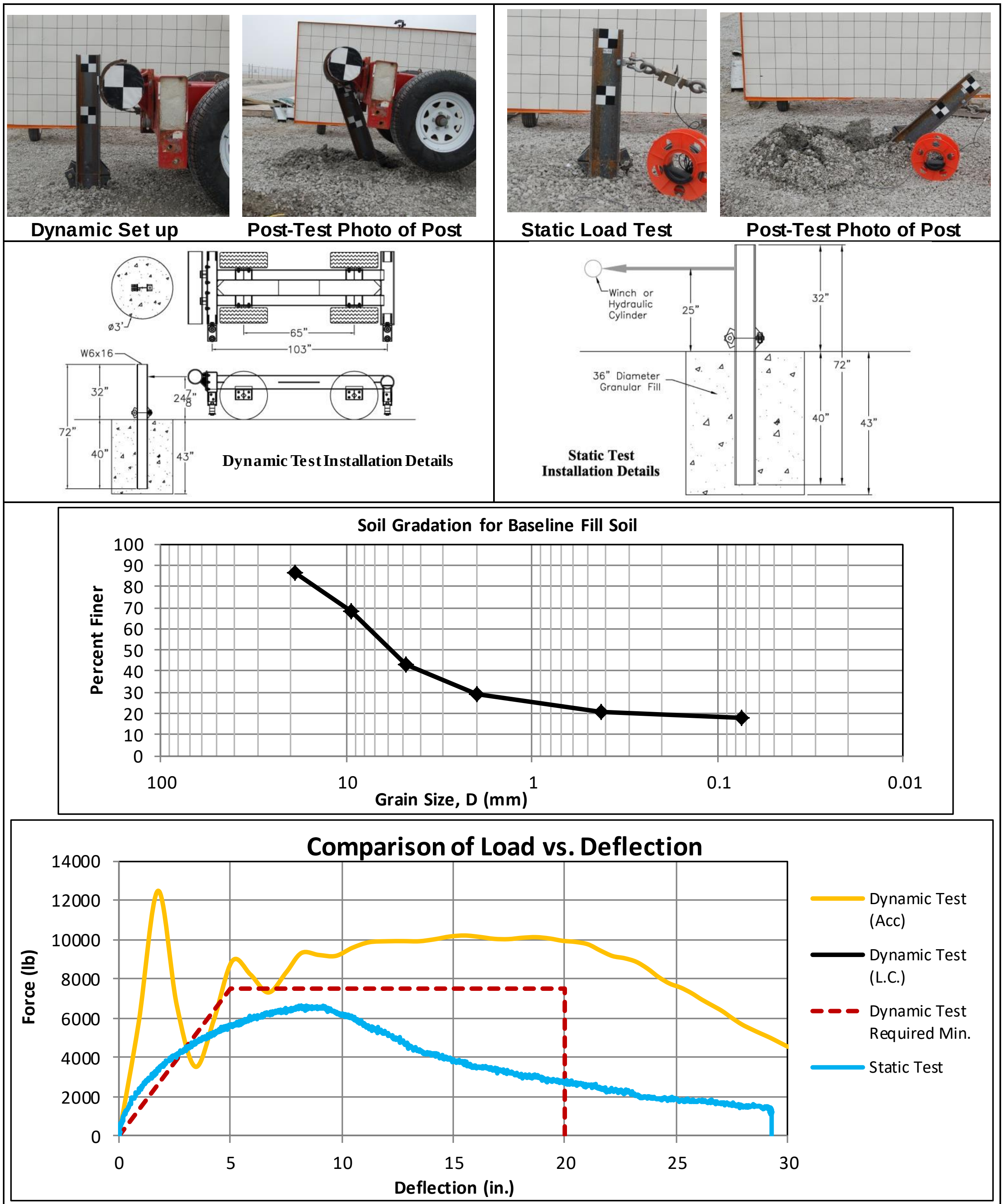
Vehicle CG Determination

VEHICLE	Equipment	Long CG (in.)	Lat CG (in.)	Long M (lb.-in.)	Lat M (lb.-in.)
+	Unballasted Truck (Curb)	61 4/7	-1	313784.1	-4993.406
+	Hub	0	44	0	836
+	Brake activation cylinder & frame	37	-19 1/2	222	-117
+	Pneumatic tank (Nitrogen)	79 1/2	-20	2146.5	-540
+	Strobe/Brake Battery	89 1/2	-19 3/4	447.5	-98.75
+	Brake Receiver/Wires	116	0	580	0
+	CG Plate including DAS	69	0	3450	0
-	Battery	-8	-24 1/2	312	955.5
-	Oil	-5	3	55	-33
-	Interior	63	0	-6678	0
-	Fuel	112	-12	-19264	2064
-	Coolant	-25	0	450	0
-	Washer fluid	-28 1/2	-16 1/2	256.5	148.5
+	Water Ballast (In Fuel Tank)	112	-12	4368	-468
+	Onboard Supplemental Battery	71	-17 1/2	923	-227.5
		0	0	0	0
Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle				301052.6	-2473.656
			Estimated CG Location (in.)	61.36416	-0.50421

Calibrated Scales Used			
Equipment Type	Manufacturer	Serial #	Capacity
Pad Scale	Pennsylvania Scale	95-228908	5000 lbs.
Pad Scale	Pennsylvania Scale	95-228909	5000 lbs.
Race Wheel Scales	Intercomp	22033056	1500/pad

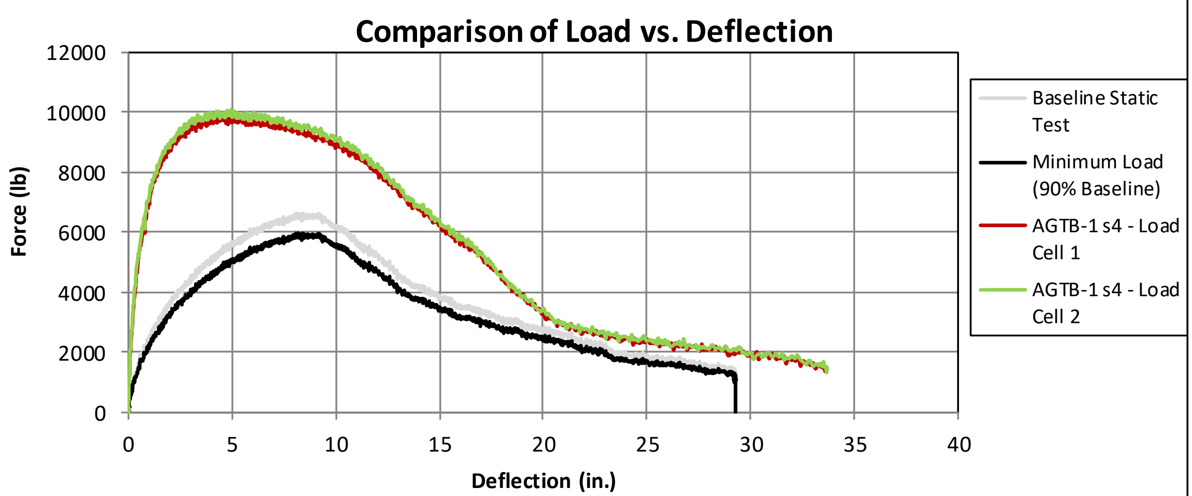
Figure B-3. Vehicle Mass Distribution, Test No. AGTB-2, Continued

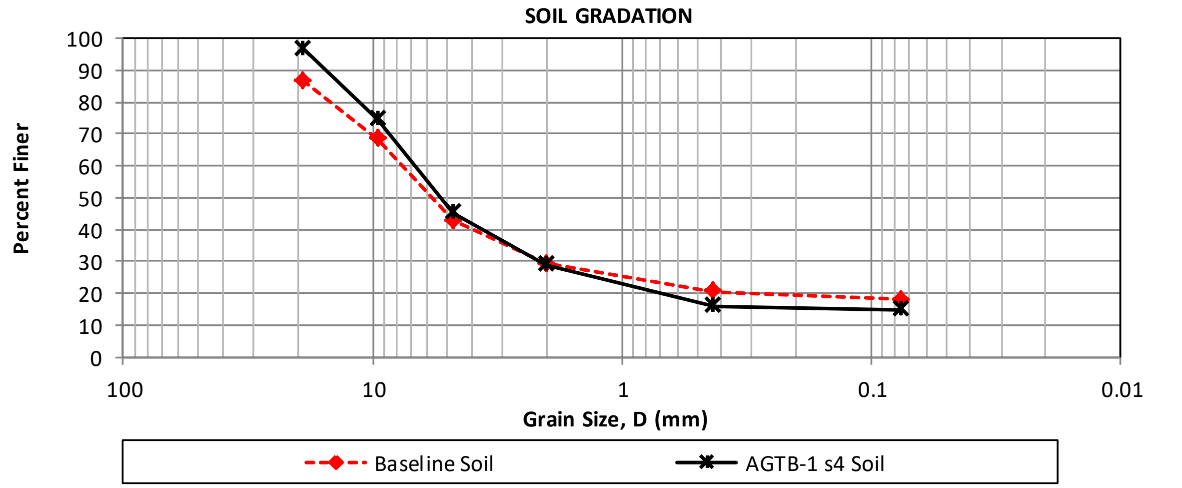
Appendix C. Static Soil Tests



Date...	4/4/2012			
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.....	3 Pass, 8" Lift			
Bogie Weight...	1844	lb	836	kg
Impact Velocity......................................	20.1	mph	32.3	km/h

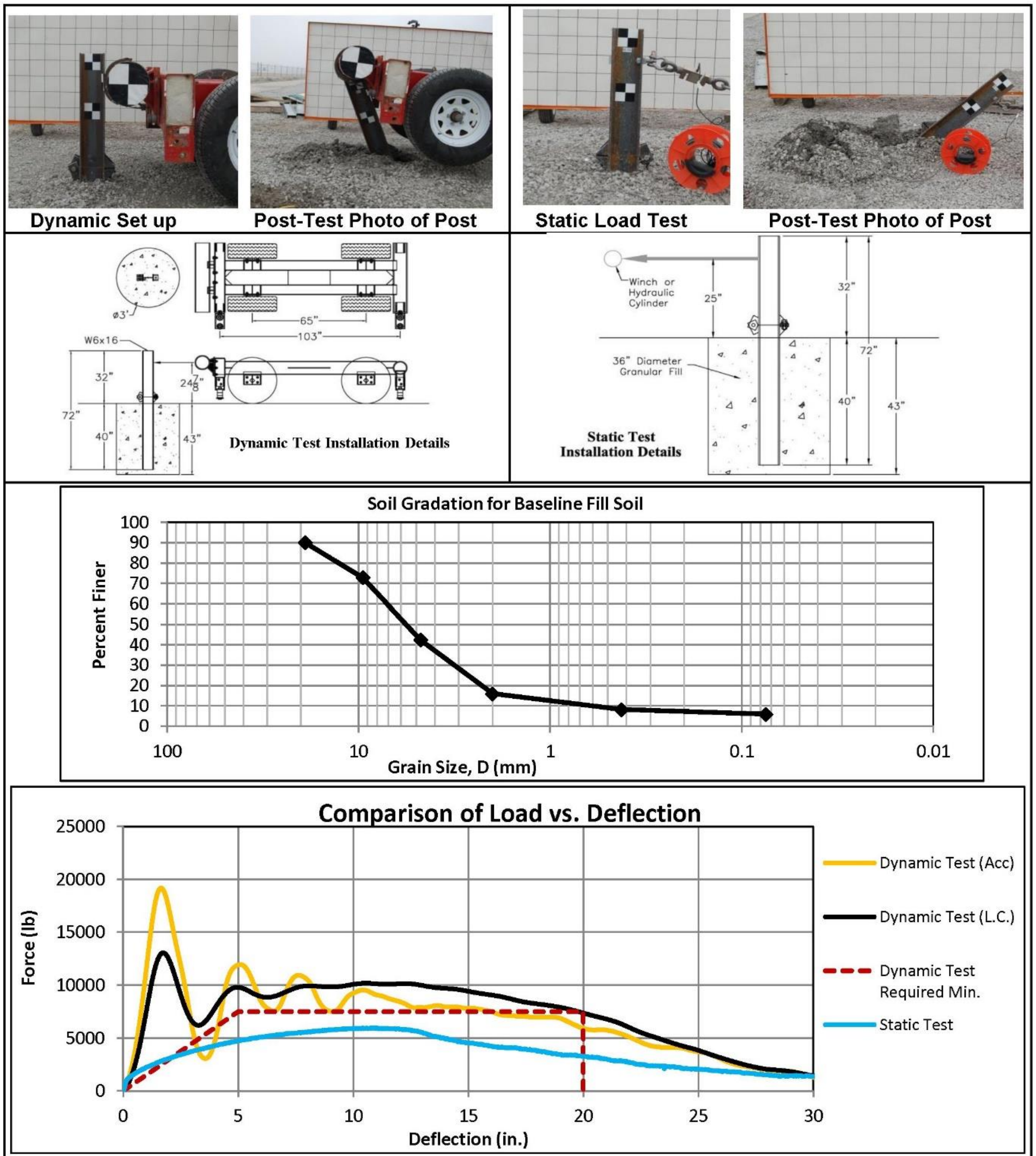
Figure C-1. Soil Strength, Initial Calibration Tests, Test No. AGTB-1





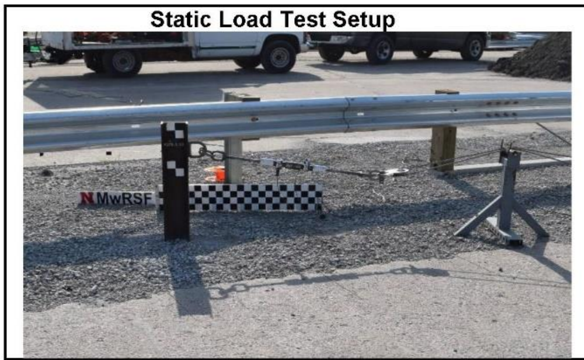
Date	12/21/2015
Test Facility & Site Location	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)	Well-Graded Gravel (GW)
Fill material description (ASTM D2487)	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure	8-inch lifts tamped with a pneumatic compactor

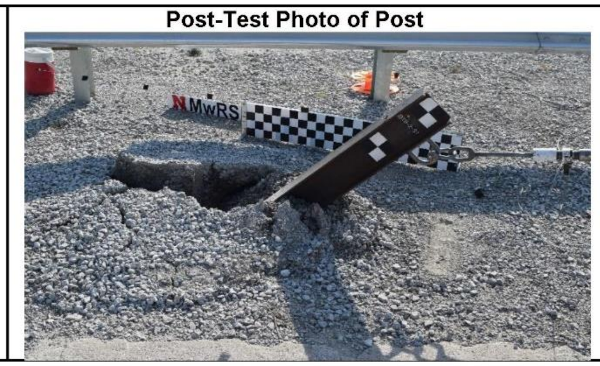
Figure C-2. Soil Strength Test, Test No. AGTB-1

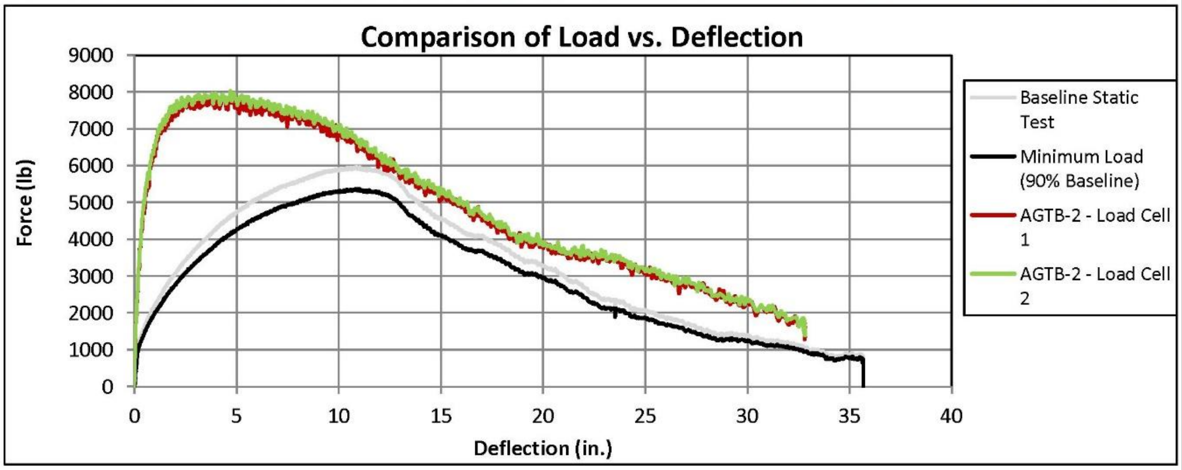


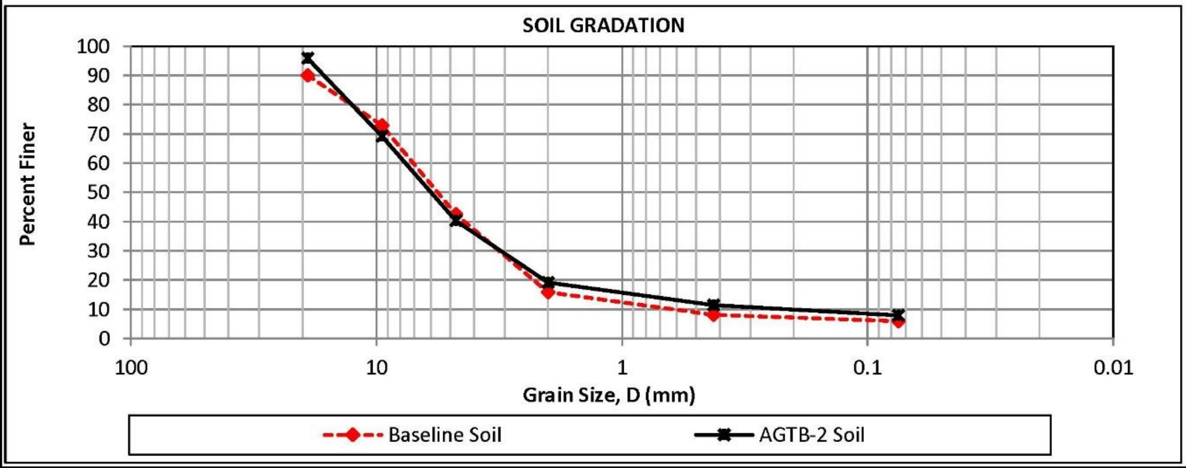
Date	3/20/2012
Test Facility & Site Location	Midwest Roadside Safety Facility
In situ soil description (ASTM D2487)	Well-Graded Gravel (GW)
Fill material description (ASTM D2487)	Well-Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure	8" lift 3-4 passes
Bogie Weight	1843 lb — 836 kg
Impact Velocity	20.0 mph — 32.2 km/h

Figure C-3. Soil Strength, Initial Calibration Tests, Test No. AGTB-2









Date..	7/19/2017
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. Soil Strength Test, Test No. AGTB-2

Appendix D. Vehicle Deformation Records

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 1

TEST: AGTB-1
VEHICLE: Dodge Ram 1500

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
1	30.615	-27.462	5.012	28.696	-24.009	7.153	-1.919	3.453	2.142
2	33.016	-24.545	4.722	31.068	-21.987	6.379	-1.948	2.558	1.658
3	33.682	-19.719	2.281	33.104	-19.236	2.644	-0.578	0.484	0.364
4	33.205	-14.948	1.181	32.764	-14.276	1.309	-0.441	0.672	0.128
5	28.071	-27.897	1.470	25.243	-23.930	4.580	-2.829	3.968	3.110
6	30.157	-23.909	0.460	27.894	-21.008	2.529	-2.263	2.901	2.069
7	30.565	-19.009	-0.516	29.657	-18.256	0.235	-0.908	0.753	0.751
8	28.322	-10.198	-0.554	28.127	-9.752	-0.292	-0.195	0.445	0.262
9	25.292	-29.018	-2.132	22.277	-25.411	1.235	-3.016	3.607	3.367
10	24.971	-23.202	-2.722	25.312	-19.568	-1.321	0.341	3.635	1.402
11	24.901	-16.361	-3.454	24.350	-15.477	-2.795	-0.551	0.884	0.659
12	25.258	-11.319	-3.758	25.142	-10.609	-3.580	-0.116	0.710	0.178
13	20.155	-28.659	-4.204	18.451	-27.435	-2.794	-1.704	1.224	1.409
14	20.382	-22.408	-4.742	19.669	-21.468	-4.145	-0.714	0.940	0.598
15	20.348	-16.835	-5.275	19.895	-15.970	-4.982	-0.452	0.865	0.293
16	20.384	-11.701	-5.756	19.926	-10.879	-5.456	-0.458	0.822	0.300
17	16.545	-29.109	-4.238	15.921	-28.063	-3.789	-0.624	1.046	0.449
18	16.592	-22.349	-4.811	16.121	-21.589	-4.796	-0.471	0.760	0.015
19	16.690	-16.312	-5.426	16.191	-15.428	-5.316	-0.499	0.884	0.110
20	16.659	-11.779	-5.800	16.253	-10.876	-5.555	-0.406	0.903	0.245
21	10.680	-29.117	-3.977	10.496	-28.344	-4.797	-0.185	0.773	-0.820
22	10.719	-22.463	-4.530	10.402	-21.647	-4.909	-0.318	0.816	-0.379
23	10.655	-16.239	-5.140	10.170	-15.338	-5.101	-0.485	0.901	0.040
24	10.659	-12.052	-5.510	10.181	-11.230	-5.175	-0.478	0.822	0.335
25	1.047	-27.175	0.108	1.544	-26.937	-0.065	0.497	0.238	-0.173
26	1.002	-20.809	-0.536	1.193	-20.487	-0.369	0.190	0.321	0.167
27	0.947	-13.467	-1.278	0.925	-13.088	-0.729	-0.021	0.379	0.550
28	1.702	-6.289	0.582	1.673	-6.075	1.306	-0.029	0.214	0.723

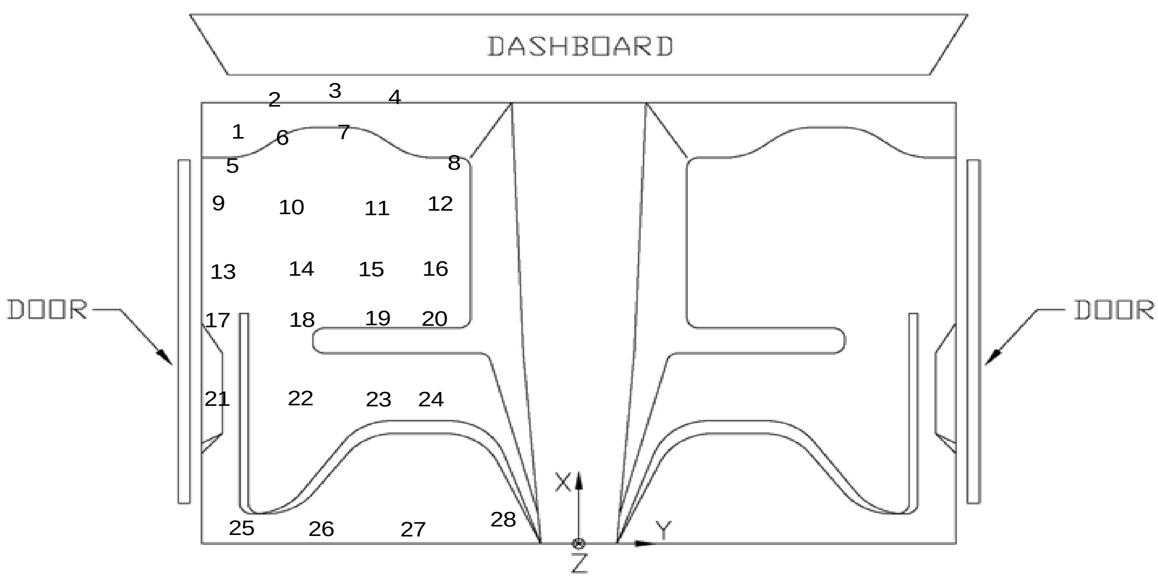


Figure D-1. Floor Pan Deformation Data – Set 1, Test No. AGTB-1

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 2

TEST: AGTB-1
VEHICLE: Dodge Ram 1500

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
1	46.884	-36.094	2.243	44.836	-33.277	2.444	-2.048	2.817	0.201
2	49.375	-33.169	2.180	47.255	-31.078	2.022	-2.120	2.091	-0.159
3	50.075	-28.304	0.167	49.269	-27.815	-1.087	-0.807	0.489	-1.253
4	49.658	-23.296	-0.459	49.103	-22.743	-1.468	-0.555	0.553	-1.009
5	44.247	-36.182	-1.247	41.228	-32.547	0.077	-3.019	3.636	1.324
6	46.401	-32.180	-1.932	44.047	-29.324	-1.551	-2.354	2.856	0.381
7	46.907	-27.174	-2.474	45.775	-26.256	-3.138	-1.133	0.918	-0.664
8	44.932	-18.460	-1.654	44.467	-17.732	-2.179	-0.465	0.728	-0.526
9	41.380	-36.891	-4.909	38.191	-33.217	-3.509	-3.189	3.674	1.400
10	41.200	-31.027	-4.956	41.345	-27.084	-4.902	0.145	3.943	0.054
11	41.365	-24.147	-5.001	40.525	-22.839	-5.501	-0.839	1.308	-0.500
12	41.739	-19.085	-4.879	41.370	-17.964	-5.432	-0.369	1.120	-0.553
13	36.201	-36.238	-6.843	34.333	-34.397	-7.666	-1.868	1.841	-0.823
14	36.585	-29.907	-6.798	35.658	-28.326	-7.883	-0.926	1.581	-1.085
15	36.644	-24.304	-6.804	35.981	-22.609	-7.661	-0.663	1.695	-0.857
16	36.870	-19.250	-6.814	36.243	-17.651	-7.160	-0.627	1.599	-0.346
17	32.593	-36.594	-6.852	31.633	-34.648	-8.718	-0.961	1.946	-1.866
18	32.813	-29.816	-6.786	31.961	-28.031	-8.418	-0.853	1.785	-1.632
19	33.058	-23.734	-6.839	32.339	-21.932	-7.721	-0.719	1.802	-0.882
20	33.184	-19.119	-6.796	32.574	-17.513	-7.166	-0.610	1.607	-0.370
21	26.766	-36.480	-6.490	26.338	-34.610	-9.688	-0.429	1.870	-3.198
22	26.964	-29.749	-6.415	26.427	-27.942	-8.474	-0.537	1.807	-2.059
23	27.024	-23.510	-6.437	26.421	-21.810	-7.482	-0.604	1.700	-1.045
24	27.158	-19.355	-6.425	26.469	-17.747	-6.727	-0.689	1.608	-0.303
25	17.282	-34.637	-2.065	17.436	-33.718	-4.494	0.155	0.919	-2.429
26	17.323	-28.277	-2.104	17.277	-27.394	-3.585	-0.046	0.882	-1.481
27	17.404	-20.866	-2.159	17.236	-20.164	-2.531	-0.168	0.702	-0.372
28	18.412	-13.861	0.320	18.281	-13.750	0.786	-0.131	0.111	0.466

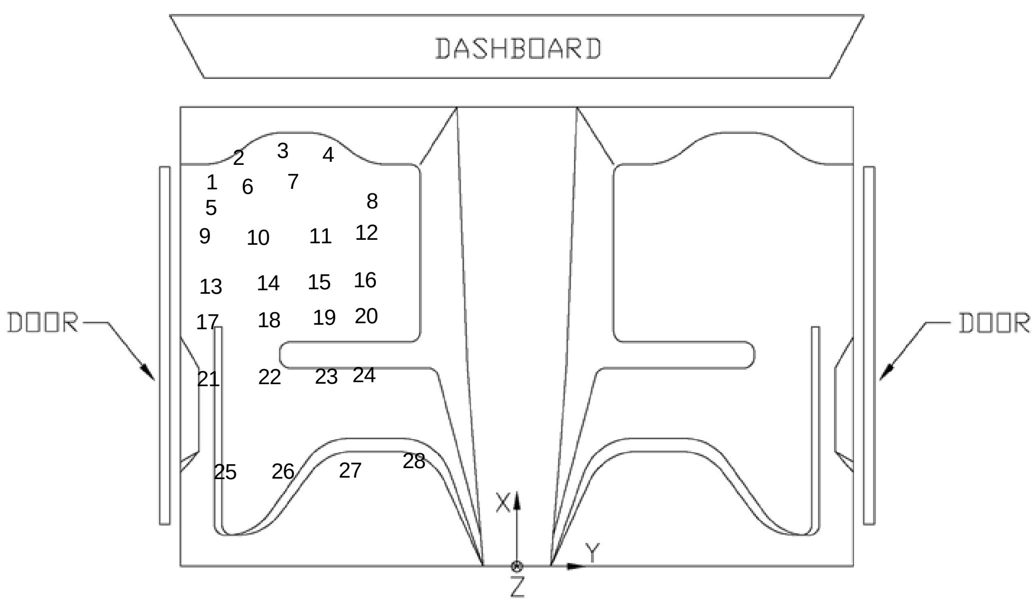


Figure D-2. Floor Pan Deformation Data – Set 2, Test No. AGTB-1

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 1

TEST: AGTB-1
VEHICLE: Dodge Ram 1500

	POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
DASH	1	16.104	-28.512	27.618	16.479	-26.719	29.406	0.376	1.794	1.788
	2	15.046	-15.747	28.656	15.368	-13.870	29.684	0.323	1.876	1.028
	3	14.357	2.160	26.970	14.696	3.831	26.747	0.339	1.671	-0.223
	4	13.087	-29.198	19.321	13.243	-27.882	21.283	0.157	1.316	1.962
	5	12.396	-10.728	17.144	12.413	-9.701	18.123	0.017	1.026	0.980
	6	11.140	1.105	15.558	11.088	2.003	15.642	-0.051	0.898	0.084
SIDE PANEL	7	20.977	-31.333	7.491	20.448	-27.922	8.997	-0.530	3.411	1.505
	8	21.346	-32.061	-0.330	20.584	-28.989	1.056	-0.762	3.072	1.386
	9	26.197	-31.594	4.425	25.361	-27.849	5.810	-0.836	3.745	1.386
IMPACT SIDE DOOR	10	-12.726	-32.016	24.664	-13.258	-33.984	25.879	-0.533	-1.968	1.215
	11	0.873	-32.147	23.913	0.256	-33.259	25.070	-0.617	-1.112	1.157
	12	11.685	-32.166	23.112	10.938	-31.872	24.265	-0.746	0.294	1.153
	13	-10.623	-33.204	9.019	-11.444	-35.306	10.302	-0.821	-2.102	1.283
	14	0.810	-33.198	9.009	-0.114	-32.903	10.378	-0.924	0.296	1.369
	15	11.421	-33.355	5.679	10.162	-30.353	6.982	-1.259	3.002	1.303
ROOF	1	4.047	-19.983	43.276	4.672	-17.780	44.201	0.625	2.203	0.925
	2	5.876	-13.105	43.177	6.302	-10.905	43.638	0.426	2.199	0.461
	3	6.807	-6.935	42.867	7.177	-4.758	42.891	0.371	2.177	0.024
	4	7.508	-0.776	42.365	7.816	1.293	41.987	0.308	2.069	-0.377
	5	7.641	3.813	41.943	7.951	5.861	41.246	0.310	2.048	-0.697
	6	-2.322	-16.361	46.364	-1.891	-14.038	46.835	0.432	2.322	0.471
	7	-1.510	-9.597	46.201	-1.072	-7.337	46.360	0.438	2.261	0.159
	8	-1.500	-3.270	45.931	-1.048	-1.068	45.703	0.452	2.202	-0.228
	9	-0.731	5.026	45.109	-0.432	7.152	44.392	0.298	2.125	-0.718
	10	-8.167	-15.396	47.348	-7.724	-13.121	47.849	0.443	2.275	0.501
	11	-7.800	-9.126	47.202	-7.344	-6.875	47.369	0.456	2.250	0.167
	12	-7.141	-3.058	46.817	-6.751	-0.872	46.618	0.390	2.186	-0.199
	13	-7.279	4.694	46.193	-7.019	6.846	45.514	0.260	2.153	-0.679
	14	-14.384	-12.028	48.037	-14.026	-9.817	48.477	0.358	2.211	0.440
	15	-14.685	-0.773	47.451	-14.447	1.408	46.874	0.239	2.181	-0.578

Figure D-3. Occupant Compartment Deformation Data – Set 1, Test No. AGTB-1

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 2

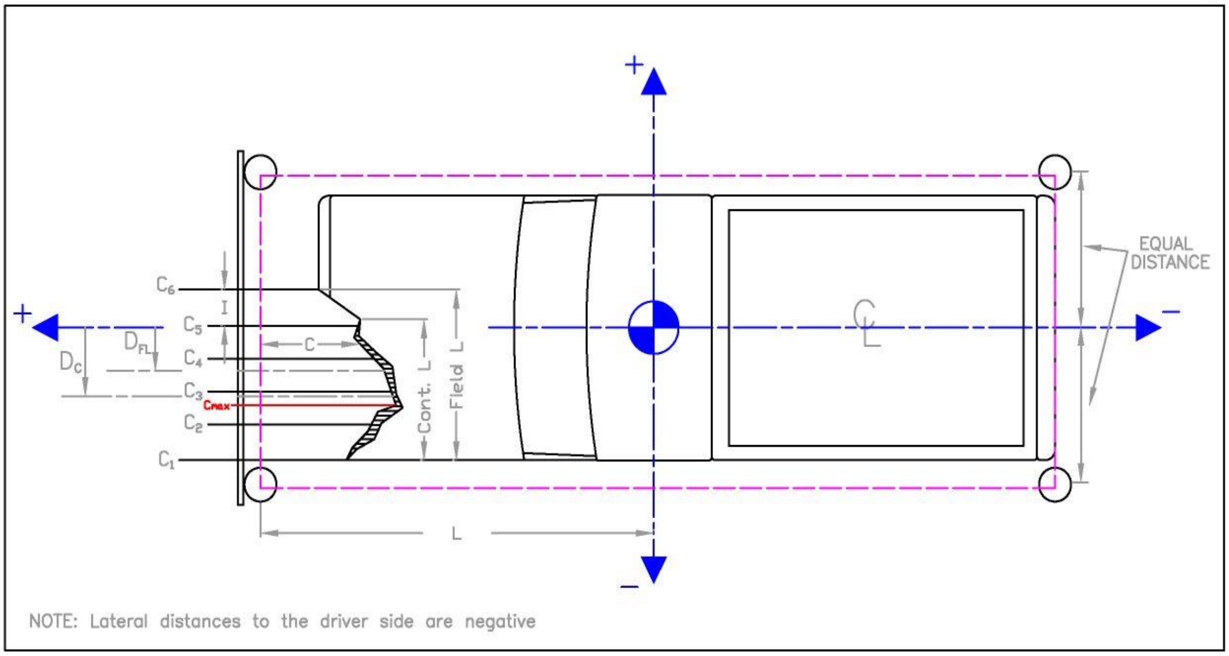
TEST: AGTB-1
VEHICLE: Dodge Ram 1500

	POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
DASH	1	32.719	-38.935	24.968	32.811	-39.804	24.093	0.093	-0.869	-0.874
	2	31.974	-26.290	27.192	32.217	-27.225	26.842	0.243	-0.935	-0.351
	3	31.827	-8.269	27.153	32.068	-9.171	27.356	0.241	-0.902	0.204
	4	29.526	-38.778	16.674	29.413	-39.238	15.940	-0.113	-0.460	-0.734
	5	29.257	-20.192	16.265	29.102	-20.644	16.222	-0.155	-0.451	-0.043
	6	28.284	-8.314	15.885	28.188	-8.758	16.152	-0.096	-0.443	0.266
SIDE PANEL	7	37.148	-39.989	4.505	36.458	-37.135	3.666	-0.690	2.854	-0.839
	8	37.398	-39.986	-3.373	36.379	-36.678	-4.172	-1.019	3.308	-0.799
	9	42.297	-40.080	1.380	41.332	-36.613	0.576	-0.965	3.467	-0.804
IMPACT SIDE DOOR	10	3.701	-41.488	22.216	2.768	-45.307	19.881	-0.933	-3.819	-2.336
	11	17.263	-41.864	21.149	16.292	-44.853	18.933	-0.971	-2.989	-2.216
	12	28.118	-42.063	20.169	27.003	-43.655	18.097	-1.115	-1.592	-2.072
	13	5.502	-41.243	6.438	4.390	-43.660	4.296	-1.112	-2.416	-2.143
	14	16.936	-41.515	6.258	15.685	-41.686	4.547	-1.250	-0.170	-1.711
	15	27.526	-41.607	2.707	26.019	-38.837	1.500	-1.508	2.770	-1.207
ROOF	1	21.205	-31.708	41.476	21.563	-33.431	40.559	0.359	-1.724	-0.917
	2	23.123	-24.871	42.029	23.380	-26.612	41.299	0.257	-1.742	-0.731
	3	24.210	-18.634	42.280	24.386	-20.499	41.747	0.175	-1.865	-0.533
	4	25.046	-12.535	42.351	25.258	-14.323	41.983	0.212	-1.788	-0.368
	5	25.325	-7.933	42.334	25.482	-9.717	42.148	0.158	-1.784	-0.185
	6	14.963	-28.193	45.033	15.160	-30.098	44.089	0.197	-1.905	-0.943
	7	15.885	-21.468	45.506	16.090	-23.415	44.823	0.204	-1.948	-0.683
	8	16.059	-15.179	45.826	16.317	-17.170	45.371	0.259	-1.991	-0.455
	9	17.042	-6.836	45.764	17.243	-8.840	45.624	0.201	-2.004	-0.141
	10	9.097	-27.178	46.236	9.390	-29.155	45.299	0.293	-1.977	-0.936
	11	9.645	-20.916	46.666	9.954	-22.867	46.024	0.310	-1.950	-0.643
	12	10.528	-14.865	46.829	10.753	-16.872	46.410	0.225	-2.007	-0.419
	13	10.486	-7.079	46.944	10.667	-9.163	46.799	0.181	-2.084	-0.145
	14	2.906	-23.822	47.346	3.260	-25.885	46.660	0.354	-2.063	-0.687
	15	3.004	-12.390	47.818	3.211	-14.545	47.233	0.207	-2.155	-0.585

Figure D-4. Occupant Compartment Deformation Data – Set 2, Test No. AGTB-1

Date: 12/23/2015 **Test Number:** AGTB-1

Make: Dodge **Model:** Ram 1500 **Year:** 2008



Blue Cells to be filled out Before Test
Orange Cells to Be filled out After Test

	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	108	(2743)
Total Vehicle Width:	77.25	(1962)
Width of contact and induced crush - Field L:	58	(1472)
Crush measurement spacing interval (L/5) - I:	11.5875	(294)
Distance from center of vehicle to center of Field L - D_{FL}:	-9 1/2	-(241)
Width of Contact Damage:	19 1/3	(491)
Distance from center of vehicle to center of contact damage - D_C:	-29	-(736)

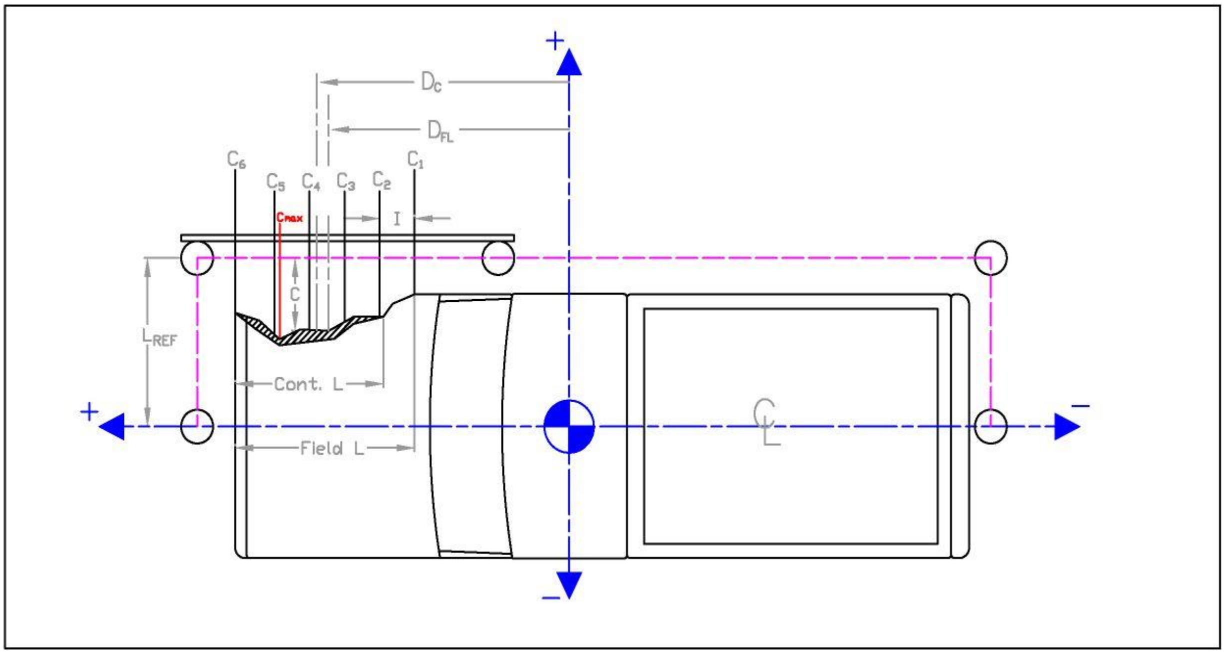
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual	Crush
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	NA	NA	-38 1/2	-(977)	29	(737)	-3	-(79)	NA	NA
C_2	NA	NA	-26 7/8	-(683)	14 7/8	(378)			NA	NA
C_3	11 1/4	(286)	-15 2/7	-(388)	11 2/3	(296)			2 2/3	(68)
C_4	6 1/2	(165)	-3 5/7	-(94)	10 1/4	(260)			- 2/3	-(17)
C_5	5 1/2	(140)	7 7/8	(200)	10 1/2	(266)			-1 8/9	-(48)
C_6	7 1/2	(191)	19 1/2	(495)	12 1/3	(314)			-1 3/4	-(45)
C_{MAX}	23	(584)	23	(584)	13 1/3	(338)			12 7/9	(325)

Figure D-5. Exterior Vehicle Crush (NASS) - Front, Test No. AGTB-1

Date: 12/23/2015 **Test Number:** AGTB-1

Make: Dodge **Model:** Ram 1500 **Year:** 2008



Blue Cells to be filled out Before Test
Orange Cells to Be filled out After Test

	in.	(mm)
Distance from centerline to reference line - L_{REF}:	48	(1219)
Total Vehicle Length:	227.38	(5775)
Width of contact and induced crush - Field L:	227 3/8	(5775)
Crush measurement spacing interval (L/5) - I:	45.475	(1155)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-12	-(307)
Width of Contact Damage:	227 3/8	(5775)
Distance from vehicle c.g. to center of contact damage - D_C:	12	(305)

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

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	NA	NA	-125 7/9	-(3195)	15 3/8	(391)	-2	-(51)	NA	NA
C_2	NA	NA	-80 1/3	-(2040)	10 1/2	(267)			NA	NA
C_3	9	(229)	-34 5/6	-(885)	11 4/7	(294)			- 4/7	-(14)
C_4	8 3/4	(222)	10 2/3	(270)	11 1/4	(286)			- 1/2	-(13)
C_5	NA	NA	56 1/9	(1425)	10 1/2	(267)			NA	NA
C_6	NA	NA	101 3/5	(2580)	35 1/4	(895)			NA	NA
C_{MAX}	23 1/2	(597)	76	(1930)	10 1/2	(267)			15	(381)

Figure D-6. Exterior Vehicle Crush (NASS) - Side, Test No. AGTB-1

Date: 5/24/2017 Test Name: AGTB-2 VIN: 1D7RB1CT0AS246796
Year: 2010 Make: Dodge Model: Ram 1500 Hemi

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 1

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)	Total Δ (in.)
1	26.525	15.910	-1.070	26.240	15.947	-0.993	-0.284	0.037	0.077	0.297
2	28.148	18.600	-3.920	28.226	17.932	-4.094	0.078	-0.668	-0.175	0.695
3	28.314	23.919	-4.375	25.729	21.735	-2.579	-2.585	-2.184	1.796	3.831
4	27.113	27.939	-3.968	23.209	24.347	-0.448	-3.904	-3.591	3.520	6.366
5	22.914	13.716	-1.314	22.773	13.331	-1.352	-0.140	-0.385	-0.039	0.411
6	24.703	17.506	-5.478	24.840	16.742	-5.866	0.137	-0.764	-0.388	0.868
7	24.751	24.009	-6.156	NA	NA	NA	NA	NA	NA	NA
8	24.956	28.028	-6.789	21.852	25.302	-3.529	-3.104	-2.726	3.261	5.263
9	19.413	12.956	-3.531	19.498	12.365	-3.677	0.085	-0.590	-0.146	0.614
10	21.283	17.352	-7.526	21.404	16.410	-7.880	0.121	-0.942	-0.353	1.013
11	21.608	23.733	-8.131	20.976	22.045	-7.873	-0.632	-1.688	0.259	1.821
12	21.756	28.274	-8.694	20.253	24.916	-7.264	-1.503	-3.358	1.430	3.947
13	16.785	11.288	-4.492	16.821	10.526	-4.626	0.036	-0.762	-0.133	0.774
14	17.655	15.584	-8.111	17.792	14.669	-8.349	0.137	-0.915	-0.238	0.955
15	17.982	22.410	-8.961	18.324	21.360	-10.020	0.342	-1.049	-1.059	1.530
16	18.086	27.701	-9.657	17.886	25.480	-9.166	-0.200	-2.221	0.491	2.284
17	12.976	10.382	-7.410	12.904	9.648	-7.473	-0.072	-0.733	-0.063	0.740
18	13.178	14.764	-8.160	13.297	13.937	-8.431	0.119	-0.827	-0.271	0.879
19	13.726	21.936	-8.943	14.005	21.081	-9.872	0.279	-0.855	-0.928	1.293
20	13.947	27.188	-9.626	14.081	25.624	-10.885	0.134	-1.565	-1.259	2.012
21	6.659	10.750	-7.767	6.651	10.074	-7.810	-0.008	-0.676	-0.043	0.677
22	6.837	15.179	-8.303	6.974	14.501	-8.501	0.137	-0.678	-0.198	0.719
23	7.106	21.464	-8.981	7.427	20.751	-9.746	0.321	-0.713	-0.765	1.094
24	7.504	26.902	-9.625	7.881	26.070	-10.896	0.377	-0.831	-1.271	1.565
25	-0.112	11.335	-3.875	-0.013	10.992	-4.054	0.099	-0.343	-0.179	0.400
26	0.003	14.882	-4.264	0.122	14.563	-4.527	0.120	-0.320	-0.264	0.431
27	0.050	20.556	-4.900	0.328	20.126	-5.313	0.278	-0.431	-0.414	0.659
28	0.379	24.706	-5.341	0.766	24.295	-5.888	0.387	-0.410	-0.548	0.786

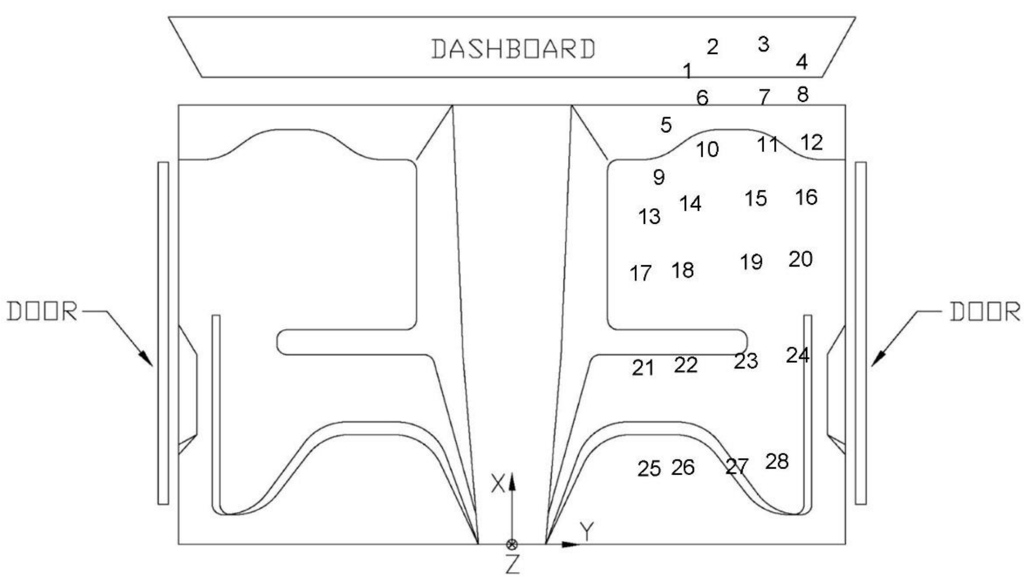


Figure D-7. Floor Pan Deformation Data – Set 1, Test No. AGTB-2

Date: 5/24/2017 Test Name: AGTB-2 VIN: 1D7RB1CT0AS246796
Year: 2010 Make: Dodge Model: Ram 1500 Hemi

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 2

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)	Total Δ (in.)
1	59.499	10.491	2.347	58.916	10.793	0.975	-0.583	0.303	-1.372	1.521
2	61.020	13.514	-0.161	60.709	13.243	-1.950	-0.311	-0.271	-1.789	1.836
3	61.025	18.811	-0.057	58.312	16.700	0.116	-2.713	-2.111	0.173	3.442
4	59.782	22.681	0.778	55.697	19.025	2.683	-4.085	-3.656	1.904	5.803
5	55.877	8.222	1.898	55.572	8.199	0.456	-0.305	-0.023	-1.442	1.474
6	57.533	12.533	-1.876	57.236	12.085	-3.678	-0.297	-0.448	-1.803	1.881
7	57.523	19.116	-1.758	NA	NA	NA	NA	NA	NA	NA
8	57.553	23.056	-2.005	54.161	20.249	-0.212	-3.392	-2.808	1.793	4.754
9	52.376	7.686	-0.431	52.168	7.332	-1.793	-0.208	-0.354	-1.362	1.423
10	54.121	12.511	-3.904	53.849	11.965	-5.543	-0.273	-0.545	-1.640	1.749
11	54.376	18.844	-3.751	53.153	17.533	-4.860	-1.223	-1.311	-1.109	2.108
12	54.450	23.375	-3.802	52.456	20.227	-3.866	-1.993	-3.149	-0.064	3.727
13	49.716	5.980	-1.529	49.545	5.521	-2.776	-0.171	-0.459	-1.247	1.339
14	50.592	10.696	-4.631	50.255	10.206	-6.064	-0.337	-0.490	-1.433	1.551
15	50.730	17.531	-4.738	50.469	16.978	-6.943	-0.261	-0.553	-2.204	2.288
16	50.762	22.933	-4.841	49.984	20.957	-5.577	-0.778	-1.977	-0.736	2.248
17	45.988	5.347	-4.485	45.545	4.873	-5.573	-0.443	-0.474	-1.088	1.266
18	46.085	9.828	-4.770	45.761	9.269	-6.036	-0.324	-0.559	-1.266	1.421
19	46.478	17.064	-4.761	46.197	16.551	-6.645	-0.281	-0.513	-1.884	1.972
20	46.533	22.358	-4.858	46.108	21.168	-7.115	-0.425	-1.191	-2.257	2.587
21	39.575	5.624	-4.802	39.237	5.218	-5.613	-0.338	-0.405	-0.811	0.967
22	39.745	10.071	-4.854	39.378	9.585	-5.760	-0.367	-0.486	-0.906	1.092
23	39.853	16.478	-4.836	39.635	15.958	-6.269	-0.217	-0.520	-1.433	1.540
24	40.122	22.037	-4.873	39.875	21.423	-6.795	-0.247	-0.614	-1.923	2.033
25	32.837	5.664	-0.866	32.716	5.341	-1.468	-0.120	-0.323	-0.602	0.693
26	32.950	9.313	-0.856	32.765	8.983	-1.513	-0.185	-0.330	-0.658	0.759
27	32.868	14.917	-0.862	32.828	14.607	-1.637	-0.039	-0.310	-0.775	0.836
28	33.043	19.136	-0.848	33.102	18.820	-1.726	0.059	-0.316	-0.878	0.935

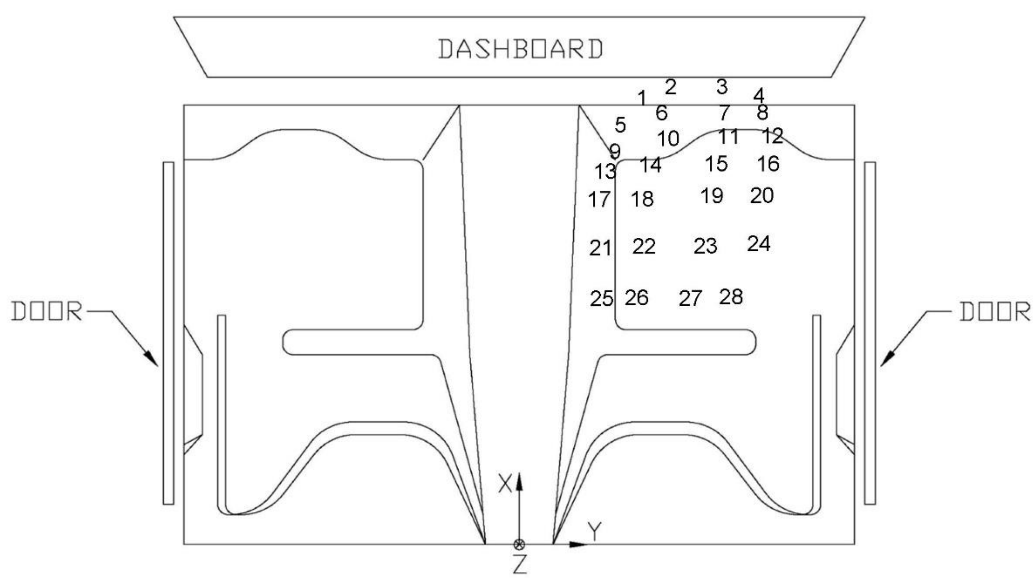


Figure D-8. Floor Pan Deformation Data – Set 2, Test No. AGTB-2

Date: 5/24/2017 Test Name: AGTB-2 VIN: 1D7RB1CT0AS246796
Year: 2010 Make: Dodge Model: Ram 1500 Hemi

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 1

	POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)	Total Δ (in.)
DASH	1	10.870	2.368	25.096	10.205	2.431	25.487	-0.665	0.063	0.391	0.774
	2	14.220	19.661	22.543	13.442	19.772	23.107	-0.778	0.111	0.564	0.967
	3	15.036	29.061	21.172	14.135	29.147	21.670	-0.901	0.085	0.498	1.033
	4	8.606	1.175	12.971	7.731	1.321	13.411	-0.875	0.146	0.441	0.991
	5	10.602	19.246	12.307	9.952	19.124	12.833	-0.650	-0.122	0.526	0.845
	6	11.591	31.441	10.958	10.619	31.345	11.592	-0.971	-0.096	0.634	1.164
SIDE PANEL	7	25.361	31.948	-0.554	23.844	25.726	1.563	-1.517	-6.222	2.117	6.745
	8	20.958	31.171	-6.799	20.285	26.597	-5.073	-0.673	-4.574	1.726	4.935
	9	20.450	31.994	-0.410	19.176	26.738	1.308	-1.273	-5.257	1.718	5.675
IMPACT SIDE DOOR	10	11.774	35.407	17.391	9.847	37.152	17.639	-1.928	1.746	0.248	2.612
	11	-1.170	35.603	17.643	-2.803	39.420	17.017	-1.633	3.817	-0.626	4.198
	12	-13.587	35.881	17.703	-15.049	38.403	16.823	-1.462	2.522	-0.880	3.045
	13	6.645	35.458	0.583	5.703	33.902	1.502	-0.942	-1.556	0.919	2.038
	14	0.127	35.224	-1.347	-0.724	33.460	-0.878	-0.851	-1.763	0.469	2.013
	15	-10.395	35.216	-1.063	-11.135	34.956	-1.481	-0.740	-0.260	-0.418	0.889
ROOF	16	3.727	26.712	38.162	2.613	27.993	38.450	-1.113	1.282	0.288	1.722
	17	5.298	21.209	39.023	4.213	22.598	39.218	-1.084	1.389	0.195	1.773
	18	6.113	16.883	39.634	5.049	18.222	39.771	-1.065	1.339	0.136	1.716
	19	6.766	11.590	40.307	5.709	12.964	40.358	-1.057	1.374	0.051	1.734
	20	6.948	4.240	41.176	5.936	5.477	41.091	-1.012	1.238	-0.085	1.601
	21	-4.095	26.254	41.249	-5.235	27.443	41.205	-1.140	1.190	-0.044	1.648
	22	-3.244	21.029	42.178	-4.486	22.349	42.111	-1.242	1.320	-0.068	1.814
	23	-2.674	16.180	42.936	-3.884	17.455	42.836	-1.210	1.275	-0.100	1.761
	24	-2.460	9.947	43.820	-3.551	11.238	43.651	-1.091	1.291	-0.170	1.699
	25	-2.558	2.011	44.759	-3.656	3.213	44.584	-1.099	1.202	-0.175	1.638
	26	-8.771	25.891	41.885	-9.990	26.955	41.763	-1.219	1.064	-0.123	1.623
	27	-8.628	21.051	42.706	-9.772	22.156	42.543	-1.144	1.105	-0.163	1.599
	28	-8.448	15.704	43.557	-9.571	16.747	43.367	-1.122	1.043	-0.190	1.544
	29	-7.742	9.401	44.470	-8.850	10.377	44.285	-1.108	0.976	-0.184	1.488
	30	-7.318	2.305	45.259	-8.311	3.437	45.055	-0.993	1.132	-0.203	1.519
A PILLAR	31	21.227	33.521	23.138	20.205	34.472	23.596	-1.022	0.950	0.458	1.469
	32	17.290	33.047	26.311	16.261	33.974	26.649	-1.029	0.926	0.338	1.425
	33	11.831	32.360	30.493	10.764	33.450	30.846	-1.067	1.090	0.353	1.566
	34	4.804	31.329	34.840	3.695	32.538	35.135	-1.109	1.209	0.295	1.666
B PILLAR	35	-19.574	33.966	18.642	-20.064	33.479	17.953	-0.489	-0.487	-0.688	0.975
	36	-22.899	33.987	18.211	-23.397	33.415	17.539	-0.498	-0.573	-0.673	1.014
	37	-20.414	33.505	27.171	-21.209	33.647	26.603	-0.796	0.142	-0.567	0.988
	38	-23.435	33.628	26.774	-24.115	33.673	26.059	-0.680	0.045	-0.716	0.989
	39	-21.095	31.196	36.617	-22.138	32.074	36.123	-1.043	0.878	-0.494	1.450
	40	-24.286	31.237	36.680	-25.354	32.019	36.074	-1.069	0.782	-0.606	1.456

Figure D-9. Occupant Compartment Deformation Data – Set 1, Test No. AGTB-2

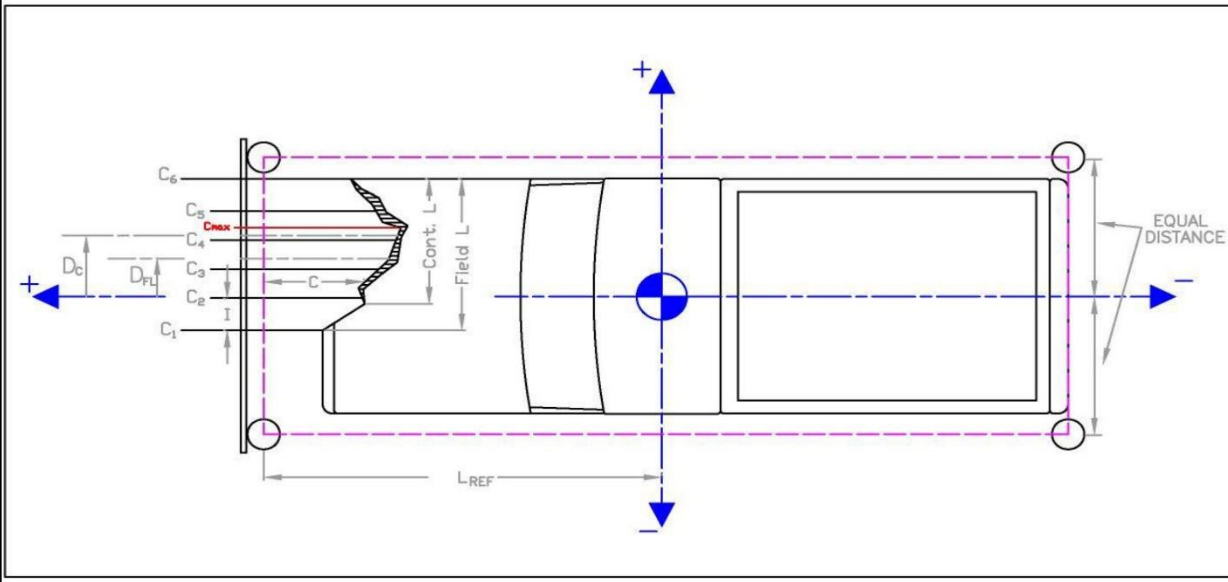
Date: 5/24/2017 Test Name: AGTB-2 VIN: 1D7RB1CT0AS246796
Year: 2010 Make: Dodge Model: Ram 1500 Hemi

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 2

	POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)	Total Δ (in.)
DASH	1	44.214	-6.255	26.975	44.581	-6.243	26.348	0.367	0.012	-0.627	0.726
	2	47.191	11.410	26.344	47.211	11.394	25.900	0.020	-0.016	-0.444	0.445
	3	47.767	20.799	25.942	47.588	20.855	25.568	-0.178	0.057	-0.374	0.418
	4	41.861	-6.162	14.842	41.548	-5.957	14.336	-0.313	0.205	-0.507	0.630
	5	43.513	11.927	16.098	43.251	11.815	15.770	-0.262	-0.112	-0.328	0.434
	6	44.256	24.315	16.090	43.540	24.124	15.974	-0.716	-0.191	-0.116	0.750
SIDE PANEL	7	57.875	26.297	4.707	56.400	20.127	4.769	-1.475	-6.170	0.061	6.344
	8	53.615	26.134	-1.523	52.550	21.668	-1.600	-1.066	-4.466	-0.077	4.592
	9	53.125	26.230	4.793	51.721	21.010	4.853	-1.403	-5.220	0.061	5.405
IMPACT SIDE DOOR	10	44.304	27.487	22.891	42.900	29.140	22.732	-1.404	1.652	-0.159	2.174
	11	31.447	27.418	23.139	30.165	31.063	22.865	-1.282	3.644	-0.274	3.873
	12	19.048	27.420	23.329	18.018	29.689	23.125	-1.030	2.269	-0.204	2.500
	13	39.215	29.293	6.147	38.085	27.675	6.489	-1.130	-1.618	0.341	2.003
	14	32.681	29.138	4.226	31.547	27.310	4.396	-1.134	-1.828	0.170	2.157
	15	22.103	28.893	4.542	21.149	28.494	4.402	-0.954	-0.399	-0.140	1.044
ROOF	16	36.583	16.425	42.635	36.925	17.407	42.541	0.343	0.982	-0.094	1.044
	17	38.248	10.992	42.873	38.675	11.914	42.623	0.427	0.922	-0.250	1.046
	18	39.266	6.669	42.951	39.668	7.584	42.601	0.402	0.915	-0.350	1.059
	19	40.021	1.341	43.048	40.409	2.278	42.577	0.388	0.937	-0.471	1.118
	20	40.385	-6.298	43.089	40.915	-5.167	42.384	0.530	1.131	-0.706	1.434
	21	28.867	15.284	45.662	29.174	16.248	45.583	0.307	0.965	-0.079	1.016
	22	29.702	10.186	46.008	30.118	11.083	45.842	0.416	0.897	-0.166	1.002
	23	30.439	5.275	46.213	30.969	6.154	45.943	0.530	0.879	-0.269	1.060
	24	30.844	-0.956	46.392	31.356	-0.116	46.044	0.511	0.840	-0.347	1.043
	25	30.917	-8.945	46.449	31.590	-8.144	45.984	0.673	0.801	-0.465	1.145
	26	24.169	14.890	46.257	24.498	15.650	46.233	0.329	0.759	-0.023	0.828
	27	24.482	9.997	46.531	24.925	10.789	46.430	0.443	0.792	-0.102	0.913
	28	24.774	4.535	46.786	25.246	5.311	46.615	0.472	0.776	-0.171	0.924
	29	25.598	-1.891	46.997	26.193	-1.013	46.745	0.595	0.878	-0.252	1.090
	30	26.167	-8.856	46.991	26.905	-8.081	46.676	0.739	0.775	-0.315	1.116
A PILLAR	31	53.888	25.175	28.451	53.610	26.148	27.704	-0.277	0.973	-0.747	1.257
	32	50.019	24.276	31.501	49.789	25.162	30.976	-0.230	0.886	-0.526	1.055
	33	44.535	22.992	35.546	44.592	23.992	35.261	0.057	1.000	-0.284	1.041
	34	37.569	21.368	39.833	37.740	22.354	39.778	0.170	0.986	-0.056	1.002
B PILLAR	35	13.132	25.287	24.061	13.121	24.488	23.862	-0.011	-0.799	-0.199	0.824
	36	9.718	25.282	23.747	9.704	24.360	23.588	-0.015	-0.922	-0.158	0.936
	37	12.315	23.844	32.577	12.432	23.605	32.510	0.118	-0.239	-0.066	0.274
	38	9.239	23.967	32.141	9.444	23.596	32.107	0.206	-0.371	-0.034	0.425
	39	11.681	20.506	41.663	11.976	20.892	41.852	0.294	0.386	0.189	0.521
	40	8.537	20.458	41.794	8.760	20.752	41.889	0.222	0.294	0.095	0.381

Figure D-10. Occupant Compartment Deformation Data – Set 2, Test No. AGTB-2

Date:	7/21/2017	Test Name:	AGTB-2	VIN:	1D7RB1CT0AS246796
Year:	2010	Make:	Dodge	Model:	Ram 1500 Hemi



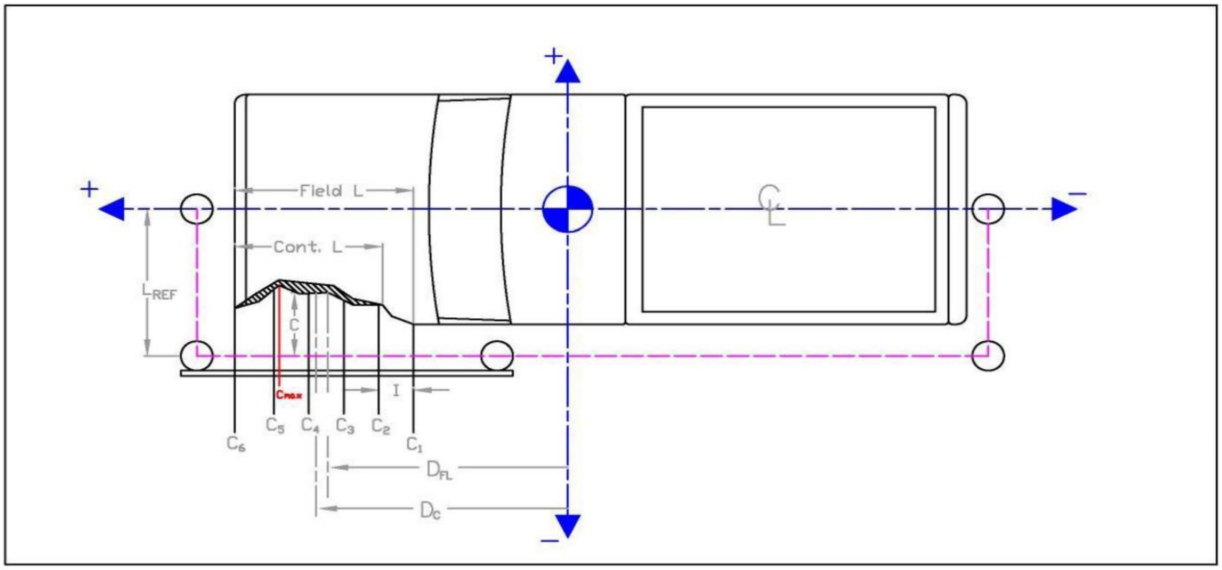
	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	111	(2819)
Total Vehicle Width:	77 3/8	(1965)
Width of contact and induced crush - Field L:	77 3/8	(1965)
Crush measurement spacing interval (L/5) - I:	15 1/2	(394)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	58	(1474)
Distance from center of vehicle to center of contact damage - D_C:	9 2/3	(246)

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

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	NA	NA	-38 3/4	-(984)	22 1/2	(572)	5 4/7	(141)	NA	NA
C_2	12	(305)	-23 1/4	-(591)	6 1/2	(165)			-0	-(2)
C_3	18 1/8	(460)	-7 3/4	-(197)	4 1/4	(108)			8 1/3	(211)
C_4	25 1/4	(641)	7 3/4	(197)	4 1/4	(108)			15 4/9	(392)
C_5	39 3/8	(1000)	23 1/4	(591)	6 1/4	(159)			27 4/7	(700)
C_6	NA	NA	38 3/4	(984)	20 1/2	(521)			NA	NA
C_{MAX}	43 1/2	(1105)	26 1/2	(673)	7 1/4	(184)			30 2/3	(779)

Figure D-11. Exterior Vehicle Crush (NASS) - Front, Test No. AGTB-2

Date:	7/21/2017	**Test Name:**	AGTB-2	**VIN:**	1D7RB1CT0AS246796
Year:	2010	**Make:**	Dodge	**Model:**	Ram 1500 Hemi



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	44 1/4	(1124)
Total Vehicle Length:	229 3/8	(5826)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-13	-(330)
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	-(330)
Width of Contact Damage:	229 3/8	(5826)
Distance from vehicle c.g. to center of contact damage - D_C:	-13	-(330)

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., front of vehicle has been pushed inward or tire has been removed)

NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual	Crush
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	NA	NA	-127 3/4	-(3245)	33 1/2	(851)	1/4	(6)	NA	NA
C_2	NA	NA	-81 7/8	-(2080)	5 1/4	(133)			NA	NA
C_3	5 1/2	(140)	-36	-(914)	5 5/8	(143)			- 3/8	-(10)
C_4	5	(127)	9 7/8	(251)	5 1/8	(130)			- 3/8	-(10)
C_5	NA	NA	55 3/4	(1416)	5	(127)			NA	NA
C_6	NA	NA	101 5/8	(2581)	30	(762)			NA	NA
C_{MAX}	17 3/4	(451)	-99 3/8	-(2524)	5 5/8	(143)			11 7/8	(302)

Figure D-12. Exterior Vehicle Crush (NASS) - Side, Test No. AGTB-2

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

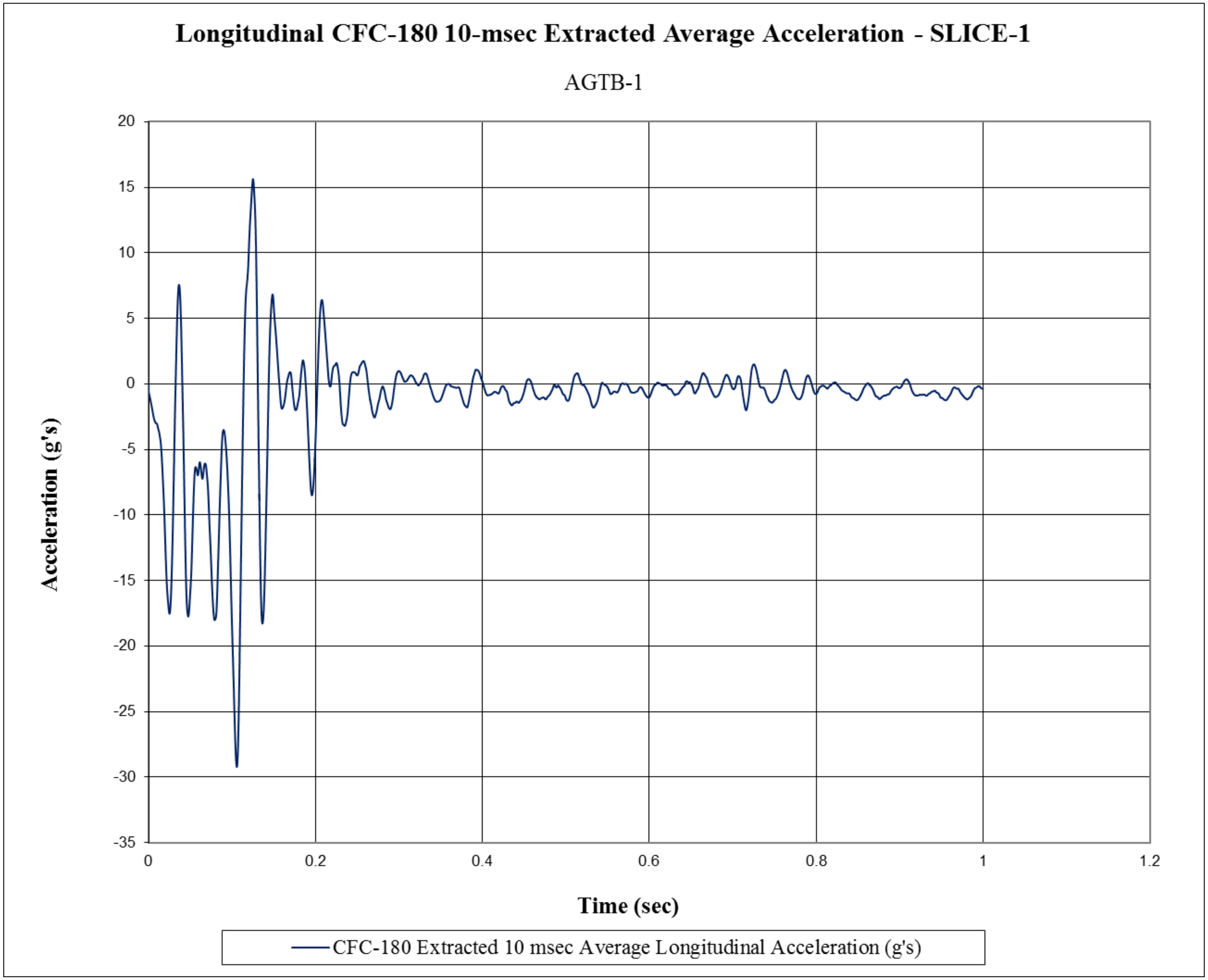


Figure E-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. AGTB-1

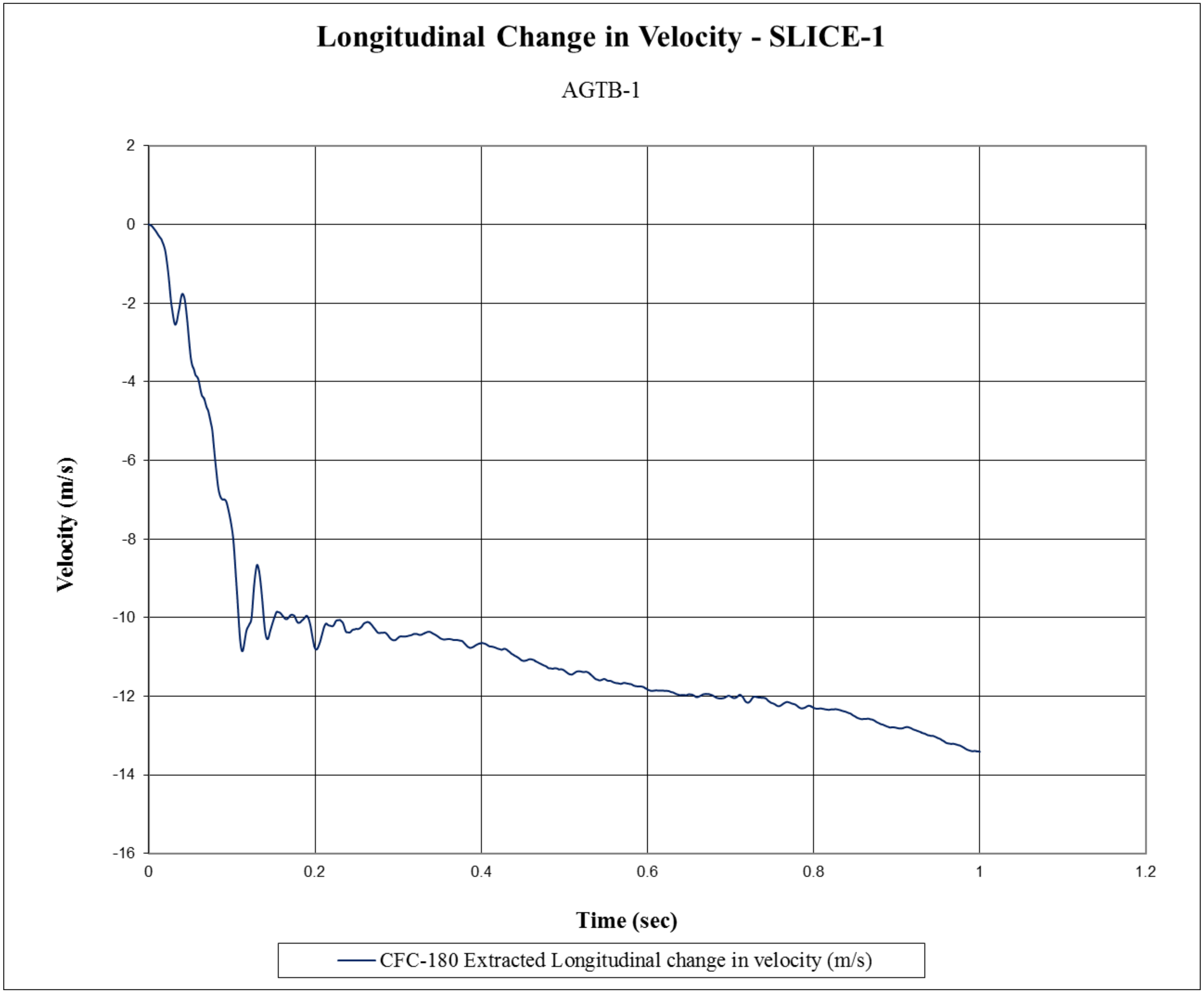


Figure E-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. AGTB-1

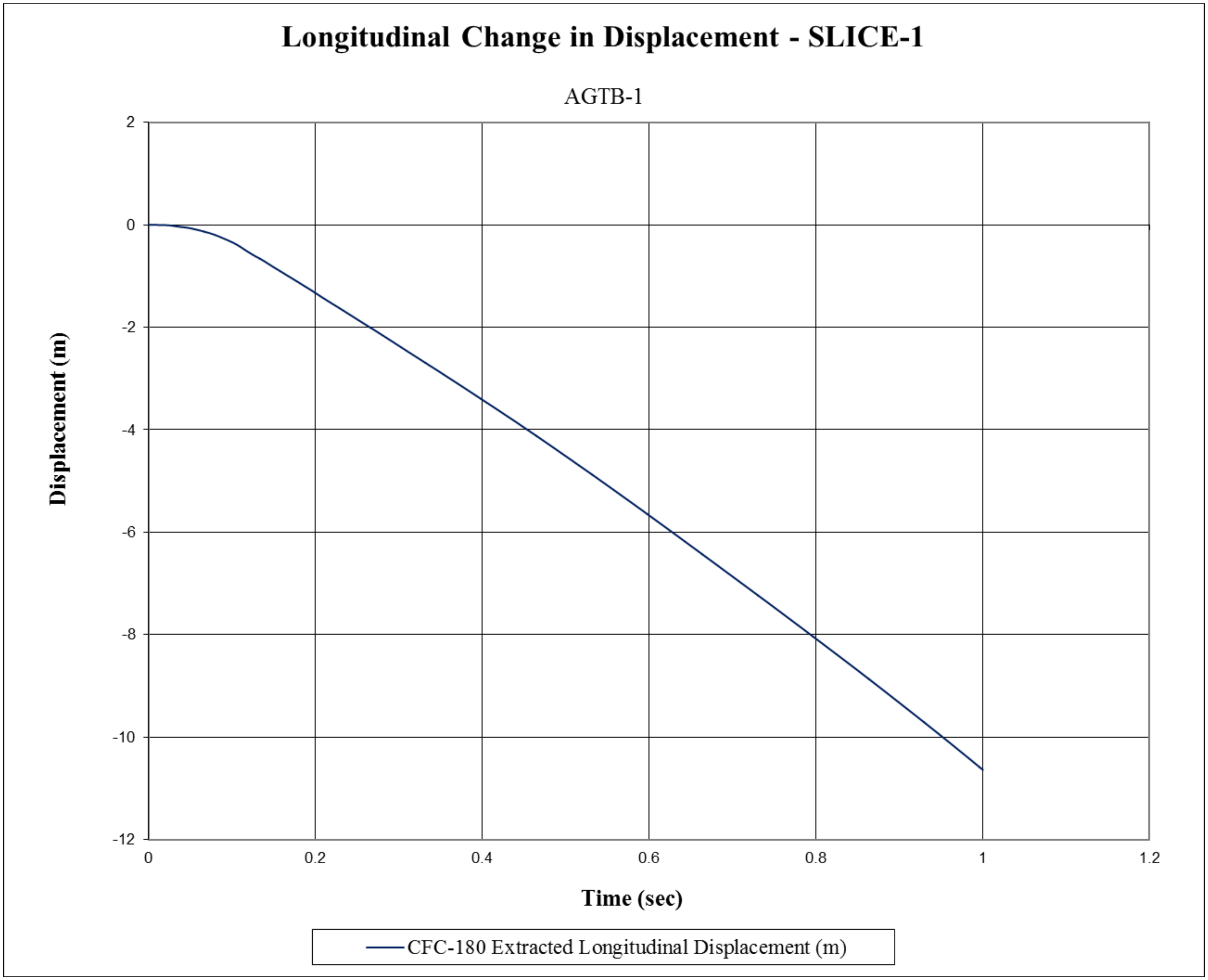


Figure E-3. Longitudinal Occupant Displacement (SLICE-1), Test No. AGTB-1

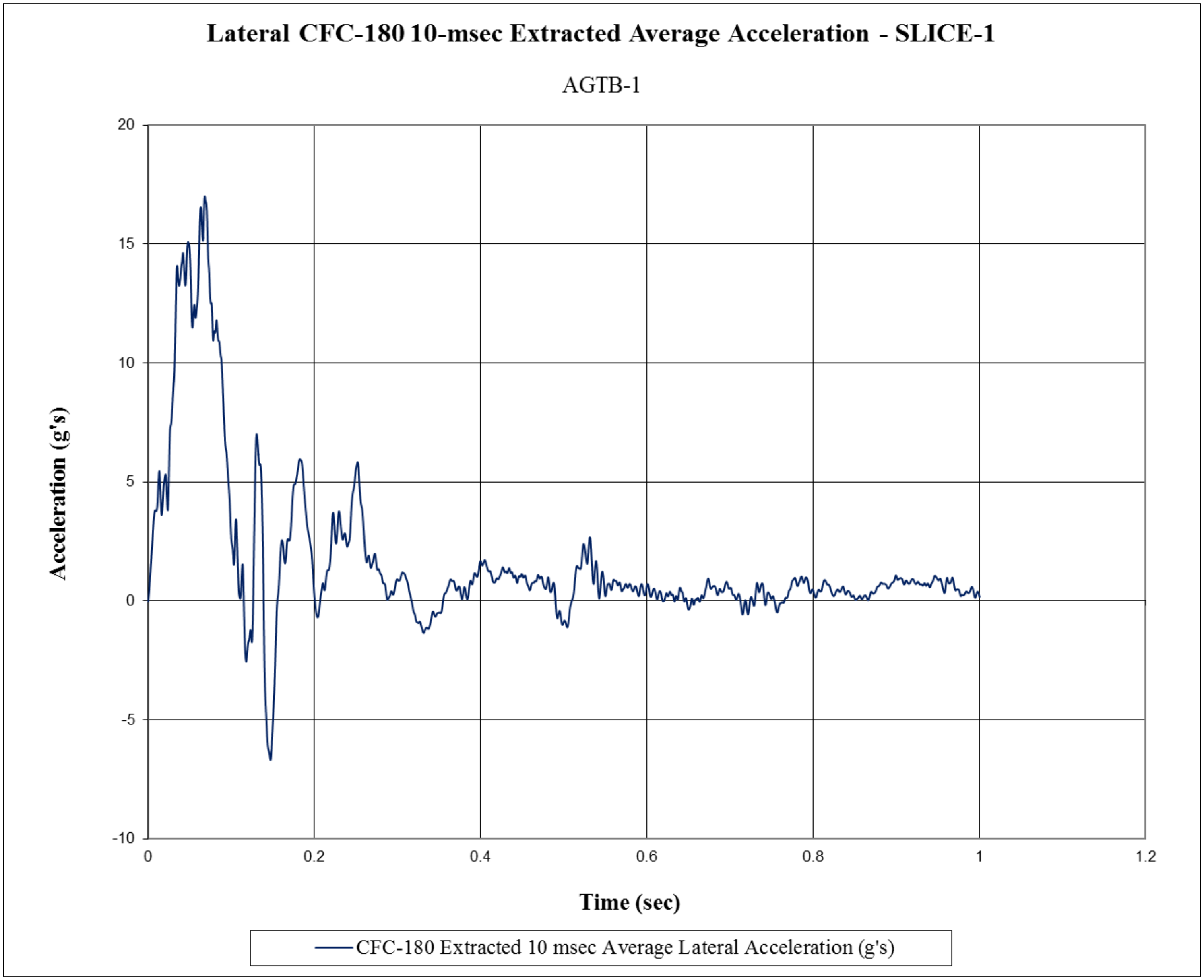


Figure E-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. AGTB-1

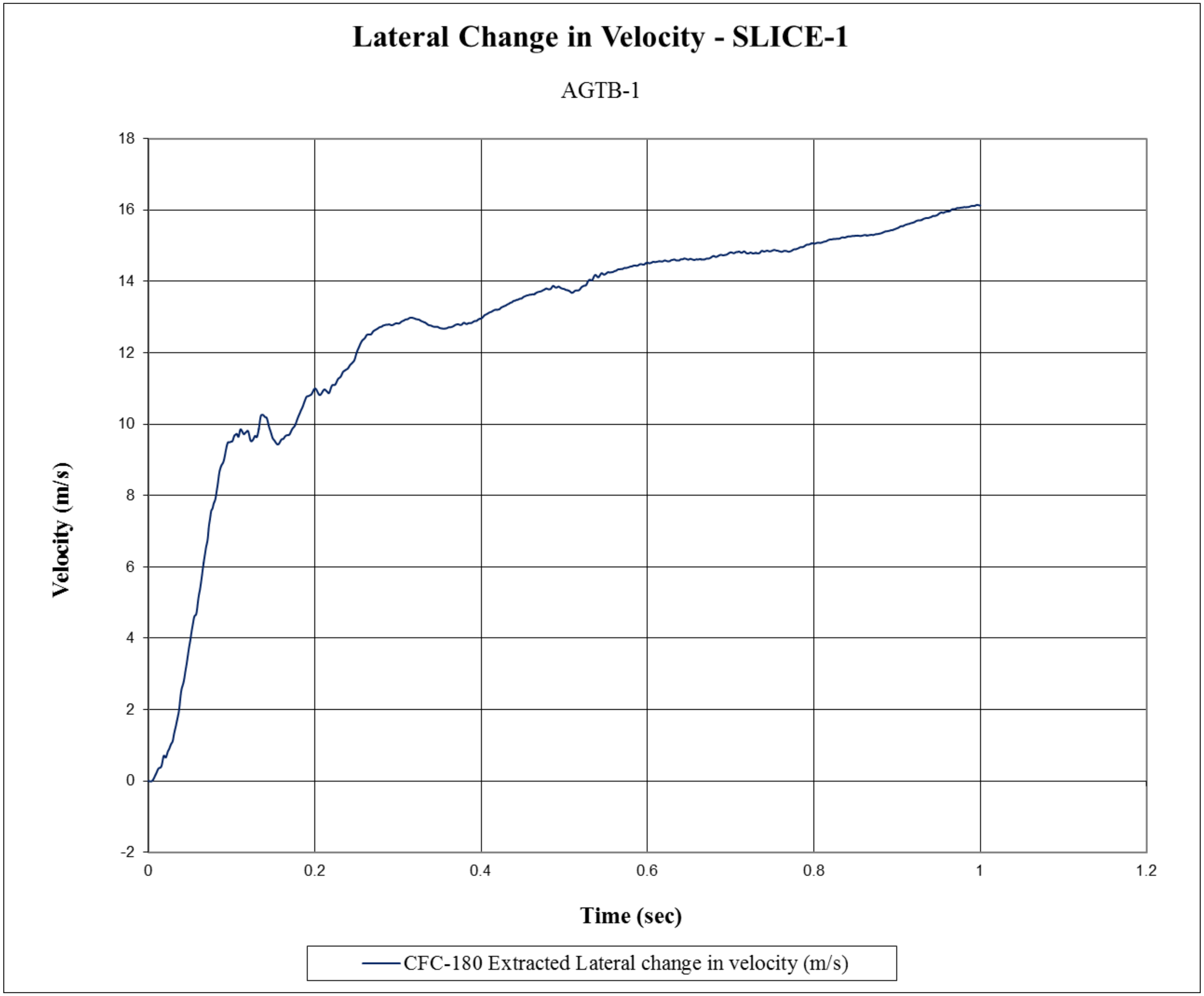


Figure E-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. AGTB-1

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

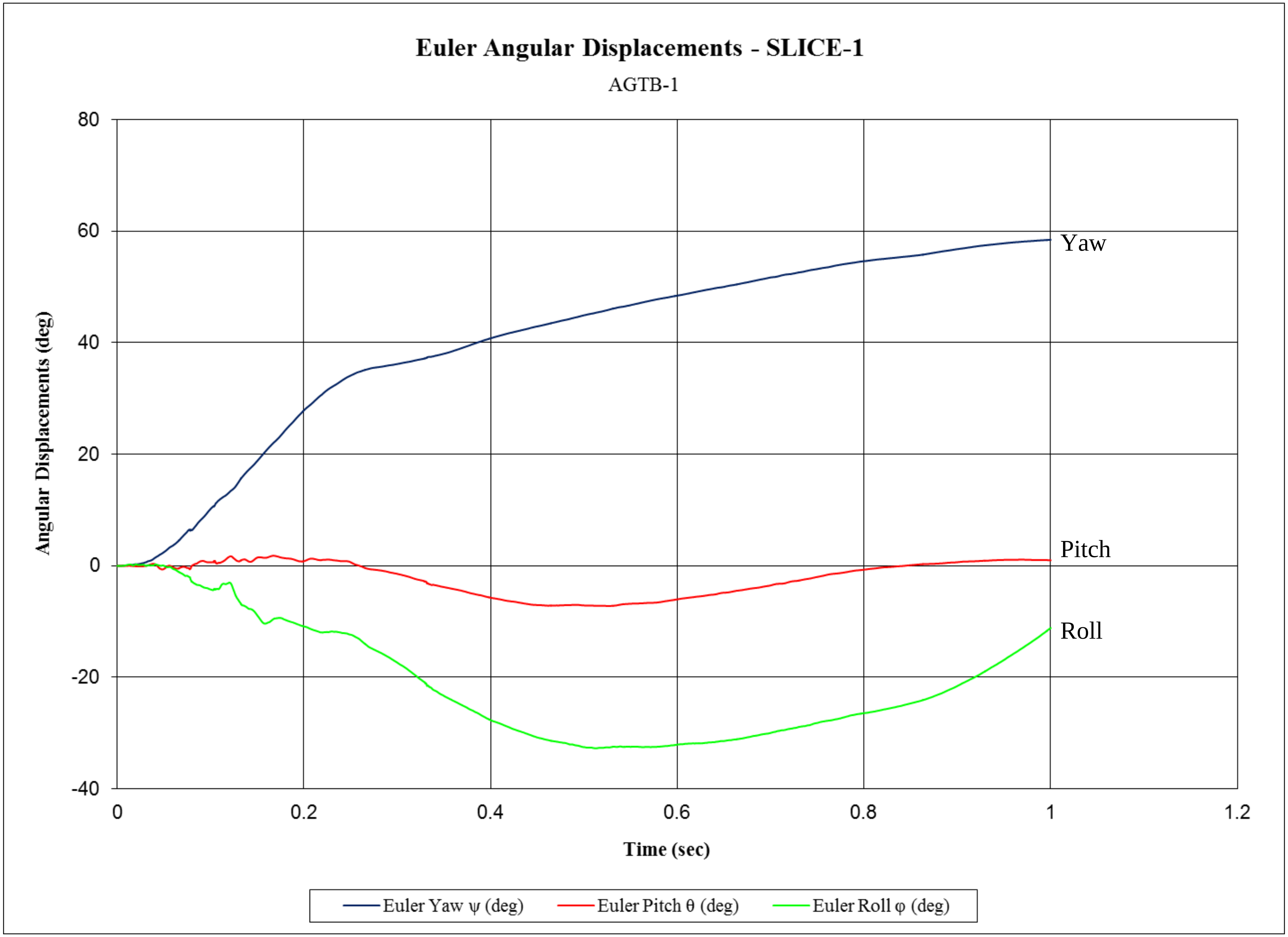


Figure E-7. Vehicle Angular Displacements (SLICE-1), Test No. AGTB-1

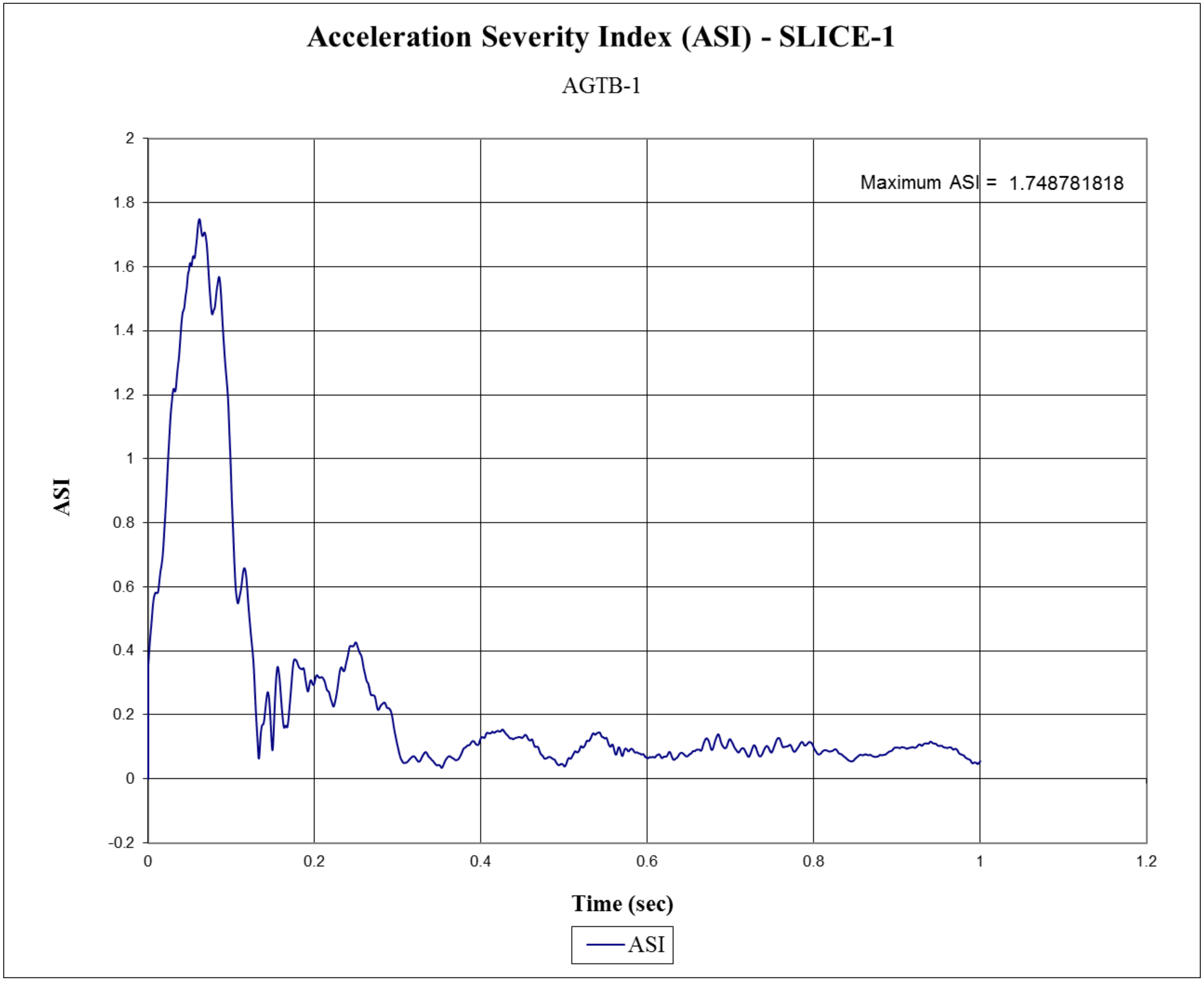


Figure E-8. Acceleration Severity Index (SLICE-1), Test No. AGTB-1

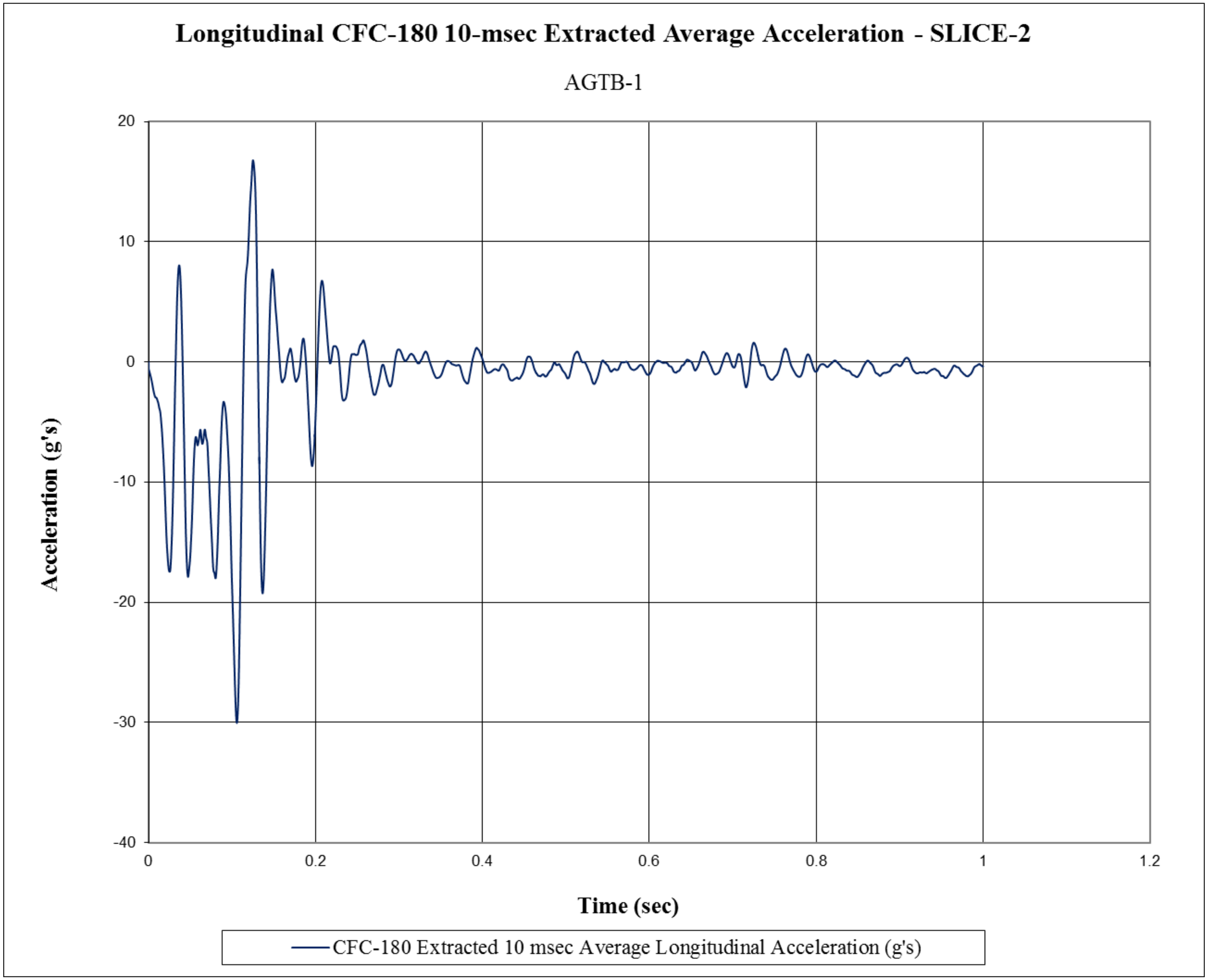


Figure E-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. AGTB-1

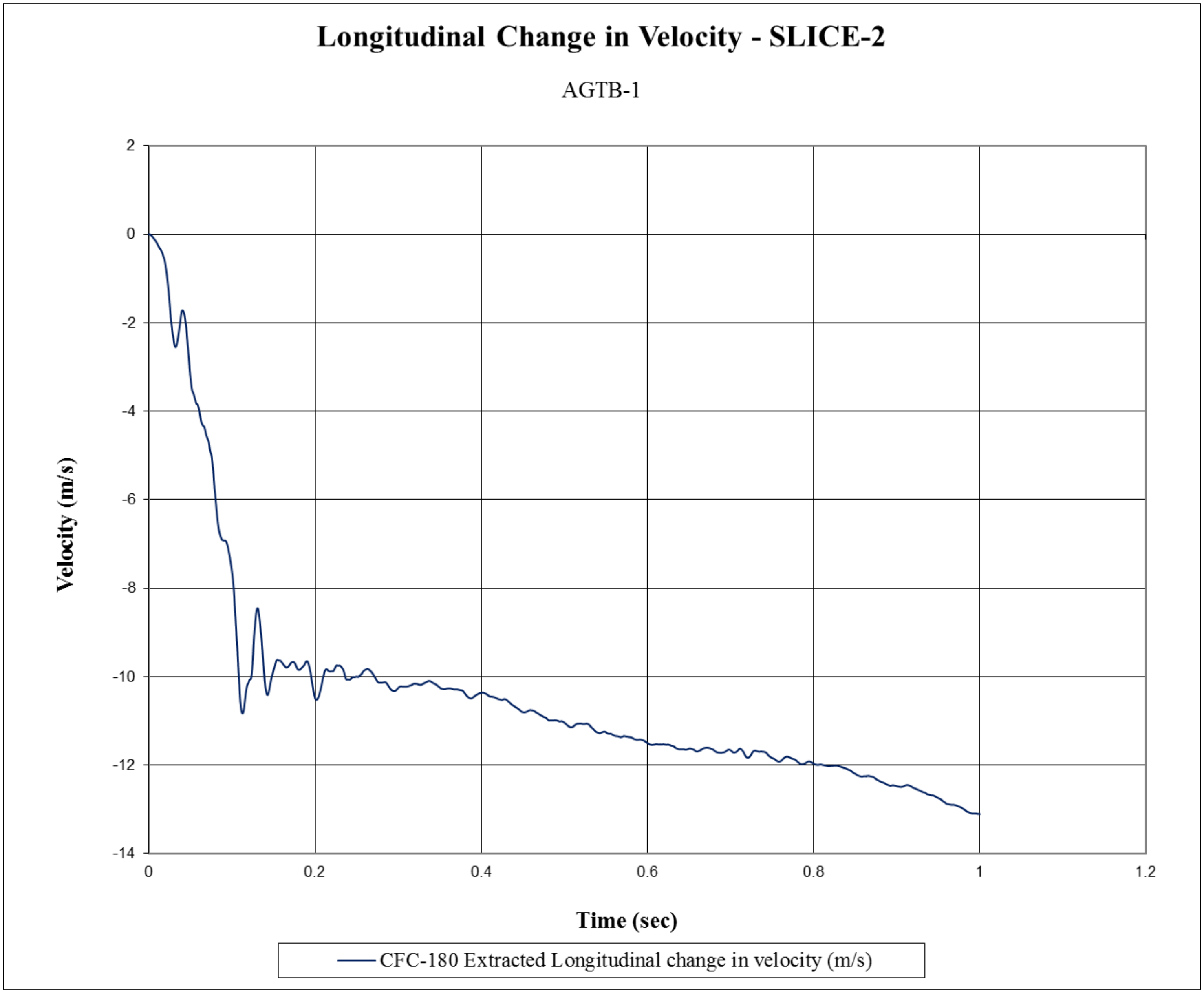


Figure E-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. AGTB-1

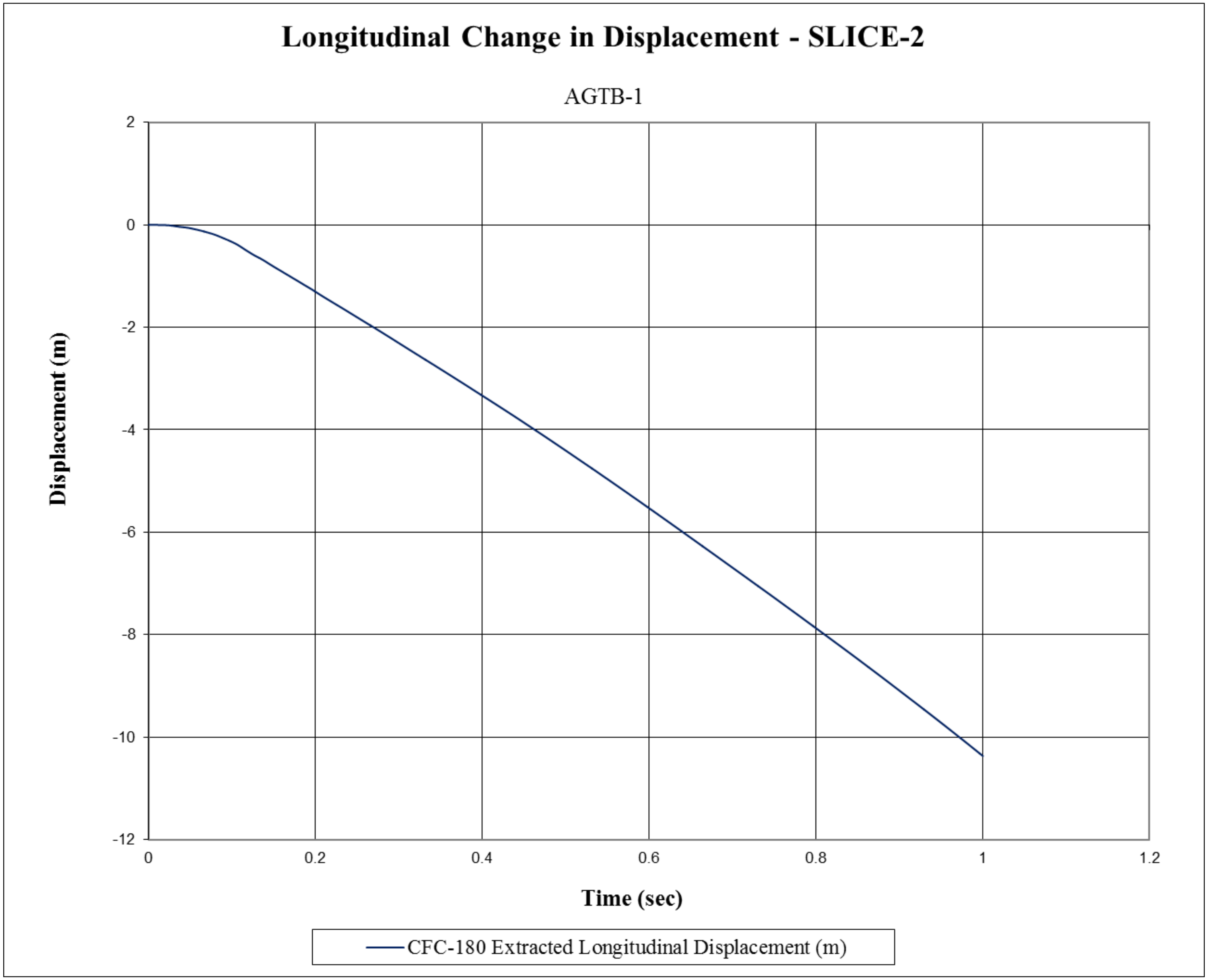


Figure E-11. Longitudinal Occupant Displacement (SLICE-2), Test No. AGTB-1

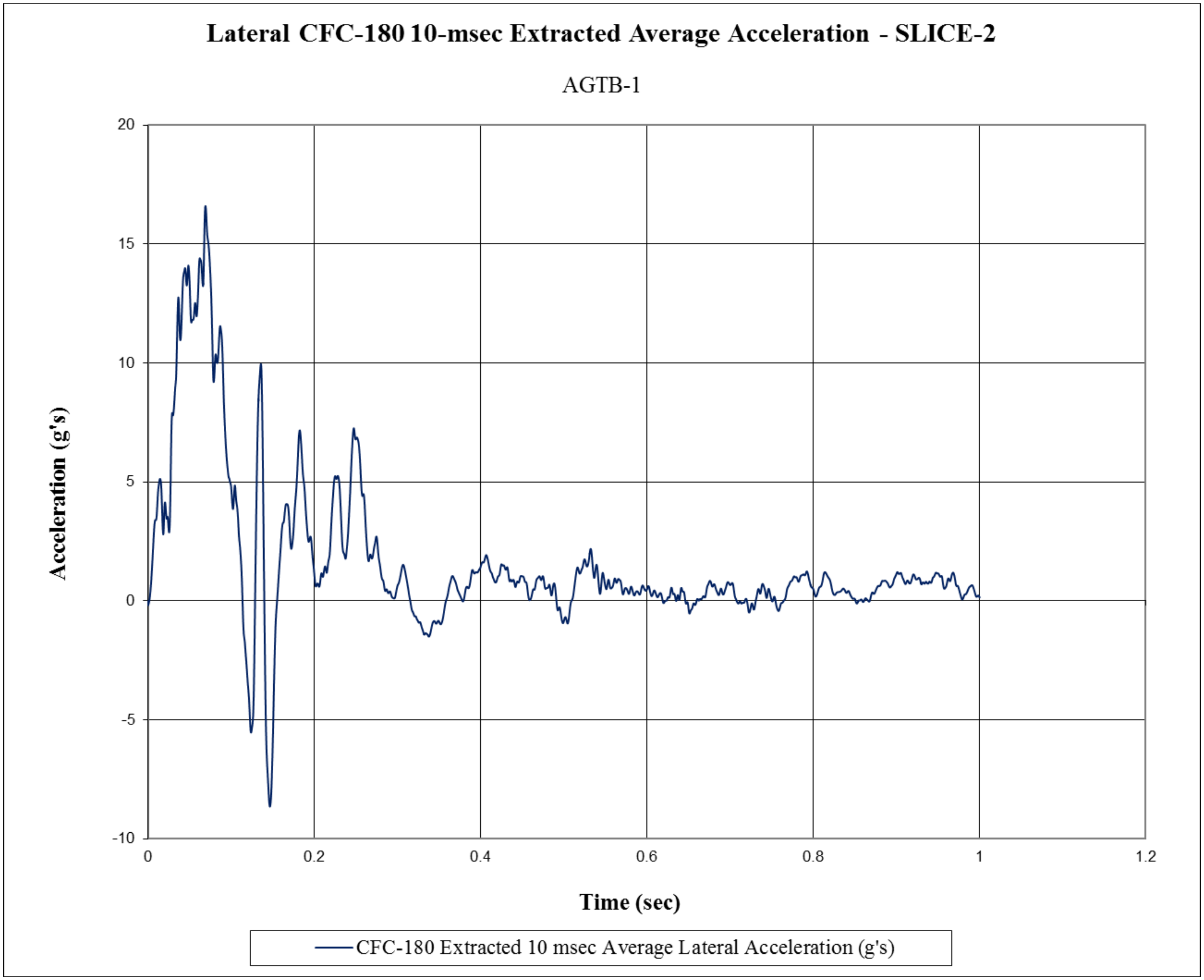


Figure E-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. AGTB-1

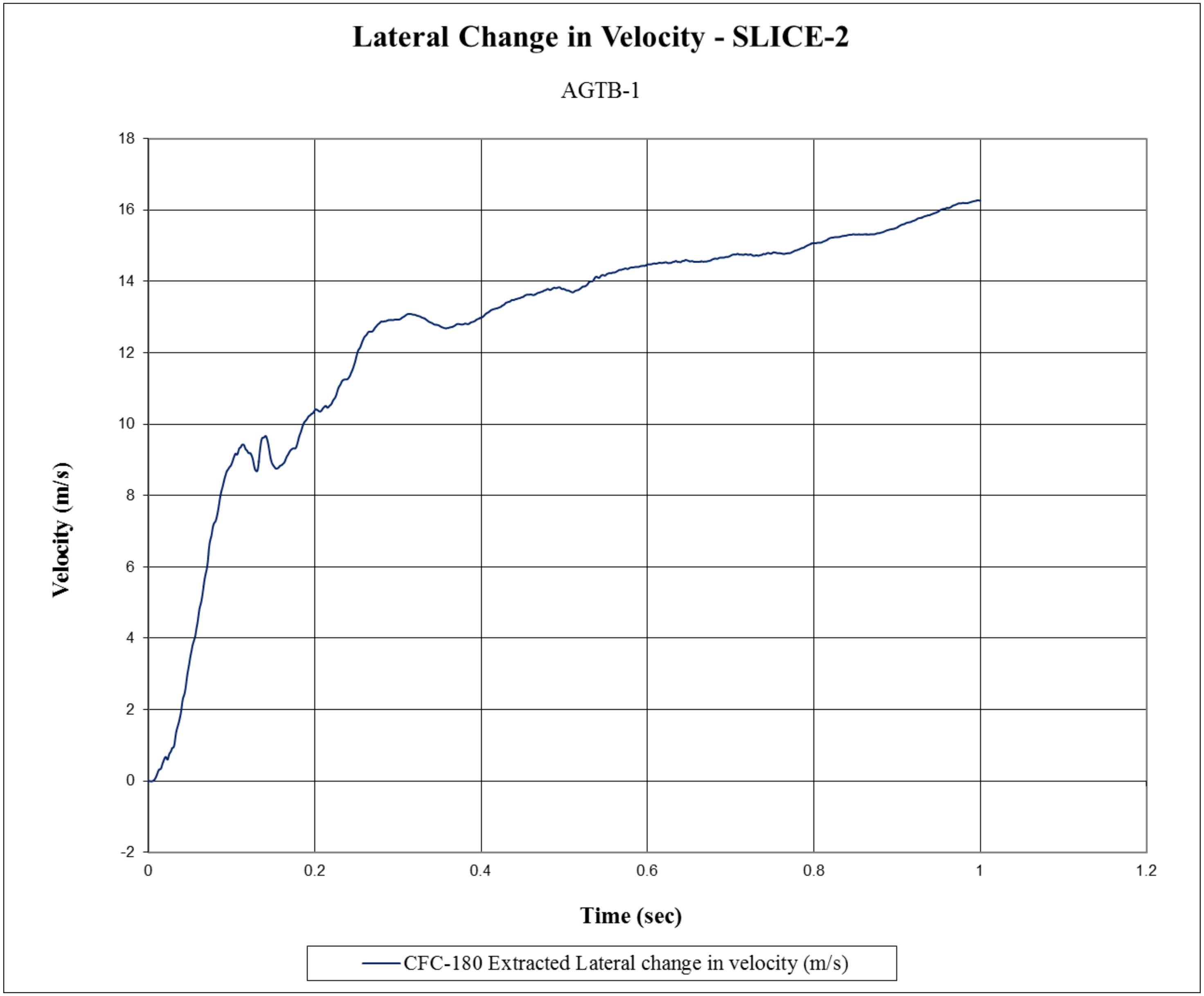


Figure E-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. AGTB-1

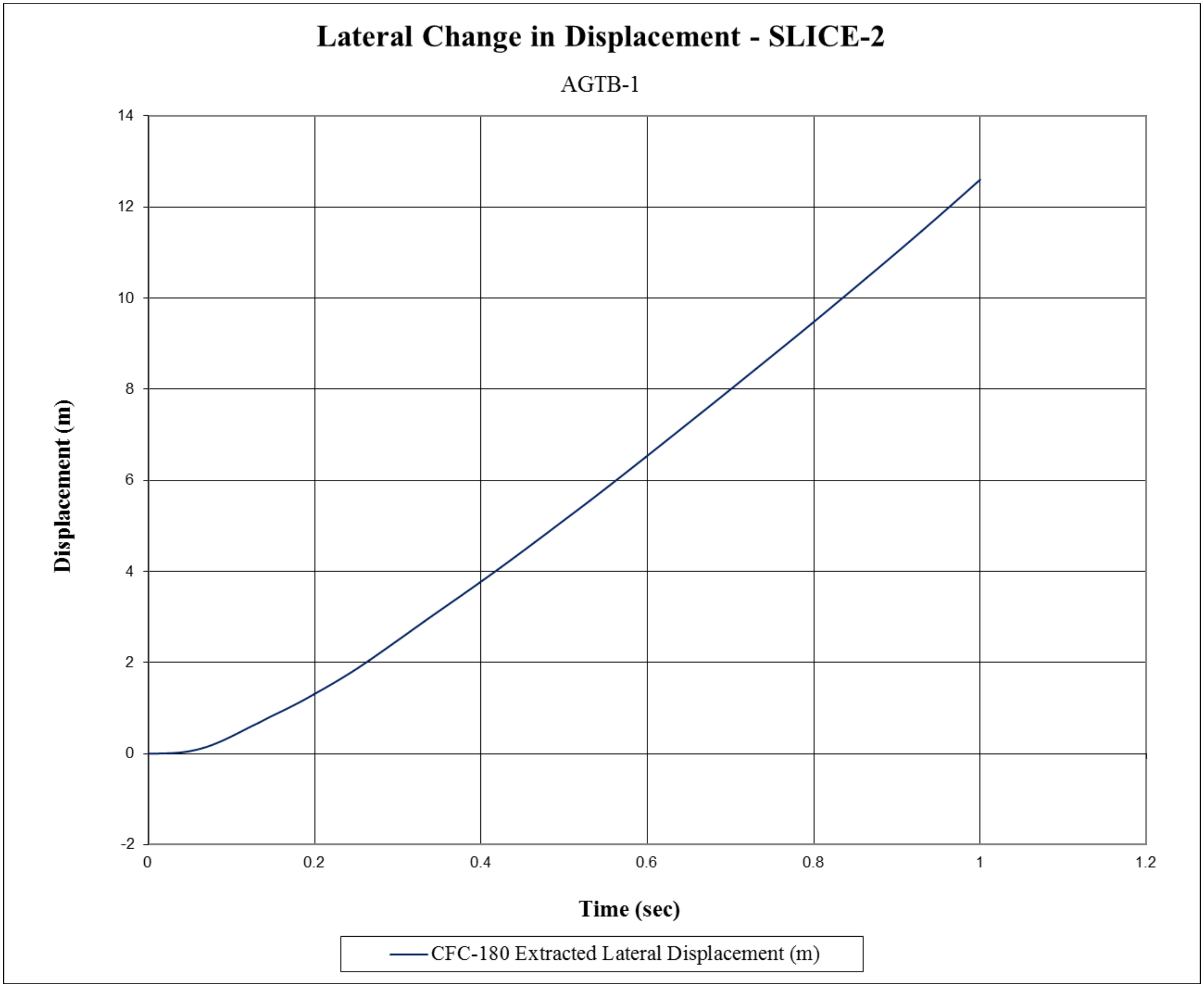


Figure E-14. Lateral Occupant Displacement (SLICE-2), Test No. AGTB-1

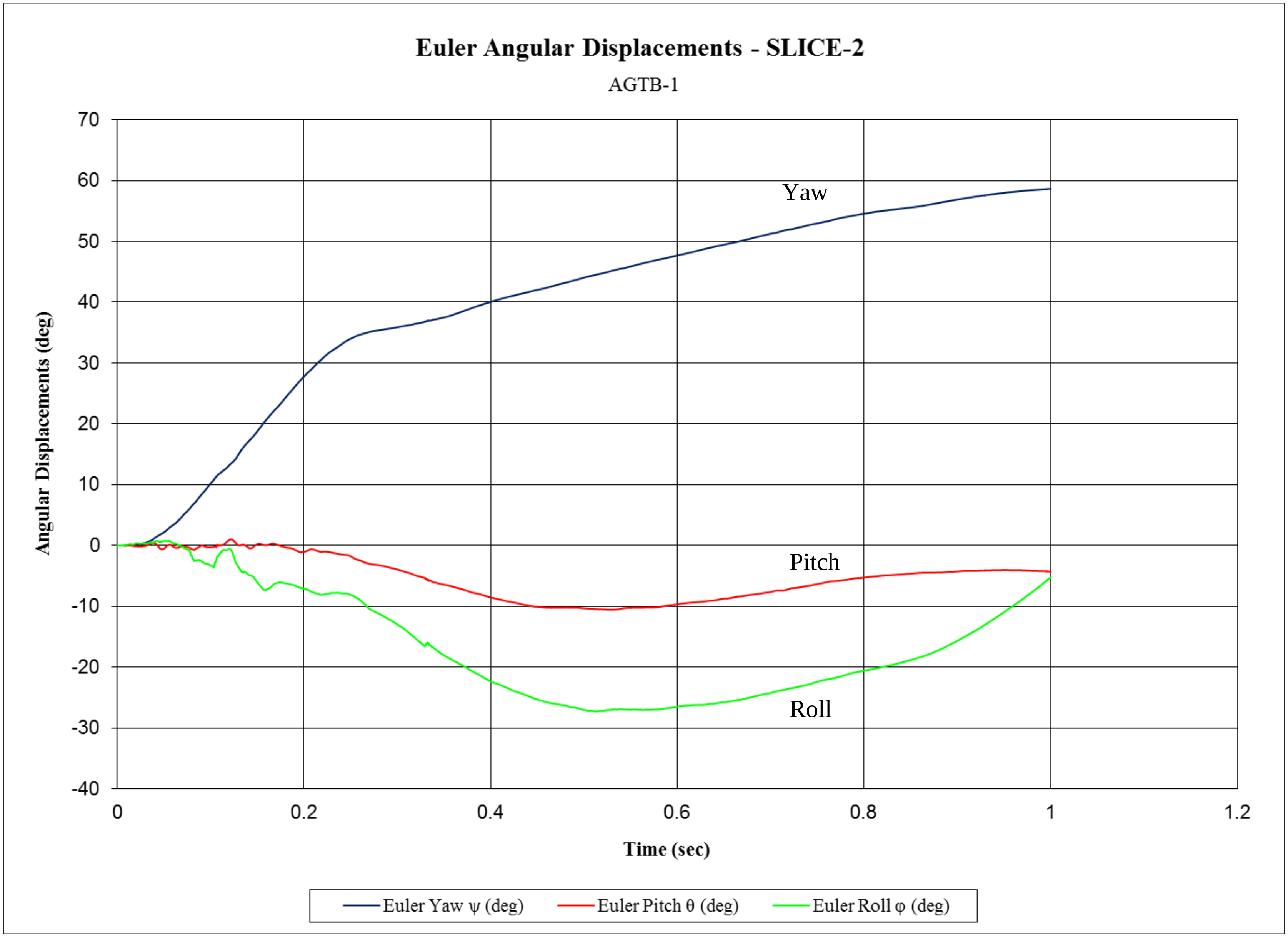


Figure E-15. Vehicle Angular Displacements (SLICE-2), Test No. AGTB-1

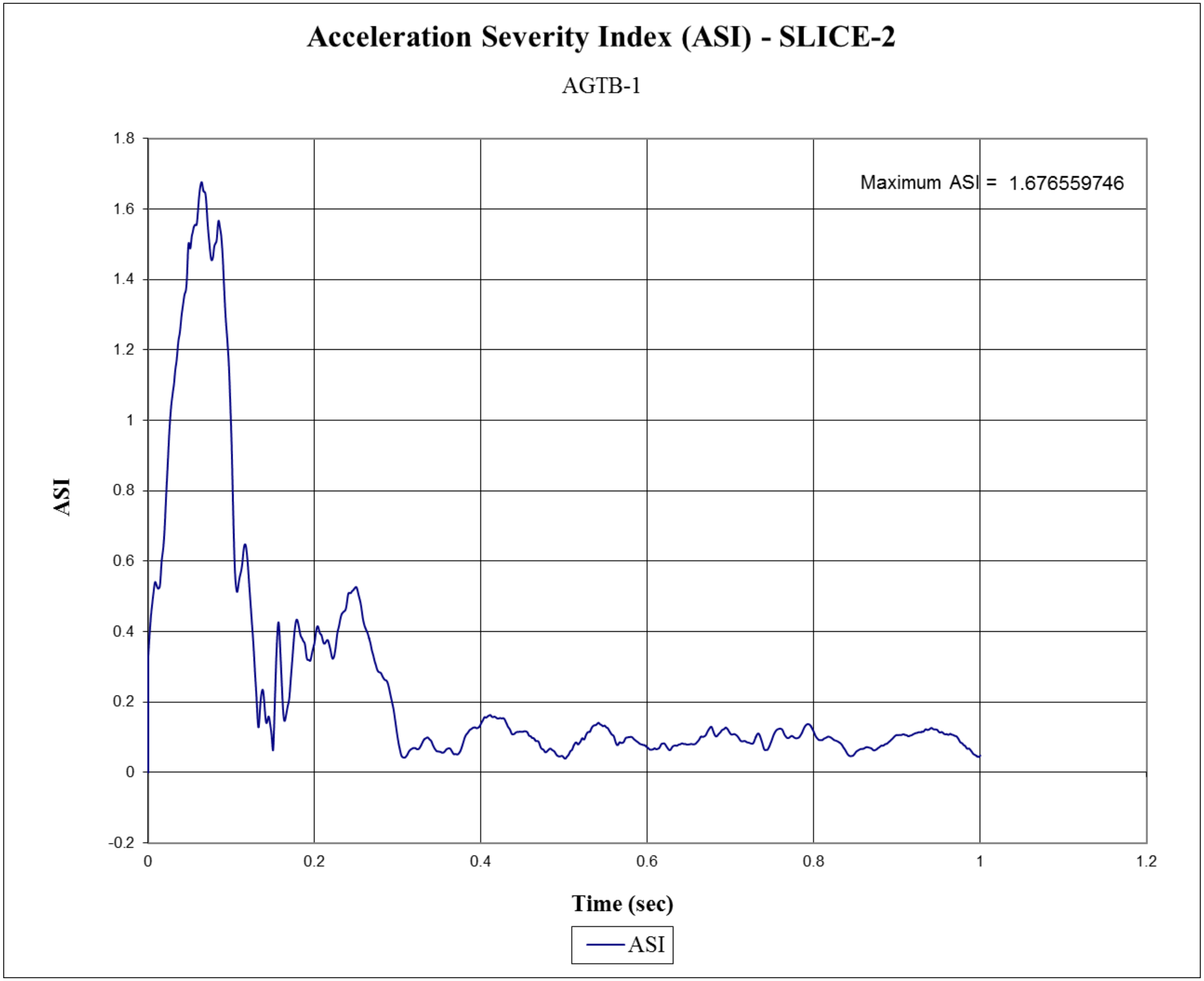


Figure E-16. Acceleration Severity Index (SLICE-2), Test No. AGTB-1

Appendix F. Accelerometer and Rate Transducer Data Plots, Test No. AGTB-2

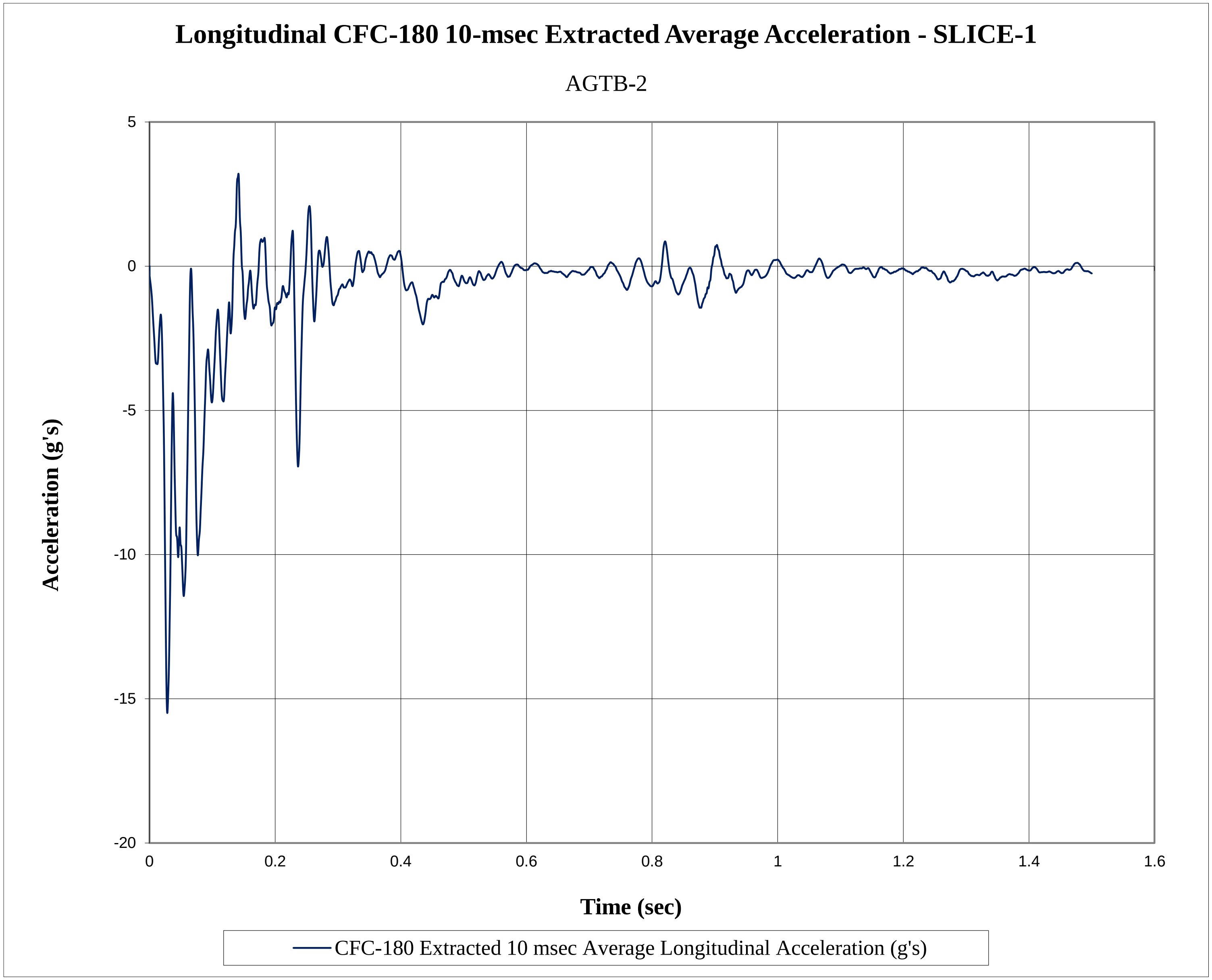


Figure F-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. AGTB-2

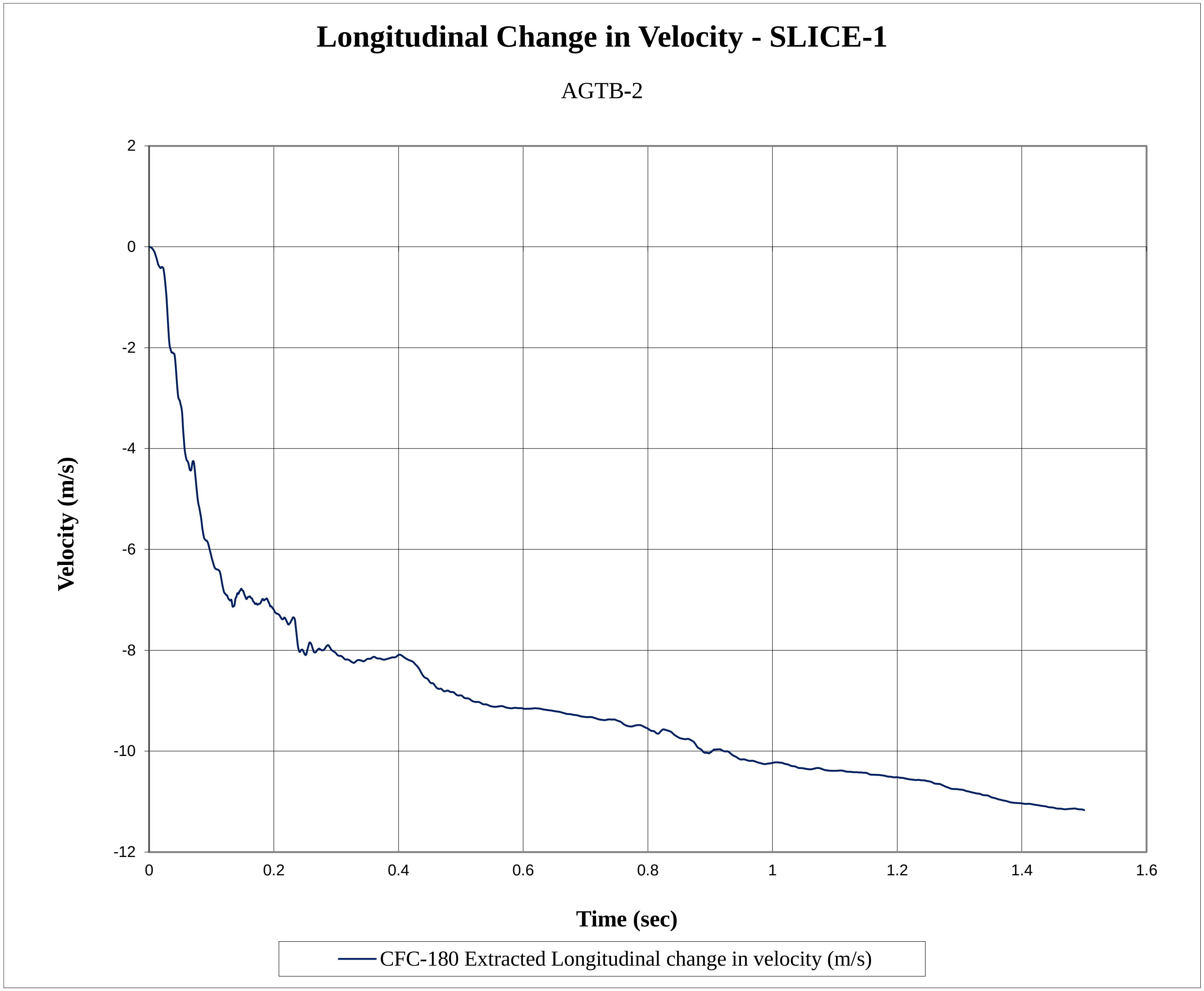


Figure F-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. AGTB-2

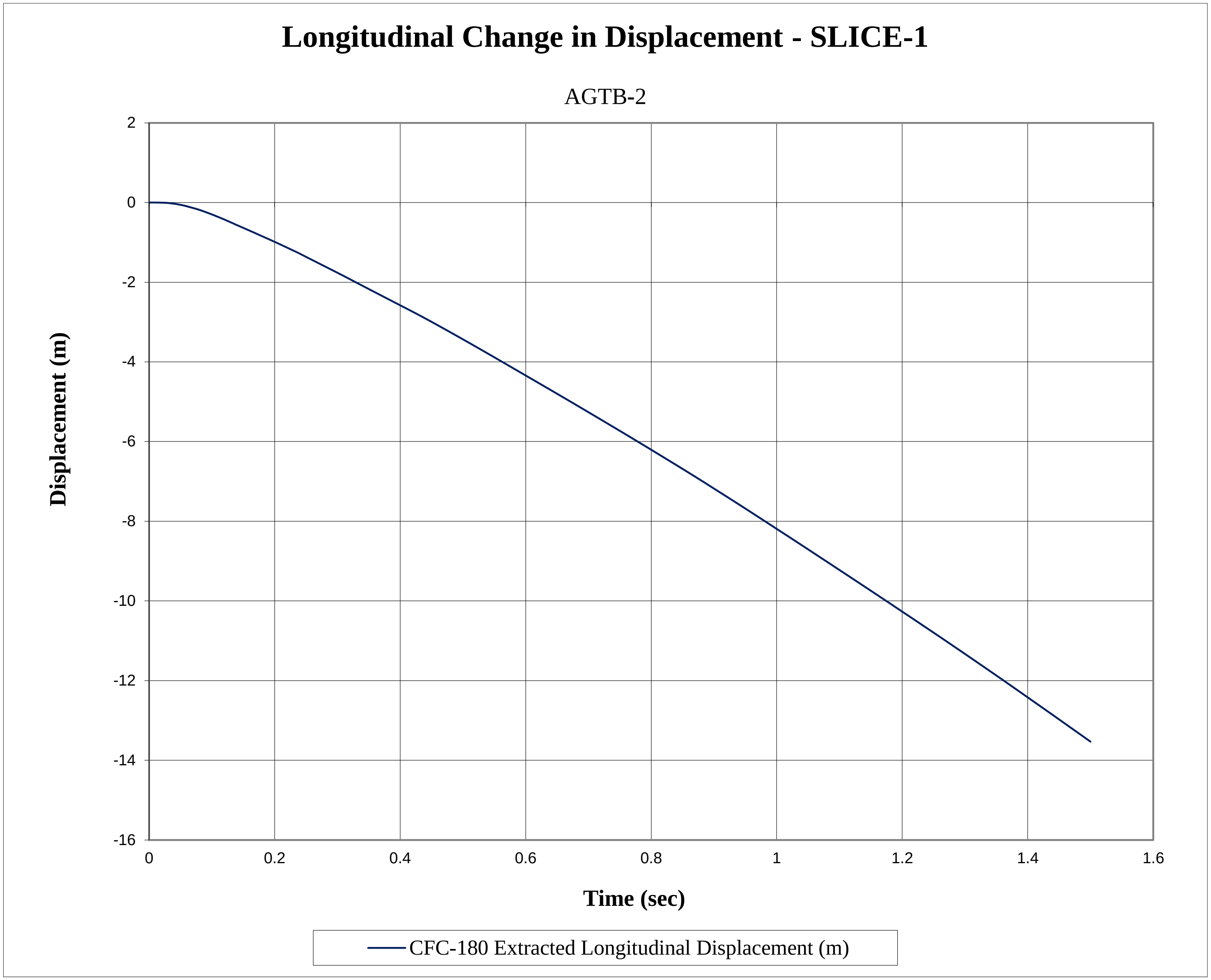


Figure F-3. Longitudinal Occupant Displacement (SLICE-1), Test No. AGTB-2

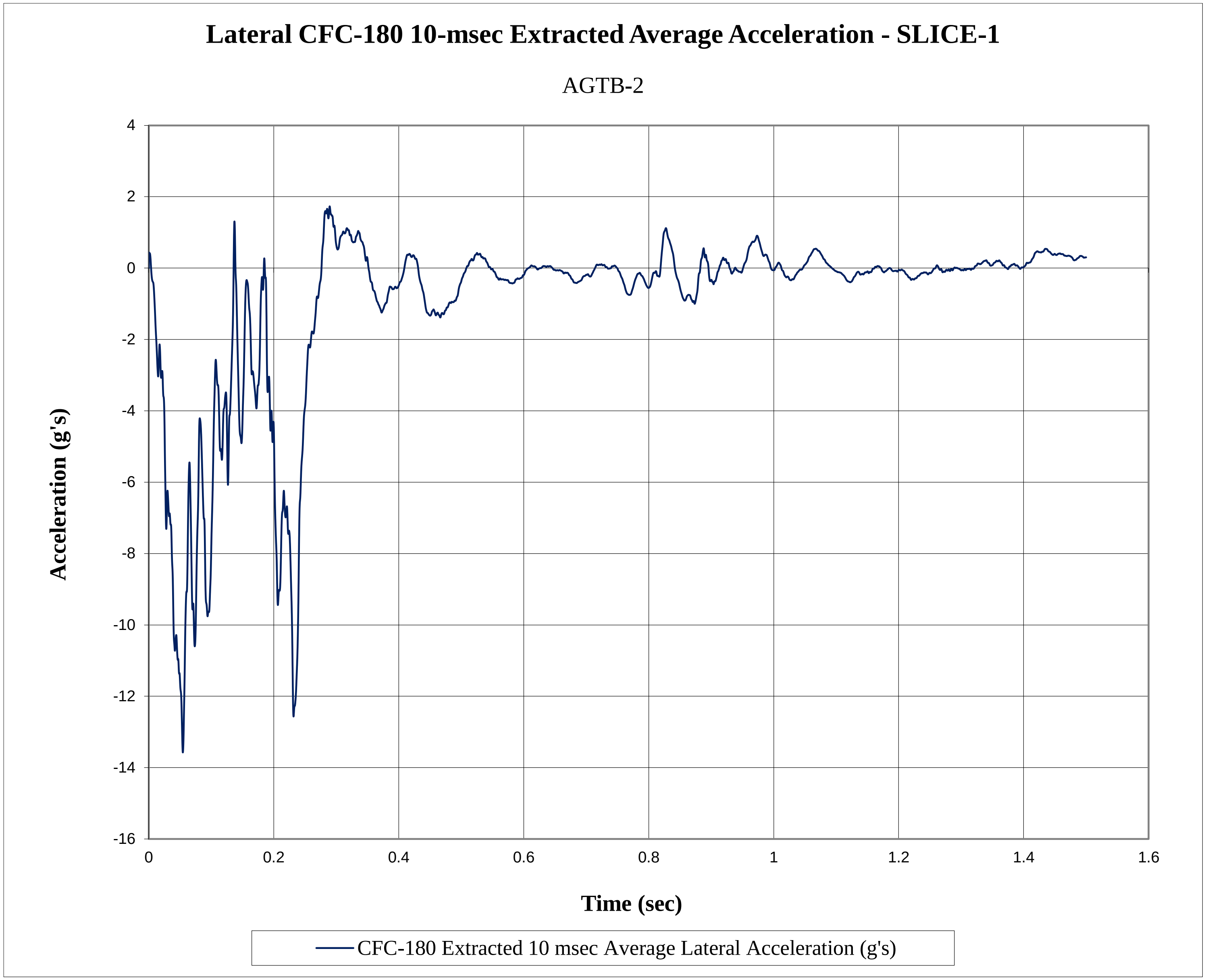


Figure F-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. AGTB-2

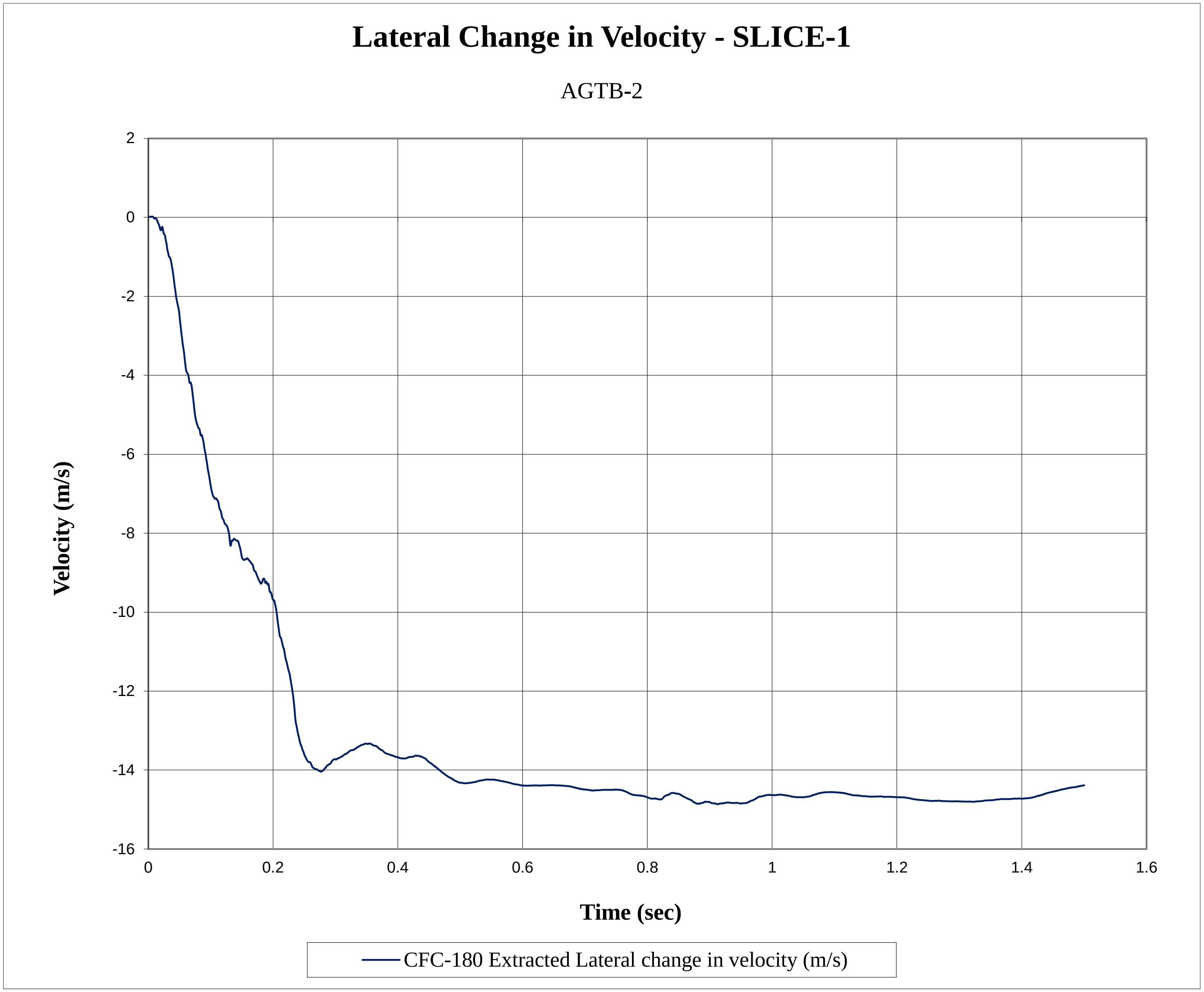


Figure F-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. AGTB-2

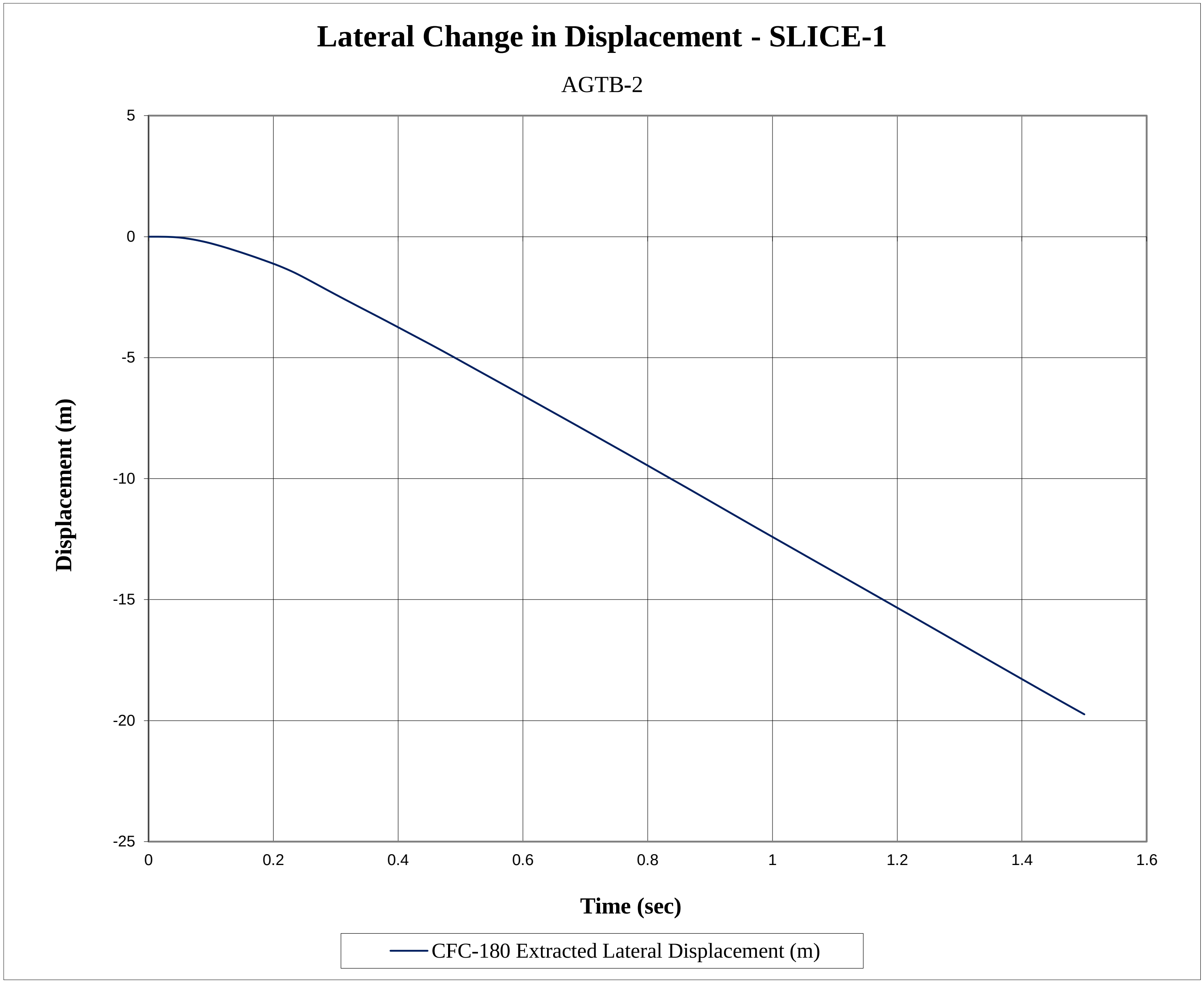


Figure F-6. Lateral Occupant Displacement (SLICE-1), Test No. AGTB-2

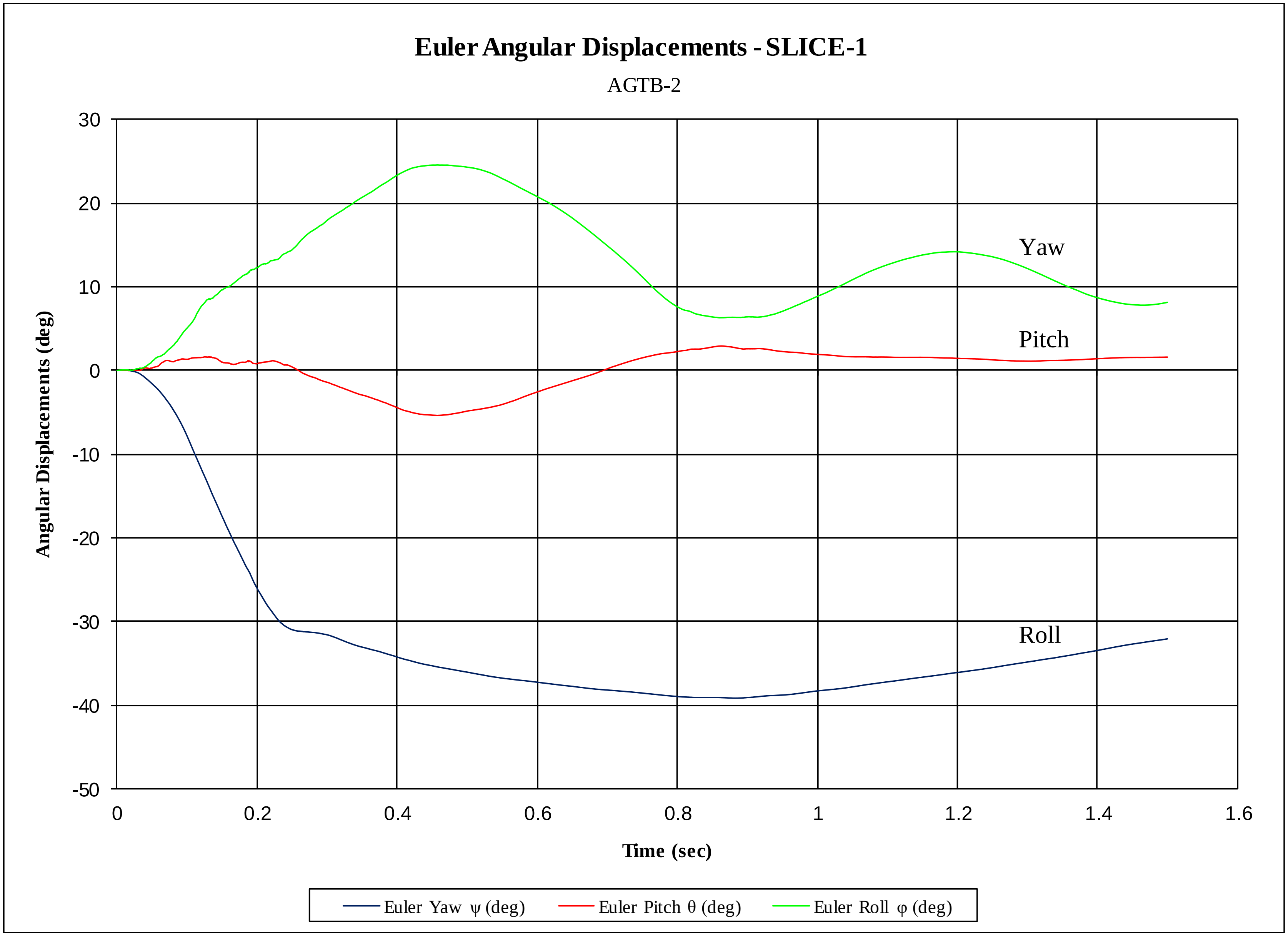


Figure F-7. Vehicle Angular Displacements (SLICE-1), Test No. AGTB-2

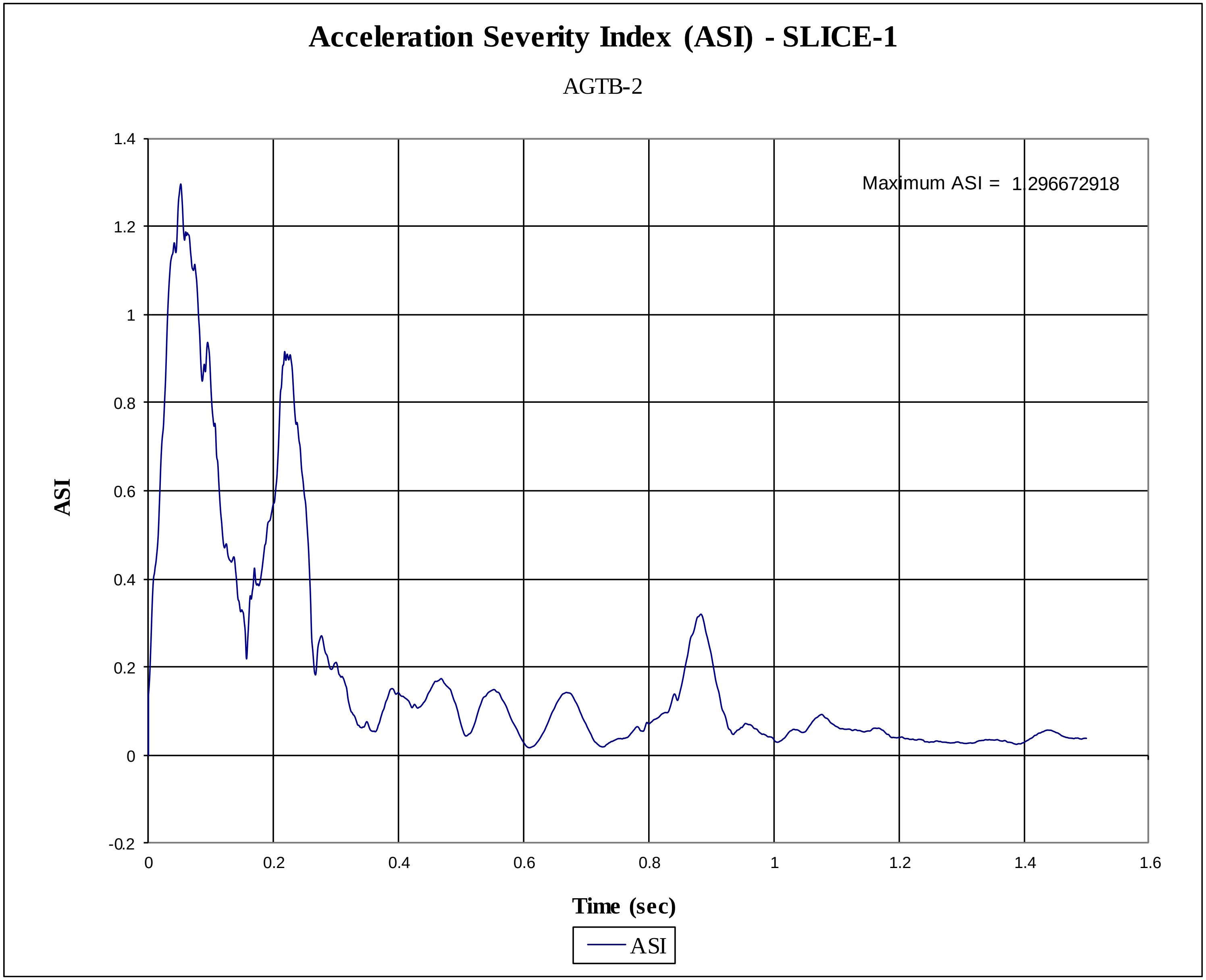


Figure F-8. Acceleration Severity Index (SLICE-1), Test No. AGTB-2

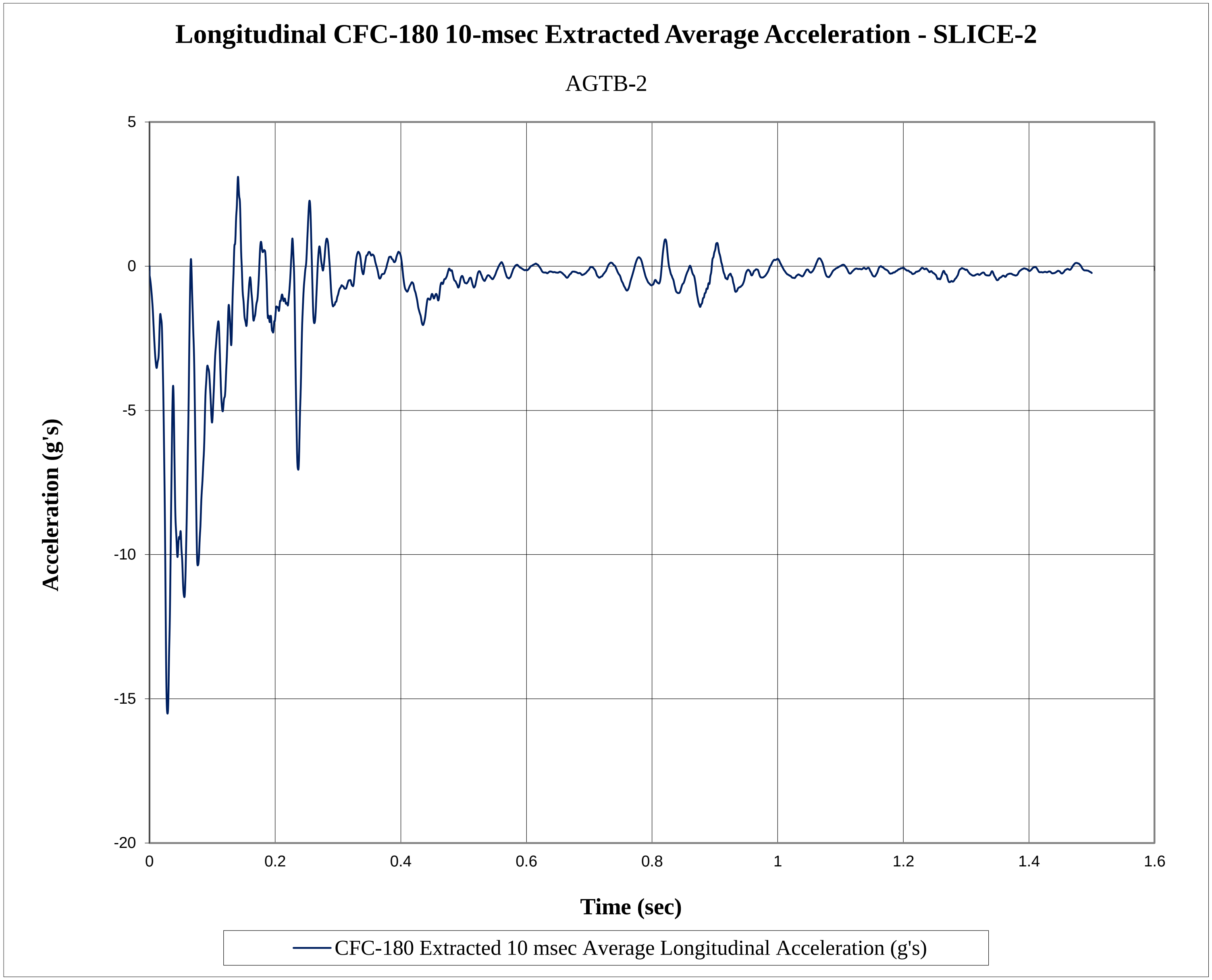


Figure F-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. AGTB-2

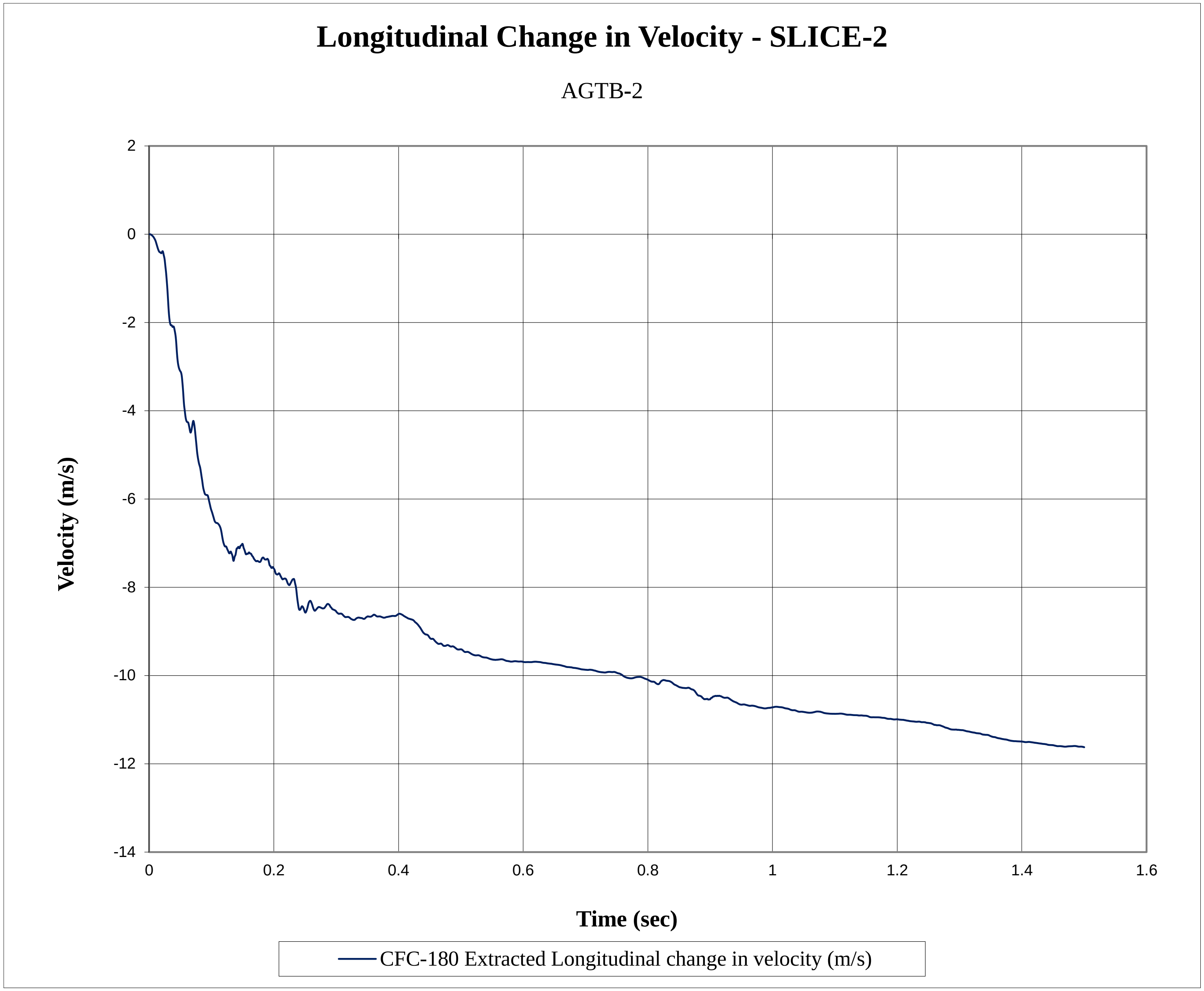


Figure F-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. AGTB-2

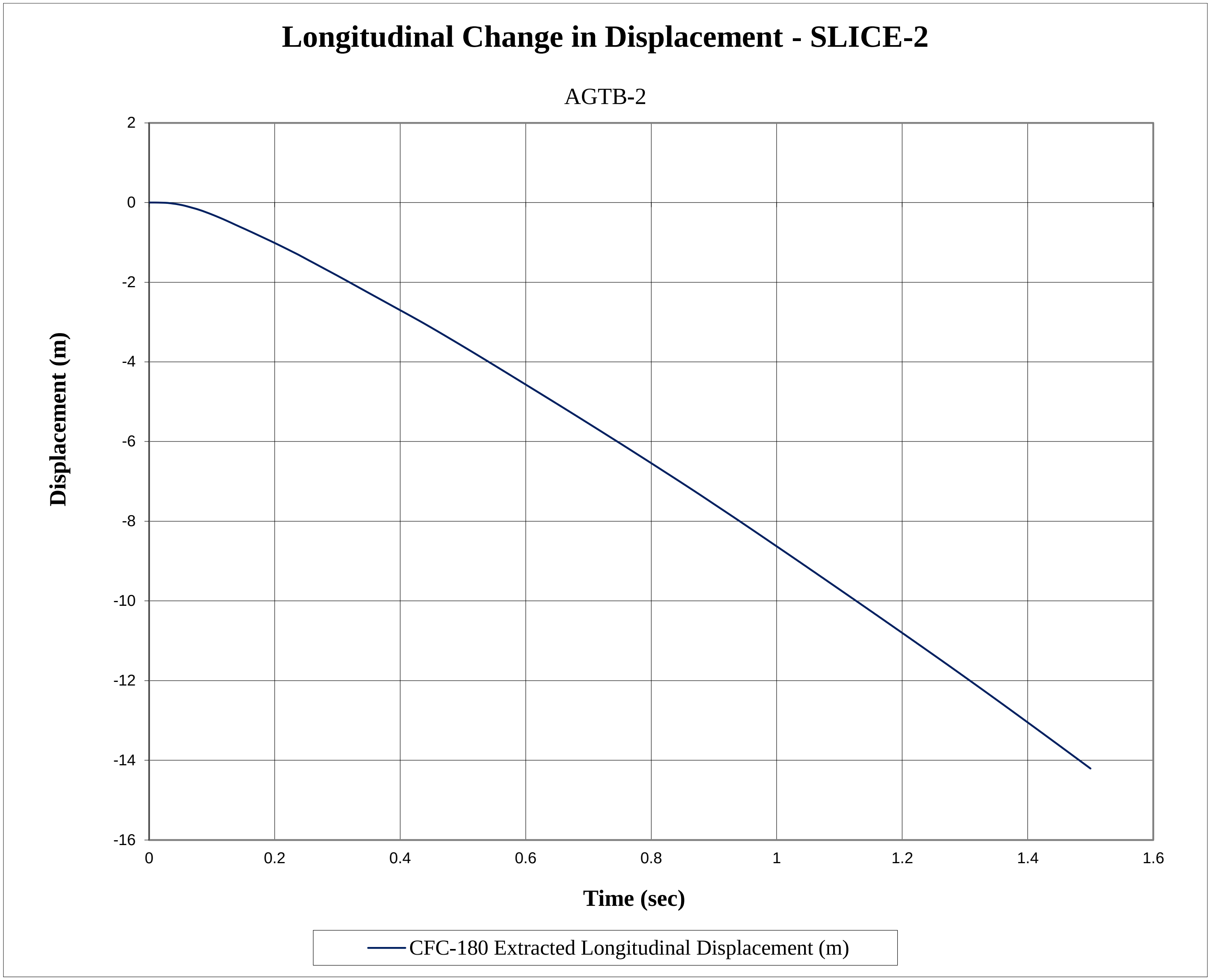


Figure F-11. Longitudinal Occupant Displacement (SLICE-2), Test No. AGTB-2

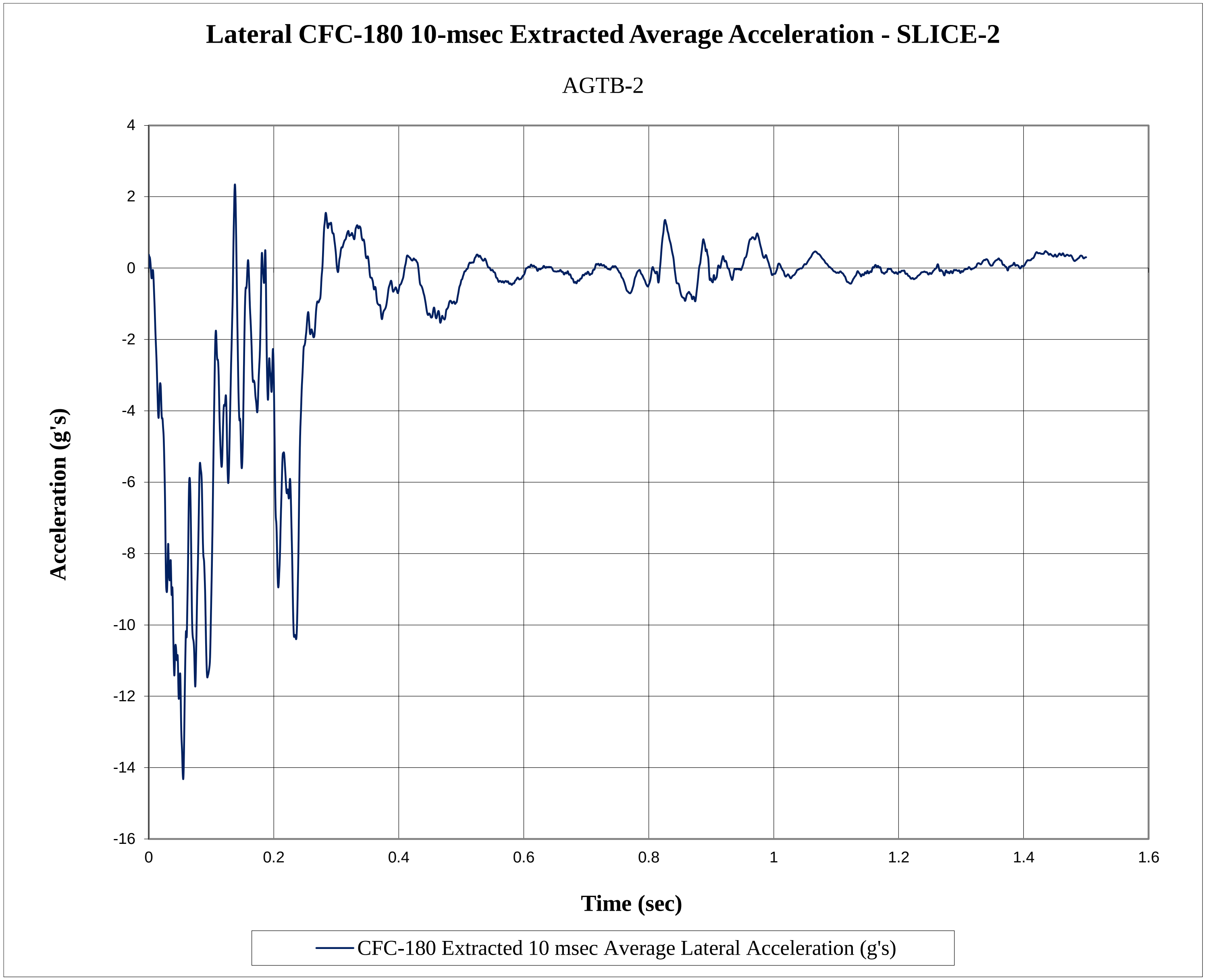


Figure F-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. AGTB-2

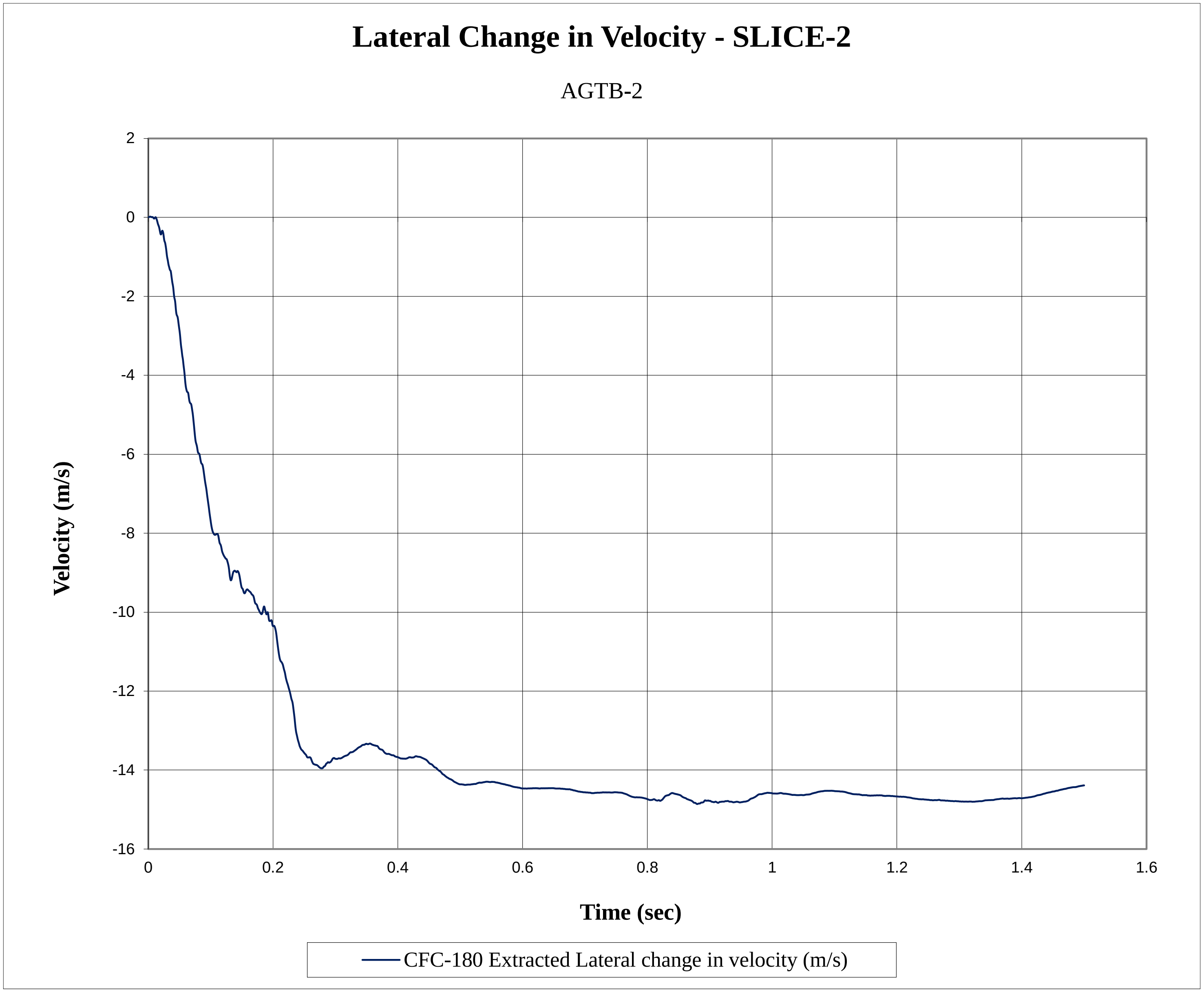


Figure F-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. AGTB-2

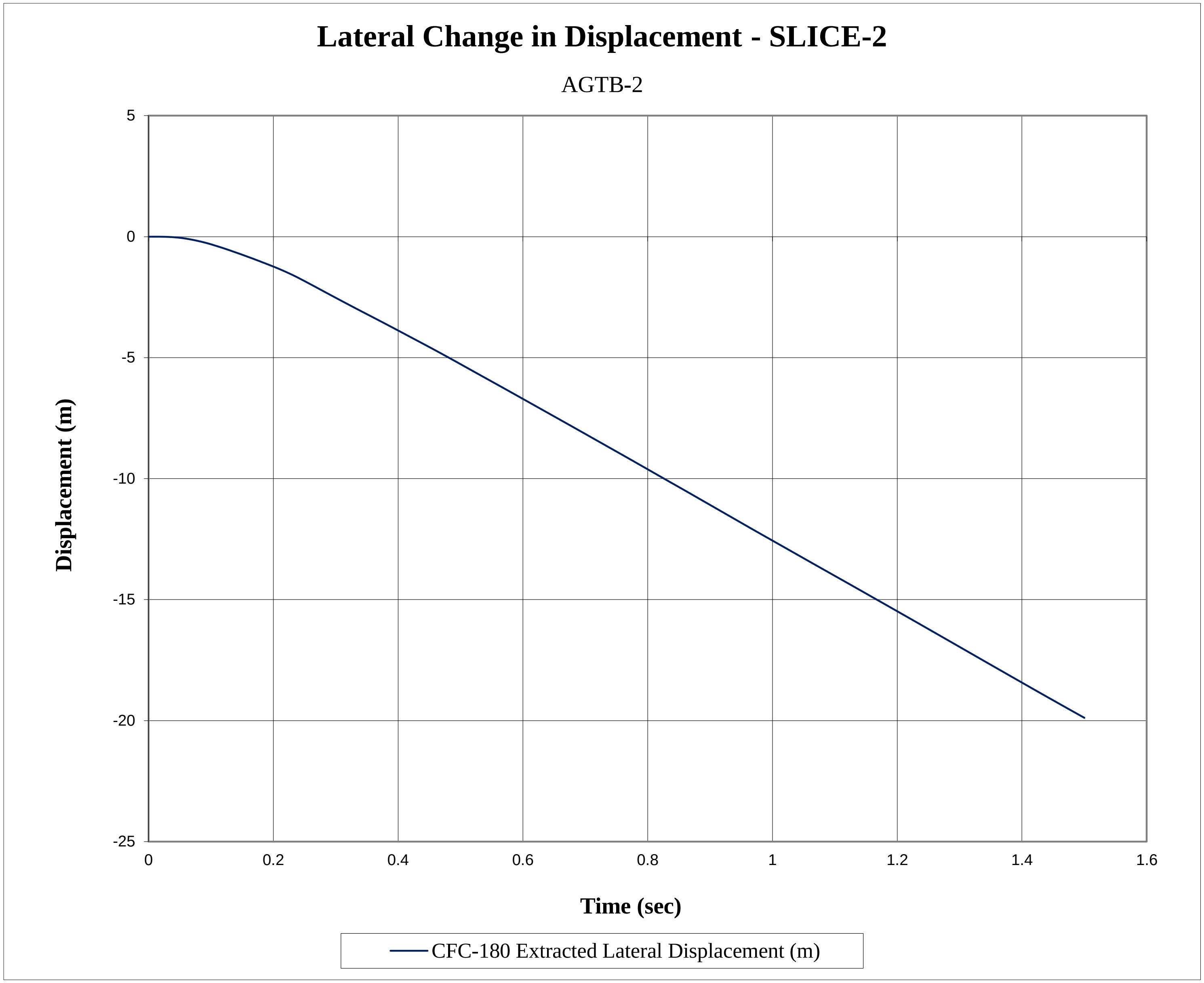


Figure F-14. Lateral Occupant Displacement (SLICE-2), Test No. AGTB-2

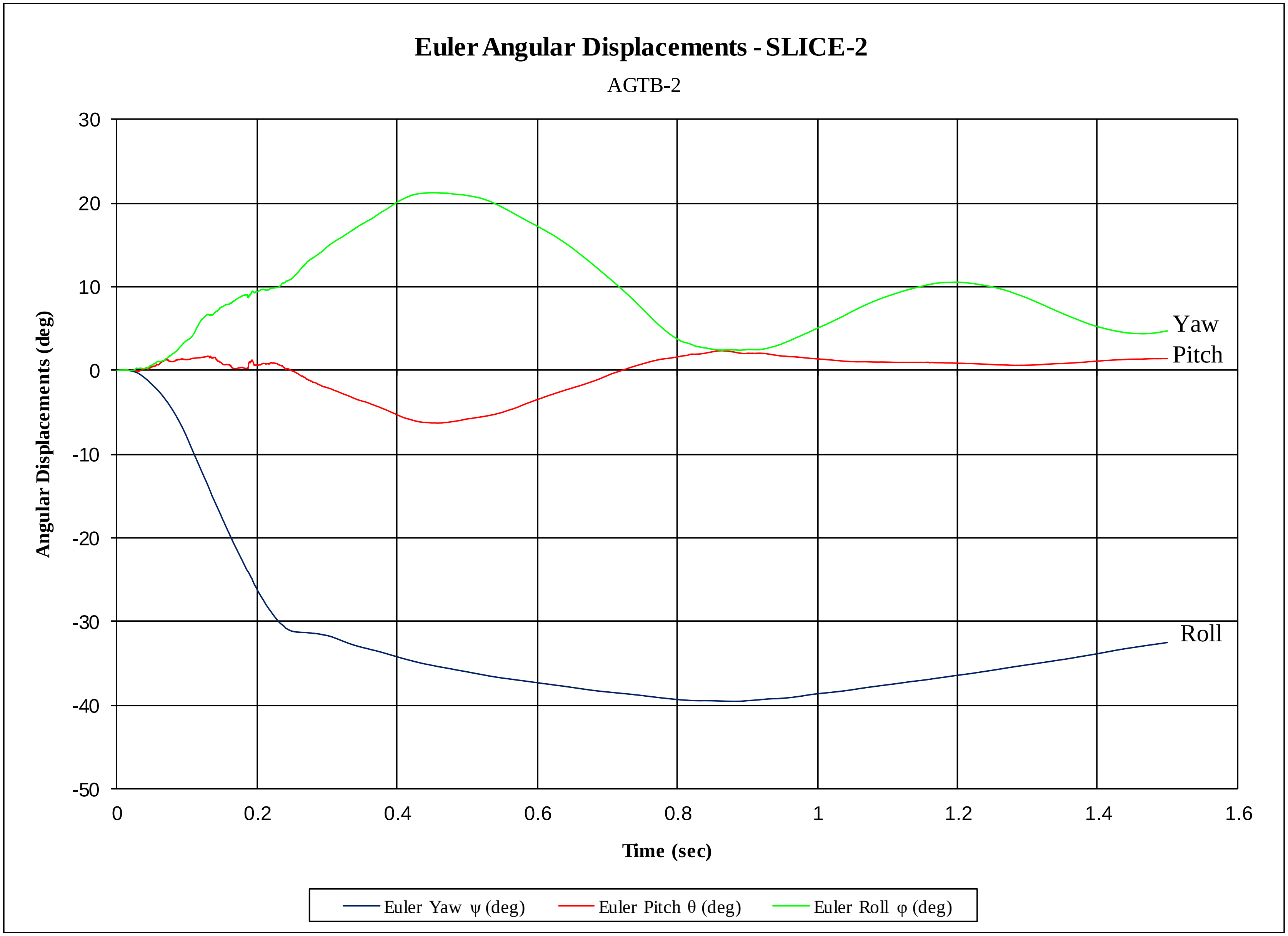


Figure F-15. Vehicle Angular Displacements (SLICE-2), Test No. AGTB-2

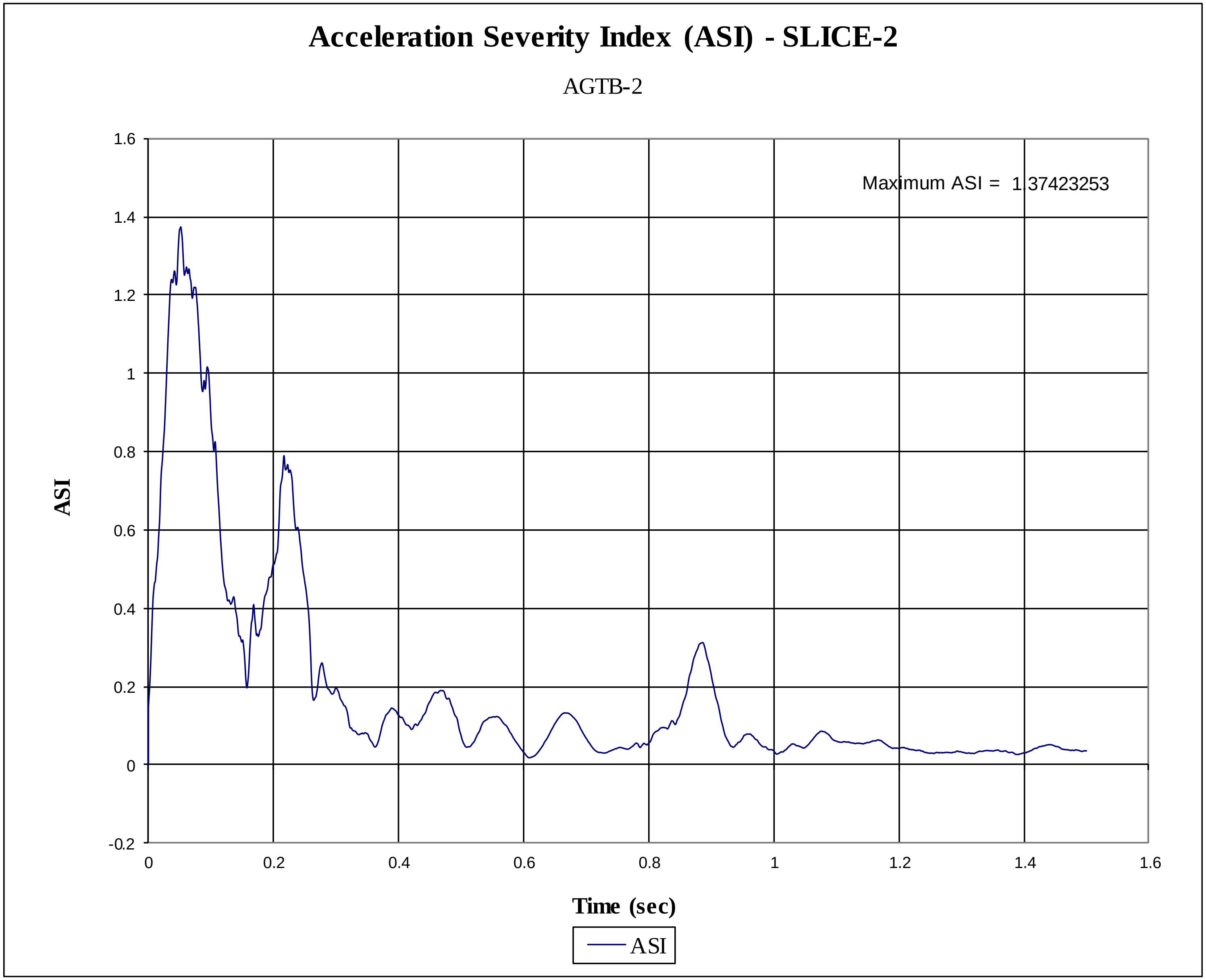


Figure F-16. Acceleration Severity Index (SLICE-2), Test No. AGTB-2

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