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DESIGN AND EVALUATION OF THE MERRITT PARKWAY GUIDERAIL ACCORDING TO *MASH* TL-3

Sponsored by

Connecticut DOT and

Roadside Safety Pooled Fund

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16. Abstract

The Merritt Parkway Guiderail was previously testing and evaluated according to guidelines included in the second edition of the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) (*1*). The system was found to be unsatisfactory for Test Level 3 (TL-3).

Finite element computer simulations were used to evaluate design concepts developed to improve the crashworthy performance of the Merritt Parkway Guiderail.

A design which incorporated a 1-inch-thick splice plate was evaluated according to MASH TL-3. The system did not meet the MASH TL-3 evaluation criteria. A second design was tested and evaluated that incorporated a 1-inch-thick splice plate and joints at midspan. This system was successful in meeting the MASH TL-3 criteria. The satisfactory performance of the system was based upon the presence of a 4-inch curb. The design was also tested without a curb but did not meet the MASH TL-3 criteria. Another design was evaluated with full-scale crash testing that incorporated 1-inch-thick splice plates, joints at midspan, and a rubrail. This system was successful in meeting the MASH TL-3 criteria.

Two designs for the Merrit Parkway Guiderail met the performance criteria for *MASH* TL-3 Longitudinal Barrier. One design had a 4-inch curb and incorporated 1-inch-thick splice plates and joints at midspan. The second design did not have a curb and incorporated 1-inch-thick splice plates, joints at midspan, and a rubrail.

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Design and Evaluation of the Merritt Parkway Guiderail According to *MASH* TL-3

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The results reported herein apply only to the article tested. The full-scale crash test was performed according to TTI Proving Ground quality procedures and American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware, Second Edition (*MASH*) guidelines and standards.

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REVISION LOG

Revision Number	Change(s) Made	Date

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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 yards	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 1000L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 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
		FORCE and 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 yards	yd^2
ha	hectares	2.47	acres	ac
km^2	Square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	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 tons (2000lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lb/in^2

*SI is the symbol for the International System of Units

CHAPTER 1.
INTRODUCTION

Previous testing and evaluation of the Merritt Parkway Guiderail system with a 4-inch curb resulted in unsatisfactory crashworthy performance (*1*) according to the guidelines included in the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*), Second Edition (*2*). The Merritt Parkway Guiderail was assessed according to Test Level 3 (TL-3) evaluation criteria. Ridedown accelerations above the MASH limits were observed in MASH Test 3-11. A modification was made to the system by reducing the post spacing to 5 feet. The system was found to be satisfactory for MASH TL-3. However, the 5 ft design modification was evaluated without a curb and failed to meet the criteria for MASH Test 3-11. The ridedown acceleration exceeded the MASH limits. It should be noted that a transition design connecting the Merritt Parkway Guiderail to a concrete parapet was tested and evaluated according to MASH TL-3 and was found to be satisfactory (*1*). Thus, the primary focus of this project was the length-of-need section of the Merritt Parkway Guiderail design.

The objectives of this project were to:

1. Develop design concepts to improve the crashworthy performance of the Merritt Parkway Guiderail
2. Evaluate the performance of the design concepts using computer simulations. Identify a candidate design concept for further evaluation through full-scale crash testing.
3. Conduct full-scale crash tests and evaluate the performance of the design according to MASH TL-3.

This report presents the research efforts and findings for the design and evaluation of the Merritt Parkway Guiderail system.

CHAPTER 2. DESIGN ANALYSIS

This chapter presents the details of the modeling and simulation effort related to the development and evaluation of the Merritt Parkway Guiderail system. Finite element (FE) simulations were used as the primary tool to aid in the design and evaluation process.

2.1. DESIGN CONCEPTS

Previous full-scale crash testing indicated unsatisfactory performance of the current Merritt Parkway Guiderail system (*1*). The system failed *MASH* Test 3-11 due to excessive longitudinal ridedown acceleration. The high ridedown acceleration occurred as the pickup truck vehicle engaged the splice connection at the post.

Four design concepts were developed to improve the crashworthy performance of the system. Each design was analyzed using finite element computer simulations. The design concepts are summarized as follows:

- Addition of a rubrail. A 6-inch x 8-inch timber rail was added below the main rail. The height to the top edge of the rubrail was 14 inches.
    - Design Intent: Reduce potential for snagging and increase overall system stiffness.
- Smaller steel posts. Reduce the steel post size to W6x9.
    - Design Intent: Allow increased system deflection and reduce potential for vehicle pocketing and snagging.
- Thicker splice plate. Increase the thickness of the splice plate to 1 inch. Previous thickness was 3/8-inch.
    - Design Intent: Reduce deflection of splice plate to reduce vehicle snagging and accelerations.
- Front splice plate. Add splice plate to the front side of the timber rails.
    - Design Intent: Reduce potential for vehicle snagging on front edges of timber rails.

An initial focus was placed on evaluation of the design concepts with a 4-inch curb. This was the configuration that failed *MASH* Test 3-11 due to excessive ridedown acceleration and was considered the most critical configuration. If the design concept was satisfactory, then additional evaluation would be considered for a no curb configuration.

2.2. MODEL

A finite model of each design concept was developed for evaluation through computer simulations. Each model generally included the following components: steel posts, steel-backed timber rail, timber blockouts, splice plate, guiderail bolts, and lag screws. The timber components were modeled using MAT_WOOD. The guiderail posts, splice plates, and steel-backed plates were modeled using MAT_SIMPLIFIED_JOHNSOON_COOK. At each lag screw location, the surrounding nodes between the steel plate and timber rail were constrained using CONTACT_TIED_NODES_TO_SURFACE. Figure 2.1 and Figure 2.2 show elevation and plan views of the FE model. This model represents the original system prior to the integration of the components for the four different design concepts. This model also includes a 4-inch curb.

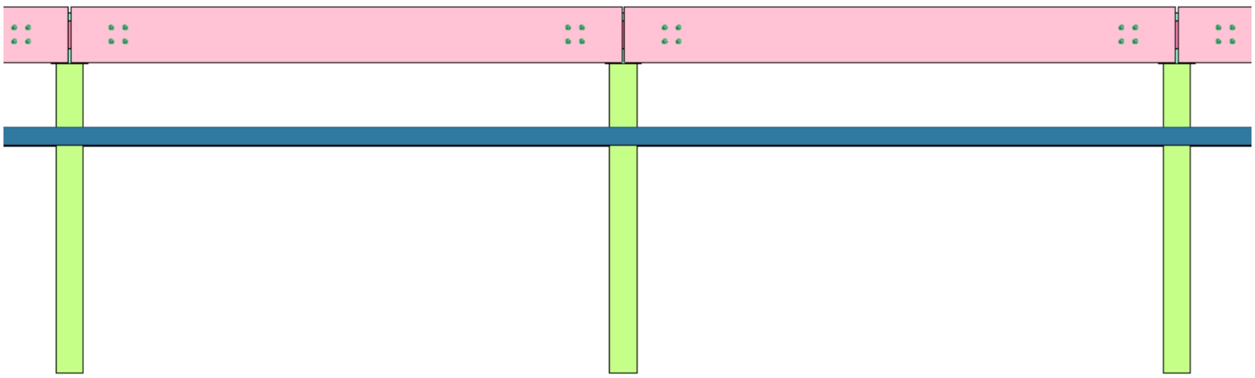

Figure 2.1. Elevation View of FE Model.

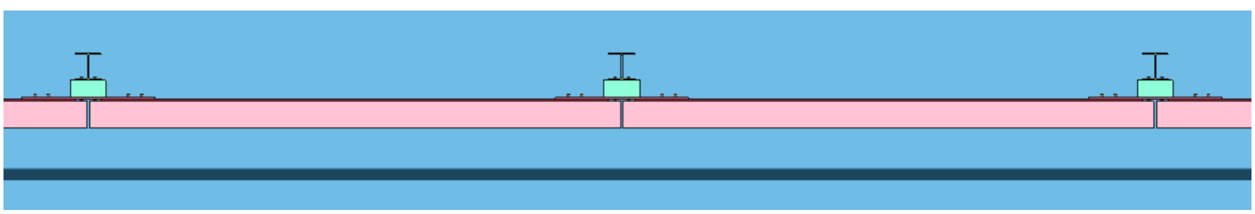

Figure 2.2. Plan View of FE Model.

2.3. SIMULATIONS

Computer simulations were performed using the finite element method to evaluate each design concept according to *MASH* Test 3-11. If the design concept was found to be satisfactory for *MASH* Test 3-11, then additional simulations were conducted to evaluate the performance according to *MASH* Test 3-10.

LS-DYNA, which is a commercially available general purpose FE software, was used for all the finite element analyses. A 5,000-lb Dodge Ram pickup truck vehicle model was used for the *MASH* Test 3-11 computer simulations (Figure 2.3). A 2,425-lb Toyota Yaris small car vehicle model was used for the *MASH* Test 3-10 computer simulations (Figure 2.4).

The *MASH* Test 3-11 computer simulations were performed with an impact speed and angle of 62 mi/h and 25 degrees. The critical impact location was 14 ft upstream from the centerline of post 7. This impact location was selected based on the previous testing of the Merritt Parkway Guiderail system (*1*).

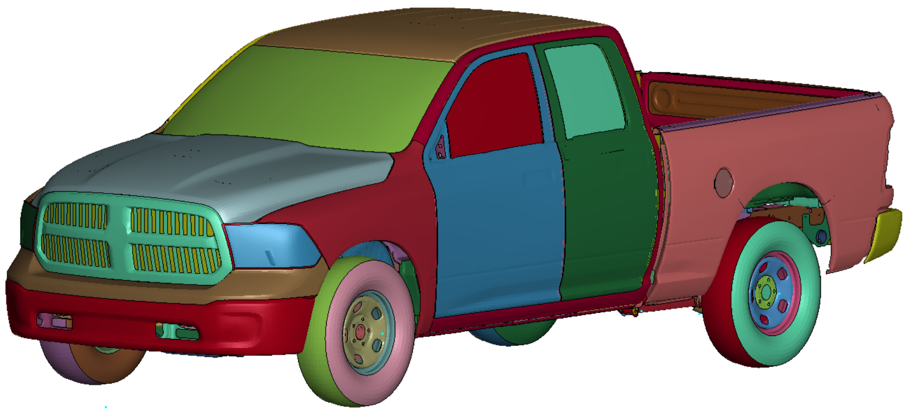

Figure 2.3. 2270P FE Vehicle Model.

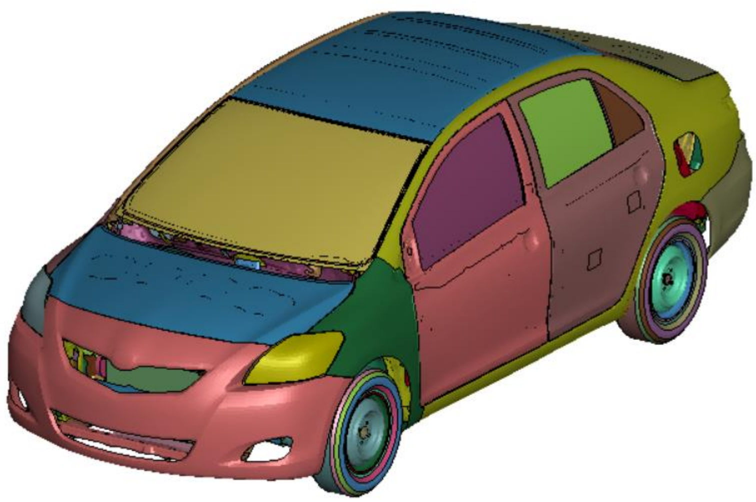

Figure 2.4. 1100C FE Vehicle Model.

MASH Test 3-11 computer simulations were performed for all four design concepts. Figure 2.5 through Figure 2.8 show sequential images for the simulation runs. Table 2.1 shows the occupant risk values for the simulation runs.

The rubrail and W6x9 (i.e., smaller posts) design concepts both indicated unsatisfactory crashworthy performance due to vehicle rollover. The front splice plate design concept indicated satisfactory crashworthy performance. The vehicle remained stable throughout the simulation and the occupant risk results were below the *MASH* limits. However, there was concern about the edge of the steel plate being exposed to the vehicle if the timber rail were to sustain any fractures during impact. Thus, this design concept was not considered for further evaluation. The 1-inch-thick splice plate design concept indicated satisfactory crashworthy performance. The vehicle remained stable throughout the simulation and the occupant risk results were below the *MASH* limits.

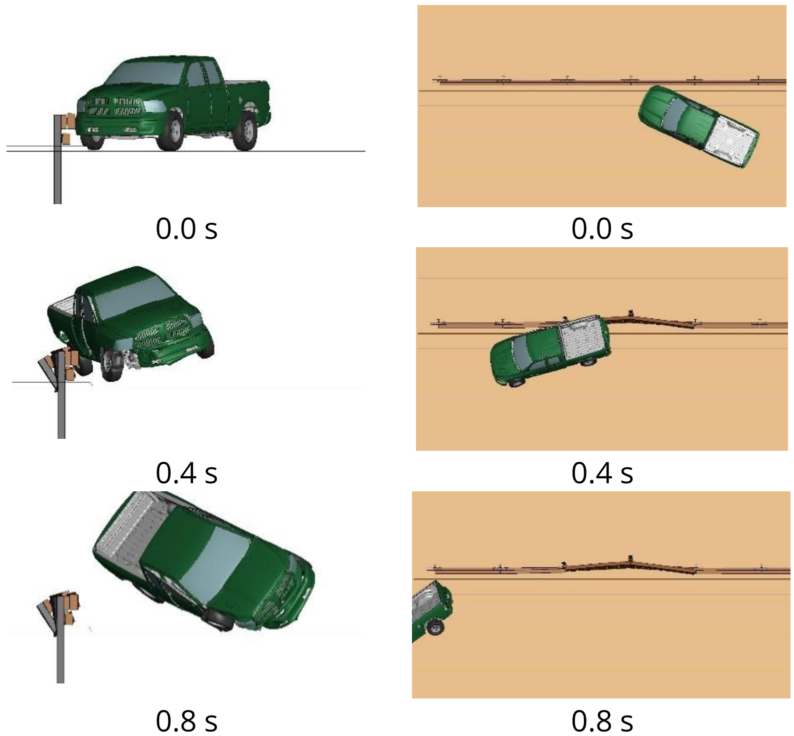

Figure 2.5. Sequential Images for MASH Test 3-11 Simulation – Rubrail.

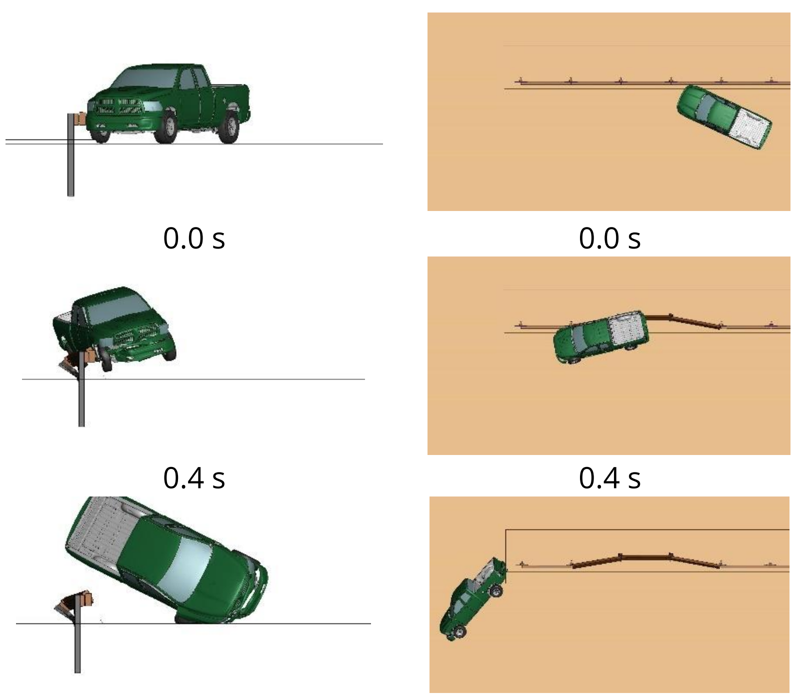

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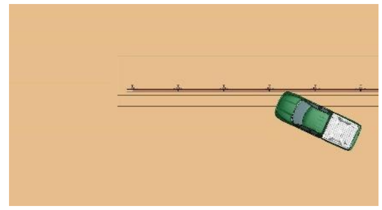
Figure 2.6. Sequential Images for MASH Test 3-11 Simulation – W6x9 Posts.

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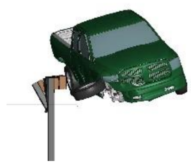 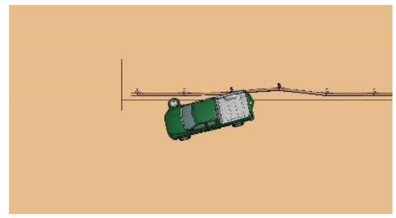

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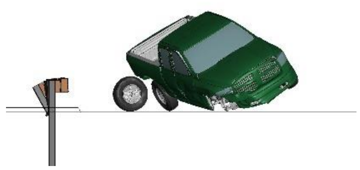 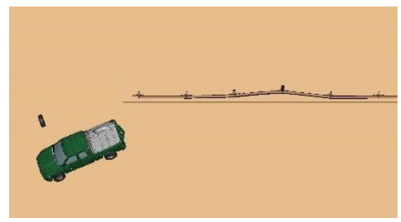

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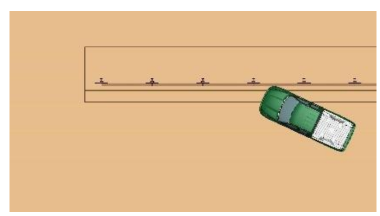
Figure 2.7. Sequential Images for MASH Test 3-11 Simulation – Front Splice Plate.

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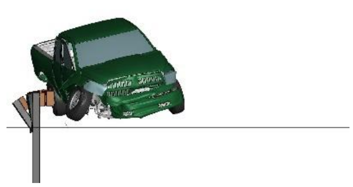 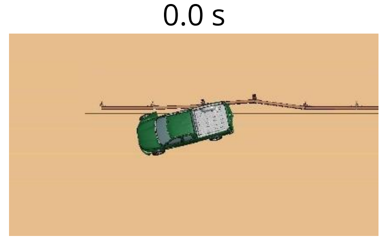

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 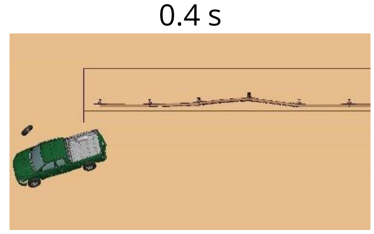

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Figure 2.8. Sequential Images for MASH Test 3-11 Simulation – 1 inch Thick Splice Plate.

Table 2.1. Occupant Risk Values for Design Concepts.

	Rubrail	W6x9 Posts	Front Splice Plate	1in Splice Plate
OIV, Longitudinal (ft/s)	20.5	17.4	17.4	18.1
OIV, Lateral (ft/s)	22.2	19.8	21.3	21.0
RDA, Longitudinal (g)	13.5	8.2	11.6	9.9
RDA, Lateral (g)	12.9	9.2	12.5	12.5
Roll (deg)	59.8	134.2	45.7	33.1
Pitch (deg)	45.8	40.1	27.1	14.6
Yaw (deg)	38.1	37.3	41.8	40.2

The design concept with the 1-inch splice indicated the best crashworthy performance. This concept was further evaluated for *MASH* Test 3-10 and for *MASH* TL-3 evaluation with a no curb configuration.

In all three computer simulations, the system with a 1-inch-thick splice plate indicated satisfactory performance. Thus, the design concept with the 1-inch-thick splice plate was considered for further evaluation through full-scale crash testing. Chapter 3 through Chapter 6 presents details of the system, test procedures, and crash test results.

CHAPTER 3.
SYSTEM DETAILS

3.1. TEST ARTICLE AND INSTALLATION DETAILS

3.1.1. Test 620061-01-2

The Merritt Parkway Guiderail test installation for crash test 620061-01-2 was a roadside safety barrier system incorporating galvanized (except for the section above ground) steel posts, timber rails, an anchor block, and a concrete parapet. The total installation length was 166 feet, divided into three primary segments: the Anchor Section, the Length of Need (LON), and the Transition Section.

The Anchor Section spanned 29 feet and ¾ inch, beginning at the anchor block and extending to Post 3. It tapered up from the ground at the anchor block to a nominal height of 30 inches, which continued throughout the rail system. It also flared laterally toward the traffic side to a final offset of 34-1/4 inches from the front face of the rail at the LON.

The Length of Need was the primary segment, extending 100 feet and comprising 10 posts spaced at 10-foot intervals. This section used standard timber rails and galvanized (expect for the section above ground) steel posts with consistent connection details.

A 50-foot-long cast-in-place concrete curb was installed along the LON, centered between Posts 5 and 10. The curb measured 26 inches in width and 12 inches in thickness, with an integrated 4-inch-tall by 5-3/4-inch-wide raised curb on the side closest to the traffic rail, extending above grade. The base edge of the raised curb was positioned 12 inches from the traffic-side face of the timber rail. The curb was constructed from 4,000 psi concrete and reinforced.

The Transition Section measured 20 feet, bridging the LON and the concrete parapet. It included specialized transition rails and backup plates, and had varied post spacing spanning Posts 13 through 19. At the Transition Section, ten curb sections were tapered across a length of 19 ft from ground level up to a height of 8 inches at the concrete parapet.

A reinforced concrete parapet was also constructed as part of the installation. This parapet was built using high-strength concrete and reinforced with multiple layers of steel rebar. It included embedded anchor bolts and epoxy anchorage, with standard concrete cover and chamfered edges to meet structural and safety requirements.

Figure 3.1 presents the overall information on the Merritt Parkway Guiderail, and Figure 3.2 thru Figure 3.7 provide photographs of the installation. A.1 provides further details on the Merritt Parkway Guiderail for Test 620061-01-2. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by TTI Proving Ground personnel.

3.1.2. Tests 620061-01-1&3

For crash tests 620061-01-1 and 620061-01-3, the test installation incorporated several modifications to the original 620061-01-2 configuration. The Anchor Section was slightly extended to 29 feet 1½ inches, and the Length of Need began at the joint between Posts 3 and 4, utilizing a bent splice plate at that location. While the LON retained its 100-foot span, the post layout was revised to include only nine 10-foot spaces. Additionally, the depth of backfill behind the posts located in front of the curb section increased from 16 inches to 17 inches. All other elements of the installation, including materials, curb and parapet construction, and connection details, remained the same as in test 620061-01-2.

Figure 3.8 presents the overall information on the Merritt Parkway Guiderail, and Figure 3.9 thru Figure 3.14 provide photographs of the installation. A.2 provides further details on the Merritt Parkway Guiderail for Tests 620061-01-1&3. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by TTI Proving Ground personnel.

3.1.3. Test 620061-01-4

For crash test 620061-01-4, all elements of the installation remained the same as test 620061-01-1 and 620061-01-3, except for the curb which was removed creating a consistent rail height of 30 inches throughout the LON and transition.

Figure 3.15 presents the overall information on the Merritt Parkway Guiderail, and Figure 3.16 thru Figure 3.21 provide photographs of the installation. A.3 provides further details on the Merritt Parkway Guiderail for Test 620061-01-4. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by TTI Proving Ground personnel.

3.1.4. Tests 620061-01-5&6

For crash test 620061-01-5 and 620061-01-6, a rub rail was added below the traffic rail along the LON that was composed of timber and steel backup plates as used in the traffic rail. All other elements of the installation, including materials, curb and parapet construction, and connection details, remained the same as in test 620061-01-4.

Figure 3.22 presents the overall information on the Merritt Parkway Guiderail, and Figure 3.23 thru Figure 3.28 provide photographs of the installation. A.4 provides further details on the Merritt Parkway Guiderail for Tests 620061-01-5&6. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by TTI Proving Ground personnel.

3.2. DESIGN MODIFICATIONS DURING TESTING

No modifications were made to the test installation during the testing phase other than the ones described previously.

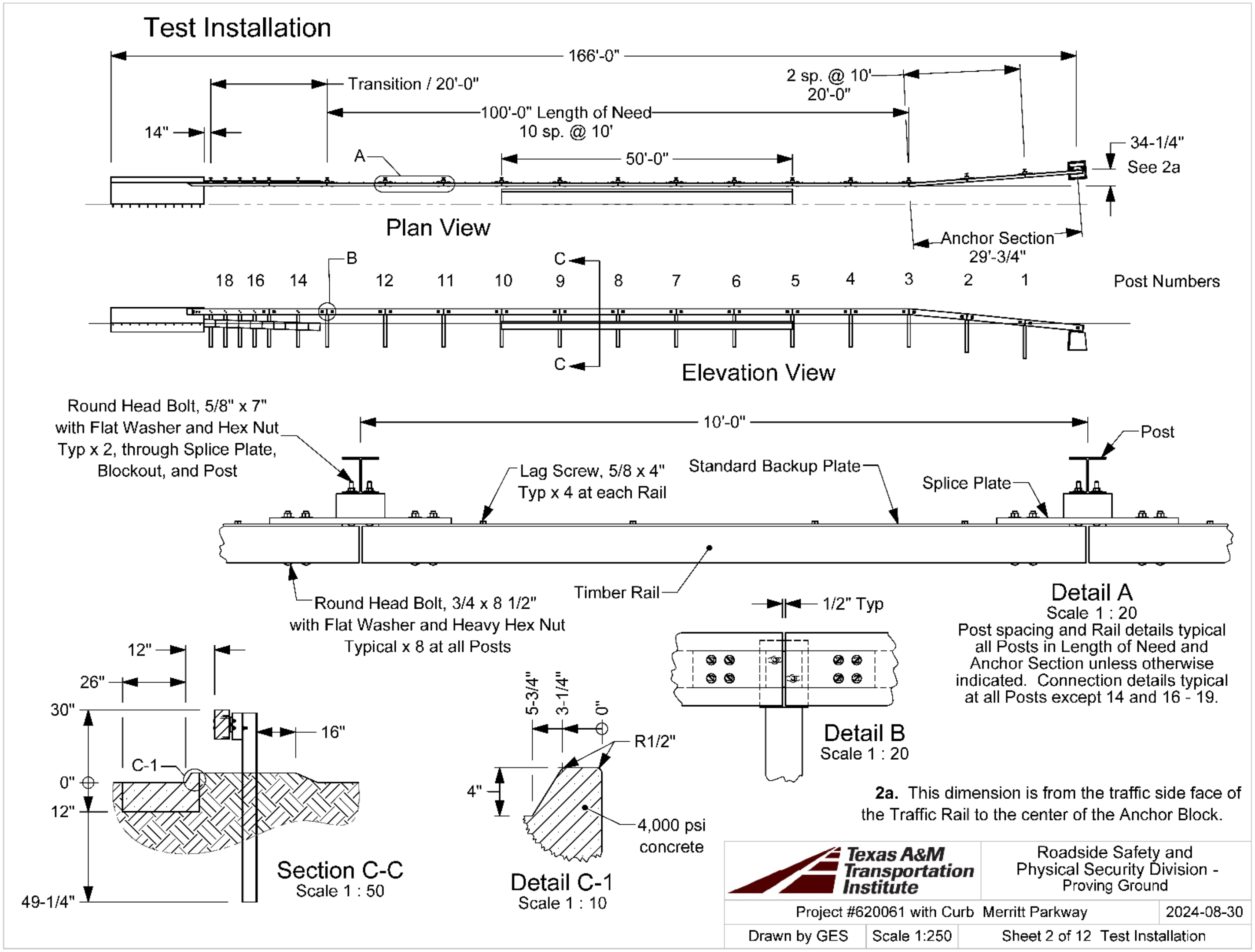

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Figure 3.1. Details of Merritt Parkway Guiderail for Test 620061-01-2.

Figure 3.2. Merritt Parkway Guiderail Test Installation prior to Test 620061-01-2.

Figure 3.3. Merritt Parkway Guiderail Oblique Downstream View of Test Installation prior to Test 620061-01-2.

Figure 3.4. Merritt Parkway Guiderail Traffic Side View of Joint between Posts 7 and 8 prior to Test 620061-01-2.

Figure 3.5. Merritt Parkway Guiderail Field Side Oblique Downstream View of Test Installation prior to Test 620061-01-2.

Figure 3.6. Merritt Parkway Guiderail Anchor Section prior to Test 620061-01-2.

Figure 3.7. Merritt Parkway Guiderail Downstream In-Line View of Test Installation prior to Test 620061-01-2.

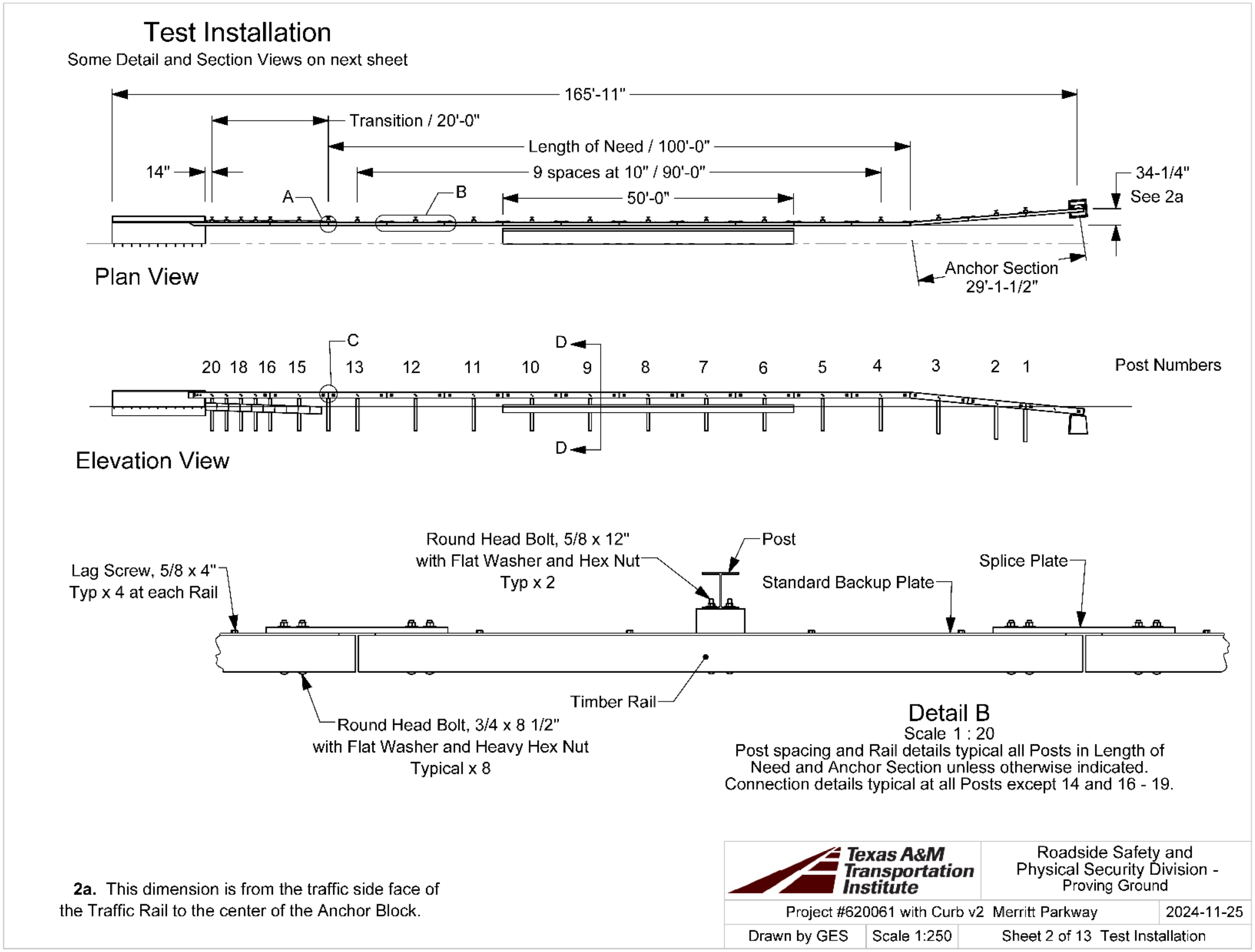

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Figure 3.8. Details of Merritt Parkway Guiderail for Tests 620061-01-1&3.

Figure 3.9. Merritt Parkway Guiderail Test Installation prior to Tests 620061-01-1&3.

Figure 3.10. Merritt Parkway Guiderail Oblique Downstream View of Test Installation prior to Tests 620061-01-1&3.

Figure 3.11. Merritt Parkway Guiderail Traffic Side View of Joint at Midspan between Posts 7 and 8 prior to Tests 620061-01-1&3.

Figure 3.12. Merritt Parkway Guiderail Field Side View of Joint at Midspan between Posts 7 and 8 prior to Tests 620061-01-1&3.

Figure 3.13. Merritt Parkway Guiderail Downstream In-Line View of Test Installation prior to Tests 620061-01-1&3.

Figure 3.14. Merritt Parkway Guiderail Field Side Downstream View of Test Installation prior to Tests 620061-01-1&3.

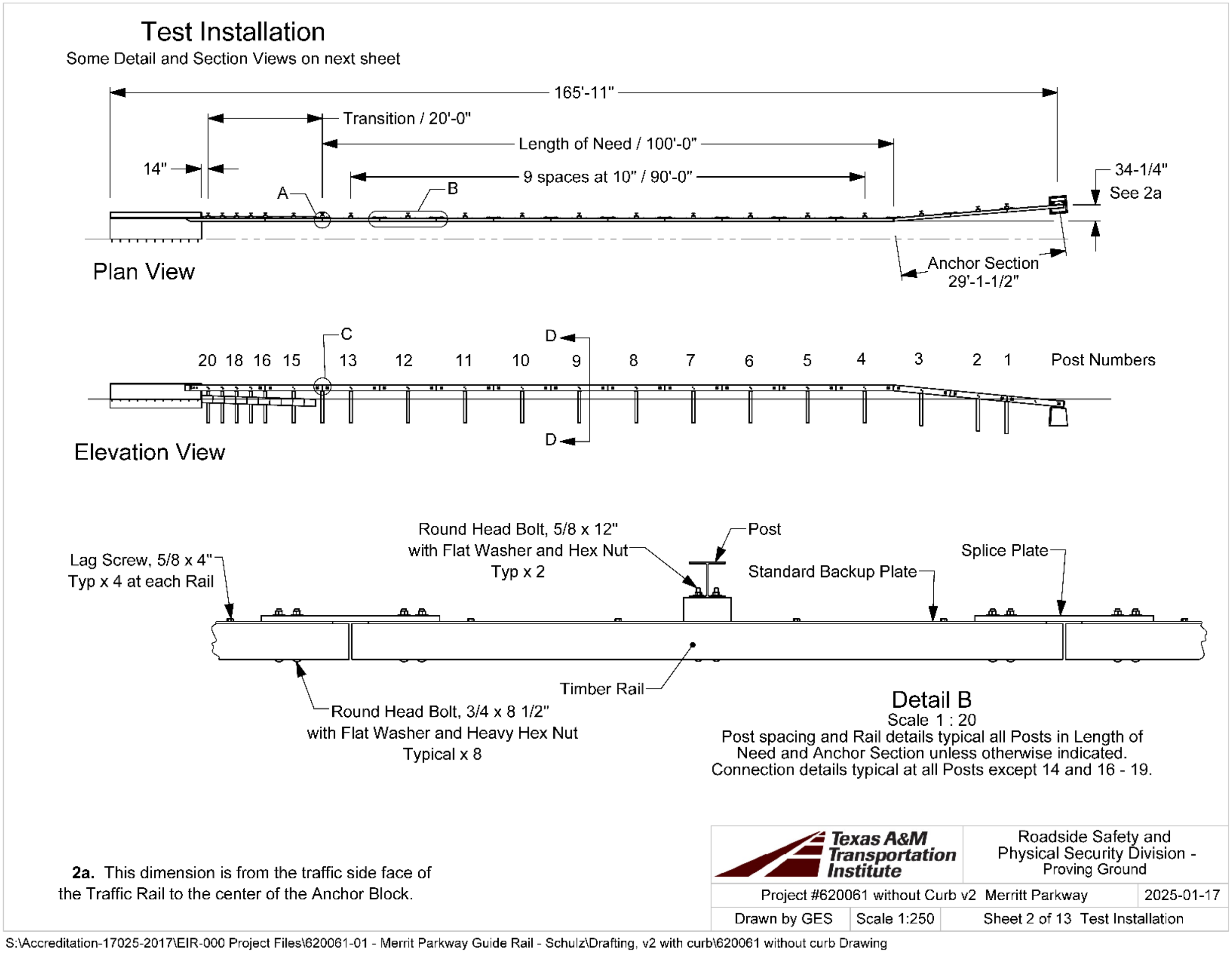


Figure 3.15. Details of Merritt Parkway Guiderail for Test 620061-01-4.

Figure 3.16. Merritt Parkway Guiderail Test Installation prior to Test 620061-01-4.

Figure 3.17. Merritt Parkway Guiderail Oblique Downstream View of Test Installation prior to Tests 620061-01-1&3.

Figure 3.18. Merritt Parkway Guiderail Traffic Side View of Joint at Midspan between Posts 7 and 8 prior to Test 620061-01-4.

Figure 3.19. Merritt Parkway Guiderail Field Side View of Joint at Midspan between Posts 7 and 8 prior to Test 620061-01-4.

Figure 3.20. Merritt Parkway Guiderail Downstream In-Line View of Test Installation prior to Test 620061-01-4.

Figure 3.21. Merritt Parkway Guiderail Field Side Downstream View of Test Installation prior to Test 620061-01-4.

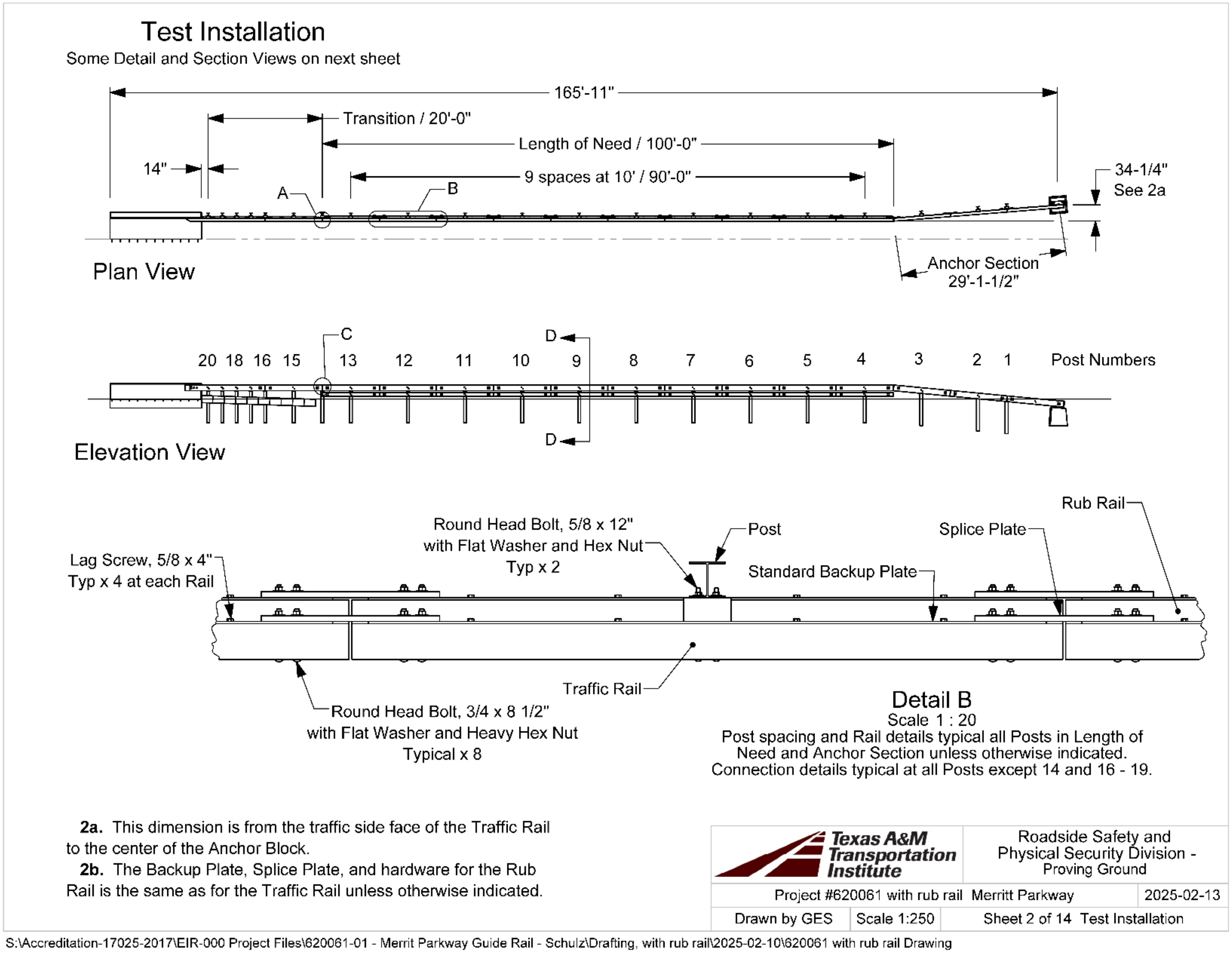


Figure 3.22. Details of Merritt Parkway Guiderail for Test 620061-01-5&6.

Figure 3.23. Merritt Parkway Guiderail Test Installation prior to Tests 620061-01-5&6.

Figure 3.24. Merritt Parkway Guiderail Oblique Downstream View of Test Installation prior to Tests 620061-01-1&3.

Figure 3.25. Merritt Parkway Guiderail Traffic Side View of Joint at Midspan between Posts 7 and 8 prior to Tests 620061-01-5&6.

Figure 3.26. Merritt Parkway Guiderail Field Side View of Joint at Midspan between Posts 7 and 8 prior to Tests 620061-01-5&6.

Figure 3.27. Merritt Parkway Guiderail Downstream In-Line View of Test Installation prior to Tests 620061-01-5&6.

Figure 3.28. Merritt Parkway Guiderail Field Side Upstream View of Test Installation prior to Tests 620061-01-5&6.

3.3. MATERIAL SPECIFICATIONS

Appendix B provides material certification documents for the materials used to install/construct the Merritt Parkway Guiderail. Table 3.1 shows the average compressive strengths of the concrete on the day of the test 1/13/2025.

Table 3.1. Concrete Strength.

Location	Design Strength (psi)	Avg. Strength (psi)	Age (days)	Detailed Location
100% of deck	3600	5103	71	100% of deck
100% of parapet	3600	4557	60	100% of parapet
100% of curb	4000	7703	56	100% of curb

3.4. SOIL CONDITIONS

The test installation was installed in standard soil meeting Type 1 Grade D of AASHTO standard specification M147-17 “Materials for Aggregate and Soil Aggregate Subbase, Base, and Surface Courses.”

In accordance with Appendix B of *MASH*, soil strength was measured the day of the crash test. During installation of the Merritt Parkway Guiderail for full-scale crash testing, two 6-ft long W6×16 posts were installed in the immediate vicinity of the Merritt Parkway Guiderail using the same fill materials and installation procedures used in the test installation and the standard dynamic test.

On the day of Test 620061-01-2, 9/10/2024, loads on the post at deflections are shown in Table 3.2. The backfill material in which the Merritt Parkway Guiderail was installed met minimum MASH requirements for soil strength. A reading was not taken at 15 inches of displacement as the load at 10 inches exceeded 10,000 pounds.

Table 3.2. Soil Strength for Test 620061-01-2.

Displacement (inches)	Minimum Load (lb)	Actual Load (lb)
5	4420	8400
10	4981	>11,000
15	5282	----

On the day of Test 620061-01-1, 1/13/2025, loads on the post at deflections are shown in Table 3.3. The backfill material in which the Merritt Parkway Guiderail was installed met meet minimum *MASH* requirements for soil strength.

Table 3.3. Soil Strength for Test 620061-01-1.

Displacement (inches)	Minimum Load (lb)	Actual Load (lb)
5	4420	4424
10	4981	5788
15	5282	7182

On the day of Test 620061-01-3, 1/17/2025, loads on the post at deflections are shown in Table 3.4. The backfill material in which the Merritt Parkway Guiderail was installed met minimum *MASH* requirements for soil strength.

Table 3.4. Soil Strength for Test 620061-01-3.

Displacement (inches)	Minimum Load (lb)	Actual Load (lb)
5	4420	5393
10	4981	5727
15	5282	5939

On the day of Test 620061-01-4, 1/17/2025, loads on the post at deflections are shown in Table 3.5. The backfill material in which the Merritt Parkway Guiderail was installed met minimum *MASH* requirements for soil strength.

Table 3.5. Soil Strength for Test 620061-01-4.

Displacement (inches)	Minimum Load (lb)	Actual Load (lb)
5	4420	6454
10	4981	8757
15	5282	10,363

On the day of Test 620061-01-5, 1/17/2025, loads on the post at deflections are shown in Table 3.6. The backfill material in which the Merritt Parkway Guiderail was installed met minimum *MASH* requirements for soil strength.

Table 3.6. Soil Strength for Test 620061-01-5.

Displacement (inches)	Minimum Load (lb)	Actual Load (lb)
5	4420	7181
10	4981	8575
15	5282	8789

On the day of Test 620061-01-6, 5/5/2025, loads on the post at deflections are shown in Table 3.7. The backfill material in which the Merritt Parkway Guiderail was installed met minimum *MASH* requirements for soil strength.

Table 3.7. Soil Strength for Test 620061-01-6.

Displacement (inches)	Minimum Load (lb)	Actual Load (lb)
5	4420	6300
10	4981	7400
15	5282	8600

CHAPTER 4.

TEST REQUIREMENTS AND EVALUATION CRITERIA

4.1. CRASH TEST PERFORMED/MATRIX

Table 4.1 shows the test conditions and evaluation criteria for *MASH* TL-3 for Longitudinal Barriers.

Table 4.1. Test Conditions and Evaluation Criteria Specified for *MASH* TL-3 Longitudinal Barriers.

Test Designation	Test Vehicle	Impact Speed (mi/h)	Impact Angle (°)	Evaluation Criteria
3-10	1100C	62	25	A, D, F, H, I
3-11	2700P	62	25	A, D, F, H, I

The crash tests and data analysis procedures were in accordance with guidelines presented in *MASH*. Chapter 4 presents brief descriptions of these procedures.

4.2. EVALUATION CRITERIA

The appropriate safety evaluation criteria from Tables 2-2 and 5-1 of *MASH* were used to evaluate the crash test reported herein. Table 4.1 lists the test conditions and evaluation criteria required for *MASH* TL-3, and Table 4.2 provides detailed information on the evaluation criteria.

Table 4.2. Evaluation Criteria Required for *MASH* Testing.

Evaluation Factors	Evaluation Criteria
A.	Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.
D.	Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present 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*.
F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.
H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s, or maximum allowable value of 40 ft/s.
I.	The occupant ridedown accelerations should satisfy the following: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.

CHAPTER 5.

TEST CONDITIONS

5.1. TEST FACILITY

The full-scale crash tests reported herein were performed at the TTI Proving Ground, an International Standards Organization (ISO)/International Electrotechnical Commission (IEC) 17025-accredited laboratory with American Association for Laboratory Accreditation (A2LA) Mechanical Testing Certificate 2821.01. The full-scale crash tests were performed according to TTI Proving Ground quality procedures, as well as *MASH* guidelines and standards.

The test facilities of the TTI Proving Ground are located on The Texas A&M University System RELLIS Campus, which consists of a 2000-acre complex of research and training facilities situated 10 mi northwest of the flagship campus of Texas A&M University. The site, formerly a United States Army Air Corps base, has large expanses of concrete runways and parking aprons well suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, highway pavement durability and efficacy, and roadside safety hardware and perimeter protective device evaluation. The sites selected for construction and testing are along the edge of an out-of-service apron/runway. The apron/runway consists of an unreinforced jointed-concrete pavement in 12.5-ft × 15-ft blocks nominally 6 inches deep. The aprons were built in 1942, and the joints have some displacement but are otherwise flat and level.

5.2. VEHICLE TOW AND GUIDANCE SYSTEM

For the testing utilizing the 1100C and 2270P vehicles, each was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable was connected to the test vehicle, passed around a pulley near the impact point and through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. A 2:1 speed ratio between the test and tow vehicle existed with this system. Just prior to impact with the installation, the test vehicle was released and ran unrestrained. The vehicle remained freewheeling (i.e., no steering or braking inputs) until it cleared the immediate area of the test site.

5.3. DATA ACQUISITION SYSTEMS

5.3.1. Vehicle Instrumentation and Data Processing

Each test vehicle was instrumented with a self-contained onboard data acquisition system. The signal conditioning and acquisition system is a multi-channel data acquisition system (DAS) produced by Diversified Technical Systems Inc. The accelerometers, which measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra-small, solid-state units designed for crash test service. The data acquisition hardware and software conform to the *MASH* recommended version of SAE J211, Instrumentation for Impact Test. Each of the channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 samples per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit in case the primary battery cable is severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark and initiates the recording process. After each test, the data are downloaded from the DAS unit into a laptop computer at the test site. The Test Risk Assessment Program (TRAP) software then processes the raw data to produce detailed reports of the test results.

Each DAS is returned to the factory annually for complete recalibration and to ensure that all instrumentation used in the vehicle conforms to the specifications outlined by SAE J211. All accelerometers are calibrated annually by means of an ENDEVCOÒ 2901 precision primary vibration standard. This standard and its support instruments are checked annually and receive a calibration traceable to the International System of Units (SI). Measurement Uncertainties have been determined for critical parameters involved in this testing, and are available upon request by the Sponsor.

TRAP uses the DAS-captured data to compute the occupant to vehicle contact impact velocities, time of occupant to vehicle contact after vehicle impact, and highest 10-millisecond (ms) average ridedown acceleration. TRAP calculates change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-ms intervals in each of the three directions are computed. For reporting purposes, the data from the vehicle-mounted accelerometers are filtered with an SAE Class 180-Hz low-pass digital filter, and acceleration versus time curves for the longitudinal, lateral, and vertical directions are plotted using TRAP.

TRAP uses the data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.0001-s intervals, and then plots yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation being initial impact. Measurement Uncertainties have been determined for critical parameters involved in this testing, and are available upon request by the Sponsor.

5.3.2. Anthropomorphic Dummy Instrumentation

An Alderson Research Laboratories Hybrid II, 50th percentile male anthropomorphic dummy, restrained with lap and shoulder belts, was placed in the front seat on the impact side of the 1100C vehicle. The dummy was not instrumented.

According to *MASH*, use of a dummy in the 2270P vehicle is optional, and no dummy was used in the test.

5.3.3. Photographic Instrumentation Data Processing

Photographic coverage of each test included three digital high-speed cameras:

- One placed with a field of view parallel to and aligned with the installation at the downstream end.
- One placed overhead with a field of view perpendicular to the ground and directly over the impact point.
- One placed at an oblique angle upstream from the installation on the field side.

A flashbulb on the impacting vehicle was activated by a pressure-sensitive tape switch to indicate the instant of contact with the Merritt Parkway Guiderail. The flashbulb was visible from each camera. The video files from these digital high-speed cameras were analyzed to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A digital camera recorded and documented conditions of each test vehicle and the installation before and after the test.

CHAPTER 6.

MASH TEST 3-11 (CRASH TEST 620061-01-2)

6.1. CRITICAL IMPACT POINT LOCATION

The Critical Impact Point (CIP) for this test was 168 inches (14ft) upstream from the centerline of post 7 at 25 degrees. The target CIP for this test was determined using the information provided in *MASH* Section 2.2.1 and MASH Section 2.3.2. Figure 6.1 shows the target CIP for Test 620061-01-2. Figure 6.2 and Figure 6.3 depict the vehicle at the CIP prior to Test 620061-01-2.

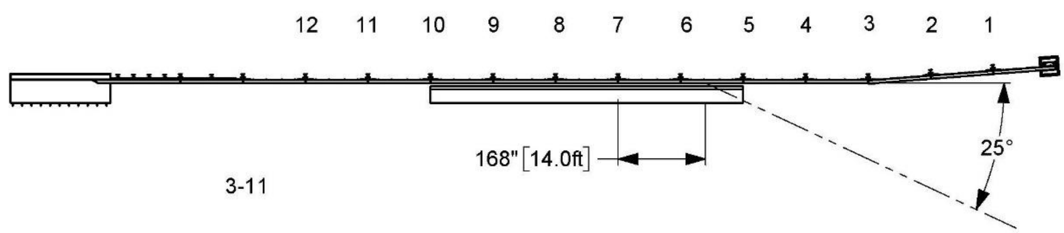


Figure 6.1. Target CIP for Test 620061-01-2.

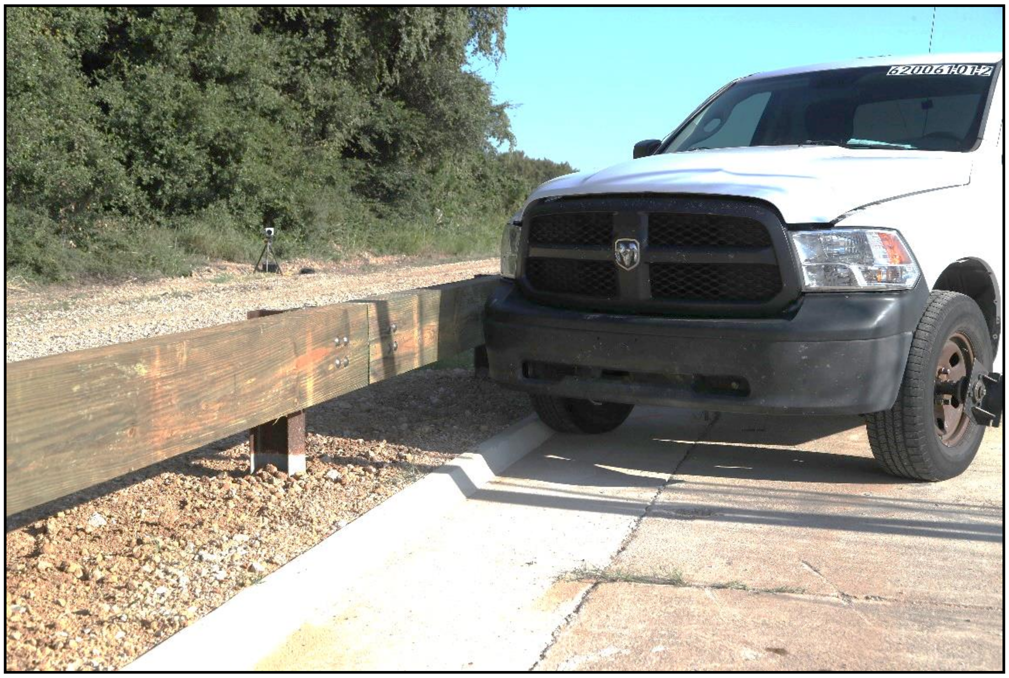


Figure 6.2. Merritt Parkway Guiderail/Test Vehicle Geometrics for Test 620061-01-2.

Figure 6.3. Merritt Parkway Guiderail/Test Vehicle Impact Location 620061-01-2.

6.2. TEST VEHICLE DETAILS PRIOR TO IMPACT

Table 6.1 shows the vehicle measurements. Figure 6.4 and Figure 6.5 show the 2018 RAM 1500 used for the crash test. Figure C.1in Appendix C.1 gives additional dimensions and information on the vehicle.

Table 6.1. Vehicle Measurements for Test 620061-01-2.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a] (lb)	165	N/A	N/A
Inertial Mass (lb)	5000	±110	5048
Gross Static[a] Mass (lb)	5000	±110	5048
Wheelbase (inches)	148	±12	140.5
Front Overhang (inches)	39	±3	40.3
Overall Length (inches)	237	±13	229.0
Overall Width (inches)	78	±2	78.5
Hood Height (inches)	43	±4	46.0
Track Width[b] (inches)	67	±1.5	68.3
CG aft of Front Axle[c] (inches)	63	±4	61.5
CG above Ground[c,d] (inches)	28	28	28.5

Note: N/A = not applicable; CG = center of gravity.
[a] If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy.
[b] Average of front and rear axles.
[c] For test inertial mass.
[d] 2270P vehicle must meet minimum CG height requirement.

Figure 6.4. Impact Side of Test Vehicle before Test 620061-01-2.

Figure 6.5. Opposite Impact Side of Test Vehicle before Test 620061-01-2.

6.3. TEST DESCRIPTION

6.3.1. Weather Conditions

Table 6.2 provides the weather conditions for Test 620061-01-2.

Table 6.2. Weather Conditions for Test 620061-01-2.

Date of Test	9/10/2024
Wind Speed	8 mi/h
Wind Direction	56°
Temperature	84°F
Relative Humidity	58 %
Vehicle Traveling	195°

6.3.2. Test Events

Table 6.3 lists events that occurred during Test 620061-01-2. The figures in Appendix C.2 present sequential photographs during the test.

Table 6.3. Events during Test 620061-01-2.

Time (seconds)	Events
-0.0012	Impact with Curb
0.0000	Vehicle impacted the installation
0.0300	Post 6 began to move toward field side
0.0420	Vehicle began to redirect
0.0680	Post 7 began to move toward field side
0.2330	Rear drivers side tire began to lift off pavement
0.3930	Vehicle was parallel with installation

6.4. TEST ACTUAL IMPACT CONDITIONS

Table 6.4 lists the details of the *MASH* impact conditions for this test and Table 6.5 lists the exit parameters.

Table 6.4. Impact Conditions for *MASH* TEST 3-11, Crash Test 620061-01-2.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5	63.6
Impact Angle (°)	25	±1.5	25.0
Impact Severity (kip-ft)	106	≥106	125.0
Impact Location	168 inches upstream from the centerline of post 7	±1 foot (12 inches)	171.1 inches upstream from the centerline of post 7.

Table 6.5. Exit Parameters for *MASH* TEST 3-11, Crash Test 620061-01-2.

Exit Parameter	Measured
Speed	Out of frame
Trajectory	Out of frame
Heading	Out of frame
Brakes applied post impact	Brakes not applied
Vehicle at rest position	96 ft downstream of impact point 3 ft to the traffic side
Comments:	Vehicle remained upright and stable. The vehicle met the exit box criteria[a]

[a]Per the *MASH* guidelines in Section 5.2.3, the exit box for the 2270P used in this test was 16.8 ft toward the traffic side as measured from the traffic side face of the rail and 32.8 ft downstream from loss of contact.

6.5. DAMAGE TO TEST INSTALLATION

The rail between posts 5 and 6 split, with multiple places gouged and scuffed. The rail between posts 6 and 7 shattered and was heavily damaged, with the backing plate deformed. The splice plate at post 7 was deformed. The upstream rail at the joint between post 7 and 8 was splintered and gouged. At the upstream end of post 7, the tire snagged and tore off.

Table 6.6 describes the damage to the test installation and Table 6.7 describes the deflection and working width of the Merritt Parkway Guiderail. Figure 6.6 and Figure 6.7 show the damage to the Merritt Parkway Guiderail.

Table 6.6. Damage to the Merritt Parkway Guiderail for Test 620061-01-2.

Post #	Soil Gap (Inches)	Post Lean (Degrees)	Comments
2	Soil Disturbed	----	----
3	Soil Disturbed	----	----
4	Soil cracking, 0.5 traffic side	----	----
5	0.3 traffic side, 1 upstream	88.3 field side	----
6	Gravel blown out	75.3 field side	Blockout was split
7	5- field side	73.2 field side	Blockout split, post was twisted counterclockwise
8	0.3 field side, 0.5 upstream-	89 field side	----
9	0.1 field side	89.7 field side	----
10	Soil disturbed	----	----
11-18	No movement	No lean	----

Table 6.7. Deflection and Working Width of the Merritt Parkway Guiderail for Test 620061-01-2.

Test Parameter	Measured
Permanent Deflection/Location	21 inches toward field side, 45 inches upstream of centerline of post 7
Dynamic Deflection	48.7 inches on the rail between posts 6 and 7
Working Width [a] and Height	48.7 inches, at a height of 30 inches at the top of the rail

[a] Per *MASH*, "The working width is the maximum dynamic lateral position of any major part of the system or vehicle. These measurements are all relative to the pre-impact traffic face of the test

article." In other words, working width is the total barrier width plus the maximum dynamic intrusion of any portion of the barrier or test vehicle past the field side edge of the barrier.

Figure 6.6. Merritt Parkway Guiderail at Impact Location after Test 620061-01-2.

Figure 6.7. Merritt Parkway Guiderail In-Line Downstream View after Test 620061-01-2.

6.6. DAMAGE TO TEST VEHICLE

Figure 6.8 and Figure 6.9 show the damage sustained by the vehicle. Figure 6.10 and Figure 6.11 show the interior of the test vehicle. Table 6.8 and Table 6.9 provide details on the occupant compartment deformation and exterior vehicle damage. Figure C.2 and Figure C.3 in Appendix C.1 provide exterior crush and occupant compartment measurements.

Figure 6.8. Impact Side of Test Vehicle after Test 620061-01-2.

Figure 6.9. Rear Impact Side of Test Vehicle after Test 620061-01-2.

Figure 6.10. Overall Interior of Test Vehicle after Test 620061-01-2.

Figure 6.11. Interior of Test Vehicle on Impact Side after Test 620061-01-2.

Table 6.8. Occupant Compartment Deformation for Test 620061-01-2.

Test Parameter	Specification (inches)	Measured (inches)
Roof	≤4.0	0.0
Windshield	≤3.0	0.0
A and B Pillars	≤5.0 overall/≤3.0 lateral	0.0
Foot Well/Toe Pan	≤9.0	1.8
Floor Pan/Transmission Tunnel	≤12.0	0.0
Side Front Panel	≤12.0	2.3
Front Door (above Seat)	≤9.0	0.0
Front Door (below Seat)	≤12.0	0.0

Table 6.9. Exterior Vehicle Damage for Test 620061-01-2.

Test Parameter	Details
Side Windows	Remained intact
Maximum Exterior Deformation	20 inches at front bumper
VDS	01RFQ5
CDC	01FREE5
Fuel Tank Damage	None
Description of Damage to Vehicle:	Both headlights were fractured and the grill, bumper, hood, fender, radiator, and support were damaged, and the control arm was fractured. The left front frame was bent and the right front tire and wheel were separated. The right front door was scraped and dented and the lower portion deformed and created an 8-inch long × 7.5-inch wide hole where the floor pan was visible and elements of the test article had penetrated through. The right front door also had a 5.5-inch gap at the top, and its side view mirror was dislodged.

6.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 6.10. Figure C.8 in Appendix C.3 shows the vehicle angular displacements, and Figure C.7 through Figure C.9 in Appendix C.4 show acceleration versus time traces.

Table 6.10. Occupant Risk Factors for Test 620061-01-2.

Test Parameter	Specification [a]	Measured	Time
OIV, Longitudinal (ft/s)	≤40.0 *30.0*	22.8	0.1539 seconds on right side of interior
OIV, Lateral (ft/s)	≤40.0 *30.0*	13.4	0.1539 seconds on right side of interior
Ridedown, Longitudinal (g)	≤20.49 *15.0*	16.2	0.1907 - 0.2007 seconds
Ridedown, Lateral (g)	≤20.49 *15.0*	8.5	0.1539 - 0.1639 seconds
Theoretical Head Impact Velocity (THIV) (m/s)	N/A	7.3	0.1471 seconds on right side of interior
Acceleration Severity Index	N/A	1.1	0.1842 - 0.2342 seconds
50-ms Moving Avg. Accelerations (MA) Longitudinal (g)	N/A	-11.2	0.1708 - 0.2208 seconds
50-ms MA Lateral (g)	N/A	-6	0.1400 - 0.1900 seconds
50-ms MA Vertical (g)	N/A	2.9	0.2470 - 0.2970 seconds
Roll (°)	≤75	14.9	0.7883 seconds
Pitch (°)	≤75	8.5	0.5092 seconds
Yaw (°)	N/A	41.1	0.8465 seconds

a. *Values in italics are the preferred MASH values*

Note: N/A = Not Applicable

6.8. TEST SUMMARY

Figure 6.12 summarizes the results of *MASH* Test 3-11 (Test 620061-01-2).

0.000 s

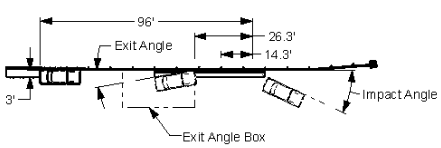
0.2000 s

0.4000 s

0.6000s

GENERAL INFORMATION	
Test Agency:	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.:	*MASH* 2016, Test 3-11
Project No.:	620061-01-2
Test Date:	9/10/2024
TEST ARTICLE	
Type:	Longitudinal Barrier
Name:	Merritt Parkway Guiderail
Length:	166 feet
Key Materials:	Weathering steel, commercial lumber grade No.1, galvanized steel
Soil Type and Condition:	Type D grade 1 crushed concrete road base, damp
TEST VEHICLE	
Type/Designation:	2270P
Year, Make and Model:	2018 RAM 1500
Inertial Mass:	5048 lb
Dummy Mass:	N/A lb
Gross Static Mass:	5048 lb
IMPACT CONDITIONS	
Impact Speed:	63.6 mi/h
Impact Angle:	25.0°
Impact Location:	171.1 inches upstream from the centerline of post 7
Impact Severity:	125.0 kip-ft
EXIT CONDITIONS	
Exit Speed:	Out of frame
Trajectory/Heading Angle:	Out of frame
Exit Box Criteria:	The vehicle met the exit box criteria

Stopping Distance:	96 ft downstream 3 ft to the traffic side
TEST ARTICLE DEFLECTIONS	
Dynamic:	48.7 inches
Permanent:	21 inches
Working Width:	48.7 inches
Working Width Height:	30.00 inches
VEHICLE DAMAGE	
VDS:	01RFQ5
CDC:	01FREE5
Max Exterior Deformation:	20 inches at front bumper
Max Occupant Compartment Deformation:	2.3 inches in the side front panel
OCCUPANT RISK VALUES	
Longitudinal OIV:	22.8 ft/s
Lateral OIV:	13.4 ft/s
Longitudinal Ridedown:	16.2 g
Lateral Ridedown:	8.5 g
THIV:	7.3 m/s
ASI:	1.1
Max 50ms Longitudinal:	-11.2 g
Max 50ms Lateral:	-6 g
Max 50ms Vertical:	2.9 g
Max Roll:	14.9°
Max Pitch:	8.5°
Max Yaw:	41.1°



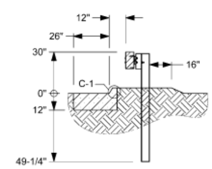


Figure 6.12. Summary of Results for *MASH* Test 3-11 (Test 620061-01-2) on Merritt Parkway Guiderail.

CHAPTER 7. DESIGN ANALYSIS – PART II

The design concept that incorporated 1-inch-thick splice plates was evaluated with full-scale crash testing. The system failed to meet the criteria for *MASH* Test 3-11. The leading edge of the pickup truck impact side door snagged on the rail element and peeled the edge backwards. This exposed a large hole that allowed pieces of the timber rail to penetrate into the occupant compartment.

The snagging of the pickup truck door on the rail occurred near the joint location at post 7. Figure 7.1 shows the rail deflection profile as the pickup truck vehicle is being redirected after impact. This joint displacement presented edges of the rail that snagged on the pickup truck vehicle door.

To counteract this snagging effect, an alternative design was considered that moved the joint and splice connection to midspan between the posts. The goal of this design change was to allow for a smoother deflection profile that would reduce vehicle pocketing and snagging behavior.

Figure 7.1. Rail Displacement at Post 7 in Crash Test 620061-01-2.

Using the FE model developed in Chapter 2, computer simulations were performed to evaluate this alternative design. The 1-inch-thick splice plates were incorporated into the model along with moving the joint to midspan between posts. Figure 7.2 and Figure 7.3 show elevation and plan views of the FE model.

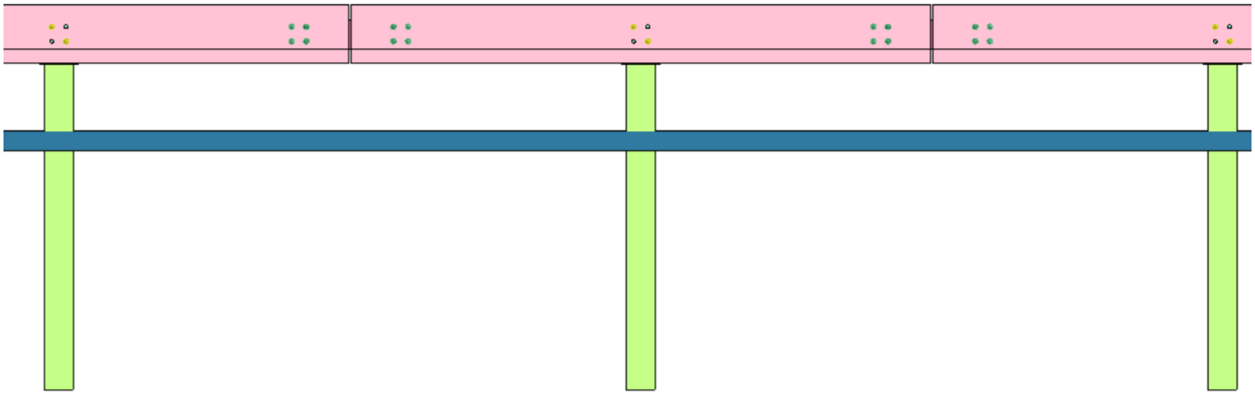


Figure 7.2. Elevation View of FE Model.

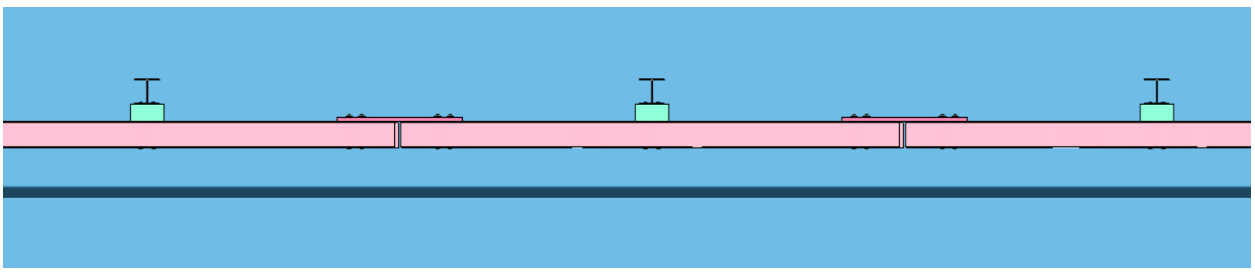


Figure 7.3. Plan View of FE Model.

The alternative design was evaluated according to *MASH* Test 3-11 with computer simulations. The system was impacted with the 2270P vehicle at an impact speed and angle of 62 mi/h and 25 degrees. The critical impact location was 14 ft upstream from the centerline of the joint between posts 7 and 8. This impact location aligns with the CIP used for Test 620061-01-2.

Figure 7.4 shows sequential images for the simulation run. Table 7.1 shows the occupant risk values for the simulation run compared to the previous design. The occupant risk values were similar when comparing the two simulation outputs for the systems. Figure 7.5 shows the rail deflection profile as the vehicle is being redirected and is beginning to engage the critical joint between posts 7 and 8. The alternative design indicated improved deflection and less relative displacement of the rails at the splice joint in comparison to the crash tested system (see Figure 7.1).

Installation details for the alternative design were finalized, and the system was constructed and evaluated through full-scale crash testing. This evaluation is described in Chapters 8 and 9.

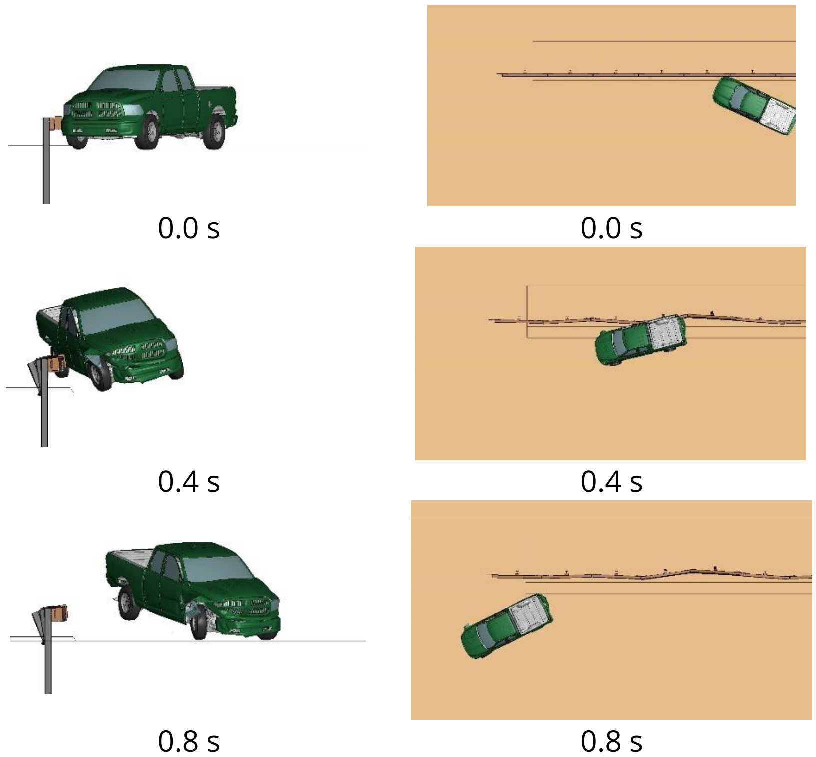


Figure 7.4. Sequential Images for MASH Test 3-11 Simulation – Splice at Midspan.

Table 7.1. Occupant Risk Comparison for Design Concepts.

	1in Splice Plate – at Post	1in Splice Plate - at Midspan
OIV, Longitudinal (ft/s)	18.1	14.9
OIV, Lateral (ft/s)	21.0	20.9
RDA, Longitudinal (g)	9.9	7.7
RDA, Lateral (g)	12.5	13.6
Roll (deg)	33.1	19.1
Pitch (deg)	14.6	21.1
Yaw (deg)	40.2	56.0

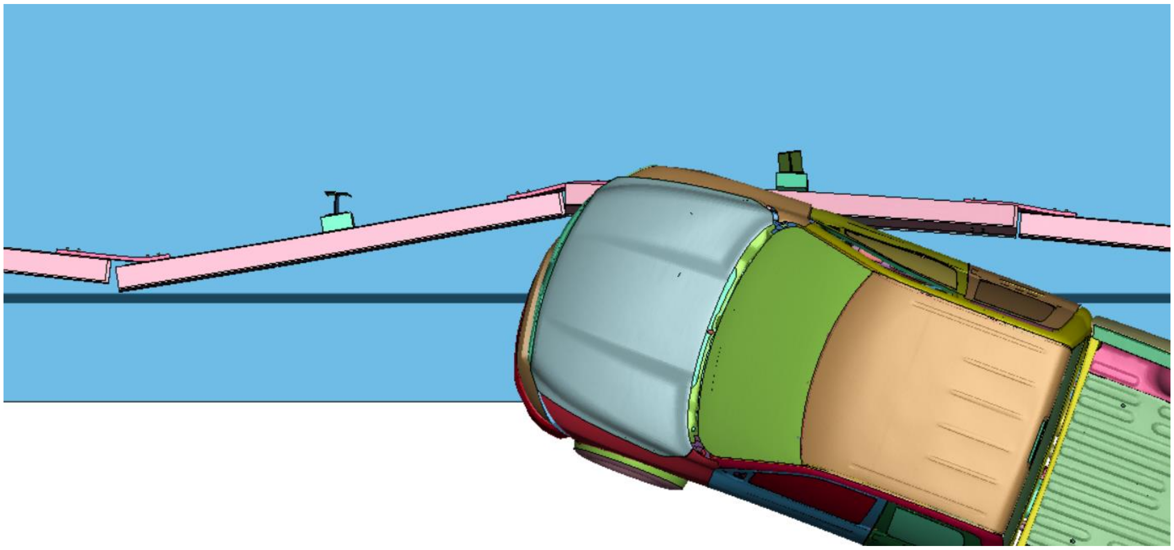


Figure 7.5. Rail Deflection Profile as Truck Engages CIP Joint.

CHAPTER 8.

MASH TEST 3-11 (CRASH TEST 620061-01-1)

8.1. CRITICAL IMPACT POINT LOCATION

The Critical Impact Point (CIP) for this test was 168 inches (14ft) upstream from the centerline of the joint between posts 7 and 8 at 25 degrees. The target CIP for this test was determined using the information provided in *MASH* Section 2.2.1 and MASH Section 2.3.2. Figure 8.1 shows the target CIP for Test 620061-01-1. Figure 8.2 and Figure 8.3 depict the vehicle at the CIP prior to Test 620061-01-1.

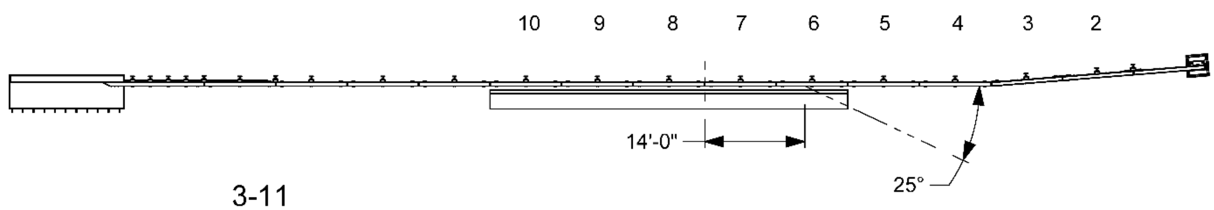


Figure 8.1. Target CIP for Test 620061-01-1.

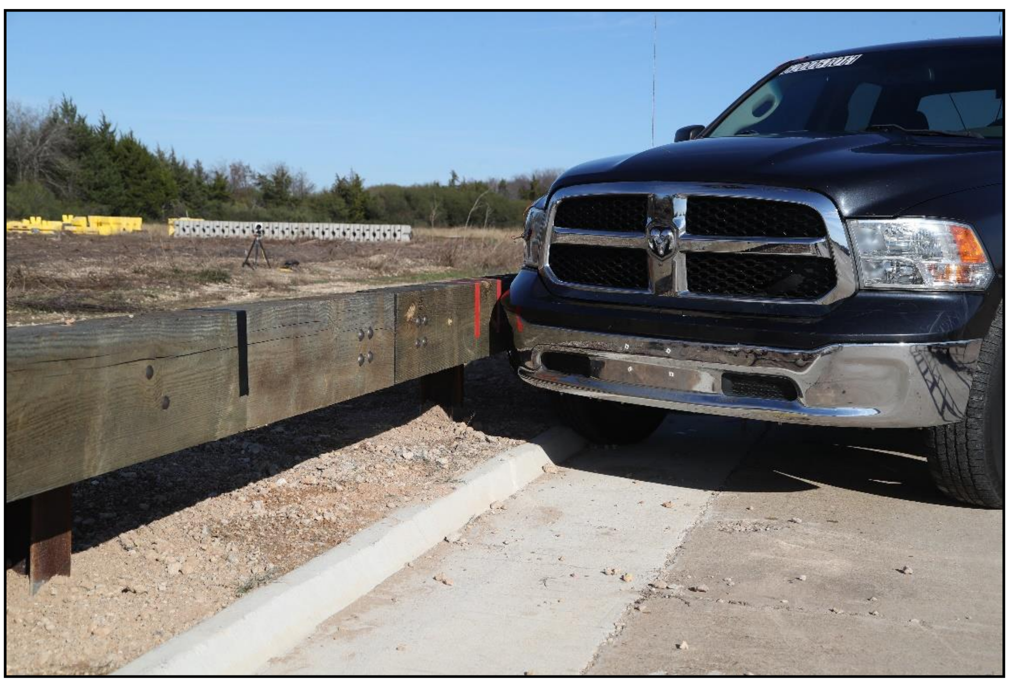


Figure 8.2. Merritt Parkway Guiderail/Test Vehicle Geometrics for Test 620061-01-1.

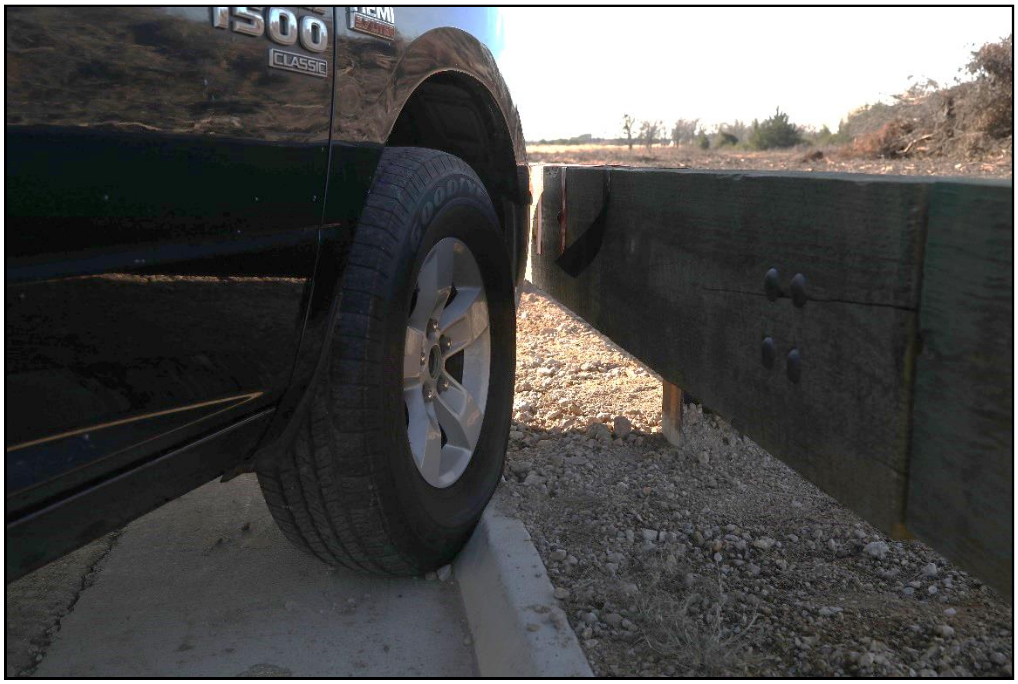


Figure 8.3. Merritt Parkway Guiderail/Test Vehicle Impact Location for Test 620061-01-1.

8.2. TEST VEHICLE DETAILS PRIOR TO IMPACT

Table 8.1 shows the vehicle measurements. Figure 8.4 and Figure 8.5 show the 2019 RAM 1500 used for the crash test. Figure D.1 in Appendix D.1 gives additional dimensions and information on the vehicle.

Table 8.1. Vehicle Measurements for Test 620061-01-1.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a] (lb)	165	N/A	N/A
Inertial Mass (lb)	5000	±110	5026
Gross Static[a] Mass (lb)	5165	±110	5026
Wheelbase (inches)	148	±12	140.5
Front Overhang (inches)	39	±3	40.3
Overall Length (inches)	237	±13	229.0
Overall Width (inches)	78	±2	78.5
Hood Height (inches)	43	±4	46.0
Track Width[b] (inches)	67	±1.5	68.3
CG aft of Front Axle[c] (inches)	63	±4	60.8
CG above Ground[c,d] (inches)	28	28	28.5

Note: N/A = not applicable; CG = center of gravity.

[a] If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy.
[b] Average of front and rear axles.
[c] For test inertial mass.
[d] 2270P vehicle must meet minimum CG height requirement.

Figure 8.4. Impact Side of Test Vehicle before Test 620061-01-1.

Figure 8.5. Impact Side Rear View of Test Vehicle before Test 620061-01-1.

8.3. TEST DESCRIPTION

8.3.1. Weather Conditions

Table 8.2 provides the weather conditions for Test 620061-01-1.

Table 8.2. Weather Conditions for Test 620061-01-1.

Date of Test	1/13/2025
Wind Speed	6 mi/h
Wind Direction	40°
Temperature	49°F
Relative Humidity	62 %
Vehicle Traveling	195°

8.3.2. Test Events

Table 8.3 lists events that occurred during Test 620061-01-1. The figures in Appendix D.2 present sequential photographs during the test.

Table 8.3. Events during Test 620061-01-1.

Time (seconds)	Events
0.0000	Vehicle impacted the installation
0.0170	Post 6 began to move
0.0450	Vehicle began to redirect
0.1890	Front left tire lost contact with the pavement
0.2130	Rear left tire lost contact with the pavement
0.3190	Vehicle was parallel with installation
0.6090	Vehicle exited the installation

8.4. TEST ACTUAL IMPACT CONDITIONS

Table 8.4 lists the details of the *MASH* impact conditions for this test and Table 8.5 lists the exit parameters.

Table 8.4. Impact Conditions for *MASH* TEST 3-11, Crash Test 620061-01-1.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5	64.2
Impact Angle (°)	25	±1.5	25.1
Impact Severity (kip-ft)	106	≥106	124.6
Impact Location	168 inches (14ft) upstream from the centerline of the joint between posts 7 and 8.	±1 foot (12 inches)	171 inches (14.3 ft) upstream from the centerline of the joint between posts 7 and 8

Table 8.5. Exit Parameters for *MASH* TEST 3-11, Crash Test 620061-01-1.

Exit Parameter	Measured
Brakes applied post impact	Brakes not applied
Vehicle at rest position	105 ft downstream of impact point In-line
Comments:	Vehicle remained upright and stable. The vehicle did not meet the exit box criteria[a] by crossing the exit box 26 feet downstream from loss of contact.

[a]Per the *MASH* guidelines in Section 5.2.3, the exit box for the 2270P used in this test was 16.8 ft toward the traffic side as measured from the traffic side face of the rail and 32.8 ft downstream from loss of contact.

8.5. DAMAGE TO TEST INSTALLATION

There was a large gouge on the rail approximately 1-inch downstream of post 6. The full length of the rail at post 7, along with the blockout, was split and fractured. At post 8, the rail split and was gouged from upstream end to 2 feet downstream of post. The system experienced a secondary impact near the end of the installation where the vehicle came to rest.

Table 8.6 describes the damage to the test installation and Table 8.7 describes the deflection and working width of the Merritt Parkway Guiderail. Figure 8.6 and Figure 8.7 show the damage to the Merritt Parkway Guiderail.

Table 8.6. Damage of the Merritt Parkway Guiderail for Test 620061-01.

Post #	Soil Gap (Inches)	Post Lean (Degrees)	Comments
5	1 traffic side	86 field side	----
6	5.5 traffic side	73 field side	----
7	13 traffic side	64 field side	----
8	6 traffic side	79 field side	----
9	0.8 traffic side	88 field side	----
10	Soil Disturbed	----	----

Table 8.7. Deflection and Working Width of the Merritt Parkway Guiderail for Test 620061-01-1.

Test Parameter	Measured
Permanent Deflection/Location	21.0 inches toward field side, at post 7
Dynamic Deflection	35.0 inches toward field side 7.6 inches upstream from the joint between posts 7 and 8
Working Width [a] and Height	48.5 inches, at a height of 49.7 inches, at the right-side view mirror.

[a] Per *MASH*, "The working width is the maximum dynamic lateral position of any major part of the system or vehicle. These measurements are all relative to the pre-impact traffic face of the test article." In other words, working width is the total barrier width plus the maximum dynamic intrusion of any portion of the barrier or test vehicle past the field side edge of the barrier.

Figure 8.6. Merritt Parkway Guiderail at Impact Location after Test 620061-01-1.

Figure 8.7. Merritt Parkway Guiderail In-Line Downstream View after Test 620061-01-1.

8.6. DAMAGE TO TEST VEHICLE

Figure 8.8 and Figure 8.9 show the damage sustained by the vehicle. Figure 8.10 and Figure 8.11 show the interior of the test vehicle. Table 8.8 and Table 8.9 provide details on the occupant compartment deformation and exterior vehicle damage. Figure D.2 and Figure D.3 in Appendix D.1 provide exterior crush and occupant compartment measurements.

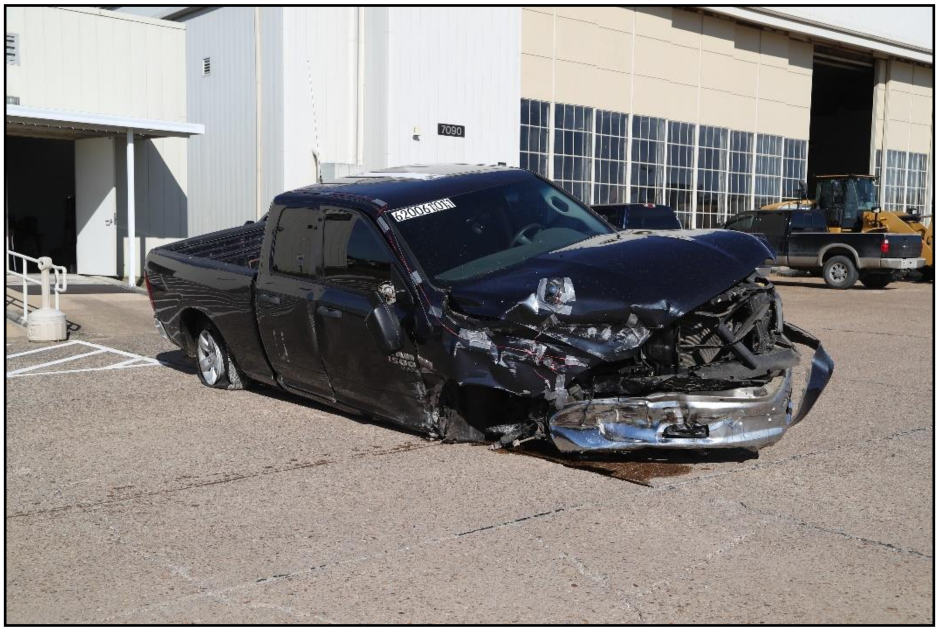


Figure 8.8. Impact Side of Test Vehicle after Test 620061-01-1.

Figure 8.9. Rear Impact Side of Test Vehicle after Test 620061-01-1.


Figure 8.10. Overall Interior of Test Vehicle after Test 620061-01-1.


Figure 8.11. Interior of Test Vehicle on Impact Side after Test 620061-01-1.

Table 8.8. Occupant Compartment Deformation for Test 620061-01-1.

Test Parameter	Specification (inches)	Measured (inches)
Roof	≤4.0	0.0
Windshield	≤3.0	0.0
A and B Pillars	≤5.0 overall/≤3.0 lateral	0.0
Foot Well/Toe Pan	≤9.0	1.0
Floor Pan/Transmission Tunnel	≤12.0	0.0
Side Front Panel	≤12.0	0.5
Front Door (above Seat)	≤9.0	0.0
Front Door (below Seat)	≤12.0	0.0

Table 8.9. Exterior Vehicle Damage for Test 620061-01-1.

Test Parameter	Details
Side Windows	Remained intact
Maximum Exterior Deformation	22 inches at front bumper
VDS	01RFQ5
CDC	01FREE4
Fuel Tank Damage	None
Description of Damage to Vehicle:	On the impact side of vehicle, the headlight was removed, the front fender was crushed, the front door was deformed, the front tire ruptured, and the front wheel was dislodged at the A-Arm. The right and left mirrors fractured and the right rear tire was deflated. The hood, bumper, grill, and radiator were significantly damaged. On the lower right rear bed there was a small deformation and a 1.5-inch gap at the top of the right front door. Visible cracks in the right-side windshield were evident.

8.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 8.10. Figure D.7 in Appendix D.3 shows the vehicle angular displacements, and Figure D.8 through Figure D.10 in Appendix D.4 show acceleration versus time traces.

Table 8.10. Occupant Risk Factors for Test 620061-01-1.

Test Parameter	Specification [a]	Measured	Time
OIV, Longitudinal (ft/s)	≤40.0 *30.0*	25.4	0.1392 seconds on right side of interior
OIV, Lateral (ft/s)	≤40.0 *30.0*	19.1	0.1392 seconds on right side of interior
Ridedown, Longitudinal (g)	≤20.49 *15.0*	17.1	0.1392 - 0.1492 seconds
Ridedown, Lateral (g)	≤20.49 *15.0*	8.1	0.2454 - 0.2554 seconds
Theoretical Head Impact Velocity (THIV) (m/s)	N/A	8.7	0.1343 seconds on right side of interior
Acceleration Severity Index	N/A	1.2	0.1252 - 0.1752 seconds
50-ms Moving Avg. Accelerations (MA) Longitudinal (g)	N/A	-11.2	0.1000 - 0.1500 seconds
50-ms MA Lateral (g)	N/A	-7.7	0.1004 - 0.1504 seconds
50-ms MA Vertical (g)	N/A	-3.8	0.5718 - 0.6218 seconds
Roll (°)	≤75	28.3	0.7863 seconds
Pitch (°)	≤75	8.5	0.5924 seconds
Yaw (°)	N/A	43.5	0.4792 seconds

[a.] *Values in italics are the preferred MASH values*

Note: N/A = Not Applicable

8.8. TEST SUMMARY

Figure 8.12 summarizes the results of *MASH* Test 3-11 (Test 620061-01-1).

0.000 s

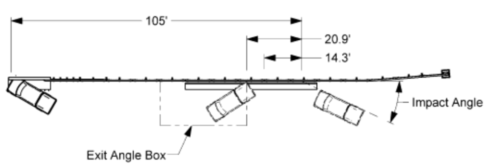
0.2000 s

0.4000 s

0.6000s

GENERAL INFORMATION	
Test Agency:	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.:	*MASH* 2016, Test 3-11
Project No.:	620061-01-1
Test Date:	1/13/2025
TEST ARTICLE	
Type:	Longitudinal Barrier
Name:	Merritt Parkway Guiderail
Length:	166 feet
Key Materials:	Weathering steel, commercial lumber grade No.1, galvanized steel
Soil Type and Condition:	Type D grade 1 crushed concrete road base, damp
TEST VEHICLE	
Type/Designation:	2270P
Year, Make and Model:	2019 RAM 1500
Inertial Mass:	5026 lb
Dummy Mass:	N/A
Gross Static Mass:	5026 lb
IMPACT CONDITIONS	
Impact Speed:	64.2 mi/h
Impact Angle:	25.10°
Impact Location:	171 inches (14.3 ft) upstream from the centerline of the joint between posts 7 and 8
Impact Severity:	124.6 kip-ft
EXIT CONDITIONS	
Exit Box Criteria:	The vehicle did not meet the exit box criteria

Stopping Distance:	105 feet ft downstream In-line
TEST ARTICLE DEFLECTIONS	
Dynamic:	35.0 inches
Permanent:	21 inches
Working Width:	48.5 inches
Working Width Height:	49.7 inches
VEHICLE DAMAGE	
VDS:	01RFQ5
CDC:	01FREE4
Max Exterior Deformation:	22 at front bumper
Max Occupant Compartment Deformation:	1 inch in the foot well/toe pan
OCCUPANT RISK VALUES	
Longitudinal OIV:	25.4 ft/s
Lateral OIV:	19.1 ft/s
Longitudinal Ridedown:	17.1 g
Lateral Ridedown:	8.1 g
THIV:	8.7 m/s
ASI:	1.2
Max 50ms Longitudinal:	-11.2 g
Max 50ms Lateral:	-7.7 g
Max 50ms Vertical:	-3.8 g
Max Roll:	28.3°
Max Pitch:	8.5°
Max Yaw:	43.5°



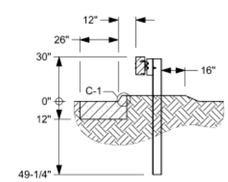


Figure 8.12. Summary of Results for *MASH* Test 3-11 (Test 620061-01-1) on Merritt Parkway Guiderail.

CHAPTER 9.

MASH TEST 3-10 (CRASH TEST 620061-01-3)

9.1. CRITICAL IMPACT POINT LOCATION

The Critical Impact Point (CIP) for this test was 60 inches (5 ft) upstream from the centerline of the joint between posts 7 and 8 at 25 degrees. The target CIP for this test was determined using the information provided in *MASH* Section 2.2.1 and MASH Section 2.3.2. Figure 9.1 shows the target CIP for Test 620061-01-3. Figure 9.2 and Figure 9.3 depict the vehicle at the CIP prior to Test 620061-01-3.

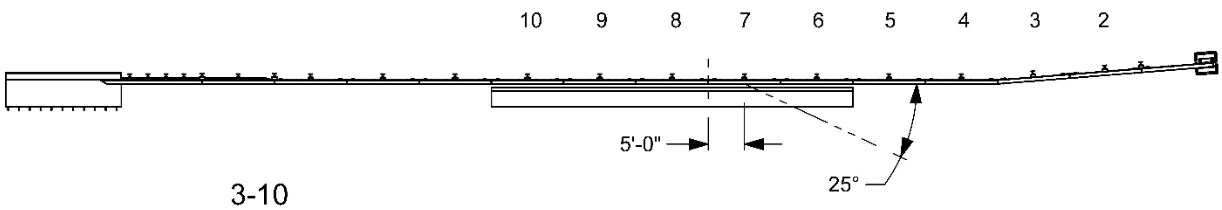


Figure 9.1. Target CIP for Test 620061-01-3.

Figure 9.2. Merritt Parkway Guiderail/Test Vehicle Geometrics for Test 620061-01-3.

Figure 9.3. Merritt Parkway Guiderail/Test Vehicle Impact Location for Test 620061-01-3.

9.2. TEST VEHICLE DETAILS PRIOR TO IMPACT

Table 9.1 shows the vehicle measurements. Figure 9.4 and Figure 9.5 show the 2019 Nissan Versa used for the crash test. Figure E.1 in Appendix E.1 gives additional dimensions and information on the vehicle.

Table 9.1. Vehicle Measurements for Test 620061-01-3.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a] (lb)	165	N/A	165
Inertial Mass (lb)	2420	±55	2431
Gross Static[a] Mass (lb)	2585	±55	2596
Wheelbase (inches)	98	±5	102.4
Front Overhang (inches)	35	±4	32.5
Overall Length (inches)	169	±8	175.4
Overall Width (inches)	65	±3	66.7
Hood Height (inches)	28	±4	30.5
Track Width[b] (inches)	59	±2	58.4
CG aft of Front Axle[c] (inches)	39	±4	41.6
CG above Ground[c,d] (inches)	N/A	N/A	N/A

Note: N/A = not applicable; CG = center of gravity.

[a] If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy.

[b] Average of front and rear axles.

[c] For test inertial mass.

[d] 2270P vehicle must meet minimum CG height requirement.

Figure 9.4. Impact Side of Test Vehicle before Test 620061-01-3.

Figure 9.5. Opposite Impact Side of Test Vehicle before Test 620061-01-3.

9.3. TEST DESCRIPTION

9.3.1. Weather Conditions

Table 9.2 provides the weather conditions for Test 620061-01-3.

Table 9.2. Weather Conditions for Test 620061-01-3.

Date of Test	1/17/2025
Wind Speed	12 mi/h
Wind Direction	171°
Temperature	57°F
Relative Humidity	70 %
Vehicle Traveling	195°

9.3.2. Test Events

Table 9.3 lists events that occurred during Test 620061-01-3. The figures in Appendix E.2 present sequential photographs during the test.

Table 9.3. Events during Test 620061-01-3.

Time (seconds)	Events
-0.0012	Vehicle impacted the curb
0.0000	Vehicle impacted the installation
0.0170	Post 7 began to move toward field side
0.0150	Vehicle began to redirect
0.0290	Post 8 began to move toward field side
0.3100	Vehicle was parallel with installation
0.3890	Front driver's side tire began to lift off pavement
0.5030	Front driver's side tire landed on pavement
0.5430	Vehicle exited the installation

9.4. TEST ACTUAL IMPACT CONDITIONS

Table 9.4 lists the details of the *MASH* impact conditions for this test and Table 9.5 lists the exit parameters.

Table 9.4. Impact Conditions for *MASH* TEST 3-10, Crash Test 620061-01-3.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5	61.7
Impact Angle (°)	25	±1.5	24.2
Impact Severity (kip-ft)	51	≥51	51.9
Impact Location	60 inches upstream from the centerline of the joint between posts 7 and 8	±1 foot (12 inches)	59.7 inches upstream from the centerline of the joint between posts 7 and 8

Table 9.5. Exit Parameters for *MASH* TEST 3-10, Crash Test 620061-01-3.

Exit Parameter	Measured
Speed	33.9 mi/h
Trajectory	10.5°
Heading	14.2°
Brakes applied post impact	1.7 seconds
Vehicle at rest position	102 feet ft downstream of impact point 54 ft to the traffic side
Comments:	Vehicle remained upright and stable. The vehicle did meet the exit box criteria[a] by crossing the exit box 42 feet downstream from loss of contact.

[a]Per the *MASH* guidelines in Section 5.2.3, the exit box for the 1100C used in this test was 15.1 ft toward the traffic side as measured from the traffic side face of the rail and 32.8 ft downstream from loss of contact.

9.5. DAMAGE TO TEST INSTALLATION

The rail was deformed at the joint between 7 and 8 with scuffing and gouging of the rail. The downstream rail at joint between 7 and 8 was heavily splintered.

Table 9.6 describes the damage to the test installation and Table 9.7 describes the deflection and working width of the Merritt Parkway Guiderail. Figure 9.6 and Figure 9.7 show the damage to the Merritt Parkway Guiderail.

Table 9.6. Damage to the Merritt Parkway Guiderail for Test 620061-01-3.

Post #	Soil Gap (Inches)	Post Lean (Degrees)	Comments
3	0.3 upstream	----	----
4	0.3 upstream, 0.2 field side	----	----
5	Soil disturbed	89.5 traffic side	----
6	0.5 field side, 0.4 upstream	82.5 field side	----
7	2.5 traffic side, 0.3 downstream	79.1 field side	Slight clockwise twist
8	2.6 field side	87.8 field side	Webbing is deformed, blockout is heavily splintered, and traffic side flange is deformed
9	.07 traffic side, 0.3 field side	----	----
10	0.3 field side	----	----
11	0.2 field side	----	----
12 - 13	Soil disturbed	----	----

Table 9.7. Deflection and Working Width of the Merritt Parkway Guiderail for Test 620061-01-3.

Test Parameter	Measured
Permanent Deflection/Location	15.8 inches toward field side, 11 inches downstream from the joint between posts 7 and 8
Dynamic Deflection	23.4 inches toward field side joint between posts 7 and 8
Working Width [a] and Height	33.7 inches, at a height of 28 inches at the top of post 8

[a] Per *MASH*, "The working width is the maximum dynamic lateral position of any major part of the system or vehicle. These measurements are all relative to the pre-impact traffic face of the test article." In other words, working width is the total barrier width plus the maximum dynamic intrusion of any portion of the barrier or test vehicle past the field side edge of the barrier.

Figure 9.6. Merritt Parkway Guiderail at Impact Location after Test 620061-01-3.

Figure 9.7. Merritt Parkway Guiderail In-Line Downstream View after Test 620061-01-3.

9.6. DAMAGE TO TEST VEHICLE

Figure 9.8 and Figure 9.9 show the damage sustained by the vehicle. Figure 9.10 and Figure 9.11 show the interior of the test vehicle. Table 9.8 and Table 9.9 provide details on the occupant compartment deformation and exterior vehicle damage. Figure E.2 and Figure E.3 in Appendix E.1 provide exterior crush and occupant compartment measurements.

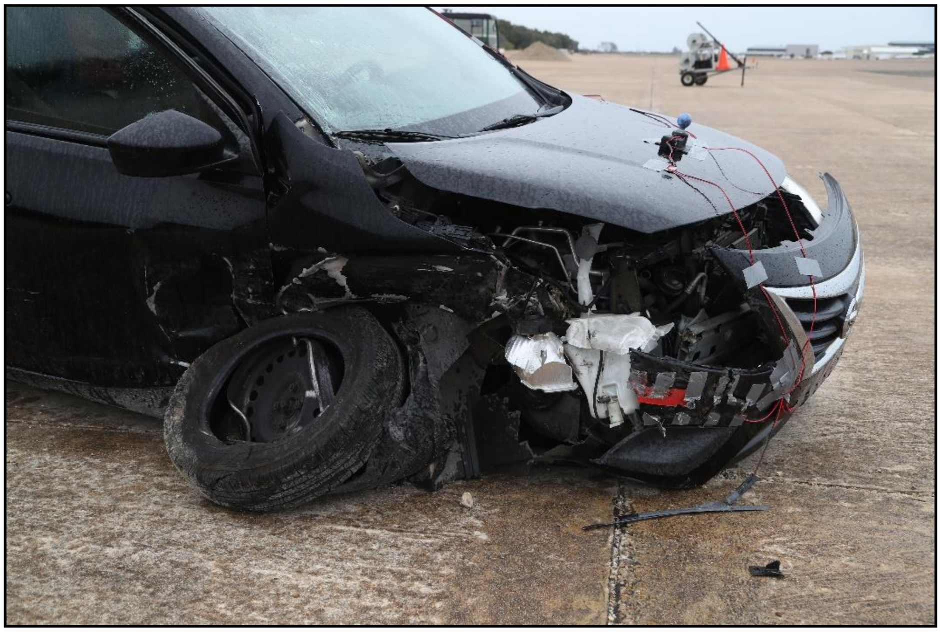


Figure 9.8. Impact Side of Test Vehicle after Test 620061-01-3.

Figure 9.9. Rear Impact Side of Test Vehicle after Test 620061-01-3.

Figure 9.10. Overall Interior of Test Vehicle after Test 620061-01-3.

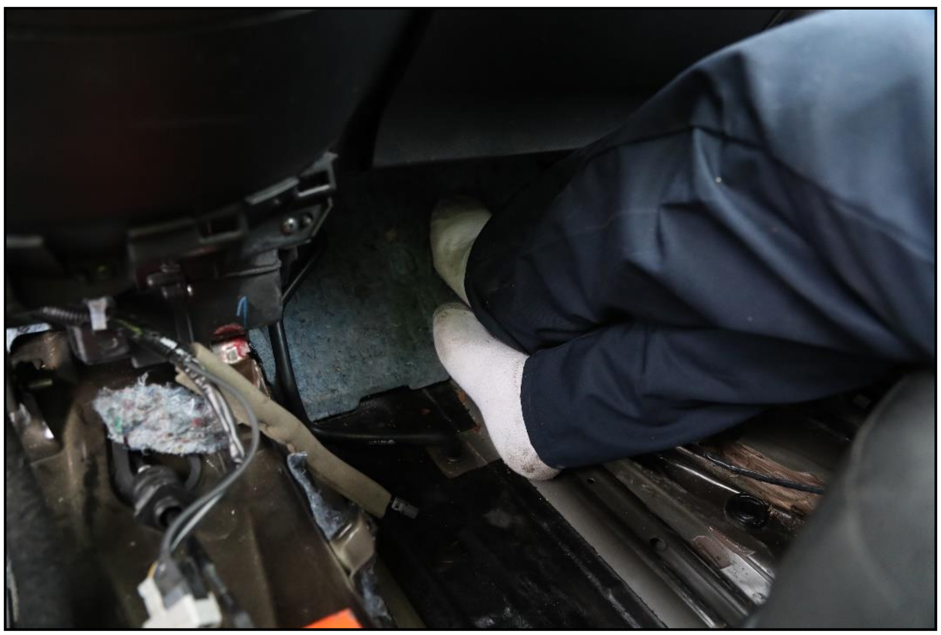


Figure 9.11. Interior of Test Vehicle on Impact Side after Test 620061-01-3.

Table 9.8. Occupant Compartment Deformation for Test 620061-01-3.

Test Parameter	Specification (inches)	Measured (inches)
Roof	≤4.0	0.8
Windshield	≤3.0	0.0
A and B Pillars	≤5.0 overall/≤3.0 lateral	0.0
Foot Well/Toe Pan	≤9.0	1.3
Floor Pan/Transmission Tunnel	≤12.0	2.3
Side Front Panel	≤12.0	3.8
Front Door (above Seat)	≤9.0	0.0
Front Door (below Seat)	≤12.0	0.0

Table 9.9. Exterior Vehicle Damage for Test 620061-01-3.

Test Parameter	Details
Side Windows	Remained intact
Maximum Exterior Deformation	12 inches at front bumper
VDS	01FRQ5
CDC	01FREN4
Fuel Tank Damage	None
Description of Damage to Vehicle:	The bumper and bumper cover were damaged, the radiator was fractured, and the support was deformed. The right headlight dislodged, there were cracks on the right side of the windshield along with scratches and deformations on the front door and rear quarter panel. The right front tire ruptured and the wheel dislodged. The right front subframe, A-arm, and strut were all deformed. The ball joint was separated from the strut and the control arm at the CV axle were deformed. There was a 3.5-inch gap at top of the right front door.

9.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 9.10. Figure E.7 in Appendix E.3 shows the vehicle angular displacements, and Figure E.8 through Figure E.10 in Appendix E.4 show acceleration versus time traces.

Table 9.10. Occupant Risk Factors for Test 620061-01-3.

Test Parameter	Specification [a]	Measured	Time
OIV, Longitudinal (ft/s)	≤40.0 *30.0*	27.8	0.1266 seconds on right side of interior
OIV, Lateral (ft/s)	≤40.0 *30.0*	21.6	0.1266 seconds on right side of interior
Ridedown, Longitudinal (g)	≤20.49 *15.0*	14.6	0.1579 - 0.1679 seconds
Ridedown, Lateral (g)	≤20.49 *15.0*	12.4	0.1271 - 0.1371 seconds
Theoretical Head Impact Velocity (THIV) (m/s)	N/A	10.5	0.1235 seconds on right side of interior
Acceleration Severity Index	N/A	1.4	0.1221 - 0.1721 seconds
50-ms Moving Avg. Accelerations (MA) Longitudinal (g)	N/A	-11.3	0.0908 - 0.1408 seconds
50-ms MA Lateral (g)	N/A	-9.1	0.0965 - 0.1465 seconds
50-ms MA Vertical (g)	N/A	-3.9	0.1415 - 0.1915 seconds
Roll (°)	≤75	10.6	0.2159 seconds
Pitch (°)	≤75	6.1	0.6158 seconds
Yaw (°)	N/A	55.4	1.4999 seconds

[a.] *Values in italics are the preferred MASH values*

Note: N/A = Not Applicable

9.8. TEST SUMMARY

Figure 9.12 summarizes the results of *MASH* Test 3-10 (Test 620061-01-3).

0.000 s

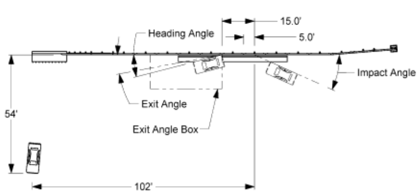
0.2000 s

0.4000 s

0.6000s

GENERAL INFORMATION	
Test Agency:	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.:	*MASH* 2016, Test 3-10
Project No.:	620061-01-3
Test Date:	1/17/2025
TEST ARTICLE	
Type:	Longitudinal Barrier
Name:	Merritt Parkway Guiderail
Length:	166 feet
Key Materials:	Weathering steel, commercial lumber grade No.1, galvanized steel
Soil Type and Condition:	Type D grade 1 crushed concrete road base, damp
TEST VEHICLE	
Type/Designation:	1100C
Year, Make and Model:	2019 Nissan Versa
Inertial Mass:	2431 lb
Dummy Mass:	165 lb
Gross Static Mass:	2596 lb
IMPACT CONDITIONS	
Impact Speed:	61.7 mi/h
Impact Angle:	24.17°
Impact Location:	59.7 inches upstream from the centerline of the joint between posts 7 and 8
Impact Severity:	51.9 kip-ft
EXIT CONDITIONS	
Exit Speed:	33.90 mi/h
Trajectory/Heading Angle:	10.45° / 14.22°

Exit Box Criteria:	The vehicle did meet the exit box criteria
Stopping Distance:	102 feet ft downstream 54 ft to the traffic side
TEST ARTICLE DEFLECTIONS	
Dynamic:	23.38 inches
Permanent:	15.8 inches
Working Width:	33.72 inches
Working Width Height:	28.00 inches
VEHICLE DAMAGE	
VDS:	01FRQ5
CDC:	01FREN4
Max Exterior Deformation:	12 inches at the front bumper
Max Occupant Compartment Deformation:	3.75 inches in the side front panel
OCCUPANT RISK VALUES	
Longitudinal OIV:	27.8 ft/s
Lateral OIV:	21.6 ft/s
Longitudinal Ridedown:	14.6 g
Lateral Ridedown:	12.4 g
THIV:	10.5 m/s
ASI:	1.4
Max 50ms Longitudinal:	-11.3 g
Max 50ms Lateral:	-9.1 g
Max 50ms Vertical:	-3.9 g
Max Roll:	10.6°
Max Pitch:	6.1°
Max Yaw:	55.4°



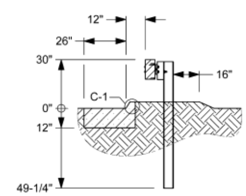


Figure 9.12. Summary of Results for *MASH* Test 3-10 (Test 620061-01-3) on Merritt Parkway Guiderail.

CHAPTER 10.

MASH TEST 3-11 (CRASH TEST 620061-01-4)

10.1. CRITICAL IMPACT POINT LOCATION

The Critical Impact Point (CIP) for this test was 168 inches (14 ft) upstream from the centerline of the joint between posts 7 and 8 at 25 degrees. The target CIP for this test was determined using the information provided in *MASH* Section 2.2.1 and MASH Section 2.3.2. Figure 10.1 shows the target CIP for Test 620061-01-4. Figure 10.2 and Figure 10.3 depict the vehicle at the CIP prior to Test 620061-01-4.

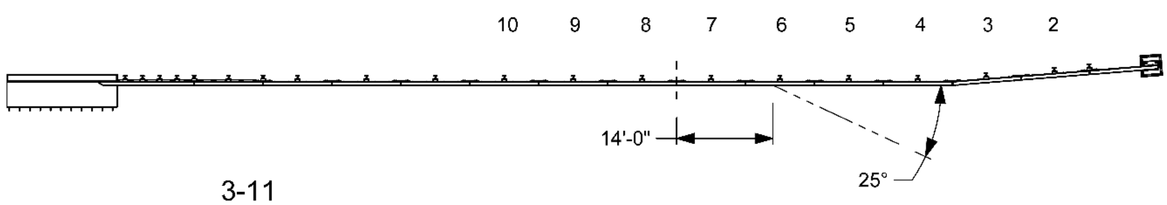


Figure 10.1. Target CIP for Test 620061-01-4.

Figure 10.2. Merritt Parkway Guiderail/Test Vehicle Geometrics for Test 620061-01-4.

Figure 10.3. Merritt Parkway Guiderail/Test Vehicle Impact Location 620061-01-4.

10.2. TEST VEHICLE DETAILS PRIOR TO IMPACT

Table 10.1 shows the vehicle measurements. Figure 10.4 and Figure 10.5 show the 2019 RAM 1500 used for the crash test. Figure F.1 in Appendix F.1 gives additional dimensions and information on the vehicle.

Table 10.1. Vehicle Measurements for Test 620061-01-4.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a] (lb)	165	N/A	N/A
Inertial Mass (lb)	5000	±110	5032
Gross Static[a] Mass (lb)	5000	±110	5032
Wheelbase (inches)	148	±12	140.5
Front Overhang (inches)	39	±3	40.25
Overall Length (inches)	237	±13	229
Overall Width (inches)	78	±2	78.5
Hood Height (inches)	43	±4	46
Track Width[b] (inches)	67	±1.5	68.25
CG aft of Front Axle[c] (inches)	63	±4	62.15
CG above Ground[c,d] (inches)	28	28	28.5

Note: N/A = not applicable; CG = center of gravity.

[a] If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy.

[b] Average of front and rear axles.

[c] For test inertial mass.

[d] 2270P vehicle must meet minimum CG height requirement.

Figure 10.4. Impact Side of Test Vehicle before Test 620061-01-4.

Figure 10.5. Opposite Impact Side of Test Vehicle before Test 620061-01-4.

10.3. TEST DESCRIPTION

10.3.1. Weather Conditions

Table 10.2 provides the weather conditions for Test 620061-01-4.

Table 10.2. Weather Conditions for Test 620061-01-4.

Date of Test	1/24/2025
Wind Speed	4 mi/h
Wind Direction	181°
Temperature	49°F
Relative Humidity	51 %
Vehicle Traveling	195°

10.3.2. Test Events

Table 10.3 lists events that occurred during Test 620061-01-4. The figures in Appendix F.2 present sequential photographs during the test.

Table 10.3. Events during Test 620061-01-4.

Time (seconds)	Events
0.0000	Vehicle impacted the installation
0.0180	Post 6 began to move toward field side
0.0270	Post 7 began to move toward field side
0.0310	Rail at post 7 began to break
0.0430	Vehicle began to redirect
0.0670	Post 8 began to lean upstream
0.1270	Rail at post 8 began to break
0.3520	Vehicle was parallel with installation
0.8250	Vehicle exited the installation

10.4. TEST ACTUAL IMPACT CONDITIONS

Table 10.4 lists the details of the *MASH* impact conditions for this test and Table 10.5 lists the exit parameters.

Table 10.4. Impact Conditions for *MASH* TEST 3-11, Crash Test 620061-01-4.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5	62.6
Impact Angle (°)	25	±1.5	25.3
Impact Severity (kip-ft)	106	≥106	120.3
Impact Location	168 inches upstream from the centerline of the joint between posts 7 and 8	±1 foot (12 inches)	169.2 inches upstream from the centerline of the joint between posts 7 and 8

Table 10.5. Exit Parameters for *MASH* TEST 3-11, Crash Test 620061-01-4.

Exit Parameter	Measured
Speed	Not measured, out of camera frame
Brakes applied post impact	Brakes not applied
Vehicle at rest position	82 feet ft downstream of impact point 1 ft to the traffic side
Comments:	Vehicle remained upright and stable. The vehicle did not meet the exit box criteria[a] by crossing the exit box 31 feet downstream from loss of contact.

[a]Per the *MASH* guidelines in Section 5.2.3, the exit box for the 2270P used in this test was 16.8 ft toward the traffic side as measured from the traffic side face of the rail and 32.8 ft downstream from loss of contact.

10.5. DAMAGE TO TEST INSTALLATION

Secondary impact was at post 15. The rails between posts 6 and 9 were heavily damaged, splintered and fractured. Large portions of the rails released from the backing plates and the posts. The traffic side flange on post 7 was also damaged.

Table 10.6 describes the damage to the test installation and Table 10.7 describes the deflection and working width of the Merritt Parkway Guiderail. Figure 10.6 and Figure 10.7 show the damage to the Merritt Parkway Guiderail.

Table 10.6. Damage to the Merritt Parkway Guiderail for Test 620061-01-4.

Post #	Soil Gap (Inches)	Post Lean (Degrees)	Comments
4	Soil disturbed	----	----
5	0.4 upstream, 0.4 traffic side	88.5 field side	----
6	1.7 traffic side, 0.7 field side	83.4 field side	-----
7	Soil blown out	60.8 field side	Counterclockwise twist, blockout shattered, bolts connecting post to rail bent
8	Soil blown out	73.7 field side	Blockout fractured, bolds are bent
9	0.5 traffic side, 0.2 field side	89.3 field side	Blockout fractured
10	0..4 traffic side, 0.4 field side	89.2 field side	----

Table 10.7. Deflection and Working Width of the Merritt Parkway Guiderail for Test 620061-01-4.

Test Parameter	Measured
Permanent Deflection/Location	20.3 inches toward field side, joint between posts 7 and 8
Dynamic Deflection	37.1 inches toward field side at post 7
Working Width [a] and Height	46.7 inches, at a height of 10.0 inches at the top of post 7

[a] Per *MASH*, "The working width is the maximum dynamic lateral position of any major part of the system or vehicle. These measurements are all relative to the pre-impact traffic face of the test article." In other words, working width is the total barrier width plus the maximum dynamic intrusion of any portion of the barrier or test vehicle past the field side edge of the barrier.

Figure 10.6. Merritt Parkway Guiderail at Impact Location after Test 620061-01-4.

Figure 10.7. Merritt Parkway Guiderail In-Line Downstream View after Test 620061-01-4.

10.6. DAMAGE TO TEST VEHICLE

Figure 10.8 and Figure 10.9 show the damage sustained by the vehicle. Figure 10.10 and Figure 10.11 show the interior of the test vehicle. Table 10.8 and Table 10.9 provide details on the occupant compartment deformation and exterior vehicle damage. Figure F.2 and Figure F.3 in Appendix F.1 provide exterior crush and occupant compartment measurements.

Figure 10.8. Impact Side of Test Vehicle after Test 620061-01-4.

Figure 10.9. Rear Impact Side of Test Vehicle after Test 620061-01-4.

Figure 10.10. Overall Interior of Test Vehicle after Test 620061-01-4.

Figure 10.11. Interior of Test Vehicle on Impact Side after Test 620061-01-4.

Table 10.8. Occupant Compartment Deformation for Test 620061-01-4.

Test Parameter	Specification (inches)	Measured (inches)
Roof	≤4.0	0.0
Windshield	≤3.0	0.0
A and B Pillars	≤5.0 overall/≤3.0 lateral	0.0
Foot Well/Toe Pan	≤9.0	0.0
Floor Pan/Transmission Tunnel	≤12.0	0.0
Side Front Panel	≤12.0	1.8
Front Door (above Seat)	≤9.0	0.0
Front Door (below Seat)	≤12.0	0.0

Table 10.9. Exterior Vehicle Damage for Test 620061-01-4.

Test Parameter	Details
Side Windows	Remained intact
Maximum Exterior Deformation	25 inches at front bumper
VDS	01FRQ5
CDC	01FREW5
Fuel Tank Damage	None
Description of Damage to Vehicle:	The bumper, grill, hood, radiator, and support were all damaged. Both headlights dislodged, the right front fender and door had tears, deformations, and abrasions. The A-arm dislodged, and the shock and steering control arm were both damaged. The right front wheel fractured and the tire dislodged. The right rear wheel was fractured and the tire ruptured. There was a 2.8-inch gap at the top of the right front door. The door was peeled back at the lower front corner which created an opening 14 inches long by 10 inches wide and allowed elements of the test article to enter the cab.

10.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 10.10. Figure F.6 in Appendix F.3 shows the vehicle angular displacements, and Figure F.7 through Figure F.9 in Appendix F.4 show acceleration versus time traces.

Table 10.10. Occupant Risk Factors for Test 620061-01-4.

Test Parameter	Specification [a]	Measured	Time
OIV, Longitudinal (ft/s)	≤40.0 *30.0*	31.4	0.1579 seconds on right side of interior
OIV, Lateral (ft/s)	≤40.0 *30.0*	18.4	0.1579 seconds on right side of interior
Ridedown, Longitudinal (g)	≤20.49 *15.0*	15.6	0.1579 - 0.1679 seconds
Ridedown, Lateral (g)	≤20.49 *15.0*	7.1	0.2740 - 0.2840 seconds
Theoretical Head Impact Velocity (THIV) (m/s)	N/A	10.2	0.1514 seconds on right side of interior
Acceleration Severity Index	N/A	1.2	0.1435 - 0.1935 seconds
50-ms Moving Avg. Accelerations (MA) Longitudinal (g)	N/A	-12.1	0.1188 - 0.1688 seconds
50-ms MA Lateral (g)	N/A	-7.2	0.1057 - 0.1557 seconds
50-ms MA Vertical (g)	N/A	-4.2	0.1219 - 0.1719 seconds
Roll (°)	≤75	24.4	0.8963 seconds
Pitch (°)	≤75	10.2	0.5865 seconds
Yaw (°)	N/A	48.9	0.9464 seconds

[a.] *Values in italics are the preferred MASH values*

Note: N/A = Not Applicable

10.8. TEST SUMMARY

Figure 10.12 summarizes the results of *MASH* Test 3-11 (Test 620061-01-4).


0.000 s

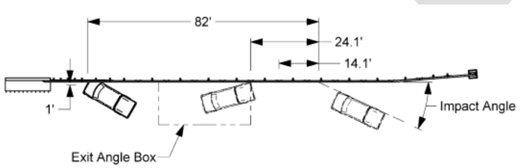

0.2000 s


0.4000 s


0.6000s

GENERAL INFORMATION	
Test Agency:	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.:	*MASH* 2016, Test 3-11
Project No.:	620061-01-4
Test Date:	1/24/2025
TEST ARTICLE	
Type:	Longitudinal Barrier
Name:	Merritt Parkway Guiderail
Length:	166 feet
Key Materials:	Weathering steel, commercial lumber grade No.1, galvanized steel
Soil Type and Condition:	Type D grade 1 crushed concrete road base, damp
TEST VEHICLE	
Type/Designation:	2270P
Year, Make and Model:	2019 RAM 1500
Inertial Mass:	5032 lb
Dummy Mass:	N/A lb
Gross Static Mass:	5032 lb
IMPACT CONDITIONS	
Impact Speed:	62.6 mi/h
Impact Angle:	25.3°
Impact Location:	169.2 inches upstream from the centerline of the joint between posts 7 and 8
Impact Severity:	120.3 kip-ft
EXIT CONDITIONS	
Exit Speed:	Not measured, out of frame
Exit Box Criteria:	The vehicle did not meet the exit box criteria

Stopping Distance:	82 feet ft downstream 1 ft to the traffic side
TEST ARTICLE DEFLECTIONS	
Dynamic:	37.1 inches
Permanent:	20.3 inches
Working Width:	46.7 inches
Working Width Height:	10.0 inches
VEHICLE DAMAGE	
VDS:	01FRQ5
CDC:	01FREW5
Max Exterior Deformation:	25 inches at front bumper
Max Occupant Compartment Deformation:	1.8 inches in the side front panel
OCCUPANT RISK VALUES	
Longitudinal OIV:	31.4 ft/s
Lateral OIV:	18.4 ft/s
Longitudinal Ridedown:	15.6 g
Lateral Ridedown:	7.1 g
THIV:	10.2 m/s
ASI:	1.2
Max 50ms Longitudinal:	-12.1 g
Max 50ms Lateral:	-7.2 g
Max 50ms Vertical:	-4.2 g
Max Roll:	24.4°
Max Pitch:	10.2°
Max Yaw:	48.9°



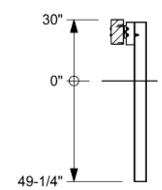


Figure 10.12. Summary of Results for *MASH* Test 3-11 (Test 620061-01-4) on Merritt Parkway Guiderail.

CHAPTER 11. DESIGN ANALYSIS – PART III

The design concept that incorporated 1-inch-thick splice plates and joints at midspan was evaluated with full-scale crash testing. The system met the criteria for *MASH* TL-3. The system was then evaluated according to *MASH* TL-3 with no curb present. During *MASH* Test 3-11, the leading edge of the pickup truck door snagged on the rail elements and pieces of the rail penetrated the occupant compartment penetration. Thus, the system with no curb present was found to be unsatisfactory for *MASH* TL-3.

A review of the crash test results was conducted to identify any potential design changes that could be made to the design to improve crashworthy performance for the no curb configuration. Design changes were first considered for the splice connection, but no design alternatives were identified that were believed to significantly improve the crashworthy performance. The next design change considered was the addition of a rubrail. This design concept was evaluated in the computer simulation analyses presented in Chapter 2 of this report. The simulation indicated a significant amount of vehicle roll after being redirected. However, after comparing some of the simulation results to the crash test results, it was believed that the vehicle model may be overpredicting the roll angle. Another reason for considering the rubrail design was the possible improved strength in the rail system. Part of the snagging that occurred in the previous crash was due to damage and fracture of the rail. The additional strength of the rubrail may help counteract this damage and fracture.

The design with the rubrail was selected for further evaluation through full-scale crash testing. The system incorporated the 1-inch-thick splice plates, joints at midspan, and a 6-inch by 8-inch timber rubrail. Chapters 12 and 13 present the evaluation of the rubrail design with full-scale crash testing.

CHAPTER 12.

MASH TEST 3-11 (CRASH TEST 620061-01-5)

12.1. CRITICAL IMPACT POINT LOCATION

The Critical Impact Point (CIP) for this test was 14 ft upstream from the centerline of the joint between posts 7 and 8 at 25°. The target CIP for this test was determined using the information provided in *MASH* Section 2.2.1 and MASH Section 2.3.2. Figure 12.1 shows the target CIP for Test 620061-01-5. Figure 12.2 and Figure 12.3 depict the vehicle at the CIP prior to Test 620061-01-5.

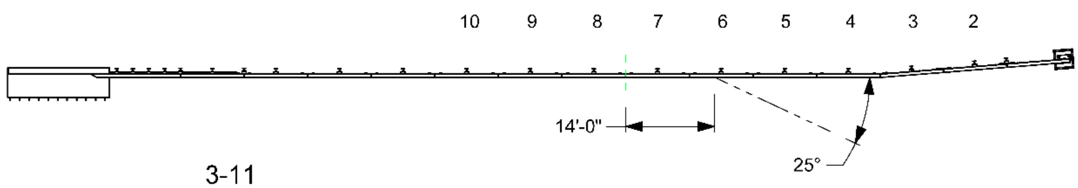


Figure 12.1. Target CIP for Test 620061-01-5.

Figure 12.2. Merritt Parkway Guiderail/Test Vehicle Geometrics for Test 620061-01-5.

Figure 12.3. Merritt Parkway Guiderail/Test Vehicle Impact Location 620061-01-5.

12.2. TEST VEHICLE DETAILS PRIOR TO IMPACT

Table 12.1 shows the vehicle measurements. Figure 12.4 and Figure 12.5 show the 2019 RAM 1500 used for the crash test. Figure G.1 in Appendix G.1 gives additional dimensions and information on the vehicle.

Table 12.1. Vehicle Measurements for Test 620061-01-5.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a] (lb)	165	N/A	N/A
Inertial Mass (lb)	5000	±110	5024
Gross Static[a] Mass (lb)	5000	±110	5024
Wheelbase (inches)	148	±12	140.5
Front Overhang (inches)	39	±3	40.3
Overall Length (inches)	237	±13	229.0
Overall Width (inches)	78	±2	78.5
Hood Height (inches)	43	±4	46.0
Track Width[b] (inches)	67	±1.5	68.3
CG aft of Front Axle[c] (inches)	63	±4	61.0
CG above Ground[c,d] (inches)	28	28	28.5

Note: N/A = not applicable; CG = center of gravity.

[a] If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy.

[b] Average of front and rear axles.

[c] For test inertial mass.

[d] 2270P vehicle must meet minimum CG height requirement.

Figure 12.4. Impact Side of Test Vehicle before Test 620061-01-5.

Figure 12.5. Opposite Impact Side of Test Vehicle before Test 620061-01-5.

12.3. TEST DESCRIPTION

12.3.1. Weather Conditions

Figure 12.2 provides the weather conditions for Test 620061-01-5.

Table 12.2. Weather Conditions for Test 620061-01-5.

Date of Test	4/16/2025
Wind Speed	8 mi/h
Wind Direction	166°
Temperature	74°F
Relative Humidity	77 %
Vehicle Traveling	195°

12.3.2. Test Events

Table 12.3 lists events that occurred during Test 620061-01-5. The figures in Appendix G.2 present sequential photographs during the test.

Table 12.3. Events during Test 620061-01-5.

Time (seconds)	Events
0.0000	Vehicle impacted the installation
0.0100	Post 6 began to deflect towards the field side
0.0120	The upstream rail at the joint between posts 6 and 7 began to fracture on the field side
0.0500	Vehicle began to redirect
0.0540	The downstream rail at the joint between posts 6 and 7 began to fracture on the field side
0.1590	Left front and rear tires lifted off the ground
0.2300	Post 7 began to deflect towards the field side
0.2780	Vehicle was parallel with installation
0.5990	Vehicle exited the installation

12.4. TEST ACTUAL IMPACT CONDITIONS

Table 12.4 lists the details of the *MASH* impact conditions for this test and Table 12.5 lists the exit parameters.

Table 12.4. Impact Conditions for *MASH* TEST 3-11, Crash Test 620061-01-5.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5	61.2
Impact Angle (°)	25	±1.5	25.2
Impact Severity (kip-ft)	106	≥106	114.0
Impact Location	14 ft upstream from the centerline of the joint between posts 7 and 8	±1 foot (12 inches)	14ft upstream from the centerline of the joint between posts 7 and 8

Table 12.5. Exit Parameters for *MASH* TEST 3-11, Crash Test 620061-01-5.

Exit Parameter	Measured
Speed	Not measured, out of camera frame
Brakes applied post impact	Brakes not applied
Vehicle at rest position	170 ft downstream of impact point 67 ft to the traffic side
Comments:	Vehicle remained upright and stable. The vehicle did not meet the exit box criteria[a] by crossing the exit box 32 feet downstream from loss of contact.

[a]Per the *MASH* guidelines in Section 5.2.3, the exit box for the 2270P used in this test was 16.8 ft toward the traffic side as measured from the traffic side face of the rail and 32.8 ft downstream from loss of contact.

12.5. DAMAGE TO TEST INSTALLATION

The rub rail fractured at post 5 and 2 feet upstream from post 6, and both rails were gouged 2 feet downstream from post 6. There was a 4 foot long section of the downstream traffic rail at the joint between posts 6 and 7 that was fractured on the top field side corner. The rub rail was severely gouged 3 feet upstream from post 7 to the joint between 7 and 8. At the joint between posts 7 and 8, the upstream traffic rail had a 1.5-inch vertical displacement and the upstream rub rail had 0.5 inches of vertical displacement.

Table 12.6 describes the damage to the test installation and Table 12.6 describes the deflection and working width of the Merritt Parkway Guiderail. Figure 12.6 and Figure 12.7 show the damage to the Merritt Parkway Guiderail.

Table 12.6. Damage to the Merritt Parkway Guiderail for Test 620061-01-5.

Post#	Soil Gap (Inches)	Post Lean (Degrees)	Comments
5	----	----	Soil disturbed
6	4 traffic side, 1.5 field side	79.4	----
7	5 field side	72	----
8	3 traffic side, 2.5 field side	86	----
9	0.5 traffic side, 0.5 field side	89.6	----
10	----	----	Soil disturbed

Table 12.7. Deflection and Working Width of the Merritt Parkway Guiderail for Test 620061-01-5.

Test Parameter	Measured
Permanent Deflection/Location	17.6 inches toward field side, joint between posts 6 & 7
Dynamic Deflection	28.4 inches toward field side 21.9 inches downstream from the joint between posts 6 and 7
Working Width [a] and Height	39.5 inches, at a height of 30 inches top of the rail at the joint between posts 6 and 7

[a] Per *MASH*, "The working width is the maximum dynamic lateral position of any major part of the system or vehicle. These measurements are all relative to the pre-impact traffic face of the test article." In other words, working width is the total barrier width plus the maximum dynamic intrusion of any portion of the barrier or test vehicle past the field side edge of the barrier.

Figure 12.6. Merritt Parkway Guiderail at Impact Location after Test 620061-01-5.

Figure 12.7. Merritt Parkway Guiderail In-Line Downstream View after Test 620061-01-5.

12.6. DAMAGE TO TEST VEHICLE

Figure 12.8 and Figure 12.9 show the damage sustained by the vehicle. Figure 12.10 and Figure 12.11 show the interior of the test vehicle. Table 12.8 and Table 12.9 provide details on the occupant compartment deformation and exterior vehicle damage. Figure G.2 and Figure G.3 in Appendix G.1 provide exterior crush and occupant compartment measurements.

Figure 12.8. Impact Side of Test Vehicle after Test 620061-01-5.

Figure 12.9. Rear Impact Side of Test Vehicle after Test 620061-01-5.

Figure 12.10. Overall Interior of Test Vehicle after Test 620061-01-5.

Figure 12.11. Interior Closeup View of Test Vehicle Floor Pan after Test 620061-01-5.

Table 12.8. Occupant Compartment Deformation for Test 620061-01-5.

Test Parameter	Specification (inches)	Measured (inches)
Roof	≤4.0	0.0
Windshield	≤3.0	0.0
A and B Pillars	≤5.0 overall/≤3.0 lateral	0.0
Foot Well/Toe Pan	≤9.0	0.3
Floor Pan/Transmission Tunnel	≤12.0	0.0
Side Front Panel	≤12.0	0.0
Front Door (above Seat)	≤9.0	0.5
Front Door (below Seat)	≤12.0	0.0

Table 12.9. Exterior Vehicle Damage for Test 620061-01-5.

Test Parameter	Details
Side Windows	Remained intact
Maximum Exterior Deformation	16 inches at the front bumper
VDS	01RFQ5
CDC	01FREW5
Fuel Tank Damage	None
Description of Damage to Vehicle:	The bumper, grill, fender, sway belt, and right headlight were damaged. The right A-Arm fractured. The right front tire ruptured and the wheel was deformed. There were deformations and abrasions on the right front door with a 1.5-inch gap at the top. The right rear wheel was deformed and the tire was deflated. There were deformations and abrasions on the right rear panel with a deformation on the rear bumper.

12.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 12.10. Figure G.7 in Appendix G.3 shows the vehicle angular displacements, and Figure G.8 through Figure G.10 in Appendix G.4 show acceleration versus time traces.

Table 12.10. Occupant Risk Factors for Test 620061-01-5.

Test Parameter	Specification [a]	Measured	Time
OIV, Longitudinal (ft/s)	≤40 *30*	20.0	0.1342 seconds on right side of interior
OIV, Lateral (ft/s)	≤40 *30*	19.2	0.1342 seconds on right side of interior
Ridedown, Longitudinal (g)	≤20.49 *15*	9.9	0.1342 - 0.1442 seconds
Ridedown, Lateral (g)	≤20.49 15	8.6	0.1342 - 0.1442 seconds
Theoretical Head Impact Velocity (THIV) (m/s)	N/A	8.0	0.1293 seconds on right side of interior
Acceleration Severity Index	N/A	1.0	0.1265 - 0.1765 seconds
50-ms Moving Avg. Accelerations (MA) Longitudinal (g)	N/A	-7.4	0.0923 - 0.1423 seconds
50-ms MA Lateral (g)	N/A	-7.2	0.0984 - 0.1484 seconds
50-ms MA Vertical (g)	N/A	2.8	0.1795 - 0.2295 seconds
Roll (°)	≤75	41.8	0.6608 seconds
Pitch (°)	≤75	13.3	0.8408 seconds
Yaw (°)	N/A	78.1	1.9207 seconds

[a.] *Values in italics are the preferred MASH values*

Note: N/A = Not Applicable

12.8. TEST SUMMARY

Figure 12.12 summarizes the results of *MASH* Test 3-11 (Test 620061-01-5).

0.000 s

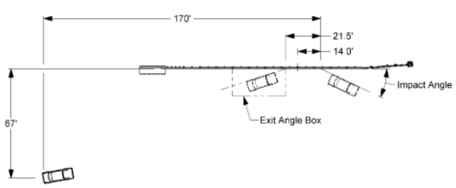
0.2000 s

0.4000 s

0.6000s

GENERAL INFORMATION	
Test Agency:	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.:	*MASH* 2016, Test 3-11
Project No.:	620061-01-5
Test Date:	4/16/2025
TEST ARTICLE	
Type:	Longitudinal Barrier
Name:	Merritt Parkway Guiderail
Length:	166 feet
Key Materials:	Weathering steel, commercial lumber grade No.1, galvanized steel, Type D grade 1 crushed concrete road base
Soil Type and Condition:	Type D grade 1 crushed concrete, damp
TEST VEHICLE	
Type/Designation:	2270P
Year, Make and Model:	2019 RAM 1500
Inertial Mass:	5024 lb
Dummy Mass:	N/A lb
Gross Static Mass:	5024 lb
IMPACT CONDITIONS	
Impact Speed:	61.2 mi/h
Impact Angle:	25.2°
Impact Location:	14ft upstream from the centerline of the joint between posts 7 and 8
Impact Severity:	114 kip-ft
EXIT CONDITIONS	
Exit Speed:	Not measured, out of the camera frame
Exit Box Criteria:	The vehicle did not meet the exit box criteria

Stopping Distance:	170 ft downstream 67 ft to the traffic side
TEST ARTICLE DEFLECTIONS	
Dynamic:	28.4 inches
Permanent:	17.6 inches
Working Width:	39.5 inches
Working Width Height:	30 inches
VEHICLE DAMAGE	
VDS:	01RFQ5
CDC:	01FREW5
Max Exterior Deformation:	16 inches at the front bumper
Max Occupant Compartment Deformation:	0.5 inches in the front door (above seat)
OCCUPANT RISK VALUES	
Longitudinal OIV:	20 ft/s
Lateral OIV:	19.2 ft/s
Longitudinal Ridedown:	9.9 g
Lateral Ridedown:	8.6 g
THIV:	8 m/s
ASI:	1.0
Max 50ms Longitudinal:	-7.4 g
Max 50ms Lateral:	-7.2 g
Max 50ms Vertical:	2.8 g
Max Roll:	41.8°
Max Pitch:	13.3°
Max Yaw:	78.1°



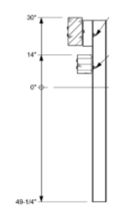


Figure 12.12. Summary of Results for *MASH* Test 3-11 (Test 620061-01-5) on Merritt Parkway Guiderail.

CHAPTER 13.

MASH TEST 3-10 (CRASH TEST 620061-01-6)

13.1. CRITICAL IMPACT POINT LOCATION

The Critical Impact Point (CIP) for this test was 5 ft upstream from the centerline of the joint between posts 7 and 8 at 25 degrees. The target CIP for this test was determined using the information provided in *MASH* Section 2.2.1 and MASH Section 2.3.2. Figure 13.1 shows the target CIP for Test 620061-01-6. Figure 13.2 and Figure 13.3 depict the vehicle at the CIP prior to Test 620061-01-6.

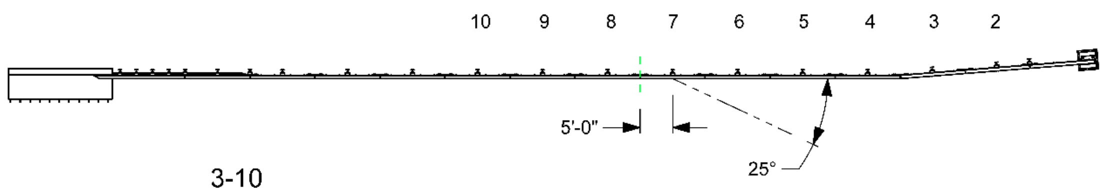


Figure 13.1. Target CIP for Test 620061-01-6.

Figure 13.2. Merritt Parkway Guiderail/Test Vehicle Geometrics for Test 620061-01-6.

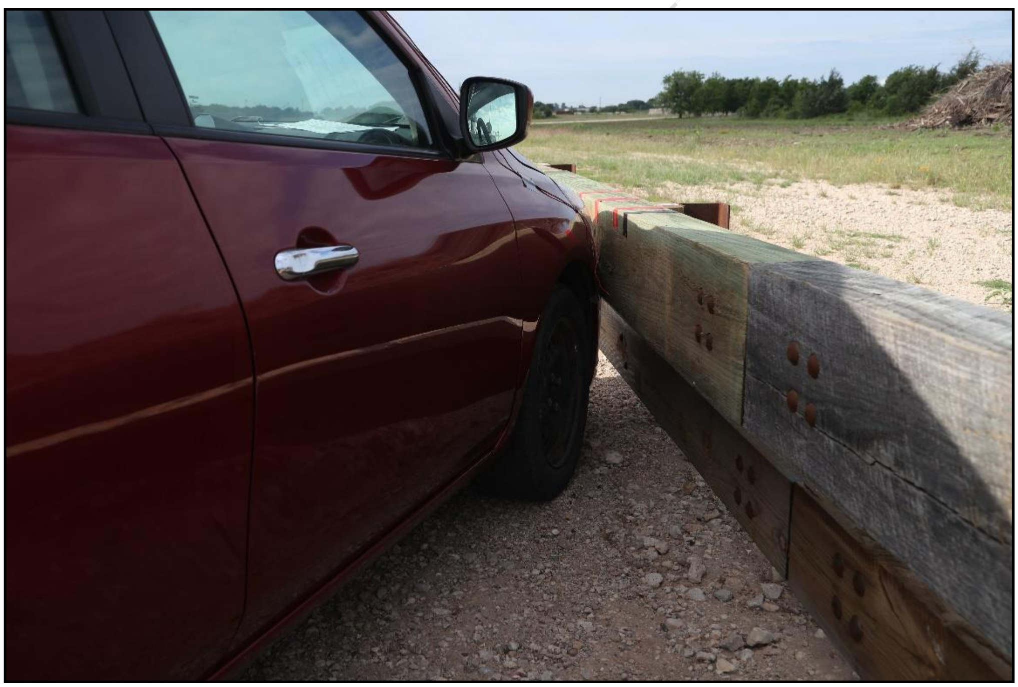


Figure 13.3. Merritt Parkway Guiderail/Test Vehicle Impact Location 620061-01-6.

13.2. TEST VEHICLE DETAILS PRIOR TO IMPACT

Table 13.1 shows the vehicle measurements. Figure 13.4 and Figure 13.5 show the 2019 Nissan Versa used for the crash test. Figure H.1 in Appendix H.1 gives additional dimensions and information on the vehicle.

Table 13.1. Vehicle Measurements for Test 620061-01-6.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a] (lb)	165	N/A	165
Inertial Mass (lb)	2420	±55	2434
Gross Static[a] Mass (lb)	2585	±55	2599
Wheelbase (inches)	98	±5	102.4
Front Overhang (inches)	35	±4	32.5
Overall Length (inches)	169	±8	175.4
Overall Width (inches)	65	±3	66.7
Hood Height (inches)	28	±4	30.5
Track Width[b] (inches)	59	±2	58.4
CG aft of Front Axle[c] (inches)	39	±4	41.4
CG above Ground[c,d] (inches)	N/A	N/A	N/A

Note: N/A = not applicable; CG = center of gravity.

[a] If a dummy is used, the gross static vehicle mass should be increased by the mass of the dummy.

[b] Average of front and rear axles.

[c] For test inertial mass.

[d] 2270P vehicle must meet minimum CG height requirement.

Figure 13.4. Impact Side of Test Vehicle before Test 620061-01-6.

Figure 13.5. Opposite Impact Side of Test Vehicle before Test 620061-01-6.

13.3. TEST DESCRIPTION

13.3.1. Weather Conditions

Table 13.2 provides the weather conditions for Test 620061-01-6.

Table 13.2. Weather Conditions for Test 620061-01-6.

Date of Test	5/5/2025
Wind Speed	6 mi/h
Wind Direction	101°
Temperature	76°F
Relative Humidity	66 %
Vehicle Traveling	195°

13.3.2. Test Events

Table 13.3 lists events that occurred during Test 620061-01-6. The figures in Appendix H.2 present sequential photographs during the test.

Table 13.3. Events during Test 620061-01-6.

Time (seconds)	Events
0.0000	Vehicle impacted the installation
0.0169	Post 7 began to deflect towards the field side
0.0230	Post 8 began to deflect towards the field side
0.0290	Vehicle began to redirect
0.1360	Driver side rear tire lifted off the ground
0.2080	Vehicle was parallel with installation
0.2363	Rear passenger side bumper impacted the rail
0.4380	Vehicle exited the installation

13.4. TEST ACTUAL IMPACT CONDITIONS

Table 13.4 lists the details of the *MASH* impact conditions for this test and Table 13.5 lists the exit parameters.

Table 13.4. Impact Conditions for *MASH* TEST 3-10, Crash Test 620061-01-6.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5	62.6
Impact Angle (°)	25	±1.5	24.6
Impact Severity (kip-ft)	51	≥51	55.3
Impact Location	5 ft upstream from the centerline of the joint between posts 7 and 8	±1 foot (12 inches)	5.3 ft upstream from the centerline of the joint between posts 7 and 8

Table 13.5. Exit Parameters for *MASH* TEST 3-10, Crash Test 620061-01-6.

Exit Parameter	Measured
Speed	40.5 mi/h
Trajectory	11.2°
Heading	17.0°
Brakes applied post impact	Brakes not applied
Vehicle at rest position	137 ft downstream of impact point 6 ft to the traffic side
Comments:	Vehicle remained upright and stable. The vehicle met the exit box criteria[a] by crossing the exit box 48 feet downstream from loss of contact.

[a]Per the *MASH* guidelines in Section 5.2.3, the exit box for the 1100C used in this test was 15.097 ft toward the traffic side as measured from the traffic side face of the rail and 32.8 ft downstream from loss of contact.

13.5. DAMAGE TO TEST INSTALLATION

The rail was scuffed and gouged at impact. There was heavy gouging on the rub rail downstream of joint 7 and 8. The rail upstream of joint 7 and 8 was slightly fractured.

Table 13.6 describe the damage to the test installation and Table 13.7 describes the deflection and working width of the Merritt Parkway Guiderail. Figure 13.6 and Figure 13.7 show the damage to the Merritt Parkway Guiderail.

Table 13.6. Damage of the Merritt Parkway Guiderail for Test 620061-01-6.

Post#	Soil Gap (Inches)	Post Lean (Degrees)	Comments
3	Soil disturbed	----	----
4	0.1 field side	----	----
5	0.2 field side	----	----
6	0.2 field side and traffic side	89.8	----
7	1.5 field side, 2 traffic side	85.2	----
8	3.5 field side	84.4	Front was filled in
9	0.4 field side, 0.5 traffic side	90	----
10	0.4 field side	89.1	----
11-13	Soil disturbed	----	----

Table 13.7. Deflection and Working Width of the Merritt Parkway Guiderail for Test 620061-01-6.

Test Parameter	Measured
Permanent Deflection/Location	8.0 inches toward field side, joint between posts 7 and 8
Dynamic Deflection	16.6 inches toward field side joint between posts 7 and 8
Working Width [a] and Height	31.0 inches, at a height of 30.0 inches at the top of post 8 on the field side

[a] Per *MASH*, "The working width is the maximum dynamic lateral position of any major part of the system or vehicle. These measurements are all relative to the pre-impact traffic face of the test article." In other words, working width is the total barrier width plus the maximum dynamic intrusion of any portion of the barrier or test vehicle past the field side edge of the barrier.

Figure 13.6. Merritt Parkway Guiderail at Impact Location after Test 620061-01-6.

Figure 13.7. Merritt Parkway Guiderail In-line Downstream View after Test 620061-01-6.

13.6. DAMAGE TO TEST VEHICLE

Figure 13.8 and Figure 13.9 show the damage sustained by the vehicle. Figure 13.10 and Figure 13.11 show the interior of the test vehicle. Table 13.8 and Table 13.9 provide details on the occupant compartment deformation and exterior vehicle damage. Figure H.2 and Figure H.3 in Appendix H.1 provide exterior crush and occupant compartment measurements.

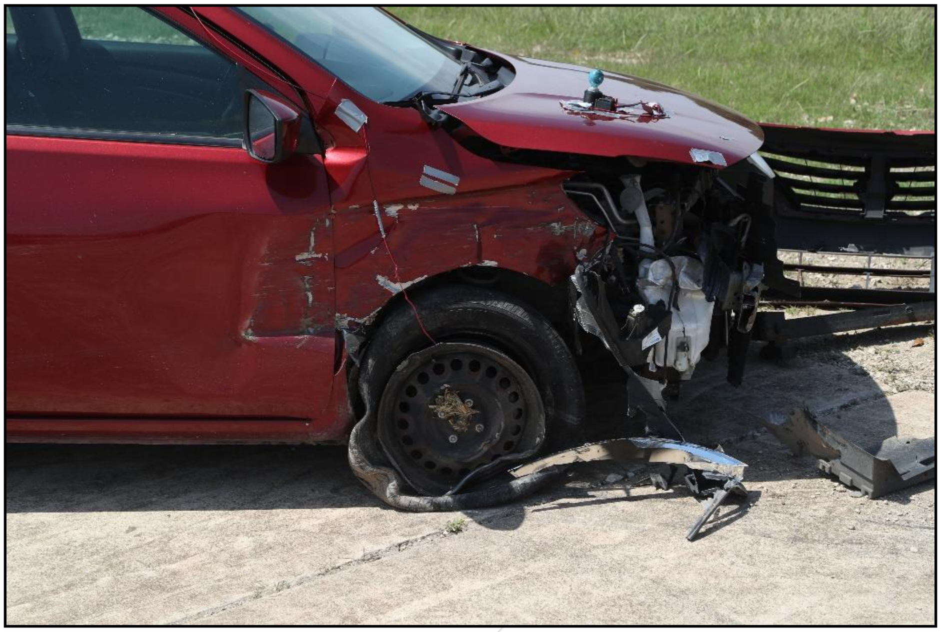


Figure 13.8. Impact Side of Test Vehicle after Test 620061-01-6.

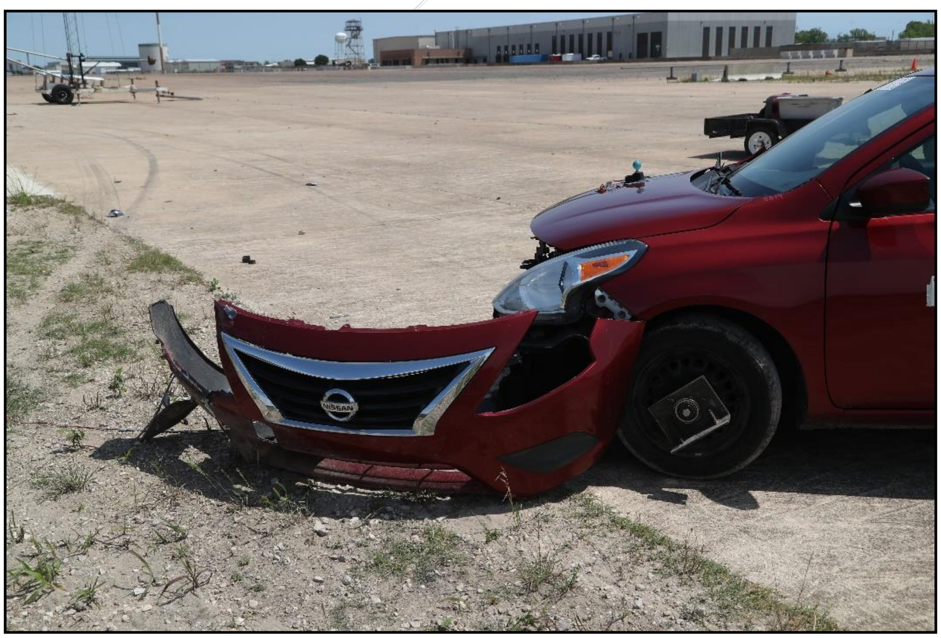


Figure 13.9. Opposite Impact Side of Test Vehicle after Test 620061-01-6.

Figure 13.10. Overall Interior of Test Vehicle after Test 620061-01-6.

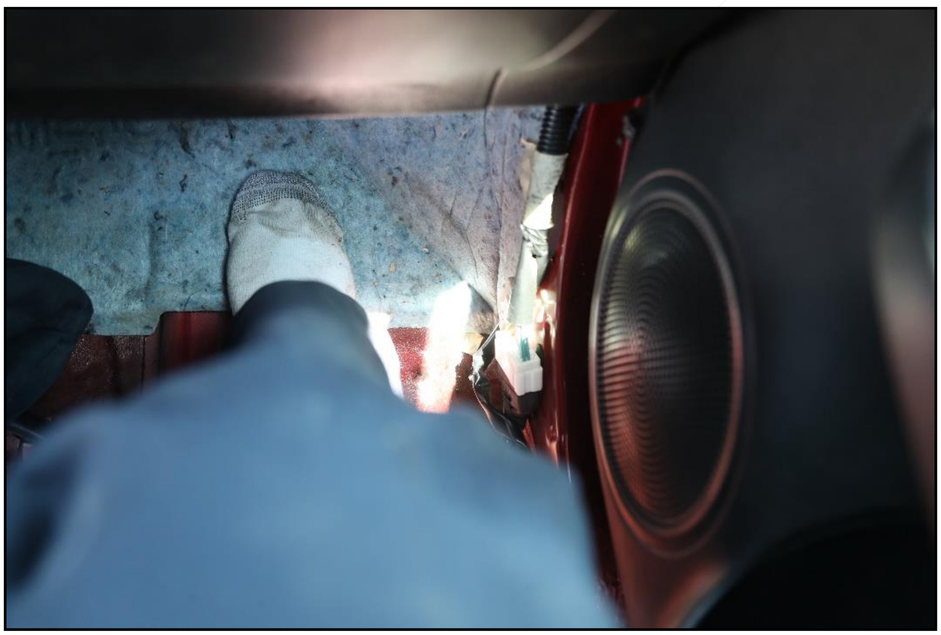


Figure 13.11. Interior of Test Vehicle on Impact Side after Test 620061-01-6.

Table 13.8. Occupant Compartment Deformation for Test 620061-01-6.

Test Parameter	Specification (inches)	Measured (inches)
Roof	≤4.0	0.0
Windshield	≤3.0	0.0
A and B Pillars	≤5.0 overall/≤3.0 lateral	0.0
Foot Well/Toe Pan	≤9.0	0.0
Floor Pan/Transmission Tunnel	≤12.0	0.0
Side Front Panel	≤12.0	0.0
Front Door (above Seat)	≤9.0	0.0
Front Door (below Seat)	≤12.0	0.0

Table 13.9. Exterior Vehicle Damage for Test 620061-01-6.

Test Parameter	Details
Side Windows	Remained intact
Maximum Exterior Deformation	10 at front bumper
VDS	01RFQ5
CDC	01FREW4
Fuel Tank Damage	None
Description of Damage to Vehicle:	The bumper, grill, and right front fender were damaged. The right front headlight was fractured, the right front wheel was deformed, the right front tire was deflated, and the right front frame rail was deformed. There were abrasions and deformations along the right side of the car. There was a 2-inch gap at the top of the right front door.

13.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 13.10. Figure H.7 in Appendix H.3 shows the vehicle angular displacements, and Figure H.8 through Figure H.10 in Appendix H.4 show acceleration versus time traces.

Table 13.10. Occupant Risk Factors for Test 620061-01-6.

Test Parameter	Specification [a]	Measured	Time
OIV, Longitudinal (ft/s)	≤40.0 *30.0*	25.0	0.1015 seconds on right side of interior
OIV, Lateral (ft/s)	≤40.0 *30.0*	24.8	0.1015 seconds on right side of interior
Ridedown, Longitudinal (g)	≤20.49 *15.0*	10.7	0.1079 - 0.1179 seconds
Ridedown, Lateral (g)	≤20.49 *15.0*	12.8	0.1032 - 0.1132 seconds
Theoretical Head Impact Velocity (THIV) (m/s)	N/A	10.4	0.0988 seconds on right side of interior
Acceleration Severity Index	N/A	1.5	0.0955 - 0.1455 seconds
50-ms Moving Avg. Accelerations (MA) Longitudinal (g)	N/A	-10.6	0.0680 - 0.1180 seconds
50-ms MA Lateral (g)	N/A	-10.6	0.0711 - 0.1211 seconds
50-ms MA Vertical (g)	N/A	-2.3	0.0428 - 0.0928 seconds
Roll (°)	≤75	8.4	3.7362 seconds
Pitch (°)	≤75	9.8	0.4161 seconds
Yaw (°)	N/A	122.4	3.4877 seconds

a. *Values in italics are the preferred MASH values*

Note: N/A = Not Applicable

13.8. TEST SUMMARY

Figure 13.12 summarizes the results of *MASH* Test 3-10 (Test 620061-01-6).

0.000 s

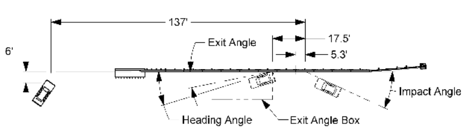
0.2000 s

0.4000 s

0.6000s

GENERAL INFORMATION	
Test Agency:	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.:	*MASH* 2016, Test 3-10
Project No.:	620061-01-6
Test Date:	5/5/2025
TEST ARTICLE	
Type:	Longitudinal Barrier
Name:	Merritt Parkway Guiderail
Length:	166 feet
Key Materials:	Weathering steel, commercial lumber grade No.1, galvanized steel, Type D grade 1 crushed concrete road base
Soil Type and Condition:	Type D grade 1 crushed concrete, damp
TEST VEHICLE	
Type/Designation:	1100C
Year, Make and Model:	2019 Nissan Versa
Inertial Mass:	2434 lb
Dummy Mass:	165 lb
Gross Static Mass:	2599 lb
IMPACT CONDITIONS	
Impact Speed:	62.6 mi/h
Impact Angle:	24.6°
Impact Location:	5.3 ft upstream from the centerline of the joint between posts 7 and 8
Impact Severity:	55.3 kip-ft
EXIT CONDITIONS	
Exit Speed:	40.5 mi/h
Trajectory/Heading Angle:	11.2° / 17.0°

Exit Box Criteria:	The vehicle met the exit box criteria
Stopping Distance:	137 ft downstream 6 ft to the traffic side
TEST ARTICLE DEFLECTIONS	
Dynamic:	16.6 inches
Permanent:	8.0 inches
Working Width:	31.0 inches
Working Width Height:	30.0 inches
VEHICLE DAMAGE	
VDS:	01RFQ5
CDC:	01FREW4
Max Exterior Deformation:	10 inches at the front bumper
Max Occupant Compartment Deformation:	There was no deformation into the occupant compartment
OCCUPANT RISK VALUES	
Longitudinal OIV:	25 ft/s
Lateral OIV:	24.8 ft/s
Longitudinal Ridedown:	10.7 g
Lateral Ridedown:	12.8 g
THIV:	10.4 m/s
ASI:	1.5
Max 50ms Longitudinal:	-10.6 g
Max 50ms Lateral:	-10.6 g
Max 50ms Vertical:	-2.3 g
Max Roll:	8.4°
Max Pitch:	9.8°
Max Yaw:	122.4°



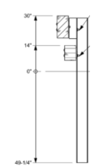


Figure 13.12. Summary of Results for *MASH* Test 3-10 (Test 620061-01-6) on Merritt Parkway Guiderail.

CHAPTER 14.

SUMMARY AND CONCLUSIONS

Design concepts were developed to improve the crashworthy performance of the Merritt Parkway Guiderail. The crashworthy performance of the Meritt Parkway Guiderail was evaluated with computer simulations. A design concept that incorporated a 1-inch-thick splice plate indicated the best crashworthy performance. Specifically, this design concept resulted in stable redirection of the vehicle and ridedown accelerations below the MASH limit. This design concept was selected for further evaluation with full-scale crash testing.

The Merritt Parkway Guiderail with a 1-inch-thick splice plate was evaluated with full-scale testing according to *MASH* TL-3. The system was first evaluated with a 4-inch curb. The Merritt Parkway Guiderail with a 1-inch-thick splice plate failed to meet the *MASH* criteria for Test 3-11. The leading edge of the pickup truck impact-side passenger door was peeled back and opened a hole. Parts of the timber rail penetrated into the occupant compartment through this opening.

After reviewing the results of the crash test, the primary cause of the door snag was determined to be interaction between the vehicle and the splice joint. There was significant displacement of the timber rails relative to each other leading to pocketing of the pickup truck vehicle. This observed relative displacement was allowed through the deflection and rotation of the 1-inch thick splice plate. To reduce the potential for this snagging, another design concept was developed that moved the joint to midspan between the posts. Computer simulation analysis of this design indicated satisfactory performance for *MASH* TL-3. This design concept was considered for further evaluation with full-scale crash testing.

The Merritt Parkway Guiderail with a 1-inch-thick splice plate and joints at midspan was evaluated with full-scale crash testing according to *MASH* TL-3. The system was first evaluated with a 4-inch curb. The Merritt Parkway Guiderail with a 1-inch-thick splice plate and joints at midspan was found to be satisfactory for *MASH* TL-3. The system was then evaluated without a curb. The system without a curb failed to meet the *MASH* criteria for Test 3-11. The leading edge of the pickup truck impact-side passenger door was peeled back and opened a hole. Parts of the timber rail penetrated into the occupant compartment through this opening.

Another design concept was considered to improve the crashworthy performance of the Merritt Parkway Guiderail system without a curb. This design concept incorporated a 6-inch by 8-inch timber rubrail. This system was considered for further evaluation with full-scale crash testing.

The Merritt Parkway Guiderail with a 1-inch-thick splice plate, joints at midspan, and a rubrail was evaluated with full-scale crash testing according to *MASH* TL-3. The system did not have a curb present. The Merritt Parkway Guiderail with a 1-inch-thick splice plate, joints at midspan, and a rubrail was found to be satisfactory for *MASH* TL-3.

Table 14.1 summarizes the evaluation of the Merritt Parkway Guiderail according to *MASH* TL-3 criteria. The first system consisting of a 4-inch curb and 1-inch-thick splice plates failed to meet the MASH TL-3 criteria (Test 620061-01-2). The second system consisting of a 4-inch curb, 1-inch-thick splice plates, and joints at midspan met the MASH TL-3 criteria (Tests 620061-01-1 and 620061-01-3). The third system consisting of no curb, 1-inch-thick splice plates, and joints at midspan failed to meet the MASH TL-3 criteria (Test 620061-01-4). The third system consisting of no curb, 1-inch-thick splice plates, joints at midspan, and a rubrail met the MASH TL-3 criteria (Tests 620061-01-5 and 620061-01-6).

Two designs were developed and evaluated that met the *MASH* TL-3 criteria. The first design had a 4-inch curb and incorporated a 1-inch-thick splice plate and joints at midspan. The second design did not have a curb and incorporated a 1-inch-thick splice plate, joints at midspan, and a rubrail. These two systems should be considered for use as a *MASH*-compliant system. Additional details regarding the implementation of these systems can be found in Chapter 15.

Table 14.1. Assessment Summary for *MASH* TL-3 Evaluation of the Merritt Parkway Guiderail.

Evaluation Criteria	Description	Test 620061-01-1 *(MASH* Test 3-11)	Test 620061-01-2 *(MASH* Test 3-11)	Test 620061-01-3 *(MASH* Test 3-10)	Test 620061-01-4 *(MASH* Test 3-11)	Test 620061-01-5 *(MASH* Test 3-11)	Test 620061-01-6 *(MASH* Test 3-10)
A	Contain, Redirect, or Controlled Stop	S	S	S	S	S	S
D	No Penetration into Occupant Compartment	S	FAIL	S	FAIL	S	S
F	Roll and Pitch Limit	S	S	S	S	S	S
H	OIV Threshold	S	S	S	S	S	S
I	Ridedown Threshold	S	S	S	S	S	S
Overall	Evaluation	Pass	Fail	Pass	Fail	Pass	Pass

Note: S = Satisfactory; N/A = Not Applicable.
[1] See Table 4.2 for details

CHAPTER 15.
IMPLEMENTATION

15.1. LENGTH OF NEED – CURB CONFIGURATION

A design for the Merritt Parkway Guiderail was found to be compliant for *MASH* Test Level 3 which included a 4-inch curb. The design incorporated two primary changes from the original Merritt Parkway Guiderail system: (1) a 1-inch-thick splice plate at the joint connection, and (2) joint connection moved to midspan. Detailed drawings of this design are presented in Appendix A.2. The implementation of this system can be completed through the inclusion of this design in standard drawings.

15.2. LENGTH OF NEED – NO CURB CONFIGURATION

A design for the Merritt Parkway Guiderail was found to be compliant for *MASH* Test Level 3 without a curb. The design incorporated three primary changes from the original Merritt Parkway Guiderail system: (1) a 1-inch-thick splice plate at the joint connection, (2) joint connection moved to midspan, and (3) inclusion of a 6-inch by 8-inch rubrail. Detailed drawings of this design are presented in Appendix A.4. The implementation of this system can be completed through the inclusion of this design in standard drawings.

The rubrail should be terminated prior to the transition section. As shown in the drawings in Appendix A.4, this consists of the final rubrail piece ending prior to the first concrete curb in the transition section. As this system is intended for use with one-way traffic, there was no consideration for terminating the rubrail behind a post to protect the end of the rubrail.

15.3. TRANSITION

The Merritt Parkway Guiderail transitions from the standard length of need section to a vertical concrete parapet section. A transition system that connects these two sections was previously evaluated and found to be satisfactory according to *MASH* Test Level 3 (*1*). The changes made to the length of need sections discussed in the previous sections would not influence the performance of the transition system. Thus, this transition system should be considered for implementation. Detailed drawings for this transition system are presented in Appendix A.2 and A.4. The implementation of this transition system can be completed through the inclusion of this design in standard drawings.

Transitions to concrete parapets or bridge railings different than what was tested previously (*1*) may require additional analysis. Recommendations were also made by TTI (*3*) regarding which variations should be considered acceptable and which may require further analysis when attaching thrie beam transitions to rigid barriers. The guidance developed under that project should be considered in most applications for the Merritt Parkway Guiderail system.

15.4. OTHER CONSIDERATIONS

In median applications, this should be considered acceptable for use with a double-sided rail configuration. This applies for the LON curb MASH TL-3 design and LON without curb MASH TL-3 design. The addition of the secondary rail (and secondary rubrail for no-curb configuration) will result in a slight increase in overall system stiffness. However, there are no concerns with this additional system stiffness affecting the overall crashworthiness of the system in a median design application. This recommendation further applies to the use of double-sided rail in the transition section.

REFERENCES

1. Dobrovolny, C., Schulz, N., Menges, W., Schroeder, W., Griffith, B., and Kuhn, D. *MASH TL-3 Evaluation of Merritt Parkway Guiderail with 4-Inch Curb.* Report No. 612061-08-01. Texas A&M Transportation Institute, College Station, TX, 2021.
2. AASHTO. *Manual for Assessing Safety Hardware*, Second Edition. American Association of State Highway and Transportation Officials, Washington, DC, 2016.
3. Bligh, R., Zalani, A., Dobrovolny, C., and Kiani, M. *Guidelines for Attaching MASH-Compliant Thrie Beam Transitions to Rigid Concrete Barriers Other than the Rigid Barrier Tested.* Report No. 616001-01. Texas A&M Transportation Institute, College Station, TX, 2023.

APPENDIX A.

DETAILS OF MERRITT PARKWAY GUIDERAIL

A.1. DETAILS OF MERRITT PARKWAY GUIDERAIL FOR TEST 620061-01-2

Notes

1a. Drill Ø24" holes for Posts. Backfill Post holes and around Anchor Block with Type D grade 1 crushed concrete road base, compacted to MASH standard.

1b. Threads not shown on Bolts, Nuts, etc for clarity.

1c. Material:

Steel: All steel posts, back-up rails, splice plates and channel rubrails which are to be used as "Weathering Steel", shall meet the requirements of ASTM A588. The fabricator shall notify the manufacturer that it is "Weathering Steel" (structural steel for use in bare, unpainted applications) and that the steel shall not be marked with paint or steel die stamped, but identification shall be stenciled with permanent ink. The dimensions of each component shall conform to the plans and ASTM A6. All steel posts shall be galvanized after fabrication to meet the requirements of ASTM A123 and conform to the galvanizing limits and tolerances shown on the plans. A single ¾" diameter hole may be drilled 2" from the top of each post, in the center of the web, to facilitate the galvanizing process on the bottom of all posts.

Timber: All timber rail and block-out components shall conform with the following:
a) Commercial lumber grade No. 1 or better after treatment;
b) AASHTO M 168;
c) Minimum stress rating of 1350 psi
d) Rough sawn (non-planed) or S4S (surface four side) Southern Yellow Pine or Douglas Fir- Larch with nominal dimensions as indicated on the plans. Variations in the size of any dimension shall not be more than ± ¼"
e) All timber components shall be pressure treated with CCA or ACZA depending on species supplied conforming to AWPA Standard P5 to a minimum net retention of 0.60lb/cubic foot in the assay zone in accordance with AWPA Standard C14.
f) All timber components shall be fabricated (including but not necessarily limited to cutting, drilling, dapping and chamfering) prior to treatment.
g) All timber components shall be free of excess preservative and solvent at the conclusion of the treating process. Post treatment cleaning shall be by expansion bath or steaming in accordance with AWPA Standard C2;
h) Kiln or air dried to a maximum moisture content of 25% after treatment (KDAT - 25);
i) Grade-marked after treatment by an agency certified by the American Lumber Standard Committee (ALSC).

Fasteners:
a) Round head bolts shall be manufactured in accordance with the sizes designated on the plans, the geometric specifications included in ANSI B18.5.1.2.2 and the material specifications for ASTM A449 steel. All round head bolts shall be marked with the manufacturers symbol and A449.
b) Hex Lag Screws shall be manufactured in accordance with ASTM A307 Grade A specifications. All Hex Lag Screws used between the Anchor Block and Post 2 shall be hot-dipped galvanized in accordance with ASTM A153 Class C.
c) Nuts, and Washers shall be ASTM A449 steel.

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Project #620061 with Curb	Merritt Parkway	2024-08-30
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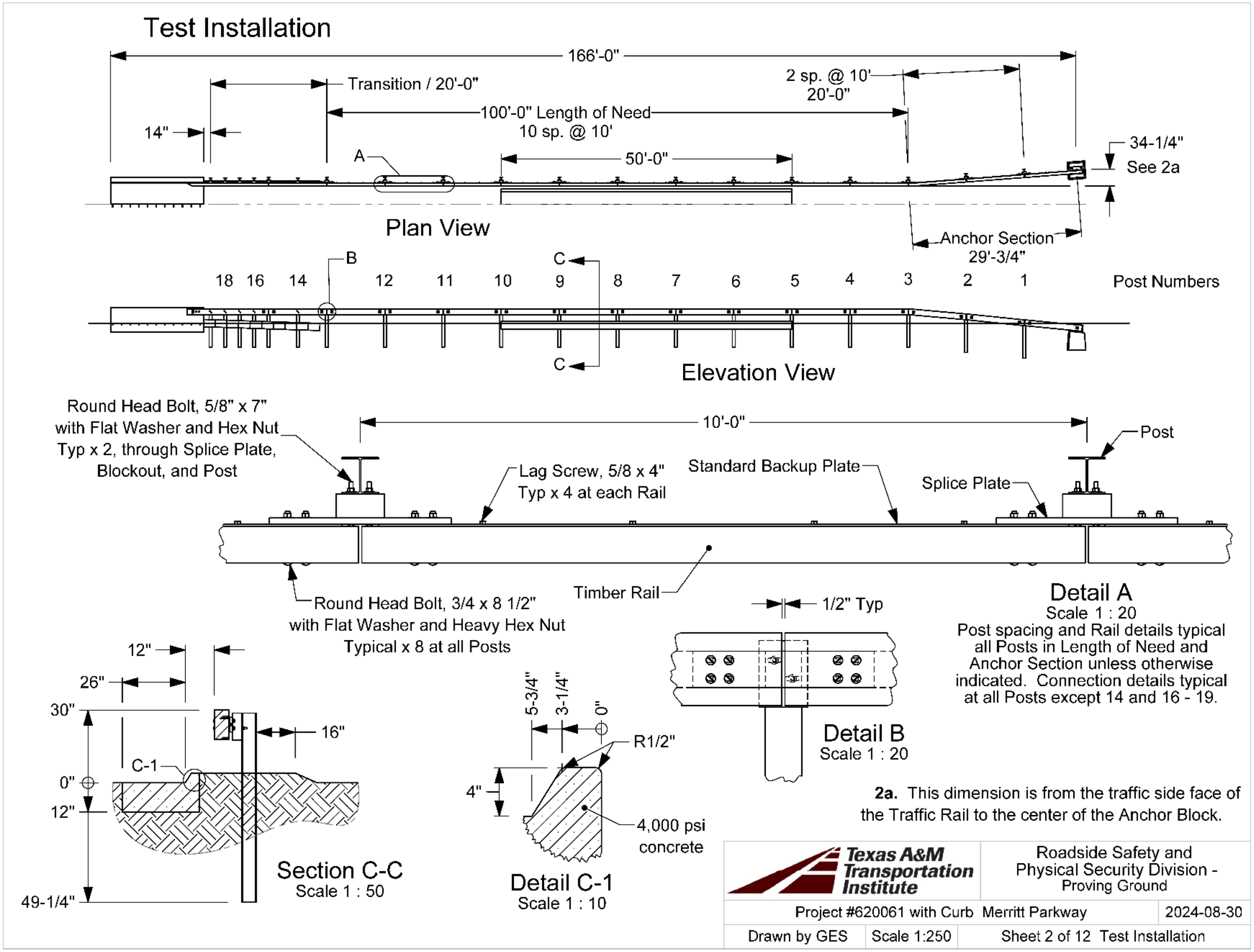

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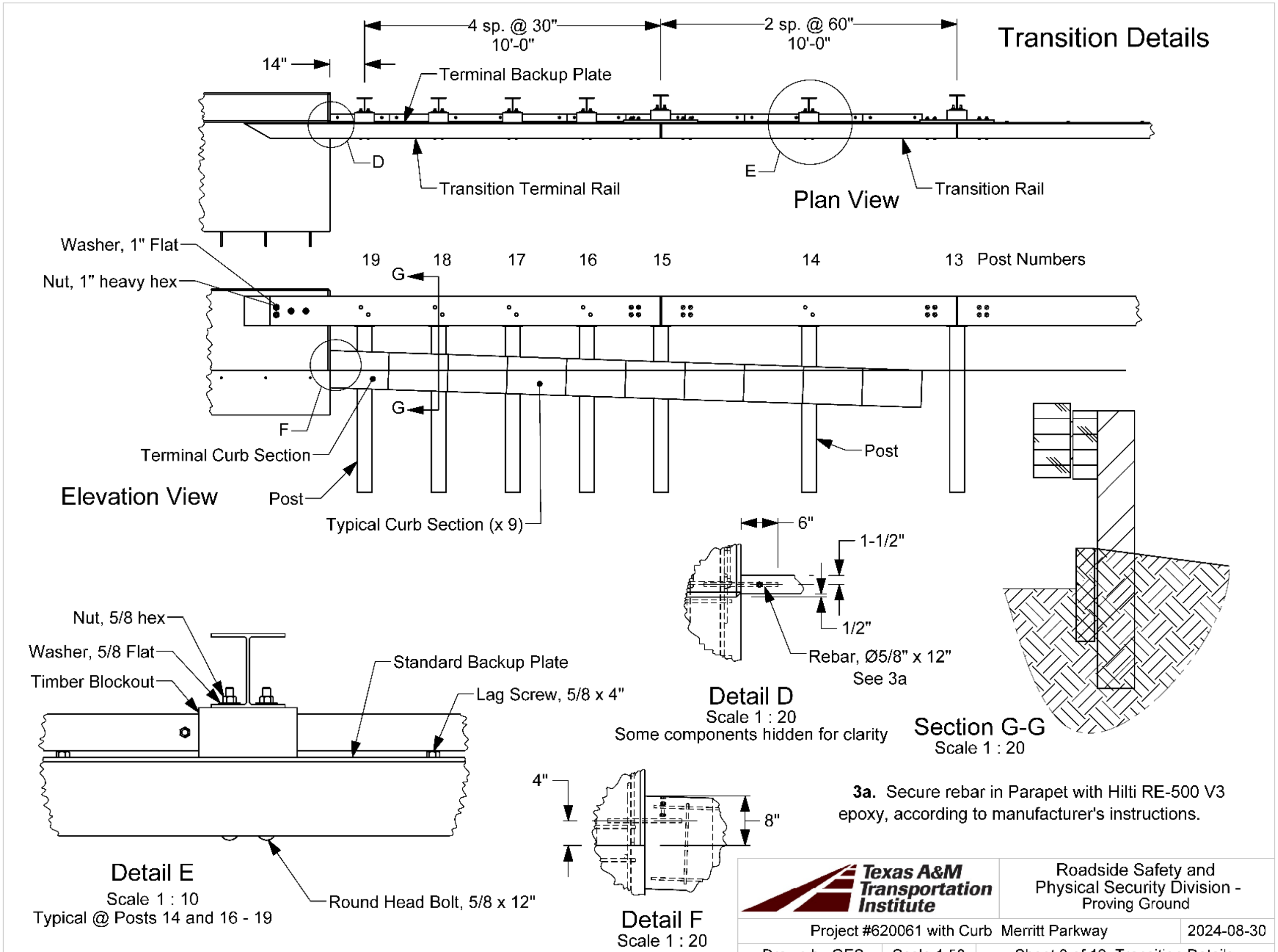
Transition Details



3a. Secure rebar in Parapet with Hilti RE-500 V3 epoxy, according to manufacturer's instructions.

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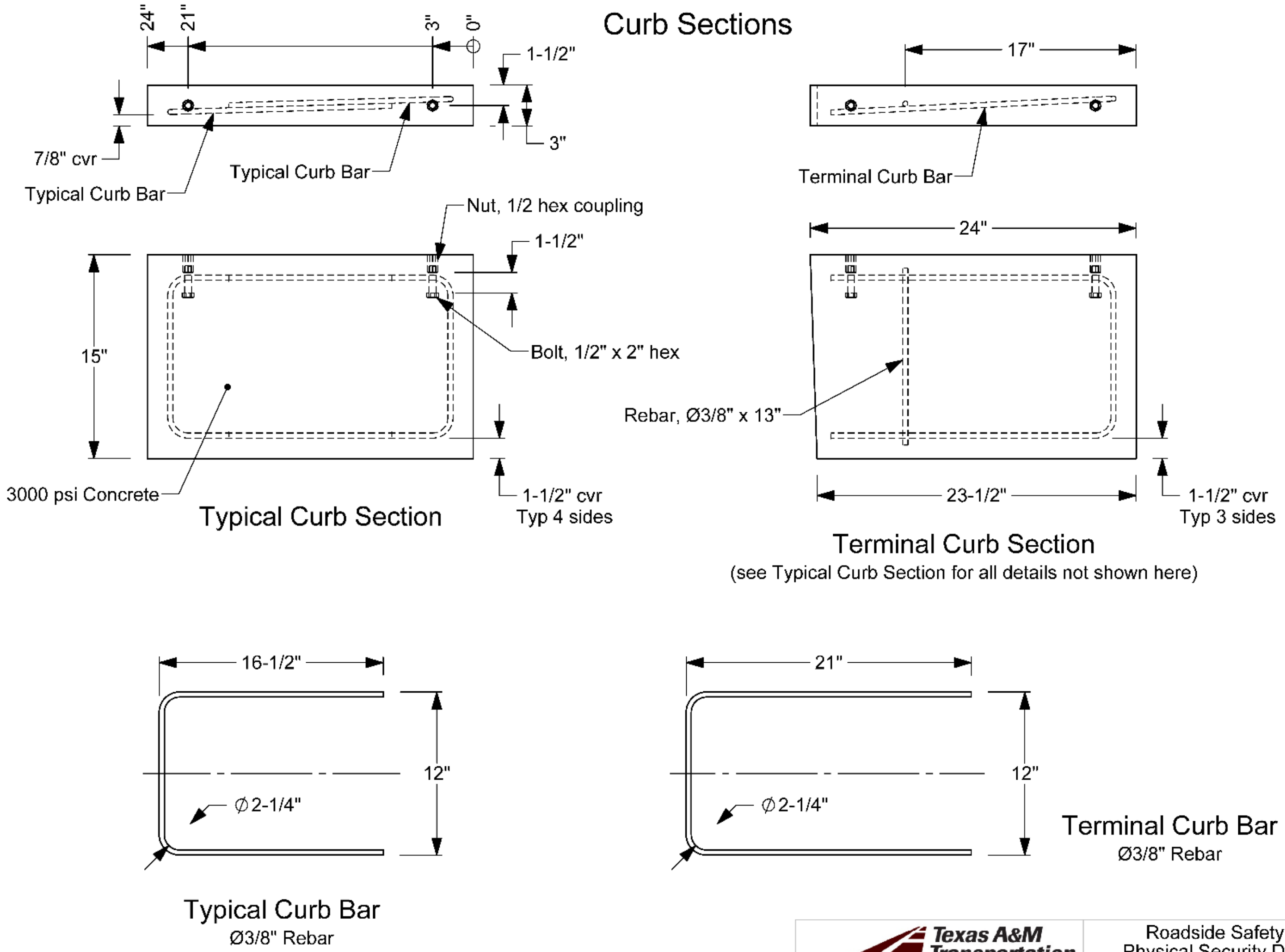

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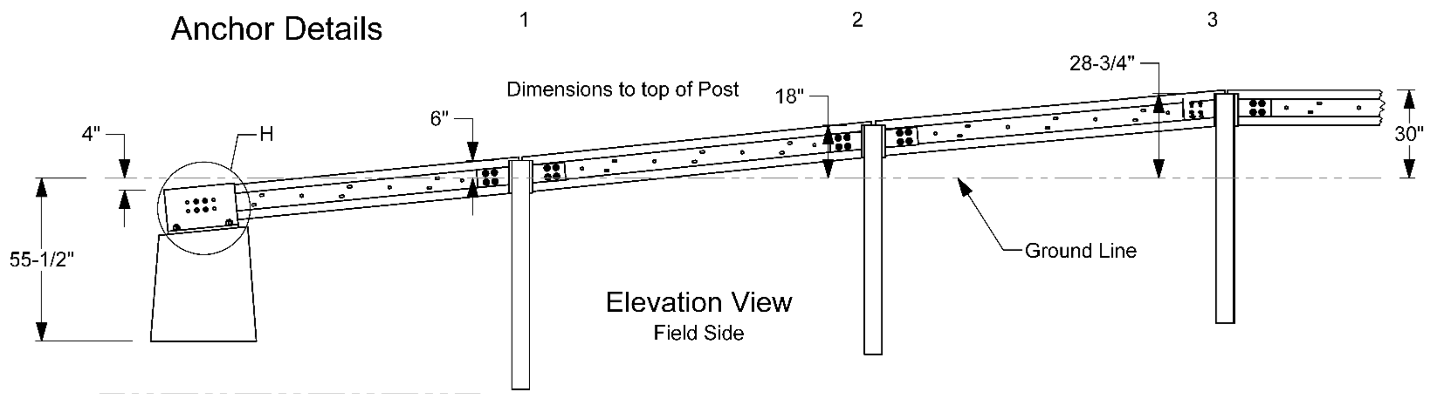
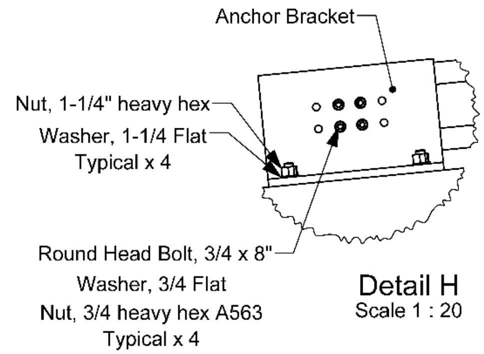
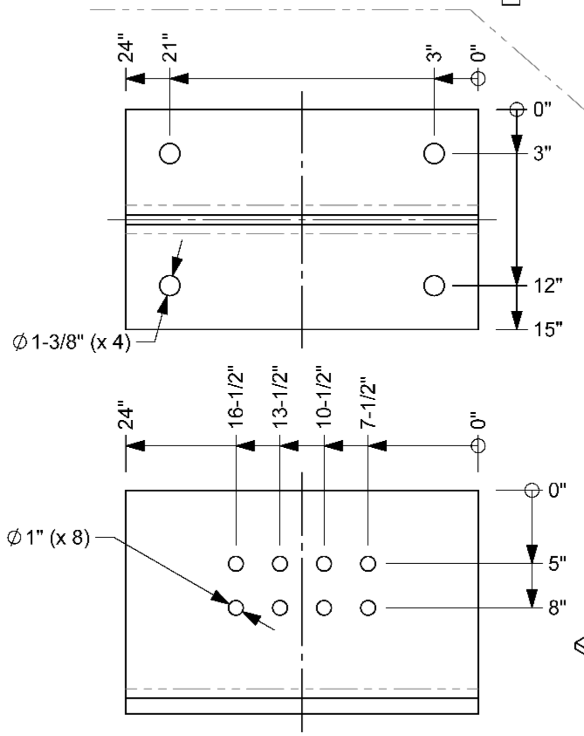
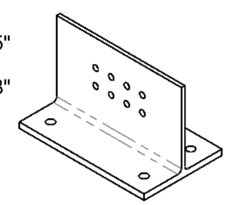
Anchor Details







Anchor Bracket
WT 15 x 86.5
Galvanize after all fabrication is complete.
Scale 1:10



5a. All steel components, from the Anchor Block up to Post 2, including hardware and the Splice Plate at Post 2, but excluding the rebar in the Anchor Block, shall be galvanized.

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Drawn by GES	Scale 1:50	Sheet 5 of 12 Anchor Details

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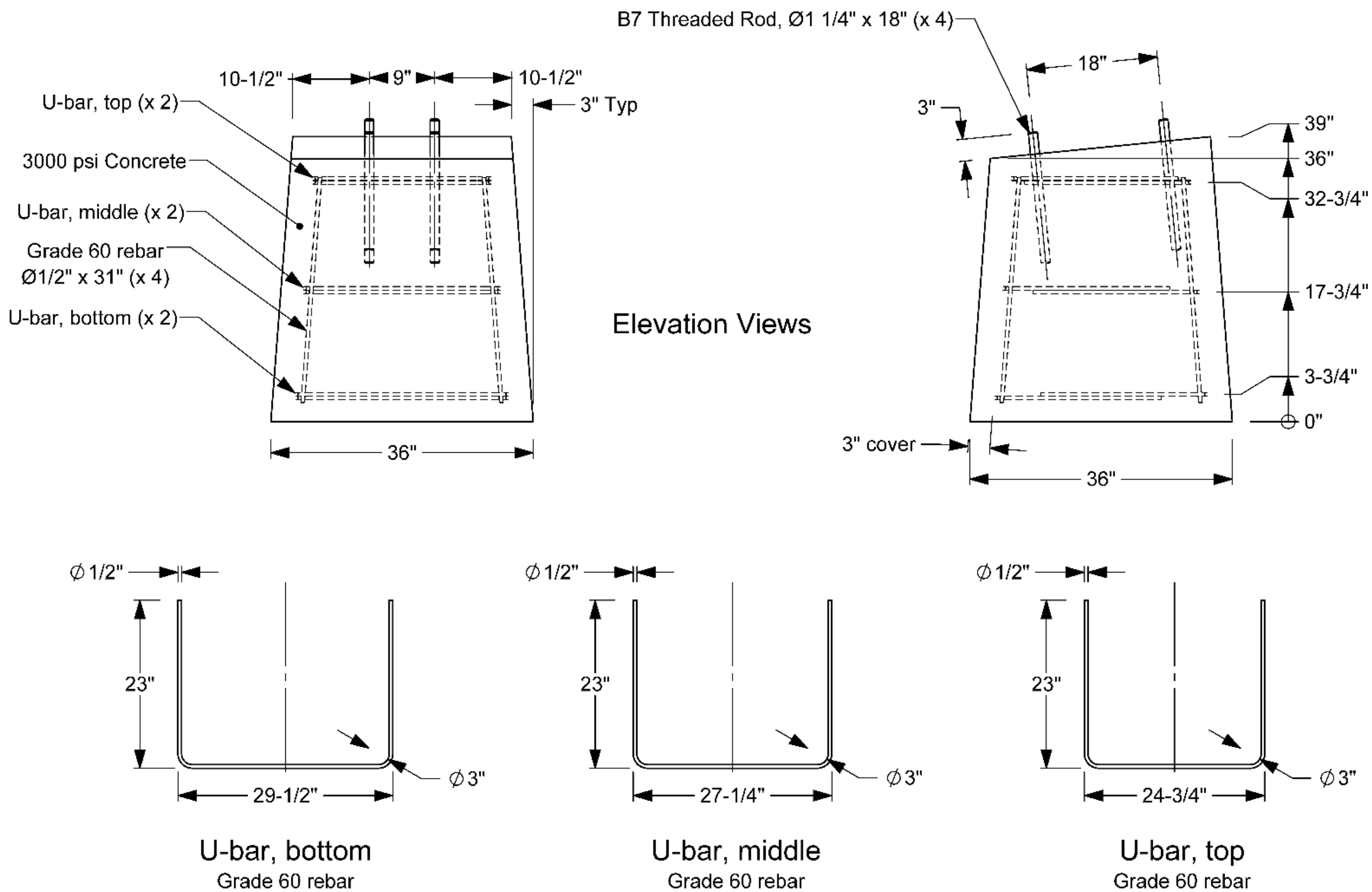
Anchor Block



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Drawn by GES	Scale 1:20	Sheet 6 of 12 Anchor Block

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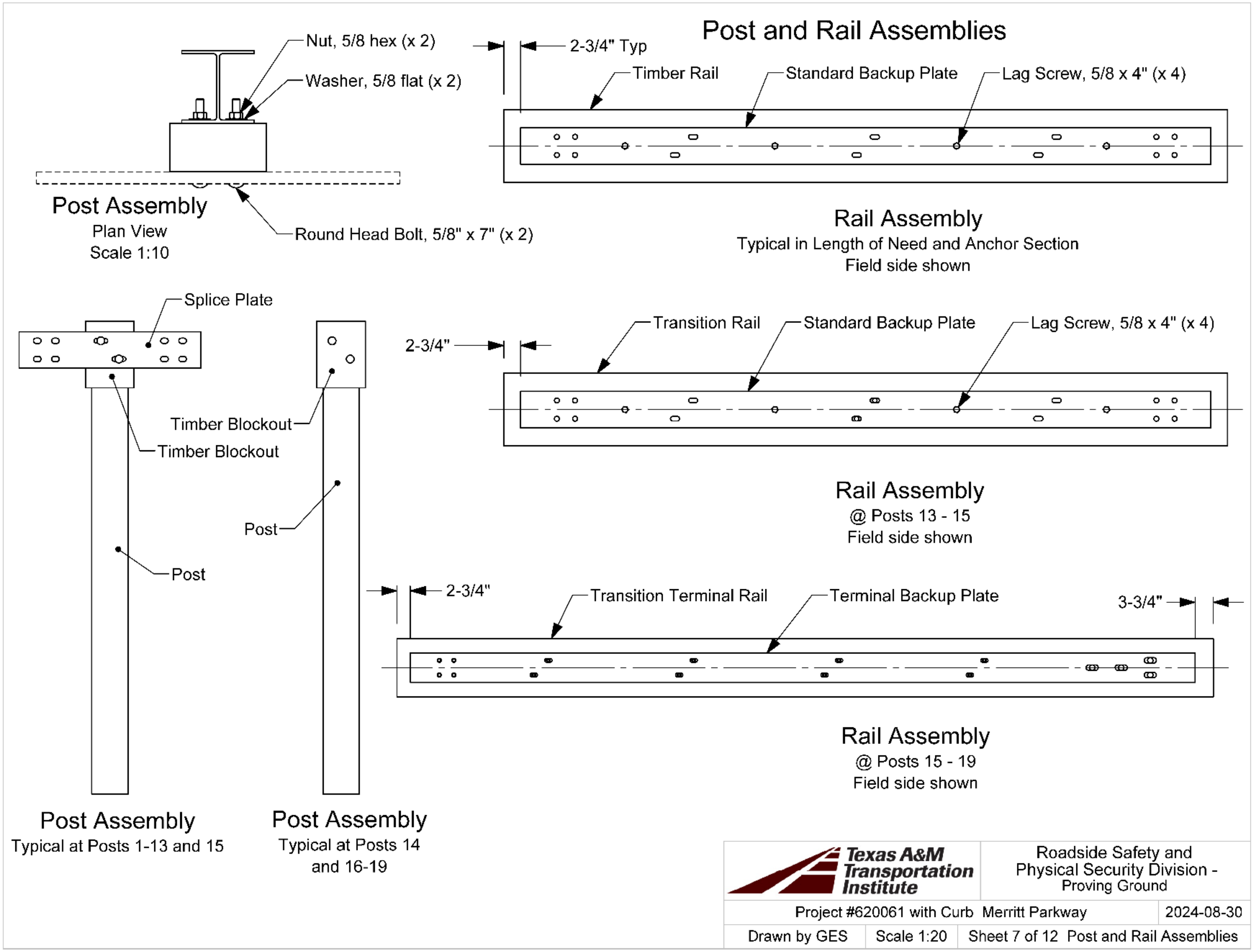

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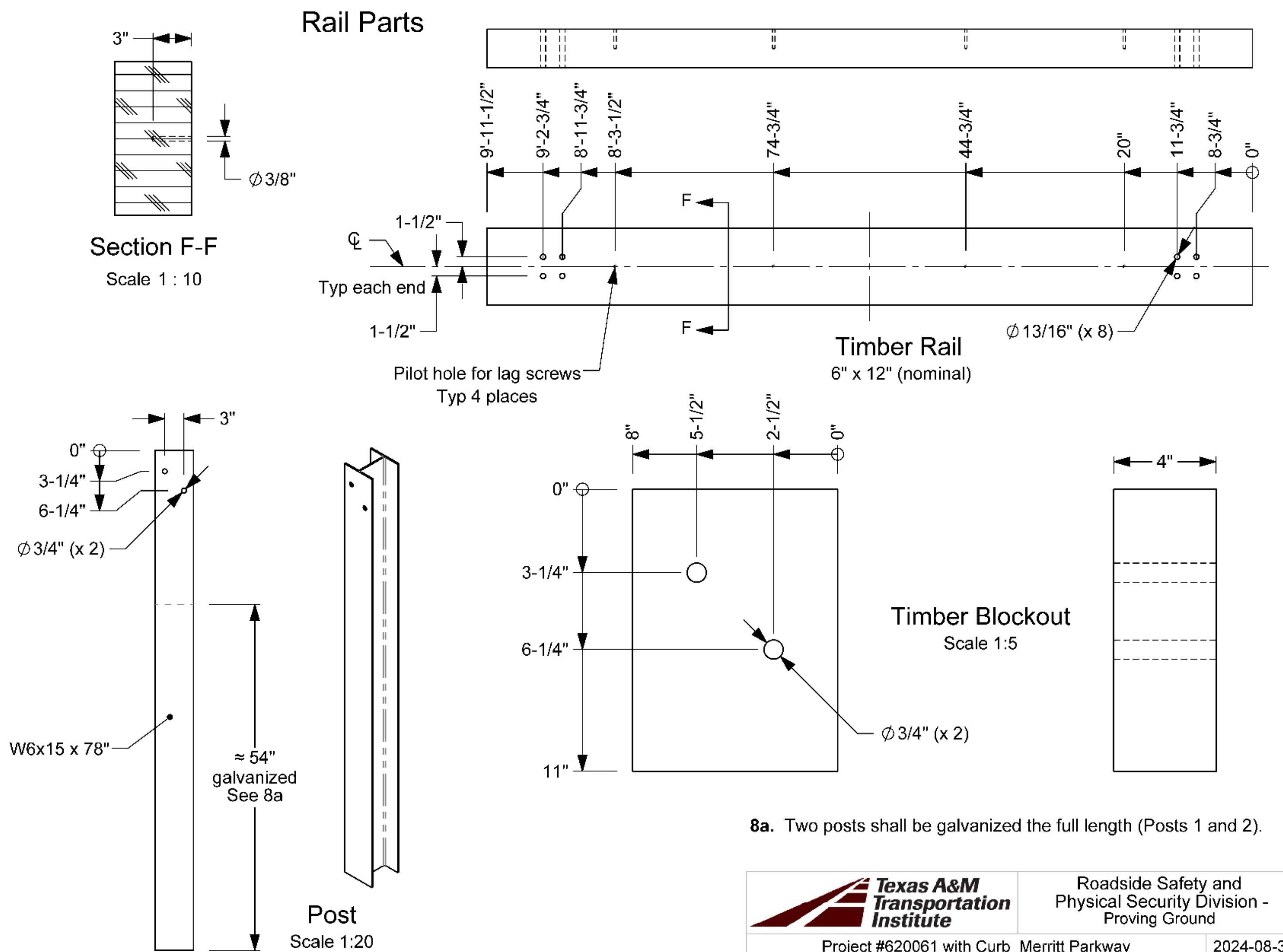
Rail Parts



8a. Two posts shall be galvanized the full length (Posts 1 and 2).

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Project #620061 with Curb Merritt Parkway		2024-08-30
Drawn by GES	Scale 1:20	Sheet 8 of 12 Rail Parts

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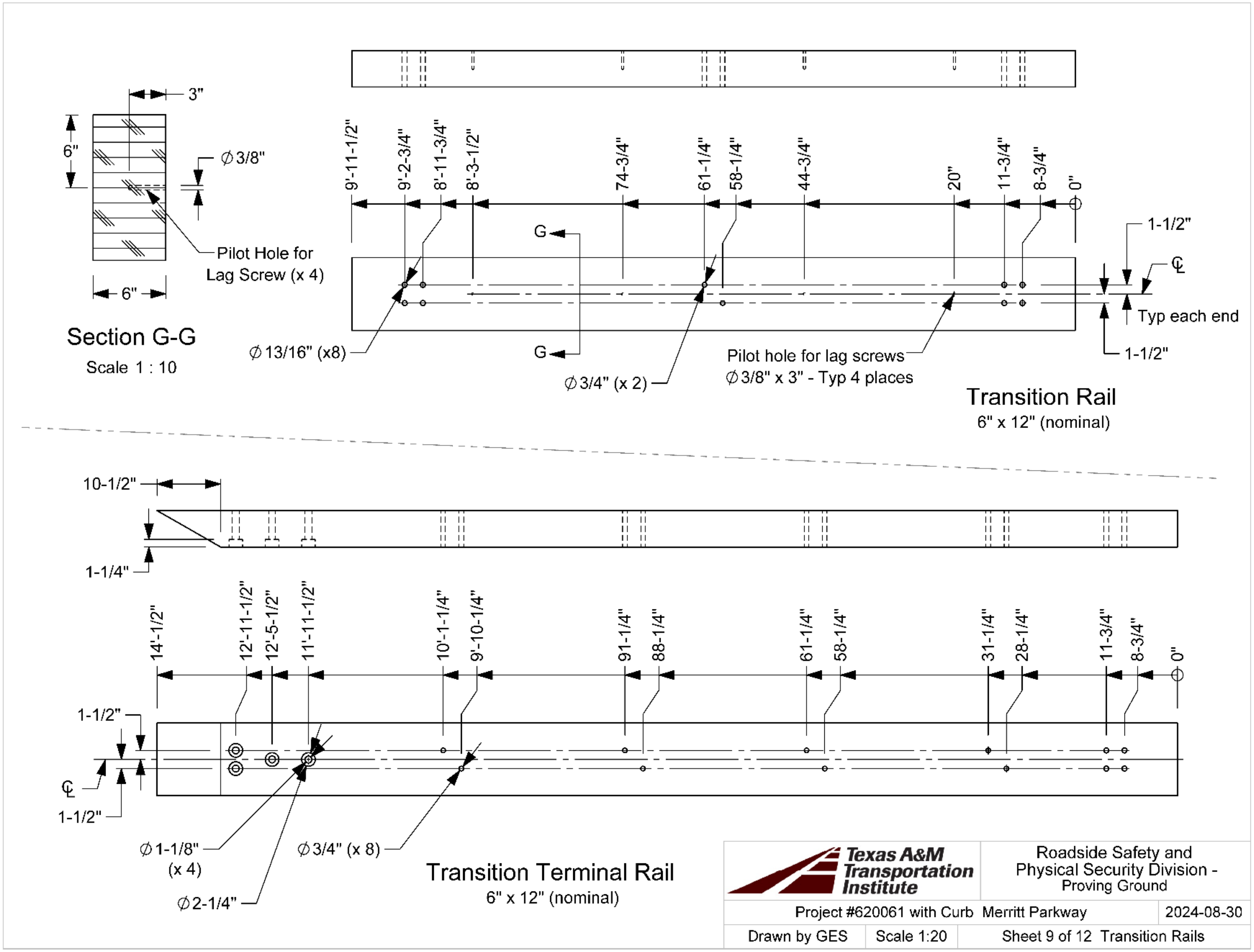

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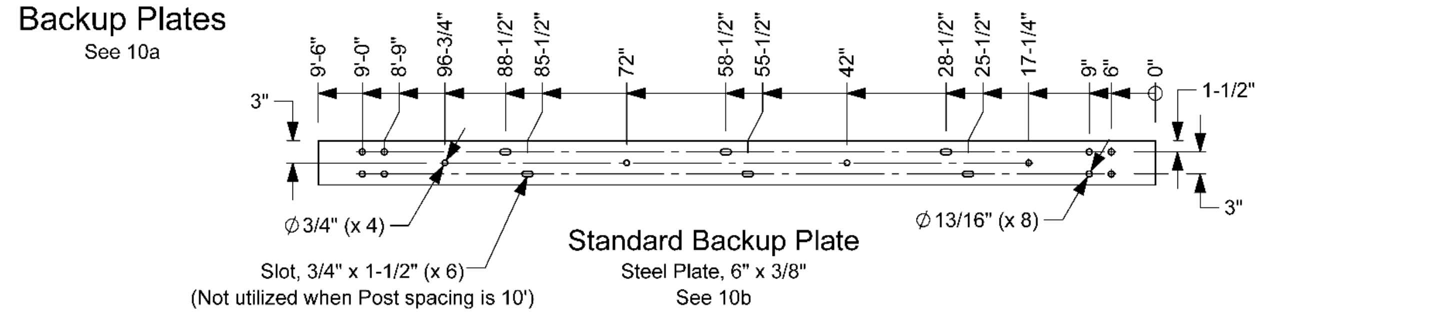

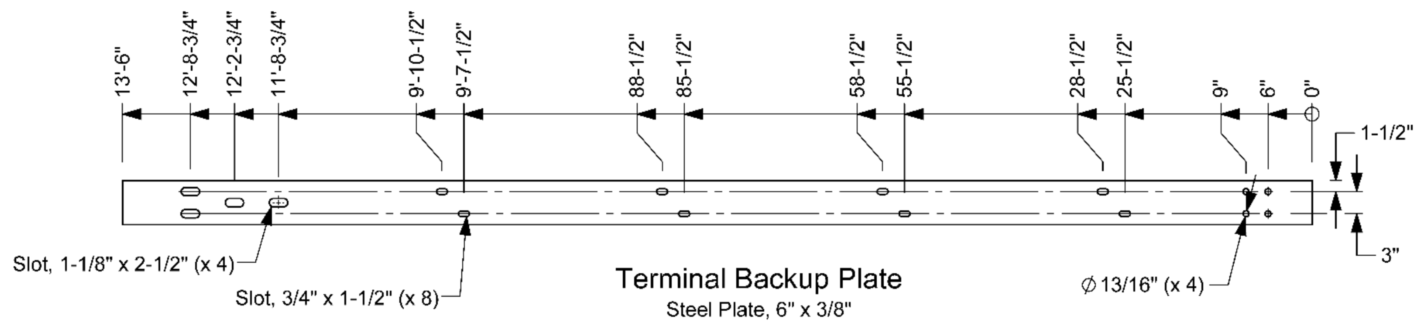

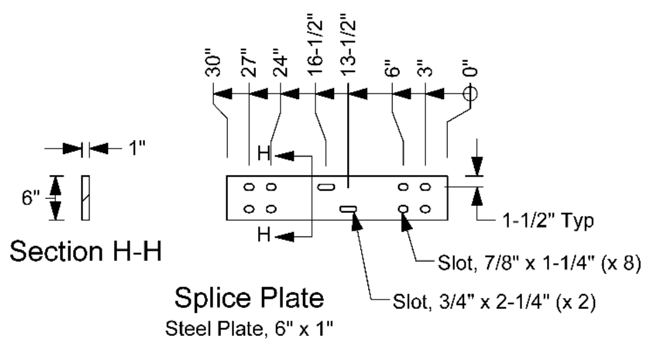

10a. Galvanize two Standard Backup Plates (used from Anchor Block to Post 1 and Post 1 to Post 2) and two Splice Plates (used at Posts 1 and 2).

10b. Slots at 25-1/2" , 28-1/2" , 85-1/2" ,and 88-1/2" are not used in this installation. Slots at 55-1/2" and 58-1/2" are used only at Post 14.

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Drawn by GES	Scale 1:20	Sheet 10 of 12 Backup Plates

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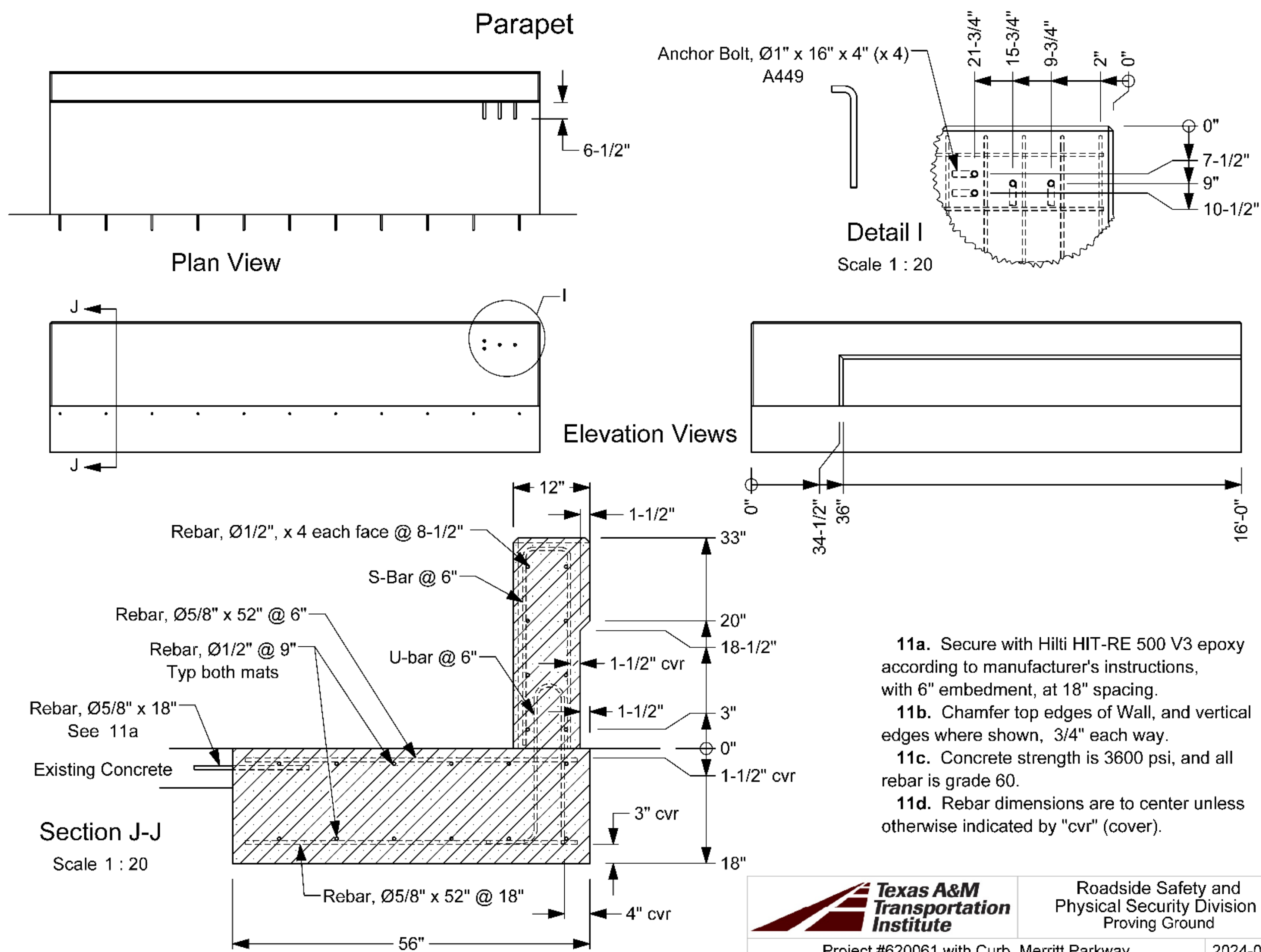

11a. Secure with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions, with 6" embedment, at 18" spacing.

11b. Chamfer top edges of Wall, and vertical edges where shown, 3/4" each way.

11c. Concrete strength is 3600 psi, and all rebar is grade 60.

11d. Rebar dimensions are to center unless otherwise indicated by "cvr" (cover).

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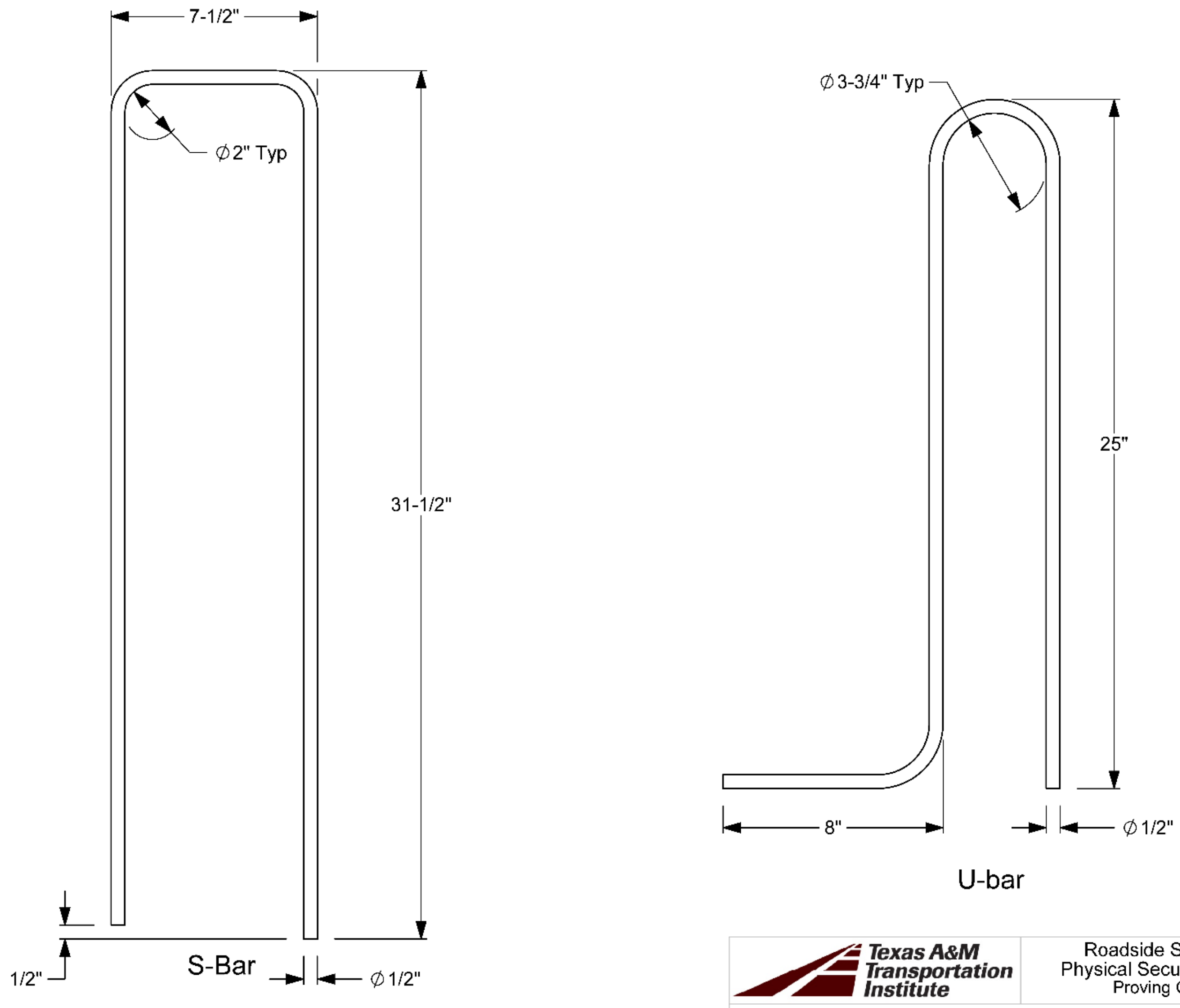
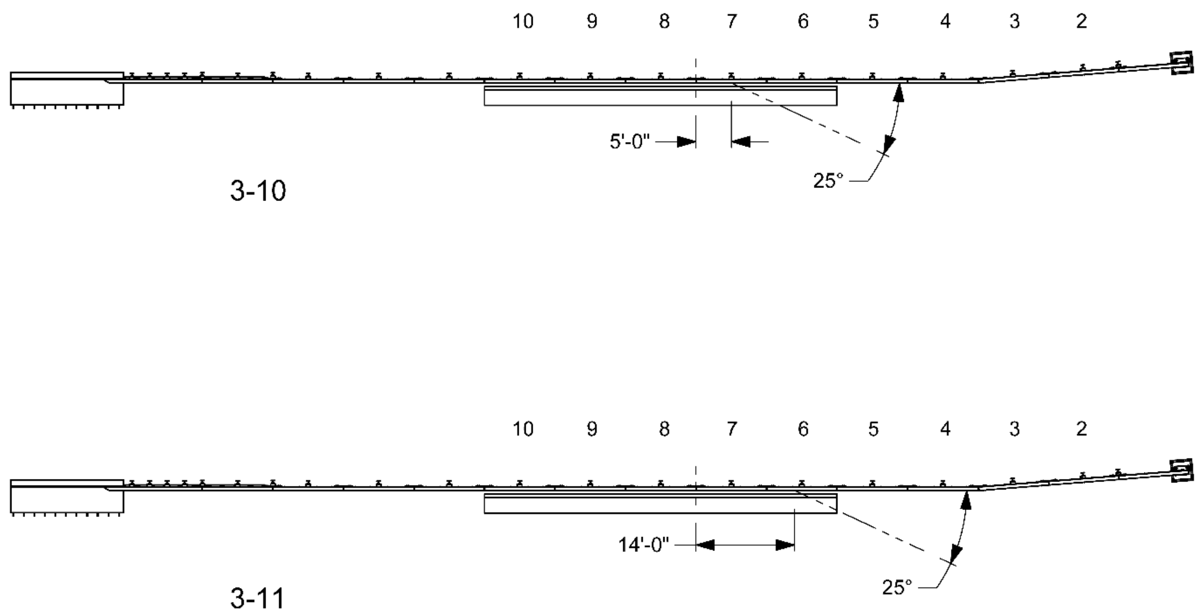
Project #620061 with Curb Merritt Parkway		2024-08-30
Drawn by GES	Scale 1:50	Sheet 11 of 12 Parapet



Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 with Curb Merritt Parkway		2024-08-30
Drawn by GES	Scale 1:5	Sheet 12 of 12 Rebar

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, 620061 with curb\620061 w curb Drawing

A.2. DETAILS OF MERRITT PARKWAY GUIDERAIL FOR TESTS 620061-01 & 3



Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Project #620061 v2 with curb

Drawn by GES

Sheet 1 of 1 Impact

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Notes

1a. Drill Ø24" holes for Posts. Backfill Post holes and around Anchor Block with Type D grade 1 crushed concrete road base, compacted to MASH standard.

1b. Threads not shown on Bolts, Nuts, etc for clarity.

1c. Material:

Steel: All steel posts, back-up rails, splice plates and channel rubrails which are to be used as "Weathering Steel", shall meet the requirements of ASTM A588. The fabricator shall notify the manufacturer that it is "Weathering Steel" (structural steel for use in bare, unpainted applications) and that the steel shall not be marked with paint or steel die stamped, but identification shall be stenciled with permanent ink. The dimensions of each component shall conform to the plans and ASTM A6. All steel posts shall be galvanized after fabrication to meet the requirements of ASTM A123 and conform to the galvanizing limits and tolerances shown on the plans. A single ¾" diameter hole may be drilled 2" from the top of each post, in the center of the web, to facilitate the galvanizing process on the bottom of all posts.

Timber: All timber rail and block-out components shall conform with the following:

a) Commercial lumber grade No. 1 or better after treatment;
b) AASHTO M 168;
c) Minimum stress rating of 1350 psi
d) Rough sawn (non-planed) or S4S (surface four side) Southern Yellow Pine or Douglas Fir- Larch with nominal dimensions as indicated on the plans. Variations in the size of any dimension shall not be more than ± ¼"
e) All timber components shall be pressure treated with CCA or ACZA depending on species supplied conforming to AWPA Standard P5 to a minimum net retention of 0.60lb/cubic foot in the assay zone in accordance with AWPA Standard C14.
f) All timber components shall be fabricated (including but not necessarily limited to cutting, drilling, dapping and chamfering) prior to treatment.
g) All timber components shall be free of excess preservative and solvent at the conclusion of the treating process. Post treatment cleaning shall be by expansion bath or steaming in accordance with AWPA Standard C2;
h) Kiln or air dried to a maximum moisture content of 25% after treatment (KDAT - 25);
i) Grade-marked after treatment by an agency certified by the American Lumber Standard Committee (ALSC).

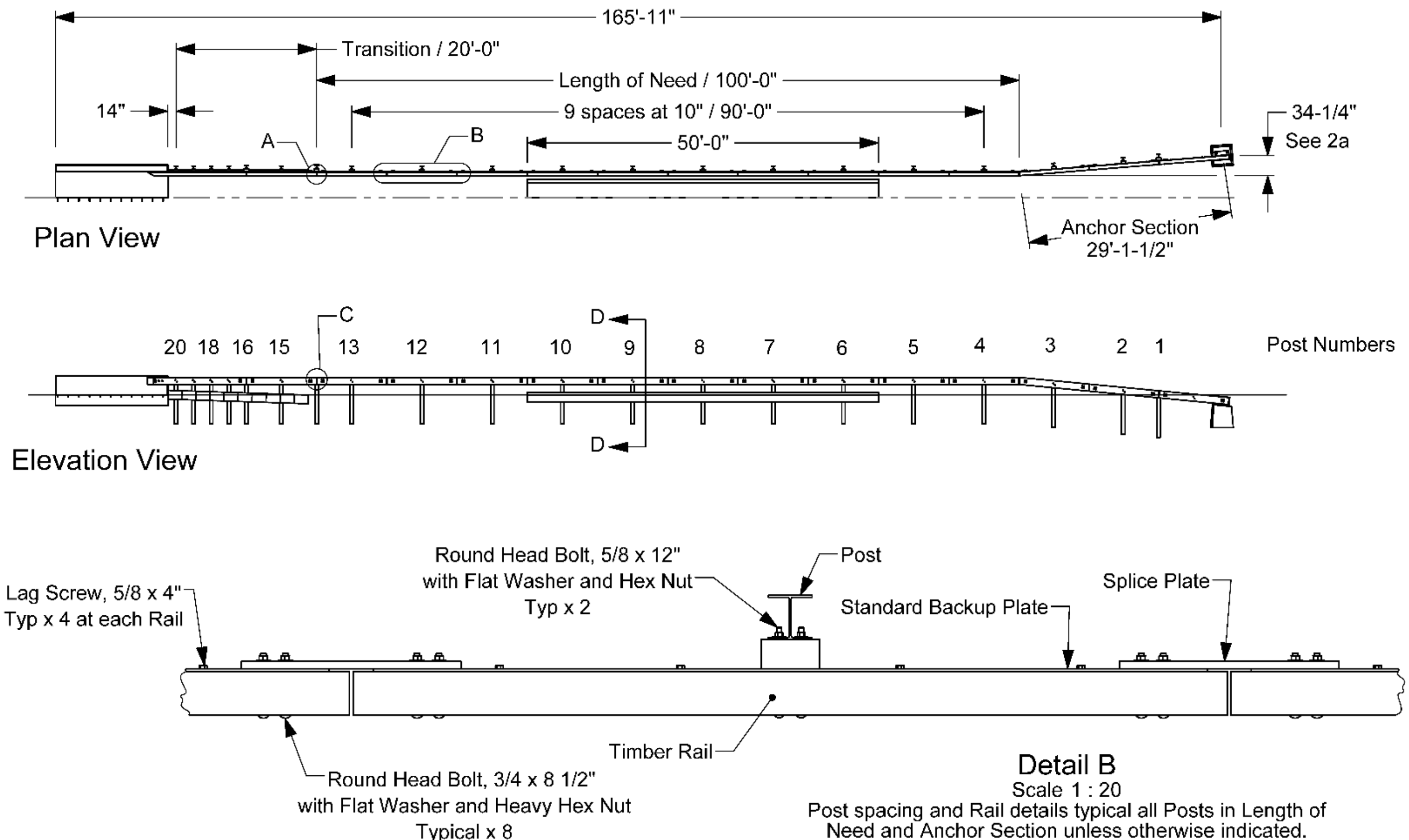
Fasteners:

a) Round head bolts shall be manufactured in accordance with the sizes designated on the plans, the geometric specifications included in ANSI B18.5.1.2.2 and the material specifications for ASTM A449 steel. All round head bolts shall be marked with the manufacturers symbol and A449.
b) Hex Lag Screws shall be manufactured in accordance with ASTM A307 Grade A specifications. All Hex Lag Screws used between the Anchor Block and Post 2 shall be hot-dipped galvanized in accordance with ASTM A153 Class C.
c) Nuts, and Washers shall be ASTM A449 steel.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 with Curb v2 Merritt Parkway			2024-11-25
Drawn by GES	Scale 1:250	Sheet 1 of 13 Notes	

Test Installation

Some Detail and Section Views on next sheet



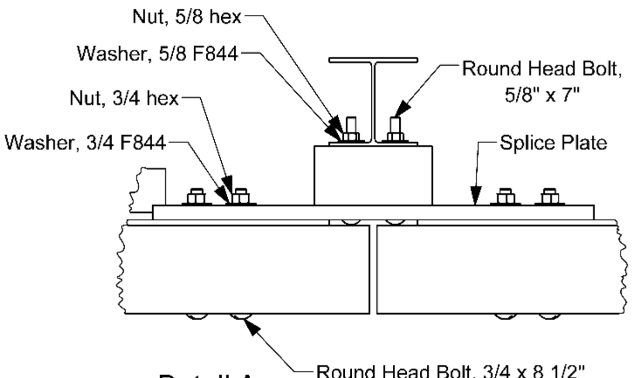
Detail B
Scale 1 : 20
Post spacing and Rail details typical all Posts in Length of Need and Anchor Section unless otherwise indicated.
Connection details typical at all Posts except 14 and 16 - 19.

2a. This dimension is from the traffic side face of the Traffic Rail to the center of the Anchor Block.

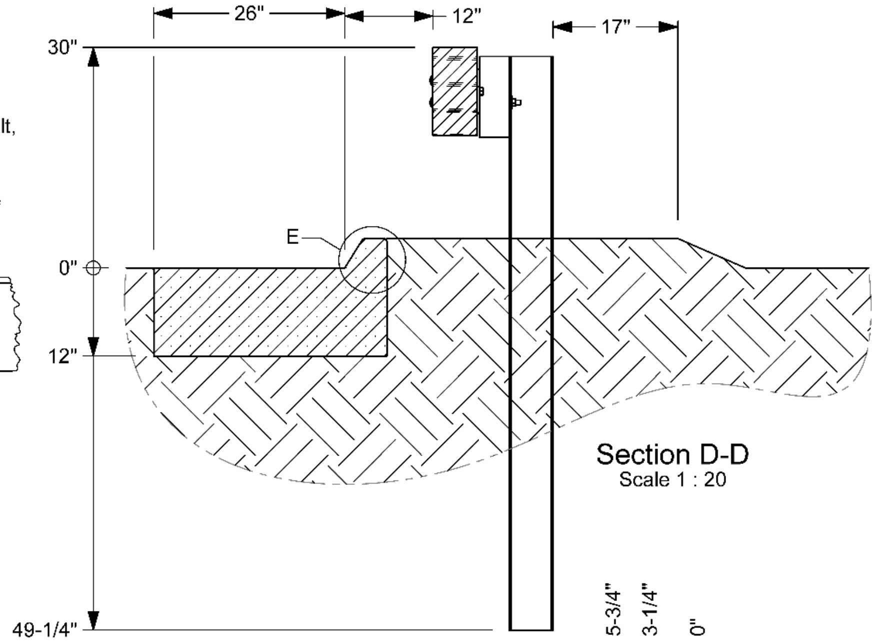
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 with Curb v2 Merritt Parkway		2024-11-25
Drawn by GES	Scale 1:250	Sheet 2 of 13 Test Installation

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, v2 with curb\620061 w curb Drawing

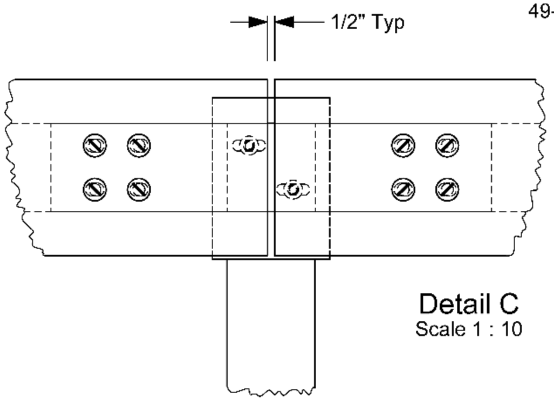
Detail and Section Views



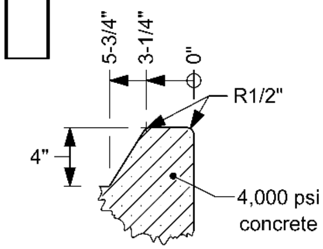
Detail A
Scale 1 : 10
Typ at Posts 1, 14, and 16



Section D-D
Scale 1 : 20



Detail C
Scale 1 : 10



Detail E
Scale 1 : 10

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 with Curb v2 Merritt Parkway		2024-11-25
Drawn by GES	Scale 1:250	Sheet 3 of 13 Detail and Section Views

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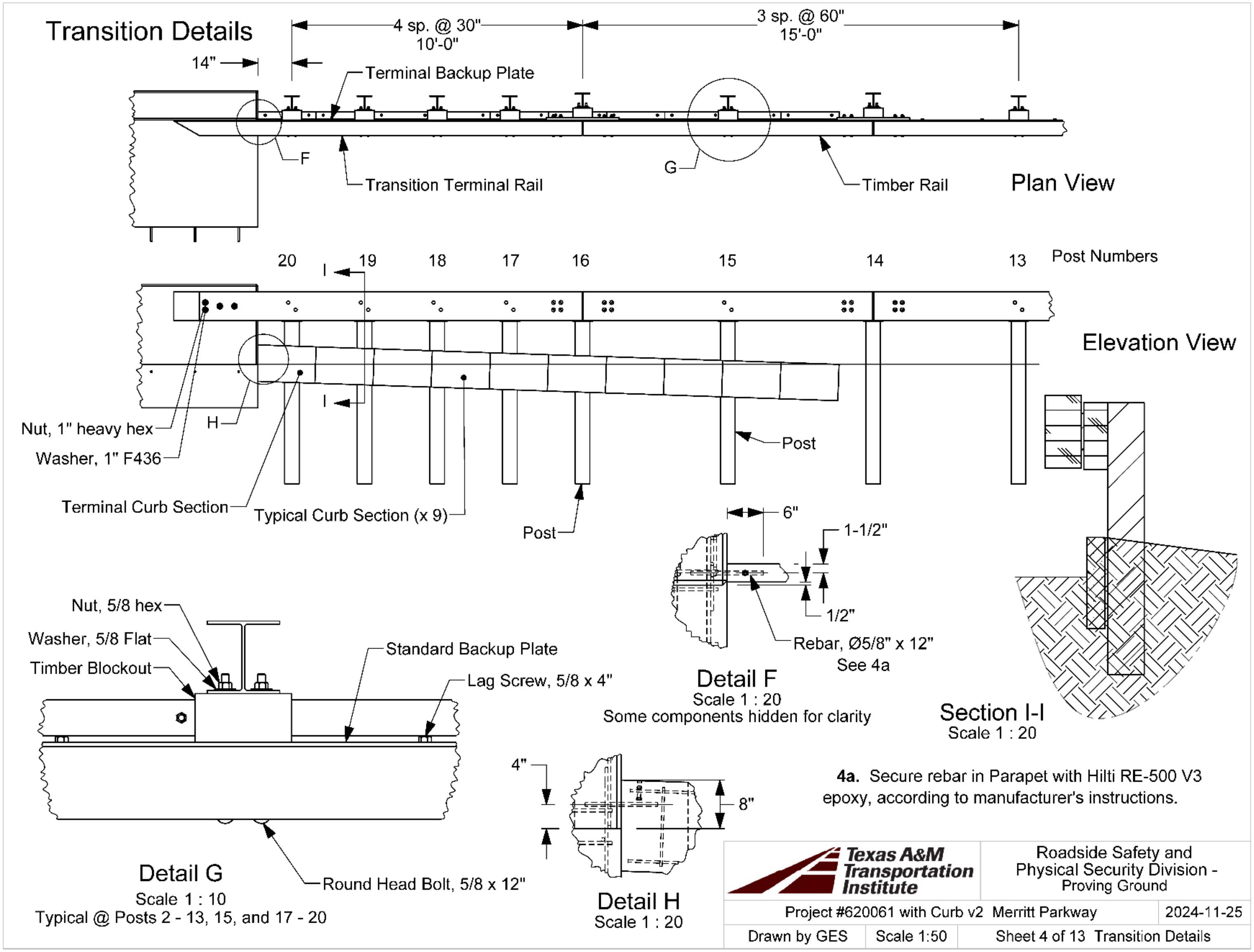

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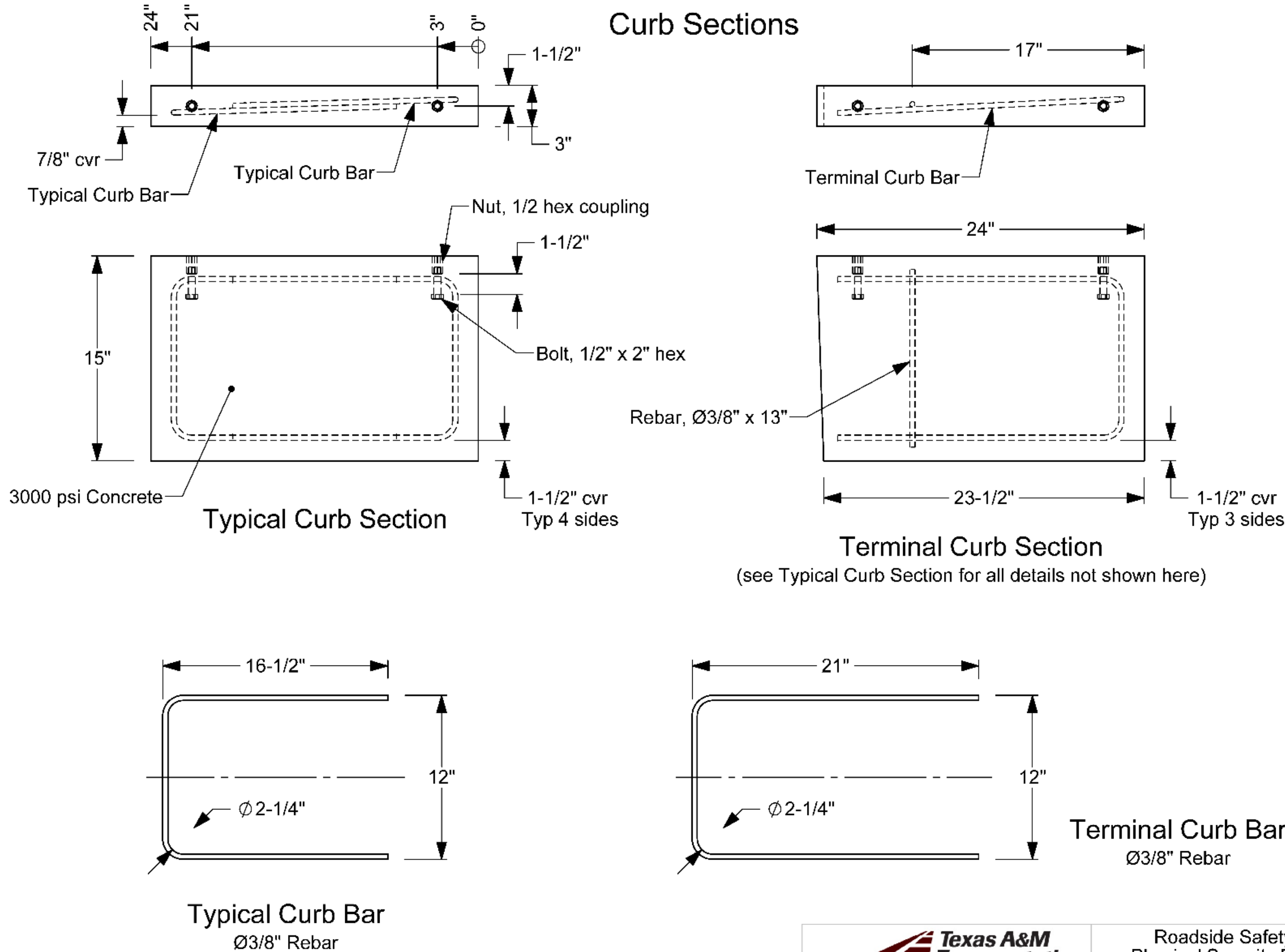
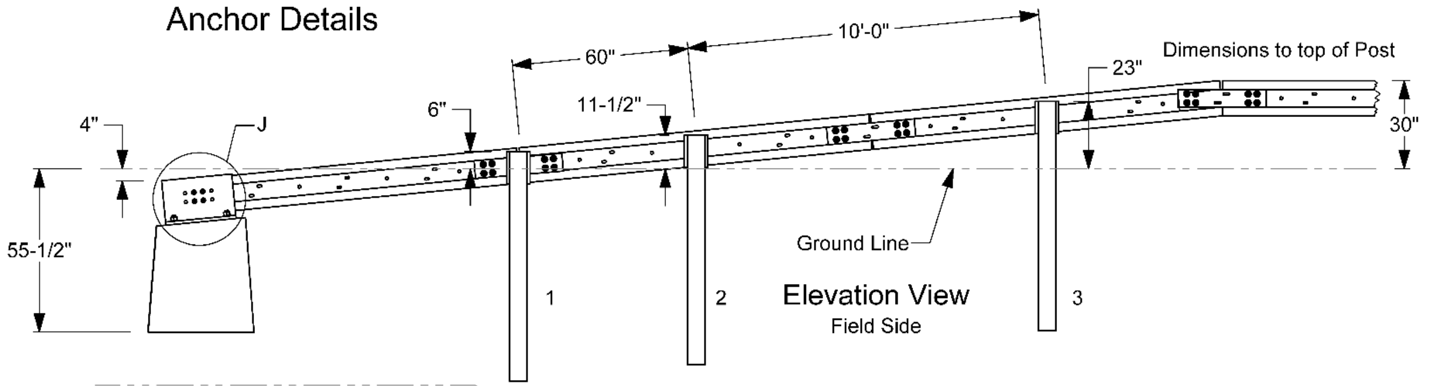
Curb Sections



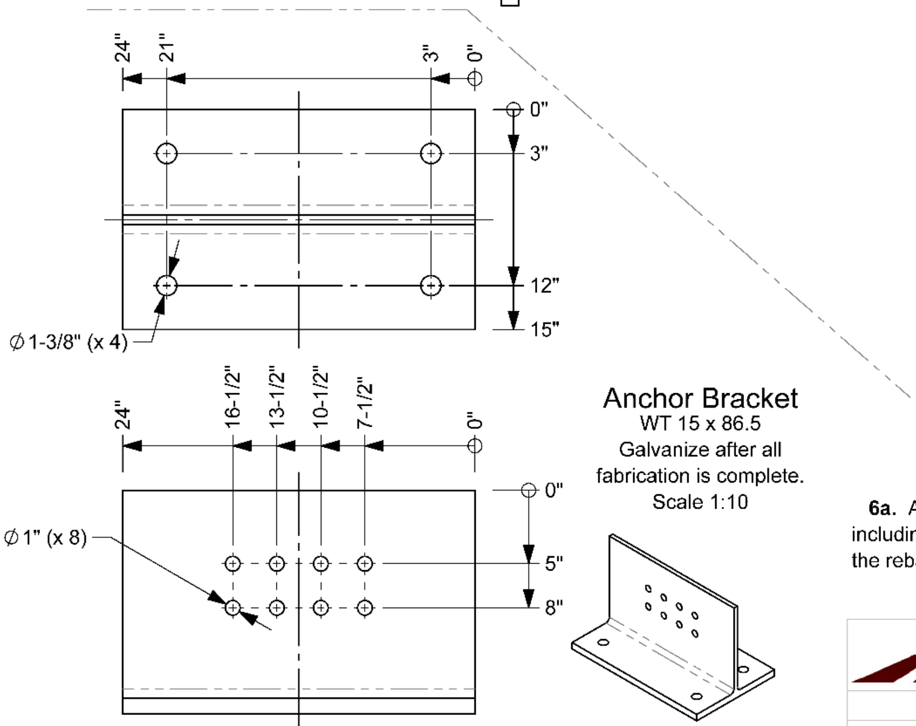
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 with Curb v2 Merritt Parkway		2024-11-25
Drawn by GES	Scale 1:10	Sheet 5 of 13 Curb Sections

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, v2 with curb\620061 w curb Drawing

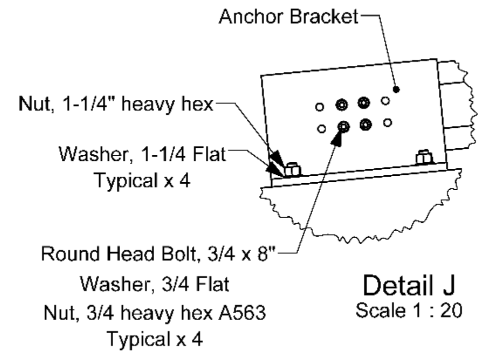
Anchor Details



Elevation View
Field Side



Anchor Bracket
WT 15 x 86.5
Galvanize after all
fabrication is complete.
Scale 1:10



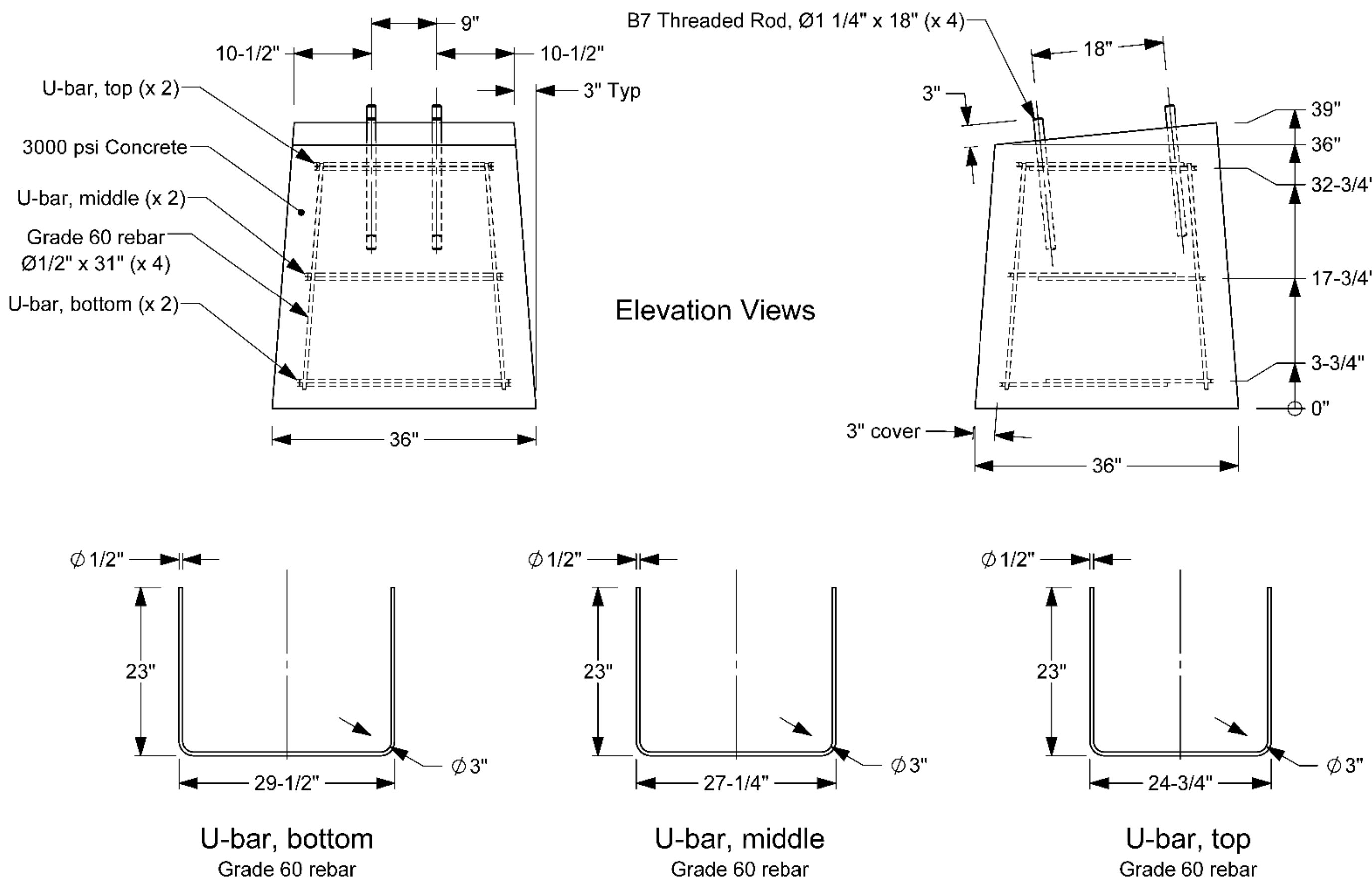
Detail J
Scale 1 : 20

6a. All steel components, from the Anchor Block up to Post 2, including hardware and the Splice Plate at Post 2, but excluding the rebar in the Anchor Block, shall be galvanized.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 with Curb v2 Merritt Parkway		2024-11-25
Drawn by GES	Scale 1:50	Sheet 6 of 13 Anchor Details

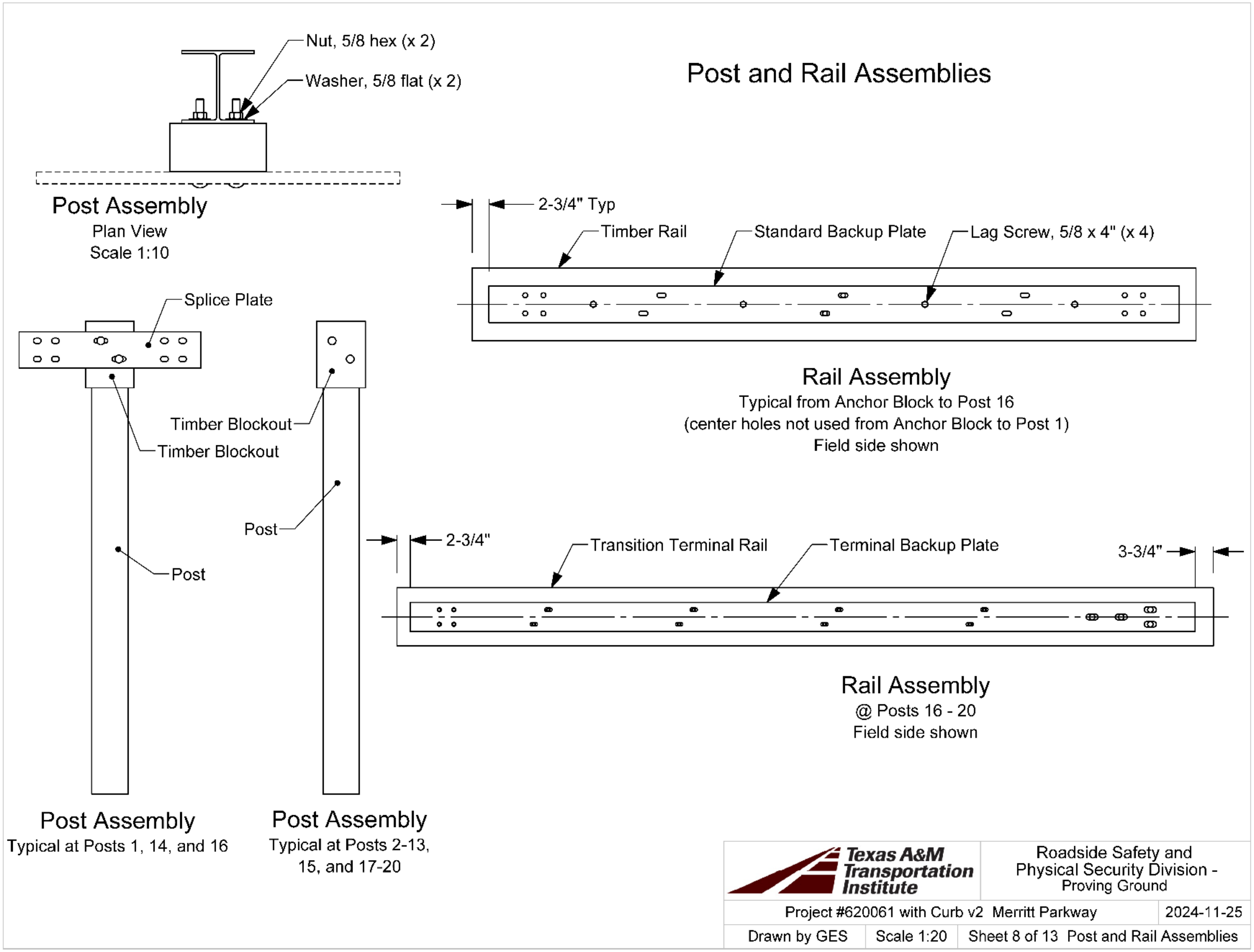
S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, v2 with curb\620061 w curb Drawing

Anchor Block



Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 with Curb v2 Merritt Parkway		2024-11-25
Drawn by GES	Scale 1:20	Sheet 7 of 13 Anchor Block

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, v2 with curb\620061 w curb Drawing



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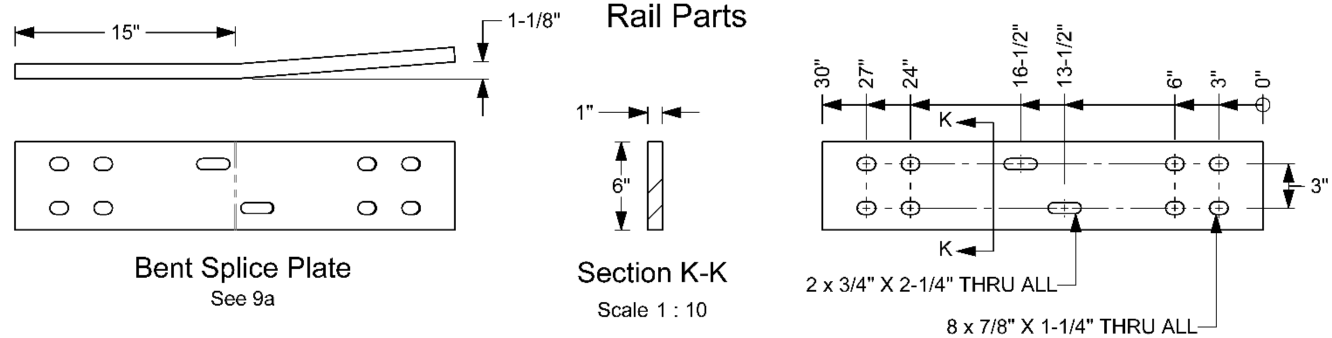
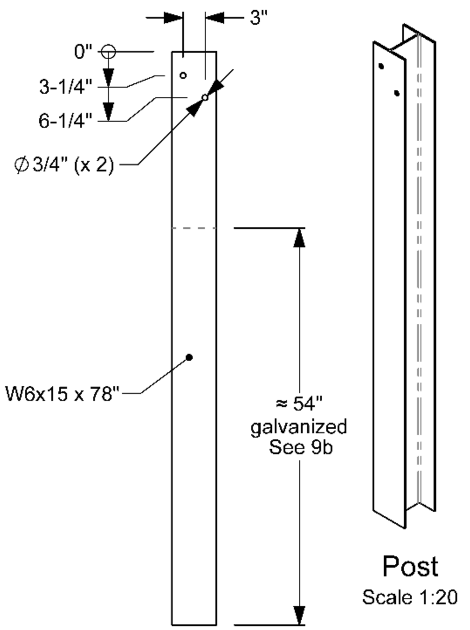
Rail Parts



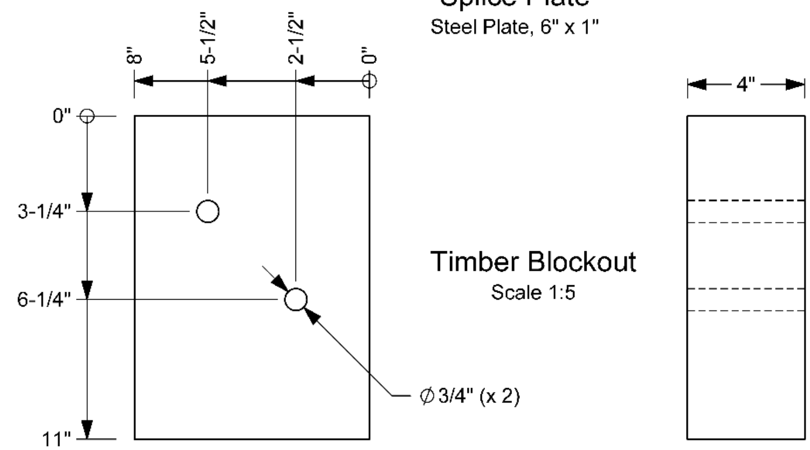
Bent Splice Plate
See 9a

Section K-K
Scale 1 : 10

Splice Plate
Steel Plate, 6" x 1"



Post
Scale 1:20

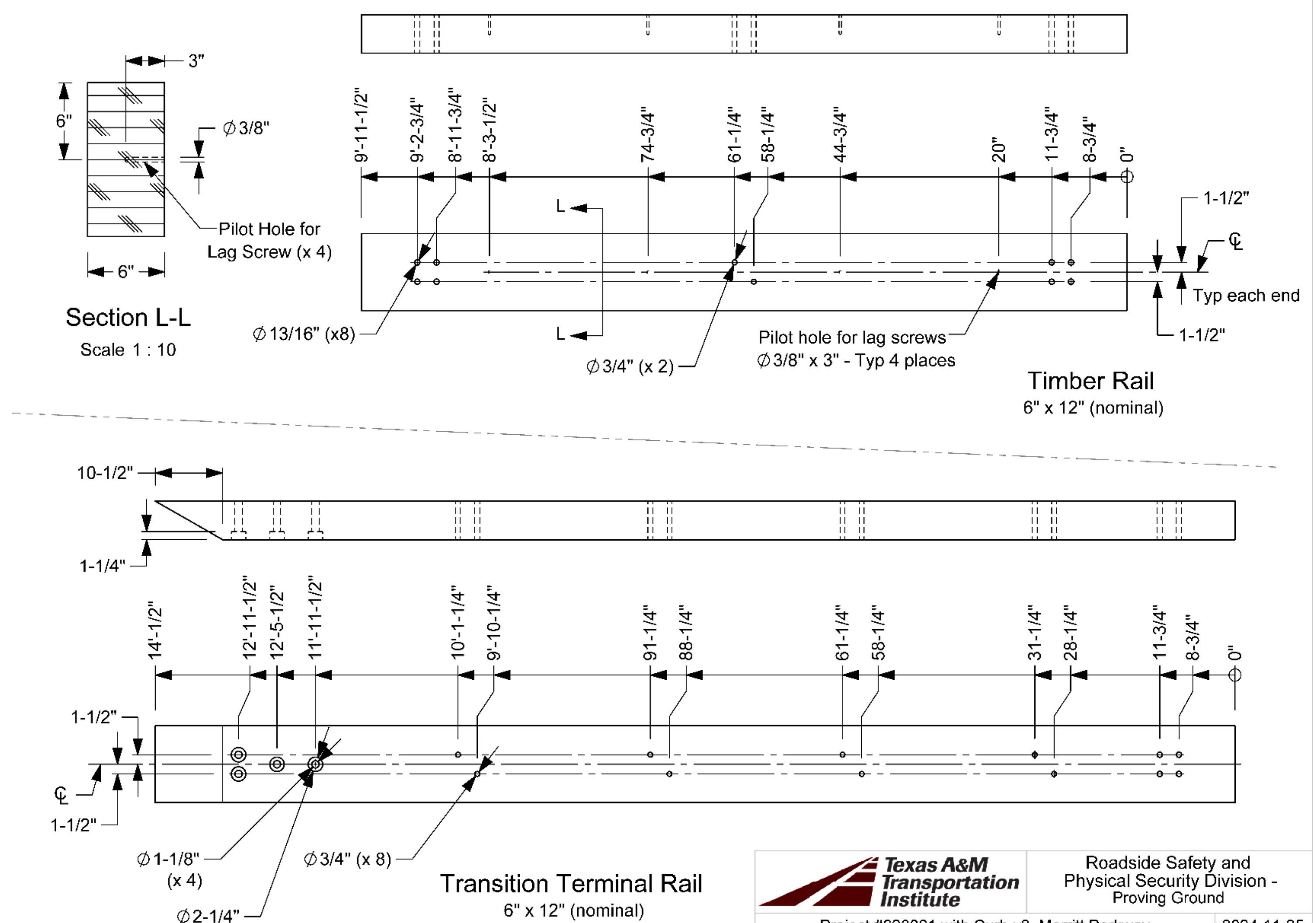


Timber Blockout
Scale 1:5

9a. Used between Posts 3 and 4; all other details same as standard Splice Plate (Standard Splice Plate is not bent). May be bent or cut and welded according to standard industry practice.

9b. Three posts shall be galvanized the full length (Posts 1 - 3).
9c. Galvanize two Splice Plates (used at Post 1 and the joint between Posts 2 and 3).

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 with Curb v2 Merritt Parkway		2024-11-25
Drawn by GES	Scale 1:10	Sheet 9 of 13 Rail Parts

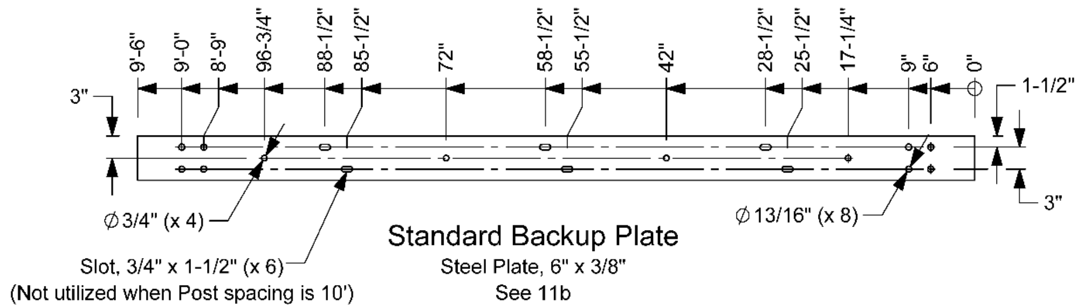


Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 with Curb v2 Merritt Parkway		2024-11-25
Drawn by GES	Scale 1:20	Sheet 10 of 13 Timber Rail Details

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, v2 with curb\620061 w curb Drawing

Backup Plates

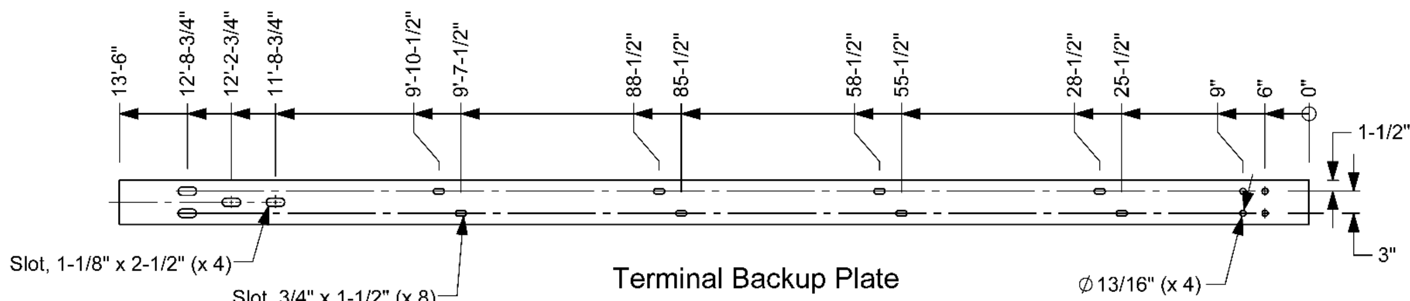
See 11a



Standard Backup Plate

Steel Plate, 6" x 3/8"

See 11b



Terminal Backup Plate

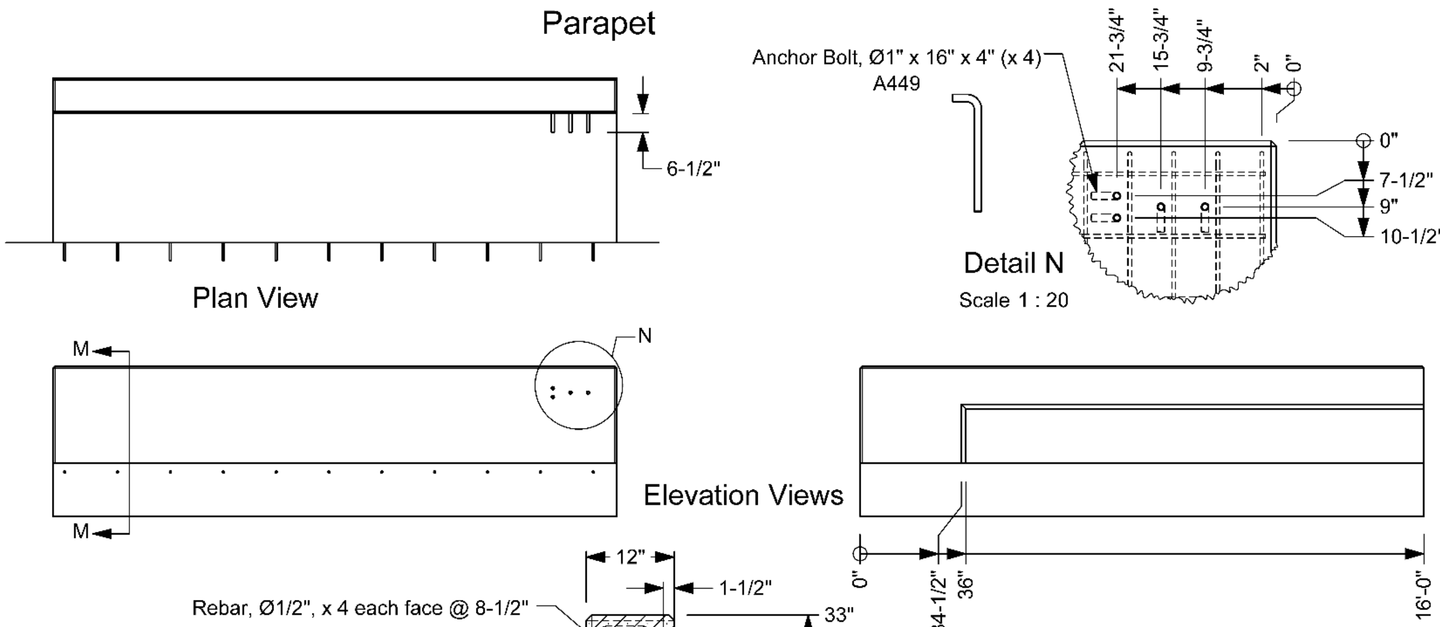
Steel Plate, 6" x 3/8"

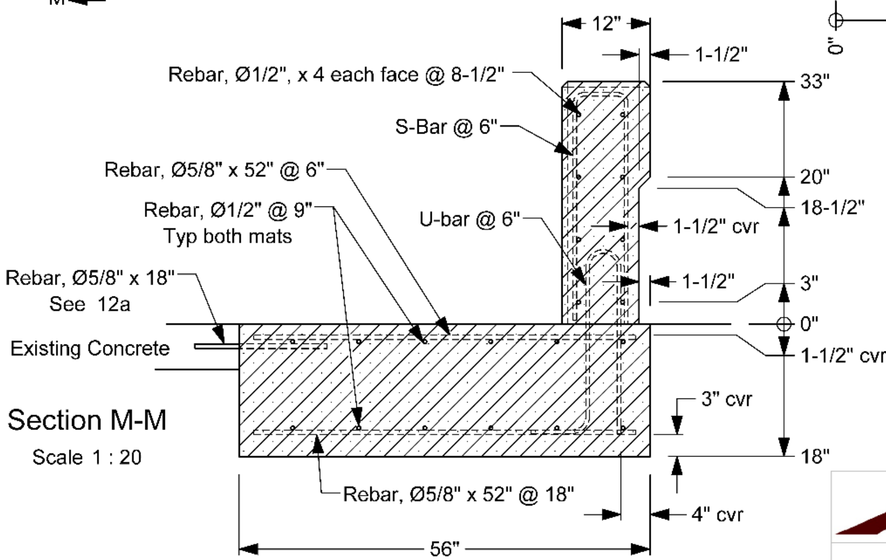
11a. Galvanize two Standard Backup Plates (used from Anchor Block to Post 1 and Post 1 to the joint between Posts 2 and 3.

11b. Slots at 25-1/2" , 28-1/2" , 85-1/2" ,and 88-1/2" are not used in this installation. Slots at 55-1/2" and 58-1/2" are not used at all locations.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 with Curb v2 Merritt Parkway		2024-11-25
Drawn by GES	Scale 1:20	Sheet 11 of 13 Backup Plates

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, v2 with curb\620061 w curb Drawing

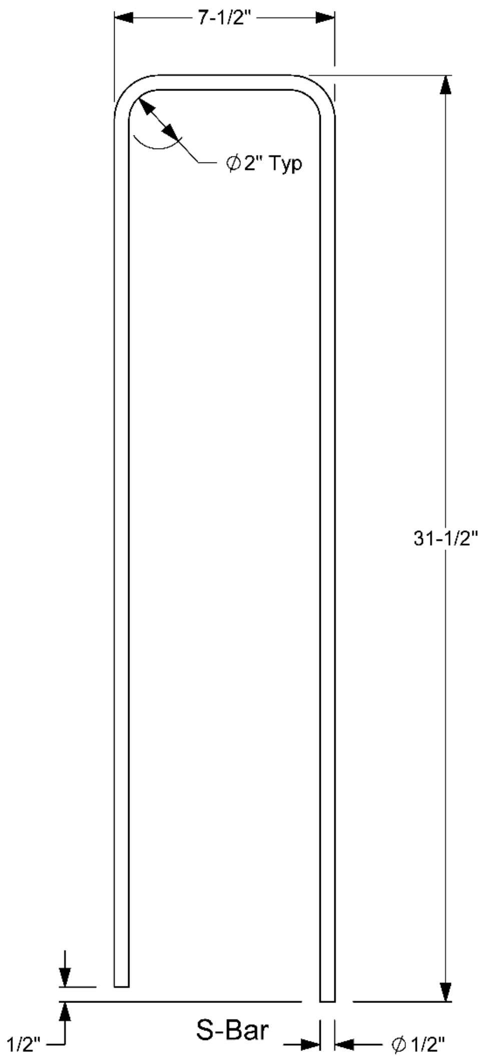




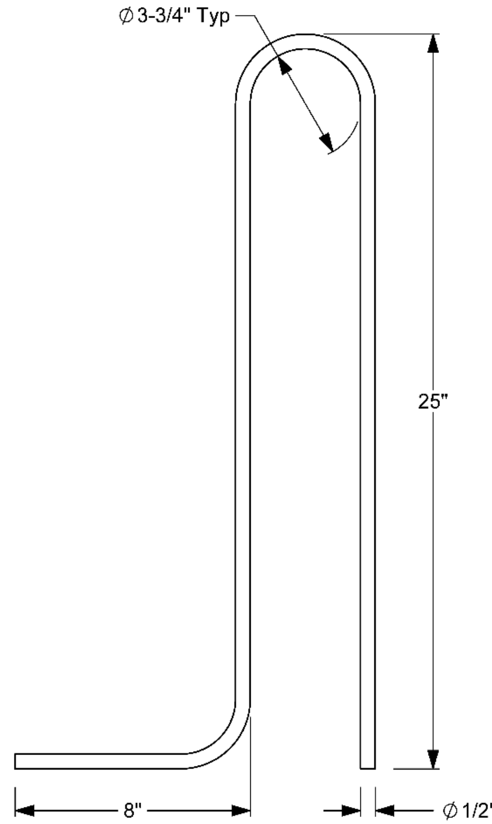
12a. Secure with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions, with 6" embedment, at 18" spacing.
12b. Chamfer top edges of Wall, and vertical edges where shown, 3/4" each way.
12c. Concrete strength is 3600 psi, and all rebar is grade 60.
12d. Rebar dimensions are to center unless otherwise indicated by "cvr" (cover).

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 with Curb v2 Merritt Parkway		2024-11-25
Drawn by GES	Scale 1:50	Sheet 12 of 13 Parapet

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, v2 with curb\620061 w curb Drawing



S-Bar

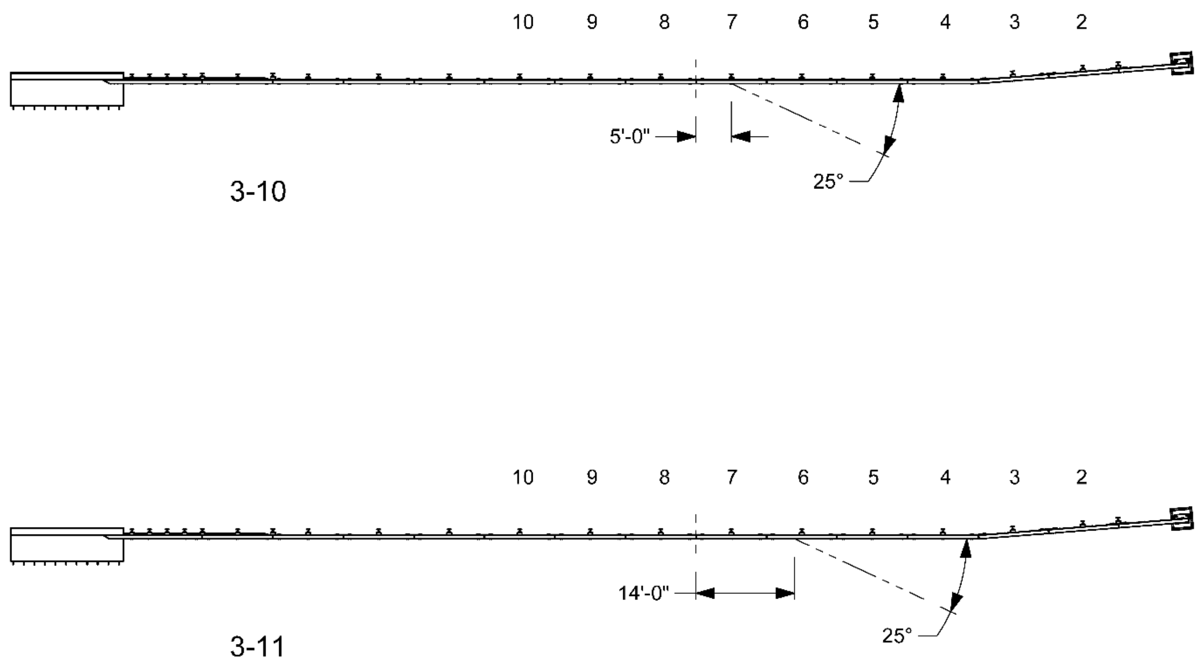


U-bar

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 with Curb v2 Merritt Parkway		2024-11-25
Drawn by GES	Scale 1:5	Sheet 13 of 13 Rebar

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, v2 with curb\620061 w curb Drawing

A.3. DETAILS OF MERRITT PARKWAY GUIDERAIL FOR TEST 620061-01-4



Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground
Project #620061 v2 with curb	
Drawn by GES	Sheet 2 of 3 no curb impacts

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, v2 with curb\620061 impacts and summaries

Notes

1a. Drill Ø24" holes for Posts. Backfill Post holes and around Anchor Block with Type D grade 1 crushed concrete road base, compacted to MASH standard.

1b. Threads not shown on Bolts, Nuts, etc for clarity.

1c. Material:

Steel: All steel posts, back-up rails, splice plates and channel rubrails which are to be used as "Weathering Steel", shall meet the requirements of ASTM A588. The fabricator shall notify the manufacturer that it is "Weathering Steel" (structural steel for use in bare, unpainted applications) and that the steel shall not be marked with paint or steel die stamped, but identification shall be stenciled with permanent ink. The dimensions of each component shall conform to the plans and ASTM A6. All steel posts shall be galvanized after fabrication to meet the requirements of ASTM A123 and conform to the galvanizing limits and tolerances shown on the plans. A single ¾" diameter hole may be drilled 2" from the top of each post, in the center of the web, to facilitate the galvanizing process on the bottom of all posts.

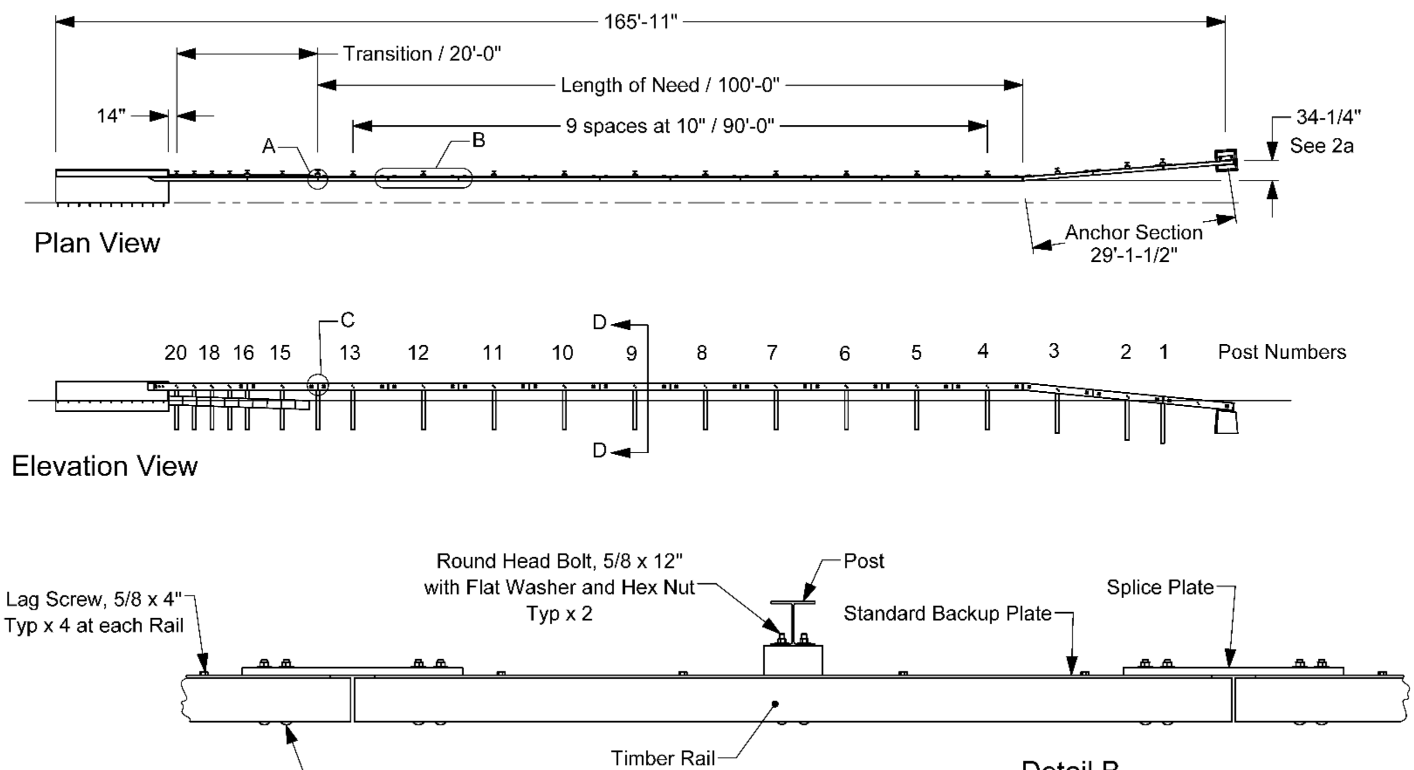
Timber: All timber rail and block-out components shall conform with the following:
a) Commercial lumber grade No. 1 or better after treatment;
b) AASHTO M 168;
c) Minimum stress rating of 1350 psi
d) Rough sawn (non-planed) or S4S (surface four side) Southern Yellow Pine or Douglas Fir- Larch with nominal dimensions as indicated on the plans. Variations in the size of any dimension shall not be more than ± ¼"
e) All timber components shall be pressure treated with CCA or ACZA depending on species supplied conforming to AWPA Standard P5 to a minimum net retention of 0.60lb/cubic foot in the assay zone in accordance with AWPA Standard C14.
f) All timber components shall be fabricated (including but not necessarily limited to cutting, drilling, dapping and chamfering) prior to treatment.
g) All timber components shall be free of excess preservative and solvent at the conclusion of the treating process. Post treatment cleaning shall be by expansion bath or steaming in accordance with AWPA Standard C2;
h) Kiln or air dried to a maximum moisture content of 25% after treatment (KDAT - 25);
i) Grade-marked after treatment by an agency certified by the American Lumber Standard Committee (ALSC).

Fasteners:
a) Round head bolts shall be manufactured in accordance with the sizes designated on the plans, the geometric specifications included in ANSI B18.5.1.2.2 and the material specifications for ASTM A449 steel. All round head bolts shall be marked with the manufacturers symbol and A449.
b) Hex Lag Screws shall be manufactured in accordance with ASTM A307 Grade A specifications. All Hex Lag Screws used between the Anchor Block and Post 2 shall be hot-dipped galvanized in accordance with ASTM A153 Class C.
c) Nuts, and Washers shall be ASTM A449 steel.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 without Curb v2 Merritt Parkway			2025-01-17
Drawn by GES	Scale 1:250	Sheet 1 of 13 Notes	

Test Installation

Some Detail and Section Views on next sheet



Detail B

Scale 1 : 20

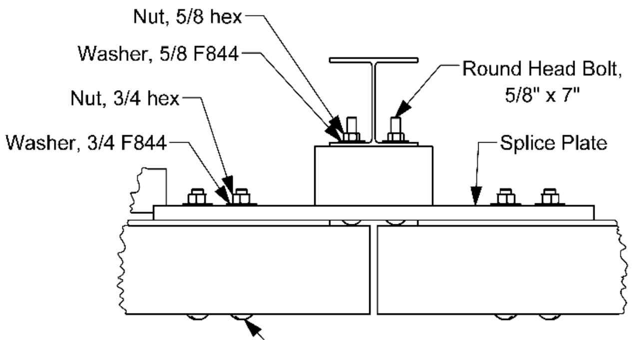
Post spacing and Rail details typical all Posts in Length of Need and Anchor Section unless otherwise indicated.
Connection details typical at all Posts except 14 and 16 - 19.

2a. This dimension is from the traffic side face of the Traffic Rail to the center of the Anchor Block.

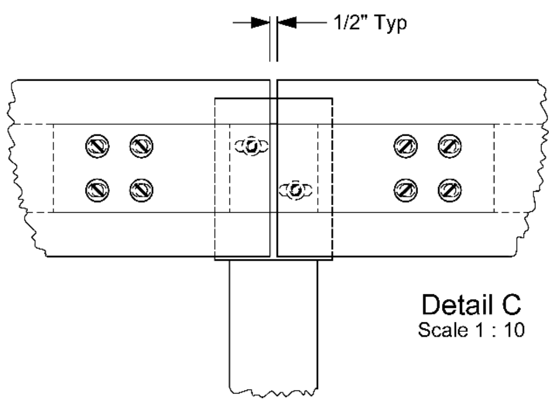
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 without Curb v2 Merritt Parkway		2025-01-17
Drawn by GES	Scale 1:250	Sheet 2 of 13 Test Installation

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, v2 with curb\620061 without curb Drawing

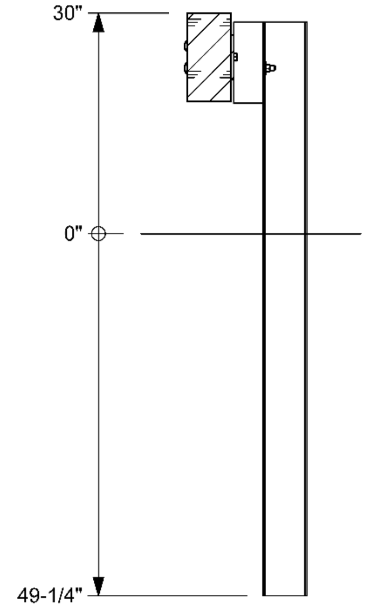
Detail and Section Views



Detail A
Scale 1 : 10
Typ at Posts 1, 14, and 16

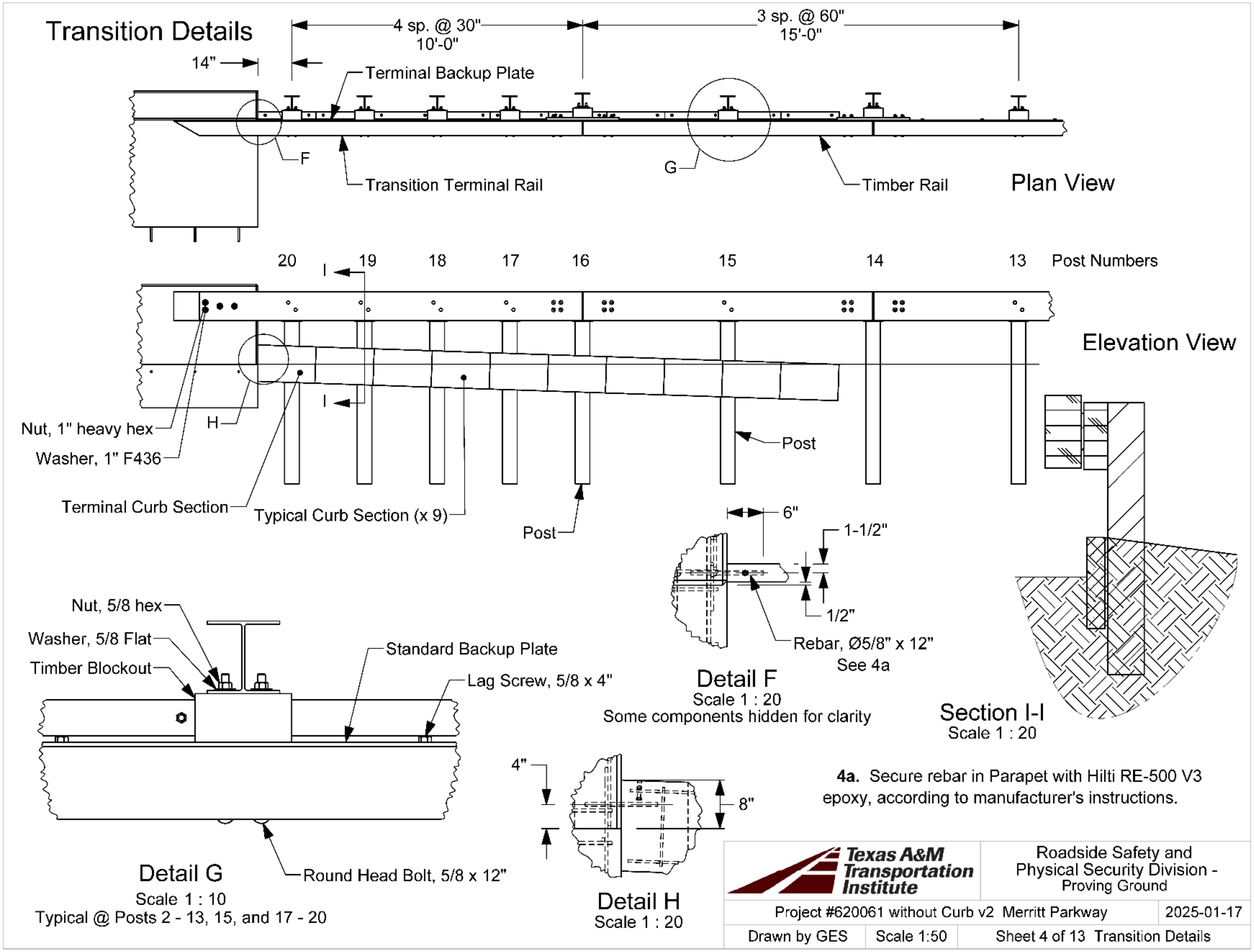


Detail C
Scale 1 : 10



Section D-D
Scale 1 : 20

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 without Curb v2 Merritt Parkway		2025-01-17
Drawn by GES	Scale 1:250	Sheet 3 of 13 Detail and Section Views



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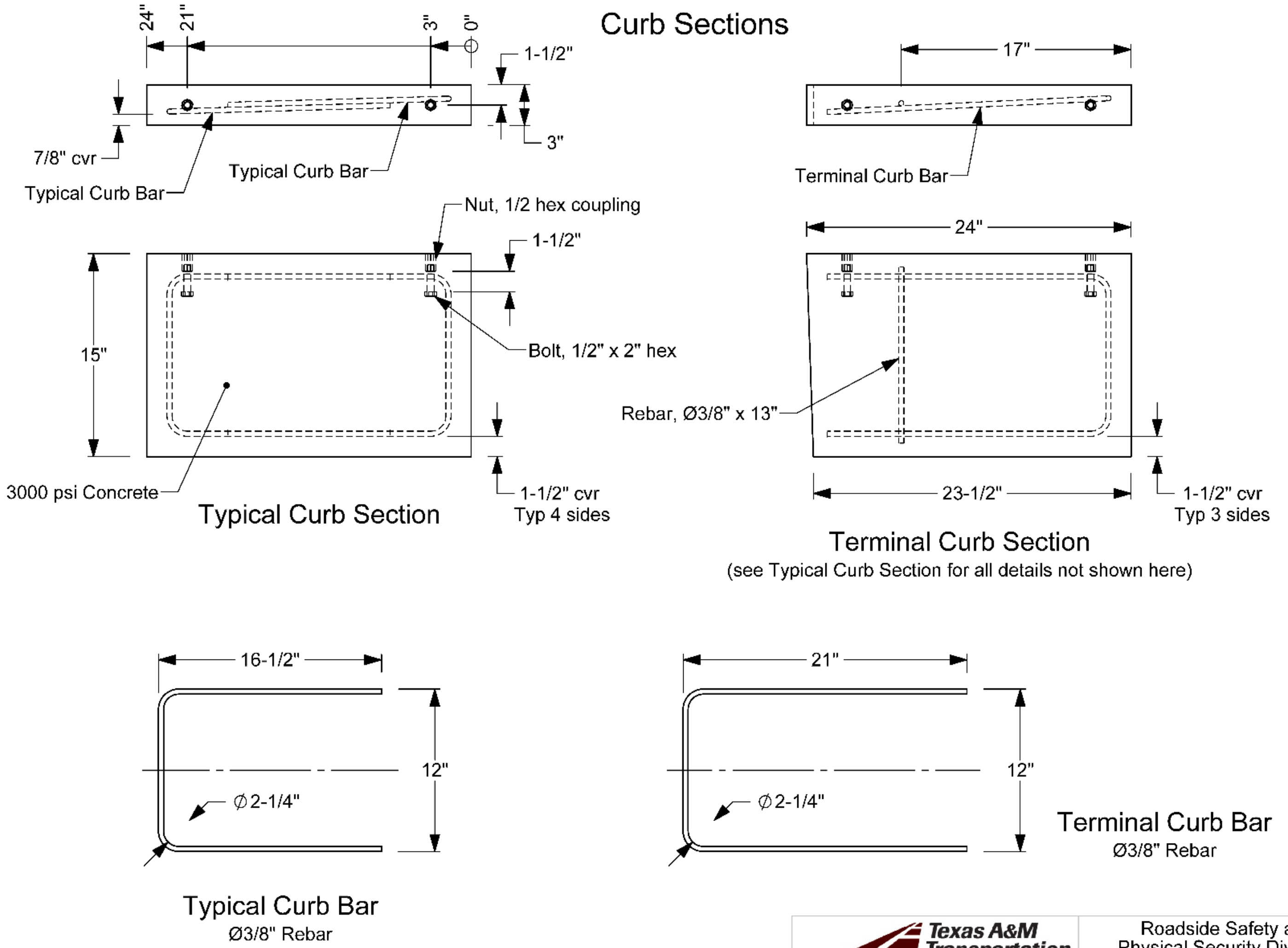
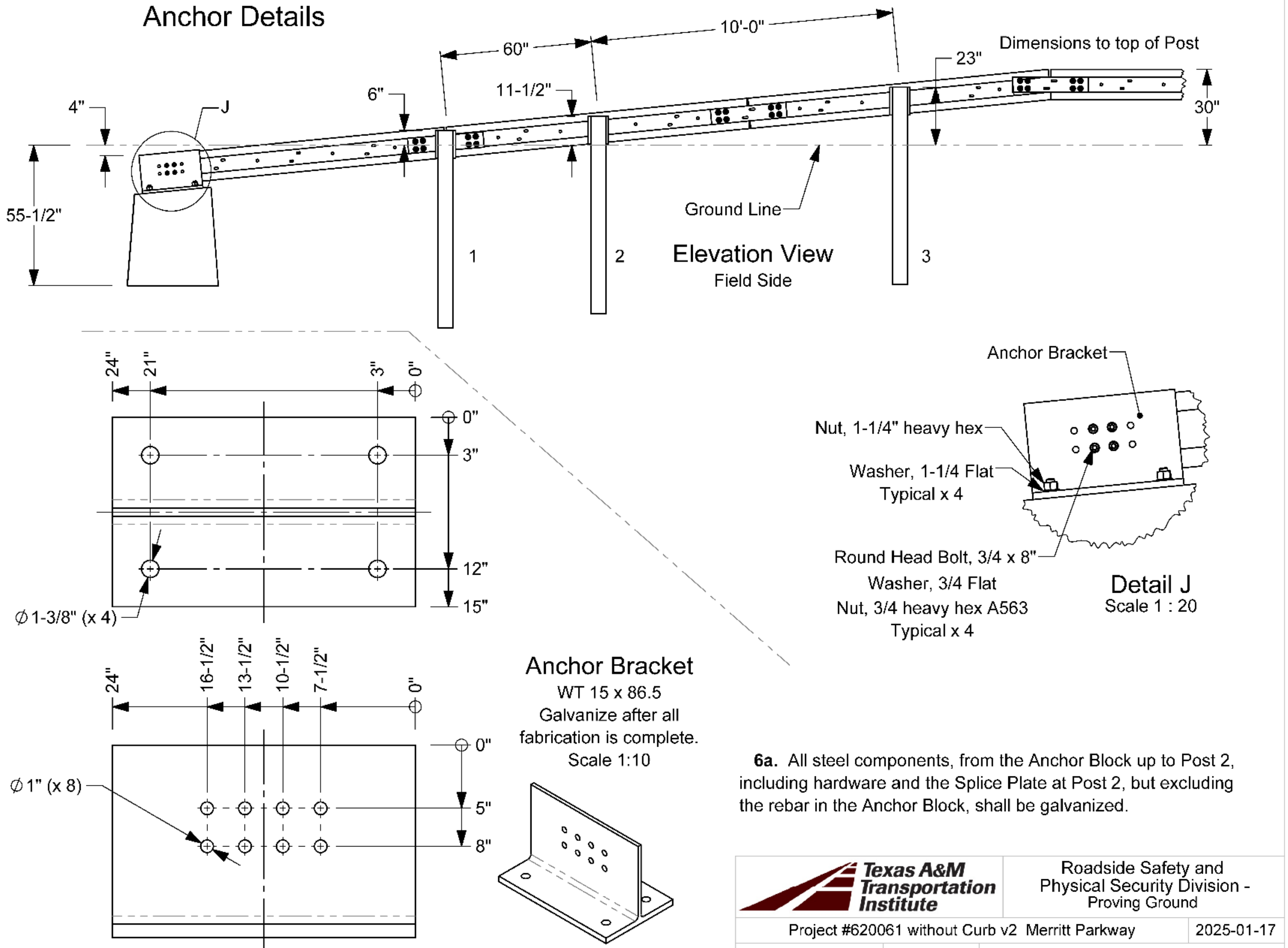


Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 without Curb v2 Merritt Parkway		2025-01-17
Drawn by GES	Scale 1:10	Sheet 5 of 13 Curb Sections

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, v2 with curb\620061 without curb Drawing

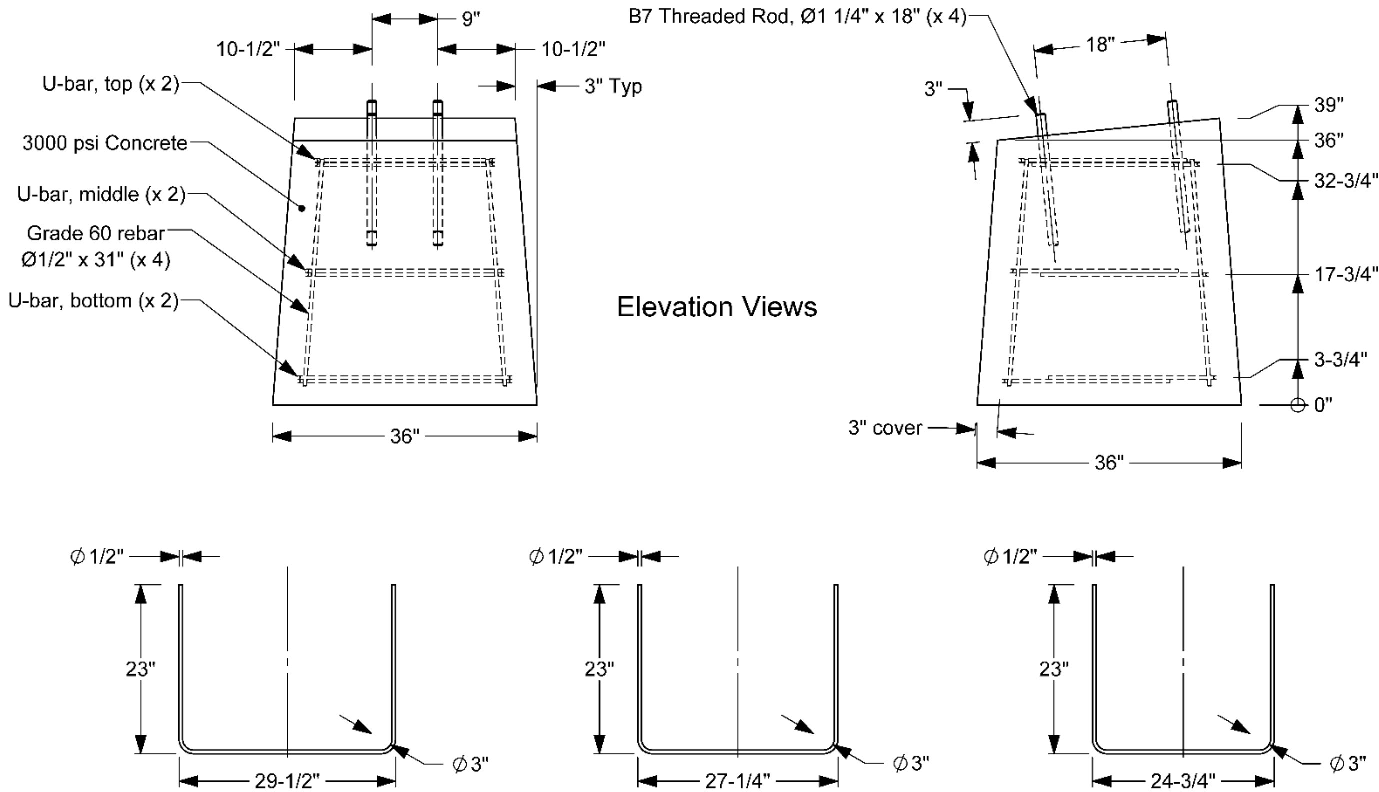
Anchor Details



6a. All steel components, from the Anchor Block up to Post 2, including hardware and the Splice Plate at Post 2, but excluding the rebar in the Anchor Block, shall be galvanized.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 without Curb v2 Merritt Parkway		2025-01-17
Drawn by GES	Scale 1:50	Sheet 6 of 13 Anchor Details

Anchor Block



U-bar, bottom
Grade 60 rebar

U-bar, middle
Grade 60 rebar

U-bar, top
Grade 60 rebar

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 without Curb v2 Merritt Parkway		2025-01-17
Drawn by GES	Scale 1:20	Sheet 7 of 13 Anchor Block

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TR No. 620061-01-1:6

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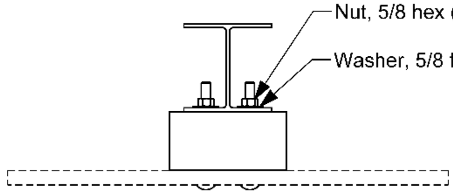
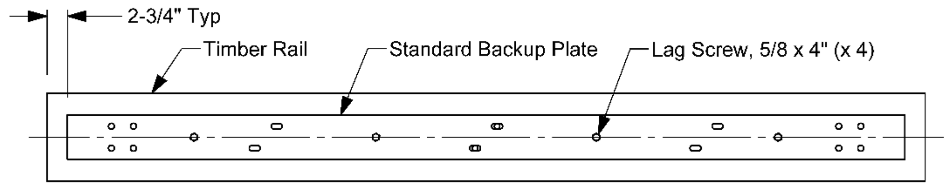
2025-10-01

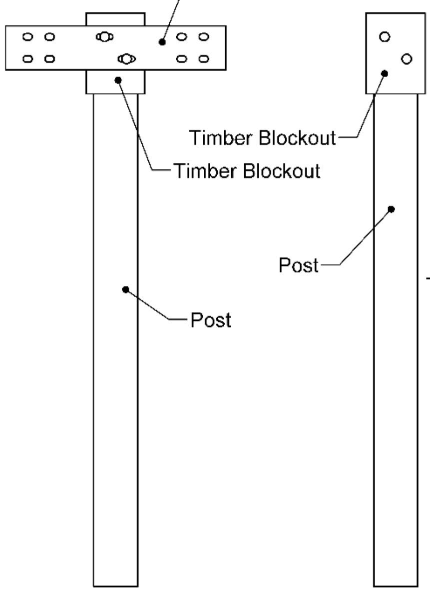
Post and Rail Assemblies



Post Assembly
Plan View
Scale 1:10

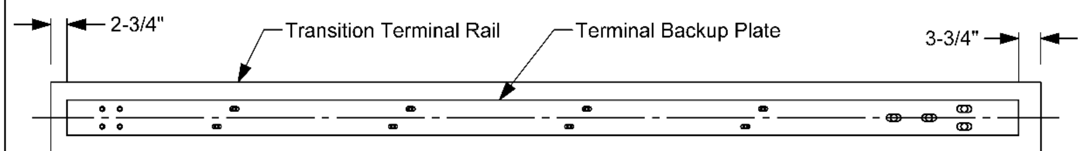


Rail Assembly
Typical from Anchor Block to Post 16
(center holes not used from Anchor Block to Post 1)
Field side shown



Post Assembly
Typical at Posts 1, 14, and 16

Post Assembly
Typical at Posts 2-13, 15, and 17-20

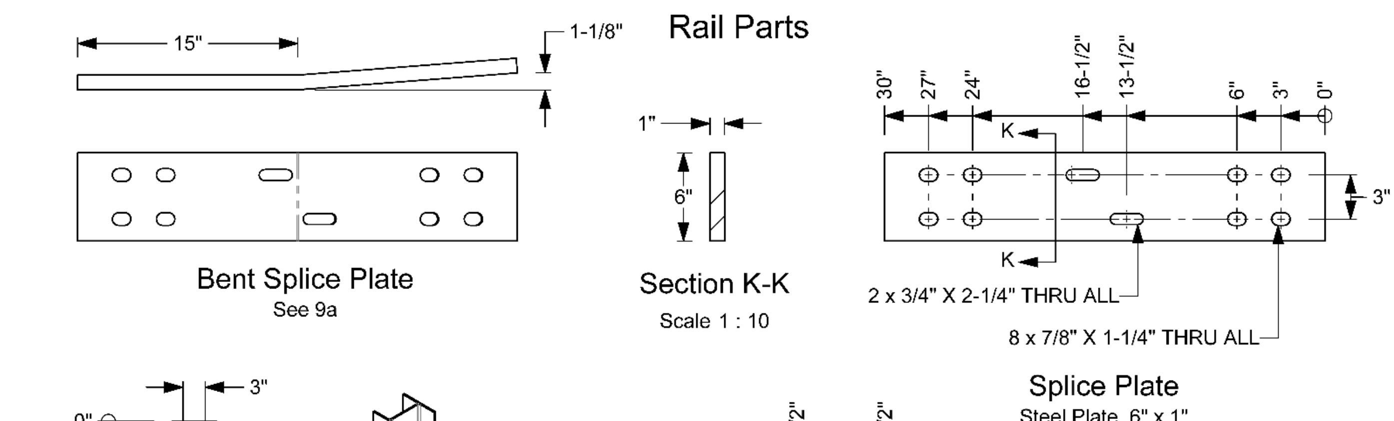


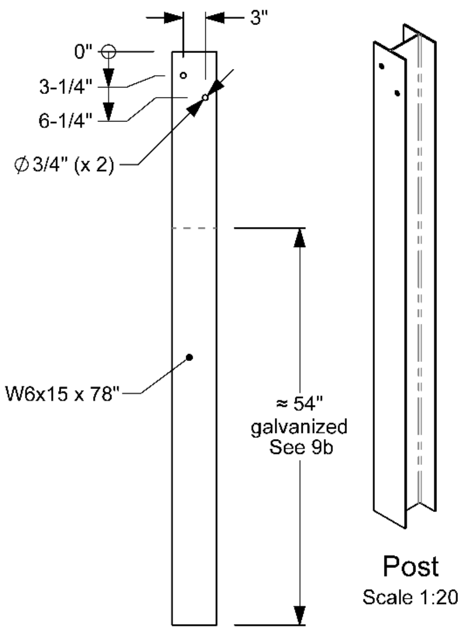
Rail Assembly
@ Posts 16 - 20
Field side shown

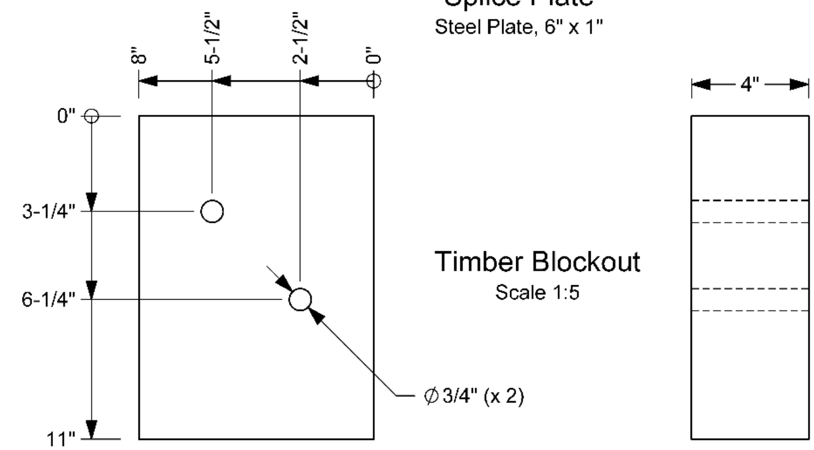
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 without Curb v2 Merritt Parkway		2025-01-17
Drawn by GES	Scale 1:20	Sheet 8 of 13 Post and Rail Assemblies

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, v2 with curb\620061 without curb Drawing

Rail Parts







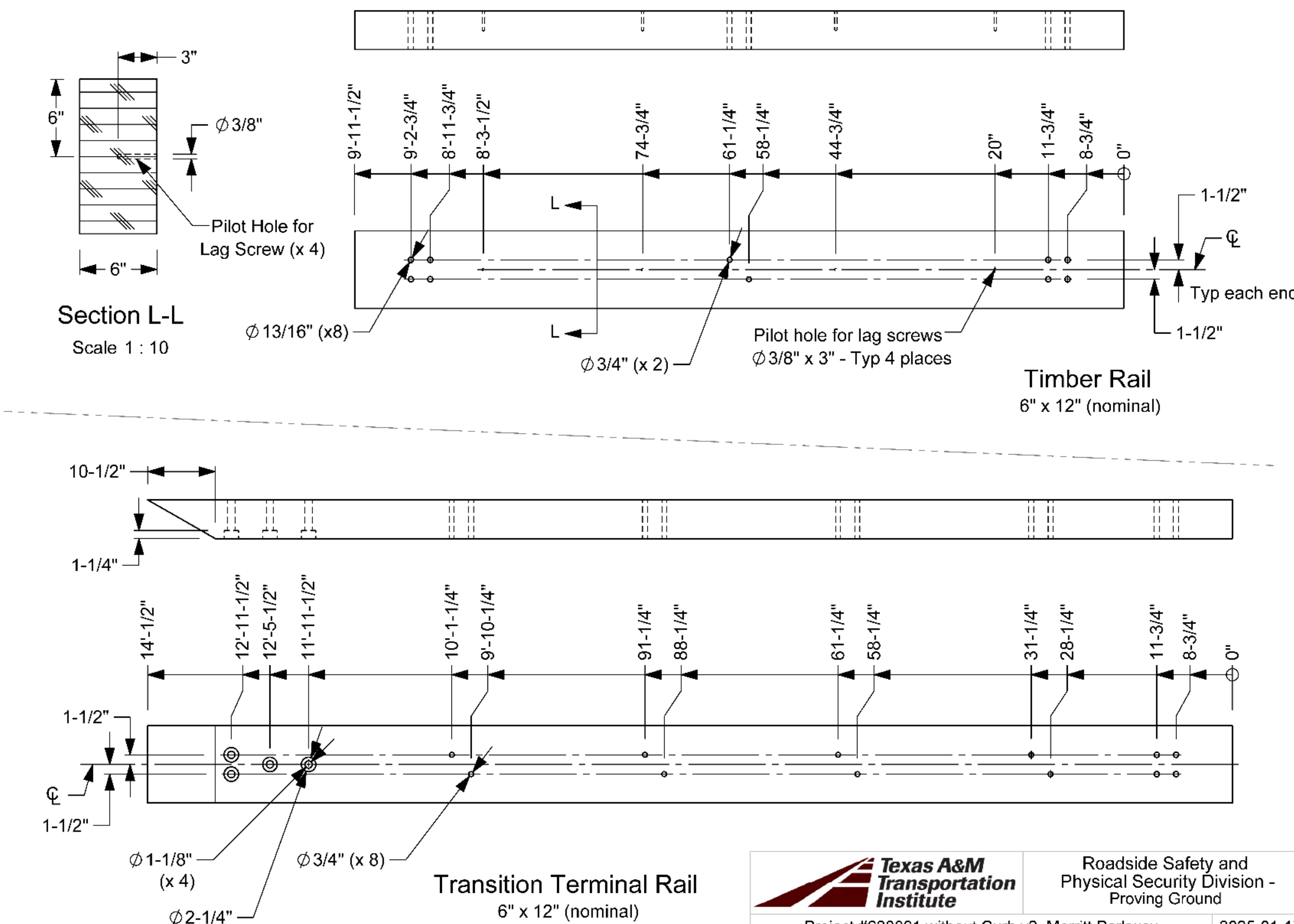
9b. Three posts shall be galvanized the full length (Posts 1 - 3).

9c. Galvanize two Splice Plates (used at Post 1 and the joint between Posts 2 and 3).

9a. Used between Posts 3 and 4; all other details same as standard Splice Plate (Standard Splice Plate is not bent). May be bent or cut and welded according to standard industry practice.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 without Curb v2 Merritt Parkway		2025-01-17
Drawn by GES	Scale 1:10	Sheet 9 of 13 Rail Parts

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, v2 with curb\620061 without curb Drawing

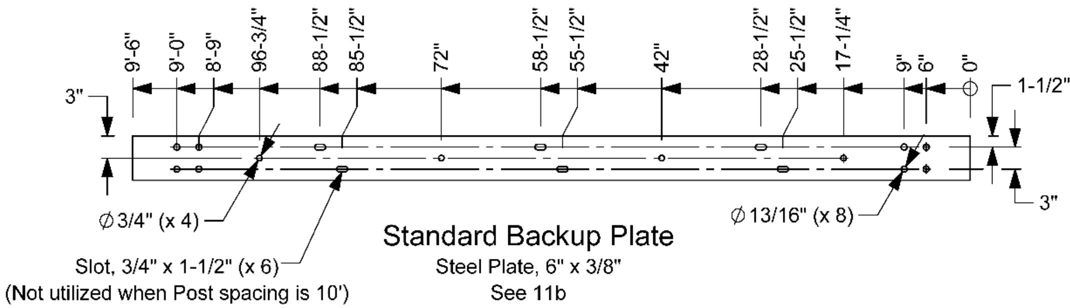


Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 without Curb v2 Merritt Parkway		2025-01-17
Drawn by GES	Scale 1:20	Sheet 10 of 13 Timber Rail Details

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, v2 with curb\620061 without curb Drawing

Backup Plates

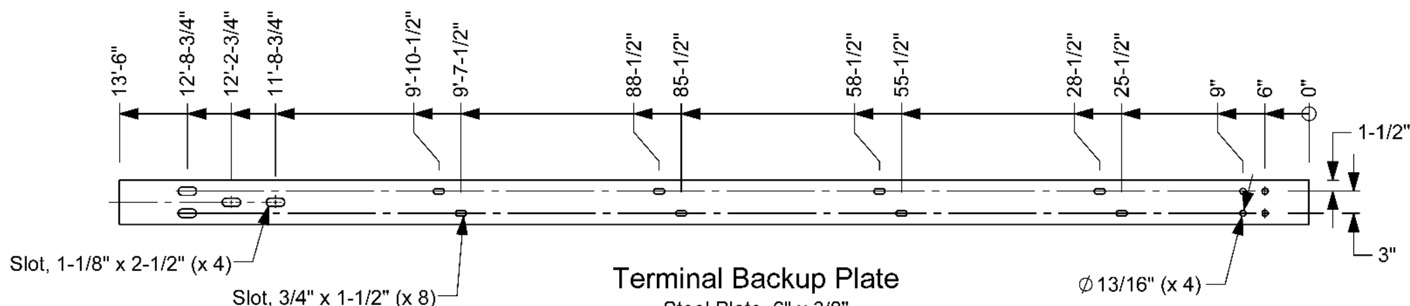
See 11a



Standard Backup Plate

Steel Plate, 6" x 3/8"

See 11b



Terminal Backup Plate

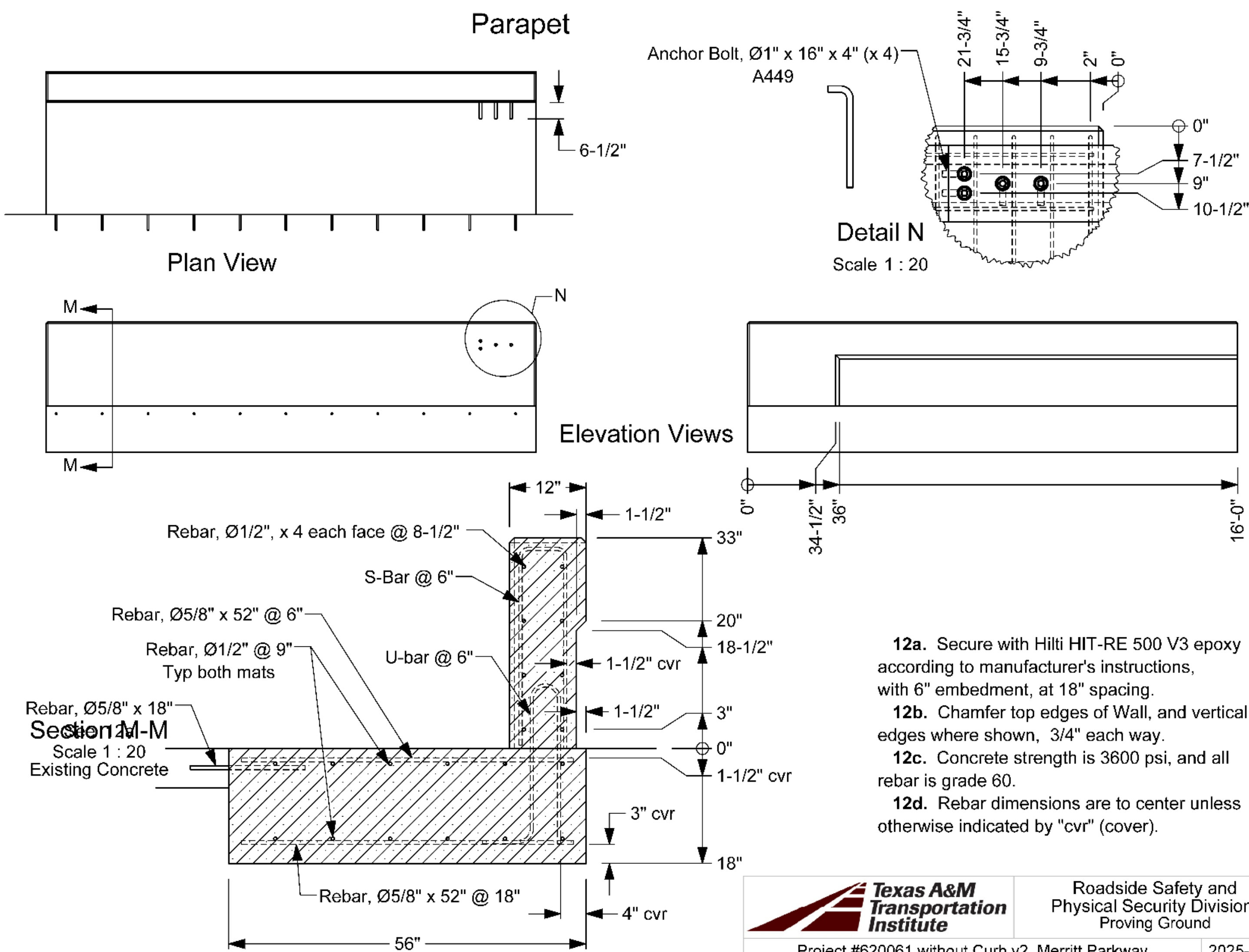
Steel Plate, 6" x 3/8"

11a. Galvanize two Standard Backup Plates (used from Anchor Block to Post 1 and Post 1 to the joint between Posts 2 and 3.

11b. Slots at 25-1/2" , 28-1/2" , 85-1/2" ,and 88-1/2" are not used in this installation. Slots at 55-1/2" and 58-1/2" are not used at all locations.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 without Curb v2 Merritt Parkway		2025-01-17
Drawn by GES	Scale 1:20	Sheet 11 of 13 Backup Plates

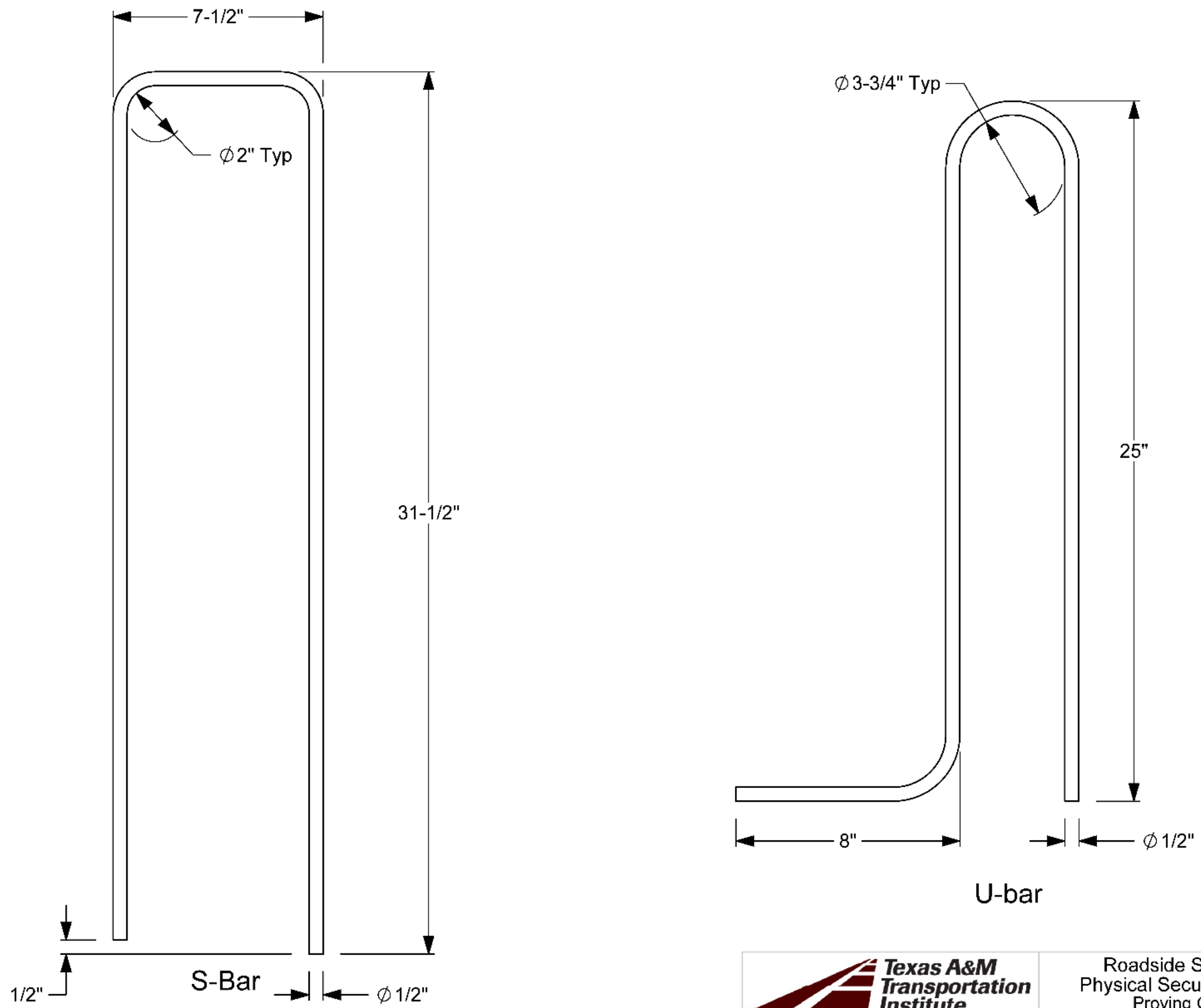
Parapet



12a. Secure with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions, with 6" embedment, at 18" spacing.
12b. Chamfer top edges of Wall, and vertical edges where shown, 3/4" each way.
12c. Concrete strength is 3600 psi, and all rebar is grade 60.
12d. Rebar dimensions are to center unless otherwise indicated by "cvr" (cover).

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 without Curb v2 Merritt Parkway		2025-01-17
Drawn by GES	Scale 1:50	Sheet 12 of 13 Parapet

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, v2 with curb\620061 without curb Drawing



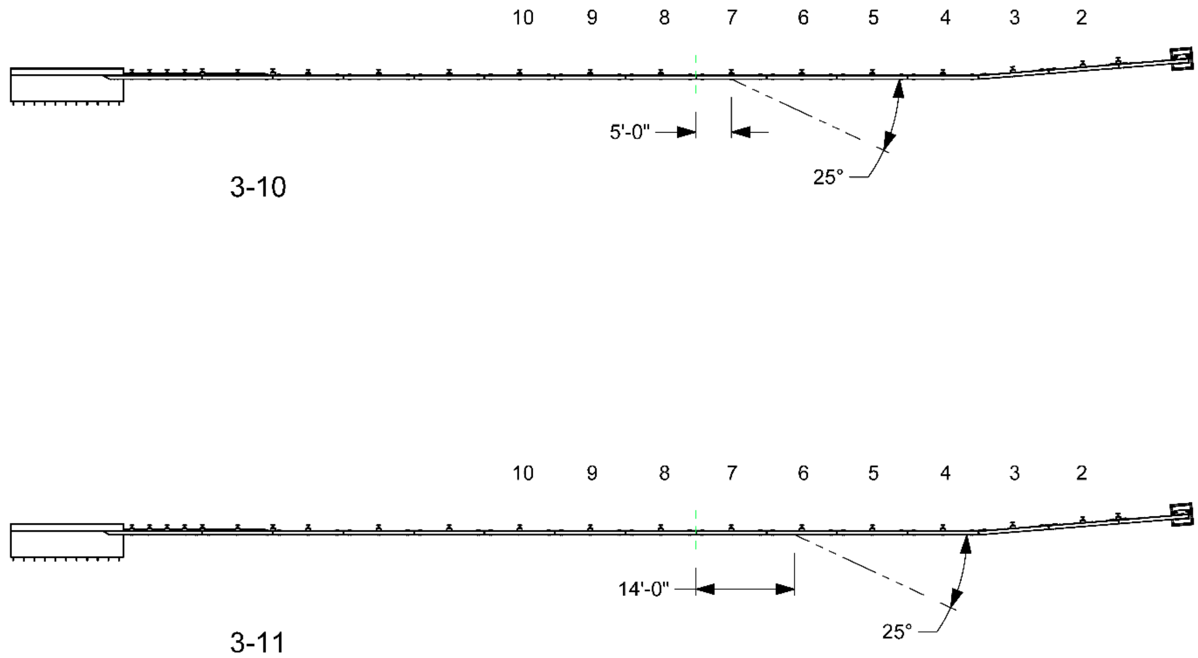
Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Project #620061 without Curb v2 Merritt Parkway		2025-01-17
Drawn by GES	Scale 1:5	Sheet 13 of 13 Rebar

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, v2 with curb\620061 without curb Drawing

A.4. DETAILS OF MERRITT PARKWAY GUIDERAIL FOR TESTS 620061-01-5&6



Texas A&M Transportation Institute

Roadside Safety and Physical Security Division - Proving Ground

Project #620061 v2 with curb

Drawn by GES | Sheet 2 of 3 no curb impacts

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, tests 1, 3, and 4\620061 impacts and summaries

Notes

1a. Drill Ø24" holes for Posts. Backfill Post holes and around Anchor Block with Type D grade 1 crushed concrete road base, compacted to MASH standard.

1b. Threads not shown on Bolts, Nuts, etc for clarity.

1c. Material:

Steel: All steel posts, back-up rails, splice plates and channel rubrails which are to be used as "Weathering Steel", shall meet the requirements of ASTM A588. The fabricator shall notify the manufacturer that it is "Weathering Steel" (structural steel for use in bare, unpainted applications) and that the steel shall not be marked with paint or steel die stamped, but identification shall be stenciled with permanent ink. The dimensions of each component shall conform to the plans and ASTM A6. All steel posts shall be galvanized after fabrication to meet the requirements of ASTM A123 and conform to the galvanizing limits and tolerances shown on the plans. A single ¾" diameter hole may be drilled 2" from the top of each post, in the center of the web, to facilitate the galvanizing process on the bottom of all posts.

Timber: All timber rail and block-out components shall conform with the following:

a) Commercial lumber grade No. 1 or better after treatment;
b) AASHTO M 168;
c) Minimum stress rating of 1350 psi
d) Rough sawn (non-planed) or S4S (surface four side) Southern Yellow Pine or Douglas Fir- Larch with nominal dimensions as indicated on the plans. Variations in the size of any dimension shall not be more than $\pm$ ¼"
e) All timber components shall be pressure treated with CCA or ACZA depending on species supplied conforming to AWPA Standard P5 to a minimum net retention of 0.60lb/cubic foot in the assay zone in accordance with AWPA Standard C14.
f) All timber components shall be fabricated (including but not necessarily limited to cutting, drilling, dapping and chamfering) prior to treatment.
g) All timber components shall be free of excess preservative and solvent at the conclusion of the treating process. Post treatment cleaning shall be by expansion bath or steaming in accordance with AWPA Standard C2;
h) Kiln or air dried to a maximum moisture content of 25% after treatment (KDAT - 25);
i) Grade-marked after treatment by an agency certified by the American Lumber Standard Committee (ALSC).

Fasteners:

a) Round head bolts shall be manufactured in accordance with the sizes designated on the plans, the geometric specifications included in ANSI B18.5.1.2.2 and the material specifications for ASTM A449 steel. All round head bolts shall be marked with the manufacturers symbol and A449.
b) Hex Lag Screws shall be manufactured in accordance with ASTM A307 Grade A specifications. All Hex Lag Screws used between the Anchor Block and Post 2 shall be hot-dipped galvanized in accordance with ASTM A153 Class C.
c) Nuts, and Washers shall be ASTM A449 steel.

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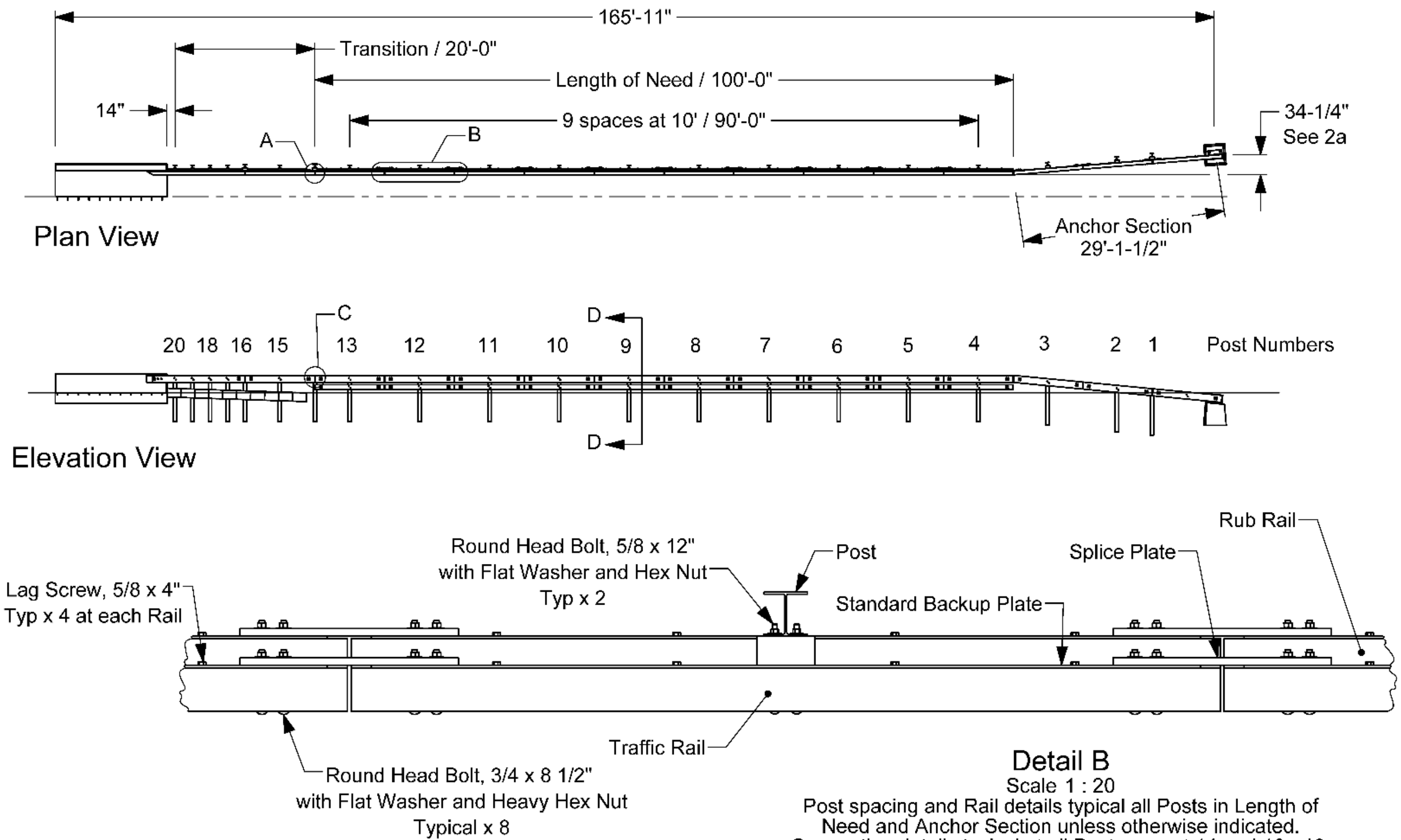
Project #620061 with rub rail	Merritt Parkway	2025-02-13
Drawn by GES	Scale 1:250	Sheet 1 of 14 Notes

Test Installation

Some Detail and Section Views on next sheet



Detail B

Scale 1 : 20

Post spacing and Rail details typical all Posts in Length of Need and Anchor Section unless otherwise indicated.
Connection details typical at all Posts except 14 and 16 - 19.

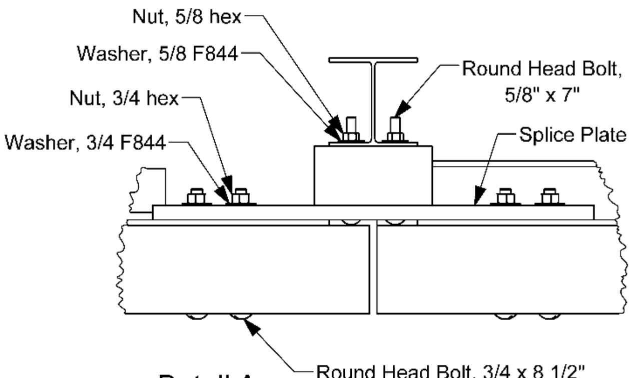
2a. This dimension is from the traffic side face of the Traffic Rail to the center of the Anchor Block.

2b. The Backup Plate, Splice Plate, and hardware for the Rub Rail is the same as for the Traffic Rail unless otherwise indicated.

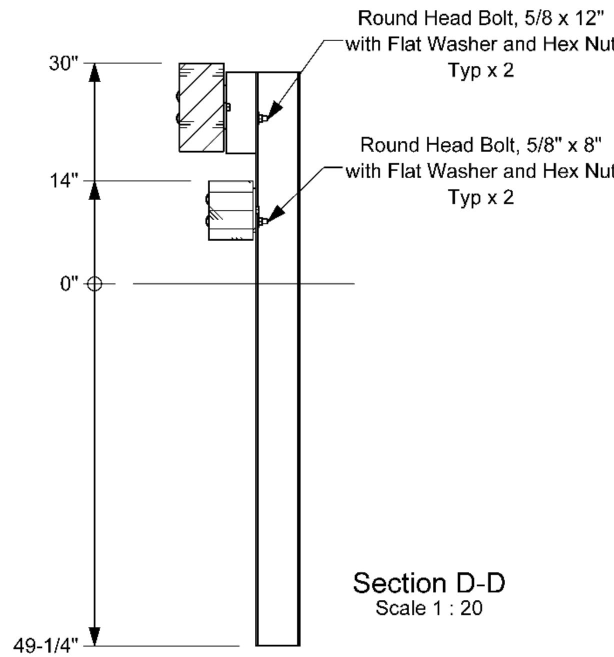
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 with rub rail	Merritt Parkway	2025-02-13
Drawn by GES	Scale 1:250	Sheet 2 of 14 Test Installation

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, with rub rail\2025-02-10\620061 with rub rail Drawing

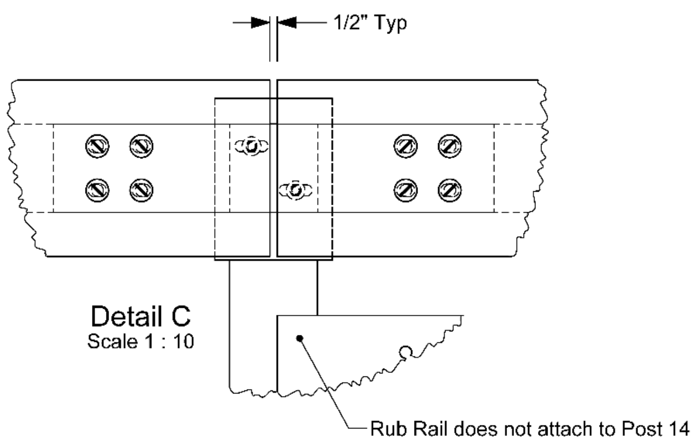
Detail and Section Views



Detail A
Scale 1 : 10
Typ at Posts 1, 14, and 16



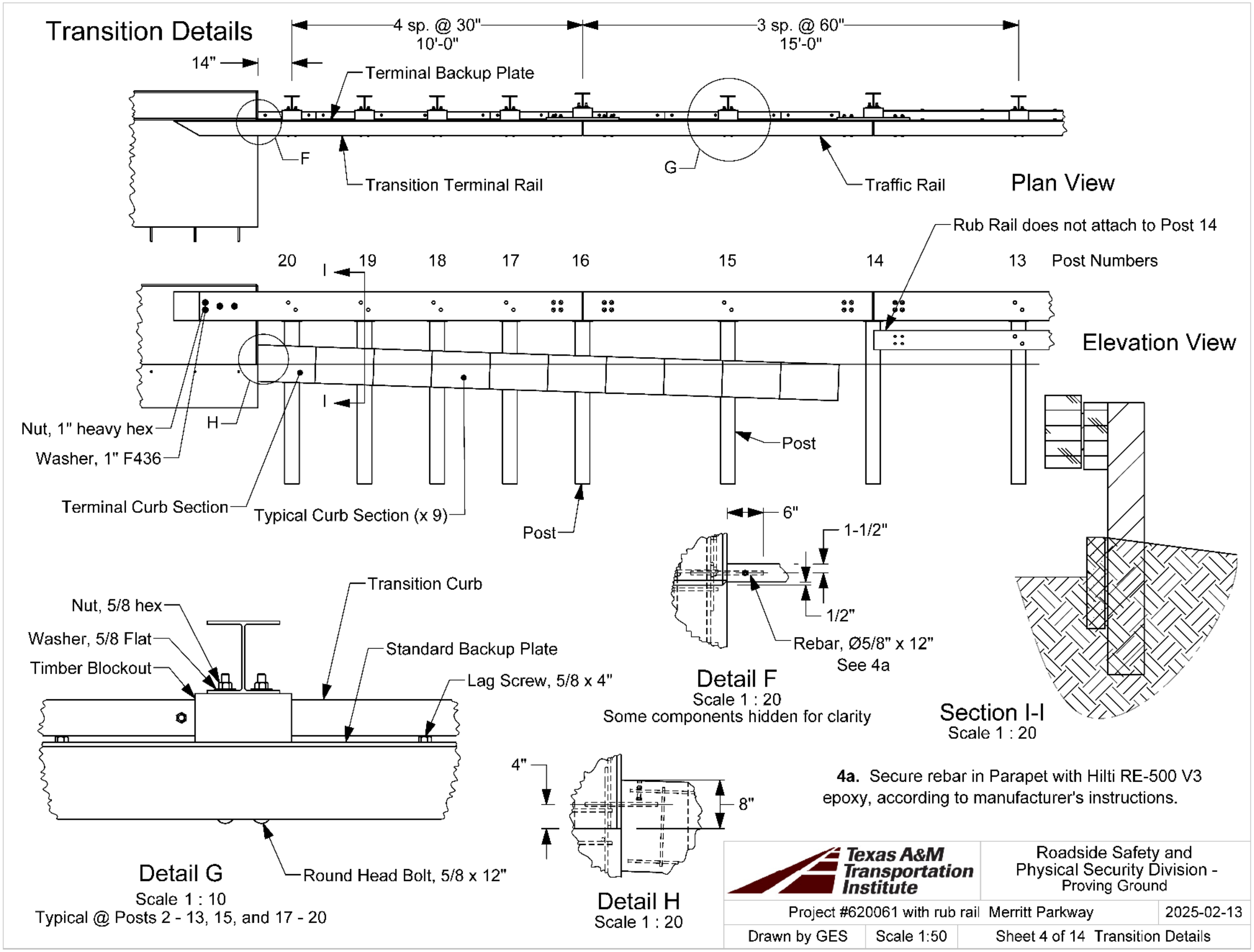
Section D-D
Scale 1 : 20

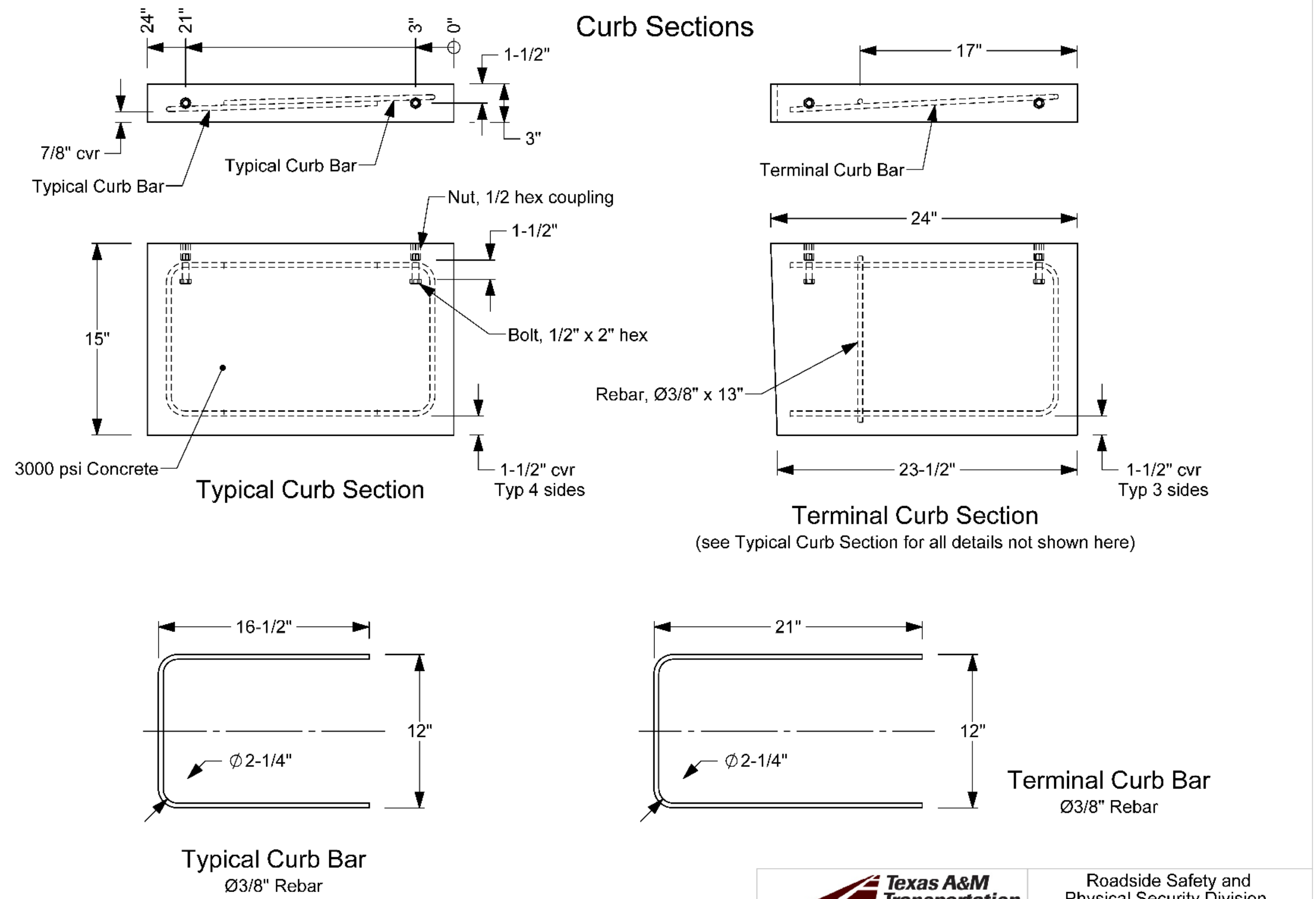


Detail C
Scale 1 : 10

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground		
Project #620061 with rub rail	Merritt Parkway		2025-02-13
Drawn by GES	Scale 1:250	Sheet 3 of 14	Detail and Section Views

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, with rub rail\2025-02-10\620061 with rub rail Drawing

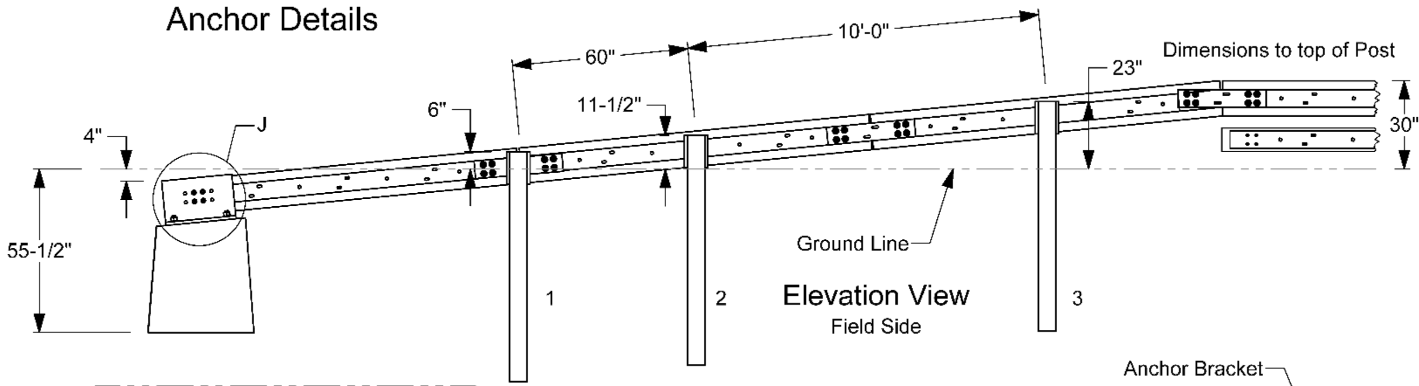

Transition Details
4 sp. @ 30"
10'-0"
3 sp. @ 60"
15'-0"
14"
Terminal Backup Plate
F
Transition Terminal Rail
G
Traffic Rail
Plan View
Rub Rail does not attach to Post 14
20
19
18
17
16
15
14
13
Post Numbers
I
Elevation View
Nut, 1" heavy hex
H
Washer, 1" F436
Post
Terminal Curb Section
Typical Curb Section (x 9)
Post
6"
1-1/2"
1/2"
Rebar, Ø5/8" x 12"
See 4a
Detail F
Scale 1 : 20
Some components hidden for clarity
Section I-I
Scale 1 : 20
Transition Curb
Nut, 5/8 hex
Washer, 5/8 Flat
Standard Backup Plate
Timber Blockout
Lag Screw, 5/8 x 4"
Round Head Bolt, 5/8 x 12"
Detail G
Scale 1 : 10
Typical @ Posts 2 - 13, 15, and 17 - 20
4"
8"
Detail H
Scale 1 : 20
4a. Secure rebar in Parapet with Hilti RE-500 V3 epoxy, according to manufacturer's instructions.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #620061 with rub rail
Merritt Parkway
2025-02-13
Drawn by GES
Scale 1:50
Sheet 4 of 14
Transition Details



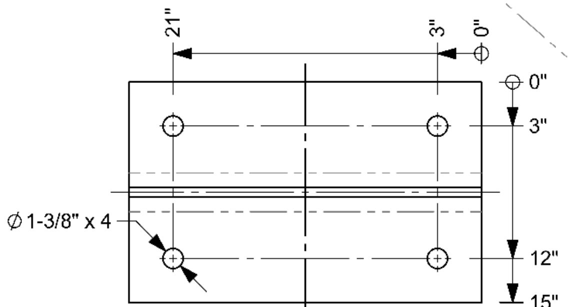
Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground
Project #620061 with rub rail	Merritt Parkway	2025-02-13
Drawn by GES	Scale 1:10	Sheet 5 of 14 Curb Sections

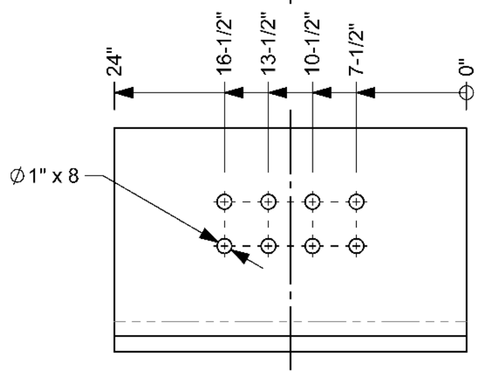
S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, with rub rail\2025-02-10\620061 with rub rail Drawing

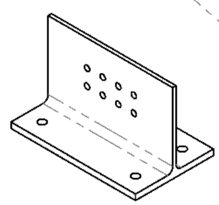
Anchor Details



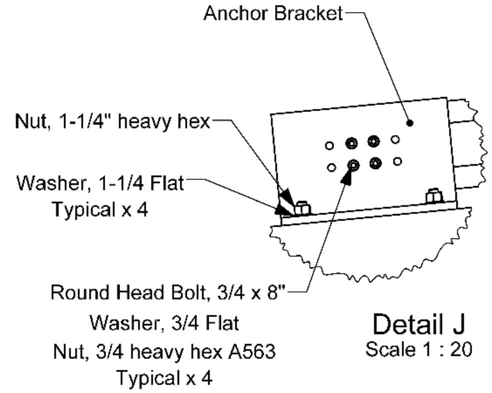
Elevation View
Field Side







Anchor Bracket
WT15x86.5
Galvanize after all fabrication is complete
Scale 1:10



Detail J
Scale 1 : 20

6a. All steel components, from the Anchor Block up to Post 2, including hardware and the Splice Plate at Post 2, but excluding the rebar in the Anchor Block, shall be galvanized.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
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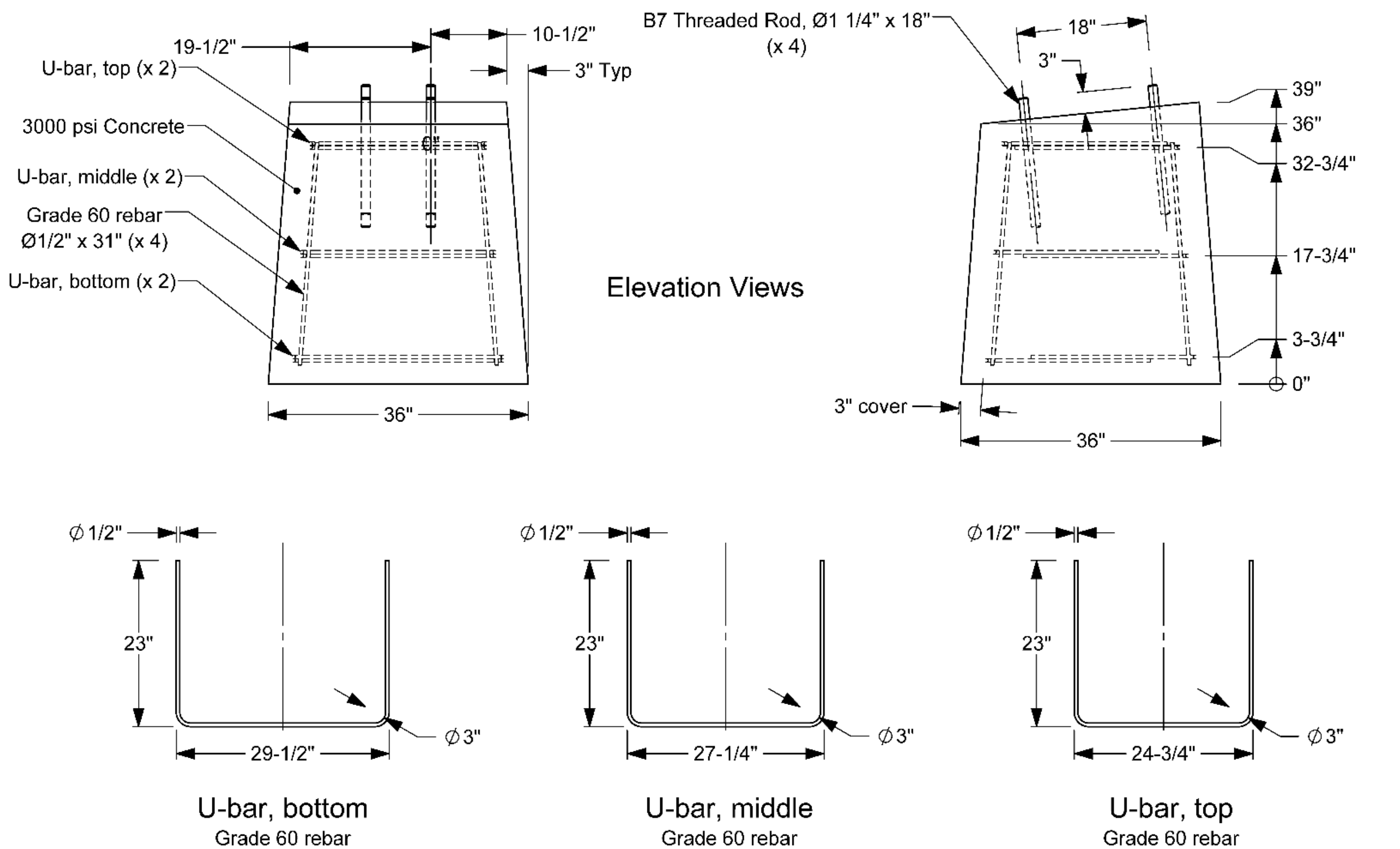
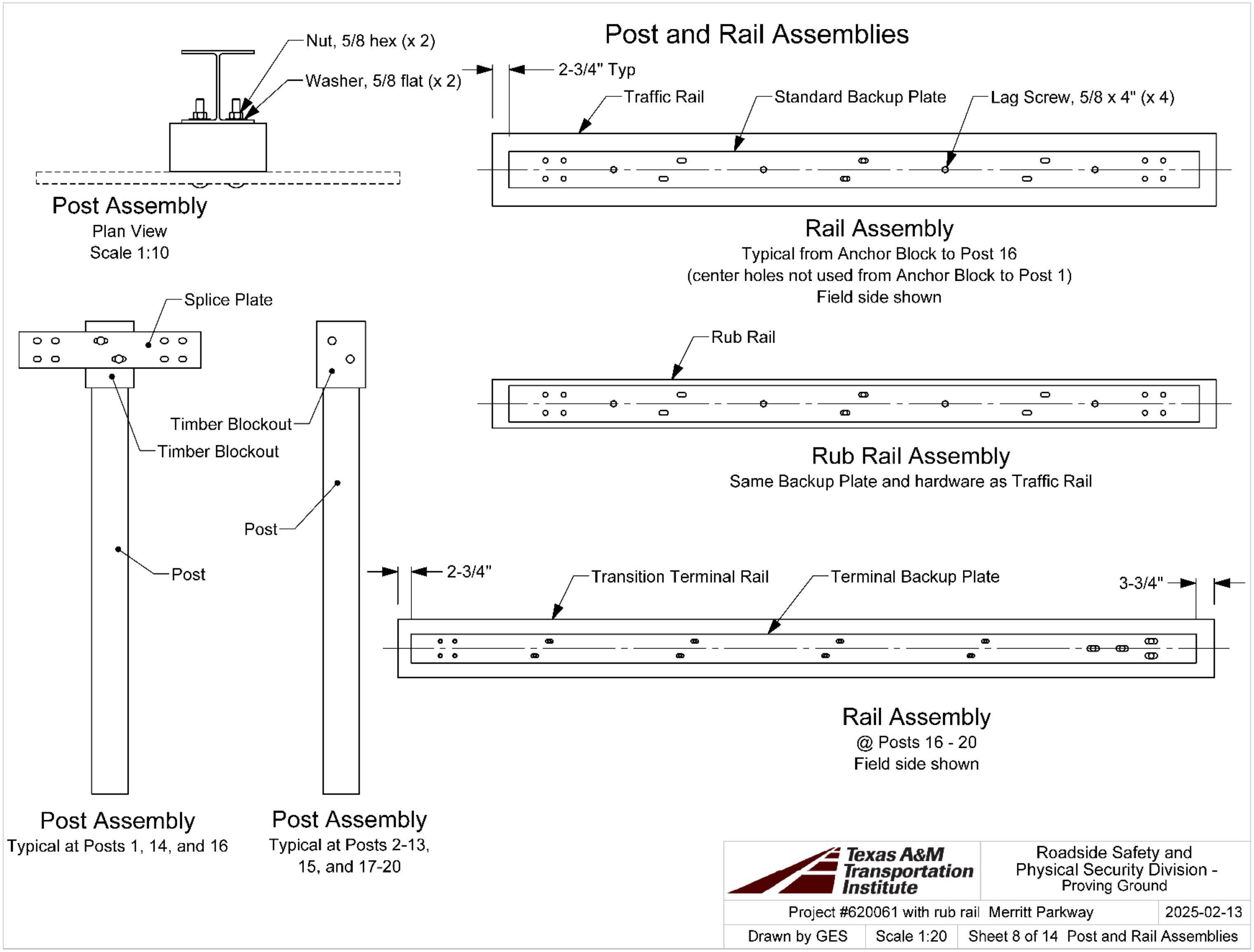
Drawn by GES	Scale 1:50	Sheet 6 of 14 Anchor Details

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, with rub rail\2025-02-10\620061 with rub rail Drawing

Anchor Block



Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground
Project #620061 with rub rail	Merritt Parkway	2025-02-13
Drawn by GES	Scale 1:20	Sheet 7 of 14 Anchor Block



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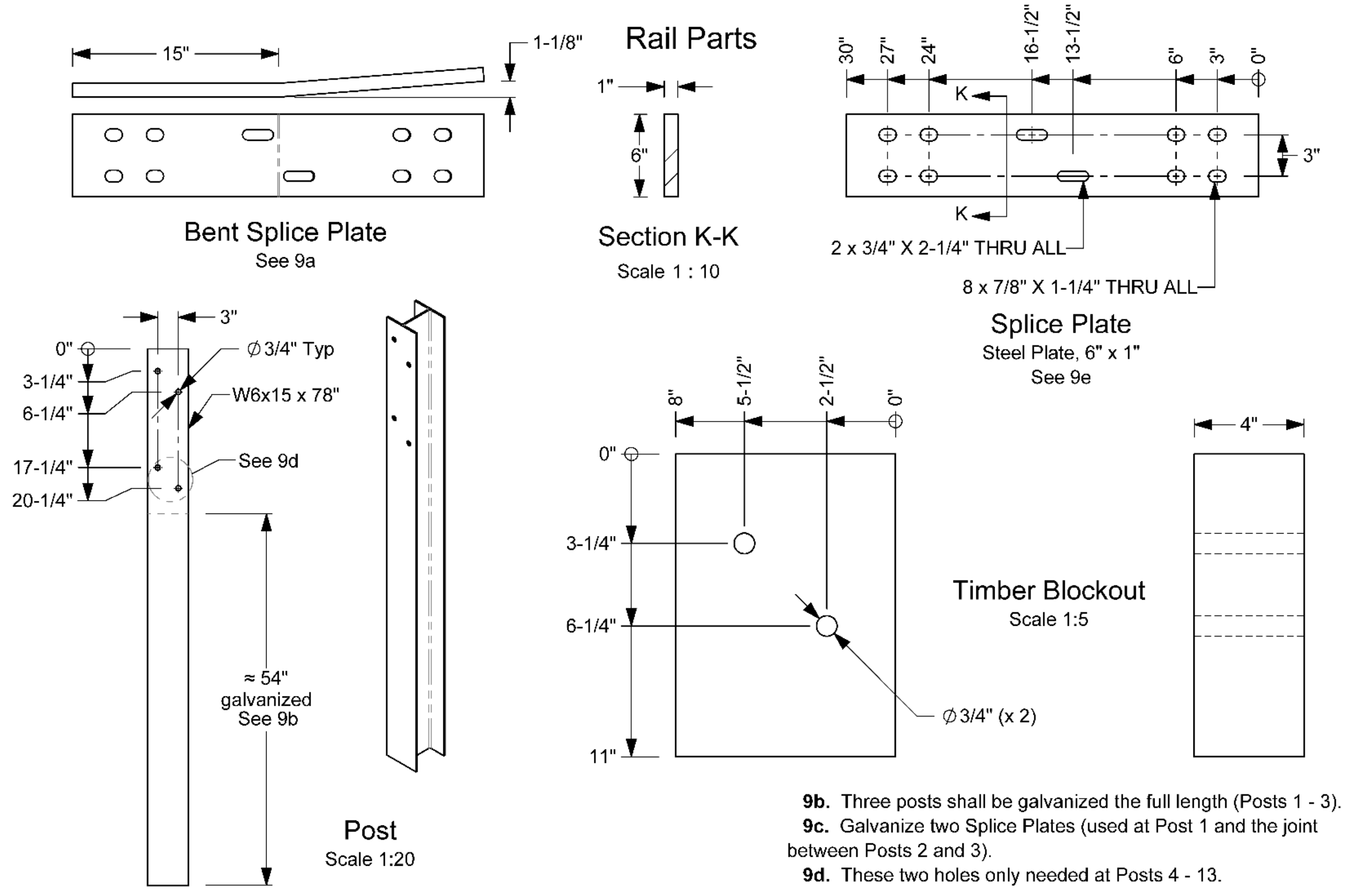

9b. Three posts shall be galvanized the full length (Posts 1 - 3).
9c. Galvanize two Splice Plates (used at Post 1 and the joint between Posts 2 and 3).
9d. These two holes only needed at Posts 4 - 13.
9e. Splice Plate used with Traffic Rails and Rub Rails.

9a. Used between Posts 3 and 4; all other details same as standard Splice Plate (Standard Splice Plate is not bent). May be bent or cut and welded according to standard industry practice.

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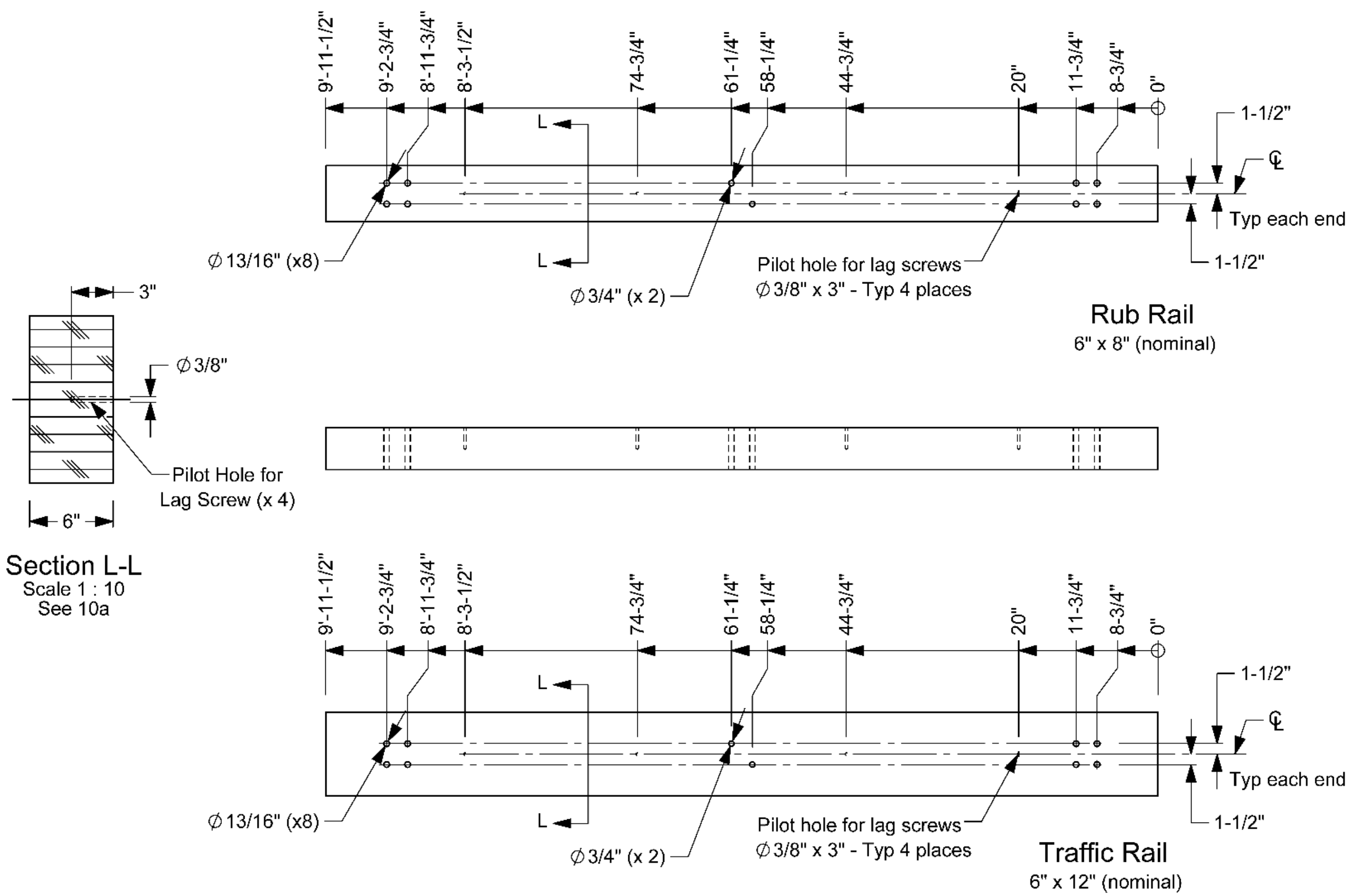
Project #620061 with rub rail	Merritt Parkway	2025-02-13
Drawn by GES	Scale 1:10	Sheet 9 of 14 Rail Parts



10a. Pilot holes for Lag Screws are centered vertically for Traffic Rail and Rub Rail.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
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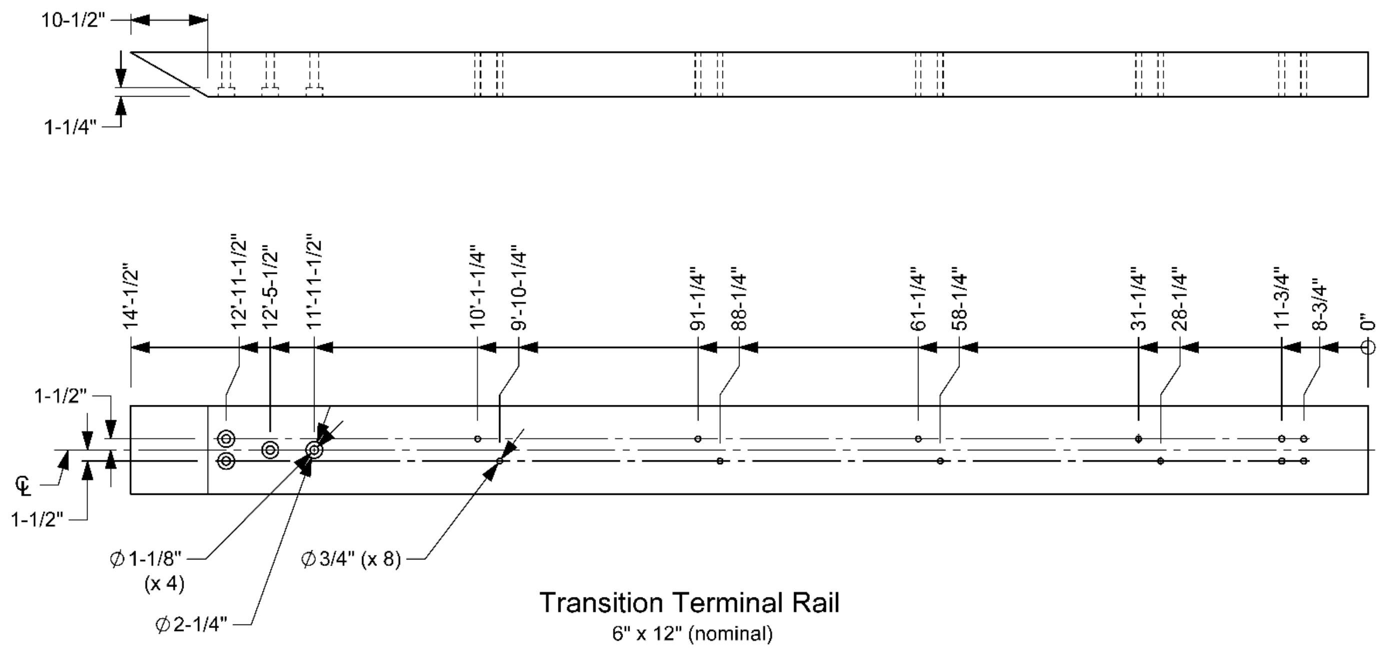
Drawn by GES	Scale 1:20	Sheet 10 of 14 Timber Rail Details

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, with rub rail\2025-02-10\620061 with rub rail Drawing

Transition Rail Details



Transition Terminal Rail
6" x 12" (nominal)

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 with rub rail	Merritt Parkway	2025-02-13
Drawn by GES	Scale 1:20	Sheet 11 of 14 Transition Rail Details

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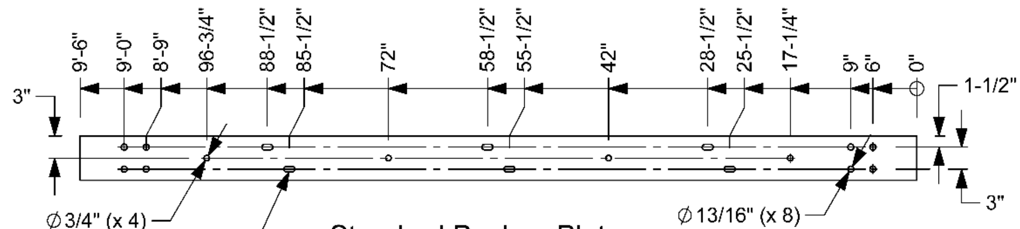
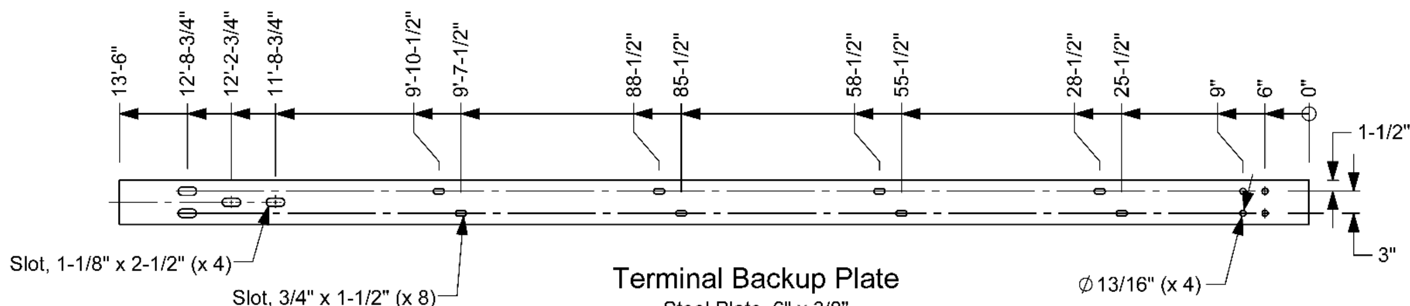
Backup Plates

See 12a



Standard Backup Plate

Steel Plate, 6" x 3/8"
See 12b and 12c



Terminal Backup Plate

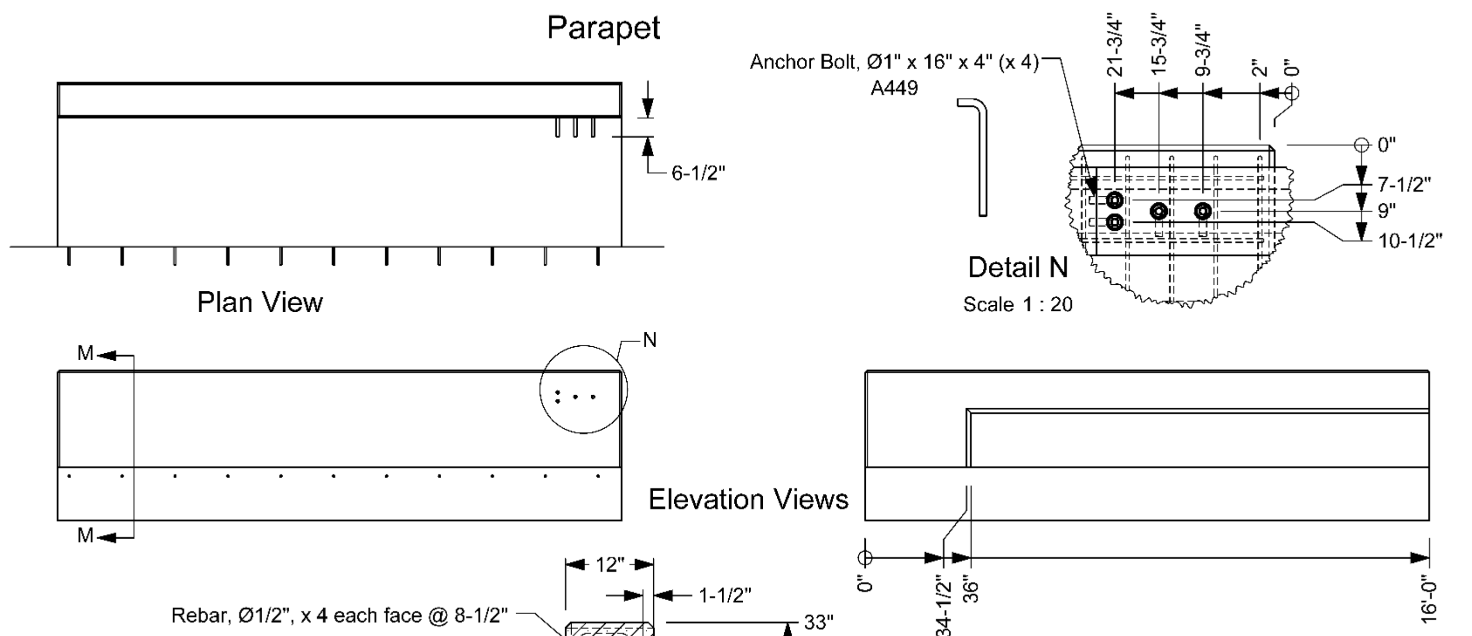
Steel Plate, 6" x 3/8"

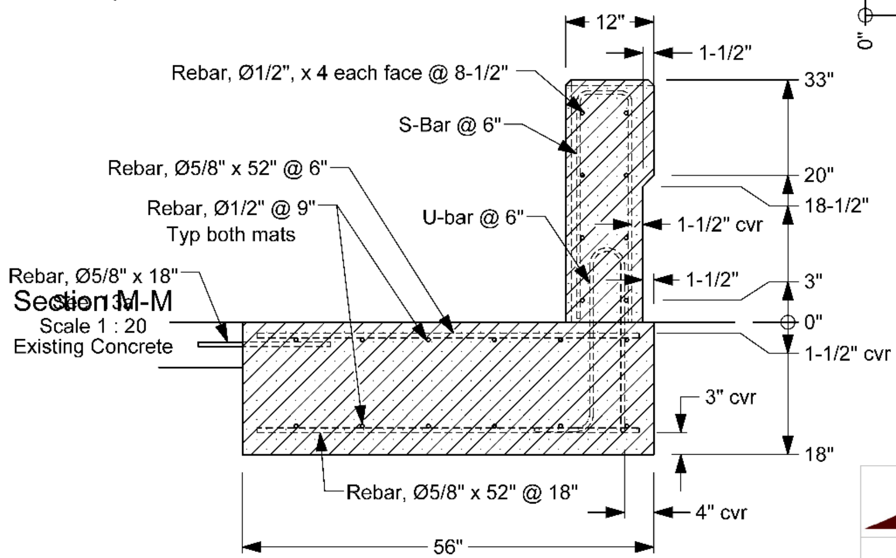
12a. Galvanize two Standard Backup Plates (used from Anchor Block to Post 1 and Post 1 to the joint between Posts 2 and 3.
12b. Slots at 25-1/2" , 28-1/2" , 85-1/2" ,and 88-1/2" are not used in this installation. Slots at 55-1/2" and 58-1/2" are not used at all locations.
12c. Standard Backup Plate used with Traffic Rails and Rub Rails.

Texas A&M Transportation Institute | Roadside Safety and Physical Security Division - Proving Ground

Project #620061 with rub rail	Merritt Parkway	2025-02-13
Drawn by GES	Scale 1:20	Sheet 12 of 14 Backup Plates

S:\Accreditation-17025-2017\EIR-000 Project Files\620061-01 - Merrit Parkway Guide Rail - Schulz\Drafting, with rub rail\2025-02-10\620061 with rub rail Drawing





13a. Secure with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions, with 6" embedment, at 18" spacing.
13b. Chamfer top edges of Wall, and vertical edges where shown, 3/4" each way.
13c. Concrete strength is 3600 psi, and all rebar is grade 60.
13d. Rebar dimensions are to center unless otherwise indicated by "cvr" (cover).

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 with rub rail	Merritt Parkway	2025-02-13
Drawn by GES	Scale 1:50	Sheet 13 of 14 Parapet

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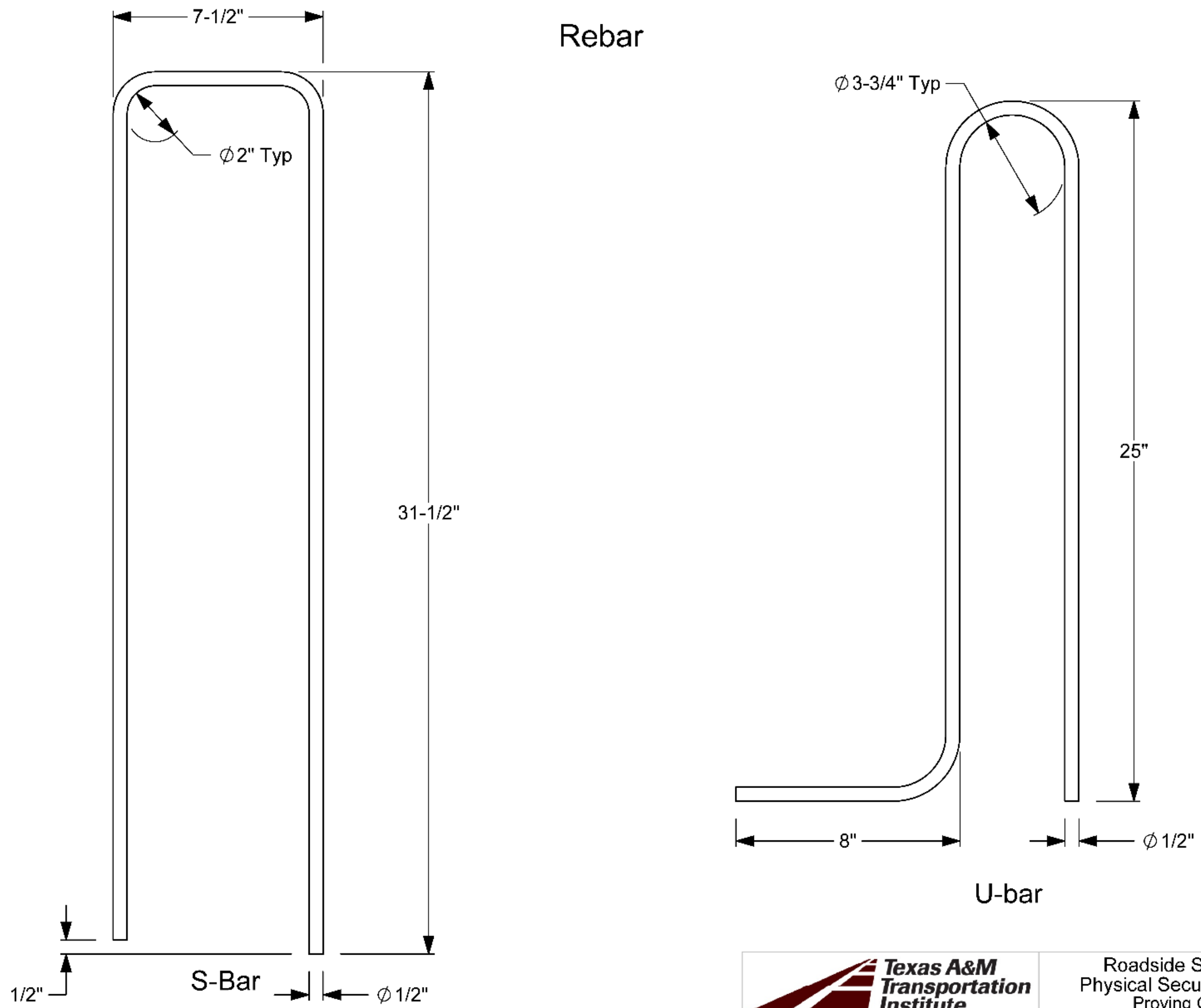
Rebar



Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #620061 with rub rail	Merritt Parkway	2025-02-13
Drawn by GES	Scale 1:5	Sheet 14 of 14 Rebar

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APPENDIX B.

SUPPORTING CERTIFICATION DOCUMENTS

620061

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT
For additional copies call
800-227-6489

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

Drew M Fischer
Quality Assurance Manager

HEAT NO.:3130419 SECTION: REBAR 10MM (#3) 20'0" 420/60 GRADE: ASTM A615-22 Gr 420/60 ROLL DATE: 04/28/2024 MELT DATE: 04/27/2024 Cert. No.: 85799395 / 130419A353	SOLD TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 85799395 BOL#: 75960650 CUST PO#: 982286 CUST P/N: DLVRY LBS / HEAT: 48438.000 LB DLVRY PCS / HEAT: 6440 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.46%	Bend Test Diameter	1.313IN		
Mn	0.78%				
P	0.010%				
S	0.060%				
Si	0.18%				
Cu	0.35%				
Cr	0.07%				
Ni	0.08%				
Mo	0.019%				
V	0.000%				
Cb	0.000%				
Sn	0.009%				
Al	0.001%				
Yield Strength test 1	68.7ksi				
Tensile Strength test 1	104.9ksi				
Elongation test 1	15%				
Elongation Gage Lgth test 1	8IN				
Tensile to Yield ratio test1	1.53				
Bend Test 1	Passed				

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

REMARKS :

Page 1 OF 1 05/13/2024 23:32:15

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT
For additional copies call
800-227-6489

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

Drew M Fischer
Quality Assurance Manager

HEAT NO.:3129610 SECTION: REBAR 13MM (#4) 20'0" 420/60 GRADE: ASTM A615-22 Gr 420/60 ROLL DATE: 03/25/2024 MELT DATE: 03/24/2024 Cert. No.: 85794736 / 129610A130	SOLD TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 85794736 BOL#: 75953748 CUST PO#: 951318 CUST P/N: DLVRY LBS / HEAT: 13148.000 LB DLVRY PCS / HEAT: 984 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.44%	Bend Test Diameter	1.750IN		
Mn	0.88%				
P	0.007%				
S	0.056%				
Si	0.18%				
Cu	0.32%				
Cr	0.09%				
Ni	0.26%				
Mo	0.062%				
V	0.000%				
Cb	0.001%				
Sn	0.011%				
Al	0.002%				
Yield Strength test 1	65.8ksi				
Tensile Strength test 1	103.9ksi				
Elongation test 1	14%				
Elongation Gage Lgth test 1	8IN				
Tensile to Yield ratio test1	1.58				
Bend Test 1	Passed				

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

REMARKS :

Page 1 OF 1 05/09/2024 15:29:19

CMC

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT
For additional copies call
800-227-6489

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

Drew M Fischer
Quality Assurance Manager

HEAT NO.:3129196 SECTION: REBAR 16MM (#5) 20'0" 420/60 GRADE: ASTM A615-22 Gr 420/60 ROLL DATE: 03/06/2024 MELT DATE: 03/03/2024 Cert. No.: 85777889 / 129196A371	SOLD TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 85777889 BOL#: 75927346 CUST PO#: 980316 CUST P/N: DLVRY LBS / HEAT: 20030.000 LB DLVRY PCS / HEAT: 960 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.44%	Bend Test Diameter	2.188IN		
Mn	0.96%				
P	0.008%				
S	0.058%				
Si	0.18%				
Cu	0.28%				
Cr	0.10%				
Ni	0.15%				
Mo	0.052%				
V	0.000%				
Cb	0.001%				
Sn	0.008%				
Al	0.000%				
Yield Strength test 1	61.8ksi				
Tensile Strength test 1	99.5ksi				
Elongation test 1	13%				
Elongation Gage Lgth test 1	8IN				
Tensile to Yield ratio test1	1.61				
Bend Test 1	Passed				

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

REMARKS :

Page 1 OF 1 04/29/2024 20:04:02

FOR	TEXAS A&M TRANSPORTATION INST
PB INVOICE	179405
CUSTOMER PO	620061
SHIP DATE	12/27/2024

Certificate of Conformance

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

5/8" X 12" DOM. PLAIN A449 ROUND HEAD BOLT WITH 1-3/4" THD.

HEAT	8000015619	BASE STEEL	A449	DIAMETER	0.625	SOURCE	Kreher	
C	CR	CU	MN	MO	NI	P	S	SI
0.460	0.060	0.150	0.800	0.010	0.050	0.012	0.030	0.221

HR	PROOF	TN
269 HBN	19,200	31,500 LBF

Certification Department Quality Assurance
Dane McKinnon

KREHER STEEL COMPANY, LLC.

PORTLAND BOLT & MFG. CO.

HOT ROLLED ROUNDS 1045
.6250 X 24'3"
PART NO.

PO/Rel 58768

I hereby certify that this data is correct as contained in the records of this company. I hereby certify that no mercury came in contact with or no weld repair was done to this product while in our possession.
Attn:

Certificate of Mill Test Results

SO I -374415-001 30Nov22
Pg 1/2

NUCOR

Mill Certification

03/21/2022

MTR#:979336-3
Lot #:800001561922
300 STEEL MILL RD
DARLINGTON, SC 29540 US
843 393-5841
Fax: 843 395-8701

Sold To: KREHER STEEL CO LLC
1550 N 25TH AVE
MELROSE PARK, IL 60160 US

Ship To: KREHER STEEL CO LLC
1550 N 25TH AVE
MELROSE PARK, IL 60160 US

Customer PO	1-65462	Sales Order #	80028504 - 4.1
Product Group	Hot Roll - Engineered Bar	Product #	1121251
Grade	1045QL2	Lot #	800001561922
Size	0.625"	Heat #	8000015619
BOL #	BOL-1079111	Load #	979336
Description	Hot Roll - Engineered Bar Round 0.625" (5/8") 1045QL2 24' 3" [291"] 6001-10000 lbs	Customer Part #	.625 X 24' 3" 1045
Production Date	03/04/2022	Qty Shipped LBS	7587
Product Country Of Origin	United States	Qty Shipped EA	300
Original Item Description		Original Item Number	

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

Melt Country of Origin : United States

Melting Date: 01/20/2022

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	V (%)	Nb (%)	Al (%)
0.46	0.80	0.012	0.030	0.221	0.05	0.06	0.01	0.15	0.023	0.001	0.004

Pb (%)
0.002

Ni + Cr + Mo (%) . 0.12

Reduction Ratio 159.61 : 1

ASTM E45 Method A (Worst)
(1) Sulfides T: 1.0 H: 0.0 Alumina T: 0.5 H: 0.0 Silicates T: 0.5 H: 0.0 Globular T: 1.0 H: 0.5

ASTM E45 Method C
(1) Oxides : 0 Silicates : 0

E381 Macroetch

	Macroetch E381 Surface	Macroetch E381 Mid Radius	Macroetch E381 Center
(1)	1	1	4

Hardness

	Brinell (HBW)
(1)	219

Other Test Results
ASTM E112 Grain Size : 9 DI Value : 1.240

Comments:
MATERIAL CONFORMS TO JDM A0 QL-2, ASTM A576
Meets ASTM A29, A576
Meets JDM A0 QL2
Conforms to EN 10204 3.1

Welding or weld repair was not performed on this material.

Melted and Manufactured in the U.S.A and complies with the Buy American Act.

Mark Schmidt, Chief Metallurgist

Page 1 of 2

58768

Doc No. 152694 Indexed 21Mar22 by heidi

KREHER STEEL COMPANY, LLC.

Certificate of Mill Test Results

PORTLAND BOLT & MFG. CO.
HOT ROLLED ROUNDS 1045
.6250 X 24'3"
PART NO.

PO/Rel 56768
I hereby certify that this data is correct as contained in the records of this company.
I hereby certify that no mercury came in contact with or no weld repair was done to this product while in our possession.
Attn:

SO 1 -374415-001 30Nov22
Pg 2/2

NUCOR

Mill Certification
03/21/2022

MTR#:979336-3
Lot #:800001561922
300 STEEL MILL RD
DARLINGTON, SC 29540 US
843 393-5841
Fax: 843 395-8701

Mercury, radium, or alpha source materials not intentionally added at any point during manufacturing or testing of this material.

Material is certified to the most recent revision of the specification(s) and grade indicated at the time of production.

Mark Schmidt, Chief Metallurgist

Page 2 of 2

Doc No. 152694 Indexed 21Mar22 by heidi

PORTLAND BOLT

sales@portlandbolt.com
www.portlandbolt.com

Sales Order No. 179405

Date	11/22/2024
Salesperson	Harrison Emery
Email	harrison@portlandbolt.com
Phone	803.339.1181

PB Northwest
800.547.6758
3441 NW Guam St.
Portland, OR 97210

PB Southeast
800.631.2076
890 W Five Notch Rd.
North Augusta, SC 29860

Sold To	Ship To
979.317.2755 TEXAS A&M TRANSPORTATION INST TTI FINANCIAL SERVICES 3135 TAMU COLLEGE STATION, TX 77843-3135	Attn: Adam Mayer 512.635.3115 TEXAS A&M TRANSPORTATION INST 1111 RELLIS PARKWAY BRYAN, TX 77807

Attention	Terms	Customer PO
Adam<a-mayer@tti.tamu.edu>	30 Days	620061

Ship Date (scheduled)	Delivery	Certs
12/27/2024	UPS Ground (Prepaid)	Emailed Mill Test Reports

No.	Qty	UOM	Description
1	50	EA	5/8" x 12" dom. plain A449 round head bolt with 1-3/4" thd. HEAD STAMP MANUFACTURER'S LOGO ONLY NO GRADE STAMP
2	0	EA	FREIGHT CHARGES

Total Weight (lbs.) 54.02

THREADED PRODUCTS, INC.

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

JOB MATERIAL CERTIFICATION

Job No: 800018 — **Job Information** — **Certified Date:** 1/17/23

Containers: S20945989

Customer: American Anchor Bolt, Mfg.

Ship To: 13913 Buxley
Houston, TX 77045

Vulcan Part No: HRB A449 1.000x290

Customer Part No: HRB A449 1.000x290

Customer PO No: 72423-J SO. 7/27/23

Shipped Qty: 4520 lbs

Order No: 479863

Line No: 1

Note:

Applicable Specifications

Type	Specification	Rev	Amend	Option
-	ASTM A449 Type 1	2014		

Test Results

See following pages for tests

Certified Chemical Analysis

Heat No: 224012 Lot 1.000 — Origin: USA

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V
0.47	0.81	0.014	0.030	0.21	0.24	0.09	0.12	0.024	0.006
Sn	**Nb**	**Al**	**Ti**	**N**	**B**	**DI**	**RR**	**G.S.**	
0.014	0.025	0.003	0.001	0.0108	0.0003	1.50	62.39:1	7	

Notes

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

Plex 1/17/23 2:53 PM vulc.sano Page 1 of 2

Vulcan THREADED PRODUCTS, INC.

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

JOB MATERIAL CERTIFICATION

Job No: 800018 **Job Information** **Certified Date:** 1/17/23

Containers: S20945989

Test Results

Part No: HRB A449 1.000x290

Test No: 76477 **Test**: Heat Treat Info

Description	Austenitizing Temp (F)	Tempering Temp (F)	Run Speed (ft/min)	Quench Water Temp (F)	Note
	1,579	1,281	32	89	

Test No: 76478 **Test**: Tensile Test

Description	Tensile Strength (ksi)	Yield Strength (0.2% Offset) (ksi)	Elongation (4D) (%)	ROA (%)	Note
	131	111	20	51	
	133	113	18	44	
	135	115	18	50	

Test No: 76479 **Test**: Hardness Test

Description	Midradius Hardness	Surface Hardness	Core Hardness	Hardness Scale	Note
	28	30	26	HRC	
	28	30	27	HRC	
	28	30	27	HRC	

The reported test results conform to the specifications listed above.
The reported test results are the actual values measured on the samples taken from the production lot.
Material was manufactured, tested, and inspected as required by the product standard and in accordance with Vulcans ISO 9001:2015 Quality Management System registered June 30th, 2017.
Vulcan Steel Products lab is ISO 17025:2017 accredited for tensile, Brinell and Rockwell hardness, Charpy impact, and carb/decarb testing.
Material was tested in accordance with the current revision of ASTM A370, F606, and F2328 test methods.
All Q&T material is demagnetized.
This test report shall not be reproduced or distributed, except in full, nor shall it be modified in any way without the written permission of Vulcan Steel Products.
Document is in accordance with EN 10204 - 3.1B of 2004 (3.1).

Sallie Norwood 1/17/23

Norwood, Sallie - Certification Engineer Date

Plex 1/17/23 2:53 PM vulc.sano Page 2 of 2

NUCOR® PLATE MILL GROUP

P.O.Box 279
Winton, NC 27986
(252) 356-3700

Mill Test Report
Page 1

1505 River Rd
Cofield, NC 27922
(252) 356-3700

Issuing Date : 02/21/2024 **B/L No. :** 666598 **Load No. :** 685828 **Cust. Order No. :** 7903246

Vehicle No: ROYALTY 1026

Specification: 1.0000" x 96.000" x 240.000"
ASTM A709-21 GR50W/345 W /AASHTO M270-2023 GR50W/ASTM A588-19 Gr A/B

Marking :

Heat No	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Al(tot)	V	Nb	Ti	N	Ca	B	Sn	Ceq	Pcm
4600752	0.15	1.03	0.009	0.002	0.32	0.28	0.24	0.48	0.03	0.029	0.029	0.002	0.002		0.0011	0.0001	0.009	0.46	0.26

Plate Serial No	Pieces	Tons	Tensile Test				
			Dir.	(psi) Yield	(psi) Tensile	Elong. % in 2"	Elong. % in 8"
4600752-03	5	16.33	T	57,200	84,500		20.2
			T	51,800	78,500		24.1

Manufactured to fully killed fine grain practice by Electric Arc Furnace. Welding or weld repair was not performed on this material.
Mercury has not been used in the direct manufacturing of this material. Produced as continuous cast discrete plate as-rolled, unless otherwise noted in Specification. For Mexico shipments:nhc-SalesMX@nucor.com
Yield by 0.5EUL method unless otherwise specified. Ceq = C+(Mn/6)+((Cr+Mo+V)/5)+((Cu+Ni)/15)
Pcm = C+(Si/30)+(Mn/20)+(Cu/20)+(Ni/60)+(Cr/20)+(Mo/15)+(V/10)+5B
Melted and Manufactured in the USA. ISO 9001:2015 certified, PED 2014/68/EU, 97/23/EC 7/2 Annex 1, Para. 4.3 Compliant. API Q1-1851
DIN 50049 3.1.B/EN 10204 3.1(2004) 3.1B(1993)/ DIN EN 10204 3.1(2005) compliant. ABS QA-3624366

We 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 the applicable specifications, including customer specifications.

C. L. Cooper, Metallurgist

2/21/2024 8:33:08 AM

TEXCRETE

REMIT PAYMENT TO:
P.O. BOX138
KURTEN, TX 77862

5222 Sandy Point RD.
Bryan, TX 77807

18935 Circle Lake Dr.
Pinehurst, TX 77362

17534 SH 6 South
College Station, TX 77845

17263 Hwy 75N
Willis, TX 77378

2687 HWY 105
Montgomery, TX 77333

232947

PINEHURST DISPATCH - 936-232-5815
BCS DISPATCH - 979-316-2906
OFFICE - 979-985-3636

TEXAS A&M TRANSPORTATIO
RELLIS CAMPUS, BRYAN TX

RT 2818, RT HWY 21, LT SILVER HILL, RT AT THE "T", RT HWY 47, LT INTORELLIS ENTRANCE, STAY STRAIGHTALL THE WAY DOWN TO THE GATE

TIME	FORMULA	LOAD SIZE	YARDS ORDERED		DRIVER/TRUCK		PLANT TRANSACTION#
6:57	FN94020050	6.00	6.00	PO#	620061	HOSEY, JUSTIN1	96360
DATE	PROJECT	LOAD#	YARDS DEL	BATCH#	WATER TRIM	SLUMP	TICKET NUMBER
7/5/24	TTIRELL	6.00	6.00			3.00 in	94562

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
6.00 yd	FN940200503	CON, 4000, PR, 5", 3		
1.00 ea.	FUEL	Fuel Charge		

Thank you for your business

LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP	AIR TEMP
706	727				
FINISH UNLOADING	LEFT JOB	ARRIVED AT PLANT	ON SITE TESTING		
			TESTING LAB: TERRACON / GESSNER / CMB / OTHER		
	TESTED		AIR	CYLINDERS	
	☐ YES ☐ NO				

Tax
Prev. AMT
Ticket Total

ADDITIONAL CHARGE 1 ________

ADDITIONAL CHARGE 2 ________

GRAND TOTAL

WARNING
IRRITATING TO THE SKIN AND EYES

Contains Portland Cement. Wear Rubber Boots and Gloves. PROLONGED CONTACT MAY CAUSE BURNS. Avoid Contact With Eyes and Prolonged Contact with Skin. In Case of Contact with Skin or Eyes, Rinse Thoroughly With Water. If Irritation Persists, Get Medical Attention. **KEEP CHILDREN AWAY.**

CONCRETE is a PERISHABLE COMMODITY and BECOMES THE PROPERTY of the PURCHASER UPON LEAVING the PLANT. ANY CHANGES or CANCELLATION of ORIGINAL INSTRUCTIONS MUST be TELEPHONED to the OFFICE BEFORE LOADING starts. The undersigned promises to pay all costs, including reasonable attorney's fees incurred in collecting any sums owed.

All accounts not paid within 30 days of delivery will bear interest at the rate of 10% per annum. Not Responsible for Reactive Aggregate or Color Quality. No Claim Allowed Unless Made at Time Material is Delivered.
A $25.00 Service Charge and Loss of the Cash Discounted will be Collected on all Returned Checks. **Demerge charge after 90 min. will be $100.00/hr.**

PROPERTY DAMAGE RELEASE

(TO BE SIGNED IF DELIVERY TO BE MADE INSIDE CURB LINE)

Dear Customer: [illegible] RELEASE [illegible]
SIGNED

X ________

Excessive Water is Detrimental to Concrete Performance.
H_2O Added by Request/Authorized By:

____ GAL X ________

WEIGHMASTER

Surcharge for credit cards

NOTICE: MY SIGNATURE BELOW INDICATES THAT I HAVE READ THE HEALTH WARNING NOTICE AND SUPPLIER WILL NOT BE RESPONSIBLE FOR ANY DAMAGE CAUSED WHEN DELIVERING INSIDE CURB LINE.

LOAD RECEIVED BY

232947

TEXCRETE
Redi-mix Concrete Company

140326

TEXCRETE

REMIT PAYMENT TO:
P.O. BOX138
KURTEN, TX 77862

5222 Sandy Point RD. Bryan, Tx 77807 | 17534 SH 6 South College Station, TX 77845 | 18935 Circle Lake Dr. Pinehurst, TX 77362

BCS DISPATCH - 979-316-2906
PINEHURST DISPATCH - 936-232-5815
OFFICE - 979-985-3636

TEXAS A&M TRANSPORTATIO
RELLIS CAMPUS, BRYAN TX

RT 2818, RT HWY 21, LT SILVER HILL, RT AT THE "T", RT HWY 47, LT INTORELLIS ENTRANCE, STAY STRAIGHTALL THE WAY DOWN TO THE GATE 5

TIME	FORMULA	LOAD SIZE	YARD ORDERED		DRIVER/TRUCK		PLANT TRANSACTION#
8:48	XC3600	3.00	3.00	PO# 62006	JACKSON, RICK6		96139
DATE	**PROJECT**	**LOAD#**	**YARDS DEL**	**BATCH#**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
7/1/24	TTIRELL	3.00	3.00			5.00 in	94341

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
3.00 yd	TXC3600	DOTC.3600,RG,5",		
1.00 ea	FUEL	Fuel Charge		

Thank you for your business

LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP	AIR TEMP
8:53	9:20				
FINISH UNLOADING	**LEFT JOB**	**ARRIVED AT PLANT**	ON SITE TESTING		
			TESTING LAB: TERRACON GESSNER CME	OTHER	
	TESTED		AIR	CYLINDERS	
	☐ YES ☐ NO				

Tax
Prev. AMT
Ticket Total

ADDITIONAL CHARGE 1 ________
ADDITIONAL CHARGE 2 ________
GRAND TOTAL

WARNING
IRRITATING TO THE SKIN AND EYES

Contains Portland Cement, Wear Rubber Boots and Gloves. PROLONGED CONTACT MAY CAUSE BURNS. Avoid Contact With Eyes and Prolonged Contact with Skin. In Case of Contact with Skin or Eyes, Rinse Thoroughly With Water. If Irritation Persists. Get Medical Attention. **KEEP CHILDREN AWAY.**

CONCRETE is a PERISHABLE COMMODITY and BECOMES THE PROPERTY of the PURCHASER UPON LEAVING the PLANT. ANY CHANGES or CANCELLATION of ORIGINAL INSTRUCTIONS MUST be TELEPHONED to the OFFICE BEFORE LOADING starts. The undersigned promises to pay all costs, including reasonable attorney's fees incurred in collecting any sums owed.

All accounts not paid within 30 days of delivery will bear interest at the rate of 18% per annum. Not Responsible For Reactive Aggregate or Color Quality. No Claim Allowed Unless Made at Time Material is Delivered.
A $25.00 Service Charge and Loss of the Cash Discounted will be Collected on all Returned Checks. Demerge charge after 90 min. will be $100.00/hr.

PROPERTY DAMAGE RELEASE
(TO BE SIGNED IF DELIVERY TO BE MADE INSIDE CURB LINE)

Dear Customer - The driver of this truck in presenting this RELEASE to you for your signature is of the opinion that the size and weight of this truck may possibly cause damage to the premises and/or adjacent property if he places the material in this load where you desire it. It is our wish to help you in everyway that we can, but in order to do this the driver is requesting that you sign this RELEASE relieving him and this supplier from any responsibility from damage that may occur to the premises and or adjacent property, buildings, sidewalks, driveways, curbs, etc. by the delivery of this material and that you also agree to help him remove mud from the wheels of his vehicle so that he will not liter the public streets. Further as additional consideration, the undersigned agrees to indemnify and hold harmless the driver of this truck and this supplier for any and all damage to the premises and /or adjacent property, which may be claimed by anyone to have arisen out of delivery of this order.
SIGNED:

X________________________

Excessive Water is Detrimental to Concrete Performance.
H_2O Added by Request/Authorized By:

______GAL X________________

WEIGHMASTER

Surcharge for credit cards

NOTICE: MY SIGNATURE BELOW INDICATES THAT I HAVE READ THE HEALTH WARNING NOTICE AND SUPPLIER WILL NOT BE RESPONSIBLE FOR ANY DAMAGE CAUSED WHEN DELIVERING INSIDE CURB LINE.

LOAD RECEIVED BY
x________________

140326

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0294
Service Date: 06/20/24
Report Date: 09/09/24
Task: PO# 620061

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Client
Texas Transportation Institute
Attn: Bill Griffith
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project
Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information
Specified Strength:

Mix ID: DOTC
Supplier: Texcrete
Batch Time: 0931 **Plant:**
Truck No.: Raymo **Ticket No.:** 93786

Sample Information
Sample Date: 06/20/24 **Sample Time:** 1007
Sampled By: Vince Thomas
Weather Conditions: Cloudy
Accumulative Yards: 5/5 **Batch Size (cy):** 5
Placement Method: Direct Discharge
Water Added Before (gal): 0
Water Added After (gal): 0
Sample Location: West side of run way, 360 ft from southwest corner of runway
Placement Location: Slab on Runway
Sample Description: 6-inch diameter cylinders

Field Test Data

Test	Result	Specification
Slump (in):	4 1/2	Not Provided
Air Content (%):	1.6	Not Provided
Concrete Temp. (F):	91	Not Provided
Ambient Temp. (F):	82	Not Provided
Plastic Unit Wt. (pcf):	148.4	Not Provided
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Spec ID	Cyl. Cond.	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Max Load (lbs)	Comp Strength (psi)	Frac Type	Tested By
1	A	Irregular	6.00	28.27		08/30/24	71 F	145,125	5,130	2	JLR
1	B	Good	6.00	28.27		08/30/24	71 F	144,619	5,110	2	JLR
1	C	Irregular	6.00	28.27		08/30/24	71 F	143,319	5,070	2	JLR
1	D						Hold				

Initial Cure: Outside Plastic Lids **Final Cure:** Field Cured

Comments: **F = Field Cured**
Note: Reported air content does not include Aggregate Correction Factor (ACF).

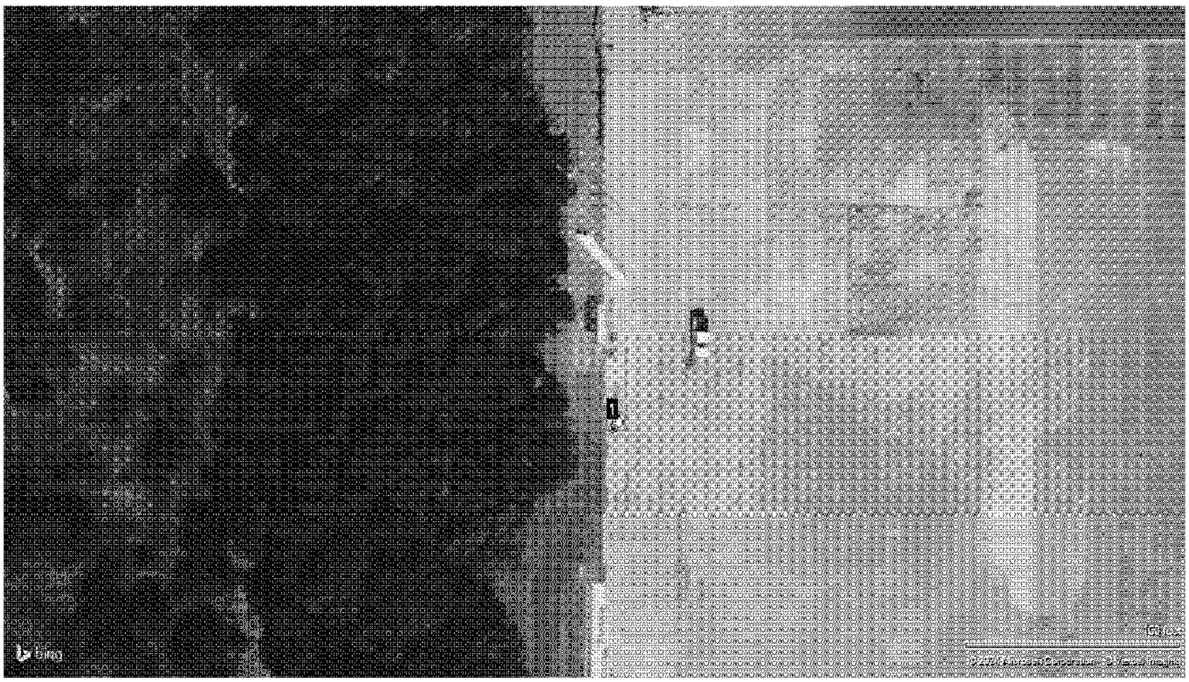
Samples Made By: Terracon
Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).

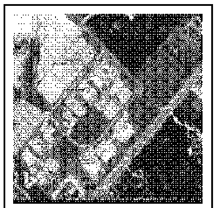
Terracon Rep.: Vince Thomas
Reported To: Bill with TTI
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith (1) Texas Transportation Institute, Adam Mayer

Start/Stop: 0900-1200

Reviewed By:
Alexander Dunigan, P.E.
Project Manager

Test Methods: ASTM C 31, ASTM C143, ASTM C231, ASTM C1064





Test

Retested / Accepted

Deviation

terracon	Riverside Campus	Exhibit
6198 Imperial Loop College Station, TX 77845-5765	Concrete Compressive Strength Test	A-1
979-846-3767 terracon.com		

Report Number:	Service Date:	Employee:	Scale:
A1171057.0294	06/20/2024	Thomas, Vince	Refer to Drawing

Photo Log

Report Number:	A1171057.0294
Service Date:	06/20/24
Report Date:	09/09/24
Task:	PO# 620061

Terracon

6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

(P1) Batch ticket

(P3) Sample Placement Location

(P2) Cylinder Storage Location

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0295
Service Date: 06/25/24
Report Date: 09/09/24
Task: PO# 620061

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Client
Texas Transportation Institute
Attn: Bill Griffith
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project
Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information
Specified Strength: 3,000 psi @ 28 days

Mix ID: FN930200500
Supplier: Texcrete
Batch Time: 0921 **Plant:**
Truck No.: 153 **Ticket No.:** 94018

Sample Information
Sample Date: 06/25/24 **Sample Time:** 0956
Sampled By: Vince Thomas
Weather Conditions: Partly cloudy
Accumulative Yards: 3/3 **Batch Size (cy):** 3
Placement Method: Direct Discharge
Water Added Before (gal): 0
Water Added After (gal): 0
Sample Location: Test Panels
Placement Location: Test Panels
Sample Description: 6-inch diameter cylinders

Field Test Data

Test	Result	Specification
Slump (in):	7	
Air Content (%):	1.4	
Concrete Temp. (F):	93	
Ambient Temp. (F):	86	
Plastic Unit Wt. (pcf):	148.4	
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Spec ID	Cyl. Cond.	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Max Load (lbs)	Comp Strength (psi)	Frac Type	Tested By
1	A	Good	4.00	12.57		08/30/24	66 F	55,035	4,380	2	JLR
1	B	Good	4.00	12.57		08/30/24	66 F	47,165	3,750	2	JLR
1	C	Good	4.00	12.57		08/30/24	66 F	49,504	3,940	2	JLR
1	D						Hold				

Initial Cure: Outside in shade **Final Cure:** Field Cured

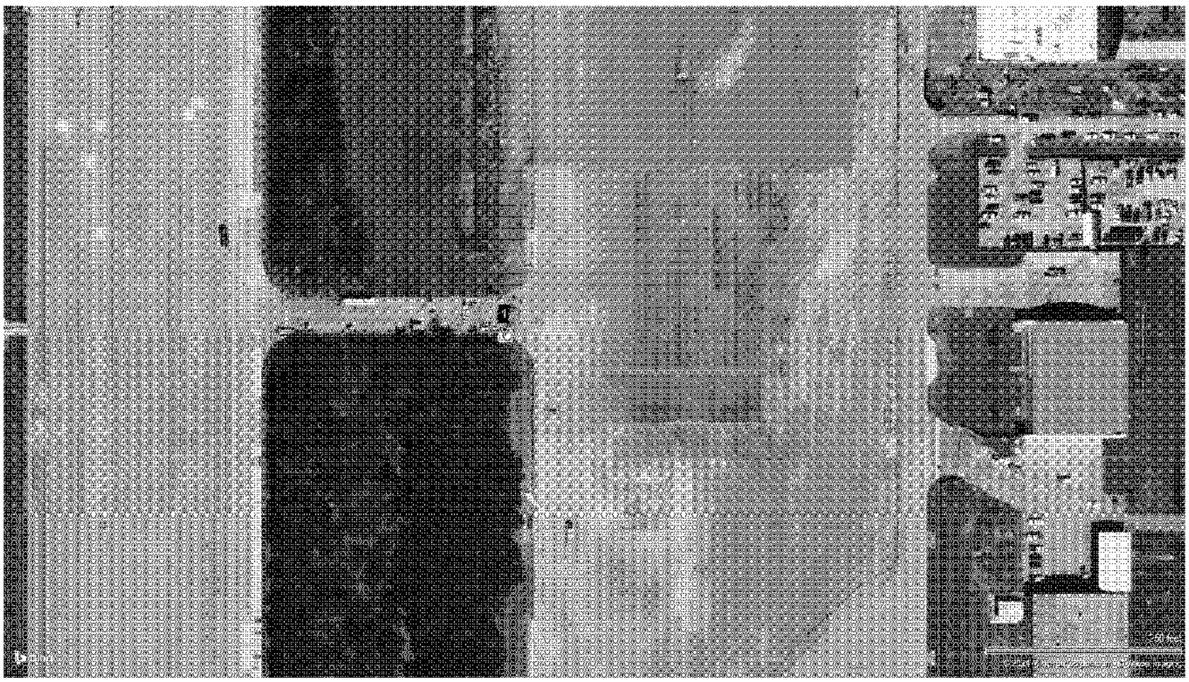
Comments: **F = Field Cured**
Note: Reported air content does not include Aggregate Correction Factor (ACF).

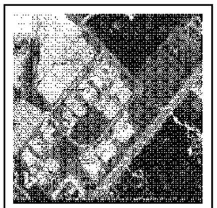
Samples Made By: Terracon
Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).

Terracon Rep.: Vince Thomas **Start/Stop:** 0900-1100
Reported To: Bill Griffith with TTI
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith (1) Texas Transportation Institute, Adam Mayer

Reviewed By:
Alexander Dunigan, P.E.
Project Manager

Test Methods: ASTM C 31, ASTM C143, ASTM C231, ASTM C1064





Test

Retested / Accepted

Deviation

terracon

6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767
terracon.com

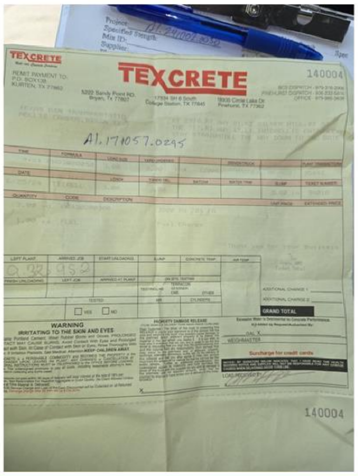
Riverside Campus	Exhibit
Concrete Compressive Strength Test	A-1

Report Number:	Service Date:	Employee:	Scale:
A1171057.0295	06/25/2024	Thomas, Vince	Refer to Drawing

Photo Log

Report Number: A1171057.0295
Service Date: 06/25/24
Report Date: 09/09/24
Task: PO# 620061

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272



(P1) Batch Ticket

(P3) Cylinder Storage Location

(P2) Sample Placement Location

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0297
Service Date: 07/01/24
Report Date: 09/09/24
Task: PO# 620061

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Client
Texas Transportation Institute
Attn: Bill Griffith
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project
Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information
Specified Strength: 3,600 psi @ 28 days

Mix ID: TXC3600
Supplier: Texcrete
Batch Time: 0848 **Plant:** Bryan
Truck No.: 156 **Ticket No.:** 94341

Sample Information
Sample Date: 07/01/24 **Sample Time:** 0930
Sampled By: Vince Thomas
Weather Conditions: Partly cloudy
Accumulative Yards: 3/3 **Batch Size (cy):** 3
Placement Method: Direct Discharge
Water Added Before (gal): 0
Water Added After (gal): 0
Sample Location: South End of Wall
Placement Location: Stub Wall on SW Side of Runway
Sample Description: 4-inch diameter cylinders

Field Test Data

Test	Result	Specification
Slump (in):	3 1/2	Not Provided
Air Content (%):	1.4	Not Provided
Concrete Temp. (F):	96	Not Provided
Ambient Temp. (F):	88	Not Provided
Plastic Unit Wt. (pcf):	148.4	Not Provided
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Spec ID	Cyl. Cond.	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Max Load (lbs)	Comp Strength (psi)	Frac Type	Tested By
1	A	Good	4.00	12.57		08/30/24	60 F	61,119	4,860	2	JLR
1	B	Good	4.00	12.57		08/30/24	60 F	52,648	4,190	2	JLR
1	C	Good	4.00	12.57		08/30/24	60 F	58,026	4,620	2	JLR
1	D						Hold				

Initial Cure: Outside in shade **Final Cure:** Field Cured

Comments: **F = Field Cured**
Note: Reported air content does not include Aggregate Correction Factor (ACF).

Samples Made By: Terracon
Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).

Terracon Rep.: Vince Thomas **Start/Stop:** 0630-1000
Reported To: Adam Mayer w/ TTI
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith (1) Texas Transportation Institute, Adam Mayer

Reviewed By:
Alexander Dunigan, P.E.
Project Manager

Test Methods: ASTM C 31, ASTM C143, ASTM C231, ASTM C1064

Photo Log

Report Number:	A1171057.0297
Service Date:	07/01/24
Report Date:	09/09/24
Task:	PO# 620061

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

(P1) Placement Location

(P2) Cylinder Storage Location

CONCRETE COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0298
Service Date: 07/05/24
Report Date: 09/09/24
Task: PO# 620061

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Client
Texas Transportation Institute
Attn: Bill Griffith
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project
Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information
Specified Strength: 4,000 psi @ 28 days

Mix ID: FN940200503
Supplier: Texcrete
Batch Time: **Plant:**
Truck No.: 620061 **Ticket No.:** 232947

Sample Information
Sample Date: 07/05/24 **Sample Time:** 0732
Sampled By: Colby Berger
Weather Conditions: Sunny
Accumulative Yards: 10/10 **Batch Size (cy):** 10
Placement Method: Direct Discharge
Water Added Before (gal): 0
Water Added After (gal): 0
Sample Location: Paving west side of runway 400ft from south end
Placement Location: Paving west side of runway 400ft from south end
Sample Description: 6-inch diameter cylinders

Field Test Data

Test	Result	Specification
Slump (in):	2	
Air Content (%):		
Concrete Temp. (F):	89	
Ambient Temp. (F):	78	
Plastic Unit Wt. (pcf):		
Yield (Cu. Yds.):		

Laboratory Test Data

Set No.	Spec ID	Cyl. Cond.	Avg Diam. (in)	Area (sq in)	Date Received	Date Tested	Age at Test (days)	Max Load (lbs)	Comp Strength (psi)	Frac Type	Tested By
1	A	Good	4.00	12.57		08/30/24	56 F	110,034	8,760	2	JLR
1	B	Good	4.00	12.57		08/30/24	56 F	84,983	6,760	2	JLR
1	C	Good	4.00	12.57		08/30/24	56 F	95,435	7,590	2	JLR
1	D						Hold				

Initial Cure: Outside Plastic Lids **Final Cure:** Field Cured

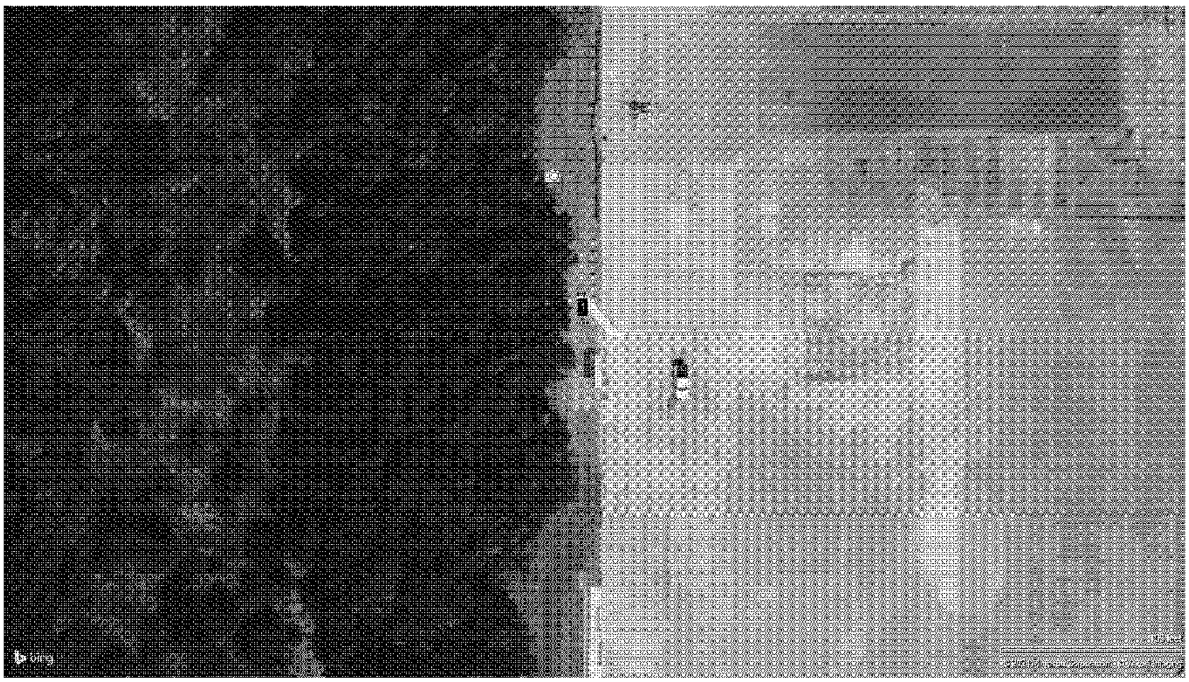
Comments: **Not tested for plastic unit weight. F = Field Cured**
Note: Reported air content does not include Aggregate Correction Factor (ACF).

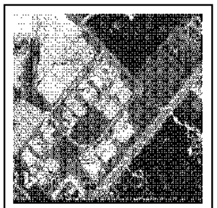
Samples Made By: Terracon
Services: Obtain samples of fresh concrete at the placement locations (ASTM C 172), perform required field tests and cast, cure, and test compressive strength samples (ASTM C 31, C 39, C 1231).

Terracon Rep.: Colby Berger **Start/Stop:** 0700-0830
Reported To: Will Schroder with TTI
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Bill Griffith (1) Texas Transportation Institute, Adam Mayer

Reviewed By:
Alexander Dunigan, P.E.
Project Manager

Test Methods: ASTM C 31, ASTM C143, ASTM C231, ASTM C1064





Test

Retested / Accepted

Deviation

6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767
terracon.com

Riverside Campus

Concrete Compressive Strength Test

Exhibit

A-1

Report Number:	Service Date:	Employee:	Scale:
A1171057.0298	07/05/2024	Berger, Colby	Refer to Drawing

TEXCRETE
Redi-mix Concrete Company

TEXCRETE

139776

REMIT PAYMENT TO:
P.O. BOX138
KURTEN, TX 77862

5222 Sandy Point RD.
Bryan, Tx 77807

17534 SH 6 South
College Station, TX 77845

18935 Circle Lake Dr.
Pinehurst, TX 77362

BCS DISPATCH - 979-316-2906
PINEHURST DISPATCH - 936-232-5815
OFFICE - 979-985-3636

TEXAS A&M TRANSPORTATIO
RELLIS CAMPUS, BRYAN TX

RT 2818, RT HWY 21, LT SILVER HILL, RT AT THE "T", RT HWY 47, LT INTORELLIS ENTRANCE, STAY STRAIGHTALL THE WAY DOWN TO THE GATE

TIME	FORMULA	LOAD SIZE	YARD ORDERED		DRIVER/TRUCK		PLANT TRANSACTION#
9:31	TXC3600	5.00	5.00	PO# 620061	GOOSBY	RAYMO3	95585
DATE	**PROJECT**	**LOAD#**	**YARDS DEL.**	**BATCH#**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
6/20/24	TTIRELL	5.00	5.00			5.00 in	93786

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
5.00 yd	TXC3600	DOTC, 3600, RG, 5".		
1.00 ea	FUEL	Fuel Charge		

Thank you for your business

LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP.	AIR TEMP
9:41	10:00				
FINISH UNLOADING	**LEFT JOB**	**ARRIVED AT PLANT**	**ON SITE TESTING**		
			TESTING LAB: TERRACON GESSNER CME OTHER		
	TESTED		**AIR**	**CYLINDERS**	
	☐ YES ☐ NO				

Tax
Prev. AMT
Ticket Total

ADDITIONAL CHARGE 1 ________

ADDITIONAL CHARGE 2 ________

GRAND TOTAL

WARNING
IRRITATING TO THE SKIN AND EYES

Contains Portland Cement, Wear Rubber Boots and Gloves. PROLONGED CONTACT MAY CAUSE BURNS. Avoid Contact With Eyes and Prolonged Contact with Skin. In Case of Contact with Skin or Eyes, Rinse Thoroughly With Water. If Irritation Persists. Get Medical Attention. **KEEP CHILDREN AWAY.**

CONCRETE Is a PERISHABLE COMMODITY and BECOMES THE PROPERTY of the PURCHASER UPON LEAVING the PLANT. ANY CHANGES or CANCELLATION of ORIGINAL INSTRUCTIONS MUST be TELEPHONED to the OFFICE BEFORE LOADING starts. The undersigned promises to pay all costs, including reasonable attorney's fees. incurred in collecting any sums owed.

All accounts not paid within 30 days of delivery will bear interest at the rate of 18% per annum. Not Responsible For Reactive Aggregate or Color Quality. No Claim Allowed Unless Made at Time Material is Delivered.
A $25.00 Service Charge and Loss of the Cash Discounted will be Collected on all Returned Checks. Demerge charge after 90 min. will be $100.00/hr.

PROPERTY DAMAGE RELEASE
(TO BE SIGNED IF DELIVERY TO BE MADE INSIDE CURB LINE)

Dear Customer - The driver of this truck in presenting this RELEASE to you for your signature is of the opinion that the size and weight of this truck may possibly cause damage to the premises and/or adjacent property if he places the material in this load where you desire it. It is our wish to help you in everyway that we can, but in order to do this the driver is requesting that you sign this RELEASErelieving him and this supplier from any responsibility from damage that may occur to the premises and or adjacent property, buildings, sidewalks, driveways, curbs, etc. by the delivery of this material and that you also agree to help him remove mud from the wheels of his vehicle so that he will not liter the public streets. Further as additional consideration; the undersigned agrees to indemnify and hold harmless the driver of this truck and this supplier for any and all damage to the premises and /or adjacent property which may be claimed by anyone to have arisen out of delivery of this order SIGNED:

X________________

Excessive Water is Detrimental to Concrete Performance.
H_2O Added by Request/Authorized By:

________GAL. X________________

WEIGHMASTER

Surcharge for credit cards

NOTICE: MY SIGNATURE BELOW INDICATES THAT I HAVE READ THE HEALTH WARNING NOTICE AND SUPPLIER WILL NOT BE RESPONSIBLE FOR ANY DAMAGE CAUSED WHEN DELIVERING INSIDE CURB LINE.

LOAD RECEIVED BY
X________________

139776

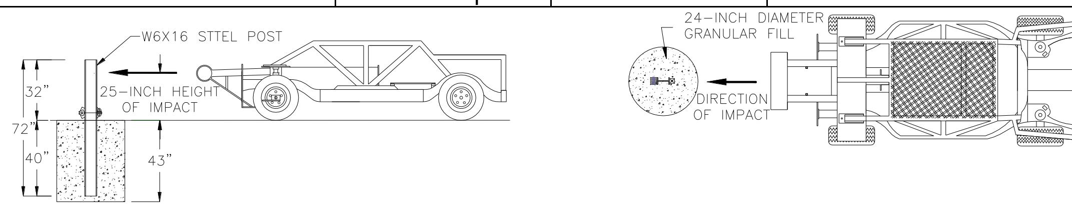
Table B.1. Soil Strength Analysis.

Dynamic Test Setup

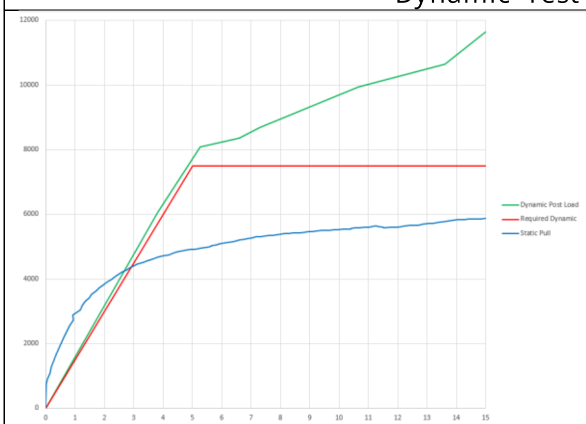
Post-Test Photo of post

Static Load Test

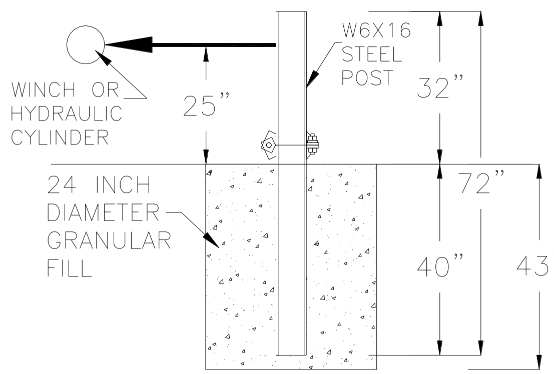
Post-Test Photo



Dynamic Test Installation Details



Comparison of Load vs. Displacement



Static Load Test Installation Details

Date	2020-02-02
Test Facility and Site Location	TTI Proving Ground, 3100 SH 47, Bryan, TX 77807
In Situ Soil Description (ASTM D2487)	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis	Type 1 Grade D Crushed Concrete Road Base
Description of Fill Placement Procedure	12-inch lifts tamped with a pneumatic compactor for 20 sec
Bogie Mass	2020 lb
Impact Velocity	19.2 mph

APPENDIX C.

MASH TEST 3-11 (CRASH TEST 620061-01-2)

C.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2024-09-10 Test No.: 620061-01-2 VIN No.: 1C6RR6FTSJS131854

Year: 2018 Make: RAM Model: 1500

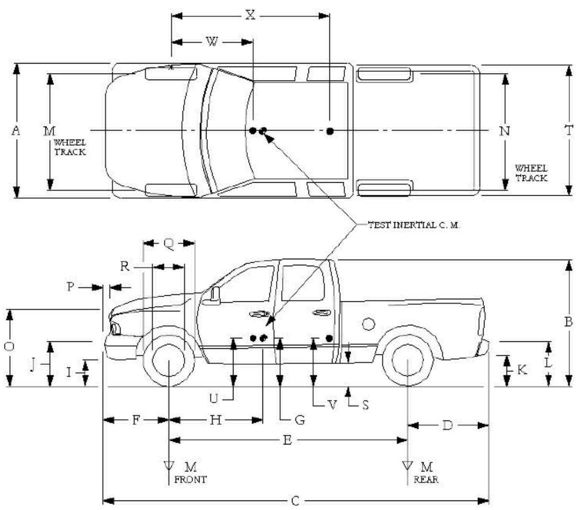
Tire Size: 265/70 R 17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 154460

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES: None



Engine Type: V-8
Engine CID: 5.7 liter

Transmission Type:
☑ Auto or ☐ Manual
☐ FWD ☑ RWD ☐ 4WD

Optional Equipment:
None

Dummy Data:
Type:
Mass:
Seat Position:

Geometry: inches

A	78.50	F	40.25	K	20.00	P	3.00	U	26.75
B	74.00	G	28.50	L	30.00	Q	30.50	V	30.25
C	229.00	H	61.50	M	68.50	R	18.00	W	61.50
D	48.25	I	11.75	N	68.00	S	13.00	X	79.00
E	140.50	J	27.00	O	46.00	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	12.50
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	22.50

RANGE LIMIT: A=78 ±2 inches; C=237 ±13 inches; E=148 ±12 inches; F=39 ±3 inches; G = > 28 inches; H = 63 ±4 inches; O=43 ±4 inches; (M+N)/2=67 ±1.5 inches

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2910	2838	2838
Back	3900	M_{rear}	2044	2210	2210
Total	6700	M_{Total}	4954	5048	5048

(Allowable Range for TIM and GSM = 5000 lb ±110 lb)

Mass Distribution:
lb LF: 1450 RF: 1388 LR: 1115 RR: 1095

Figure C.1. Vehicle Properties for Test 620061-01-2.

Date:	2024-09-10	Test No.:	620061-01-2	VIN No.:	1C6RR6FTSJS131854
Year:	2018	Make:	RAM	Model:	1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width ________	Bowing: B1 _____ X1 _____
Corner shift: A1 ________	B2 _____ X2 _____
A2 ________	
End shift at frame (CDC)	Bowing constant
(check one)	$\frac{X1+X2}{2}$ = ______
< 4 inches ________	
≥ 4 inches ________	

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FRONT BUMPER	20	19	52	-	-	-	-	-	-	+9
2	SAME	20	20	62	-	-	-	-	-	-	72
	Measurements recorded										
	☑ **inches** or ☐ **mm**										

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

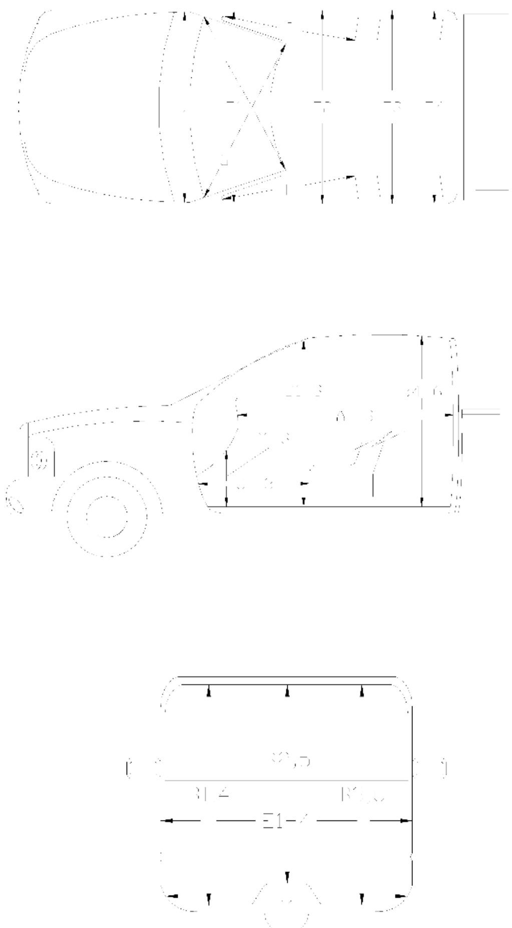
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***Measure and document on the vehicle diagram the location of the maximum crush.

Note: Use as many lines/columns as necessary to describe each damage profile.

Figure C.2. Exterior Crush Measurements for Test 620061-01-2.

Date:	2024-09-10	Test No.:	620061-01-2	VIN No.:	1C6RR6FTSJS131854
Year:	2018	Make:	RAM	Model:	1500



*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	24.25	-1.75
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	59.50	1.00
E2	63.50	63.75	0.25
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	22.75	-2.25

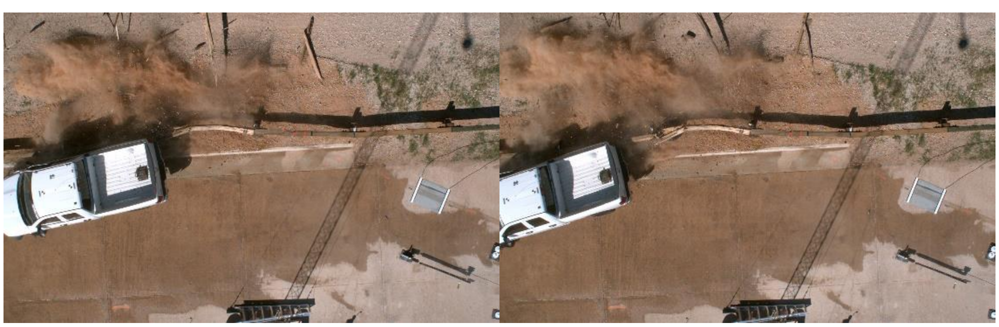
Figure C.3. Occupant Compartment Measurements for Test 620061-01-2.

C.2. SEQUENTIAL PHOTOGRAPHS

(a) 0.000 s (b) 0.1000 s

(c) 0.2000 s (d) 0.3000 s

(e) 0.4000 s (f) 0.5000 s



(g) 0.6000 s (h) 0.7000 s

Figure C.4. Sequential Photographs for Test 620061-01-2 (Overhead Views).

(a) 0.000 s (b) 0.1000 s

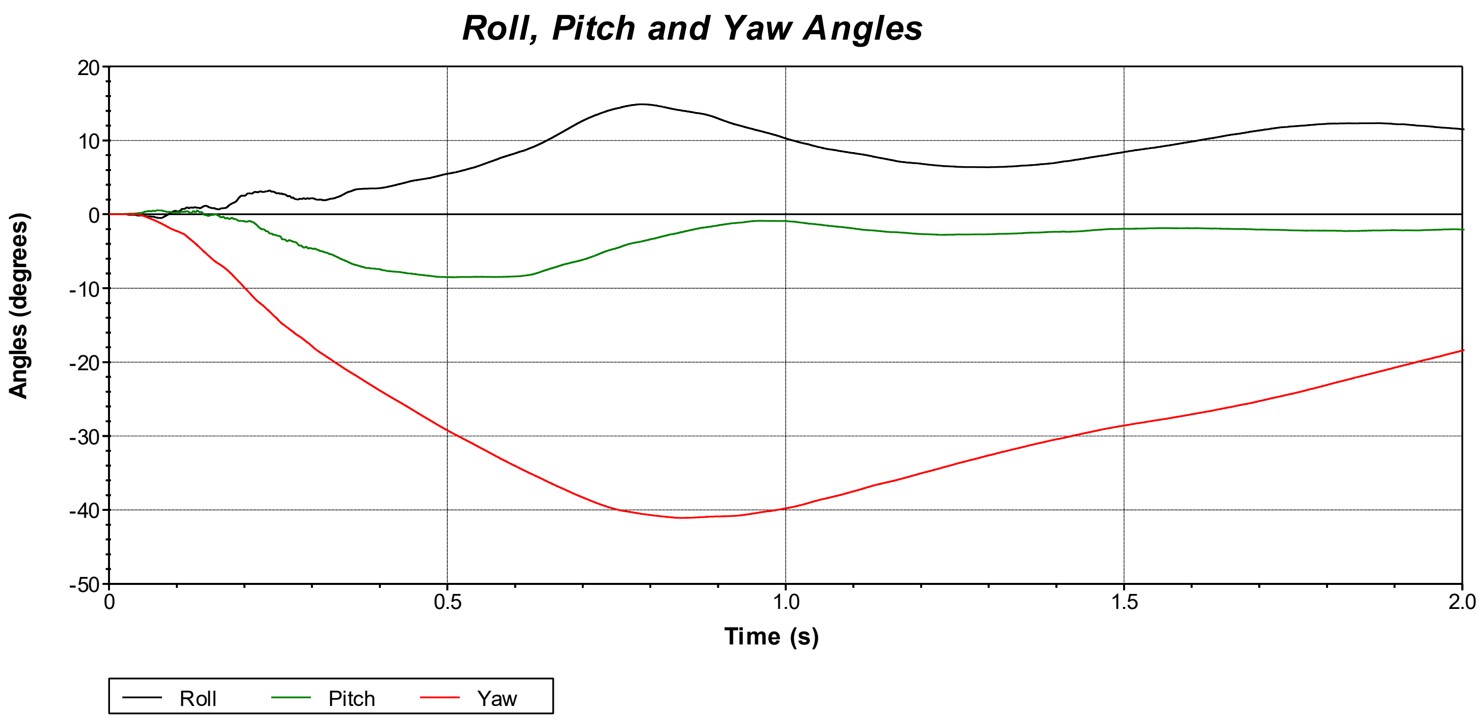
(c) 0.2000 s (d) 0.3000 s

(e) 0.4000 s (f) 0.5000 s

(g) 0.6000 s (h) 0.7000 s

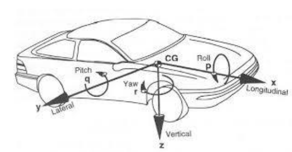
Figure C.5. Sequential Photographs for Test 620061-01-2 (Downstream In-Line Views).

C.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

1. Yaw.
2. Pitch.
3. Roll.



Test Number: 620061-01-2
Test Standard Test Number: *MASH* Test 3-11
Test Article: Merritt Parkway Guiderail
Test Vehicle: 2018 RAM 1500
Inertial Mass: 5048 lbs
Gross Mass: 5048 lbs
Impact Speed: 63.6 mi/h
Impact Angle: 24.17°

Figure C.6. Vehicle Angular Displacements for Test 620061-01-2.

C.4. VEHICLE ACCELERATIONS

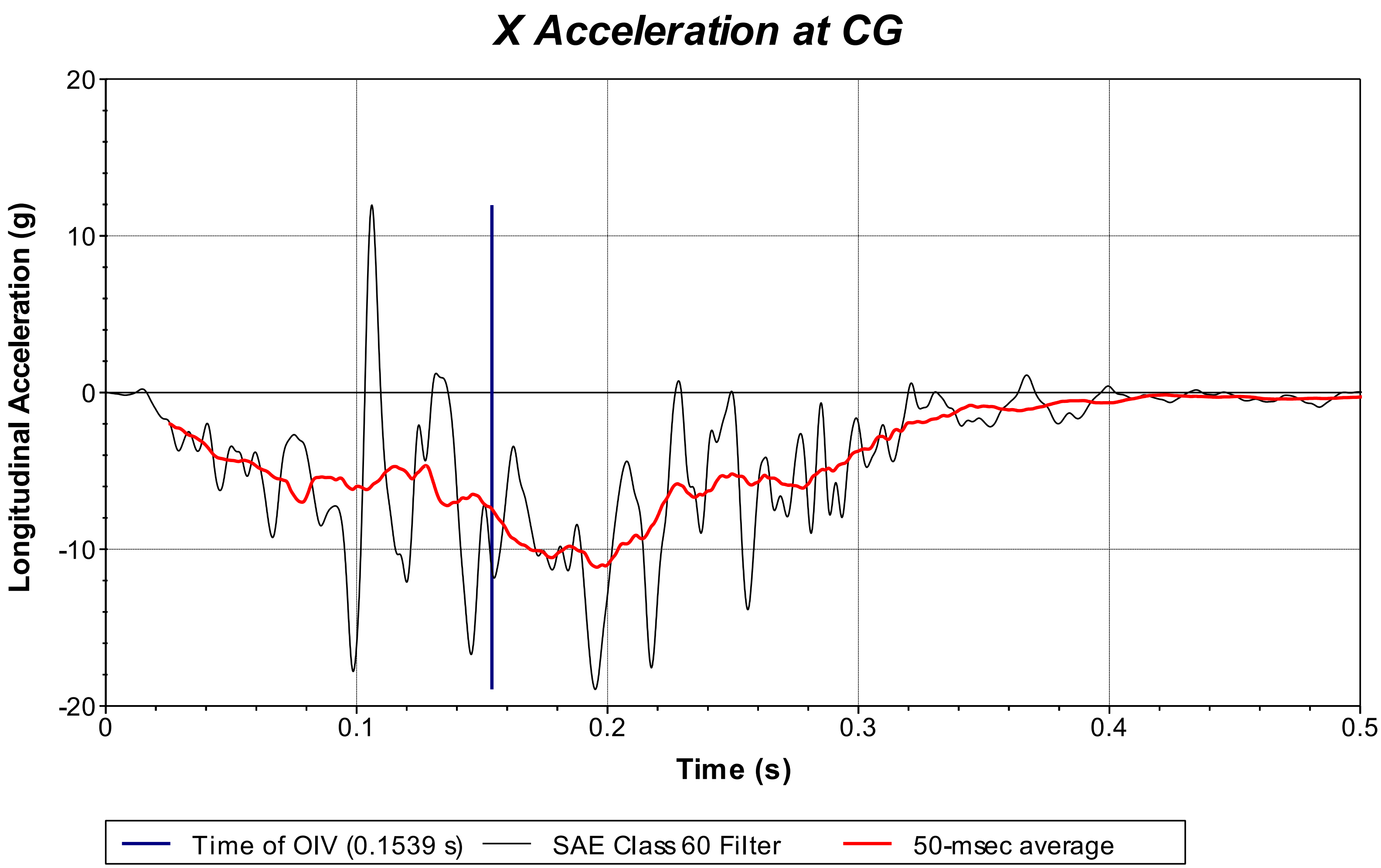


Figure C.7. Vehicle Longitudinal Accelerometer Trace for Test 620061-01-2 (Accelerometer Located at Center of Gravity).

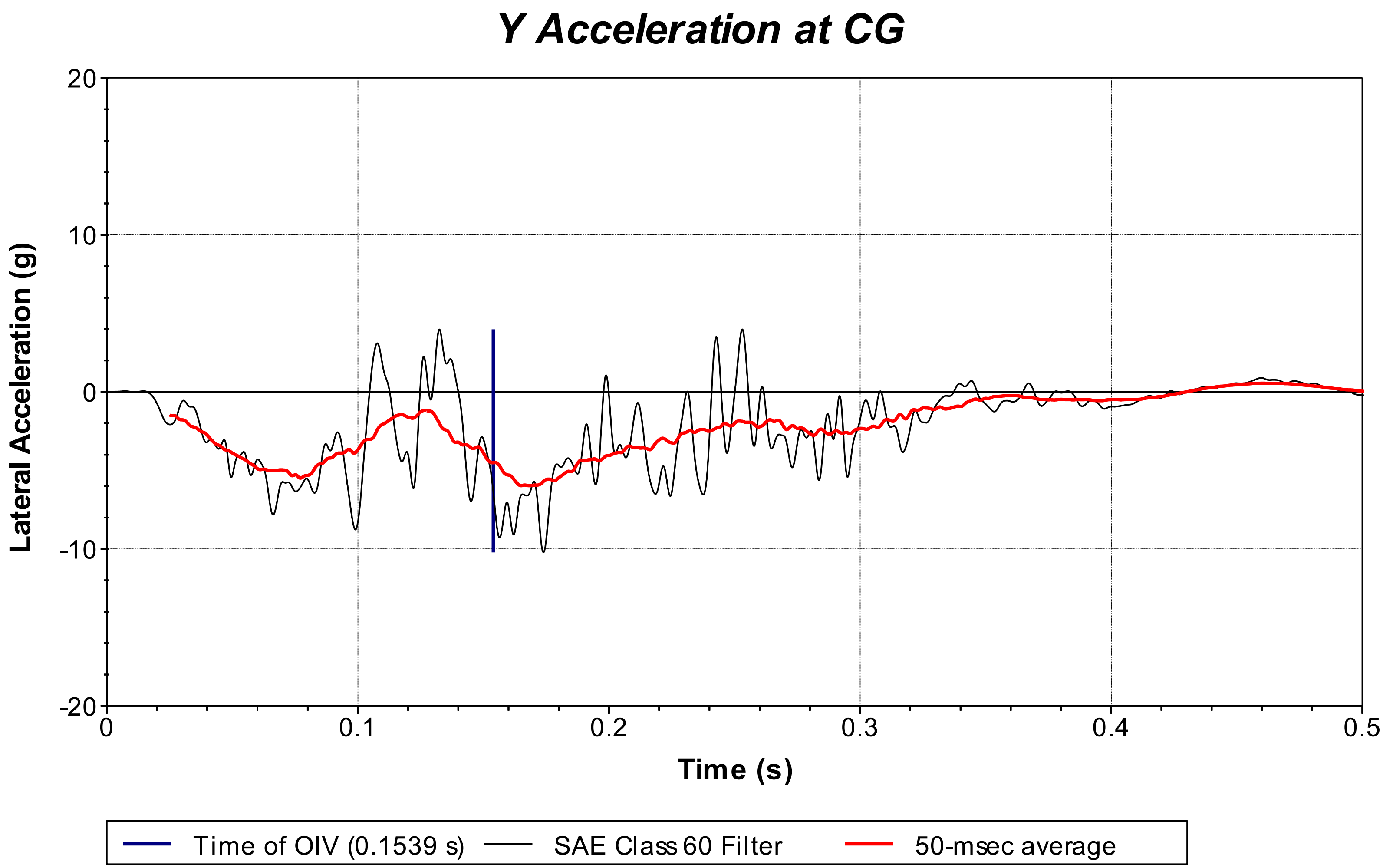


Figure C.8. Vehicle Lateral Accelerometer Trace for Test 620061-01-2 (Accelerometer Located at Center of Gravity).

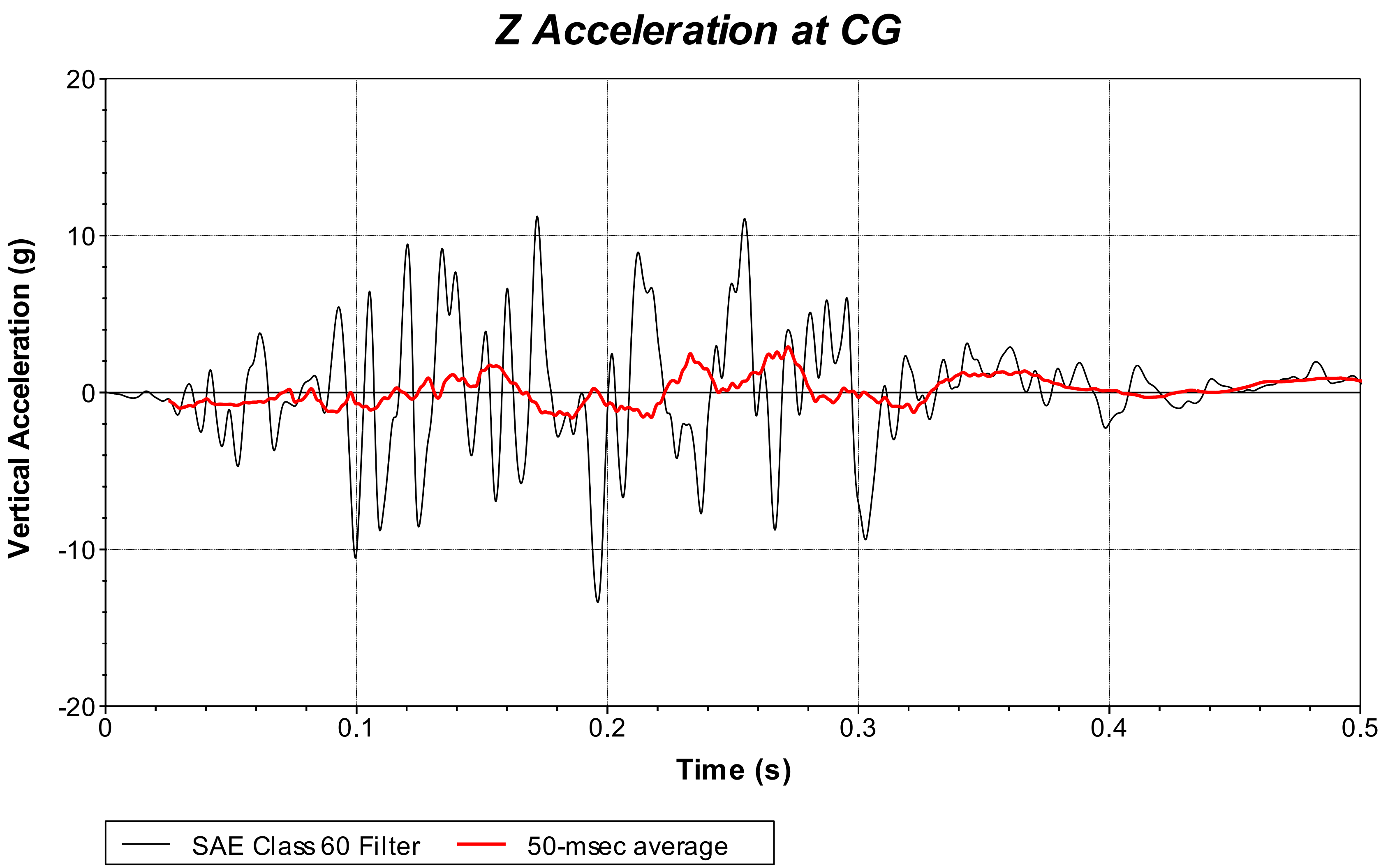


Figure C.9. Vehicle Vertical Accelerometer Trace for Test 620061-01-2
(Accelerometer Located at Center of Gravity).

APPENDIX D.

MASH TEST 3-11 (CRASH TEST 620061-01-1)

D.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2025-01-13 Test No.: 620061-01-1 VIN No.: 1C6RR6FT2KS744182

Year: 2019 Make: RAM Model: 1500

Tire Size: 265/70 R 17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 120254

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

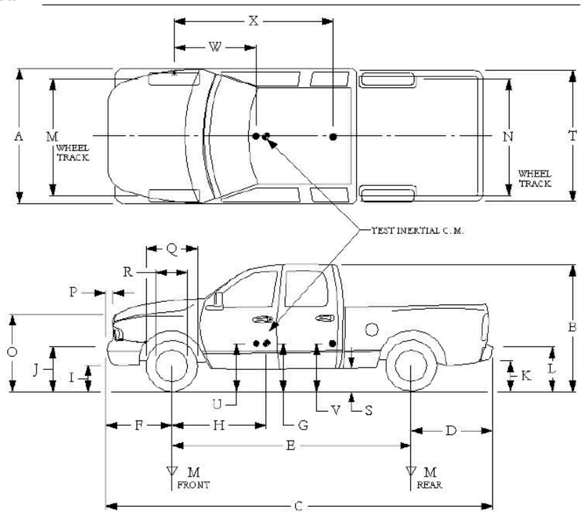
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

Transmission Type:
☑ Auto or ☐ Manual
☐ FWD ☑ RWD ☐ 4WD

Optional Equipment:
None

Dummy Data:
Type:
Mass:
Seat Position:



Geometry: inches

A	78.50	F	40.25	K	20.00	P	3.00	U	26.75
B	74.00	G	28.50	L	30.00	Q	30.50	V	30.25
C	229.00	H	60.80	M	68.50	R	18.00	W	61.00
D	48.25	I	11.75	N	68.00	S	13.00	X	79.00
E	140.50	J	27.00	O	46.00	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	12.50
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	22.50

RANGE LIMIT: A=78 ±2 inches; C=237 ±13 inches; E=148 ±12 inches; F=39 ±3 inches; G = > 28 inches; H = 63 ±4 inches; O=43 ±4 inches; (M+N)/2=67 ±1.5 inches

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2922	2850	2850
Back	3900	M_{rear}	2023	2176	2176
Total	6700	M_{Total}	4945	5026	5026

(Allowable Range for TIM and GSM = 5000 lb ±110 lb)

Mass Distribution:
lb LF: 1452 RF: 1398 LR: 1089 RR: 1087

Figure D.1. Vehicle Properties for Test 620061-01-1.

Date: 2025-01-13 Test No.: 620061-01-1 VIN No.: 1C6RR6FT2KS744182

Year: 2019 Make: RAM Model: 1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width ________ Corner shift: A1 ________ A2 ________ End shift at frame (CDC) (check one) < 4 inches ________ ≥ 4 inches ________	Bowing: B1 _____ X1 _____ B2 _____ X2 _____ Bowing constant $\frac{X1+X2}{2}$ = _______

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FRONT BUMPER	18	22	44	-	-	-	-	-	-	+14
2	AT FRONT BUMPER	18	20	62	-	-	-	-	-	-	75
	Measurements recorded										
	☑ **inches** or ☐ **mm**										

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

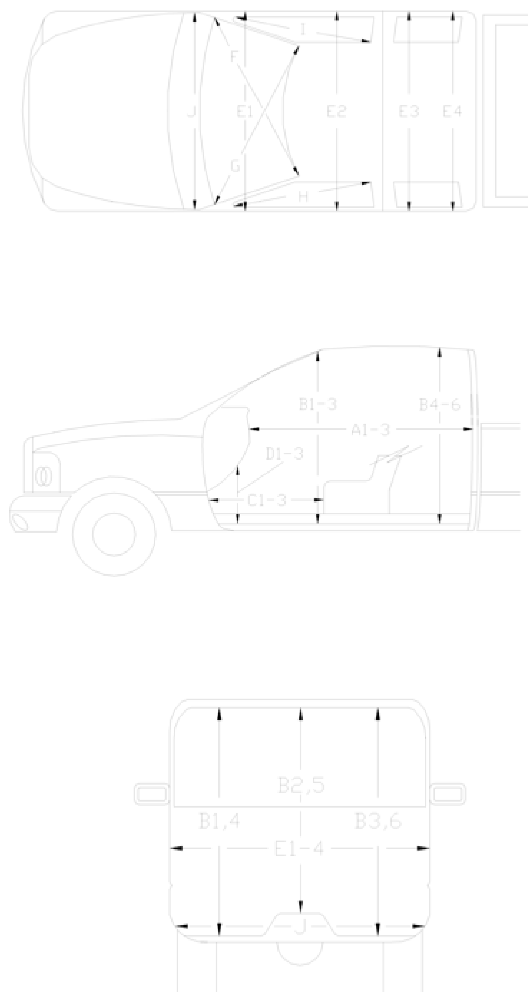
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***Measure and document on the vehicle diagram the location of the maximum crush.

Note: Use as many lines/columns as necessary to describe each damage profile.

Figure D.2. Exterior Crush Measurements for Test 620061-01-1.

Date:	2025-01-13	Test No.:	620061-01-1	VIN No.:	1C6RR6FT2KS744182
Year:	2019	Make:	RAM	Model:	1500



*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

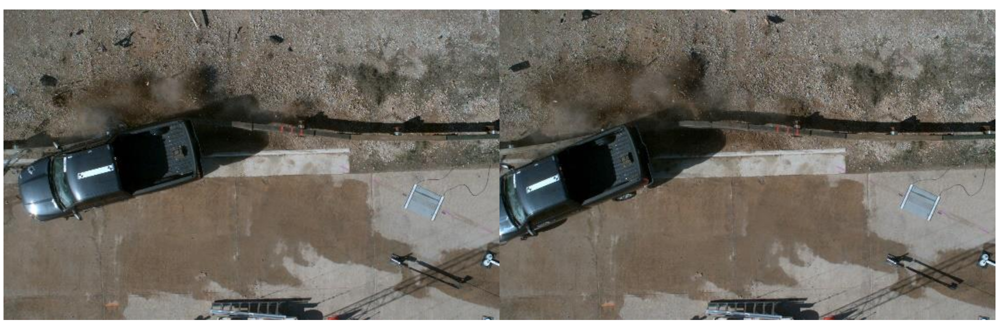
	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	25.00	-1.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	58.75	0.25
E2	63.50	63.50	0.00
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	24.50	-0.50

Figure D.3. Occupant Compartment Measurements for Test 620061-01-1.

D.2. SEQUENTIAL PHOTOGRAPHS

(a) 0.000 s (b) 0.1000 s

(c) 0.2000 s (d) 0.3000 s



(e) 0.4000 s (f) 0.5000 s

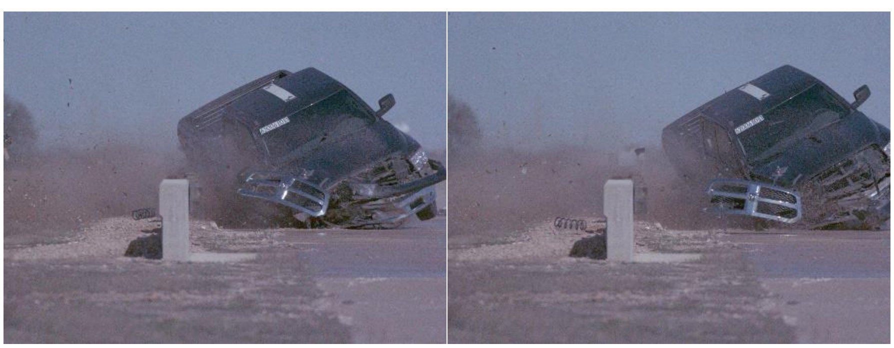
(g) 0.6000 s (h) 0.7000 s

Figure D.4. Sequential Photographs for Test 620061-01-1 (Overhead Views).

(a) 0.000 s (b) 0.1000 s

(c) 0.2000 s (d) 0.3000 s

(e) 0.4000 s (f) 0.5000 s



(g) 0.6000 s (h) 0.7000 s

Figure D.5. Sequential Photographs for Test 620061-01-1 (Downstream In-Line Views).

(a) 0.000 s

(b) 0.1000 s

(c) 0.2000 s

(d) 0.3000 s

(e) 0.4000 s

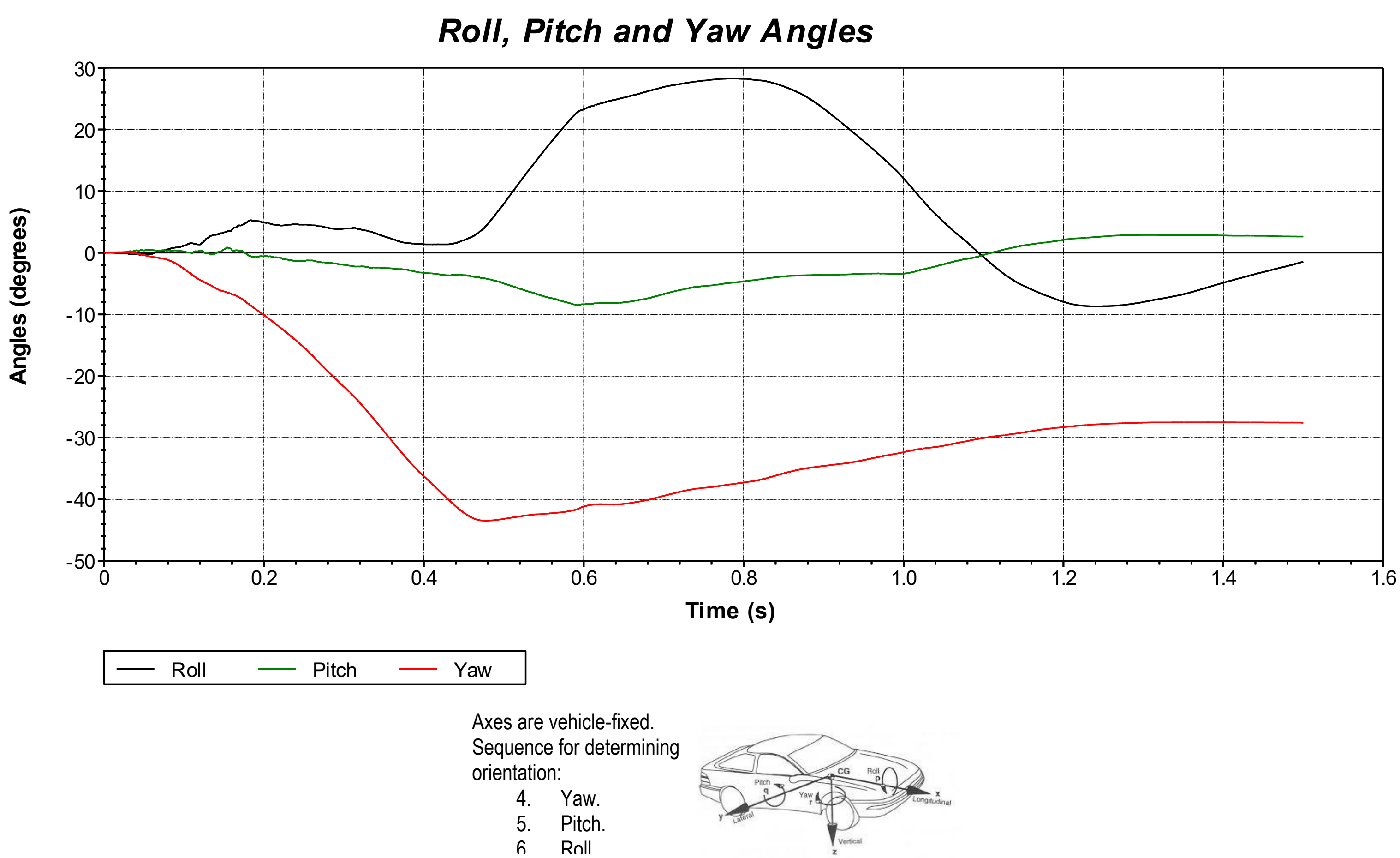
(f) 0.5000 s

(g) 0.6000 s

(h) 0.7000 s

Figure D.6. Sequential Photographs for Test 620061-01-1 (Upstream Field Side Oblique Views).

D.3. VEHICLE ANGULAR DISPLACEMENTS



Test Number: 620061-01-1
Test Standard Test Number: *MASH* Test 3-11
Test Article: Merritt Parkway Guiderail
Test Vehicle: 2019 RAM 1500
Inertial Mass: 5026 lbs
Gross Mass: 5191 lbs
Impact Speed: 64.2 mi/h
Impact Angle: 25.10°

Figure D.7. Vehicle Angular Displacements for Test 620061-01-1.

D.4. VEHICLE ACCELERATIONS

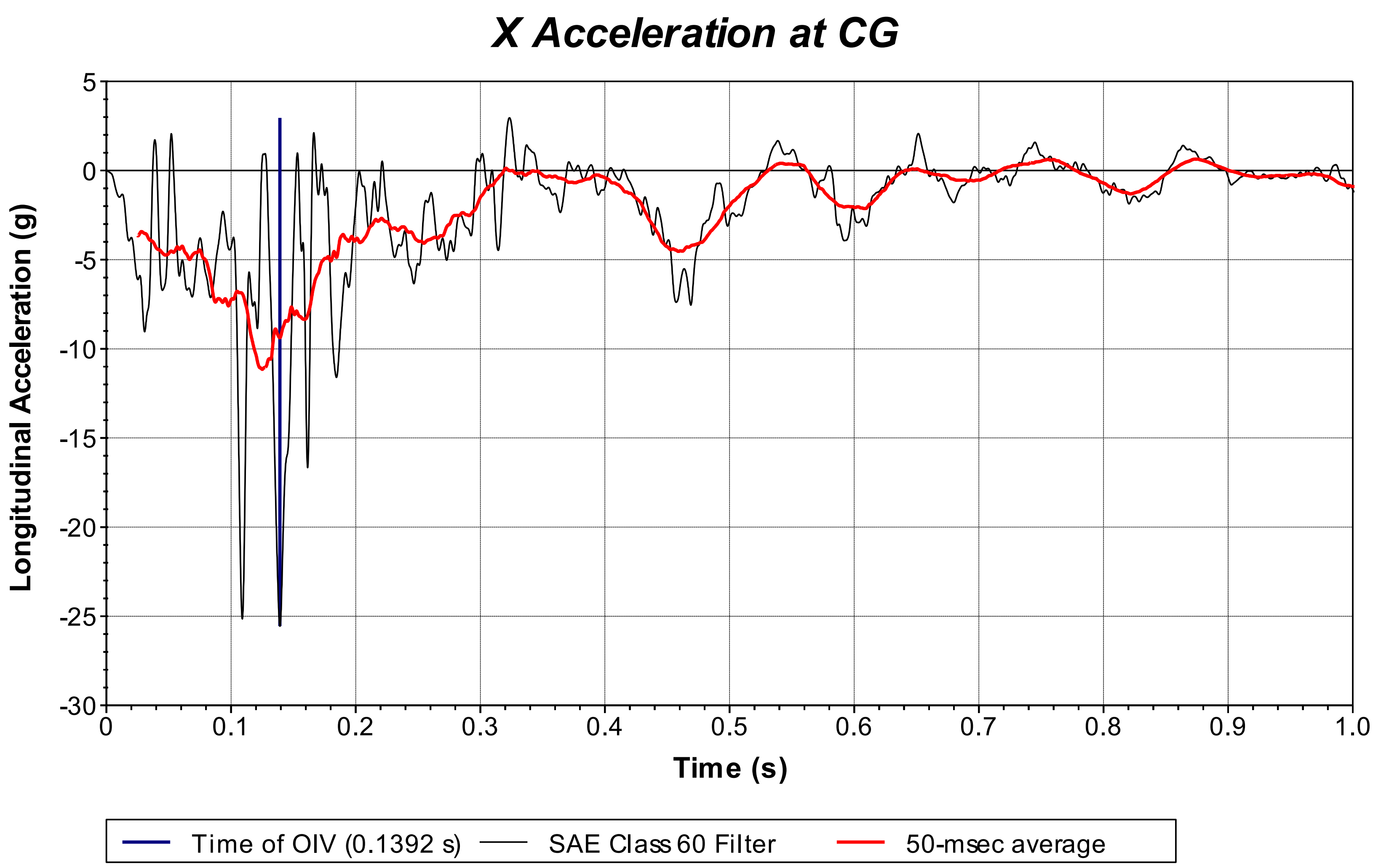


Figure D.8. Vehicle Longitudinal Accelerometer Trace for Test 620061-01-1 (Accelerometer Located at Center of Gravity).

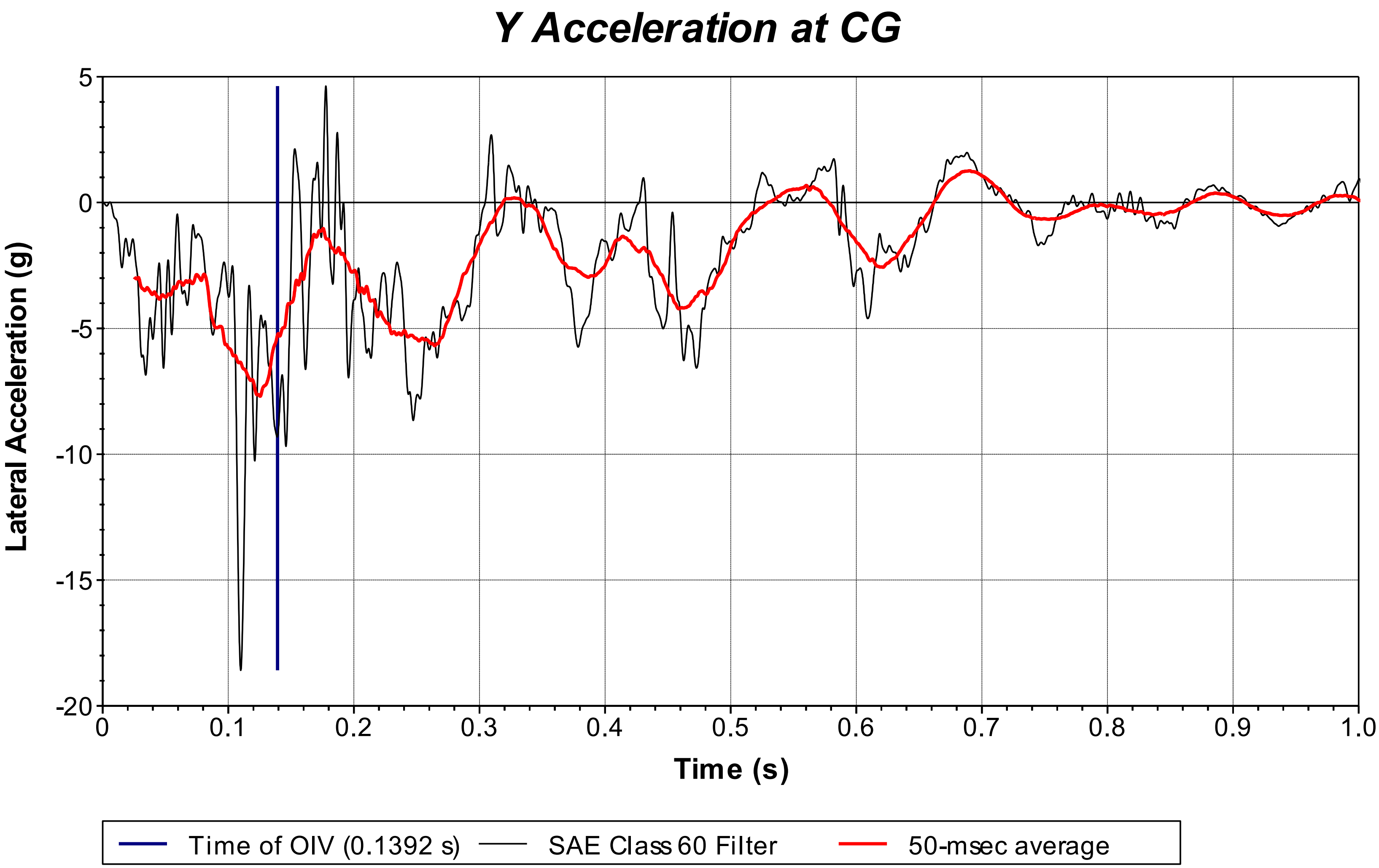


Figure D.9. Vehicle Lateral Accelerometer Trace for Test 620061-01-1
(Accelerometer Located at Center of Gravity).

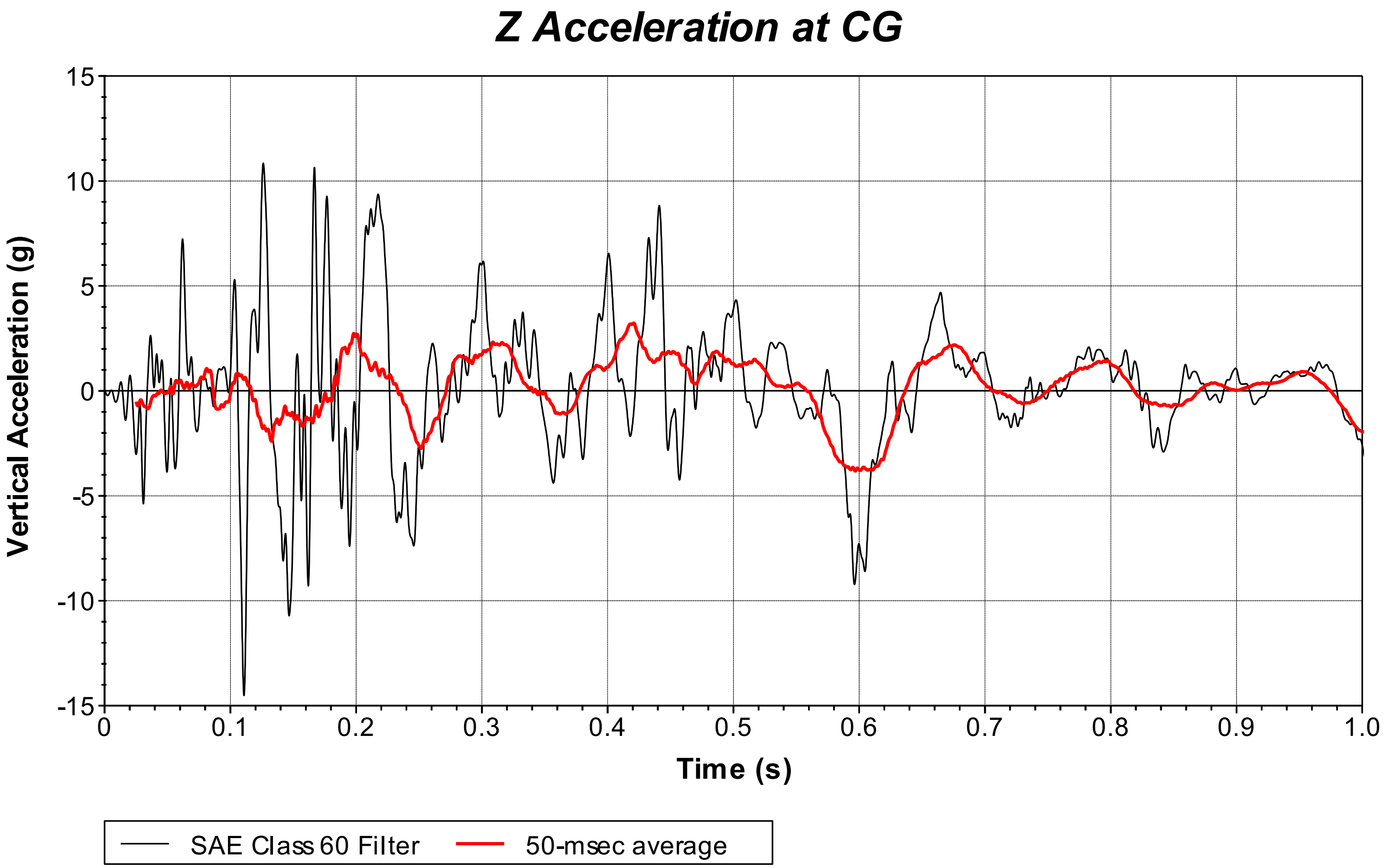


Figure D.10. Vehicle Vertical Accelerometer Trace for Test 620061-01-1
(Accelerometer Located at Center of Gravity).

APPENDIX E.

MASH TEST 3-10 (CRASH TEST 620061-01-3)

E.1. VEHICLE PROPERTIES AND INFORMATION

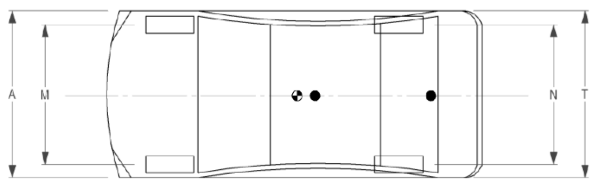
Date: 2025-01-17 Test No.: 620061-01-3 VIN No.: 3N1CN7AP0KL871881

Year: 2019 Make: Nissan Model: Versa

Tire Inflation Pressure: 36 PSI Odometer: 145218 Tire Size: P185/65R15

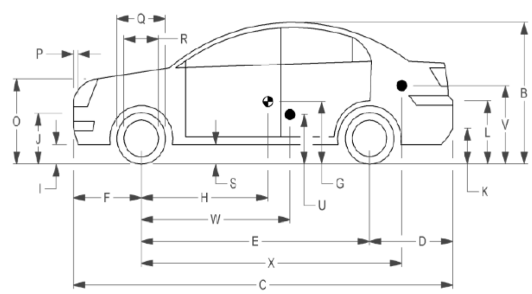
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.



NOTES: None

Engine Type: 4 CYL
Engine CID: 1.6 L
Transmission Type:
☑ Auto or ☐ Manual
☑ FWD ☐ RWD ☐ 4WD
Optional Equipment:
None



Dummy Data:
Type: 50th Percentile Male
Mass: 165 lb
Seat Position: IMPACT SIDE

Geometry: inches

A	66.70	F	32.50	K	12.50	P	4.50	U	15.50
B	59.60	G	0.00	L	26.00	Q	24.00	V	21.25
C	175.40	H	41.60	M	58.30	R	16.25	W	41.50
D	40.50	I	7.00	N	58.50	S	7.50	X	79.75
E	102.40	J	22.50	O	30.50	T	64.50		

Wheel Center Ht Front 11.50 Wheel Center Ht Rear 11.50 W-H -0.10

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Top of Radiator Support) = 28 ±4 inches
(M+N)/2 = 59 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1750	M_{front}	1415	1442	1527
Back	1687	M_{rear}	1002	989	1069
Total	3389	M_{Total}	2417	2431	2596

Allowable TIM = 2420 lb ±55 lb | Allowable GSM = 2585 lb ± 55 lb

Mass Distribution:
lb LF: 743 RF: 699 LR: 516 RR: 473

Figure E.1. Vehicle Properties for Test 620061-01-3.

Date:	2025-01-17	Test No.:	620061-01-3	VIN No.:	3N1CN7AP0KL871881
Year:	2019	Make:	Nissan	Model:	Versa

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width ________	Bowing: B1 _____ X1 _____
Corner shift: A1 ________	B2 _____ X2 _____
A2 ________	
End shift at frame (CDC)	Bowing constant
(check one)	$\frac{X1+X2}{2}$ = ______
< 4 inches ________	
≥ 4 inches ________	

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FRONT BUMPER	14	7	20	-	-	-	-	-	-	+13
2	AT FRONT BUMPER	15	12	45	-	-	-	-	-	-	59
	Measurements recorded										
	☑ **inches** or ☐ **mm**										

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

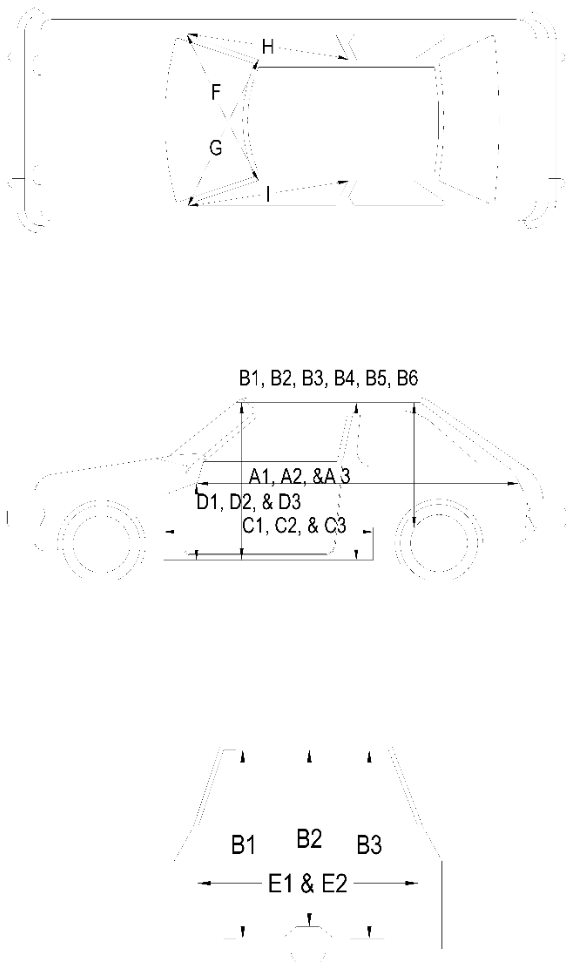
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***Measure and document on the vehicle diagram the location of the maximum crush.

Note: Use as many lines/columns as necessary to describe each damage profile.

Figure E.2. Exterior Crush Measurements for Test 620061-01-3.

Date:	2025-01-17	Test No.:	620061-01-3	VIN No.:	3N1CN7AP0KL871881
Year:	2019	Make:	Nissan	Model:	Versa



*Lateral area across the cab from
driver's side kick panel to passenger's side kick panel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

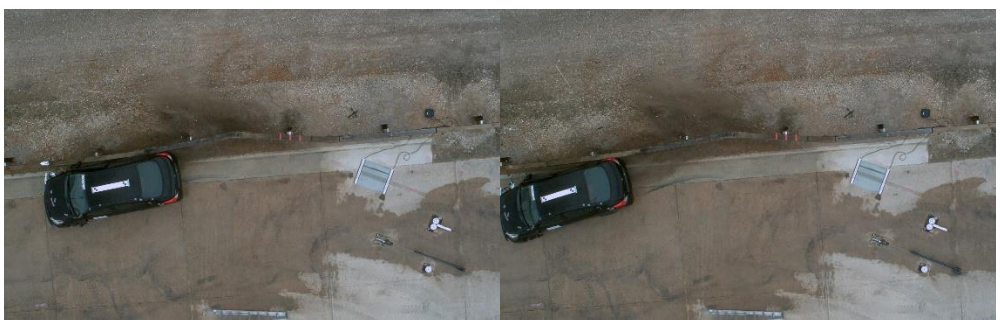
	Before	After (inches)	Differ.
A1	67.50	67.50	0.00
A2	67.25	67.25	0.00
A3	67.75	67.75	0.00
B1	40.50	40.50	0.00
B2	39.00	39.00	0.00
B3	40.50	39.75	-0.75
B4	36.25	36.25	0.00
B5	36.00	36.00	0.00
B6	36.25	36.25	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	24.75	-1.25
D1	9.50	9.50	0.00
D2	0.00	0.00	0.00
D3	9.50	7.25	-2.25
E1	51.50	52.25	0.75
E2	51.00	51.00	0.00
F	51.00	51.00	0.00
G	51.00	51.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	51.00	47.25	-3.75

Figure E.3. Occupant Compartment Measurements for Test 620061-01-3.

E.2. SEQUENTIAL PHOTOGRAPHS

(a) 0.000 s (b) 0.1000 s

(c) 0.2000 s (d) 0.3000 s



(e) 0.4000 s (f) 0.5000 s

(g) 0.6000 s (h) 0.7000 s

Figure E.4. Sequential Photographs for Test 620061-01-3 (Overhead Views).

(a) 0.000 s

(b) 0.1000 s

(c) 0.2000 s

(d) 0.3000 s

(e) 0.4000 s

(f) 0.5000 s

(g) 0.6000 s

(h) 0.7000 s

Figure E.5. Sequential Photographs for Test 620061-01-3 (Downstream In-Line Views).


(a) 0.000 s (b) 0.1000 s

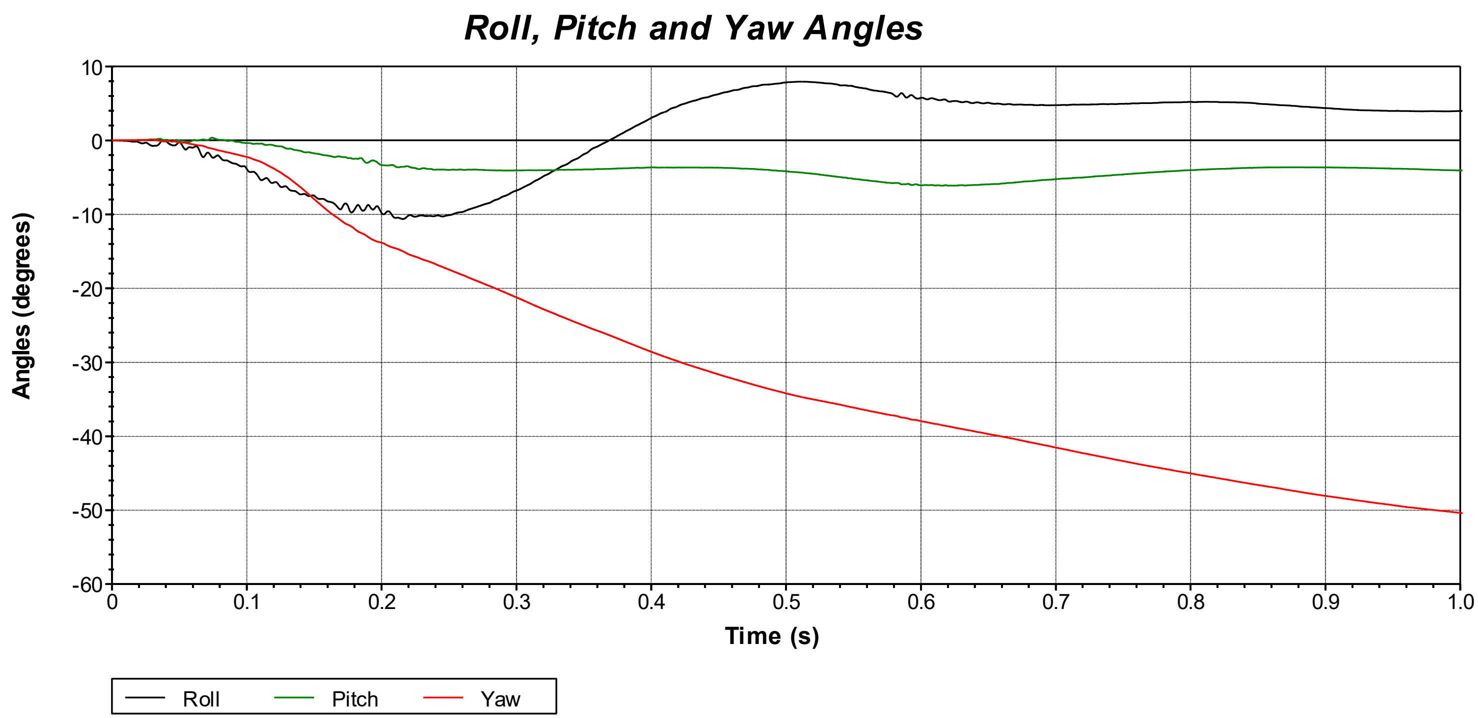

(c) 0.2000 s (d) 0.3000 s


(e) 0.4000 s (f) 0.5000 s


(g) 0.6000 s (h) 0.7000 s

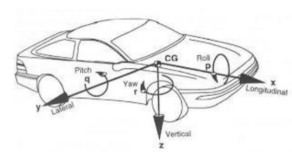
Figure E.6. Sequential Photographs for Test 620061-01-3 (Upstream Field Side Oblique Views).

E.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

7. Yaw.
8. Pitch.
9. Roll.



Test Number: 620061-01-3
Test Standard Test Number: *MASH* Test 3-10
Test Article: Merritt Parkway Guiderail
Test Vehicle: 2019 Nissan Versa
Inertial Mass: 2431 lbs
Gross Mass: 2596 lbs
Impact Speed: 61.7 mi/h
Impact Angle: 24.17°

Figure E.7. Vehicle Angular Displacements for Test 620061-01-3.

E.4. VEHICLE ACCELERATIONS

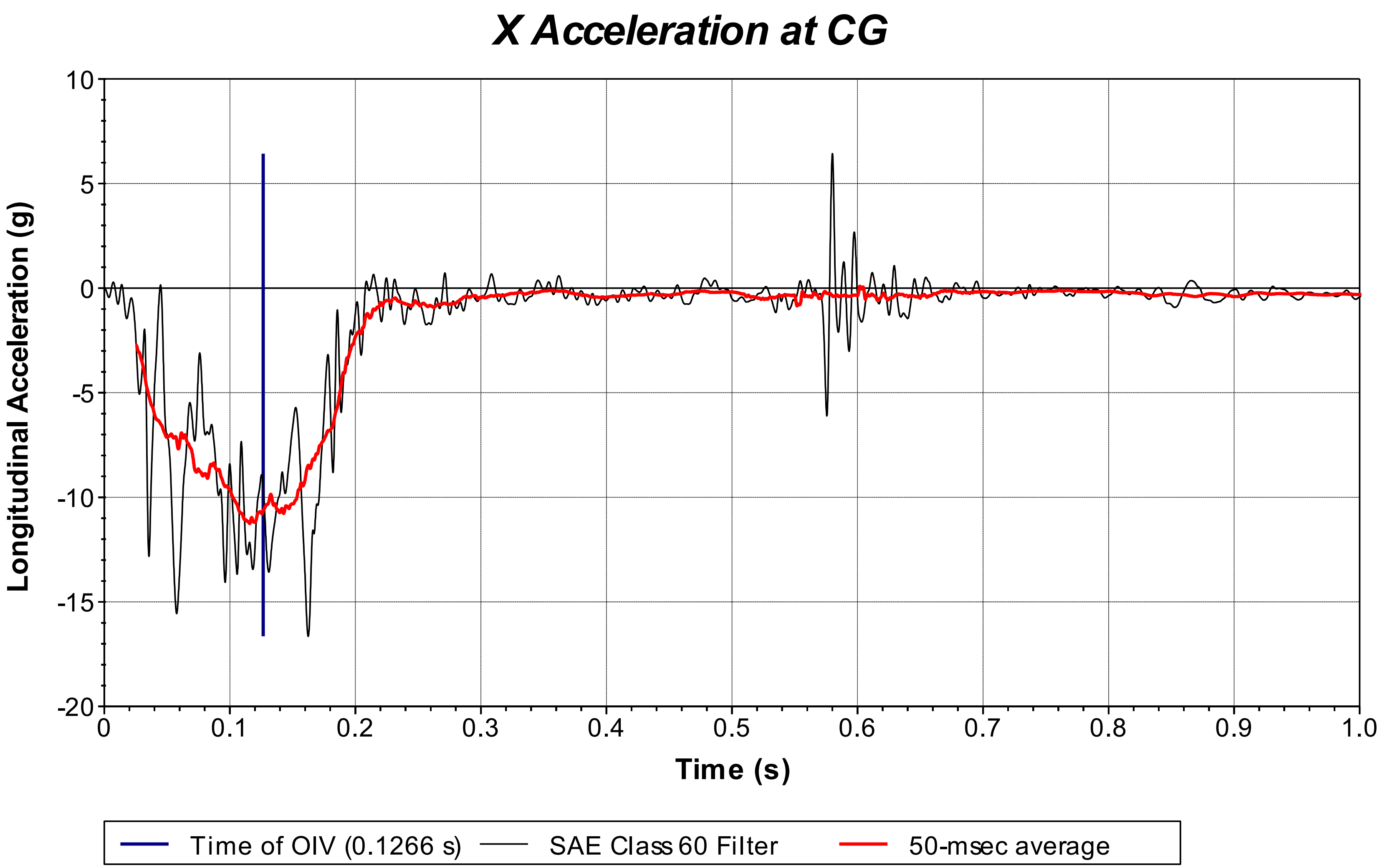


Figure E.8. Vehicle Longitudinal Accelerometer Trace for Test 620061-01-3
(Accelerometer Located at Center of Gravity).

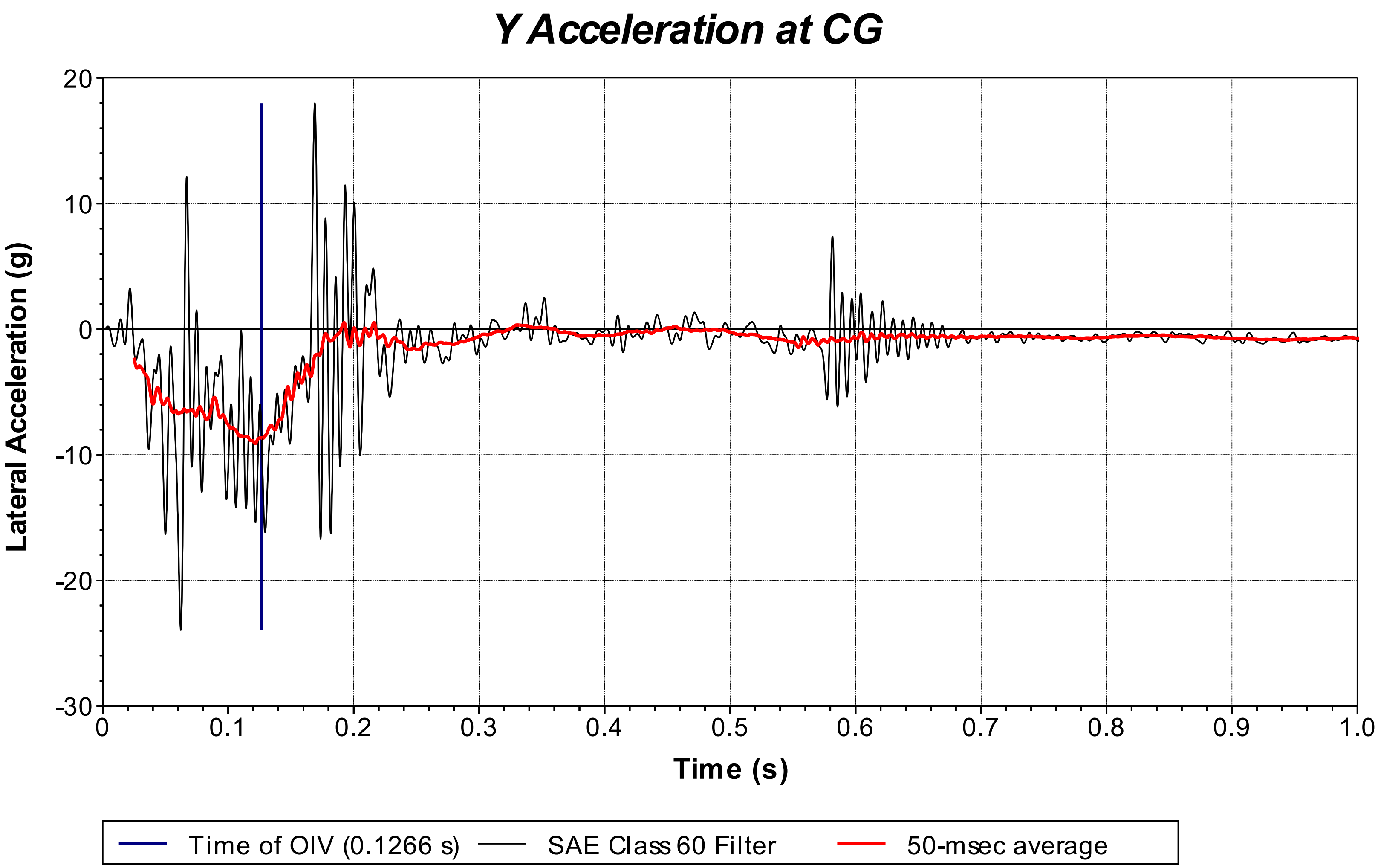


Figure E.9. Vehicle Lateral Accelerometer Trace for Test 620061-01-3 (Accelerometer Located at Center of Gravity).

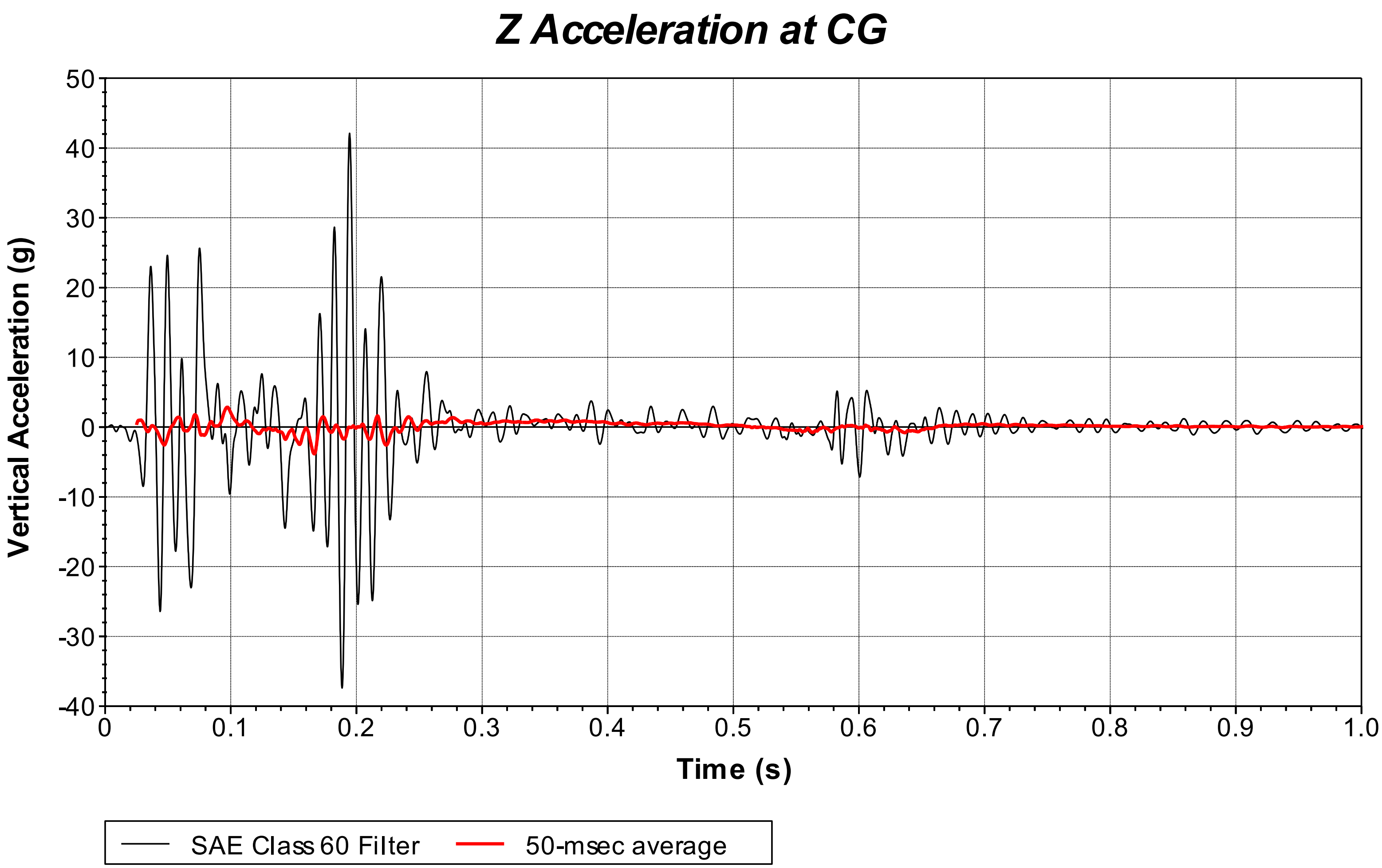


Figure E.10. Vehicle Vertical Accelerometer Trace for Test 620061-01-3
(Accelerometer Located at Center of Gravity).

APPENDIX F.

MASH TEST 3-11 (CRASH TEST 620061-01-4)

F.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2025-01-24 Test No.: 620061-01-4 VIN No.: 1C6RR6FT6KS515164

Year: 2019 Make: RAM Model: 1500

Tire Size: 265/70 R 17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 161,884

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

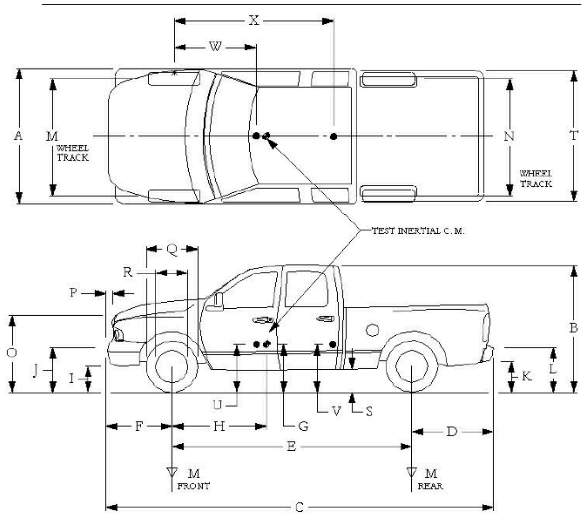
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

Transmission Type:
☑ Auto or ☐ Manual
☐ FWD ☑ RWD ☐ 4WD

Optional Equipment:
None

Dummy Data:
Type:
Mass:
Seat Position:



Geometry: inches

A	78.50	F	40.25	K	20.00	P	3.00	U	26.75
B	74.00	G	28.50	L	30.00	Q	30.50	V	30.25
C	229.00	H	62.15	M	68.50	R	18.00	W	62.00
D	48.25	I	11.75	N	68.00	S	13.00	X	79.00
E	140.50	J	27.00	O	46.00	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	12.50
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	22.50

RANGE LIMIT: A=78 ±2 inches; C=237 ±13 inches; E=148 ±12 inches; F=39 ±3 inches; G = > 28 inches; H = 63 ±4 inches; O=43 ±4 inches; (M+N)/2=67 ±1.5 inches

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2903	2806	2806
Back	3900	M_{rear}	2052	2226	2226
Total	6700	M_{Total}	4955	5032	5032

(Allowable Range for TIM and GSM = 5000 lb ±110 lb)

Mass Distribution:
lb LF: 1409 RF: 1397 LR: 1130 RR: 1096

Figure F.1. Vehicle Properties for Test 620061-01-4.

Date:	2025-01-24	Test No.:	620061-01-4	VIN No.:	1C6RR6FT6KS515164
Year:	2019	Make:	RAM	Model:	1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width ________	Bowing: B1 _____ X1 _____
Corner shift: A1 ________	B2 _____ X2 _____
A2 ________	
End shift at frame (CDC)	Bowing constant
(check one)	$\frac{X1+X2}{2}$ = _______
< 4 inches ________	
≥ 4 inches ________	

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FRONT BUMPER	18	25	44	-	-	-	-	-	-	+14
2	AT FRONT BUMPER	18	18	58	-	-	-	-	-	-	72
	Measurements recorded										
	☑ **inches** or ☐ **mm**										

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

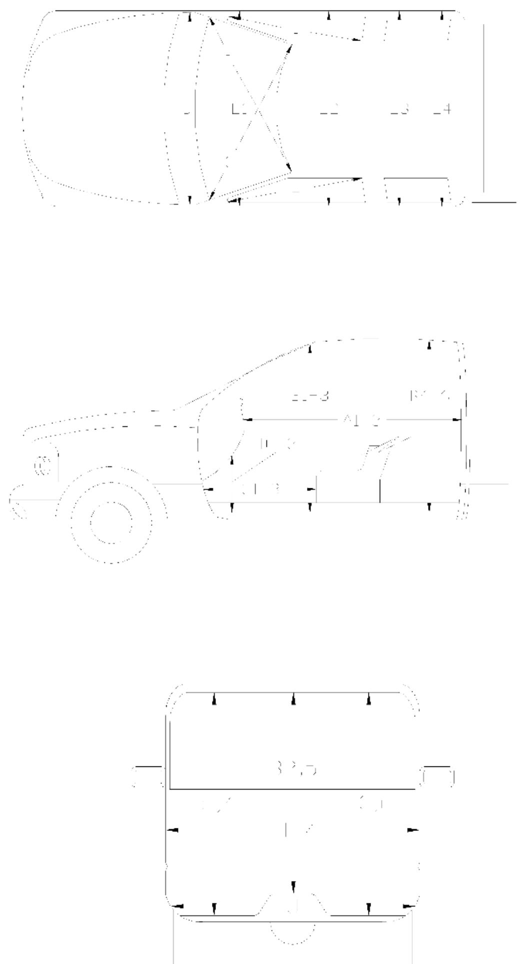
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***Measure and document on the vehicle diagram the location of the maximum crush.

Note: Use as many lines/columns as necessary to describe each damage profile.

Figure F.2. Exterior Crush Measurements for Test 620061-01-4.

Date:	2025-01-24	Test No.:	620061-01-4	VIN No.:	1C6RR6FT6KS515164
Year:	2019	Make:	RAM	Model:	1500



*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

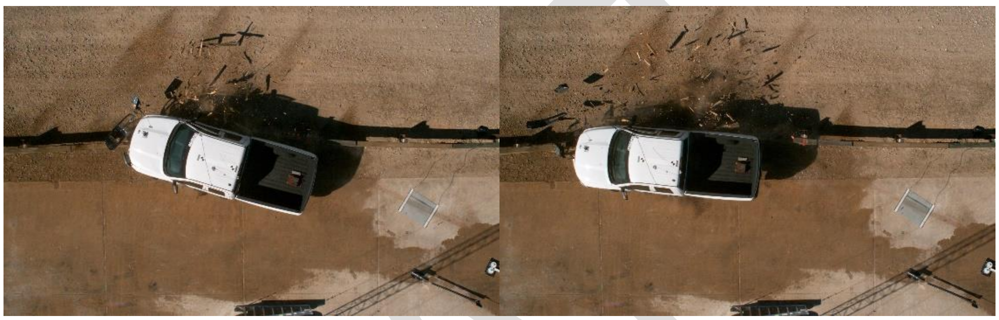
OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.75	0.75
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	59.50	1.00
E2	63.50	63.75	0.25
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	23.25	-1.75

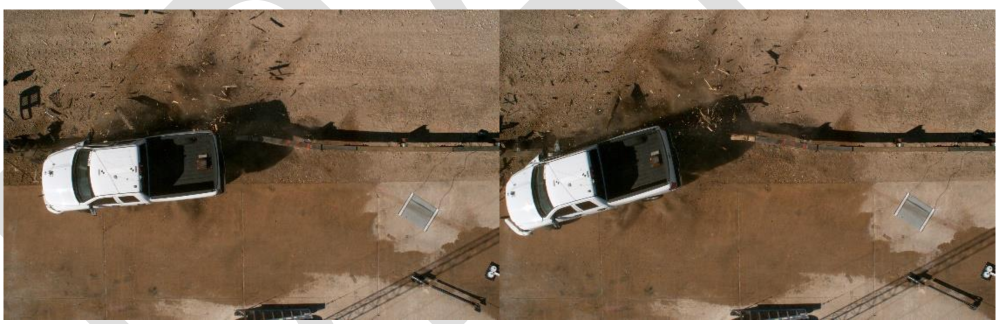
Figure F.3. Occupant Compartment Measurements for Test 620061-01-4.

F.2. SEQUENTIAL PHOTOGRAPHS

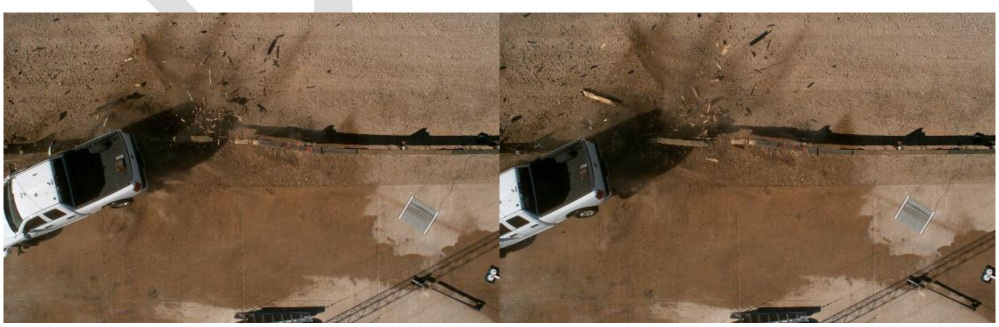
(a) 0.000 s (b) 0.1000 s



(c) 0.2000 s (d) 0.3000 s

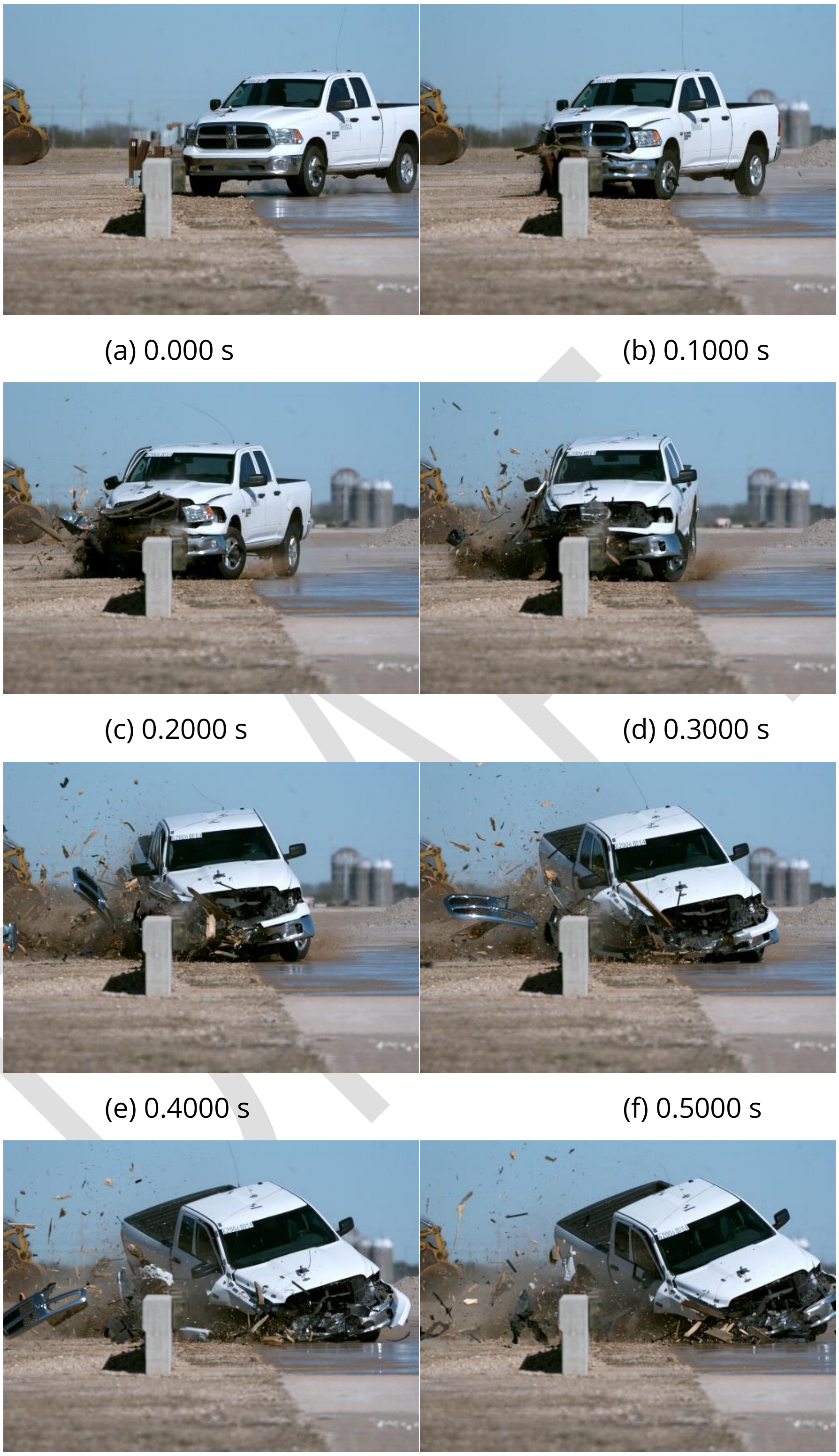


(e) 0.4000 s (f) 0.5000 s



(g) 0.6000 s (h) 0.7000 s

Figure F.4. Sequential Photographs for Test 620061-01-4 (Overhead Views).



(a) 0.000 s (b) 0.1000 s

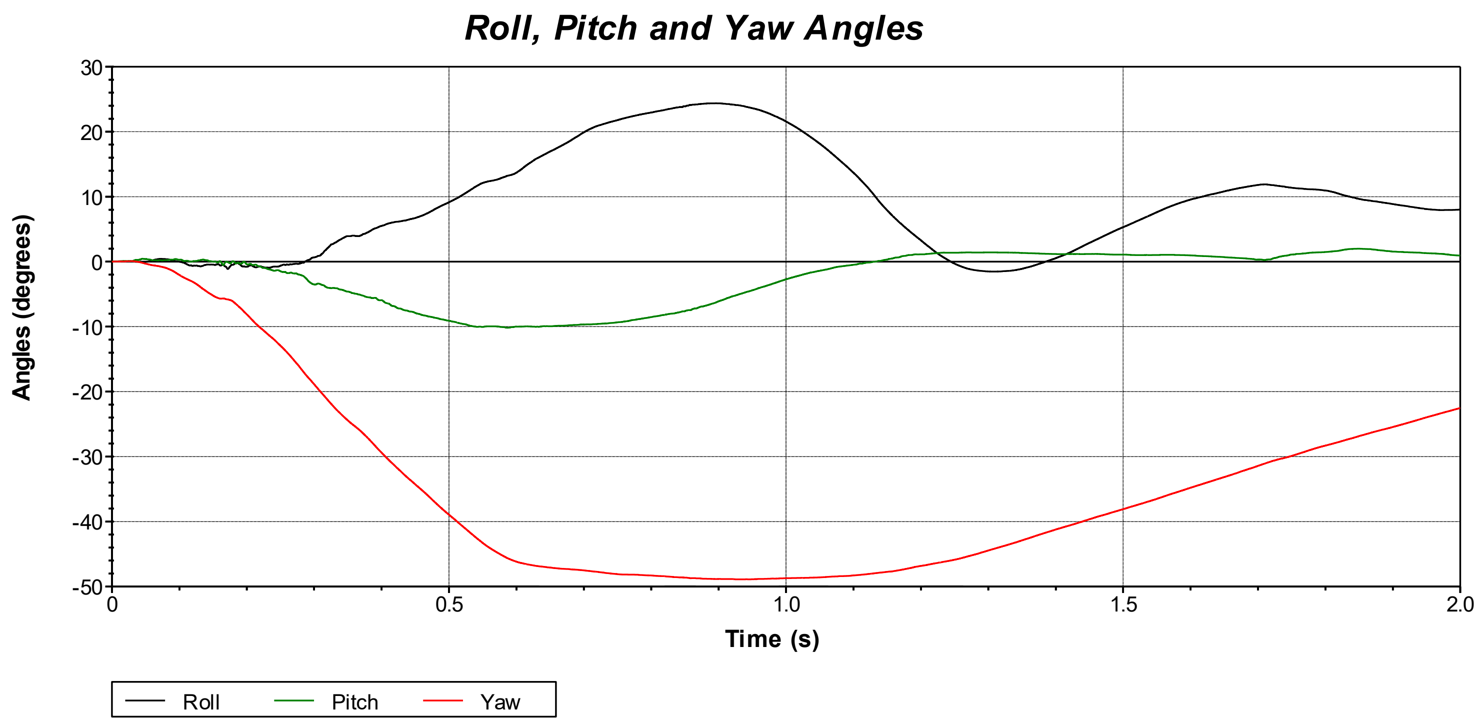
(c) 0.2000 s (d) 0.3000 s

(e) 0.4000 s (f) 0.5000 s

(g) 0.6000 s (h) 0.7000 s

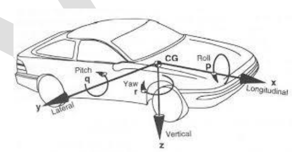
Figure F.5. Sequential Photographs for Test 620061-01-4 (Downstream In-Line Views).

F.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

10. Yaw.
11. Pitch.
12. Roll.



Test Number: 620061-01-4
Test Standard Test Number: *MASH* Test 3-11
Test Article: Merritt Parkway Guiderail
Test Vehicle: 2019 RAM 1500
Inertial Mass: 5032 lbs
Gross Mass: 5032 lbs
Impact Speed: 62.6 mi/h
Impact Angle: 25.29°

Figure F.6. Vehicle Angular Displacements for Test 620061-01-4.

F.4. VEHICLE ACCELERATIONS

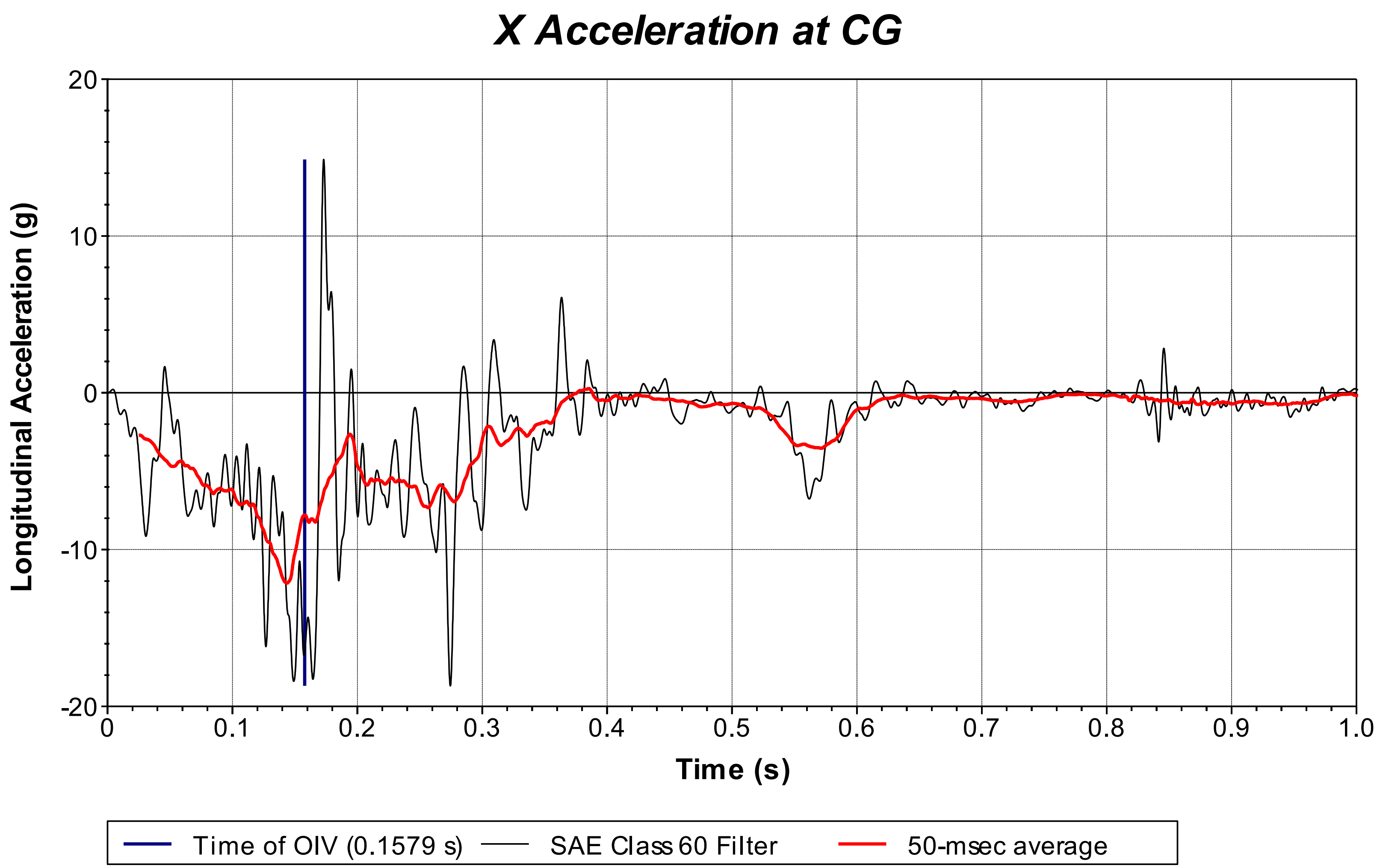


Figure F.7. Vehicle Longitudinal Accelerometer Trace for Test 620061-01-4 (Accelerometer Located at Center of Gravity).

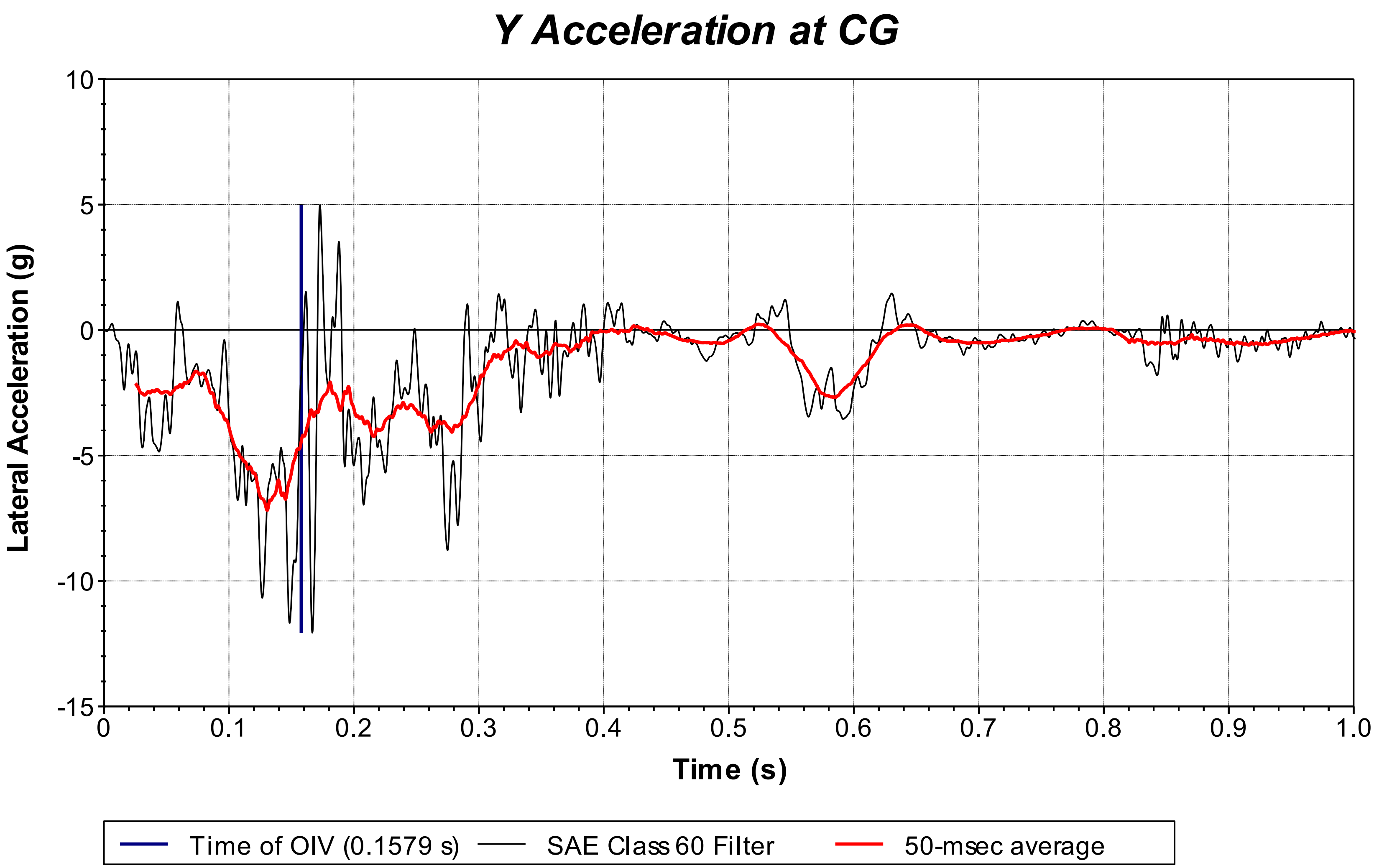


Figure F.8. Vehicle Lateral Accelerometer Trace for Test 620061-01-4 (Accelerometer Located at Center of Gravity).

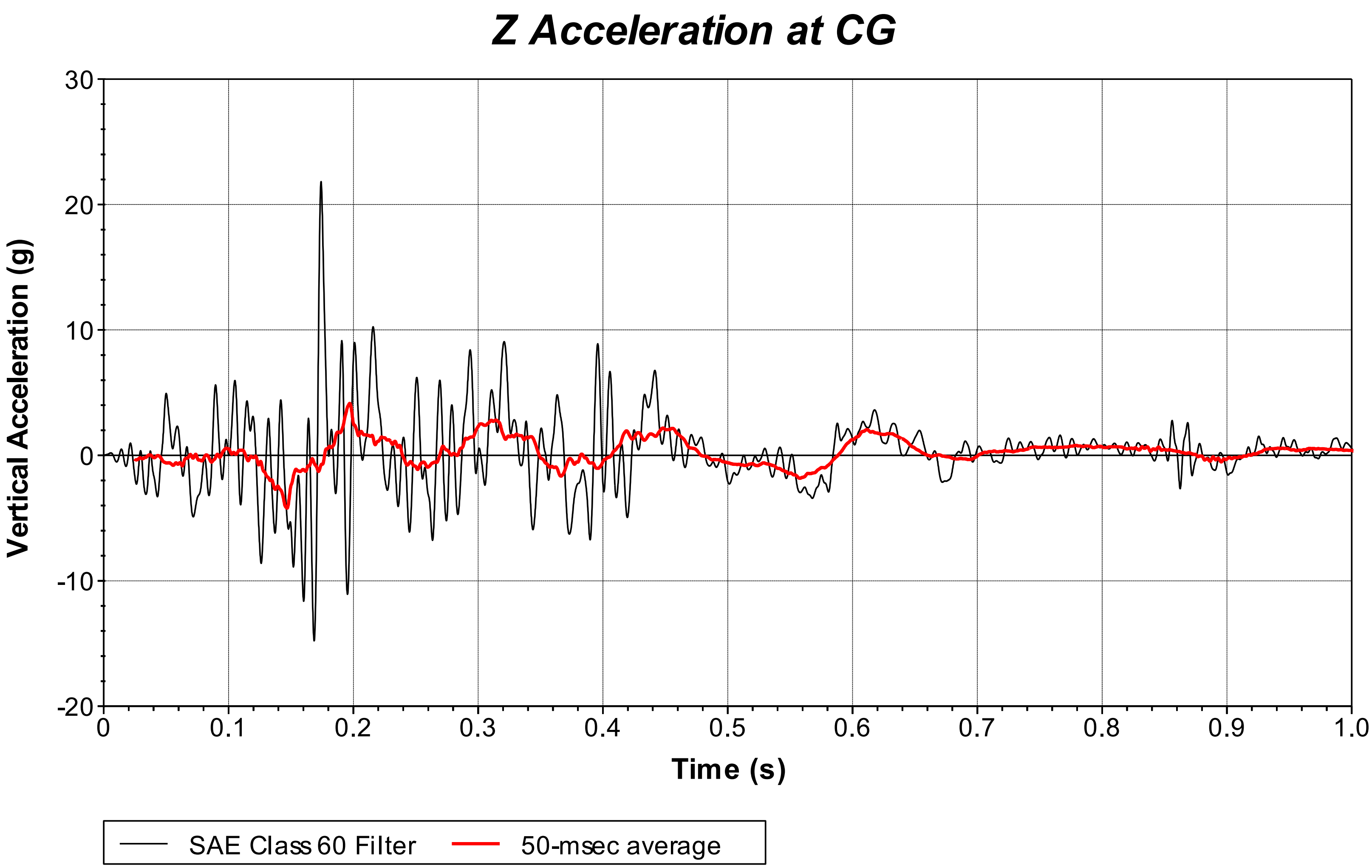


Figure F.9. Vehicle Vertical Accelerometer Trace for Test 620061-01-4
(Accelerometer Located at Center of Gravity).

APPENDIX G.

MASH TEST 3-11 (CRASH TEST 620061-01-5)

G.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2025-04-16 Test No.: 620061-01-5 VIN No.: 1C6RR6FT6KS585571

Year: 2019 Make: RAM Model: 1500

Tire Size: 265/70 R 17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 182878

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

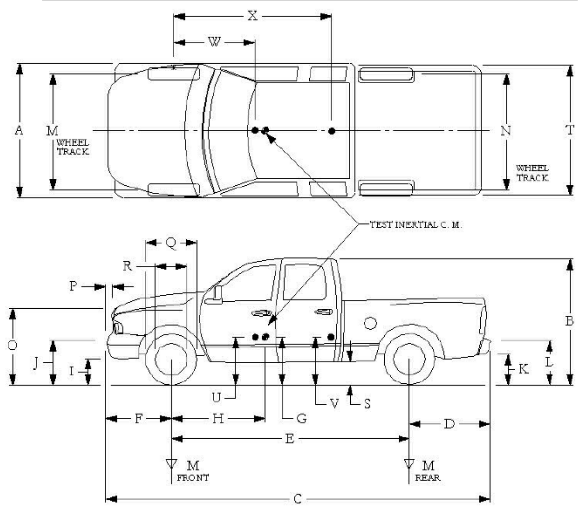
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

Transmission Type:
☑ Auto or ☐ Manual
☐ FWD ☑ RWD ☐ 4WD

Optional Equipment:
None

Dummy Data:
Type:
Mass:
Seat Position:



Geometry: inches

A	78.50	F	40.25	K	20.00	P	3.00	U	26.75
B	74.00	G	28.50	L	30.00	Q	30.50	V	30.25
C	229.00	H	61.04	M	68.50	R	18.00	W	61.00
D	48.25	I	11.75	N	68.00	S	13.00	X	79.00
E	140.50	J	27.00	O	46.00	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	12.50
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	22.50

RANGE LIMIT: A=78 ±2 inches; C=237 ±13 inches; E=148 ±12 inches; F=39 ±3 inches; G = > 28 inches; H = 63 ±4 inches; O=43 ±4 inches; (M+N)/2=67 ±1.5 inches

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2924	2841	2841
Back	3900	M_{rear}	2071	2183	2183
Total	6700	M_{Total}	4995	5024	5024

(Allowable Range for TIM and GSM = 5000 lb ±110 lb)

Mass Distribution:
lb LF: 1407 RF: 1434 LR: 1100 RR: 1083

Figure G.1. Vehicle Properties for Test 620061-01-5.

Date:	2025-04-16	Test No.:	620061-01-5	VIN No.:	1C6RR6FT6KS585571
Year:	2019	Make:	RAM	Model:	1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width ________	Bowing: B1 _____ X1 _____
Corner shift: A1 ________	B2 _____ X2 _____
A2 ________	
End shift at frame (CDC)	Bowing constant
(check one)	$\frac{X1+X2}{2} =$ _______
< 4 inches ________	
≥ 4 inches ________	

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FRONT BUMPER	18	16	42	-	-	-	-	-	-	+13
2	SAME	18	15	60	-	-	-	-	-	-	71
	Measurements recorded										
	☑ inches or ☐ mm										

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

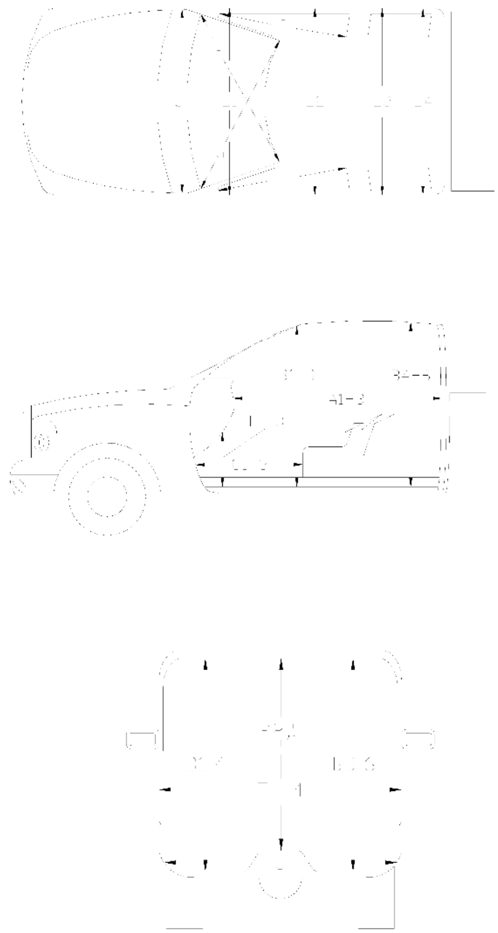
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***Measure and document on the vehicle diagram the location of the maximum crush.

Note: Use as many lines/columns as necessary to describe each damage profile.

Figure G.2. Exterior Crush Measurements for Test 620061-01-5.

Date:	2025-04-16	Test No.:	620061-01-5	VIN No.:	1C6RR6FT6KS585571
Year:	2019	Make:	RAM	Model:	1500



OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	25.75	-0.25
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	59.00	0.50
E2	63.50	63.75	0.25
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	25.00	0.00

*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

Figure G.3. Occupant Compartment Measurements for Test 620061-01-5.

G.2. SEQUENTIAL PHOTOGRAPHS

(a) 0.000 s (b) 0.1000 s

(c) 0.2000 s (d) 0.3000 s

(e) 0.4000 s (f) 0.5000 s

(g) 0.6000 s (h) 0.7000 s

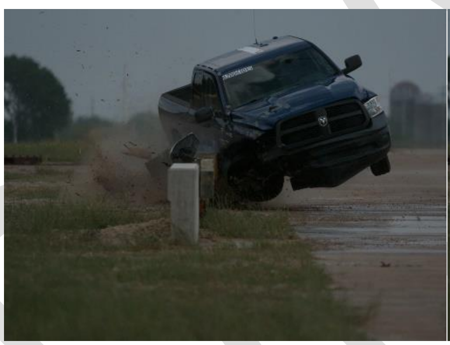
Figure G.4. Sequential Photographs for Test 620061-01-5 (Overhead Views).

(a) 0.000 s

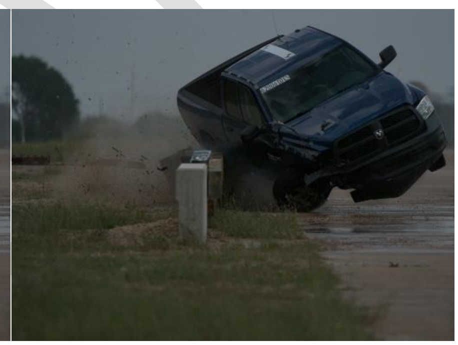
(b) 0.1000 s

(c) 0.2000 s

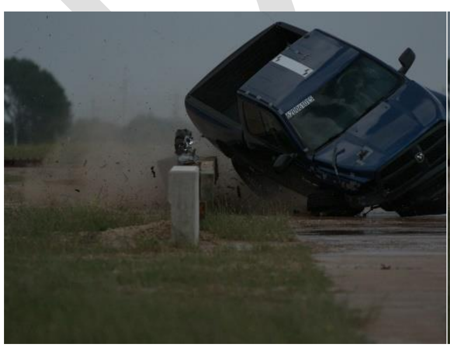
(d) 0.3000 s



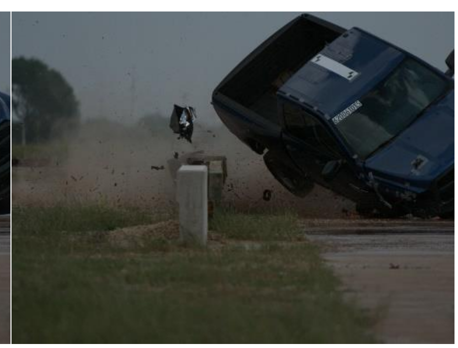
(e) 0.4000 s



(f) 0.5000 s



(g) 0.6000 s



(h) 0.7000 s

Figure G.5. Sequential Photographs for Test 620061-01-5 (Downstream In-Line Views).


(a) 0.000 s

(b) 0.1000 s


(c) 0.2000 s

(d) 0.3000 s


(e) 0.4000 s

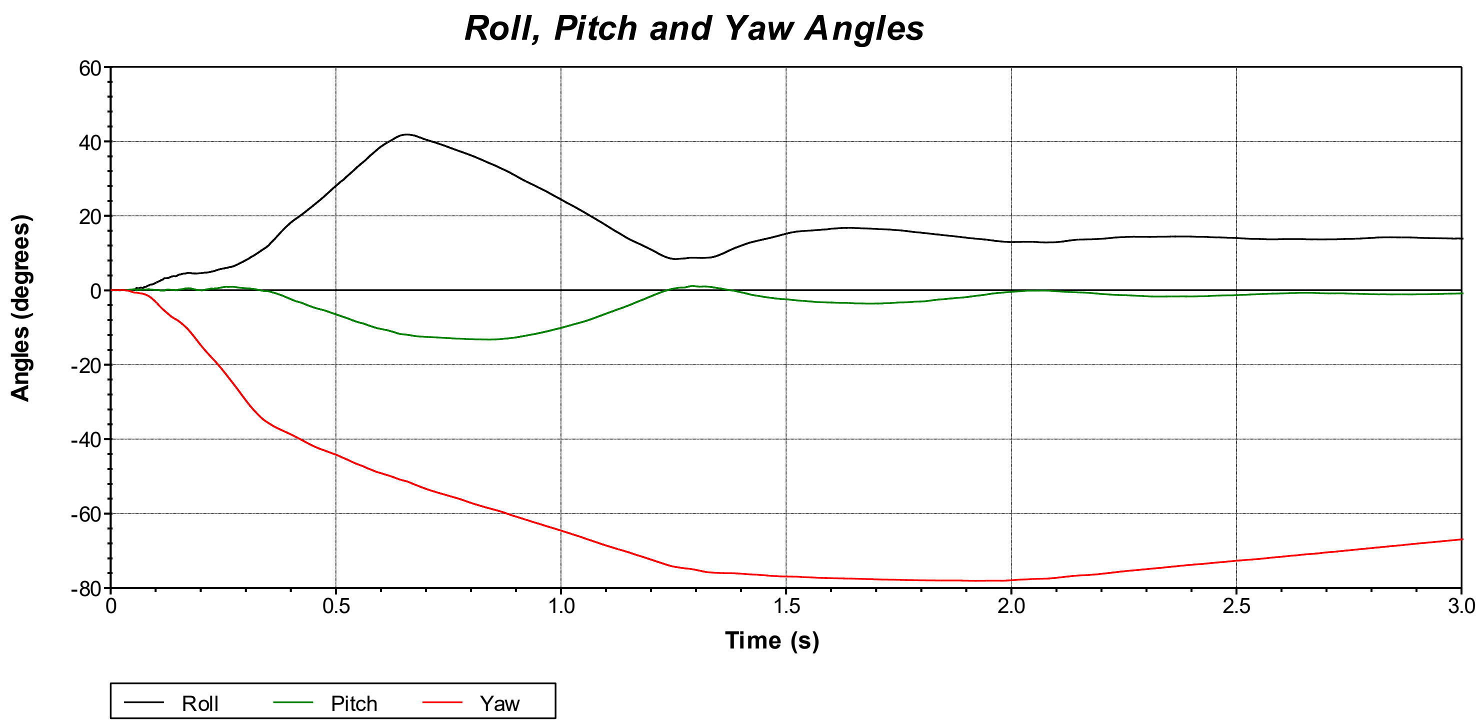
(f) 0.5000 s

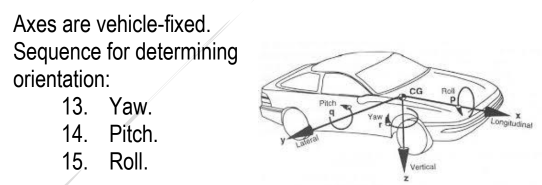

(g) 0.6000 s

(h) 0.7000 s

Figure G.6. Sequential Photographs for Test 620061-01-5 (Upstream Field Side Oblique Views).

G.3. VEHICLE ANGULAR DISPLACEMENTS





Test Number: 620061-01-5
Test Standard Test Number: *MASH* Test 3-11
Test Article: Merritt Parkway Guiderail
Test Vehicle: 2019 RAM 1500
Inertial Mass: 5024 lbs
Gross Mass: 5024 lbs
Impact Speed: 61.2 mi/h
Impact Angle: 25.2°

Figure G.7. Vehicle Angular Displacements for Test 620061-01-5.

G.4. VEHICLE ACCELERATIONS

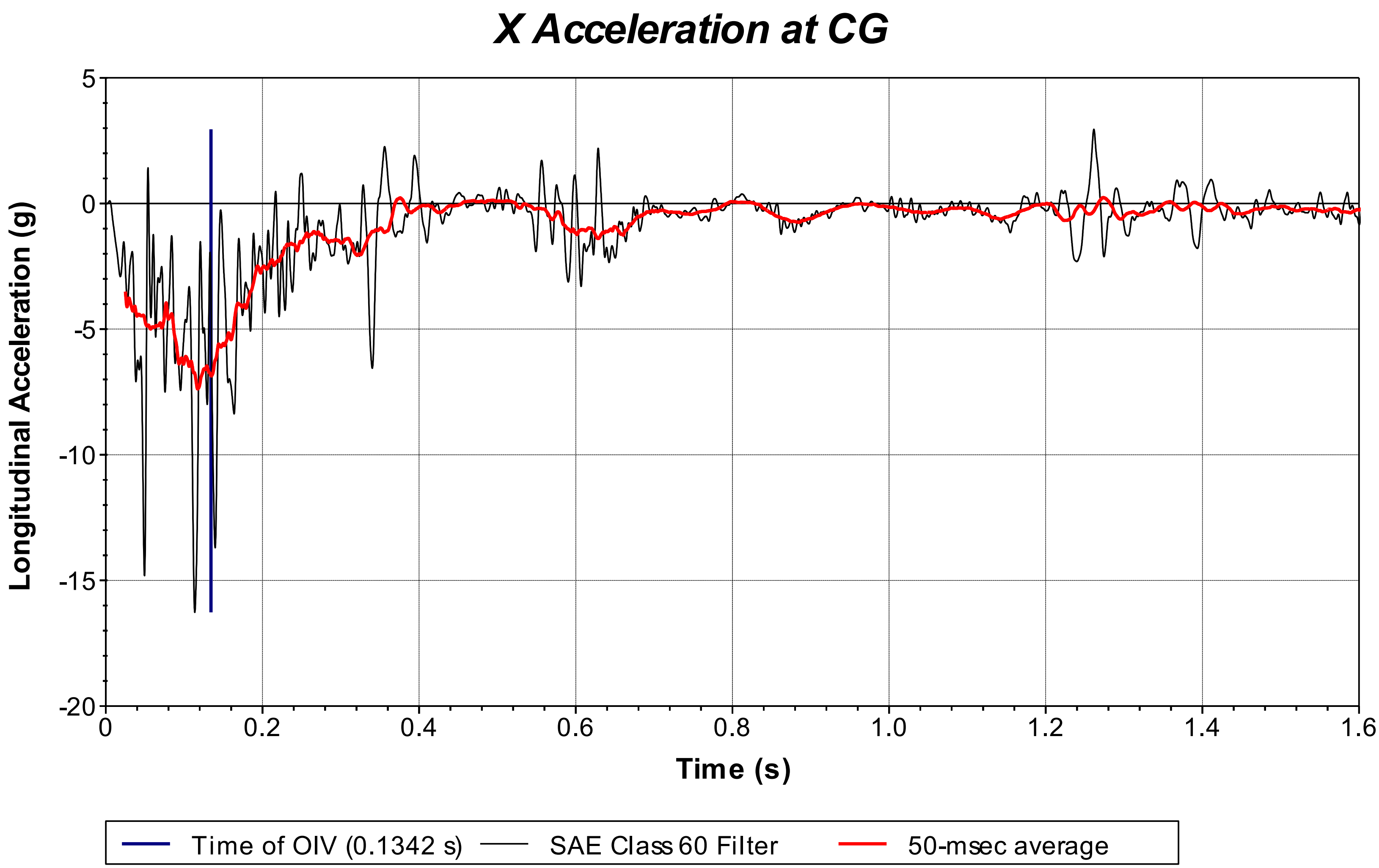


Figure G.8. Vehicle Longitudinal Accelerometer Trace for Test 620061-01-5
(Accelerometer Located at Center of Gravity).

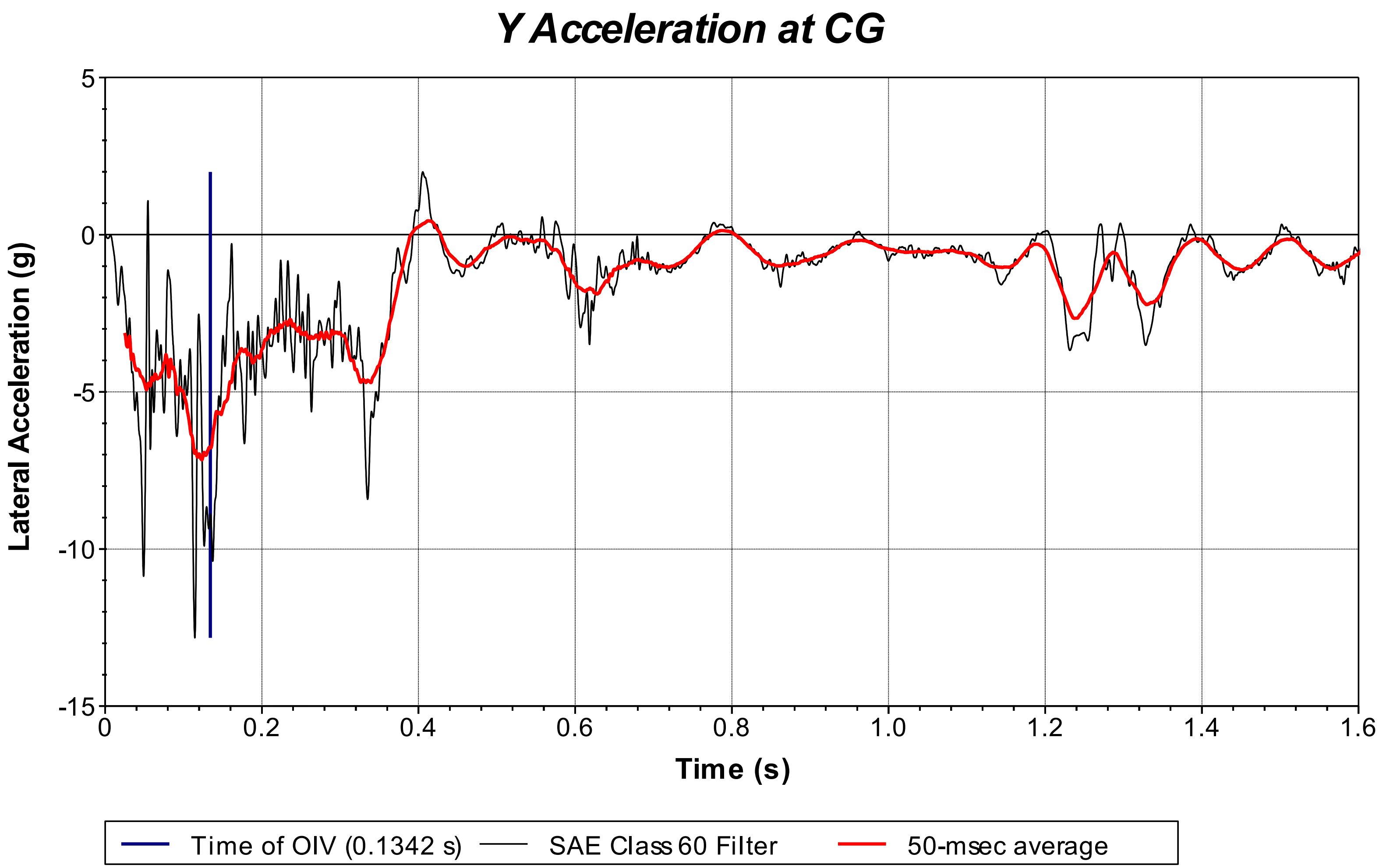


Figure G.9. Vehicle Lateral Accelerometer Trace for Test 620061-01-5 (Accelerometer Located at Center of Gravity).

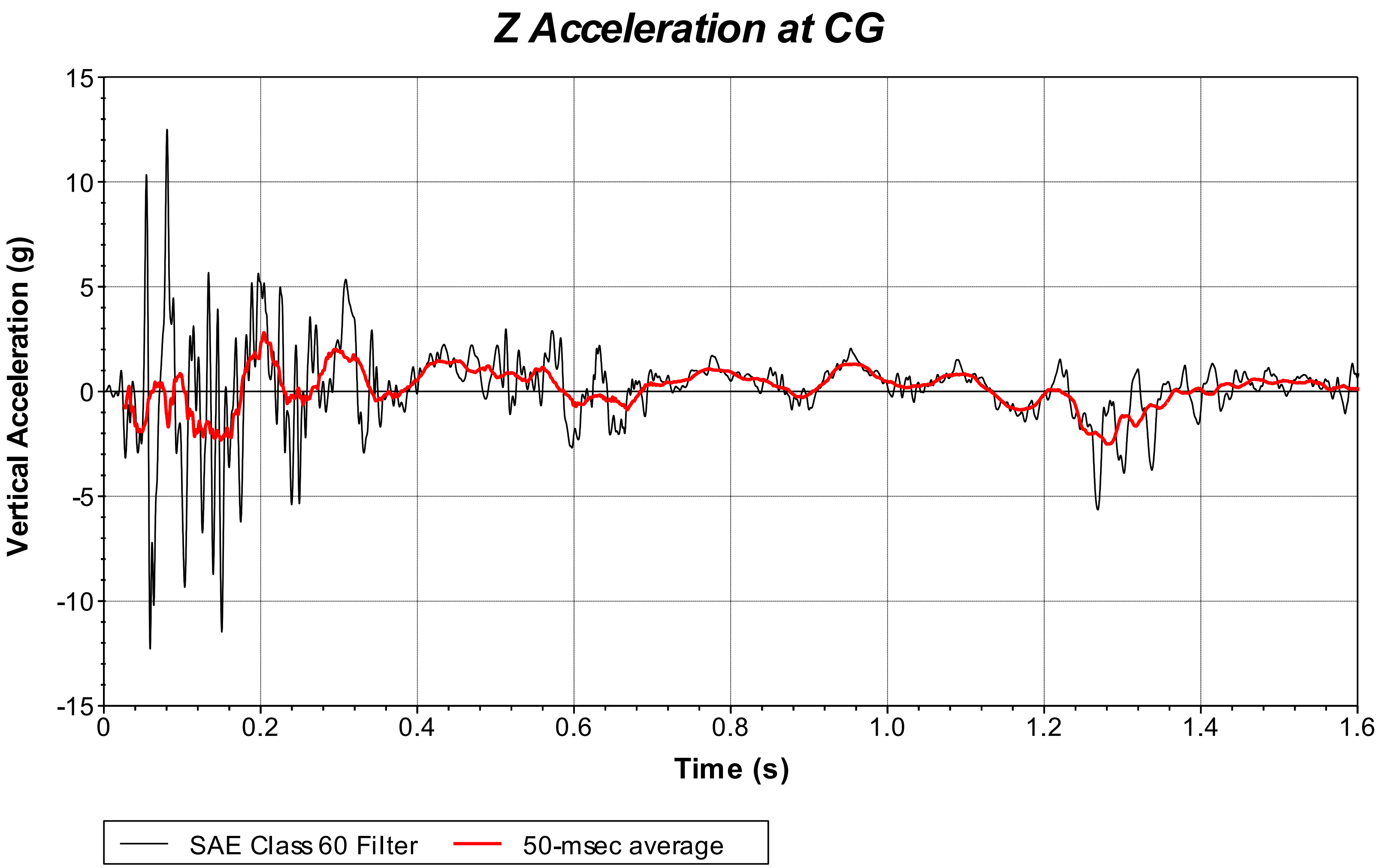


Figure G.10. Vehicle Vertical Accelerometer Trace for Test 620061-01-5 (Accelerometer Located at Center of Gravity).

APPENDIX H.

MASH TEST 3-10 (CRASH TEST 620061-01-6)

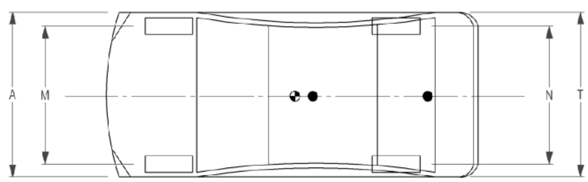
H.1. VEHICLE PROPERTIES AND INFORMATION

Date:	2025-05-05	Test No.:	620061-01-6	VIN No.:	3N1CN7AP7KL807157
Year:	2019	Make:	NISSAN	Model:	VERSA
Tire Inflation Pressure:	36 PSI	Odometer:	200403	Tire Size:	P185/65R15

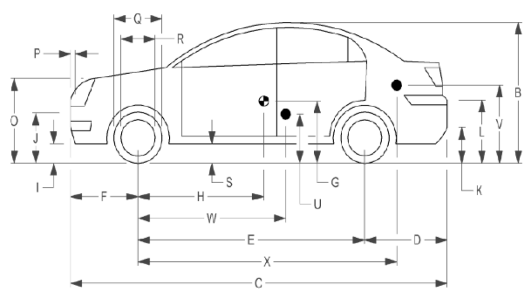
Describe any damage to the vehicle prior to test: NONE

● Denotes accelerometer location.

NOTES: None



Engine Type: 4 CYL
Engine CID: 1.6L
Transmission Type:
☑ Auto or ☐ Manual
☐ FWD ☐ RWD ☐ 4WD
Optional Equipment:
NONE



Dummy Data:
Type: 50th Percentile Male
Mass: 165 lb
Seat Position: IMPACT SIDE

Geometry: inches

A	66.70	F	32.50	K	12.50	P	4.50	U	15.50
B	59.60	G	0.00	L	26.00	Q	24.00	V	21.25
C	175.40	H	41.40	M	58.30	R	16.25	W	41.50
D	40.50	I	7.00	N	58.50	S	7.50	X	79.75
E	102.40	J	22.50	O	30.50	T	64.50		

Wheel Center Ht Front 11.50 Wheel Center Ht Rear 11.50 W-H 0.10

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Top of Radiator Support) = 28 ±4 inches
(M+N)/2 = 59 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1750	M_{front}	1422	1450	1535
Back	1687	M_{rear}	986	984	1064
Total	3389	M_{Total}	2408	2434	2599

Allowable TIM = 2420 lb ±55 lb | Allowable GSM = 2585 lb ± 55 lb

Mass Distribution:
lb LF: 735 RF: 715 LR: 467 RR: 517

Figure H.1. Vehicle Properties for Test 620061-01-6.

Date: 2025-05-05 Test No.: 620061-01-6 VIN No.: 3N1CN7AP7KL807157

Year: 2019 Make: NISSAN Model: VERSA

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	**Side Damage**
Undeformed end width ________	Bowing: B1 _____ X1 _____
Corner shift: A1 ________	B2 _____ X2 _____
A2 ________	
End shift at frame (CDC)	Bowing constant
(check one)	$\frac{X1+X2}{2}$ = ______
< 4 inches ________	
≥ 4 inches ________	

Note: Measure C_1 to C_6 from Driver to Passenger Side in Front or Rear Impacts – Rear to Front in Side Impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FRONT BUMPER	12	3.5	16	-	-	-	-	-	-	+17
2	AT FRONT BUMPER	12	10	40	-	-	-	-	-	-	57
	Measurements recorded										
	☑ **inches** or ☐ **mm**										

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

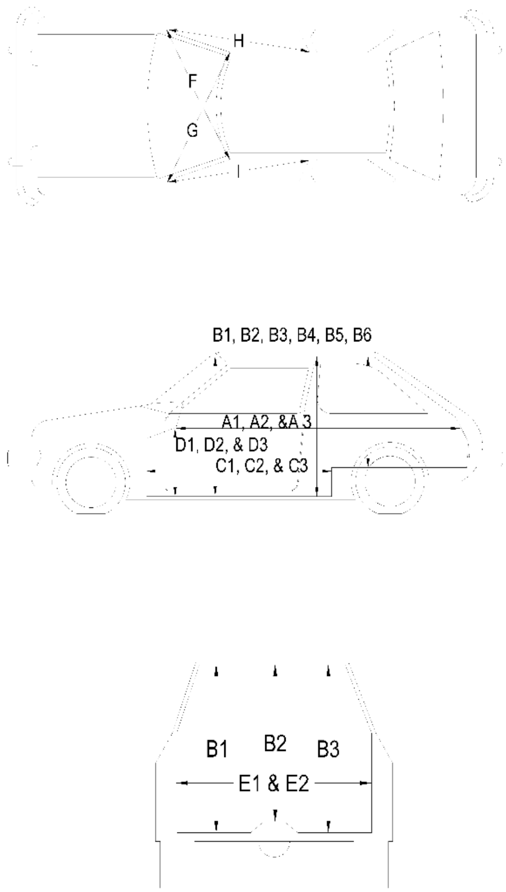
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***Measure and document on the vehicle diagram the location of the maximum crush.

Note: Use as many lines/columns as necessary to describe each damage profile.

Figure H.2. Exterior Crush Measurements for Test 620061-01-6.

Date:	2025-05-05	Test No.:	620061-01-6	VIN No.:	3N1CN7AP7KL807157
Year:	2019	Make:	NISSAN	Model:	VERSA



*Lateral area across the cab from driver's side kick panel to passenger's side kick panel.

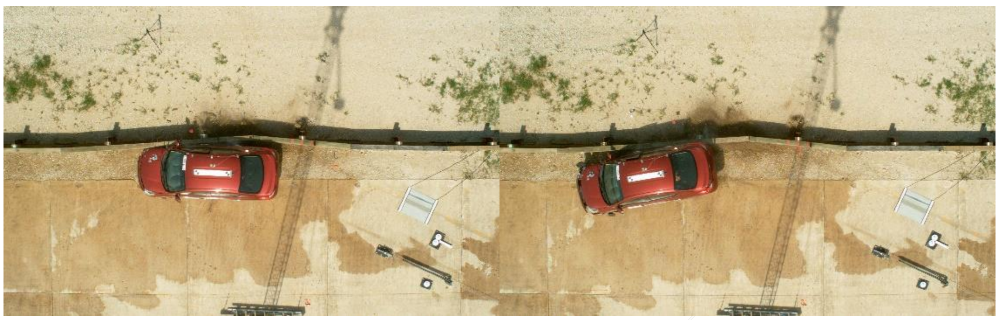
OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	67.50	67.50	0.00
A2	67.25	67.25	0.00
A3	67.75	67.75	0.00
B1	40.50	40.50	0.00
B2	39.00	39.00	0.00
B3	40.50	40.50	0.00
B4	36.25	36.25	0.00
B5	36.00	36.00	0.00
B6	36.25	36.25	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	9.50	9.50	0.00
D2	0.00	0.00	0.00
D3	9.50	9.50	0.00
E1	51.50	51.75	0.25
E2	51.00	51.25	0.25
F	51.00	51.00	0.00
G	37.50	37.50	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	51.00	51.00	0.00

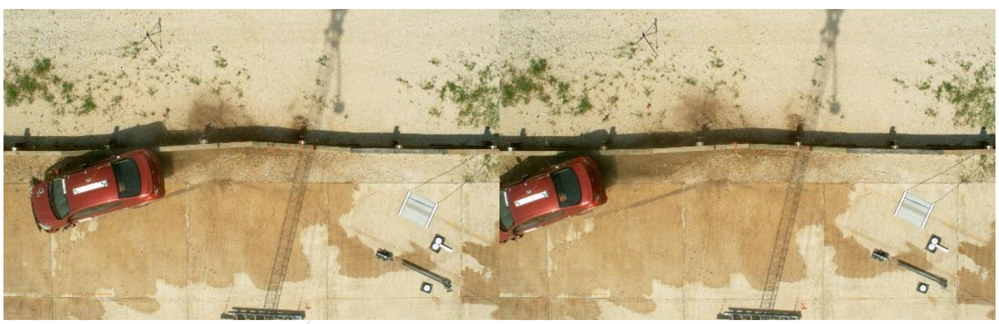
Figure H.3. Occupant Compartment Measurements for Test 620061-01-6.

H.2. SEQUENTIAL PHOTOGRAPHS

(a) 0.000 s (b) 0.1000 s



(c) 0.2000 s (d) 0.3000 s



(e) 0.4000 s (f) 0.5000 s

(g) 0.6000 s (h) 0.7000 s

Figure H.4. Sequential Photographs for Test 620061-01-6 (Overhead Views).

(a) 0.000 s (b) 0.1000 s

(c) 0.2000 s (d) 0.3000 s

(e) 0.4000 s (f) 0.5000 s

(g) 0.6000 s (h) 0.7000 s

Figure H.5. Sequential Photographs for Test 620061-01-6 (Downstream In-Line Views).

(a) 0.000 s

(b) 0.1000 s

(c) 0.2000 s

(d) 0.3000 s

(e) 0.4000 s

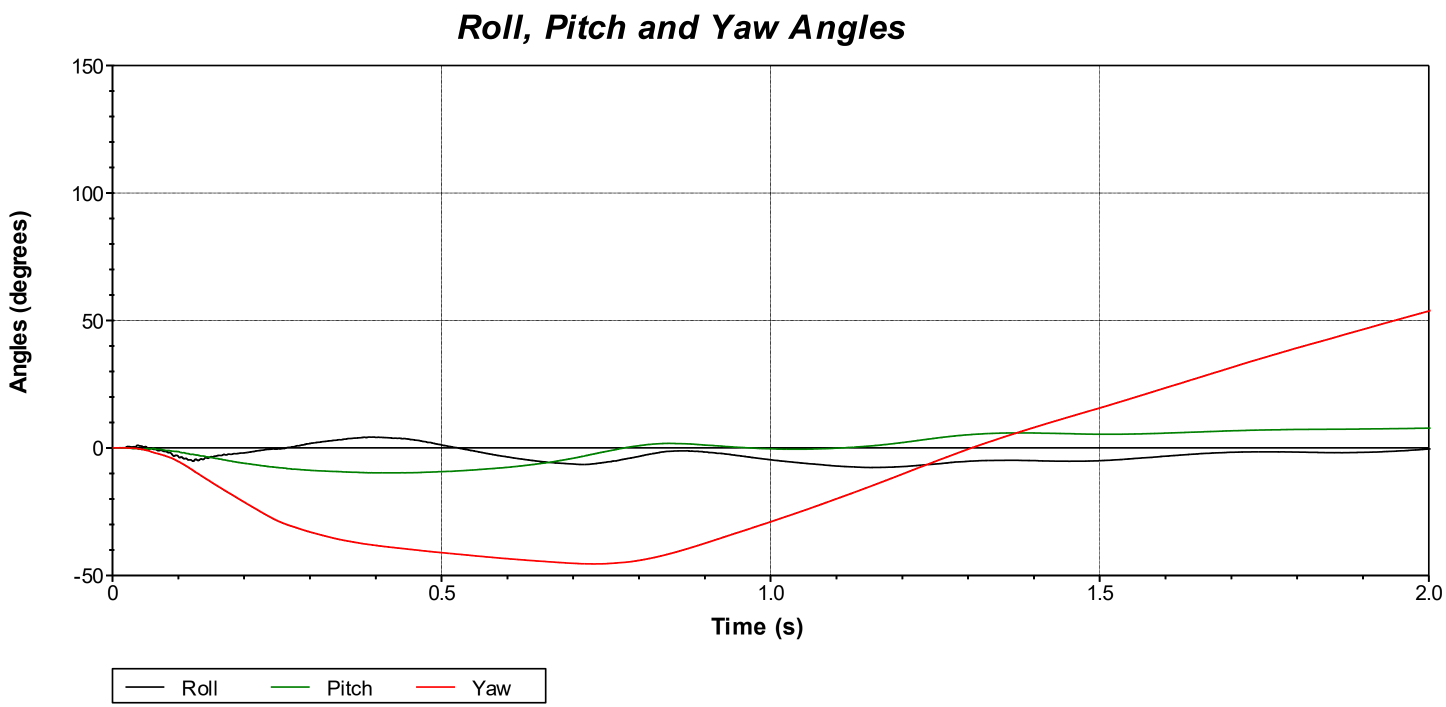
(f) 0.5000 s

(g) 0.6000 s

(h) 0.7000 s

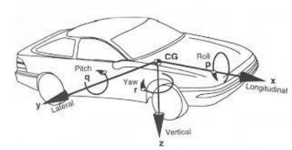
Figure H.6. Sequential Photographs for Test 620061-01-6 (Upstream Field Side Oblique Views).

H.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

16. Yaw.
17. Pitch.
18. Roll.



Test Number: 620061-01-6
Test Standard Test Number: *MASH* Test 3-10
Test Article: Merritt Parkway Guiderail
Test Vehicle: 2019 Nissan Versa
Inertial Mass: 2434 lbs
Gross Mass: 2599 lbs
Impact Speed: 62.6 mi/h
Impact Angle: 24.6°

Figure H.7. Vehicle Angular Displacements for Test 620061-01-6.

H.4. VEHICLE ACCELERATIONS

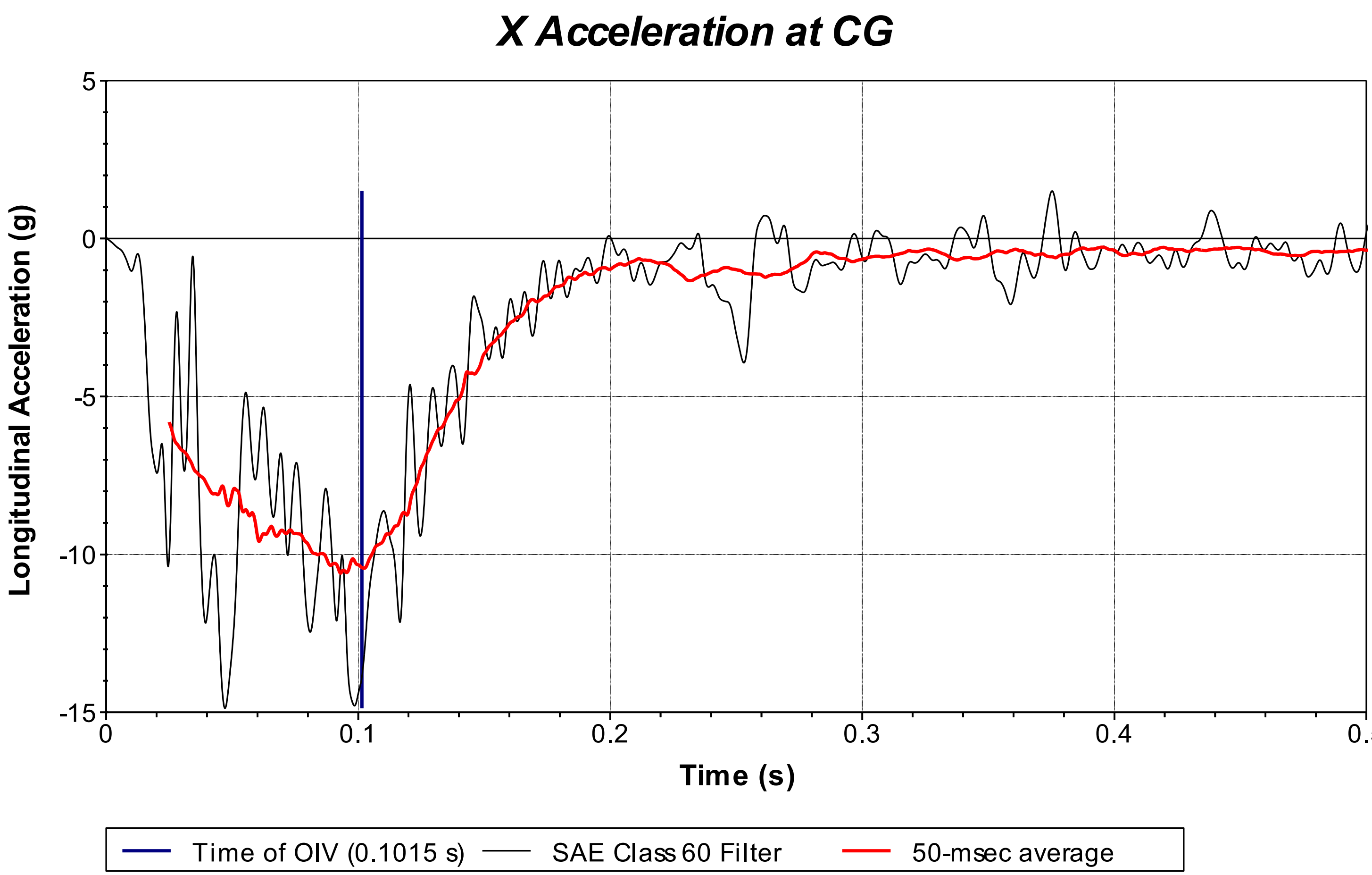


Figure H.8. Vehicle Longitudinal Accelerometer Trace for Test 620061-01-6
(Accelerometer Located at Center of Gravity).

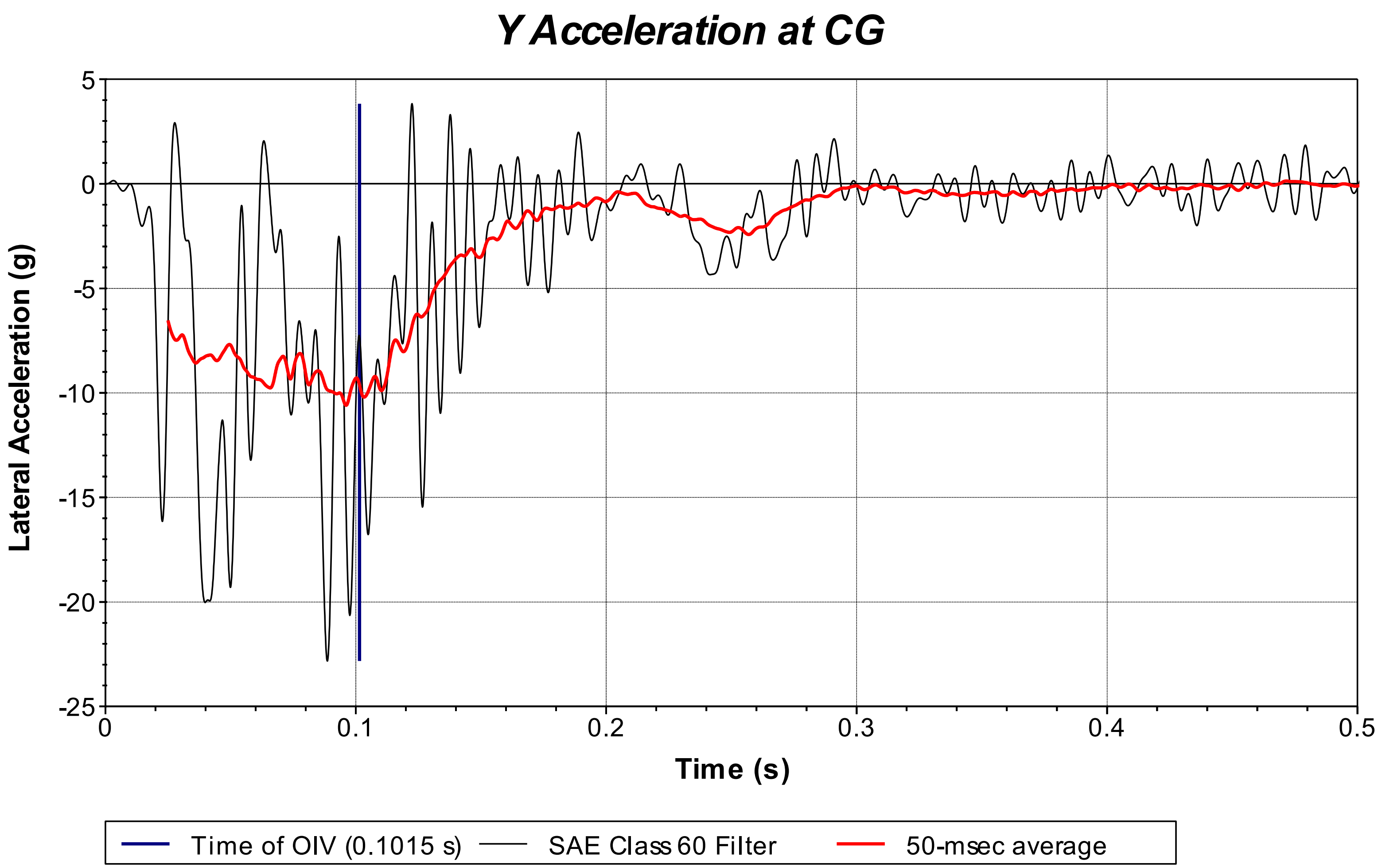


Figure H.9. Vehicle Lateral Accelerometer Trace for Test 620061-01-6
(Accelerometer Located at Center of Gravity).

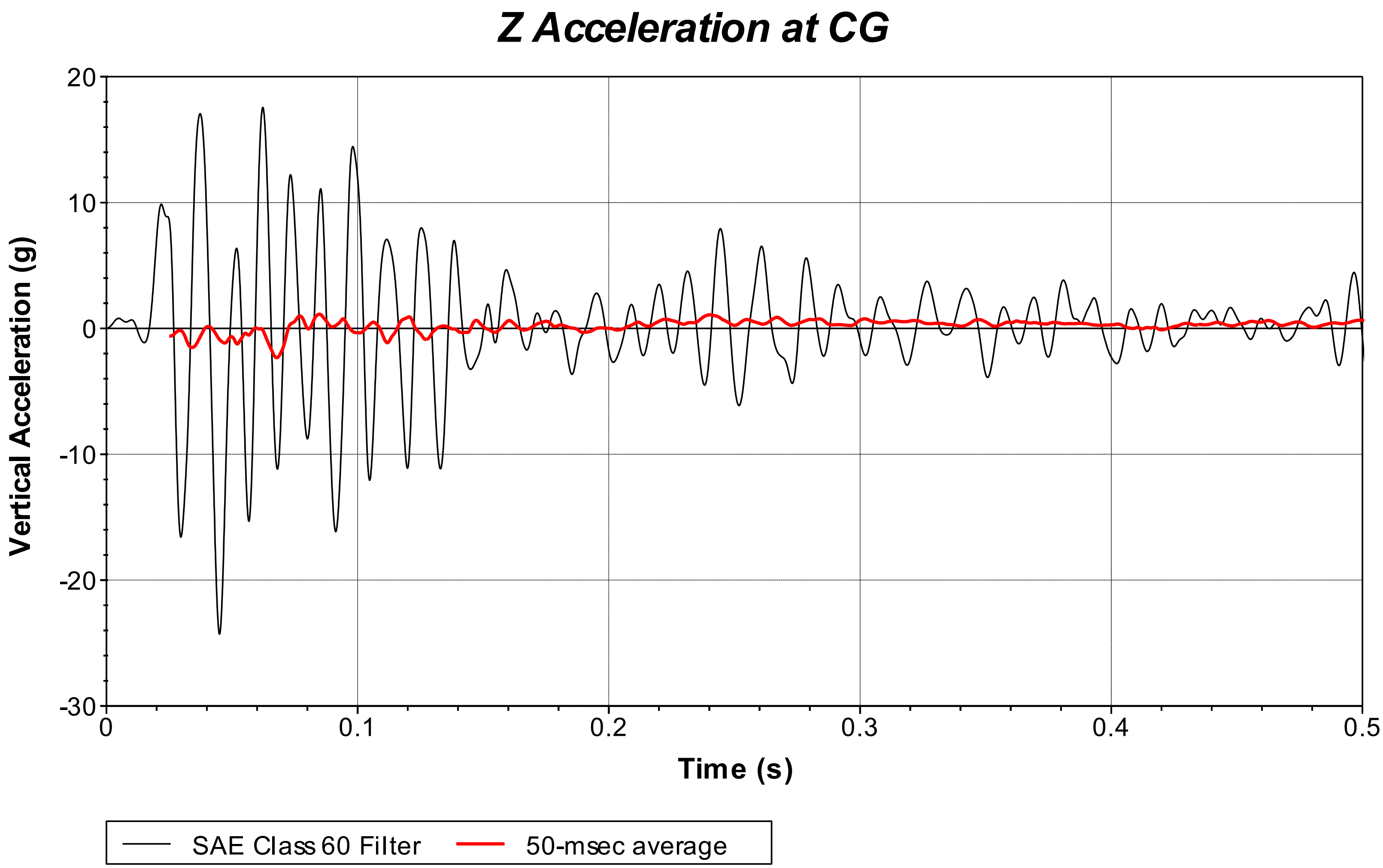


Figure H.10. Vehicle Vertical Accelerometer Trace for Test 620061-01-6
(Accelerometer Located at Center of Gravity).