Texas A&M Transportation Institute
Proving Ground

Test Report No. 618901-01-2-1:7

PORTABLE SIGN SUPPORTS FOR ALUMINUM SIGNS WITH VARIATIONS ON MOUNTING HEIGHT

Sponsored by
The Roadside Safety Pooled Fund

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16. Abstract

Channelizing devices are often used in conjunction with signage within work zones to guide traffic. These channelizing devices can obscure drivers' vision of the signage. The objective of this project was to evaluate the AASHTO *MASH* compliance of a tall portable sign stand which raises the sign above the channelizing devices. The research team first reviewed previous literature and current state standards. Subsequently, the research team selected a design for *MASH* crash testing. This report documents this effort and provides recommendations for future research. The research team evaluated three different designs through MASH crash testing. All three designs failed to meet MASH evaluation criteria in either test 3-71 or 3-72. The research team recommends additional research projects to continue this investigation.

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Portable Sign Supports for Aluminum Signs with Variations on Mounting Height

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The results reported herein apply only to the article tested. The full-scale crash tests were 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

Channelizing devices are often used in conjunction with signage within work zones to guide traffic. These channelizing devices can obscure drivers' vision of the signage. The signage is a key aspect to safety within the work zone, and the Roadside Safety Pooled Fund prioritized an effort to mitigate this conflict. The objective of this project was to evaluate the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) (*1*) compliance of a tall portable sign stand. The mounting height of the sign was to be of sufficient height to clear the channelizing devices and prevent visibility conflicts. A five-foot mounting height was minimal, and 7 feet was preferred. The research team first reviewed previous literature and current state standards. Subsequently, the research team selected a design for *MASH* crash testing. This report documents this effort and provides recommendations for future research.

Chapter 2. LITERATURE REVIEW

2.1. OVERVIEW

This chapter documents the literature review performed during this project. Previous research was reviewed for relevance to this project. The previous research was divided into two categories: single mast designs and dual mast designs. This chapter documents this review effort.

2.2. SINGLE MAST SIGN TESTING

This section summarizes the literature review effort of single mast sign supports.

2.2.1. Temporary High-Mounting Height Sign Support – High Slip Joint Operation (Option A) (*2*)

The test installation for Design Option A was fabricated using a single aluminum sign mounted on 1¾-inch, 12-gauge perforated steel tubing. The aluminum test sign panel measured 36 inches square and was 0.100-inch thick. The sign was mounted in a diamond configuration. The H-shaped base was comprised of three sections of 1¾-inch perforated square steel tubing (PSST). Two 40-lbs sandbags were placed on top of the H-shaped base; one at the midpoint of each leg. The approximate total weight of the test assembly was 60 lbs, exclusive of the two 40-lbs sandbags.

The upper and lower sections of the vertical support post were connected with an 8-inch sleeve fabricated from 1½-inch, 12-gauge perforated steel tubing. This insert was secured in the lower section with a smooth pin located in the holes 2½ inches below the joint. The pin was welded to one side of the lower post once the insert was installed. The bottom of the aluminum sign was mounted 83½ inches above grade. Figure 2.1, Figure 2.2, and Figure 2.3 show details of the Option A temporary work zone sign support installation.

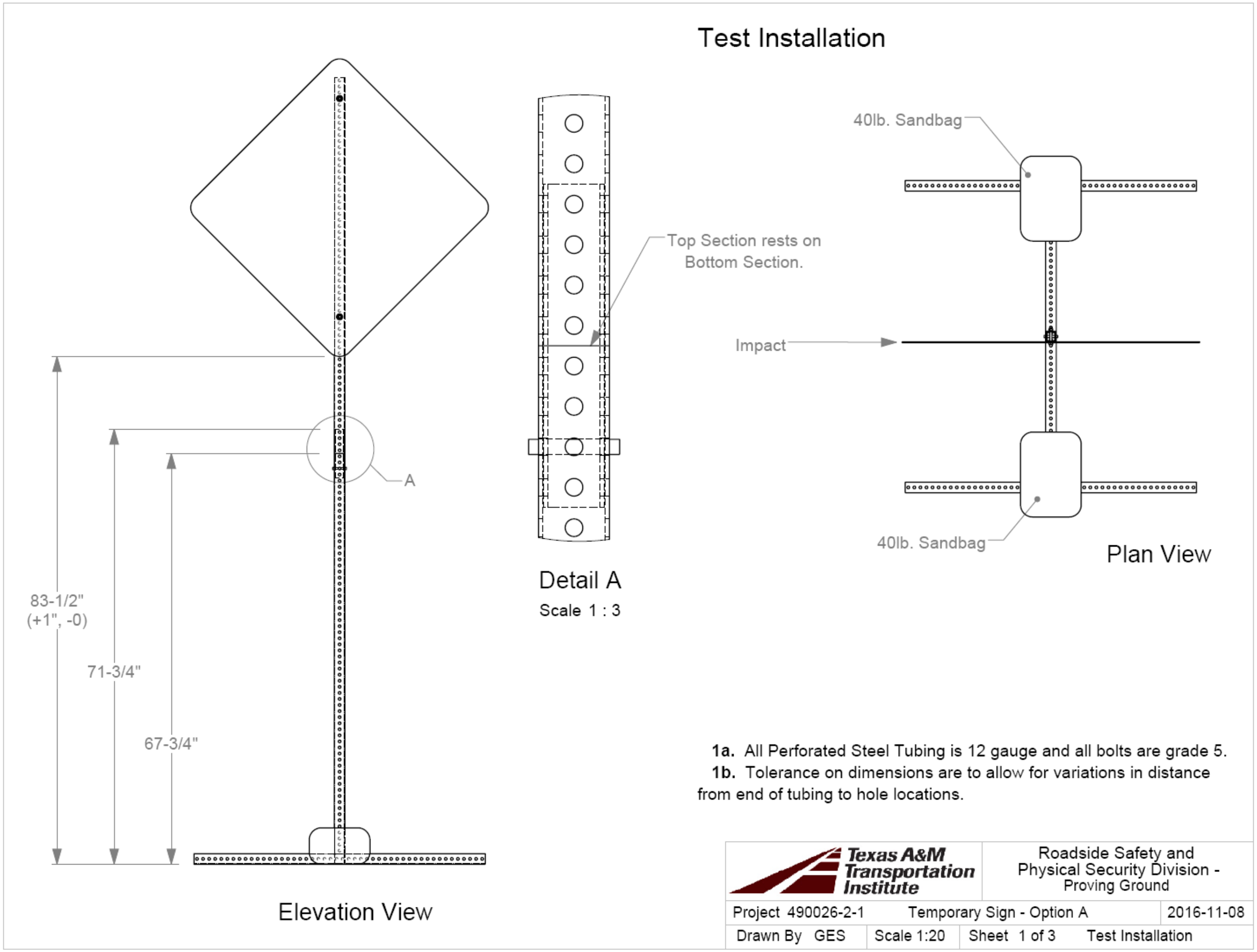


Figure 2.1. Specifications of Temporary High-Mounting Sign Support, Option A (*2*)

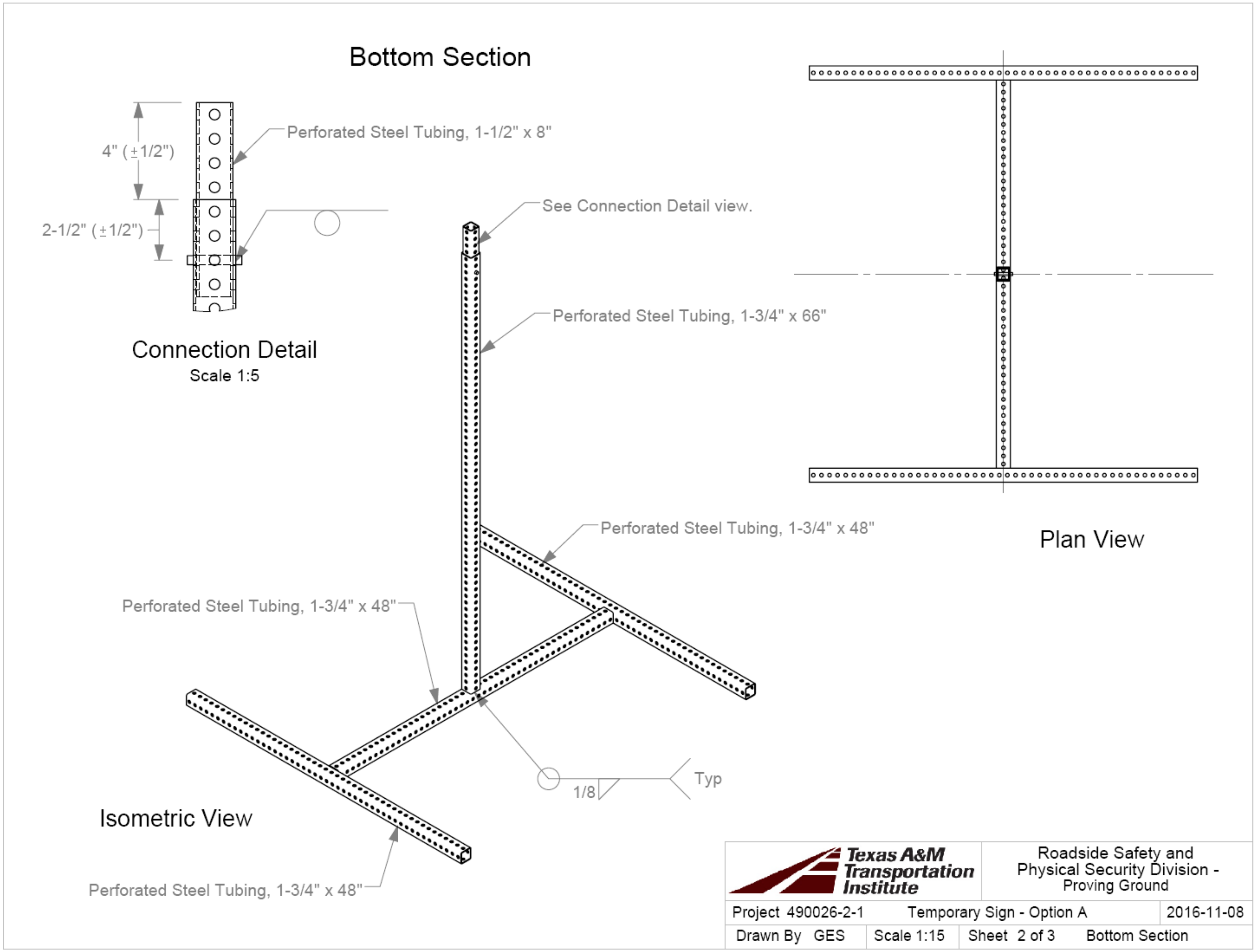


Figure 2.2. Specifications of Temporary High-Mounting Sign Support, Option A (Continued) (*2*)

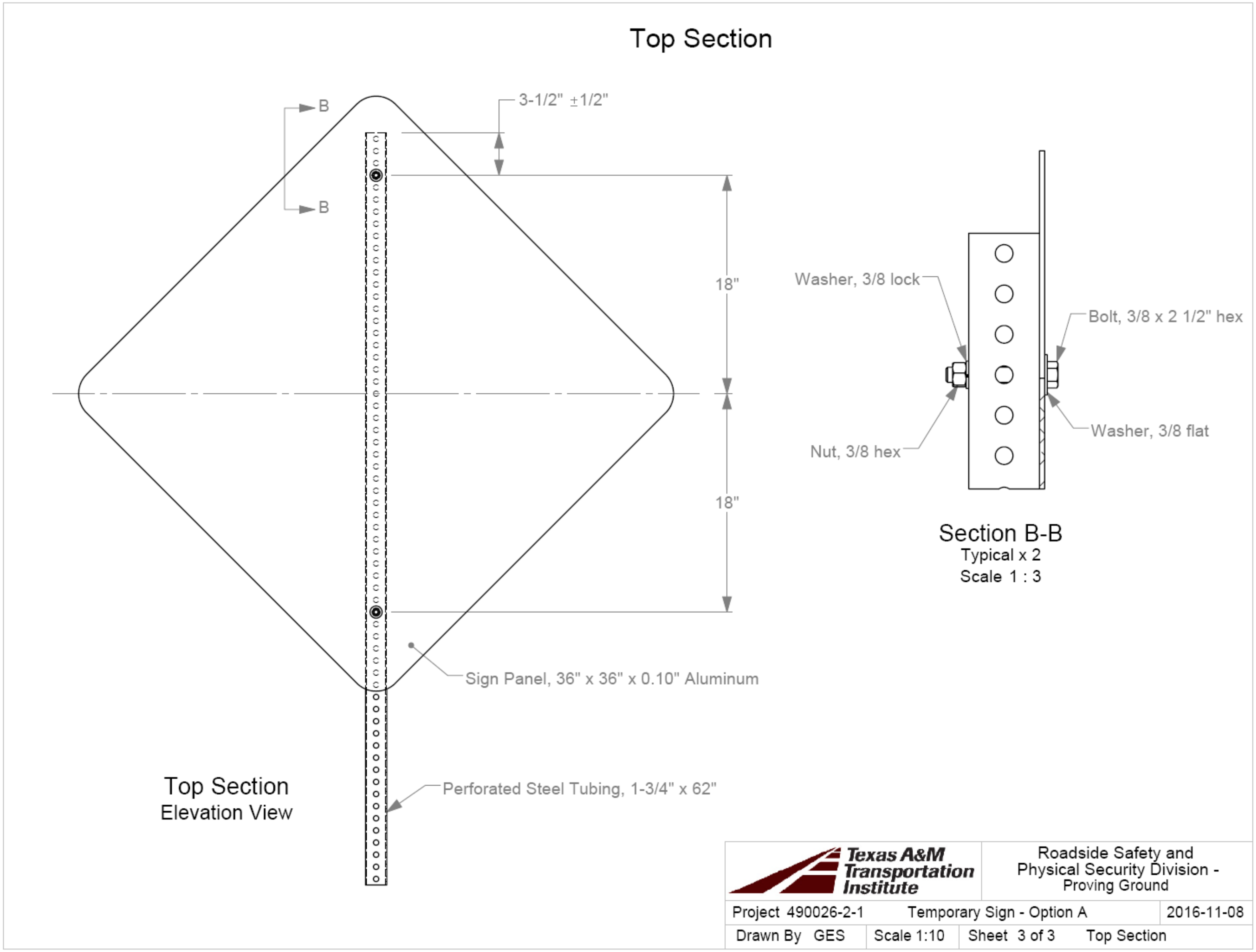


Figure 2.3. Specifications of Temporary High-Mounting Sign Support, Option A (Continued) (*2*)

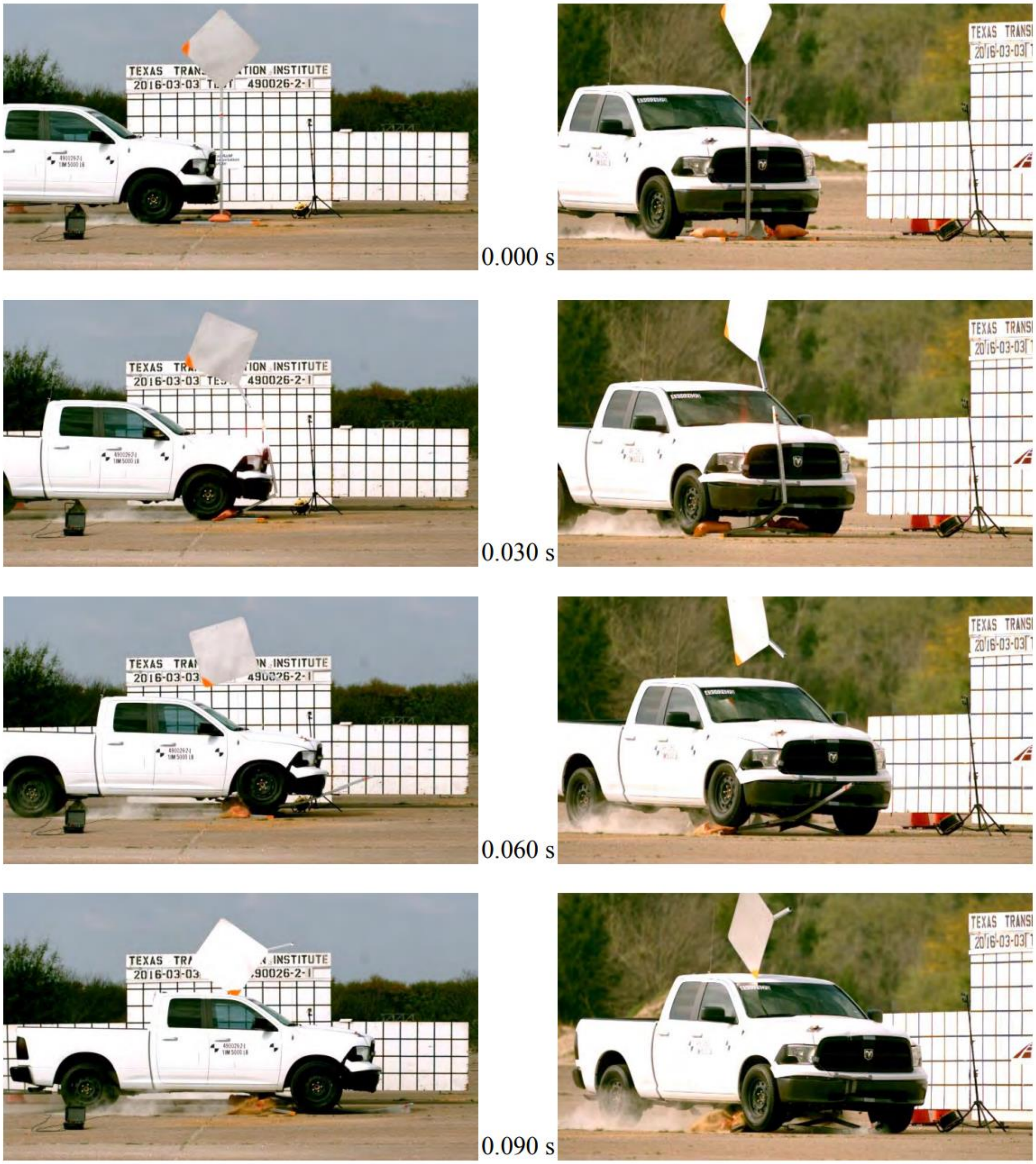


Figure 2.4. Temporary High-Mounting Sign Support, Option A Test 3-72, 90-degree Impact Sequential Photos (*2*)

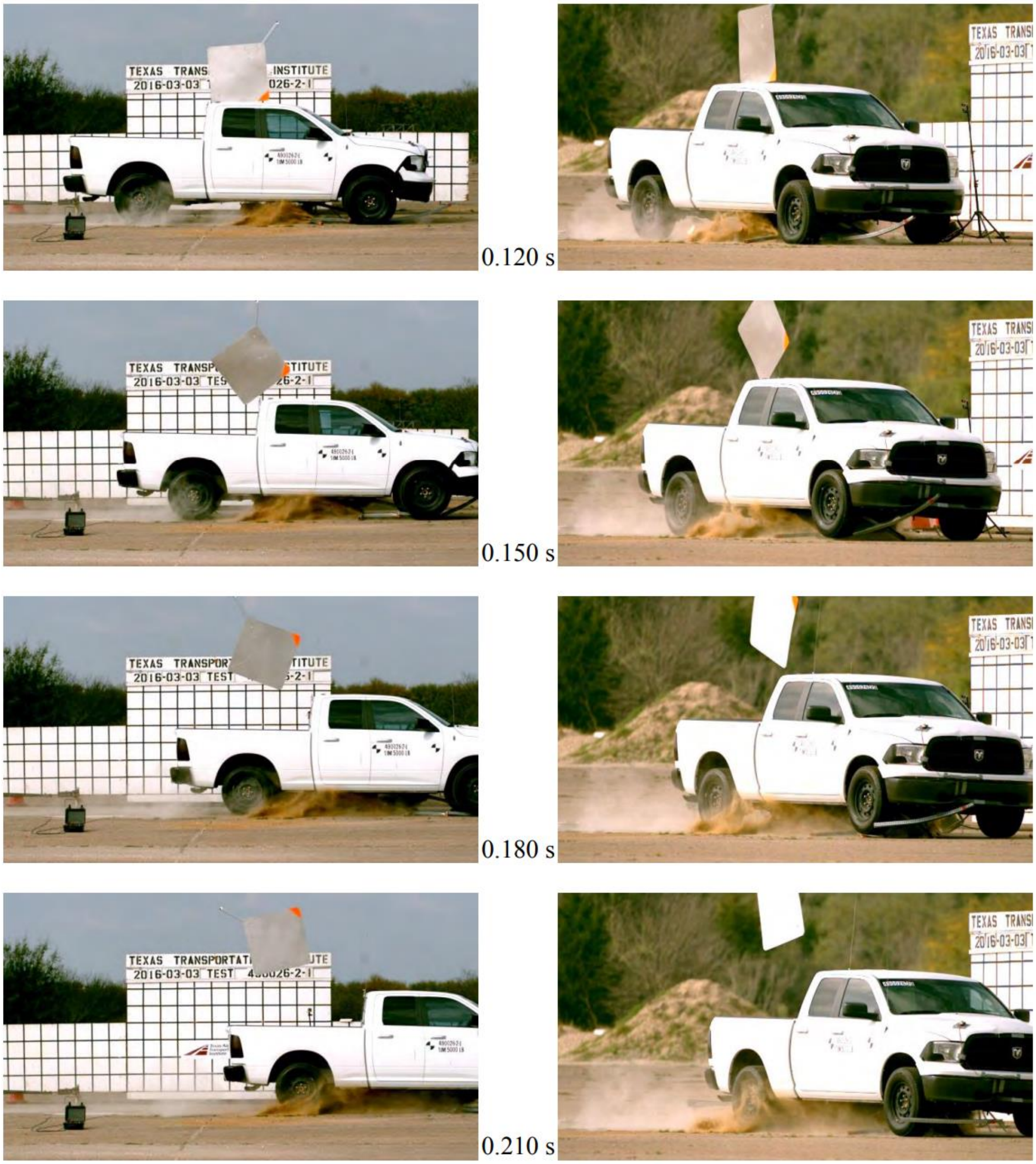


Figure 2.5. Temporary High-Mounting Sign Support, Option A Test 3-72, 90-degree Impact Sequential Photos (Continued) (*2*)

In *MASH* test 3-72 (test 4900026-2-1), the 2270P pickup truck contacted the Option A temporary work zone sign support 10 inches to the right of centerline of the vehicle at an impact angle of 90 degrees while traveling at an impact speed of 62.9 mi/h. Figure 2.4 and Figure 2.5 present sequential photographs of the test. Figure 2.6 shows the damage to the Option A temporary work zone sign support.

Figure 2.7 shows the damage sustained by the vehicle. On the rear of the roof, there was a 16-inch scratch that ended in a 5-inch tear on the outer surface. The cut did not extend into the passenger compartment. The interior roof around the cut was dented approximately one inch, as shown in Figure 2.8. No other occupant compartment deformation or intrusion was noted.

Figure 2.9 provides a summary of the test results. The slip connection incorporated into the vertical support post of the Option A temporary work zone sign support allowed the top of the system to release from the lower section of the vertical support post and base as intended. The corner of the sign panel impacted the vehicle roof, and no tear occurred with this first impact. However, as the vehicle continued forward, the sign panel continued to rotate and impacted the rear of the roof causing a 5-inch tear in the exterior of the roof. The tear did not extend into the occupant compartment but did cause a 1-inch dent in the interior roof panel at this location of the right rear passenger compartment. Consequently, the test article failed to meet *MASH* evaluation criteria.

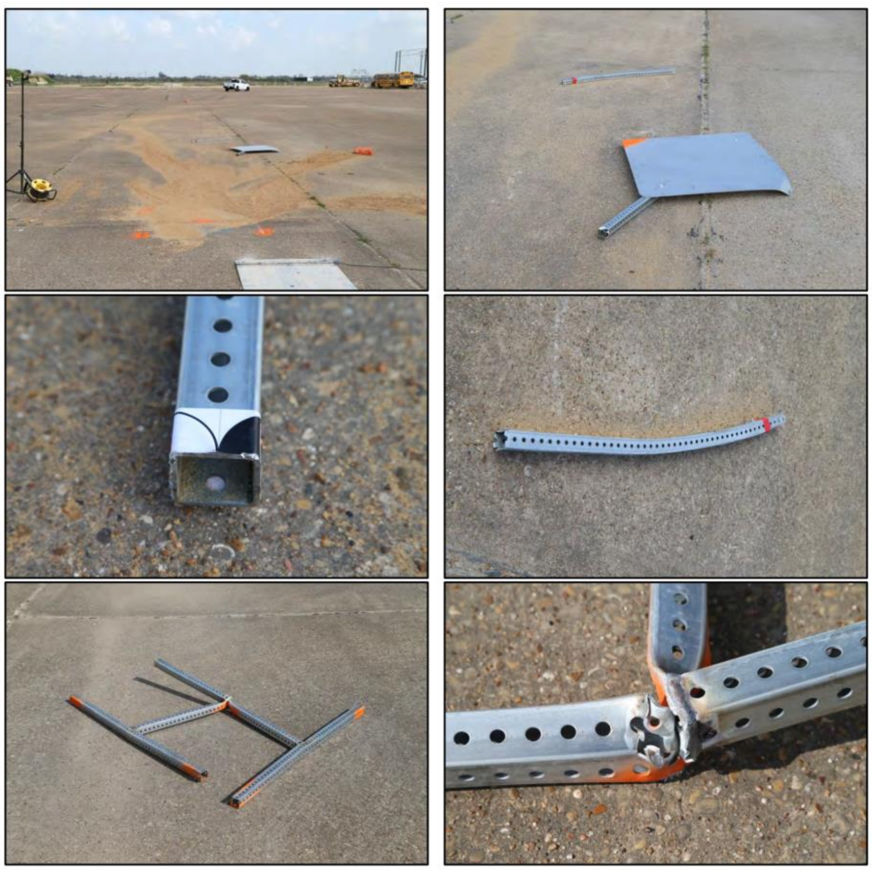
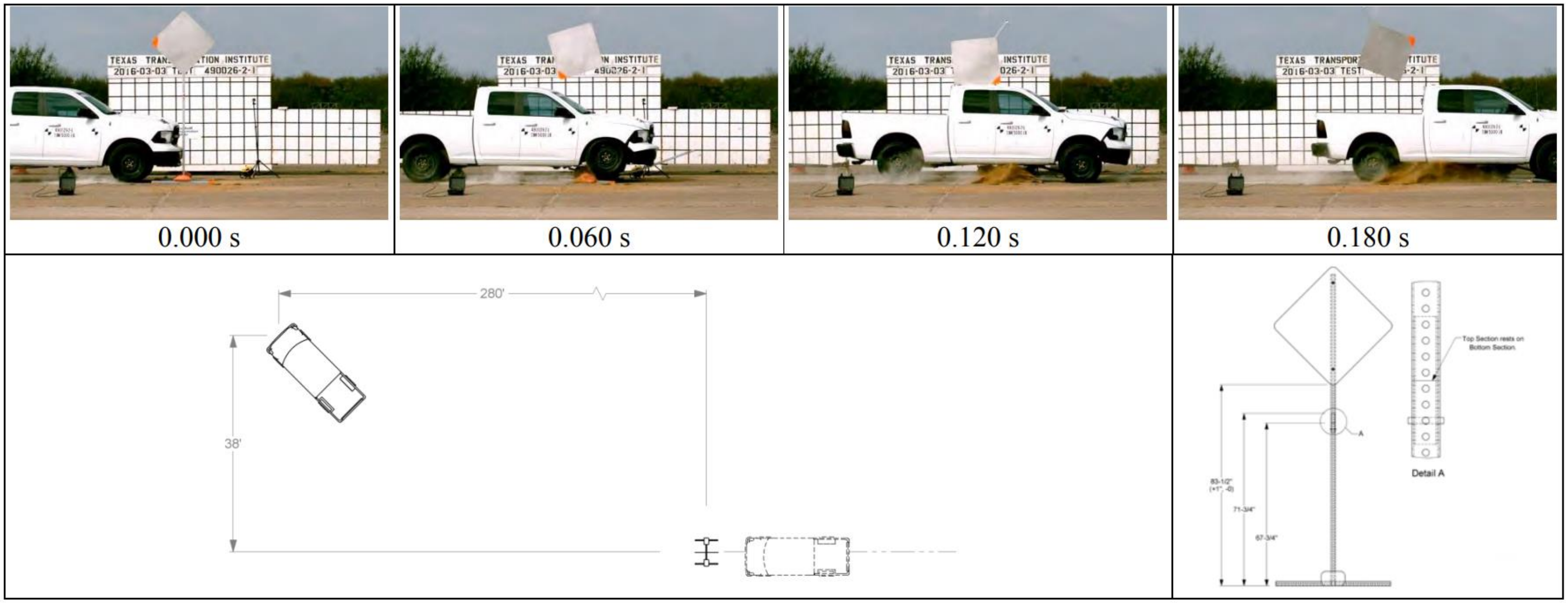


Figure 2.6. Temporary High-Mounting Sign Support, Option A Test 3-72, 90-degree Impact System Damage (*2*)

Figure 2.7. Temporary High-Mounting Sign Support, Option A Test 3-72, 90-degree Impact Vehicle Damage (*2*)

Figure 2.8. Temporary High-Mounting Sign Support, Option A Test 3-72, 90-degree Impact Vehicle Interior Damage (*2*)



General Information
- Test Agency .... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. .... MASH Test 3-72
- TTI Test No. 490026-2-1
- Test Date 2016-03-03

Test Article
- Type .... Temporary Work Zone Sign Support
- Name .... Option A Temporary Work Zone Sign Support
- Installation Height .... 83½ inches to bottom of sign; 132 ⅝ to top

Material or Key Elements .... Upper & lower sections connected with 8-inch long insert sleeve of 1½-inch, 12-gauge perforated square steel tubing secured with ⅜-inch diameter × 2½-inch long smooth pin located in holes 2½ inches below joint

Soil Type and Condition ...... Placed on dry concrete surface

Test Vehicle
- Type/Designation 2270P
- Make and Model .... 2010 Dodge Ram 1500
- Curb .... 4898 lb
- Test Inertial .... 5014 lb
- Dummy .... No dummy
- Gross Static .... 5014 lb

Impact Conditions
- Speed .... 62.9 mi/h
- Angle .... 90 degrees
- Location/Orientation .... 10 inches right of centerline

Kinetic Energy .... 663 kip-ft

Exit Conditions
- Speed .... 61.8 mi/h
- Angle .... NA

Occupant Risk Values ..... Assessment of occupant risk factors not required for test articles of 60 lb

Test Article Debris Scatter
- Longitudinal .... 98 ft downstream
- Lateral .... 12 ft left of center

Post-Impact Trajectory
- Stopping Distance .... 280 ft downstream 38 ft right of center

Vehicle Stability
- Maximum Yaw Angle .... Vehicle
- Maximum Pitch Angle .... remained
- Maximum Roll Angle .... upright
- Vehicle Snagging .... No
- Vehicle Pocketing .... No

Vehicle Damage
- VDS 12FR1
- CDC 12FREN1
- Max. Exterior Deformation .... 2.5 inches
- OCDI RR0000000
- Max. Occupant Compartment Deformation .... 1 inch

Figure 2.9. Temporary High-Mounting Sign Support, Option A Test 3-72, 90-degree Impact Results (*2*)

2.2.2. Temporary High-Mounting Height Sign Support– High Slip Joint Operation (Option B) (*2*)

The Option B test installations were each fabricated with a single aluminum sign mounted on a 3-piece vertical support post fabricated from 1¾-inch and 1½-inch, 12-gauge PSST. The aluminum sign panel measured 36 inches square and was 0.10 inches thick. The H-shaped base comprised of three sections of 1¾-inch PSST. Two 40-lb sandbags were placed on top of the H-shaped base; one at the midpoint of each leg. The approximate total weight of each test assembly was 58 lb, (exclusive of two 40-lb sandbags).

The vertical support post was comprised of three sections. The middle and upper sections of the vertical support post were fabricated from 1½-inch, 12-gauge PSST. The top and middle sections were joined with two fuse plates. The bottom of the aluminum sign was mounted 83½ inches above grade. Figure 2.10, Figure 2.11, and Figure 2.12 show details of the Option B sign support installation.

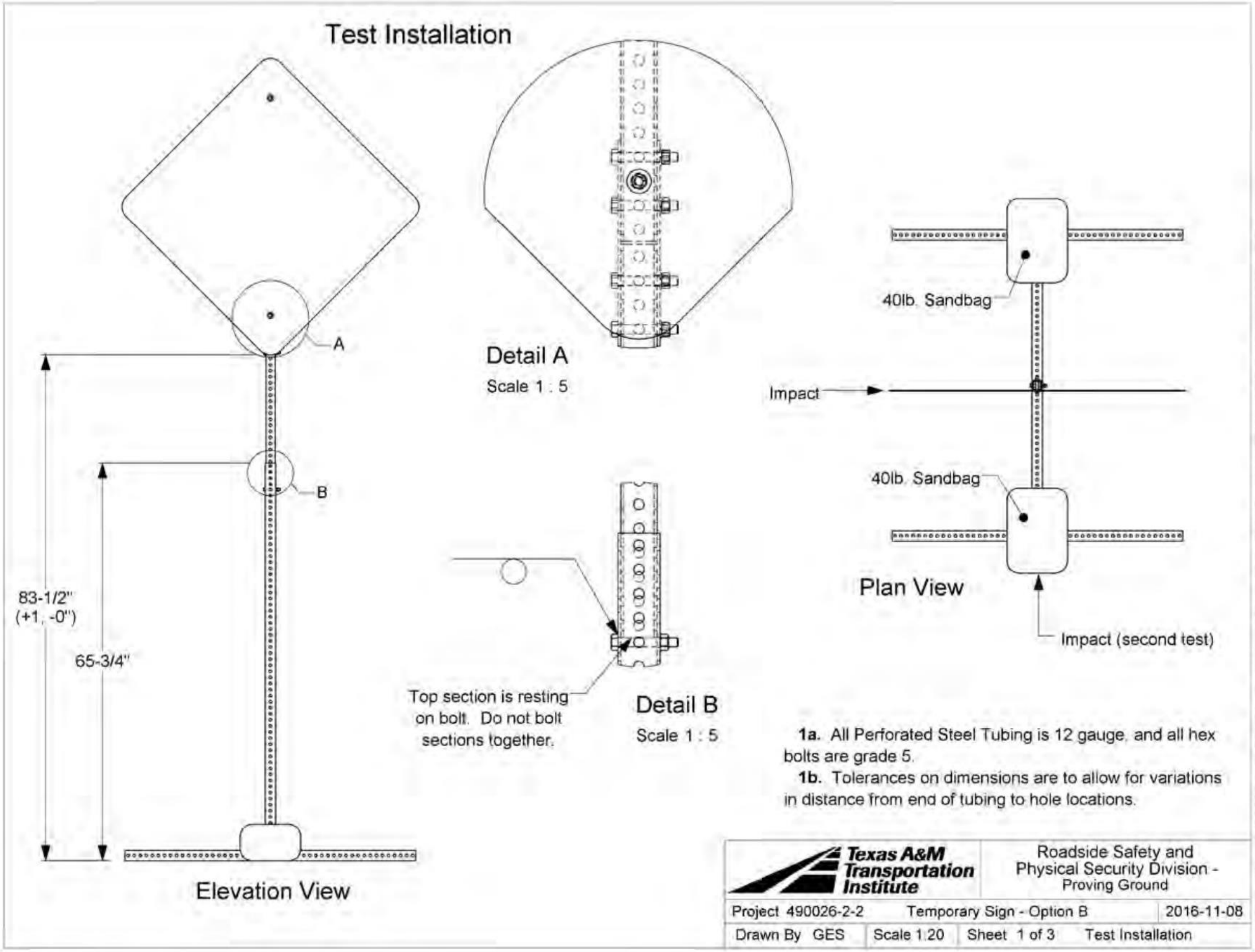


Figure 2.10. Specifications of Temporary High-Mounting Sign Support, Option B (*2*)

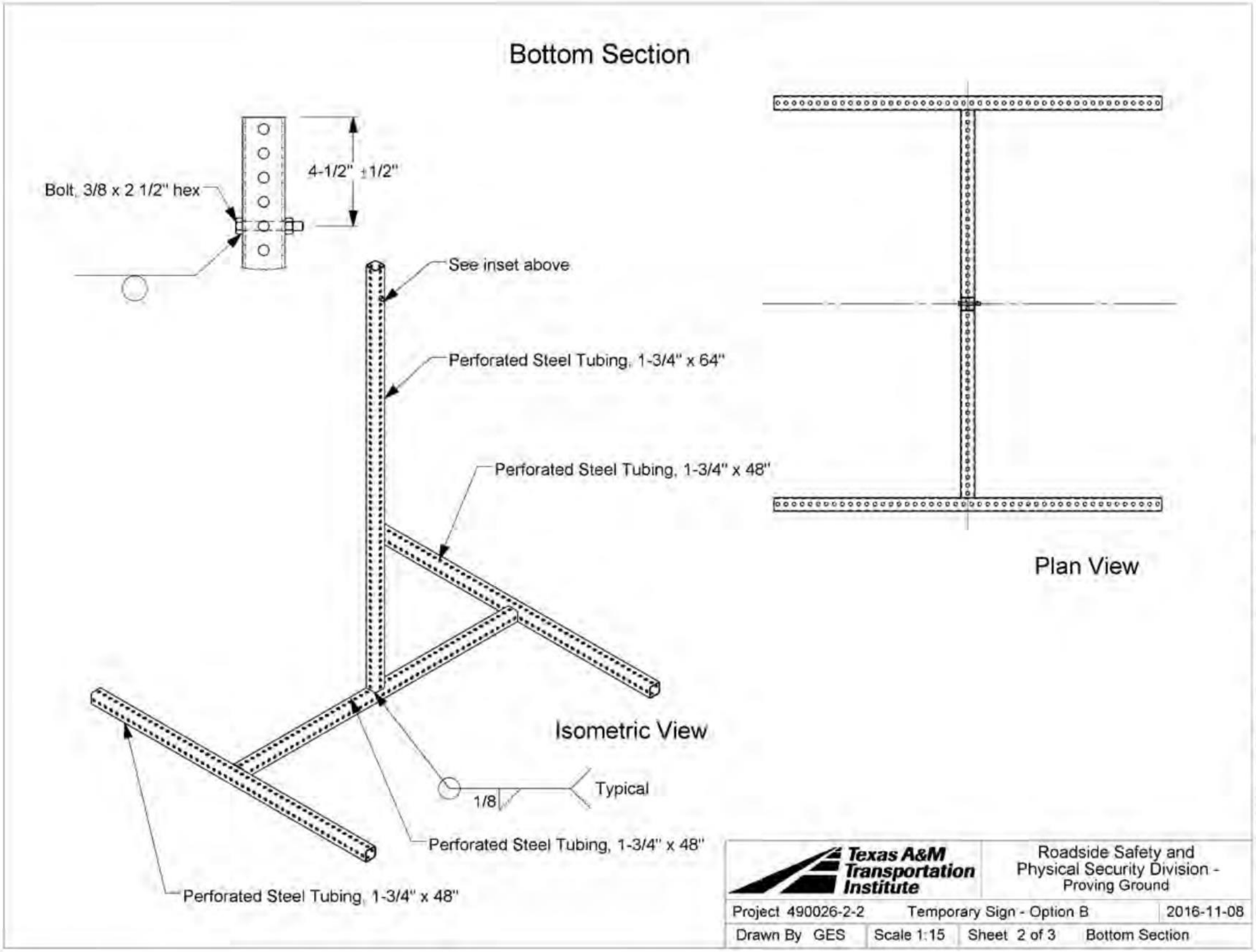


Figure 2.11. Specifications of Temporary High-Mounting Sign Support, Option B (Continued) (*2*)

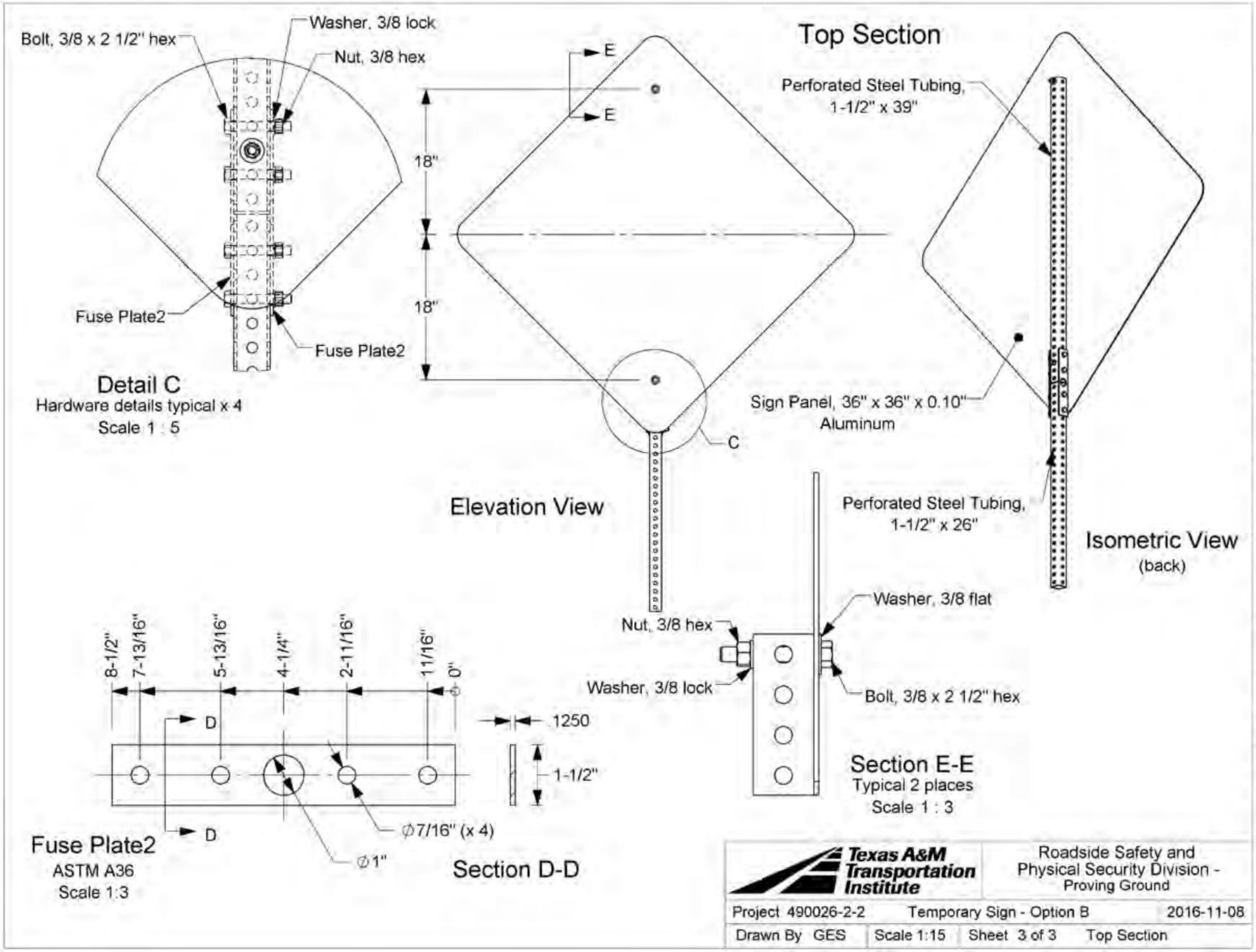


Figure 2.12. Specifications of Temporary High-Mounting Sign Support, Option B (Continued) (*2*)

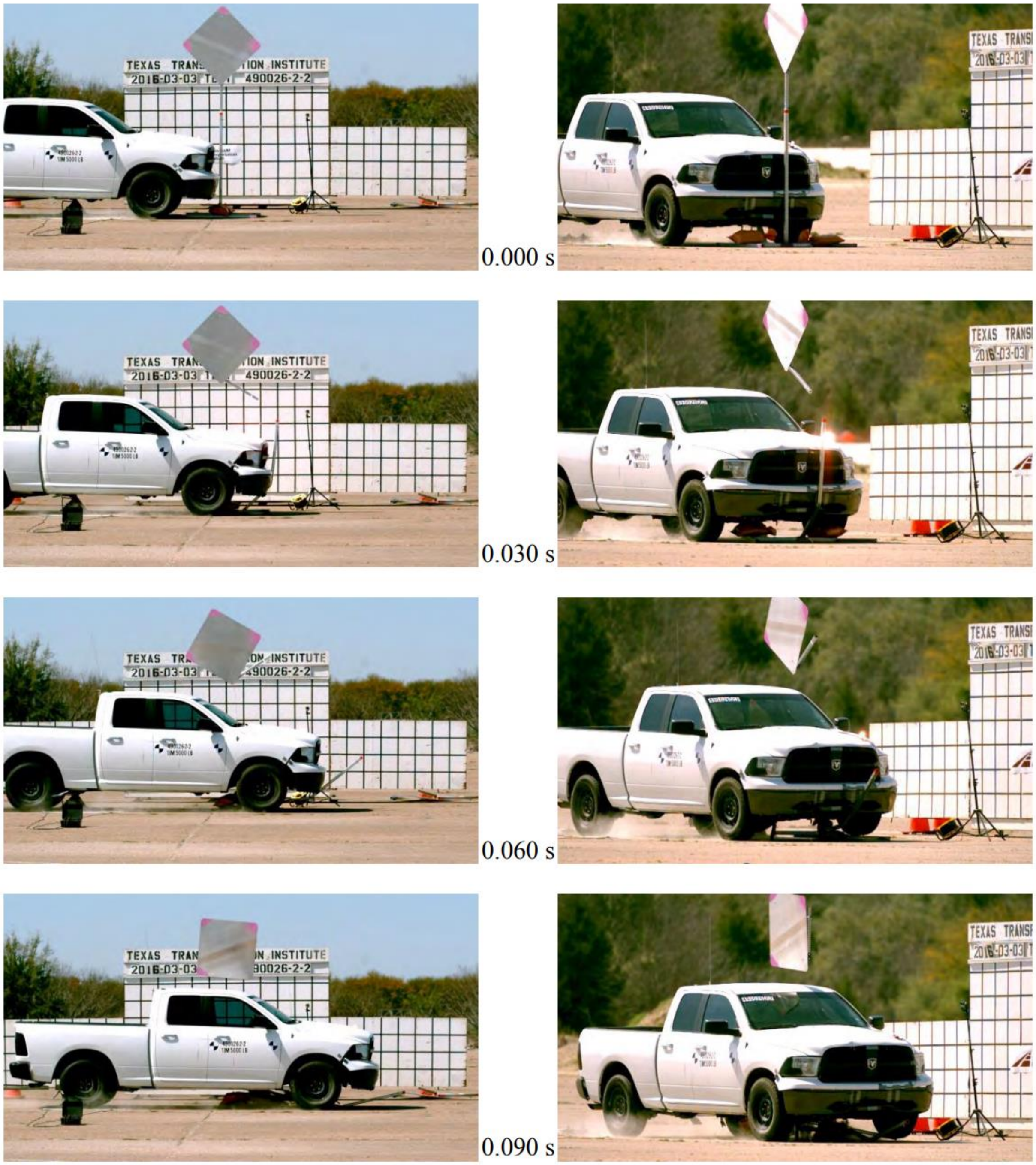


Figure 2.13. Temporary High-Mounting Sign Support, Option B Test 3-72, 90-degree Impact Sequential Photos (*2*)

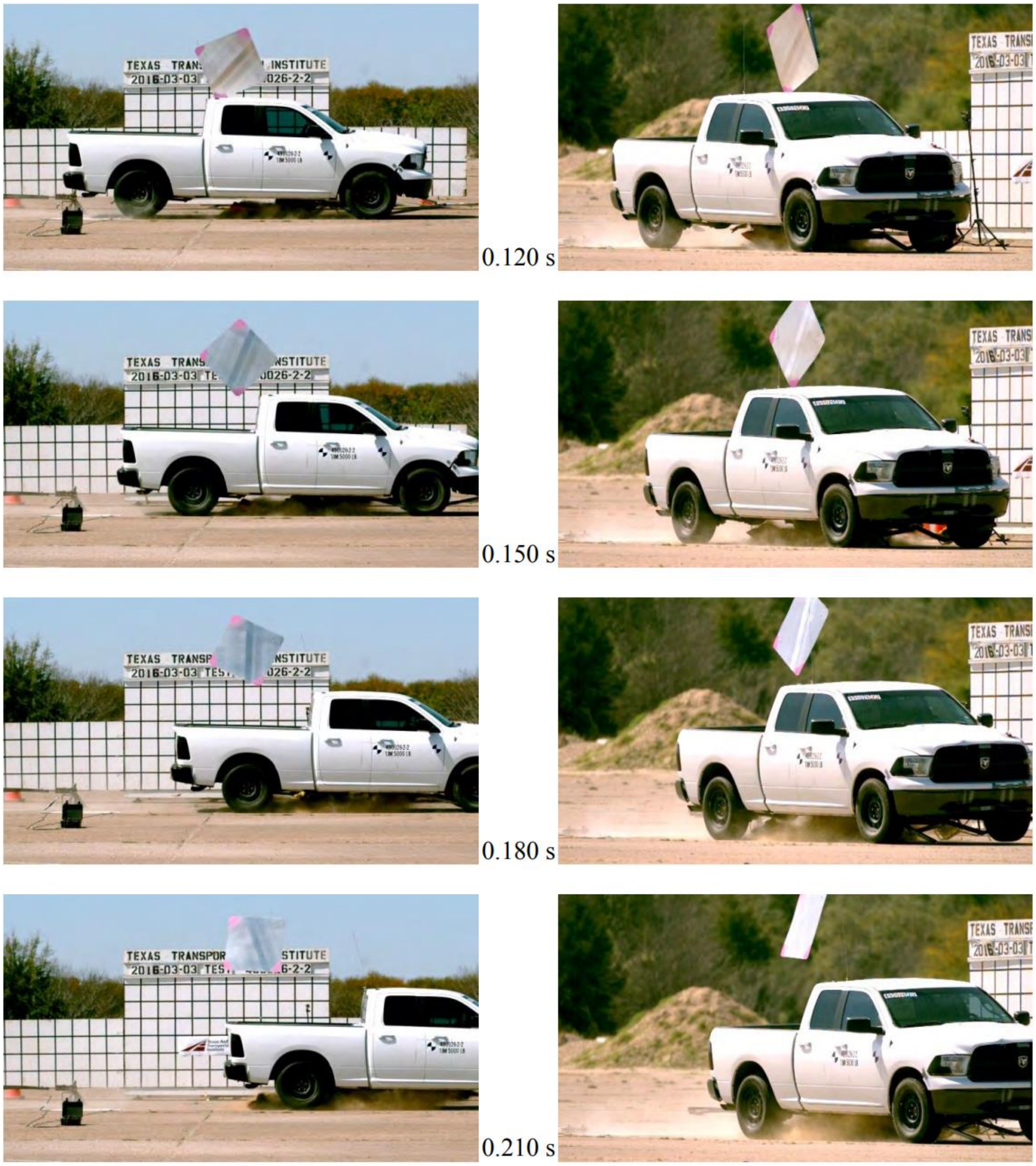


Figure 2.14. Temporary High-Mounting Sign Support, Option B Test 3-72, 90-degree Impact Sequential Photos (Continued) (*2*)

In *MASH* test 3-72 (test 4900026-2-2), the 2270P pickup truck contacted the Option B temporary work zone sign support 10 inches to the left of centerline of the vehicle at an impact angle of 90 degrees while traveling at an impact speed of 62.6 mi/h. The fuse plates connecting the middle and upper sections of the vertical support successfully activated. Figure 2.13 and Figure 2.14 present sequential photographs of the test. Figure 2.15 shows the damage to the Option B temporary work zone sign support.

Figure 2.15. Temporary High-Mounting Sign Support, Option B Test 3-72, 90-degree Impact System Damage (*2*)

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Figure 2.16. Temporary High-Mounting Sign Support, Option B Test 3-72, 90-degree Impact Vehicle Damage (*2*)

In *MASH* test 3-71 (test 4900026-2-4), the 1100C small car, traveling at an impact speed of 60.9 mi/h, contacted the Option B temporary work zone sign support 10 inches to the right of centerline of the vehicle at an impact angle of 90 degrees. The fuse plates connecting the middle and upper section of the support successfully activated. Figure 2.17 and Figure 2.18 present sequential photographs of the test. Figure 2.19 shows the damage to the Option B temporary work zone sign support. Figure 2.20 shows the damage sustained by the vehicle. No occupant compartment deformation or intrusion was noted.

Figure 2.17. Temporary High-Mounting Sign Support, Option B Test 3-71, 90-degree Impact Sequential Photos (*2*)

Figure 2.18. Temporary High-Mounting Sign Support, Option B Test 3-71, 90-degree Impact Sequential Photos (Continued) (*2*)

Figure 2.19. Temporary High-Mounting Sign Support, Option B Test 3-71, 90-degree Impact System Damage (*2*)

Figure 2.20. Temporary High-Mounting Sign Support, Option B Test 3-71, 90-degree Impact Vehicle Damage (*2*)

In *MASH* test 3-71 (test 4900026-2-6), the 1100C contacted the Option B temporary work zone sign support 10 inches to the right of centerline of the vehicle at an impact angle of 0 degrees while traveling at an impact speed of 61.7 mi/h. Figure 2.21 and Figure 2.22 present sequential photographs during the test. Figure 2.23 shows the damage to the Option B temporary work zone sign support. Figure 2.24 shows the damage sustained by the vehicle. No occupant compartment penetration, deformation, or intrusion was noted.

Figure 2.21. Temporary High-Mounting Sign Support, Option B Test 3-71, 0-degree Impact Sequential Photos (*2*)

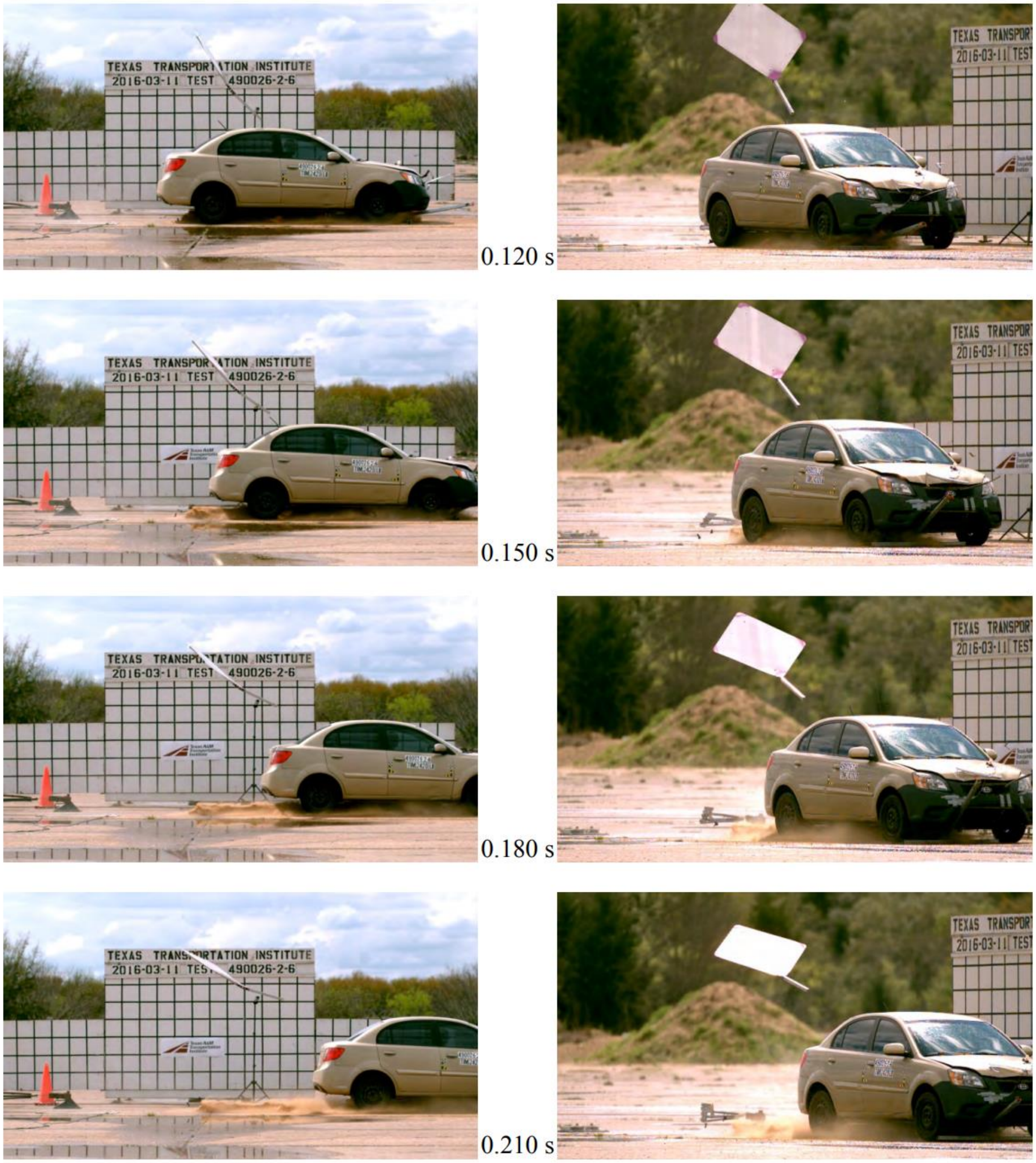


Figure 2.22. Temporary High-Mounting Sign Support, Option B Test 3-71, 0 degree Impact Sequential Photos (Continued) (*2*)

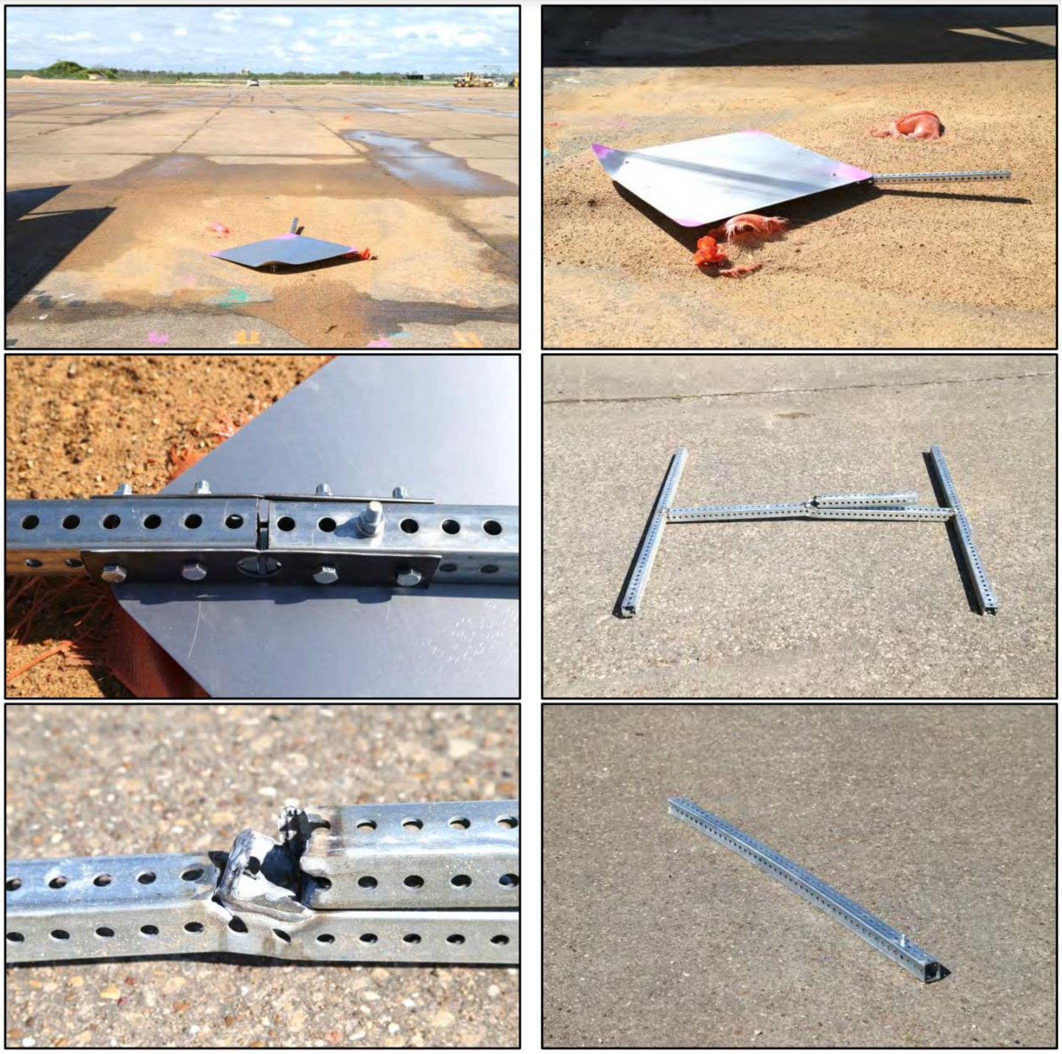


Figure 2.23. Temporary High-Mounting Sign Support, Option B Test 3-71, 0-degree Impact System Damage (*2*)

Figure 2.24. Temporary High-Mounting Sign Support, Option B Test 3-71, 0-degree Impact Vehicle Damage (*2*)

In *MASH* test 3-72 (test 4900026-2-8), The 2270P pickup truck contacted the Option B temporary work zone sign support 10 inches to the left of centerline of the vehicle at an impact angle of 0 degrees while traveling at an impact speed of 62.1 mi/h. Figure 2.25 and Figure 2.26 present sequential photographs during the test. Figure 2.27 shows the damage to the Option B temporary work zone sign support. Figure 2.28 shows the damage sustained by the vehicle. No occupant compartment deformation or intrusion was noted.

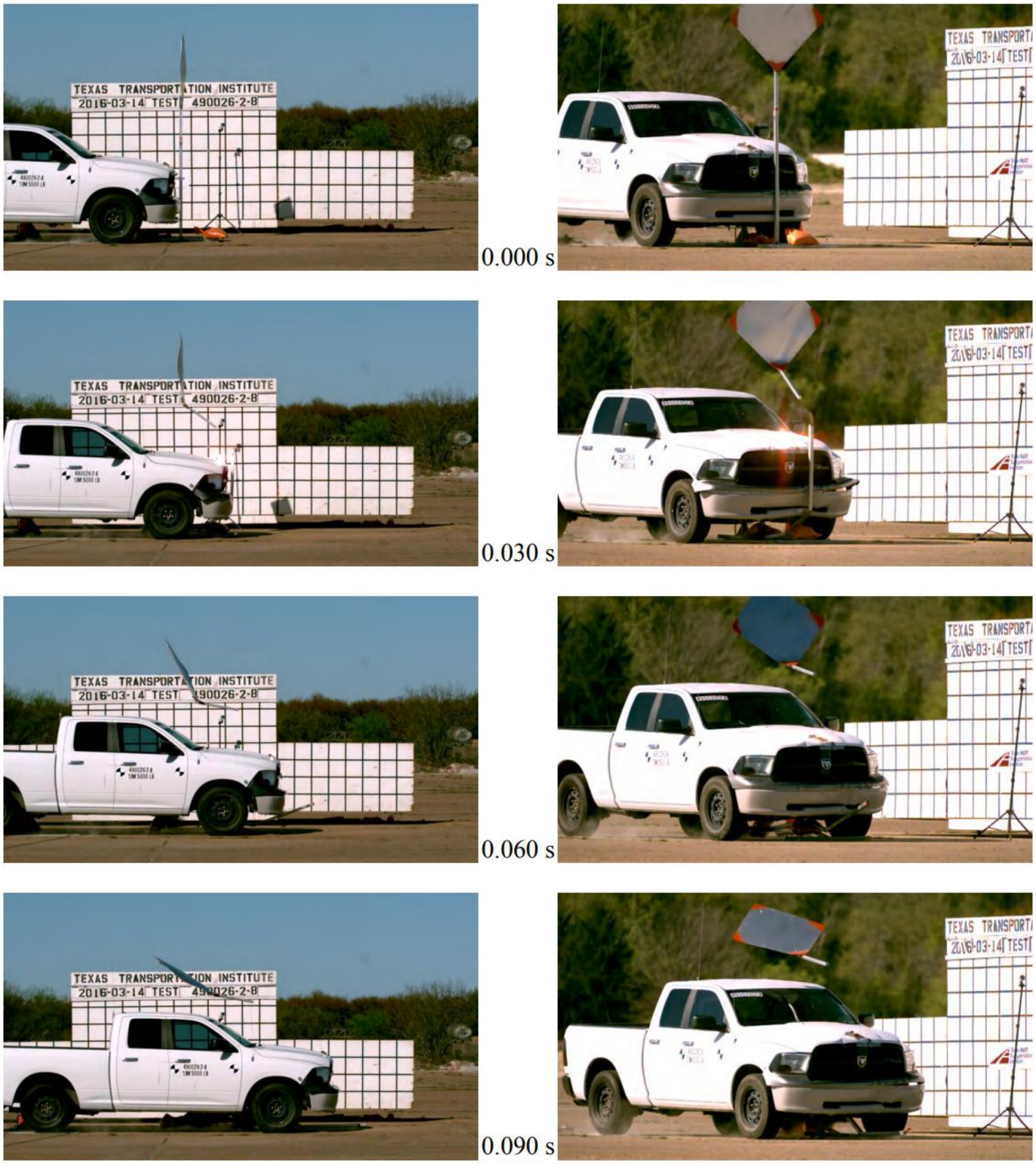


Figure 2.25. Temporary High-Mounting Sign Support, Option B Test 3-72, 0-degree Impact Sequential Photos (*2*)

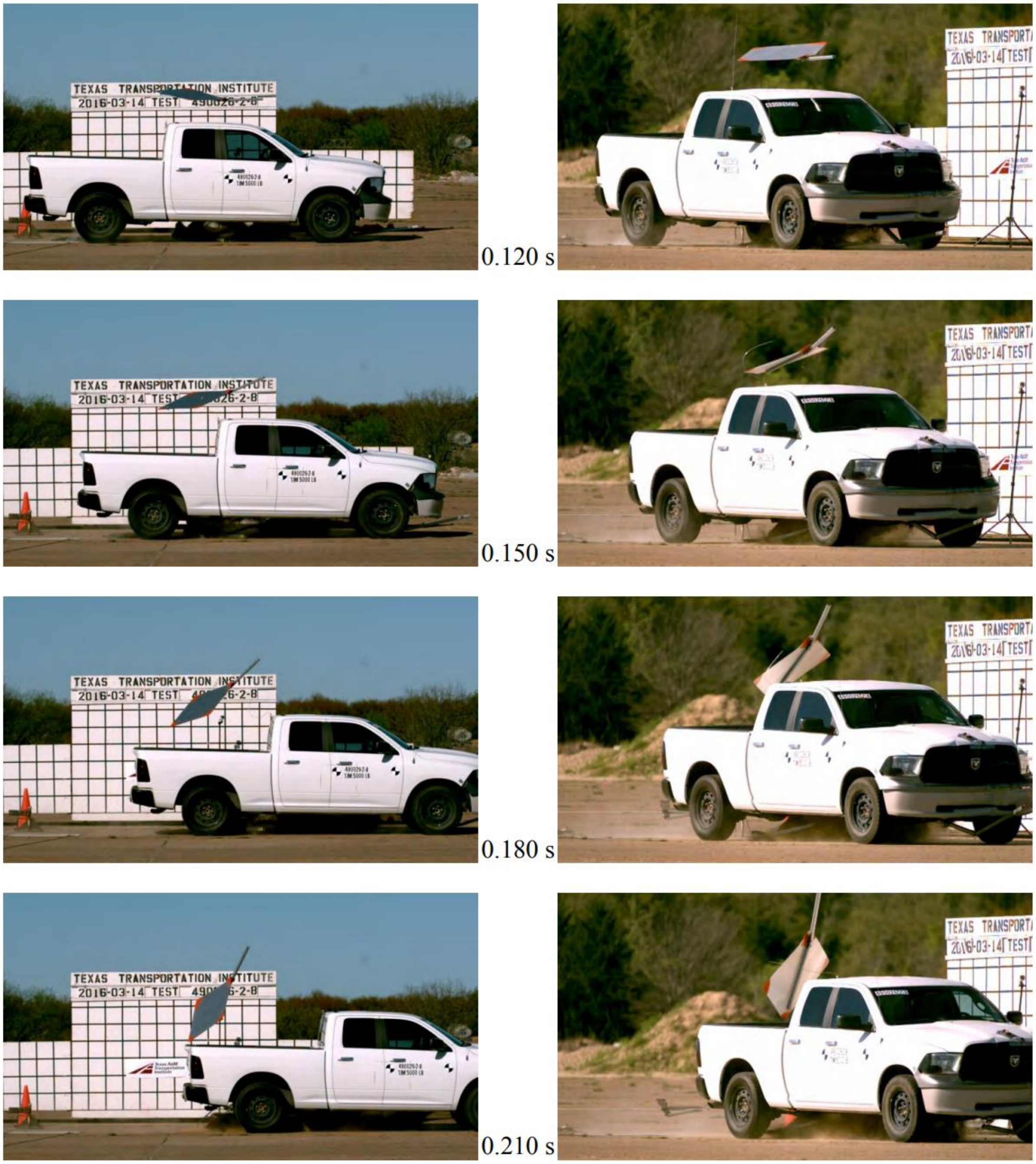


Figure 2.26. Temporary High-Mounting Sign Support, Option B Test 3-72, 0-degree Impact Sequential Photos (Continued) (*2*)

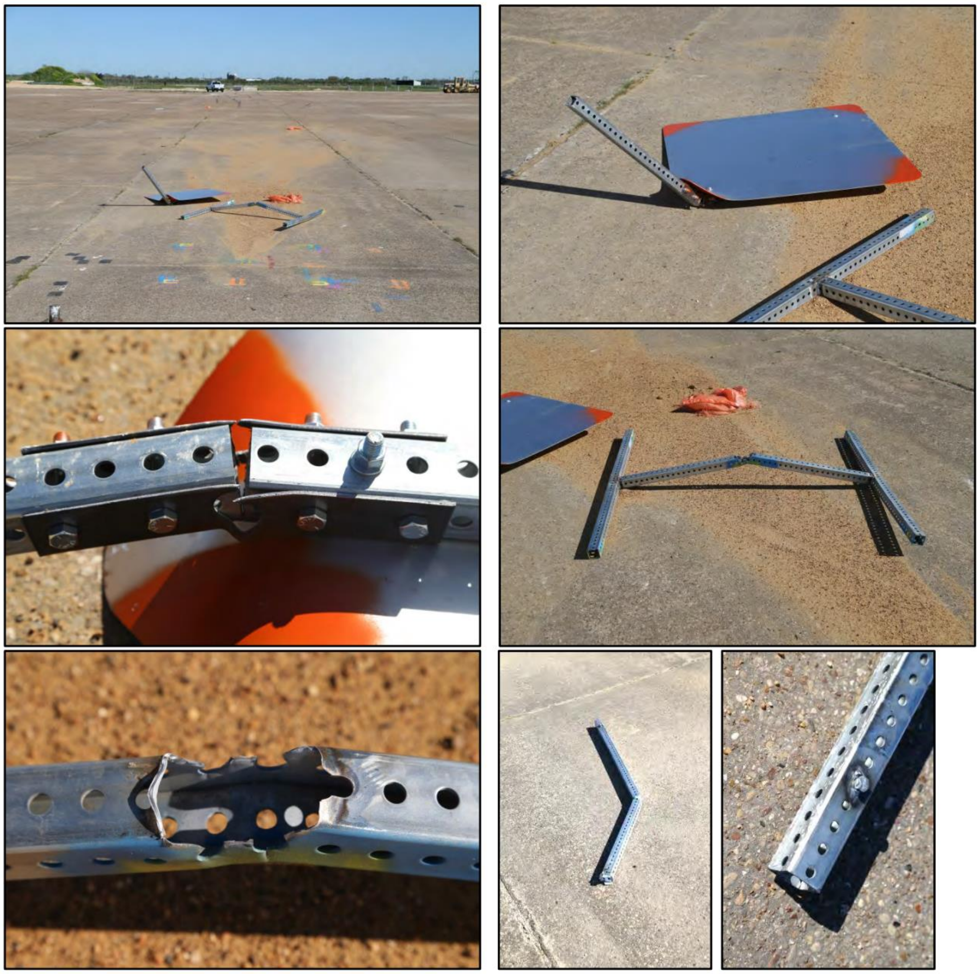


Figure 2.27. Temporary High-Mounting Sign Support, Option B Test 3-72, 0-degree Impact System Damage (*2*)

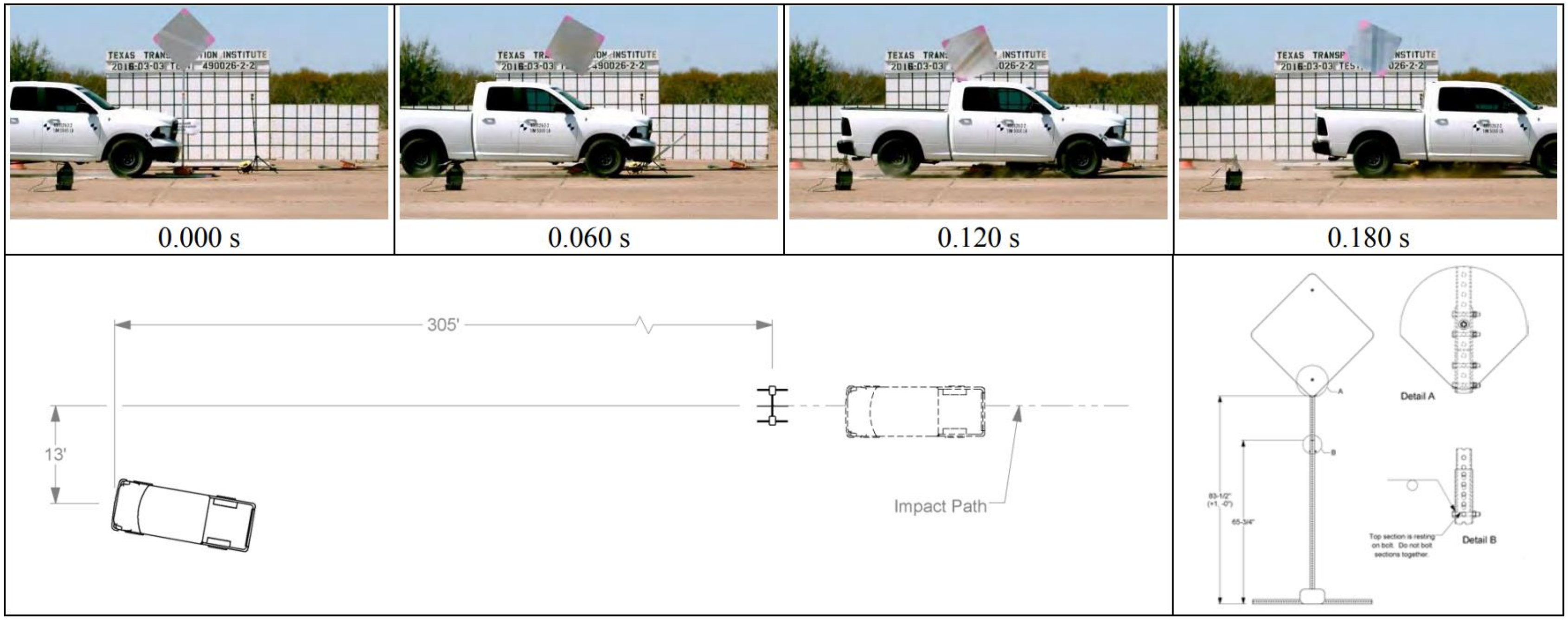
Figure 2.28. Temporary High-Mounting Sign Support, Option B Test 3-72, 0-degree Impact Vehicle Damage (*2*)

Figure 2.29 provides a summary of the results of test 3-72 with a 90-degree impact. The fuse plate between the upper and middle sections of the vertical support activated as designed. Although the sign panel impacted the roof, this contact did not result in any tear or penetration of the roof. The slight roof deformation that occurred was within MASH criteria.

Figure 2.30 provides a summary of the results of test 3-71 with a 90-degree impact. The fuse plate between the upper and middle sections of the vertical support activated as designed. There was no secondary contact between the sign panel and the roof of the vehicle.

Figure 2.31 provides a summary of the results of test 3-71 with a 0-degree impact. There was no secondary contact between the sign panel and the roof of the vehicle. Figure 2.32 provides a summary of the results of test 3-72 with a 0-degree impact. The lower section of the vertical support fractured but did not penetrate or show potential for penetrating the vehicle. No occupant compartment deformation or intrusion was noted.

The Option B design successfully met *MASH* evaluation criteria for tests 3-72 and 3-71 in both the 0 degree and 90 degree impact angles. Test 3-70 was not performed because of the *MASH* guidance regarding lightweight work zone products.



General Information
- Test Agency: Texas A&M Transportation Institute (TTI)
- Test Standard Test No.: MASH Test 3-72
- TTI Test No.: 490026-2-2
- Test Date: 2016-03-03

Test Article
- Type: Temporary Work Zone Sign Support
- Name: Option B Temporary Work Zone Sign Support
- Installation Height: 83½ inches to bottom of sign; 132⅝ to top

Material or Key Elements: Upper & middle sections joined with two opposing fuse plates; smaller 1½ inch middle section had telescopic slip joint inside 1 ¾ inch lower section of vertical support

Soil Type and Condition: Placed on dry concrete surface

Test Vehicle
- Type/Designation: 2270P
- Make and Model: 2010 Dodge Ram 1500
- Curb: 4898 lb
- Test Inertial: 5014 lb
- Dummy: No dummy
- Gross Static: 5014 lb

Impact Conditions
- Speed: 62.6 mi/h
- Angle: 90 degrees
- Location/Orientation: 10 inches left of centerline 655 kip-ft

Kinetic Energy: 61.6 mi/h

Exit Conditions: NA
- Speed: Assessment of
- Angle: occupant risk factors not

Occupant Risk Values: required for test articles of 58 lb

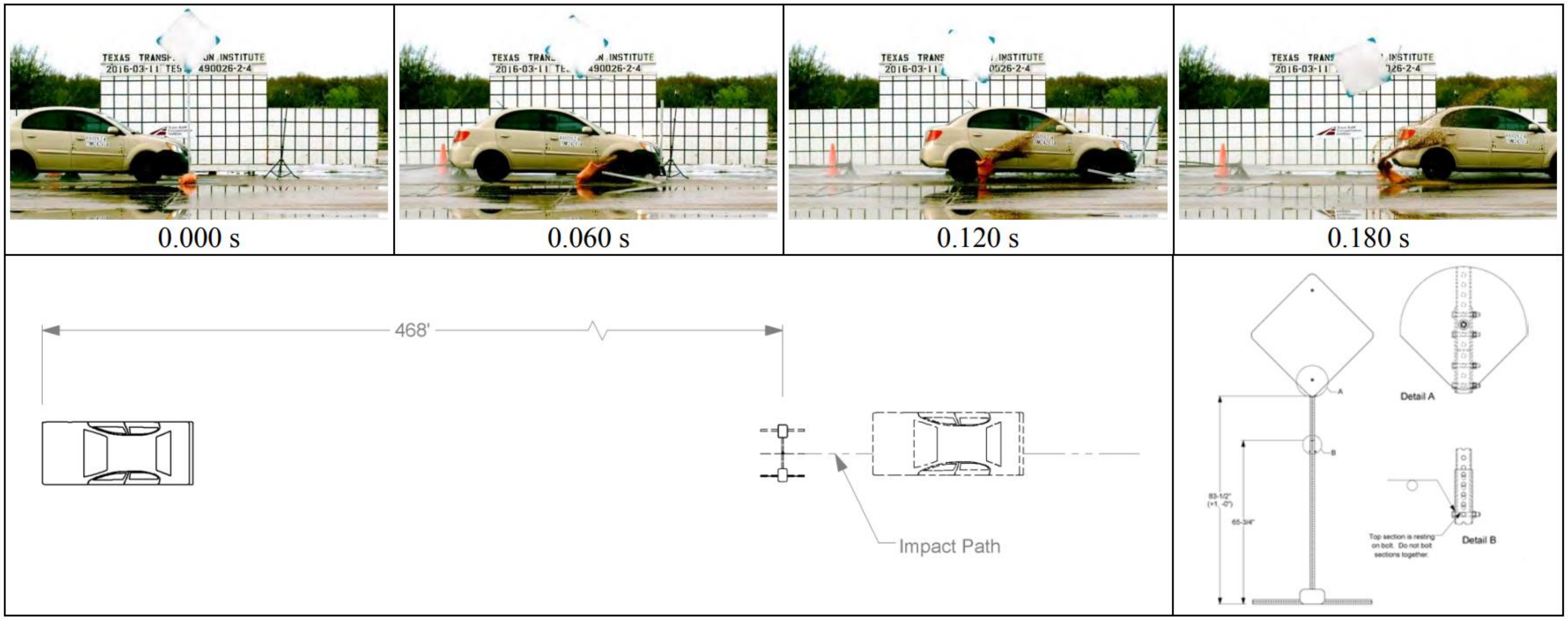
Test Article Debris Scatter
- Longitudinal: 108 downstream
- Lateral: 2 ft left – 6 ft right

Post-Impact Trajectory
- Stopping Distance: 305 ft downstream 13 ft left of center

Vehicle Stability
- Maximum Yaw Angle: Vehicle
- Maximum Pitch Angle: remained
- Maximum Roll Angle: upright
- Vehicle Snagging: No
- Vehicle Pocketing: No

Vehicle Damage
- VDS: 12FL1
- CDC: 12FLEN1
- Max. Exterior Deformation: 2.5 inches
- OCDI: RR0000000
- Max. Occupant Compartment Deformation: None

Figure 2.29. Temporary High-Mounting Sign Support, Option B Test 3-72, 90-degree Impact Results (*2*)



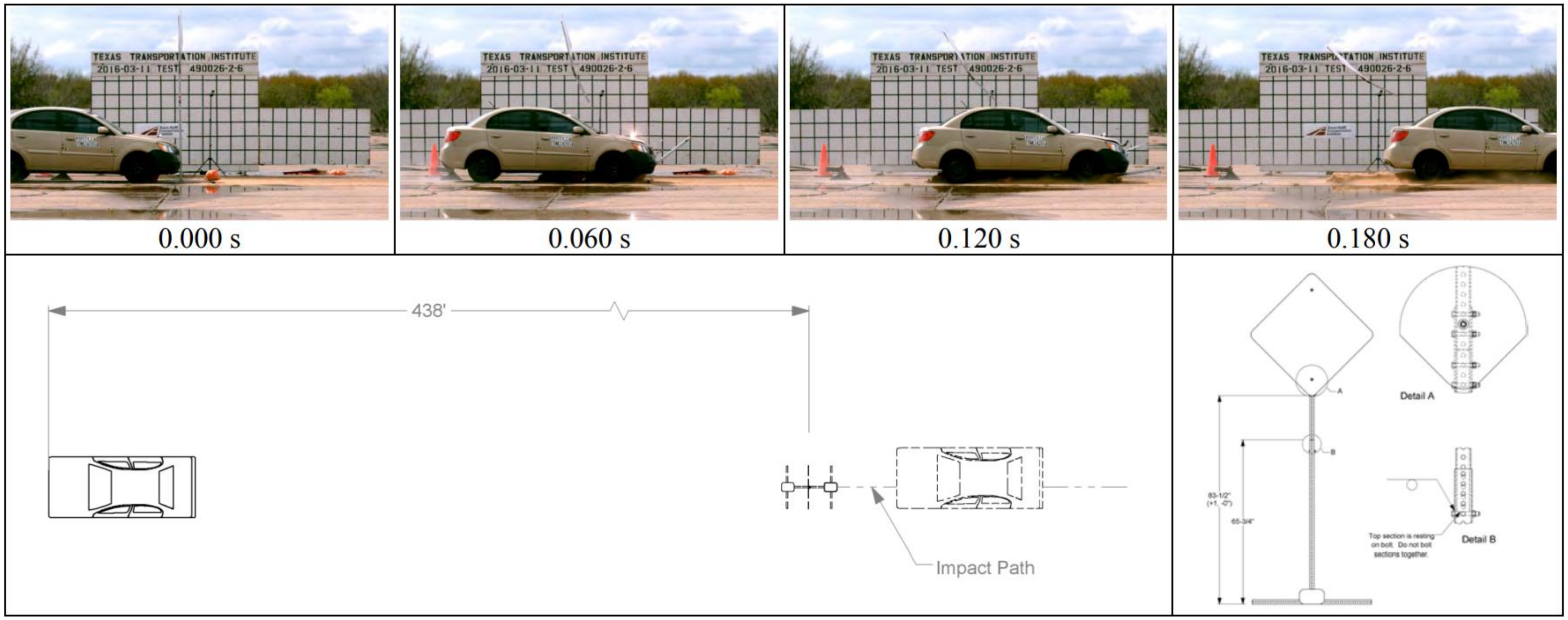
General Information
Test Agency........................ Texas A&M Transportation Institute (TTI)
Test Standard Test No......... MASH Test 3-71
TTI Test No. 490026-2-4
Test Date 2016-03-11

Test Article
Type .... Temporary Work Zone Sign Support
Name................................. Option B Temporary Work Zone Sign Support
Installation Height .... 83½ inches to bottom; 132⅝ to top
Material or Key Elements .... Upper & lower sections joined with two opposing fuse plates, Upper & middle sections joined with two opposing fuse plates; smaller 1½ inch middle section had telescopic slip joint inside 1 ¾ inch lower section of vertical support
Soil Type and Condition ...... Placed on dry concrete surface

Test Vehicle
Type/Designation 1100C
Make and Model ....2011 Kia Rio
Curb ....2479 lb
Test Inertial ....2443 lb
Dummy..........................165 lb
Gross Static...................2608 lb
Impact Conditions
Speed............................60.9 mi/h
Angle.............................90 degrees
Location/Orientation ......10 inches right of centerline 303 kip-ft
Kinetic Energy ....58.8 mi/h
Exit Conditions NA
Speed............................Assessment of occupant
Angle.............................risk factors not required
Occupant Risk Values....for test articles of 58 lb

Test Article Debris Scatter
Longitudinal ....483 downstream
Lateral ....Centerline
Post-Impact Trajectory
Stopping Distance......................468 ft downstream Centerline
Vehicle Stability
Maximum Yaw Angle.................Vehicle
Maximum Pitch Angle .... remained
Maximum Roll Angle.................. upright
Vehicle Snagging.......................No
Vehicle Pocketing ....No
Vehicle Damage
VDS...12FR1
CDC 12FREN1
Max. Exterior Deformation ....None
OCDI RF0000000
Max. Occupant Compartment Deformation...........................None

Figure 2.30. Temporary High-Mounting Sign Support, Option B Test 3-71, 90-degree Impact Results (*2*)



General Information
- Test Agency .... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. .... MASH Test 3-71
- TTI Test No. 490026-2-6
- Test Date 2016-03-11

Test Article
- Type .... Temporary Work Zone Sign Support
- Name .... Option B Temporary Work Zone Sign Support
- Installation Height .... 83½ inches to bottom; 132⅝ to top
- Material or Key Elements .... Upper & middle sections joined with two opposing fuse plates; smaller 1½ inch middle section had telescopic slip joint inside 1 ¾ inch lower section of vertical support

Soil Type and Condition .... Placed on dry concrete surface

Test Vehicle
- Type/Designation 1100C
- Make and Model .... 2011 Kia Rio
- Curb .... 2479 lb
- Test Inertial .... 2443 lb
- Dummy .... 165 lb
- Gross Static .... 2608 lb

Impact Conditions
- Speed .... 61.7 mi/h
- Angle .... 0 degrees
- Location/Orientation .... 10 inches right of centerline 311 kip-ft

Kinetic Energy .... 59.7 mi/h

Exit Conditions NA
- Speed .... Assessment of occupant
- Angle .... risk factors not required

Occupant Risk Values .... for test articles of 58 lb

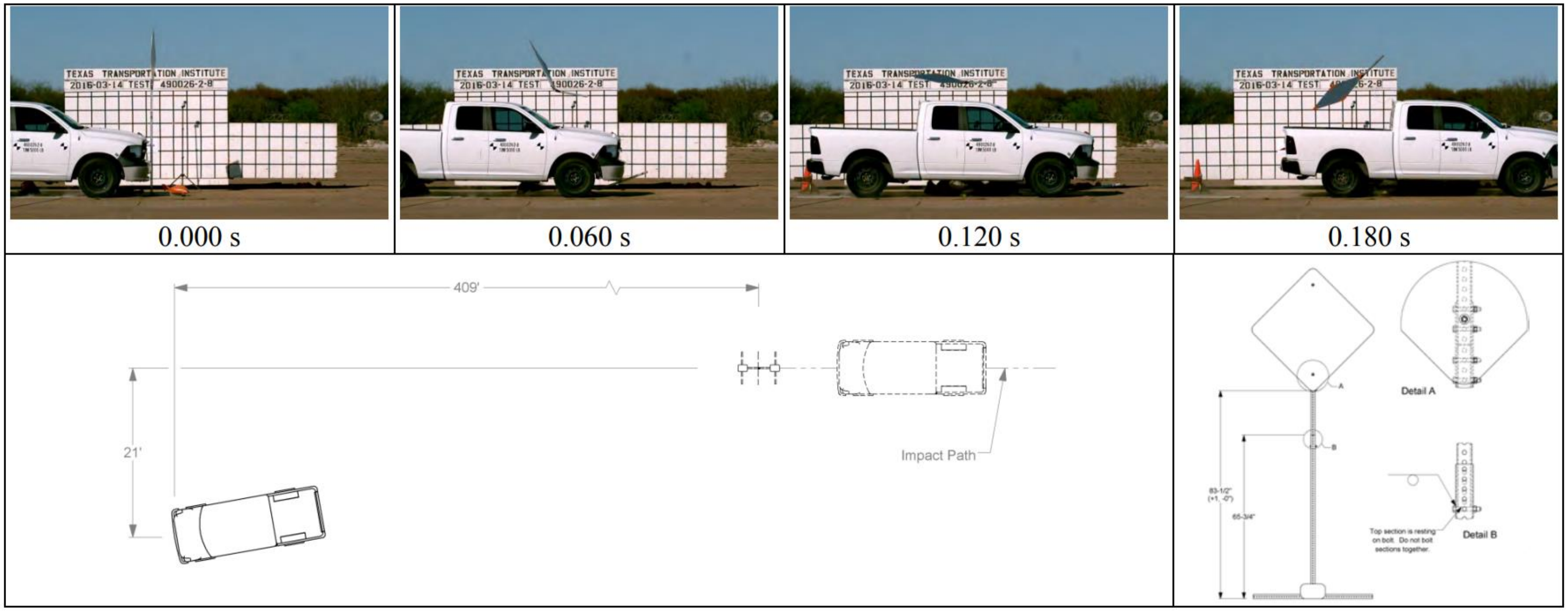
Test Article Debris Scatter
- Longitudinal .... 185 ft downstream
- Lateral .... 12 ft right of center

Post-Impact Trajectory
- Stopping Distance .... 438 ft downstream Centerline

Vehicle Stability
- Maximum Yaw Angle .... Vehicle
- Maximum Pitch Angle .... remained
- Maximum Roll Angle .... upright
- Vehicle Snagging .... No
- Vehicle Pocketing .... No

Vehicle Damage
- VDS 12FR1
- CDC 12FREN1
- Max. Exterior Deformation .... None
- OCDI RF0000000
- Max. Occupant Compartment Deformation .... None

Figure 2.31. Temporary High-Mounting Sign Support, Option B Test 3-71, 0-degree Impact Results (*2*)



General Information
Test Agency .... Texas A&M Transportation Institute (TTI)
Test Standard Test No. .... MASH Test 3-72
TTI Test No. 490026-2-8
Test Date 2016-03-14

Test Article
Type .... Temporary Work Zone Sign Support
Name .... Option B Temporary Work Zone Sign Support
Installation Height .... 83½ inches to bottom; 132⅝ to top
Material or Key Elements .... Upper & middle sections joined with two opposing fuse plates; smaller 1½ inch middle section had telescopic slip joint inside 1 ¾ inch lower section of vertical support ,
Soil Type and Condition .... Placed on dry concrete surface

Test Vehicle
Type/Designation 2270P
Make and Model .... 2010 Dodge Ram 1500
Curb .... 4898 lb
Test Inertial .... 5014 lb
Dummy .... No dummy
Gross Static .... 5014 lb

Impact Conditions
Speed .... 62.1 mi/h
Angle .... 0 degrees
Location/Orientation .... 10 inches left of centerline
Kinetic Energy .... 646 kip-ft
Exit Conditions
Speed .... 61.1 mi/h
Angle .... NA
Occupant Risk Values .... Assessment of occupant risk factors not required for test articles of 58 lb

Test Article Debris Scatter
Longitudinal .... 125 downstream
Lateral .... 15 ft left of center
3 ft right of center
Post-Impact Trajectory
Stopping Distance .... 409 ft downstream
21 ft left of center
Vehicle Stability
Maximum Yaw Angle .... Vehicle
Maximum Pitch Angle .... remained
Maximum Roll Angle .... upright
Vehicle Snagging .... No
Vehicle Pocketing .... No
Vehicle Damage
VDS 01FL1
CDC 01FLEN1
Max. Exterior Deformation .... 4.0 inches
OCDI FR0000000
Max. Occupant Compartment Deformation .... None

Figure 2.32. Temporary High-Mounting Sign Support, Option B Test 3-72, 0-degree Impact Results (*2*)

2.2.3. Temporary High-Mounting Height Sign Support– High Slip Joint Operation (Option C) (*2*)

The Option C test installation consisted of an aluminum sign mounted on a two-piece vertical support fabricated from 1¾-inch and 1½-inch, 12-gauge PSST. The aluminum sign panel measured 36 inches square and was 0.100-inch thick. The H-shaped base comprised of three sections of 1¾-inch PSST. Two 40-lbs sandbags were placed on top of the H-shaped base, one at the midpoint of each leg. The approximate total weight of each test assembly was 57 lbs, exclusive of two 40-lbs sandbags.

The upper section of the vertical support was comprised of a 1½-inch, 12-gauge PSST. The upper section rested on a smooth pin located in the holes 4½ inches below the top end of the lower section. The pin was welded to one side of the lower section. Figure 2.33, Figure 2.34, and Figure 2.35 show details of the Option C temporary work zone sign and post installation.

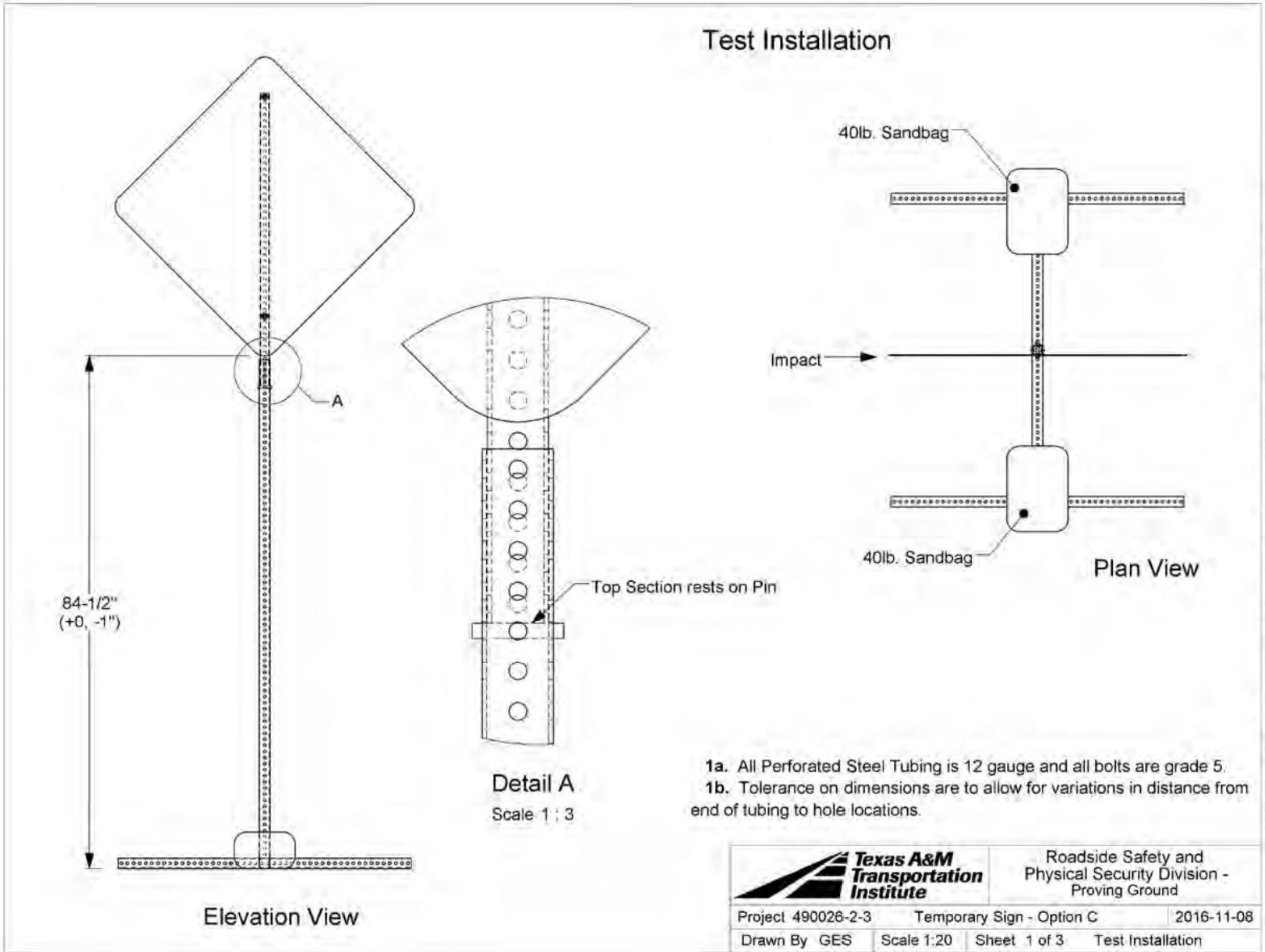


Figure 2.33. Specifications of Temporary High-Mounting Sign Support, Option C (*2*)

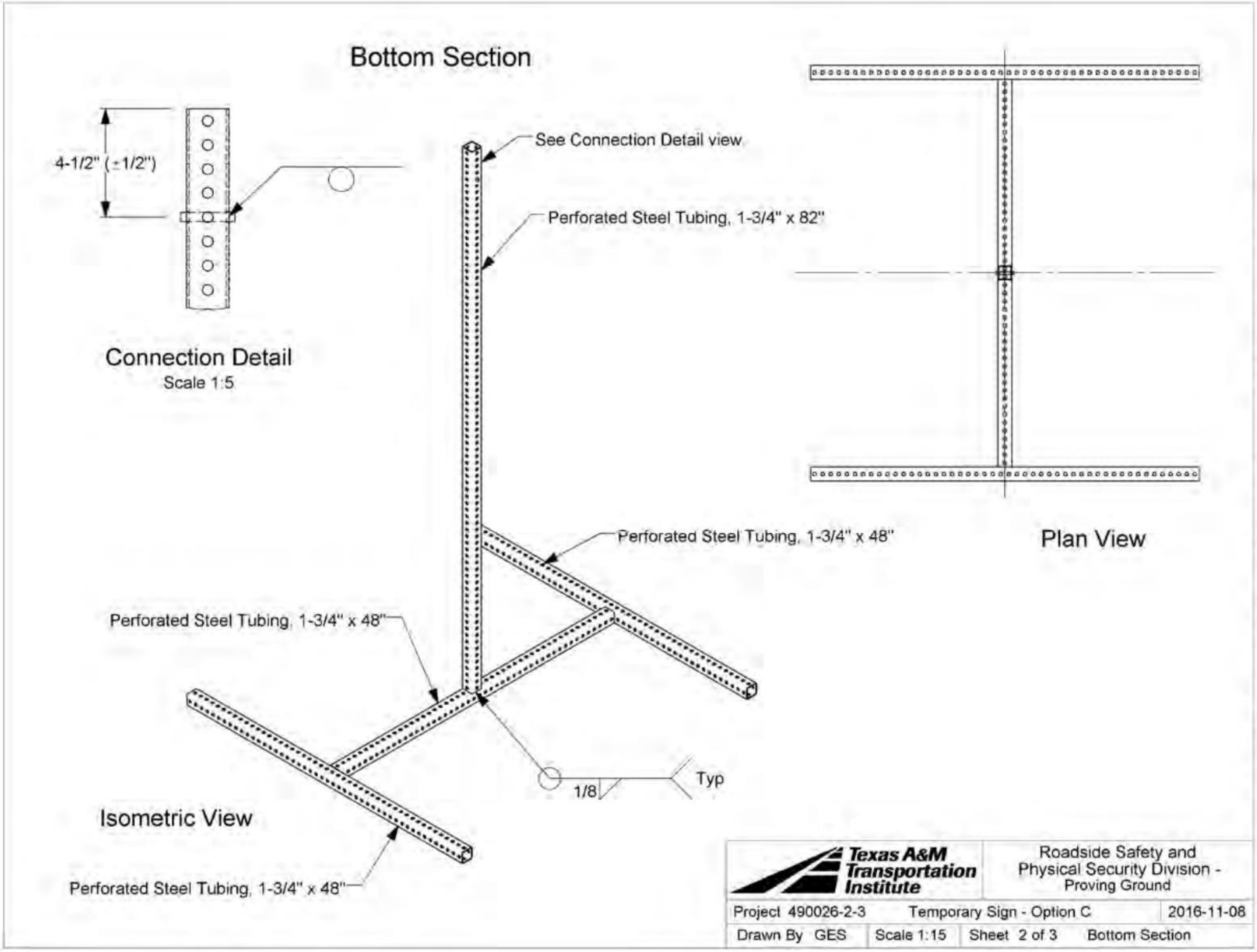


Figure 2.34. Specifications of Temporary High-Mounting Sign Support, Option C (Continued) (*2*)

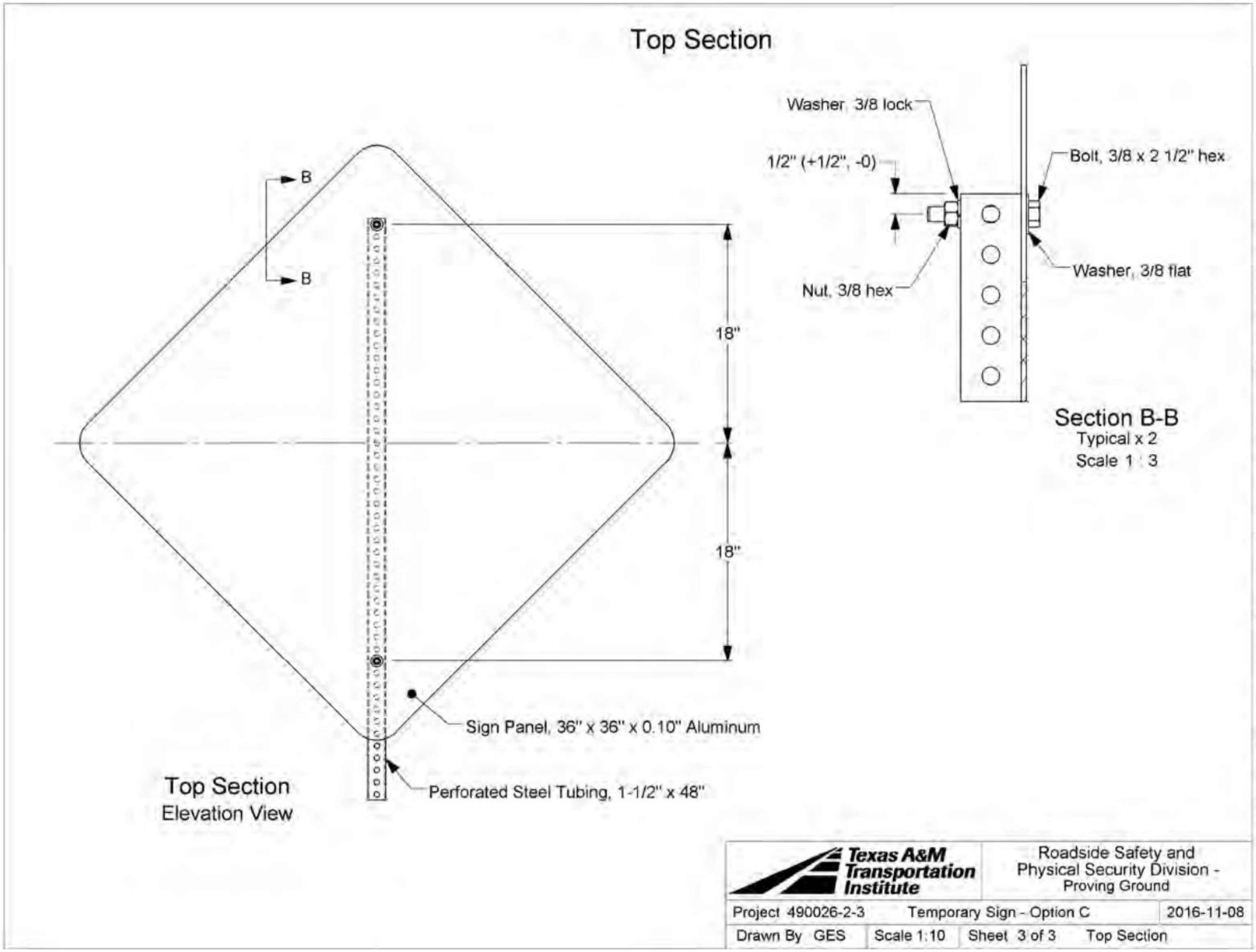


Figure 2.35. Specifications of Temporary High-Mounting Sign Support, Option C (Continued) (*2*)

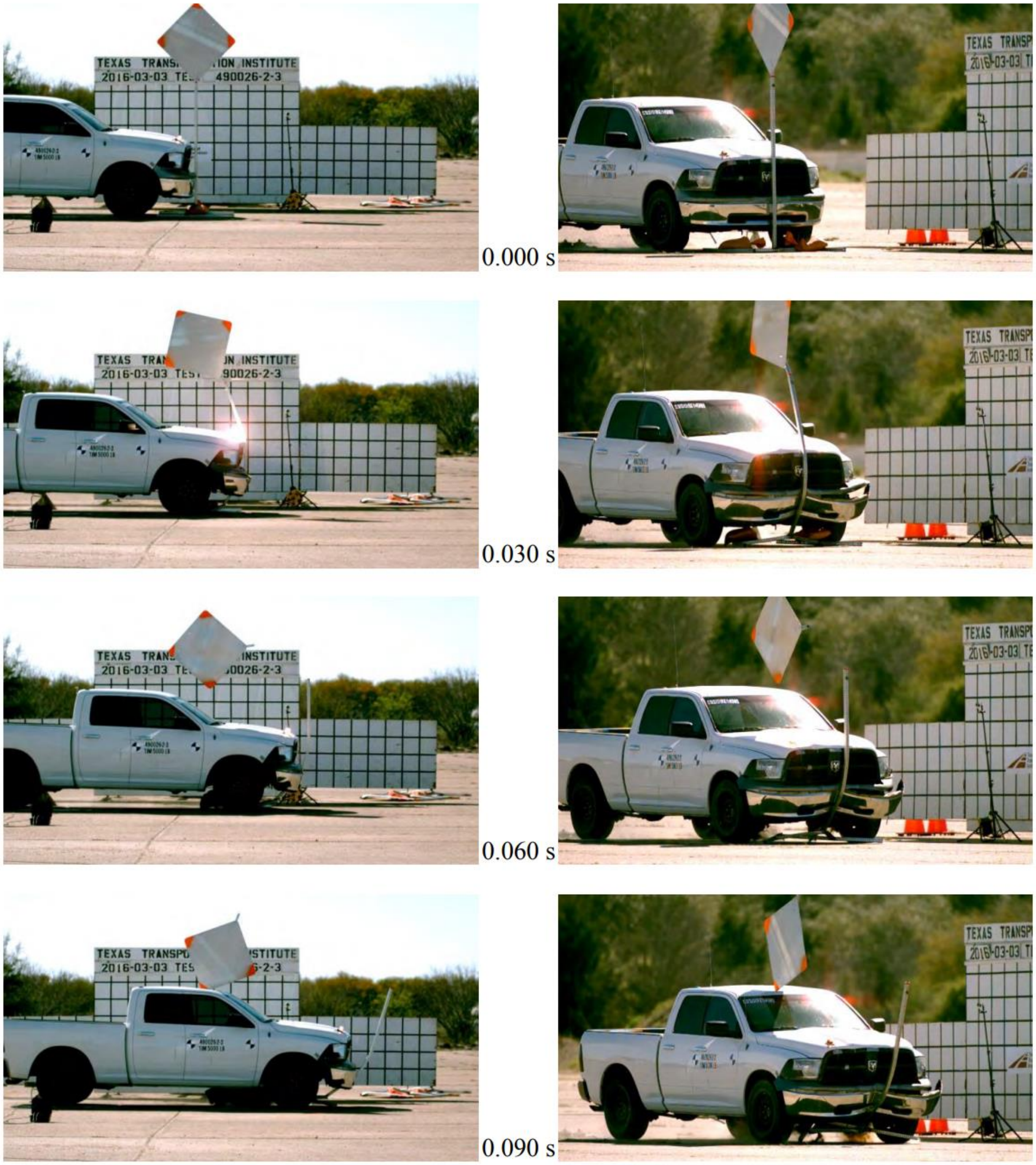


Figure 2.36. Temporary High-Mounting Sign Support, Option C Test 3-72, 90-degree Impact Sequential Photos (*2*)

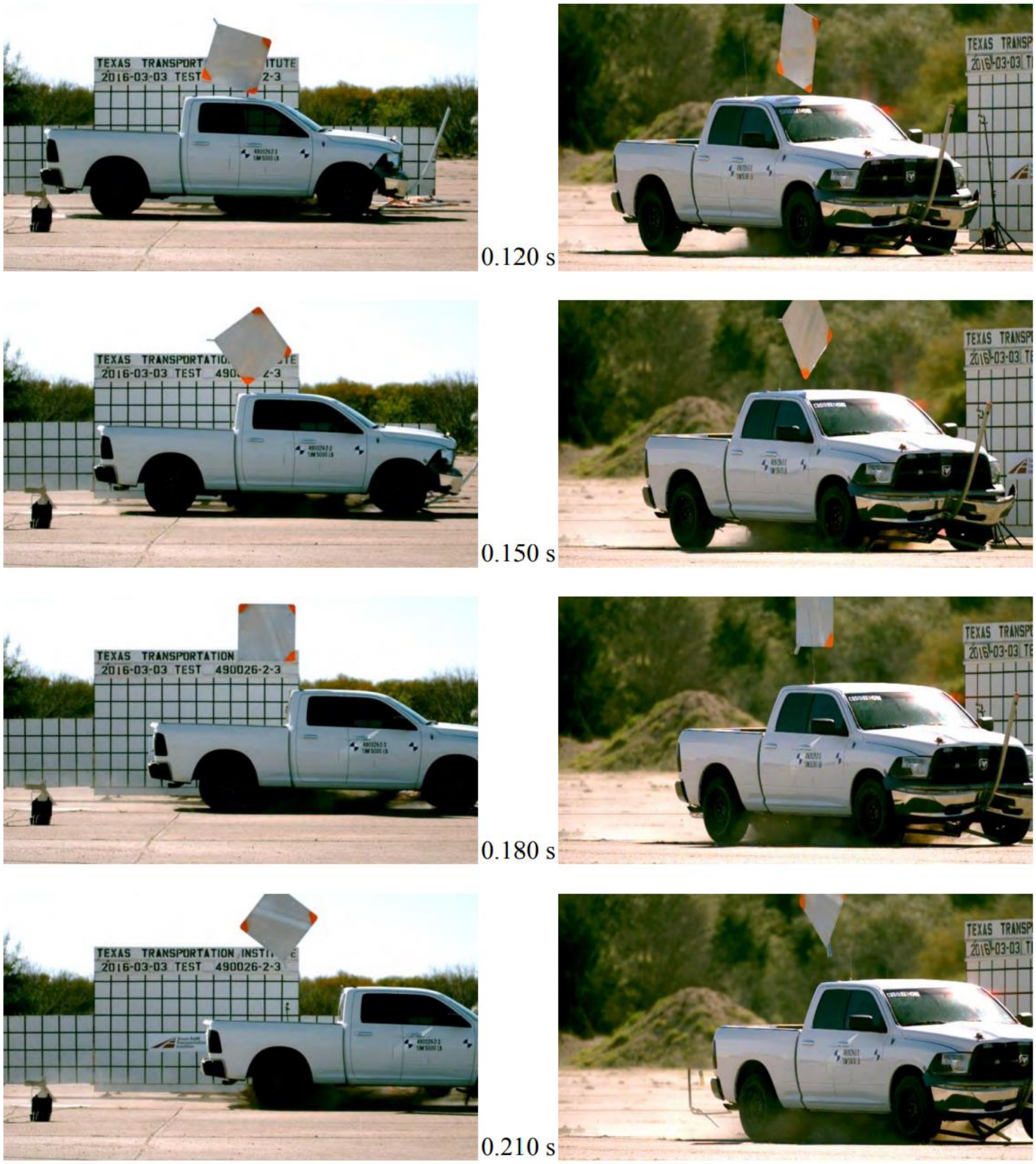


Figure 2.37. Temporary High-Mounting Sign Support, Option C Test 3-72, 90-degree Impact Sequential Photos (Continued) (*2*)

In *MASH* test 3-72 (test 4900026-2-3), the 2270P pickup truck, traveling at an impact speed of 62.5 mi/h, contacted the Option C temporary work zone sign support with the centerline of the front bumper at an impact angle of 90 degrees. Figure 2.36 and Figure 2.37 present sequential photographs during the test. Figure 2.38 shows the damage to the Option C temporary work zone sign support. Figure 2.39 shows the damage sustained by the vehicle. There was a 3-inch-long dent on the outer surface of the front of the roof of the cab, but no occupant compartment deformation or intrusion was noted.

Figure 2.38. Temporary High-Mounting Sign Support, Option C Test 3-72, 90-degree Impact System Damage (*2*)

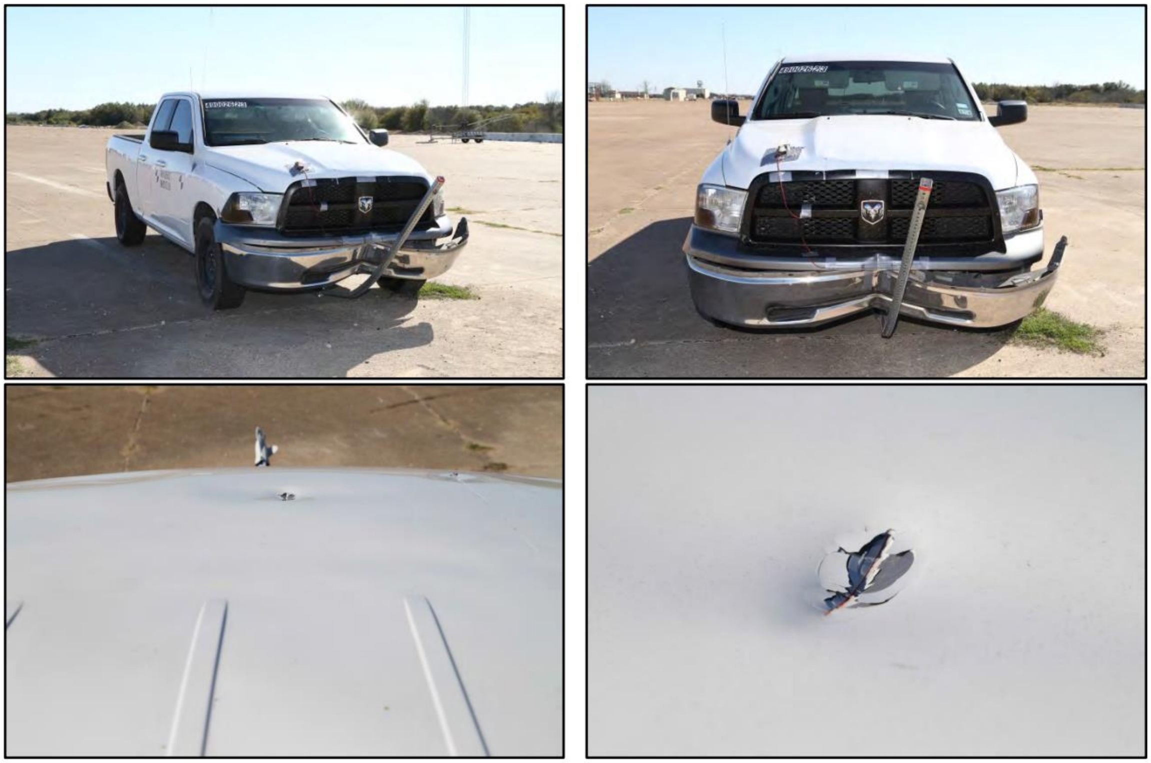


Figure 2.39. Temporary High-Mounting Sign Support, Option C Test 3-72, 90-degree Impact Vehicle Damage (*2*)

In *MASH* test 3-71 (test 4900026-2-5), the 1100C small car, traveling at an impact speed of 61.5 mi/h, contacted the Option C temporary work zone sign support 10 inches to the left of centerline of the vehicle at an impact angle of 90 degrees. Figure 2.40 and Figure 2.41 present sequential photographs of the test. Figure 2.42 shows the damage to the Option C temporary work zone sign support. Figure 2.43 shows the damage sustained by the vehicle. The 1100C vehicle sustained only scrapes to the bumper and hood with no measurable exterior vehicle deformation. No occupant compartment deformation or intrusion was noted.

Figure 2.40. Temporary High-Mounting Sign Support, Option C Test 3-71, 90-degree Impact Sequential Photos (*2*)

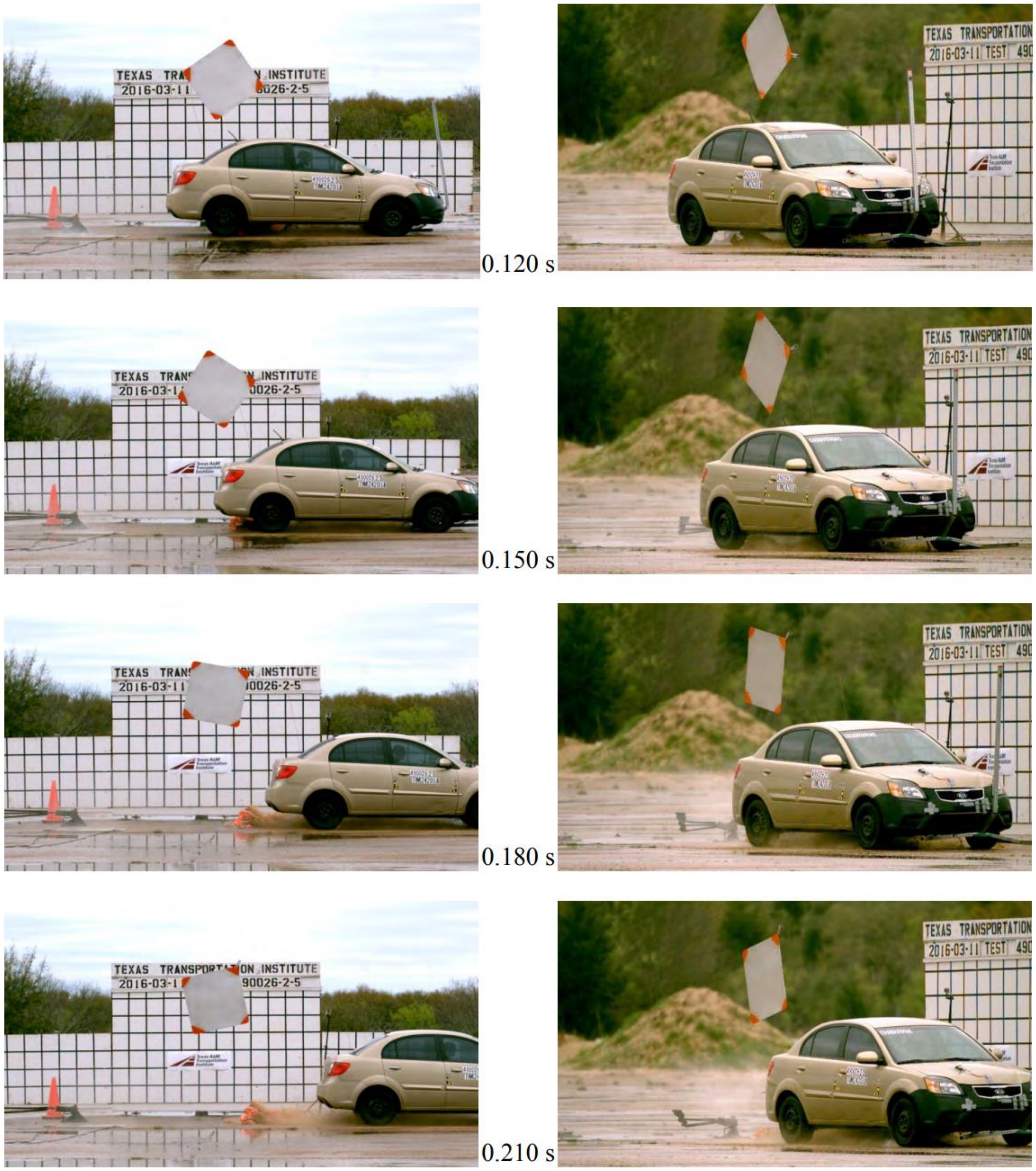


Figure 2.41. Temporary High-Mounting Sign Support, Option C Test 3-71, 0-degree Impact Sequential Photos (Continued) (*2*)

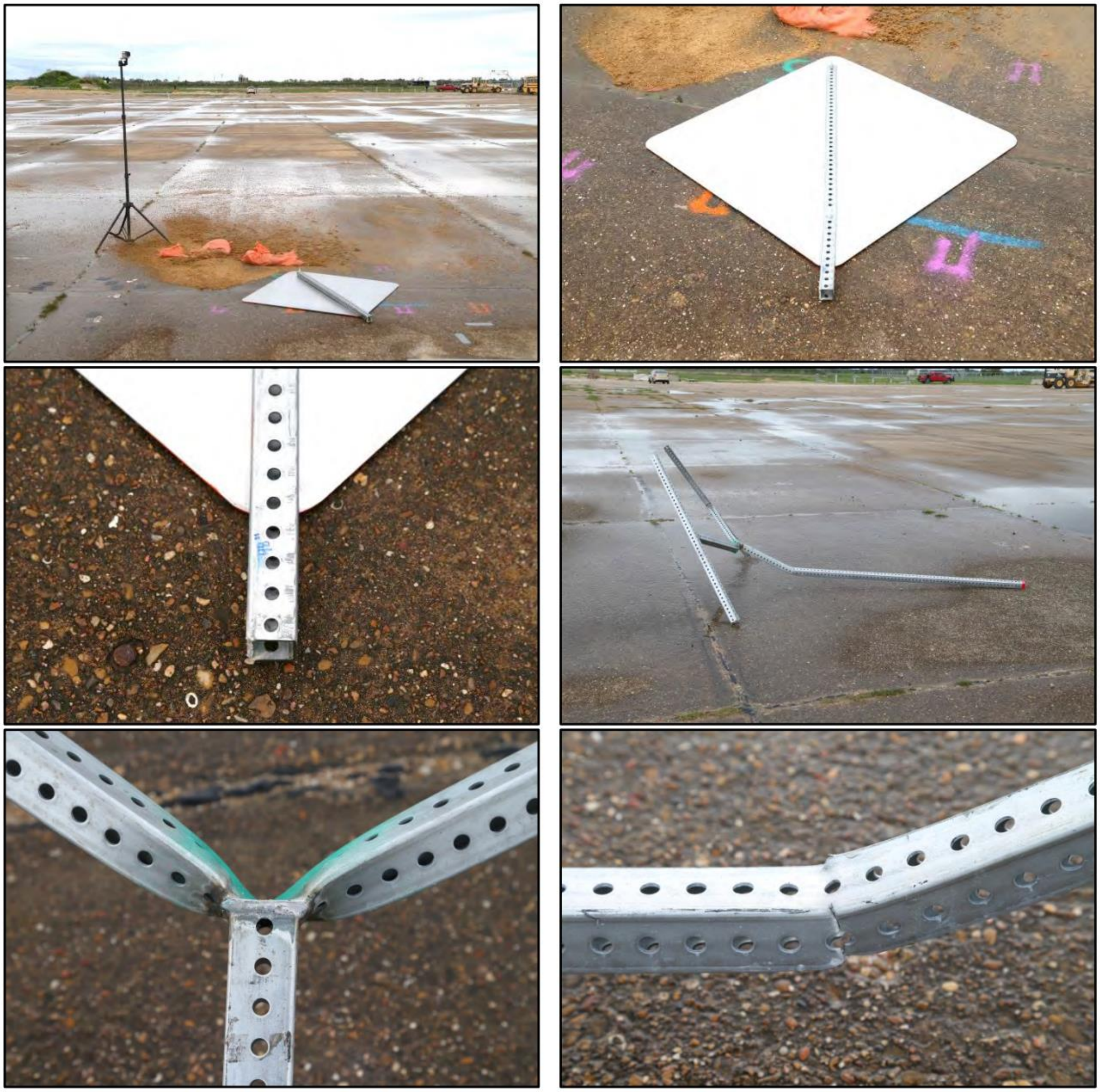


Figure 2.42. Temporary High-Mounting Sign Support, Option C Test 3-71, 90-degree Impact System Damage (*2*)

Figure 2.43. Temporary High-Mounting Sign Support, Option C Test 3-71, 90-degree Impact Vehicle Damage (*2*)

In *MASH* test 3-71 (test 4900026-2-7), the 1100C small car, traveling at an impact speed of 61.9 mi/h, contacted the Option C temporary work zone sign support 10 inches to the left of centerline of the vehicle at an impact angle of 0 degrees. Figure 2.44 and Figure 2.45 present sequential photographs during the test. Figure 2.46 shows the damage to the Option C temporary work zone sign support. Figure 2.47 shows the damage sustained by the vehicle. The 1100C vehicle sustained only scrapes to the bumper and hood with no measurable exterior vehicle deformation. No occupant compartment deformation or intrusion was noted.

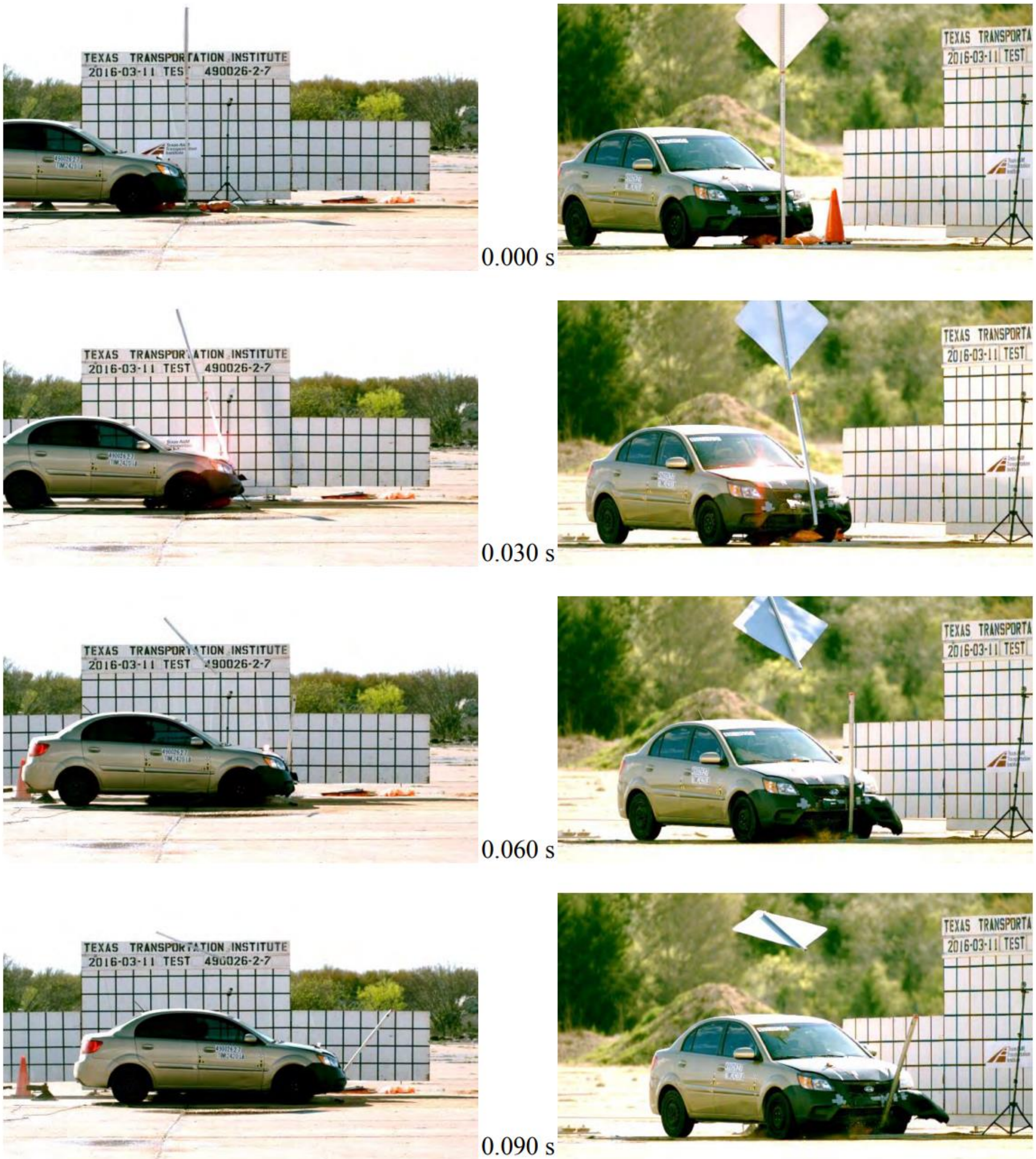


Figure 2.44. Temporary High-Mounting Sign Support, Option C Test 3-71, 0-degree Impact Sequential Photos (*2*)

Figure 2.45. Temporary High-Mounting Sign Support, Option C Test 3-71, 0-degree Impact Sequential Photos (Continued) (*2*)

Figure 2.46. Temporary High-Mounting Sign Support, Option C Test 3-71, 0-degree Impact System Damage (*2*)

Figure 2.47. Temporary High-Mounting Sign Support, Option C Test 3-71, 0-degree Impact Vehicle Damage (*2*)

In *MASH* test 3-72 (test 4900026-2-9), the 2270P pickup truck, traveling at an impact speed of 62.9 mi/h, contacted the Option C temporary work zone sign support 10 inches to the left of centerline of the vehicle at an impact angle of 0 degrees. Figure 2.48 and Figure 2.49 present sequential photographs of the test. Figure 2.50 shows the damage to the Option C temporary work zone sign support. Figure 2.51 shows the damage sustained by the vehicle. No occupant compartment deformation or intrusion was noted.

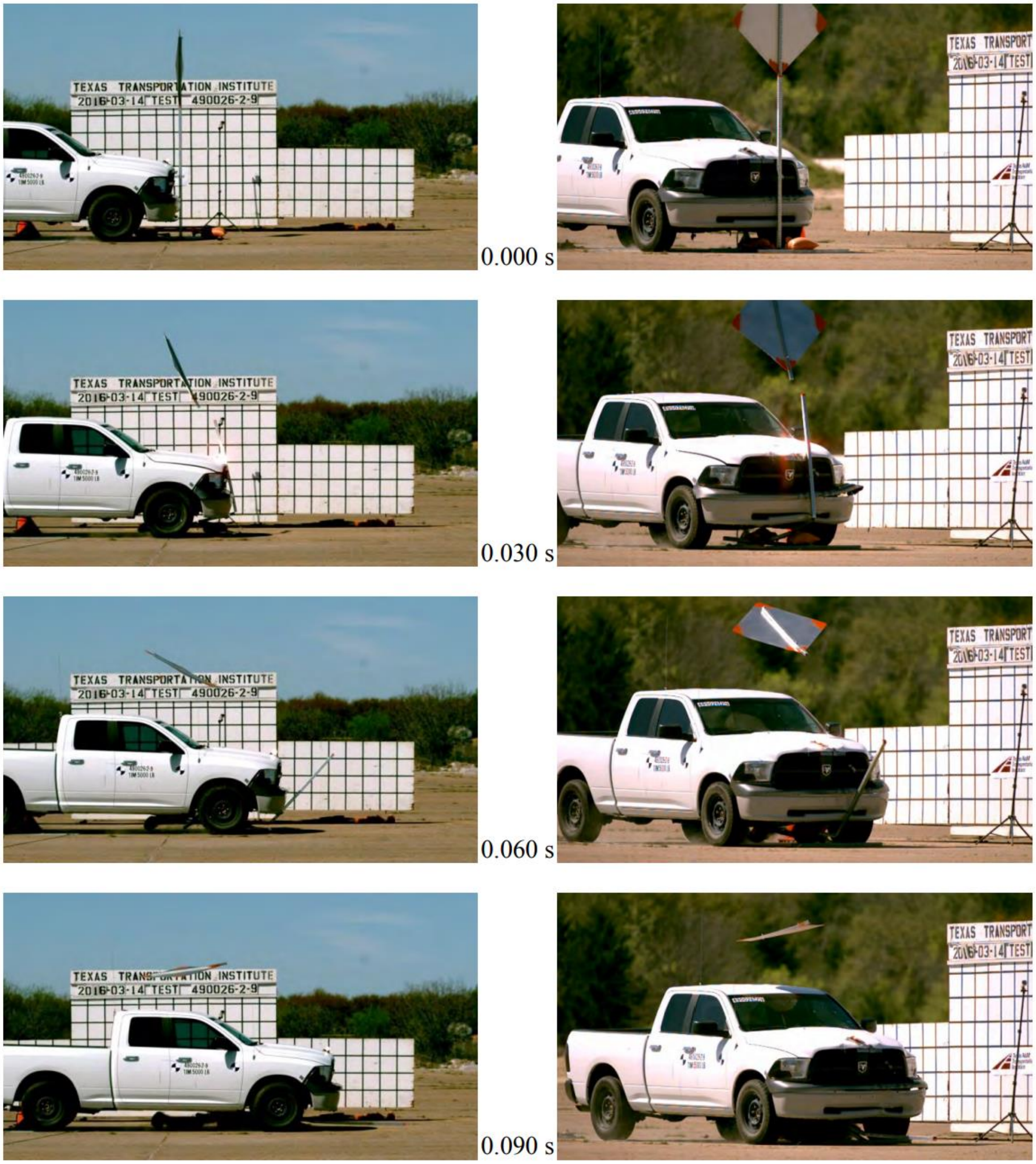


Figure 2.48. Temporary High-Mounting Sign Support, Option C Test 3-72, 0-degree Impact Sequential Photos (*2*)

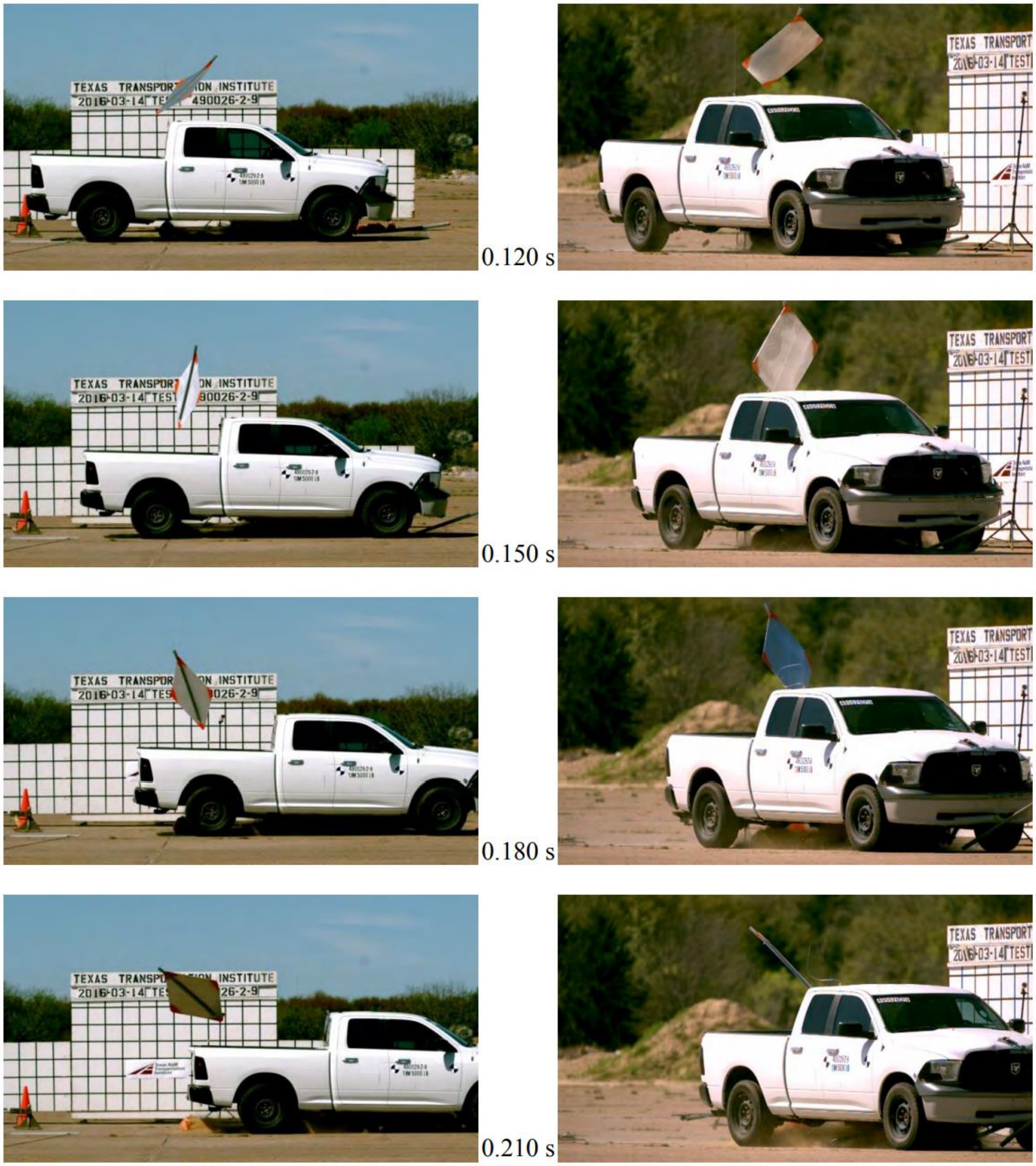


Figure 2.49. Temporary High-Mounting Sign Support, Option C Test 3-72, 0-degree Impact Sequential Photos (Continued) (*2*)

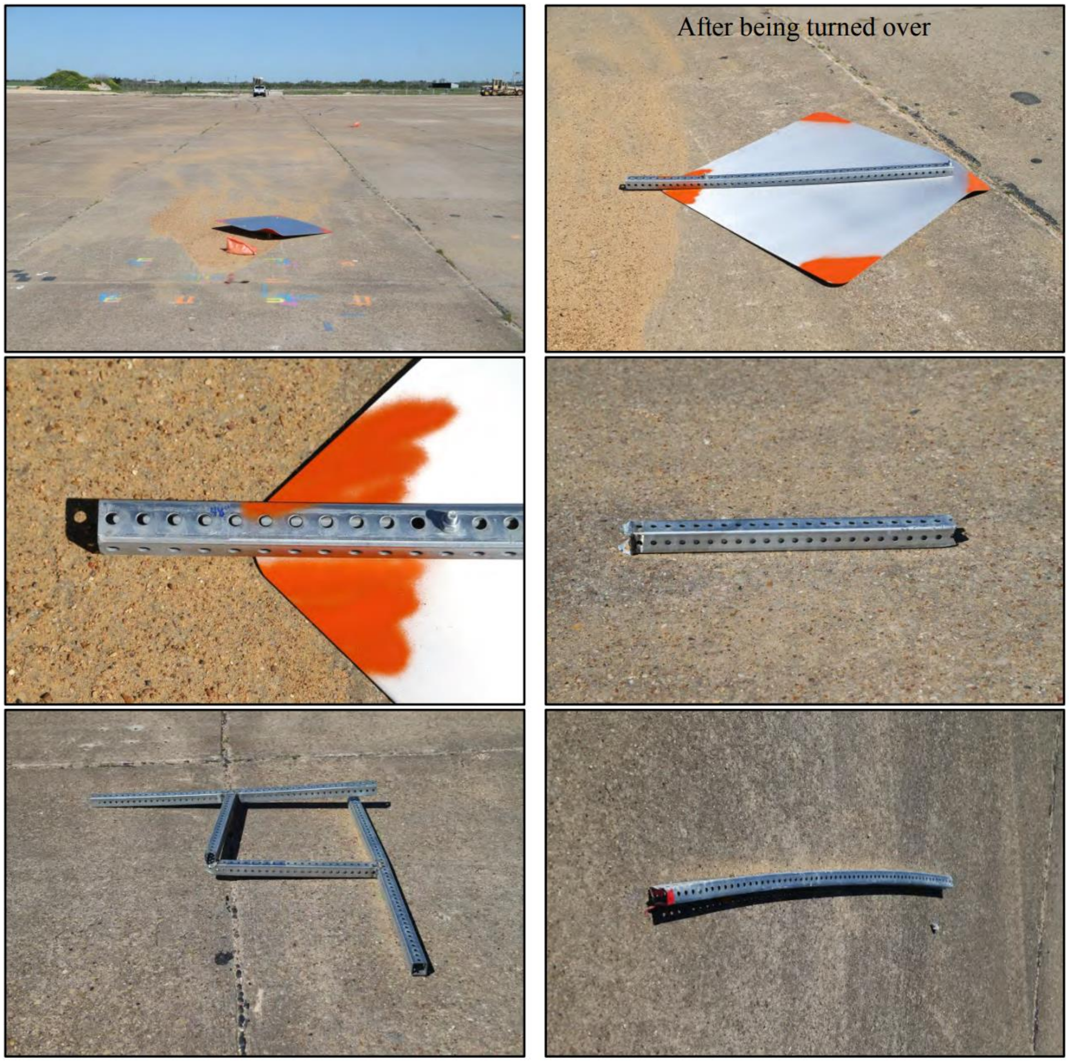


Figure 2.50. Temporary High-Mounting Sign Support, Option C Test 3-72, 0-degree Impact System Damage (*2*)

Figure 2.51. Temporary High-Mounting Sign Support, Option C Test 3-72, 0-degree Impact Vehicle Damage (*2*)

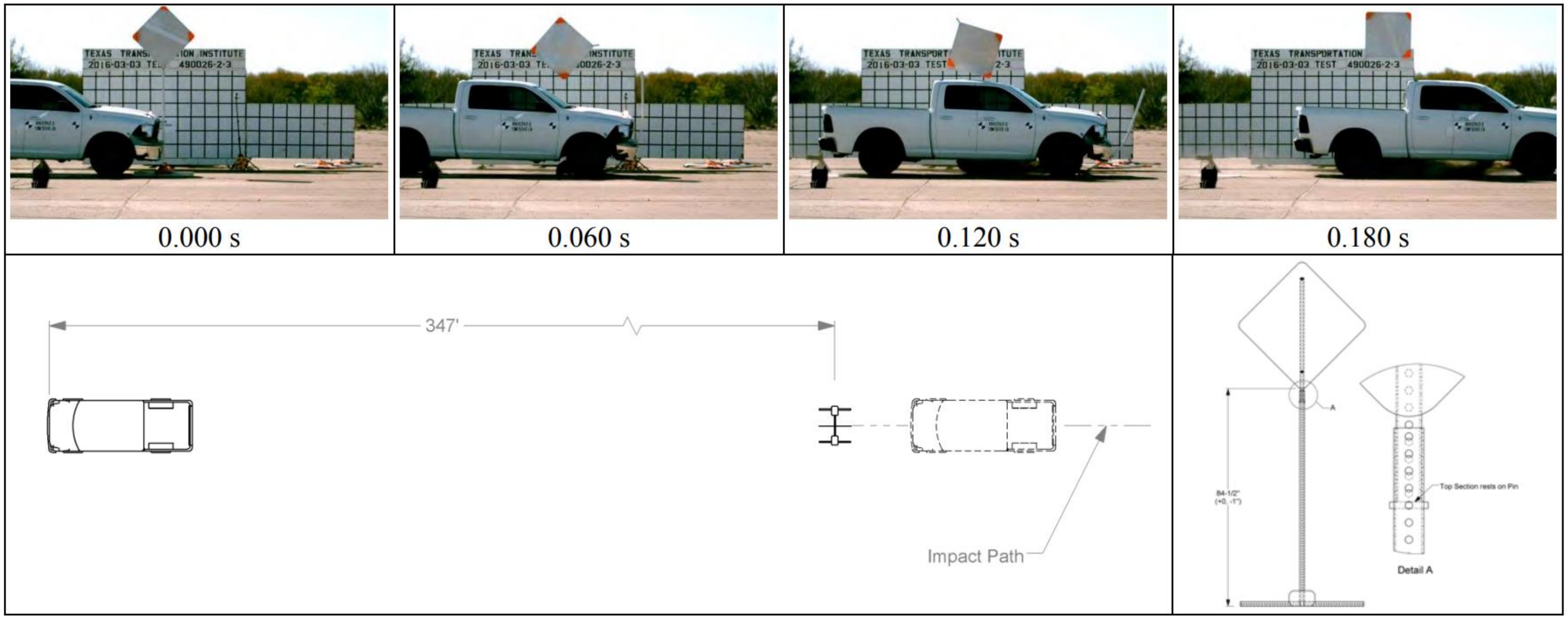
Figure 2.52 provides a summary of the results of test 3-72 with a 90-degree impact. The sign panel contacted the roof; however, it did not cause any tears or penetration. The resulting roof deformation was within MASH criteria.

Figure 2.53 provides a summary of the results of test 3-71 with a 90-degree impact. The support structure contacted the bumper and hood, but the sign panel did not contact the roof of the vehicle.

Figure 2.54 provides a summary of the results of test 3-71 with a 0-degree impact. The support structure contacted the bumper and hood, but the sign panel did not contact the roof of the vehicle.

Figure 2.55 provides a summary of the results of test 3-72 with a 0-degree impact. The sign panel did not contact the roof.

The Option C design successfully met *MASH* evaluation criteria for tests 3-72 and 3-71 in both the 0 degree and 90 degree impact angles. Test 3-70 was not performed because of the *MASH* guidance regarding lightweight work zone products.



General Information
- Test Agency: Texas A&M Transportation Institute (TTI)
- Test Standard Test No.: MASH Test 3-72
- TTI Test No.: 490026-2-3
- Test Date: 2016-03-03

Test Article
- Type: Temporary Work Zone Sign Support
- Name: Option C Temporary Work Zone Sign Support
- Installation Height: 84½ inches to bottom; 133⅝ to top
- Material or Key Elements: Upper section inserted $4^{9}/_{32}$ inches into the lower 1¾-inch square tubing post and rested on a ⅜-inch diameter × 2¼-inch long smooth pin located in holes 4½ inches below the top of post

Soil Type and Condition: Placed on dry concrete surface

Test Vehicle
- Type/Designation: 2270P
- Make and Model: 2010 Dodge Ram 1500
- Curb: 4898 lb
- Test Inertial: 5014 lb
- Dummy: No dummy
- Gross Static: 5014 lb

Impact Conditions
- Speed: 62.5 mi/h
- Angle: 90 degrees
- Location/Orientation: Centerline

Kinetic Energy: 653 kip-ft

Exit Conditions
- Speed: 60.8 mi/h
- Angle: NA

Occupant Risk Values: Assessment of occupant risk factors not required for test articles of 57 lb

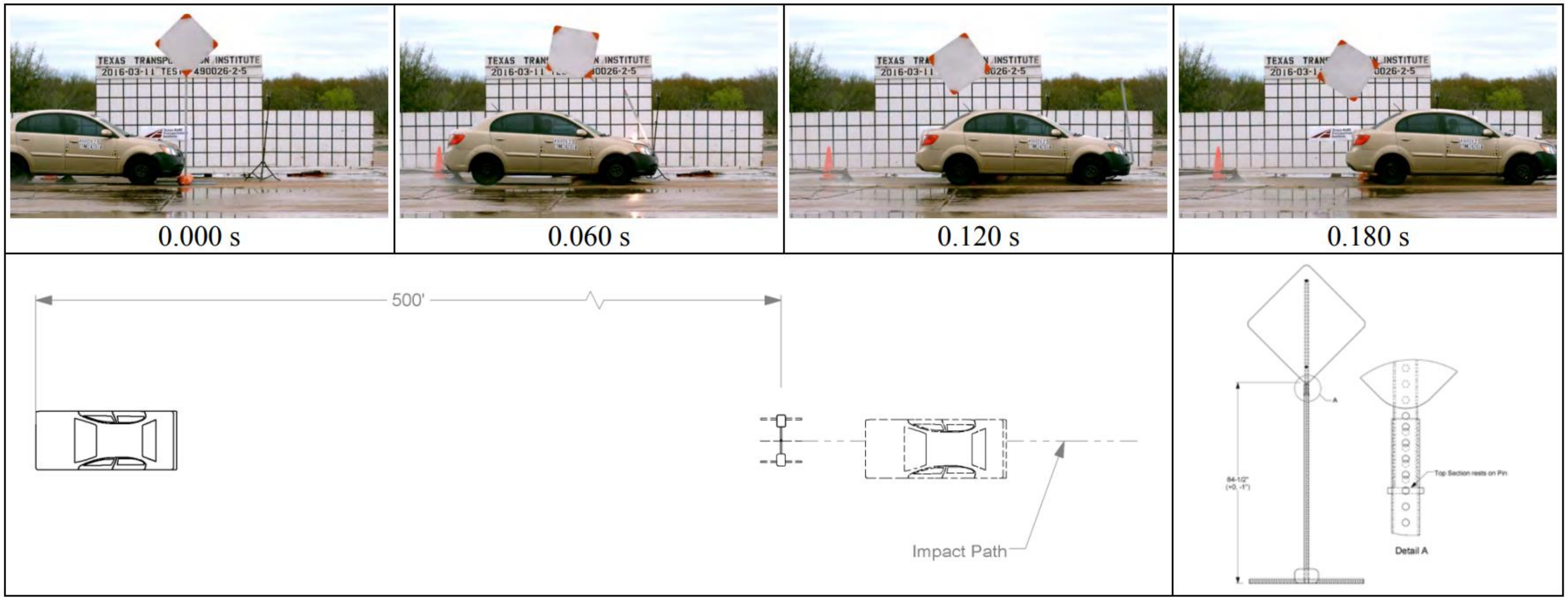
Test Article Debris Scatter
- Longitudinal: 347 downstream
- Lateral: Centerline

Post-Impact Trajectory
- Stopping Distance: 347 ft downstream on center

Vehicle Stability
- Maximum Yaw Angle: Vehicle
- Maximum Pitch Angle: remained
- Maximum Roll Angle: upright
- Vehicle Snagging: No
- Vehicle Pocketing: No

Vehicle Damage
- VDS: 12FC1
- CDC: 12FCEN1
- Max. Exterior Deformation: 6.0 inches
- OCDI: RR0000000
- Max. Occupant Compartment Deformation: None

Figure 2.52. Temporary High-Mounting Sign Support, Option C Test 3-72, 90-degree Impact Results (*2*)



General Information
Test Agency........................ Texas A&M Transportation Institute (TTI)
Test Standard Test No. .... MASH Test 3-71
TTI Test No. 490026-2-5
Test Date 2016-03-11

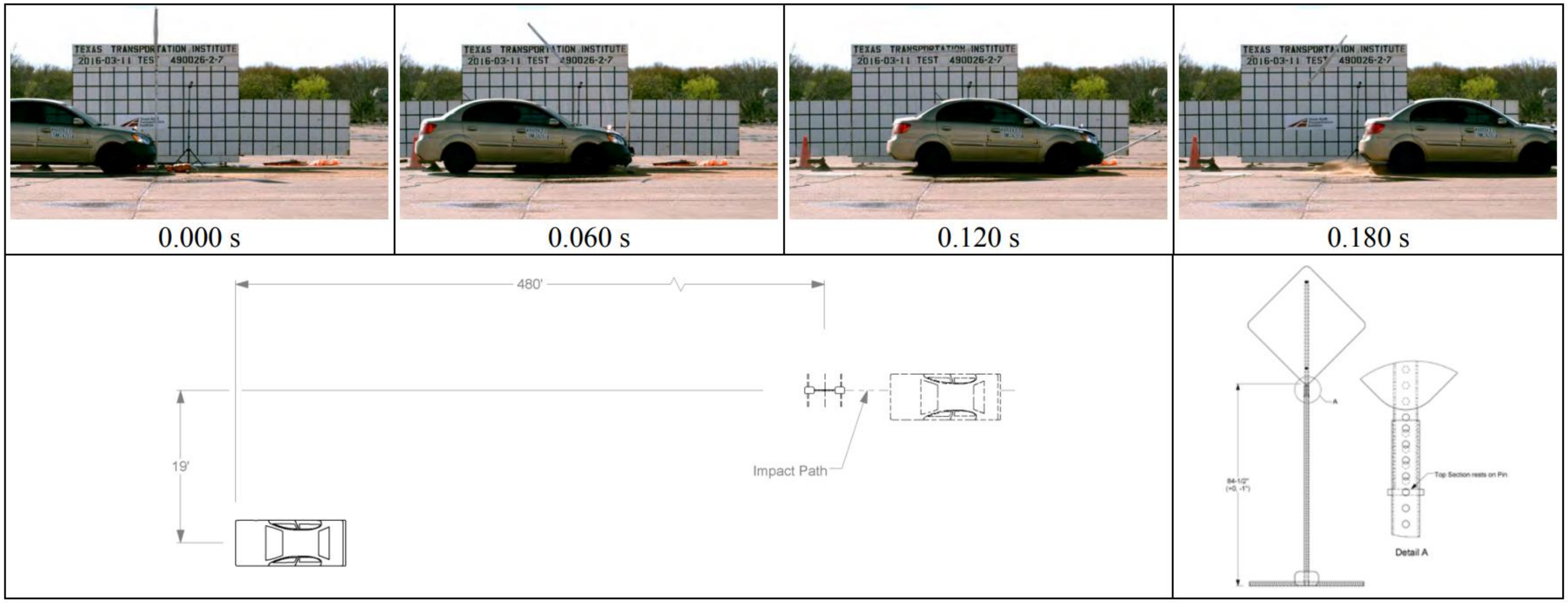
Test Article
Type .... Temporary Work Zone Sign Support
Name................................. Option C Temporary Work Zone Sign Support
Installation Height .... 84½ inches to bottom; 133⅝ to top
Material or Key Elements .... Upper section inserted $4^{9}/_{32}$ inches into the lower 1¾-inch square tubing post and rested on a ⅜-inch diameter × 2¼-inch long smooth pin located in holes 4½ inches below the top of post
Soil Type and Condition ...... Placed on dry concrete surface

Test Vehicle
Type/Designation 1100C
Make and Model............2011 Kia Rio
Curb ....2479 lb
Test Inertial ....2443 lb
Dummy...........................165 lb
Gross Static...................2608 lb

Impact Conditions
Speed............................61.5 mi/h
Angle.............................90 degrees
Location/Orientation ....10 inches left of centerline
Kinetic Energy ....309 kip-ft
Exit Conditions
Speed............................59.5 mi/h
Angle.............................NA
Occupant Risk Values .....Assessment of occupant risk factors not required for test articles of 57 lb

Test Article Debris Scatter
Longitudinal ....230 downstream
Lateral...25 ft left of center
Post-Impact Trajectory
Stopping Distance.......................500 ft downstream Centerline
Vehicle Stability
Maximum Yaw Angle ....Vehicle
Maximum Pitch Angle .... remained
Maximum Roll Angle .... upright
Vehicle Snagging ....No
Vehicle Pocketing ....No
Vehicle Damage
VDS 12FL1
CDC..12FLEN1
Max. Exterior Deformation..........None
OCDI...LF0000000
Max. Occupant Compartment Deformation ....None

Figure 2.53. Temporary High-Mounting Sign Support, Option C Test 3-71, 90-degree Impact Results (*2*)



General Information
Test Agency........................ Texas A&M Transportation Institute (TTI)
Test Standard Test No........ MASH Test 3-71
TTI Test No. 490026-2-7
Test Date 2016-03-11

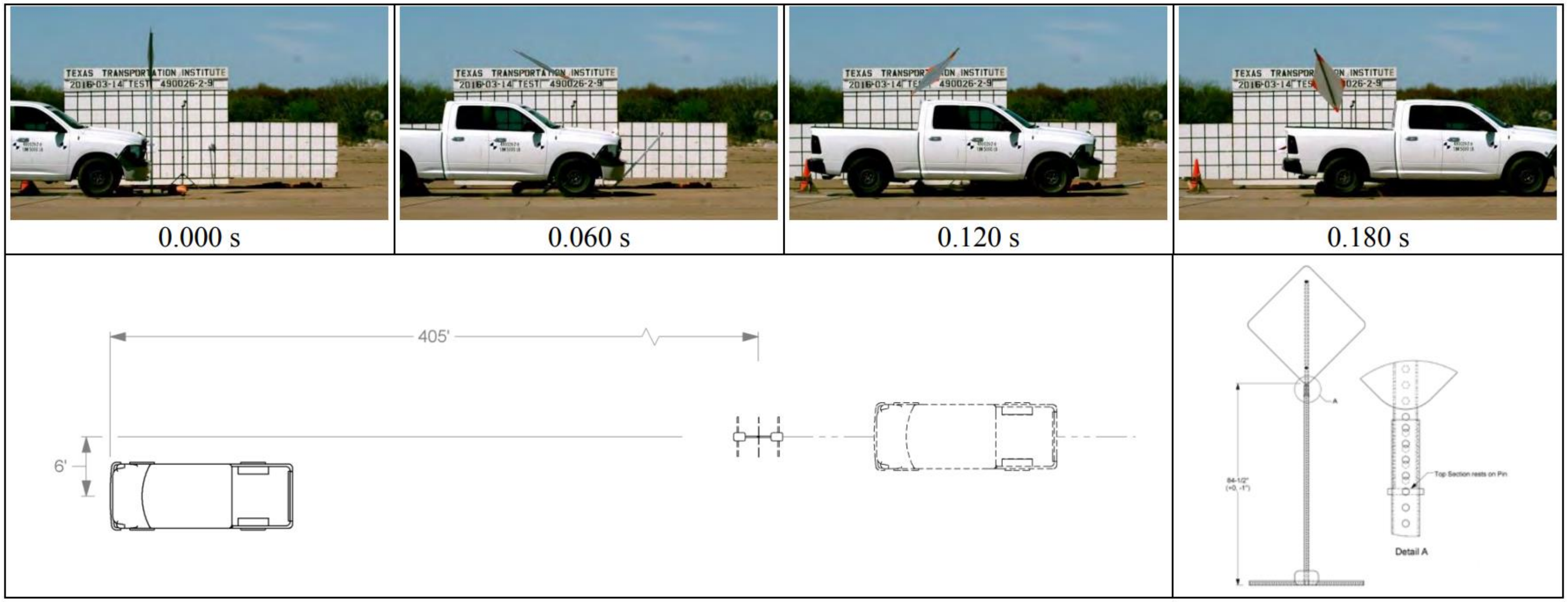
Test Article
Type .... Temporary Work Zone Sign Support
Name.................................. Option C Temporary Work Zone Sign Support
Installation Height .... 84½ inches to bottom; 133⅝ to top
Material or Key Elements .... Upper section inserted $4^{9}/_{32}$ inches into the lower 1¾-inch square tubing post and rested on a ⅜-inch diameter × 2¼-inch long smooth pin located in holes 4½ inches below the top of post
Soil Type and Condition ...... Placed on dry concrete surface

Test Vehicle
Type/Designation 1100C
Make and Model............2011 Kia Rio
Curb ....2479 lb
Test Inertial ....2443 lb
Dummy..........................165 lb
Gross Static...................2608 lb

Impact Conditions
Speed............................61.9 mi/h
Angle.............................0 degrees
Location/Orientation ....10 inches left of centerline
Kinetic Energy ....311 kip-ft
Exit Conditions
Speed............................59.8 mi/h
Angle.............................NA
Occupant Risk Values ....Assessment of occupant risk factors not required for test articles of 57 lb

Test Article Debris Scatter
Longitudinal ....275 downstream
Lateral...18 ft right – 2 ft left
Post-Impact Trajectory
Stopping Distance.......................480 ft downstream 19 ft left of center
Vehicle Stability
Maximum Yaw Angle ....Vehicle
Maximum Pitch Angle .... remained
Maximum Roll Angle .... upright
Vehicle Snagging ....No
Vehicle Pocketing ....No
Vehicle Damage
VDS 12FL1
CDC...12FLEN1
Max. Exterior Deformation..........None
OCDI...LF0000000
Max. Occupant Compartment Deformation ....None

Figure 2.54. Temporary High-Mounting Sign Support, Option C Test 3-71, 0-degree Impact Results (*2*)



General Information
- Test Agency: Texas A&M Transportation Institute (TTI)
- Test Standard Test No.: MASH Test 3-72
- TTI Test No.: 490026-2-9
- Test Date: 2016-03-14

Test Article
- Type: Temporary Work Zone Sign Support
- Name: Option C Temporary Work Zone Sign Support
- Installation Height: 84½ inches to bottom; 133⅝ to top
- Material or Key Elements: Upper section inserted $4^{9}/_{32}$ inches into the lower 1¾-inch square tubing post and rested on a ⅜-inch diameter × 2¼-inch long smooth pin located in holes 4½ inches below the top of post

Soil Type and Condition: Placed on dry concrete surface

Test Vehicle
- Type/Designation: 2270P
- Make and Model: 2010 Dodge Ram 1500
- Curb: 4898 lb
- Test Inertial: 5014 lb
- Dummy: No dummy
- Gross Static: 5014 lb

Impact Conditions
- Speed: 62.9 mi/h
- Angle: 0 degrees
- Location/Orientation: 10 inches left of centerline

Kinetic Energy: 663 kip-ft

Exit Conditions
- Speed: 61.9 mi/h
- Angle: NA

Occupant Risk Values: Assessment of occupant risk factors not required for test articles of 57 lb

Test Article Debris Scatter
- Longitudinal: 120 downstream
- Lateral: 10 ft right of center

Post-Impact Trajectory
- Stopping Distance: 405 ft downstream 6 ft left of center

Vehicle Stability
- Maximum Yaw Angle: Vehicle
- Maximum Pitch Angle: remained
- Maximum Roll Angle: upright
- Vehicle Snagging: No
- Vehicle Pocketing: No

Vehicle Damage
- VDS: 12FL1
- CDC: 12FLEN1
- Max. Exterior Deformation: 3.5 inches
- OCDI: FR0000000
- Max. Occupant Compartment Deformation: None

Figure 2.55. Temporary High-Mounting Sign Support, Option C Test 3-72, 0-degree Impact Results (*2*)

2.2.4. Development and MASH Full-Scale Crash Testing of a High-Mounting-Height Temporary Single Sign Support with Aluminum Sign (Modified Design 2) (*3*)

Three 1¾-inch PSST were welded together to form an H-base assembly system. A 1¾-inch PSST was welded to the center of the H-base assembly. The vertical support of the temporary single sign support was comprised of two parts: a 1½-inch PSST and a 1¾-inch PSST. The tubes were nested inside each other to provide height adjustment to the sign assembly. This inner 1½-inch tube of the telescopic connection was extended 4½ inches beyond the edge of the 1¾-inch square outer tube. The extension was inserted into the top of the sleeve and rested on a bolt to provide a slip connection. All PSST sections were 12 gauge.

A 48-inch length of 1½-inch PSST was used to provide bracing for the sign panel. A 36-inch × 36-inch × 0.1-inch aluminum diamond-shaped sign was attached to the 1½-inch PSST The insertion depth of 4½ inches was controlled by a bolt inserted through the 1½-inch sign brace PSST that rested on the top edge of the vertical support. The mounting height to the bottom of the sign blank was 7 ft. Figure 2.56 through Figure 2.59 give details of the sign support system. A 40-lb sandbag was laid on each side of the base assembly.

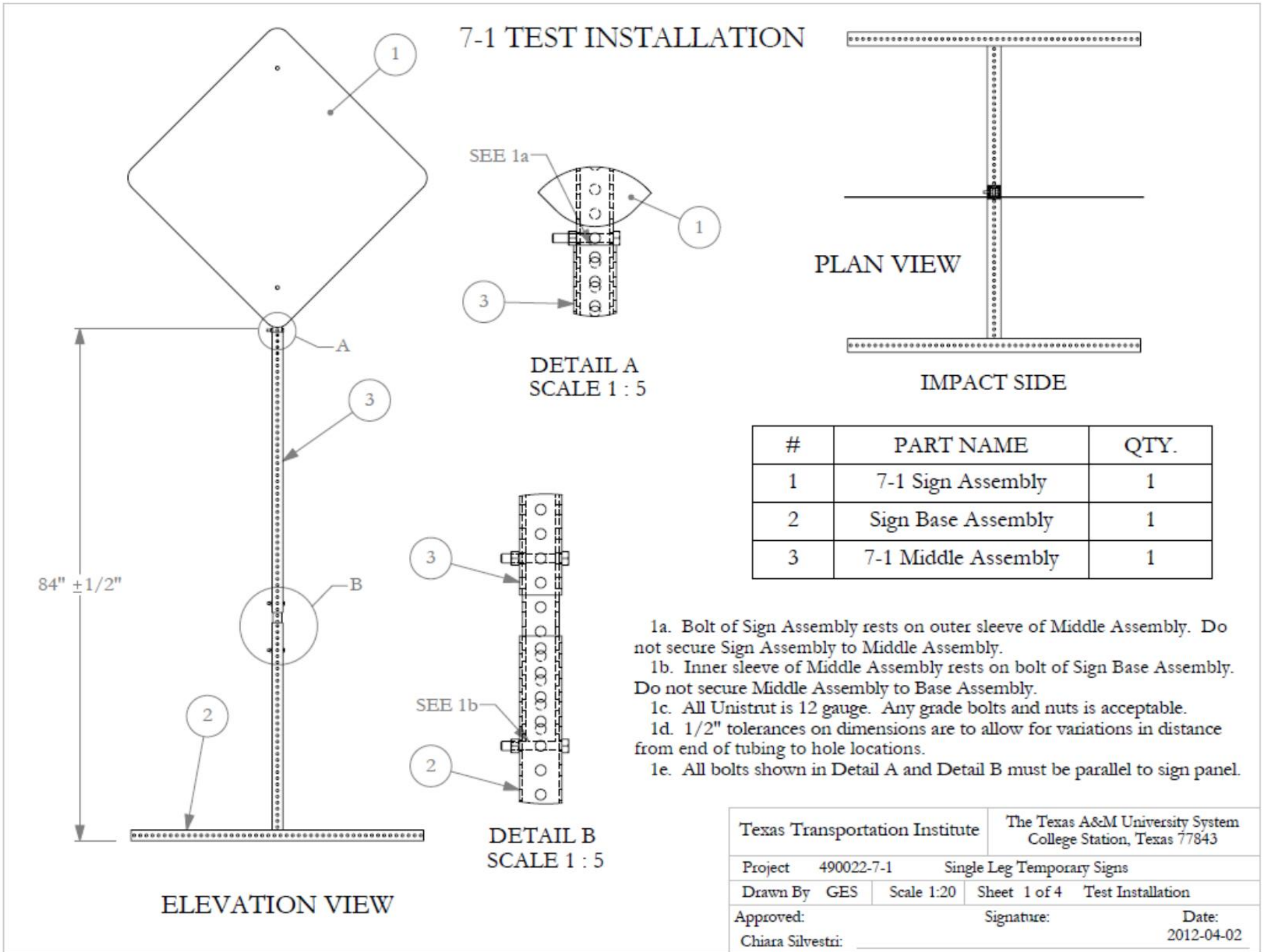
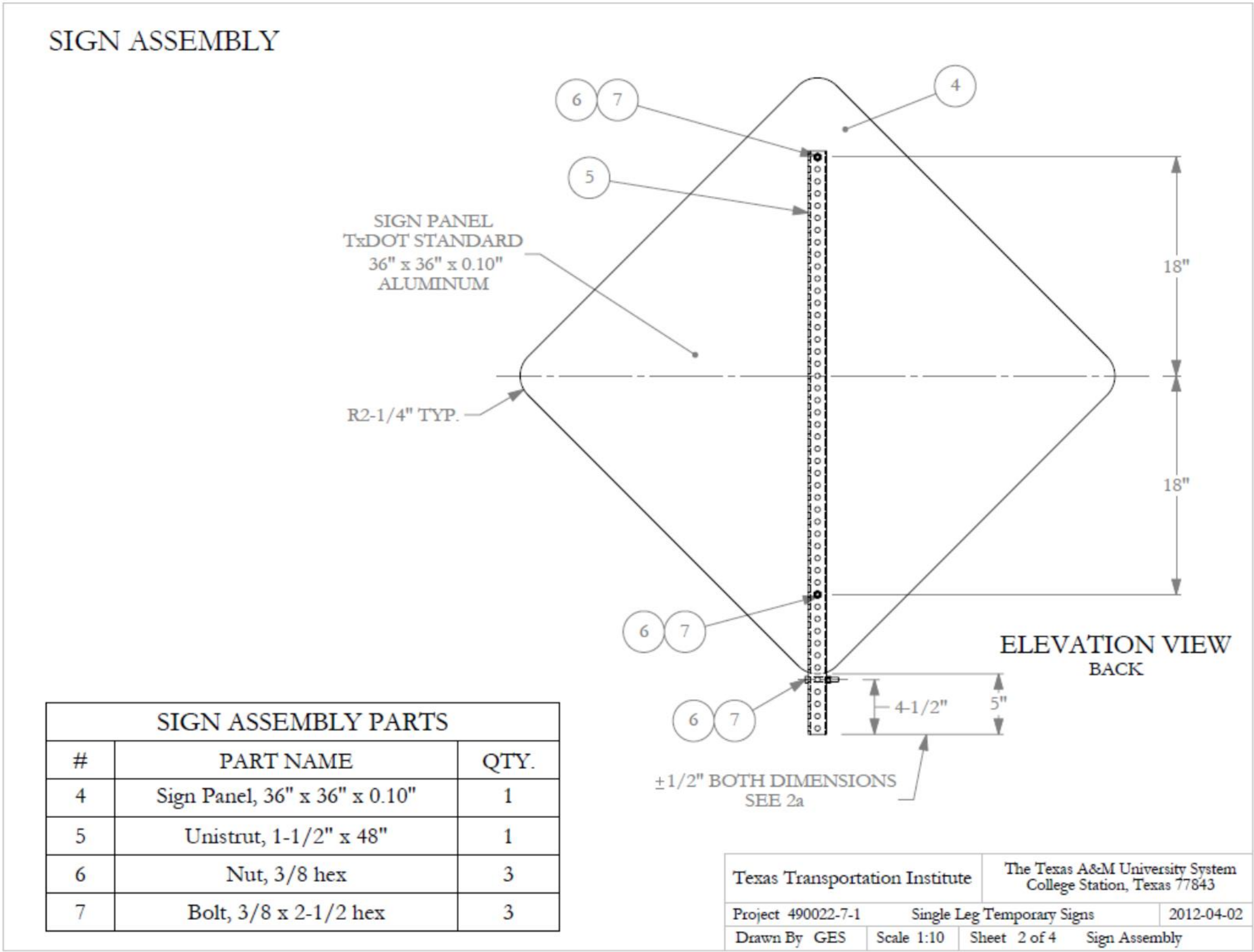


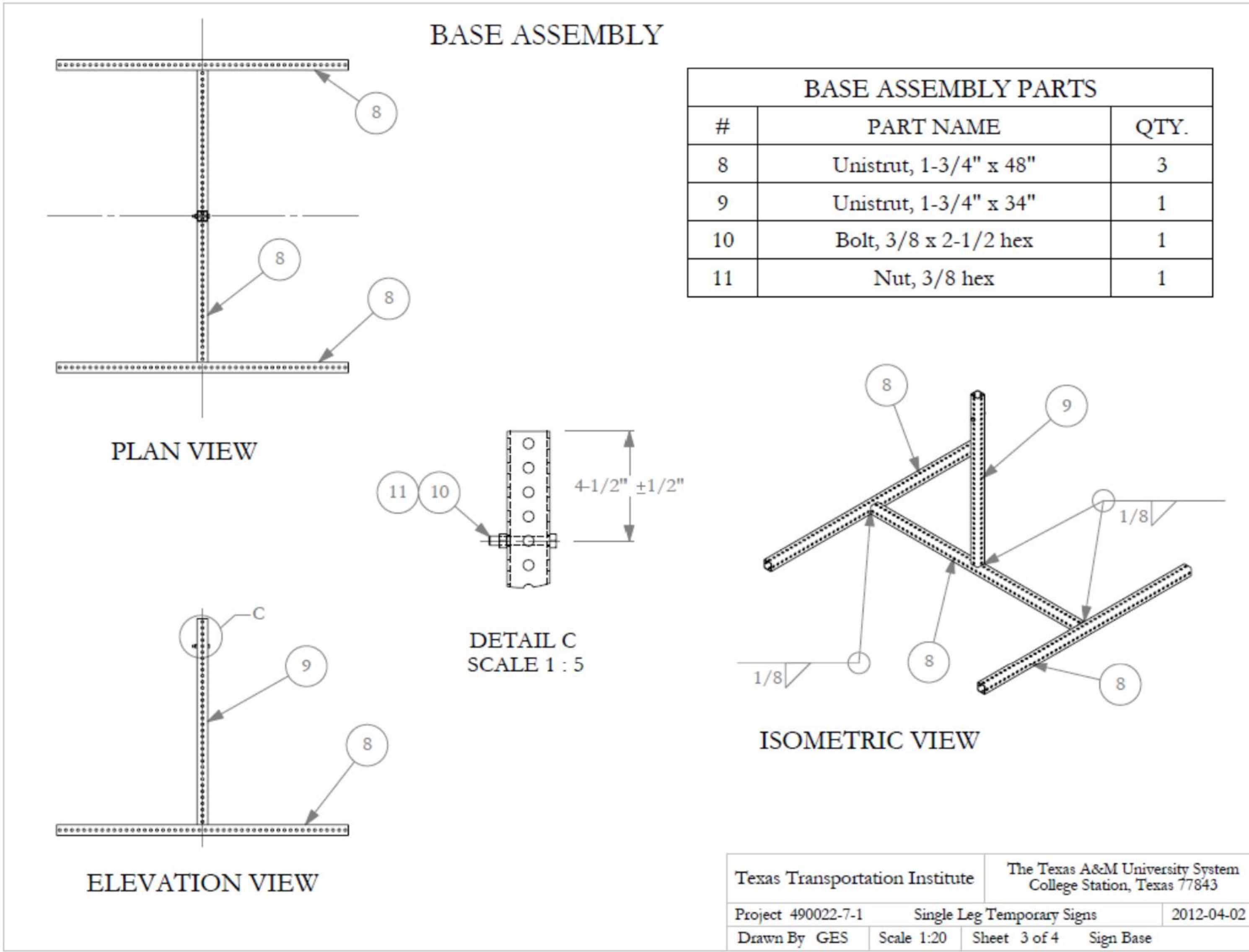
Figure 2.56. Specifications of High-Mounting-Height Temporary Single Sign Support, Modified Design 2 (*3*)



SIGN ASSEMBLY PARTS

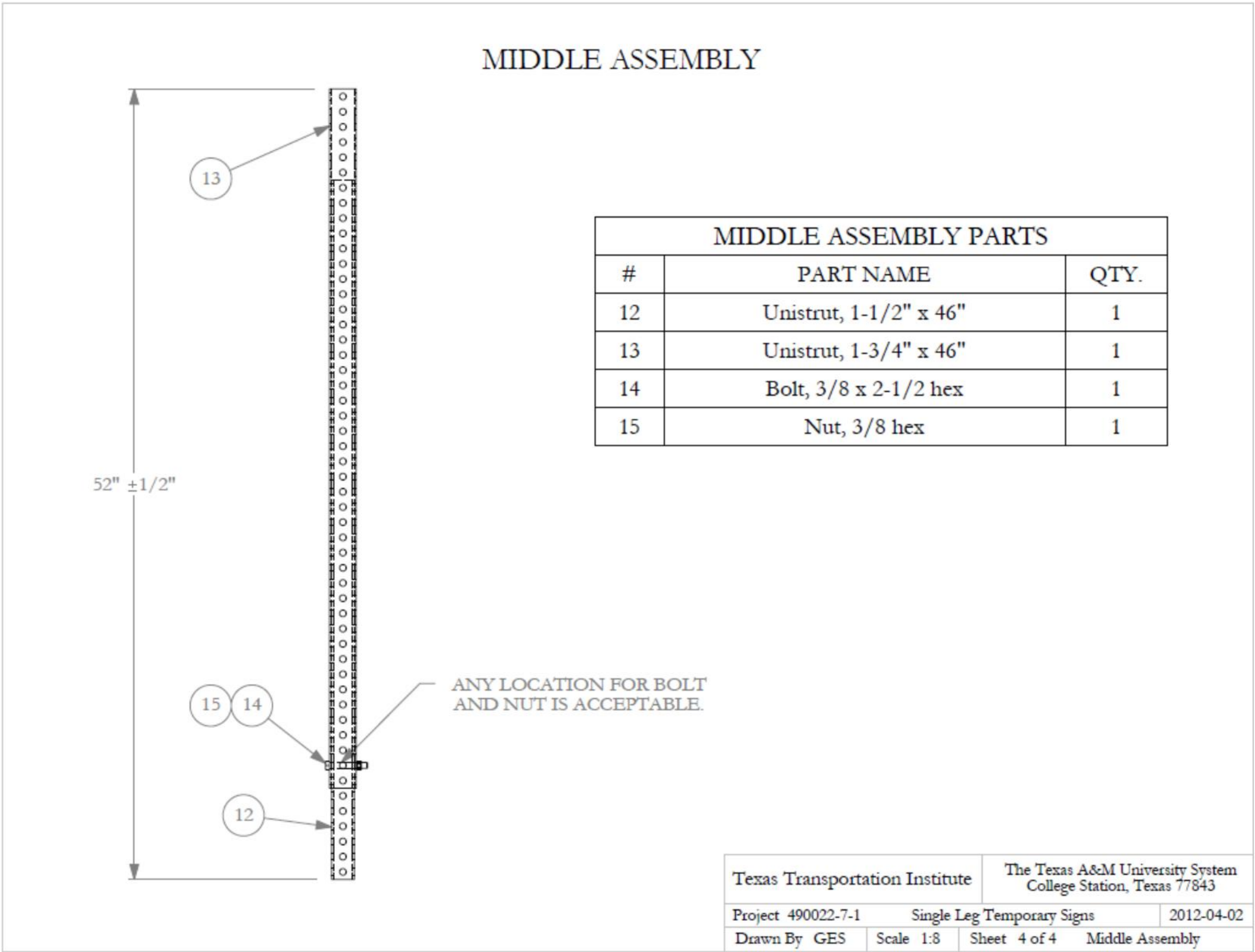
#	PART NAME	QTY.
4	Sign Panel, 36" x 36" x 0.10"	1
5	Unistrut, 1-1/2" x 48"	1
6	Nut, 3/8 hex	3
7	Bolt, 3/8 x 2-1/2 hex	3

Figure 2.57. Specifications of High-Mounting-Height Temporary Single Sign Support, Modified Design 2 (Continued) (*3*)



BASE ASSEMBLY PARTS		
#	PART NAME	QTY.
8	Unistrut, 1-3/4" x 48"	3
9	Unistrut, 1-3/4" x 34"	1
10	Bolt, 3/8 x 2-1/2 hex	1
11	Nut, 3/8 hex	1

Figure 2.58. Specifications of High-Mounting-Height Temporary Single Sign Support, Modified Design 2 (Continued) (*3*)



MIDDLE ASSEMBLY PARTS		
#	PART NAME	QTY.
12	Unistrut, 1-1/2" x 46"	1
13	Unistrut, 1-3/4" x 46"	1
14	Bolt, 3/8 x 2-1/2 hex	1
15	Nut, 3/8 hex	1

Figure 2.59. Specifications of High-Mounting-Height Temporary Single Sign Support, Modified Design 2 (Continued) (*3*)

In *MASH* test 3-71, the 1100C vehicle, traveling at an impact speed of 62.9 mi/h, contacted the sign support at an impact angle of 90 degrees, with the left front quarter point aligned with the centerline of the support. The released vertical support and sign assembly never contacted the vehicle. Figure 2.60 presents sequential photographs of the test. Both slip joints activated, but the upper slip joint only activated after significant rotation (almost 180 degrees) of the released vertical support. Figure 2.61 shows damage to the sign support system. The 1100C vehicle sustained minimal damage during the impact with the temporary single sign support. Figure 2.62 shows photographs of the exterior of the vehicle.

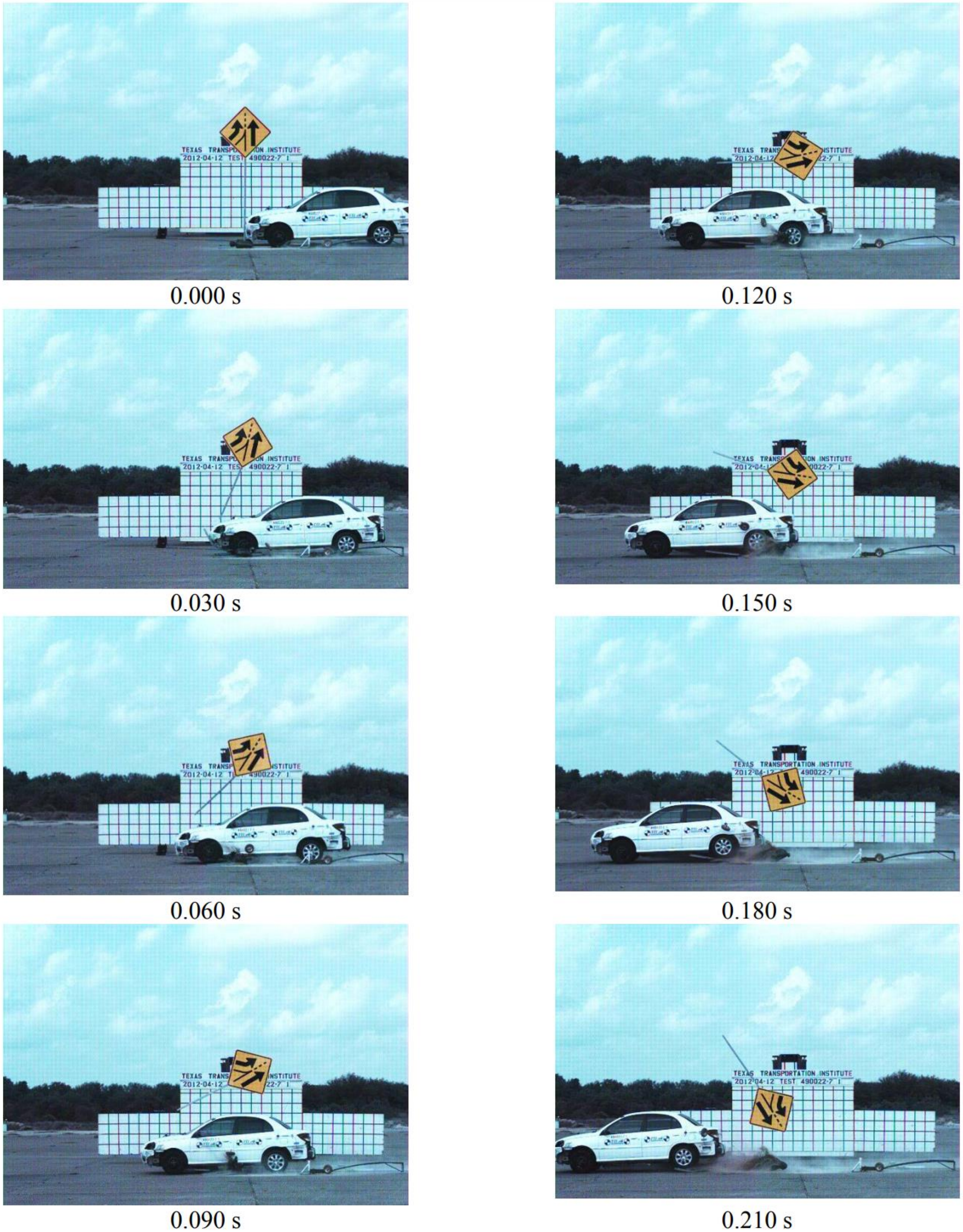


Figure 2.60. High-Mounting-Height Temporary Single Sign Support, Modified Design 2 Test 3-71, 90-degree Impact Sequential Photos (*3*)

Figure 2.61. High-Mounting-Height Temporary Single Sign Support, Modified Design 2 Test 3-71, 90-degree Impact System Damage (*3*)

Figure 2.62. High-Mounting-Height Temporary Single Sign Support, Modified Design 2 Test 3-71, 90-degree Impact Vehicle Damage (*3*)

In *MASH* test 3-72, the 2270P vehicle, traveling at an impact speed of 60.9 mi/h, contacted the 90-degree oriented temporary single sign support at an impact angle of 90 degrees, with the centerline of the support aligned at 10 inches from the centerline of the vehicle on the driver's side. The vehicle subsequently impacted the second test article, positioned approximately 30 ft downstream from the first and oriented at 0 degrees with respect to the direction of vehicle travel. Figure 2.63 and Figure 2.64 present sequential photographs of the test.

Figure 2.65 shows damage to the sign support systems. The lower telescopic slip connection activated on both test articles as designed. The 2270P vehicle sustained a small dent in the bumper, hood, and grill due to the initial impact with the 90-degree oriented sign support. A secondary impact of the edge of the aluminum sign panel caused a 29-inch-long cut in the roof of the pickup truck. Additionally, the roof was deformed over an area measuring 51 inches in length and 40 inches in width. The 2270P vehicle sustained a small dent in the bumper, hood, and grill, due to the initial impact with the 0-degree oriented sign support. Figure 2.66 and Figure 2.67 show photographs of the exterior and interior of the vehicle after the test.

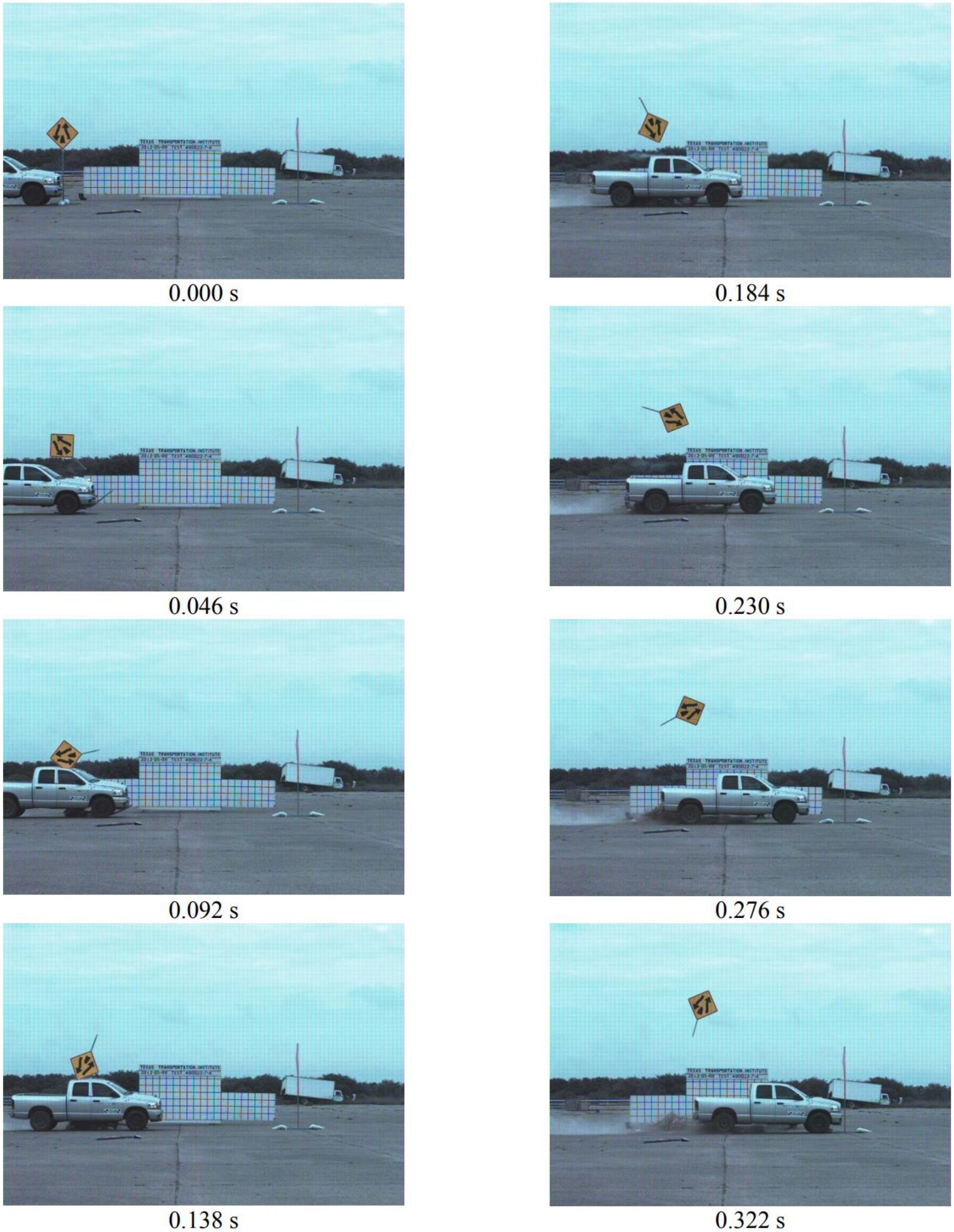
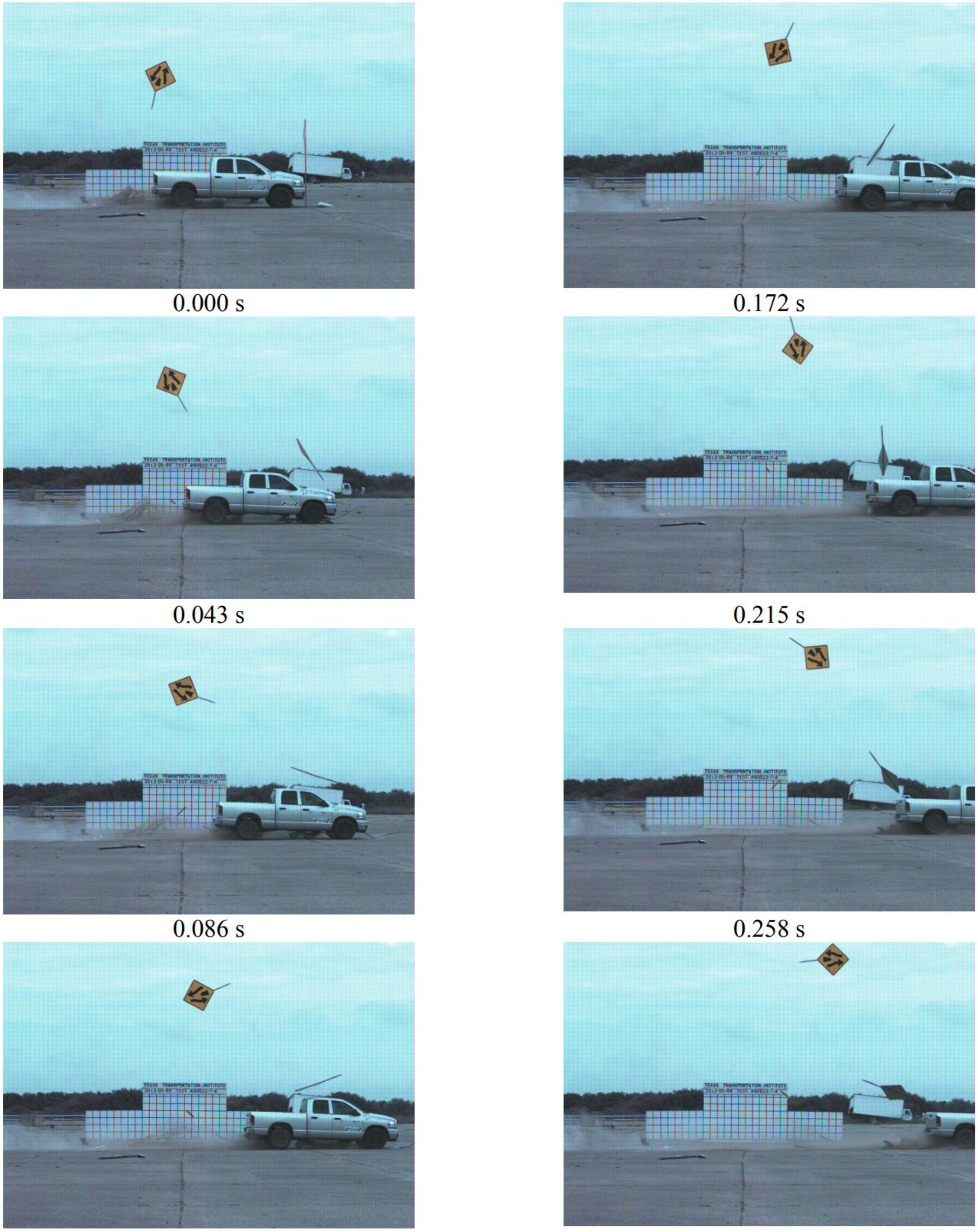


Figure 2.63. High-Mounting-Height Temporary Single Sign Support, Modified Design 2 Test 3-72, 90-degree Impact Sequential Photos (*3*)



0.000 s
0.172 s
0.043 s
0.215 s
0.086 s
0.258 s
0.129 s
0.301 s

Figure 2.64. High-Mounting-Height Temporary Single Sign Support, Modified Design 2 Test 3-72, 0-degree Impact Sequential Photos (*3*)

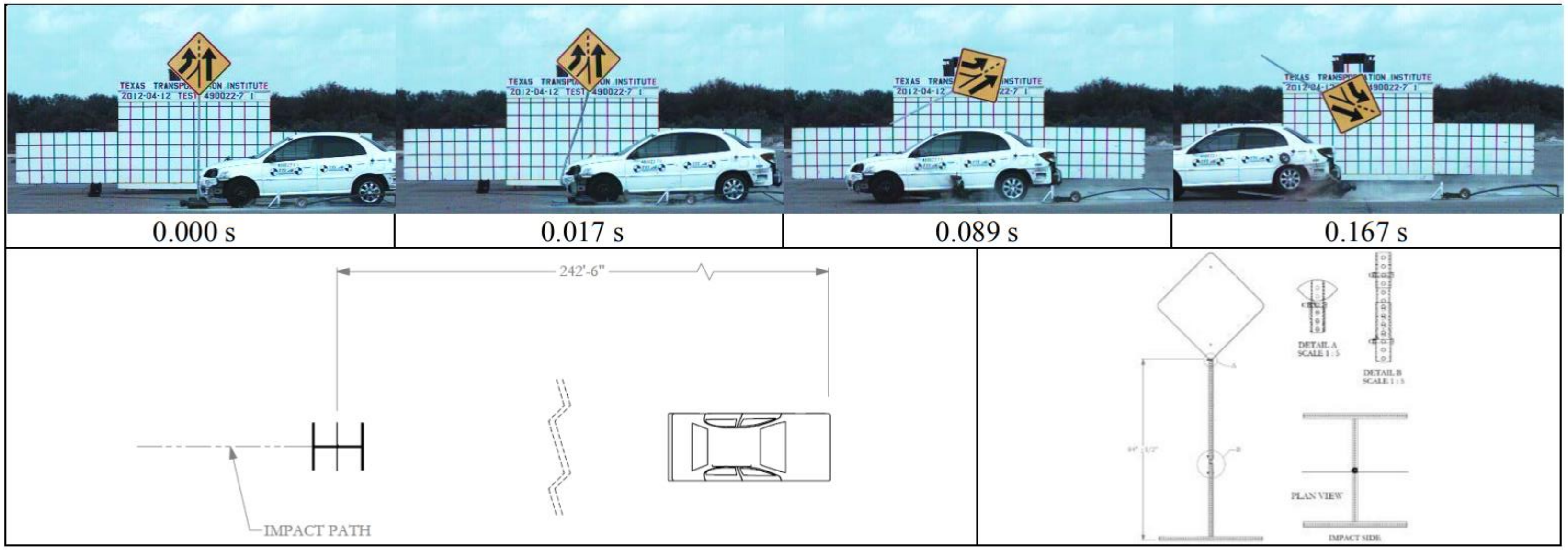
Figure 2.65. High-Mounting-Height Temporary Single Sign Support, Modified Design 2 Test 3-72 System Damage (*3*)

Figure 2.66. High-Mounting-Height Temporary Single Sign Support, Modified Design 2 Test 3-72 Vehicle Damage (*3*)

Figure 2.67. High-Mounting-Height Temporary Single Sign Support, Modified Design 2 Test 3-72 Vehicle Interior Damage (*3*)

In test 3-71, the temporary sign support yielded to the vehicle and the bottom slip connection activated as designed. The upper slip connection activated only after the released support rotated almost 180 degrees. A summary of the results from test 3-71 with a 90-degree impact point is presented in Figure 2.68.

In both 3-72 tests, the telescopic slip connection activated as designed and released the sign support assembly from its base. In the impact with the sign system oriented at 0 degrees, the released sign panel assembly did not contact the vehicle, and all MASH criteria were satisfied. However, during the impact with the sign system oriented at 90 degrees, the edge of the sign panel contacted, deformed, and cut the roof of the vehicle. It was evident from review of the high-speed video and inspection of the vehicle and sign panel that the corner of the sign panel penetrated the occupant compartment. MASH states that “detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment...” Therefore, the impact with the sign system oriented at 90-degrees did not satisfy Occupant Risk Criterion “D” of *MASH*.



General Information
- Test Agency........................ Texas A&M Transportation Institute
- MASH Test No. .... *MASH* Test 3-71
- TTI-PG Test No. 490022-7-1
- Date.................................... 2012-04-12

Test Article
- Type.................................... Temporary Single Sign Support
- Name .... Top and bottom slip connections/9 ft^2 aluminum sign panel
- Installation Height .... 7 ft to bottom of sign panel
- Material or Key Elements .... Aluminum sign panel mounted on 1-3/4 inch perforated steel tubing with H-base

Soil Type and Condition....... Concrete Pavement, Dry

Test Vehicle
- Type/Designation................. 1100C
- Make and Model .... 2003 Kia Rio
- Curb.................................... 2411 lb
- Test Inertial.......................... 2425 lb
- Dummy .... No dummy
- Gross Static......................... 2425 lb

Impact Conditions
- Speed ....62.9 mph
- Angle ....90 degrees
- Location/Orientation ....Left quarter point of vehicle with centerline of sign support

Exit Conditions
- Speed ....61.67 mph
- Angle ....0 degrees

Occupant Risk Values
- Impact Velocity
  - Longitudinal ....N/A
  - Lateral ....N/A
- Ridedown Accelerations
  - Longitudinal ....N/A
  - Lateral ....N/A
- THIV ....N/A
- ASI ....N/A
- Max. 0.050-s Average
  - Longitudinal ....N/A
  - Lateral ....N/A
  - Vertical ....N/A

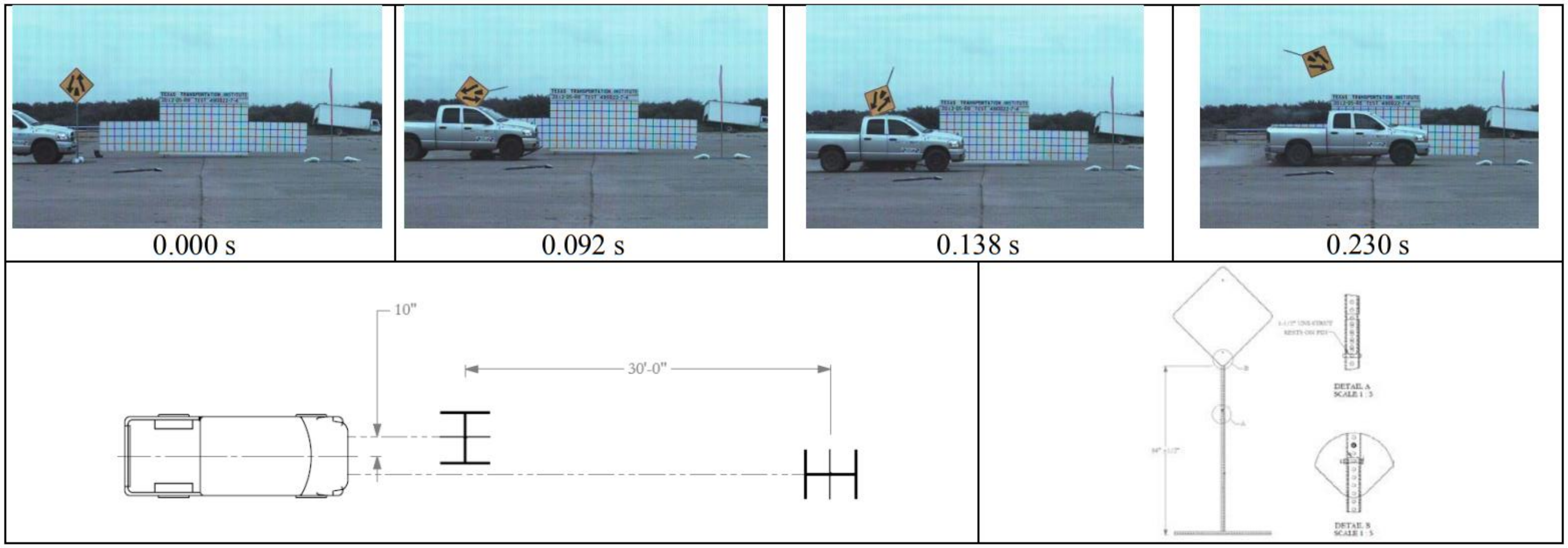
Post-Impact Trajectory
- Stopping Distance 242-ft 6-inches

Vehicle Stability
- Maximum Yaw Angle....................... N/A
- Maximum Pitch Angle...................... N/A
- Maximum Roll Angle .... N/A
- Vehicle Snagging .... No
- Vehicle Pocketing............................ No

Test Article Deflections
- Dynamic 242-ft 6-inches
- Permanent....................................... 242-ft 6-inches
- Working Width .... N/A

Vehicle Damage
- VDS 12FD1
- CDC... 12FDEN1
- Max. Exterior Deformation............... None
- OCDI.. FS0000000
- Max. Occupant Compartment Deformation............................... None

Figure 2.68. High-Mounting-Height Temporary Single Sign Support, Modified Design 2 Test 3-71, 90-degree Impact Results (*3*)



General Information
Test Agency....................... Texas A&M Transportation Institute
MASH Test No. .... *MASH* Test 3-72
TTI-PG Test No. .... 490022-7-4 90-degree Impact
Date.................................. 2012-05-09

Test Article
Type.................................. Temporary Single Sign Support
Name .... Telescopic slip connection at 5-ft; internal post for height adjustability; 9 ft^2 sign panel
Installation Height .... 7 ft to bottom of sign panel
Material or Key Elements .. Aluminum sign panel mounted on a 1-3/4-inch steel tube support; 1-3/4 steel tube base assembly; internal 1-1/2-inch steel tube

Soil Type and Condition..... Dry concrete surface

Test Vehicle
Type/Designation............... 2270P
Make and Model .... 2006 Dodge Ram 1500
Curb.................................. 4792 lb
Test Inertial....................... 5050 lb
Dummy .... No dummy
Gross Static....................... 5050 lb

Impact Conditions
Speed ....60.9 mph
Angle ....90 degrees
Location/Orientation ....10 inches from centerline of vehicle (driver's side)

Exit Conditions
Speed ....59.0 mph
Angle ....90 degrees

Occupant Risk Values
Impact Velocity
Longitudinal ....No Contact
Lateral ....No Contact
Ridedown Accelerations
Longitudinal ....No Contact
Lateral ....No Contact
THIV ....No Contact
PHD ....No Contact
ASI 0.15
Max. 0.050-s Average
Longitudinal ....-0.6 G
Lateral ....-1.2 G
Vertical .... 1.0 G

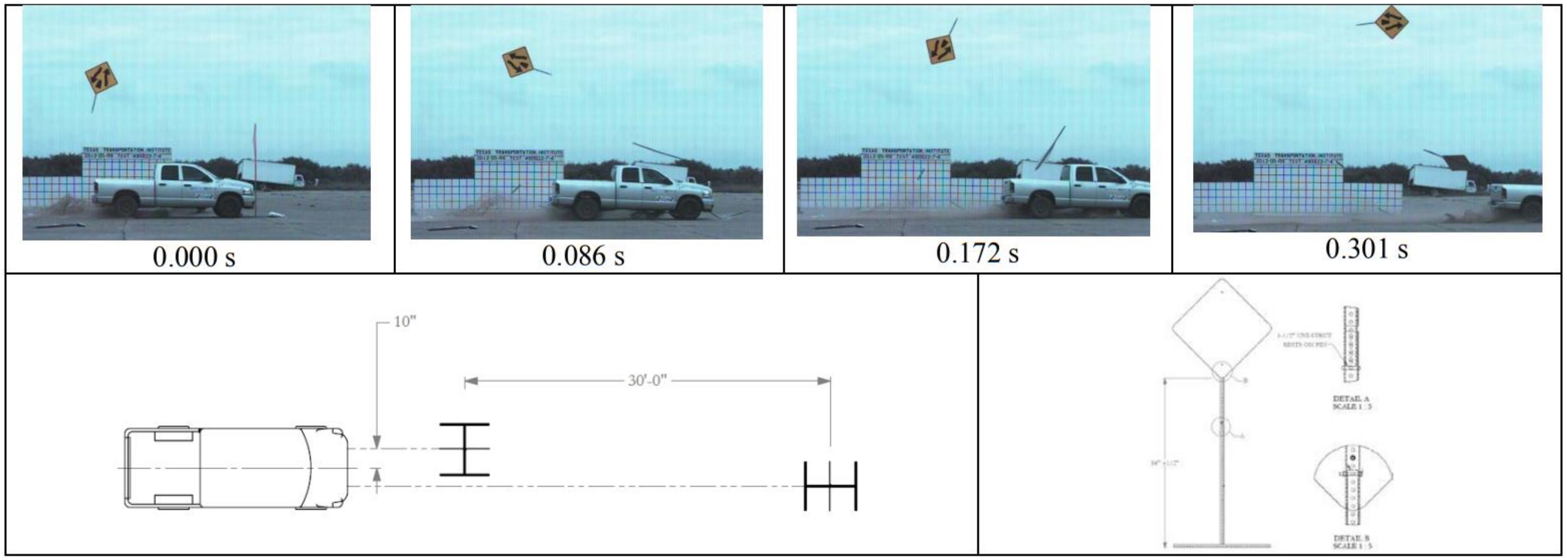
Post-Impact Trajectory
Stopping Distance .... 270 ft

Vehicle Stability
Maximum Yaw Angle............... -0.5
Maximum Pitch Angle.............. 0.6
Maximum Roll Angle 1.5
Vehicle Snagging .... No
Vehicle Pocketing.................... No

Test Article Deflections
Dynamic .... 270 ft
Permanent............................... 270 ft
Working Width .... N/A

Vehicle Damage
VDS 12FL1
CDC... 12FLEN1
Max. Exterior Deformation....... None
OCDI FS0100000
Max. Occupant Compartment Deformation....................... 1.5 inches

Figure 2.69. High-Mounting-Height Temporary Single Sign Support, Modified Design 2 Test 3-72, 90-degree Impact Results (*3*)



General Information
Test Agency...................... Texas A&M Transportation Institute
MASH Test No. .... *MASH* Test 3-72
TTI-PG Test No. .... 490022-7-4 0-degree Impact
Date 2012-05-09

Test Article
Type.................................. Temporary Single Sign Support
Name .... Telescopic slip connection at 5-ft; internal post for height adjustability; 9 ft^2 sign panel
Installation Height .... 7 ft to bottom of sign panel
Material or Key Elements .. Aluminum sign panel mounted on a 1-3/4-inch steel tube support; 1-3/4 steel tube base assembly; internal 1-1/2-inch steel tube
Soil Type and Condition..... Dry concrete surface

Test Vehicle
Type/Designation...............
Make and Model 2270P
Curb.................................. 2006 Dodge Ram 1500
Test Inertial....................... 4792 lb
Dummy .... 5050 lb
Gross Static....................... No dummy
5050 lb

Impact Conditions
Speed 59.0mph
Angle ....0 degrees
Location/Orientation ....10 inches from centerline of vehicle (passenger's side)

Exit Conditions
Speed 58.9
Angle ....0 degrees

Occupant Risk Values
Impact Velocity
Longitudinal ....No Contact
Lateral ....No Contact
Ridedown Accelerations
Longitudinal ....No Contact
Lateral ....No Contact
THIV ....No Contact
PHD ....No Contact
ASI 0.14
Max. 0.050-s Average
Longitudinal ....-0.9 G
Lateral ....-1.2 G
Vertical .... 0.8 G

Post-Impact Trajectory
Stopping Distance .... 270 ft

Vehicle Stability
Maximum Yaw Angle.............. -0.7
Maximum Pitch Angle............. -1.1
Maximum Roll Angle .... -1.9
Vehicle Snagging .... No
Vehicle Pocketing................... No

Test Article Deflections
Dynamic .... 270 ft
Permanent.............................. 270 ft
Working Width .... N/A

Vehicle Damage
VDS 12FR1
CDC.. 12FREN1
Max. Exterior Deformation....... None
OCDI FS0000000
Max. Occupant Compartment Deformation...................... None

Figure 2.70. High-Mounting-Height Temporary Single Sign Support, Modified Design 2 Test 3-72, 0-degree Impact Results (*3*)

2.2.5. Development and MASH Full-Scale Crash Testing of a High-Mounting-Height Temporary Single Sign Support with Aluminum Sign (Design 4) (*3*)

Three 1¾-inch PSST were welded together to form an H-base assembly system. A 1¾-inch PSST sleeve was welded to the center of the H-base assembly. 1½-inch PSST was used as the vertical support and bracing for the sign panel. The vertical support inserted 4½ inches into the top of the sleeve and rested on a bolt inserted through the sleeve. All PSST was 12 gauge.

A 36-inch × 36-inch × 0.1-inch aluminum diamond-shaped sign was attached to the 1½-inch vertical support PSST. The mounting height to the bottom of the sign blank was 7 ft. A 40-lb sandbag was laid on each side of the base assembly. Figure 2.71, Figure 2.72, and Figure 2.73 give details of the sign support system.

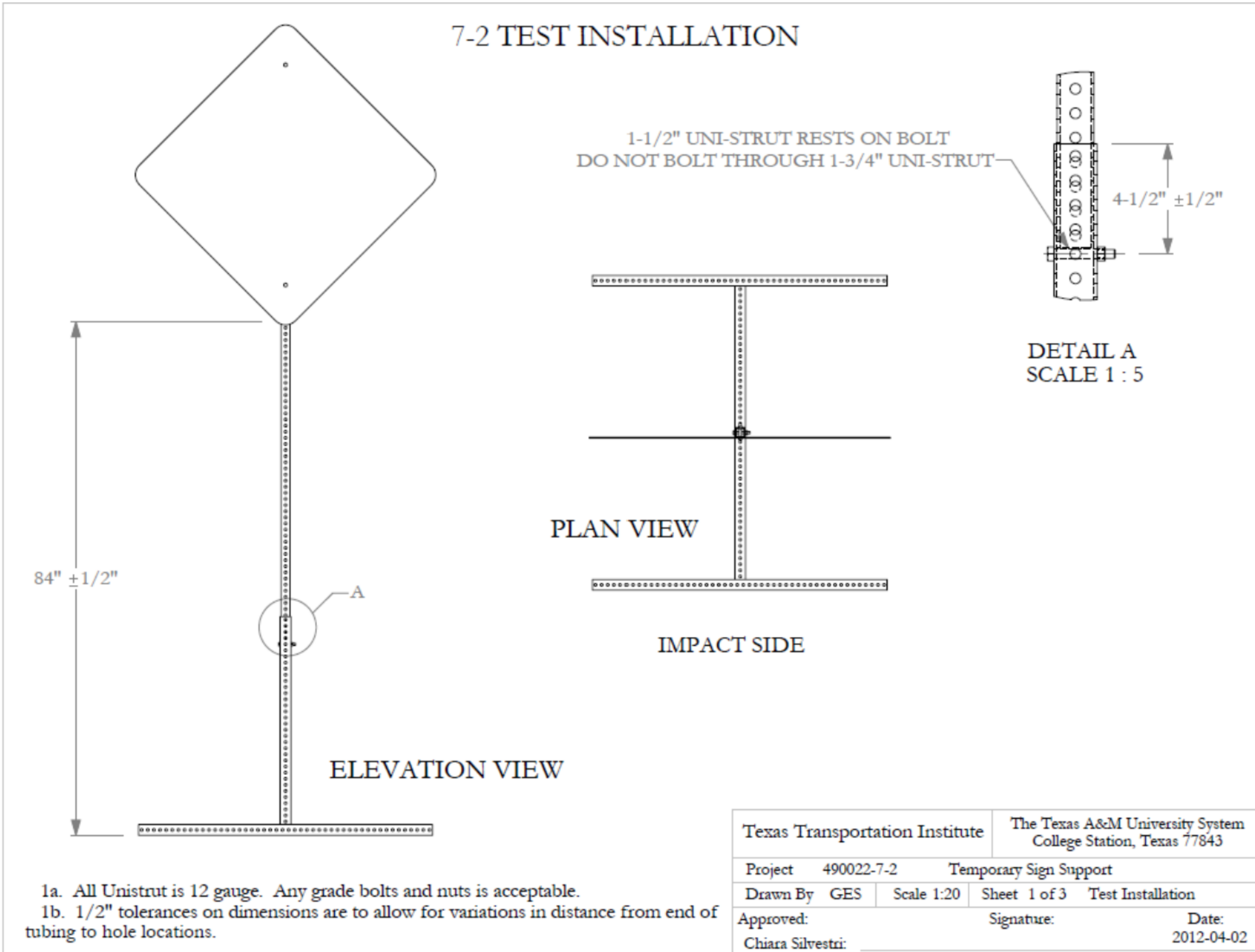
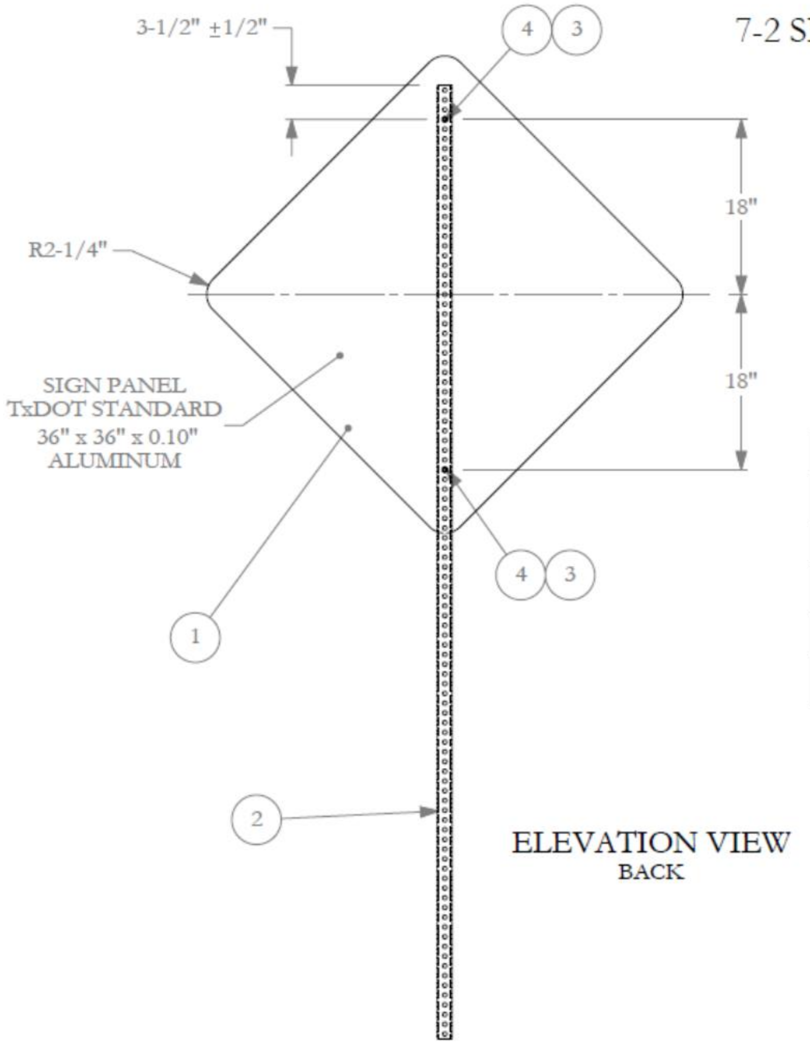


Figure 2.71. Specifications of High-Mounting-Height Temporary Single Sign Support, Modified Design 4 (*3*)

7-2 SIGN ASSEMBLY

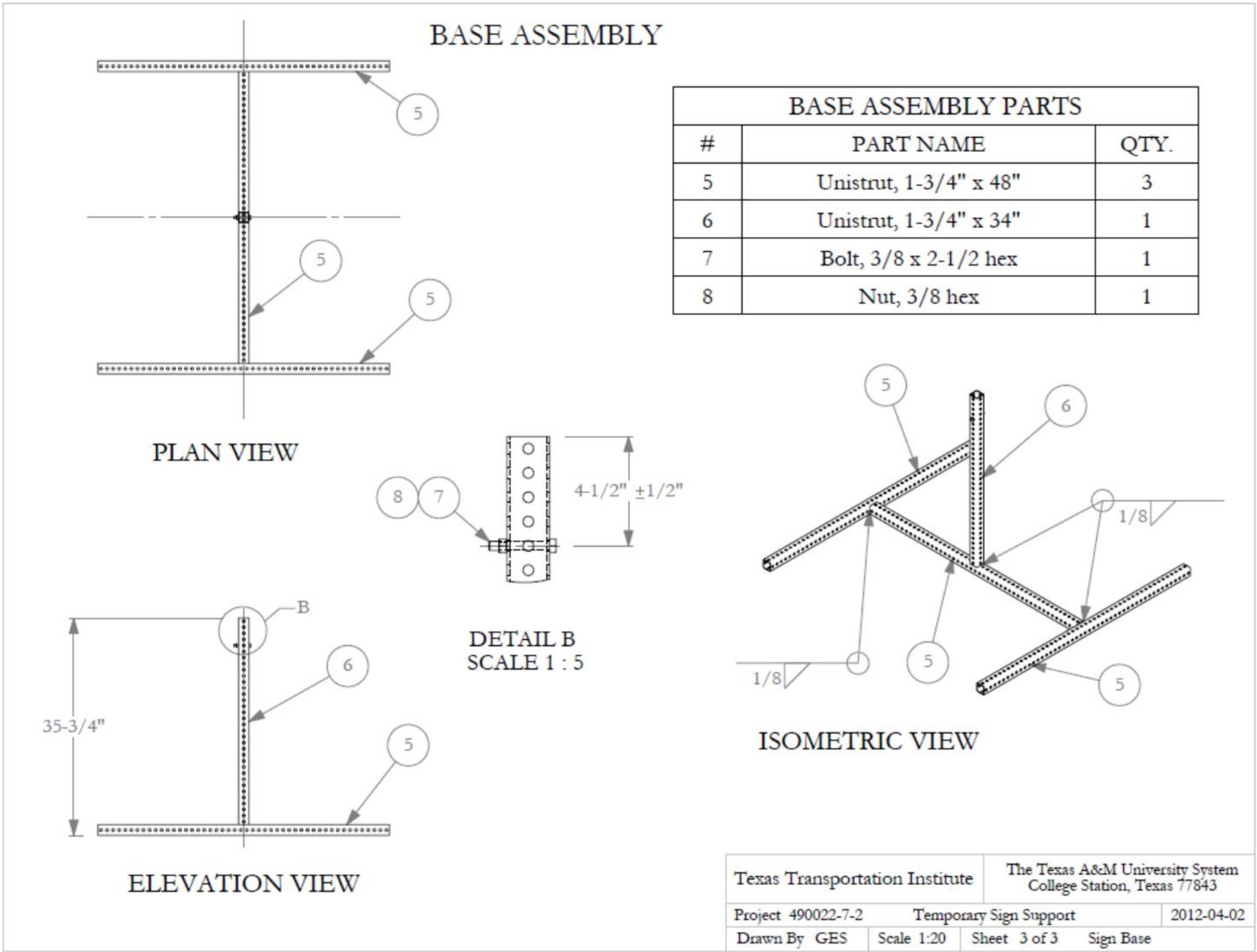


SIGN ASSEMBLY PARTS		
#	PART NAME	QTY.
1	Sign Panel, 36" x 36" x 0.10"	1
2	Unistrut, 1-1/2" x 98"	1
3	Nut, 3/8 hex	2
4	Bolt, 3/8 x 2-1/2 hex	2

2a. 1/2" tolerances on bolt locations are to allow for distance from end of tubing to hole locations.

Texas Transportation Institute		The Texas A&M University System College Station, Texas 77843	
Project 490022-7-2	Temporary Sign Support		2012-04-02
Drawn By GES	Scale 1:15	Sheet 2 of 3	Sign Assembly

Figure 2.72. Specifications of High-Mounting-Height Temporary Single Sign Support, Modified Design 4 (Continued) (*3*)



BASE ASSEMBLY PARTS		
#	PART NAME	QTY.
5	Unistrut, 1-3/4" x 48"	3
6	Unistrut, 1-3/4" x 34"	1
7	Bolt, 3/8 x 2-1/2 hex	1
8	Nut, 3/8 hex	1

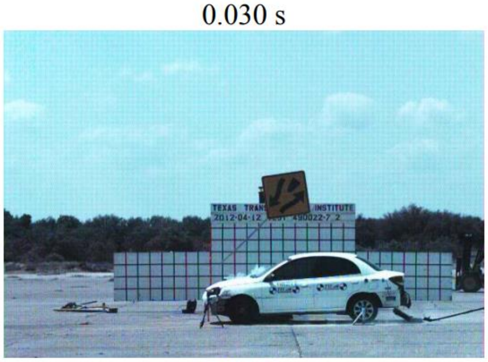
Figure 2.73. Specifications of High-Mounting-Height Temporary Single Sign Support, Modified Design 4 (Continued) (*3*)

In *MASH* test 3-71, the 1100C vehicle, traveling at an impact speed of 62.4 mi/h, contacted the sign support at an impact angle of 90 degrees, with the right front quarter point aligned with the centerline of the support. Figure 2.74 presents sequential photographs of the test period. The telescopic slip connection activated as designed and released the vertical support and sign panel from the base. The vertical sleeve and middle brace in the H-base to which it was attached were both deformed. Figure 2.75 shows damage to the sign support system. The 1100C vehicle sustained minimal damage during the impact with the temporary single sign support. Figure 2.76 shows photographs of the exterior of the vehicle.

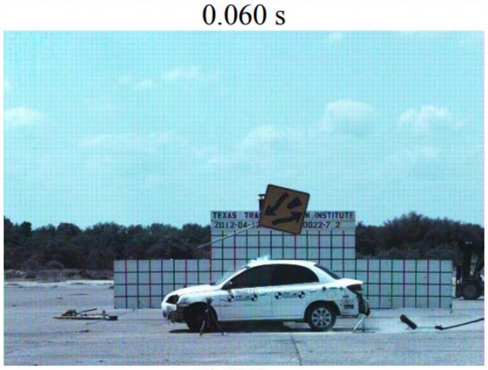
The temporary sign support yielded to the vehicle and the bottom slip connection activated as designed. There was no secondary contact between the test article and the vehicle. A summary of the results from Test 3-71 with a 0-degree impact is presented in Figure 2.77.

0.000 s

0.030 s



0.060 s

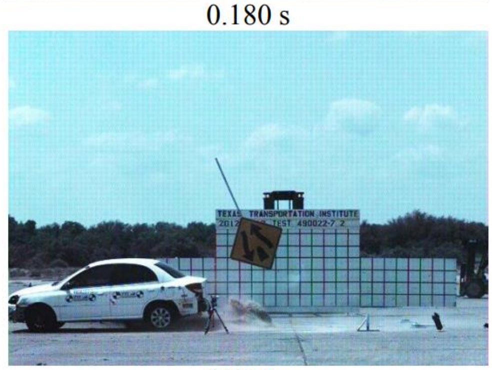


0.090 s

0.120 s

0.150 s

0.180 s

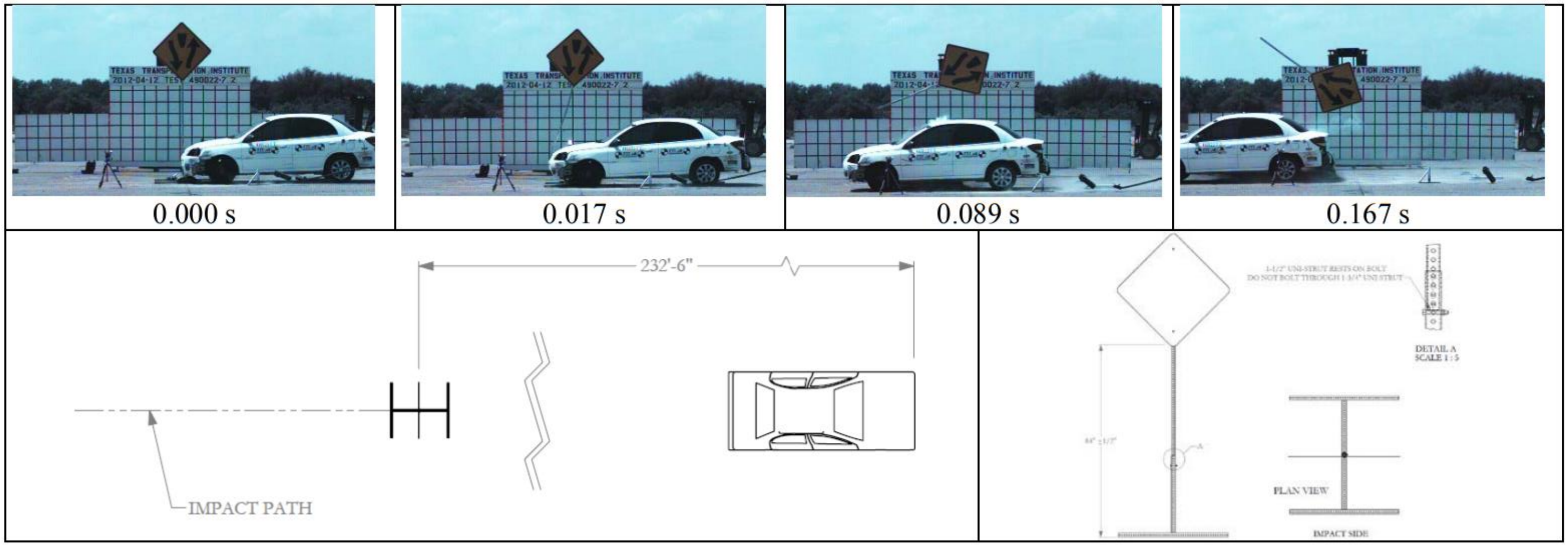


0.210 s

Figure 2.74. High-Mounting-Height Temporary Single Sign Support, Modified Design 4 Test 3-71, 90-degree Impact Sequential Photos (*3*)

Figure 2.75. High-Mounting-Height Temporary Single Sign Support, Modified Design 4 Test 3-71, 0-degree Impact System Damage (*3*)

Figure 2.76. High-Mounting-Height Temporary Single Sign Support, Modified Design 4 Test 3-71, 0-degree Impact Vehicle Damage (*3*)



General Information
Test Agency .... Texas A&M Transportation Institute
MASH Test No. .... *MASH* Test 3-71
TTI-PG Test No. 490022-7-2
Date 2012-04-12

Test Article
Type.................................... Temporary Single Sign Support
Name .... Bottom telescopic slip joint/9 ft^2 aluminum sign panel
Installation Height .... 7 ft to bottom of sign panel
Material or Key Elements .... Aluminum sign panel mounted on 1-1/2-inch perforated steel tubing; H-base fabricated from 1-3/4 inch steel tubing

Soil Type and Condition....... Concrete Pavement, Dry

Test Vehicle
Type/Designation................. 1100C
Make and Model .... 2003 Kia Rio
Curb.................................... 2411 lb
Test Inertial.......................... 2425 lb
Dummy .... No dummy
Gross Static......................... 2425 lb

Impact Conditions
Speed ....62.4 mph
Angle ....90 degrees
Location/Orientation ....Right quarter point of vehicle with centerline of sign support

Exit Conditions
Speed ....62.4 mph
Angle ....0 degrees

Occupant Risk Values
Impact Velocity
Longitudinal.......................N/A
Lateral ....N/A
Ridedown Accelerations
Longitudinal.......................N/A
Lateral ....N/A
THIV ....N/A
ASI ....N/A
Max. 0.050-s Average
Longitudinal.......................N/A
Lateral ....N/A
Vertical ....N/A

Post-Impact Trajectory
Stopping Distance 232-ft 6-in

Vehicle Stability
Maximum Yaw Angle...................... N/A
Maximum Pitch Angle..................... N/A
Maximum Roll Angle .... N/A
Vehicle Snagging .... No
Vehicle Pocketing........................... No

Test Article Deflections
Dynamic 232-ft 6-in
Permanent 232-ft 6-in
Working Width .... N/A

Vehicle Damage
VDS 12FD1
CDC... 12FDEN1
Max. Exterior Deformation............... None
OCDI.. FS0000000
Max. Occupant Compartment Deformation.............................. None

Figure 2.77. High-Mounting-Height Temporary Single Sign Support, Modified Design 4 Test 3-71, 0-degree Impact Results (*3*)

2.2.6. Development and MASH Full-Scale Crash Testing of a High-Mounting-Height Temporary Single Sign Support with Aluminum Sign (Modified Design 8) (*3*)

Three 1¾-inch PSST were welded together to form an H-base assembly system. A 1¾-inch PSST was welded to the center of the H-base assembly. 1½-inch PSST served as the vertical support. The vertical support inserted 4½ inches into the top of the sleeve and rested on a bolt inserted through the sleeve. A section of 1½-inch perforated square steel tube was used to provide bracing for the sign panel. Two 1½-inch-wide × 8½-inch-long × 1/8-inch-thick steel fuse plates were used to connect the vertical support and sign panel brace. All PSST was 12 gauge.

A 36-inch × 36-inch × 0.1-inch-thick aluminum diamond-shaped sign was attached to the 1½-inch brace. The mounting height to the bottom of the sign blank was 7 ft. A 40-lb sandbag was laid on each side of the base assembly. Figure 2.78, Figure 2.79, and Figure 2.80 give details of the sign support system.

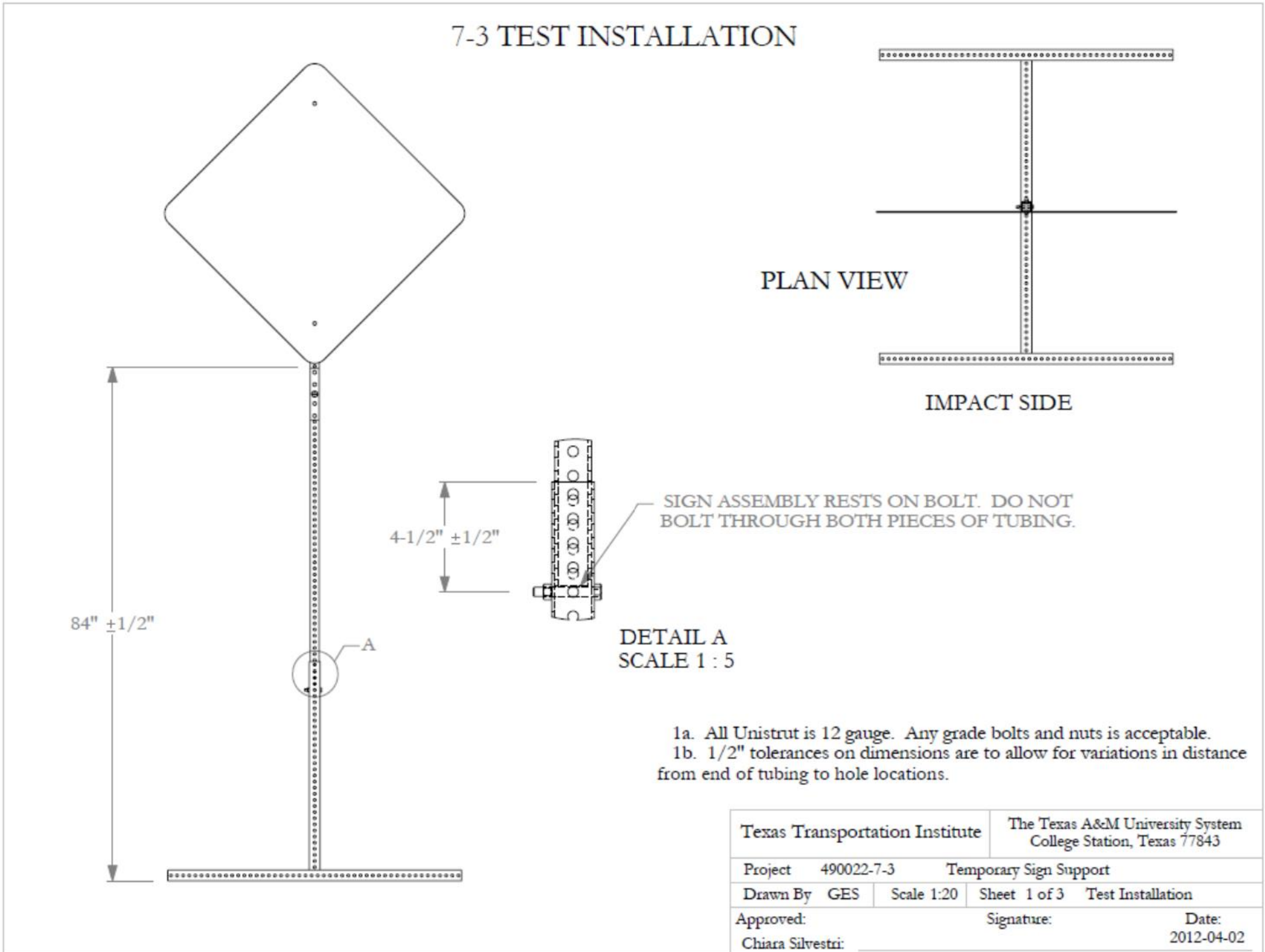
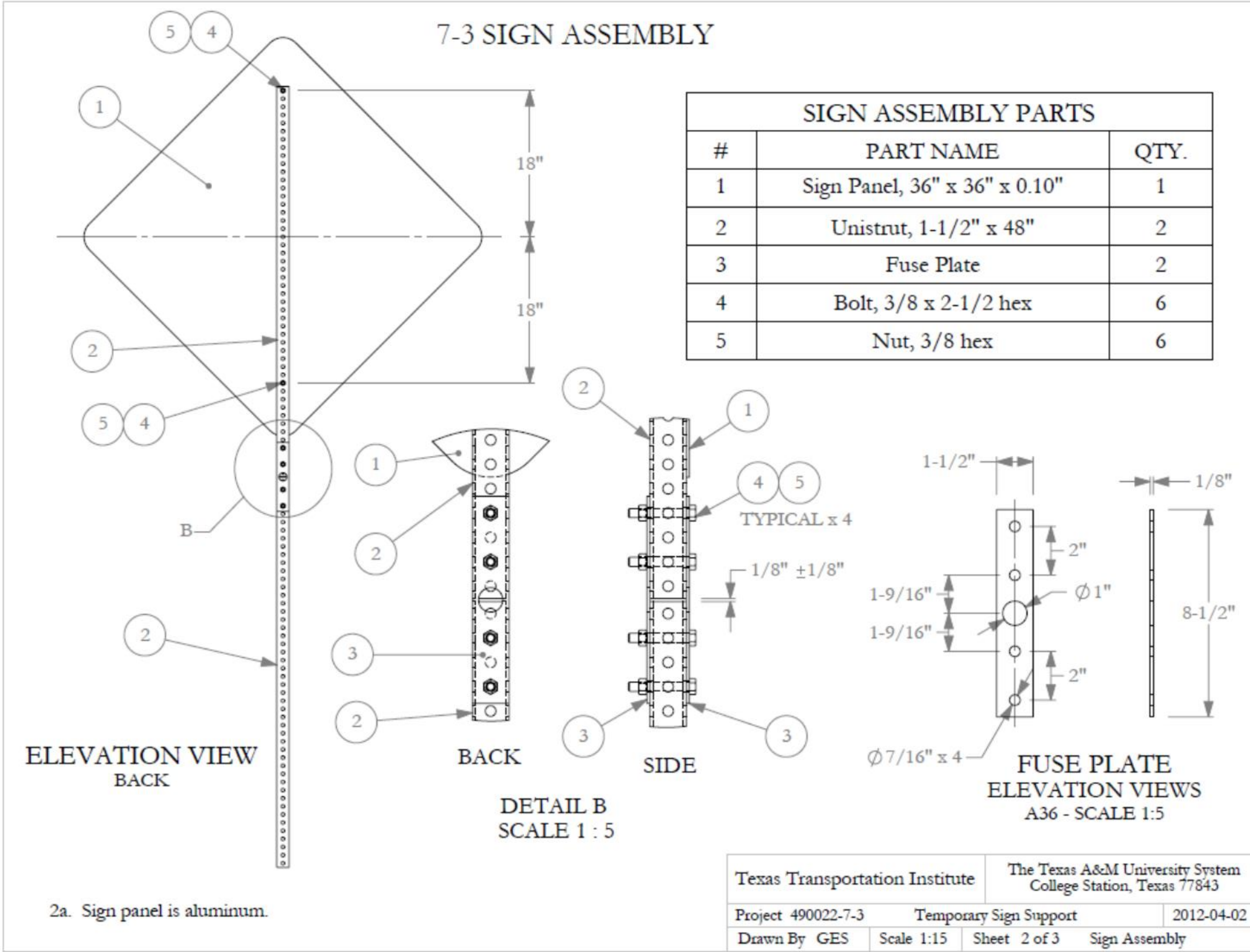
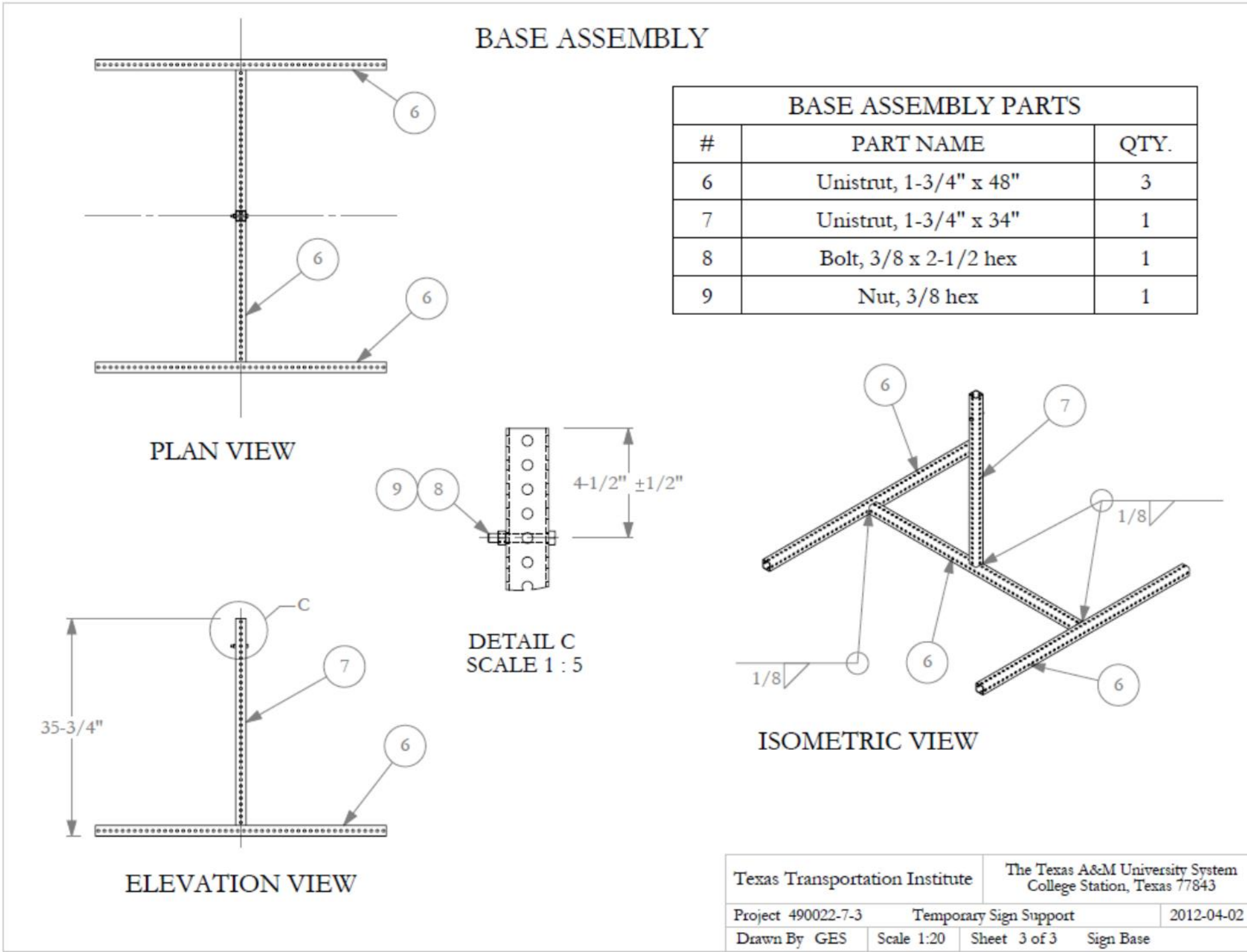


Figure 2.78. Specifications of High-Mounting-Height Temporary Single Sign Support, Modified Design 8 (*3*)



SIGN ASSEMBLY PARTS		
#	PART NAME	QTY.
1	Sign Panel, 36" x 36" x 0.10"	1
2	Unistrut, 1-1/2" x 48"	2
3	Fuse Plate	2
4	Bolt, 3/8 x 2-1/2 hex	6
5	Nut, 3/8 hex	6

Figure 2.79. Specifications of High-Mounting-Height Temporary Single Sign Support, Modified Design 8 (Continued) (*3*)



BASE ASSEMBLY PARTS

#	PART NAME	QTY.
6	Unistrut, 1-3/4" x 48"	3
7	Unistrut, 1-3/4" x 34"	1
8	Bolt, 3/8 x 2-1/2 hex	1
9	Nut, 3/8 hex	1

Figure 2.80. Specifications of High-Mounting-Height Temporary Single Sign Support, Modified Design 8 (Continued) (*3*)

In *MASH* test 3-71, The 1100C vehicle, traveling at an impact speed of 63.6 mi/h, contacted the sign support at an impact angle of 90 degrees, with the centerline point aligned with the centerline of the support. Figure 2.81 presents sequential photographs of the test period.

Figure 2.82 shows damage to the sign support system. The lower telescopic slip connection and fuse plates activated as designed. The 1100C vehicle did not sustain any additional damage during the impact with the temporary single sign support. Figure 2.83 shows photographs of the exterior of the vehicle.

The temporary sign support yielded to the vehicle and the bottom slip connection activated as designed. The fuse plates fractured on their tension sides as designed. There was no secondary contact between the test article and the vehicle. A summary of the results from Test 3-71 with a 90-degree impact is presented in Figure 2.84.

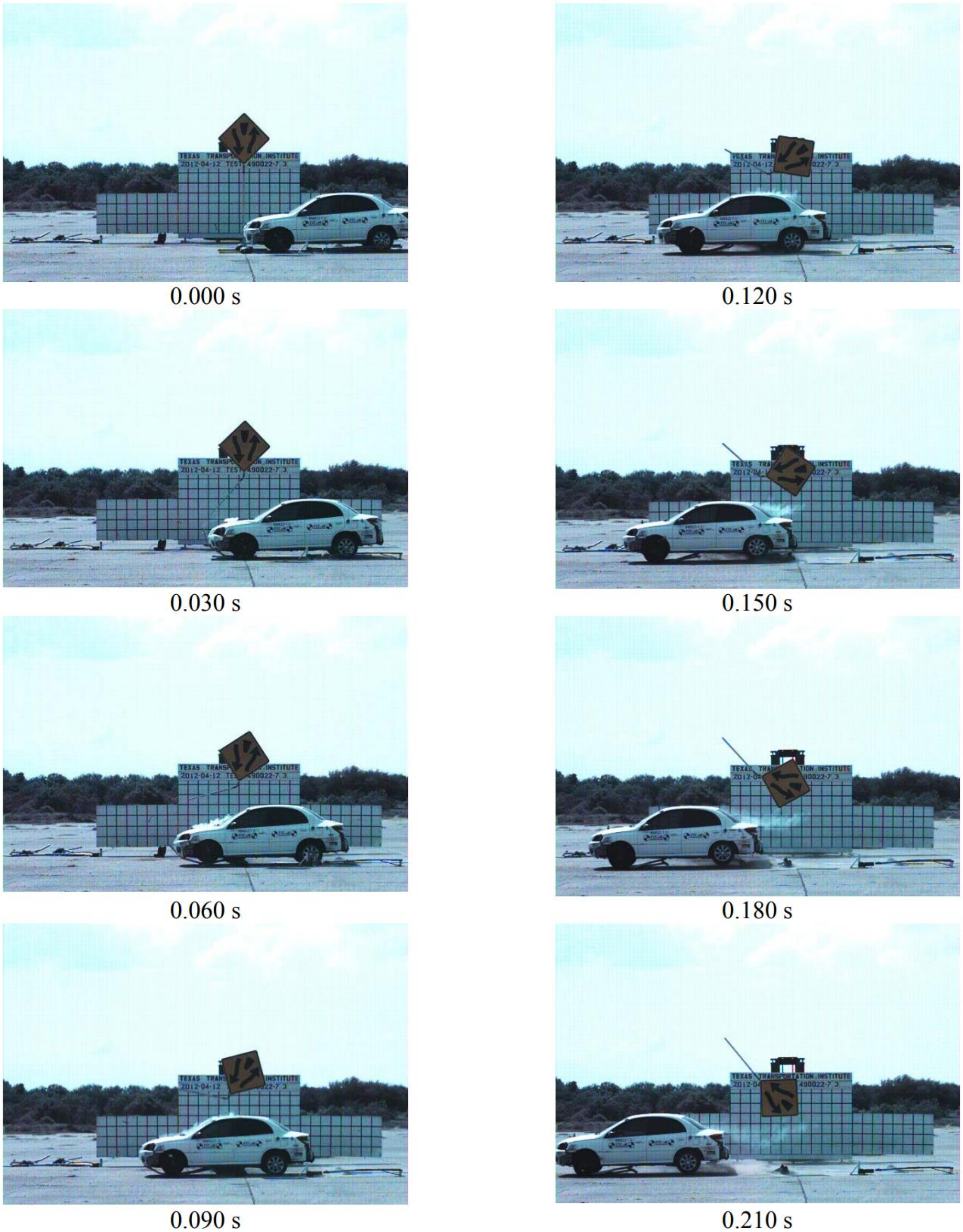
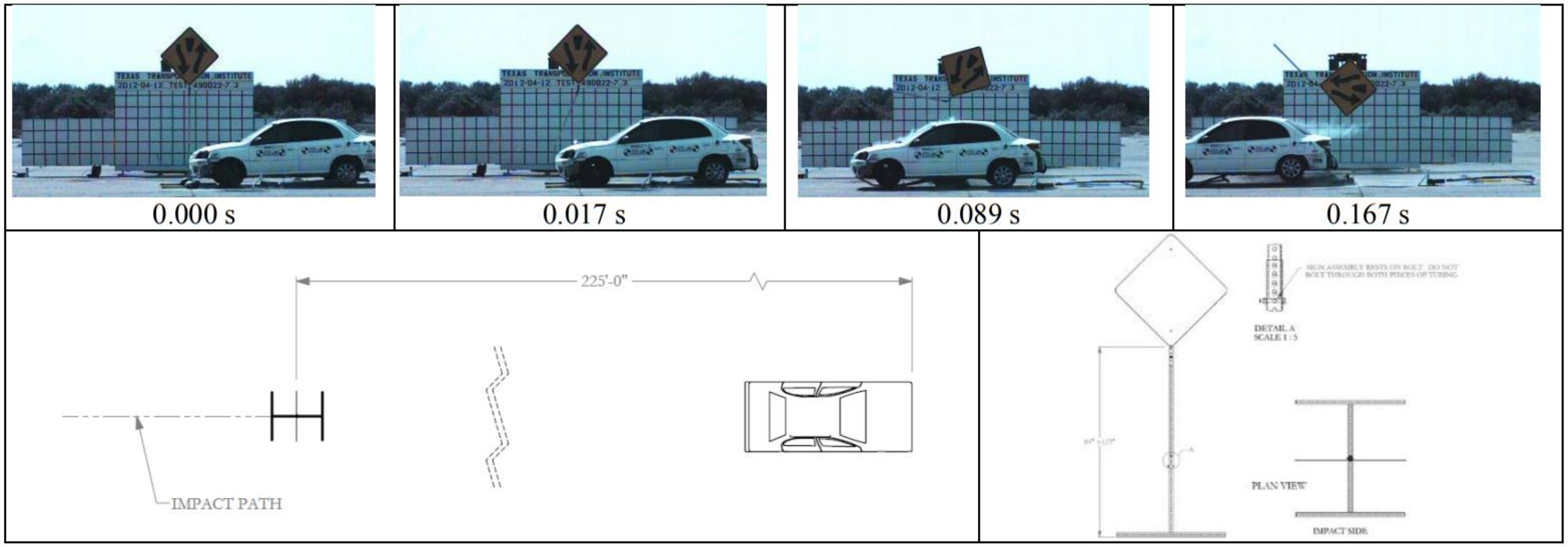


Figure 2.81. High-Mounting-Height Temporary Single Sign Support, Modified Design 8 Test 3-71, 90-degree Impact Sequential Photos (*3*)

Figure 2.82. High-Mounting-Height Temporary Single Sign Support, Modified Design 8 Test 3-71, 90-degree Impact System Damage (*3*)

Figure 2.83. High-Mounting-Height Temporary Single Sign Support, Modified Design 8 Test 3-71, 90-degree Impact Vehicle Damage (*3*)



General Information

Test Agency	Texas A&M Transportation Institute
MASH Test No.	*MASH* Test 3-71
TTI-PG Test No.	490022-7-3
Date	2012-04-12

Test Article

Type	Temporary Single Sign Support
Name	Bottom telescopic slip connection and upper fuse plates/9 ft^2 sign panel
Installation Height	7 ft to bottom of sign panel
Material or Key Elements	Aluminum sign panel mounted on a 1-1/2-inch perforated steel tube support; 1-3/4 perforated steel tube H-base
Soil Type and Condition	Concrete Pavement, Dry

Test Vehicle

Type/Designation	1100C
Make and Model	2003 Kia Rio
Curb	2411 lb
Test Inertial	2425 lb
Dummy	No dummy
Gross Static	2425 lb

Impact Conditions

Speed	63.6 mph
Angle	90 degrees
Location/Orientation	Centerline of vehicle with centerline of sign support

Exit Conditions

Speed	62.93 mph
Angle	0 degrees

Occupant Risk Values

Impact Velocity	
Longitudinal	N/A
Lateral	N/A
Ridedown Accelerations	
Longitudinal	N/A
Lateral	N/A
THIV	N/A
ASI	N/A
Max. 0.050-s Average	
Longitudinal	N/A
Lateral	N/A
Vertical	N/A

Post-Impact Trajectory

Stopping Distance	225-ft

Vehicle Stability

Maximum Yaw Angle	N/A
Maximum Pitch Angle	N/A
Maximum Roll Angle	N/A
Vehicle Snagging	No
Vehicle Pocketing	No

Test Article Deflections

Dynamic	225-ft
Permanent	225-ft
Working Width	N/A

Vehicle Damage

VDS	12FD1
CDC	12FDEN1
Max. Exterior Deformation	None
OCDI	FS0000000
Max. Occupant Compartment Deformation	None

Figure 2.84. High-Mounting-Height Temporary Single Sign Support, Modified Design 8 Test 3-71, 90-degree Impact Results (*3*)

2.2.7. Skid-Mounted Single-Post Perforated Steel Tube Temporary Sign Support (*4*)

A 36-inch square extruded, hollowcore plastic sign panel was secured to a section of 1¾-inch PSST. This tubing was inserted into a four foot long sleeve fabricated from 2-inch PSST. The sleeve was welded to an I-shaped skid fabricated from 1¾-inch and 2-inch PSST. All square perforated tubing was 12 gauge. Excluding the four 40-lb sandbags, the test article weighed 63 lb. Figure 2.85 and Figure 2.86 present overall information on the skid-mounted single perforated steel tube temporary sign support system.

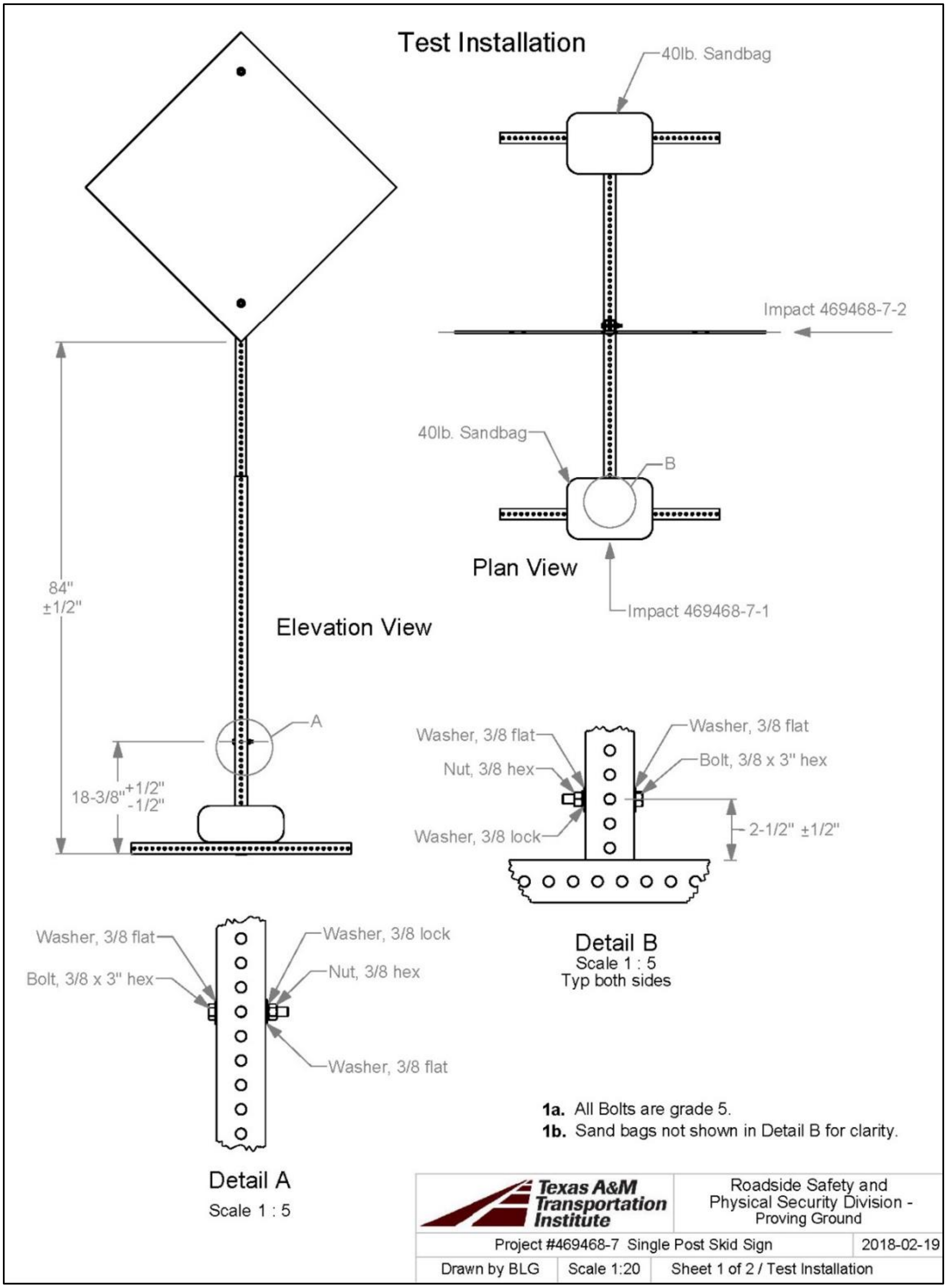


Figure 2.85. Specifications of Skid-Mounted Single-Post Perforated Steel Tube Temporary Sign Support (*4*)

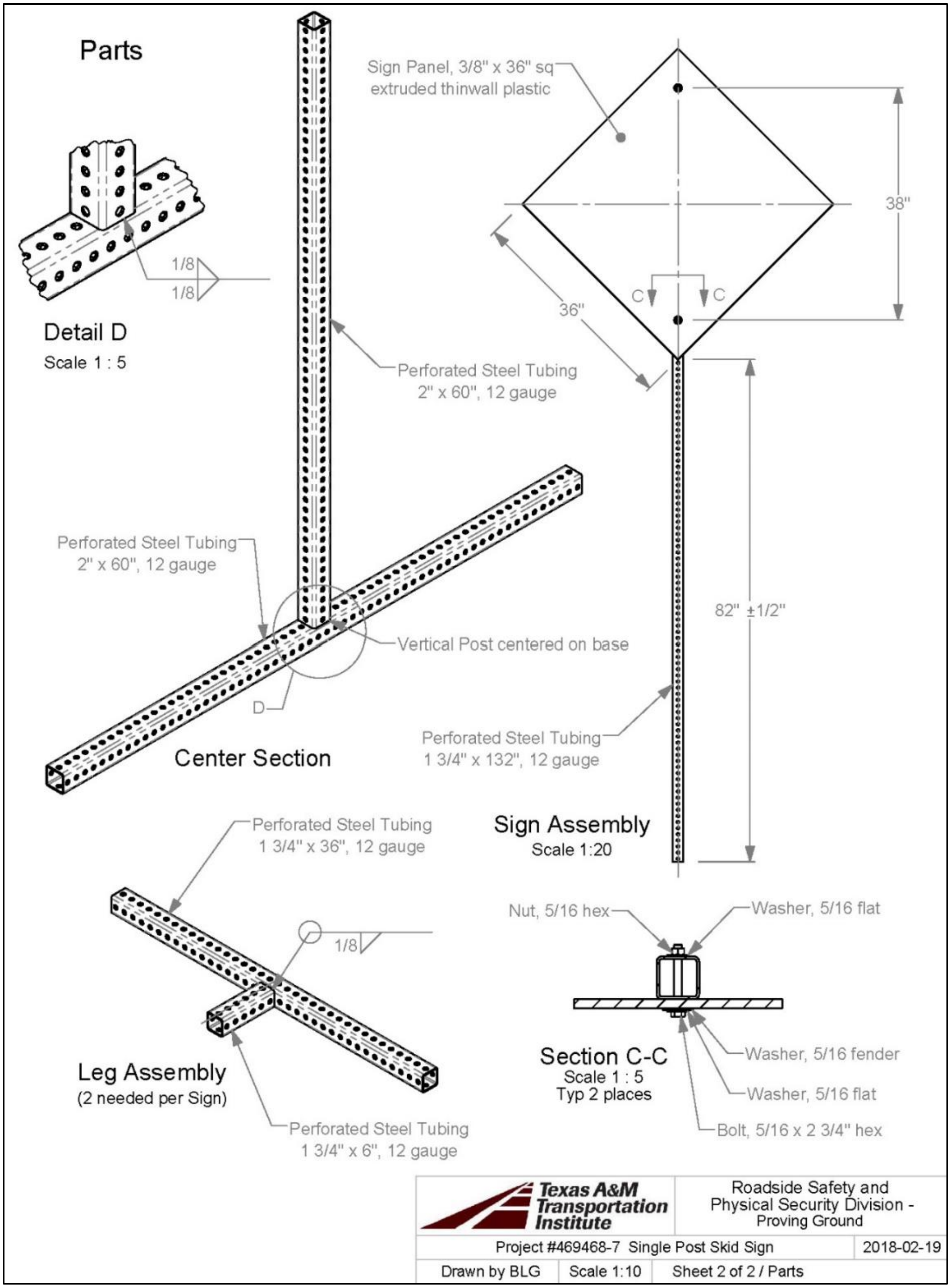


Figure 2.86. Specifications of Skid-Mounted Single-Post Perforated Steel Tube Temporary Sign Support (Continued) (*4*)

In *MASH* test 3-72, the test vehicle impacted the skid-mounted single perforated steel tube temporary sign support system with the left quarter point of the vehicle aligned with the centerline of the device at a speed of 62.7 mi/h and an angle of 0°. Figure 2.87 and Figure 2.88 present sequential photographs of the test.

Figure 2.89 shows the damage to the skid-mounted single perforated steel tube temporary sign support system. Figure 2.90 shows the damage sustained by the vehicle. A very small depression in the left side of the bumper and hood were observed. The windshield was cracked at the upper left corner, and the edge of the roof just above this location was slightly dented. The windshield also had a slight indentation, but no hole or tear was observed in the windshield. No occupant compartment deformation or intrusion was observed.

The skid-mounted single perforated steel tube temporary sign support system met all applicable criteria for MASH Test 3-72 at 0°.

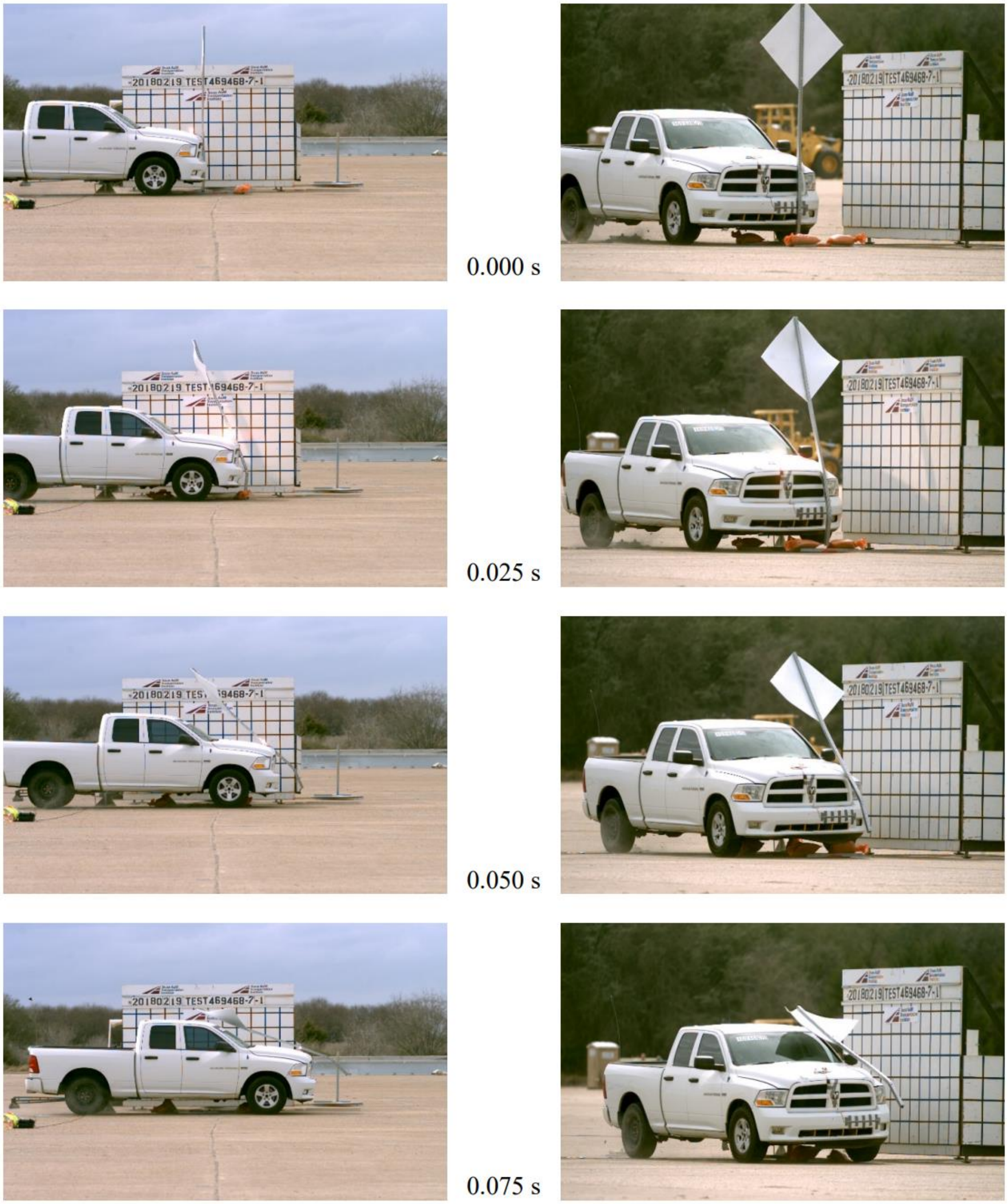


Figure 2.87. Skid-Mounted Single-Post Perforated Steel Tube Temporary Sign Support Test 3-72, 0-degree Impact Sequential Photos (*4*)

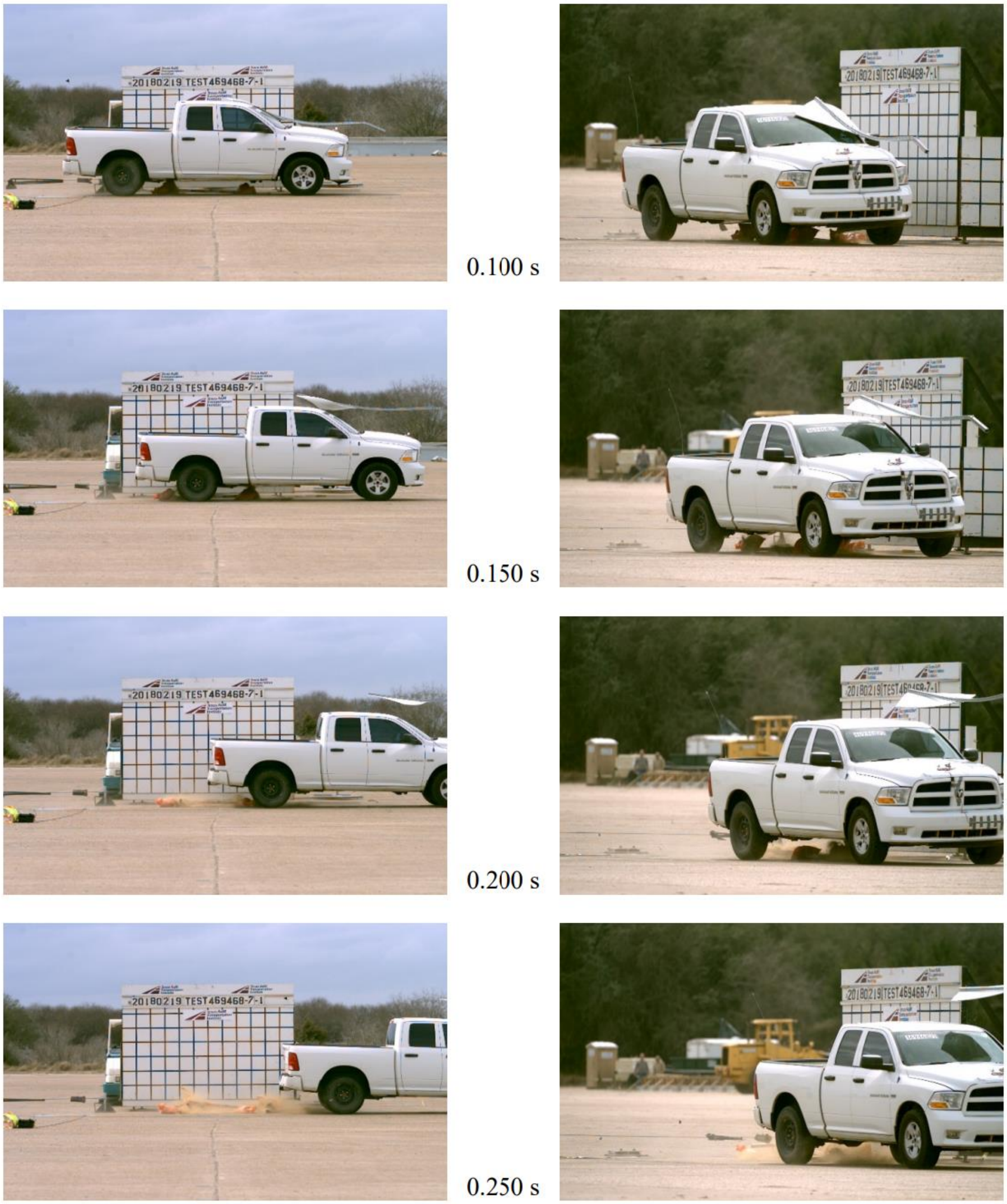


Figure 2.88. Skid-Mounted Single-Post Perforated Steel Tube Temporary Sign Support Test 3-72, 0-degree Impact Sequential Photos (Continued) (*4*)

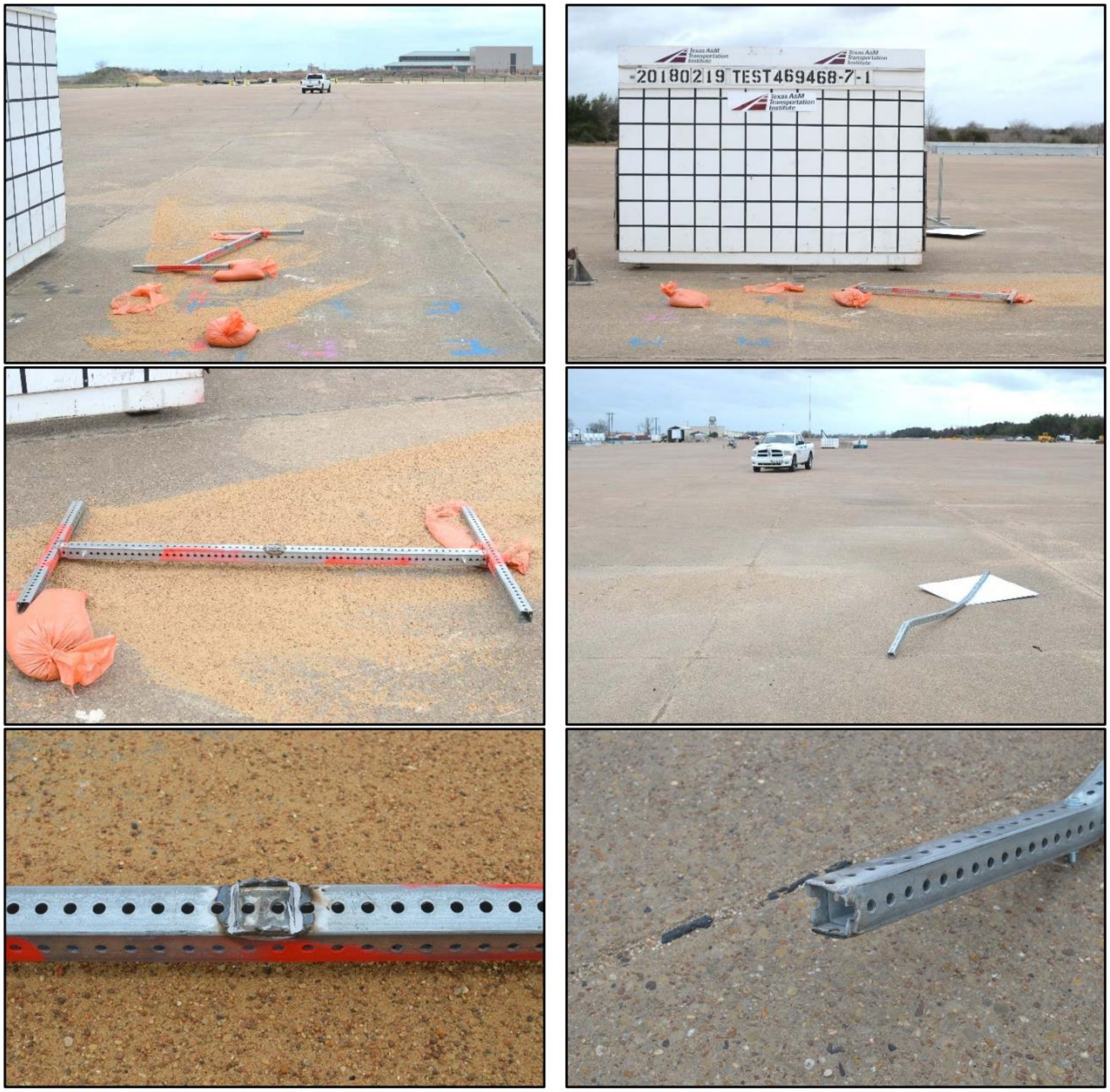
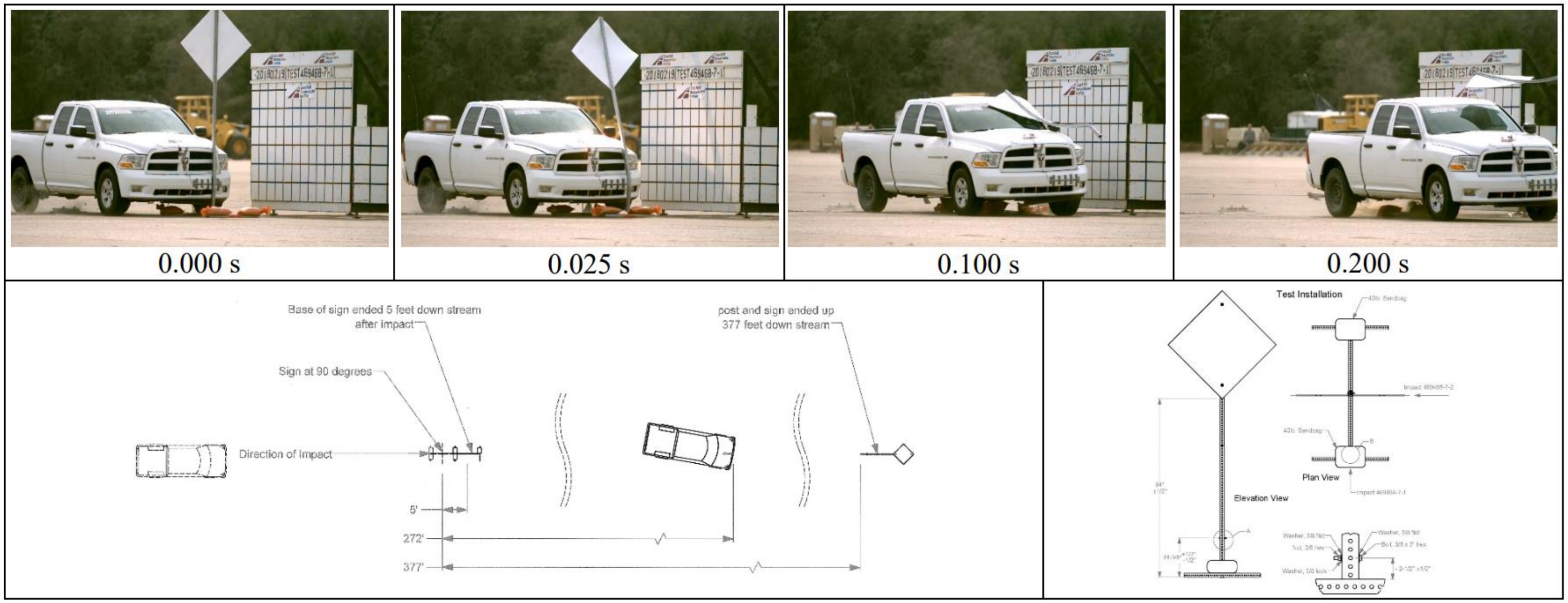


Figure 2.89. Skid-Mounted Single-Post Perforated Steel Tube Temporary Sign Support Test 3-72, 0-degree Impact System Damage (*4*)

Figure 2.90. Skid-Mounted Single-Post Perforated Steel Tube Temporary Sign Support Test 3-72, 0-degree Impact Vehicle Damage (*4*)

Figure 2.91 provides an assessment of the test based on the applicable safety evaluation criteria for MASH Test 3-72. The skid-mounted single perforated steel tube temporary sign support system met all applicable criteria for *MASH* Test 3-72 at 0°.



General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-72 at 0°
TTI Test No.	469468-7-1
Test Date	2018-02-19
Test Article	
Type	Work Zone Traffic Control Device
Name	Skid-mounted single perforated steel tube temporary sign support system
Installation Height	84 inches from ground to bottom of sign.
Material or Key Elements	36-inch square hollow core plastic sign panel secured to 1¾-inch square perforated tubing inserted into a sleeve made from 2-inch square perforated steel tubing attached to an I-shaped skid
Soil Type and Condition	Placed on concrete surface, dry

Test Vehicle	
Type/Designation	2270P
Make and Model	2012 Dodge RAM 1500
Curb	4870 lb
Test Inertial	5034 lb
Dummy	No dummy
Gross Static	5034 lb
Impact Conditions	
Speed	62.7 mi/h
Angle	0°
Location/Orientation	Left quarter point
Kinetic Energy	662 kip-ft
Exit Conditions	
Speed	62.4 mi/h
Angle	0°

Post-Impact Trajectory	
Stopping Distance	272 ft downstream
Test Article Debris Scatter	
Longitudinal	377 ft
Lateral	7 ft
Vehicle Damage	
VDS	12FL1
CDC	12FLEN1
Max. Exterior Deformation	Not measurable
OCDI	LF0000000
Max. Occupant Compartment Deformation	None

Figure 2.91. Skid-Mounted Single-Post Perforated Steel Tube Temporary Sign Support Test 3-72, 0-degree Impact Results (*4*)

In *MASH* test 3-72, the test vehicle impacted the skid-mounted single perforated steel tube temporary sign support system with the right quarter point of the vehicle aligned with the centerline of the device at a speed of 62.6 mi/h and an angle of 90°. Figure 2.92 and Figure 2.93 present sequential photographs during the test.

Figure 2.94 shows the damage to the skid-mounted single perforated steel tube temporary sign support system. Figure 2.95 shows the damage sustained by the vehicle. The windshield was cracked with a maximum deformation of 2.0 inches. No holes or tears occurred in the windshield. An indentation and a small cut in the oil pan were observed. No other occupant compartment deformation or intrusion was noted.

Figure 2.96 provides an assessment of the test based on the applicable safety evaluation criteria for MASH Test 3-72. Figure 2.96 shows the skid-mounted single perforated steel tube temporary sign support system met applicable criteria for MASH Test 3-72 at 90°.

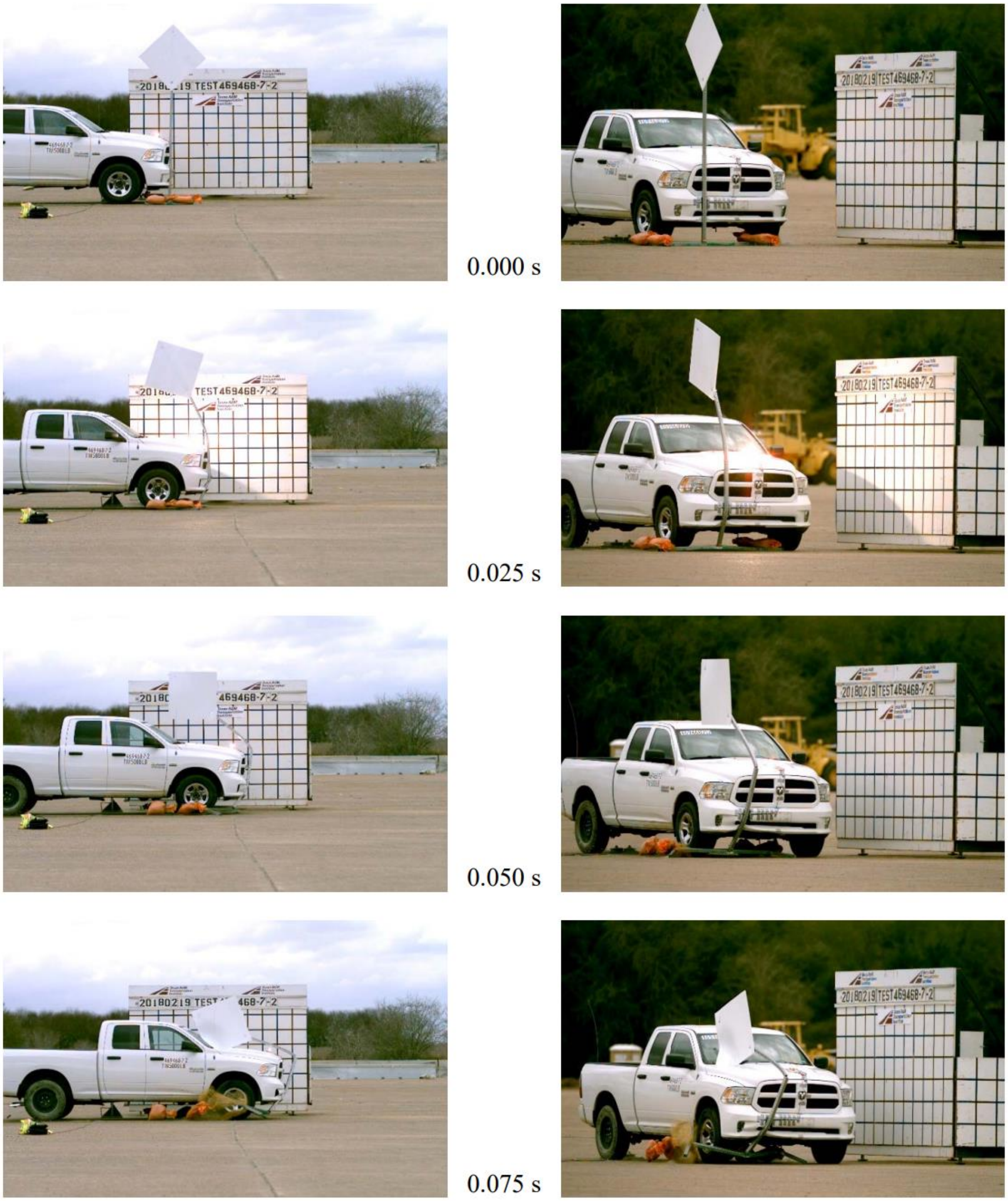


Figure 2.92. Skid-Mounted Single-Post Perforated Steel Tube Temporary Sign Support Test 3-72, 90-degree Impact Sequential Photos (*4*)

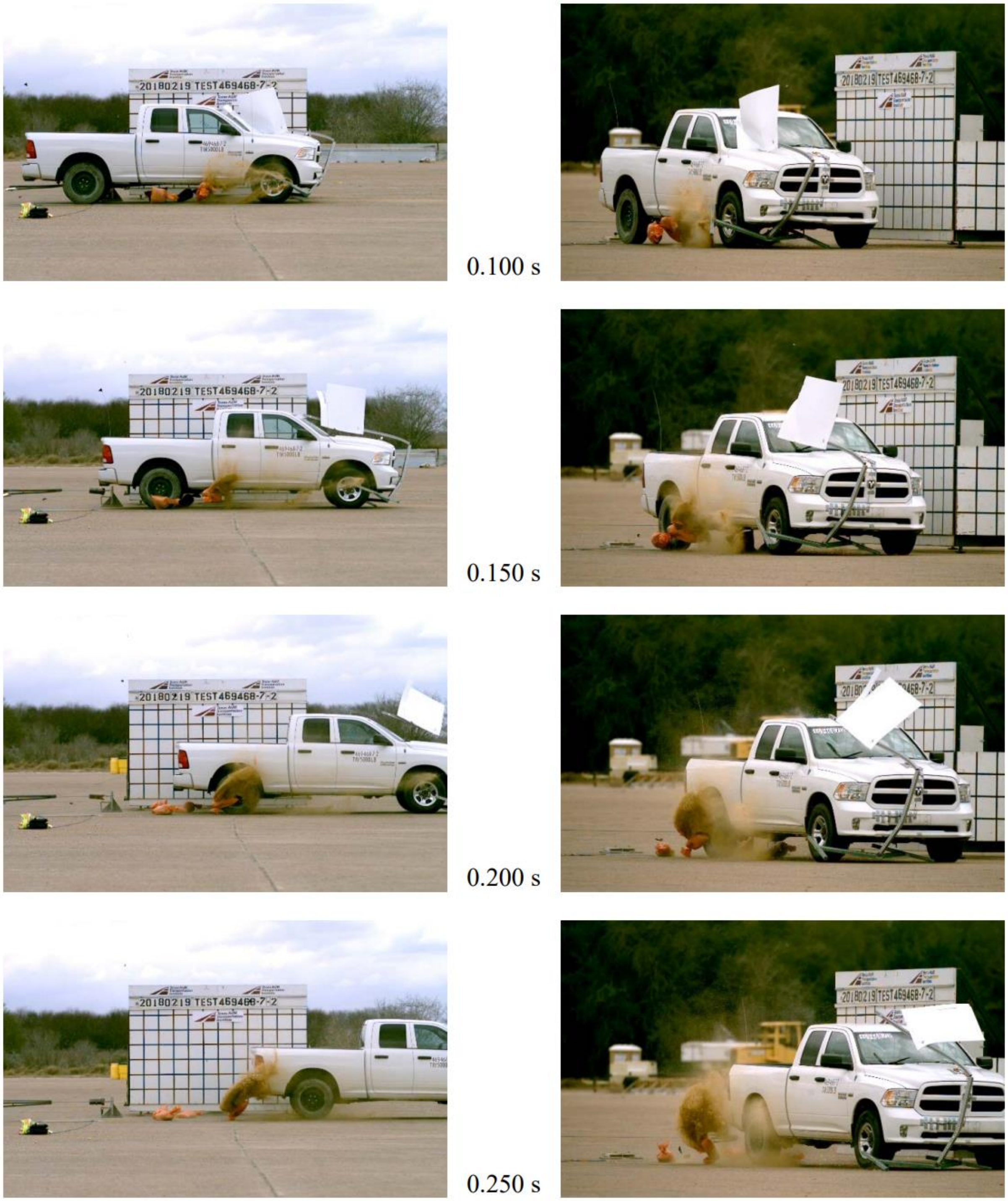
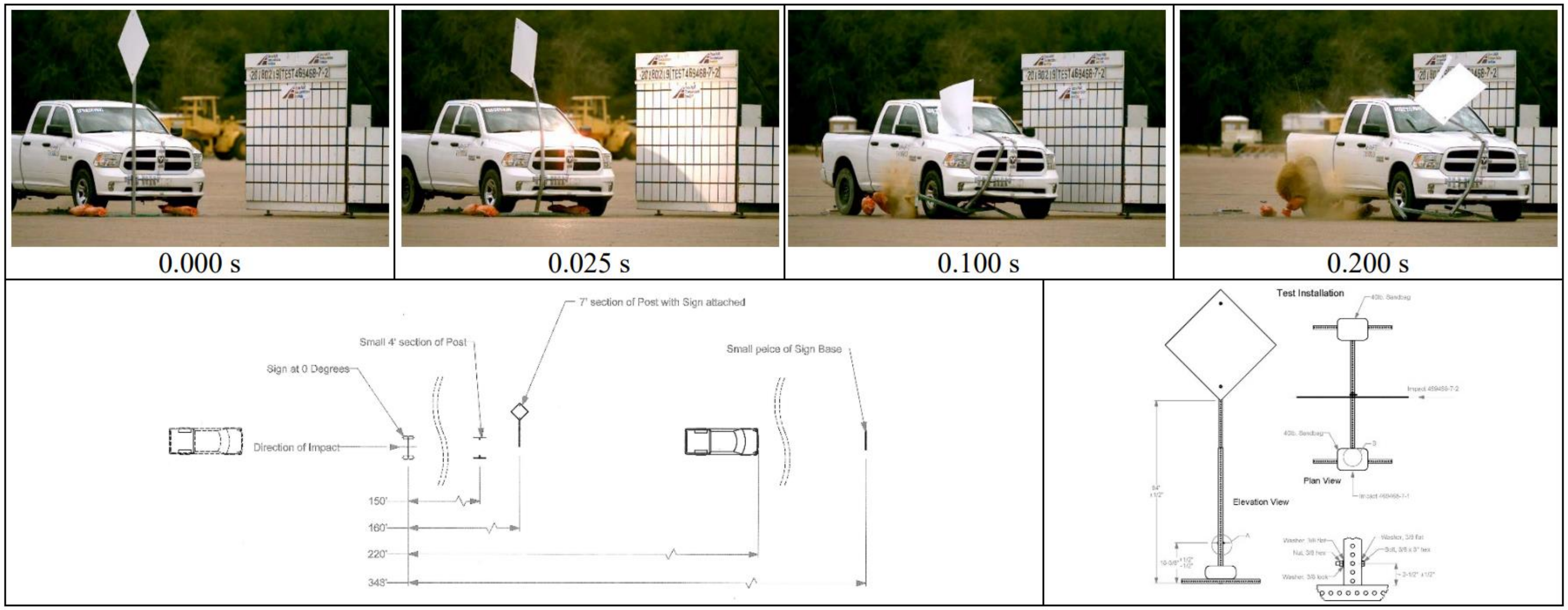


Figure 2.93. Skid-Mounted Single-Post Perforated Steel Tube Temporary Sign Support Test 3-72, 90-degree Impact Sequential Photos (Continued) (*4*)

Figure 2.94. Skid-Mounted Single-Post Perforated Steel Tube Temporary Sign Support Test 3-72, 90-degree Impact System Damage (*4*)

Figure 2.95. Skid-Mounted Single-Post Perforated Steel Tube Temporary Sign Support Test 3-72, 90-degree Impact Vehicle Damage (*4*)



General Information
- Test Agency .... Texas A&M Transportation Institute (TTI)
- Test Standard Test No. ...... *MASH* Test 3-72 at 90°
- TTI Test No. 469468-7-2
- Test Date 2018-02-19

Test Article
- Type .... Work Zone Traffic Control Device
- Name .... Skid-mounted single perforated steel tube temporary sign support system
- Installation Height .... 84 inches from ground to bottom of sign.
- Material or Key Elements ... 36-inch square hollow core plastic sign panel secured to 1¾-inch square perforated tubing inserted into a sleeve made from 2-inch square perforated steel tubing attached to an I-shaped skid

Soil Type and Condition ..... Placed on concrete surface, dry

Test Vehicle
- Type/Designation 2270P
- Make and Model .... 2013 RAM 1500
- Curb .... 5026 lb
- Test Inertial .... 5029 lb
- Dummy .... No dummy
- Gross Static .... 5029 lb

Impact Conditions
- Speed .... 62.6 mi/h
- Angle .... 90°
- Location/Orientation .... Right quarter point

Kinetic Energy .... 659 kip-ft

Exit Conditions
- Speed .... 60.4 mi/h
- Angle .... 90°

Post-Impact Trajectory
- Stopping Distance .... 220 ft downstream

Test Article Debris Scatter
- Longitudinal .... 348 ft
- Lateral .... 2 ft

Vehicle Damage
- VDS 12RF1
- CDC 12FREN1
- Max. Exterior Deformation .... Not measurable
- OCDI RF0000000
- Max. Occupant Compartment Deformation .... 2.0 inches

Figure 2.96. Skid-Mounted Single-Post Perforated Steel Tube Temporary Sign Support Test 3-72, 90-degree Impact Results (*4*)

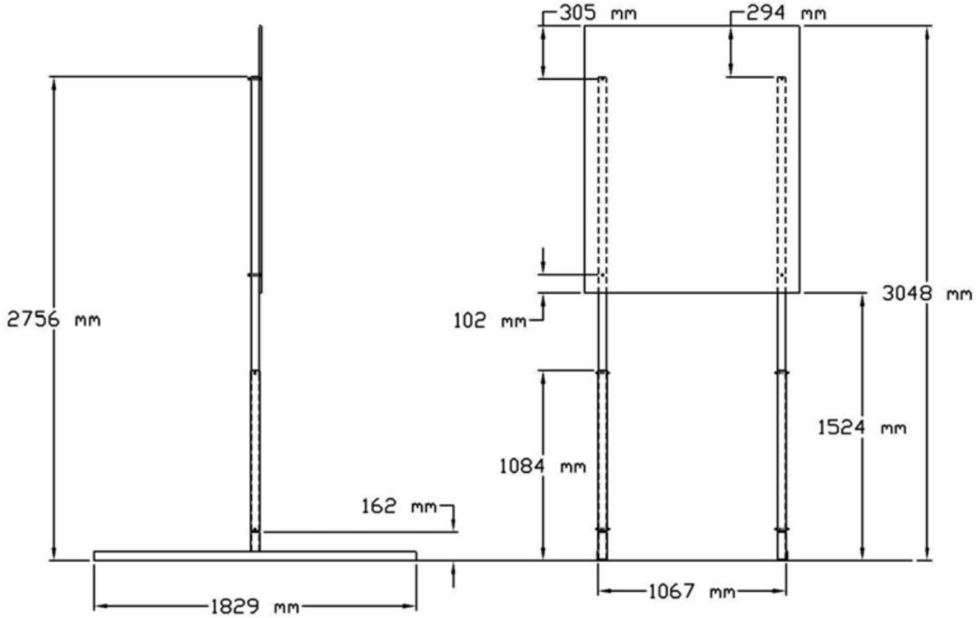
2.3. DOUBLE MAST SIGN TESTING

This section summarizes the literature review effort of single mast sign supports.

2.3.1. Safety Performance Evaluation of Michigan's 4x5 Portable Sign Support (*5*)

The details of Michigan's 4x5 Portable Sign Support System are shown in Figure 2.97. The test vehicle impacted System No. 7 with the right-front quarter point of the vehicle aligned with the centerline of the sign support, Approximately 0.73 sec after impact with System No. 7, the vehicle impacted System No. 8 with the centerline of the vehicle aligned with the centerline of the sign support.

Damage to System Nos. 7 and 8 is shown in Figure 2.100. Exterior vehicle damage is shown in Figure 2.101. Detached elements and debris from System No. 7 penetrated the right region of the windshield and the right side of the roof. Detached elements and debris from System No. 8 deformed the upper middle region of the windshield. Systems 7 and 8 failed to meet NCHRP Report 350 (*6*) evaluation criteria due to the hole in the windshield and occupant compartment deformation. Figure 2.102 and Figure 2.103 summarize the testing results.



4X5 Portable Rigid Panel System

- Vertical Upright Mast - 44.5 mm x 44.5 mm x 2.8 mm wall x 2743 long galvanized telespar steel tubing
- Outside Vertical Upright Tubing - 50.8 mm x 50.8 mm x 2.7 mm wall x 914 mm long galvanized telespar steel tubing
- Legs, Horizontal Portion - 50.8 mm x 50.8 mm x 6.4 mm thicknesses x 1829 mm long L-shaped steel angle
- Legs, Vertical Stub - 50.8 mm x 50.8 mm x 2.7 mm wall x 154 mm long steel tubing
- All telespar steel tubing contain 9.5 mm diameter punched holes, spaced 25.4 mm on center, along the total length
- Vertical stub of the leg is tack welded to horizontal portion of the leg with 6.4 mm x 50.8 mm welds on three sides
- Outside stiffening tubes slide over the vertical upright masts and are bolted at the top and bottom of the stiffening tubes with 9.5 mm x 63.5 mm - 16 zinc coated steel hex bolts with 14.3 mm nut
- Masts slide inside vertical stub of legs - No bolt or fasenting device used
- Panel - Reflective plywood, 1219 mm wide x 1524 mm long with a 17.3 mm thickness. At each bolt location, a 31.75-mm diameter hole was drilled in the panel.
- Panel fastened to vertical mast supports with 9.5 mm x 76 mm - 16 zinc coated steel hex bolts with 14.3 mm nut and 38.1 mm x 1.6 mm thick flat washer. The bolts were tightened to the point that the washers were cupped.
- Ballast - 31.75-kg of sandbags at end of each leg

Figure 2.97. Specifications of Michigan's 4x5 Portable Sign Support System (*5*)

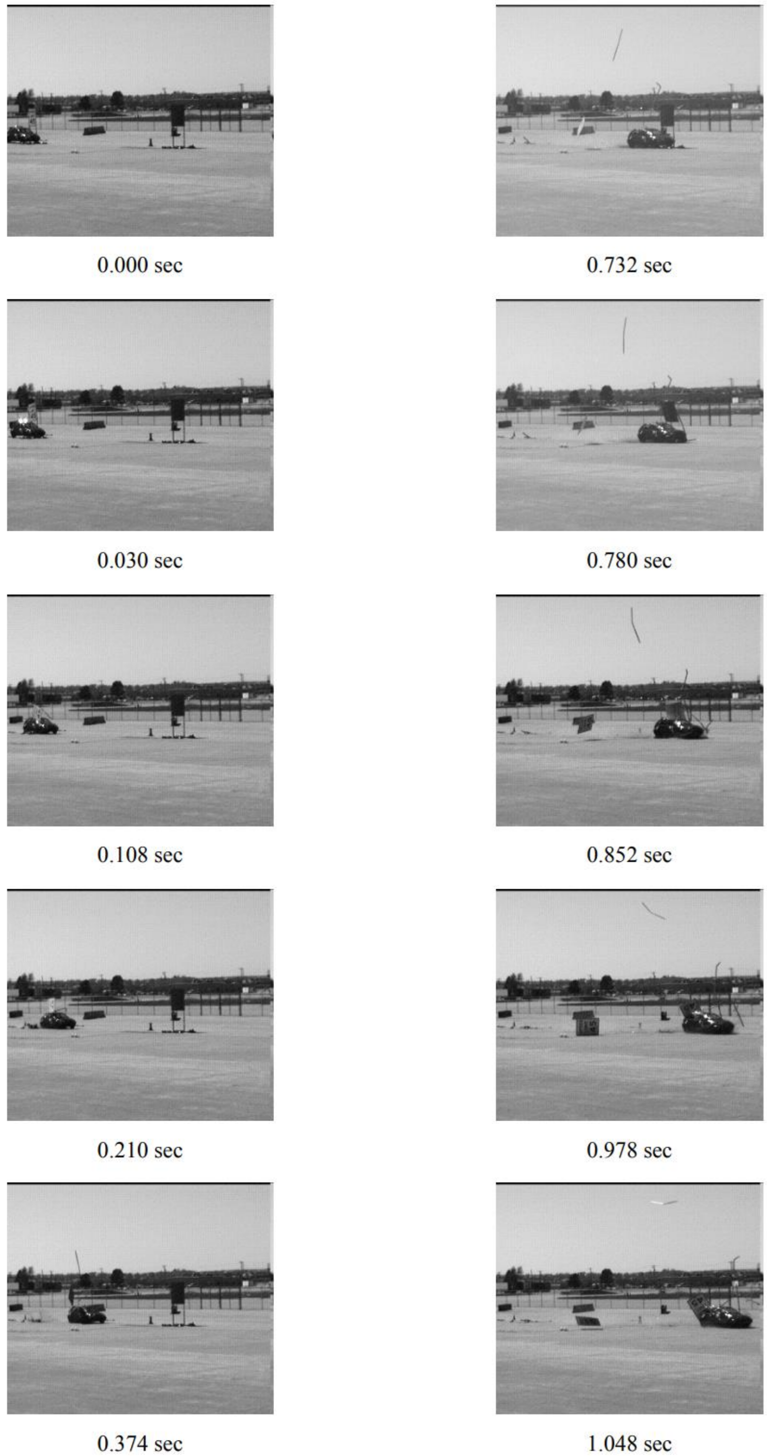


Figure 2.98. Michigan's 4x5 Portable Sign Support Test 3-71, 0-degree Impact Sequential Photos (*5*)

0.017 sec

0.000 sec

0.083 sec

0.067 sec

0.150 sec

0.133 sec

0.217 sec

0.200 sec

0.284 sec

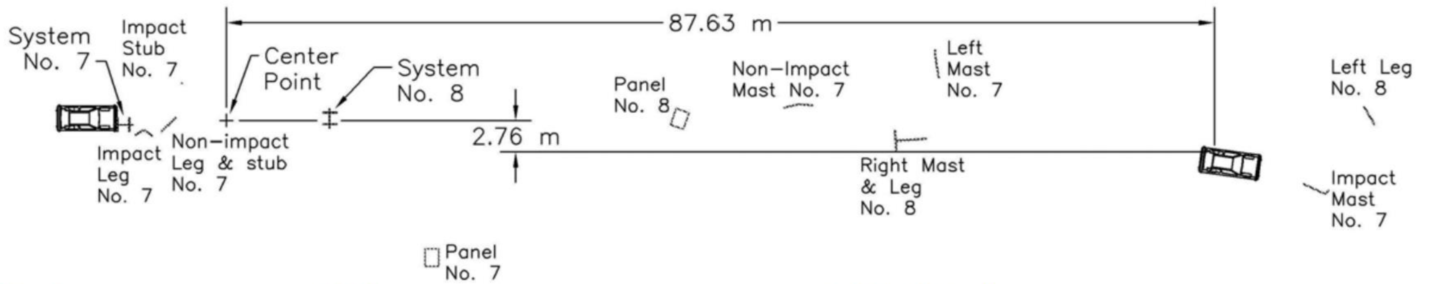
0.267 sec

Figure 2.99. Michigan's 4x5 Portable Sign Support Test 3-71, 90-degree Impact Sequential Photos (*5*)

Figure 2.100. Michigan’s 4x5 Portable Sign Support Test 3-71 System Damage (*5*)

Figure 2.101. Michigan’s 4x5 Portable Sign Support Test 3-71 Vehicle Damage (*5*)

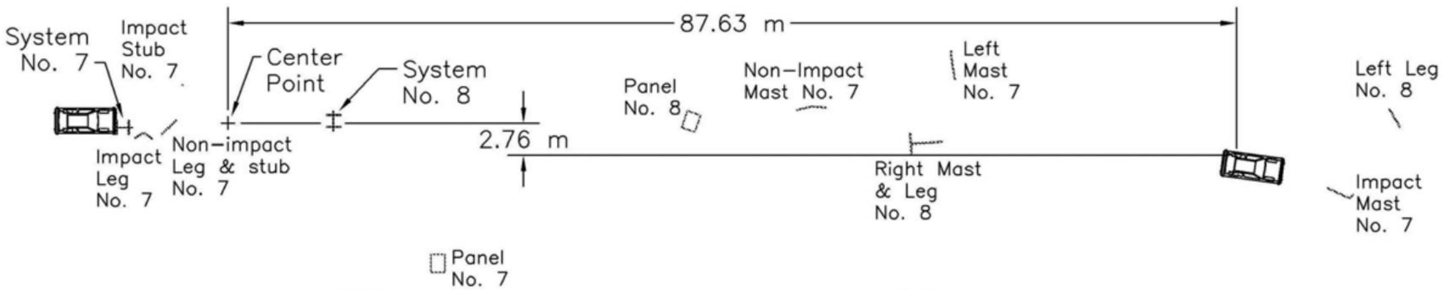
0.000 sec 0.042 sec 0.098 sec 0.144 sec 0.174 sec



- Test Number MI-4
- System Number 7
- Date 4/9/03
- Test Article
  - Type . . . . Traffic Control Device – Steel Sign Support With Wood Sign Panel
  - Stand . . . . Michigan's 4x5 Portable Sign Support
  - Sign Panel . . . . Rigid Plywood, 1219 x 1524 x 17.3-mm thick
    - Height above ground . . . . 1,524 mm to panel bottom
  - Warning Light . . . . none
  - Key Elements
    - Size and/or dimension . . . 3.0 m high
    - Material . . . . Telespar Steel Tubing
  - Orientation . . . . End-on with right quarter point
- Soil Type . . . . On dry pavement
- Vehicle Model . . . . 1996 Geo Metro
  - Curb . . . . 811 kg
  - Test Inertial . . . . 818 kg
  - Gross Static . . . . 893 kg
- Vehicle Speed
  - Impact . . . . 103.6 km/hr
  - Exit . . . . NA
- Vehicle Angle
  - Impact . . . . 90 deg
  - Exit . . . . 90 deg
- Vehicle Stability . . . . Satisfactory
- Occupant Ridedown Deceleration (10 msec avg.)
  - Longitudinal . . . . NA
  - Lateral (not required) . . . . . NA
- Occupant Impact Velocity (Normalized)
  - Longitudinal . . . . NA
  - Lateral (not required) . . . . . NA
- Vehicle Damage . . . . Roof and windshield penetration
  - TAD[29] 12-FR-1
  - SAE[30] 12-FRAN9
- Vehicle Stopping Distance . . . . 87.63 m downstream 2.76 m right
- Test Article Damage . . . . Moderate – Broke apart

Figure 2.102. Michigan's 4x5 Portable Sign Support Test 3-71, 90-degree Impact Results (*5*)

0.000 sec 0.038 sec 0.106 sec 0.140 sec 0.200 sec



- Test Number MI-4
- System Number 8
- Date 4/9/03
- Test Article
  - Type . . . . Traffic Control Device – Steel Sign Support With Wood Sign Panel
  - Stand . . . . Michigan's 4x5 Portable Sign Support
  - Sign Panel . . . . Rigid Plywood, 1219 x 1524 x 17.3-mm thick
    - Height above ground . . . . 1,524 mm to panel bottom
  - Warning Light . . . . none
  - Key Elements
    - Size and/or dimension . . . 3.0 m high
    - Material . . . . Telespar Steel Tubing
  - Orientation . . . . Head-on with centerline
- Soil Type . . . . On dry pavement
- Vehicle Model . . . . 1996 Geo Metro
  - Curb . . . . 811 kg
  - Test Inertial . . . . 818 kg
  - Gross Static . . . . 893 kg
- Vehicle Speed
  - Impact . . . . 91.7 km/hr
  - Exit . . . . NA
- Vehicle Angle
  - Impact . . . . 0 deg
  - Exit . . . . 0 deg
- Vehicle Stability . . . . Satisfactory
- Occupant Ridedown Deceleration (10 msec avg.)
  - Longitudinal . . . . NA
  - Lateral (not required) . . . . . NA
- Occupant Impact Velocity (Normalized)
  - Longitudinal . . . . NA
  - Lateral (not required) . . . . . NA
- Vehicle Damage . . . . Windshield cracking and indentation
  - TAD[29] 12-FC-1
  - SAE[30] 12-FCAW9
- Vehicle Stopping Distance . . . . 87.63 m downstream 2.76 m right
- Test Article Damage . . . . Moderate – Broke apart

Figure 2.103. Michigan's 4x5 Portable Sign Support Test 3-71, 0-degree Impact Results (*5*)

2.3.2. Work Zone Sign Support Crash Test (*7*)

The system was fabricated from PSST and had a 4 feet × 4 feet diamond-shaped plywood sign substrate mounted at a height of 7 ft above the ground. The sign panel was attached to two 1¾×1¾ inch PSST uprights. The uprights were inserted into 2×2 inch vertical sleeves that were welded to the tops of 2×2 inch × 5 ft long skids. The welds were designed to fracture and release the sleeves from the uprights in a frontal impact. A 2×2 inch cross brace was bolted to the back sides of the sleeves just above the skids. The bolts connecting the brace to the sleeves limited the insertion depth of the uprights into the sleeves to 1 inch above the top of the skids. Photographs of the test installation are shown in Figure 2.104.

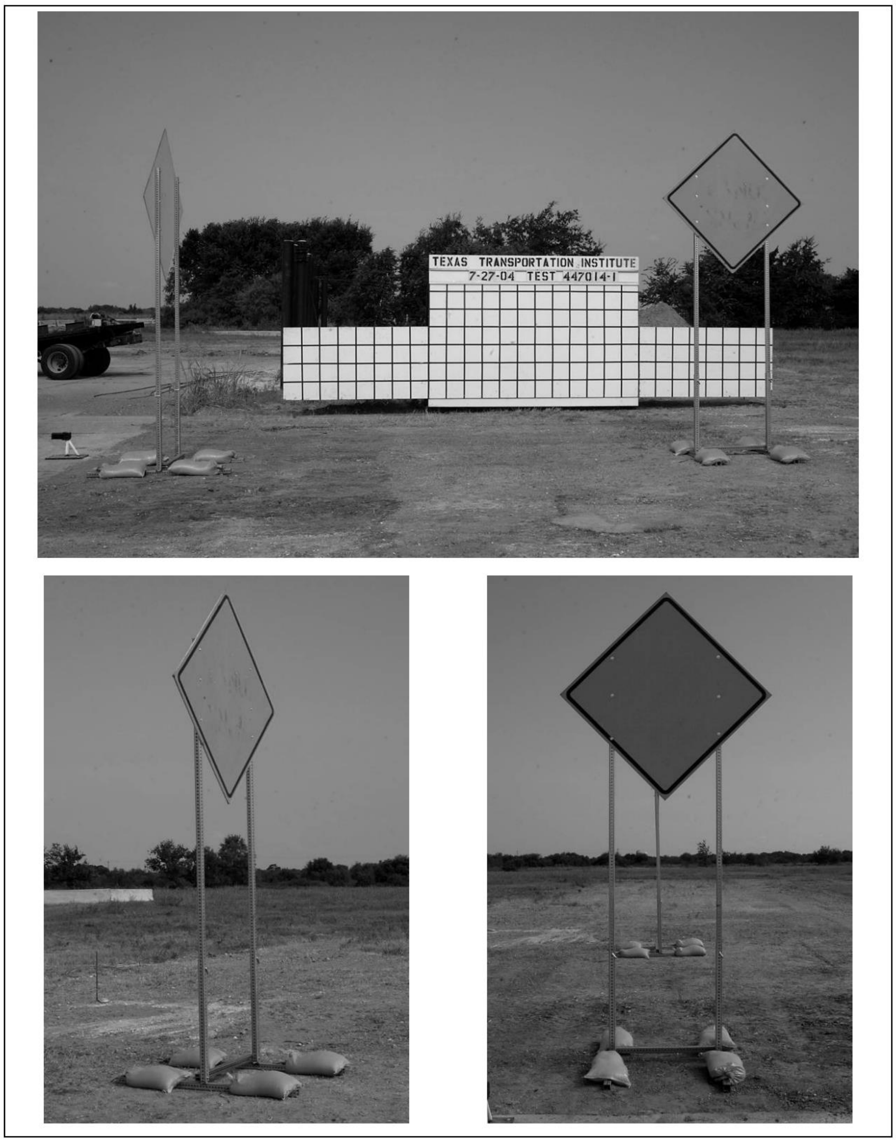


Figure 2.104. Work Zone Sign Support Test System (*7*)

The 1997 Geo Metro, traveling at a speed of 63.0 mi/h (101.4 km/h), impacted the first support head-on at 0 degrees. Upon impact with the first support, both uprights deformed around the front of the vehicle and subsequently released from the skids through fracture of the welds. The sign panel and its supports rotated toward the vehicle and contacted the roof. As the vehicle traveled forward, the panel and supports carried up and over the vehicle. The vehicle then impacted the second sign support system at 90 degrees. Upon impact with the second support, the leg on the impact side of the support began to deform and pulled the sign panel downward towards the vehicle. The corner of the sign panel contacted the windshield just below the roof edge, shattering the windshield and deforming the roof. Figure 2.105 shows the damaged test article. The vehicle sustained damage to the front bumper, hood, windshield, and roof, as shown in Figure 2.106. Maximum occupant compartment deformation was 8 inches in the windshield. Therefore, the sign support did not meet the NCHRP Report 350 evaluation criteria.

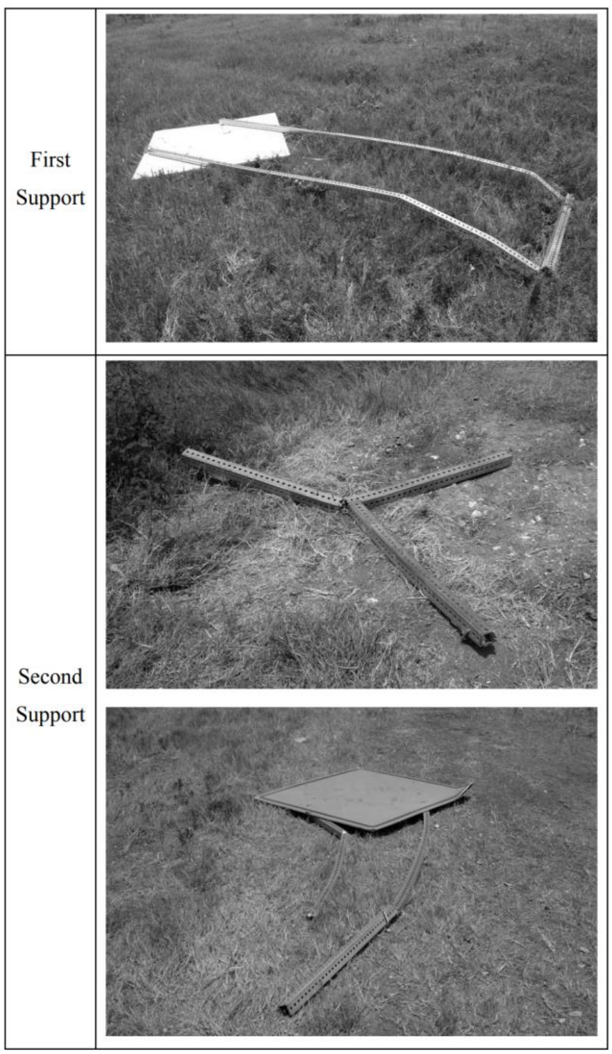


Figure 2.105. Work Zone Sign Support Test 3-71 System Damage (*7*)

Figure 2.106. Work Zone Sign Support Test 3-71 Vehicle Damage (*7*)

Chapter 3. SYSTEM DETAILS

3.1. TEST ARTICLE AND INSTALLATION DETAILS

The test articles evaluated in this project were developed from the standards utilized by the Roadside Safety Pooled Fund members. For tests 618901-01-2-1 - 3 the test article was 84 and 1/2 inches tall to the bottom of the diamond shape aluminum sign. The sign was 0.10 inches thick. The posts, the feet, and the cross shaped support arms were made of PSST. There were two 40lbs sandbags weighing down the feet on each side.

Figure 3.1 presents the overall information on the Tall Sign Supports for Aluminum Signs for tests 618901-01-2-1 through 618901-01-2-3, and Figure 3.2 thru Figure 3.7 provide photographs of the installation. Appendix A provides further details on the Tall Sign Supports for Aluminum Signs.

Following the results of test 618901-01-2-3, the design was modified to increase the stiffness of the lower portion of the vertical posts. This portion was stiffened to promote rotation of the sign stand over the vehicle. For tests 618901-01-2-4 – 6 the test article was 84 and 1/2 inches tall to the bottom of the diamond shape aluminum sign. The sign was 0.125 inches thick.

Figure 3.8 presents the overall information on the Tall Sign Supports for Aluminum Signs for tests 618901-01-2-4 through 618901-01-2-6, and Figure 3.9 thru Figure 3.14 provide photographs of the installation. Appendix B provides further details on the Tall Sign Supports for Aluminum Signs.

Following the results of test 618901-01-2-6, the test article was designed to emulate a *MASH* compliant Type III barricade which was tested previously by the research team (*8*). For tests 618901-01-2-7 the test article was 60 and 1/2 inches tall to the bottom of the diamond shape aluminum sign. The sign was 0.10 inches thick. The posts, the feet, and the cross shaped support arms were made of PSST. The posts were set 48 inches apart with a horizontal support beam installed at a height of 17 and ½ inches, and the crossbeams were installed diagonally.

Figure 3.15 presents the overall information on the Tall Sign Supports for Aluminum Signs for tests 618901-01-2-7, and Figure 3.16 thru Figure 3.21 provide photographs of the installation. Appendix C provides further details on the Tall Sign Supports for Aluminum Signs.

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 TESTS

No modifications were made to the installation during the testing phase.

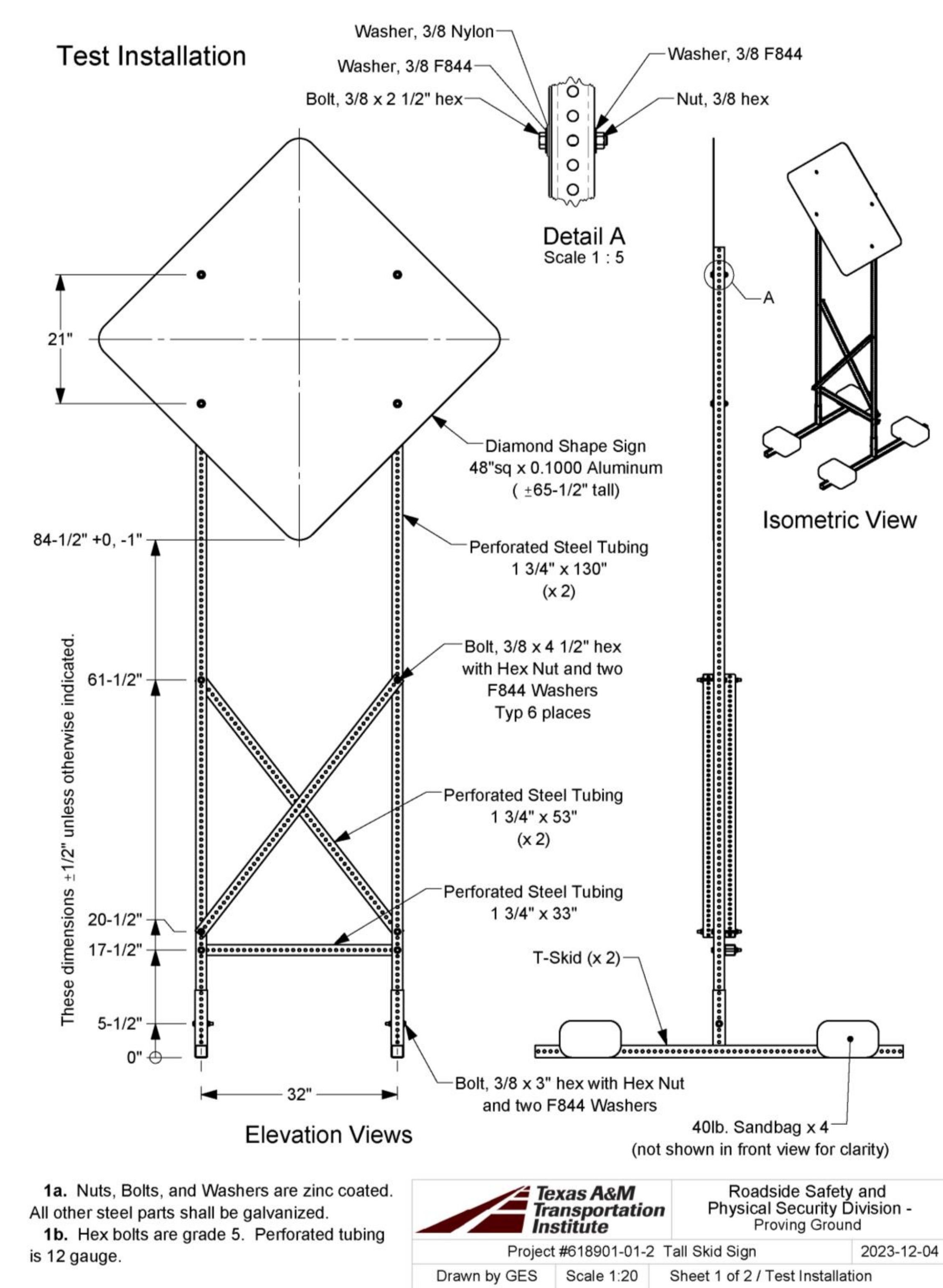


Figure 3.1. Details of Tall Sign Supports for Aluminum Signs for Test 618901-01-2-1 - 3.

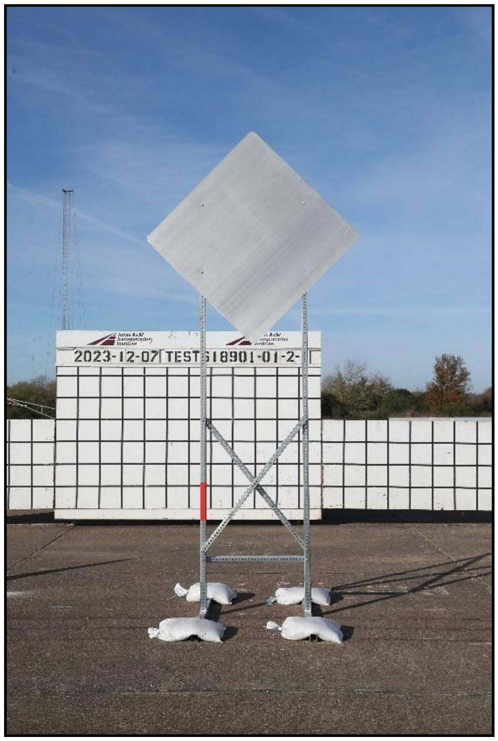


Figure 3.2. Tall Sign Supports for Aluminum Signs prior to Tests 618901-01-2-1-3.

Figure 3.3. Tall Sign Supports for Aluminum Signs prior to Tests 618901-01-2-1-3.

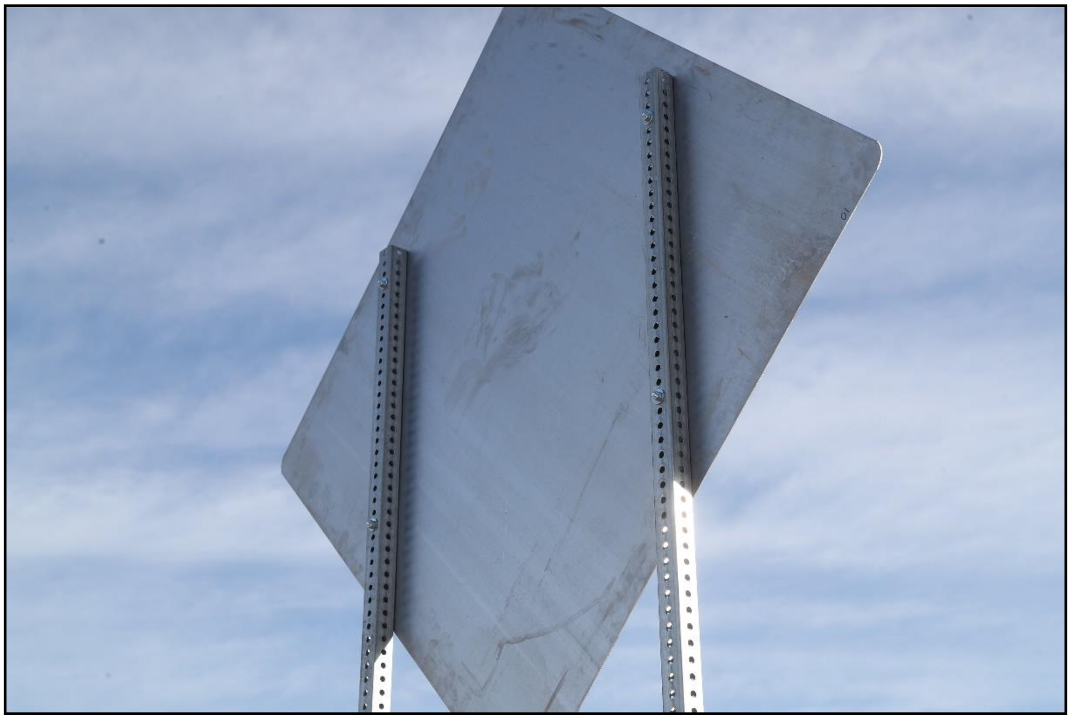


Figure 3.4. Field Side View of Tall Sign Supports for Aluminum Signs prior to Tests 618901-01-2-1-3.

Figure 3.5. Cross Section of Tall Sign Supports for Aluminum Signs prior to Tests 618901-01-2-1-3.

Figure 3.6. Feet with Sandbags of Tall Sign Supports for Aluminum Signs prior to Tests 618901-01-2-1-3.

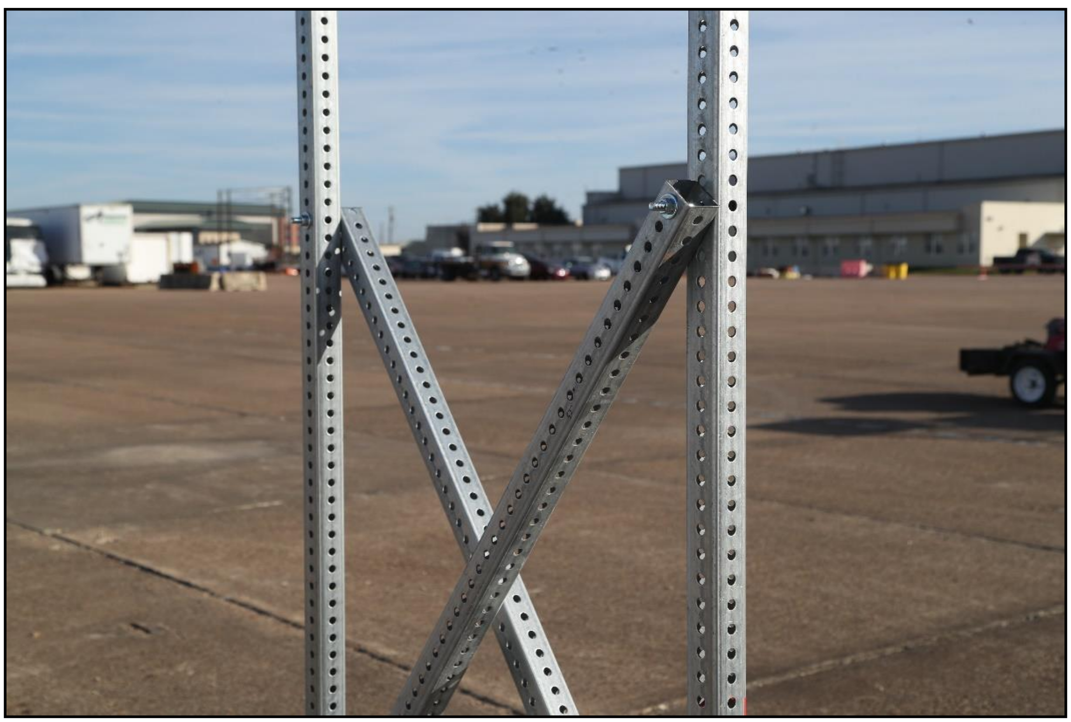


Figure 3.7. Oblique View of Cross Section of Tall Sign Supports for Aluminum Signs prior to Tests 618901-01-2-1-3.

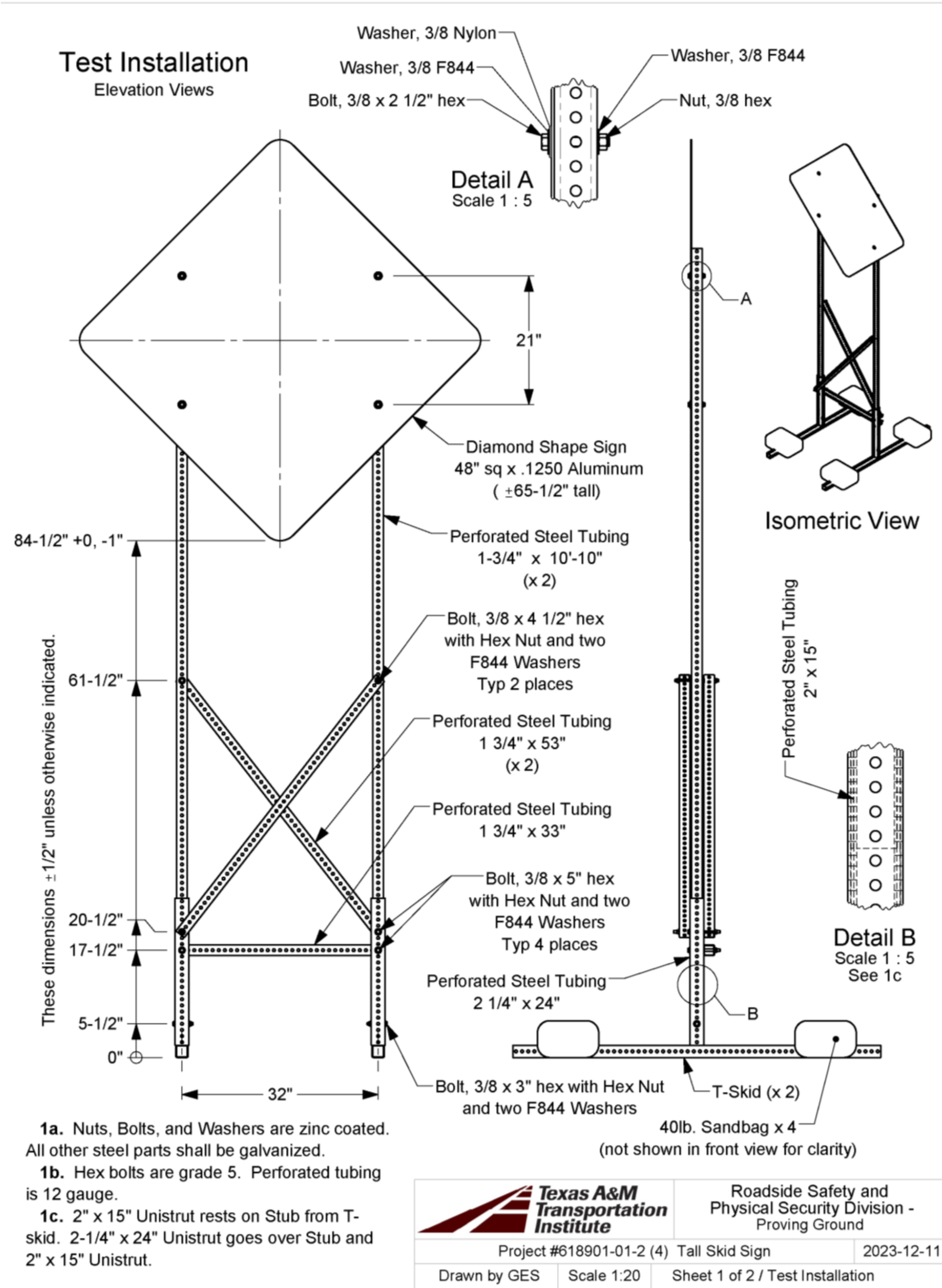


Figure 3.8. Details of Tall Sign Supports for Aluminum Signs for Test 618901-01-2-4 - 6.

Figure 3.9. Tall Sign Supports for Aluminum Signs prior to Tests 618901-01-2-4 - 6.

Figure 3.10. Tall Sign Supports for Aluminum Signs prior to Tests 618901-01-2-4 - 6.

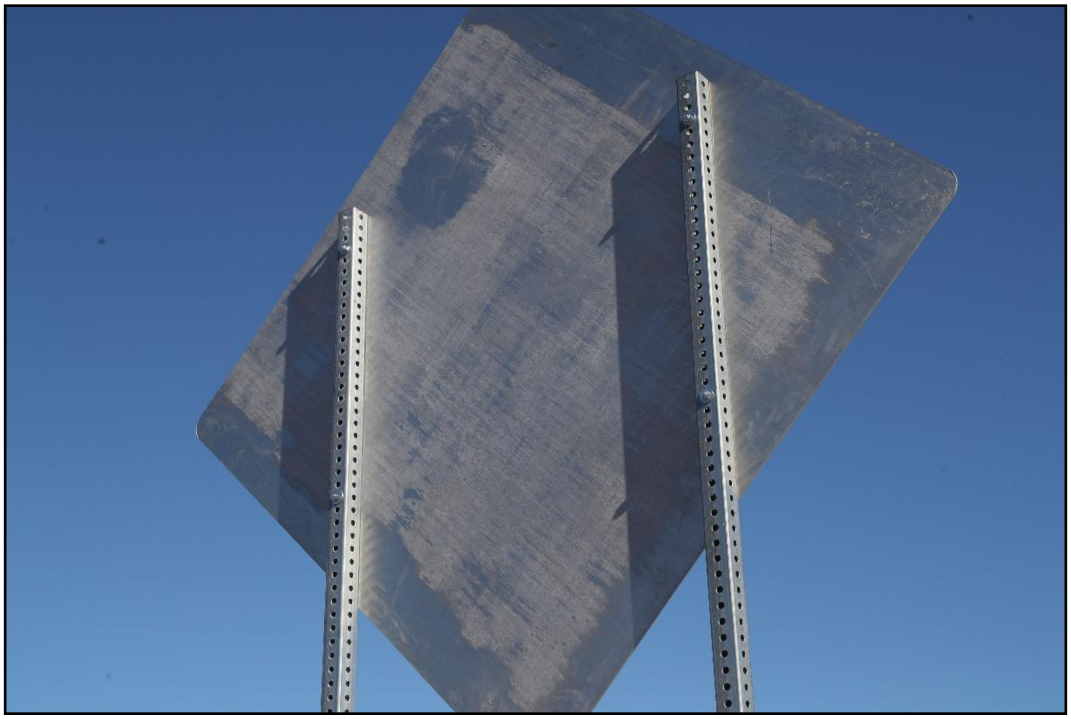


Figure 3.11. Field Side View of Tall Sign Supports for Aluminum Signs prior to Tests 618901-01-2-4 - 6.

Figure 3.12. Oblique View of Cross Section of Tall Sign Supports for Aluminum Signs prior to Tests 618901-01-2-4 - 6.

Figure 3.13. Feet with Sandbags of Tall Sign Supports for Aluminum Signs prior to Tests 618901-01-2-4 - 6.

Figure 3.14. Cross Section of Tall Sign Supports for Aluminum Signs prior to Tests 618901-01-2-4 - 6.

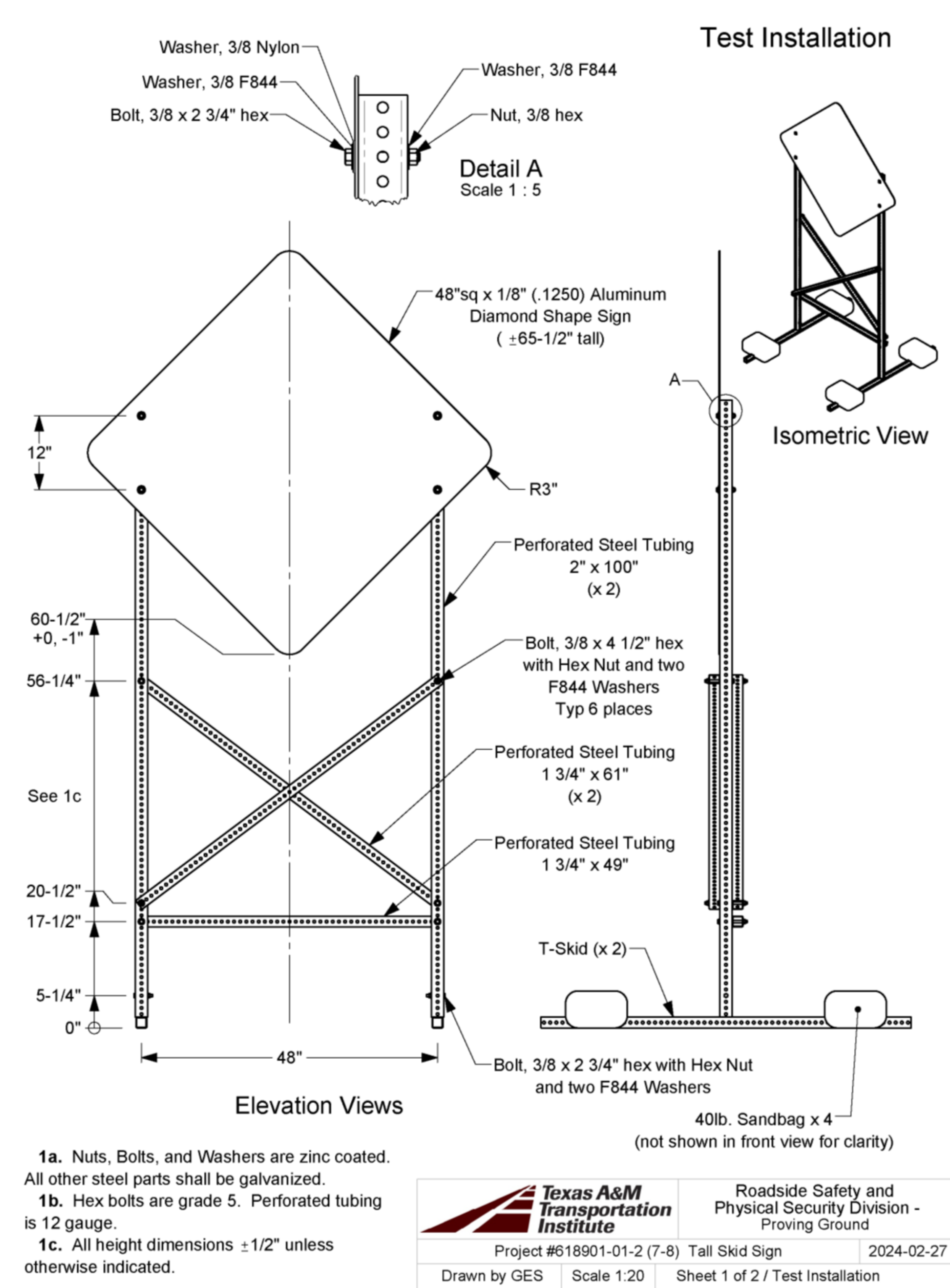


Figure 3.15. Details of Tall Sign Supports for Aluminum Signs for Test 618901-01-2-7.

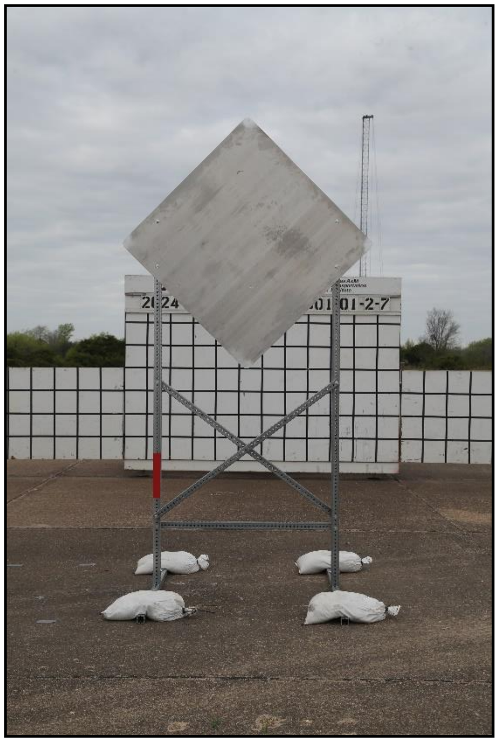


Figure 3.16. Tall Sign Supports for Aluminum Signs prior to Test 618901-01-2-7.

Figure 3.17. Tall Sign Supports for Aluminum Signs prior to Test 618901-01-2-7.

Figure 3.18. Field Side View of Tall Sign Supports for Aluminum Signs prior to Test 618901-01-2-7.

Figure 3.19. Cross Section of Tall Sign Supports for Aluminum Signs prior to Test 618901-01-2-7.

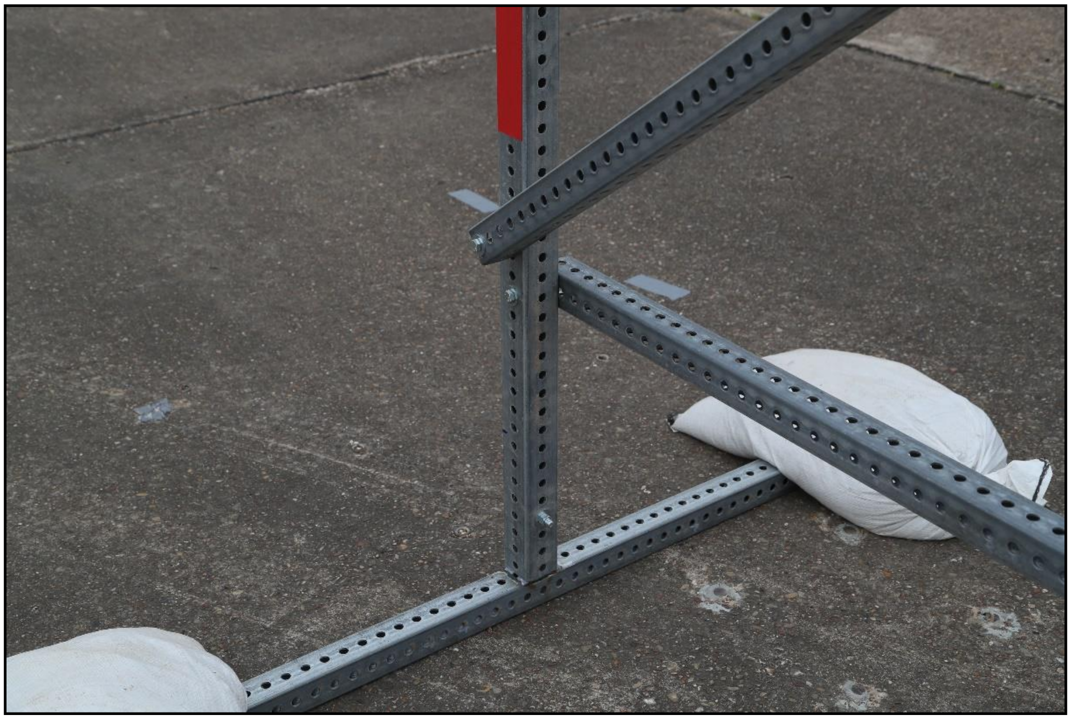


Figure 3.20. Feet with Sandbags of Tall Sign Supports for Aluminum Signs prior to Test 618901-01-2-7.

Figure 3.21. Oblique View of Cross Section of Tall Sign Supports for Aluminum Signs prior to Test 618901-01-2-7.

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 Work-Zone Traffic Control Devices. The target critical impact points (CIPs) for each test were determined using the information provided in *MASH* Section 2.2.4 . Figure 4.1 shows the target CIP for *MASH* TL-3 tests on the Tall Sign Supports for Aluminum Signs. *MASH* states that “Test 70 is considered optional for work-zone traffic control devices weighing less than 220 lb.” The installation weighed 120 lbs.

Table 4.1. Test Conditions and Evaluation Criteria Specified for *MASH* TL-3 Work-Zone Traffic Control Devices.

Test Designation	Test Vehicle	Impact Speed	Impact Angle	Evaluation Criteria
3-71	1100C	62 mi/h	90º	B, D, E, F, N
3-71	1100C	62 mi/h	0º	B, D, E, F, N
3-72	2270P	62 mi/h	90º	B, D, E, F, N
3-72	2270P	62 mi/h	0º	B, D, E, F, N

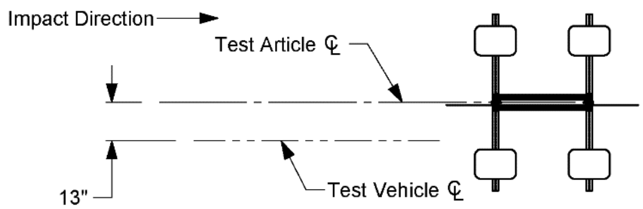


Figure 4.1. Target CIP for *MASH* TL-3 Test on Tall Sign Supports for Aluminum Signs for Test 618901-01-2-1.

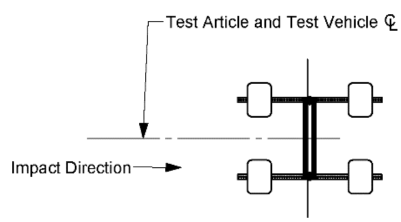


Figure 4.2. Target CIP for MASH TL-3 Test on Tall Sign Supports for Aluminum Signs for Test 618901-01-2-2.

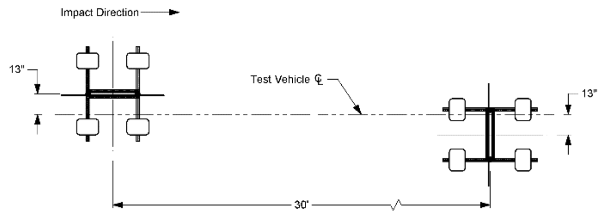


Figure 4.3. Target CIP for MASH TL-3 Test on Tall Sign Supports for Aluminum Signs for Test 618901-01-2-3.

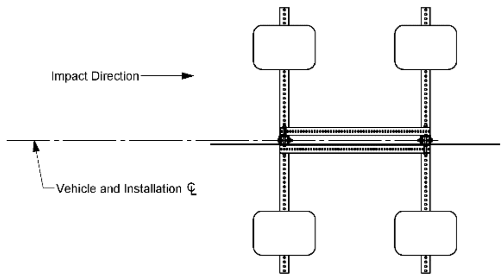


Figure 4.4. Target CIP for MASH TL-3 Test on Tall Sign Supports for Aluminum Signs for Test 618901-01-2-4.

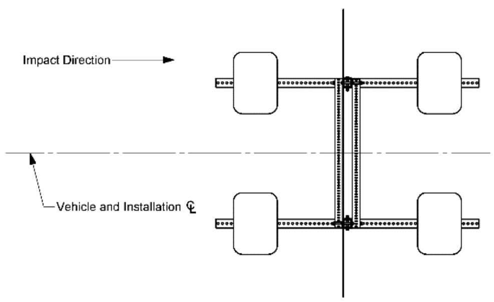


Figure 4.5. Target CIP for MASH TL-3 Test on Tall Sign Supports for Aluminum Signs for Test 618901-01-2-5.

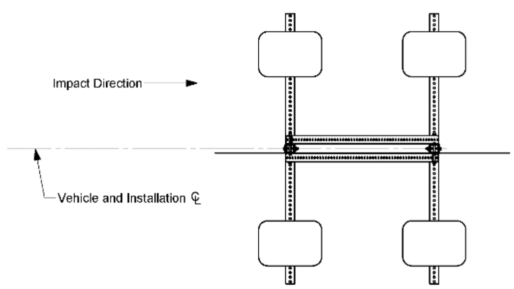


Figure 4.6. Target CIP for MASH TL-3 Test on Tall Sign Supports for Aluminum Signs for Test 618901-01-2-6.

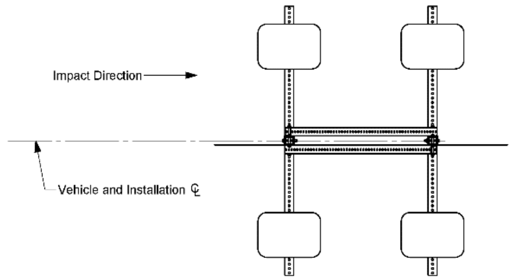


Figure 4.7. Target CIP for MASH TL-3 Test on Tall Sign Supports for Aluminum Signs for Test 618901-01-2-7.

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 Table 4.1. and Table 4.2. of *MASH* were used to evaluate the crash tests 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
B.	The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.
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*.
E.	Detached elements, fragments, or other debris from the test article, or vehicle damage, should not block the driver’s vision or otherwise cause the driver to lose control of the vehicle.
F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.
N.	Vehicle trajectory behind the test article is acceptable.

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 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

MASH states that “lightweight free-standing features cannot cause sufficient velocity change to result in failure of the test under occupant risk criteria,[…] therefore tests 71 and 72 can be conducted without instrumentation,” therefore no instrumentation was used.

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 passenger 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 two digital high-speed cameras:

- One placed with a field of view parallel to and aligned with the installation at the downstream end.
- One placed at an oblique angle upstream from the installation on the traffic side.

A flashbulb on the impacting vehicle was activated by a pressure-sensitive tape switch to indicate the instant of contact with the Tall Sign Supports for Aluminum Signs. 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 3-71 (CRASH TEST 618901-01-2-1)

6.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 6.1 for details of *MASH* impact conditions for this test and Table 6.2 for the exit parameters. Figure 6.1 and Figure 6.2 depict the target impact setup.

Table 6.1. Impact Conditions for *MASH TEST 3-71,* Crash Test 618901-01-2-1.

Test Parameter	Specification	Tolerance	Measured
Impact Speed	62 mi/h	±2.5 mi/h	62.2 mi/h
Impact Angle	90°	±1.5°	90°
Kinetic Energy	288 kip-ft	≥288 kip-ft	316.9 kip-ft
Impact Location	Centerline of the sign aligned 13 inches off centerline of the vehicle on the driver's side	±6 inches	Centerline of the sign aligned 13 inches off centerline of the vehicle on the driver's side

Table 6.2. Exit Parameters for *MASH TEST 3-71,* Crash Test 618901-01-2-1.

Exit Parameter	Measured
Speed	58.8 mi/h
Brakes applied post impact	The brakes were applied. Due to the vehicle not being instrumented, the exact time of brake application was not recorded.
Vehicle at rest position	562.5 ft downstream of impact point 38 ft to the left
Comments:	Vehicle remained upright and stable.

Figure 6.1. Tall Sign Supports for Aluminum Signs/Test Vehicle Geometrics for Test 618901-01-2-1.

Figure 6.2. Tall Sign Supports for Aluminum Signs/Test Vehicle Impact Location 618901-01-2-1.

6.2. WEATHER CONDITIONS

Table 6.3 provides the weather conditions for 618901-01-2-1.

Table 6.3. Weather Conditions 618901-01-2-1.

Date of Test	2023-12-07
Wind Speed	9 mi/h
Wind Direction	181°
Temperature	65 °F
Relative Humidity	72 %
Vehicle Traveling	350°

6.3. TEST VEHICLE

Figure 6.3 and Figure 6.4 show the 2017 Nissan Versa used for the crash test. Table 6.4 shows the vehicle measurements. Figure E.1 in Appendix E.1 gives additional dimensions and information on the vehicle.

Figure 6.3. Front of Test Vehicle before Test 618901-01-2-1.

Figure 6.4. Rear of Test Vehicle before Test 618901-01-2-1.

Table 6.4. Vehicle Measurements for Test 618901-01-2-1.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a]	165 lb	N/A	165 lb
Inertial Mass	2420 lb	±55 lb	2450 lb
Gross Static[a] Mass	2585 lb	±55 lb	2615 lb
Wheelbase	98 inches	±5 inches	102.4 inches
Front Overhang	35 inches	±4 inches	32.5 inches
Overall Length	169 inches	±8 inches	175.4 inches
Overall Width	65 inches	±3 inches	66.7 inches
Hood Height	28 inches	±4 inches	30.5 inches
Track Width[b]	59 inches	±2 inches	58.4 inches
CG aft of Front Axle[c]	39 inches	±4 inches	41.7 inches
CG above Ground[c,d]	N/A inches	N/A inches	N/A inches

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.

6.4. TEST DESCRIPTION

Table 6.5 lists events that occurred during Test 618901-01-2-1. Figures E.4, E.5, and E.6 in Appendix E.2 present sequential photographs during the test.

Table 6.5. Events during Test 618901-01-2-1.

Time	Events
0.0000 s	Vehicle impacted the installation
0.0120 s	Post legs began to bend
0.0240 s	Downstream post leg fractured at cross bracing
0.0820 s	Corner of sign impacted roof

6.5. DAMAGE TO TEST INSTALLATION

The sign stand came to rest 195 feet downstream and 43.8 feet left of impact. Posts were released from the legs and the sign was dented on one corner.

Figure 6.5 and Figure 6.6 show the damage to the Tall Sign Supports for Aluminum Signs.

Figure 6.5. Debris Field after Test 618901-01-2-1.

Figure 6.6. Tall Sign Supports for Aluminum Signs at Resting Position after Test 618901-01-2-1.

6.6. DAMAGE TO TEST VEHICLE

Figure 6.7 and Figure 6.8 show the damage sustained by the vehicle. Figure 6.9 shows the interior of the test vehicle. Table 6.6 and Table 6.7 provide details on the occupant compartment deformation and exterior vehicle damage. Figures E.2 and E.3 in Appendix E.1 provide exterior crush and occupant compartment measurements.

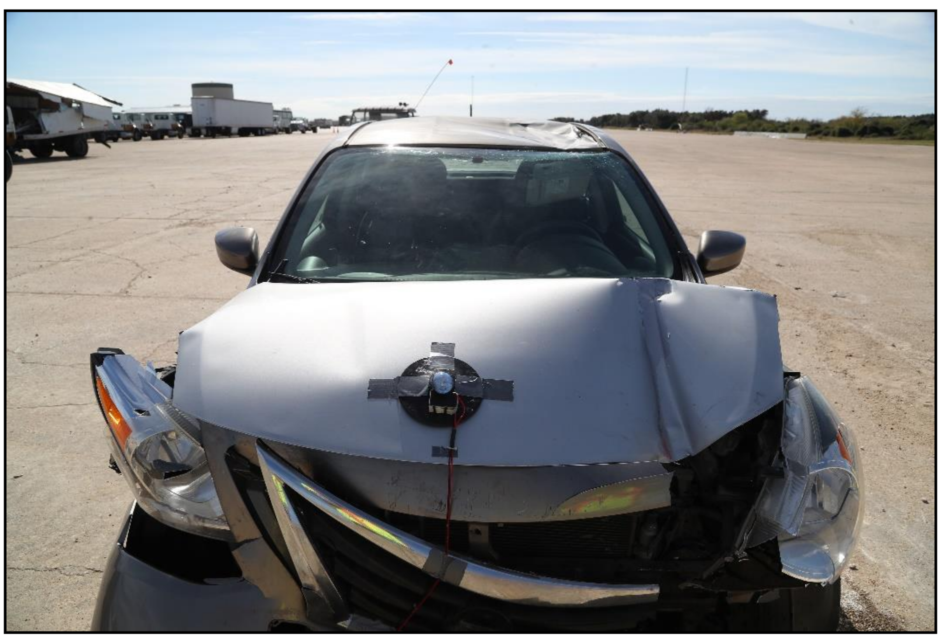


Figure 6.7. Front of Test Vehicle after Test 618901-01-2-1.

Figure 6.8. Roof of Test Vehicle after Test 618901-01-2-1.

Figure 6.9. Overall Interior of Test Vehicle after Test 618901-01-2-1.

Table 6.6. Occupant Compartment Deformation 618901-01-2-1.

Test Parameter	Specification	Measured
Roof	≤4.0 inches	2.5 inches
Windshield	≤3.0 inches	0 inches
A and B Pillars	≤5.0 overall/≤3.0 lateral inches	0 inches
Foot Well/Toe Pan	≤9.0 inches	0 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0 inches
Side Front Panel	≤12.0 inches	0 inches
Front Door (above Seat)	≤9.0 inches	0 inches
Front Door (below Seat)	≤12.0 inches	0 inches

Table 6.7. Exterior Vehicle Damage 618901-01-2-1.

Side Windows	Side windows remained intact
Maximum Exterior Deformation	2.5 inches in the roof
VDS	12FC2
CDC	12FCHN2
Fuel Tank Damage	None
Description of Damage to Vehicle:	There was a 17-inch long×2-inch wide × 1-inch deep dent in the hood and a 24-inch long × 22-inch wide × 2.5-inch deep dent in the roof on the driver's side. The windshield was cracked at the top near the roof. After the vehicle was clear of the test article, it made a secondary contact with a portable concrete barrier, which caused additional damage to the front the vehicle than was present after impact with the target installation.

6.7. TEST SUMMARY

Figure 6.10 summarizes the results of *MASH* Test 618901-01-2-1.

0.000 s

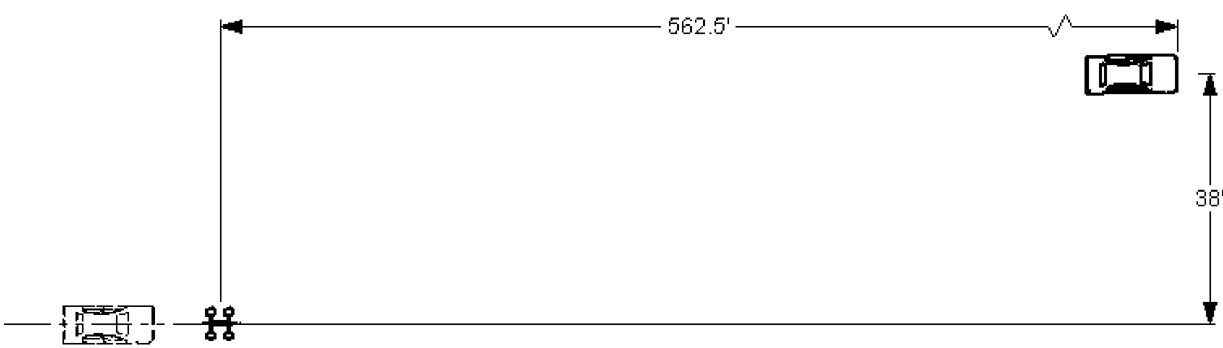
0.200 s

0.400 s

0.600 s

GENERAL INFORMATION	
Test Agency:	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.:	*MASH* 2016, Test 3-71
Project No.:	618901-01-2-1
Test Date:	2023-12-07
TEST ARTICLE	
Type:	Work-Zone Traffic Control Devices
Name:	Tall Sign Supports for Aluminum Signs
Length:	12.5 feet (150 inches)
Key Materials:	Aluminum sigh, PSST
Soil Type and Condition:	Concrete, dry
TEST VEHICLE	
Type/Designation:	1100C
Year, Make and Model:	2017 Nissan Versa
Inertial Mass:	2450 lb
Dummy Mass:	165 lb
Gross Static Mass:	2615 lb

IMPACT CONDITIONS	
Impact Speed:	62.2 mi/h
Impact Angle:	90°
Impact Location:	Centerline of the sign aligned 13 inches off centerline of the vehicle on the driver's side
Kinetic Energy:	316.9 kip-ft
EXIT CONDITIONS	
Exit Speed:	58.8 mi/h
Stopping Distance:	562.5 ft downstream 37.5 ft to the left side
VEHICLE DAMAGE	
VDS:	12FC2
CDC:	12FCHN2
Max Exterior Deformation:	2.5 inches in the roof
Max Occupant Compartment Deformation:	2.5 inches in the roof



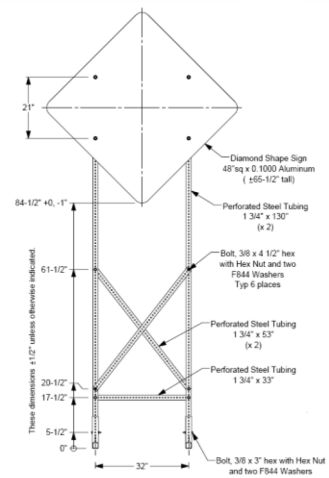


Figure 6.10. Summary of Results for *MASH* Test 3-71 on Tall Sign Supports for Aluminum Signs.

Chapter 7. *MASH* TEST 3-71 (CRASH TEST 618901-01-2-2)

7.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 7.1 for details of *MASH* impact conditions for this test and Table 7.2 for the exit parameters. Figure 7.1 and Figure 7.2 depict the target impact setup.

Table 7.1. Impact Conditions for *MASH* TEST 3-71, Crash Test 618901-01-2-2.

Test Parameter	Specification	Tolerance	Measured
Impact Speed	62 mi/h	±2.5 mi/h	61.6 mi/h
Impact Angle	0°	±1.5°	0°
Kinetic Energy	288 kip-ft	≥288 kip-ft	310.5 kip-ft
Impact Location	Centerline of the sign aligned with centerline of vehicle	±6 inches	Centerline of the sign aligned with centerline of vehicle

Table 7.2. Exit Parameters for *MASH* TEST 3-71, Crash Test 618901-01-2-2.

Exit Parameter	Measured
Speed	58.0 mi/h
Brakes applied post impact	The brakes were applied. Due to the vehicle not being instrumented, the exact time of brake application was not recorded.
Vehicle at rest position	330 ft downstream of impact point 6 ft to the right
Comments:	Vehicle remained upright and stable.

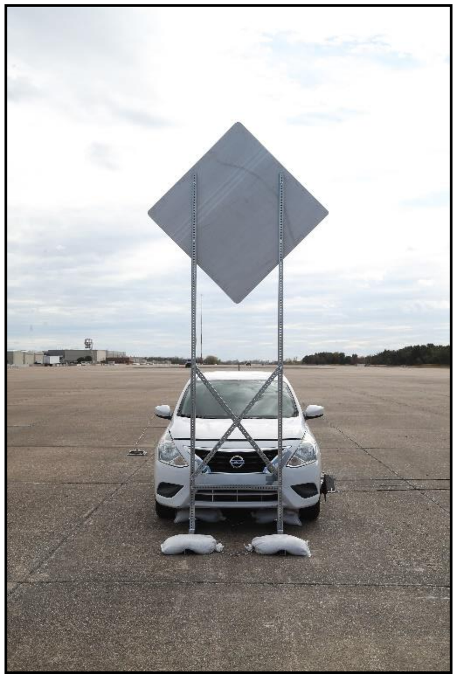


Figure 7.1. Tall Sign Supports for Aluminum Signs/Test Vehicle Geometrics for Test 618901-01-2-2.

Figure 7.2. Tall Sign Supports for Aluminum Signs/Test Vehicle Impact Location 618901-01-2-2.

7.2. WEATHER CONDITIONS

Table 7.3 provides the weather conditions for 618901-01-2-2.

Table 7.3. Weather Conditions 618901-01-2-2.

Date of Test	2023-12-07
Wind Speed	15 mi/h
Wind Direction	195°
Temperature	70 °F
Relative Humidity	70 %
Vehicle Traveling	350°

7.3. TEST VEHICLE

Figure 7.3 and Figure 7.4 show the 2017 Nissan Versa used for the crash test. Table 7.4 shows the vehicle measurements. Figure F.1 in Appendix F.1 gives additional dimensions and information on the vehicle.

Figure 7.3. Front of Test Vehicle before Test 618901-01-2-2.

Figure 7.4. Rear of Test Vehicle before Test 618901-01-2-2.

Table 7.4. Vehicle Measurements 618901-01-2-2.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a]	165 lb	N/A	165 lb
Inertial Mass	2420 lb	±55 lb	2448 lb
Gross Static[a] Mass	2585 lb	±55 lb	2613 lb
Wheelbase	98 inches	±5 inches	102.4 inches
Front Overhang	35 inches	±4 inches	32.5 inches
Overall Length	169 inches	±8 inches	175.4 inches
Overall Width	65 inches	±3 inches	66.7 inches
Hood Height	28 inches	±4 inches	30.5 inches
Track Width[b]	59 inches	±2 inches	58.4 inches
CG aft of Front Axle[c]	39 inches	±4 inches	42.7 inches
CG above Ground[c,d]	N/A inches	N/A inches	N/A inches

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.

7.4. TEST DESCRIPTION

Table 7.5 lists events that occurred during Test 618901-01-2-2. Figures F.4, F.5, and F.6 in Appendix F.2 present sequential photographs during the test.

Table 7.5. Events during Test 618901-01-2-2.

Time (s)	Events
0.0000 s	Vehicle impacted the installation
0.0090 s	Sign began to shift downstream
0.1100 s	Lower corner of sign made contact with upper windshield

7.5. DAMAGE TO TEST INSTALLATION

The test article came to rest 315 feet downstream of impact. The sign was slightly bent on two corners. The post was bent near the base on both legs, and the welds between the post and legs were cracked.

Figure 7.5 and Figure 7.6 show the damage to the Tall Sign Supports for Aluminum Signs.

Figure 7.5. Tall Sign Supports for Aluminum Signs at Resting Position after Test 618901-01-2-2.

Figure 7.6. Lower Half of the Tall Sign Supports for Aluminum Signs at Resting Position after Test 618901-01-2-2.

7.6. DAMAGE TO TEST VEHICLE

Figure 7.7 and Figure 7.8 show the damage sustained by the vehicle. Figure 7.9 shows the interior of the test vehicle. Table 7.6 and Table 7.7 provide details on the occupant compartment deformation and exterior vehicle damage. Figures F.2 and F.3 in Appendix F.1 provide exterior crush and occupant compartment measurements.

Figure 7.7. Impact Side of Test Vehicle after Test 618901-01-2-2.

Figure 7.8. Rear Impact Side of Test Vehicle after Test 618901-01-2-2.

Figure 7.9. Overall Interior of Test Vehicle after Test 618901-01-2-2.

Table 7.6. Occupant Compartment Deformation 618901-01-2-2.

Test Parameter	Specification	Measured
Roof	≤4.0 inches	1.8 inches
Windshield	≤3.0 inches	0 inches
A and B Pillars	≤5.0 overall/≤3.0 inches lateral	0 inches
Foot Well/Toe Pan	≤9.0 inches	0 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0 inches
Side Front Panel	≤12.0 inches	0 inches
Front Door (above Seat)	≤9.0 inches	0 inches
Front Door (below Seat)	≤12.0 inches	0 inches

Table 7.7. Exterior Vehicle Damage 618901-01-2-2.

Side Windows	Side windows remained intact
Maximum Exterior Deformation	1.8 inches in the roof
VDS	12FC1
CDC	12TCHN1
Fuel Tank Damage	None
Description of Damage to Vehicle:	There was a 24-inch long × 11-inch wide × 1.8-inch deep dent in the roof on the passenger side and a 9-inch long × 9-inch wide × 0.3-inch deep dent in the roof on the driver's side. There was a small dent in the hood and the grill and windshield were cracked.

7.7. TEST SUMMARY

Figure 7.10 summarizes the results of *MASH* Test 618901-01-2-2.

0.000 s

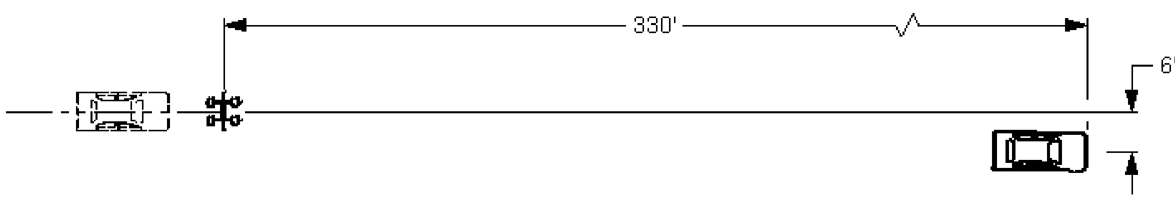
0.200 s

0.400 s

0.600 s

GENERAL INFORMATION	
Test Agency:	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.:	*MASH* 2016, Test 3-71
Project No.:	618901-01-2-2
Test Date:	2023-12-07
TEST ARTICLE	
Type:	Work-Zone Traffic Control Devices
Name:	Tall Sign Supports for Aluminum Signs
Length:	12.5 feet (150 inches)
Key Materials:	Aluminum sigh, PSST
Soil Type and Condition:	Concrete, dry
TEST VEHICLE	
Type/Designation:	1100C
Year, Make and Model:	2017 Nissan Versa
Inertial Mass:	2448 lb
Dummy Mass:	165 lb
Gross Static Mass:	2613 lb

IMPACT CONDITIONS	
Impact Speed:	61.6 mi/h
Impact Angle:	0°
Impact Location:	Centerline of the sign aligned with centerline of vehicle
Kinetic Energy:	310.5 kip-ft
EXIT CONDITIONS	
Exit Speed:	58.0 mi/h
Stopping Distance:	330 ft downstream 6 ft to the right side
VEHICLE DAMAGE	
VDS:	12FC1
CDC:	12TCHN1
Max Exterior Deformation:	1.8 inches in the roof
Max Occupant Compartment Deformation:	1.8 inches in the roof



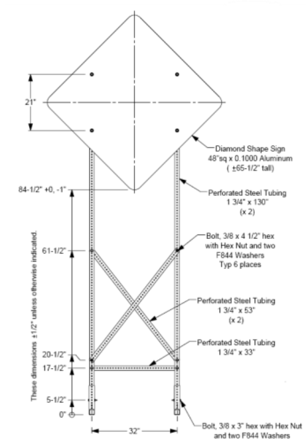


Figure 7.10. Summary of Results for *MASH* Test 3-71 on Tall Sign Supports for Aluminum Signs.

Chapter 8. *MASH* TEST 3-72 (CRASH TEST 618901-01-2-3)

8.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 8.1 for details of *MASH* impact conditions for this test and Table 8.2 for the exit parameters. Figure 8.1 and Figure 8.2 depict the target impact setup.

Table 8.1. Impact Conditions for *MASH* TEST 3-72, Crash Test 618901-01-2-3.

Test Parameter	**Specification**	**Tolerance**	**Measured**
Impact Speed	62 mi/h	±2.5 mi/h	63.5 mi/h
Impact Angle	90°	±1.5°	90°
Kinetic Energy	594 kip-ft	≥594 kip-ft	674.7 kip-ft
Impact Location	Centerline of 90 degree sign aligned 13 inches off centerline of vehicle toward driver's side, and centerline of 0 degree sign aligned 13 inches off centerline of vehicle toward the passenger side.	±6 inches	Centerline of 90 degree sign aligned 13 inches off centerline of vehicle toward the driver side. Secondary impact sign not included as there was interference with the first sign.

Table 8.2. Exit Parameters for *MASH* TEST 3-72, Crash Test 618901-01-2-3.

Exit Parameter	**Measured**
Speed	61.7 mi/h
Brakes applied post impact	The brakes were applied. Due to the vehicle not being instrumented, the exact time of brake application was not recorded.
Vehicle at rest position	337 ft downstream of impact point 6 ft to the right side
Comments:	Vehicle remained upright and stable.

Figure 8.1. Tall Sign Supports for Aluminum Signs/Test Vehicle Geometrics for Test 618901-01-2-3.

Figure 8.2. Tall Sign Supports for Aluminum Signs/Test Vehicle Impact Location 618901-01-2-3.

8.2. WEATHER CONDITIONS

Table 8.3 provides the weather conditions for 618901-01-2-3.

Table 8.3. Weather Conditions 618901-01-2-3.

Date of Test	2023-12-08
Wind Speed	18 mi/h
Wind Direction	201°
Temperature	72 °F
Relative Humidity	86 %
Vehicle Traveling	350°

8.3. TEST VEHICLE

Figure 8.3 and Figure 8.4 show the 2018 RAM 1500 used for the crash test. Table 8.4 shows the vehicle measurements. Figure G.1 in Appendix G.1 gives additional dimensions and information on the vehicle.

Figure 8.3. Front of Test Vehicle before Test 618901-01-2-3.

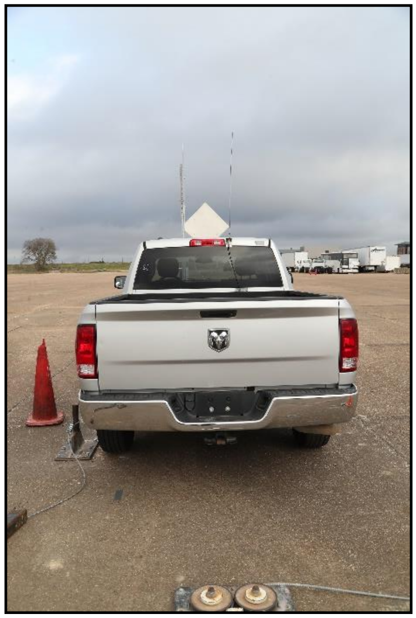


Figure 8.4. Rear of Test Vehicle before Test 618901-01-2-3.

Table 8.4. Vehicle Measurements 618901-01-2-3.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a]	165 lb	N/A	N/A lb
Inertial Mass	5000 lb	±110 lb	5005 lb
Gross Static[a] Mass	5000 lb	±110 lb	5005 lb
Wheelbase	148 inches	±12 inches	140.5 inches
Front Overhang	39 inches	±3 inches	40 inches
Overall Length	237 inches	±13 inches	227.5 inches
Overall Width	78 inches	±2 inches	78.5 inches
Hood Height	43 inches	±4 inches	46 inches
Track Width[b]	67 inches	±1.5 inches	68.3 inches
CG aft of Front Axle[c]	63 inches	±4 inches	61.4 inches
CG above Ground[c,d]	28 inches	28 inches	28.5 inches

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.

8.4. TEST DESCRIPTION

Table 8.5 lists events that occurred during Test 618901-01-2-3. Figures G.4, G.5, and G.6 in Appendix G.2 present sequential photographs during the test.

Table 8.5. Events during Test 618901-01-2-3.

Time (s)	Events
0.0000 s	Vehicle impacted the installation
0.0100 s	Downstream post of sign began to fracture
0.0630 s	Corner of sign impacted windshield
0.0710 s	Sign impacted dashboard inside occupant compartment

8.5. DAMAGE TO TEST INSTALLATION

The first impacted sign came to rest 255 feet downstream and 28 feet left of impact. Both posts fractured and released from the legs of the installation. One leg released from the installation and came to rest 362 feet downstream and 41 feet to the left of impact. The horizontal crossmember released from one post, and the bolt on the other post was significantly deformed but remained attached to the lower portion of the post. The sign panel was deformed, with one of the posts deformed just below the bottom attachment bolt. The second impacted sign came to rest 314 feet downstream and 22 feet to the right of impact. The sign was deformed, and the posts were bent slightly inward between the horizontal crossmember and the legs.

Figure 8.5 and Figure 8.6 show the damage to the Tall Sign Supports for Aluminum Signs.

Figure 8.5. The First Impacted Tall Sign Support for Aluminum Sign at Resting Position after Test 618901-01-2-3.

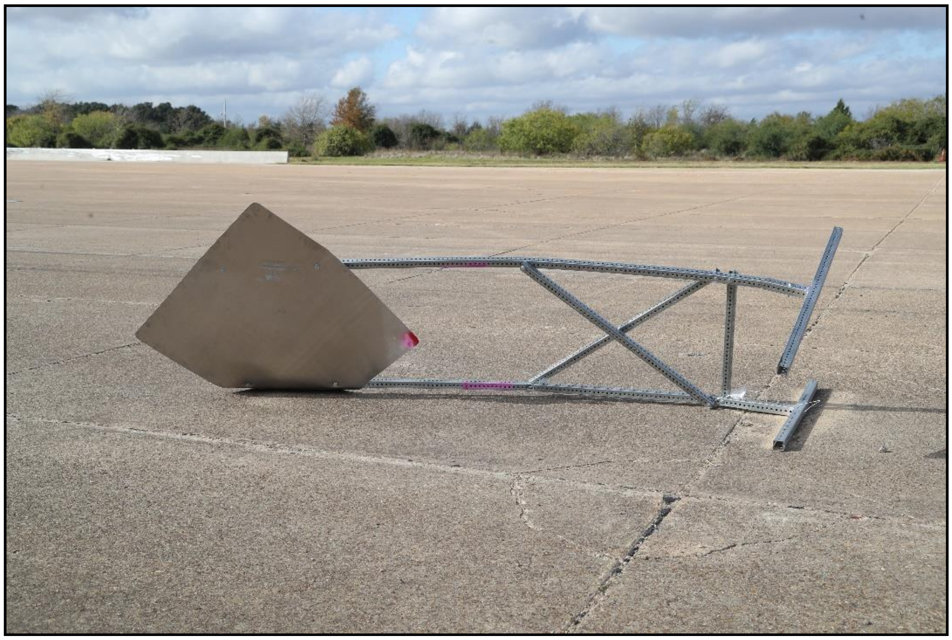


Figure 8.6. The Second Impacted Tall Sign Support for Aluminum Sign at Resting Position after Test 618901-01-2-3.

8.6. DAMAGE TO TEST VEHICLE

Figure 8.7 and Figure 8.8 show the damage sustained by the vehicle. Figure 8.9 shows the interior of the test vehicle. Table 8.6 and Table 8.7 provide details on the occupant compartment deformation and exterior vehicle damage. Figures G.2 and G.3 in Appendix G.1 provide exterior crush and occupant compartment measurements.

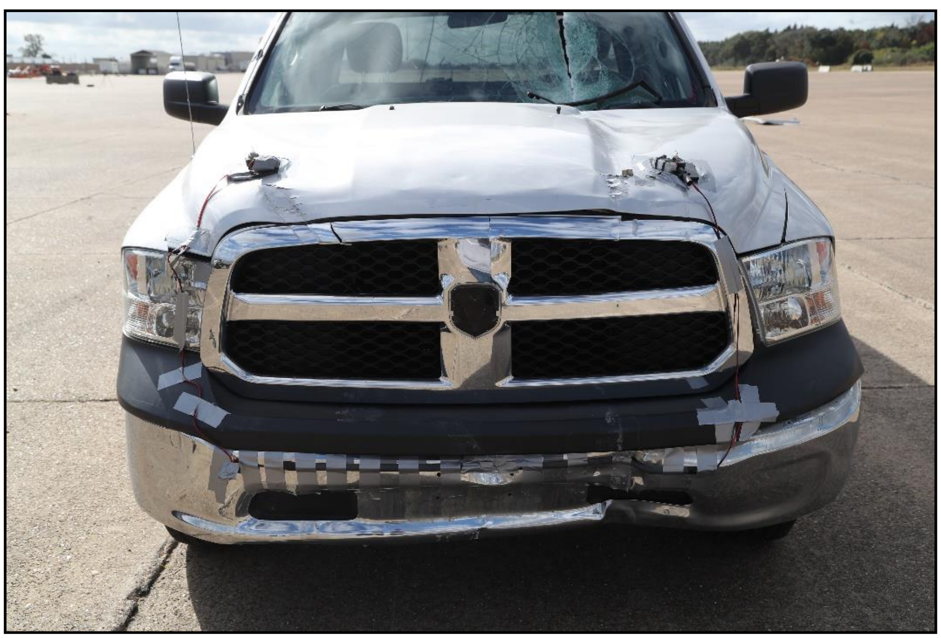


Figure 8.7. Front of Test Vehicle after Test 618901-01-2-3.

Figure 8.8. Rear of Test Vehicle after Test 618901-01-2-3.

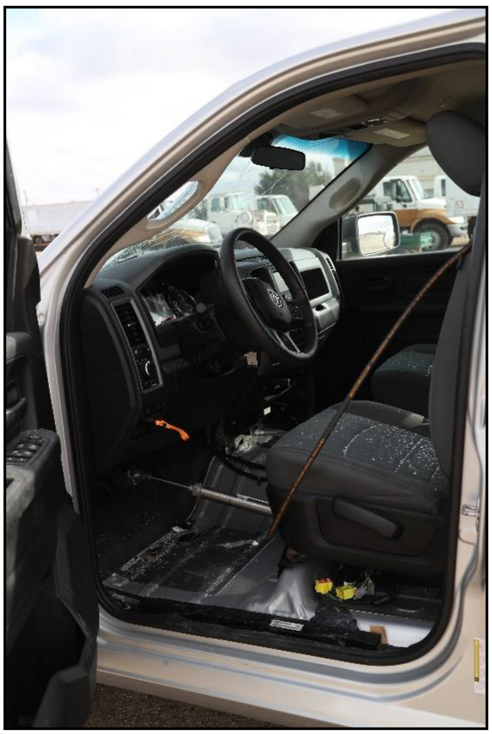


Figure 8.9. Overall Interior of Test Vehicle after Test 618901-01-2-3.

Table 8.6. Occupant Compartment Deformation 618901-01-2-3.

Test Parameter	Specification	Measured
Roof	≤4.0 inches	0 inches
Windshield	≤3.0 inches	0.5 inches
A and B Pillars	≤5.0 overall/≤3.0 inches lateral	0 inches
Foot Well/Toe Pan	≤9.0 inches	0 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0 inches
Side Front Panel	≤12.0 inches	0 inches
Front Door (above Seat)	≤9.0 inches	0 inches
Front Door (below Seat)	≤12.0 inches	0 inches

Table 8.7. Exterior Vehicle Damage 618901-01-2-3.

Side Windows	Side windows remained intact
Maximum Exterior Deformation	0.5 inches in the hood and windshield
VDS	12FC1
CDC	12FCGN6
Fuel Tank Damage	None
Description of Damage to Vehicle:	The bumper, grill, hood, and windshield were damaged. There was a 9-inch long × 5-inch wide × 0.5-inch deep dent in hood on driver's side, and a 27-inch long × 0.5-inch wide × 0.5-inch deep hole where the sign went through the windshield, which also cut the dash and damaged the instrument gauges.

8.7. TEST SUMMARY

Figure 8.10 summarizes the results of *MASH* Test 618901-01-2-3.

0.000 s

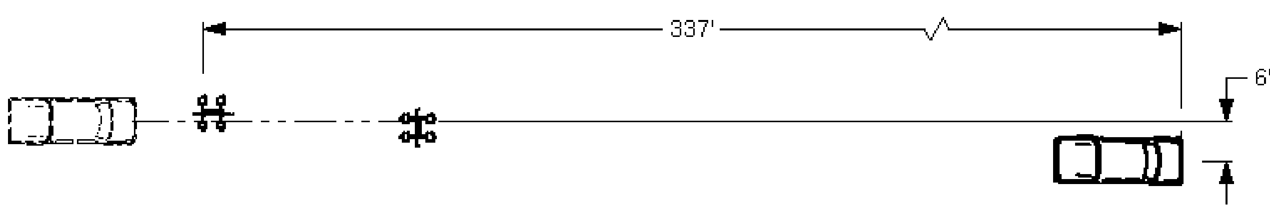
0.200 s

0.400 s

0.600 s

GENERAL INFORMATION	
Test Agency:	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.:	*MASH* 2016, Test 3-72
Project No.:	618901-01-2-3
Test Date:	2023-12-08
TEST ARTICLE	
Type:	Work-Zone Traffic Control Devices
Name:	Tall Sign Supports for Aluminum Signs
Length:	12.5 feet (150 inches)
Key Materials:	Aluminum sigh, PSST
Soil Type and Condition:	Concrete, dry
TEST VEHICLE	
Type/Designation:	2270P
Year, Make and Model:	2018 RAM 1500
Inertial Mass:	5005 lb
Dummy Mass:	N/A lb
Gross Static Mass:	5005 lb

IMPACT CONDITIONS	
Impact Speed:	63.5 mi/h
Impact Angle:	90°
Impact Location:	Centerline of 90° sign aligned 13 inches off centerline of vehicle toward the driver side. Secondary impact sign not included as there was interference from the first sign.
Kinetic Energy:	674.7 kip-ft
EXIT CONDITIONS	
Exit Speed:	61.7 mi/h
Stopping Distance:	337 ft downstream 6 ft to the right side
VEHICLE DAMAGE	
VDS:	12FC1
CDC:	12FCGN6
Max Exterior Deformation:	0.5 inches in the hood and windshield
Max Occupant Compartment Deformation:	0.5 inches in the windshield with penetration by test article



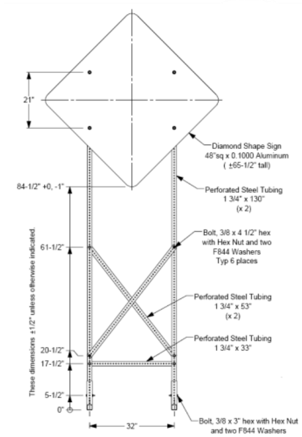


Figure 8.10. Summary of Results for *MASH* Test 3-72 on Tall Sign Supports for Aluminum Signs.

Chapter 9. *MASH* TEST 3-72 (CRASH TEST 618901-01-2-4)

9.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 9.1 for details of *MASH* impact conditions for this test and Table 9.2 for the exit parameters. Figure 9.1 and Figure 9.2 depict the target impact setup.

Table 9.1. Impact Conditions for *MASH* TEST 3-72, Crash Test 618901-01-2-4.

Test Parameter	Specification	Tolerance	Measured
Impact Speed	62 mi/h	±2.5 mi/h	62.6 mi/h
Impact Angle	90°	±1.5°	90°
Kinetic Energy	594 kip-ft	≥594 kip-ft	658.7 kip-ft
Impact Location	Centerline of sign posts aligned with centerline of vehicle	±6 inches	Centerline of sign posts aligned with centerline of vehicle

Table 9.2. Exit Parameters for *MASH* TEST 3-72, Crash Test 618901-01-2-4.

Exit Parameter	Measured
Speed	60.0 mi/h
Brakes applied post impact	The brakes were applied. Due to the vehicle not being instrumented, the exact time of brake application was not recorded.
Vehicle at rest position	350 ft downstream of impact point 12 ft to the left
Comments:	Vehicle remained upright and stable.

Figure 9.1. Tall Sign Supports for Aluminum Signs/Test Vehicle Geometrics for Test 618901-01-2-4.

Figure 9.2. Tall Sign Supports for Aluminum Signs/Test Vehicle Impact Location 618901-01-2-4.

9.2. WEATHER CONDITIONS

Table 9.3 provides the weather conditions for 618901-01-2-4.

Table 9.3. Weather Conditions 618901-01-2-4.

Date of Test	2023-12-12
Wind Speed	3 mi/h
Wind Direction	94°
Temperature	55°F
Relative Humidity	77%
Vehicle Traveling	350°

9.3. TEST VEHICLE

Figure 9.3 and Figure 9.4 show the 2019 RAM 1500 used for the crash test. Table 9.4 shows the vehicle measurements. Figure H.1 in Appendix H.1 gives additional dimensions and information on the vehicle.

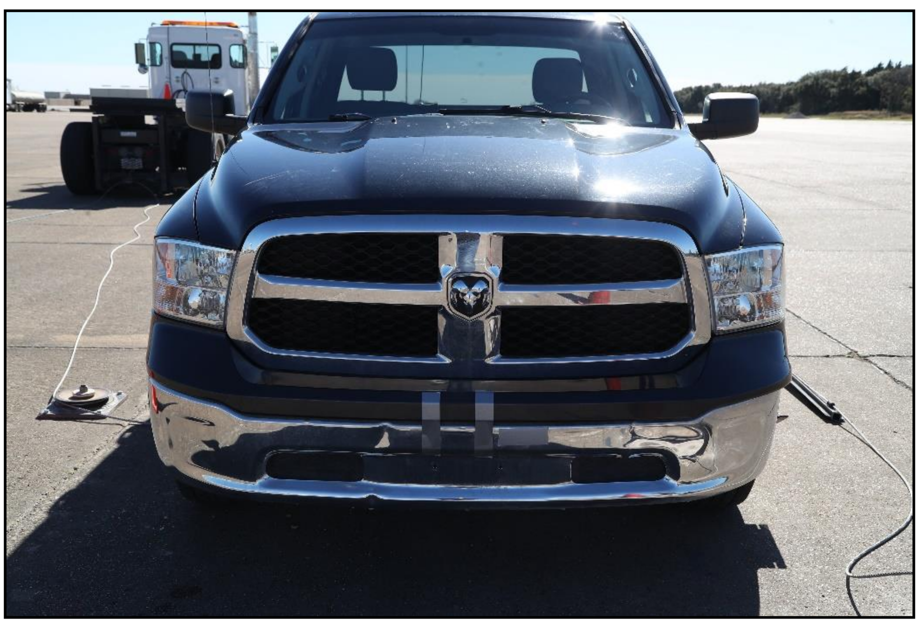


Figure 9.3. Impact Side of Test Vehicle before Test 618901-01-2-4.

Figure 9.4. Opposite Impact Side of Test Vehicle before Test 618901-01-2-4.

Table 9.4. Vehicle Measurements 618901-01-2-4.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a]	165 lb	N/A	N/A lb
Inertial Mass	5000 lb	±110 lb	5028 lb
Gross Static[a] Mass	5000 lb	±110 lb	5028 lb
Wheelbase	148 inches	±12 inches	140.5 inches
Front Overhang	39 inches	±3 inches	40.0 inches
Overall Length	237 inches	±13 inches	227.5 inches
Overall Width	78 inches	±2 inches	78.5 inches
Hood Height	43 inches	±4 inches	46.0 inches
Track Width[b]	67 inches	±1.5 inches	68.3 inches
CG aft of Front Axle[c]	63 inches	±4 inches	61.1 inches
CG above Ground[c,d]	28 inches	28 inches	28.3 inches

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.

9.4. TEST DESCRIPTION

Table 9.5 lists events that occurred during Test 618901-01-2-4. Figures H.4, H.5, and H.6 in Appendix H.2 present sequential photographs during the test.

Table 9.5. Events during Test 618901-01-2-4.

Time (s)	Events
0.0000	Vehicle impacted the installation
0.0220	Downstream sign post began to break
0.1900	Corner of sign impacted windshield

9.5. DAMAGE TO TEST INSTALLATION

The sign landed 375 feet downstream and 10 feet to the right from impact to the center of the sign. The base of the sign deformed, and the downstream post fractured just above the connection to the leg.

Figure 9.5 and Figure 9.6 show the damage to the Tall Sign Supports for Aluminum Signs.

Figure 9.5. Tall Sign Supports for Aluminum Signs at Resting Position after Test 618901-01-2-4.

Figure 9.6. Lower Half of the Tall Sign Supports for Aluminum Signs at Resting Position after Test 618901-01-2-4.

9.6. DAMAGE TO TEST VEHICLE

Figure 9.7 and Figure 9.8 show the damage sustained by the vehicle. Figure 9.9 and Figure 9.10 show the interior of the test vehicle. Table 9.6 and Table 9.7 provide details on the occupant compartment deformation and exterior vehicle damage. Figures H.2 and H.3 in Appendix H.1 provide exterior crush and occupant compartment measurements.

Figure 9.7. Impact Side of Test Vehicle after Test 618901-01-2-4.

Figure 9.8. Hood of Test Vehicle after Test 618901-01-2-4.

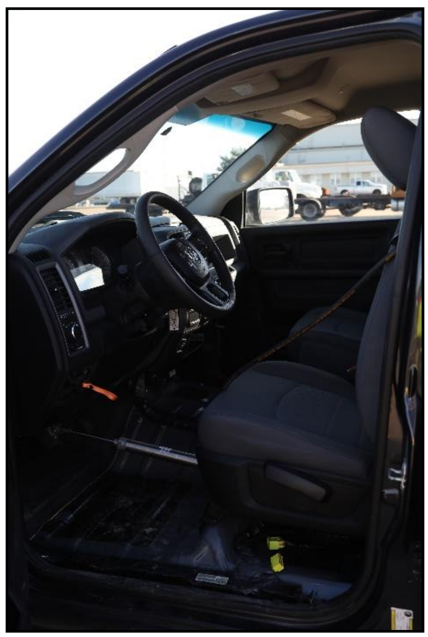


Figure 9.9. Overall Interior of Test Vehicle after Test 618901-01-2-4.

Figure 9.10. Upper Interior of Test Vehicle after Test 618901-01-2-4.

Table 9.6. Occupant Compartment Deformation 618901-01-2-4.

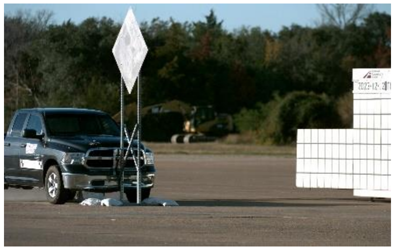
Test Parameter	Specification	Measured
Roof	≤4.0 inches	0.5 inches
Windshield	≤3.0 inches	0 inches
A and B Pillars	≤5.0 overall/≤3.0 inches lateral	0 inches
Foot Well/Toe Pan	≤9.0 inches	0 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0 inches
Side Front Panel	≤12.0 inches	0 inches
Front Door (above Seat)	≤9.0 inches	0 inches
Front Door (below Seat)	≤12.0 inches	0 inches

Table 9.7. Exterior Vehicle Damage 618901-01-2-4.

Side Windows	Side windows remained intact
Maximum Exterior Deformation	3 inches in the front bumper
VDS	12FC3
CDC	12FCMN3
Fuel Tank Damage	None
Description of Damage to Vehicle:	There was a 9-inch long × 6-inch wide × 3-inch deep dent in the bumper and a 7-inch long × 3-inch wide × 1.5-inch deep dent in the front center of the hood. There was a 12-inch long × 4-inch wide × 0.5-inch deep dent in the roof at the front left-hand side and a 14-inch long × 9-inch wide × 0.5-inch deep dent in the roof at the front right-hand side. There was a 10-inch long gash in the middle of the hood near the windshield. There were also cracks at the top portion of the windshield, but no holes.

9.7. TEST SUMMARY

Figure 9.11 summarizes the results of *MASH* Test 618901-01-2-4.



0.000 s

0.200 s

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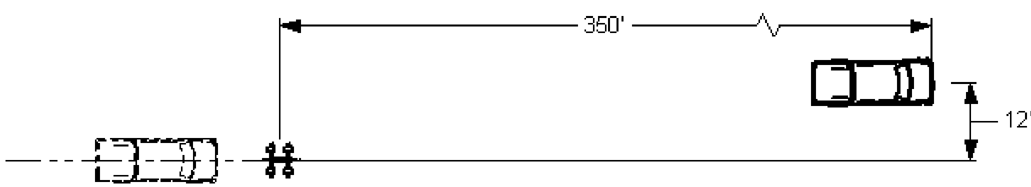
0.600 s

GENERAL INFORMATION	
Test Agency:	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.:	*MASH* 2016, Test 3-72
Project No.:	618901-01-2-4
Test Date:	2023-12-12
TEST ARTICLE	
Type:	Work-Zone Traffic Control Devices
Name:	Tall Sign Supports for Aluminum Signs
Length:	12.5 feet (150 inches)
Key Materials:	Aluminum sigh, PSST
Soil Type and Condition:	Concrete, dry
TEST VEHICLE	
Type/Designation:	2270P
Year, Make and Model:	2019 RAM 1500
Inertial Mass:	5028 lb
Dummy Mass:	N/A lb
Gross Static Mass:	5028 lb

IMPACT CONDITIONS	
Impact Speed:	62.6 mi/h
Impact Angle:	90°
Impact Location:	Centerline of sign aligned 13 inches off centerline of vehicle toward the driver side. Secondary impact sign not included as there was interference from the first sign.
Kinetic Energy:	658.7 kip-ft
EXIT CONDITIONS	
Exit Speed:	60.0 mi/h
Stopping Distance:	350 ft downstream 12 ft to the left
VEHICLE DAMAGE	
VDS:	12FC3
CDC:	12FCMN3
Max Exterior Deformation:	3 inches in the front bumper
Max Occupant Compartment Deformation:	0.5 inches in the roof



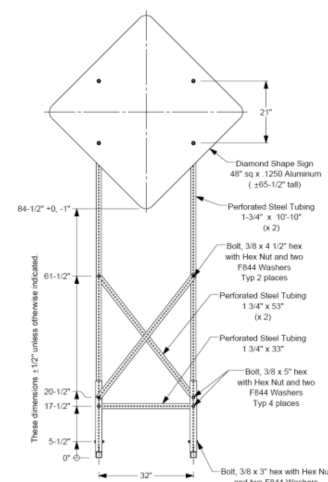


Figure 9.11. Summary of Results for *MASH* Test 3-72 on Tall Sign Supports for Aluminum Signs.

Chapter 10. *MASH* TEST 3-72 (CRASH TEST 618901-01-2-5)

10.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 10.1 for details of *MASH* impact conditions for this test and Table 10.2 for the exit parameters. Figure 10.1 and Figure 10.2 depict the target impact setup.

Table 10.1. Impact Conditions for *MASH* TEST 3-72, Crash Test 618901-01-2-5.

Test Parameter	**Specification**	**Tolerance**	**Measured**
Impact Speed	62 mi/h	±2.5 mi/h	62.2 mi/h
Impact Angle	0°	±1.5°	0°
Kinetic Energy	594 kip-ft	≥594 kip-ft	649.8 kip-ft
Impact Location	Centerline of sign aligned with centerline of vehicle	±6 inches	Centerline of sign aligned with centerline of vehicle

Table 10.2. Exit Parameters for *MASH* TEST 3-72, Crash Test 618901-01-2-5.

Exit Parameter	**Measured**
Speed	60.7 mi/h
Brakes applied post impact	The brakes were applied. Due to the vehicle not being instrumented, the exact time of brake application was not recorded.
Vehicle at rest position	315 ft downstream of impact point 12 ft to the left
Comments:	Vehicle remained upright and stable.

Figure 10.1. Tall Sign Supports for Aluminum Signs/Test Vehicle Geometrics for Test 618901-01-2-5.

Figure 10.2. Tall Sign Supports for Aluminum Signs/Test Vehicle Impact Location 618901-01-2-5.

10.2. WEATHER CONDITIONS

Table 10.3 provides the weather conditions for 618901-01-2-5.

Table 10.3. Weather Conditions 618901-01-2-5.

Date of Test	2023-12-12
Wind Speed	5 mi/h
Wind Direction	88°
Temperature	62°F
Relative Humidity	67%
Vehicle Traveling	350°

10.3. TEST VEHICLE

Figure 10.3 and Figure 10.4 show the 2018 RAM 1500 used for the crash test. Table 10.4 shows the vehicle measurements. Figure I.1 in Appendix I.1 gives additional dimensions and information on the vehicle.

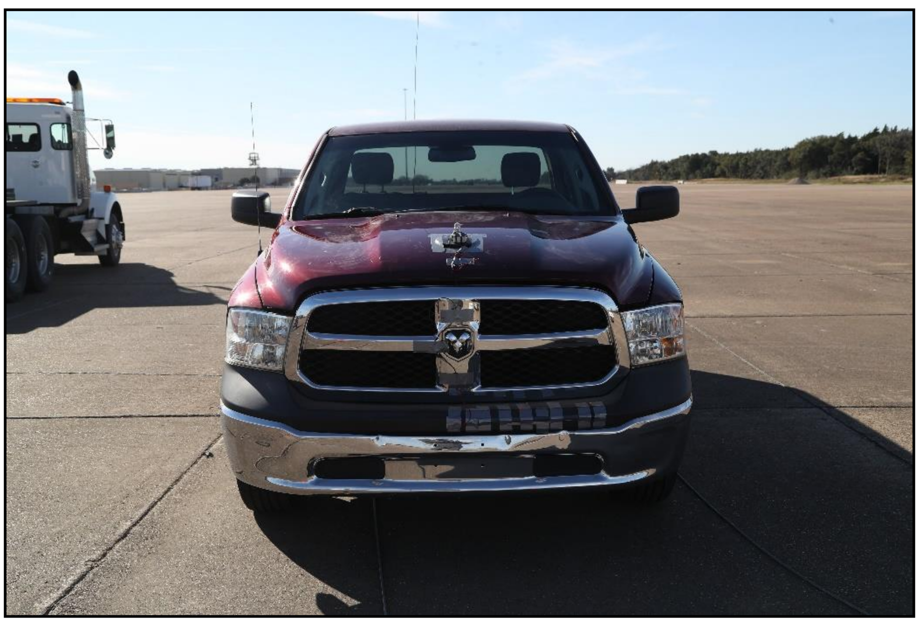


Figure 10.3. Front of Test Vehicle before Test 618901-01-2-5.

Figure 10.4. Rear of Test Vehicle before Test 618901-01-2-5.

Table 10.4. Vehicle Measurements 618901-01-2-5.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a]	165 lb	N/A	N/A lb
Inertial Mass	5000 lb	±110 lb	5024 lb
Gross Static[a] Mass	5000 lb	±110 lb	5024 lb
Wheelbase	148 inches	±12 inches	140.5 inches
Front Overhang	39 inches	±3 inches	40.0 inches
Overall Length	237 inches	±13 inches	227.5 inches
Overall Width	78 inches	±2 inches	78.5 inches
Hood Height	43 inches	±4 inches	46.0 inches
Track Width[b]	67 inches	±1.5 inches	68.3 inches
CG aft of Front Axle[c]	63 inches	±4 inches	61.3 inches
CG above Ground[c,d]	28 inches	28 inches	28.5 inches

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.

10.4. TEST DESCRIPTION

Table 10.5 lists events that occurred during Test 618901-01-2-5. Figures I.4, I.5, and I.6 in Appendix I.2 present sequential photographs during the test.

Table 10.5. Events during Test 618901-01-2-5.

Time (s)	Events
0.0000	Vehicle impacted the installation
0.0050	Sign base began to slide
0.0060	Left side sign post began to break, above lower cross connection
0.1130	Sign impacted left side of the roof and windshield
0.2330	Sign lost contact with the vehicle

10.5. DAMAGE TO TEST INSTALLATION

The sign landed 270ft downstream and 8 feet to the right. One of the legs was knocked askew, and the post was damaged above its connection to the left. leg The sign was bent on the lower corner.

Figure 10.5 and Figure 10.6 show the damage to the Tall Sign Supports for Aluminum Signs.

Figure 10.5. Tall Sign Supports for Aluminum Signs at Resting Position after Test 618901-01-2-5.

Figure 10.6. Damaged Base on the Tall Sign Supports for Aluminum Signs after Test 618901-01-2-5.

10.6. DAMAGE TO TEST VEHICLE

Figure 10.7 and Figure 10.8 show the damage sustained by the vehicle. Figure 10.9 shows the interior of the test vehicle. Table 10.6 and Table 10.7 provide details on the occupant compartment deformation and exterior vehicle damage. Figures I.2 and I.3 in Appendix I.1 provide exterior crush and occupant compartment measurements.

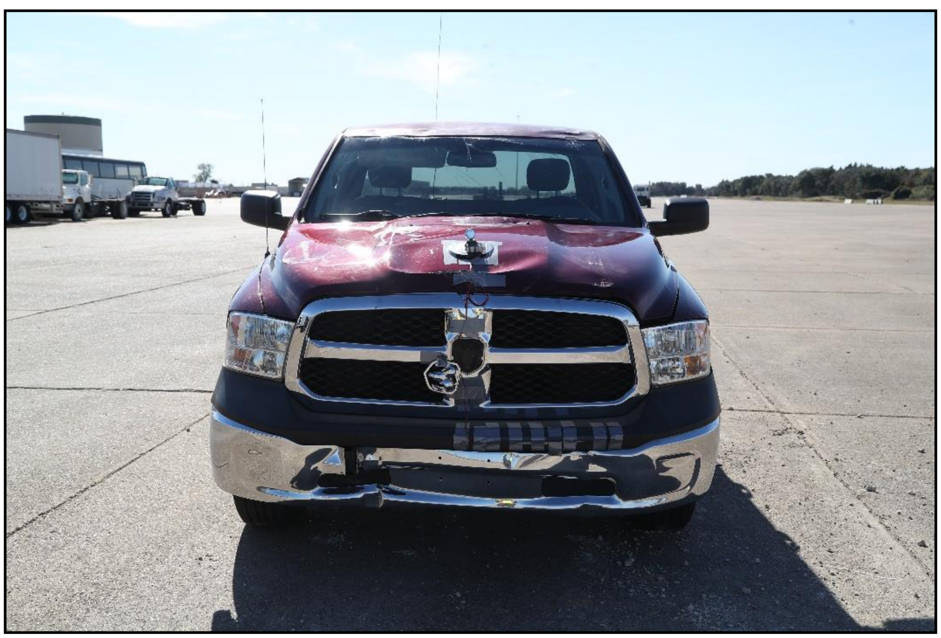


Figure 10.7. Front of Test Vehicle after Test 618901-01-2-5.

Figure 10.8. Rear of Test Vehicle after Test 618901-01-2-5.

Figure 10.9. Upper Interior of Test Vehicle after Test 618901-01-2-5.

Table 10.6. Occupant Compartment Deformation 618901-01-2-5.

Test Parameter	Specification	Measured
Roof	≤4.0 inches	0 inches
Windshield	≤3.0 inches	0 inches
A and B Pillars	≤5.0 overall/≤3.0 inches lateral	0 inches
Foot Well/Toe Pan	≤9.0 inches	0 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0 inches
Side Front Panel	≤12.0 inches	0 inches
Front Door (above Seat)	≤9.0 inches	0 inches
Front Door (below Seat)	≤12.0 inches	0 inches

Table 10.7. Exterior Vehicle Damage 618901-01-2-5.

Side Windows	Side windows remained intact
Maximum Exterior Deformation	11 inches in the front bumper
VDS	12FC1
CDC	12FCHN1
Fuel Tank Damage	None
Description of Damage to Vehicle:	The bumper, grill, hood, radiator, and support were damaged. There were windshield cracks on the driver's side. At the front center of the hood there was a 7 inch long tear. There was a 1-inch long × 0.5-inch wide puncture in the hood, 15 inches up and 3 inches from the centerline toward the driver's side. There was a 4-inch wide × 11-inch deep dent in the bumper, and the hood buckled up.

10.7. TEST SUMMARY

Figure 10.10 summarizes the results of *MASH* Test 618901-01-2-5.

0.000 s

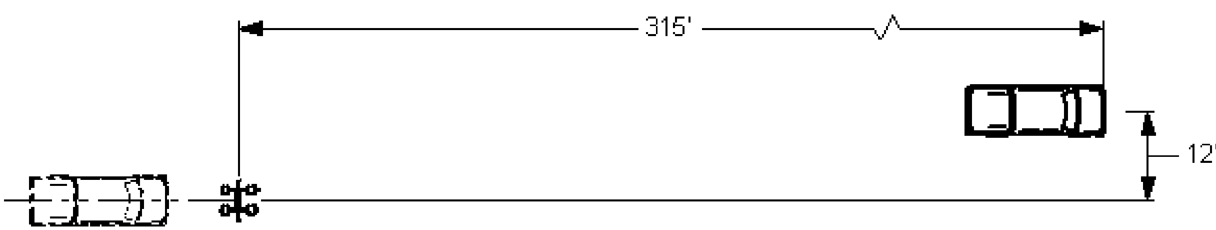
0.200 s

0.400 s

0.600 s

GENERAL INFORMATION	
Test Agency:	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.:	*MASH* 2016, Test 3-72
Project No.:	618901-01-2-5
Test Date:	2023-12-12
TEST ARTICLE	
Type:	Work-Zone Traffic Control Devices
Name:	Tall Sign Supports for Aluminum Signs
Length:	12.5 feet (150 inches)
Key Materials:	Aluminum sigh, PSST
Soil Type and Condition:	Concrete, dry
TEST VEHICLE	
Type/Designation:	2270P
Year, Make and Model:	2018 RAM 1500
Inertial Mass:	5024 lb
Dummy Mass:	N/A lb
Gross Static Mass:	5024 lb

IMPACT CONDITIONS	
Impact Speed:	62.2 mi/h
Impact Angle:	90°
Impact Location:	Centerline of sign aligned with centerline of vehicle
Kinetic Energy:	649.8 kip-ft
EXIT CONDITIONS	
Exit Speed:	61.3mi/h
Stopping Distance:	315 ft downstream 12 ft to the left
VEHICLE DAMAGE	
VDS:	12FC1
CDC:	12FCHN1
Max Exterior Deformation:	11 inches in the front bumper
Max Occupant Compartment Deformation:	No occupant compartment deformation



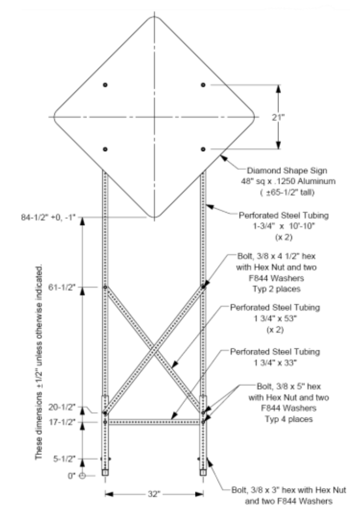


Figure 10.10. Summary of Results for *MASH* Test 3-72 on Tall Sign Supports for Aluminum Signs.

Chapter 11. *MASH* TEST 3-71 (CRASH TEST 618901-01-2-6)

11.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 11.1 for details of *MASH* impact conditions for this test and Table 11.2 for the exit parameters. Figure 11.1 and Figure 11.2 depict the target impact setup.

Table 11.1. Impact Conditions for *MASH* TEST 3-71, Crash Test 618901-01-2-6.

Test Parameter	Specification	Tolerance	Measured
Impact Speed	62 mi/h	±2.5 mi/h	63.9 mi/h
Impact Angle	90°	±1.5°	90°
Kinetic Energy	288 kip-ft	≥288 kip-ft	334.8 kip-ft
Impact Location	Centerline of the sign with centerline of vehicle	±6 inches	Centerline of the sign with centerline of vehicle

Table 11.2. Exit Parameters for *MASH* TEST 3-71, Crash Test 618901-01-2-6.

Exit Parameter	Measured
Speed	57.9 mi/h
Brakes applied post impact	The brakes were applied. Due to the vehicle being uninstrumented, the exact time of brake application was not recorded.
Vehicle at rest position	304 ft downstream of impact point 12 ft to the left
Comments:	Vehicle remained upright and stable.

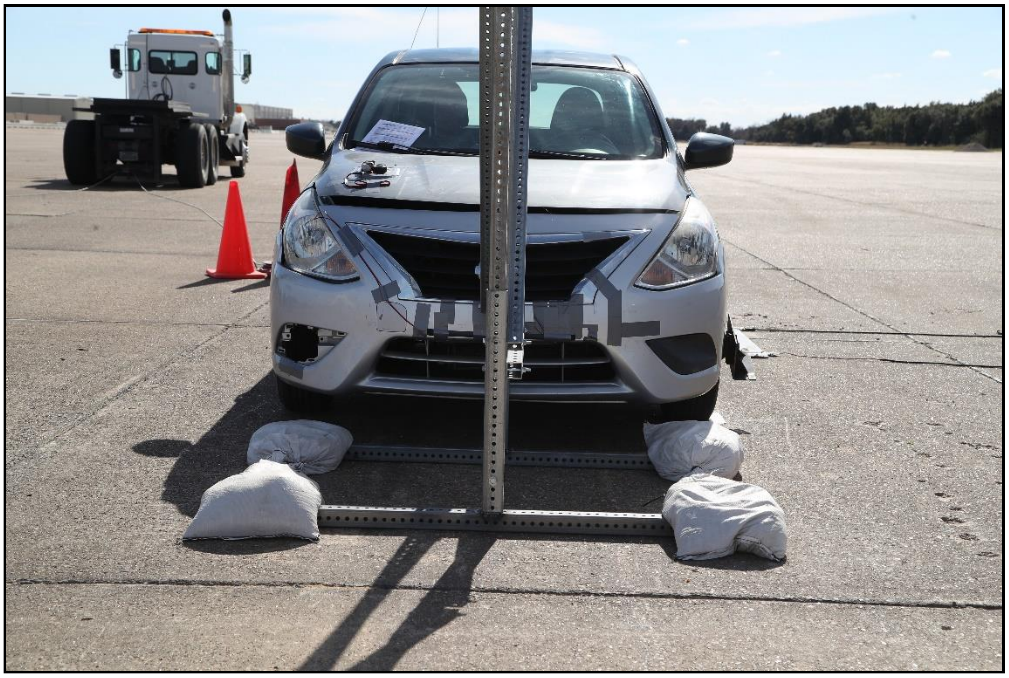


Figure 11.1. Tall Sign Supports for Aluminum Signs/Test Vehicle Geometrics for Test 618901-01-2-6.

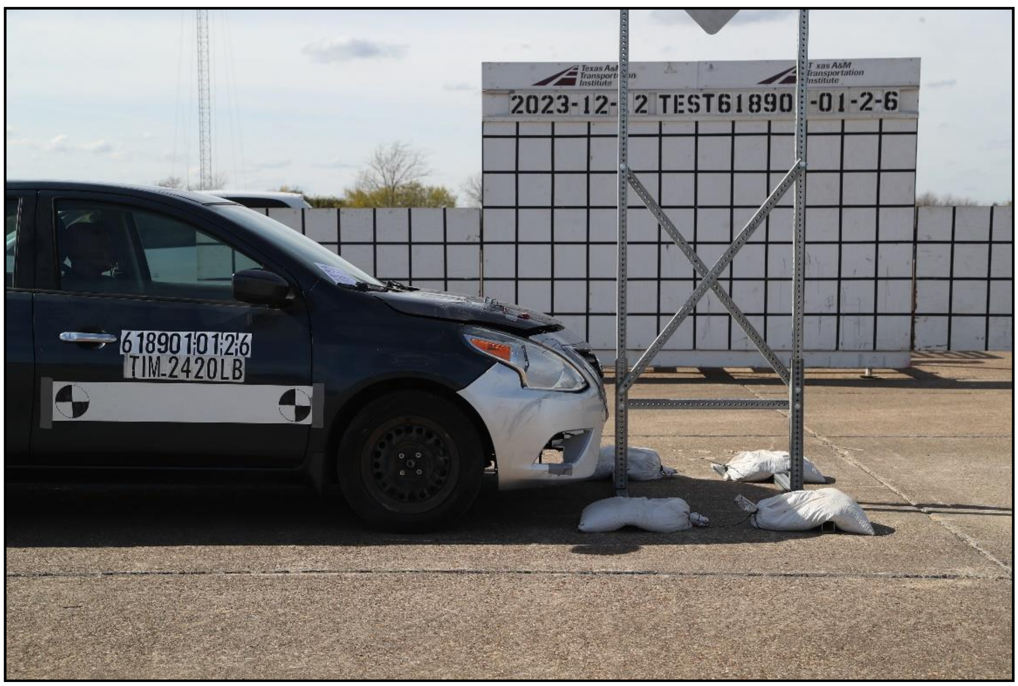


Figure 11.2. Tall Sign Supports for Aluminum Signs/Test Vehicle Impact Location 618901-01-2-6.

11.2. WEATHER CONDITIONS

Table 11.3 provides the weather conditions for 618901-01-2-6.

Table 11.3. Weather Conditions 618901-01-2-6.

Date of Test	2023-12-12
Wind Speed	4 mi/h
Wind Direction	123°
Temperature	68 °F
Relative Humidity	58 %
Vehicle Traveling	350°

11.3. TEST VEHICLE

Figure 11.3 and Figure 11.4 show the 2017 Nissan Versa used for the crash test. Table 11.4 shows the vehicle measurements. Figure J.1 in Appendix J.1 gives additional dimensions and information on the vehicle.

Figure 11.3. Front of Test Vehicle before Test 618901-01-2-6.

Figure 11.4. Rear of Test Vehicle before Test 618901-01-2-6.

Table 11.4. Vehicle Measurements 618901-01-2-6.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a]	165 lb	N/A	165 lb
Inertial Mass	2420 lb	±55 lb	2453 lb
Gross Static[a] Mass	2585 lb	±55 lb	2618 lb
Wheelbase	98 inches	±5 inches	102.4 inches
Front Overhang	35 inches	±4 inches	32.5 inches
Overall Length	169 inches	±8 inches	175.4 inches
Overall Width	65 inches	±3 inches	66.7 inches
Hood Height	28 inches	±4 inches	30.5 inches
Track Width[b]	59 inches	±2 inches	58.4 inches
CG aft of Front Axle[c]	39 inches	±4 inches	41.5 inches
CG above Ground[c,d]	N/A inches	N/A inches	N/A inches

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.

11.4. TEST DESCRIPTION

Table 11.5 lists events that occurred during Test 618901-01-2-6. Figures J.4, J.5, and J.6 in Appendix J.2 present sequential photographs during the test.

Table 11.5. Events during Test 618901-01-2-6.

Time (s)	Events
0.0000 s	Vehicle impacted the installation
0.0170 s	Downstream post began to lift from pavement
0.0270 s	Downstream post began to break at lower joint
0.1300 s	Sign impacted roof

11.5. DAMAGE TO TEST INSTALLATION

The sign landed 188 feet downstream of impact. The impacted support fractured where it connects to the leg, and the leg was dislodged from the installation. The other leg tore, and the sign was slightly deformed.

Figure 11.6 and Figure 11.5 show the damage to the Tall Sign Supports for Aluminum Signs.

Figure 11.5. Tall Sign Supports for Aluminum Signs at Resting Position after Test 618901-01-2-6.

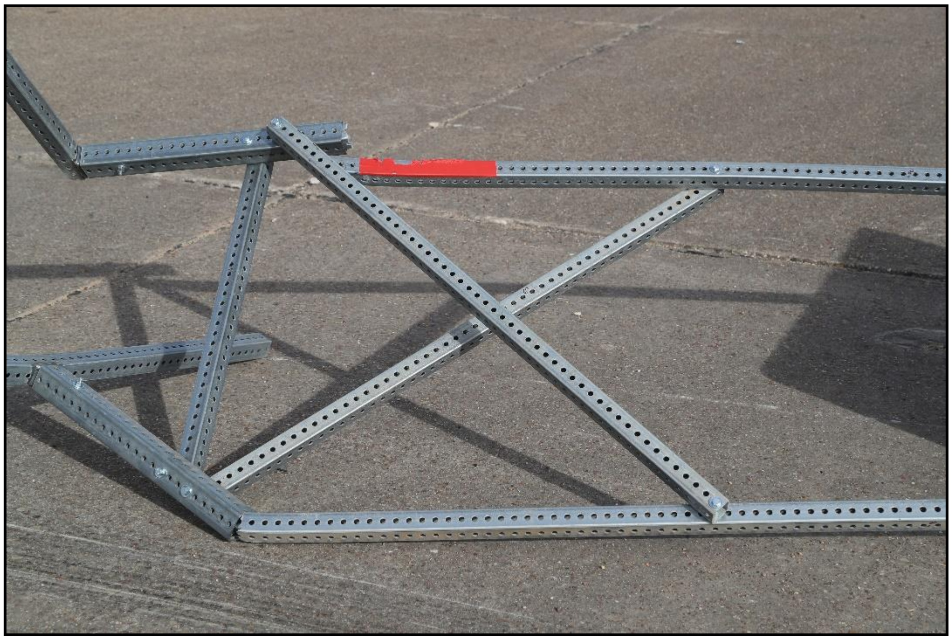


Figure 11.6. Lower Half of the Tall Sign Supports for Aluminum Signs after Test 618901-01-2-6.

11.6. DAMAGE TO TEST VEHICLE

Figure 11.7 and Figure 11.8 show the damage sustained by the vehicle. Figure 11.9 shows the interior of the test vehicle. Table 11.6 and Table 11.7 provide details on the occupant compartment deformation and exterior vehicle damage. Figures J.2 and J.3 in Appendix J.1 provide exterior crush and occupant compartment measurements.

Figure 11.7. Front of Test Vehicle after Test 618901-01-2-6.

Figure 11.8. Closeup of Tear in Roof of Test Vehicle after Test 618901-01-2-6.

Figure 11.9. Interior Roof of Test Vehicle after Test 618901-01-2-6.

Table 11.6. Occupant Compartment Deformation 618901-01-2-6.

Test Parameter	Specification	Measured
Roof	≤4.0 inches	2.8 inches
Windshield	≤3.0 inches	0 inches
A and B Pillars	≤5.0 overall/≤3.0 inches lateral	0 inches
Foot Well/Toe Pan	≤9.0 inches	0 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0 inches
Side Front Panel	≤12.0 inches	0 inches
Front Door (above Seat)	≤9.0 inches	0 inches
Front Door (below Seat)	≤12.0 inches	0 inches

Table 11.7. Exterior Vehicle Damage 618901-01-2-6.

Side Windows	Side windows remained intact
Maximum Exterior Deformation	11.5 inches at front bumper
VDS	12FC2
CDC	12FCGN2
Fuel Tank Damage	None
Description of Damage to Vehicle:	There was a 12-inch long × 0.3-inch deep slice in roof on the driver's side with a 48-inch long × 24-inch wide × 2.8-inch deep dent in the roof. The radiator and fan were pushed against the engine block. The bumper, grill, hood, and support were damaged.

11.7. TEST SUMMARY

Figure 11.10 summarizes the results of *MASH* Test 618901-01-2-6.

0.000 s

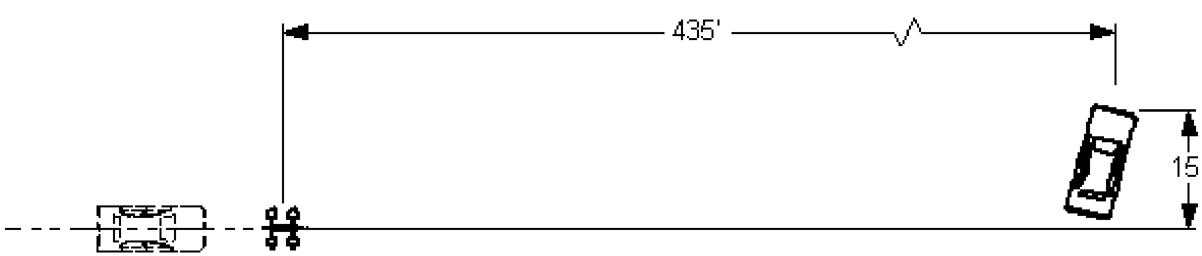
0.200 s

0.400 s

0.600 s

GENERAL INFORMATION	
Test Agency:	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.:	*MASH* 2016, Test 3-71
Project No.:	618901-01-2-6
Test Date:	2023-12-12
TEST ARTICLE	
Type:	Work-Zone Traffic Control Devices
Name:	Tall Sign Supports for Aluminum Signs
Length:	12.5 feet (150 inches)
Key Materials:	Aluminum sigh, PSST
Soil Type and Condition:	Concrete, dry
TEST VEHICLE	
Type/Designation:	1100C
Year, Make and Model:	2017 Nissan Versa
Inertial Mass:	2453 lb
Dummy Mass:	165 lb
Gross Static Mass:	2618 lb

IMPACT CONDITIONS	
Impact Speed:	63.9 mi/h
Impact Angle:	90°
Impact Location:	Centerline of sign aligned with centerline of vehicle
Kinetic Energy:	334.8 kip-ft
EXIT CONDITIONS	
Exit Speed:	57.9 mi/h
Stopping Distance:	304 ft downstream 12 ft to the left
VEHICLE DAMAGE	
VDS:	12FC2
CDC:	12FCGN2
Max Exterior Deformation:	11.5 inches
Max Occupant Compartment Deformation:	2.8 inches in the roof with tears in the roof



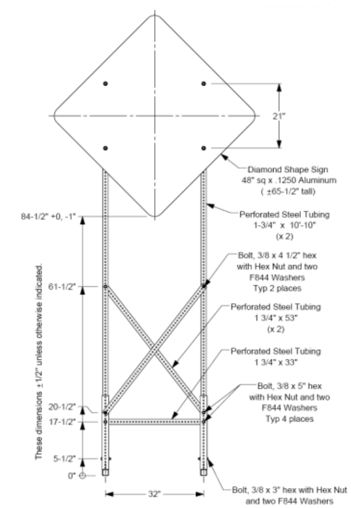


Figure 11.10. Summary of Results for *MASH* Test 3-71 on Tall Sign Supports for Aluminum Signs.

Chapter 12. *MASH* TEST 3-71 (CRASH TEST 618901-01-2-7)

12.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 12.1 for details of *MASH* impact conditions for this test and Table 12.2 for the exit parameters. Figure 12.1 and Figure 12.2 depict the target impact setup.

Table 12.1. Impact Conditions for *MASH* TEST 3-71, Crash Test 618901-01-2-7.

Test Parameter	Specification	Tolerance	Measured
Impact Speed	62 mi/h	±2.5 mi/h	62.9 mi/h
Impact Angle	0°	±1.5°	90°
Kinetic Energy	288 kip-ft	≥288 kip-ft	323.9 kip-ft
Impact Location	Centerline of the sign with centerline of vehicle	±6 inches	Centerline of the sign with centerline of vehicle

Table 12.2. Exit Parameters for *MASH* TEST 3-71, Crash Test 618901-01-2-7.

Exit Parameter	Measured
Speed	57.2 mi/h
Brakes applied post impact	The brakes were applied. Due to the vehicle not being instrumented, the exact time of brake application was not recorded.
Vehicle at rest position	435 ft downstream of impact point 15 ft to the left
Comments:	Vehicle remained upright and stable.

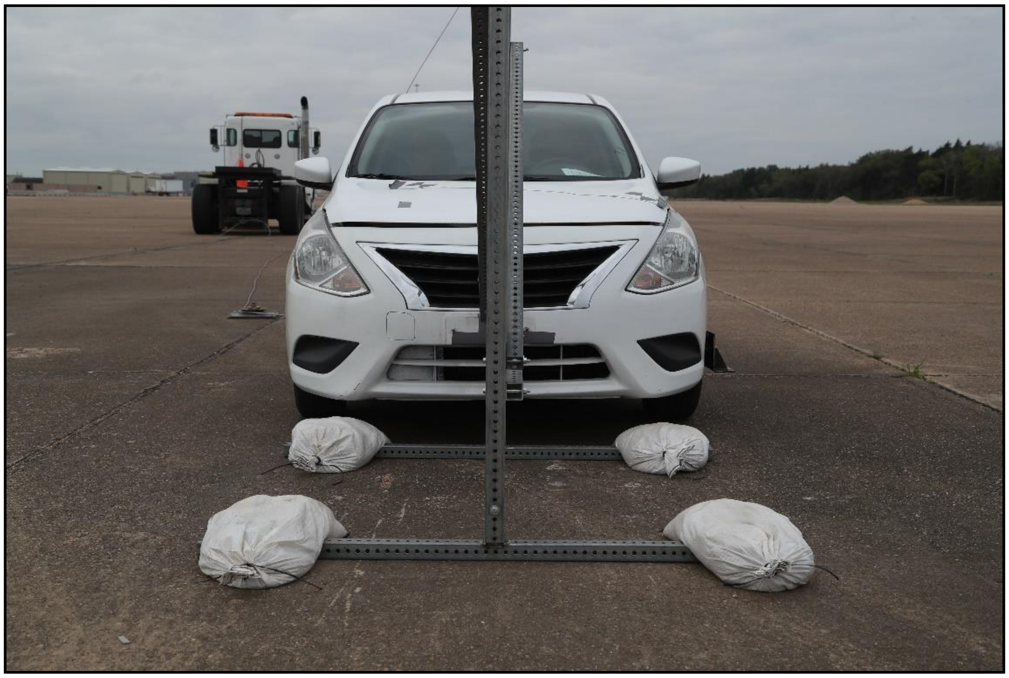


Figure 12.1. Tall Sign Supports for Aluminum Signs/Test Vehicle Geometrics for Test 618901-01-2-7.

Figure 12.2. Tall Sign Supports for Aluminum Signs/Test Vehicle Impact Location 618901-01-2-7.

12.2. WEATHER CONDITIONS

Table 12.3 provides the weather conditions for 618901-01-2-7.

Table 12.3. Weather Conditions 618901-01-2-7.

Date of Test	2024-03-12
Wind Speed	7 mi/h
Wind Direction	163°
Temperature	64°F
Relative Humidity	90%
Vehicle Traveling	350°

12.3. TEST VEHICLE

Figure 12.3 and Figure 12.4 show the 2017 Nissan Versa used for the crash test. Table 12.4 shows the vehicle measurements. Figure K.1 in Appendix K.1 gives additional dimensions and information on the vehicle.

Figure 12.3. Front of Test Vehicle before Test 618901-01-2-7.

Figure 12.4. Rear of Test Vehicle before Test 618901-01-2-7.

Table 12.4. Vehicle Measurements 618901-01-2-7.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a]	165 lb	N/A	165 lb
Inertial Mass	2420 lb	±55 lb	2441 lb
Gross Static[a] Mass	2585 lb	±55 lb	2606 lb
Wheelbase	98 inches	±5 inches	102.4 inches
Front Overhang	35 inches	±4 inches	32.5 inches
Overall Length	169 inches	±8 inches	175.4 inches
Overall Width	65 inches	±3 inches	66.7 inches
Hood Height	28 inches	±4 inches	30.5 inches
Track Width[b]	59 inches	±2 inches	58.4 inches
CG aft of Front Axle[c]	39 inches	±4 inches	42.0 inches
CG above Ground[c,d]	N/A inches	N/A inches	N/A inches

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.

12.4. TEST DESCRIPTION

Table 12.5 lists events that occurred during Test 618901-01-2-7. Figures K.4, K.5, and K.6 in Appendix K.2 present sequential photographs during the test.

Table 12.5. Events during Test 618901-01-2-7.

Time (s)	Events
0.0000 s	Vehicle impacted the installation
0.0070 s	Downstream post began to lift from pavement
0.0310 s	Downstream post began to break at lower cross joint
0.2600 s	Corner of sign impacted windshield

12.5. DAMAGE TO TEST INSTALLATION

The test article came to rest 375 feet downstream of impact. The impacted post and the sign were bent, and the other post was fractured. The leg on the non-impact post released, and the half of the leg on the impacted post fractured and released from the installation.

Figure 12.5 and Figure 12.6 show the damage to the Tall Sign Supports for Aluminum Signs.

Figure 12.5. Tall Sign Supports for Aluminum Signs at Resting Position after Test 618901-01-2-7.

Figure 12.6. Closeup of the Tall Sign Supports for Aluminum Signs after Test 618901-01-2-7.

12.6. DAMAGE TO TEST VEHICLE

Figure 12.7 and Figure 12.8 show the damage sustained by the vehicle. Figure 12.9 and Figure 12.10 show the interior of the test vehicle. Table 12.6 and Table 12.7 provide details on the occupant compartment deformation and exterior vehicle damage. Figures K.2 and K.3 in Appendix K.1 provide exterior crush and occupant compartment measurements.

Figure 12.7. Front of Test Vehicle after Test 618901-01-2-7.


Figure 12.8. Closeup of Tear in Windshield of Test Vehicle after Test 618901-01-2-7.


Figure 12.9. Overall Interior of Test Vehicle after Test 618901-01-2-7.

Figure 12.10. Interior of Test Vehicle at the Windshield Damage after Test 618901-01-2-7.

Table 12.6. Occupant Compartment Deformation 618901-01-2-7.

Test Parameter	Specification	Measured
Roof	≤4.0 inches	0 inches
Windshield	≤3.0 inches	0 inches
A and B Pillars	≤5.0 overall/≤3.0 inches lateral	0 inches
Foot Well/Toe Pan	≤9.0 inches	0 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0 inches
Side Front Panel	≤12.0 inches	0 inches
Front Door (above Seat)	≤9.0 inches	0 inches
Front Door (below Seat)	≤12.0 inches	0 inches

Table 12.7. Exterior Vehicle Damage 618901-01-2-7.

Side Windows	Side windows remained intact
Maximum Exterior Deformation	12 inches at front bumper
VDS	12FC3
CDC	12FCMW3
Fuel Tank Damage	None
Description of Damage to Vehicle:	There was a 3-inch long × 0.3-inch wide hole in the top of the center of the windshield caused by the sign. The hood, bumper, grill, radiator, and support were damaged, with a small dent in the front center of the roof.

12.7. TEST SUMMARY

Figure 12.11 summarizes the results of *MASH* Test 618901-01-2-7.

0.000 s

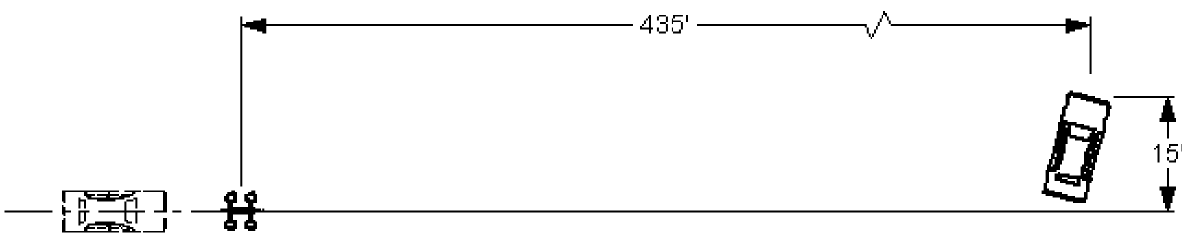
0.200 s

0.400 s

0.600 s

GENERAL INFORMATION	
Test Agency:	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.:	*MASH* 2016, Test 3-71
Project No.:	618901-01-2-7
Test Date:	2024-03-12
TEST ARTICLE	
Type:	Work-Zone Traffic Control Devices
Name:	Tall Sign Supports for Aluminum Signs
Length:	10.5 feet (126 inches)
Key Materials:	Aluminum sigh, PSST
Soil Type and Condition:	Concrete, dry
TEST VEHICLE	
Type/Designation:	1100C
Year, Make and Model:	2017 Nissan Versa
Inertial Mass:	2441 lb
Dummy Mass:	165 lb
Gross Static Mass:	2606 lb

IMPACT CONDITIONS	
Impact Speed:	62.9 mi/h
Impact Angle:	90°
Impact Location:	Centerline of sign aligned with centerline of vehicle
Kinetic Energy:	323.9 kip-ft
EXIT CONDITIONS	
Exit Speed:	57.3 mi/h
Stopping Distance:	435 ft downstream 15 ft to the left side
VEHICLE DAMAGE	
VDS:	12FC3
CDC:	12FCMW3
Max Exterior Deformation:	12 inches
Max Occupant Compartment Deformation:	Penetration of test article through windshield. No other deformation



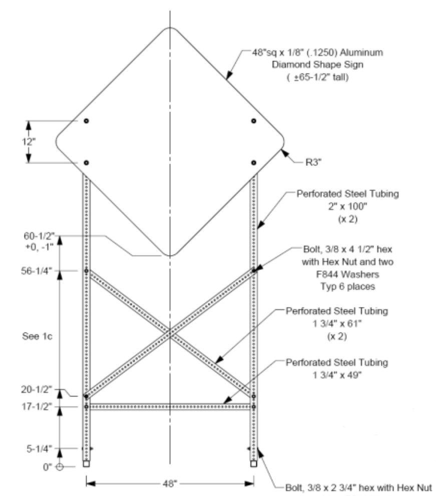


Figure 12.11. Summary of Results for *MASH* Test 3-71 on Tall Sign Supports for Aluminum Signs.

Chapter 13. SUMMARY AND CONCLUSIONS

13.1. ASSESSMENT OF TEST RESULTS

The crash tests reported herein were performed in accordance with *MASH* TL-3.

Table 13.1 summarizes the *MASH* evaluation results of the Tall Sign Supports for Aluminum Signs.

Table 13.1. Assessment Summary for *MASH* TL-3 Tests on Tall Sign Supports for Aluminum Signs.

Evaluation Criteria	Description	Test 618901-01-2-1	Test 618901-01-2-2	Test 618901-01-2-3	Test 618901-01-2-4	Test 618901-01-2-5	Test 618901-01-2-6	Test 618901-01-2-7
B	Test Article Broke Away, Fractured, Yielded	S	S	S	S	S	S	S
D	No Penetration into Occupant Compartment	S	S	**FAIL**	S	S	**FAIL**	**FAIL**
E	Driver's Vision Not Blocked	S	S	S	S	S	S	S
F	Roll and Pitch Limit	S	S	S	S	S	S	S
N	Vehicle Trajectory Behind Test Article Acceptable	S	S	S	S	S	S	S
Overall	Evaluation	Pass	Pass	**Fail**	Pass	Pass	**Fail**	**Fail**

Note: S = Satisfactory
[1] See Table 4.2 for details

13.2. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

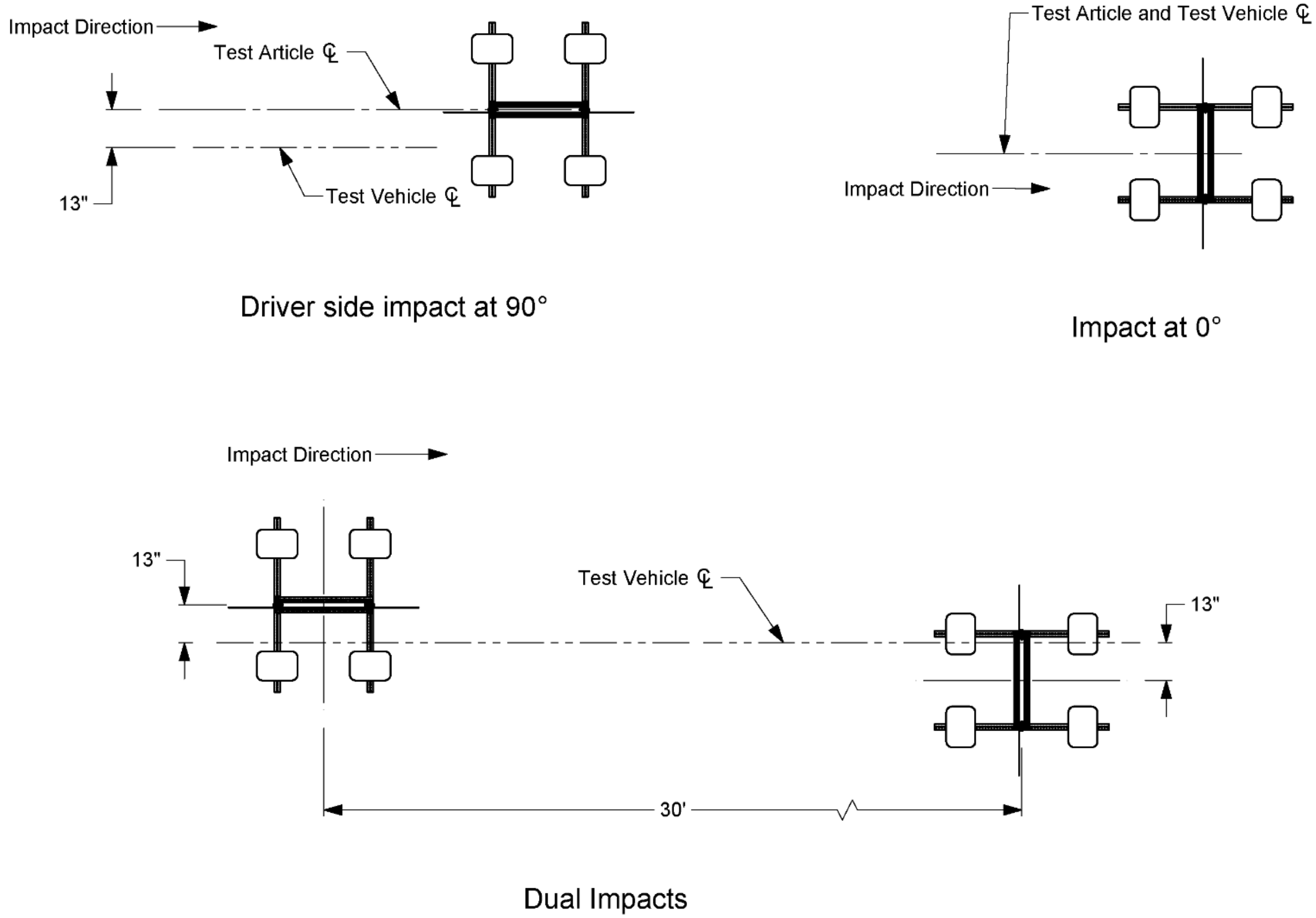
Channelizers in work zones have the potential to obscure low mounted signage from drivers' vision. Consequently, the research team was tasked with developing a *MASH* compliant design for a tall portable sign support. The research team evaluated three different designs through *MASH* crash testing. All three designs failed to meet *MASH* evaluation criteria in either test 3-71 or 3-72.

The research team recommends additional research projects to continue this investigation. A detailed examination into the crashworthy behavior of the single post options summarized in the literature review may provide further insight for improvements to the crash tested dual post designs that failed to meet *MASH* evaluation criteria. Additionally, improvements to aid the global rotation of the sign support may also be beneficial for future research.

REFERENCES

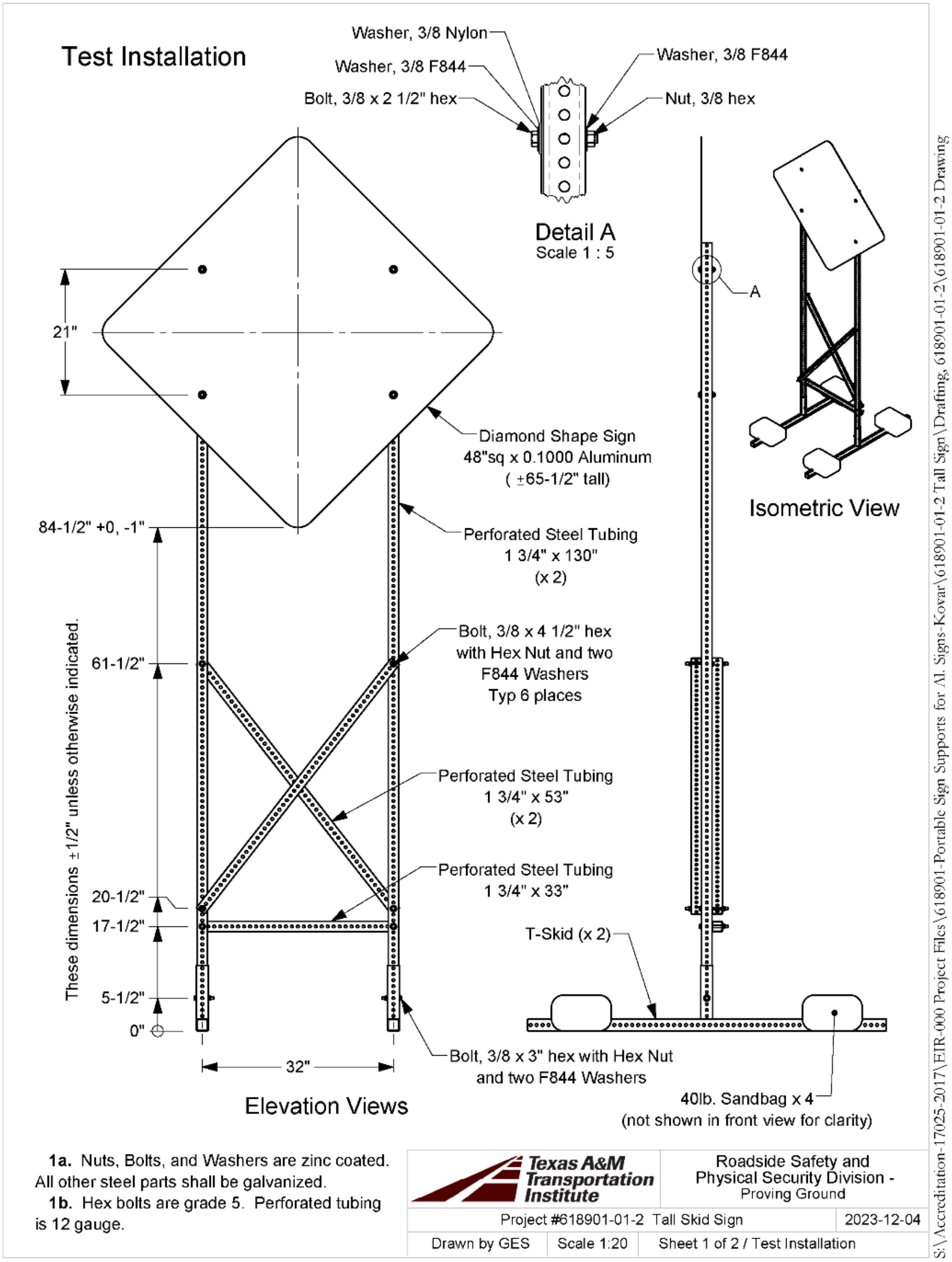
1. AASHTO. *Manual for Assessing Safety Hardware*, Second Edition. American Association of State Highway and Transportation Officials, Washington, DC, 2016.
2. Dobrovolny, C.S., Arrington, D.R., Bligh, R.P., Menges, W.L., and Kuhn, D.L., *MASH Evaluation of TxDOT High-Mounting-Height Temporary Work Zone Sign Support System,* Report No. 9-1002-15-8. Texas A&M Transportation Institute, College Station, TX, 2016.
3. Dobrovolny, C.S., Arrington, D.R., Bligh, R.P., and Menges, W.L., *Development and MASH Full-Scale Crash Testing of a High-Mounting-Height Temporary Single Sign Support with Aluminum Sign,* Report No. 9-1002-12-5. Texas A&M Transportation Institute, College Station, TX, 2013.
4. Bligh, R.P., Menges, W.L., Griffith, B.L., Schroeder, G.E., Kuhn, D.L., *MASH Evaluation of TxDOT Roadside Safety Features—Phase II,* Report No. 0-6946-R2. Texas A&M Transportation Institute, College Station, TX, 2019.
5. Polivka, K.A., Faller, R.K., Holloway, J.C., Rohde, J.R., and Sicking, D.L., *Safety Performance Evaluation of Michigan's 4x5 Portable Sign Support,* TRP-03-135-03. Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, NE, 2003.
6. Ross Jr., H.E., Sicking, D.L., Zimmer, R.A., and Michie*,* J.D.*, Recommended Procedures for the Safety Performance Evaluation of Highway Features,* NCHRP Report 350, Transportation Research Board, Washington, D.C., 1993.
7. Rose, E.R., Hawkins, Jr., H.G, Holick, A.J., Bligh, R.P., *Evaluation of Traffic Control Devices: First Year Activities*, Report 0-4701-1. Texas Transportation Institute, College Station, TX, 2004.
8. Kovar, J.C., Curran, D., Schroeder, W.J.L., Kuhn, D.L., *Evaluation of Type III Barricades with Mounted Signs*, Report 616411-01, Texas A&M Transportation Institute, College Station, TX, 2022.

APPENDIX A. DETAILS OF TALL SIGN SUPPORTS FOR ALUMINUM SIGNS FOR TESTS 618901-02-1 - 3

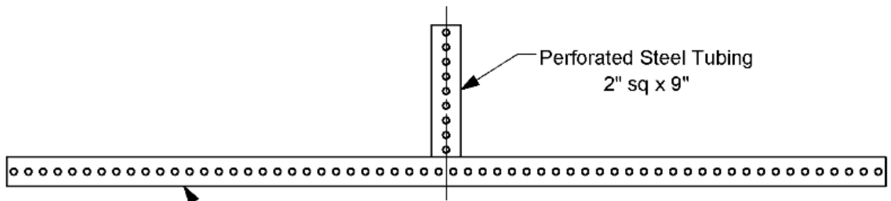


Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground
Project #618901-01-2	
Drawn by GES	Sheet 1 of 1 Impact

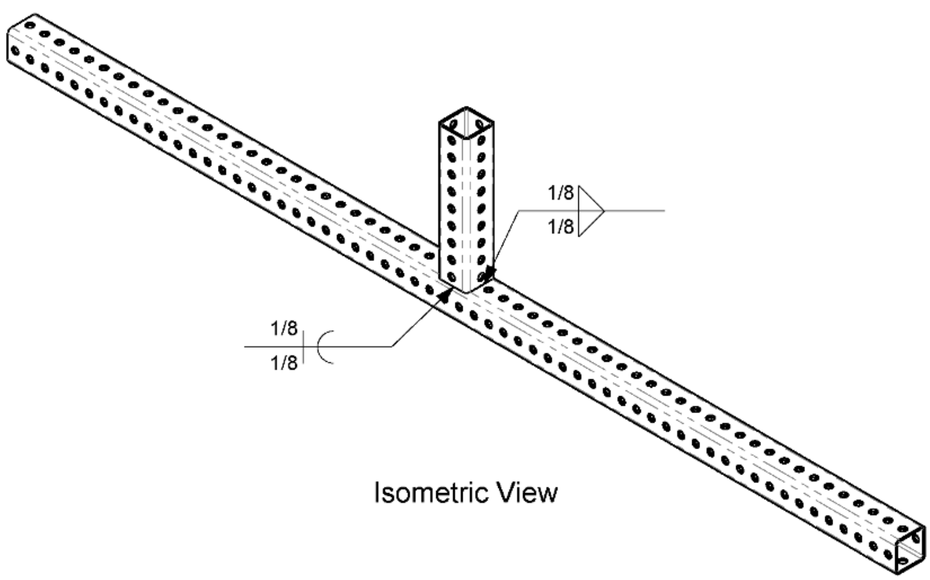
S:\Accreditation-17025-2017\EIR-000 Project Files\618901-Portable Sign Supports for Al. Signs-Kovar\618901-01-2 Tall Sign\Drafting, 618901-01-2\618901-01-2 Impacts and Summaries


Test Installation
Washer, 3/8 Nylon
Washer, 3/8 F844
Bolt, 3/8 x 2 1/2" hex
Washer, 3/8 F844
Nut, 3/8 hex
Detail A
Scale 1 : 5
A
21"
Diamond Shape Sign
48"sq x 0.1000 Aluminum
(±65-1/2" tall)
Isometric View
84-1/2" +0, -1"
Perforated Steel Tubing
1 3/4" x 130"
(x 2)
61-1/2"
Bolt, 3/8 x 4 1/2" hex
with Hex Nut and two
F844 Washers
Typ 6 places
These dimensions ±1/2" unless otherwise indicated.
Perforated Steel Tubing
1 3/4" x 53"
(x 2)
Perforated Steel Tubing
1 3/4" x 33"
20-1/2"
17-1/2"
T-Skid (x 2)
5-1/2"
0"
32"
Bolt, 3/8 x 3" hex with Hex Nut
and two F844 Washers
40lb. Sandbag x 4
(not shown in front view for clarity)
Elevation Views
1a. Nuts, Bolts, and Washers are zinc coated. All other steel parts shall be galvanized.
1b. Hex bolts are grade 5. Perforated tubing is 12 gauge.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #618901-01-2 Tall Skid Sign
2023-12-04
Drawn by GES
Scale 1:20
Sheet 1 of 2 / Test Installation
S:\Accreditation-17025-2017\EIR-000 Project Files\618901-Portable Sign Supports for Al. Signs-Kovar\618901-01-2 Tall Sign\Drafting, 618901-01-2\618901-01-2 Drawing

T-skid



Elevation View

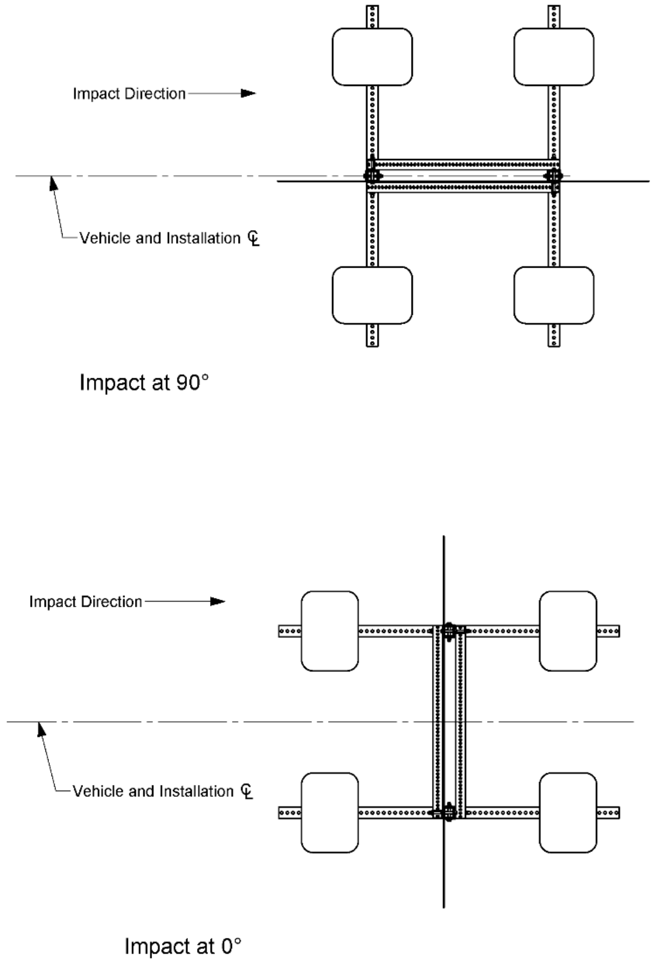


Isometric View

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #618901-01-2 Tall Skid Sign		2023-12-04
Drawn by GES	Scale 1:10	Sheet 2 of 2 / T-skid

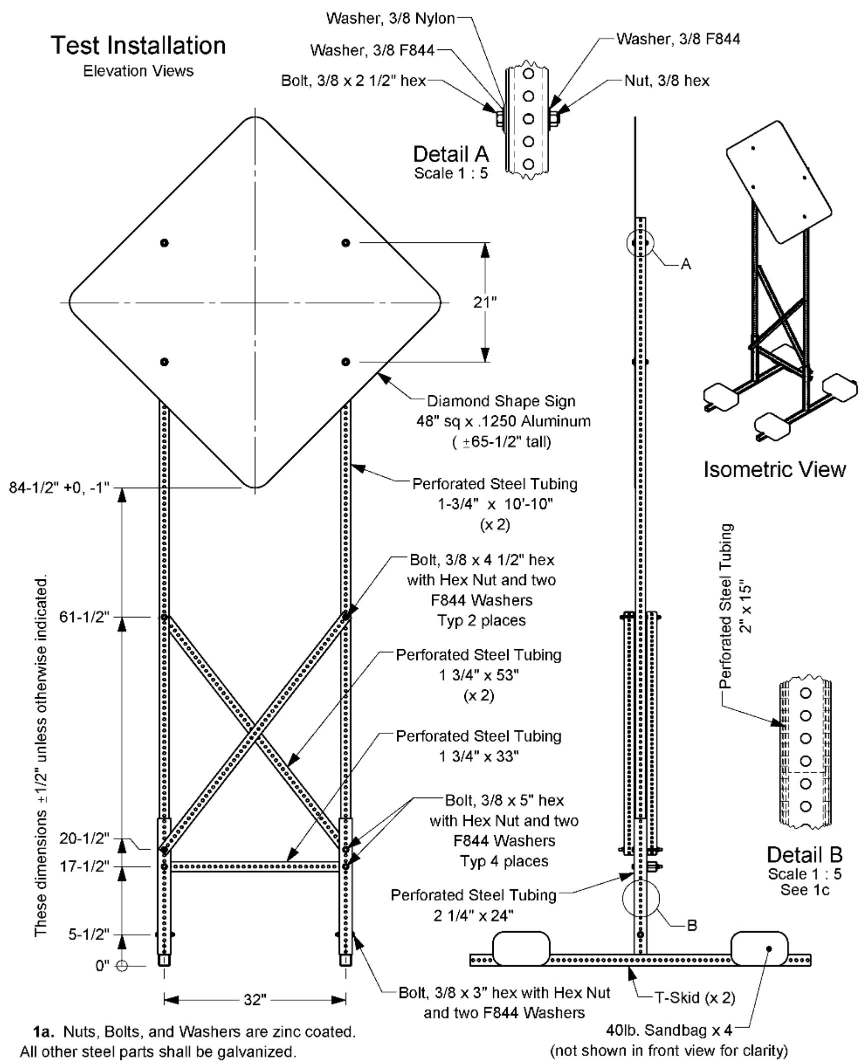
S:\Accreditation-17025-2017\EIR-000 Project Files\618901-Portable Sign Supports for Al. Signs-Kovar\618901-01-2 Tall Sign\Drafting, 618901-01-2 Drawing

APPENDIX B. DETAILS OF TALL SIGN SUPPORTS FOR ALUMINUM SIGNS FOR TESTS 618901-02-4 – 6



Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #618901-01-2 Project Name		0000-00-00
Drawn by GES	Scale 1:20	Sheet 1 of 1 / Impact

S:\Accreditation-17025-2017\EIR-000 Project Files\618901-Portable Sign Supports for Al. Signs-Kovar\618901-01-2 Tall Sign\Drafting, 618901-01-2 (4)\618901-01-2 Impacts and Summaries (4)



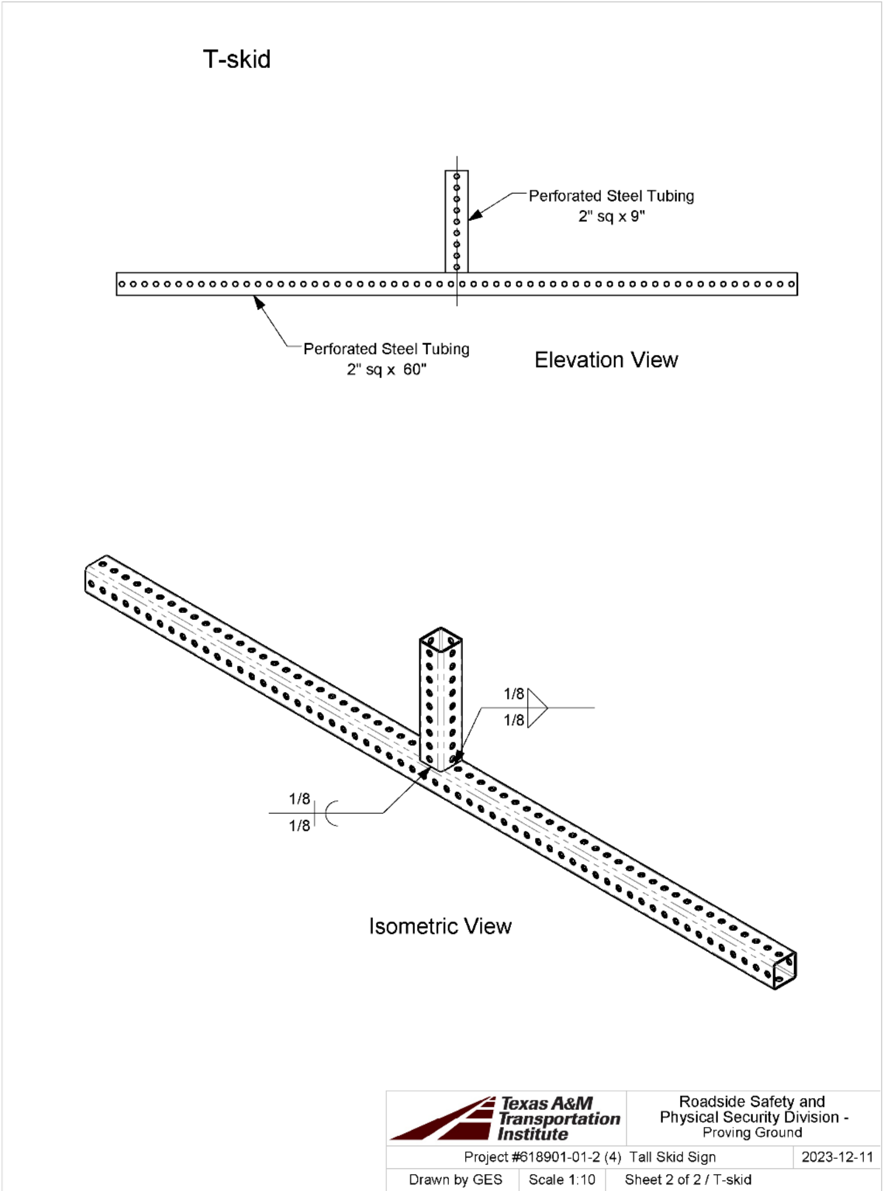
1a. Nuts, Bolts, and Washers are zinc coated. All other steel parts shall be galvanized.

1b. Hex bolts are grade 5. Perforated tubing is 12 gauge.

1c. 2" x 15" Unistrut rests on Stub from T-skid. 2-1/4" x 24" Unistrut goes over Stub and 2" x 15" Unistrut.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #618901-01-2 (4) Tall Skid Sign		2023-12-11
Drawn by GES	Scale 1:20	Sheet 1 of 2 / Test Installation

S:\Accreditation-17025-2017\EIR-000 Project Files\618901-Portable Sign Supports for Al. Signs-Kovar\618901-01-2 Tall Sign\Drafting, 618901-01-2 (4)\618901-01-2 Drawing (4)



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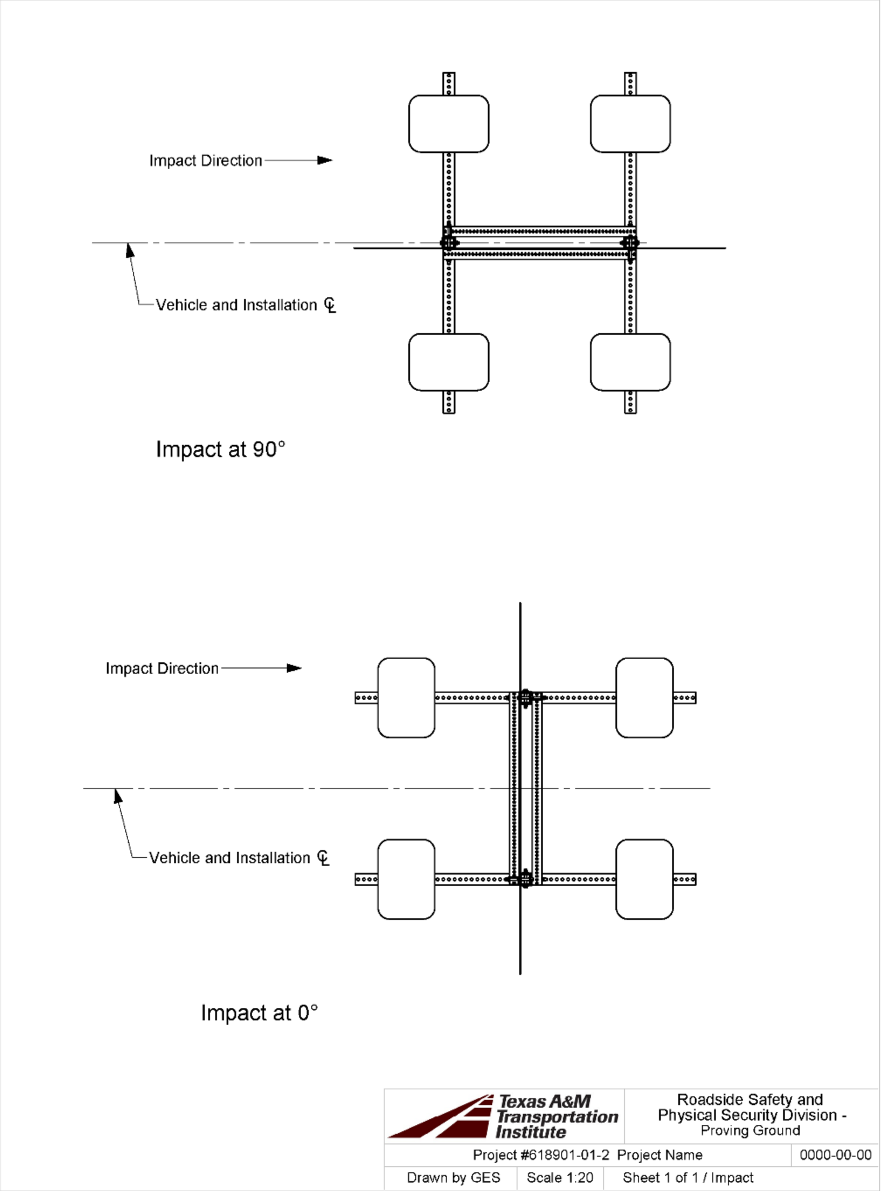
APPENDIX C. DETAILS OF TALL SIGN SUPPORTS FOR ALUMINUM SIGNS FOR TEST 618901-02-7



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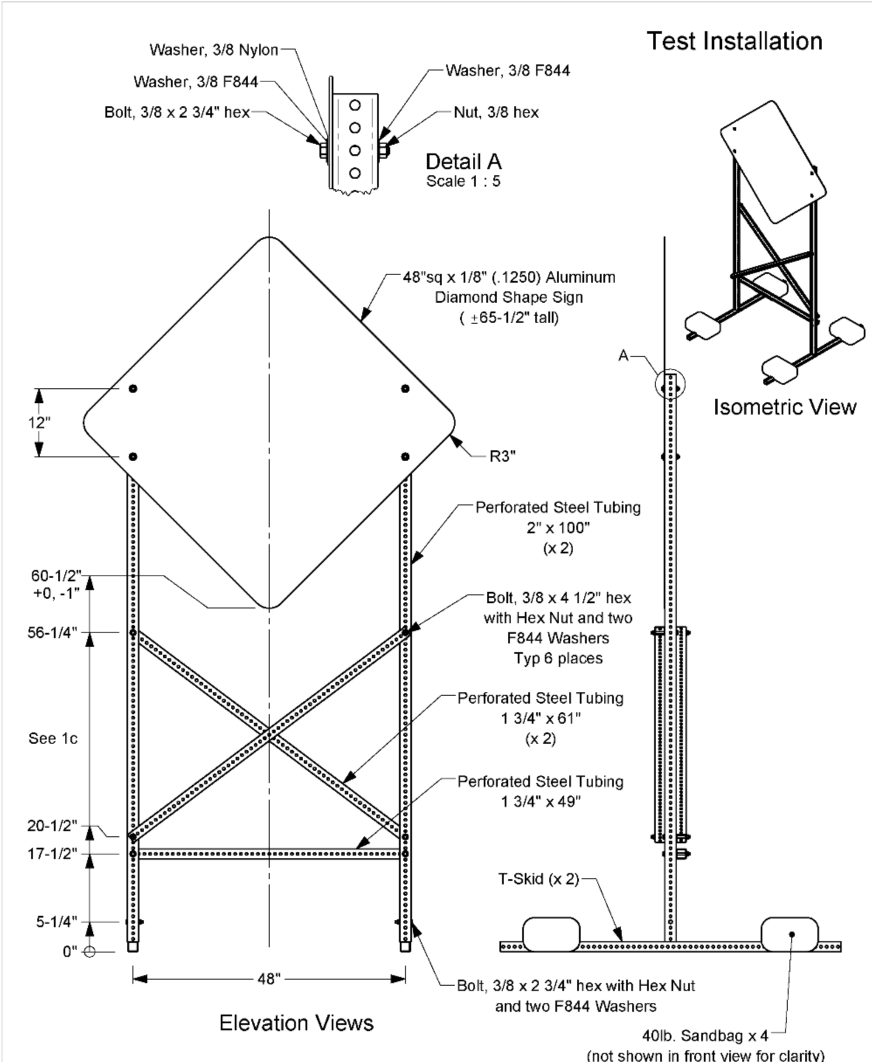


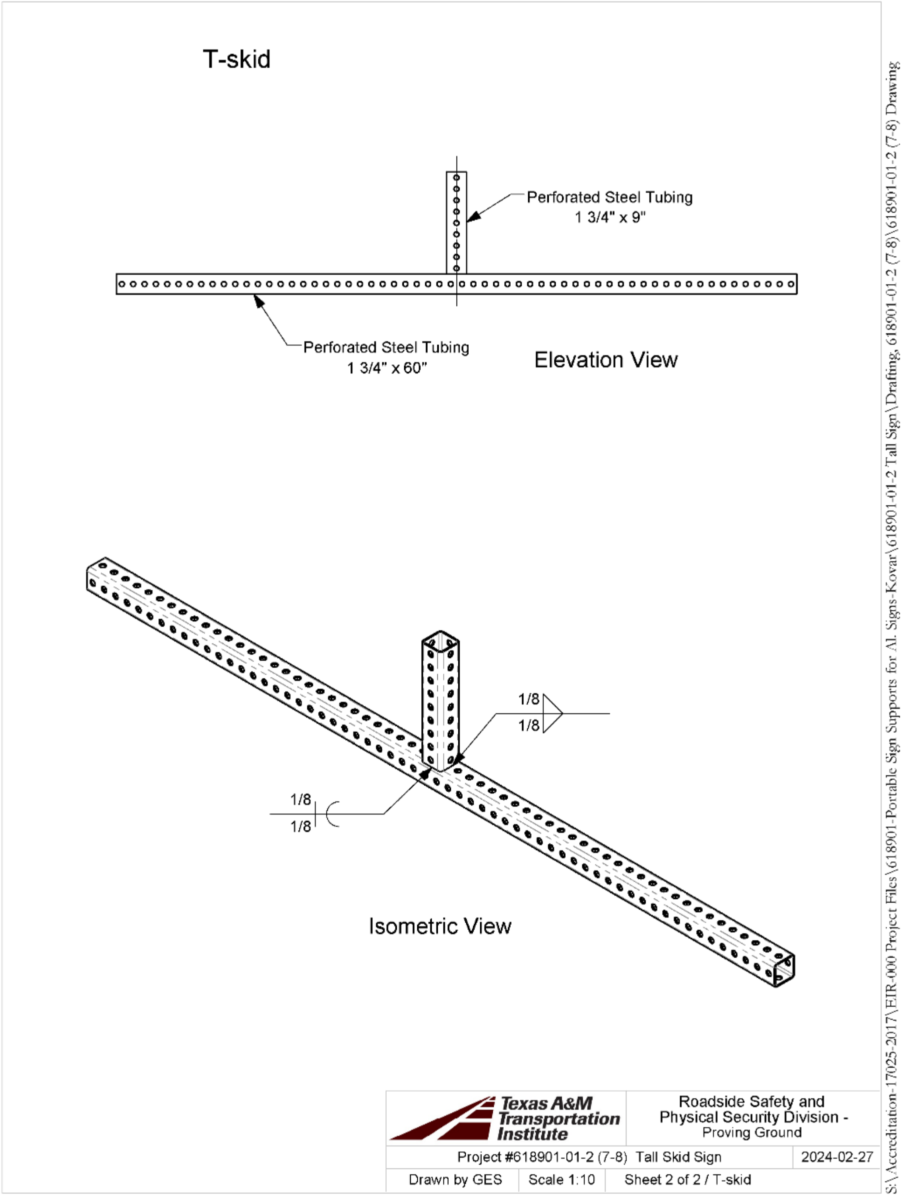
1a. Nuts, Bolts, and Washers are zinc coated. All other steel parts shall be galvanized.

1b. Hex bolts are grade 5. Perforated tubing is 12 gauge.

1c. All height dimensions ±1/2" unless otherwise indicated.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #618901-01-2 (7-8) Tall Skid Sign		2024-02-27
Drawn by GES	Scale 1:20	Sheet 1 of 2 / Test Installation

S:\Accreditation-17025-2017\EIR-000 Project Files\618901-Portable Sign Supports for Al. Signs-Kovar\618901-01-2 Tall Sign\Drafting, 618901-01-2 (7-8)\618901-01-2 (7-8) Drawing


T-skid
Perforated Steel Tubing
1 3/4" x 9"
Perforated Steel Tubing
1 3/4" x 60"
Elevation View
1/8
1/8
1/8
1/8
Isometric View
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #618901-01-2 (7-8) Tall Skid Sign
2024-02-27
Drawn by GES
Scale 1:10
Sheet 2 of 2 / T-skid
S:\Accreditation-17025-2017\EIR-000 Project Files\618901-Portable Sign Supports for Al. Signs-Kovar\618901-01-2 Tall Sign\Drafting, 618901-01-2 (7-8)\618901-01-2 (7-8) Drawing

APPENDIX D. SUPPORTING CERTIFICATION DOCUMENTS

Triple S

CERTIFICATE OF ANALYSIS

Beshert STEEL PROCESSING

Cert Number 67791-11 7/3/2023
Test Reference 88297

July 11, 2023

TRIPLE-S STEEL SUPPLY CO.
6000 JENSEN DRIVE
HOUSTON, TX 77026

Issued from
BESHERT STEEL PROCESSING
JOINT VENTURE OF
STEEL WAREHOUSE CO. &
TRIPLE-S STEEL HOLDINGS INC.
15355 JACINTO PORT BOULEVARD
HOUSTON, TX 77015

Sold To: TRIPLE-S STEEL SUPPLY CO., 6000 JENSEN DRIVE, HOUSTON, TX 77026
Ship To: DALLAS/FORT WORTH - PRIME STOCK, 3000 BRASWELL DRIVE, FORT WORTH, TX 76111

Reference

Customer 100200/4 Your Order TXN-11391 (5/30/2023)
Our Order 32688-6-1 Packing List 67791-1 (7/3/2023)

Product Information

HOT ROLLED PLATE A36/SA36
0.2500" x 60" x 120"
Part PL36TML1460
Conform To ASTM-A36-.246-.258 7/1/2019

Heat 2A5263 | Tag 38442E | Pcs 10 | LBS 5,107

C.E.: 0.2444 D.I.: 0

Chemical Composition

C	Mn	Si	P	S	Cr	Ni	Mo
0.148	0.553	0.014	0.013	0.009	0.018	0.005	0.00
Cu	Al	N	V	Ti	Cb	CbV	B
0.004	0.042	0.0046	0.00	0.001	0.00	0.00	0.0006
Sn							
0.002							

Physical Tests

YIELD - H (T)	TENSILE - H (T)	ELONGATION - H (T)	YIELD - M (T)
47.1 KSI	59.1 KSI	30.3 %	46.2 KSI
TENSILE - M (T)	ELONGATION - M (T)		
60.6 KSI	31.2 %		

PRODUCT OF COIL
COUNTRY OF ORIGIN: BRAZIL

PO# 616401
Item #1

A36 Plate
1/4 x 60 x 120

7/3/2023 01:25 PM 1

APPENDIX E. *MASH* TEST 3-71 (CRASH TEST 618901-01-2-1)

E.1. VEHICLE PROPERTIES AND INFORMATION

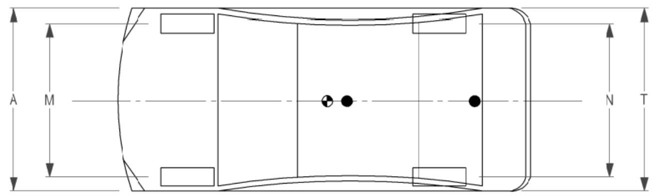
Date: 2023-12-07 Test No.: 618901-01-2-1 VIN No.: 3N1CN7AP3HK447710

Year: 2017 Make: Nissan Model: Versa

Tire Inflation Pressure: 36 PSI Odometer: 153117 Tire Size: P185/65R15

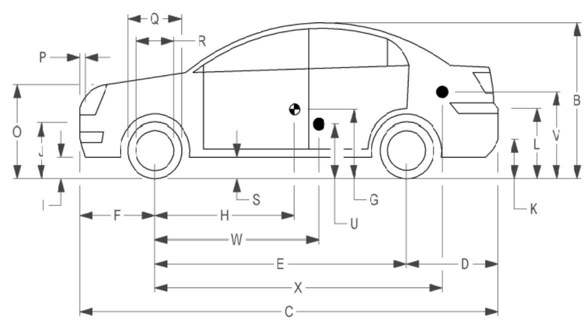
Describe any damage to the vehicle prior to test: None

● 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: OPPOSITE 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	41.70	M	58.30	R	16.25	W	0.00
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 -41.70

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}	1440	1451	1536
Back	1687	M_{rear}	953	999	1079
Total	3389	M_{Total}	2393	2450	2615

Allowable TIM = 2420 lb ±55 lb | Allowable GSM = 2585 lb ± 55 lb

Mass Distribution:
lb LF: 770 RF: 681 LR: 480 RR: 519

Figure E.1. Vehicle Properties for Test 618901-01-2-1.

Date:	2023-12-07	Test No.:	618901-01-2-1	VIN No.:	3N1CN7AP3HK447710
Year:	2017	Make:	Nissan	Model:	Versa

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		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
-	-	-	-	-	-	-	-	-	-	-	-
	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.

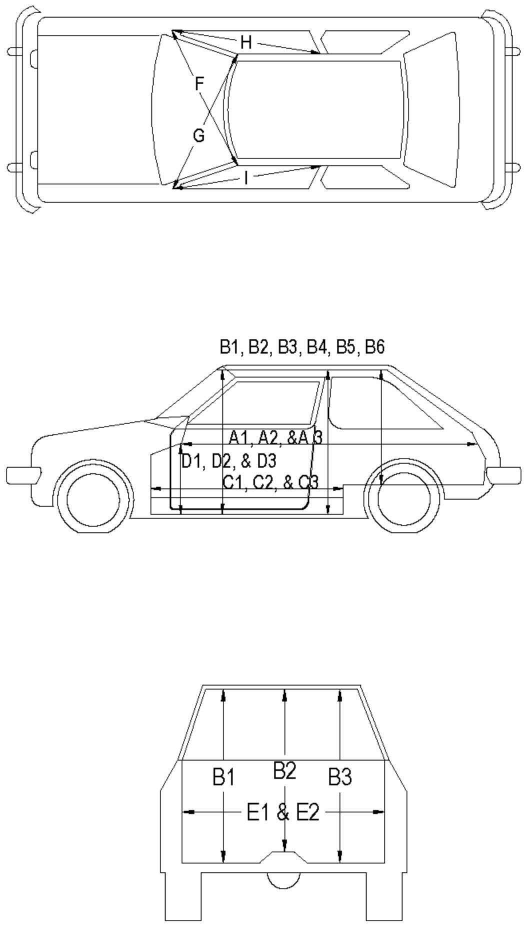
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***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 618901-01-2-1.

Date:	2023-12-07	Test No.:	618901-01-2-1	VIN No.:	3N1CN7AP3HK447710
Year:	2017	Make:	Nissan	Model:	Versa



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	38.00	-2.50
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	51.50	0.00
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	51.00	0.00

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

Figure E.3. Occupant Compartment Measurements for Test 618901-01-2-1.

E.2. SEQUENTIAL PHOTOGRAPHS

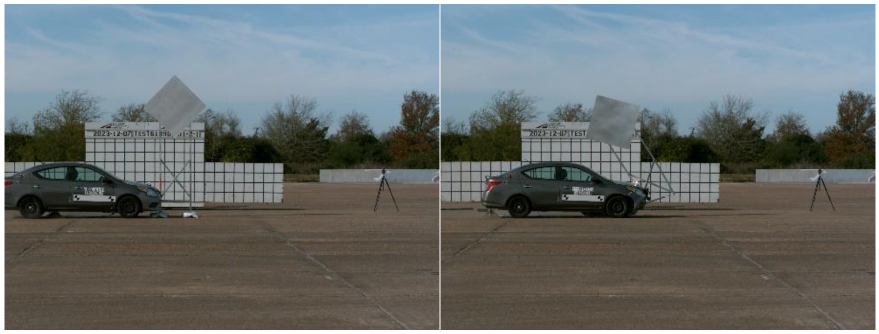

(a) 0.000 s (b) 0.100 s


(c) 0.200 s (d) 0.300 s

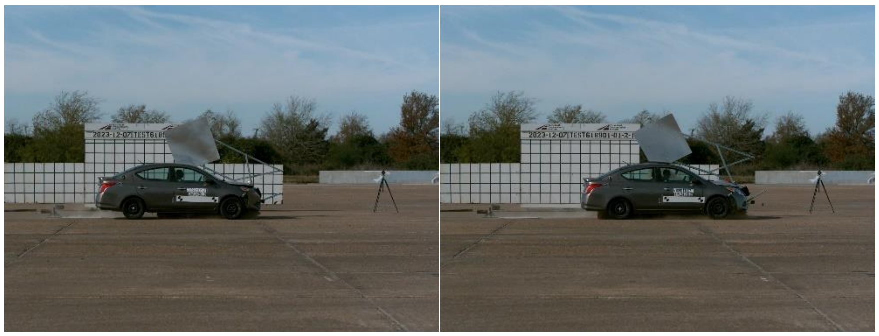

(e) 0.400 s (f) 0.500 s


(g) 0.600 s (h) 0.700 s

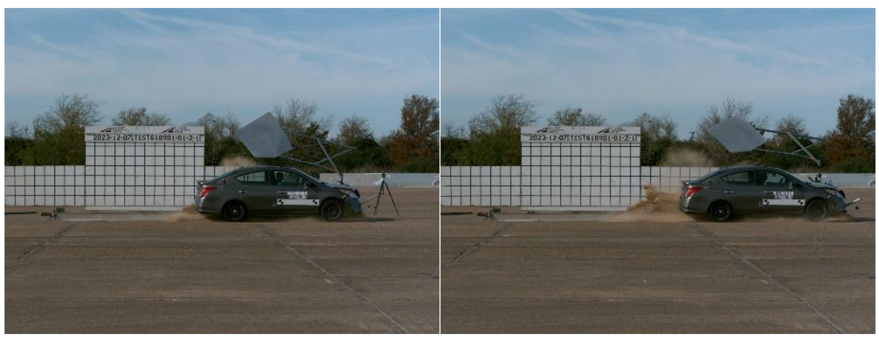
Figure E.5. Sequential Photographs for Test 618901-01-2-1 (Oblique Views).



(a) 0.000 s (b) 0.100 s



(c) 0.200 s (d) 0.300 s



(e) 0.400 s (f) 0.500 s

(g) 0.600 s (h) 0.700 s

Figure E.6. Sequential Photographs for Test 618901-01-2-1 (Right Angle Views).

APPENDIX F. *MASH* TEST 3-71 (CRASH TEST 618901-01-2-2)

F.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2023-12-07 Test No.: 618901-01-2-2 VIN No.: 3M1CN7AP3HL827396

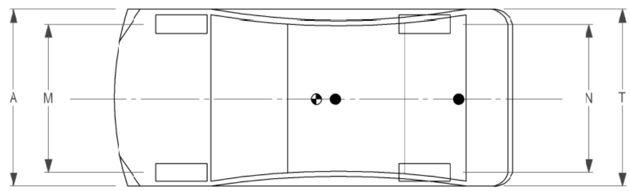
Year: 2017 Make: Nissan Model: Versa

Tire Inflation Pressure: 36 PSI Odometer: 145961 Tire Size: P185/65R15

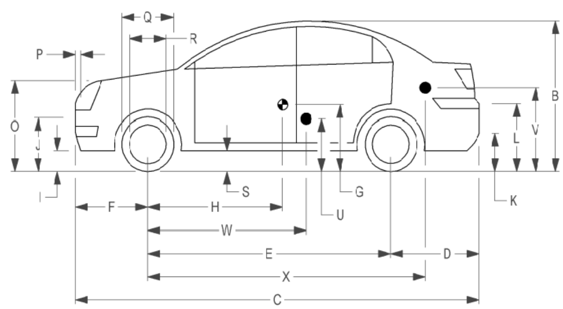
Describe any damage to the vehicle prior to test: None

● 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: OPPOSITE 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	42.70	M	58.30	R	16.25	W	0.00
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 -42.70

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}	1375	1427	1512
Back	1687	M_{rear}	980	1021	1101
Total	3389	M_{Total}	2355	2448	2613

Allowable TIM = 2420 lb ±55 lb | Allowable GSM = 2585 lb ± 55 lb

Mass Distribution:
lb LF: 740 RF: 687 LR: 483 RR: 538

Figure F.1. Vehicle Properties for Test 618901-01-2-2.

Date:	2023-12-07	Test No.:	618901-01-2-2	VIN No.:	3N1CN7AP3HL827396
Year:	2017	Make:	Nissan	Model:	Versa

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		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
-	-	-	-	-	-	-	-	-	-	-	-
	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.

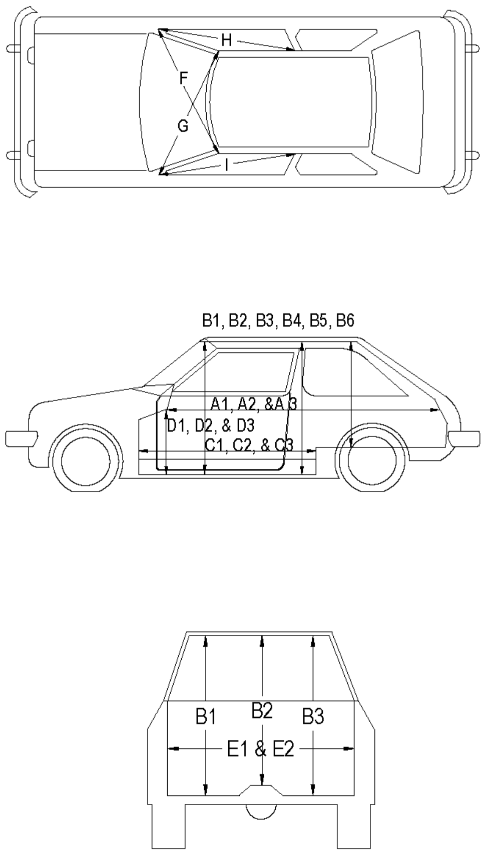
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***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 618901-01-2-2.

Date:	2023-12-07	Test No.:	618901-01-2-2	VIN No.:	3N1CN7AP3HL827396
Year:	2017	Make:	Nissan	Model:	Versa



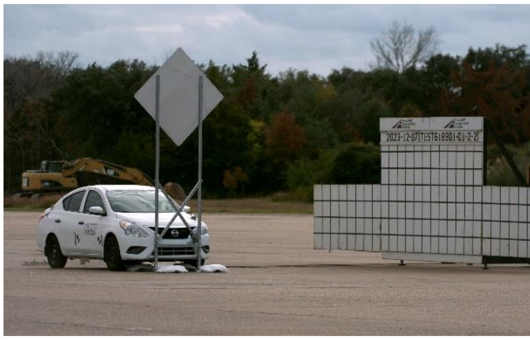
OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	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	40.25	-0.25
B2	39.00	39.00	0.00
B3	40.50	38.75	-1.75
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	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	51.50	0.00
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	51.00	0.00

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

Figure F.3. Occupant Compartment Measurements for Test 618901-01-2-2.

F.2. SEQUENTIAL PHOTOGRAPHS


(a) 0.000 s


(b) 0.100 s


(c) 0.200 s


(d) 0.300 s


(e) 0.400 s


(f) 0.500 s


(g) 0.600 s


(h) 0.700 s

Figure F.5. Sequential Photographs for Test 618901-01-2-2 (Oblique Views).


(a) 0.000 s


(b) 0.100 s


(c) 0.200 s


(d) 0.300 s


(e) 0.400 s


(f) 0.500 s


(g) 0.600 s

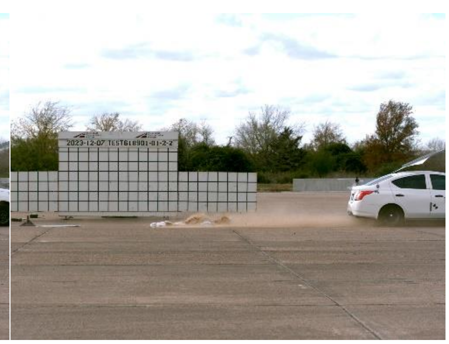

(h) 0.700 s

Figure F.6. Sequential Photographs for Test 618901-01-2-2 (Rear Views).

APPENDIX G. *MASH* TEST 3-72 (CRASH TEST 618901-01-2-3)

G.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2023-12-08 Test No.: 618901-01-2-3 VIN No.: 1C6RR6FT9JS183171

Year: 2018 Make: RAM Model: 1500

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

Tread Type: Highway Odometer: 80130

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

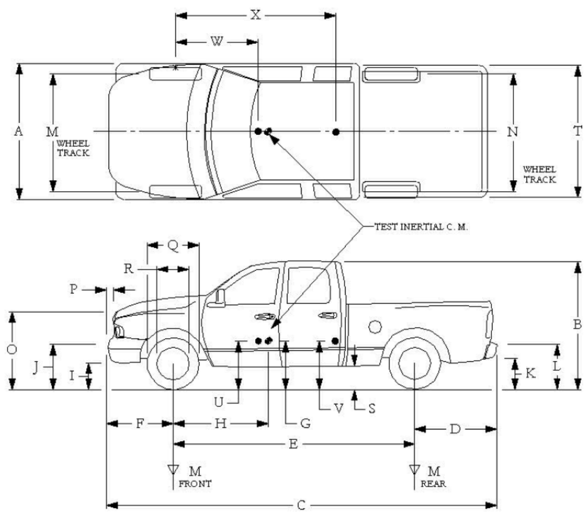
NOTES: None

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	40.00	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	227.50	H	61.36	M	68.50	R	18.00	W	0.00
D	44.00	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}	2931	2819	
Back	3900	M_{rear}	2052	2186	
Total	6700	M_{Total}	4983	5005	5005

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

Mass Distribution:
lb LF: 1402 RF: 1417 LR: 1109 RR: 1077

Figure G.1. Vehicle Properties for Test 618901-01-2-3.

Vehicle Inventory Number: 1766

Date: 2023-12-08 Test No.: 618901-01-2-3 VIN No.: 1C6RR6FT9JS183171

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		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
1	AT FRONT BUMPER	16	2.5	3	-	-	-	-	-	-	-13
	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.

Figure G.2. Exterior Crush Measurements for Test 618901-01-2-3.

G.2. SEQUENTIAL PHOTOGRAPHS

(a) 0.000 s

(b) 0.100 s

(c) 0.200 s

(d) 0.300 s

(e) 0.400 s

(f) 0.500 s

(g) 0.600 s

(h) 0.700 s

Figure G.3. Sequential Photographs for Test 618901-01-2-3 (Oblique Views).


(a) 0.000 s (b) 0.100 s


(c) 0.200 s (d) 0.300 s


(e) 0.400 s (f) 0.500 s


(g) 0.600 s (h) 0.700 s

Figure G.4. Sequential Photographs for Test 618901-01-2-3 (Rear Views).

APPENDIX H. *MASH* TEST 3-72 (CRASH TEST 618901-01-2-4)

H.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2023-12-12 Test No.: 618901-01-2-4 VIN No.: 1C6RR6FTXKS723757

Year: 2019 Make: RAM Model: 1500

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

Tread Type: Highway Odometer: 73379

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

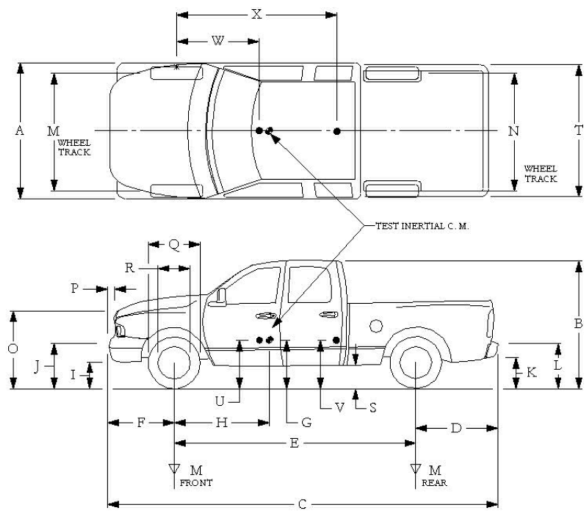
NOTES: None

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	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.25	L	30.00	Q	30.50	V	30.25
C	227.50	H	61.08	M	68.50	R	18.00	W	0.00
D	44.00	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}	2939	2842	
Back	3900	M_{rear}	2045	2186	
Total	6700	M_{Total}	4984	5028	5028

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

Mass Distribution:
lb LF: 1415 RF: 1427 LR: 1115 RR: 1071

Figure H.1. Vehicle Properties for Test 618901-01-2-4.

Date:	2023-12-12	Test No.:	618901-01-2-4	VIN No.:	1C6RR6FTXKS723757
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	17	3	6	-	-	-	-	-	-	+8
	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.

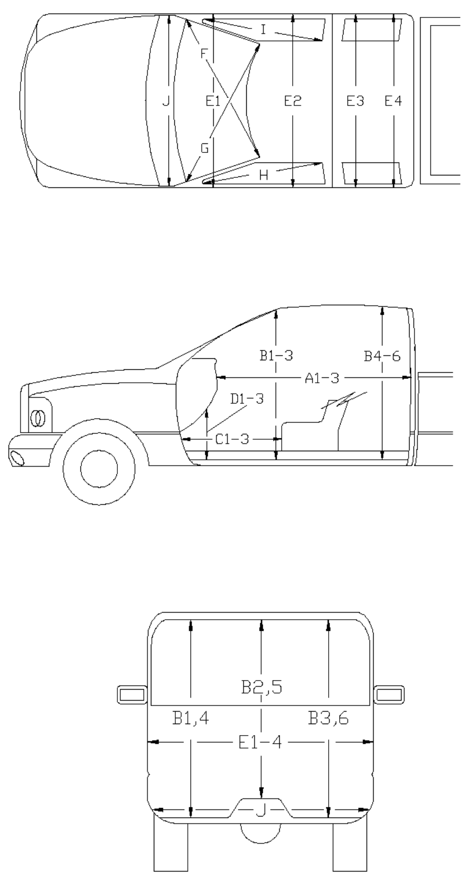
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***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 618901-01-2-4.

Date:	2023-12-12	Test No.:	618901-01-2-4	VIN No.:	1C6RR6FTXKS723757
Year:	2019	Make:	RAM	Model:	1500



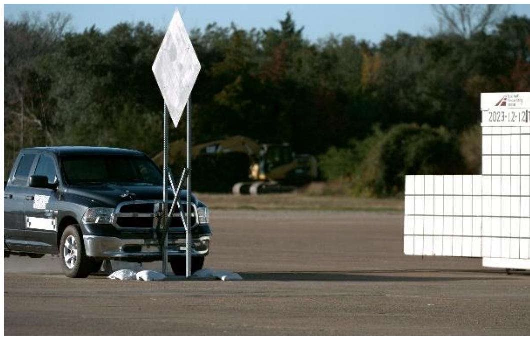
*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

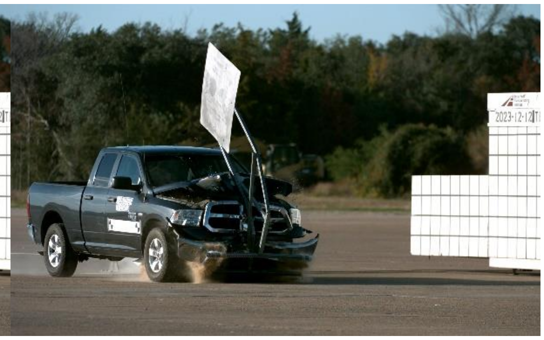
	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	44.50	-0.50
B2	38.00	38.00	0.00
B3	45.00	44.50	-0.50
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	58.50	0.00
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	25.00	0.00

Figure H.3. Occupant Compartment Measurements for Test 618901-01-2-4.

H.2. SEQUENTIAL PHOTOGRAPHS



(a) 0.000 s



(b) 0.100 s

(c) 0.200 s

(d) 0.300 s

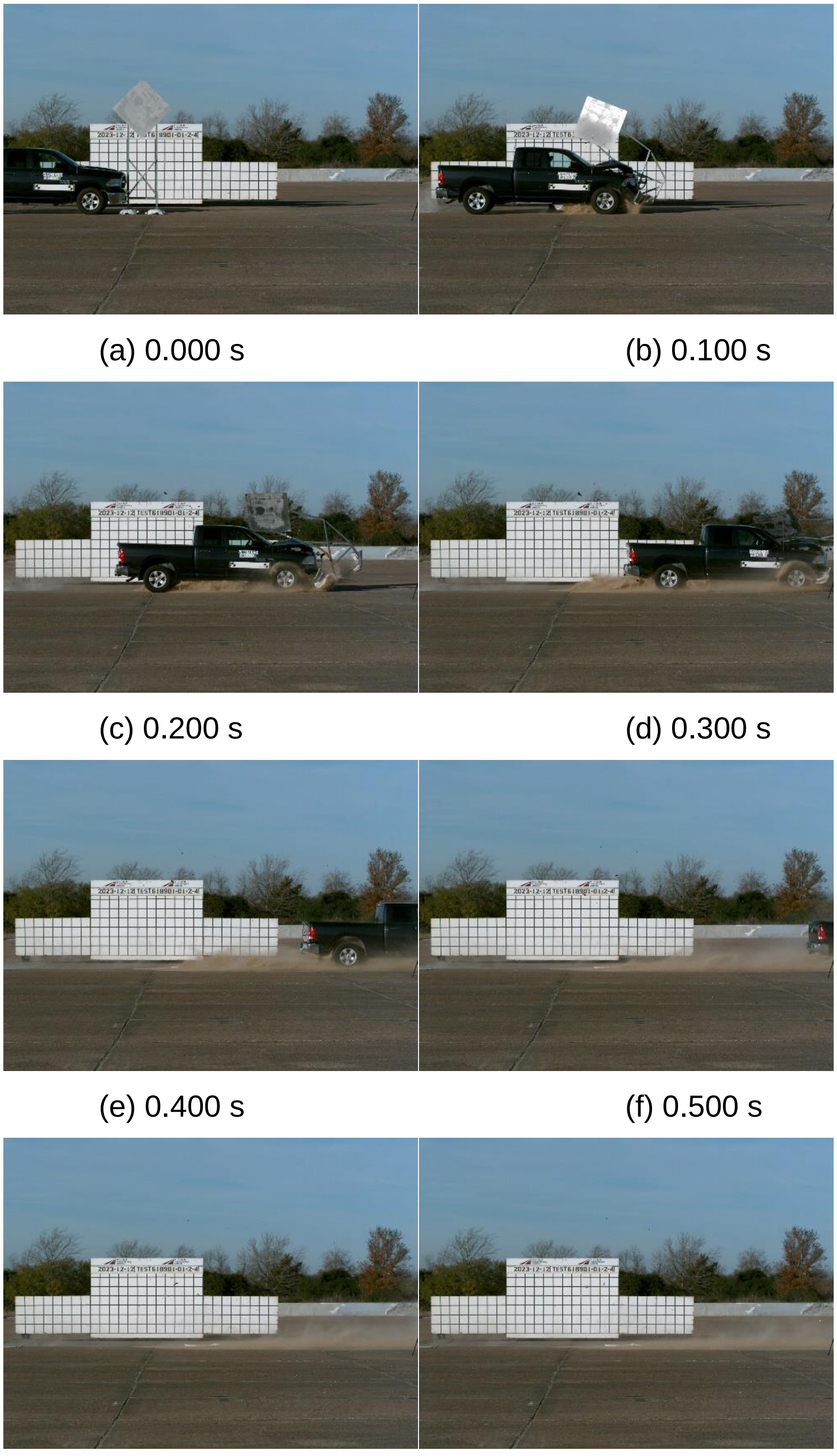
(e) 0.400 s

(f) 0.500 s

(g) 0.600 s

(h) 0.700 s

Figure H.5. Sequential Photographs for Test 618901-01-2-4 (Oblique Views).



(a) 0.000 s (b) 0.100 s

(c) 0.200 s (d) 0.300 s

(e) 0.400 s (f) 0.500 s

(g) 0.600 s (h) 0.700 s

Figure H.6. Sequential Photographs for Test 618901-01-2-4 (Rear Views).

APPENDIX I. *MASH* TEST 3-72 (CRASH TEST 618901-01-2-5)

I.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2023-12-12 Test No.: 618901-01-2-5 VIN No.: 1C6RR6FT2JS330656

Year: 2018 Make: RAM Model: 1500

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

Tread Type: Highway Odometer: 170707

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

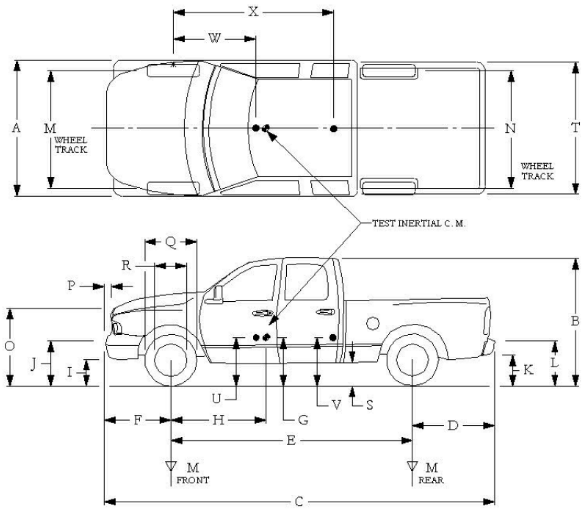
NOTES: None

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	40.00	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	227.50	H	61.27	M	68.50	R	18.00	W	0.00
D	44.00	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}	2934	2833	
Back	3900	M_{rear}	2073	2191	
Total	6700	M_{Total}	5007	5024	5024

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

Mass Distribution:
lb LF: 1416 RF: 1417 LR: 1127 RR: 1064

Figure I.1. Vehicle Properties for Test 618901-01-2-5.

Date:	2023-12-12	Test No.:	618901-01-2-5	VIN No.:	1C6RR6FT2JS330656
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	17	11	4	-	-	-	-	-	-	0
	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.

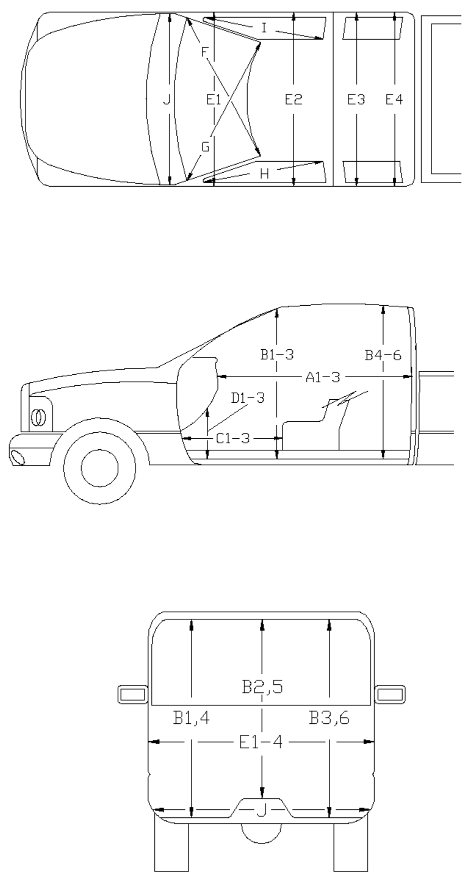
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***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 I.2. Exterior Crush Measurements for Test 618901-01-2-5.

Date:	2023-12-12	Test No.:	618901-01-2-5	VIN No.:	1C6RR6FT2JS330656
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	26.00	0.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	58.50	0.00
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	25.00	0.00

Figure I.3. Occupant Compartment Measurements for Test 618901-01-2-5.

I.2. SEQUENTIAL PHOTOGRAPHS


(a) 0.000 s


(b) 0.100 s


(c) 0.200 s


(d) 0.300 s


(e) 0.400 s


(f) 0.500 s


(g) 0.600 s


(h) 0.700 s

Figure I.5. Sequential Photographs for Test 618901-01-2-5 (Oblique Views).

(a) 0.000 s (b) 0.100 s

(c) 0.200 s (d) 0.300 s

(e) 0.400 s (f) 0.500 s

(g) 0.600 s (h) 0.700 s

Figure I.6. Sequential Photographs for Test 618901-01-2-5 (Rear Views).

APPENDIX J. *MASH* TEST 3-71 (CRASH TEST 618901-01-2-6)

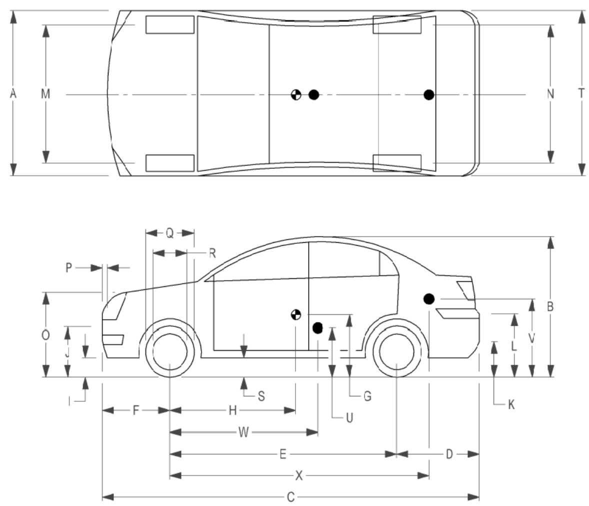
J.1. VEHICLE PROPERTIES AND INFORMATION

Date:	2023-12-12	Test No.:	618901-01-2-6	VIN No.:	3N1CN7AP8HL857218
Year:	2017	Make:	Nissan	Model:	Versa
Tire Inflation Pressure:	36 PSI	Odometer:	179633	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: PASSENGER

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	41.50	M	58.30	R	16.25	W	0.00
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 -41.50

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}	1437	1459	1544
Back	1687	M_{rear}	1004	994	1074
Total	3389	M_{Total}	2441	2453	2618

Allowable TIM = 2420 lb ±55 lb | Allowable GSM = 2585 lb ± 55 lb

Mass Distribution:
lb LF: 755 RF: 704 LR: 492 RR: 502

Figure J.1. Vehicle Properties for Test 618901-01-2-6.

Date:	2023-12-12	Test No.:	618901-01-2-6	VIN No.:	3N1CN7AP8HL857218
Year:	2017	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	18	11.5	6	-	-	-	-	-	-	0
2	AT HOOD	30.5	5	9.5	-	-	-	-	-	-	0
	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.

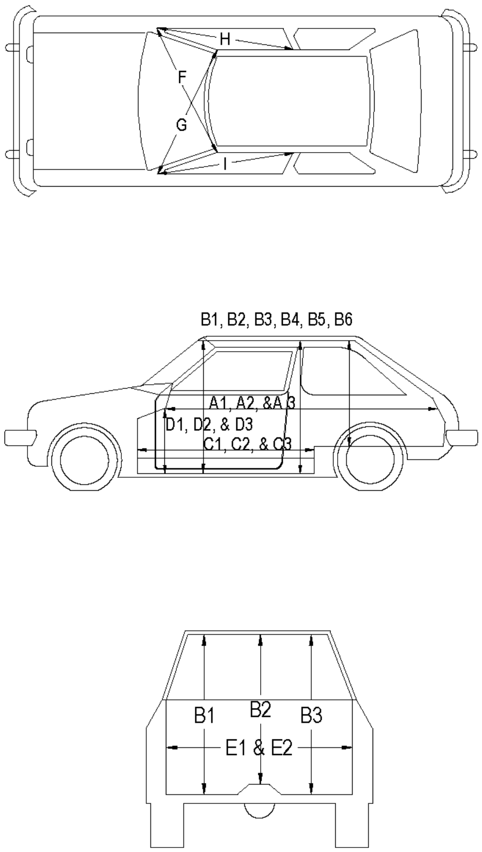
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***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 J.2. Exterior Crush Measurements for Test 618901-01-2-6.

Date:	2023-12-12	Test No.:	618901-01-2-6	VIN No.:	3N1CN7AP8HL857218
Year:	2017	Make:	Nissan	Model:	Versa



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	37.00	-2.00
B3	40.50	39.75	-0.75
B4	36.25	35.75	-0.50
B5	36.00	33.25	-2.75
B6	36.25	35.75	-0.50
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	51.50	0.00
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	51.00	0.00

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

Figure J.3. Occupant Compartment Measurements for Test 618901-01-2-6.

J.2. SEQUENTIAL PHOTOGRAPHS

(a) 0.000 s

(b) 0.100 s

(c) 0.200 s

(d) 0.300 s

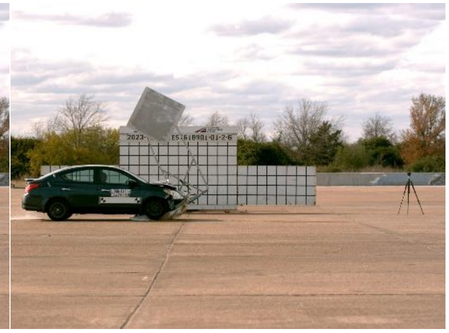
(e) 0.400 s

(f) 0.500 s

(g) 0.600 s

(h) 0.700 s

Figure J.5. Sequential Photographs for Test 618901-01-2-6 (Oblique Views).

(a) 0.000 s (b) 0.100 s


(c) 0.200 s (d) 0.300 s


(e) 0.400 s (f) 0.500 s


(g) 0.600 s (h) 0.700 s

Figure J.6. Sequential Photographs for Test 618901-01-2-6 (Rear Views).

APPENDIX K. *MASH* TEST 3-71 (CRASH TEST 618901-01-2-7)

K.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2024-03-12 Test No.: 618901-01-2-7 VIN No.: 3N1C7AP0KL842851

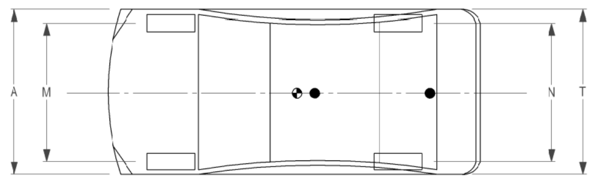
Year: 2019 Make: Nissan Model: Versa

Tire Inflation Pressure: 36 PSI Odometer: 77708 Tire Size: P185/65R15

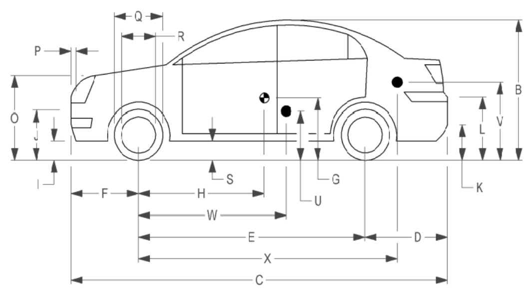
Describe any damage to the vehicle prior to test: None

● 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: PASSENGER 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	41.99	M	58.30	R	16.25	W	42.00
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 0.01

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}	1424	1440	1525
Back	1687	M_{rear}	979	1001	1081
Total	3389	M_{Total}	2403	2441	2606

Allowable TIM = 2420 lb ±55 lb | Allowable GSM = 2585 lb ± 55 lb

Mass Distribution:
lb LF: 754 RF: 686 LR: 498 RR: 503

Figure K.1. Vehicle Properties for Test 618901-01-2-7.

Date:	2024-03-12	Test No.:	618901-01-2-7	VIN No.:	3N1C7AP0KL842851
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	18	12	26	-	-	-	-	-	-	0
2	AT HOOD	31	8	2.5	-	-	-	-	-	-	0
	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.

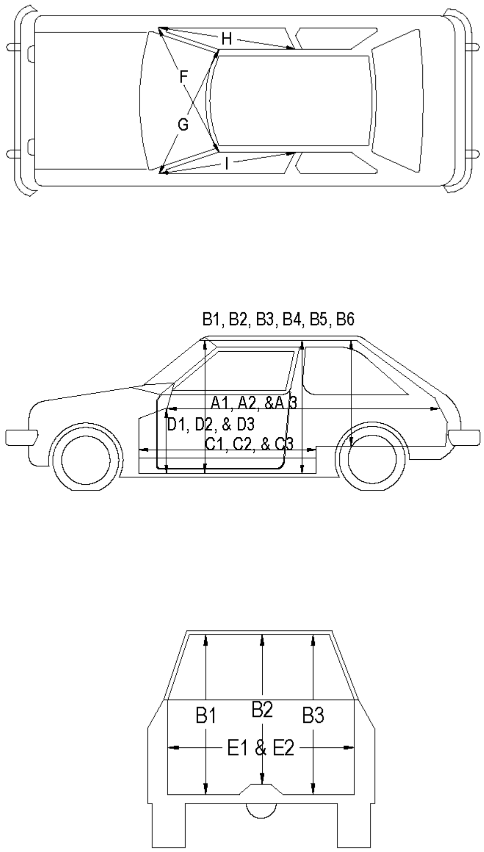
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***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 K.2. Exterior Crush Measurements for Test 618901-01-2-7.

Date:	2024-03-12	Test No.:	618901-01-2-7	VIN No.:	3N1C7AP0KL842851
Year:	2019	Make:	Nissan	Model:	Versa



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	51.50	0.00
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	51.00	0.00

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

Figure K.3. Occupant Compartment Measurements for Test 618901-01-2-7.

K.2. SEQUENTIAL PHOTOGRAPHS

(a) 0.000 s

(b) 0.100 s

(c) 0.200 s

(d) 0.300 s

(e) 0.400 s

(f) 0.500 s

(g) 0.600 s

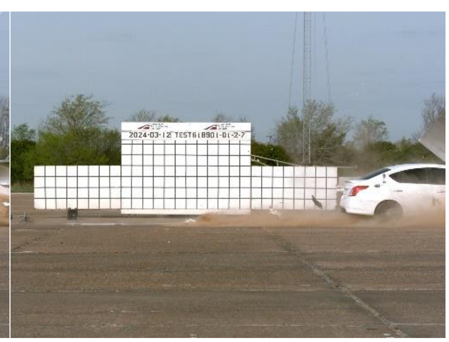
(h) 0.700 s

Figure K.5. Sequential Photographs for Test 618901-01-2-7 (Oblique Views).


(a) 0.000 s (b) 0.100 s


(c) 0.200 s (d) 0.300 s


(e) 0.400 s (f) 0.500 s

(g) 0.600 s (h) 0.700 s

Figure K.6. Sequential Photographs for Test 618901-01-2-7 (Rear Views).