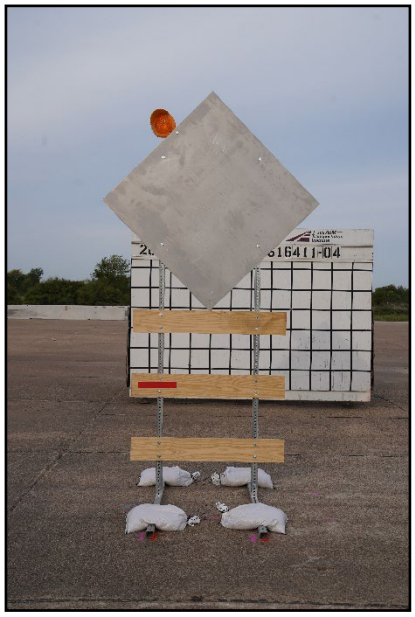
Texas A&M Transportation Institute

Proving Ground

Test Report No. 616411-01



EVALUATION OF TYPE III BARRICADES WITH MOUNTED SIGNS

Sponsored by

Roadside Safety Pooled Fund

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16. Abstract

The objective of this project was to develop a Type III barricade system with a mounted sign which successfully met American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware (MASH), Second Edition (1) criteria. The research team first reviewed relevant research and state standards to lay a foundation for the design effort. The research team subsequently developed a design for testing and evaluation according to MASH guidelines.

The purpose of the tests reported herein was to assess the performance of the Type III barricade with mounted sign according to the safety-performance evaluation guidelines for MASH Test Level 3 (TL-3). The Type III barricade with mounted sign successfully met the performance criteria. This report provides details on the Type III barricade with mounted sign, results of the MASH crash tests, performance assessments, and recommendations for implementation.

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EVALUATION OF TYPE III BARRICADES WITH MOUNTED SIGNS

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Report 616411-01
Contract No.: T4541-EL
Project Title: Evaluation of Type III Barricades with Mounted Signs

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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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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

The objective of this project was to develop a Type III barricade system with a mounted sign which successfully met American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*), Second Edition (*1*) criteria. The research team first reviewed relevant previous research and state standards to lay a foundation for the design effort. The research team subsequently developed a design for testing and evaluation according to *MASH* guidelines.

The purpose of the tests reported herein was to assess the performance of the Type III barricade with mounted sign according to the safety-performance evaluation guidelines included in *MASH*. The crash tests were performed in accordance with *MASH* Test Level 3 (TL-3), which requires four crash tests (as discussed in Chapter 3).

Chapter 2. LITERATURE REVIEW

2.1. OVERVIEW

This chapter documents the literature review performed in Phase 1 of this project. Relevant research regarding Type III barricades with mounted signs was evaluated. This includes Type III barricades of varying materials and sign shapes attached at ranging mounting heights. Tests included in the review were conducted according to *National Cooperative Highway Research Program (NCHRP) Report 350* (*2*) and *MASH* testing standards.

2.2. NCHRP REPORT 350 TESTING OF TXDOT WORK ZONE TRAFFIC CONTROL DEVICES

The objective of this project was to develop nonproprietary crashworthy work-zone traffic control devices, constructed of readily available materials. Four Type III barricades with attached signs were tested under *NCHRP Report 350* test 3-71 evaluation criteria. The first three barricades tested were made of perforated steel tubing while the fourth test was made of hollow-profile plastic lumber (HPPL). Both diamond and rectangular shaped signs were tested.

2.2.1. NCHRP Report 350 Test 1 of the Perforated Steel Type III Barricade with Diamond Sign Attachment

Test 1 evaluated a perforated square steel tubing (PSST) barricade with a diamond sign attachment shown in Figure 2.1. The 1100C small car impacted the barricade at an impact speed of 61.2 mi/h and angle of 90 degrees with the centerline of the vehicle aligned with the centerline of the barricade. The vehicle then traveled and hit the second barricade traveling 51.9 mi/h and angle of 0 degrees. The first barricade stayed in contact with the windshield during its impact with the second barricade but had no intrusion of the windshield area. Test 1 successfully met NCHRP Report 350 criteria, and the barricade with mounted sign was considered suitable for implementation. The research team considered the diamond shape sign as a critical testing condition, and therefore determined the use of a rectangular sign panel also as suitable for implementation (*3*).

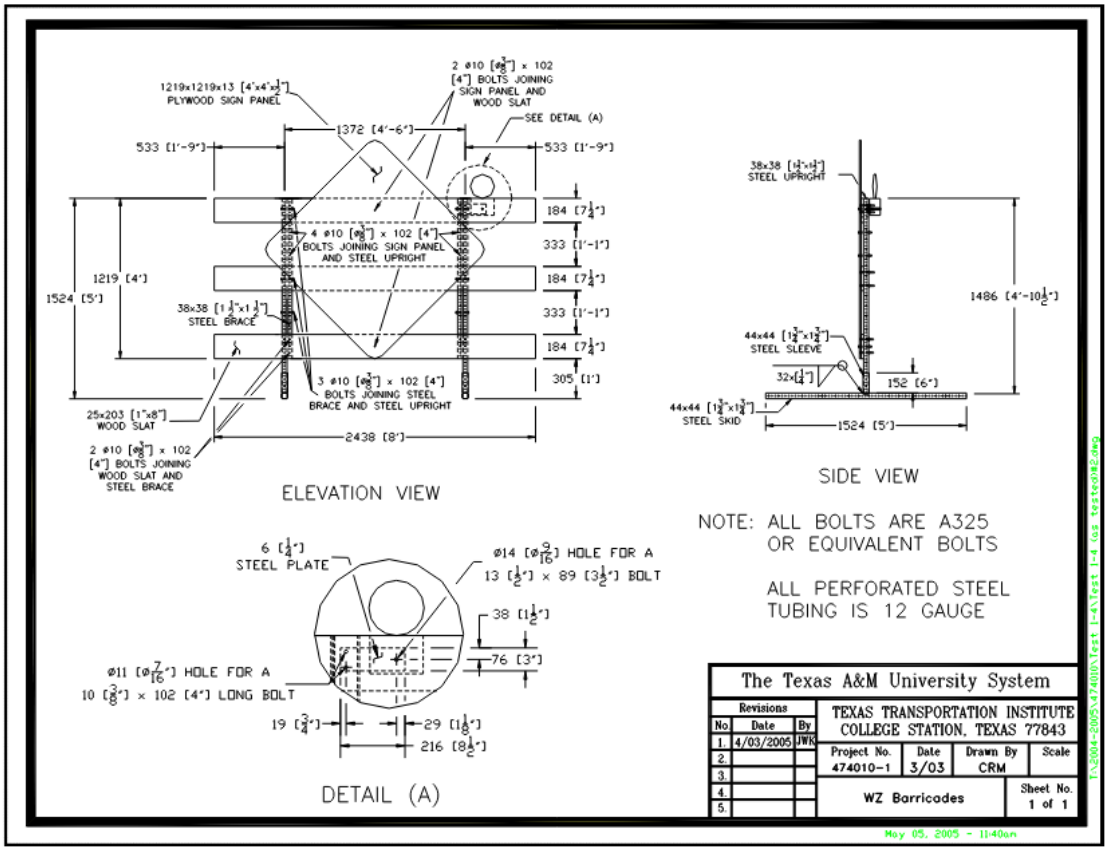


Figure 2.1: Details of Type III Barricade Evaluated in Test 1 (*3*)

2.2.2. NCHRP Report 350 Test 2 of the Perforated Steel Type III Barricade with Rectangular Sign Attachment

Test 2 was conducted using the design shown in Figure 2.2. The impact conditions replicated likely impact scenarios for wide barricades including an offset, head-on impact condition that aligned one of the barricade uprights with the center of the vehicle. An 1808 lb vehicle impacted the first barricade oriented 90 degrees with the centerline of the vehicle aligned with the centerline of the barricade at a speed of 63.6 mi/h, then shortly after impacted the second barricade oriented at 0 degrees with a speed of 51.8 mi/h. However, this test failed due to excessive windshield deformation of 2.0 inches in addition to a small hole in the windshield (*3*).

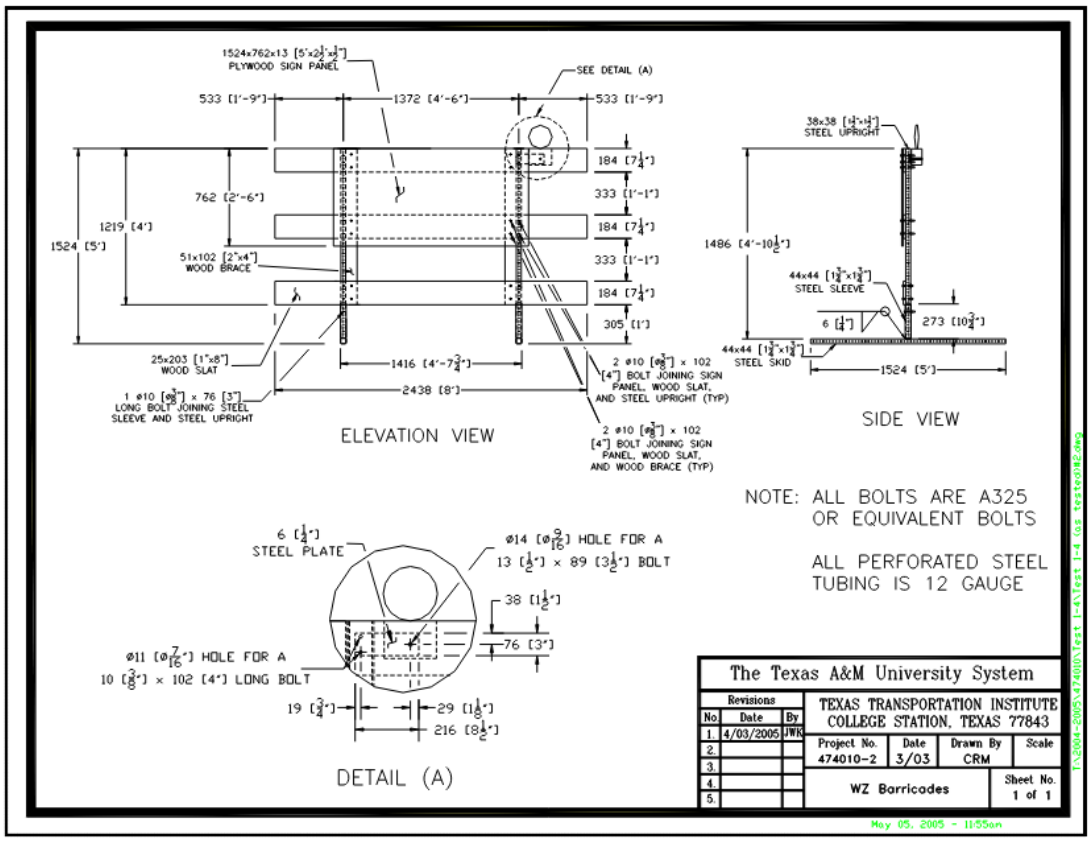


Figure 2.2: Details of Type III Barricade Evaluated in Test 2 (*3*)

2.2.3. NCHRP Report 350 Test 3 of the Perforated Steel Type III Barricade with Rectangular Sign Attachment

Test 3 was conducted using the design shown in Figure 2.3. To address the excessive windshield deformation experienced in Test 2, a horizontal cross brace was added to connect the uprights of barricade together. This would ideally provide increased torsional rigidity and therefore improve the crashworthiness of the system. The details for these modifications can be viewed in Figure 2.3. A 2019 lb vehicle was used to impact the barricades. The first barricade was impacted at an orientation of 90 degrees and a speed of 62.3 mi/h. This first barricade was also shifted 24.0 inches to the right to align the left barricade upright with the centerline of the vehicle with the intent of evaluating the torsional failure mode of the barricade mounted to the left support. The second barricade was then impacted at an orientation of 0 degrees and a speed of 50.5 mi/h. The glass for the right-side door was completely shattered because of contact with one of the barricade rails. However, high-speed film showed no intrusion of the barricade rail into the passenger compartment. Therefore, this adjustment proved successful, and the updated design met NCHRP Report 350 criteria (*3*).

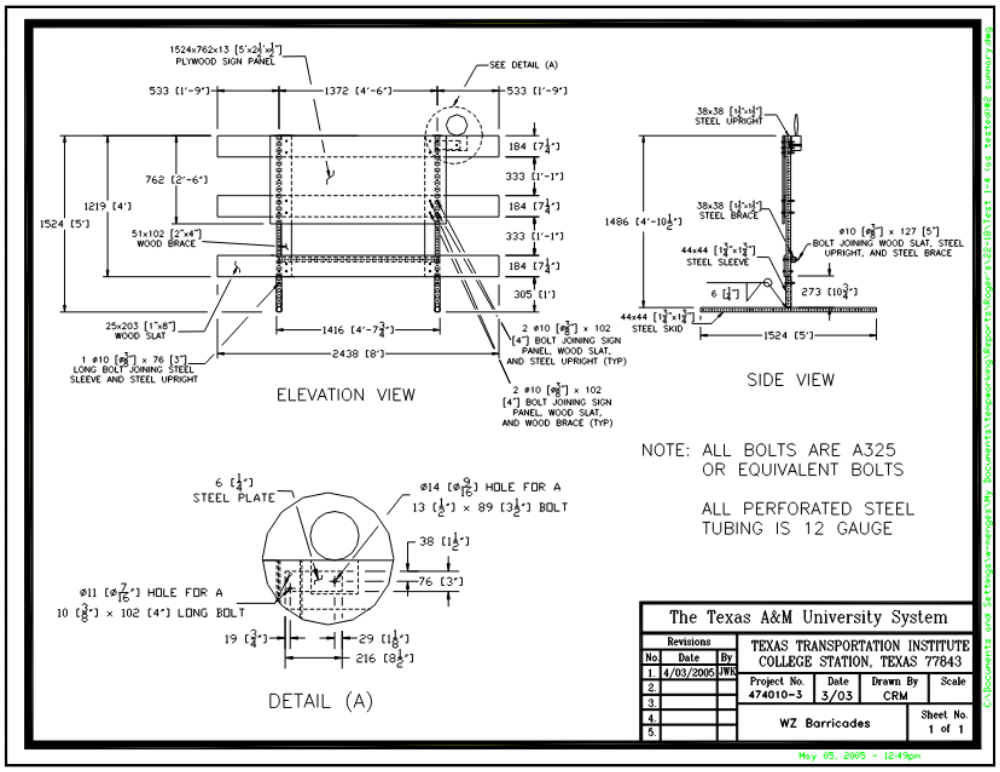


Figure 2.3: Details of Type III Barricade Evaluated in Test 3 (*3*)

To mitigate the problem with the barricade rails, a horizontal cross brace was added to the barricade to tie the two uprights together and was positioned at a height of 18.0 in to engage the vehicle bumper. This brace will theoretically keep the barricade moving in one piece, and should not affect end-on or centered, head-on impacts. The details for these perforated steel barricade modifications of the 1.2 m x 1.2 m (4 ft x 4 ft) can be viewed in Figure 2.4, and the corresponding design with a 1.5 m x 0.8 m (5 ft x 2 ft-6 in) sign panel can be viewed in Figure 2.4 (*3*).

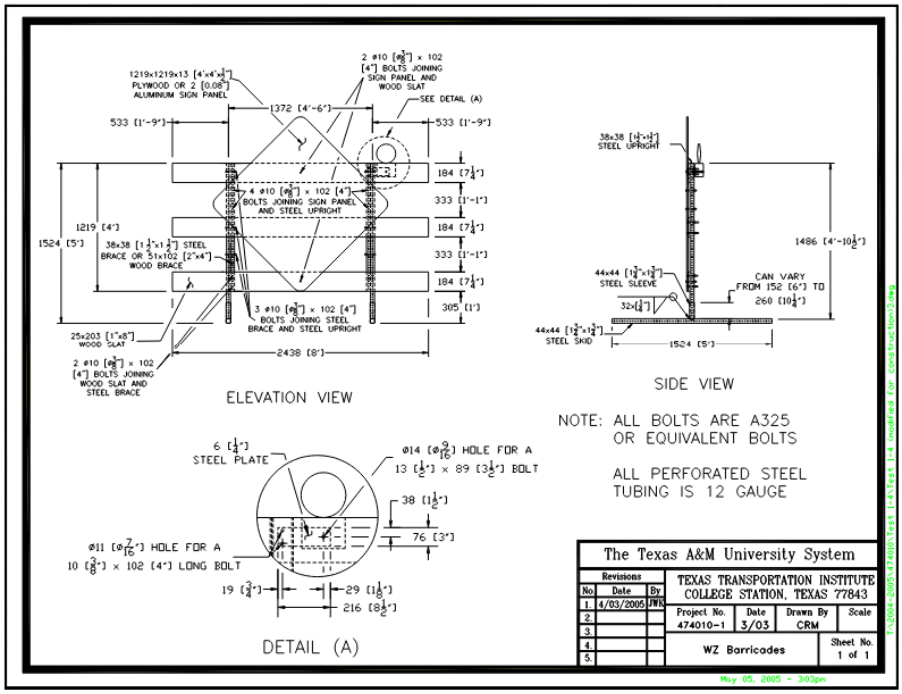


Figure 2.4: Modification Details of Perforated Steel Type III Barricade with 1.2 m x 1.2 m (4 ft x 4 ft) sign panel

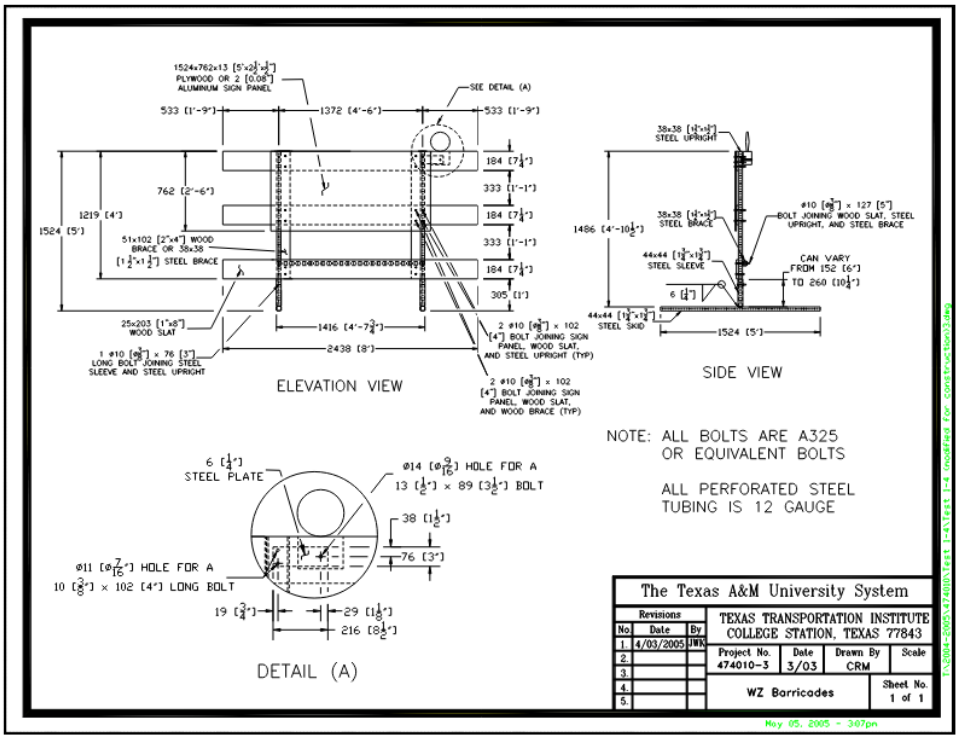


Figure 2.5: Modification Details of Perforated Steel Type III Barricade with 1.5 m x 0.8 m (5 ft x 2 ft-6 in) sign panel

2.2.4. NCHRP Report 350 Test 4 of the HPPL Type III Barricade with Rectangular Sign Attachment

Test 4 was conducted using the design shown in Figure 2.5. This final test of the project evaluated the performance of a Type III barricade constructed with wood horizontal boards and skids andhollow High-Density Polyethylene (HDPE) vertical supports. A 2019 lb vehicle was used to impact the barricades. The first barricade was impacted at an orientation of 0 degrees with the left support aligned with the centerline of the vehicle and a speed of 62.3 mi/h. Soon after, the vehicle impacted the second barricade at an orientation of 90 degrees with the centerline of the vehicle aligned with the barricade and a speed of 51.4 mi/h and an orientation of 0 degrees. The front passenger side window was cracked by the end of the upper barricade board, but remained intact and was not deformed inward. Although the windshield shattered on the right side, and high-speed film also showed no intrusion of the barricade rail into the passenger compartment. The system was considered to meet NCHRP Report 350 criteria (*3*).

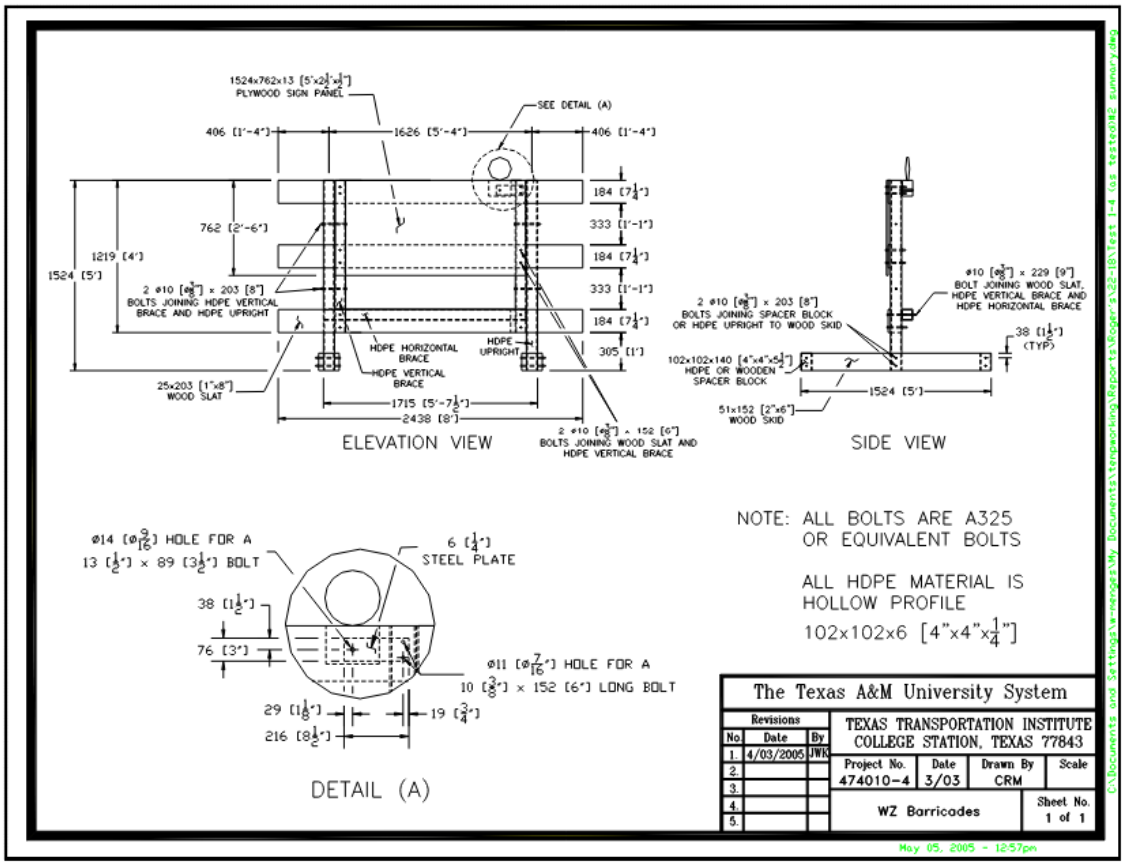


Figure 2.6: Details of Type III Barricade Evaluated in Test 4 (*3*)

To mitigate the behavior of the upper end of the barricade from intruding the right-side window, it was recommended to reduce the overhang distance of the barricade rails past the uprights. This spacing of the uprights was limited by the width of the sign panel. By increasing the spacing of the uprights from 1.4 m to 1.6 m (4 ft-6 in to 5 ft-4 in), the overhand distance was reduced from 0.5 m to 0.4 m (1 ft-7 in. To 2 ft-2 in). The recommended details for the Type III HPPL barricade with 1.2 m x 1.2 m (4 ft x 4 ft) are shown below in Figure 2.7, and the details of a similar design incorporating a 1.5 m x 0.8 m (5 ft x 2 ft-6 in) are shown below in Figure 2.4.

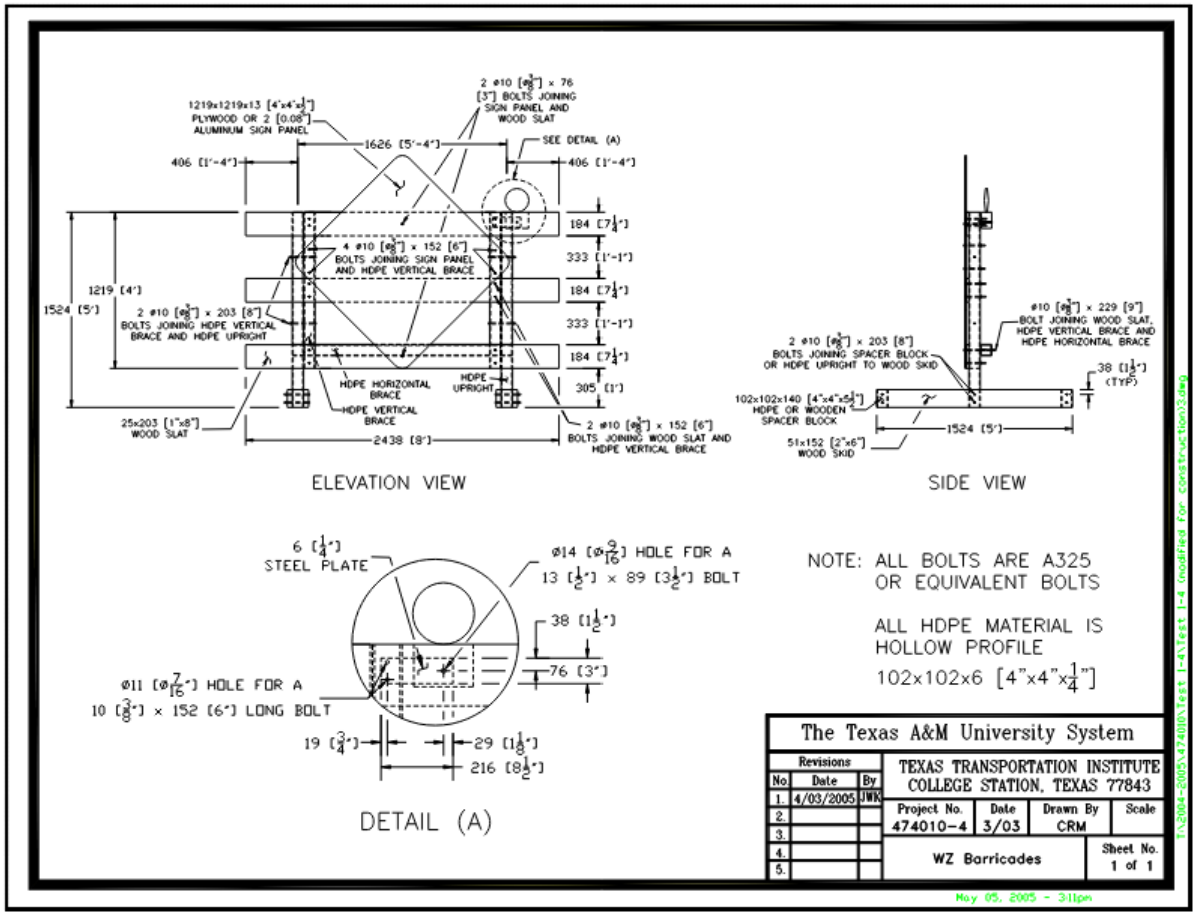


Figure 2.7: Modification Details of HPPL Type III Barricade with 1.2 m x 1.2 m (4 ft x 4 ft) sign panel

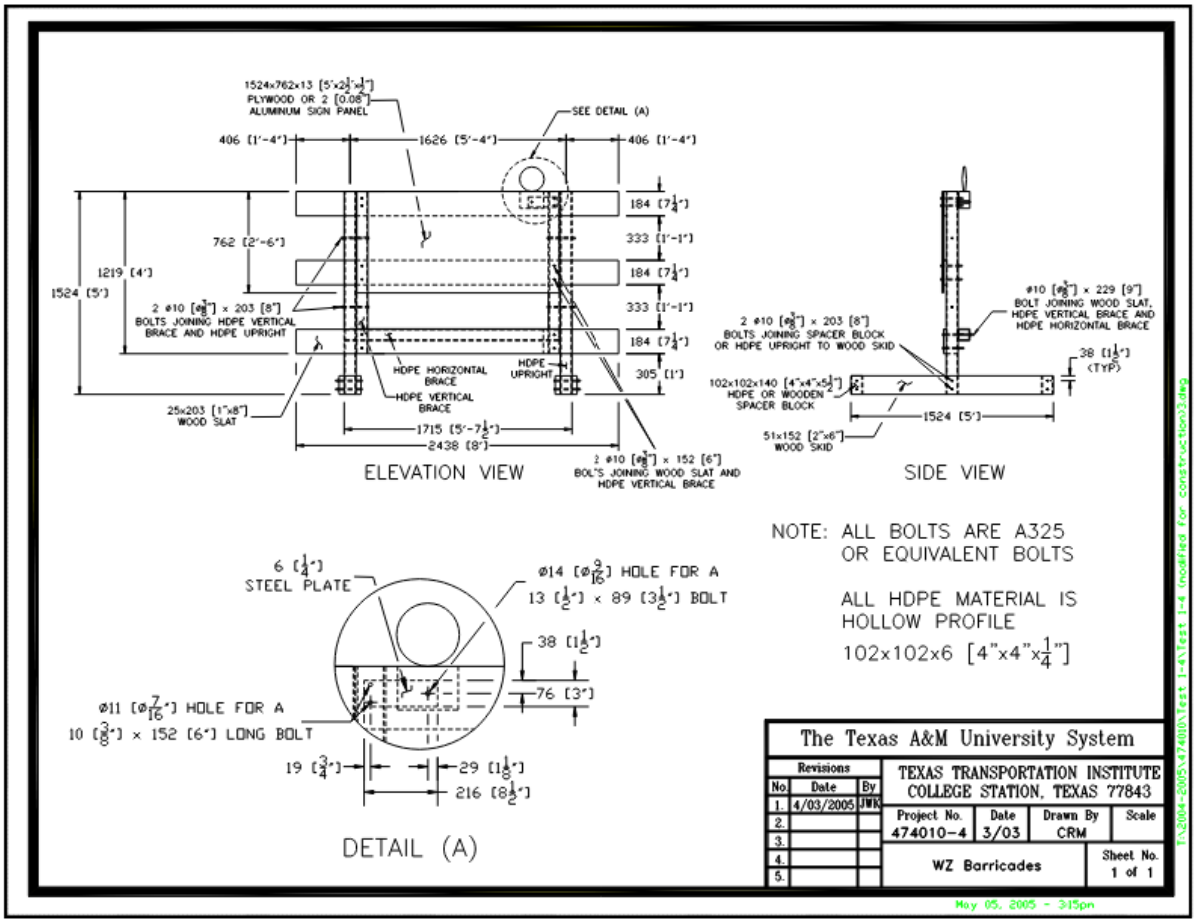


Figure 2.8: Modification Details of HPPL Type III Barricade with 1.5 m x 0.8 m (5 ft x 2 ft-6 in) sign panel

2.3. NCHRP REPORT 350 TEST 3-71 OF THE TYPE III PERFORATED STEEL TUBING BARRICADE

The objective of this project was to "design, test, and develop work zone appurtenances for use by the States." A full-scale crash test was conducted on a Type III barricade constructed with PSST frame members and wooden horizontal rails. This barricade supported a 1220 mm x 1220 mm plywood sign mounted at a height of 2.1 meters (Figure 2.6). An 820-kg passenger car was used to evaluate both 0 and 90 degree orientations of the barricade and mounted sign at the same time. The vehicle impacted the first barricade at a speed of 98.7 km/h with 0 degree orientation, and shortly after, impacted the second barricade at a speed of 87.2 km/h with an orientation of 90 degrees (*4*).

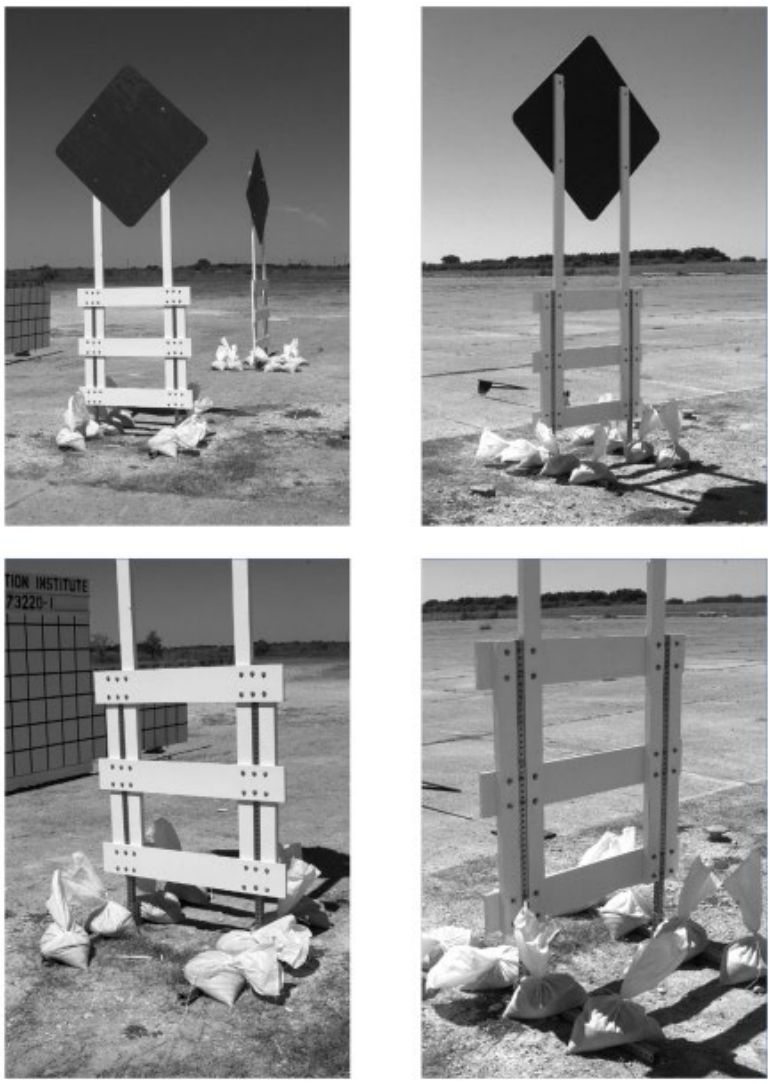


Figure 2.9: Type III Perforated Steel Tubing Barricade (*4*)

The barricade separated into multiple pieces and were scattered along the path of the vehicle. There were major dents to the grill, hood and roof of the vehicle. The bumper deformed 200mm. The roof deformed an area of 840 mm by 500 mm, with a depth of 30 mm over the rear passenger compartment, and the occupant compartment was deformed inward as well for a

maximum 41 mm depth. The windshield was shattered near the roofline, but no penetration and no separation from the roof. This test article met the criteria set forth in *NCHRP Report 350* (*4*).

2.4. NCHRP REPORT 350 TEST 3-71 OF THE NEW JERSEY DOT PVC BARRICADE WITH SIGN PANEL

A full-scale crash test was conducted on the New Jersey DOT PVC Type III barricade with 1220 mm x 1220 mm aluminum sign panel mounted at a height of 1041 mm (Figure 2.7) at 0 and 90 degree orientations. NCHRP Report 350 crash testing criteria was used to evaluate the barricade and involved an 820-kg passenger car impacting both barricades at a speed of 100 km/h (*5*).

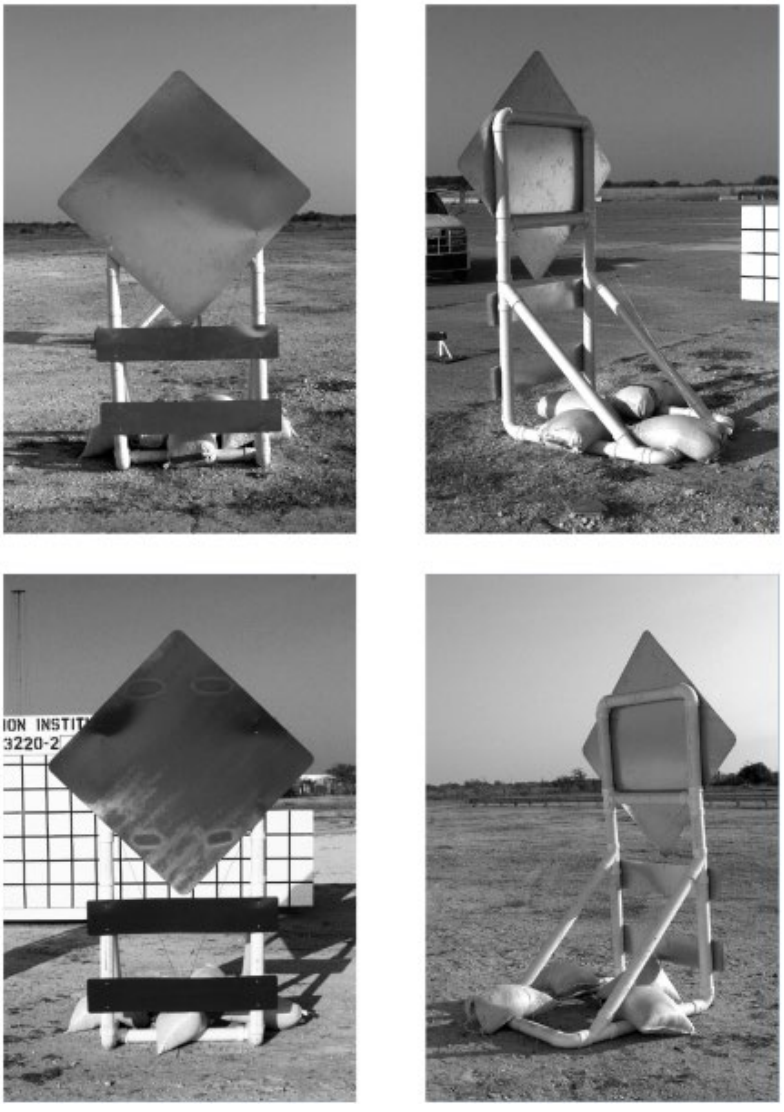


Figure 2.10: New Jersey Type III PVC Barricade (*5*)

The PVC barricade separated into multiple pieces, and the end of the second barricade's middle cross member punctured a hole in the windshield. This puncture was measured to be 178

mm long and approximately 19-25 mm wide. Additionally, the maximum deformation to the occupant compartment was measured to be 44 mm. The roof deformed over an area of 800 mm x 400mm to a depth of 55 mm. This system failed to meet NCHRP Report 350 criteria because of the windshield damage caused by a cross member of the barricade. (*5*).

Figure 2.11: Windshield Damage to Vehicle from New Jersey Type III PVC Barricade Testing (*5*)

2.5. MIDWEST ROADSIDE SAFETY FACILITY MASH 2016 EVALUATION OF NON-PROPRIETARY TYPE III BARRICADE

The objective of this project was to evaluate the performance of a non-proprietary work-zone safety device. The highest need was determined to be a non-proprietary Type III barricade, which had not been evaluated to MASH crash testing criteria. Each barricade consisted of three horizontal HPDE panels measured at 96 inches in length, with a 48 inch x 30 inch x 0.08 inch aluminum sign attached to the top of the barricade panels. This barricade is shown below in Figure 2.9. One test was conducted with the barricades at 0 and 90 degree angles according to *MASH* test designation 3-71. The barricades experienced moderate damage. Both systems experienced bends and buckles in the uprights and panels, tears in the weighted sandbags, and bolt pullouts. Damage to the vehicle was minimal. A larger dent caused by the impact was located on the left-rear door directly behind the door handle, measuring 8 inches. Additionally, the left mirror was disengaged from the vehicle, and the windshield was cracked across its

entirety. Because of this, the barricade with mounted sign successfully met *MASH* criteria and was considered acceptable for implementation (*6*).

Figure 2.12: Non-proprietary Type III Barricade (*6*)

Researchers also provided recommendations regarding variations of the as-tested design which would still be considered *MASH*-compliant. These variations included different materials, sizes and cross-sectional shapes, and it is anticipated that a Type III barricade without an aluminum sign panel would perform the same or better than the Type III barricade with the sign. Warning lights were also permitted to be mounted to the backside of the barrier. The researchers recommended completing the MASH 3-72 test with the 2270P pickup truck to complete the full testing matrix (*6*).

2.6. MASH EVALUATION OF TXDOT ROADSIDE SAFETY FEATURES

The purpose of this project was to evaluate TxDOT roadside safety devices, which included a Type III barricade. TxDOT allows for Type III barricades to vary in lengths of 4 feet to 8 feet. The 4 feet long barricade was considered to be most critical because it allows for both uprights to be impacted at the same time, increasing the chance of the uprights releasing from their skids. The Type III barricade was constructed of three 1 inch x 8 inch yellow pine boards mounted to two vertical sections of 1.5 inch PSST (Figure 2.10). This barricade was tested to MASH 3-71 and 3-72 conditions, with both 0 and 90 deg impact angles (*7*).

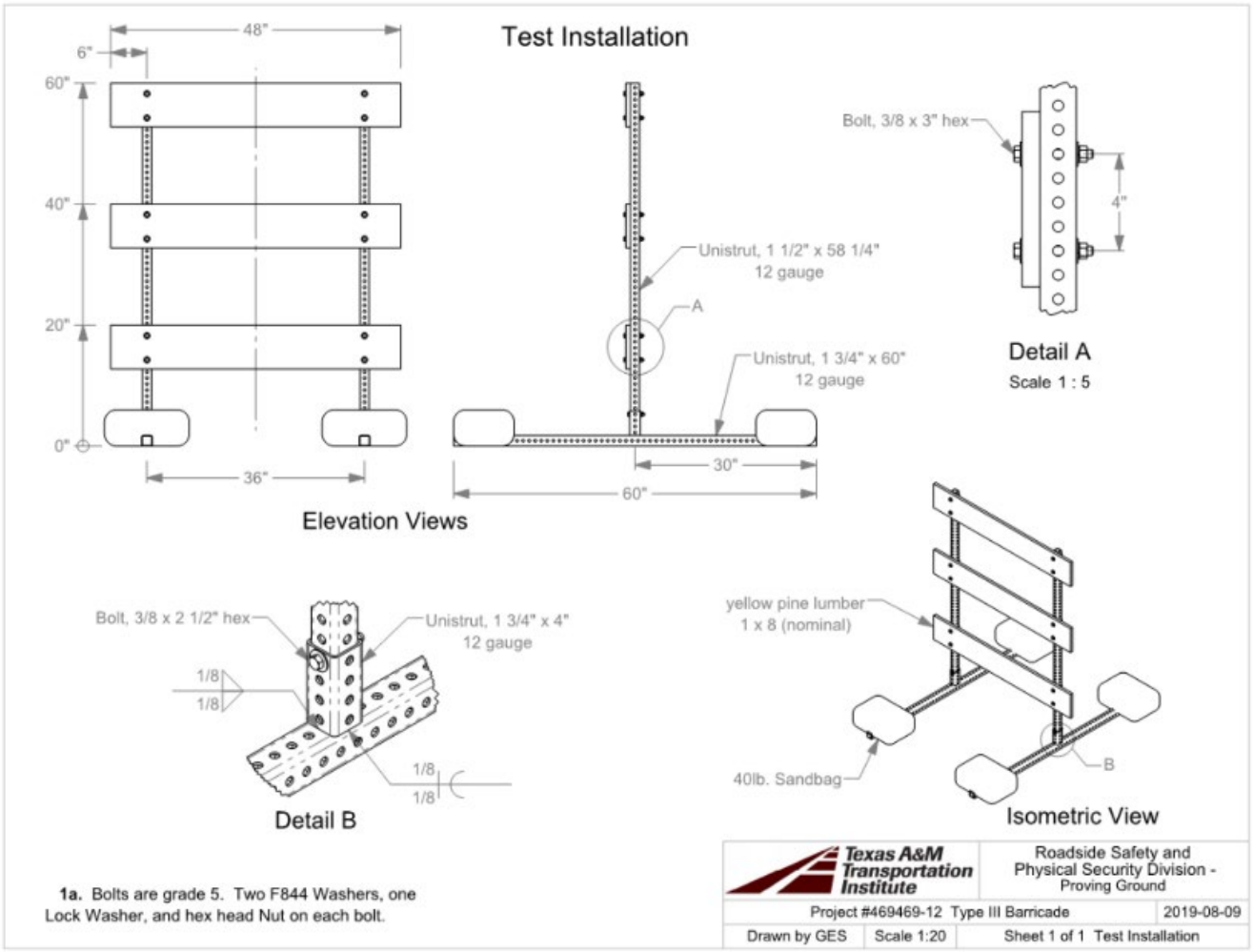


Figure 2.13: Details of Type III Barricade with Pine boards (*7*).

The first test was a MASH 3-71 test at a 90 degree orientation. A 2416 lb vehicle was used to impact the centerline of the barricade 14 inches off the centerline of the vehicle towards the driver's side at an approximate speed of 62.2 mi/h. The barricade broke into multiple pieces and scattered downstream of impact. Damage to the vehicle included a 4 inch x 8 inch, 1.75 inch deep dent in the front bumper, as well as a 24 inch x 24 inch, 2.5 inch deep dent in top left side of the hood. There was no measurable deformation to occupant compartment. This test passed all MASH performance criteria. The second test conducted was MASH test 3-72 at a 90 degree orientation. A 5044 lb vehicle was used to impact the centerline of the barricade 12 inches off the centerline of the vehicle towards the driver's side at an approximate speed of 63.5 mi/h. The barricade separated into two pieces. Damage to the vehicle included an 8 inch x 8 inch dent in the hood, and a 1 inch hole located 1 foot to the left of the centerline of the hood, but there was no measurable occupant compartment deformation. This test passed all MASH performance criteria. The third test conducted was MASH test 3-72 at a 0 degree orientation. A 5044 lb vehicle was used to impact the centerline of the barricade aligned with the centerline of the vehicle at a speed of 61.3 mi/h. The barricade remained mostly intact, except for welds that

cracked at the base and the supports bending 18 inches up from the base. Vehicle damage was minimal with only some light scuffing on the bumper and grill, and no measurable exterior crush on the vehicle or occupant compartment. This test passed all MASH performance criteria. The final test conducted was MASH test 3-71 at a 0 degree orientation. A 2450 lb vehicle was used to impact the centerline of the barricade aligned with the centerline of the vehicle at a speed of 64.5 mi/h. The barricade separated into multiple pieces. Damage to the vehicle included a 42 inch x 8 inch, 1.25 inch. deep dent along the front hood, as well as some damage to the passenger-side headlight. There was no measurable occupant compartment deformation. This test passed all MASH performance criteria. The researchers concluded the Type III barricade suitable for implementation (*7).*

Chapter 3. TYPE III BARRICADE STATE SURVEYS

3.1. OVERVIEW

This survey was designed to gather information regarding panel materials, sign sizes, mounting heights, and similar details which may vary from state to state. The survey was administered online and was sent to members of the Roadside Safety Pooled Fund The survey received 14 total responses.

3.2. SURVEY QUESTIONS AND RESPONSES

Questions 5 through 8 from the state survey are shown in the following pages. Questions 1 through 4 listed introductory information, and Question 5 began the technical aspects of the survey.

Q5 – Does your state attach signs to Type III barricades?

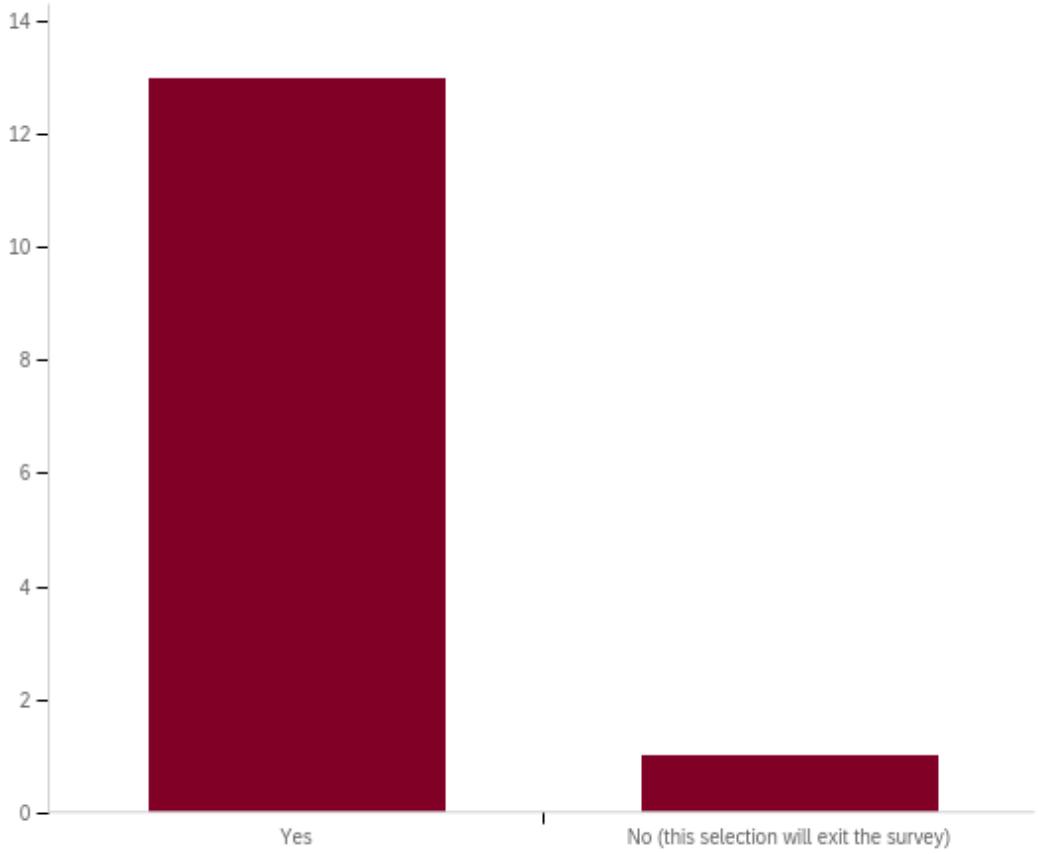


Figure 3.1: State Survey Question 5 Responses.

Q6 – Does your state attach lights and or other hardware to these Type III Barricades in addition to the sign?

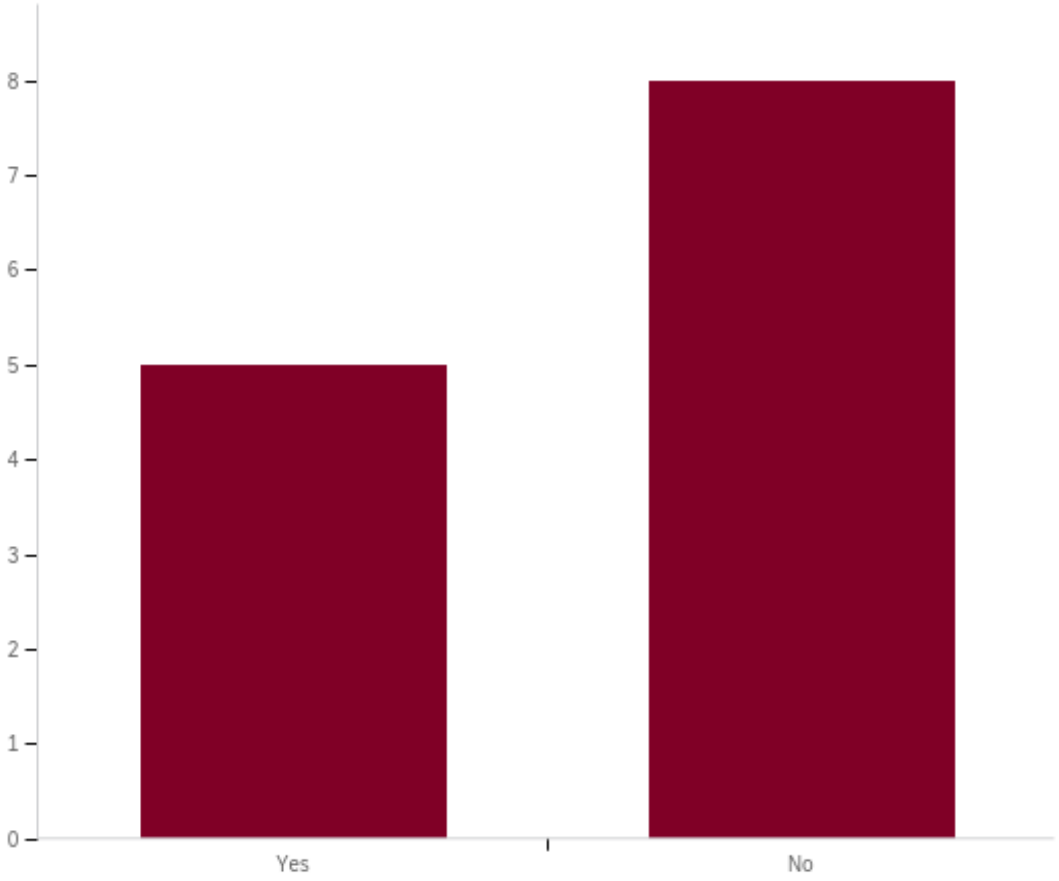


Figure 3.2: State Survey Question 6 Responses.

Q7 – What is the mounting height of the sign? Mounting height is considered as the vertical distance above grade to the lowest point on the sign.

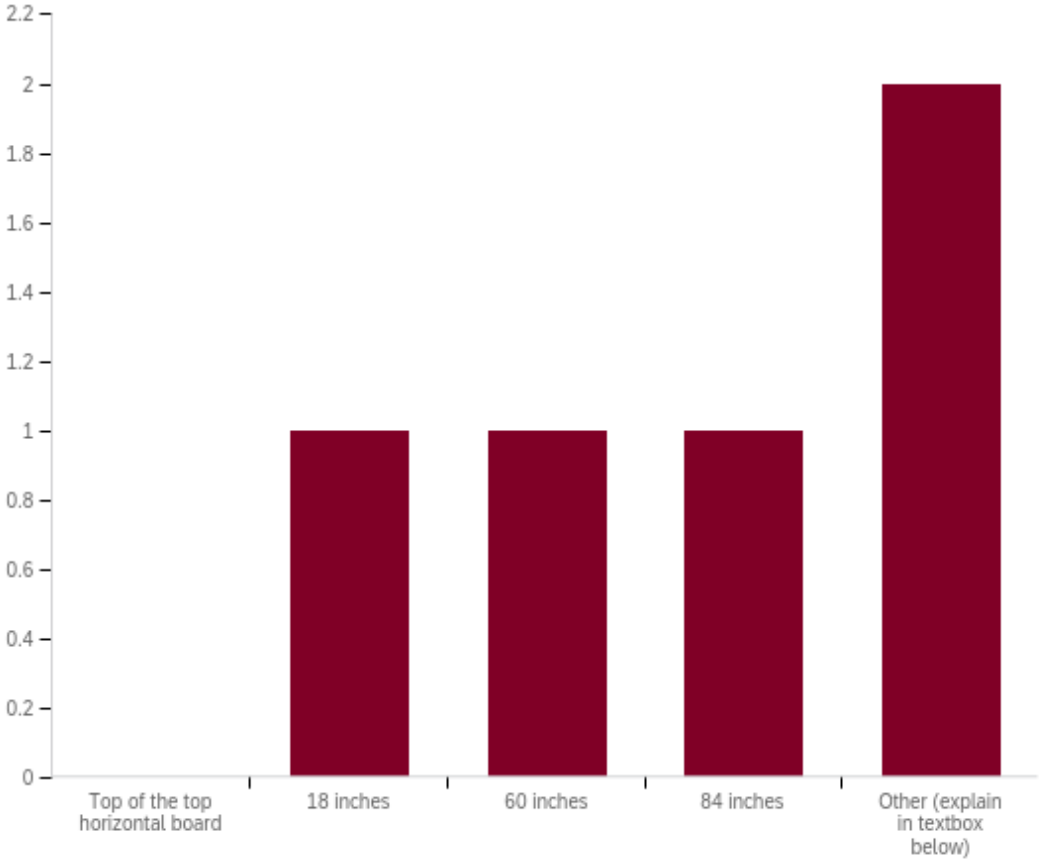


Figure 3.3: State Survey Question 7 Responses

Table 3.1: Survey Participants' Responses to "Other" option in Q7.

Louisiana	"We mount the sign on the top 4" of the middle panel and it covers the top panel with the width of the sign. Lightweight signs that pass NCHRP 350 only."
Minnesota	"Varies dependent on the sign, approximately 54"."

Q8 - Please attach a link or upload a standard, detail sheet, or drawing.

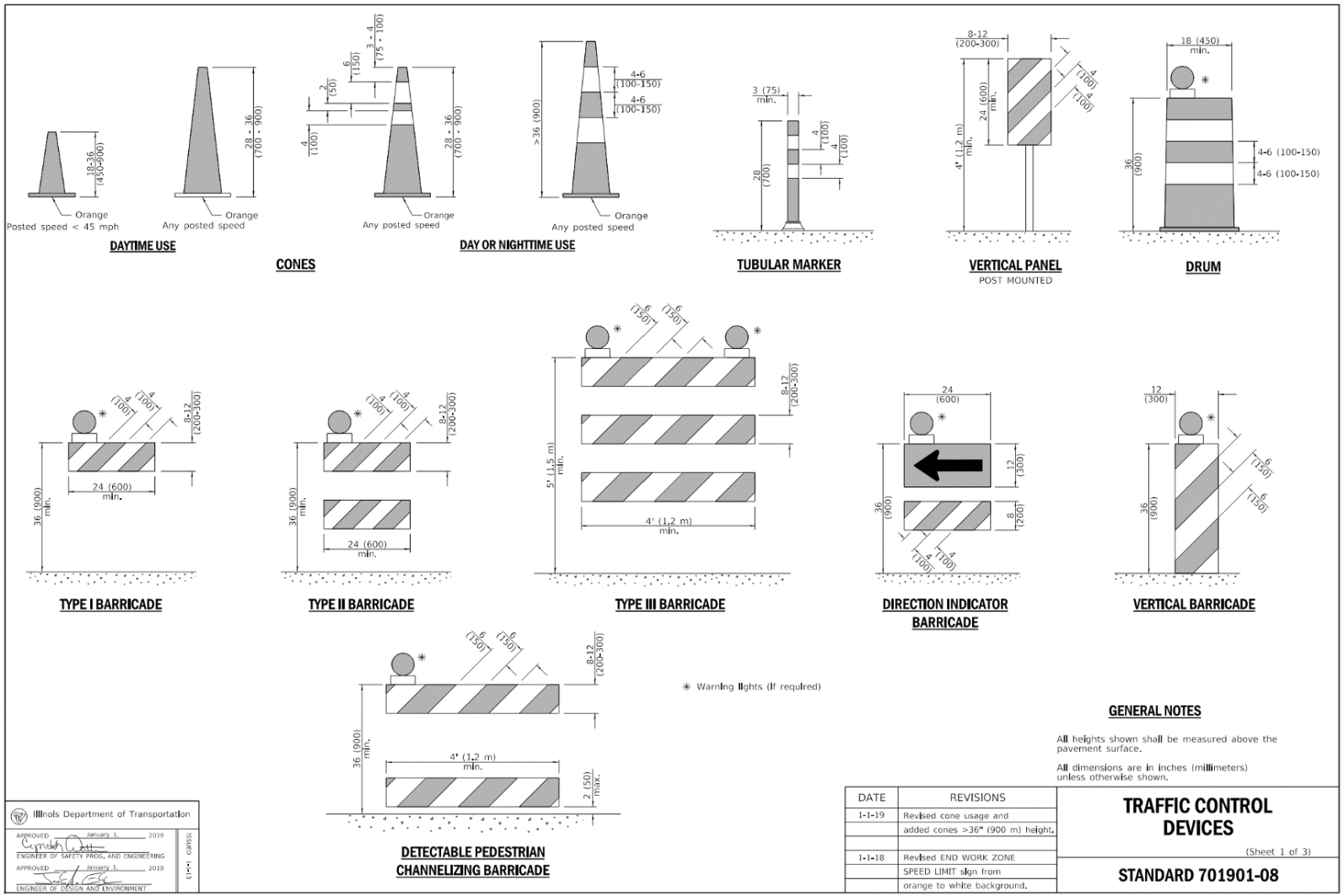


Figure 3.4: Illinois Response to State Survey Q8.

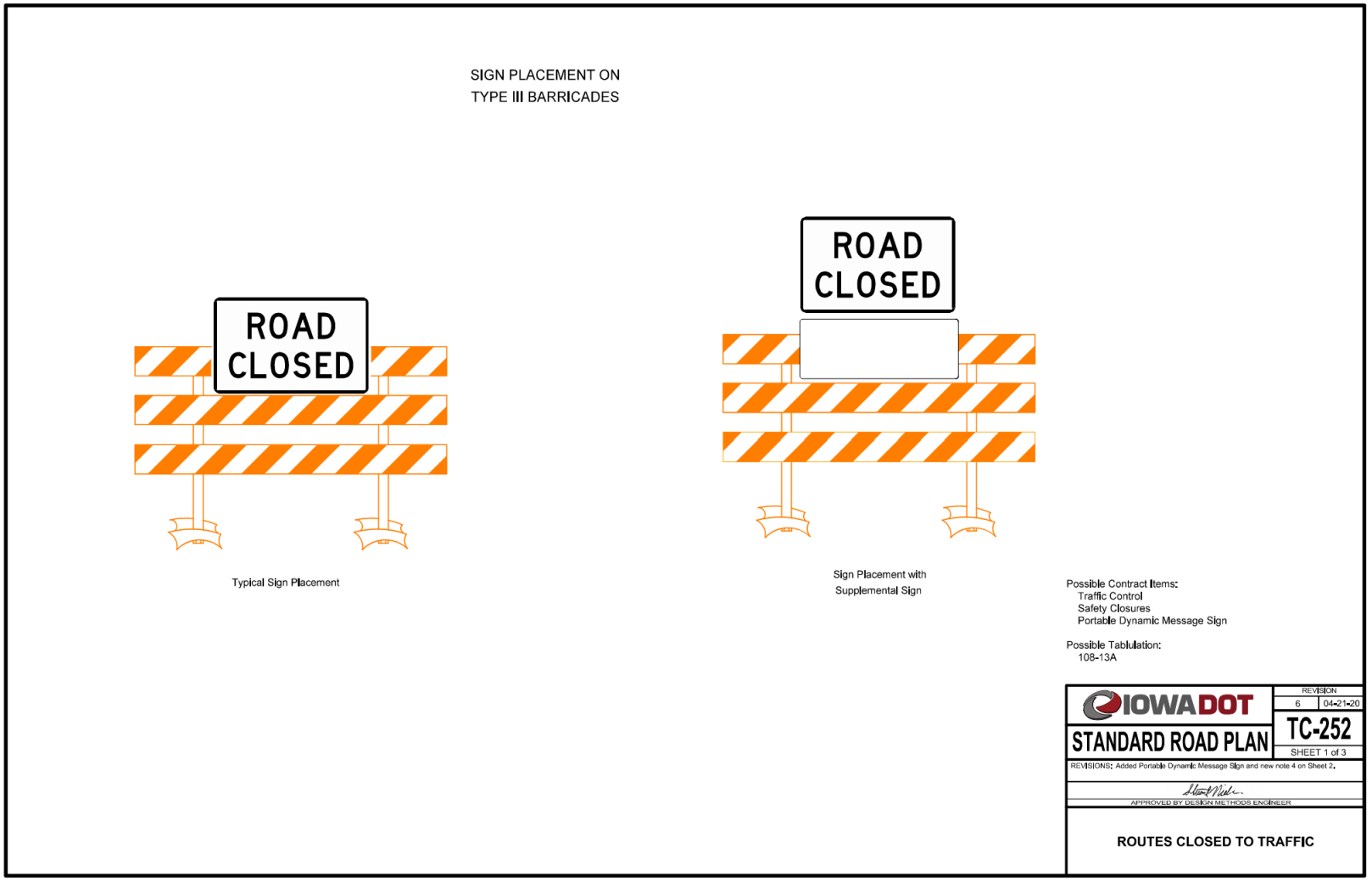


Figure 3.5: Iowa DOT Response to State Survey Q8 (1/3).

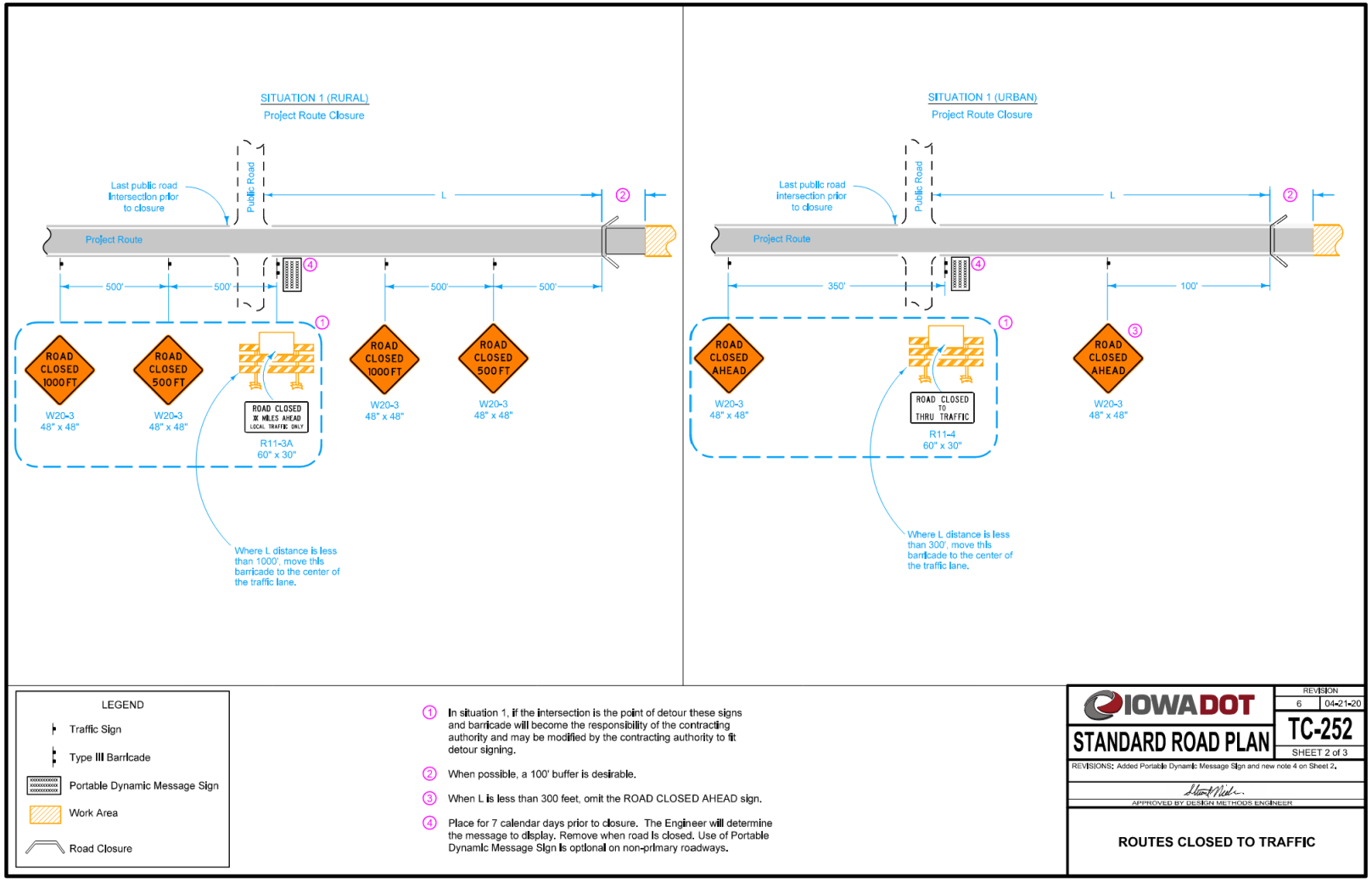


Figure 3.6: Iowa DOT Response to State Survey Q8 (2/3).

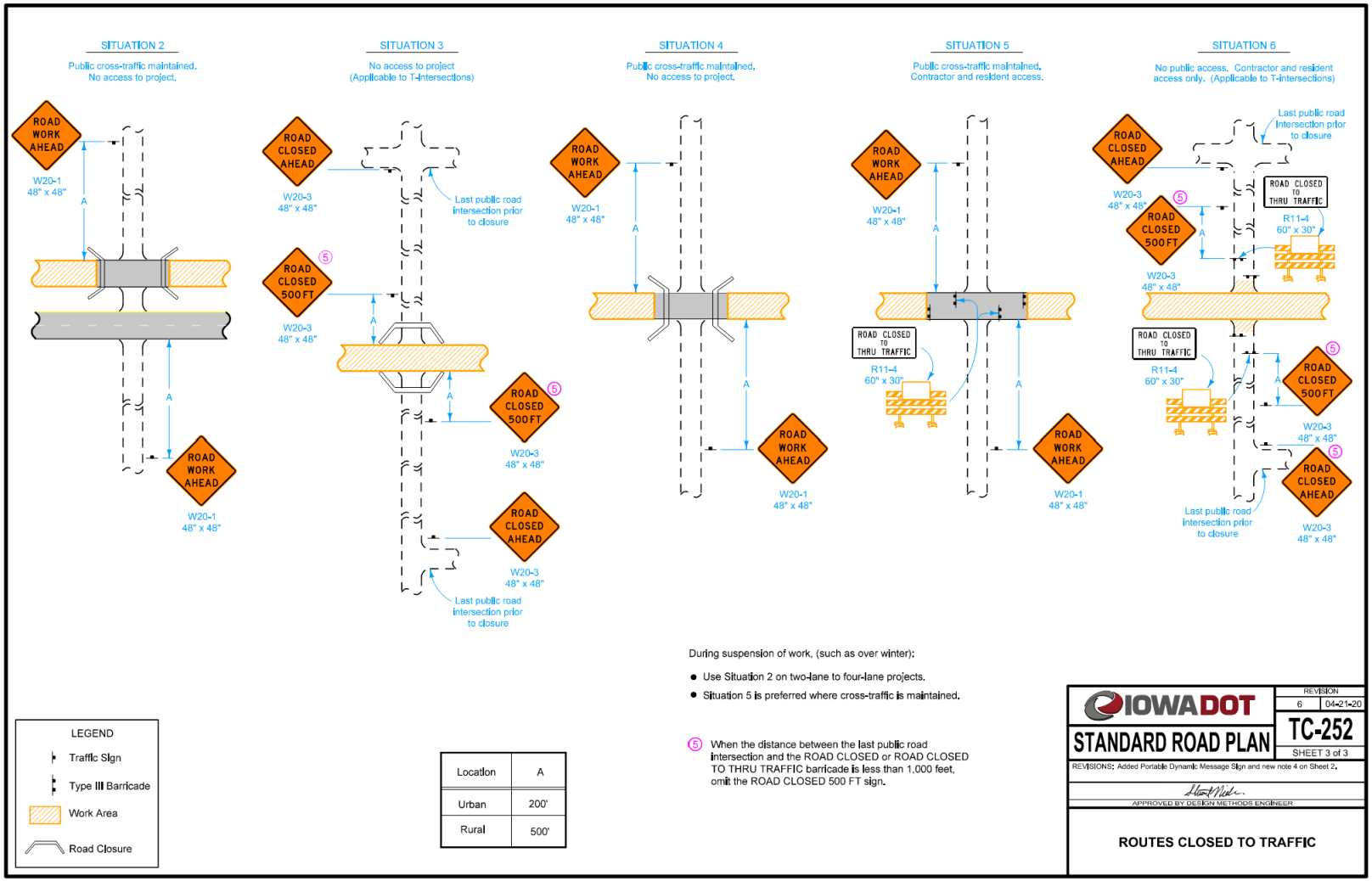


Figure 3.7: Iowa Response to State Survey Q8 (3/3).

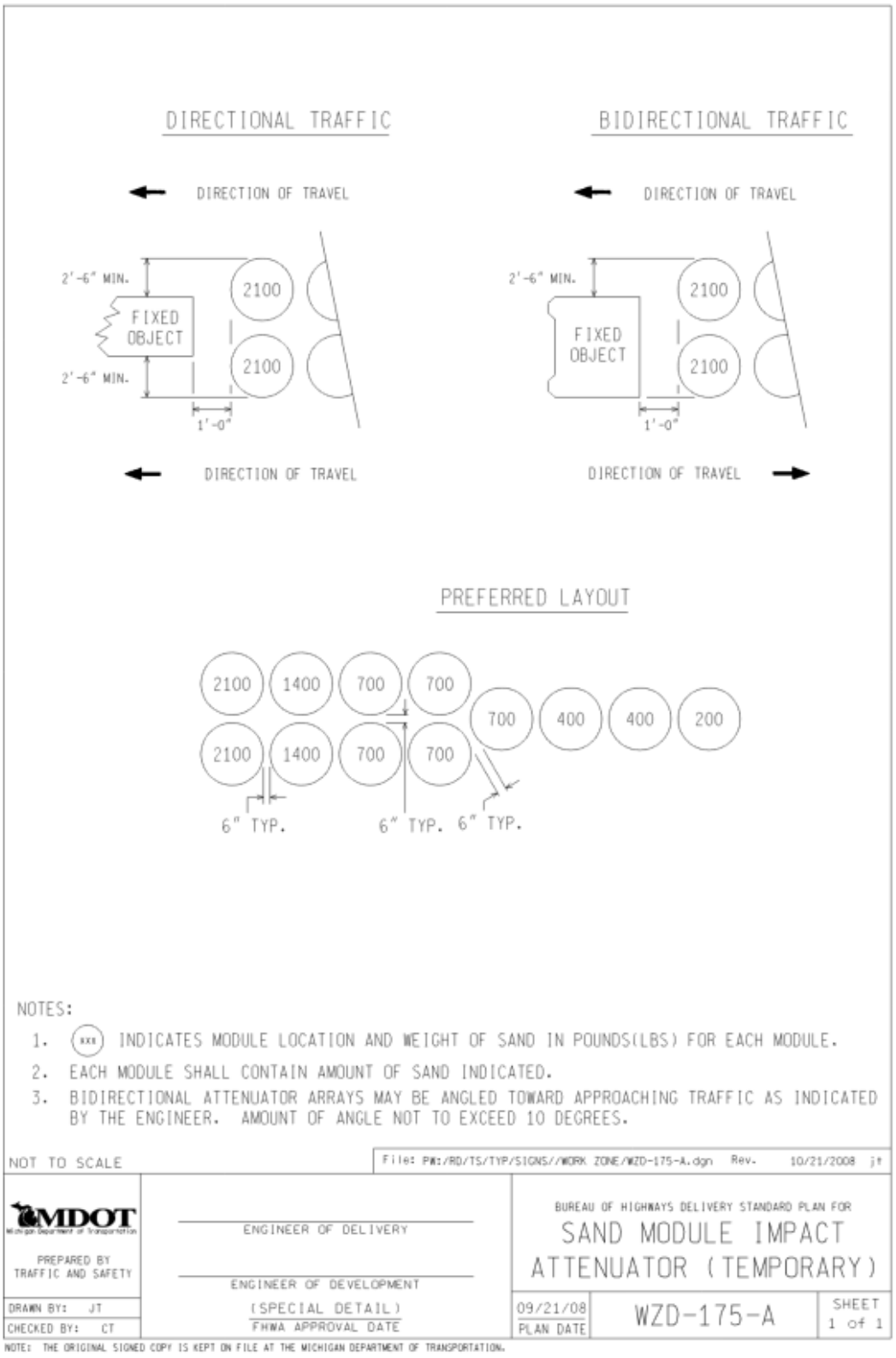
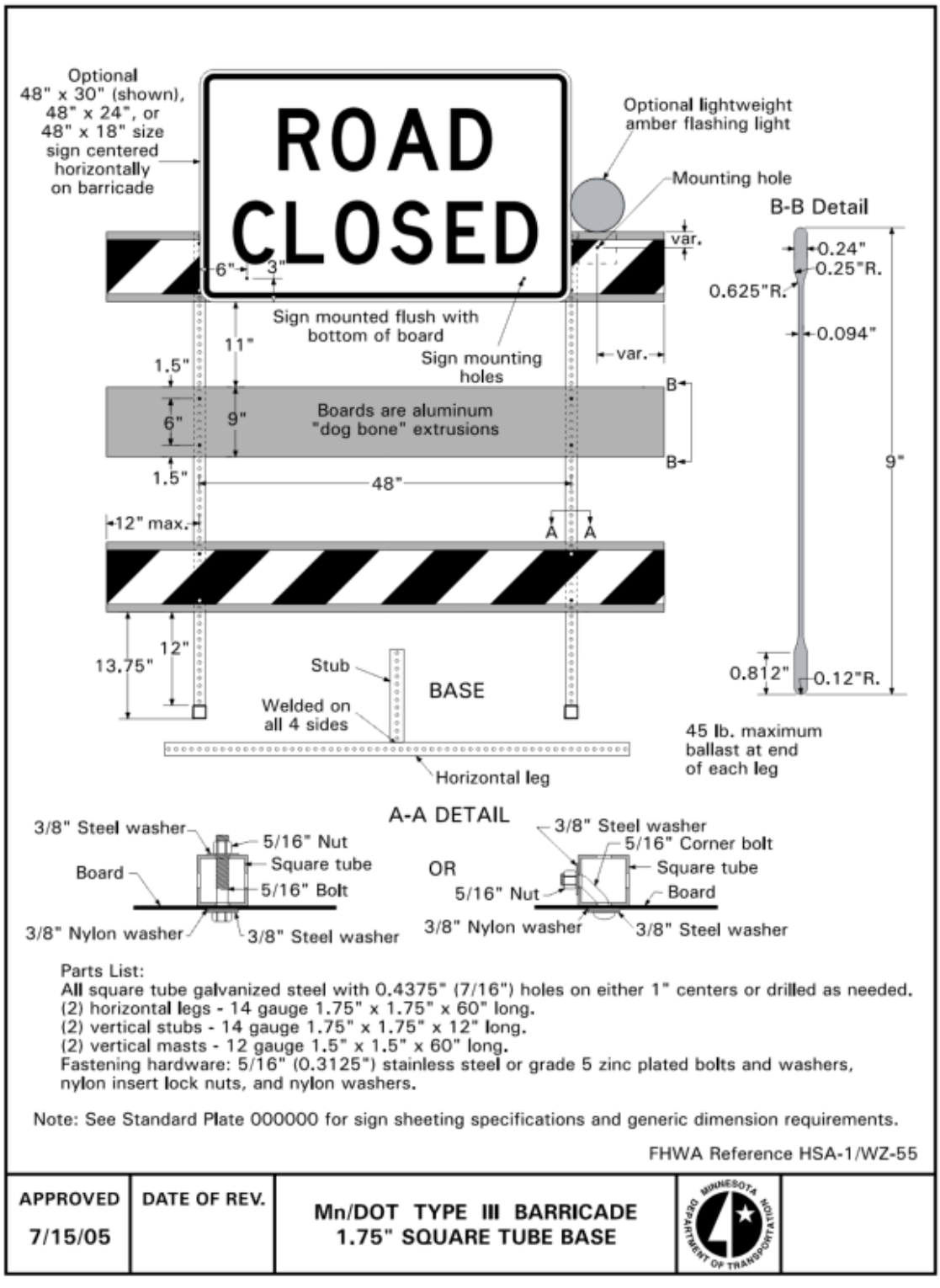


Figure 3.8: Michigan Response to State Survey Q8.



Parts List:
All square tube galvanized steel with 0.4375" (7/16") holes on either 1" centers or drilled as needed.
(2) horizontal legs - 14 gauge 1.75" x 1.75" x 60" long.
(2) vertical stubs - 14 gauge 1.75" x 1.75" x 12" long.
(2) vertical masts - 12 gauge 1.5" x 1.5" x 60" long.
Fastening hardware: 5/16" (0.3125") stainless steel or grade 5 zinc plated bolts and washers, nylon insert lock nuts, and nylon washers.

Note: See Standard Plate 000000 for sign sheeting specifications and generic dimension requirements.

FHWA Reference HSA-1/WZ-55

APPROVED	DATE OF REV.	Mn/DOT TYPE III BARRICADE 1.75" SQUARE TUBE BASE	
7/15/05			

Figure 3.9: Minnesota Response to State Survey Q8 (1/3).

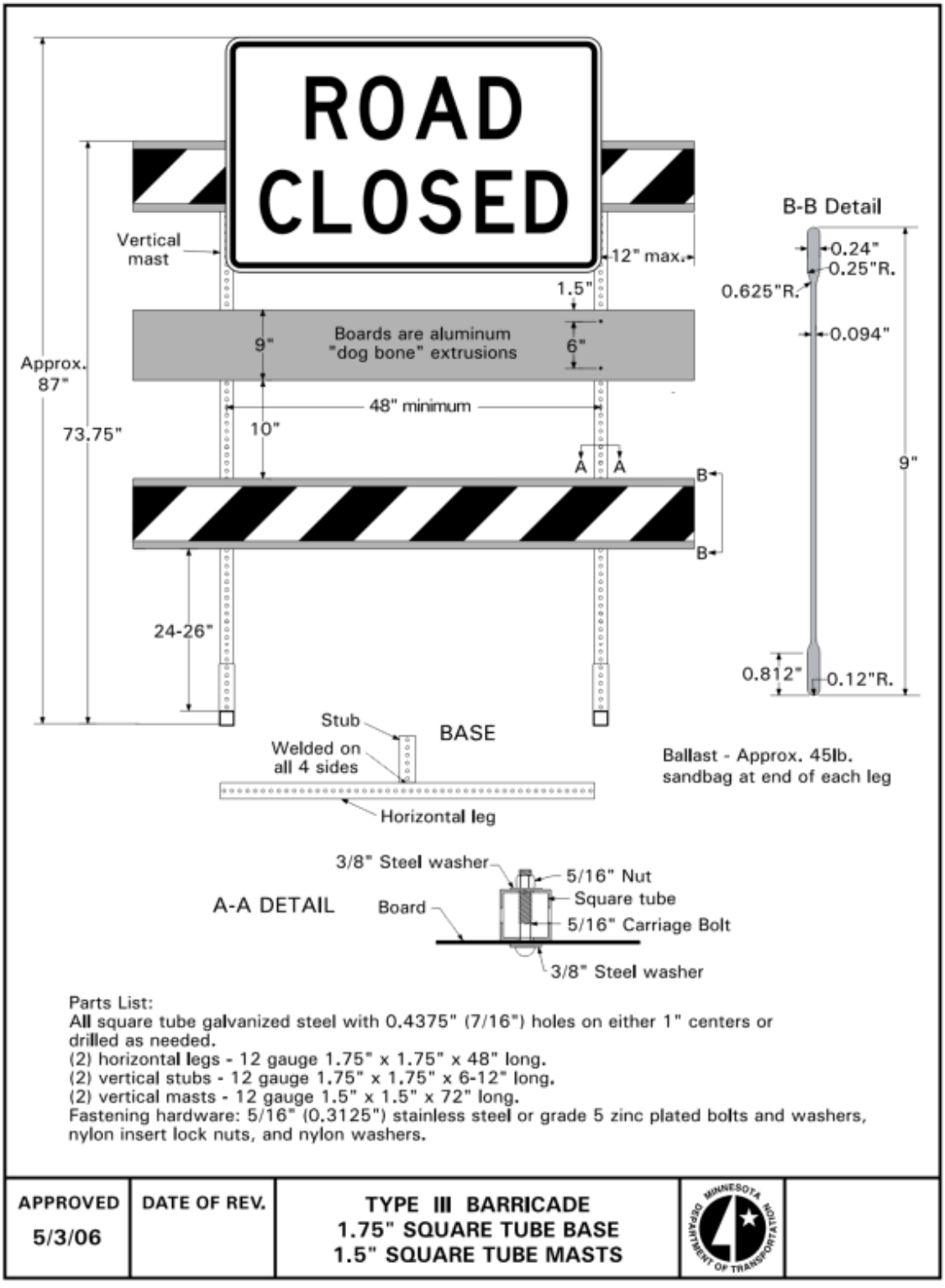
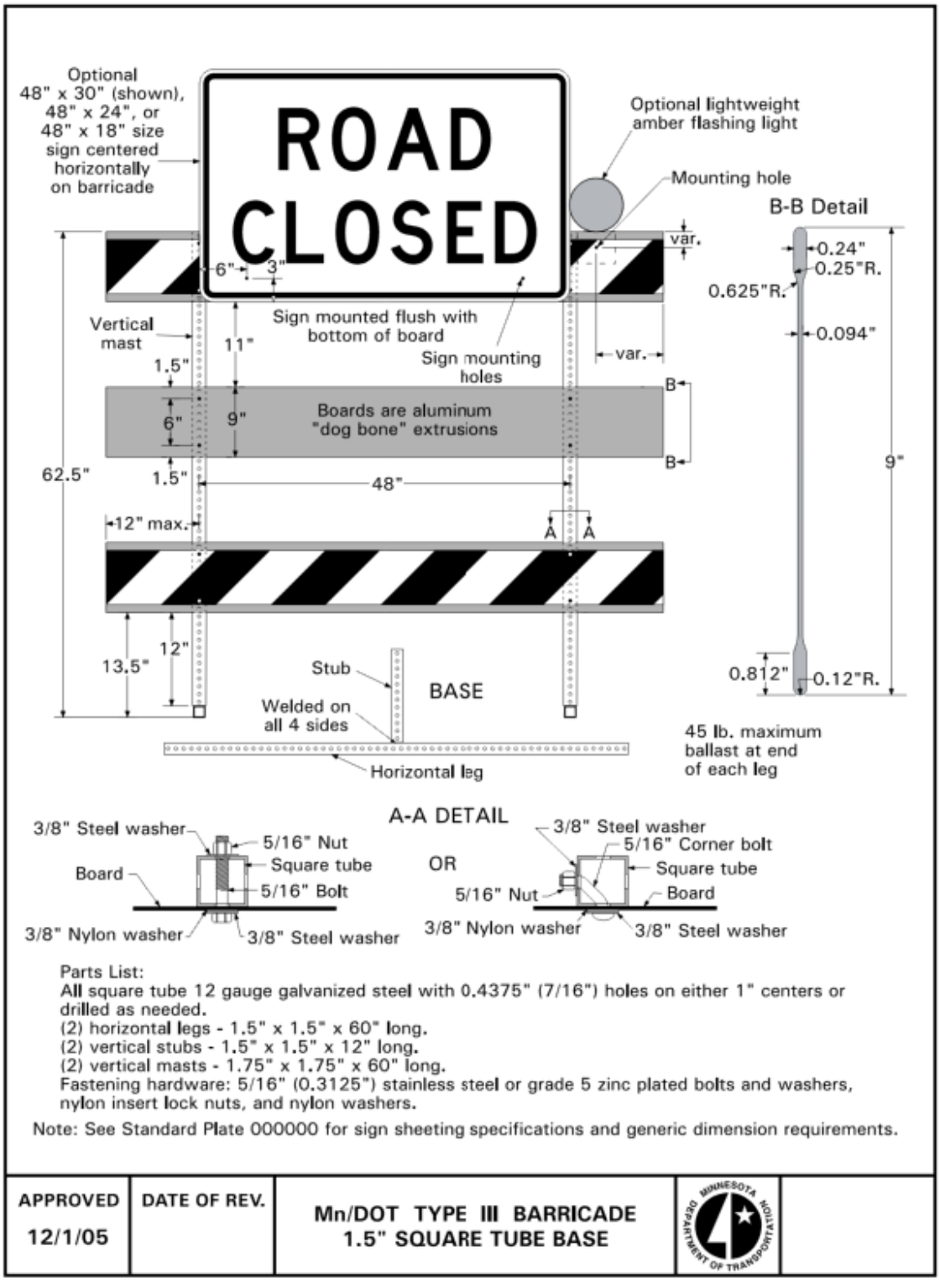


Figure 3.10: Minnesota Response to State Survey Q8 (2/3).



Parts List:
All square tube 12 gauge galvanized steel with 0.4375" (7/16") holes on either 1" centers or drilled as needed.
(2) horizontal legs - 1.5" x 1.5" x 60" long.
(2) vertical stubs - 1.5" x 1.5" x 12" long.
(2) vertical masts - 1.75" x 1.75" x 60" long.
Fastening hardware: 5/16" (0.3125") stainless steel or grade 5 zinc plated bolts and washers, nylon insert lock nuts, and nylon washers.

Note: See Standard Plate 000000 for sign sheeting specifications and generic dimension requirements.

APPROVED	DATE OF REV.	Mn/DOT TYPE III BARRICADE 1.5" SQUARE TUBE BASE	
12/1/05			

Figure 3.11: Minnesota Response to State Survey Q8 (3/3).

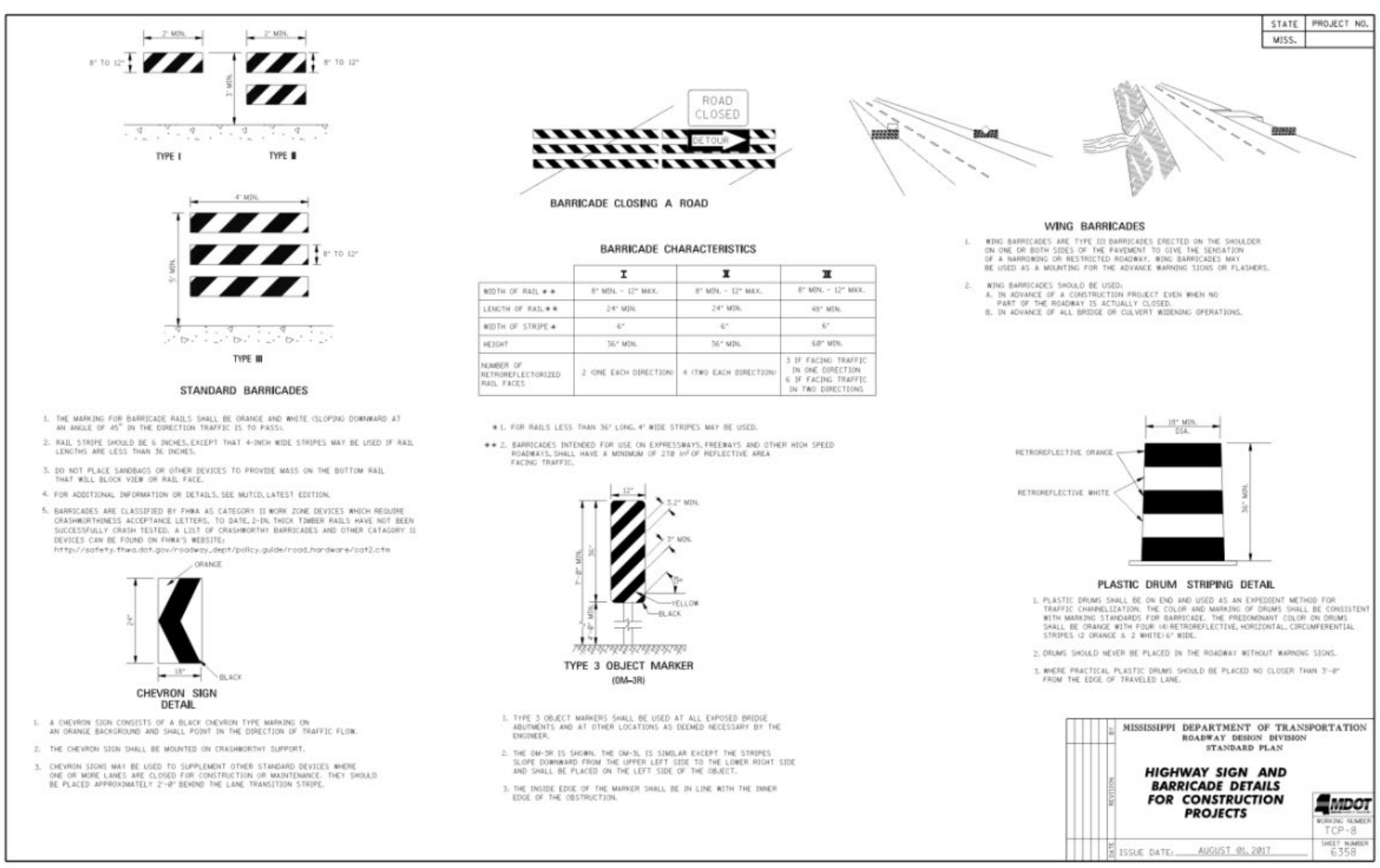


Figure 3.12: Mississippi Response to State Survey Q8.

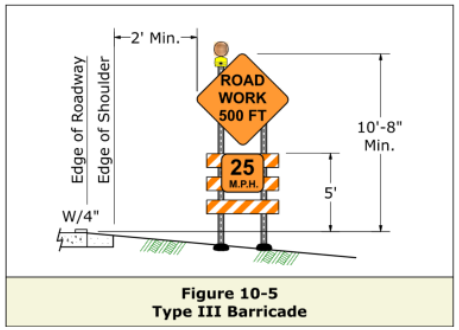


Figure 10-5
Type III Barricade

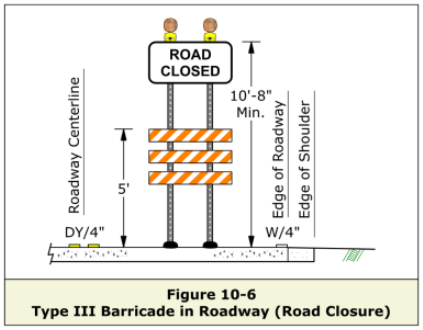


Figure 10-6
Type III Barricade in Roadway (Road Closure)

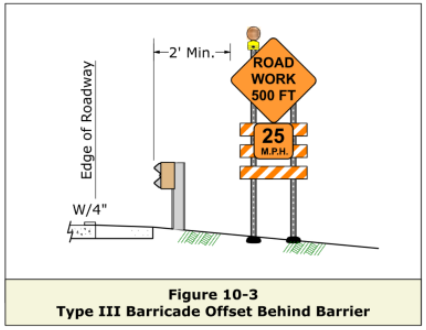


Figure 10-3
Type III Barricade Offset Behind Barrier

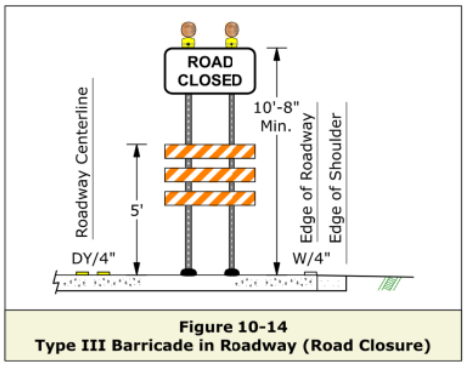


Figure 10-14
Type III Barricade in Roadway (Road Closure)

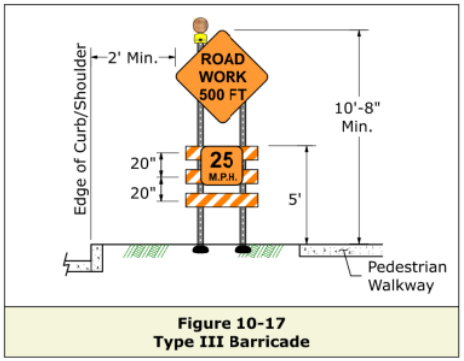


Figure 10-17
Type III Barricade

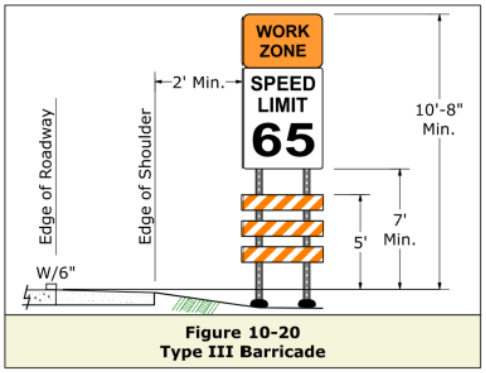


Figure 10-20
Type III Barricade

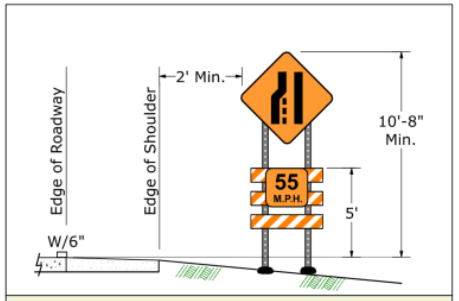


Figure 10-24
Type III Barricade

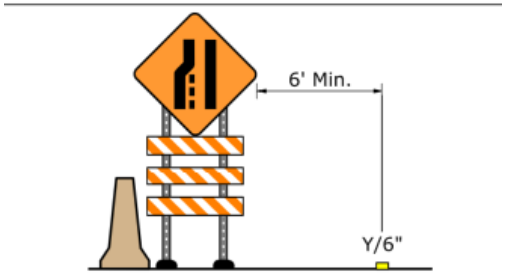


Figure 10-22
Any TTC Sign Placed Adjacent to Barrier

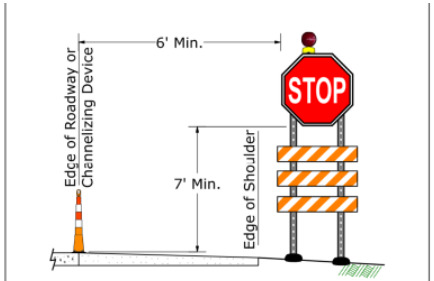


Figure 10-29
Type III Barricade

Figure 3.13 Pennsylvania Compilation of Type III Barricade Images from Response to State Survey Q8.

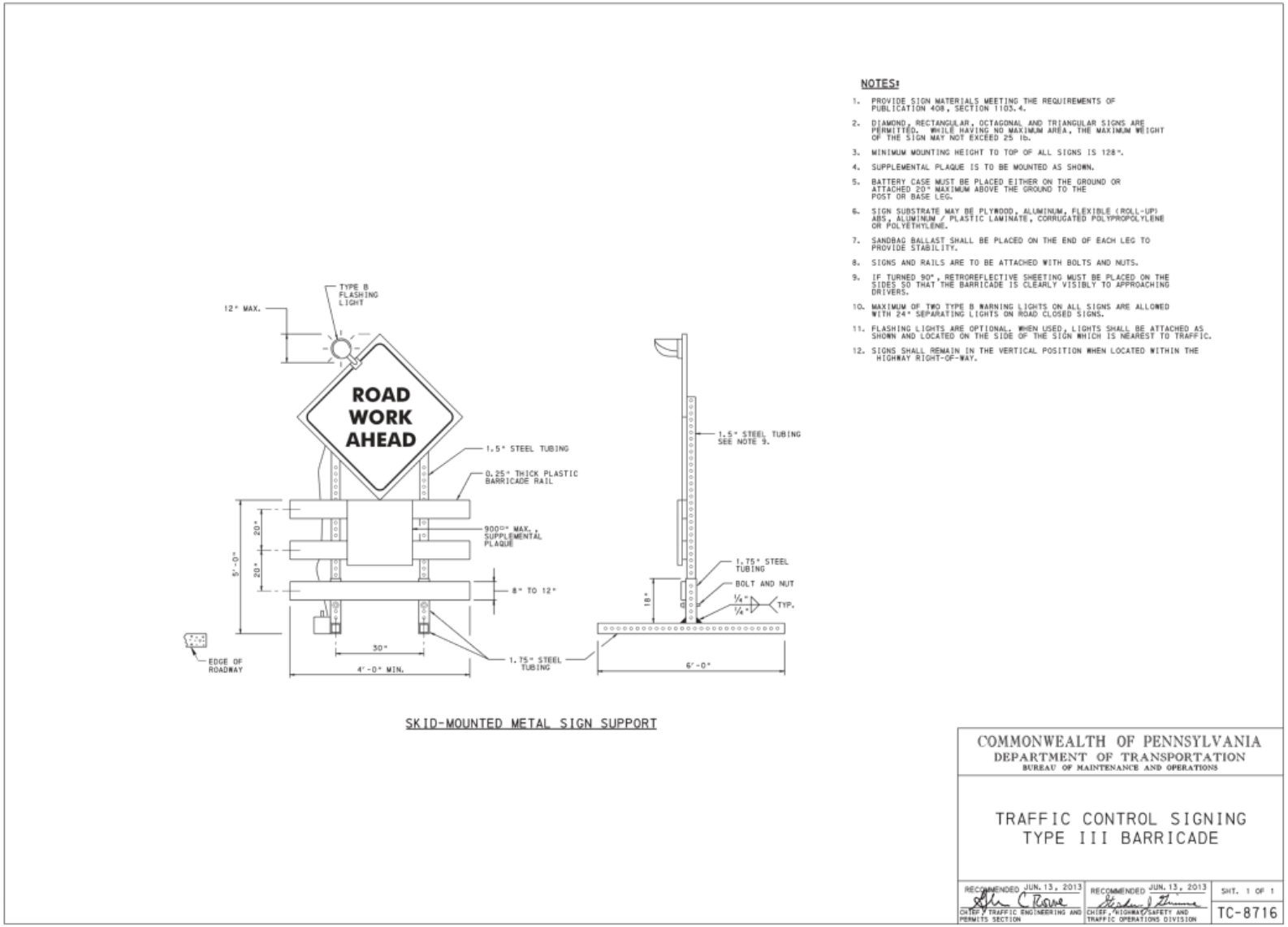


Figure 3.14: Pennsylvania Response to State Survey Q8.

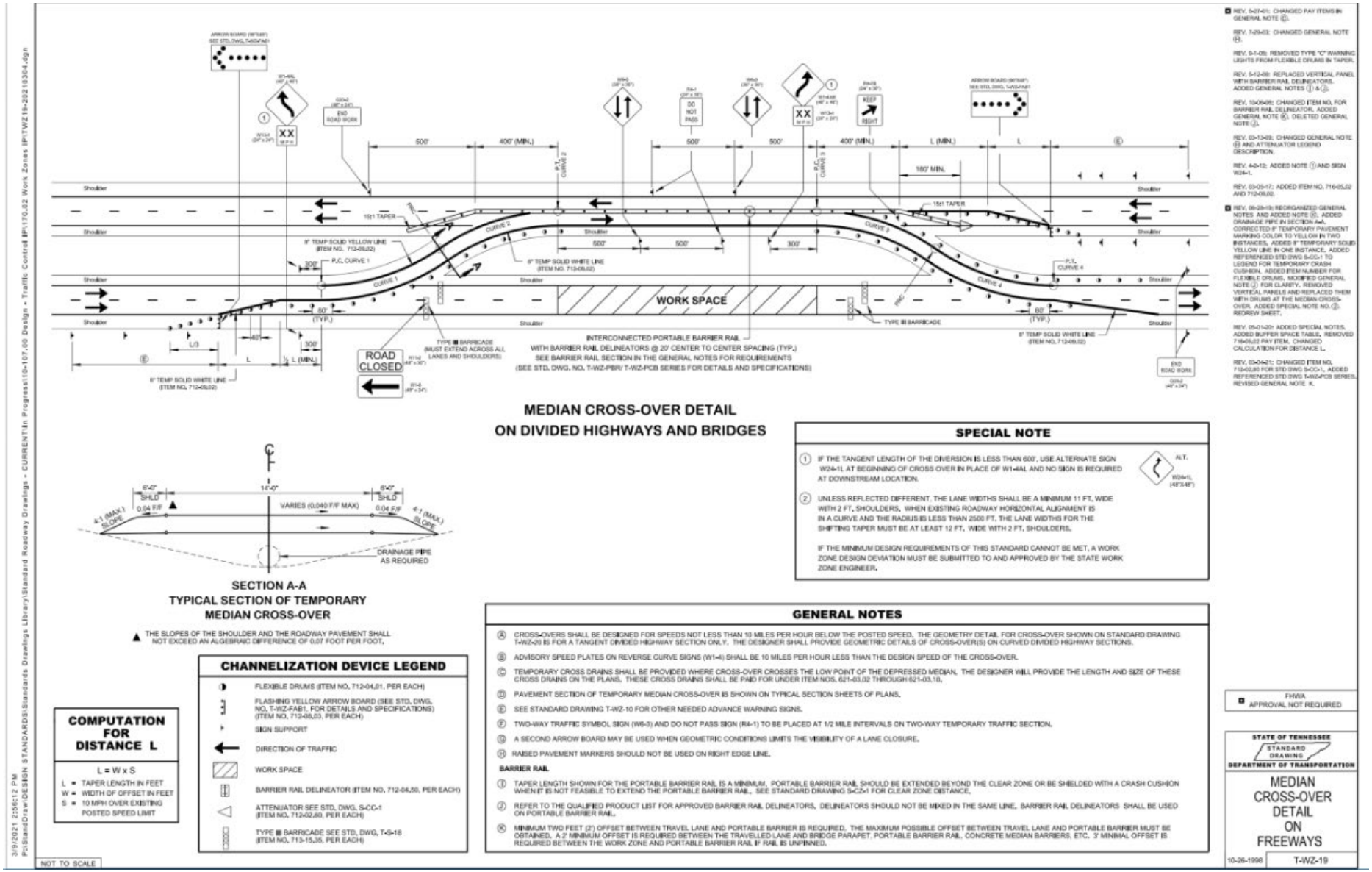


Figure 3.15: Tennessee Response to State Survey Q8.

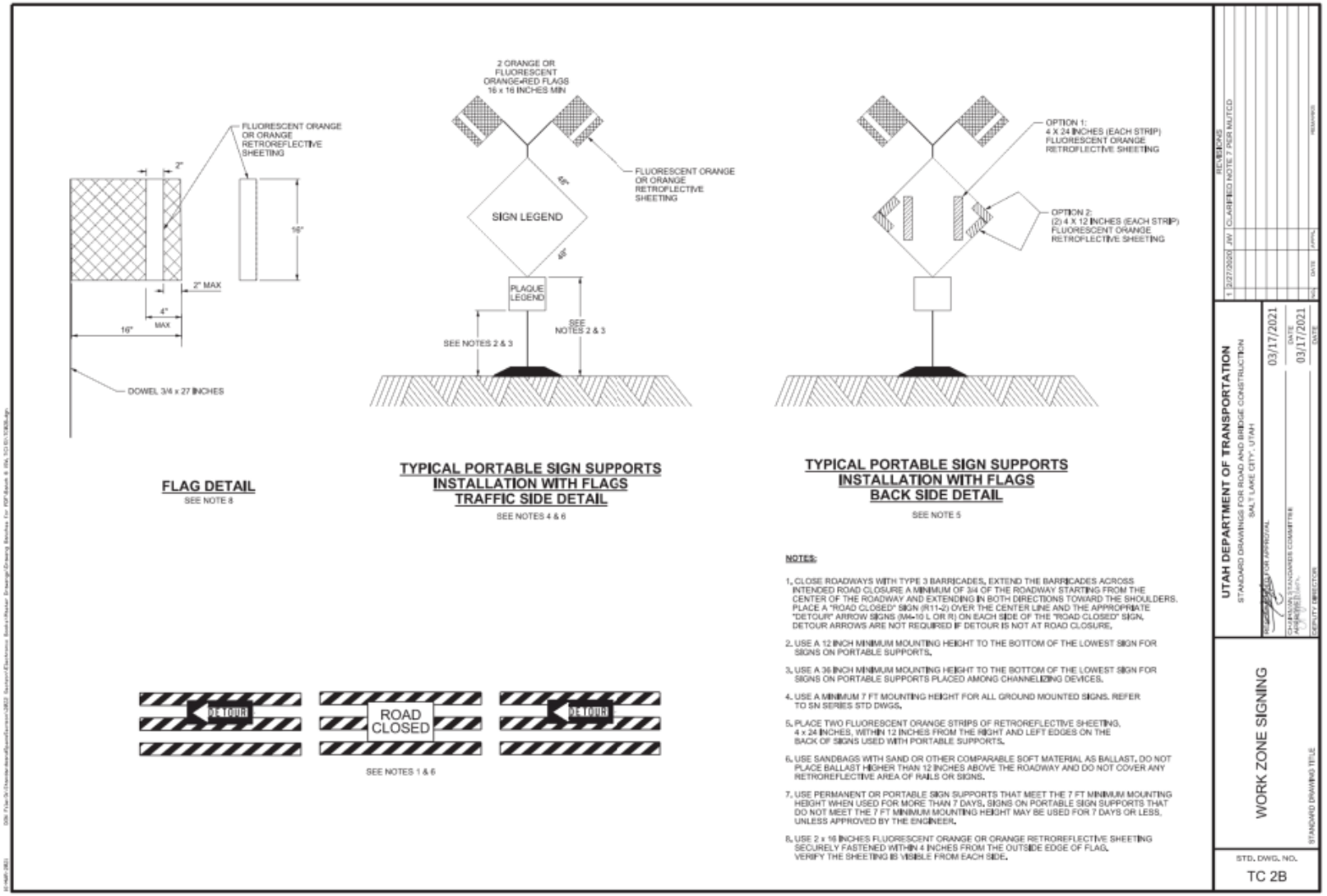


Figure 3.16: Utah Response to State Survey Q8.

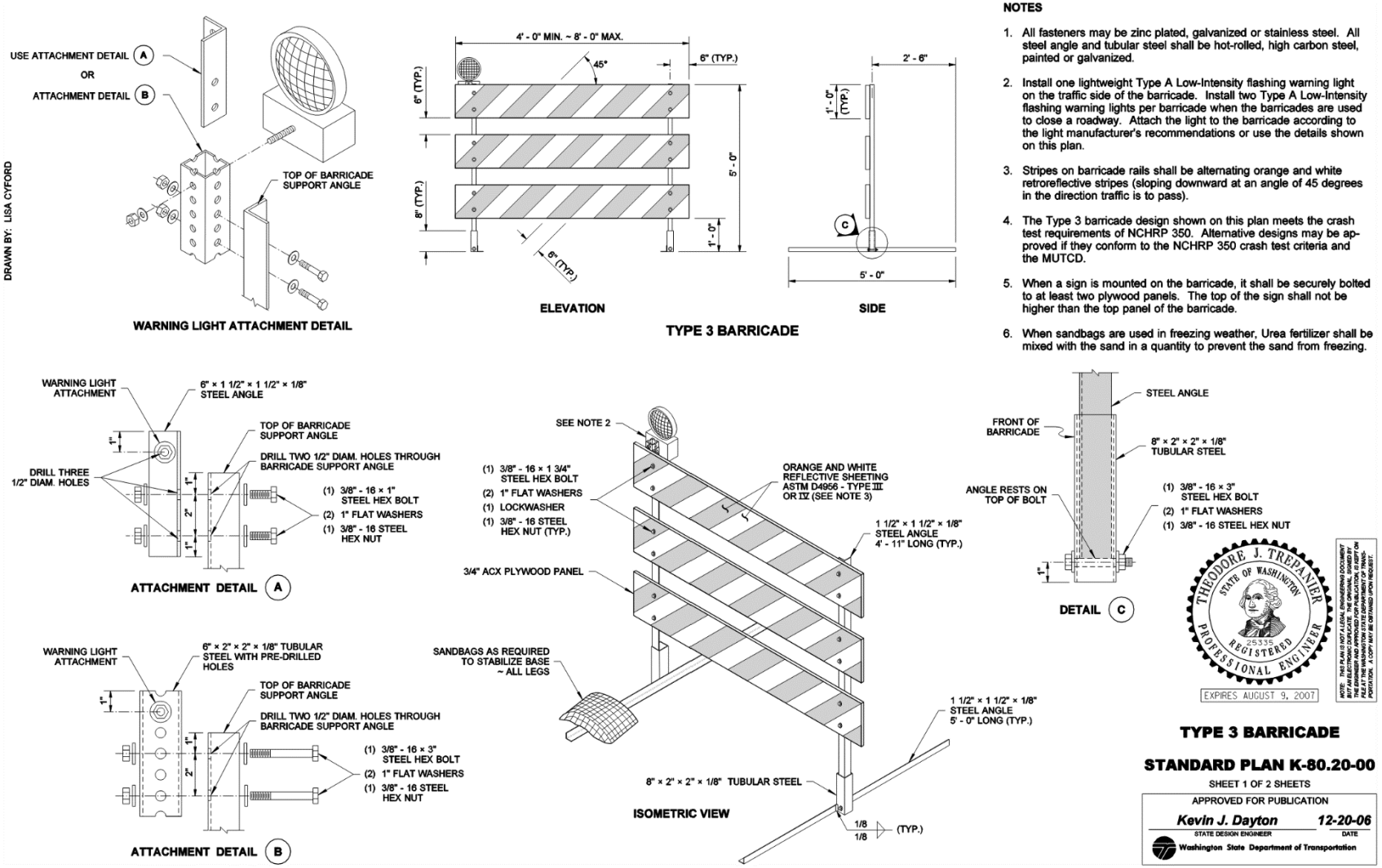


Figure 3.17: Washington Response to State Survey Q8 (1/2).

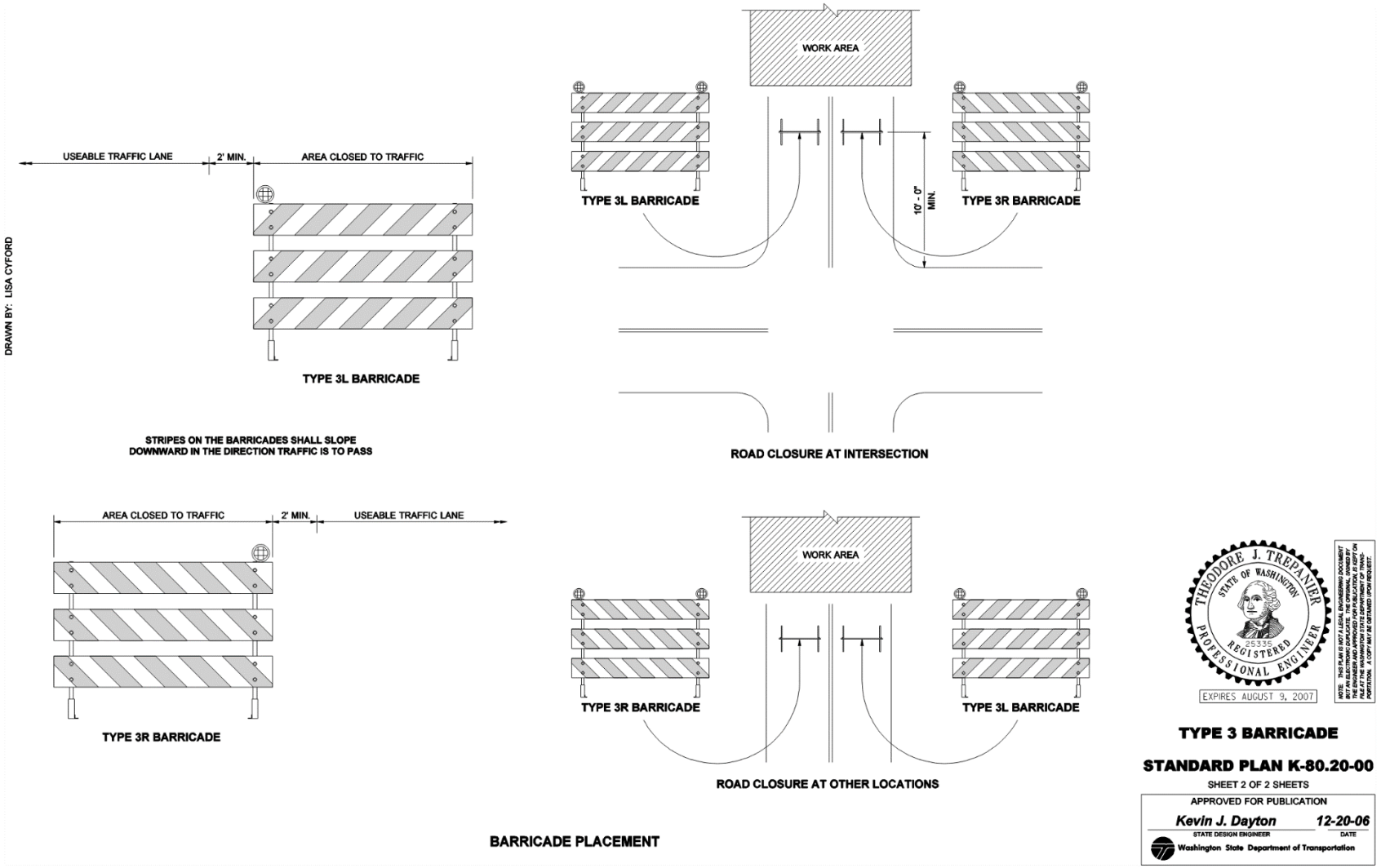


Figure 3.18: Washington Response to State Survey Q8 (2/2).

Q9 – Do you have any other information to share with the research team?

Table 3.2 Survey Participants' Responses to State Survey Q9.

Illinois	"The signs are normally 18 inches above grade, and always below the top rail, as it is shown on the attached standard 701901, sheet 3 of 3."
Louisiana	"Lights shall be mounted on the top uprights. Not through the top lightweight barricade panel. If struck, they will pull through the panel and become a projectile."
Massachusetts	"Note that the only signs we attach to Type III Barricades are directional signs for pedestrians (detour info, etc.) that are typically outside of the workzone clear zone or protected by barrier."
Minnesota	"We follow our details that were tested under NCHRP 350. If plastic panels are used into the future, it would be good to take into account cold weather effects."
Utah	"We do not attach signs above the Type III. We do not attach lights to devices. We use .08 inch aluminum for sign subsrate."

Chapter 4. SYSTEM DETAILS

4.1. TEST ARTICLE AND INSTALLATION DETAILS

The test installation consisted of a Type III barricade with a sign mounted above the horizontal boards. The barricade included PSST frame, nominal 1 × 8 × 48-inch dimensional lumber boards, a 48-inch x 0.10-inch thick square aluminum sign panel, and a beacon light assembly. Total weight of assembly was 115 lbs. Additionally, one 40-pound sandbag was placed on each end of all horizontal legs for a total of four bags. The top horizontal board was located with a maximum height of 60 inches, and the sign panel was placed in a diamond pattern, with the top corner at 10 ft-8 inches above grade.

Figure 2.1 presents the overall information on the Type III barricade with mounted sign, and Figure 2.2 thru Figure 2.7 provide photographs of the installation. Appendix A provides further details on the Type III barricade with mounted sign. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by TTI Proving Ground personnel.

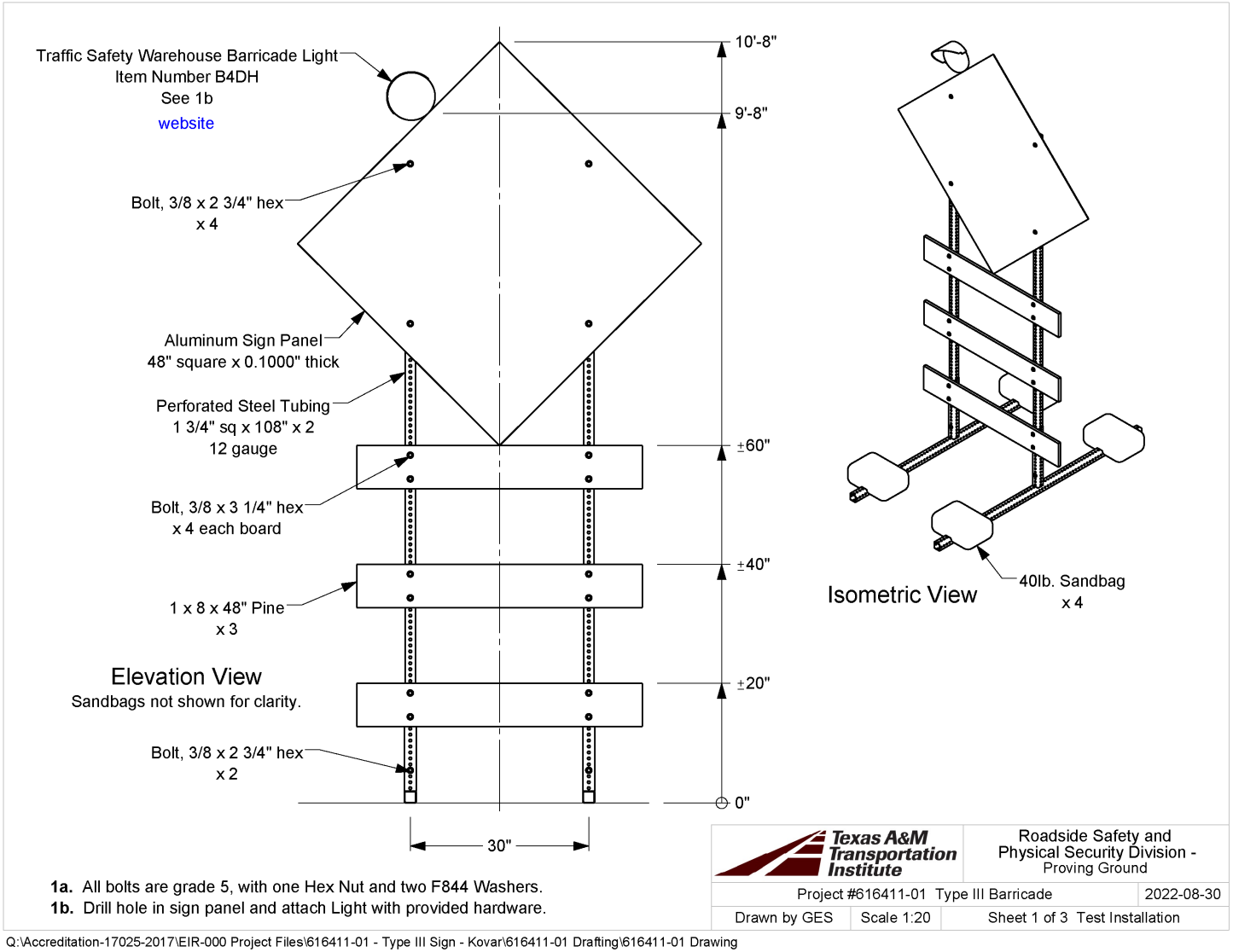


Figure 4.1. Details of Type III Barricade with Mounted Sign.

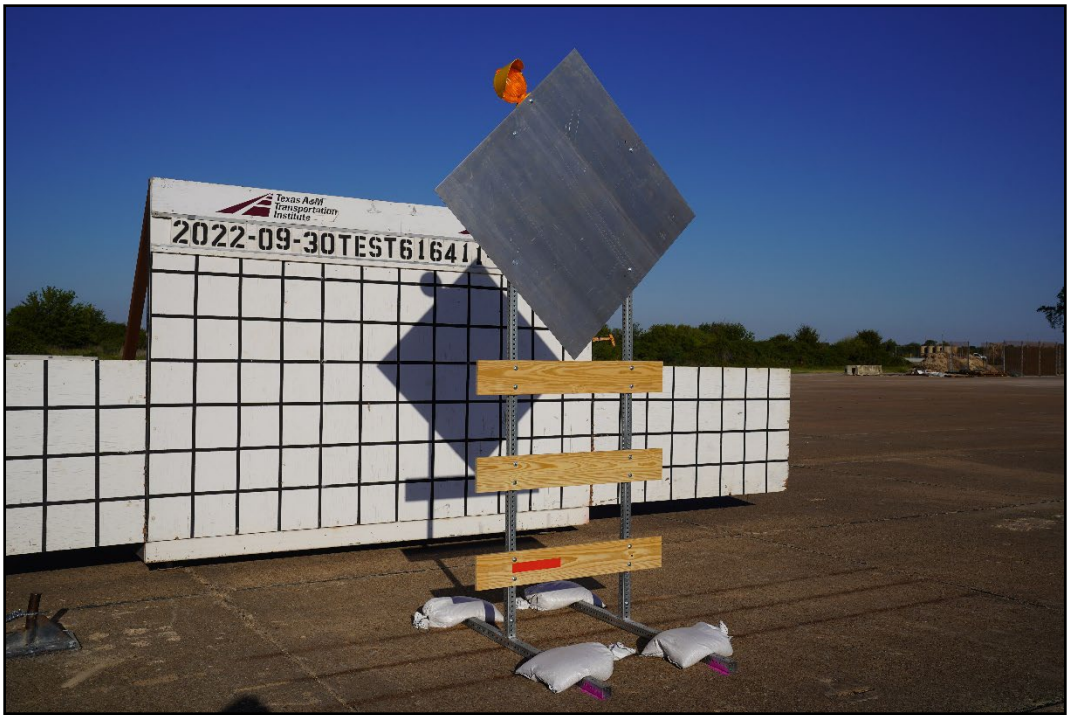


Figure 4.2. Type III Barricade with Mounted Sign prior to Testing.

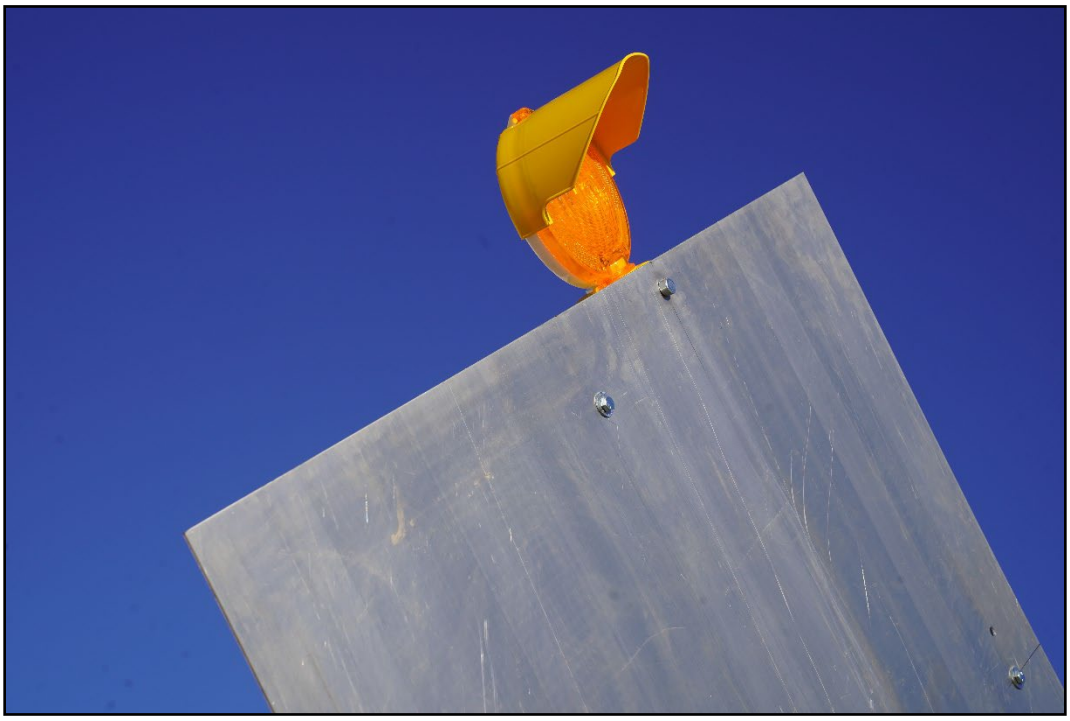


Figure 4.3. Flashing Light on Type III Barricade with Mounted Sign prior to Testing.

Figure 4.4. Base of Type III Barricade with Mounted Sign prior to Testing.

Figure 4.5. Rear View of the Base of the Type III Barricade with Mounted Sign prior to Testing.

Figure 4.6. Rear View of the Flashing Light on the Type III Barricade with Mounted Sign prior to Testing.

Figure 4.7. Pine Board and Hardware on theType III Barricade with Mounted Sign prior to Testing.

4.2. DESIGN MODIFICATIONS DURING TESTS

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

Chapter 5. TEST REQUIREMENTS AND EVALUATION CRITERIA

5.1. CRASH TEST PERFORMED/MATRIX

Table 3.1 shows the test conditions and evaluation criteria for *MASH* TL-3 Work-Zone Traffic Control Devices. The target critical impact points (CIPs) for each test were selected to maximize interaction of the barricade and sign with the vehicle and to promote the change of occupant compartment deformation and/or penetration. The target critical impact angles of 0 and 90 degree orientation were selected to represent most common in-field conditions. The 0 degree angle represents the visible condition which is utilized when the barricade is exposed to motorists' view. The 90 degree orientation represents the typical practice of rotating the sign 90 degrees to place it out-of-service. Figure 3.1 shows the target CIP for *MASH* Tests 3-71 and 3-72 on the Type III barricade with mounted sign.

MASH states that Test 3-70 is considered optional for work-zone traffic control devices weighing less than 220 lb because velocity changes during low-speed impacts with freestanding, lightweight features will be within acceptable limits (see MASH Paragraph 2.2.4.2 "Description of Tests"). Therefore, MASH Test 3-70 was not performed on the Type III barricade with mounted sign since each barricade weighed 115 lb (exclusive of the four ballast sand bags).

Table 5.1. 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	0º	B, D, E, F, H, I, N
3-71	1100C	62 mi/h	90º	B, D, E, F, H, I, N
3-72	2270P	62 mi/h	0º	B, D, E, F, H, I, N
3-72	2270P	62 mi/h	90º	B, D, E, F, H, I, N

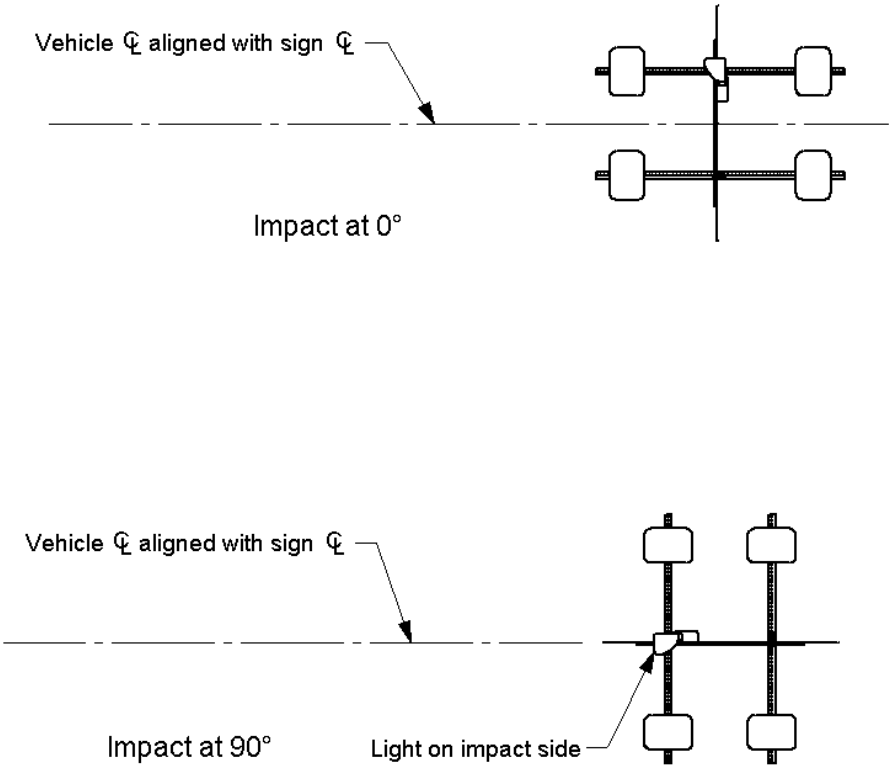


Figure 5.1. Target CIP for *MASH* TL-3 Tests on Type III Barricade with Mounted Sign.

The crash test procedures were in accordance with guidelines presented in *MASH*. Chapter 4 presents brief descriptions of these procedures.

5.2. EVALUATION CRITERIA

The appropriate safety evaluation criteria from Tables 2.5 and 5.1 of *MASH* were used to evaluate the crash tests reported herein. Table 5.1 lists the test conditions and evaluation criteria required for *MASH* TL-3, and Table 5.2 provides detailed information on the evaluation criteria.

Table 5.2. Evaluation Criteria Required for *MASH* Testing.

Evaluation Factors	Evaluation Criteria	*MASH* Test
B.	The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.	71, 72
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*.	71, 72

Evaluation Factors	**Evaluation Criteria**	***MASH* Test**
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.	71, 72
F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	71, 72
H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s, or maximum allowable value of 16 ft/s.	71, 72
I.	The occupant ridedown accelerations should satisfy the following: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	71, 72
N.	Vehicle trajectory behind the test article is acceptable.	71, 72

Chapter 6. TEST CONDITIONS

6.1. TEST FACILITY

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

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

6.2. VEHICLE TOW AND GUIDANCE SYSTEM

Each test vehicle 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.

6.3. DATA ACQUISITION SYSTEMS

6.3.1. Vehicle Instrumentation and Data Processing

MASH does not require instrumentation of the vehicle when impacting lightweight, freestanding work-zone traffic control devices weighing less than 220 lb. Each test article weighed 115 lb (excluding the sand bags). Consequently, the vehicle was not instrumented and occupant risk factors were not calculated for this test per *MASH* Section 2.2.4.2 “Description of Tests.” Roll and pitch were checked via video analysis to visually verify that the vehicle did not exceed 75 degrees on either axis.

6.3.2. 4.3.2. 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 opposite side of impact 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.

6.3.3. Photographic Instrumentation Data Processing

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

- One located at a right angle to the installation to have a field of view of the vehicle and installation at impact.
- One placed downstream from the installation at an angle to have an oblique view of the vehicle and installation at impact.

A flashbulb on the impacting vehicle was activated by a pressure-sensitive tape switch to indicate the instant of contact with the Type III barricade with mounted sign. 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 7. *MASH* TEST 3-71 (CRASH TEST NO. 616411-01-1)

7.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 5.1 for details on *MASH* impact conditions for this test and Table 5.2 for the exit parameters. Figure 5.1 and Figure 5.2 depict the target impact setup.

Table 7.1. Impact Conditions for *MASH* 3-71 616411-01-1.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5 mi/h	61.7
Impact Angle (deg)	90	±1.5°	90
Kinetic Energy (kip-ft)	288	≥288 kip-ft	309
Impact Location	Centerline of the vehicle aligned with the centerline of the barricade.	± 6 inches	Centerline of the vehicle aligned with the centerline of the barricade.

Table 7.2. Exit Parameters for *MASH* 3-71 616411-01-1.

Exit Parameter	Measured
Speed (mi/h)	57
Time of Brake Application post impact (s)	5
Vehicle at rest position	390 ft downstream of impact point. In-line with the installation. Oriented 45° to the left side.
Comments:	Vehicle remained upright and stable. Neither Pitch nor Roll exceeded 75 degrees.

Figure 7.1. Type III Barricade with Mounted Sign/Test Vehicle Geometrics for Test 616411-01-1.

Figure 7.2. Type III Barricade with Mounted Sign/Test Vehicle Impact Location 616411-01-1.

7.2. WEATHER CONDITIONS

Table 5.3 provides the weather conditions for 616411-01-1.

Table 7.3. Weather Conditions 616411-01-1.

Date of Test	September 30th, 2022
Wind Speed (mi/h)	4
Wind Direction (deg)	94
Temperature (°F)	68
Relative Humidity (%)	59
Vehicle Traveling (deg)	350

7.3. TEST VEHICLE

Figure 5.3 and Figure 5.4 show the 2017 Nissan Versa used for the crash test. Table 5.4 shows the vehicle measurements. Table B.1 in Appendix B.1 gives additional dimensions and information on the vehicle.

Figure 7.3. Impact Side of Test Vehicle before Test 616411-01-1.

Figure 7.4. Interior of the Test Vehicle before Test 616411-01-1.

Table 7.4. Vehicle Measurements 616411-01-1.

Test Parameter	*MASH*	Allowed Tolerance	Measured
Dummy (if applicable)[a] (lb)	165	N/A	165
Vehicle Inertial Weight (lb)	2420	±55 lb	2428
Gross Static[a] (lb)	2585	±55	2593
Wheelbase (inches)	98	±5	102.4
Front Overhang (inches)	35	±4	32.5
Overall Length (inches)	169	±8	175.4
Overall Width (inches)	65	±3	66.7
Hood Height (inches)	28	±4	30.5
Track Width[b] (inches)	59	±2	58.4
CG aft of Front Axle[c] (inches)	39	±4	42.0

[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.

7.4. TEST DESCRIPTION

Table 5.5 lists events that occurred during Test No. 616411-01-1. Figures B.1 and B.2 in Appendix B.2 present sequential photographs during the test.

Table 7.5. Events during Test 616411-01-1.

Time (s)	Events
0.0000	Vehicle impacted the installation
0.0040	Lower wood plank and supports began to move downstream
0.0180	Lower wood plank began to split
0.0830	Top wood plank impacted hood
0.2390	Corner of Aluminum sign impacted roof near windshield

7.5. DAMAGE TO TEST INSTALLATION

The wood debris started at 75 feet downstream and extended 42 feet to the right and 18 feet to the left of impact. The remainder of the sign was 300 feet downstream and 4 feet to the right of the installation. Figure 5.5 and Figure 5.6 show the damage to the Type III barricade with mounted sign.

Figure 7.5. Type III Barricade with Mounted Sign after Test at Impact Location 616411-01-1.

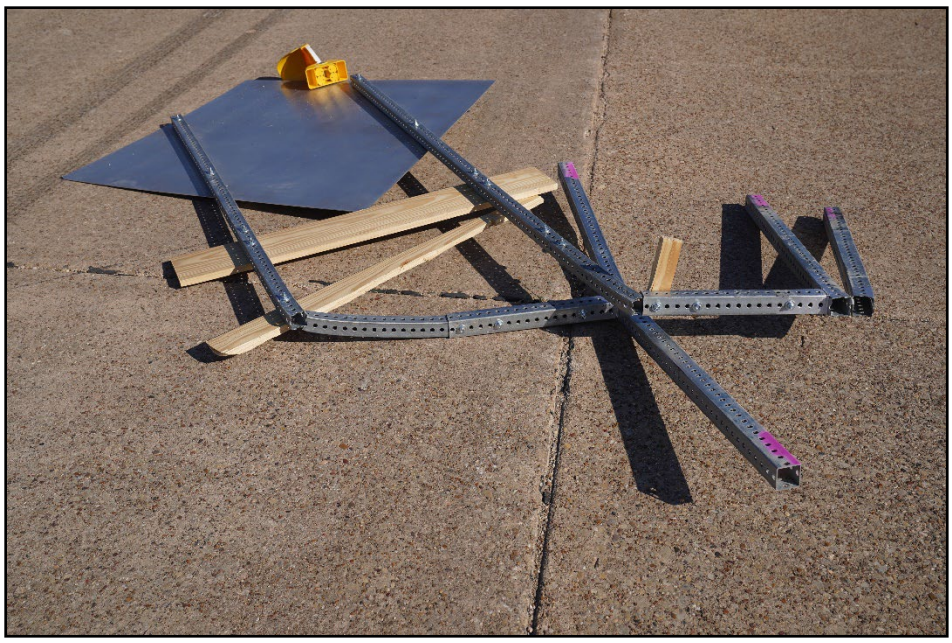


Figure 7.6. Type III Barricade with Mounted Sign after Test at its Final Location 616411-01-1.

7.6. DAMAGE TO TEST VEHICLE

Figure 5.7 and Figure 5.8 show the damage sustained by the vehicle. Figure 5.9 and Figure 5.10 show the interior of the test vehicle. Table 5.6 and Table 5.7 provide details on the occupant compartment deformation and exterior vehicle damage. Tables B.2 and B.3 in Appendix B.1 provide exterior crush and occupant compartment measurements.

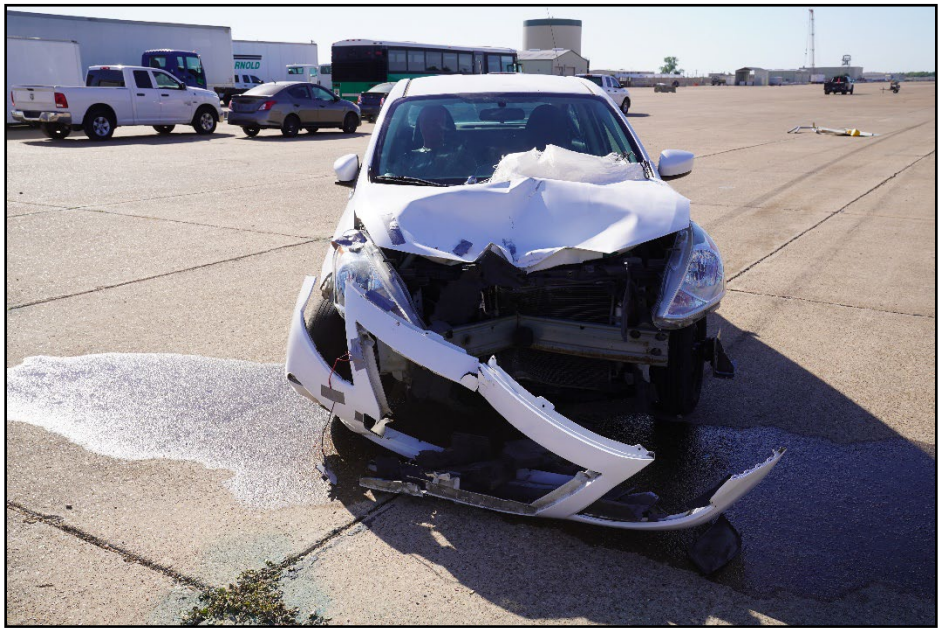


Figure 7.7. Impact Side of Test Vehicle after Test 616411-01-1.

Figure 7.8. Front Bumper of Test Vehicle after Test 616411-01-1.

Figure 7.9. Overall Interior of Test Vehicle after Test 616411-01-1.

Figure 7.10. Interior of Test Vehicle on Impact Side after Test 616411-01-1.

Table 7.6. Occupant Compartment Deformation 616411-01-1.

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

Table 7.7. Exterior Vehicle Damage 616411-01-1.

Side Windows	The side windows remained intact
Maximum Exterior Deformation	12 inches in the front plane at bumper height
VDS	12FC6
CDC	12FCAN5
Fuel Tank Damage	None
Description of Damage to Vehicle:	The front bumper, hood, grill, radiator and support were damaged. The hood had a 36-inch × 20-inch × 6-inch deep dent. There were also some scuff marks on the left front center of the roof.

7.7. OCCUPANT RISK FACTORS

MASH does not require instrumentation of the vehicle when impacting lightweight, freestanding work-zone traffic control devices weighing less than 220 lb. Each test article

weighed 115 lb (excluding the sand bags). Consequently, the vehicle was not instrumented and occupant risk factors were not calculated for this test per *MASH* Section 2.2.4.2 “Description of Tests.”

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Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-71
TTI Project No.	616411-01-1
Test Date	2022-09-30
TEST ARTICLE	
Type	Work-Zone Traffic Control Device
Name	Type III barricade with mounted sign
Height	10 ft 8 inches
Key Materials	12 GA Perforated Steel Tubing, 48-inch square Aluminum Sign Panel, 1×8×48-inch pine boards
Soil Type and Condition	Concrete, Dry
TEST VEHICLE	
Type/Designation	1100 C
Year, Make and Model	2017 Nissan Versa
Inertial Weight (lb)	2428
Dummy (lb)	165
Gross Static (lb)	2593
IMPACT CONDITIONS	
Impact Speed (mi/h)	61.7
Impact Angle (deg)	90
Impact Location	Centerline of the vehicle aligned with the centerline of the barricade.
Impact Severity (kip-ft)	309
EXIT CONDITIONS	
Exit Speed (mi/h)	57
Stopping Distance	390 ft downstream In-line with impact
VEHICLE DAMAGE	
VDS	12FC6
CDC	12FCAN5
Max. Ext. Deformation	12
Max Occupant Compartment Deformation	No occupant compartment deformation

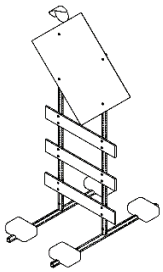

Figure 7.11. Summary of Results for *MASH* Test 3-71 on Type III Barricade with Mounted Sign.

Chapter 8. *MASH* TEST 3-71 (CRASH TEST NO. 616411-01-2)

8.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 6.1 for details on *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 8.1. Impact Conditions for *MASH* 3-71 616411-01-2.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5 mi/h	61.7
Impact Angle (deg)	0	±1.5°	0
Kinetic Energy (kip-ft)	288	≥288 kip-ft	308.9
Impact Location	Centerline of the vehicle aligned with the centerline of the barricade.	± 6 inches	Centerline of the vehicle aligned with the centerline of the barricade.

Table 8.2. Exit Parameters for *MASH* 3-71 616411-01-2.

Exit Parameter	Measured
Speed (mi/h)	57.9
Time of Brake Application post impact (s)	4
Vehicle at rest position	375 ft downstream of impact point. 4 ft to the left side. Oriented 30° to the right side.
Comments:	Vehicle remained upright and stable. Neither Pitch nor Roll exceeded 75 degrees..

Figure 8.1. Type III Barricade with Mounted Sign/Test Vehicle Geometrics for Test 616411-01-2.

Figure 8.2. Type III Barricade with Mounted Sign/Test Vehicle Impact Location 616411-01-2.

8.2. WEATHER CONDITIONS

Table 6.3 provides the weather conditions for 616411-01-2.

Table 8.3. Weather Conditions 616411-01-2.

Date of Test	September 30th, 2022
Wind Speed (mi/h)	4
Wind Direction (deg)	140
Temperature (°F)	74
Relative Humidity (%)	45
Vehicle Traveling (deg)	350

8.3. 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. Table C.1 in Appendix C.1 gives additional dimensions and information on the vehicle.

Figure 8.3. Impact Side of Test Vehicle before Test 616411-01-2.

Figure 8.4. Interior of the Impact Side of Test Vehicle before Test 616411-01-2.

Table 8.4. Vehicle Measurements 616411-01-2.

Test Parameter	*MASH*	Allowed Tolerance	Measured
Dummy (if applicable)[a] (lb)	165	N/A	165
Vehicle Inertial Weight (lb)	2420	±55 lb	2427
Gross Static[a] (lb)	2585	±25	2592
Wheelbase (inches)	98	±5	102.4
Front Overhang (inches)	35	±4	32.5
Overall Length (inches)	169	±8	175.4
Overall Width (inches)	65	±3	66.7
Hood Height (inches)	28	±4	30.5
Track Width[b] (inches)	59	±2	58.4
CG aft of Front Axle[c] (inches)	39	±4	42.6

[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.

8.4. TEST DESCRIPTION

Table 6.5 lists events that occurred during Test No. 616411-01-2. Figures C.1 and C.2 in Appendix C.2 present sequential photographs during the test.

Table 8.5. Events during Test 616411-01-2.

Time (s)	Events
0.0000	Vehicle impacted the installation
0.0060	Base began to slide downstream
0.0090	Support posts began to bend, and bottom board began to fracture
0.0130	Support posts fractured just above lower wood board
0.0810	Sign contacted the roof near the windshield

8.5. DAMAGE TO TEST INSTALLATION

The sign remained mostly intact and stayed in front of the car. Figure 6.5 and Figure 6.6 show the damage to the Type III barricade with mounted sign.

Figure 8.5. Type III Barricade with Mounted Sign after Test 616411-01-2.

Figure 8.6. Type III Barricade with Mounted Sign after Test After Being Removed from the Vehicle 616411-01-2.

8.6. DAMAGE TO TEST VEHICLE

Figure 6.7 and Figure 6.8 show the damage sustained by the vehicle. Figure 6.9 and Figure 6.10 show the interior of the test vehicle. Table 6.6 and Table 6.7 provide details on the occupant compartment deformation and exterior vehicle damage. Tables C.2 and C.3 in Appendix C.1 provide exterior crush and occupant compartment measurements.

Figure 8.7. Impact Side of Test Vehicle after Test 616411-01-2.

Figure 8.8. Rear Impact Side of Test Vehicle after Test 616411-01-2.

Figure 8.9. Overall Interior of Test Vehicle after Test 616411-01-2.

Figure 8.10. Detail View of the Interior of Test Vehicle after Test 616411-01-2.

Table 8.6. Occupant Compartment Deformation 616411-01-2.

Test Parameter	Specification	Measured
Roof	≤4.0 inches	2.75 inches
Windshield	≤3.0 inches	2.6 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 616411-01-2.

Side Windows	The side windows remained intact
Maximum Exterior Deformation	2 inches in the front plane at bumper height
VDS	12FC3
CDC	12FCAW6
Fuel Tank Damage	None
Description of Damage to Vehicle:	The front bumper, hood, grill, right and left head lights, left front fender, windshield and roof were damaged. The windshield had a 38-inch × 16-inch × 2⅝-inch deep deformation, and there was a 1-inch hole where the rearview mirror mounts to the windshield. The hole was caused by the windshield flexing, which caused the rearview mirror to pop out. The hole was not caused by penetration or potential penetration of the test article. The roof had a 38-inch × 30-inch × 2¾-inch deep dent.

8.7. OCCUPANT RISK FACTORS

MASH does not require instrumentation of the vehicle when impacting lightweight, freestanding work-zone traffic control devices weighing less than 220 lb. Each test article weighed 115 lb (excluding the sand bags). Consequently, the vehicle was not instrumented and occupant risk factors were not calculated for this test per *MASH* Paragraph 2.2.4.2 “Description of Tests.”

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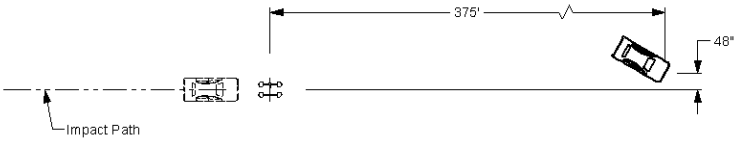
0.300 s

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-71
TTI Project No.	616411-01-2
Test Date	2022-09-30
TEST ARTICLE	
Type	Work-Zone Traffic Control Device
Name	Type III barricade with mounted sign
Height	10 ft 8 inches
Key Materials	12 GA Perforated Steel Tubing, 48-inch square Aluminum Sign Panel, 1×8×48-inch pine boards
Soil Type and Condition	Concrete, Dry
TEST VEHICLE	
Type/Designation	1100 C
Year, Make and Model	2017 Nissan Versa
Inertial Weight (lb)	2427
Dummy (lb)	165
Gross Static (lb)	2592
IMPACT CONDITIONS	
Impact Speed (mi/h)	61.7
Impact Angle (deg)	0
Impact Location	Centerline of the vehicle aligned with the centerline of the barricade.
Impact Severity (kip-ft)	308.9
EXIT CONDITIONS	
Exit Speed (mi/h)	57.9
Stopping Distance	375 ft downstream 4 ft to the left side
VEHICLE DAMAGE	
VDS	12FC3
CDC	12FCAW6
Max. Ext. Deformation	2
Max Occupant Compartment Deformation	2.75 inches in the roof



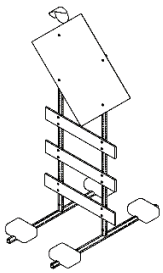


Figure 8.11. Summary of Results for *MASH* Test 3-71 on Type III Barricade with Mounted Sign.

Chapter 9. *MASH* TEST 3-72 (CRASH TEST NO. 616411-01-3)

9.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 7.1 for details on *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 9.1. Impact Conditions for *MASH* 3-72 616411-01-3.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62 mi/h	± 2.5 mi/h	61.9
Impact Angle (deg)	0°	± 1.5°	0
Kinetic Energy (kip-ft)	594 kip-ft	≥594 kip-ft	645.2
Impact Location	Centerline of the vehicle aligned with the centerline of the barricade.	± 6 inches	Centerline of the vehicle aligned with the centerline of the barricade.

Table 9.2. Exit Parameters for *MASH* 3-72 616411-01-3.

Exit Parameter	Measured
Speed (mi/h)	59.2
Time of Brake Application (s)	3
Vehicle at rest position	375 ft downstream of impact point In-line Oriented 10° to the driver's side
Comments:	Vehicle remained upright and stable. Neither Pitch nor Roll exceeded 75 degrees.

Figure 9.1. Type III Barricade with Mounted Sign/Test Vehicle Geometrics for Test 616411-01-3.

Figure 9.2. Type III Barricade with Mounted Sign/Test Vehicle Impact Location 616411-01-3.

9.2. WEATHER CONDITIONS

Table 7.3 provides the weather conditions for 616411-01-3.

Table 9.3. Weather Conditions 616411-01-3.

Date of Test	September 30th, 2022
Wind Speed (mi/h)	3
Wind Direction (deg)	48
Temperature (°F)	79
Relative Humidity (%)	34
Vehicle Traveling (deg)	350

9.3. TEST VEHICLE

Figure 7.3 and Figure 7.4 show the 2016 RAM 1500 used for the crash test. Table 7.4 shows the vehicle measurements. Table D.1 in Appendix D.1 gives additional dimensions and information on the vehicle.

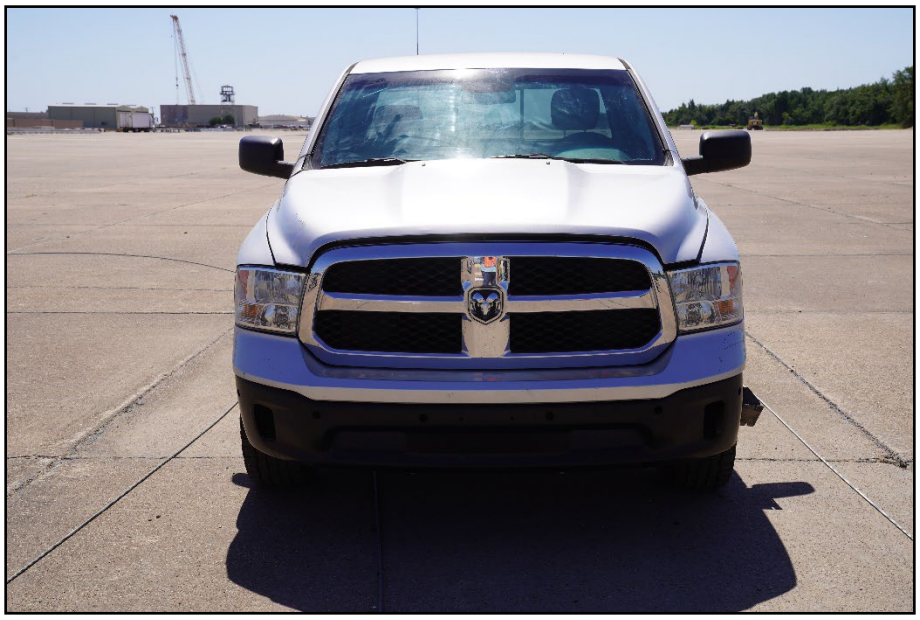


Figure 9.3. Impact Side of Test Vehicle before Test 616411-01-3.

Figure 9.4. Overall Interior of the Test Vehicle before Test 616411-01-3.

Table 9.4. Vehicle Measurements 616411-01-3.

Test Parameter	*MASH*	Allowed Tolerance	Measured
Dummy (if applicable)[a] (lb)	165	N/A	N/A
Inertial Weight (lb)	5000	± 110	5037
Gross Static[a] (lb)	5000	± 110	5037
Wheelbase (inches)	148	±12	140.5
Front Overhang (inches)	39	±3	40
Overall Length (inches)	237	±13	227.5
Overall Width (inches)	78	±2	78.5
Hood Height (inches)	43	±4	46.0
Track Width[b] (inches)	67	±1.5	68.25
CG aft of Front Axle[c] (inches)	63	±4	61.1
CG above Ground[c,d] (inches)	28	≥28	28.6

[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 7.5 lists events that occurred during Test No. 616411-01-3. Figures D.1 and D.2 in Appendix D.2 present sequential photographs during the test.

Table 9.5. Events during Test 616411-01-3.

Time (s)	Events
0.0000	Vehicle impacted the installation
0.0020	Sign Supports posts began to bend at impact
0.0050	Supports began to move downstream
0.1000	Right sign support began to break just above lower wooden board
0.0700	Top corner of sign contacted roof near windshield
0.2070	Vehicle lost contact with sign

9.5. DAMAGE TO TEST INSTALLATION

The sign came to rest 335 feet downstream and 54 feet to the left of impact and was intact with the exception of the bottom board, which had splintered and broke away. Figure 7.5 and Figure 7.6 show the damage to the Type III barricade with mounted sign.

Figure 9.5. Type III Barricade with Mounted Sign after Test at Impact Location 616411-01-3.

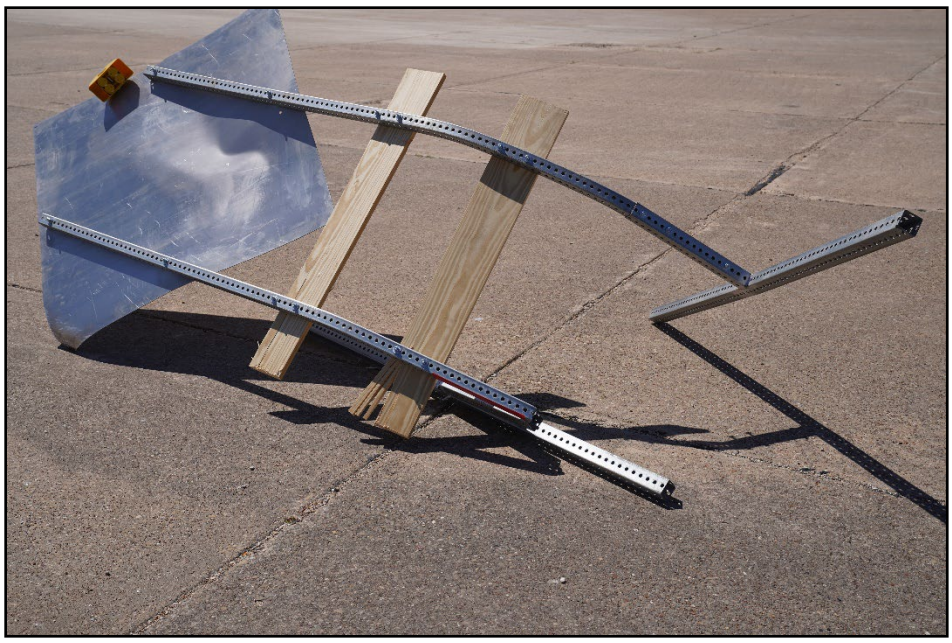


Figure 9.6. Type III Barricade with Mounted Sign after Test at its Final Resting Location 616411-01-3.

9.6. DAMAGE TO TEST VEHICLE

Figure 7.7 and Figure 7.8 show the damage sustained by the vehicle. Figure 7.9 and Figure 7.10 show the interior of the test vehicle. Table 7.6 and Table 7.7 provide details on the occupant compartment deformation and exterior vehicle damage. Tables D.2 and D.3 in Appendix D.1 provide exterior crush and occupant compartment measurements.

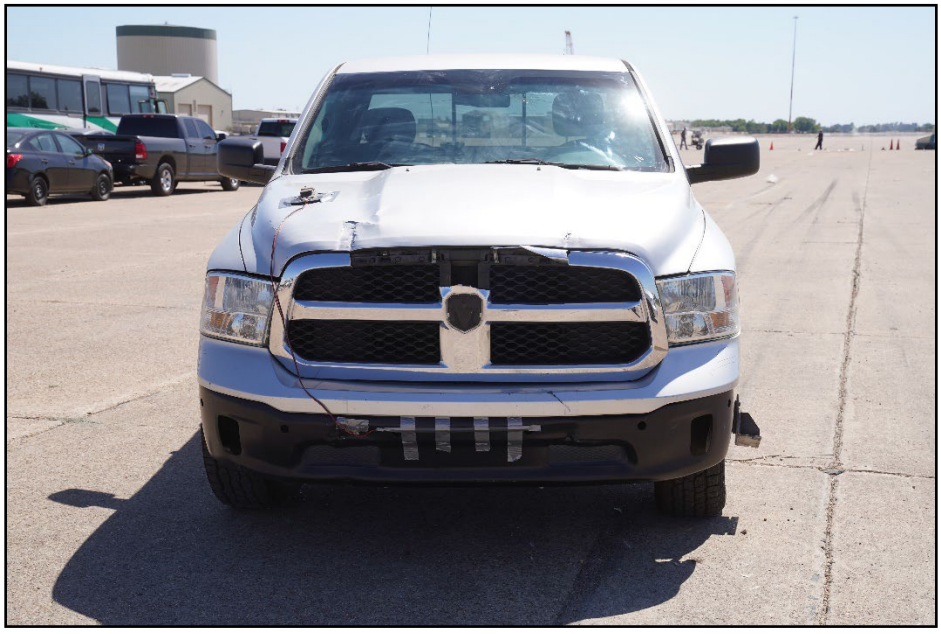


Figure 9.7. Impact Side of Test Vehicle after Test 616411-01-3.

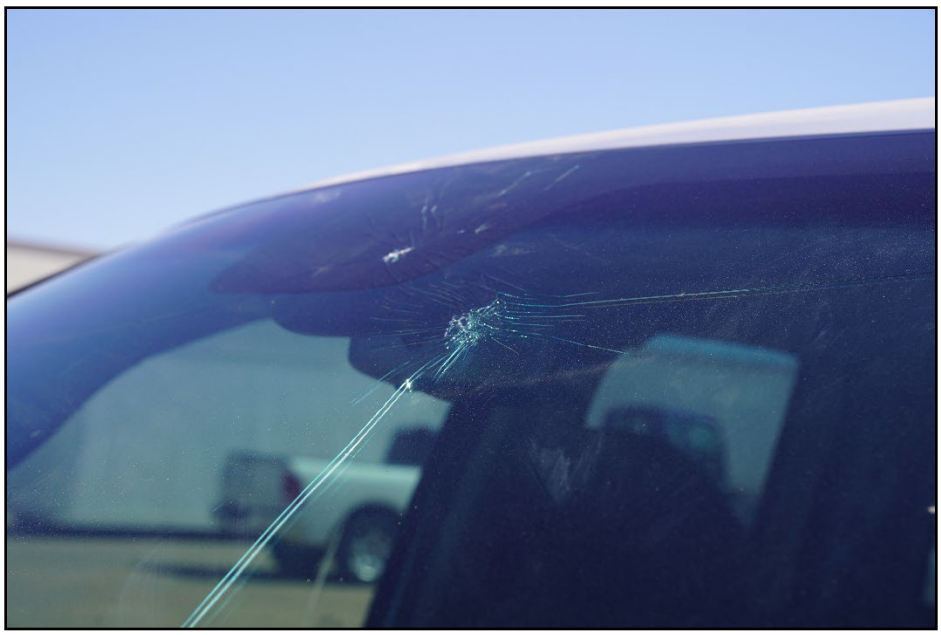


Figure 9.8. Windshield of Test Vehicle after Test 616411-01-3.

Figure 9.9. Overall Interior of Test Vehicle after Test 616411-01-3.

Figure 9.10. Interior of Test Vehicle on Impact Side after Test 616411-01-3.

Table 9.6. Occupant Compartment Deformation 616411-01-3.

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 9.7. Exterior Vehicle Damage 616411-01-3.

Side Windows	Side windows remained intact
Maximum Exterior Deformation	0.5 inches in the front plane at bumper height
VDS	12FC1
CDC	12FCAN1
Fuel Tank Damage	None
Description of Damage to Vehicle:	The front bumper, grill, hood, and windshield were damaged. There were two small dents on the front bumper, 30 inches apart and measuring 0.5 inch deep. The hood had two dents, 0.5 inches deep and 2 inches wide. One was 6 inches long and the other was 3 inches long. The windshield had some cracks but no holes or tears in the laminate.

9.7. OCCUPANT RISK FACTORS

MASH does not require instrumentation of the vehicle when impacting lightweight, freestanding work-zone traffic control devices weighing less than 220 lb. Each test article weighed 115 lb (excluding the sand bags). Consequently, the vehicle was not instrumented, and occupant risk factors were not calculated for this test per *MASH* Paragraph 2.2.4.2 “Description of Tests.”

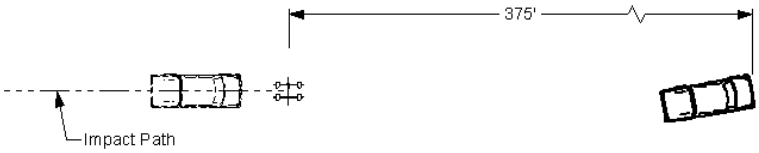
0.000 s

0.100 s

0.200 s

0.300 s

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-72
TTI Project No.	616411-01-3
Test Date	2022-09-30
TEST ARTICLE	
Type	Work-Zone Traffic Control Device
Name	Type III barricade with mounted sign
Height	10 ft 8 inches
Key Materials	12 GA Perforated Steel Tubing, 48-inch square Aluminum Sign Panel, 1×8×48-inch pine boards
Soil Type and Condition	Concrete, Dry
TEST VEHICLE	
Type/Designation	2270P
Year, Make and Model	2016 RAM 1500
Inertial Weight (lb)	5037
Dummy (lb)	N/A
Gross Static (lb)	5037
IMPACT CONDITIONS	
Impact Speed (mi/h)	61.9
Impact Angle (deg)	0
Impact Location	Centerline of the vehicle aligned with the centerline of the barricade.
Impact Severity (kip-ft)	645.2
EXIT CONDITIONS	
Exit Speed (mi/h)	59.2
Stopping Distance	375 ft downstream In-line
VEHICLE DAMAGE	
VDS	12FC1
CDC	12FCAN1
Max. Ext. Deformation	0.5
Max Occupant Compartment Deformation	No occupant compartment deformation



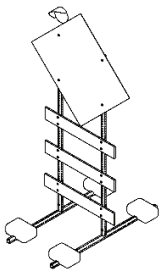


Figure 9.11. Summary of Results for *MASH* Test 3-72 on Type III Barricade with Mounted Sign.

Chapter 10. *MASH* TEST 3-72 (CRASH TEST NO. 616411-01-4)

10.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 8.1 for details on *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 10.1. Impact Conditions for *MASH* 3-72 616411-01-4.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62 mi/h	± 2.5 mi/h	60.4
Impact Angle (deg)	90°	± 1.5°	90
Kinetic Energy (kip-ft)	594 kip-ft	≥594 kip-ft	614.3
Impact Location	Centerline of the vehicle aligned with the centerline of the barricade.	± 6 inches	Centerline of the vehicle aligned with the centerline of the barricade.

Table 10.2. Exit Parameters for *MASH* 3-72 616411-01-4.

Exit Parameter	Measured
Speed (mi/h)	59.4
Brakes applied post impact (s)	3
Vehicle at rest position	345 ft downstream of impact point In-line with the installation
Comments:	Vehicle remained upright and stable. Neither Pitch nor Roll exceeded 75 degrees..

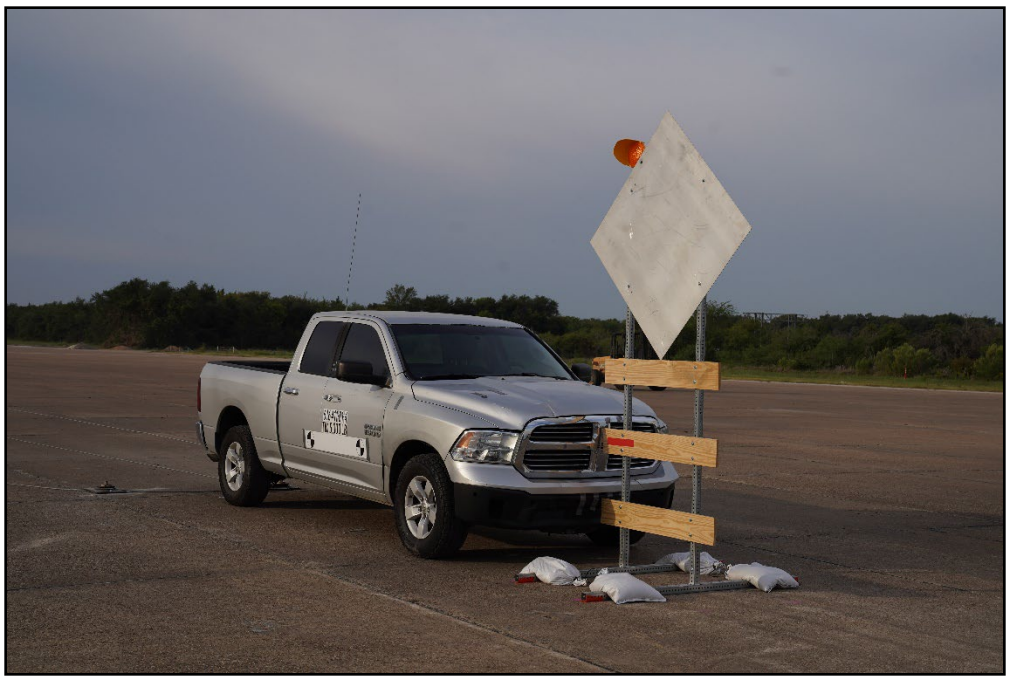


Figure 10.1. Type III Barricade with Mounted Sign/Test Vehicle Geometrics for Test 616411-01-4.

Figure 10.2. Type III Barricade with Mounted Sign/Test Vehicle Impact Location 616411-01-4.

10.2. WEATHER CONDITIONS

Table 8.3 provides the weather conditions for 616411-01-4.

Table 10.3. Weather Conditions 616411-01-4.

Date of Test	October 7th, 2022
Wind Speed (mi/h)	2
Wind Direction (deg)	184
Temperature (°F)	75
Relative Humidity (%)	73
Vehicle Traveling (deg)	350

10.3. TEST VEHICLE

Figure 8.3 and Figure 8.4 show the 2016 RAM 1500 used for the crash test. Table 8.4 shows the vehicle measurements. Table E.1 in Appendix E.1 gives additional dimensions and information on the vehicle.

Figure 10.3. Impact Side of Test Vehicle before Test 616411-01-4.

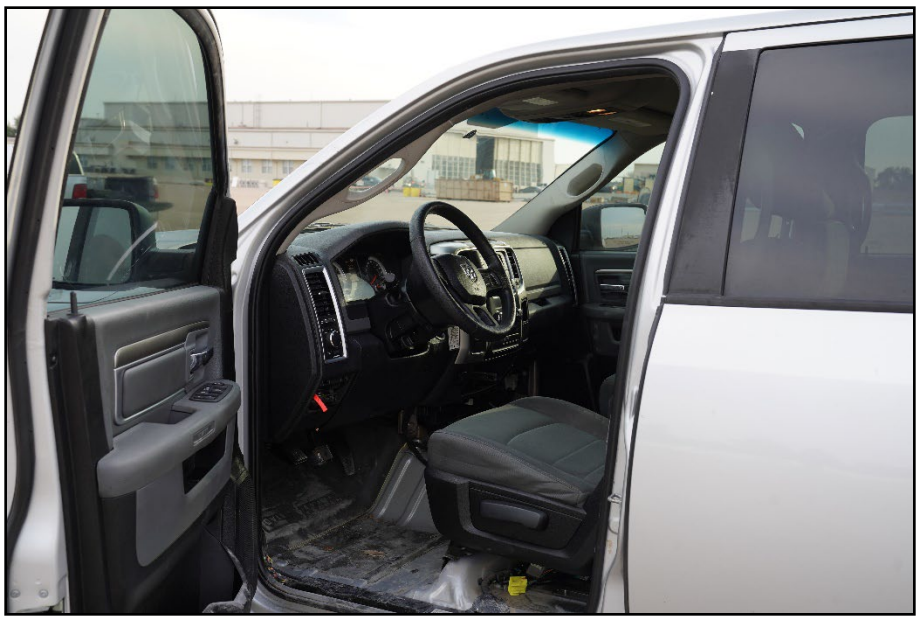


Figure 10.4. Overall Interior of Test Vehicle before Test 616411-01-4.

Table 10.4. Vehicle Measurements 616411-01-4.

Test Parameter	*MASH*	Allowed Tolerance	Measured
Dummy (if applicable)[a] (lb)	165	N/A	N/A
Vehicle Inertial Weight (lb)	5000 lbs	± 110 lbs	5037
Gross Static[a] (lb)	5000	± 110	5037
Wheelbase (inches)	148	±12	140.5
Front Overhang (inches)	39	±3	40.0
Overall Length (inches)	237	±13	227.5
Overall Width (inches)	78	±2	78.5
Hood Height (inches)	43	±4	46.0
Track Width[b] (inches)	67	±1.5	68.25
CG aft of Front Axle[c] (inches)	63	±4	61.1
CG above Ground[c,d] (inches)	28	≥28	28.6

[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 8.5 lists events that occurred during Test No. 616411-01-4. Figures E.1 and E.2 in Appendix E.2 present sequential photographs during the test.

Table 10.5. Events during Test 616411-01-4.

Time (s)	Events
0.0000	Vehicle impacted the installation
0.0100	Low board began to fracture
0.0140	Base of sign began to move
0.2190	The sign begins rotating towards the right side of the vehicle

10.5. DAMAGE TO TEST INSTALLATION

The sign assembly landed 270 feet downstream and 37.5 feet to the right of impact. One lower board and one skid was missing from the assembly. The skid was trapped underneath the vehicle. Figure 8.5 and Figure 8.6 show the damage to the Type III barricade with mounted sign.

Figure 10.5. Type III Barricade with Mounted Sign after Test at Impact Location 616411-01-4.

Figure 10.6. Type III Barricade with Mounted Sign after Test at its Final Resting Location 616411-01-4.

10.6. DAMAGE TO TEST VEHICLE

Figure 8.7 and Figure 8.8 show the damage sustained by the vehicle. Figure 8.9 and Figure 8.10 show the interior of the test vehicle. Table 8.6 and Table 8.7 provide details on the occupant compartment deformation and exterior vehicle damage. Tables E.2 and E.3 in Appendix E.1 provide exterior crush and occupant compartment measurements.

Figure 10.7. Impact Side of Test Vehicle after Test 616411-01-4.

Figure 10.8. Test Vehicle Hood Damage after Test 616411-01-4.

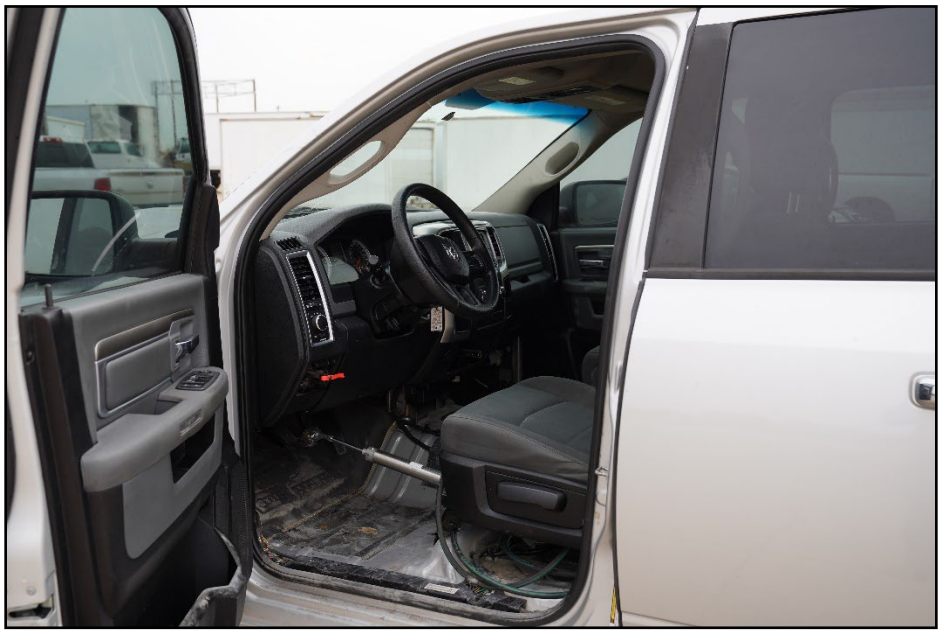


Figure 10.9. Overall Interior of Test Vehicle after Test 616411-01-4.

Figure 10.10. Interior of Test Vehicle on Impact Side after Test 616411-01-4.

Table 10.6. Occupant Compartment Deformation 616411-01-4.

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 616411-01-4.

Side Windows	Side windows remained intact
Maximum Exterior Deformation	14 inches in the front plane at bumper height
VDS	12FC2
CDC	12FCAN2
Fuel Tank Damage	None
Description of Damage to Vehicle:	The front bumper, hood, grill, radiator and support, and windshield were damaged. The windshield sustained a few small cracks but no holes or tears in the laminate. The hood had a 14-inch × 15-inch × 3-inch deep dent, and a 1¼-inch × 1½-inch hole in the front center.

10.7. OCCUPANT RISK FACTORS

MASH does not require instrumentation of the vehicle when impacting lightweight, freestanding work-zone traffic control devices weighing less than 220 lb. Each test article weighed 115 lb (excluding the sand bags). Consequently, the vehicle was not instrumented and occupant risk factors were not calculated for this test per *MASH* Paragraph 2.2.4.2 “Description of Tests.”

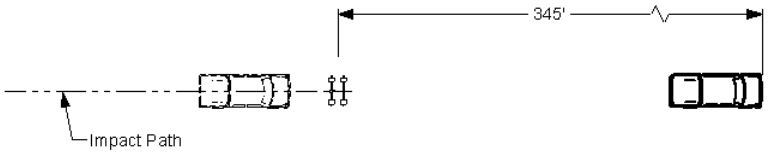
0.000 s

0.100 s

0.200 s

0.300 s

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH*, Test 3-72
TTI Project No.	616411-01-4
Test Date	2022-10-07
TEST ARTICLE	
Type	Work-Zone Traffic Control Device
Name	Type III barricade with mounted sign
Height	10 ft 8 inches
Key Materials	12 GA Perforated Steel Tubing, 48-inch square Aluminum Sign Panel, 1×8×48-inch pine boards
Soil Type and Condition	Concrete, Dry
TEST VEHICLE	
Type/Designation	2270P
Year, Make and Model	2016 RAM 1500
Inertial Weight (lb)	5037
Dummy (lb)	N/A
Gross Static (lb)	5037
IMPACT CONDITIONS	
Impact Speed (mi/h)	60.4
Impact Angle (deg)	90
Impact Location	Centerline of the vehicle aligned with the centerline of the barricade.
Impact Severity (kip-ft)	614.3
EXIT CONDITIONS	
Exit Speed (mi/h)	59.4
Stopping Distance	345 ft downstream In-line with the installation
VEHICLE DAMAGE	
VDS	12FC2
CDC	12FCAN2
Max. Ext. Deformation	14
Max Occupant Compartment Deformation	No occupant compartment deformation



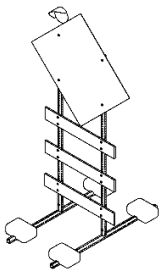


Figure 10.11. Summary of Results for *MASH* Test 3-72 on Type III Barricade with Mounted Sign.

Chapter 11. SUMMARY, CONCLUSIONS, AND IMPLEMENTATION

11.1. ASSESSMENT OF TEST RESULTS

The crash tests reported herein were performed in accordance with *MASH* TL-3, which involves four tests, on the Type III barricade with mounted sign. Tables at the end of this section provide an assessment of each test based on the applicable safety evaluation criteria for *MASH* TL-3 Work-Zone Traffic Control Devices.

11.2. CONCLUSIONS

Table 9.1, Table 9.2, Table 9.3, and Table 9.4 show that the Type III barricade with mounted sign met the performance criteria for *MASH* TL-3 Work-Zone Traffic Control Devices.

Table 11.1. Performance Evaluation Summary for *MASH* Test 3-71 on Type III Barricade with Mounted Sign, 616411-01-1, 2022-09-30.

Evaluation Criteria	*MASH* Description	Assessment
B.	The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.	Pass
D.	Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	Pass
E.	Detached elements, fragments, or other debris from the test article, of vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.	Pass
F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	Pass
H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s (10 ft/s for supports), or maximum allowable value of 40 ft/s (16 ft/s for supports).	N/A
I.	The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	N/A
N.	Vehicle trajectory behind the test article is acceptable.	Pass

Table 11.2. Performance Evaluation Summary for *MASH* Test 3-71 on Type III Barricade with Mounted Sign, 616411-01-2, 2022-09-30.

Evaluation Criteria	*MASH* Description	Assessment
B.	The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.	Pass
D.	Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	Pass
E.	Detached elements, fragments, or other debris from the test article, of vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.	Pass
F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	Pass
H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s (10 ft/s for supports), or maximum allowable value of 40 ft/s (16 ft/s for supports).	N/A
I.	The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	N/A
N.	Vehicle trajectory behind the test article is acceptable.	Pass

Table 11.3. Performance Evaluation Summary for *MASH* Test 3-72 on Type III Barricade with Mounted Sign, 616411-01-3, 2022-09-30.

Evaluation Criteria	*MASH* Description	Assessment
B.	The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.	Pass
D.	Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	Pass
E.	Detached elements, fragments, or other debris from the test article, of vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.	Pass
F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	Pass
H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s (10 ft/s for supports), or maximum allowable value of 40 ft/s (16 ft/s for supports).	N/A
I.	The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	N/A
N.	Vehicle trajectory behind the test article is acceptable.	Pass

Table 11.4. Performance Evaluation Summary for *MASH* Test 3-72 on Type III Barricade with Mounted Sign, 616411-01-4, 2022-10-07.

Evaluation Criteria	*MASH* Description	Assessment
B.	The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.	Pass
D.	Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	Pass
E.	Detached elements, fragments, or other debris from the test article, of vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.	Pass
F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	Pass
H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s (10 ft/s for supports), or maximum allowable value of 40 ft/s (16 ft/s for supports).	N/A
I.	The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	N/A
N.	Vehicle trajectory behind the test article is acceptable.	Pass

Table 11.5. Assessment Summary for *MASH* TL-3 Tests on Type III Barricade with Mounted Sign.

Evaluation Criteria	Test No. 616411-01-1 Test-71 @ 90°	Test No. 616411-01-2 Test -71 at 0°	Test No. 616411-01-3 Test-72 @ 0°	Test No. 616411-01-4 Test-72 @ 90°
B	S	S	S	S
D	S	S	S	S
E	S	S	S	S
F	S	S	S	S
H	N/A	N/A	N/A	N/A
I	N/A	N/A	N/A	N/A
N	S	S	S	S
Overall	Pass	Pass	Pass	Pass

Note: S = Satisfactory; N/A = Not Applicable.

11.3. IMPLEMENTATION*

The Type III barricade design with a mounted sign evaluated within this project successfully met MASH evaluation criteria for tests 3-71 and 3-72. MASH test 3-70 is considered optional for work-zone traffic control devices weighing less than 220 lb. Therefore, this test was not performed on the 115 lb barricade. Consequently, the as-tested Type III barricade with mounted sign is considered MASH compliant and suitable for implementation.

End users commonly utilize hollow-profile plastic lumber (HPPL) and plastic I-beam horizontal rails for Type III barricades. Two methods for attaching the alternative plastic rails are commonly used, direct bolting and plastic clips. Because of the likelihood for the plastic I-beam rails with plastic clips to separate from the PSST, further evaluation and testing of this configuration is needed. When comparing the HPPL with direct bolting to the PSST to the as-tested configuration, wood horizontal rails are viewed as more critical for crash testing. The larger weight and likelihood for fracturing of the wood rails pose an increased risk for windshield penetration by debris. Therefore, the successful testing of the wood rails allow the HPPL rails with direct bolting to the PSST to be considered as MASH compliant.

* *The opinions/interpretations identified/expressed in this section of the report are outside the scope of TTI Proving Ground's A2LA Accreditation.*

The as-tested Type III barricade configuration incorporated a light mounted towards the top of the sign. The light was incorporated to evaluate the likelihood of the light impacting the windshield or roof and causing penetration or excessive deformation. An alternative configuration which excludes the light is also considered MASH compliant.

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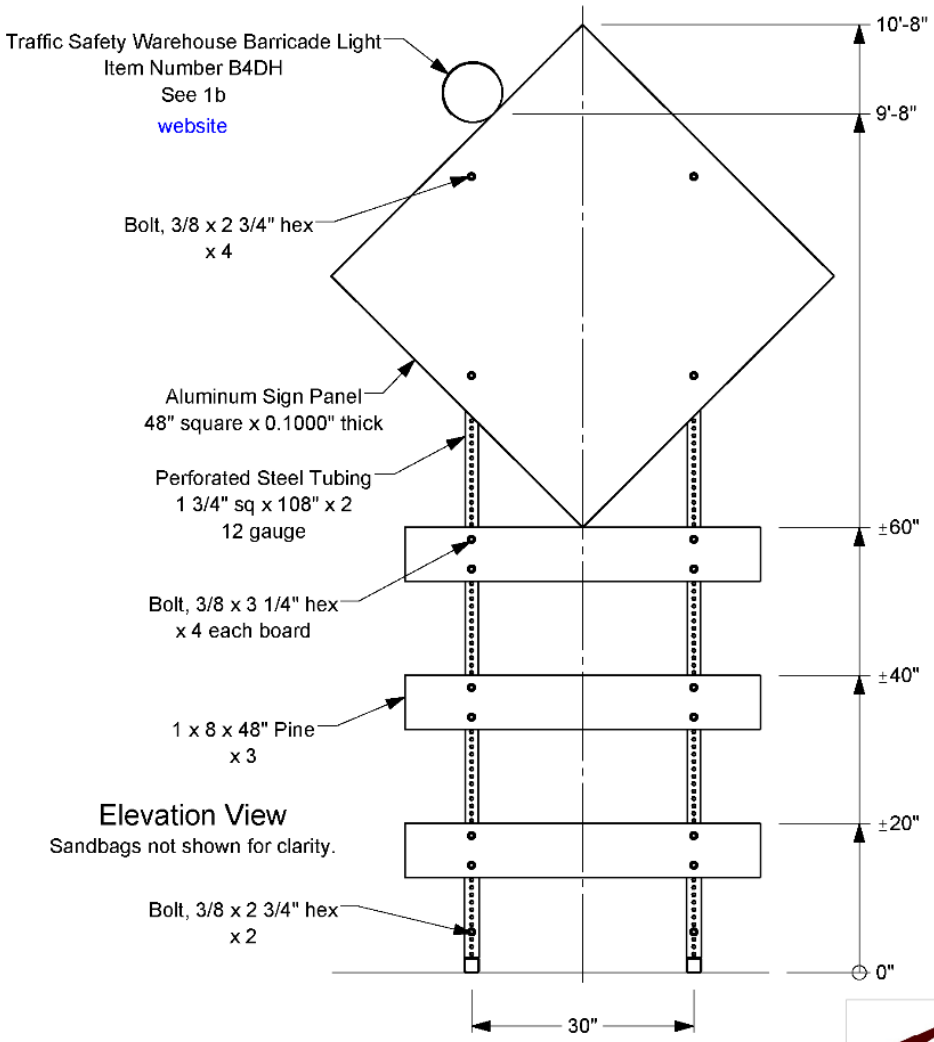
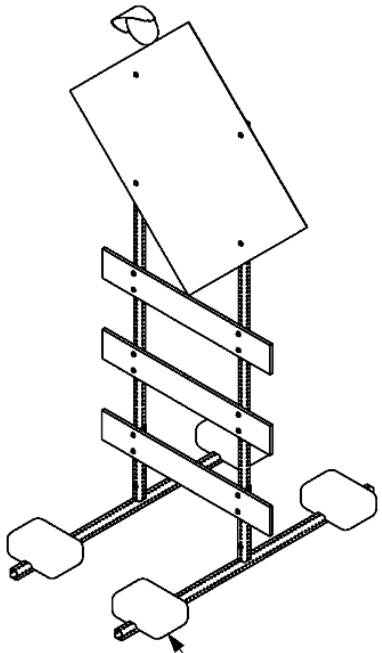
5. Mak, K. K., Menges, W. L., & Schoeneman, S. K. (1999). *NCHRP Report 350 Test 3-71 of the New Jersey DOT PVC Barricade with Sign Panel.* College Station, Texas: Texas Transportation Institute.
6. Schmidt, J. D., Langel, T. J., Asselin, N., Pajouh, M. A., & Faller, R. K. (2018). *MASH 2016 Evaluation of a Non-Proprietary Type III Barricade.* Lincoln, Nebraska: Midwest Roadside Safety Facility.
7. Bligh, R. P., Menges, W. L., Griffith, B. L., Schroeder, G. E., & Kuhn, D. L. (2020). *MASH Evaluation of TxDOT Roadside Safety Features - Phase III.* College Station, Texas: Texas A&M Transportation Institute.

APPENDIX A. DETAILS OF TYPE III BARRICADE WITH MOUNTED SIGN



Elevation View

Sandbags not shown for clarity.



Isometric View

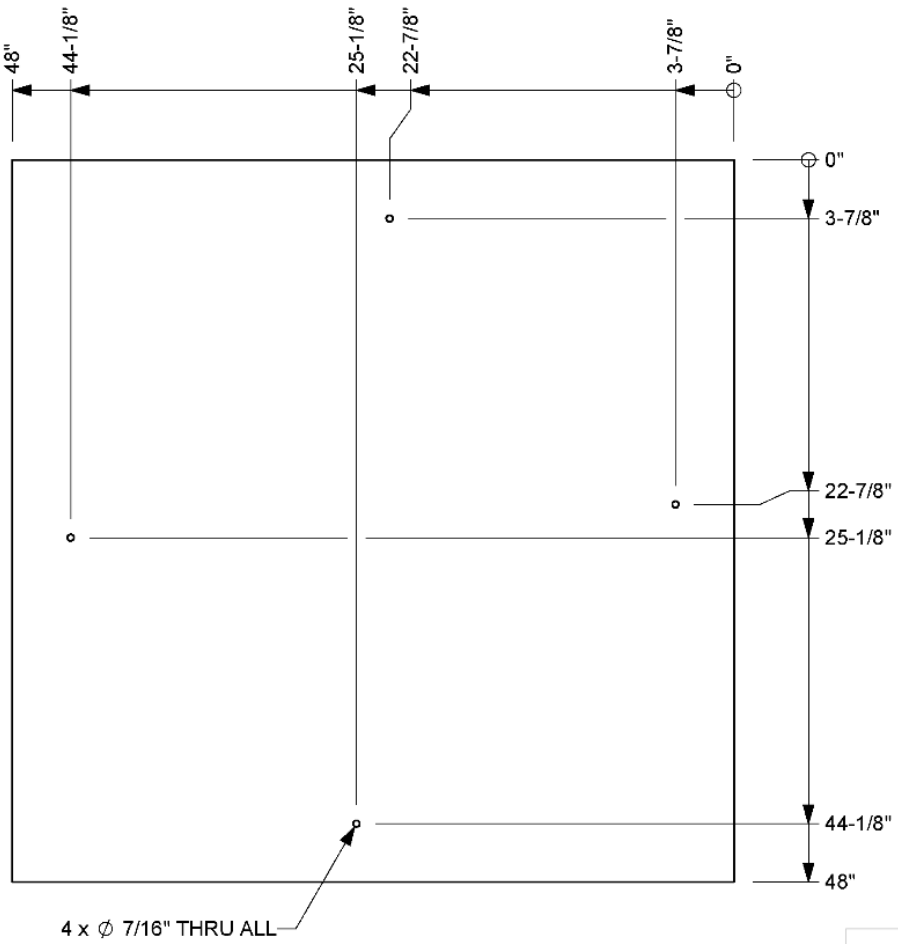
1a. All bolts are grade 5, with one Hex Nut and two F844 Washers.
1b. Drill hole in sign panel and attach Light with provided hardware.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #616411-01 Type III Barricade		2022-08-30
Drawn by GES	Scale 1:20	Sheet 1 of 3 Test Installation

Q:\Accreditation-17025-2017\EIR-000 Project Files\616411-01 - Type III Sign - Kovar\616411-01 Drafting\616411-01 Drawing

Aluminum Sign Panel

48" square x 0.1000" thick



Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #616411-01 Type III Barricade		2022-08-30
Drawn by GES	Scale 1:10	Sheet 2 of 3 Sign Panel

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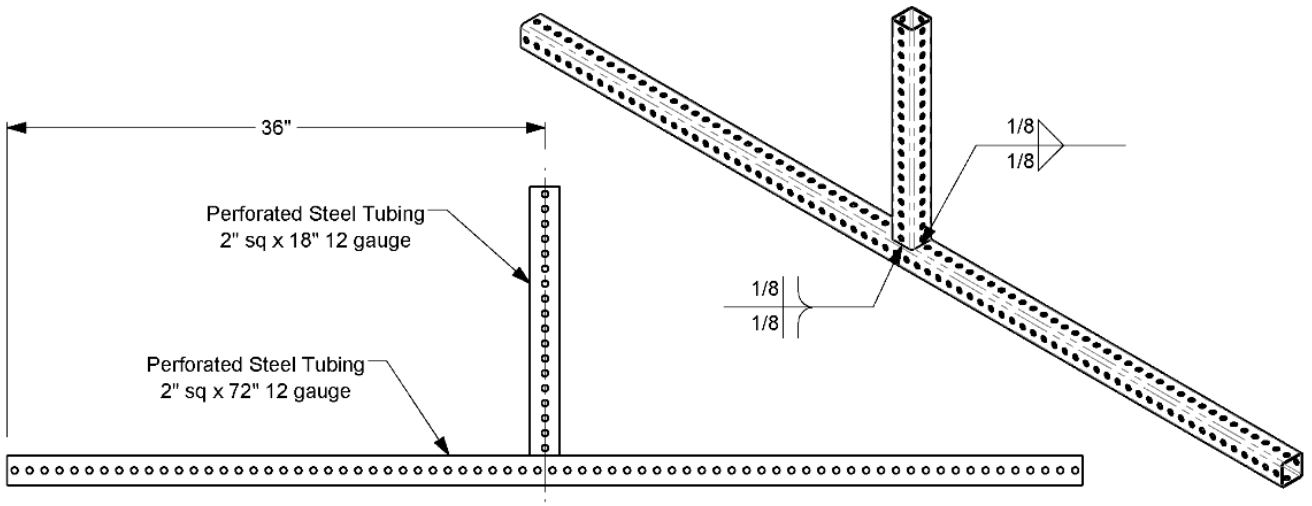
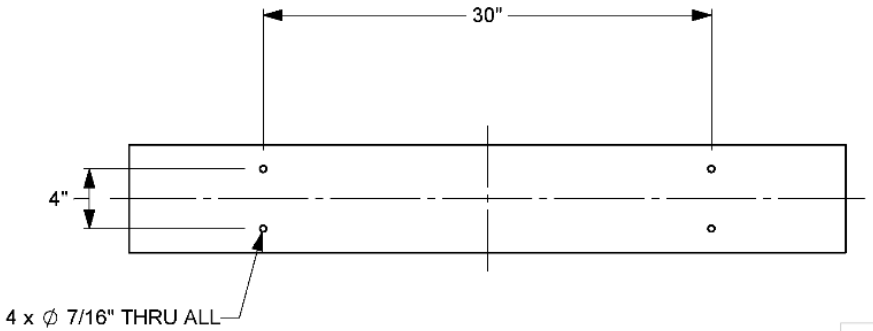


Skid
need 2



Pine Sign Panel
nominal 1 x 8 x 48"
need 3

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #616411-01 Type III Barricade		2022-08-30
Drawn by GES	Scale 1:10	Sheet 3 of 3 Skid and Board

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APPENDIX B. *MASH* TEST 3-71 (CRASH TEST NO. 616411-01-1)

B.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2022-09-30 Test No.: 616411-01-1 VIN No.: 3N1CN7AP6HL815842

Year: 2017 Make: Nissan Model: Versa

Tire Inflation Pressure: 36 PSI Odometer: 160939 Tire Size: P185/65R15

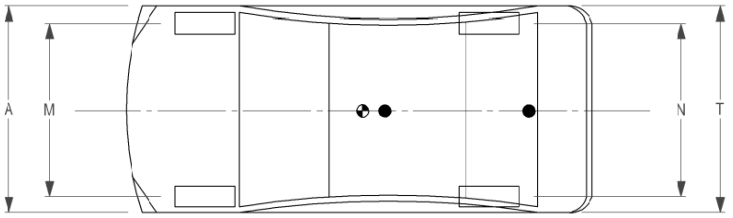
Describe any damage to the vehicle prior to test: None

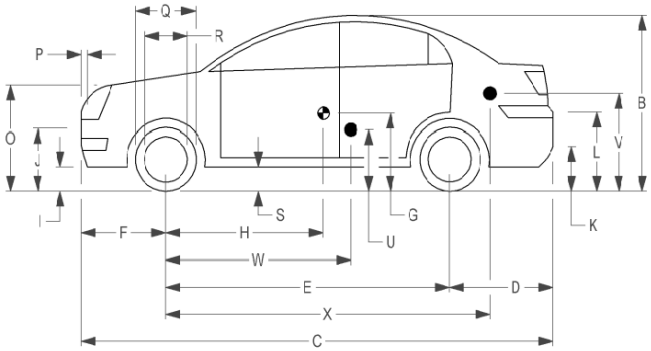
● Denotes accelerometer location.

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





Geometry: inches

A	66.70	F	32.50	K	12.50	P	4.50	U	
B	59.60	G		L	26.00	Q	24.00	V	
C	175.40	H	42.04	M	58.30	R	16.25	W	
D	40.50	I	7.00	N	58.50	S	7.50	X	
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	-42.04	

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}	1436	1431	1516
Back	1687	M_{rear}	943	997	1077
Total	3389	M_{Total}	2379	2428	2593

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

Mass Distribution:
lb LF: 757 RF: 674 LR: 493 RR: 504

Figure B.1. Vehicle Properties for Test No. 616411-01-1.

Date: 2022-09-30 Test No.: 616411-01-1 VIN No.: 3N1CN7AP6HL815842

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		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
1	AT FT BUMPER	2	12								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).

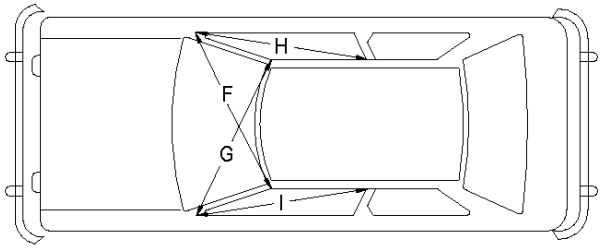
***Measure and document on the vehicle diagram the location of the maximum crush.

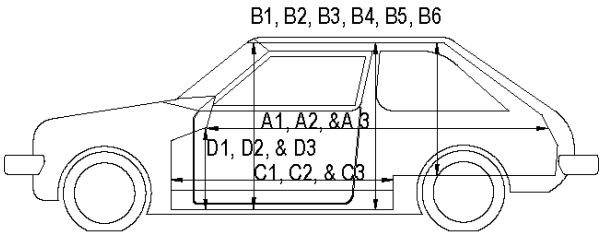
Note: Use as many lines/columns as necessary to describe each damage profile.

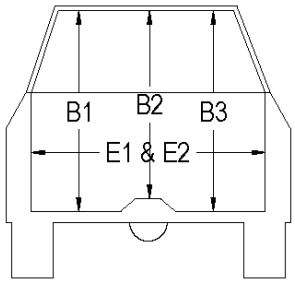
Figure B.2. Exterior Crush Measurements for Test No. 616411-01-1.

Date: 2022-09-30 Test No.: 616411-01-1 VIN No.: 3N1CN7AP6HL815842

Year: 2017 Make: Nissan Model: Versa







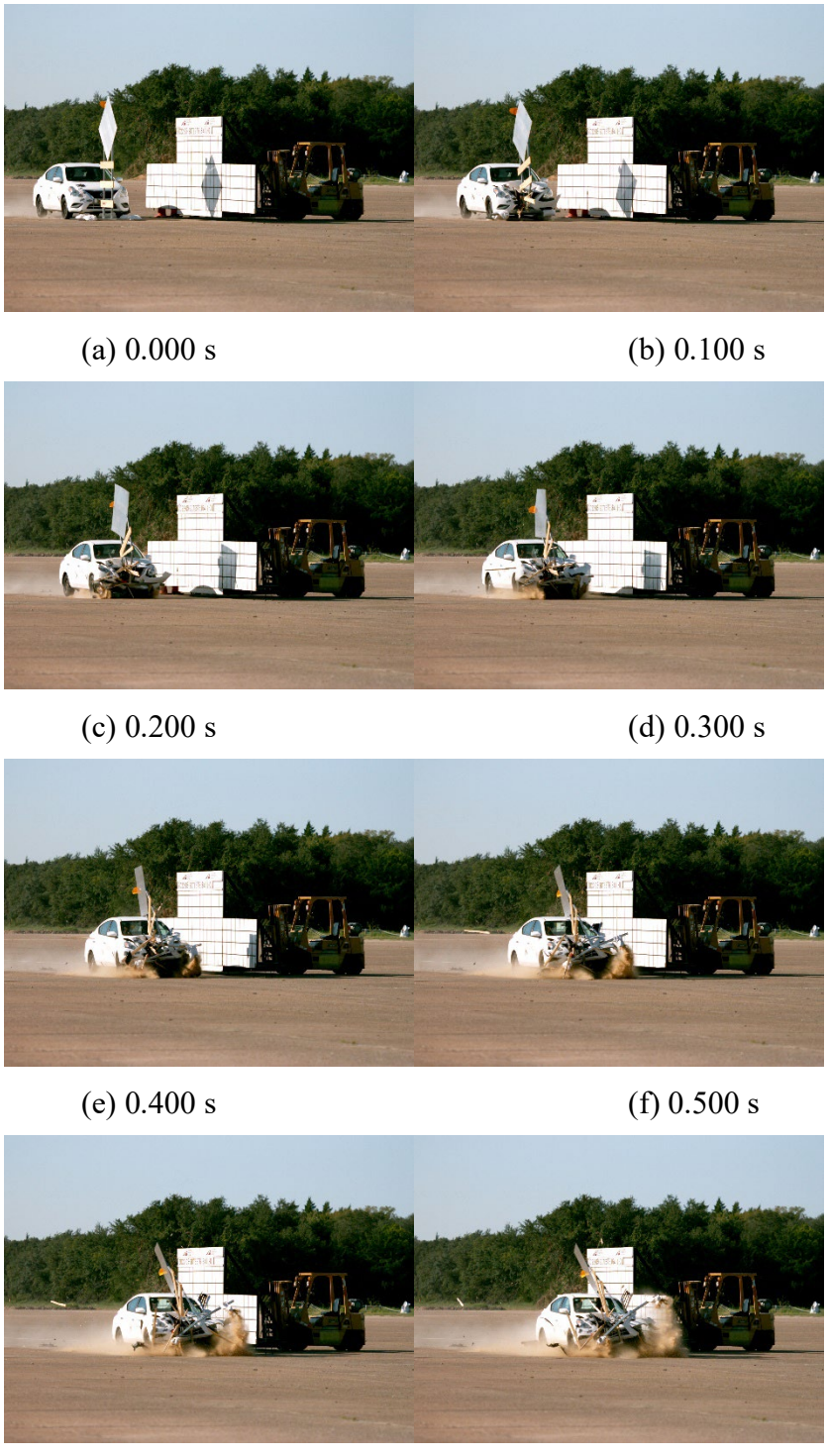
OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	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	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 B.3. Occupant Compartment Measurements for Test No. 616411-01-1.

B.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 B.4. Sequential Photographs for Test No. 616411-01-1 (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 B.5. Sequential Photographs for Test No. 616411-01-1 (Right Angle Views).

APPENDIX C. *MASH* TEST 3-71 (CRASH TEST NO. 616411-01-2)

C.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2022-09-30 Test No.: 616411-01-2 VIN No.: 3N1CN7AP6HL906514

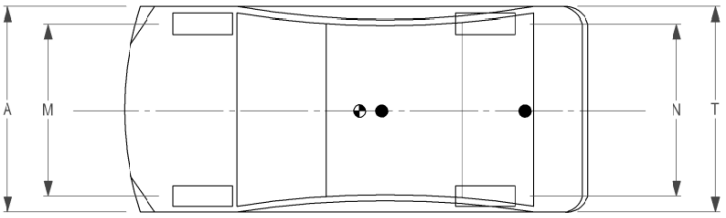
Year: 2017 Make: Nissan Model: Versa

Tire Inflation Pressure: 36 PSI Odometer: 147278 Tire Size: P185/65R15

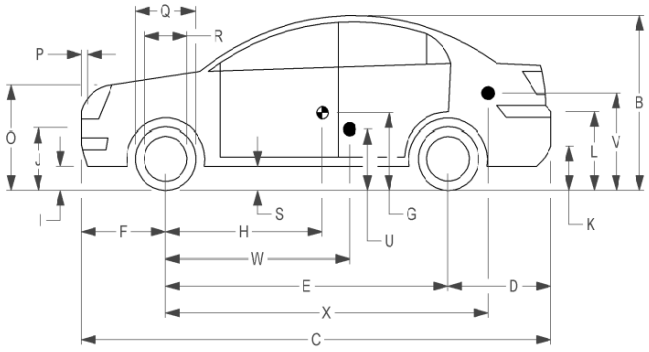
Describe any damage to the vehicle prior to test: None

● 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

Geometry: inches

A	66.70	F	32.50	K	12.50	P	4.50	U	
B	59.60	G		L	26.00	Q	24.00	V	
C	175.40	H	42.61	M	58.30	R	16.25	W	
D	40.50	I	7.00	N	58.50	S	7.50	X	
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 -42.61

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}	1439	1417	1502
Back	1687	M_{rear}	935	1010	1090
Total	3389	M_{Total}	2374	2427	2592

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

Mass Distribution:
lb LF: 711 RF: 706 LR: 520 RR: 490

Figure C.1. Vehicle Properties for Test No. 616411-01-2.

Date: 2022-09-30 Test No.: 616411-01-2 VIN No.: 3N1CN7AP6HL906514

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		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
1	at ft bumper	48	2	48							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.

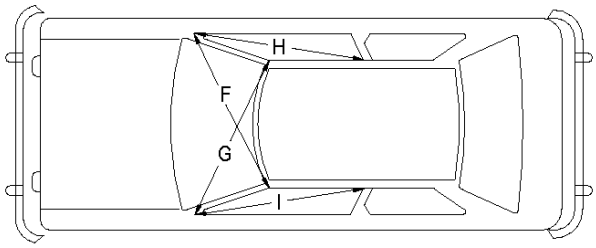
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

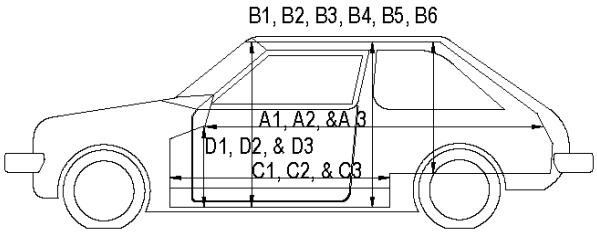
***Measure and document on the vehicle diagram the location of the maximum crush.

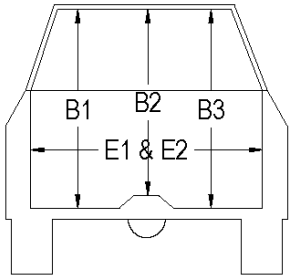
Note: Use as many lines/columns as necessary to describe each damage profile.

Figure C.2. Exterior Crush Measurements for Test No. 616411-01-2.

Date:	2022-09-30	Test No.:	616411-01-2	VIN No.:	3N1CN7AP6HL906514
Year:	2017	Make:	Nissan	Model:	Versa







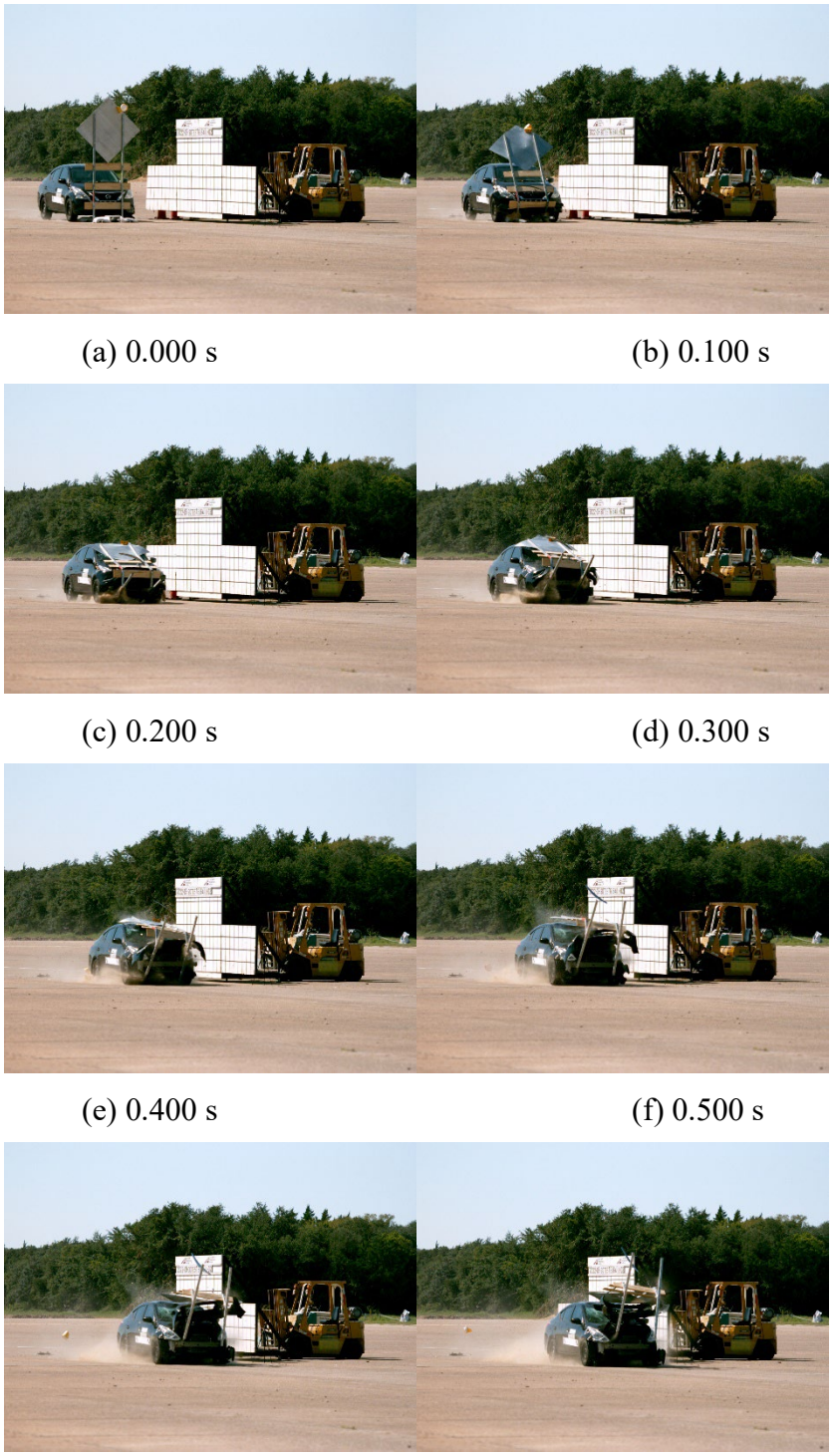
*Lateral area across the cab from driver's side kick panel to passenger's side kick panel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	67.50	67.50	0.00
A2	67.25	67.25	0.00
A3	67.75	67.75	0.00
B1	40.50	40.50	0.00
B2	39.00	36.25	-2.75
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

Figure C.3. Occupant Compartment Measurements for Test No. 616411-01-2.

C.2. SEQUENTIAL PHOTOGRAPHS



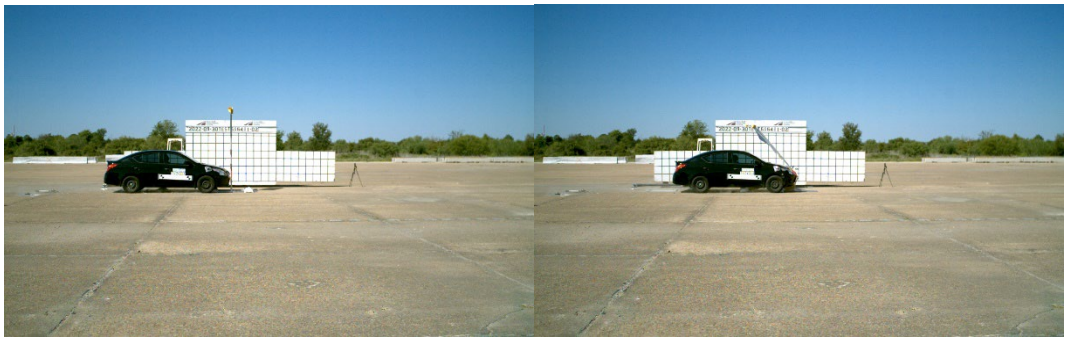
(a) 0.000 s (b) 0.100 s

(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 C.4. Sequential Photographs for Test No. 616411-01-2 (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 C.5. Sequential Photographs for Test No. 616411-01-2 (Right Angle Views).

APPENDIX D. *MASH* TEST 3-72 (CRASH TEST NO. 616411-01-3)

D.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2022-09-30 Test No.: 616411-01-3 VIN No.: 1C6RR6GT0GS201046

Year: 2016 Make: RAM Model: 1500

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

Tread Type: Highway Odometer: 192574

Note any damage to the vehicle prior to test: None

• Denotes accelerometer location.

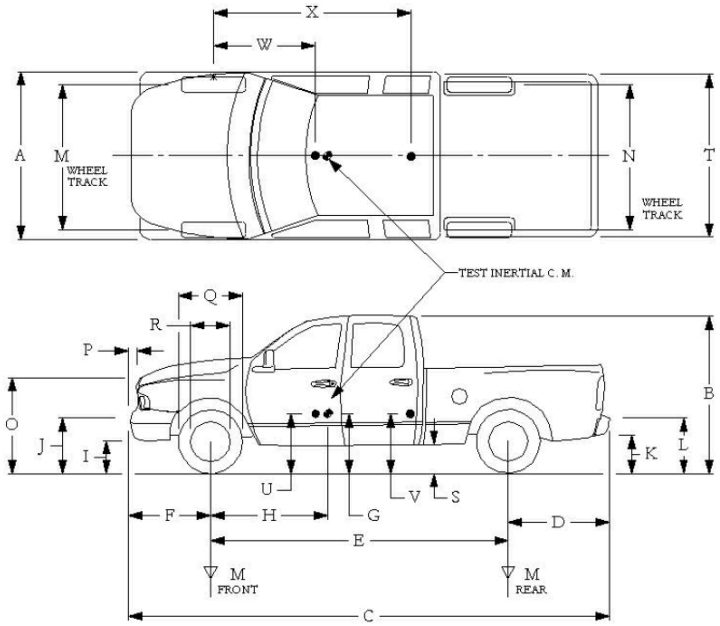
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

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

Optional Equipment:
None

Dummy Data:
Type: NONE
Mass:
Seat Position:



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	
B	74.00	G	28.60	L	30.00	Q	30.50	V	
C	227.50	H	61.11	M	68.50	R	18.00	W	
D	44.00	I	11.75	N	68.00	S	13.00	X	
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}	2927	2840	2840
Back	3900	M_{rear}	2089	2197	2197
Total	6700	M_{Total}	5016	5037	5037

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

Mass Distribution:
lb LF: 1455 RF: 1385 LR: 1090 RR: 1107

Figure D.1. Vehicle Properties for Test No. 616411-01-3.

Date: 2022-09-30 Test No.: 616411-01-3 VIN No.: 1C6RR6GT0GS201046

Year: 2016 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 FT BUMPER	30	.5	30							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.

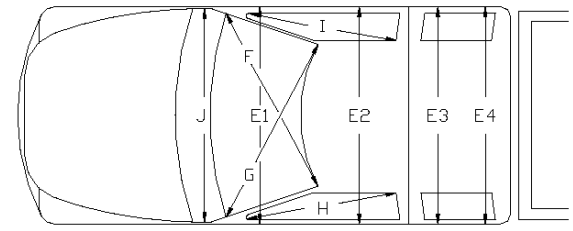
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

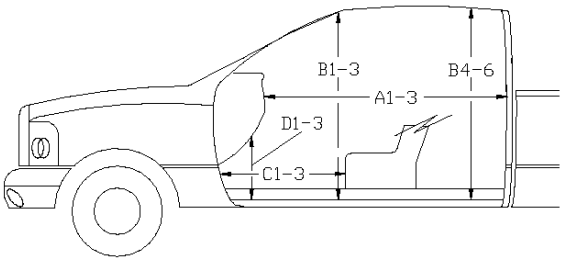
***Measure and document on the vehicle diagram the location of the maximum crush.

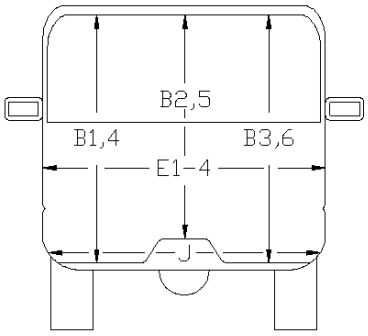
Note: Use as many lines/columns as necessary to describe each damage profile.

Figure D.2. Exterior Crush Measurements for Test No. 616411-01-3.

Date:	2022-09-30	Test No.:	616411-01-3	VIN No.:	1C6RR6GT0GS201046
Year:	2016	Make:	RAM	Model:	1500







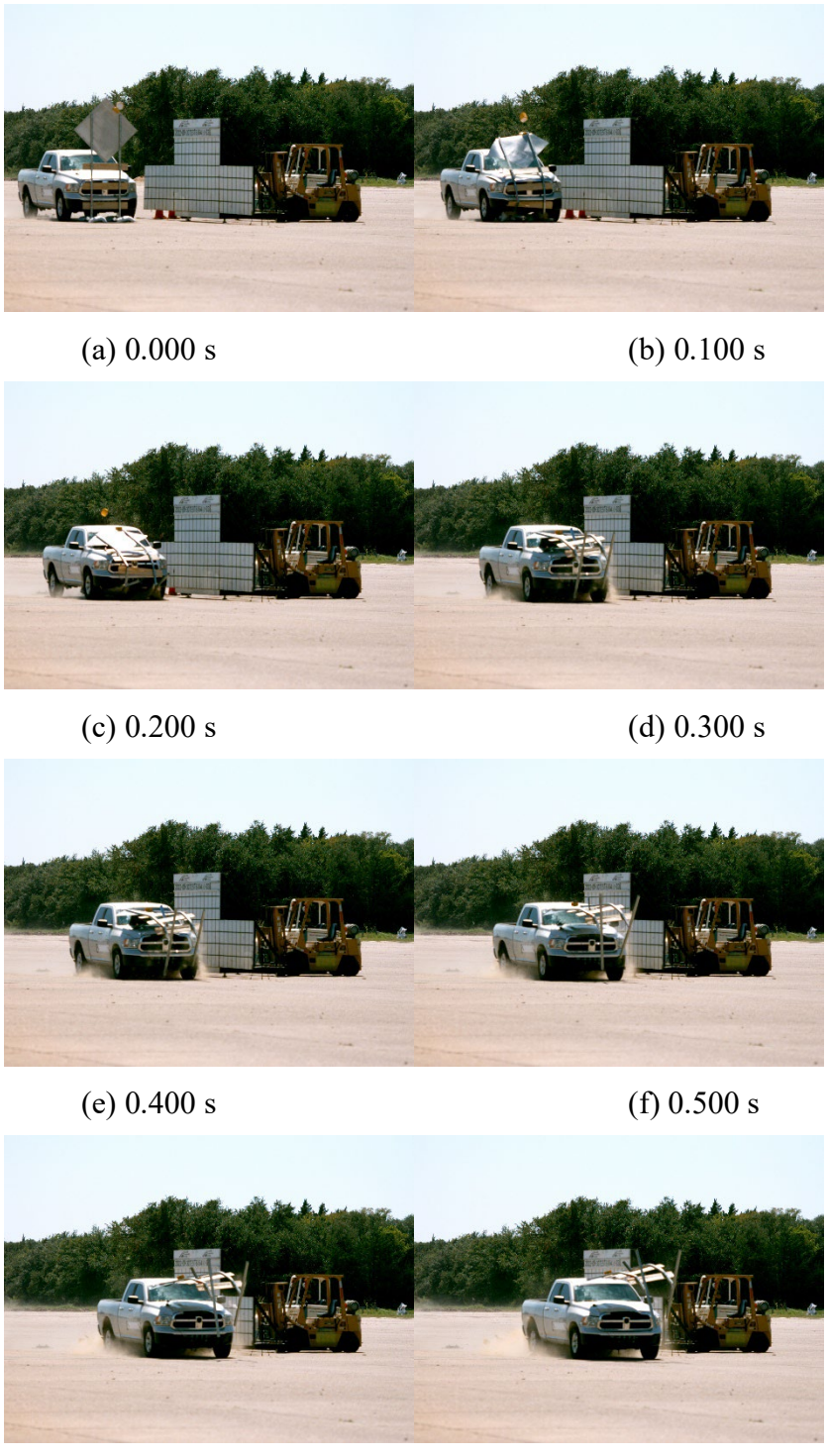
*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

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 D.3. Occupant Compartment Measurements for Test No. 616411-01-3.

D.2. SEQUENTIAL PHOTOGRAPHS



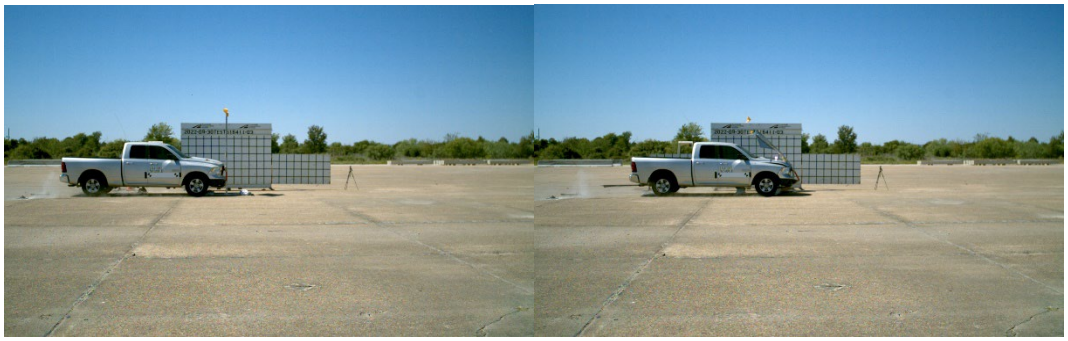
(a) 0.000 s (b) 0.100 s

(c) 0.200 s (d) 0.300 s

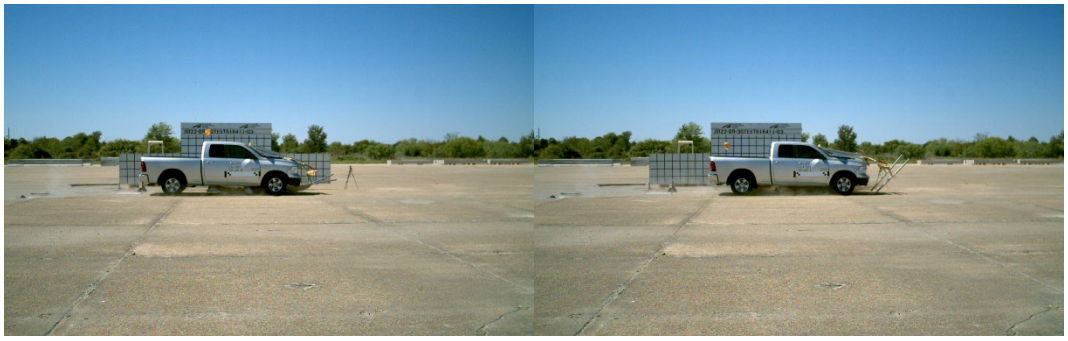
(e) 0.400 s (f) 0.500 s

(g) 0.600 s (h) 0.700 s

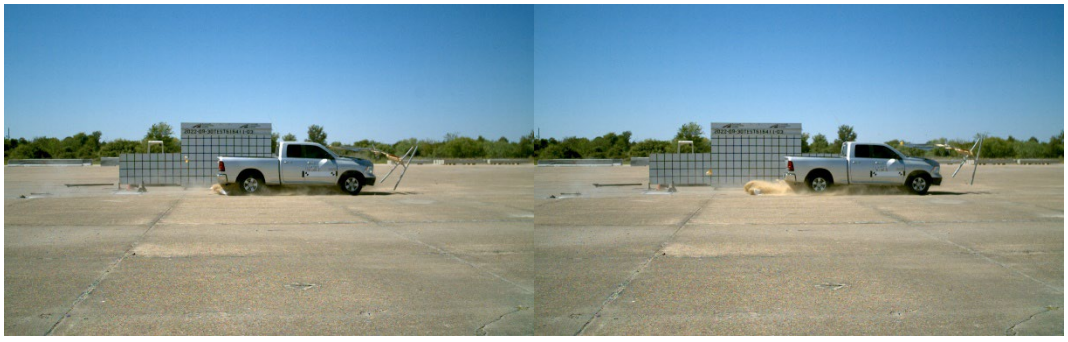
Figure D.4. Sequential Photographs for Test No. 616411-01-3 (Oblique Views).



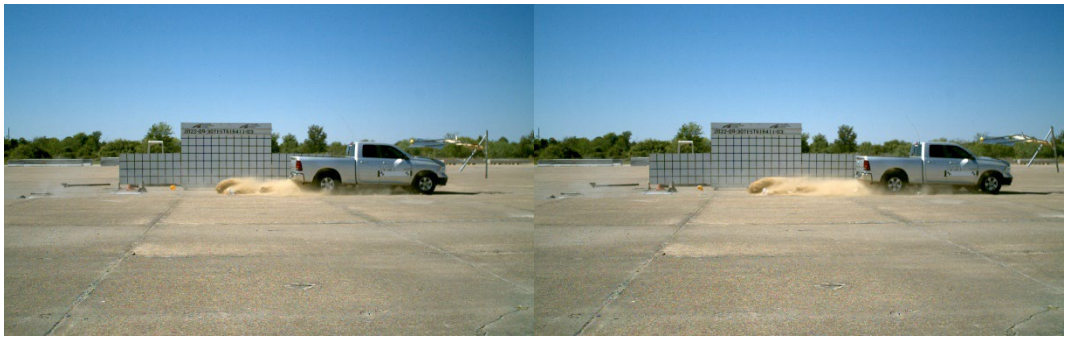
(a) 0.000 s (b) 0.100 s



(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 D.5. Sequential Photographs for Test No. 616411-01-3 (Right Angle Views).

APPENDIX E. *MASH* TEST 3-72 (CRASH TEST NO. 616411-01-4)

E.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2022-10-07 Test No.: 616411-01-4 VIN No.: 1C6RR6GT0GS201046

Year: 2016 Make: RAM Model: 1500

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

Tread Type: Highway Odometer: 192574

Note any damage to the vehicle prior to test: None

• Denotes accelerometer location.

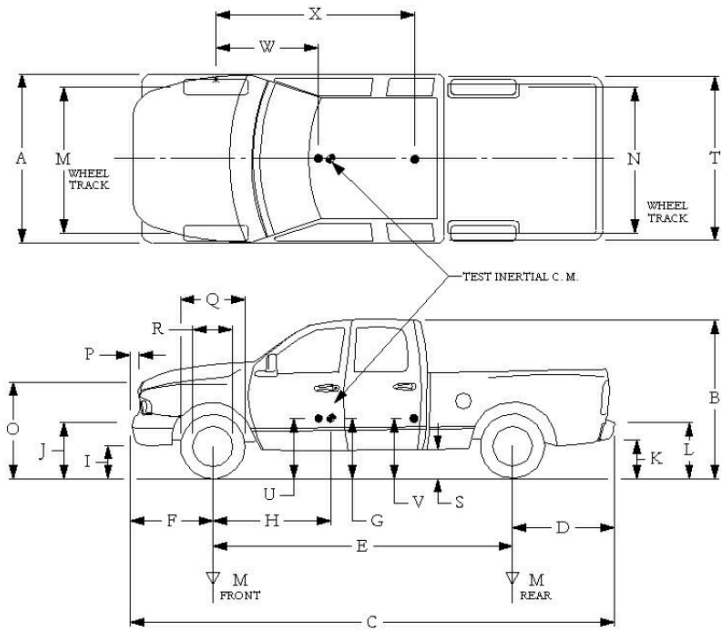
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

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

Optional Equipment:
None

Dummy Data:
Type: NONE
Mass:
Seat Position:



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	
B	74.00	G	28.60	L	30.00	Q	30.50	V	
C	227.50	H	61.11	M	68.50	R	18.00	W	
D	44.00	I	11.75	N	68.00	S	13.00	X	
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}	2927	2840	2840
Back	3900	M_{rear}	2089	2197	2197
Total	6700	M_{Total}	5016	5037	5037

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

Mass Distribution:
lb LF: 1455 RF: 1385 LR: 1090 RR: 1107

Figure E.1. Vehicle Properties for Test No. 616411-01-4.

Date: 2022-10-07 Test No.: 616411-01-4 VIN No.: 1C6RR6GT0GS201046

Year: 2016 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 FT BUMPER	2	14	72							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.

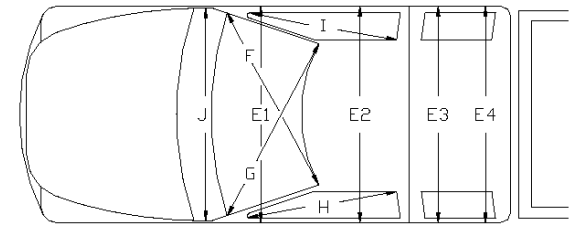
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

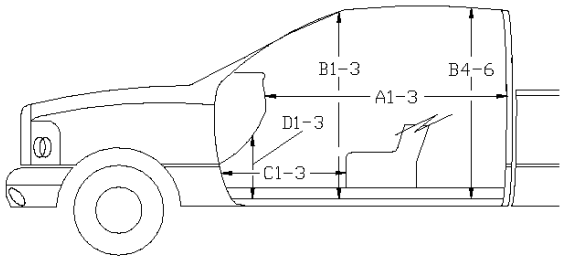
***Measure and document on the vehicle diagram the location of the maximum crush.

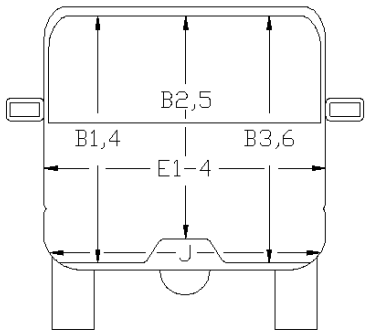
Note: Use as many lines/columns as necessary to describe each damage profile.

Figure E.2. Exterior Crush Measurements for Test No. 616411-01-4.

Date:	2022-10-07	Test No.:	616411-01-4	VIN No.:	1C6RR6GT0GS201046
Year:	2016	Make:	RAM	Model:	1500







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

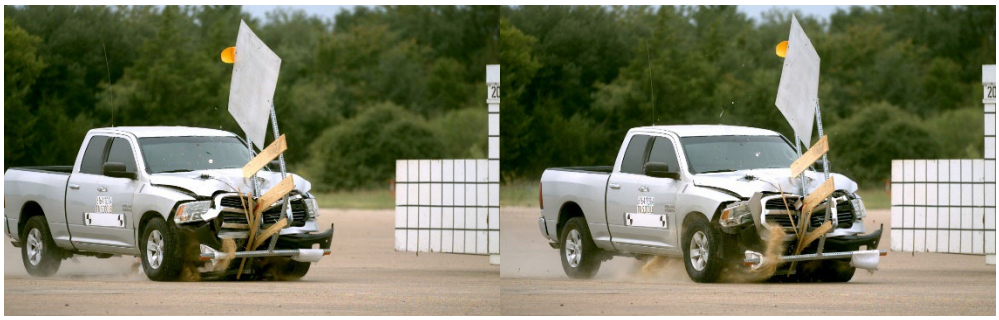
OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	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

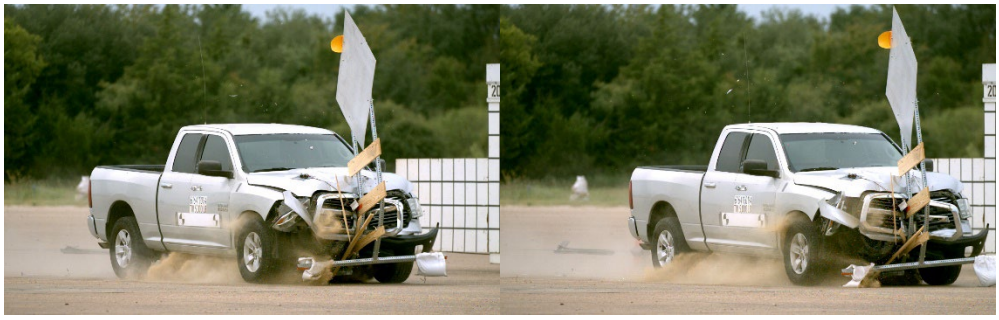
Figure E.3. Occupant Compartment Measurements for Test No. 616411-01-4.

E.2. SEQUENTIAL PHOTOGRAPHS

(a) 0.000 s (b) 0.100 s



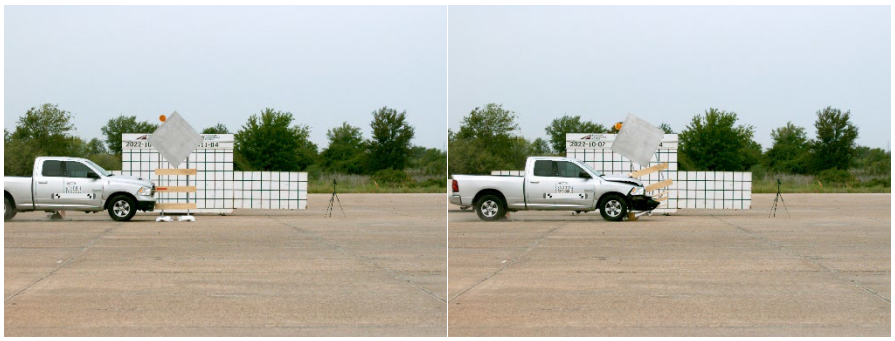
(c) 0.200 s (d) 0.300 s



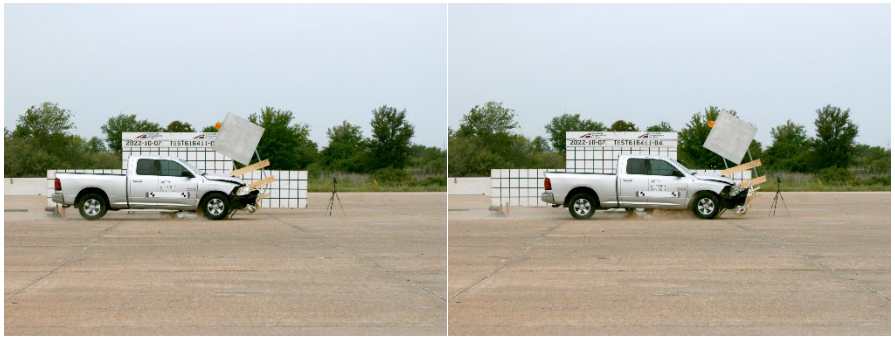
(e) 0.400 s (f) 0.500 s

(g) 0.600 s (h) 0.700 s

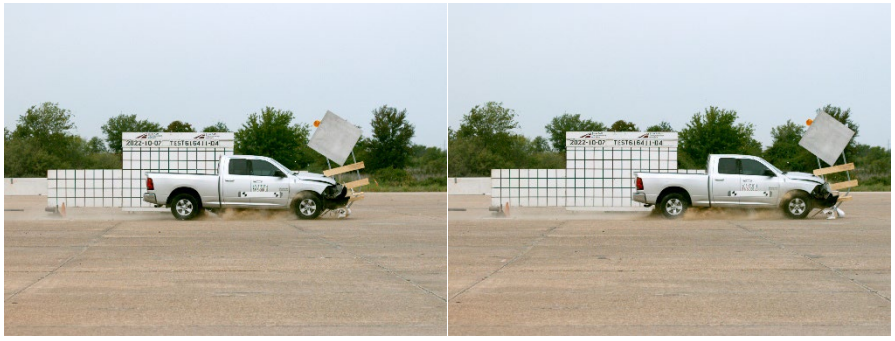
Figure E.4. Sequential Photographs for Test No. 616411-01-4 (Oblique Views).



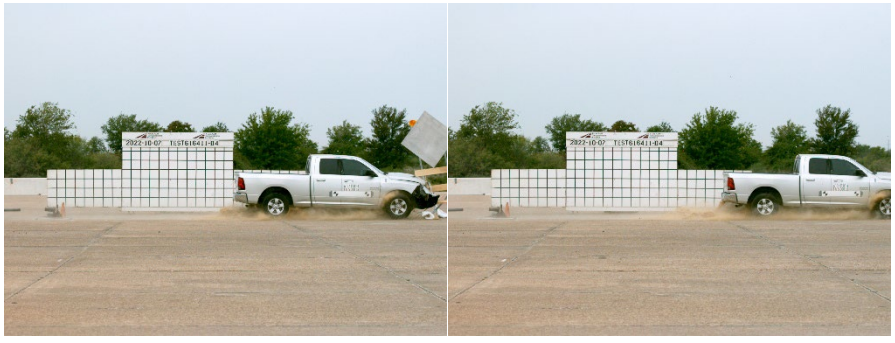
(a) 0.000 s (b) 0.100 s



(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 E.5. Sequential Photographs for Test No. 616411-01-4 (Right Angle Views).