Texas A&M Transportation Institute
Proving Ground

Test Report No. 616011-01

EVALUATION OF A NON-PROPRIETARY SIGN SUPPORT SYSTEM

Sponsored by

Roadside Safety Pooled Fund

TEXAS A&M TRANSPORTATION INSTITUTE PROVING GROUND
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A2LA ACCREDITED
ISO 17025 Laboratory
Testing Certificate # 2821.01

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Evaluation of a Non-Proprietary Sign Support System		5. Report Date June 2023 6. Performing Organization Code
7. Author(s) Nathan D. Schulz, William J. L. Schroeder, and Bill L. Griffith		8. Performing Organization Report No. Report 616011-01
9. Performing Organization Name and Address Texas A&M Transportation Institute Proving Ground 3135 TAMU College Station, Texas 77843-3135		10. Work Unit No. (TRAIS) 11. Contract or Grant No. Project T 4541
12. Sponsoring Agency Name and Address Washington State Department of Transportation Transportation Building, MS: 47372 Olympia, Washington 98504-7372		13. Type of Report and Period Covered Technical Report: June 2022 - June 2023 14. Sponsoring Agency Code
15. Supplementary Notes Name of Contacting Representative: Carlos Torres		

16. Abstract

The purpose of the tests reported herein was to assess the performance of the U-Channel Sign Support System according to the safety-performance evaluation guidelines included in the second edition of the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) (*1*). The initial objective was to evaluate the U-Channel Sign Support System according to the complete MASH Test Level 3 (TL-3) matrix. However, only MASH Test 3-62 was performed on the U-Channel Sign Support System due to excessive vehicle deformation observed during the crash test. The crash tests were performed in accordance with *MASH* Test 3-62:

> ***MASH* Test 3-62:** An 2270P vehicle weighing 5000 lb impacting the Support Structures while travelling at 62 mi/h and 0 and 90 degrees.

This report provides details on the U-Channel Sign Support System, the crash tests and results, and the performance assessment of the U-Channel Sign Support System for *MASH TL-3* Support Structures evaluation criteria.

The U-Channel Sign Support System did not meet the performance criteria for *MASH* TL-3 Support Structures.

17. Key Words	18. Distribution Statement
Support Structures, Sign, MASH, Crash Testing, Roadside Safety	No restrictions. This document is available to the public through NTIS: National Technical Information Service Alexandria, Virginia 22312 http://www.ntis.gov

19. Security Classification. (of this report)	20. Security Classification. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	64	

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Evaluation of a Non-Proprietary Sign Support System

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Report 616011-01
Contract No.:

Sponsored by the
Roadside Safety Pooled Fund

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The Washington State Department of Transportation

June 2023

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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 purpose of the tests reported herein was to assess the performance of the U-Channel Sign Support System according to the safety-performance evaluation guidelines included in the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*), Second Edition (*1*). The initial objective was to evaluate the U-Channel Sign Support System according to the complete MASH Test Level 3 matrix. However, only MASH Test 3-62 was performed on the U-Channel Sign Support System due to excessive vehicle deformation observed during the crash test. The crash tests were performed in accordance with *MASH* Test 3-62 criteria (as discussed in Chapter 3 of this report).

Chapter 2. SYSTEM DETAILS

2.1. TEST ARTICLE AND INSTALLATION DETAILS

The installation consisted of a 24-inch x 30 inch x 0.08-inch aluminum sign panel mounted to a 3lb/ft U-channel post. The sign post had a base consisting of a 42-inch long section of 3lb/ft U-channel set 38 inches into the ground, and coupled to the upper 117-inch long U-channel post via two bolts with a spacer, nut and two washers, spaced 7 inches apart. The bottom edge of the sign was at approximately 84 inches above grade.

Figure 2.1 presents the overall information on the U-Channel Sign Support System, and Figure 2.2 thru Figure 2.7 provide photographs of the installation. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by TTI Proving Ground personnel.

2.2. DESIGN MODIFICATIONS DURING TESTS

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

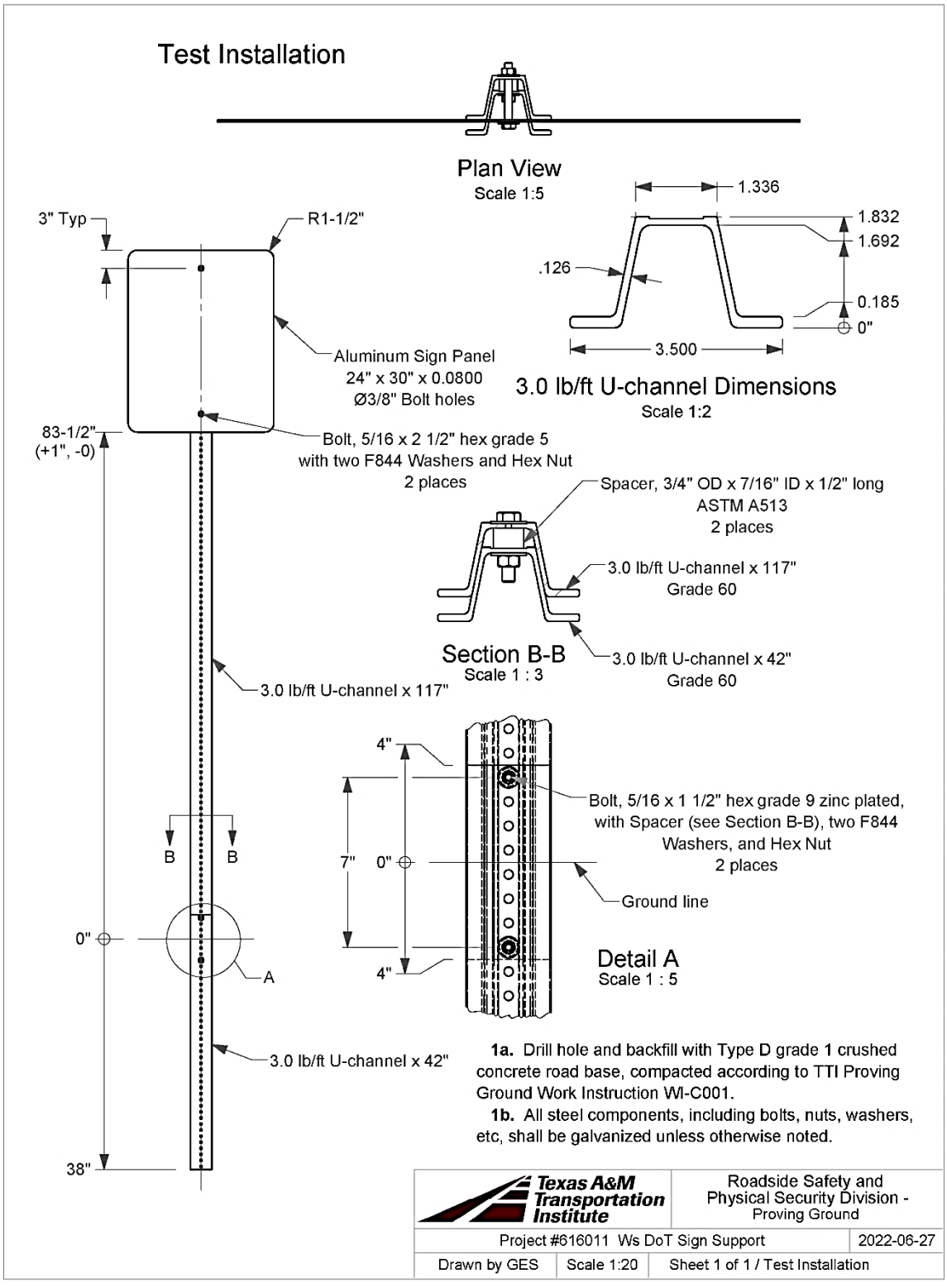


Figure 2.1. Details of U-Channel Sign Support System.

Figure 2.2. U-Channel Sign Support System prior to Testing.

Figure 2.3. Right Angle View of the U-Channel Sign Support System prior to Testing.

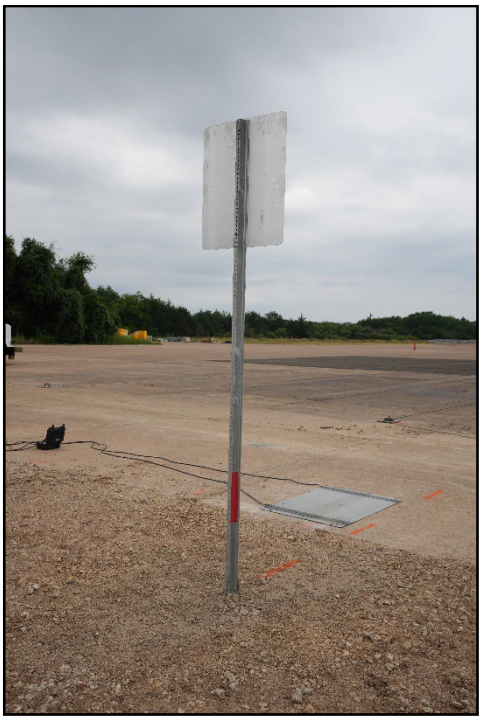


Figure 2.4. Rear of the U-Channel Sign Support System prior to Testing.

Figure 2.5. Rear Upper Section of the U-Channel Sign Support System prior to Testing.

Figure 2.6. Lower Section of the U-Channel Sign Support System prior to Testing.

Figure 2.7. Ground Stub and Connection of the U-Channel Sign Support System prior to Testing.

2.3. MATERIAL SPECIFICATIONS

Appendix A provides material certification documents for the materials used to install/construct the U-Channel Sign Support System.

2.4. SOIL CONDITIONS

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

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

On the day of the 3-62 Tests, 2022-06-28, loads on the post at deflections were as follows: the backfill material in which the U-Channel Sign Support System was installed met minimum *MASH* requirements for soil strength.

Table 2.1. Soil Strength.

Displacement (in)	Minimum Load (lb)	Actual Load (lb)
5	4420	10,696
10	4981	11,303
15	5282	9,727

Chapter 3. TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1. CRASH TEST PERFORMED/MATRIX

Table 3.1 shows the test conditions and evaluation criteria for *MASH* Test 3-62 for Support Structures. The target critical impact points (CIPs) and critical impact angles (CIAs) for each test were determined using the information provided in *MASH* Section 2.2.4. Figure 3.1 shows the target CIPs and CIAs for *MASH* Test 3-62 on the U-Channel Sign Support System.

Table 3.1. Test Conditions and Evaluation Criteria Specified for *MASH* Test 3-62 Support Structures.

Test Designation	Test Vehicle	Impact Speed	Impact Angle	Evaluation Criteria
3-62	2270P	62 mi/h	0º	B, D, F, H, I
3-62	2270P	62 mi/h	90º	B, D, F, H, I

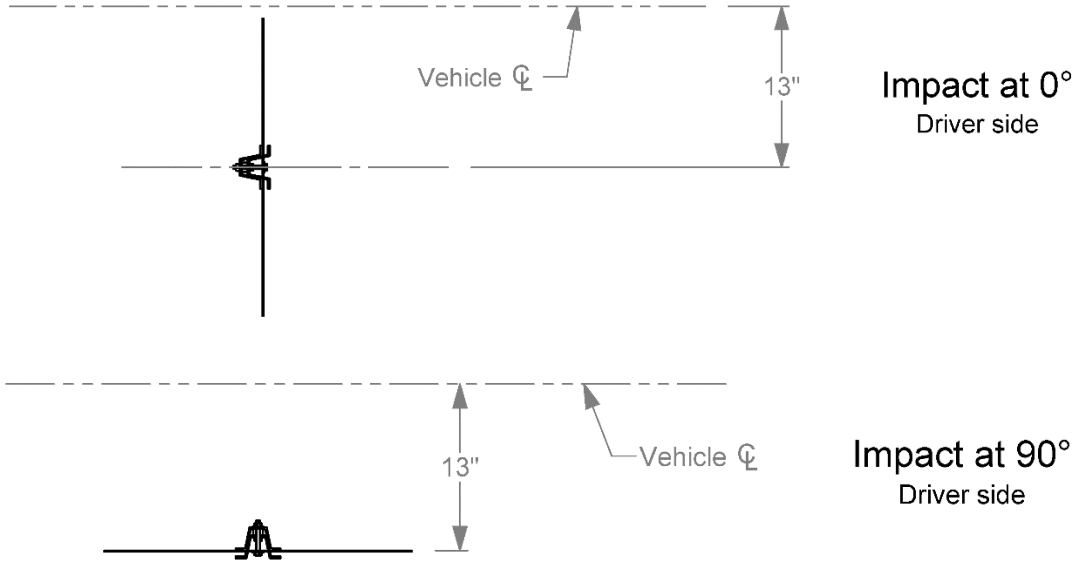


Figure 3.1. Target CIP and CIA for *MASH* 3-62 Tests on U-Channel Sign Support System.

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

3.2. EVALUATION CRITERIA

The appropriate safety evaluation criteria from Tables 2.2 and 5.1 of *MASH* were used to evaluate the crash tests reported herein. Table 3.1 lists the test conditions and

evaluation criteria required for *MASH* Test 3-62, and Table 3.2 provides detailed information on the evaluation criteria.

Table 3.2. 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.	60, 61, 62, 70, 71, 72, 80, 81, 82
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*.	All
F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	All except those listed in G
H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s, or maximum allowable value of 40 ft/s. Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s, or maximum allowable value of 16 ft/s.	10, 11, 20, 21, 30, 31, 32, 33, 34, 35, 36, 37, 38, 40, 41, 42, 43, 44, 50, 51, 52, 53, 80, 81, 82, 90, 91 60, 61, 62, 70, 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.	10, 11, 20, 21, 30, 31, 32, 33, 34, 35, 36, 37, 38, 40, 41, 42, 43, 45, 50, 51, 52, 53, 54, 60, 61, 62, 70, 71, 72, 80, 81, 90, 91

Chapter 4. TEST CONDITIONS

4.1. 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.

4.2. VEHICLE TOW AND GUIDANCE SYSTEM

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

4.3. DATA ACQUISITION SYSTEMS

4.3.1. Vehicle Instrumentation and Data Processing

Each test vehicle was instrumented with a self-contained onboard data acquisition system. The signal conditioning and acquisition system is a multi-channel data acquisition system (DAS) produced by Diversified Technical Systems Inc. The accelerometers, which measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors,

measuring vehicle roll, pitch, and yaw rates, are ultra-small, solid-state units designed for crash test service. The data acquisition hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 samples per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit in case the primary battery cable is severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark and initiates the recording process. After each test, the data are downloaded from the DAS unit into a laptop computer at the test site. The Test Risk Assessment Program (TRAP) software then processes the raw data to produce detailed reports of the test results.

Each DAS is returned to the factory annually for complete recalibration and to ensure that all instrumentation used in the vehicle conforms to the specifications outlined by SAE J211. All accelerometers are calibrated annually by means of an ENDEVCO® 2901 precision primary vibration standard. This standard and its support instruments are checked annually and receive a National Institute of Standards Technology (NIST) traceable calibration. The rate transducers used in the data acquisition system receive calibration via a Genisco Rate-of-Turn table. The subsystems of each data channel are also evaluated annually, using instruments with current NIST traceability, and the results are factored into the accuracy of the total data channel per SAE J211. Calibrations and evaluations are also made anytime data are suspect. Acceleration data are measured with an expanded uncertainty of ±1.7 percent at a confidence factor of 95 percent (k = 2).

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

TRAP uses the data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.0001-s intervals, and then plots yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation being initial impact. Rate of rotation data is measured with an expanded uncertainty of ±0.7 percent at a confidence factor of 95 percent (k = 2).

4.3.2. Anthropomorphic Dummy Instrumentation

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

4.3.3. Photographic Instrumentation Data Processing

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

- A camera placed at a right angle to the installation
- A camera placed downstream from the installation at an oblique angle.

A flashbulb on the impacting vehicle was activated by a pressure-sensitive tape switch to indicate the instant of contact with the U-Channel Sign Support System. 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 5. *MASH* TEST 3-62 (CRASH TEST 616011-01-5)

5.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

See Table 5.1 for details of *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 5.1. Impact Conditions for *MASH TEST 3-62,* Crash Test 616011-01-5.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5 mi/h	62.9
Impact Angle (deg)	0	±1.5°	0
Kinetic Energy (kip-ft)	594	≥594 kip-ft	669.2
Impact Location	Centerline of the sign aligned 13 inches off center of the vehicle towards the driver's side	±1 ft	Centerline of the sign aligned 13 inches off center of the vehicle towards the driver's side

Table 5.2. Exit Parameters for *MASH TEST 3-62,* Crash Test 616011-01-5.

Exit Parameter	Measured
Speed (mi/h)	61.4
Brakes applied post impact (s)	1.6
Vehicle at rest position	339 ft downstream of impact point In-line with impact
Comments:	Vehicle remained upright and stable.

Figure 5.1. U-Channel Sign Support System/Test Vehicle Geometrics for Test 616011-01-5.

Figure 5.2. U-Channel Sign Support System/Test Vehicle Impact Location 616011-01-5.

5.2. WEATHER CONDITIONS

Table 5.3 provides the weather conditions for Test 616011-01-5.

Table 5.3. Weather Conditions Test 616011-01-5.

Date of Test	2022-06-28 AM
Wind Speed (mi/h)	4
Wind Direction (deg)	96
Temperature (°F)	85
Relative Humidity (%)	71
Vehicle Traveling (deg)	170

5.3. TEST VEHICLE

Figure 5.3 and Figure 5.4 show the 2016 RAM 1500 used for the crash test. Table 5.4 shows the vehicle measurements. Figure B.1 in Appendix B.1 gives additional dimensions and information on the vehicle.

Figure 5.3. Impact Side of Test Vehicle before Test 616011-01-5.

Figure 5.4. Interior of the Test Vehicle before Test 616011-01-5.

Table 5.4. Vehicle Measurements for Test 616011-01-5.

Test Parameter	*MASH*	Allowed Tolerance	Measured
Dummy (if applicable)[a] (lb)	165	N/A	N/A
Inertial Weight (lb)	5000	±110	5060
Gross Static[a] (lb)	5000	±110	5060
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	60.8
CG above Ground[c,d] (inches)	28	28	28.62

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

5.4. TEST DESCRIPTION

Table 5.5 lists events that occurred during Test 616011-01-5. Figures B.4 and B.5 in Appendix B.2 present sequential photographs during the test.

Table 5.5. Events during Test 616011-01-5.

Time (s)	Events
0.0000	Vehicle impacted the installation
0.0030	Post at bumper height began to break
0.0060	Post at bumper height broke into two parts
0.0640	Sign contacted the roof near windshield on passenger side
0.1110	Sign lost contact with vehicle

5.5. DAMAGE TO TEST INSTALLATION

The soil was disturbed around the ground stub, but no damage was present. The sign landed 223 feet downstream and 3 feet to the right of impact. The sign panel was deformed. Figure 5.5 and Figure 5.6 show the damage to the U-Channel Sign Support System.

Figure 5.5. U-Channel Sign Support System at Impact Location after Test 616011-01-5.

Figure 5.6. U-Channel Sign Support System at its Landing Location after Test 616011-01-5.

5.6. 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. Figures B.2 and B.3 in Appendix B.1 provide exterior crush and occupant compartment measurements.

Figure 5.7. Impact Side of Test Vehicle after Test 616011-01-5.

Figure 5.8. Roof and Windshield of Test Vehicle after Test 616011-01-5.

Figure 5.9. Upper Interior of Test Vehicle after Test 616011-01-5.

Figure 5.10. Lower Interior of Test Vehicle after Test 616011-01-5.

Table 5.6. Occupant Compartment Deformation 616011-01-5.

Test Parameter	**Specification** (inches)	**Measured** (inches)
Roof	≤4.0	4.9
Windshield	≤3.0	3.75
A and B Pillars	≤5.0 overall/≤3.0 lateral	0.0
Foot Well/Toe Pan	≤9.0	0.0
Floor Pan/Transmission Tunnel	≤12.0	0.0
Side Front Panel	≤12.0	0.0
Front Door (above Seat)	≤9.0	0.0
Front Door (below Seat)	≤12.0	0.0

Table 5.7. Exterior Vehicle Damage 616011-01-5.

Side Windows	The side windows remained intact
Maximum Exterior Deformation	1 inch in the front plane at bumper height
VDS	12FC2
CDC	12FCAZ3
Fuel Tank Damage	None
Description of Damage to Vehicle:	The roof, windshield, hood, and bumper were damaged. The roof had a 33-inch wide, 15-inch long, and 4.9-inch deep dent. The windshield had a 35-inch wide, 15-inch long, 3.75-inch deep dent. There was a 3.5-inch wide, 1-inch deep dent on the hood and bumper.

5.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 5.8. Figure B.6 in Appendix B.3 shows the vehicle angular displacements, and Figures B.7 through B.9 in Appendix B.4 show acceleration versus time traces.

Table 5.8. Occupant Risk Factors for Test 616011-01-5.

Test Parameter	*MASH* [a]	Measured	Time
OIV, Longitudinal (ft/s)	≤16.0 *10.0*	0.7	at 0.9984 s on right side of interior
OIV, Lateral (ft/s)	≤16.0 *10.0*	2.4	at 0.9984 s on right side of interior
Ridedown, Longitudinal (g)	≤20.49 *15.0*	0.2	1.3337 - 1.3437 s
Ridedown, Lateral (g)	≤20.49 *15.0*	0.5	1.2177 - 1.2277 s
Theoretical Head Impact Velocity (THIV) (m/s)	N/A	0.8	at 0.9985 s on right side of interior
Acceleration Severity Index (ASI)	N/A	0.1	0.1068 - 0.1568 s
50-ms Moving Avg. Accelerations (MA) Longitudinal (g)	N/A	-0.3	0.0407 - 0.0907 s
50-ms MA Lateral (g)	N/A	-0.3	0.1345 - 0.1845 s
50-ms MA Vertical (g)	N/A	-0.5	0.0862 - 0.1362 s
Roll (deg)	≤75	1.5	1.4999 s
Pitch (deg)	≤75	2.2	1.4784 s
Yaw (deg)	N/A	0.2	0.6362 s

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

5.8. TEST SUMMARY

Figure 5.11 summarizes the results of *MASH* Test 616011-01-5.

0.000 s

0.050 s

0.100 s

0.150 s

Test Agency	Texas A&M Transportation Institute (TTI)				
Test Standard/Test No.	*MASH* 2016, Test 3-62				
TTI Project No.	616011-01-5				
Test Date	2022-06-28				
TEST ARTICLE					
Type	Support Structures				
Name	U-Channel Sign Support System				
Height	103.5 inches				
Key Materials	24” x 30” x 0.08” Aluminum Sign Panel 3.0 lb/ft U-Channel				
Soil Type and Condition	AASHTO M147-65(2004), Type 1, Grade D Crushed Concrete				
TEST VEHICLE					
Type/Designation	2270P				
Year, Make and Model	2016 RAM 1500				
Inertial Weight (lb)	5060				
Dummy (lb)	N/A				
Gross Static (lb)	5060				
IMPACT CONDITIONS					
Impact Speed (mi/h)	62.9				
Impact Angle (deg)	0				
Impact Location	Centerline of the sign aligned 13 inches off center of the vehicle towards the driver’s side				
Kinetic Energy (kip-ft)	669.2				
EXIT CONDITIONS					
Exit Speed (mi/h)	61.4				
Stopping Distance	339 ft downstream In-line with impact ft to the side				
VEHICLE DAMAGE					
VDS	12FC2				
CDC	12FCAZ3				
Max. Ext. Deformation (inches)	1				
Max Occupant Compartment Deformation	4.9 inches in the roof, 3.75 in the windshield				
OCCUPANT RISK VALUES					
Long. OIV (ft/s)	0.7	Max 50-ms Long. (g)	-0.3	Max Roll (deg)	1.5
Lat. OIV (ft/s)	2.4	Max 50-ms Lat. (g)	-0.3	Max Pitch (deg)	2.2
Long. Ridedown (g)	0.2	Max 50-ms Vert. (g)	-0.5	Max Yaw (deg)	0.2
Lat. Ridedown (g)	0.5	THIV (m/s)	0.8	ASI	0.1

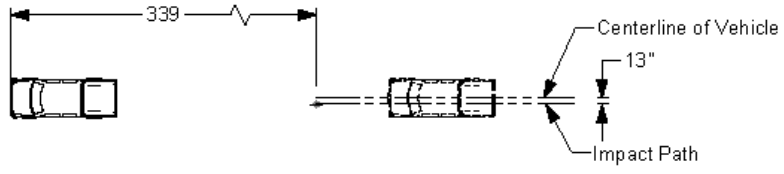


Figure 5.11. Summary of Results for *MASH* Test 3-62 on U-Channel Sign Support System.

Chapter 6. *MASH* TEST 3-62 (CRASH TEST 616011-01-6)

6.1. TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

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

Table 6.1. Impact Conditions for *MASH* TEST 3-62, Crash Test 616011-01-6.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	62	±2.5 mi/h	62.6
Impact Angle (deg)	90	±1.5°	90
Kinetic Energy (kip-ft)	594	≥594 kip-ft	664.6
Impact Location	Centerline of the sign aligned 13 inches off center of the vehicle towards the driver's side	±1 ft	Centerline of the sign aligned 13 inches off center of the vehicle towards the driver's side

Table 6.2. Exit Parameters for *MASH* TEST 3-62, Crash Test 616011-01-6.

Exit Parameter	Measured
Speed (mi/h)	61.7
Brakes applied post impact (s)	3.1
Vehicle at rest position	298 ft downstream of impact point 3 ft to the right side 5° right
Comments:	Vehicle remained upright and stable.

Figure 6.1. U-Channel Sign Support System/Test Vehicle Geometrics for Test 616011-01-6.

Figure 6.2. U-Channel Sign Support System/Test Vehicle Impact Location 616011-01-6.

6.2. WEATHER CONDITIONS

Table 6.3 provides the weather conditions for Test 616011-01-6.

Table 6.3. Weather Conditions Test 616011-01-6.

Date of Test	2022-06-28 AM
Wind Speed (mi/h)	3
Wind Direction (deg)	175
Temperature (°F)	83
Relative Humidity (%)	65
Vehicle Traveling (deg)	170

6.3. TEST VEHICLE

Figure 6.3 and Figure 6.4 show the 2016 RAM 1500 used for the crash test. Table 6.4 shows the vehicle measurements. Figure C.1 in Appendix C.1 gives additional dimensions and information on the vehicle.

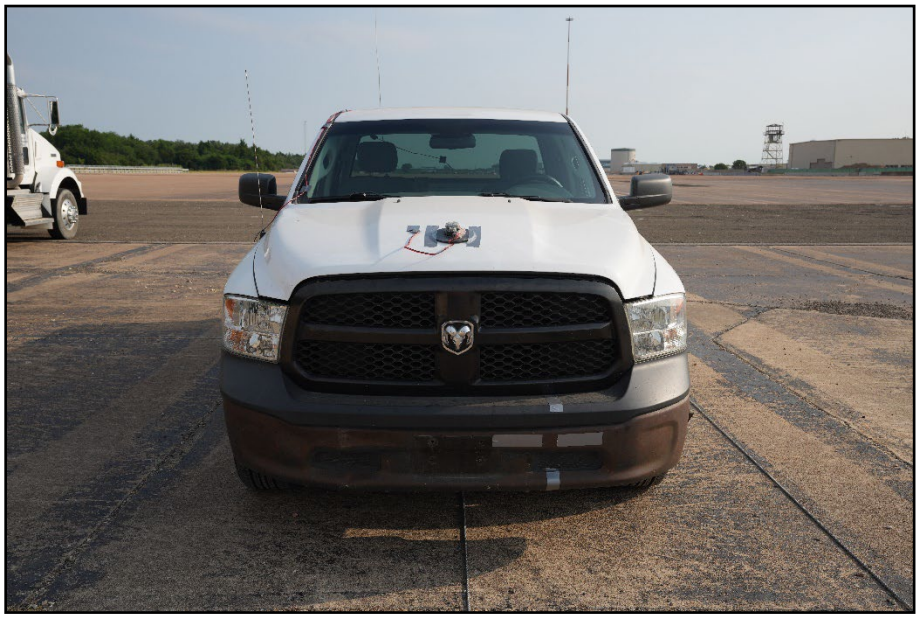


Figure 6.3. Impact Side of Test Vehicle before Test 616011-01-6.

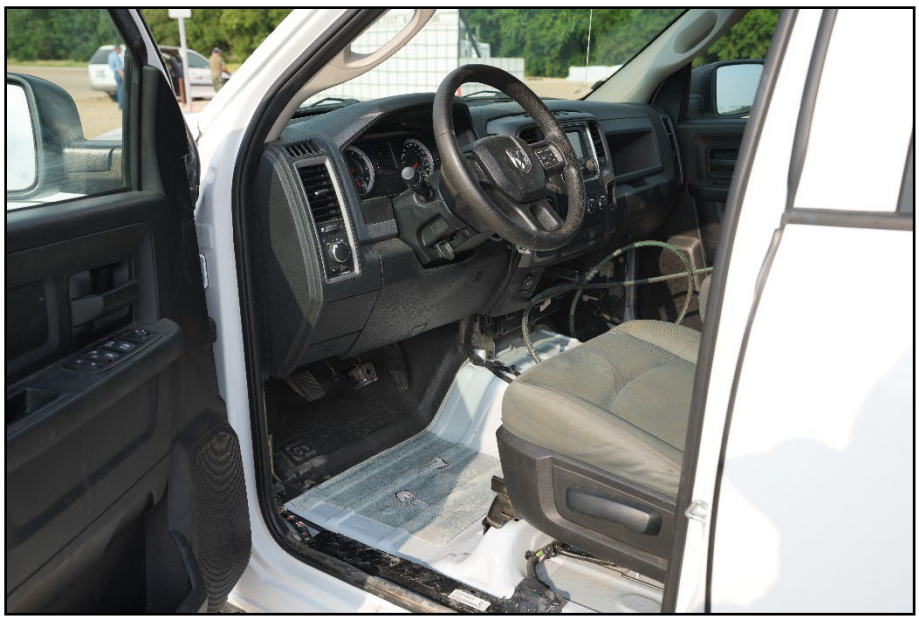


Figure 6.4. Interior of the Test Vehicle before Test 616011-01-6.

Table 6.4. Vehicle Measurements 616011-01-6.

Test Parameter	*MASH*	Allowed Tolerance	Measured
Dummy (if applicable)[a] (lb)	165	N/A	N/A
Inertial Weight (lb)	5000	±110	5025
Gross Static[a] (lb)	5000	±110	5025
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	60.9
CG above Ground[c,d] (inches)	28	≥28	28.5

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

6.4. TEST DESCRIPTION

Table 6.5 lists events that occurred during Test 616011-01-6. Figures C.4 and C.5 in Appendix C.2 present sequential photographs during the test.

Table 6.5. Events during Test 616011-01-6.

Time (s)	Events
0.0000	Vehicle impacted the installation
0.0080	Post detached from base embedded in soil
0.1670	Post still on front bumper, starting to drop under vehicle.

6.5. DAMAGE TO TEST INSTALLATION

The ground stub was fractured, and the soil was disturbed around it. The sign and post landed 165 feet downstream and 36 feet to the right of impact. The post was bent but still intact, and the sign was scuffed and slightly deformed. Figure 6.5 and Figure 6.6 show the damage to the U-Channel Sign Support System.

Figure 6.5. U-Channel Sign Support System at Impact Location after Test 616011-01-6.

Figure 6.6. U-Channel Sign Support System at its Landing Location after Test 616011-01-6.

6.6. 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. Figures C.2 and C.3 in Appendix C.1 provide exterior crush and occupant compartment measurements.

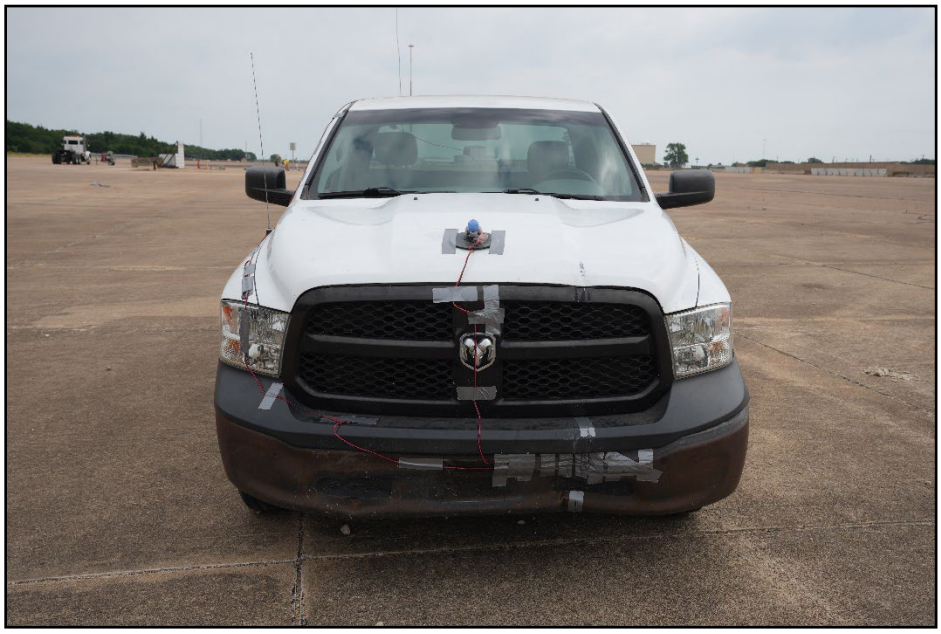


Figure 6.7. Impact Side of Test Vehicle after Test 616011-01-6.

Figure 6.8. Roof and Windshield of Test Vehicle after Test 616011-01-6.

Figure 6.9. Overall Interior of Test Vehicle after Test 616011-01-6.

Figure 6.10. Upper Interior of Test Vehicle after Test 616011-01-6.

Table 6.6. Occupant Compartment Deformation 616011-01-6.

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 6.7. Exterior Vehicle Damage 616011-01-6.

Side Windows	The side windows remained intact
Maximum Exterior Deformation	3.25 inches in the front plane at bumper height
VDS	12FC1
CDC	12FCEL1
Fuel Tank Damage	None
Description of Damage to Vehicle:	The bumper and hood were damaged. The bumper was crushed in 3.25 inches, and the hood had a 2-inch wide, 3.5-inch long dent on the left side.

6.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 6.8. Figure C.6 in Appendix C.3 shows the vehicle angular displacements, and Figures C.7 through C.9 in Appendix C.4 show acceleration versus time traces.

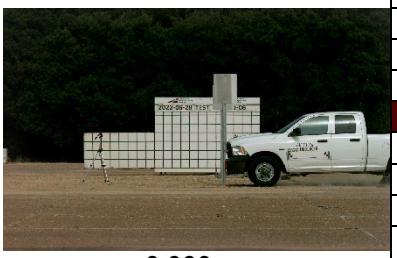
Table 6.8. Occupant Risk Factors for Test 616011-01-6.

Test Parameter	*MASH* [a]	Measured	Time
OIV, Longitudinal (ft/s)	≤16.0 *10.0*	3.2	0.8044 s on front of interior
OIV, Lateral (ft/s)	≤16.0 *10.0*	0.5	0.8044 s on front of interior
Ridedown, Longitudinal (g)	≤20.49 *15.0*	1.1	1.8277 - 1.8377 s
Ridedown, Lateral (g)	≤20.49 *15.0*	0.3	2.0761 - 2.0861 s
THIV (m/s)	N/A	1	0.8038 s on front of interior
ASI	N/A	0.1	1.8215 - 1.8715 s
50-ms MA Longitudinal (g)	N/A	-1.1	0.0180 - 0.0680 s
50-ms MA Lateral (g)	N/A	0.3	0.1954 - 0.2454 s
50-ms MA Vertical (g)	N/A	-0.3	0.0743 - 0.1243 s
Roll (deg)	≤75	0.7	1.2778 s
Pitch (deg)	≤75	3.7	2.9978 s
Yaw (deg)	N/A	1	0.4369 s

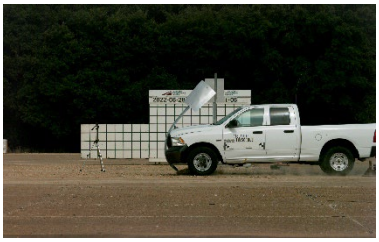
[a.] Values in italics are the preferred MASH values

6.8. TEST SUMMARY

Figure 6.11 summarizes the results of *MASH* Test 616011-01-6.



0.000 s



0.050 s

0.100 s

0.150 s

Test Agency	Texas A&M Transportation Institute (TTI)				
Test Standard/Test No.	*MASH* 2016, Test 3-62				
TTI Project No.	616011-01-6				
Test Date	2022-06-28				
TEST ARTICLE					
Type	Support Structures				
Name	U-Channel Sign Support System				
Height	103.5 inches				
Key Materials	24” x 30” x 0.08” Aluminum Sign Panel 3.0 lb/ft U-Channel				
Soil Type and Condition	AASHTO M147-65(2004), Type 1, Grade D Crushed Concrete				
TEST VEHICLE					
Type/Designation	2270P				
Year, Make and Model	2016 RAM 1500				
Inertial Weight (lb)	5025				
Dummy (lb)	N/A				
Gross Static (lb)	5025				
IMPACT CONDITIONS					
Impact Speed (mi/h)	62.6				
Impact Angle (deg)	90				
Impact Location	Centerline of the sign aligned 13 inches off center of the vehicle towards the driver’s side				
Kinetic Energy (kip-ft)	664.6				
EXIT CONDITIONS					
Exit Speed (mi/h)	7				
Stopping Distance	298 ft downstream 3 ft to the right side				
VEHICLE DAMAGE					
VDS	12FC1				
CDC	12FCEL1				
Max. Ext. Deformation (inches)	3.25				
Max Occupant Compartment Deformation	No occupant compartment damage				
OCCUPANT RISK VALUES					
Long. OIV (ft/s)	3.2	Max 50-ms Long. (g)	-1.1	Max Roll (deg)	0.7
Lat. OIV (ft/s)	0.5	Max 50-ms Lat. (g)	0.3	Max Pitch (deg)	3.7
Long. Ridedown (g)	1.1	Max 50-ms Vert. (g)	-0.3	Max Yaw (deg)	1.0
Lat. Ridedown (g)	0.3	THIV (m/s)	1.0	ASI	0.1

OCCUPANT RISK VALUES

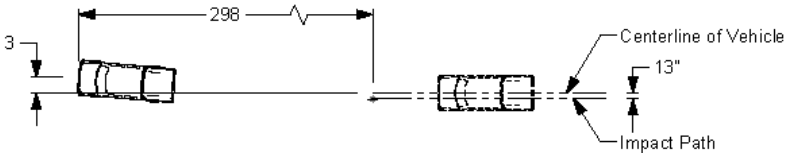


Figure 6.11. Summary of Results for *MASH* Test 3-62 on U-Channel Sign Support System.

Chapter 7. RESEARCH AND DEVELOPMENT CRASH TEST EVALUATION

7.1. R&D DESIGNS

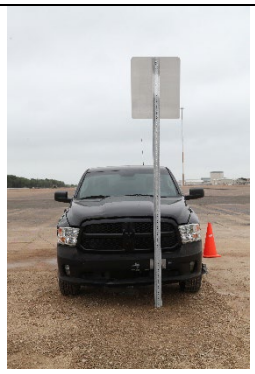
After the conclusion of the 616011-01-5 and 616011-01-6 tests, three research and development (R&D) crash tests were conducted on U-Channel systems. The purpose of the R&D tests was to evaluate the crashworthy performance of the U-Channel sign support system with a lower impact speed and two modified U-Channel sign support systems. The test installations for these R&D tests were identical to the installation described in Chapter 2, with the exceptions noted below.

Test 616011-01-1 had the height to the bottom of the sign increased from 83.5 inches to 95.5 inches.

Test 616011-01-2 had a 48-inch section of U-channel fastened to the non-impact side of the support post, with the bottom of the U-channel stiffener mounted 6 inches above grade.

Test 616011-01-3 was identical to the installation described in Chapter 2. The impact speed was reduced from 62 mi/h to 44 mi/h.

The results of these tests are summarized in Figures 7.1 through 7.3.



Installation and Vehicle Prior to Impact

Installation After Impact

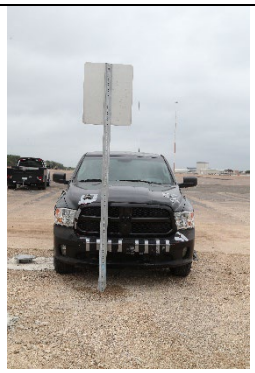
Sign and Support After Impact

Front of Vehicle After Impact

Roof of Vehicle After Impact

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-62
TTI Project No.	616011-01-1
Test Date	2022-04-20
TEST ARTICLE	
Type	Support Structures
Name	U-Channel Sign Support System
Height	125.5 inches
Key Materials	24” x 30” x 0.08” Aluminum Sign Panel 3.0 lb/ft U-Channel
Soil Type and Condition	AASHTO M147-65(2004), Type 1, Grade D Crushed Concrete
TEST VEHICLE	
Type/Designation	2270P
Year, Make and Model	2015 RAM 1500
Inertial Weight	5000 lbs (Nominal)
IMPACT CONDITIONS	
Impact Speed	62.0 mi/h (Nominal)
Impact Angle	0° (Nominal)
Impact Location	Centerline of the sign post aligned 13 inches off the centerline of the vehicle towards the driver’s side
EXIT CONDITIONS	
Stopping Distance	241 ft downstream
TEST ARTICLE DAMAGE	
There was a 0.125-inch gap in the soil on the impact side, The bottom 29-inch section of the support post broke off and landed 10 feet downstream. The remainder of the pos and sign came to rest 194 feet downstream and 11 feet to the left of impact.	
VEHICLE DAMAGE	
Max. Ext. Deformation	1.5 inches in the roof
Max Occupant Compartment Deformation	1.5 inches in the roof
VEHICLE DAMAGE DESCRIPTION	
The front bumper, hood, and roof were damaged. There was a 3-inch wide 0.25-inch deep dent in the hood, and a 20-inch long, 18-inch wide 1.5-inch deep dent in the roof.	

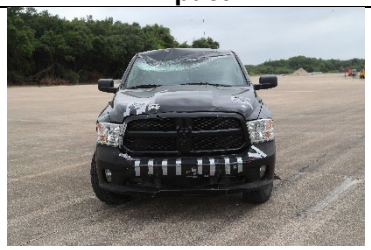
Figure 7.1. Summary of Test 616011-01-1 on U-Channel Sign Support System.



Installation and Vehicle Prior to Impact

Installation After Impact

Sign and Support After Impact

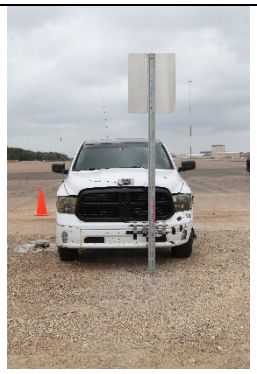


Front of Vehicle After Impact

Roof of Vehicle After Impact

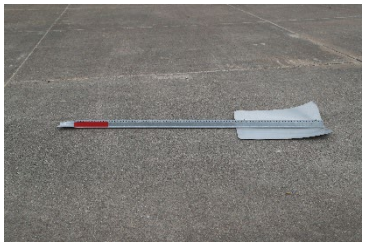
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-62
TTI Project No.	616011-01-2
Test Date	2022-04-20
TEST ARTICLE	
Type	Support Structures
Name	U-Channel Sign Support System
Height	113.5 inches
Key Materials	24” x 30” x 0.08” Aluminum Sign Panel 3.0 lb/ft U-Channel
Soil Type and Condition	AASHTO M147-65(2004), Type 1, Grade D Crushed Concrete
TEST VEHICLE	
Type/Designation	2270P
Year, Make and Model	2015 RAM 1500
Inertial Weight	5000 lbs (Nominal)
IMPACT CONDITIONS	
Impact Speed	62.0 mi/h (Nominal)
Impact Angle	0° (Nominal)
Impact Location	Centerline of the sign post aligned 13 inches off the centerline of the vehicle towards the passenger’s side
EXIT CONDITIONS	
Stopping Distance	242 ft downstream 11 feet to the left of impact Facing 40° to the left of the impact path
TEST ARTICLE DAMAGE	
There was loose dirt around the ground stub. A 28-inch long section of the lower portion of the support post came to rest 117 feet downstream and 10 feet to the right of impact. A large portion of the support post and the sign came to rest 192 feet downstream and 36 feet to the left. A 30-inch long section of u-channel came to rest 216 feet downstream and 19 feet to the left.	
VEHICLE DAMAGE	
Max. Ext. Deformation	6 inches in the roof
Max Occupant Compartment Deformation	6 inches in the roof
VEHICLE DAMAGE DESCRIPTION	
The front bumper, hood, windshield, and roof were damaged. There was a 3.5 inch wide 1-inch deep dent in the hood. The windshield had a 39-inch long, 17-inch wide, and 5.5-inch deep dent. There was a 24-inch long, 15-inch wide, and 6-inch deep dent in the roof.	

Figure 7.2. Summary of Test 616011-01-2 on U-Channel Sign Support System.

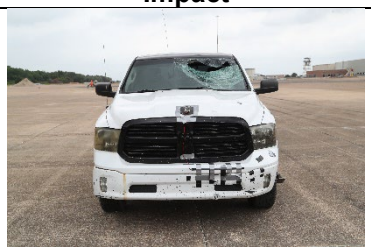


Installation and Vehicle Prior to Impact

Installation After Impact



Sign and Support After Impact



Front of Vehicle After Impact

Windshield After Impact

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 2-62
TTI Project No.	616011-01-3
Test Date	2022-04-20
TEST ARTICLE	
Type	Support Structures
Name	U-Channel Sign Support System
Height	125.5 inches
Key Materials	24” x 30” x 0.08” Aluminum Sign Panel 3.0 lb/ft U-Channel
Soil Type and Condition	AASHTO M147-65(2004), Type 1, Grade D Crushed Concrete
TEST VEHICLE	
Type/Designation	2270P
Year, Make and Model	2015 RAM 1500
Inertial Weight	5000 lbs (Nominal)
IMPACT CONDITIONS	
Impact Speed	44.0 mi/h (Nominal)
Impact Angle	0° (Nominal)
Impact Location	Centerline of the sign post aligned 13 inches off the centerline of the vehicle towards the driver’s side
EXIT CONDITIONS	
Stopping Distance	232.5 ft downstream Facing 1° to the right of the impact path

TEST ARTICLE DAMAGE

There was loose soil on the downstream side of the embedded portion of the post. The lower portion of the sign post came to rest 37 feet downstream and in-line with impact location. The remainder of the post and the sign landed 135 feet downstream and in-line with the impact location.

VEHICLE DAMAGE	
Max. Ext. Deformation	2 inches in the front bumper
Max Occupant Compartment Deformation	N/A (Hole in the windshield)

VEHICLE DAMAGE DESCRIPTION

The front bumper, hood, windshield, and roof were damaged. There was a 2-inch wide 0.25-inch deep dent in the hood. The bumper had a 2-inch wide, 1-inch deep dent in the bumper. The windshield had a hole in it measuring 23 inches long and 4 inches wide. The total size of the deformation of the windshield was 30 inches long and 28 inches wide. There was also a small dent in the roof just above the windshield deformation.

Figure 7.3. Summary of Test 616011-01-3 on U-Channel Sign Support System.

Chapter 8. SUMMARY AND CONCLUSIONS

8.1. ASSESSMENT OF TEST RESULTS

The crash tests reported herein were performed in accordance with *MASH* Test 3-62 on the U-Channel Sign Support System.

8.2. CONCLUSIONS

Table 8.1 shows that the U-Channel Sign Support System did not meet the performance criteria for *MASH* Test 3-62 Support Structures, specifically evaluation criteria D which states that detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment. The roof deformation of 4.9 inches and the windshield deformation of 3.75 inches on Test 616011-01-5 exceeded the MASH limits of 4 and 3 inches, respectively. Additionally, two of the three R&D tests (616011-01-2 and 616011-01-3) failed to meet the performance criteria for MASH Test 3-62 Support Structures. For Test 616011-01-2, the roof deformation of 6 inches exceeds the MASH limit of 4 inches. For Test 616011-01-3, the tear in the windshield caused by impact from the sign made it ineligible to meet evaluation criteria D as it penetrated into the occupant compartment.

Table 8.1. Assessment Summary for *MASH* 3-62 Tests on U-Channel Sign Support System.

Evaluation Criteria	Description	Test 616011-01-5	Test 616011-01-6	Test 616011-01-1	Test 616011-01-2	Test 616011-01-3
B	Test Article Should Readily Activate	S	S	S	S	S
D	No Penetration into Occupant Compartment	FAIL	S	S	FAIL	FAIL
F	Roll and Pitch Limit	S	S	S	S	S
H	OIV Threshold	S	S	S	S	S
I	Ridedown Threshold	S	S	S	S	S
Overall		Fail	Pass	Pass	Fail	Fail

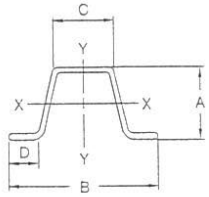
Note: S = Satisfactory; N/A = Not Applicable.
[1] See Table 3.2 for details

REFERENCES

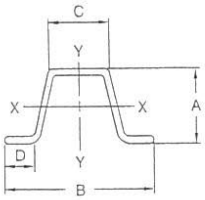
1. AASHTO. *Manual for Assessing Safety Hardware*, Second Edition. American Association of State Highway and Transportation Officials, Washington, DC, 2016.

APPENDIX A. SUPPORTING CERTIFICATION DOCUMENTS

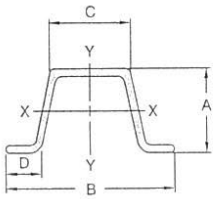
Sign Post and Base Post
Weight - 2.00 lbs/ft



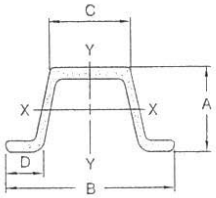
Sign Post and Base Post
Weight - 2.50 lbs/ft



Sign Post and Base Post
Weight - 3.00 lbs/ft

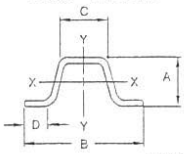


Sign Post and Base Post
Weight - 4.00 lbs/ft

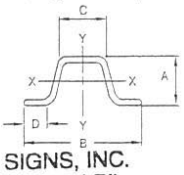


Delineator Posts

Weight - 1.12 lbs/ft



Weight - 1.33 lbs/ft



HALL SIGNS, INC.
4495 W. Vernal Pike
P.O. Box 515
Bloomington, Indiana 47402
(800) 284-7446 toll free
(812) 332-9355 (888) 329-7446 fax

Material: Posts are produced from standard "T" rails weighing 91 lbs/yd or more according to ASTM A499-81, Grade 60

Finish: Base posts and sign posts are finished with either a baked enamel paint or galvanized per ASTM A123.

Base Post: The weight of each base post before punching is 2.00 to 4.00 lbs/ft. The base post is punched with eighteen .375" diameter holes on 1.0" centers, except the first and fifth are .375" x .500" slots, with the first hole 1.0" from the top. The base post is pointed.

Sign Post: The weight of each sign post before punching is 2.00 to 4.00 lbs/ft. The sign post is punched with .375" diameter holes on 1.0" centers, full length. The first hole and last hole are 1.0" from the end of post.

Eze-Erect Hardware

Retainer-Spacer Strap: 17.125" long x 1.00" wide x .375" thick with .375" offset. The strap is galvanized to ASTM A123.

Bolts: Hex head, integral flange conforming to ASTM A354, Grade BD. Size is 5/16" - 18 UNC x 2.0".

Nuts: 5/16" - 18 UNC hex head, integral flange conforming to ASTM A563, Grade DH.

Lockwashers: 3/8" heavy duty external type.

Bolts, Nuts and Lockwashers are cadmium or zinc plated for corrosion resistance.

Base-Bolted Hardware

Spacers: 1.0" diameter x .625" thick with .438" hole. The spacers are zinc plated for corrosion resistance.

Bolts: Hex head, fully threaded Grade 9, 5/16" - 18 UNC x 1.5"

Washers: 5/16" Grade 9

Nuts: Hex head, integral flanged lock nut or standard Grade 9 hex head bolt and lockwasher.

Bolts, Nuts and Washers are cadmium or zinc plated for corrosion resistance.

Flanged Channel Properties

Weight *Lbs/Ft	Dimensions "A"	"B"	"C"	"D"	Area IN^2	X - X Axis + $I(IN^4)$	$S(IN^3)$	Y - Y Axis $I(IN^4)$	$S(IN^3)$
2.00	1.516	3.125	1.250	.625	.59	.18	.23	.42	.27
2.50	1.562	3.125	1.250	.625	.74	.24	.31	.55	.35
3.00	1.750	3.500	1.625	.718	.92	.40	.43	.87	.50
4.00	1.750	3.500	1.671	.718	1.24	.50	.56	1.22	.69

* ± 3 1/2% + Governing Section

Delineator Properties

Weight *Lbs/Ft	Dimensions "A"	"B"	"C"	"D"	Area IN^2	X - X Axis + $I(IN^4)$	$S(IN^3)$	Y - Y Axis $I(IN^4)$	$S(IN^3)$
1.12	.841	2.037	.802	.182	.329	.029	.073	.100	.098
1.33	.871	2.037	.802	.182	.391	.036	.088	.121	.119

* ± 3 1/2% + Governing Section

Ohio Galvanizing Corp.

Company Name: HALL SIGNS

GALVANIZING QUALITY CERTIFICATION TO ORDER NO. 44006531

The galvanizing applied to the items listed below, processed on or about JAN, 2021 meets all standards of the American Society for Testing Materials specifications, designated as ASTM A 123.

Zinc complying with ASTM B-6 was used throughout our operations during this period, as required by ASTM A 123. The galvanizing process originated in and was completed in the U.S.A.

Regular coating thickness tests were conducted on your products. The minimum average thickness was 3.4 mils.

Items description and quantity:

Quantity	Description
100	3# x 12' U-CHANNEL POST

OHIO GALVANIZING CORP.

By Scott A. Beisner

Scott A. Beisner
General Manager

467 West Fairground Street • Marion, OH 43302
740-387-6474 • Fax 740-382-8101

APPENDIX B. *MASH* TEST 3-62 (CRASH TEST 616011-01-5)

B.1. VEHICLE PROPERTIES AND INFORMATION

Vehicle Inventory Number: 1668

Date: 2022-06-28 Test No.: 616011-01-5 VIN No.: 1C6RR6GT7GS143582

Year: 2016 Make: RAM Model: 1500

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

Tread Type: Highway Odometer: 120002

Note any damage to the vehicle prior to test: None

• Denotes accelerometer location.

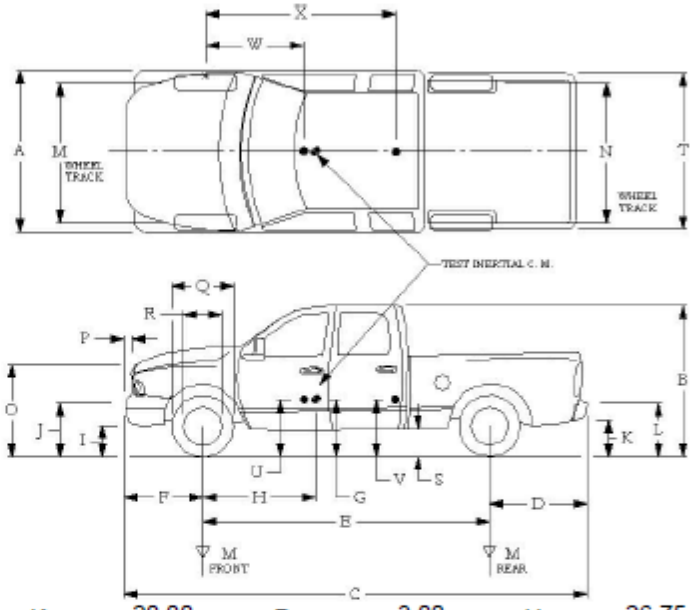
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

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

Optional Equipment:
None

Dummy Data:
Type: No Dummy
Mass: lb
Seat Position:



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.62	L	30.00	Q	30.50	V	30.25
C	227.50	H	60.80	M	68.50	R	18.00	W	
D	44.00	I	11.75	N	68.00	S	13.00	X	79.00
E	140.50	J	27.00	O	46.00	T	77.00		0.00

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}	2984	2870	2950
Back 3900	M_{rear}	2116	2190	2275
Total 6700	M_{Total}	5100	5060	5060

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

Mass Distribution:
lb LF: 1500 RF: 1370 LR: 1085 RR: 1105

Figure C.1. Vehicle Properties for Test 616011-01-5.

Date:	2022-06-28	Test No.:	616011-01-5	VIN No.:	1C6RR6GT7GS143582
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 FRONT BUMPER	16	1	-	-	-	-	-	-	-	-
	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.

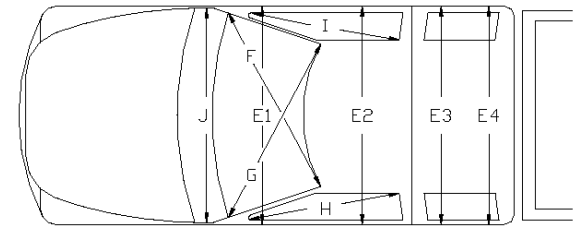
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

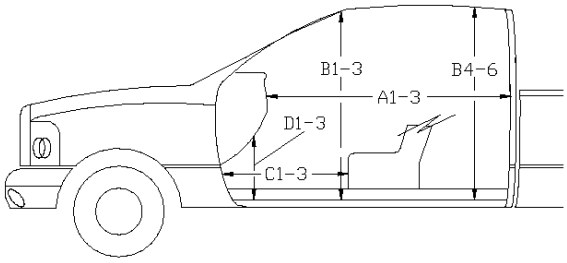
***Measure and document on the vehicle diagram the location of the maximum crush.

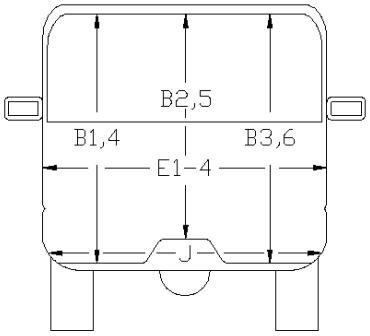
Note: Use as many lines/columns as necessary to describe each damage profile.

Figure C.2. Exterior Crush Measurements for Test 616011-01-5.

Date:	2022-06-28	Test No.:	616011-01-5	VIN No.:	1C6RR6GT7GS143582
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	40.12	-4.87
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 C.3. Occupant Compartment Measurements for Test 616011-01-5.

B.2. SEQUENTIAL PHOTOGRAPHS

(a) 0.000 s (b) 0.025 s

(c) 0.050 s (d) 0.075 s

(e) 0.100 s (f) 0.125 s

(g) 0.150 s (h) 0.175 s

Figure B.4. Sequential Photographs for Test 616011-01-5 (Right Angle Views).

(a) 0.000 s (b) 0.025 s

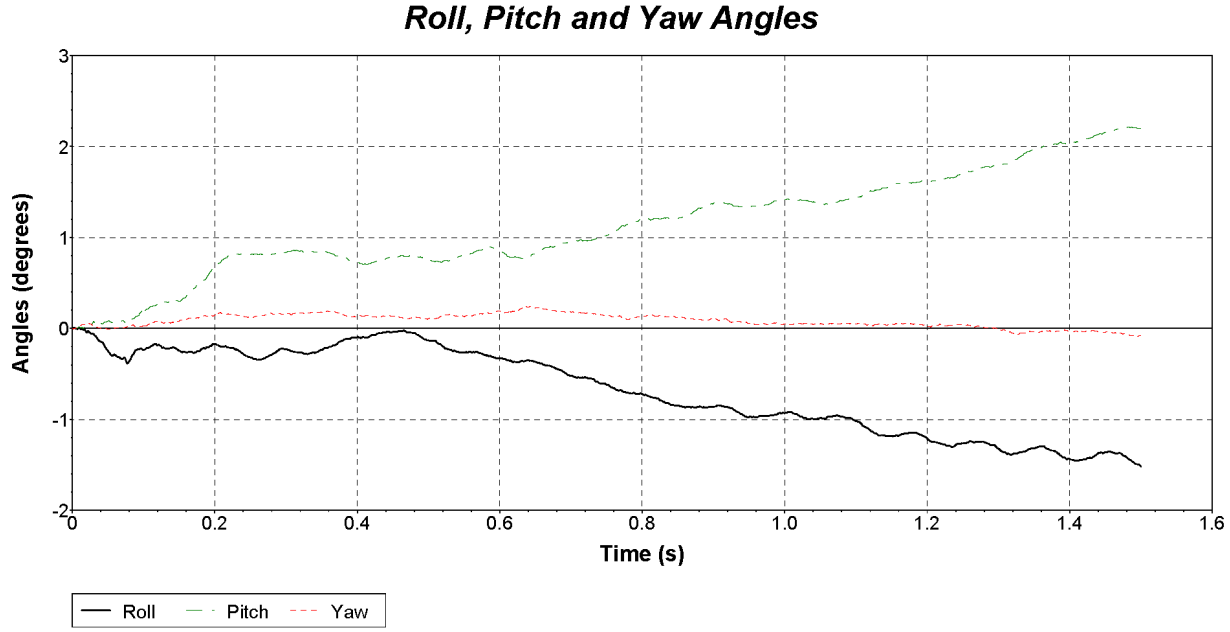
(c) 0.050 s (d) 0.075 s

(e) 0.100 s (f) 0.125 s

(g) 0.150 s (h) 0.175 s

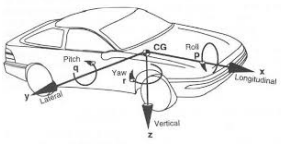
Figure B.5. Sequential Photographs for Test 616011-01-5 (Oblique Views).

B.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for
determining orientation:

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



Test Number: 616011-01-5
Test Standard Test Number: *MASH* Test 3-62
Test Article: U-Channel Sign Support System
Test Vehicle: 2016 RAM 1500
Inertial Mass: 5060 lbs
Gross Mass: 5225 lbs
Impact Speed: 62.9 mi/h
Impact Angle: 0°

Figure B.6. Vehicle Angular Displacements for Test 616011-01-5.

B.4. VEHICLE ACCELERATIONS

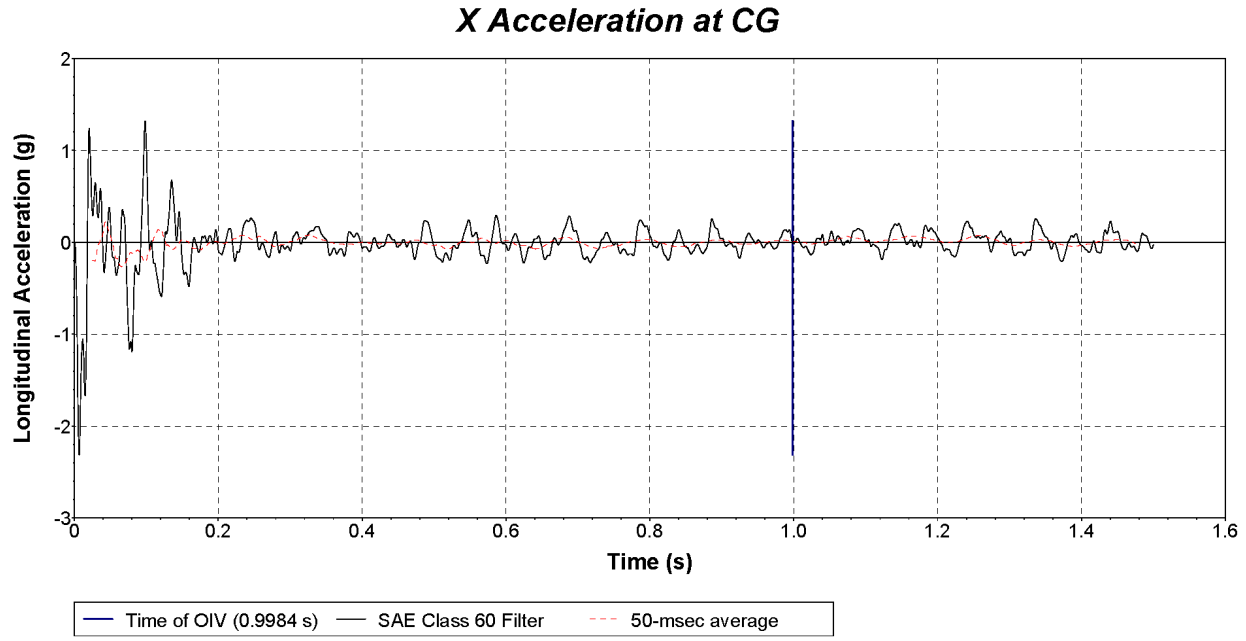


Figure B.7. Vehicle Longitudinal Accelerometer Trace for Test 616011-01-5 (Accelerometer Located at Center of Gravity).

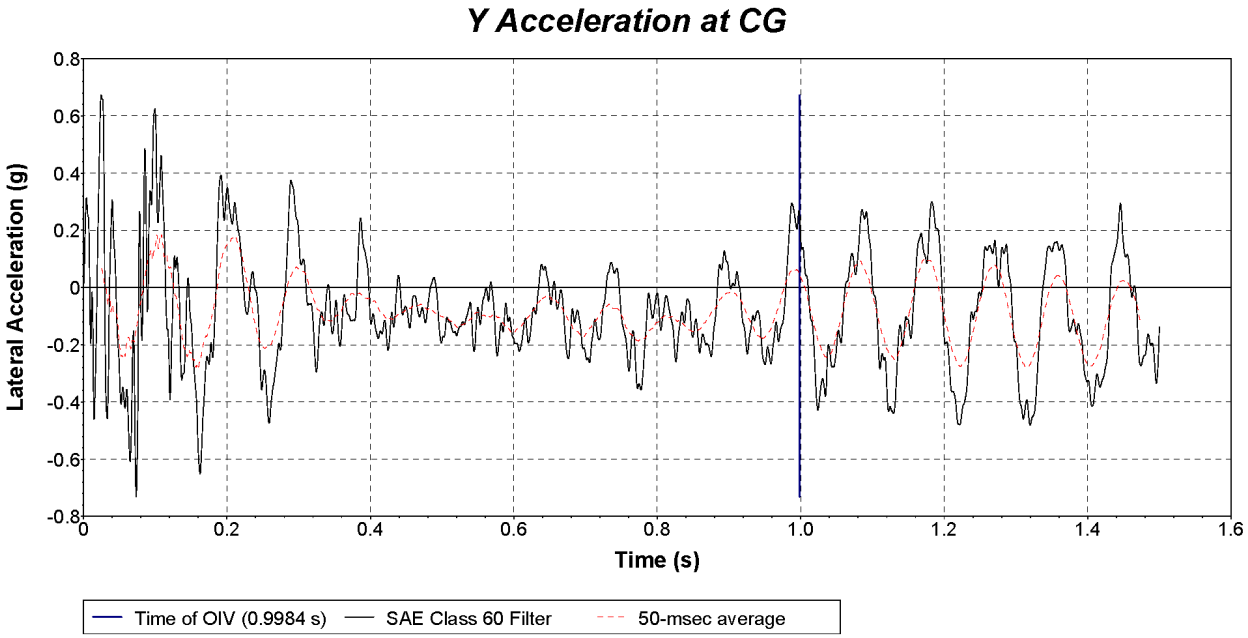


Figure B.8. Vehicle Lateral Accelerometer Trace for Test 616011-01-5 (Accelerometer Located at Center of Gravity).

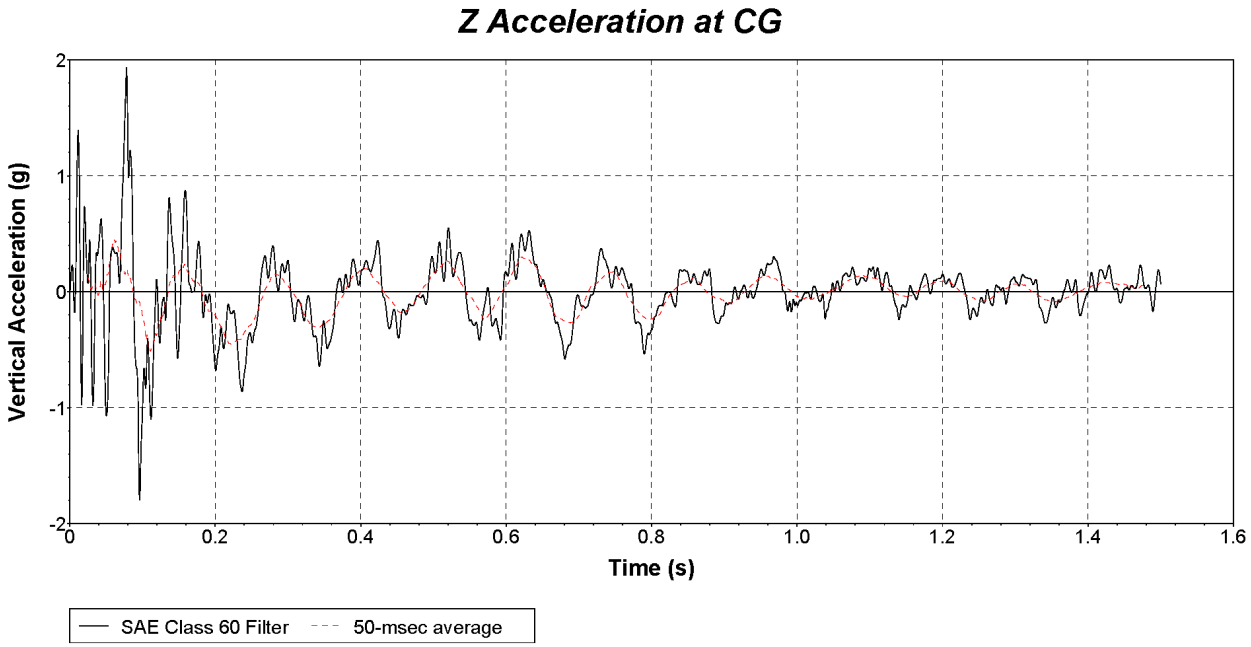


Figure B.9. Vehicle Vertical Accelerometer Trace for Test 616011-01-5 (Accelerometer Located at Center of Gravity).

APPENDIX C. *MASH* TEST 3-62 (CRASH TEST 616011-01-6)

C.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2022-06-28 Test No.: 616011-01-6 VIN No.: 1C6RR6FT8GS368319

Year: 2016 Make: RAM Model: 1500

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

Tread Type: Highway Odometer: 311391

Note any damage to the vehicle prior to test: None

• Denotes accelerometer location.

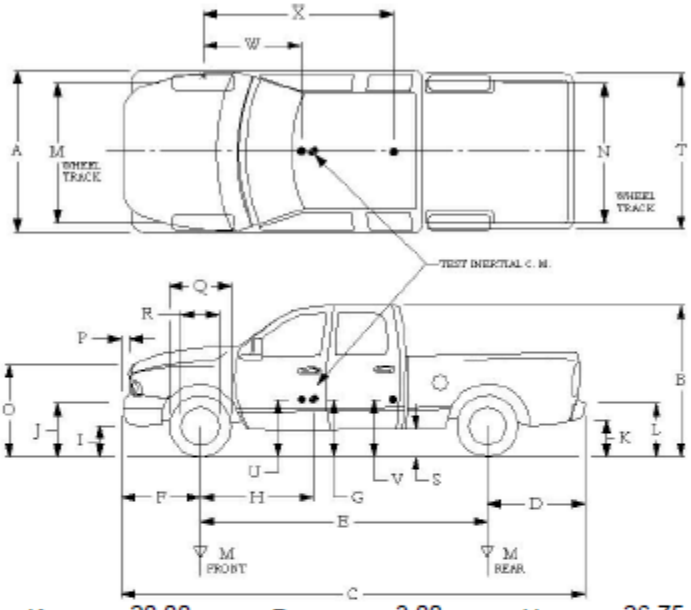
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

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

Optional Equipment:
None

Dummy Data:
Type: No Dummy
Mass: lb
Seat Position:



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.50	L	30.00	Q	30.50	V	30.25
C	227.50	H	60.90	M	68.50	R	18.00	W	60.90
D	44.00	I	11.75	N	68.00	S	13.00	X	79.00
E	140.50	J	27.00	O	46.00	T	77.00		

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

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

GVWR Ratings:		Mass: lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2983	2846	2926
Back	3900	M_{rear}	2184	2179	2264
Total	6700	M_{Total}	5167	5025	5025

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

Mass Distribution:
lb LF: 1438 RF: 1408 LR: 1093 RR: 1086

Figure C.1. Vehicle Properties for Test 616011-01-6.

Date:	2022-06-28	Test No.:	616011-01-6	VIN No.:	1C6RR6FT8GS368319
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 FRONT BUMPER	16	3.25	-	-	-	-	-	-	-	-
	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.

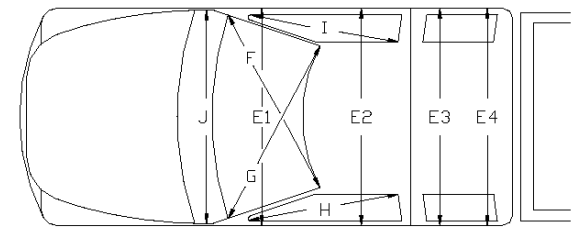
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

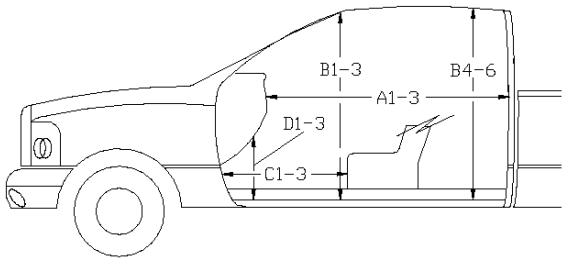
***Measure and document on the vehicle diagram the location of the maximum crush.

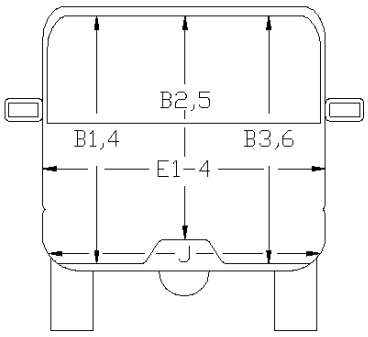
Note: Use as many lines/columns as necessary to describe each damage profile.

Figure C.2. Exterior Crush Measurements for Test 616011-01-6.

Date:	2022-06-28	Test No.:	616011-01-6	VIN No.:	1C6RR6FT8GS368319
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 C.3. Occupant Compartment Measurements for Test 616011-01-6.

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 616011-01-6 (Right Angle Views).

(a) 0.000 s (b) 0.100 s

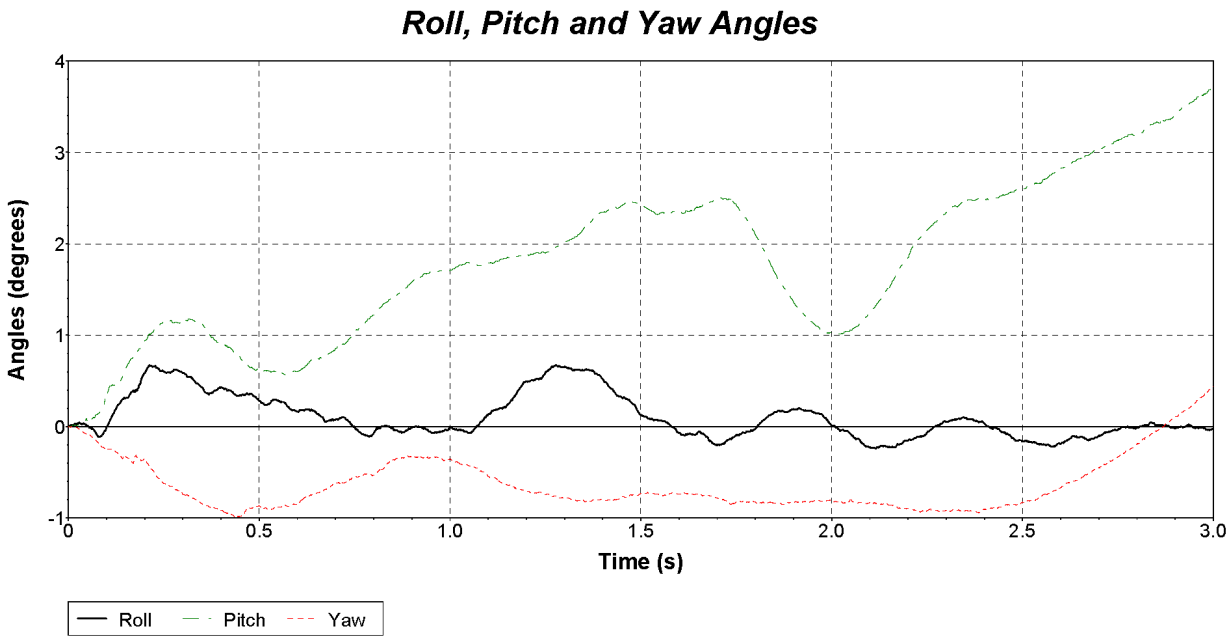
(c) 0.200 s (d) 0.300 s

(e) 0.400 s (f) 0.500 s

(g) 0.600 s (h) 0.700 s

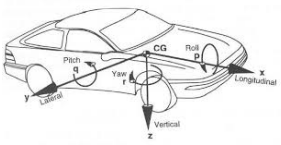
Figure C.5. Sequential Photographs for Test 616011-01-6 (Oblique Views).

C.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

4. Yaw.
5. Pitch.
6. Roll.



Test Number: 616011-01-6
Test Standard Test Number: *MASH* Test 3-62
Test Article: U-Channel Sign Support System
Test Vehicle: 2016 RAM 1500
Inertial Mass: 5025 lbs
Gross Mass: 5190 lbs
Impact Speed: 62.6 mi/h
Impact Angle: 90°

Figure C.6. Vehicle Angular Displacements for Test 616011-01-6.

C.4. VEHICLE ACCELERATIONS

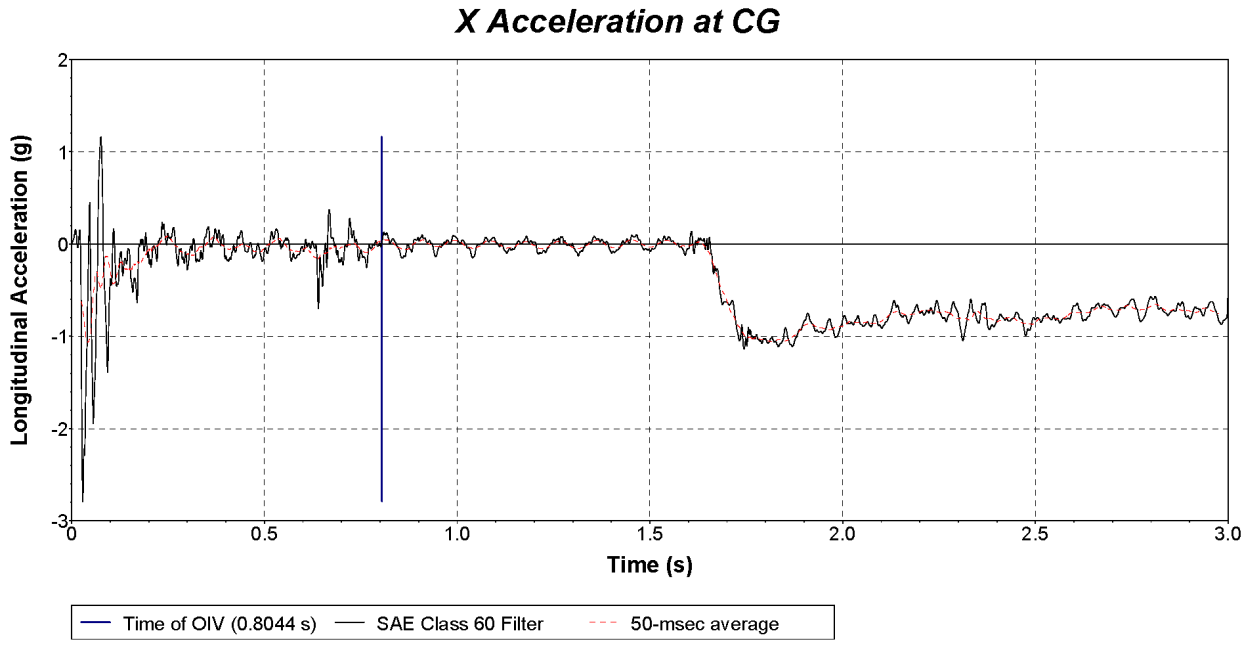


Figure C.7. Vehicle Longitudinal Accelerometer Trace for Test 616011-01-6 (Accelerometer Located at Center of Gravity).

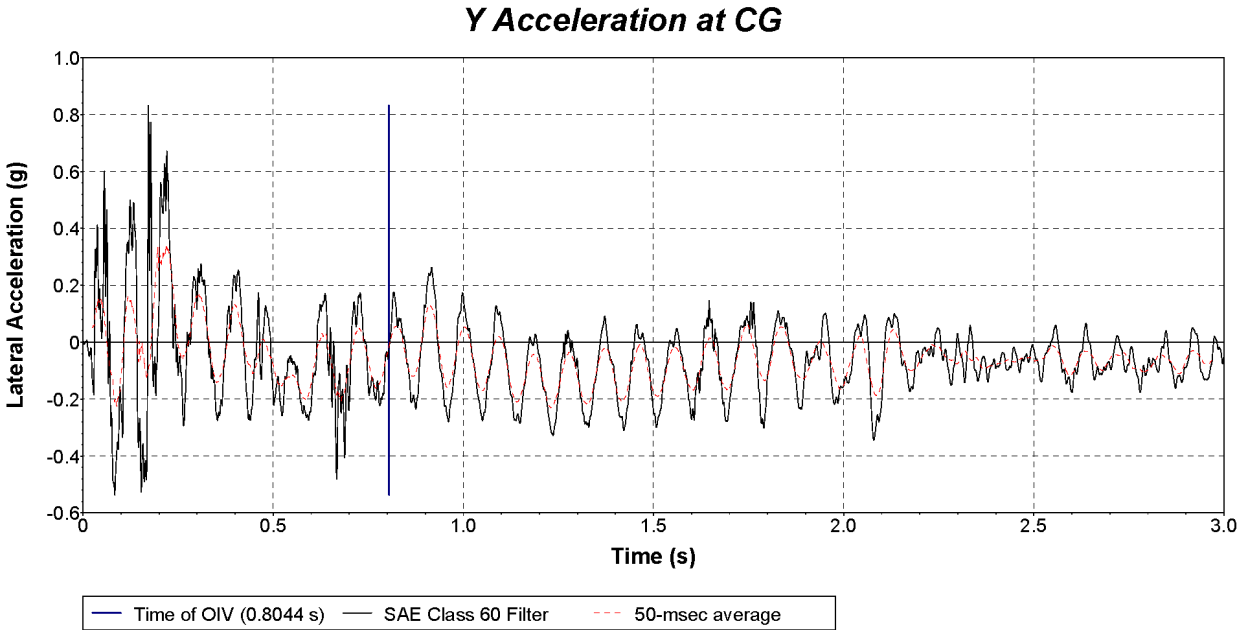


Figure C.8. Vehicle Lateral Accelerometer Trace for Test 616011-01-6 (Accelerometer Located at Center of Gravity).

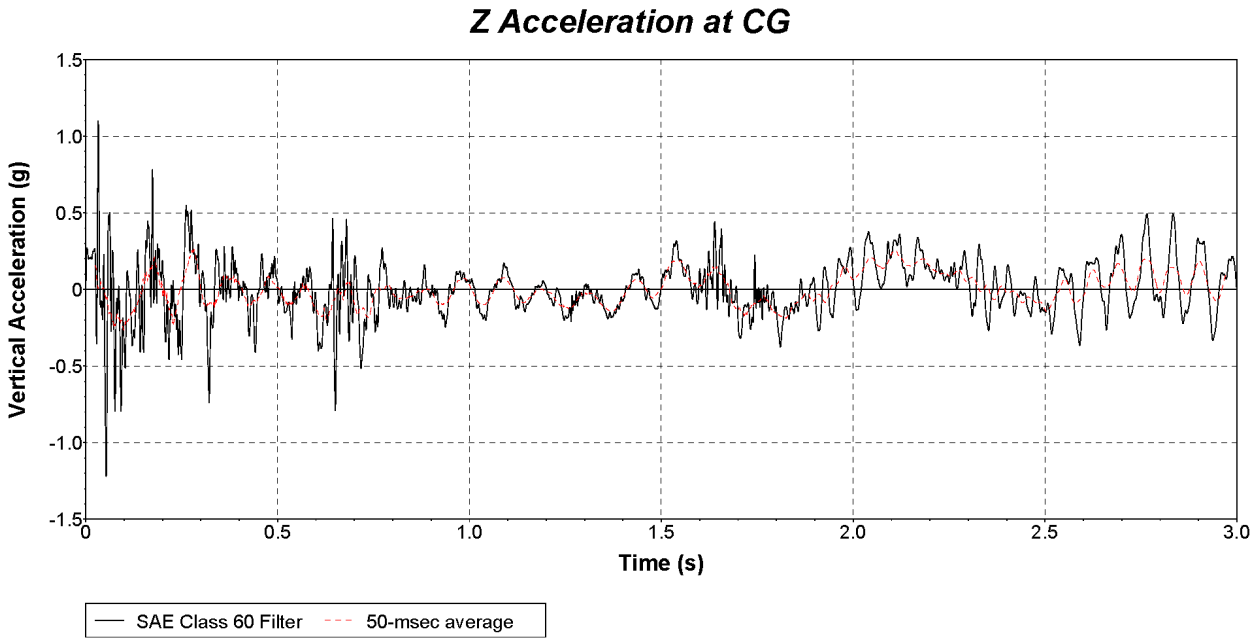


Figure C.9. Vehicle Vertical Accelerometer Trace for Test 616011-01-6 (Accelerometer Located at Center of Gravity).