Test Report No. 616161-01

EVALUATION OF CRASHWORTHY ENHANCED HIGHWAY SIGN ASSEMBLIES

Sponsored by

Roadside Safety Pooled Fund

TEXAS A&M TRANSPORTATION INSTITUTE PROVING GROUND
Roadside Safety & Physical Security
Texas A&M University System RELLIS Campus
Building 7091
1254 Avenue A
Bryan, TX 77807

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16. Abstract

The purpose of the tests reported herein was to assess the performance of the Crashworthy Enhanced Highway Sign Assemblies 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 crash tests were performed in accordance with *MASH* Test Level 3 (TL-3).

This report provides details on the Crashworthy Enhanced Highway Sign Assemblies, the crash tests and results, and the performance assessment of the Crashworthy Enhanced Highway Sign Assemblies for *MASH* TL-3 longitudinal barrier evaluation criteria.

The Crashworthy Enhanced Highway Sign Assemblies met the performance criteria for *MASH* TL-3 support structures.

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EVALUATION OF CRASHWORTHY ENHANCED HIGHWAY SIGN ASSEMBLIES

by
Maysam Kiani, Ph.D., P.E., PMP
Assistant Research Engineer
Texas A&M Transportation Institute

William J. L. Schroeder
Research Engineering Associate
Texas A&M Transportation Institute

and

Darrell L. Kuhn, P.E.
Research Specialist
Texas A&M Transportation Institute

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TEXAS A&M TRANSPORTATION INSTITUTE
College Station, Texas 77843-3135

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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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Roadside Safety Research Pooled Fund Committee
Revised January 2021

ALABAMA
Stanley (Stan) C. Biddick, P.E.
Assistant State Design Engineer
Design Bureau, Final Design Division
Alabama Dept. of Transportation
1409 Coliseum Boulevard, T-205
Montgomery, AL 36110
(334) 242-6833
biddicks@dot.state.al.us

ALASKA
Mary McRae
Statewide Standard Specifications
Alaska Depart. of Transportation & Public Facilities
3132 Channel Drive
P.O. Box 112500
Juneau, AK 99811-2500
(907) 465-8962
Jeff.Jeffers@alaska.gov

CALIFORNIA
Bob Meline, P.E.
Caltrans
Office of Materials and Infrastructure
Division of Research and Innovation
5900 Folsom Blvd
Sacramento, CA 95819
(916) 227-7031
Bob.Meline@dot.ca.gov

John Jewell, P.E.
Senior Crash Testing Engineer
Office of Safety Innovation & Cooperative Research
(916) 227-5824
John_Jewell@dot.ca.gov

COLORADO
Joshua Keith, P.E.
Standards & Specifications Engineer
Project Development Branch
Colorado Dept. of Transportation
4201 E Arkansas Ave, 4th Floor
Denver, CO 80222
(303) 757-9021
Josh.Keith@state.co.us

CONNECTICUT
David Kilpatrick
State of Connecticut Depart. of Transportation
2800 Berlin Turnpike
Newington, CT 06131-7546
(806) 594-3288
David.Kilpatrick@ct.gov

DELAWARE
Jeffery Van Horn, P.E.
Civil Engineering Program Manager
Transportation Solutions – Traffic Operations
Office: (302) 659-4606; Cell:(302) 922-7279
Jeffery.VanHorn@delaware.gov

Craig Blowers
Craig.Blowers@delaware.gov

FLORIDA
Derwood C. Sheppard, Jr., P.E.
State Roadway Design Engineer
Florida Depart. of Transportation
Roadway Design Office
605 Suwannee Street, MS-32
Tallahassee, FL 32399-0450
(850) 414-4334
Derwood.Sheppard@dot.state.fl.us

IDAHO

Marc Danley, P.E.
Technical Engineer
(208) 334-8558
Marc.danley@itd.idaho.gov

ILLINOIS

Martha A. Brown, P.E.
Safety Design Bureau Chief
Bureau of Safety Programs and Engineering
Illinois Depart. of Transportation
2300 Dirksen Parkway, Room 005
Springfield, IL 62764
(217) 785-3034
Martha.A.Brown@illinois.gov

Edgar Galofre
Safety Design Engineer
(217) 558-9089
edgar.glofre@illinois.gov

IOWA

Daniel Harness
Office of Design – Methods
Iowa Department of Transportation
Daniel.Harness@iowadot.us

Zac Abrams
Traffic and Safety Project Engineer
Iowa Department of Transportation
(515) 239-1567
Zachary.Abrams@iowadot.us

LOUISIANA

Chris Guidry
Bridge Manager
Louisiana Transportation Center
Bridge & Structural Design Section
P.O. Box 94245
Baton Rouge, LA 79084-9245
(225) 379-1933
Chris.Guidry@la.gov

Kurt Brauner, P.E.
Bridge Engineer Manager
Louisiana Transportation Center
1201 Capital Road, Suite 605G
Baton Rouge, LA 70802
(225) 379-1933
Kurt.Brauner@la.gov

MARYLAND

Matamba Kabengele
Traffic Engineer
Office of Traffic and Safety
Maryland State Highway Administration
MKabengele@mdot.maryland.gov

MASSACHUSETTS

Alex Bardow
Director of Bridges and Structure
Massachusetts Depart. of Transportation
10 Park Plaza, Room 6430
Boston, MA 02116
(517) 335-9430
Alexander.Bardow@state.ma.us

James Danila
State Traffic Engineer
(857) 368-9640
James. Danila@state.ma.us

Alex Bardow
Director of Bridges and Structure
Massachusetts Department of Transportation
10 Park Plaza, Room 6430
Boston, MA 02116
(517) 335-9430
Alexander.Bardow@state.ma.us

MICHIGAN

Carlos Torres, P.E.
Crash Barrier Engineer
Geometric Design Unit, Design Division
Michigan Depart. of Transportation
P. O. Box 30050
Lansing, MI 48909
(517) 335-2852
TorresC@michigan.gov

MINNESOTA

Khamsai Yang
Design Standards Engineer
Office of Project Management and Technical Support
(651) 366-4622
Khamsai.Yang@state.mn.us

MISSOURI
Sarah Kleinschmit, P.E.
Policy and Innovations Engineer,
Missouri Department of Transportation
P.O. Box 270
Jefferson City, MO 65102
(573) 751-7412
sarah.kleinschmit@modot.mo.gov

Kaitlyn Bower
kaitlyn.bower@modot.mo.gov

NEW MEXICO
Brad Julian
Traffic Technical Support Engineer
(505) 827-3263
Brad.Julian@state.nm.us

OHIO
Don P. Fisher, P.E.
Ohio Depart. of Transportation
1980 West Broad Street
Mail Stop 1230
Columbus, OH 43223
(614) 387-6214
Don.fisher@dot.ohio.gov

OREGON
Christopher Henson
Senior Roadside Design Engineer
Oregon Depart. of Transportation
Technical Service Branch
4040 Fairview Industrial Drive, SE
Salem, OR 97302-1142
(503) 986-3561
Christopher.S.Henson@odot.state.or.us

PENNSYLVANIA
Evan Pursel
Senior Civil Engineer
epursel@pa.gov

Nina Ertel
nertel@pa.gov

TEXAS
Chris Lindsey
Transportation Engineer
Design Division
Texas Department of Transportation
125 East 11th Street
Austin, TX 78701-2483
(512) 416-2750
Christopher.Lindsey@txdot.gov

Taya Retterer P.E.
TXDOT Bridge Standards Engineer
(512) 416-2719
Taya.Retterer@txdot.gov

UTAH
Shawn Debenham
Traffic and Safety Division
Utah Depart. of Transportation
4501 South 2700 West
PO Box 143200
Salt Lake City UT 84114-3200
(801) 965-4590
sdebenham@utah.gov

WASHINGTON
John Donahue
Design Policy and Analysis Manager
Washington State Dept. of Transportation
Development Division
P.O. Box 47329
Olympia, WA 98504-7246
(360) 704-6381
donahjo@wsdot.wa.gov

Mustafa Mohamedali
Assistant Research Project Manager
P.O. Box 47372
Olympia, WA 98504-7372
(360) 704-6307
mohamem@wsdot.wa.gov

Tim Moeckel
Policy Support Engineer
Washington State Department of Transportation
moecket@wsdot.wa.gov

WEST VIRGINIA
Donna J. Hardy, P.E.
Safety Programs Engineer
West Virginia Depart. of
Transportation – Traffic Engineering
Building 5, Room A-550
1900 Kanawha Blvd E.
Charleston, WV 25305-0430
(304) 558-9576
Donna.J.Hardy@wv.gov

Ted Whitmore
Traffic Services Engineer
(304) 558-9468
Ted.J.Whitmore@wv.gov

WISCONSIN
Erik Emerson, P.E.
Standards Development Engineer –
Roadside Design
Wisconsin Department of Transportation
Bureau of Project Development
4802 Sheboygan Avenue, Room 651
P. O. Box 7916
Madison, WI 53707-7916
(608) 266-2842
Erik.Emerson@wi.gov

CANADA – ONTARIO
Kenneth Shannon, P. Eng.
Senior Engineer, Highway Design (A)
Ontario Ministry of Transportation
301 St. Paul Street
St. Catharines, ON L2R 7R4
CANADA
(904) 704-3106
Kenneth.Shannon@ontario.ca

FEDERAL HIGHWAY ADMINISTRATION (FHWA)
WebSite: safety.fhwa.dot.gov

Richard B. (Dick) Albin, P.E.
Safety Engineer
FHWA Resource Center Safety & Design
Technical Services Team
711 S. Capital
Olympia, WA 98501
(303) 550-8804
Dick.Albin@dot.gov

Eduardo Arispe
Research Highway Safety Specialist
U.S. Department of Transportation
Federal Highway Administration
Turner-Fairbank Highway Research Center
Mail Code: HRDS-10
6300 Georgetown Pike
McLean, VA 22101
(202) 493-3291
Eduardo.arispe@dot.gov

Christine Black
Highway Safety Engineer
Central Federal Lands Highway Division
12300 West Dakota Ave.
Lakewood, CO 80228
(720) 963-3662
Christine.black@dot.gov

Isbel Ramos-Reyes
Lead Safety and Transportation Operations
Engineer
(703) 948-1442
isbel.ramos-reyes@dot.gov

Matt Hinshaw, M.S., P.E.
Highway Safety Engineer
Central Federal Lands Highway Division
(360)619-7677
matthew.hinshaw@dot.gov

TEXAS A&M TRANSPORTATION INSTITUTE (TTI)
WebSite: tti.tamu.edu
www.roadsidepooledfund.org

Roger P. Bligh, Ph.D., P.E.
Senior Research Engineer
(979) 317-2703
R-Bligh@tti.tamu.edu

Chiara Silvestri Dobrovolny, Ph.D.
Research Scientist
(979) 317-2687
C-Silvestri@tti.tamu.edu

Ariel Sheil
Associate Research Scientist
a-sheil@tti.tamu.edu

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		
in2	square inches	645.2	square millimeters	mm2
ft2	square feet	0.093	square meters	m2
yd2	square yards	0.836	square meters	m2
ac	acres	0.405	hectares	ha
mi2	square miles	2.59	square kilometers	km2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft3	cubic feet	0.028	cubic meters	m3
yd3	cubic yards	0.765	cubic meters	m3
	NOTE: volumes greater than 1000L shall be shown in m3			
		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/in2	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		
mm2	square millimeters	0.0016	square inches	in2
m2	square meters	10.764	square feet	ft2
m2	square meters	1.195	square yards	yd2
ha	hectares	2.47	acres	ac
km2	Square kilometers	0.386	square miles	mi2
		VOLUME		
mL	milliliters	0.034	fluid ounces	oz
L	liters	0.264	gallons	gal
m3	cubic meters	35.314	cubic feet	ft3
m3	cubic meters	1.307	cubic yards	yd3
		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/in2

*SI is the symbol for the International System of Units

REPORT AUTHORIZATION

REPORT REVIEWED BY:

DocuSigned by:
Glenn Schroeder
E692F9CB5047487...

Glenn Schroeder, Research Specialist
Drafting & Reporting

DocuSigned by:
Ken Reeves
60D556935596468...

Ken Reeves, Research Specialist
Electronics Instrumentation

DocuSigned by:
Adam Mayer
F7A06F754E02430...

Adam Mayer, Research Specialist
Construction

DocuSigned by:
Richard Badillo
0F51DA60AB144F9...

Richard Badillo, Research Specialist
Photographic Instrumentation

DocuSigned by:
Robert Kocman
6CF2C47B60EB409...

Robert Kocman, Research Specialist
Mechanical Instrumentation

DocuSigned by:
25F29E1BAD624E8...

William J. L. Schroeder, Research Engineering Associate
Research Evaluation and Reporting

DocuSigned by:
Bill Griffith
44A122CB271845B...

Bill L. Griffith, Research Specialist
Deputy Quality Manager

DocuSigned by:
Matt Robinson
EAA22BFA5BFD417...

Matthew N. Robinson, Research Specialist
Test Facility Manager & Technical Manager

DocuSigned by:
Maysam Kiani
AD1BD3FDAD96461...

Maysam Kiani, Ph.D., P.E., PMP
Assistant Research Engineer

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SI* (MODERN METRIC) CONVERSION FACTORS

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*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 Florida Department of Transportation' Crashworthy Enhanced Highway Sign Assemblies 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 crash tests were performed in accordance with *MASH* Test Level 3 (TL-3) (as discussed in Chapter 3).

1.1. INITIAL ANALYSIS*

We examined various mounting height combinations for the components and determined that beyond a certain point, increasing the height to achieve a higher center of gravity will not enhance the system's performance. It is important to note that our analysis tends to overestimate outcomes. While the analysis for the 18-pound solar configuration indicates a potential impact on the vehicle, it is still possible to pass MASH testing, as our analysis only predicts the trajectory and not the force exerted on the occupant compartment upon impact.

In summary, we can proceed with crash testing the 18-pound configuration. If it passes, the other two configurations in Table 1.1, provided by FDOT, should be acceptable as well.

Table 1.1. FDOT Enhanced Highway Sign Configurations.

FDOT APL #	Specific Feature	Evaluation	Test 3-60	Test 3-61	Test 3-62
654-001-014	18 lbs solar/battery combo	Most critical	**To be crash tested first**	Not critical	**To be crash tested if 3-60 passes**
654-001-012	44 lbs solar/battery combo	Less critical than 18 lbs config	Not critical	Not critical	Not critical
654-001-013	25 lbs solar panel with an 80 lbs battery cabinet	Least critical of the 3 configurations	Not critical	Not critical	Not critical

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

Chapter 2. SYSTEM DETAILS

2.1. TEST ARTICLE AND INSTALLATION DETAILS

The installation was comprised of a 15 ft-0 inch tall, 4-inch diameter, 6061-T4 Aluminum pipe pole, secured to the concrete runway, supporting multiple-sign components and associated hardware. The post measured 16 ft-4½ inches to grade, with a solar panel assembly mounted at the top. Below the solar panel assembly was a 0.080-inch × 30-inch square aluminum sign that was mounted 10 ft-3½ inches from grade, with the sign oriented to give a diamond shape appearance. A flashing beacon and small sign panel were mounted 10 inches below the diamond shaped sign. An audible button with pedestrian sign was mounted 42 inches from grade to the bottom of the sign. The post assembly was secured to a transformer base, which was anchored to the concrete runway with four threaded rods epoxied in the concrete.

Figure 2.1 presents the overall information on the Crashworthy Enhanced Highway Sign Assemblies, and Figure 2.2 thru Figure 2.7 provide photographs of the installation. Appendix A provides further details on the Crashworthy Enhanced Highway Sign Assemblies. 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.

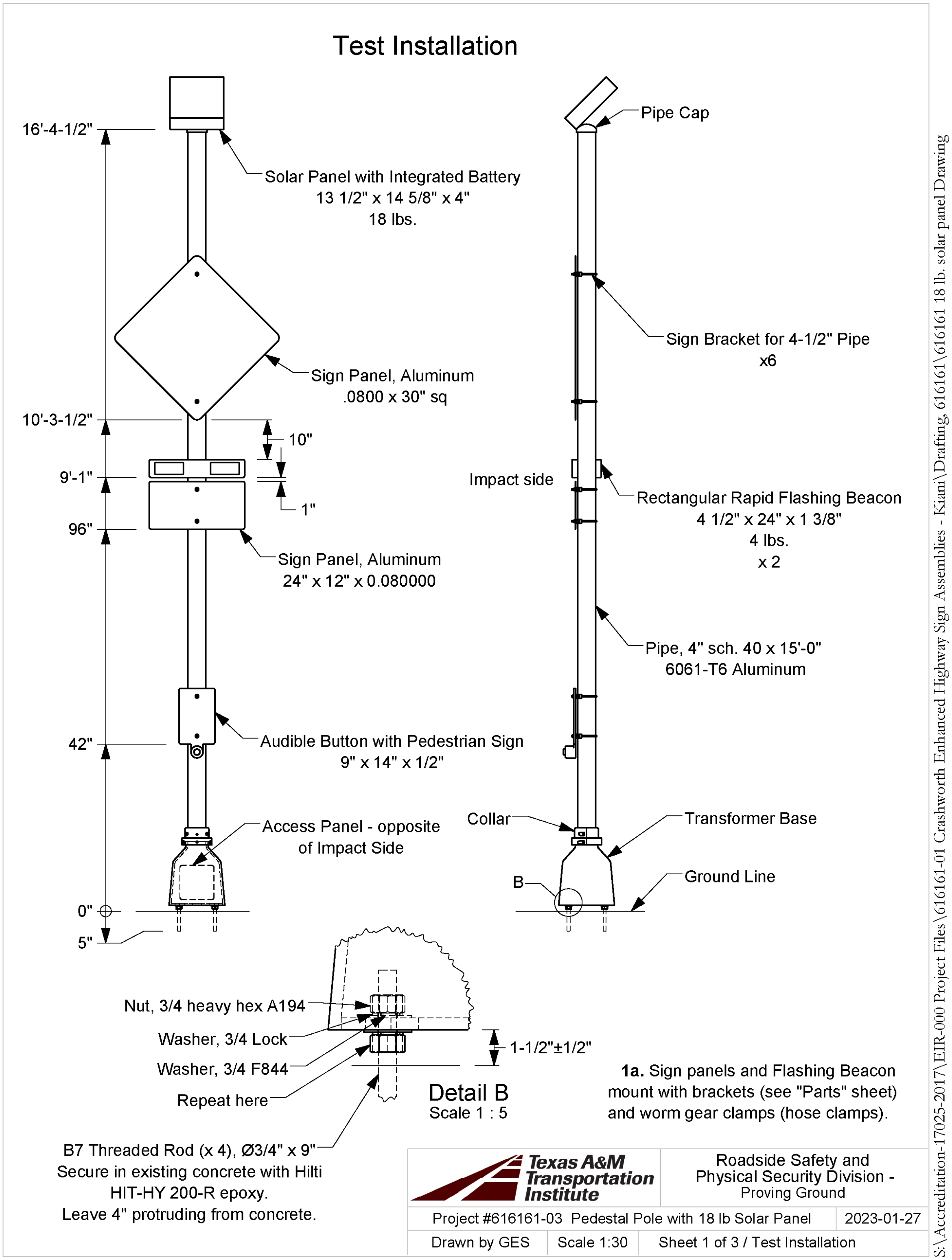


Figure 2.1. Details of Crashworthy Enhanced Highway Sign Assemblies.

Figure 2.2. Crashworthy Enhanced Highway Sign Assemblies prior to Testing.

Figure 2.3. The Rear of the Crashworthy Enhanced Highway Sign Assemblies prior to Testing.

Figure 2.4. The Top Portion of the Crashworthy Enhanced Highway Sign Assemblies prior to Testing.

Figure 2.5. The Lower Portion of the Crashworthy Enhanced Highway Sign Assemblies prior to Testing.

Figure 2.6. Rear of the Solar Panel on the Crashworthy Enhanced Highway Sign Assemblies prior to Testing.

Figure 2.7. The Anchor System of the Crashworthy Enhanced Highway Sign Assemblies prior to Testing.

2.3. MATERIAL SPECIFICATIONS

Appendix B provides material certification documents for the materials used to install/construct the Crashworthy Enhanced Highway Sign Assemblies.

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* TL-3 for support structures. The target critical impact points (CIPs) for each test were determined using the information provided in *MASH* Section 2.2.1 and Section 2.3.2. Figure 3.1 shows the target CIP for *MASH* Tests 3-60 and 3-62 on the Crashworthy Enhanced Highway Sign Assemblies. An engineering evaluation, based on the method from NCHRP Report 318, concluded that the sign would not interact with the 1100C vehicle during the 3-61 test, except for the initial impact (2). This finding concurred with previous studies, and as a result, the test was not performed (3).

Table 3.1. Test Conditions and Evaluation Criteria Specified for *MASH* TL-3 Support structures.

Test Designation	Test Vehicle	Impact Speed	Impact Angle	Evaluation Criteria
3-60	1100C	19 mi/h	0º	B, D, F, H, I, N
3-62	2270P	62 mi/h	0º	B, D, F, H, I, N

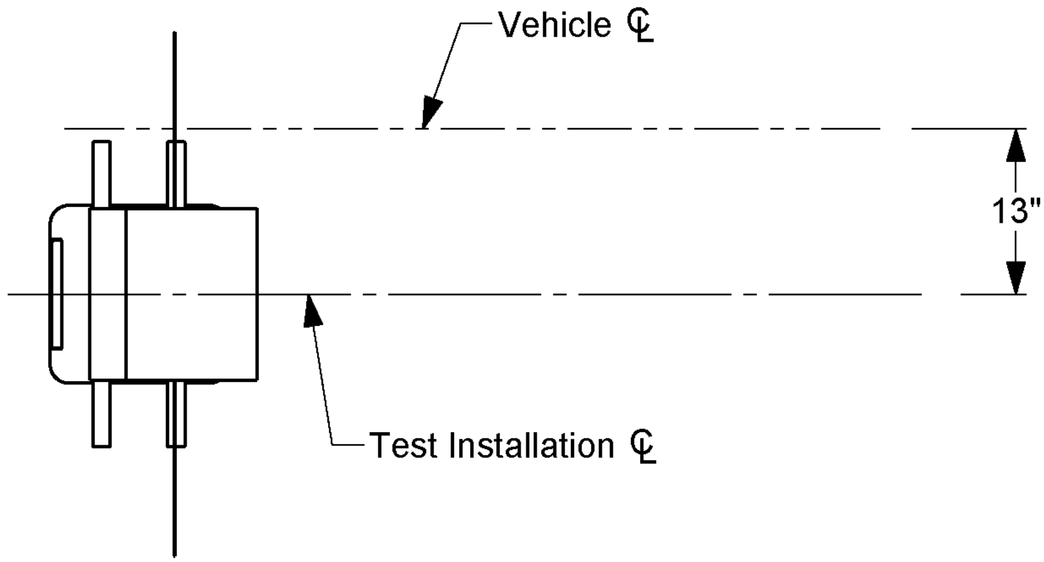


Figure 3.1. Target CIP for *MASH* TL-3 Tests on Crashworthy Enhanced Highway Sign Assemblies.

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* TL-3, and Table 3.2 provides detailed information on the evaluation criteria.

Table 3.2. Evaluation Criteria Required for *MASH* Testing.

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

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

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

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.

4.3.3. Photographic Instrumentation Data Processing

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

- One located at a right angle to the impact path and in line with the installation.
- One placed downstream from the installation at an angle to have a field of view of the interaction of the front of the vehicle with the installation.

A flashbulb on the impacting vehicle was activated by a pressure-sensitive tape switch to indicate the instant of contact with the Crashworthy Enhanced Highway Sign Assemblies. 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 3-60 (CRASH TEST NO. 616161-01-1)

5.1. 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 5.1. Impact Conditions for *MASH* 3-60 616161-01-1.

Test Parameter	Specification	Tolerance	Measured
Impact Speed (mi/h)	19	±2.5 mi/h	18.9
Impact Angle (deg)	0	±1.5°	0
Kinetic Energy (kip-ft)	34	≤34 kip-ft	29.1
Impact Location	Centerline of the sign post aligned 13 off the centerline of the vehicle towards the driver side	± 6 inches	Centerline of the sign post aligned 13 off the centerline of the vehicle towards the driver side

Table 5.2. Exit Parameters for *MASH* 3-60 616161-01-1.

Exit Parameter	Measured
Speed (mi/h)	15.0
Brakes applied post impact (s)	Greater than 5 seconds
Vehicle at rest position	127 ft downstream of impact point 7 ft to the right side 2° right
Comments:	Vehicle remained upright and stable.

Figure 5.1. Crashworthy Enhanced Highway Sign Assemblies/Test Vehicle Geometrics for Test 616161-01-1.

Figure 5.2. Crashworthy Enhanced Highway Sign Assemblies/Test Vehicle Impact Location 616161-01-1.

5.2. WEATHER CONDITIONS

Table 5.3 provides the weather conditions for 616161-01-1.

Table 5.3. Weather Conditions 616161-01-1.

Date of Test	2023-02-03 AM
Wind Speed (mi/h)	7
Wind Direction (deg)	360
Temperature (°F)	40
Relative Humidity (%)	96
Vehicle Traveling (deg)	350

5.3. 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. Figure C.1 in Appendix C.1 gives additional dimensions and information on the vehicle.

Figure 5.3. Impact Side of Test Vehicle before Test 616161-01-1.

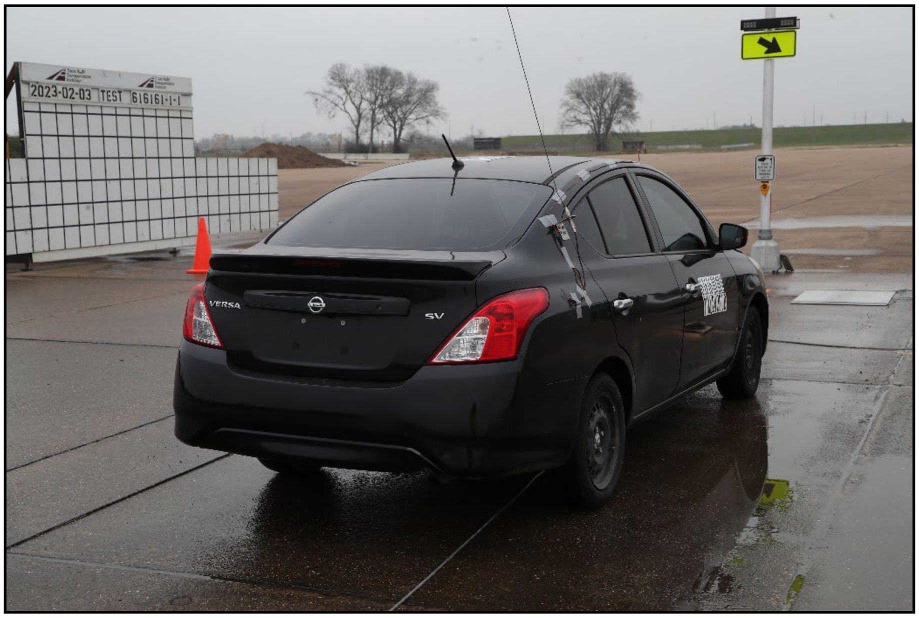


Figure 5.4. Opposite Impact Side of Test Vehicle before Test 616161-01-1.

Table 5.4. Vehicle Measurements 616161-01-1.

Test Parameter	***MASH***	**Allowed Tolerance**	**Measured**
Dummy (if applicable)[a] (lb)	165	N/A	165
Inertial Weight (lb)	2420	±55	2433
Gross Static[a] (lb)	2585	±25	2598
Wheelbase (inches)	98	±5	102.4
Front Overhang (inches)	35	±4	32.5
Overall Length (inches)	169	±8	175.4
Overall Width (inches)	65	±3	66.7
Hood Height (inches)	28	±4	30.5
Track Width[b] (inches)	59	±2	58.4
CG aft of Front Axle[c] (inches)	39	±4	41.2
CG above Ground[c,d] (inches)	N/A	N/A	N/A

[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 No. 616161-01-1. Figures C.4, C.5, and C.6 in Appendix C.2 present sequential photographs during the test.

Table 5.5. Events during Test 616161-01-1.

Time (s)	Events
0.0000	Vehicle impacted the installation
0.0190	Base began to move
0.0330	Base released from anchor bolts in ground
0.0420	Post released from base
0.8770	Top of post contacted rear spoiler on vehicle
0.9275	Vehicles lost contact with post and sign while traveling at 15 mi/h

5.5. DAMAGE TO TEST INSTALLATION

The anchor bolts remained embedded in the concrete, but they were bent. The post landed 20 feet downstream and in-line with the impact path. The debris field from minor components of the installation spanned from the impact path to 10 feet to the left and 50 feet downstream. Figure 5.5 and Figure 5.6 show the damage to the Crashworthy Enhanced Highway Sign Assemblies.

Figure 5.5. Crashworthy Enhanced Highway Sign Assemblies after Test at Impact Location 616161-01-1.

Figure 5.6. Crashworthy Enhanced Highway Sign Assemblies after Test at the Anchor Bolts 616161-01-1.

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 5.7 and Table 5.8 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 5.7. Impact Side of Test Vehicle after Test 616161-01-1.

Figure 5.8. Rear Impact Side of Test Vehicle after Test 616161-01-1.

Figure 5.9. Overall Interior of Test Vehicle after Test 616161-01-1.

Figure 5.10. Interior of Test Vehicle on Impact Side after Test 616161-01-1.

Table 5.6. Occupant Compartment Deformation 616161-01-1.

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 5.7. Exterior Vehicle Damage 616161-01-1.

Side Windows	The side windows remained intact
Maximum Exterior Deformation	½ inch in the front plane at bumper height
VDS	12FL1
CDC	12FLEN1
Fuel Tank Damage	None
Description of Damage to Vehicle:	The front bumper, trunk lid and spoiler were damaged. The trunk lid had a dent measuring 6 × 8 inches and 0.75 inches deep. The spoiler had a 14-inch long × 5-inch wide break on the left side.

5.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 5.9. Figure C.7 in Appendix C.3 shows the vehicle angular displacements, and Figures C.8 through C.10 in Appendix C.4 show acceleration versus time traces.

Table 5.8. Occupant Risk Factors for Test 616161-01-1.

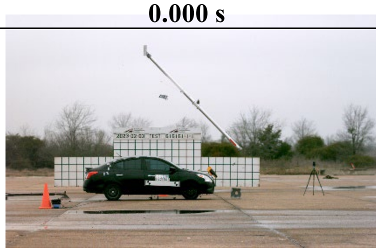
Test Parameter	*MASH* [a]	Measured	Time
OIV, Longitudinal (ft/s)	≤16.0 *10.0*	5.4	0.3964 seconds on front of interior
OIV, Lateral (ft/s)	N/A	0.7	0.3964 seconds on front of interior
Ridedown, Longitudinal (g)	≤20.49 *15.0*	0.5	0.8778 - 0.8878 seconds
Ridedown, Lateral (g)	≤20.49 *15.0*	0.5	0.9194 - 0.9294 seconds
THIV (m/s)	N/A	1.7	0.3964 seconds on front of interior
ASI	N/A	0.3	0.0280 - 0.0780 seconds
50-ms Moving Avg. Accelerations (MA) Longitudinal (g)	N/A	-3.2	0.0011 - 0.0511 seconds
50-ms MA Lateral (g)	N/A	-0.6	0.0686 - 0.1186 seconds
50-ms MA Vertical (g)	N/A	-1.7	0.0044 - 0.0544 seconds
Roll (deg)	≤75	3	1.4991 seconds
Pitch (deg)	≤75	1	1.2896 seconds
Yaw (deg)	N/A	1	0.1534 seconds

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

5.8. TEST SUMMARY

Figure 5.11 summarizes the results of *MASH* Test 616161-01-1.

0.000 s



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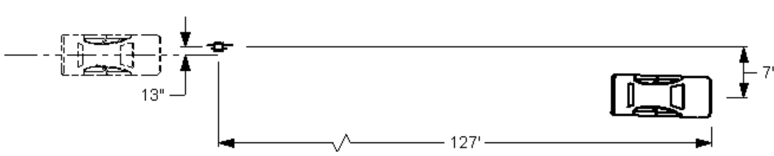
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-60
TTI Project No.	616161-01-1
Test Date	2023-02-03
TEST ARTICLE	
Type	Support Structure
Name	Crashworthy Enhanced Highway Sign Assemblies
Height	16 ft-4½ inches
Key Materials	4 inch sch. 40 Aluminum pipe, transformer base, 0.08 × 30-inch aluminum sign panel, solar panel, 24 × 12 aluminum sign panel, audible button with sign
Soil Type and Condition	Concrete, wet
TEST VEHICLE	
Type/Designation	1100C
Year, Make and Model	2017 Nissan Versa
Inertial Weight (lb)	2433
Dummy (lb)	165
Gross Static (lb)	2598
IMPACT CONDITIONS	
Impact Speed (mi/h)	18.9
Impact Angle (deg)	0
Impact Location	Centerline of the sign post aligned 13 off the centerline of the vehicle towards the driver side
Kinetic Energy (kip-ft)	29.1
EXIT CONDITIONS	
Exit Speed (mi/h)	15.0
Stopping Distance	127 ft downstream 7 ft to the right side
VEHICLE DAMAGE	
VDS	12FL1
CDC	12FLEN1
Max. Ext. Deformation	½ inch
Max Occupant Compartment Deformation	No Occupant Compartment Deformation

OCCUPANT RISK VALUES			
Long. OIV (ft/s)	5.4	Max 50-ms Long. (g)	-3.2
Lat. OIV (ft/s)	0.7	Max 50-ms Lat. (g)	-0.6
Long. Ridedown (g)	0.5	Max 50-ms Vert. (g)	-1.7
Lat. Ridedown (g)	0.5	Max Roll (deg)	3
THIV (m/s)	1.7	Max Pitch (deg)	1
ASI	0.3	Max Yaw (deg)	1

OCCUPANT RISK VALUES



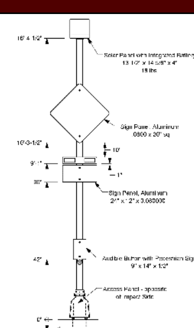


Figure 5.11. Summary of Results for *MASH* Test 3-60 on Crashworthy Enhanced Highway Sign Assemblies.

Chapter 6. *MASH* TEST 3-62 (CRASH TEST NO. 616161-01-2)

6.1. 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 6.1. Impact Conditions for *MASH* 3-62 616161-01-2.

Test Parameter	**Specification**	**Tolerance**	**Measured**
Impact Speed (mi/h)	62 mi/h	± 2.5 mi/h	60.7
Impact Angle (deg)	0°	± 1.5°	0
Kinetic Energy (kip-ft)	594 kip-ft	≥594 kip-ft	618.7
Impact Location	Centerline of the sign post aligned 13 off the centerline of the vehicle towards the driver side	± 6 inches	Centerline of the sign post aligned 13 off the centerline of the vehicle towards the driver side

Table 6.2. Exit Parameters for *MASH* 3-62 616161-01-2.

Exit Parameter	**Measured**
Speed (mi/h)	59.3
Brakes applied post impact (s)	1.75
Vehicle at rest position	328 ft downstream of impact point 4 ft to the left side 5° right
Comments:	Vehicle remained upright and stable.

Figure 6.1. Crashworthy Enhanced Highway Sign Assemblies/Test Vehicle Geometrics for Test 616161-01-2.

Figure 6.2. Crashworthy Enhanced Highway Sign Assemblies/Test Vehicle Impact Location 616161-01-2.

6.2. WEATHER CONDITIONS

Table 6.3 provides the weather conditions for 616161-01-2.

Table 6.3. Weather Conditions 616161-01-2.

Date of Test	2023-02-03 PM
Wind Speed (mi/h)	6
Wind Direction (deg)	304
Temperature (°F)	49
Relative Humidity (%)	88
Vehicle Traveling (deg)	350

6.3. TEST VEHICLE

Figure 6.3 and Figure 6.4 show the 2017 RAM 1500 used for the crash test. Table 6.4 shows the vehicle measurements. Figure D.1 in Appendix D.1 gives additional dimensions and information on the vehicle.

Figure 6.3. Impact Side of Test Vehicle before Test 616161-01-2.

Figure 6.4. Opposite Impact Side of Test Vehicle before Test 616161-01-2.

Table 6.4. Vehicle Measurements 616161-01-2.

Test Parameter	***MASH***	**Allowed Tolerance**	**Measured**
Dummy (if applicable)[a] (lb)	165	N/A	N/A
Inertial Weight (lb)	5000	± 110	5023
Gross Static[a] (lb)	5000	± 110	5023
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	61.3
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.

6.4. TEST DESCRIPTION

Table 6.5 lists events that occurred during Test No. 616161-01-2. Figures D.4, D.5, and D.6 in Appendix D.2 present sequential photographs during the test.

Table 6.5. Events during Test 616161-01-2.

Time (s)	Events
0.0000	Vehicle impacted the installation
0.0030	Base began to move
0.0070	Base released from anchor bolts in ground
0.0110	Post released from base
0.2600	Vehicle exited impact area traveling 59.3 mi/h

6.5. DAMAGE TO TEST INSTALLATION

The anchor bolts remained embedded in the concrete, but they were bent. The debris field from the components of the installation spanned from the 2.5 feet to the right to 18 feet to the left and from 2.5 feet upstream to 220 feet downstream. The base of the sign remained under the vehicle. Figure 6.5 and Figure 6.6 show the damage to the Crashworthy Enhanced Highway Sign Assemblies.

Figure 6.5. Crashworthy Enhanced Highway Sign Assemblies after Test at Impact Location 616161-01-2.

Figure 6.6. Crashworthy Enhanced Highway Sign Assemblies after Test at the Anchor Bolts 616161-01-2.

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 6.7 and Table 6.8 provide details on the occupant compartment deformation and exterior vehicle damage. Figures D.2 and D.3 in Appendix D.1 provide exterior crush and occupant compartment measurements.

Figure 6.7. Impact Side of Test Vehicle after Test 616161-01-2.

Figure 6.8. Rear Impact Side of Test Vehicle after Test 616161-01-2.

Figure 6.9. Overall Interior of Test Vehicle after Test 616161-01-2.

Figure 6.10. Interior of Test Vehicle on Impact Side after Test 616161-01-2.

Table 6.6. Occupant Compartment Deformation 616161-01-2.

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 6.7. Exterior Vehicle Damage 616161-01-2.

Side Windows	The side windows remained intact
Maximum Exterior Deformation	3.5 inches in the front plane at bumper height
VDS	12FL2
CDC	12FLEN1
Fuel Tank Damage	None
Description of Damage to Vehicle:	The front bumper, grill, and hood were damaged. The front bumper had a 8 × 14-inch dent 3.5 inches deep 13 inches to the left of the vehicle's centerline. The hood had a 16 × 11-inch dent that measured 2.5 inches convex in some places and 0.75 inches concave in others.

6.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 6.9. Figure D.7 in Appendix D.3 shows the vehicle angular displacements, and Figures D.8 through D.10 in Appendix D.4 show acceleration versus time traces.

Table 6.8. Occupant Risk Factors for Test 616161-01-2.

Test Parameter	***MASH***	**Measured**	**Time**
OIV, Longitudinal (ft/s)	≤16.0 *10.0*	1.9	1.0919 seconds on front of interior
OIV, Lateral (ft/s)	N/A	1.1	1.0919 seconds on front of interior
Ridedown, Longitudinal (g)	≤20.49 *15.0*	0.3	1.1747 - 1.1847 seconds
Ridedown, Lateral (g)	≤20.49 *15.0*	0.3	1.1692 - 1.1792 seconds
THIV (m/s)	N/A	0.7	1.1009 seconds on front of interior
ASI	N/A	0.1	0.0074 - 0.0574 seconds
50-ms MA Longitudinal (g)	N/A	-1.0	0.0003 - 0.0503 seconds
50-ms MA Lateral (g)	N/A	-0.3	0.1857 - 0.2357 seconds
50-ms MA Vertical (g)	N/A	-1.1	0.0162 - 0.0662 seconds
Roll (deg)	≤75	3	1.4873 seconds
Pitch (deg)	≤75	2	1.5000 seconds
Yaw (deg)	N/A	3	1.5000 seconds

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

6.8. TEST SUMMARY

Figure 6.11 summarizes the results of *MASH* Test 616161-01-2.

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0.100 s

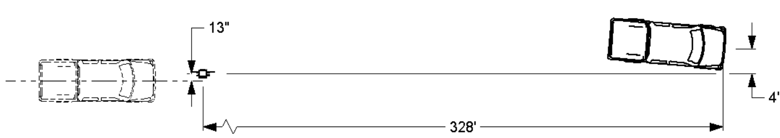
0.200 s

0.300 s

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.	*MASH* 2016, Test 3-62
TTI Project No.	616161-01-2
Test Date	2023-02-03
TEST ARTICLE	
Type	Support Structure
Name	Crashworthy Enhanced Highway Sign Assemblies
Height	16 ft-4½ inches
Key Materials	4 inch sch. 40 Aluminum pipe, transformer base, 0.08 × 30-inch aluminum sign panel, solar panel, 24 × 12 aluminum sign panel, audible button with sign
Soil Type and Condition	Concrete, wet
TEST VEHICLE	
Type/Designation	2270P
Year, Make and Model	2017 RAM 1500
Inertial Weight (lb)	5023
Dummy (lb)	N/A
Gross Static (lb)	5023
IMPACT CONDITIONS	
Impact Speed (mi/h)	60.7
Impact Angle (deg)	0
Impact Location	Centerline of the sign post aligned 13 off the centerline of the vehicle towards the driver side
Kinetic Energy (kip-ft)	618.7
EXIT CONDITIONS	
Exit Speed (mi/h)	58.7
Stopping Distance	328 ft downstream 4 ft to the left side
VEHICLE DAMAGE	
VDS	12FL2
CDC	12FLEN1
Max. Ext. Deformation	3.5
Max Occupant Compartment Deformation	No Occupant Compartment Deformation

OCCUPANT RISK VALUES

Long. OIV (ft/s)	1.9	Max 50-ms Long. (g)	-1.0
Lat. OIV (ft/s)	1.1	Max 50-ms Lat. (g)	-0.3
Long. Ridedown (g)	0.3	Max 50-ms Vert. (g)	-1.1
Lat. Ridedown (g)	0.3	Max Roll (deg)	3
THIV (m/s)	0.7	Max Pitch (deg)	2
ASI	0.1	Max Yaw (deg)	3



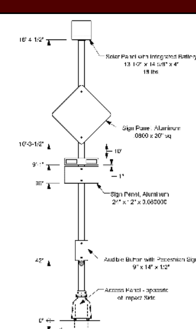


Figure 6.11. Summary of Results for *MASH* Test 3-62 on Crashworthy Enhanced Highway Sign Assemblies.

Chapter 7. SUMMARY AND CONCLUSIONS

7.1. ASSESSMENT OF TEST RESULTS

The crash tests reported herein were performed in accordance with *MASH* TL-3 on the Crashworthy Enhanced Highway Sign Assemblies.

7.2. CONCLUSIONS

Table 8.1 shows that the Crashworthy Enhanced Highway Sign Assemblies met the performance criteria for *MASH* TL-3 support structures.

Table 8.1. Assessment Summary for *MASH* TL-3 Tests on Crashworthy Enhanced Highway Sign Assemblies.

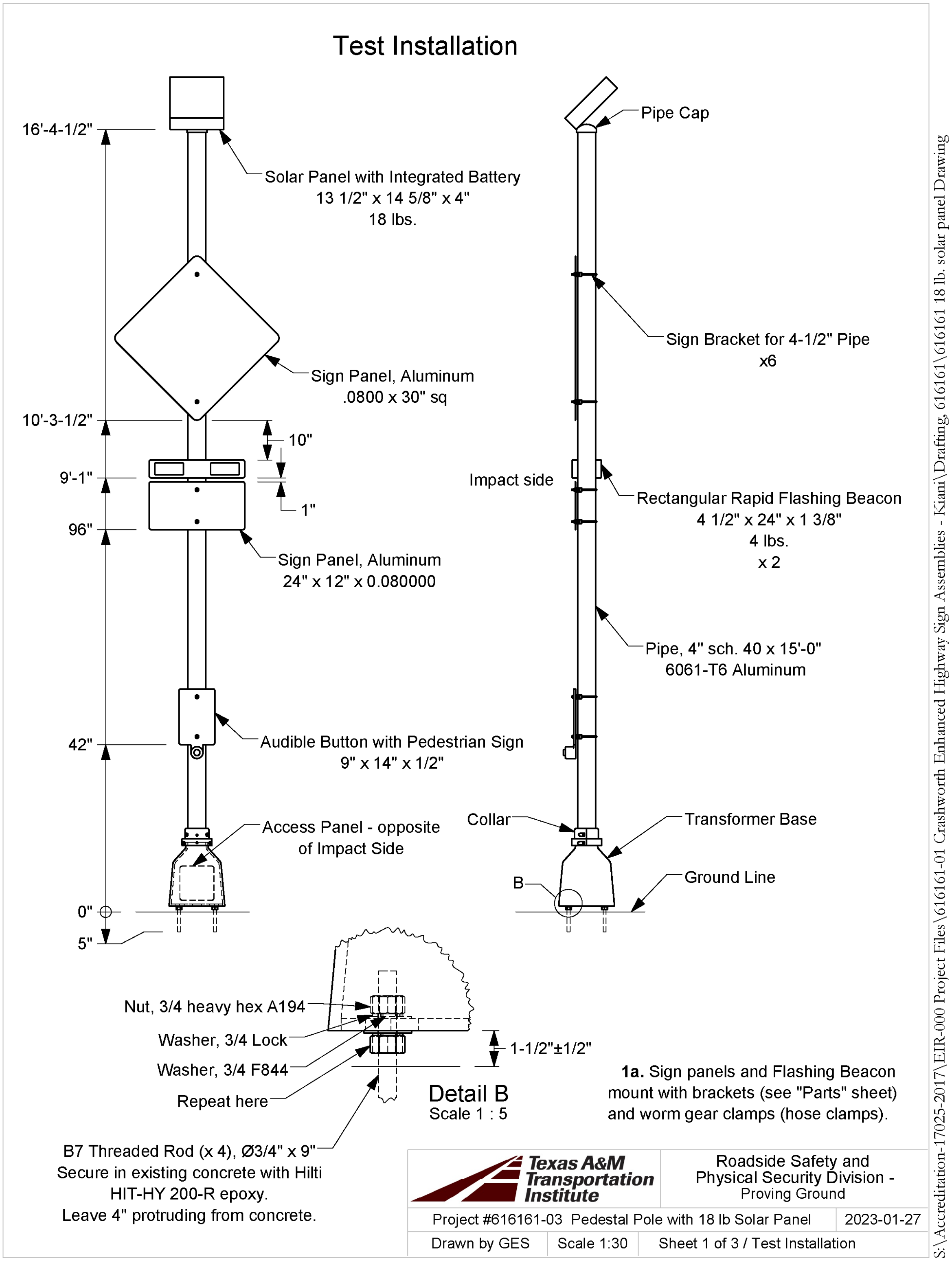
Evaluation Criteria	Description	Test No. 616161-01-1 *MASH* 3-60	Test No. 616161-01-2 *MASH* 3-62
B	Test Article Should Readily Activate	S	S
D	No Penetration into Occupant Compartment	S	S
F	Roll and Pitch Limit	S	S
H	OIV Threshold	S	S
I	Ridedown Threshold	S	S
N	Trajectory Behind Installation Acceptable	S	S
Overall		Pass	Pass

Note: S = Satisfactory
[1] See Table 3.2 for details

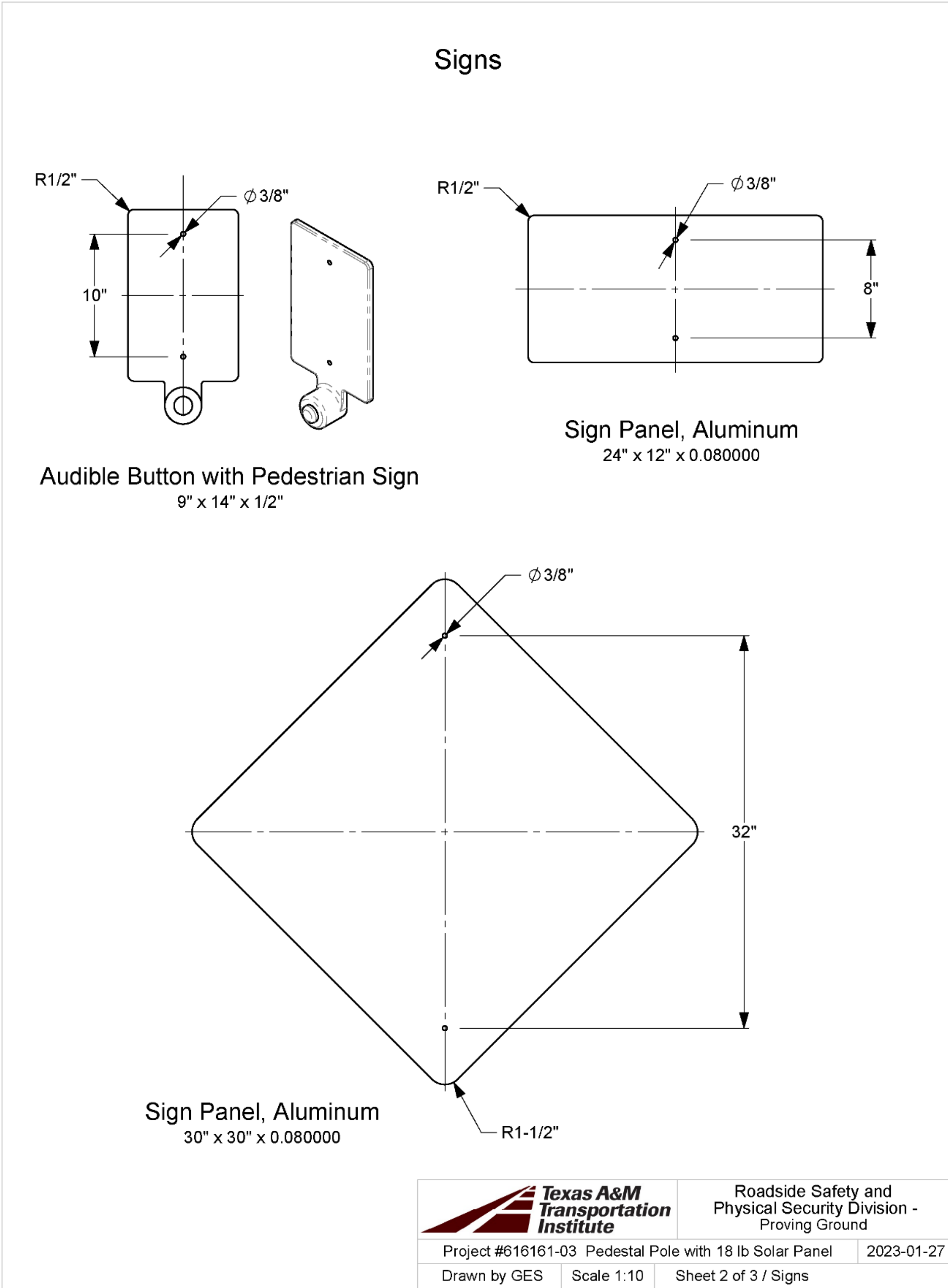
REFERENCES

1. AASHTO. *Manual for Assessing Roadside Safety Hardware*, Second Edition. American Association of State Highway and Transportation Officials, Washington, DC, 2016.
2. Ross Jr., H. E., Perera, H. S., Sicking, D. L., & Bligh, R. P., Roadside Safety Design for Small Vehicles, NCHRP Report 318, College Station, TX: Texas A&M Transportation Institute, 1987.
3. Bligh, R. P., Menges, W. L., & Kuhn, D. L., MASH Evaluation of TxDOT Roadside Safety Features – Phase I (Report No. FHWA/TX-14/0-6946-1). College Station, TX: Texas A&M Transportation Institute, 2013.

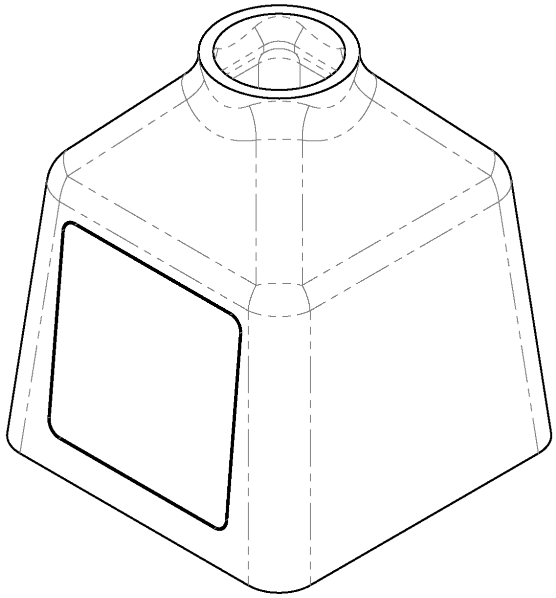
APPENDIX A. DETAILS OF CRASHWORTHY ENHANCED HIGHWAY SIGN ASSEMBLIES



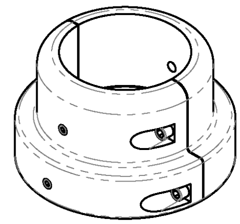
Test Installation
16'-4-1/2"
Solar Panel with Integrated Battery
13 1/2" x 14 5/8" x 4"
18 lbs.
Sign Panel, Aluminum
.0800 x 30" sq
10'-3-1/2"
10"
9'-1"
1"
96"
Sign Panel, Aluminum
24" x 12" x 0.080000
42"
Audible Button with Pedestrian Sign
9" x 14" x 1/2"
Access Panel - opposite
of Impact Side
0"
5"
Pipe Cap
Sign Bracket for 4-1/2" Pipe
x6
Impact side
Rectangular Rapid Flashing Beacon
4 1/2" x 24" x 1 3/8"
4 lbs.
x 2
Pipe, 4" sch. 40 x 15'-0"
6061-T6 Aluminum
Collar
Transformer Base
B
Ground Line
Nut, 3/4 heavy hex A194
Washer, 3/4 Lock
Washer, 3/4 F844
Repeat here
1-1/2"±1/2"
Detail B
Scale 1 : 5
B7 Threaded Rod (x 4), Ø3/4" x 9"
Secure in existing concrete with Hilti
HIT-HY 200-R epoxy.
Leave 4" protruding from concrete.
1a. Sign panels and Flashing Beacon
mount with brackets (see "Parts" sheet)
and worm gear clamps (hose clamps).
Texas A&M Transportation Institute
Roadside Safety and
Physical Security Division -
Proving Ground
Project #616161-03 Pedestal Pole with 18 lb Solar Panel
2023-01-27
Drawn by GES
Scale 1:30
Sheet 1 of 3 / Test Installation
S:\Accreditation-17025-2017\EIR-000 Project Files\616161-01 Crashworth Enhanced Highway Sign Assemblies - Kiani\Drafting, 616161\616161 18 lb. solar panel Drawing



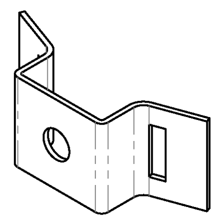
S:\Accreditation-17025-2017\EIR-000 Project Files\616161-01 Crashworth Enhanced Highway Sign Assemblies - Kiani\Drafting, 616161\616161 18 lb. solar panel Drawing



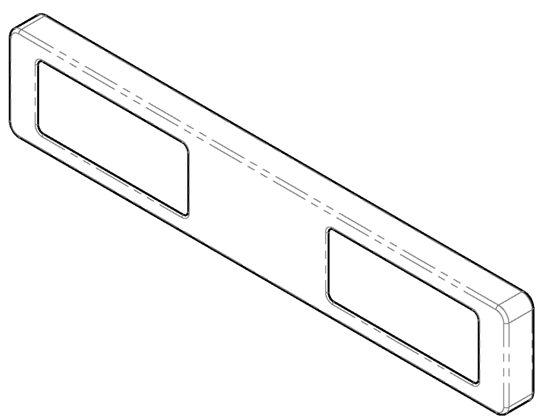
Transformer Base
(for reference only, some features not shown)



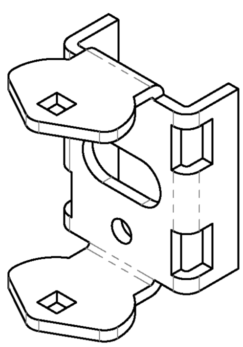
Collar



Sign Panel Bracket



Rectangular Rapid Flashing Beacon



Flashing Beacon Bracket

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #616161-03 Pedestal Pole with 18 lb Solar Panel		2023-01-27
Drawn by GES	No Scale	Sheet 3 of 3 / Parts

S:\Accreditation-17025-2017\EIR-000 Project Files\616161-01 Crashworth Enhanced Highway Sign Assemblies - Kiani\Drafting, 616161\616161 18 lb. solar panel Drawing

APPENDIX B. SUPPORTING CERTIFICATION DOCUMENTS

APPENDIX C. *MASH* TEST 3-60 (CRASH TEST NO. 616161-01-1)

C.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2023-02-03 Test No.: 616161-01-1 VIN No.: 3N1CN7AP5HL873327

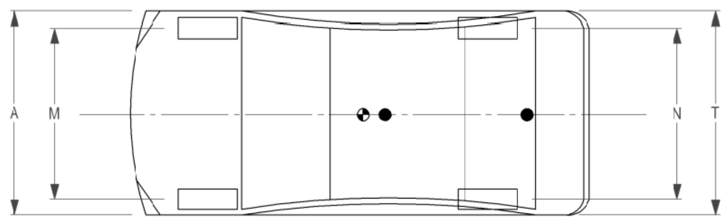
Year: 2017 Make: Nissan Model: Versa

Tire Inflation Pressure: 36 PSI Odometer: 96606 Tire Size: P185/65R15

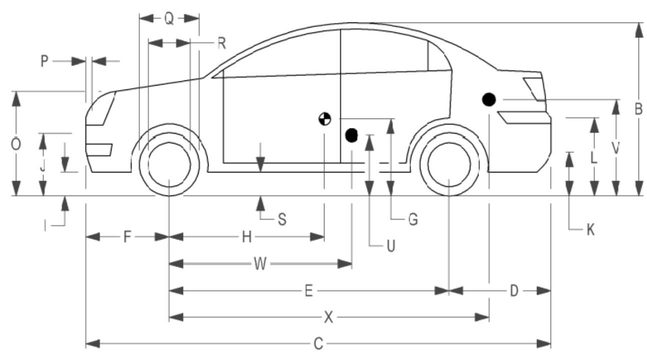
Describe any damage to the vehicle prior to test: None

● 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	15.50
B	59.60	G		L	26.00	Q	24.00	V	21.25
C	175.40	H	41.16	M	58.30	R	16.25	W	41.25
D	40.50	I	7.00	N	58.50	S	7.50	X	79.75
E	102.40	J	22.50	O	30.50	T	64.50		

Wheel Center Ht Front 11.50 Wheel Center Ht Rear 11.50 W-H 0.09

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}	1430	1455	1540
Back	1687	M_{rear}	920	978	1058
Total	3389	M_{Total}	2350	2433	2598

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

Mass Distribution:
lb LF: 732 RF: 723 LR: 513 RR: 465

Figure C.1. Vehicle Properties for Test No. 616161-01-1.

Date:	2023-02-03	Test No.:	616161-01-1	VIN No.:	3N1CN7AP5HL873327
Year:	2017	Make:	Nissan	Model:	Versa

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
	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.

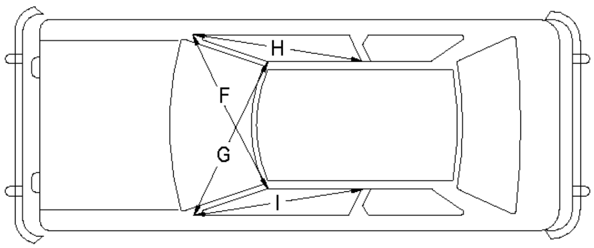
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

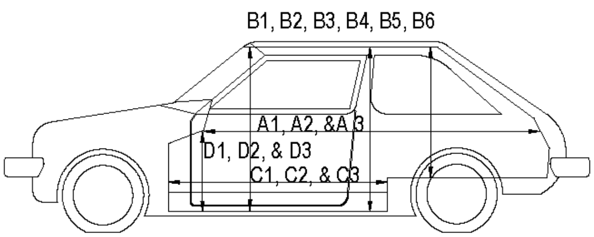
***Measure and document on the vehicle diagram the location of the maximum crush.

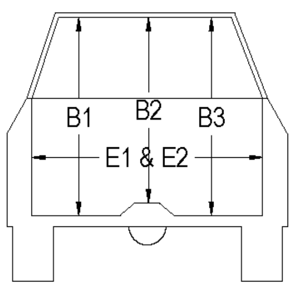
Note: Use as many lines/columns as necessary to describe each damage profile.

Figure C.2. Exterior Crush Measurements for Test No. 616161-01-1.

Date:	2023-02-03	Test No.:	616161-01-1	VIN No.:	3N1CN7AP5HL873327
Year:	2017	Make:	Nissan	Model:	Versa







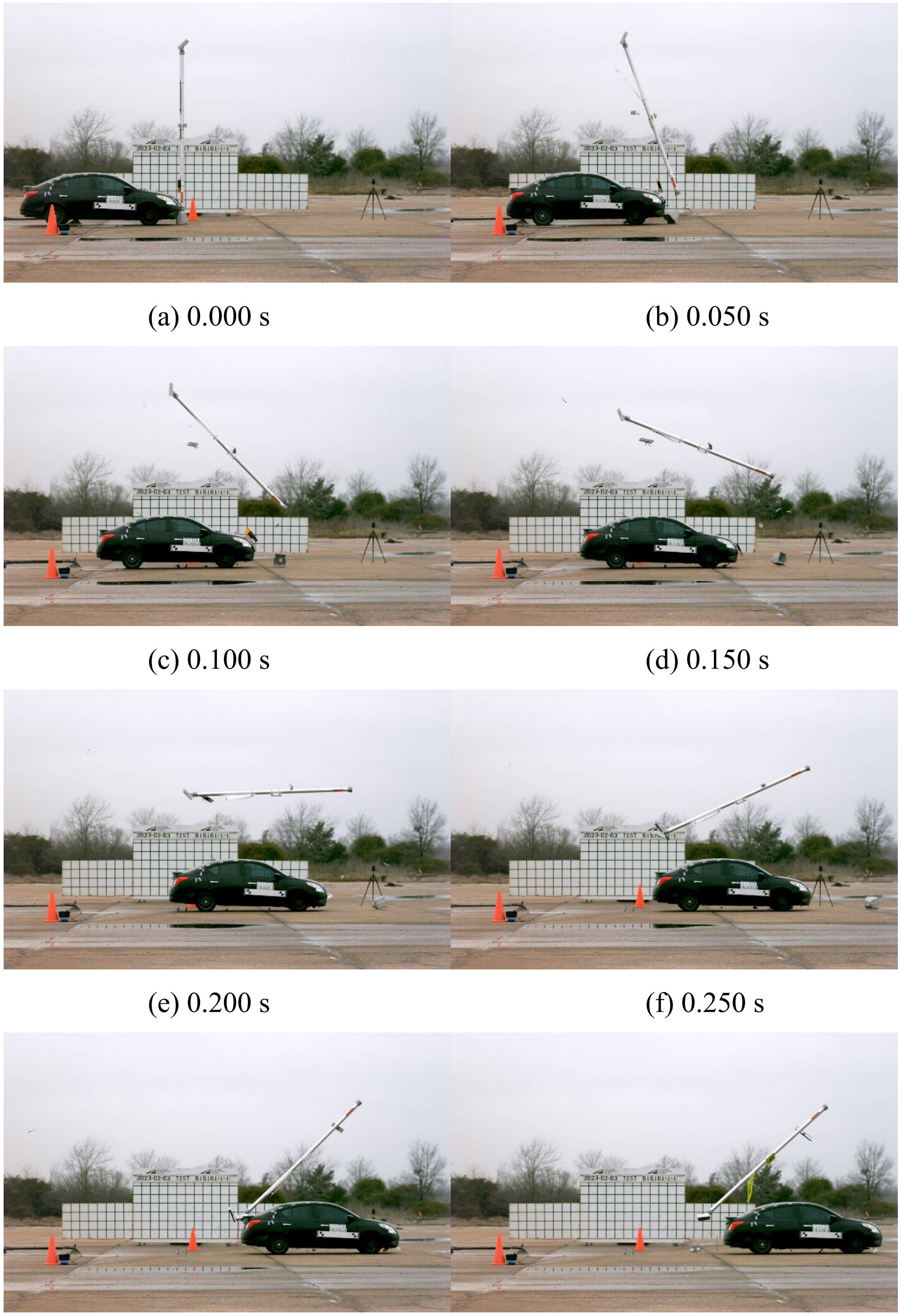
OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	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 C.3. Occupant Compartment Measurements for Test No. 616161-01-1.

C.2. SEQUENTIAL PHOTOGRAPHS



(a) 0.000 s (b) 0.050 s

(c) 0.100 s (d) 0.150 s

(e) 0.200 s (f) 0.250 s

(g) 0.300 s (h) 0.350 s

Figure C.4. Sequential Photographs for Test No. 616161-01-1 (Right Angle Views).

(a) 0.000 s (b) 0.050 s

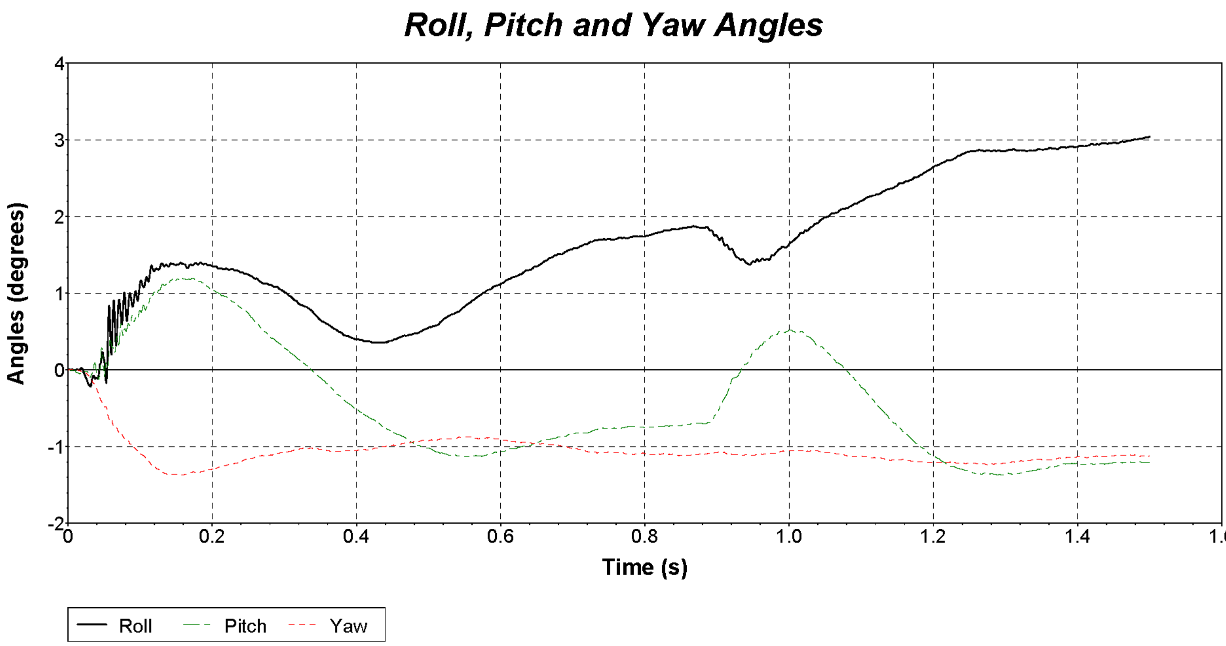
(c) 0.100 s (d) 0.150 s

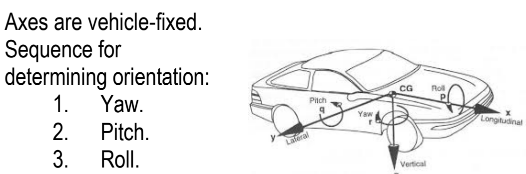
(e) 0.200 s (f) 0.250 s

(g) 0.300 s (h) 0.350 s

Figure C.5. Sequential Photographs for Test No. 616161-01-1 (Oblique Views).

C.3. VEHICLE ANGULAR DISPLACEMENTS





Test Number: 616161-01-1
Test Standard Test Number: *MASH* Test 3-60
Test Article: Crashworthy Enhanced Highway Sign Assemblies
Test Vehicle: 2017 Nissan Versa
Inertial Mass: 2433 lb
Gross Mass: 2598 lb
Impact Speed: 18.9 mi/h
Impact Angle: 0 degreees

Figure C.6. Vehicle Angular Displacements for Test No. 616161-01-1.

C.4. VEHICLE ACCELERATIONS

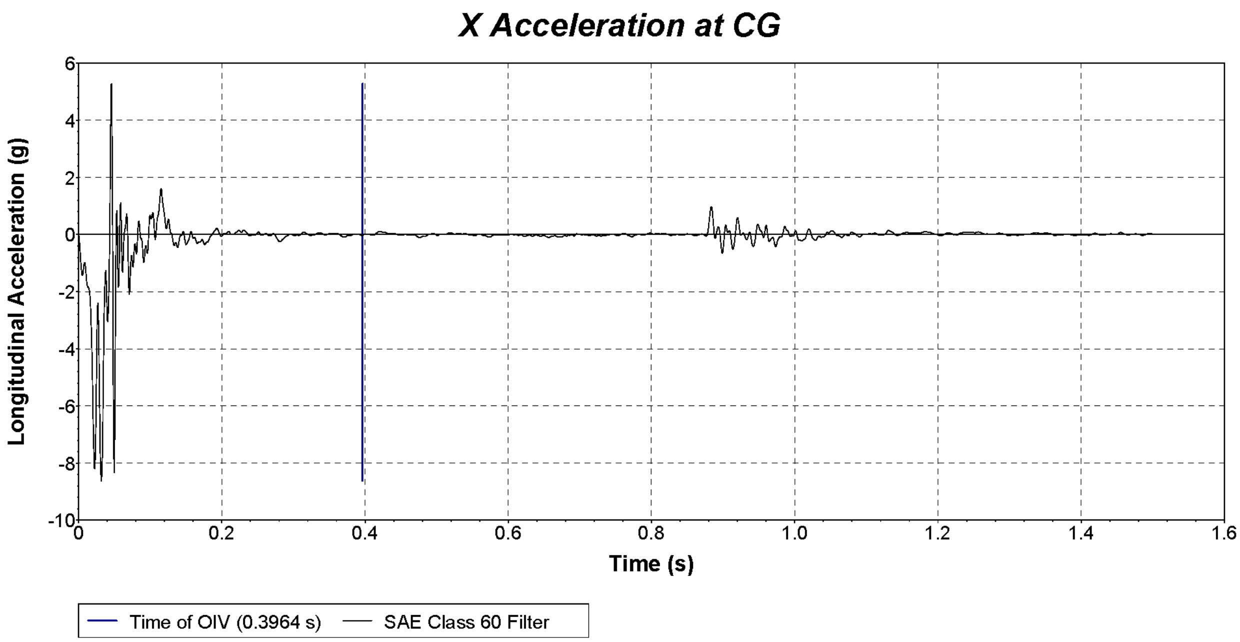


Figure C.7. Vehicle Longitudinal Accelerometer Trace for Test No. 616161-01-1 (Accelerometer Located at Center of Gravity).

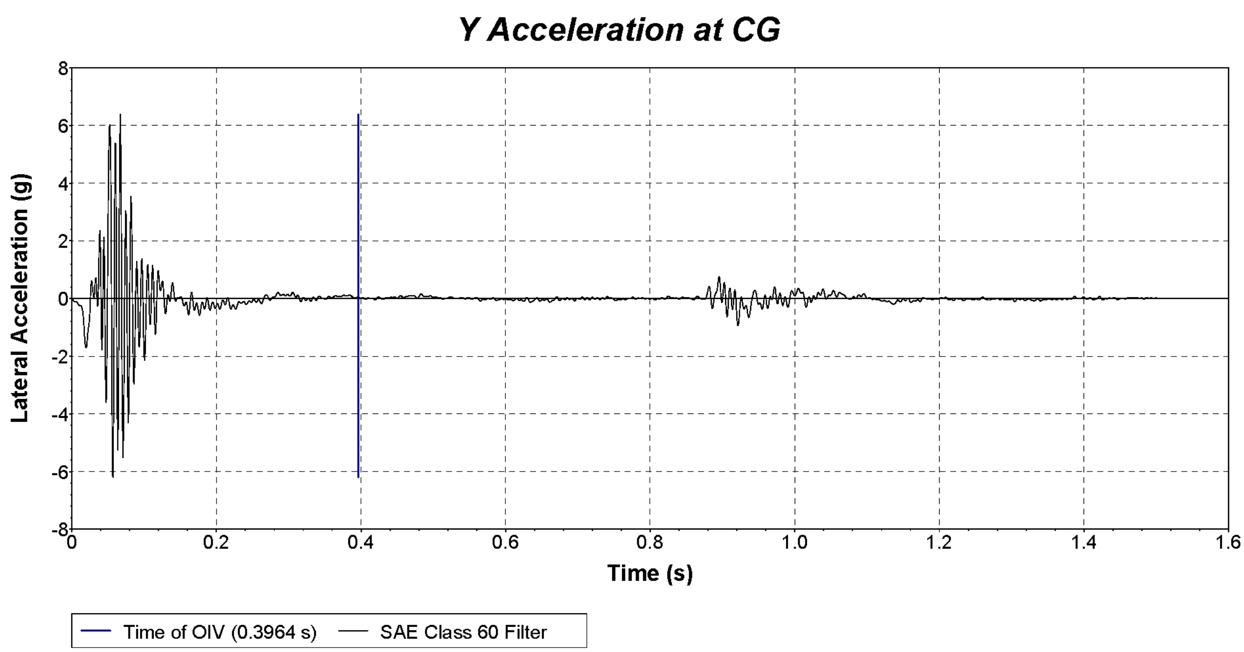


Figure C.8. Vehicle Lateral Accelerometer Trace for Test No. 616161-01-1 (Accelerometer Located at Center of Gravity).

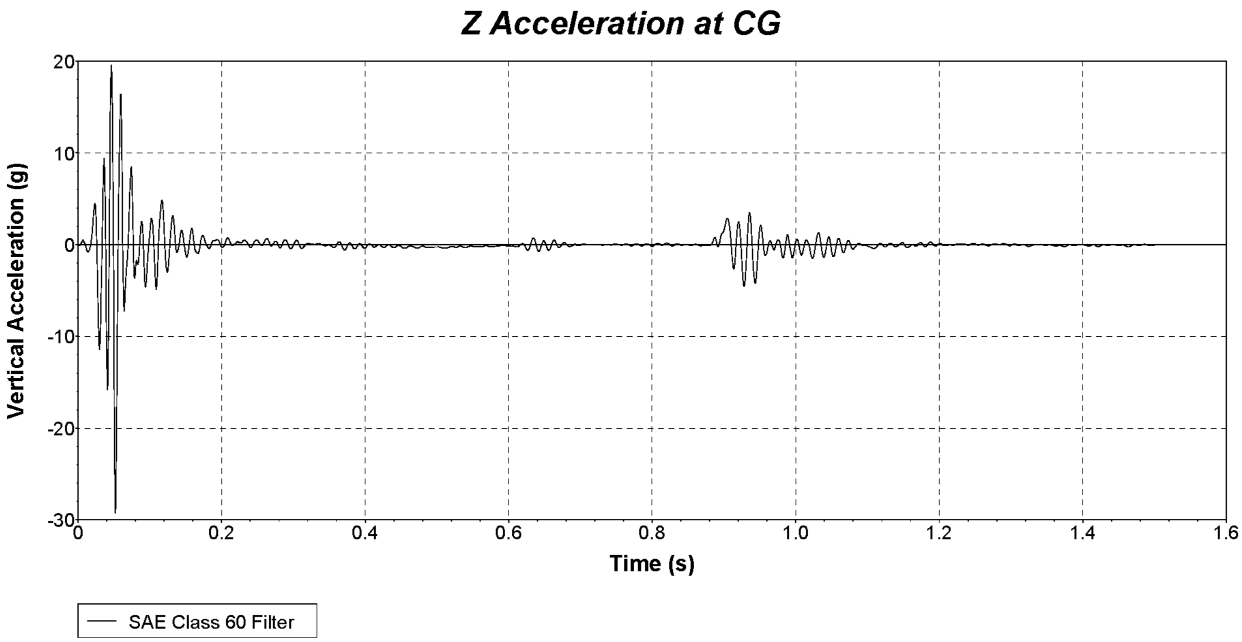


Figure C.9. Vehicle Vertical Accelerometer Trace for Test No. 616161-01-1 (Accelerometer Located at Center of Gravity).

APPENDIX D. *MASH* TEST 3-62 (CRASH TEST NO. 616161-01-2)

D.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2023-02-03 Test No.: 616161-01-2 VIN No.: 1C6RR6FT5HS855799

Year: 2017 Make: RAM Model: 1500

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

Tread Type: Highway Odometer: 102197

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

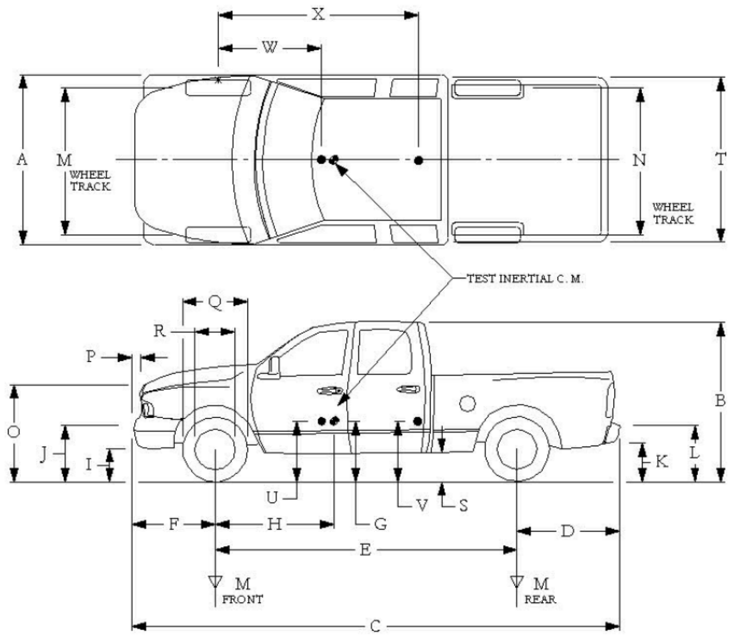
NOTES: None

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: lb
Seat Position:



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.60	L	30.00	Q	30.50	V	30.25
C	227.50	H	61.31	M	68.50	R	18.00	W	61.25
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}	2903	2831	2831
Back	3900	M_{rear}	2066	2192	2192
Total	6700	M_{Total}	4969	5023	5023

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

Mass Distribution:
lb LF: 1478 RF: 1353 LR: 1072 RR: 1120

Figure D.1. Vehicle Properties for Test No. 616161-01-2.

Date:	2023-02-03	Test No.:	616161-01-2	VIN No.:	1C6RR6FT5HS855799
Year:	2017	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	11	3.5	11							-13
	Measurements recorded										
	☑ **inches or** ☐ **mm**										

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

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

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

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

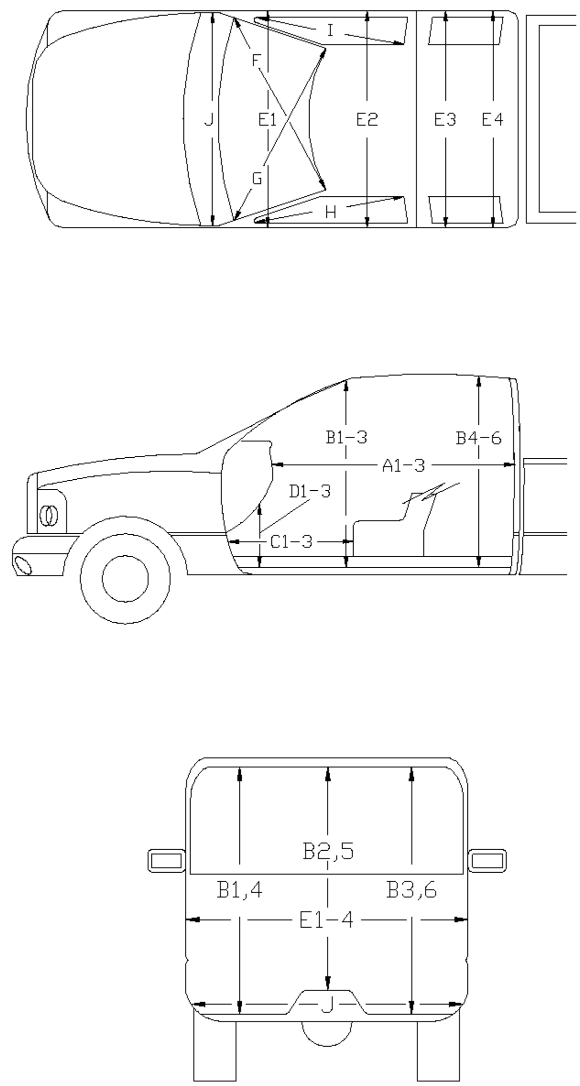
***Measure and document on the vehicle diagram the location of the maximum crush.

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

Figure D.2. Exterior Crush Measurements for Test No. 616161-01-2.

Date: 2023-02-03 Test No.: 616161-01-2 VIN No.: 1C6RR6FT5HS855799

Year: 2017 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. 616161-01-2.

D.2. SEQUENTIAL PHOTOGRAPHS


(a) 0.000 s


(b) 0.050 s


(c) 0.100 s


(d) 0.150 s


(e) 0.200 s


(f) 0.250 s


(g) 0.300 s


(h) 0.350 s

Figure D.4. Sequential Photographs for Test No. 616161-01-2 (Right Angle Views).


(a) 0.000 s

(b) 0.050 s


(c) 0.100 s

(d) 0.150 s


(e) 0.200 s

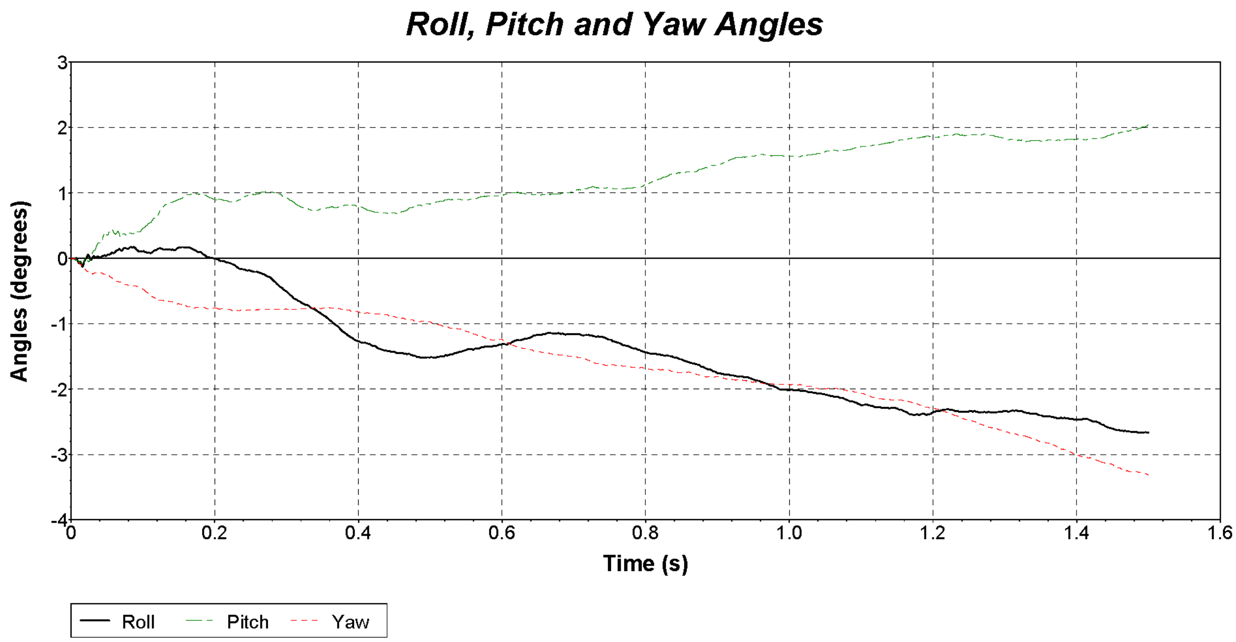
(f) 0.250 s


(g) 0.300 s

(h) 0.350 s

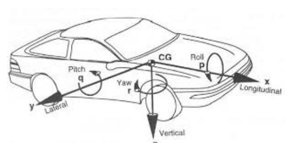
Figure D.5. Sequential Photographs for Test No. 616161-01-2 (Oblique Views).

D.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for
determining orientation:

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



Test Number: 616161-01-2
Test Standard Test Number: *MASH* Test 3-62
Test Article: Crashworthy Enhanced Highway Sign Assemblies
Test Vehicle: 2017 RAM 1500
Inertial Mass: 5023 lb
Gross Mass: 5023 lb
Impact Speed: 60.7 mi/h
Impact Angle: 0 degrees

Figure D.6. Vehicle Angular Displacements for Test No. 616161-01-2.

D.4. VEHICLE ACCELERATIONS

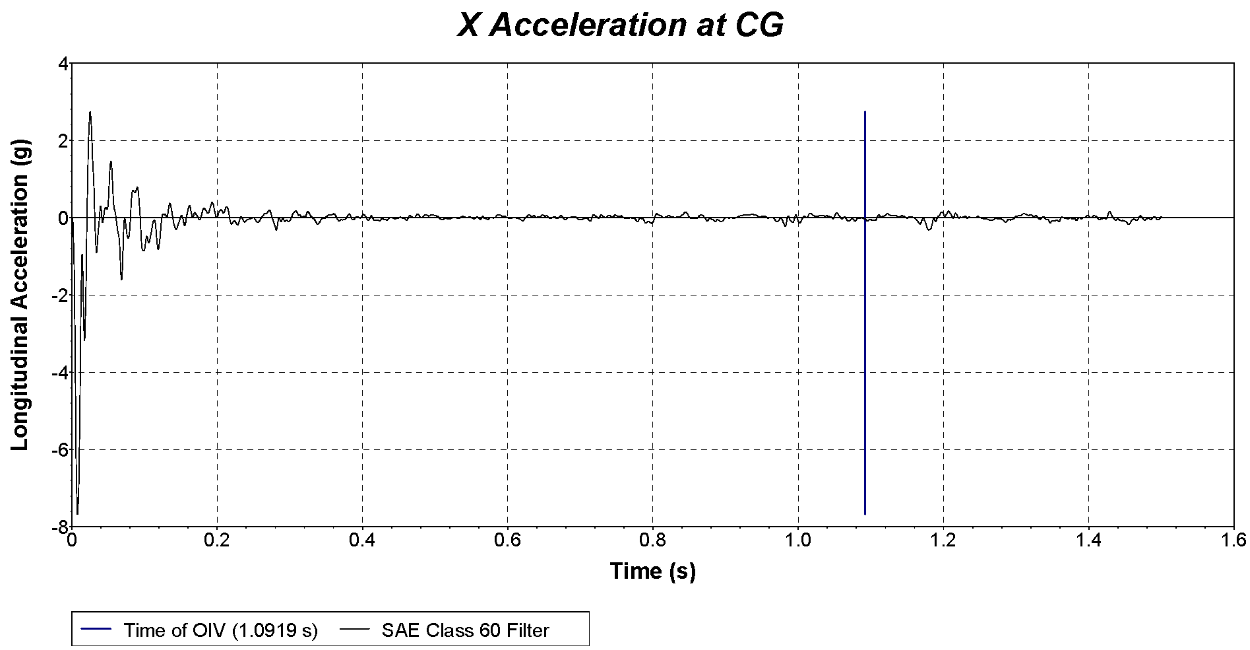


Figure D.7. Vehicle Longitudinal Accelerometer Trace for Test No. 616161-01-2 (Accelerometer Located at Center of Gravity).

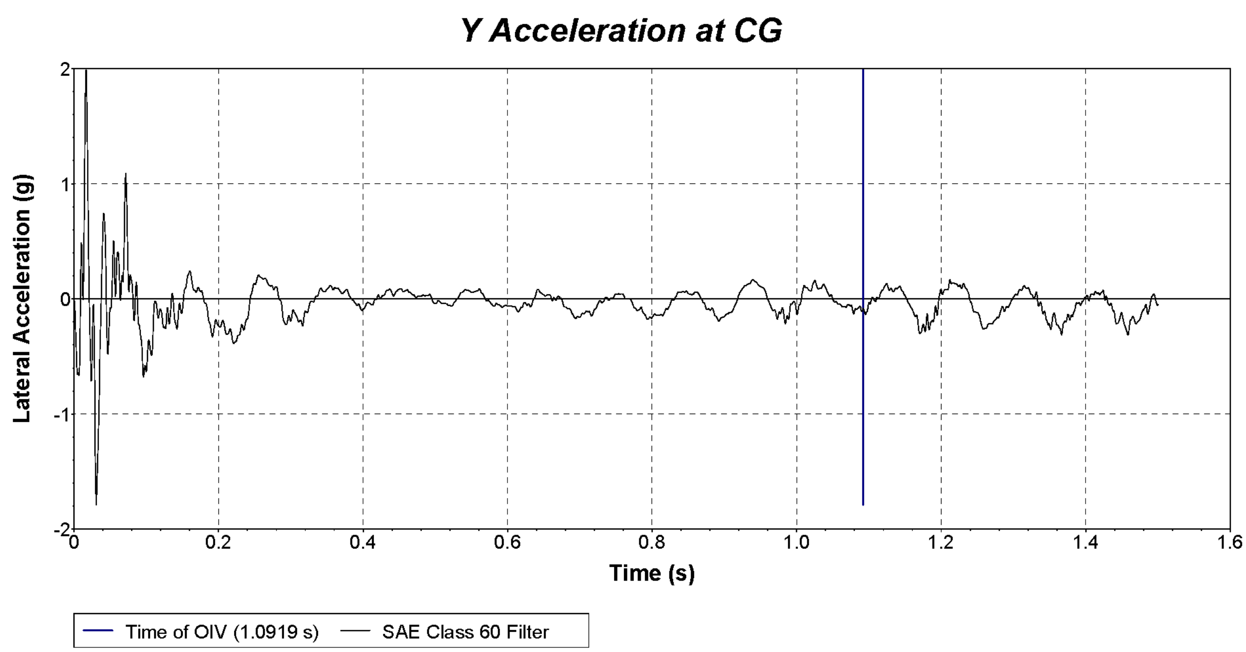


Figure D.8. Vehicle Lateral Accelerometer Trace for Test No. 616161-01-2 (Accelerometer Located at Center of Gravity).

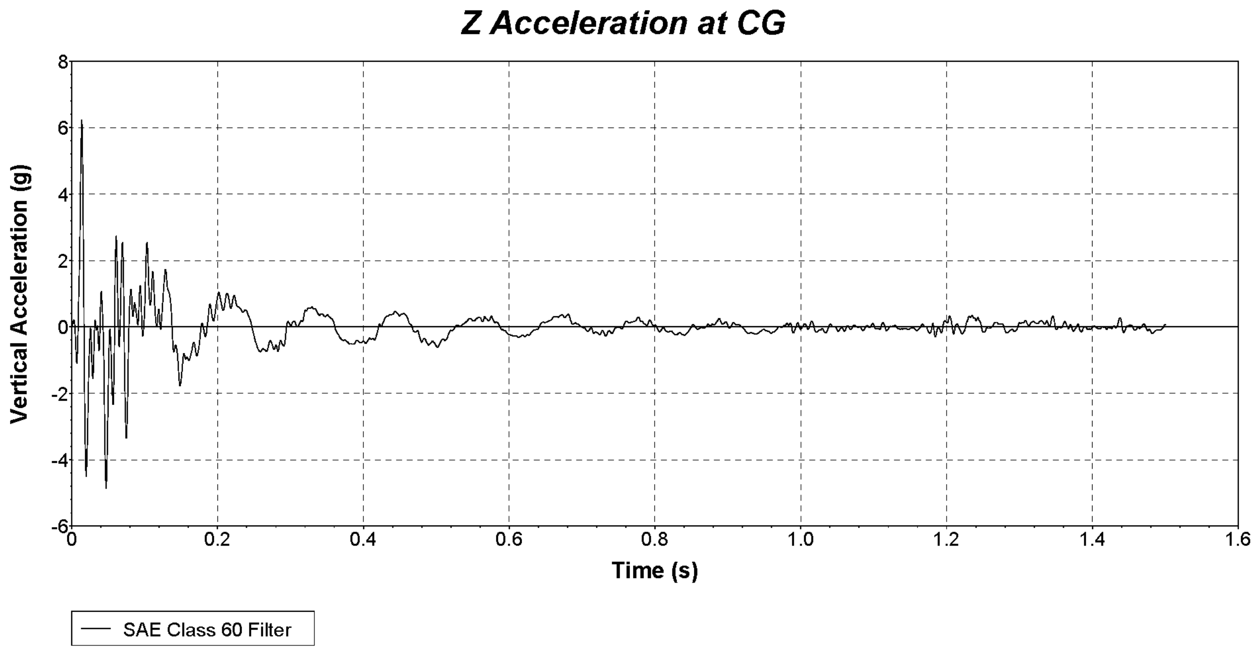


Figure D.9. Vehicle Vertical Accelerometer Trace for Test No. 616161-01-2 (Accelerometer Located at Center of Gravity).