Test Report No. 619541-01-1 & 2

MASH TL-3 EVALUATION OF SIGN POSTS WITH FLASHING BEACON EQUIPMENT

Sponsored by

Roadside Safety Pooled Fund

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ISO 17025 Laboratory
Testing Certificate # 2821.01

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16. Abstract

State DOTs often encounter situations where flashing equipment is attached to roadside sign support installations. It was necessary to evaluate the crashworthy effect of adding the flashing equipment to the top of breakaway sign support systems. A design was selected for full-scale crash testing based on previous crash testing, a state survey, and evaluation of wind loading requirements.

The breakaway sign support system with flashing equipment was evaluated 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 breakaway sign support system with flashing equipment did not meet the performance criteria for *MASH* TL-3 Support Structures.

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MASH TL-3 Evaluation of Sign Posts with Flashing Beacon Equipment

by
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November 2024

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

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REVISION LOG

Revision Number	Change(s) Made	Date

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Date: 2024-08-07 Test No.: 619541-01-1 VIN No.: 3N1CN7AP6JK414819

Year: 2018 Make: Nissan Model: Versa

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

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

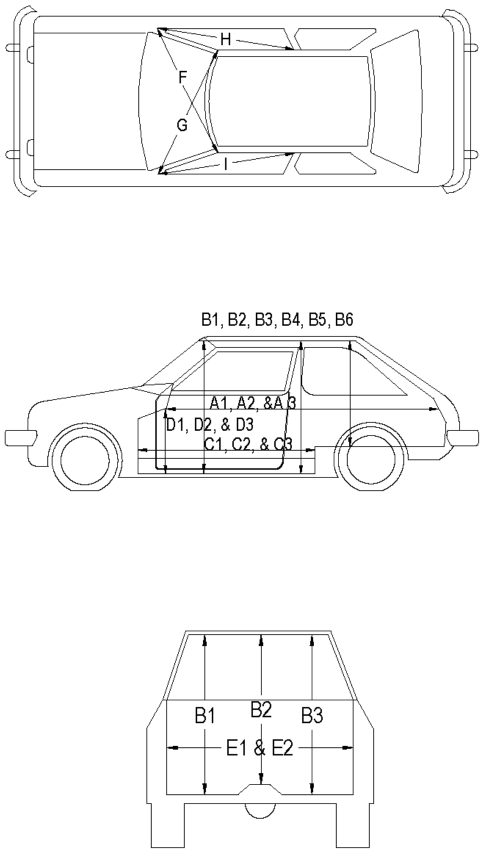
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***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.

Date: 2024-08-07 Test No.: 619541-01-1 VIN No.: 3N1CN7AP6JK414819

Year: 2018 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	33.25	-3.00
B5	36.00	33.25	-2.75
B6	36.25	36.00	-0.25
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.

Date: 2024-08-22 Test No.: 619541-01-2 VIN No.: 3N1CN7AP1KL802178

Year: 2019 Make: Nissan Model: Versa

Tire Inflation Pressure: 36 PSI Odometer: 66173 Tire Size: P185/65R15

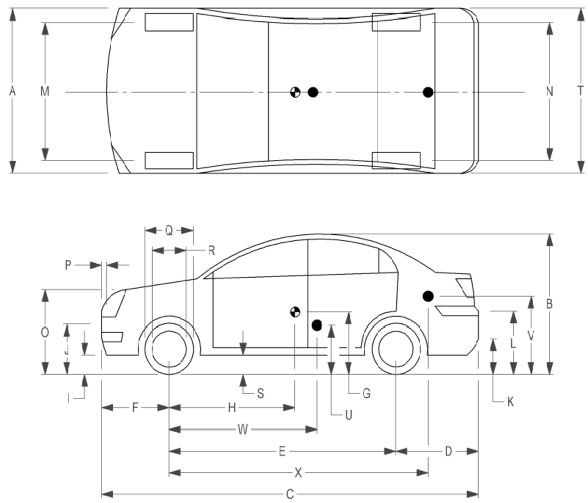
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES: None

Engine Type: 4 CYL
Engine CID: 1.6 L
Transmission Type:
☑ Auto or ☐ Manual
☑ FWD ☐ RWD ☐ 4WD
Optional Equipment:
None

Dummy Data:
Type: 50th Percentile Male
Mass: 165 lb
Seat Position: PASSENGER SIDE



Geometry: inches

A	66.70	F	32.50	K	12.50	P	4.50	U	15.50
B	59.60	G	0.00	L	26.00	Q	24.00	V	21.25
C	175.40	H	41.50	M	58.30	R	16.25	W	41.50
D	40.50	I	7.00	N	58.50	S	7.50	X	79.75
E	102.40	J	22.50	O	30.50	T	64.50		

Wheel Center Ht Front 11.50 Wheel Center Ht Rear 11.50 W-H 0.00

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}	1438	1448	1533
Back	1687	M_{rear}	947	985	1065
Total	3389	M_{Total}	2385	2433	2598

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

Mass Distribution:
lb LF: 732 RF: 716 LR: 469 RR: 516

Date: 2024-08-22 Test No.: 619541-01-2 VIN No.: 3N1CN7AP1KL802178

Year: 2019 Make: Nissan Model: Versa

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FRONT BUMPER	18	.25	2	-	-	-	-	-	-	-12
	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).

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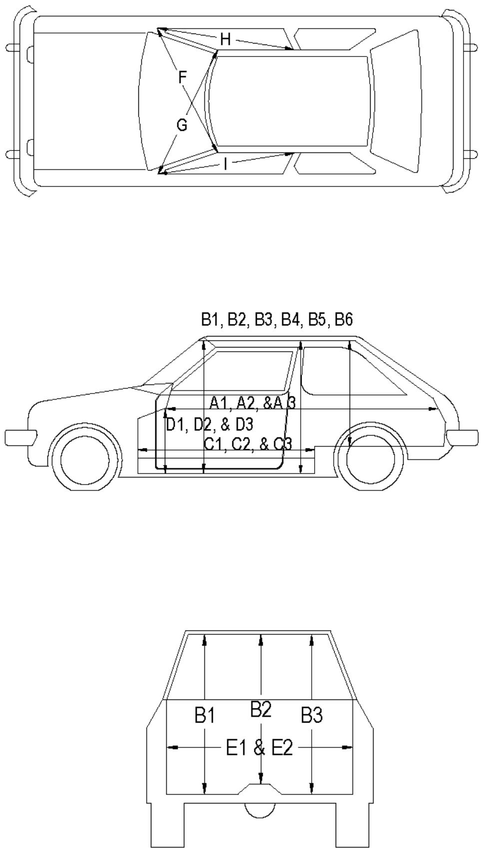
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***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.

Date: 2024-08-22 Test No.: 619541-01-2 VIN No.: 3N1CN7AP1KL802178

Year: 2019 Make: Nissan Model: Versa



OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	67.50	67.50	0.00
A2	67.25	67.25	0.00
A3	67.75	67.75	0.00
B1	40.50	40.50	0.00
B2	39.00	39.00	0.00
B3	40.50	40.50	0.00
B4	36.25	36.25	0.00
B5	36.00	36.00	0.00
B6	36.25	36.25	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	9.50	9.50	0.00
D2	0.00	0.00	0.00
D3	9.50	9.50	0.00
E1	51.50	51.50	0.00
E2	51.00	51.00	0.00
F	51.00	51.00	0.00
G	51.00	51.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	51.00	51.00	0.00

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

LIST OF TABLES

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

Equipment such as flashing beacons are regularly added to crashworthy standard roadside sign installations. The addition of the equipment alters the system weight and wind loading of the sign support system. Also, the crashworthiness of the sign support system with the added flashing beacon may be affected. Figure 1.1 shows an example of a sign support system with flashing beacon equipment.

Figure 1.1. Sign Support System with Flashing Beacon Equipment.

This project aimed to evaluate the crashworthiness of a roadside sign support system with flashing equipment attached to the support post. A system was selected for full-scale crash testing based on previous research, a survey of state department of transportations (DOTs), and engineering analysis. The selected system was evaluated according to 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).

CHAPTER 2.

BACKGROUND AND DESIGN

2.1. BACKGROUND

Bligh et al. (*2*) previously evaluated TxDOT's pedestal pole and flashing beacon assemblies according to MASH TL-3. The system consisted of a 4-inch sch. 40 aluminum pole with a sign panel and two flashing beacons attached to the pole. A pedestal base connected the pole to the concrete surface. One assembly had a solar panel mounted at the top of the pole. The other assembly did not have a solar panel attached. Figure 2.1 shows the two assemblies. Both flashing beacon assemblies indicated satisfactory performance for MASH TL-3 evaluation criteria.

Figure 2.1. Flashing Beacon Assemblies without Solar Panel (left) and with Solar Panel (right). (*2*)

Another flashing beacon system was evaluated by Kiani et al. (*3*). The system consisted of a 4-in sch. 40 aluminum pole with an audible button system, two sign panels, a rectangular rapid flashing beacon, and a solar panel attached to the pole. A pedestal base connected the pole to the concrete surface. Figure 2.1 shows the flashing beacon assembly. The assembly performed acceptably for MASH TL-3.

Figure 2.2. Rectangular Rapid Flashing Beacon Assembly. (*3*)

In summary, two sign support systems with flashing beacon equipment have been evaluated according to MASH TL-3. Both system configurations were found to be satisfactory for MASH TL-3 evaluation criteria. The systems generally consisted of a 4-inch aluminum sch. 40 pole, pedestal base, and various equipment attached to the pole. No other testing has been conducted with different pole types and bases.

2.2. STATE SURVEY

A survey questionnaire was distributed to members of the Roadside Safety Pooled Fund. The goal of the survey was to gather information on state DOT use of equipment attached to sign supports. The following information was requested:

1. Support type used when attaching equipment.
2. Support post size when attaching equipment.
3. Types of sign panels used in combination with equipment.
4. Types of equipment attached to the support posts.
5. Mounting heights and locations for the equipment.

A total of 16 responses were received. The responses were summarized as follows:

- The primary support types were round post and perforated square post when attaching equipment.
- The number of supports for these applications was primarily a single support.
- The support size varied greatly. The common size for each type is summarized as
  - Round pole – 4in sch. 40
  - Perforated square post – 2.5in x 2.5in
  - Wood – 4x6 rectangular
  - U-Channel – 3 lb/ft
- The primary sign types were 3ft x 3ft and 4ft x 4ft when attaching equipment.
- The primary equipment types were flashing beacons and solar panels.

2.3. DESIGN SELECTION AND ANALYSIS

A detailed review of the survey responses was conducted along with consideration for previous research. The sections below detail the selection of the components of the breakaway support system to be evaluated with full-scale crash testing based on survey results and engineering analysis.

2.3.1. Support Type

The two common types of supports were round post and perforated square post. The common size for the round post supports were 4-inch sch. 40 aluminum poles. Two variations of flashing beacon assemblies were previously evaluated and tested according to MASH TL-3 (*2,3*). Thus, there are already MASH compliant systems available for use with the round post support type and size. For the perforated square tube, the common sizes were 2in x 2in and 2.5in x 2.5in. There has not been any testing of these systems with equipment attached. Thus, the perforated square post was selected as the support to be evaluated with full-scale crash testing. The selection of the post size and base type is discussed in a later section.

The common number of support posts was a single support. Thus, a single post system was selected as the design to be evaluated with full-scale crash testing.

2.3.2. Equipment

The primary equipment used for these installations is a flashing beacon with a solar panel or A/C power box. Cameras and other equipment are used but are less common. Thus, they were not considered in this study.

There are three main types of configurations for a flashing beacon and solar panel assembly: an integrated flashing beacon and solar panel, a separated flashing beacon and solar panel, and a flashing beacon with an A/C power system. The integrated flashing beacon and solar panel consists of the flashing beacon and solar manufactured as one individual component. It is typically attached above the sign panel on the top of the support post. The separated flashing beacon and solar panel consists of a flashing beacon mounted above the sign panel, typically a 1 to 2 ft distance, and the solar panel mounted above the flashing beacon at the top of the pole. The flashing beacon and solar panel are manufactured as two different components. The flashing beacon and A/C power system consists of a flashing beacon mounted above the sign panel, typically a 1 to 2 ft distance, and the A/C power system mounted separately. The mounting location of the A/C power system can vary. The A/C power system can be mounted behind the sign panel or above the sign panel.

It was necessary to select one of the three types for the full-scale crash testing. The approach was to select the critical worst-case configuration type. This would allow the other types to be considered acceptable based on engineering analysis and judgment.   For breakaway sign support systems, the system that results in the lowest center of gravity is typically considered the critical worst-case. This is due to the increased likelihood of secondary contact with the vehicle when the breakaway support system center of gravity is lower.   After reviewing the three configuration types, the integrated flashing beacon and solar panel and flashing beacon with an A/C power system were found to be similar in terms of center of gravity. The integrated flashing beacon and solar panel was selected as the critical worst-case as it presented some additional components that could interact with the vehicle roof during a secondary contact.   This additional exposure would increase the chance of penetration into the occupant compartment and occupant compartment deformation.

2.3.3. Support Size

As previously discussed, the PSST was identified as the support type for evaluation with the full-scale crash testing. It was necessary to determine the appropriate size of the support.

The primary consideration was the ability of the support to withstand wind loading. The addition of the flashing beacon and solar panel would increase the wind loading for a typical roadside sign support installation. A wind loading analysis was performed to determine the minimum sign support size required.

The wind load analysis was performed according to AASHTO LRFD Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals (*4*). The wind load pressure was determined according to the equation outlined in Section 3.8.1. The wind speed was selected as 90 mi/h according to Figure 3.8-4a. A 2.5-inch x 2.5-inch 10 gauge PSST support size was determined to have adequate strength to withstand the wind load. Small post sizes (e.g., 2-inch x 2-inch) and a small thickness (12 gauge) were found to not have sufficient structural capacity.

2.3.4. Design Selection

Based on the discussions presented in the previous sections, a final design was selected for evaluation with full-scale crash testing. The design components are summarized as the following:

- Single support post, 2.5-inch x 2.5-inch 10-gauge
- 36-inch x 36-inch x 0.080-inch aluminum sign panel mounted 7 ft above grade
- Integrated flashing beacon and solar panel mounted 1 ft above the sign panel
- Triangular slip base assembly
- Ground anchor sleeve

This system was evaluated with full-scale crash testing as discussed in the next chapters. Other configurations of this system may be considered acceptable based on successful full-scale crash testing results.

CHAPTER 3.
SYSTEM DETAILS

3.1. TEST ARTICLE AND INSTALLATION DETAILS

The test installation was a breakaway sign support system, consisting of a diamond shaped aluminum sign mounted to 2-1/2-inch square perforated steel tubing, at 84 inches to the bottom of the sign, with an integrated flashing beacon and solar panel above the sign. The top of the solar panel was at 14 feet 3-1/2 inches above grade. The perforated steel tubing was inserted into a triangular slip base connector, which was in turn secured to a proprietary anchor sleeve.

Figure 3.1 presents the overall information on the breakaway sign support system with flashing equipment, and Figure 3.2 thru Figure 3.7 provide photographs of the installation. Appendix A provides further details on the breakaway sign support system with flashing equipment. Drawings were provided by the Texas A&M Transportation Institute (TTI) Proving Ground, and construction was performed by TTI Proving Ground personnel.

3.2. DESIGN MODIFICATIONS DURING TESTS

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

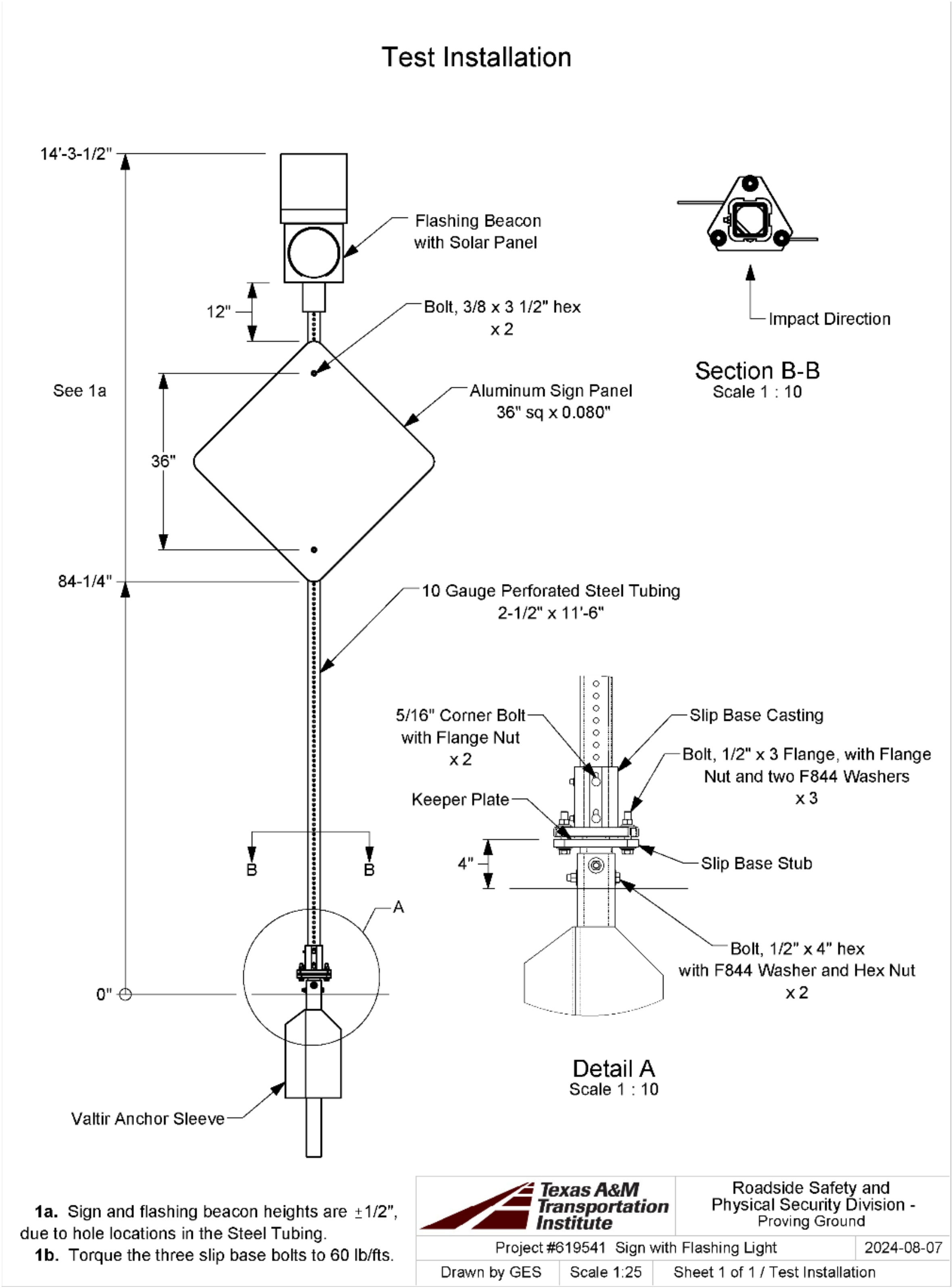


Figure 3.1. Details of the Breakaway Sign Support System with Flashing Equipment.

Figure 3.2. Breakaway Sign Support System with Flashing Equipment prior to Testing.

Figure 3.3. Close Up View of Sign Panel of Breakaway Sign Support System with Flashing Equipment prior to Testing.

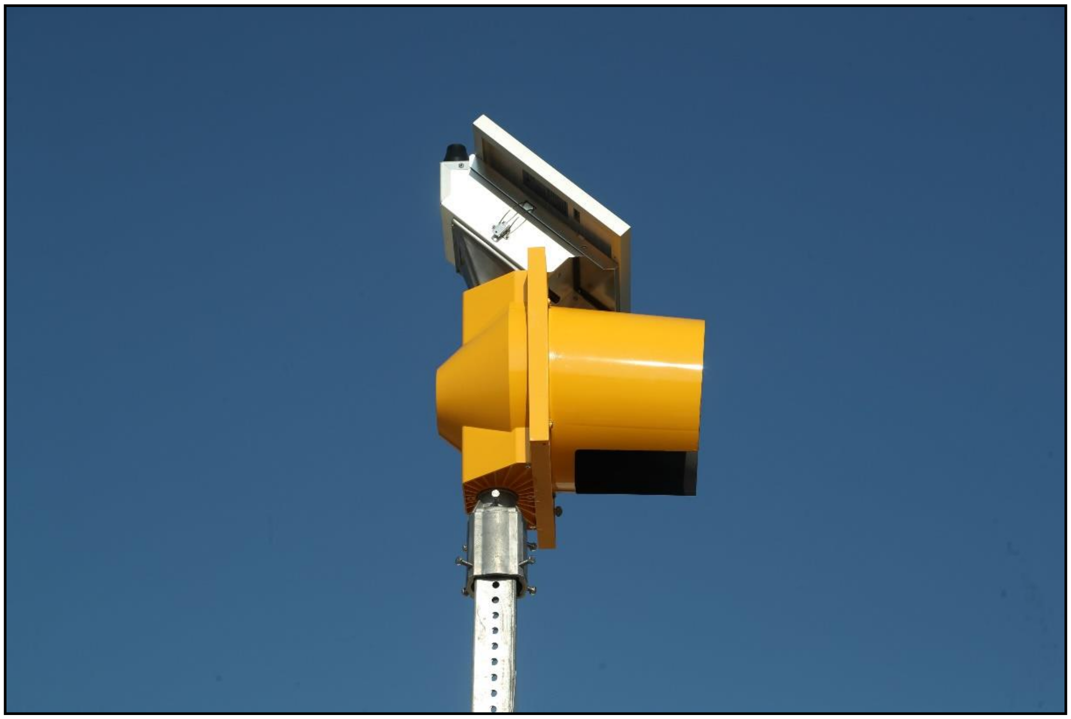


Figure 3.4. Close-Up Right-Angle View of Flashing Beacon of Breakaway Sign Support System with Flashing Equipment prior to Testing.

Figure 3.5. Close Up Parallel View of Flashing Beacon of Breakaway Sign Support System with Flashing Equipment prior to Testing.

Figure 3.6. Breakaway Sign Support System with Flashing Equipment prior to Testing.

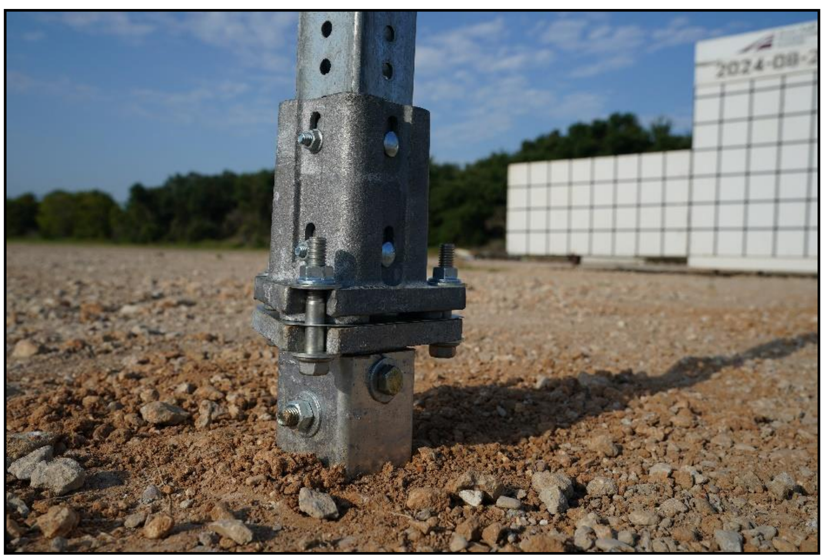


Figure 3.7. Breakaway Sign Support System with Flashing Equipment Perforated Steel Tubing prior to Testing.

3.3. 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 breakaway sign support system with flashing equipment for full-scale crash testing, two 6-ft long W6×16 posts were installed in the immediate vicinity of the system using the same fill materials and installation procedures used in the test installation and the standard dynamic test.

On the day of *MASH* Test 3-60, 8/7/2024, loads on the post at deflections are shown in Table 3.1. The backfill material in which the breakaway sign support system with flashing equipment was installed met minimum *MASH* requirements for soil strength. MASH Test 3-61 was performed at a later date of 8/22/2024. The results from the previous soil strength test were used as a basis for confirmation of the soil strength for this test.

Table 3.1. Soil Strength for Tests 619541-01-1&2.

Displacement	Minimum Load	Actual Load
5 inches	4420 lb	7000 lb
10 inches	4981 lb	8030 lb
15 inches	5282 lb	8666 lb

CHAPTER 4.

TEST REQUIREMENTS AND EVALUATION CRITERIA

4.1. CRASH TEST PERFORMED/MATRIX

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

Table 4.1. 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
3-61	1100C	62 mi/h	0º	B, D, F, H, I, N
3-62	2270P	62 mi/h	0º	B, D, F, H, I, N

The crash tests and data analysis procedures were in accordance with guidelines presented in *MASH*. Chapter 5 presents brief descriptions of these procedures.

4.2. EVALUATION CRITERIA

The appropriate safety evaluation criteria from Tables 2.2 and 5.1 of *MASH* were used to evaluate the crash tests reported herein. Table 4.1 lists the test conditions and evaluation criteria required for *MASH* TL-3, and Table 4.2 provides detailed information on the evaluation criteria.

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

Evaluation Factors	Evaluation Criteria
B.	The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.
D.	Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of *MASH*.
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.
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 5.
TEST CONDITIONS

5.1. TEST FACILITY

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

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

5.2. VEHICLE TOW AND GUIDANCE SYSTEM

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

5.3. DATA ACQUISITION SYSTEMS

5.3.1. Vehicle Instrumentation and Data Processing

Each test vehicle was instrumented with a self-contained onboard data acquisition system. The signal conditioning and acquisition system is a multi-channel data acquisition system (DAS) produced by Diversified Technical Systems Inc. The accelerometers, which measure the x, y, and z axis of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra-small, solid-state units designed for crash test service. The data acquisition hardware and software conform to the 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 ENDEVCOÒ 2901 precision primary vibration standard. This standard and its support instruments are checked annually and receive a calibration traceable to the International System of Units (SI). Measurement Uncertainties have been determined for critical parameters involved in this testing, and are available upon request by the Sponsor.

TRAP uses the DAS-captured data to compute the occupant/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).

5.3.2. Anthropomorphic Dummy Instrumentation

An Alderson Research Laboratories Hybrid II, 50th percentile male anthropomorphic dummy, restrained with lap and shoulder belts, was placed in the front seat on the 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.

5.3.3. Photographic Instrumentation Data Processing

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

- One with a field of view perpendicular to the impact path and in-line with the impact location.
- A second downstream from impact 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 Sign Posts with Flashing Beacon. The flashbulb was visible from each camera. The video files from these digital high-speed cameras were analyzed to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A digital camera recorded and documented conditions of each test vehicle and the installation before and after the test.

CHAPTER 6.

MASH TEST 3-60 (CRASH TEST 619541-01-1)

6.1. IMPACT POINT LOCATION

The Impact Point for this test was the vehicle centerline aligned 13 inches off the centerline of the installation towards the driver's side. The target impact for this test was determined using the information provided in *MASH* Section 2.2.4.1. Figure 6.1 shows the target impact for test 619541-01-1. Figure 6.2 and Figure 6.3 depict the vehicle at the impact prior to test 619541-01-1.

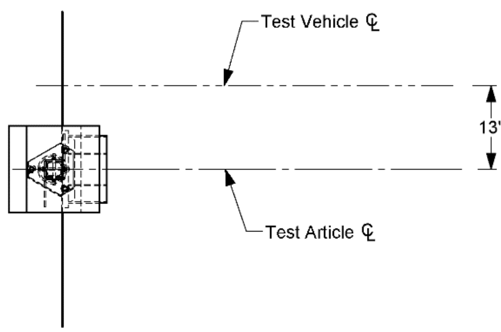


Figure 6.1. Target Impact for *MASH* Test 3-60 on Breakaway Sign Support System with Flashing Equipment.

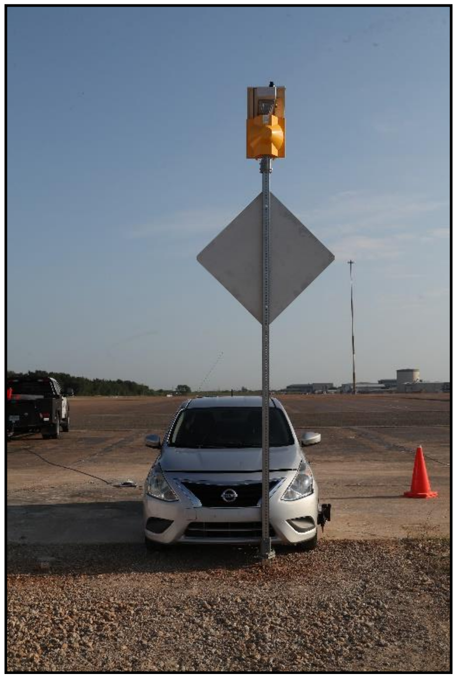


Figure 6.2. Breakaway Sign Support System with Flashing Equipment/Test Vehicle Geometrics for Test 619541-01-1.

Figure 6.3. Breakaway Sign Support System with Flashing Equipment/Test Vehicle Impact Location 619541-01-1.

6.2. TEST VEHICLE DETAILS PRIOR TO IMPACT

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

Table 6.1. Vehicle Measurements for Test 619541-01-1.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a]	165 lb	N/A	165 lb
Inertial Mass	2420 lb	±55 lb	2424 lb
Gross Static[a] Mass	2585 lb	±55 lb	2589 lb
Wheelbase	98 inches	±5 inches	102.4 inches
Front Overhang	35 inches	±4 inches	32.5 inches
Overall Length	169 inches	±8 inches	175.4 inches
Overall Width	65 inches	±3 inches	66.7 inches
Hood Height	28 inches	±4 inches	30.5 inches
Track Width[b]	59 inches	±2 inches	58.4 inches
CG aft of Front Axle[c]	39 inches	±4 inches	40.9 inches
CG above Ground[c,d]	N/A	N/A	N/A

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

Figure 6.4. Front of Test Vehicle before Test 619541-01-1.

Figure 6.5. Rear of Test Vehicle before Test 619541-01-1.

6.3. TEST DESCRIPTION

6.3.1. Weather Conditions

Table 6.2 provides the weather conditions for test 619541-01-1.

Table 6.2. Weather Conditions for Test 619541-01-1.

Date of Test	8/7/2024
Wind Speed	4 mi/h
Wind Direction	216°
Temperature	88 °F
Relative Humidity	79 %
Vehicle Traveling	170°

6.3.2. Test Events

Table 6.3 lists events that occurred during Test 619541-01-1. Figures C.4, C.5, and C.6 in Appendix C.2 present sequential photographs during the test.

Table 6.3. Events during Test 619541-01-1.

Time	Events
0.0000 s	Vehicle impacted the installation
0.0210 s	Upper slip base began to release from the anchor post
0.3630 s	Flashing beacon impacted top of roof
0.3700 s	Solar panel impacted top of roof

6.4. TEST ACTUAL IMPACT CONDITIONS

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

Table 6.4. Impact Conditions for *MASH TEST 3-60,* Crash Test 619541-01-1.

Test Parameter	Specification	Tolerance	Measured
Impact Speed	19 mi/h	±2.5 mi/h	19.4 mi/h
Impact Angle	0°	±1.5°	0°
Kinetic Energy	34 kip-ft	≤34 kip-ft	30.5 kip-ft
Impact Location	Centerline of the post aligned 13 inches off the centerline of the vehicle toward the driver's side	±6 inches	Centerline of the post impacted 13 inches off the centerline of the vehicle toward the driver's side

Table 6.5. Exit Parameters for *MASH TEST 3-60,* Crash Test 619541-01-1.

Exit Parameter	Measured
Speed	18.3 mi/h
Brakes applied post impact	3.5 seconds
Vehicle at rest position	112 ft downstream of impact point In-line
Comments:	Vehicle remained upright and stable

6.5. DAMAGE TO TEST INSTALLATION

The post landed 32 ft downstream and 6 ft to the left of the impact path. The integrated flashing beacon and solar panel fractured during impact. The batteries in the solar panel separated during impact and landed near the post. There was a 0.3-inch gap on the non-impact side of the anchor. Figure 6.6 and Figure 6.7 show the damage to the breakaway sign support system with flashing equipment.

Figure 6.6. Breakaway Sign Support System with Flashing Equipment at Impact Location after Test 619541-01-1.

Figure 6.7. Breakaway Sign Support System with Flashing Equipment at Resting Location after Test 619541-01-1.

6.6. DAMAGE TO TEST VEHICLE

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

Figure 6.8. Front of Test Vehicle after Test 619541-01-1.

Figure 6.9. Rear of Test Vehicle after Test 619541-01-1.

Figure 6.10. Overall Interior of Test Vehicle after Test 619541-01-1.

Table 6.6. Occupant Compartment Deformation for Test 619541-01-1.

Test Parameter	Specification	Measured
Roof	≤4.0 inches	3 inches
Windshield	≤3.0 inches	0 inches
A and B Pillars	≤5.0 overall/≤3.0 lateral inches	0 inches
Foot Well/Toe Pan	≤9.0 inches	0 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0 inches
Side Front Panel	≤12.0 inches	0 inches
Front Door (above Seat)	≤9.0 inches	0 inches
Front Door (below Seat)	≤12.0 inches	0 inches

Table 6.7. Exterior Vehicle Damage for Test 619541-01-1.

Test Parameter	Details
Side Windows	Side windows remained intact
Maximum Exterior Deformation	3 inches in the top of the roof
VDS	12FC1
CDC	12FCHN1
Fuel Tank Damage	None
Description of Damage to Vehicle:	There was a small fracture on the left side of the bumper cover which had released at the left fender. There was a deformation in the rear roof 32 inches wide by 32 inches long by 3 inches deep. At the passenger side cross member 9 inches away from the passenger door and 17 inches away from back glass was a 0.25 wide by a 0.25 inch long hole in the roof.

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.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 6.8. Occupant Risk Factors for Test 619541-01-1.

Test Parameter	Specification [a]	Measured	Time
OIV, Longitudinal	≤16.0 ft/s *10.0* ft/s	3.0 ft/s	0.7620 seconds on right side of interior
OIV, Lateral	N/A	2.8 ft/s	0.7620 seconds on right side of interior
Ridedown, Longitudinal	≤20.49 g *15.0* g	0.3 g	1.2092 - 1.2192 seconds
Ridedown, Lateral	≤20.49 g *15.0* g	0.4 g	1.6243 - 1.6343 seconds
Theoretical Head Impact Velocity (THIV)	N/A	1.2 m/s	0.7586 seconds on right side of interior
Acceleration Severity Index	N/A	0.1	0.0158 - 0.0658 seconds
50-ms Moving Avg. Accelerations (MA) Longitudinal	N/A	-0.7 g	0.0017 - 0.0517 seconds
50-ms MA Lateral	N/A	-0.2 g	0.6423 - 0.6923 seconds
50-ms MA Vertical	N/A	0.9 g	0.0326 - 0.0826 seconds
Roll	≤75°	3.7°	1.9999 seconds
Pitch	≤75°	1.2°	1.7430 seconds
Yaw	N/A	1.1°	1.9925 seconds

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

Note: N/A = Not Applicable

6.8. TEST SUMMARY

Figure 6.11 summarizes the results of *MASH* Test 3-60, crash test 619541-01-1.

0.000 s

0.2000 s

0.4000 s

0.6000s

GENERAL INFORMATION	
Test Agency:	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.:	*MASH* 2016, Test 3-60
Project No.:	619541-01-1
Test Date:	8/7/2024
TEST ARTICLE	
Type:	Support Structures
Name:	Breakaway Sign Support System with Flashing Equipment
Height:	14 feet 3.5 inches
Key Materials:	Perforated square post, flashing beacon, solar panel, slip base
Soil Type and Condition:	Existing soil, dry
TEST VEHICLE	
Type/Designation:	1100C
Year, Make and Model:	2018 Nissan Versa
Inertial Mass:	2424 lb
Dummy Mass:	165 lb
Gross Static Mass:	2589 lb
IMPACT CONDITIONS	
Impact Speed:	19.4 mi/h
Impact Angle:	0°
Impact Location:	Centerline of the post impacted 13 inches off the centerline of the vehicle toward the driver's side
Kinetic Energy:	30.5 kip-ft

EXIT CONDITIONS	
Exit Speed:	18.73 mi/h
Stopping Distance:	112 ft downstream of impact point In-line
VEHICLE DAMAGE	
VDS:	12FC1
CDC:	12FCHN1
Max Exterior Deformation:	3 inches in the top of the roof
Max Occupant Compartment Deformation:	3 inches at the roof
OCCUPANT RISK VALUES	
Longitudinal OIV:	3.0 ft/s
Lateral OIV:	2.8 ft/s
Longitudinal Ridedown:	0.3 g
Lateral Ridedown:	0.4 g
THIV:	1.2 m/s
ASI:	0.1
Max 50ms Longitudinal:	-0.7 g
Max 50ms Lateral:	-0.2 g
Max 50ms Vertical:	0.9 g
Max Roll:	3.7°
Max Pitch:	1.2°
Max Yaw:	1.1°

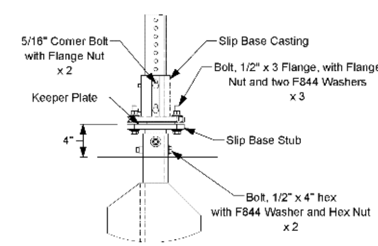


Figure 6.11. Summary of Results for *MASH* Test 3-60 on the Breakaway Sign Support System with Flashing Equipment.

CHAPTER 7.

MASH TEST 3-61 (CRASH TEST 619541-01-2)

7.1. IMPACT POINT LOCATION

The Impact Point for this test was the vehicle centerline aligned 13 inches off the centerline of the installation towards the driver's side. The target impact point for this test was determined using the information provided in *MASH* Section 2.2.4.1. Figure 7.1 shows the target impact point for test 619541-01-2. Figure 7.2 and Figure 7.3 depict the vehicle at the impact point prior to test 619541-01-2.

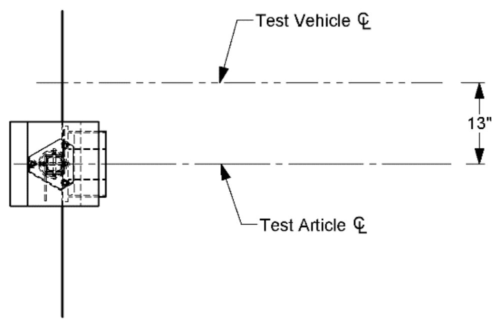


Figure 7.1. Target Impact Point for *MASH* Test 3-61 on Breakaway Sign Support System with Flashing Equipment.

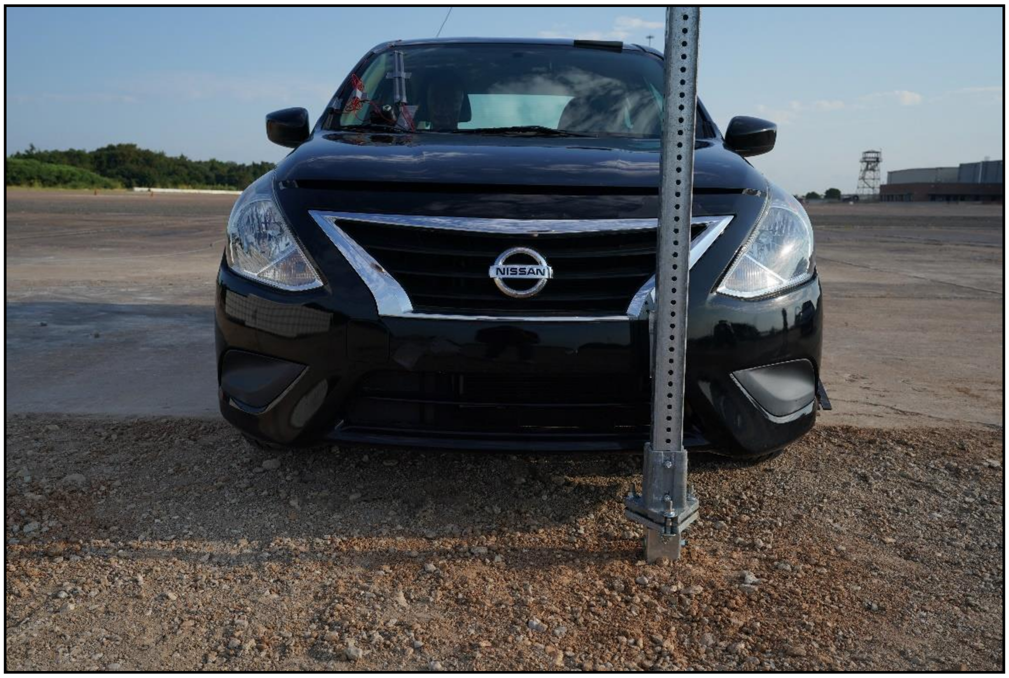


Figure 7.2. Breakaway Sign Support System with Flashing Equipment/Test Vehicle Geometrics for Test 619541-01-2.

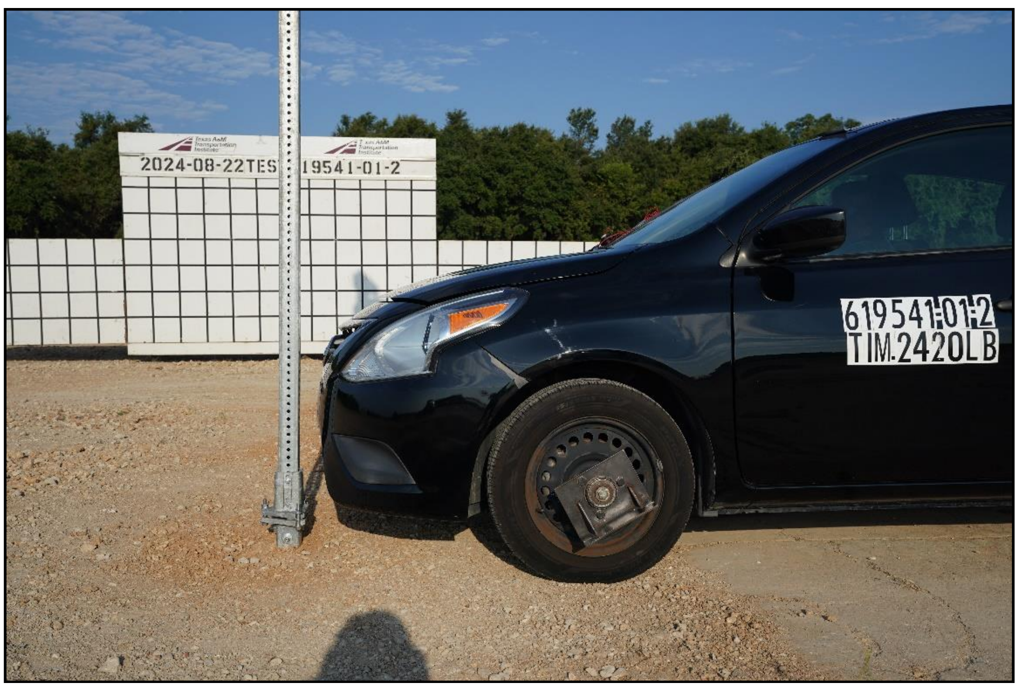


Figure 7.3. Breakaway Sign Support System with Flashing Equipment/Test Vehicle Impact Location 619541-01-2.

7.2. TEST VEHICLE DETAILS PRIOR TO IMPACT

Table 7.1 shows the vehicle measurements. Figure 7.4 and Figure 7.5 show the 2019 Nissan Versa used for the crash test. Figure D.1 in Appendix D.1 gives additional dimensions and information on the vehicle.

Table 7.1. Vehicle Measurements for Test 619541-01-2.

Test Parameter	Specification	Tolerance	Measured
Dummy Mass (if applicable)[a]	165 lb	N/A	165 lb
Inertial Mass	2420 lb	±55 lb	2433 lb
Gross Static[a] Mass	2585 lb	±55 lb	2598 lb
Wheelbase	98 inches	±5 inches	102.4 inches
Front Overhang	35 inches	±4 inches	32.5 inches
Overall Length	169 inches	±8 inches	175.4 inches
Overall Width	65 inches	±3 inches	66.7 inches
Hood Height	28 inches	±4 inches	30.5 inches
Track Width[b]	59 inches	±2 inches	58.4 inches
CG aft of Front Axle[c]	39 inches	±4 inches	41.5 inches
CG above Ground[c,d]	N/A	N/A	N/A

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

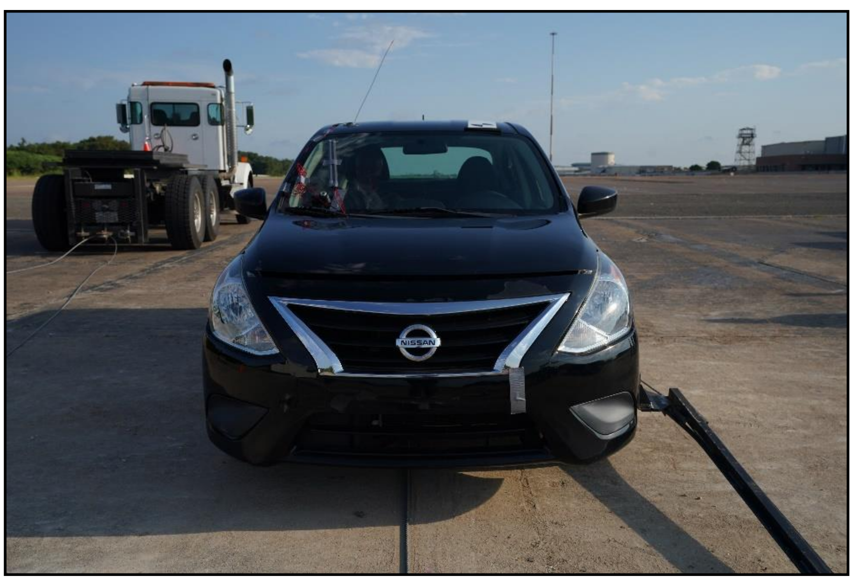


Figure 7.4. Front of Test Vehicle before Test 619541-01-2.

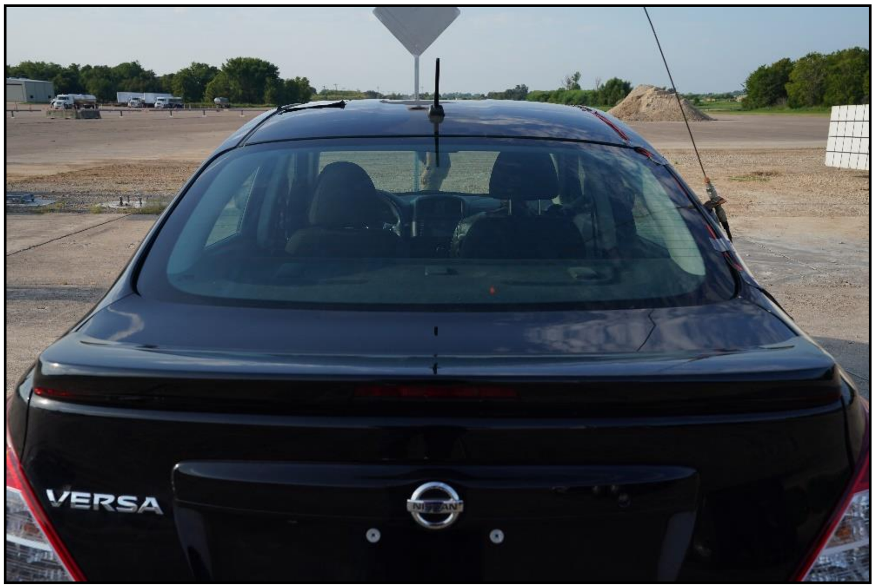


Figure 7.5. Rear of Test Vehicle before Test 619541-01-2.

7.3. TEST DESCRIPTION

7.3.1. Weather Conditions

Table 7.2 provides the weather conditions for test 619541-01-2.

Table 7.2. Weather Conditions for Test 619541-01-2.

Date of Test	8/22/2024
Wind Speed	7 mi/h
Wind Direction	170°
Temperature	89 °F
Relative Humidity	80 %
Vehicle Traveling	170°

7.3.2. Test Events

Table 7.3 lists events that occurred during Test 619541-01-2. Figures D.4, D.5, and D.6 in Appendix D.2 present sequential photographs during the test.

Table 7.3. Events during Test 619541-01-2.

Time	Events
0.0000 s	Vehicle impacted the installation
0.0080 s	Slip base began to release from the anchor
0.1680 s	Solar panel bracket contacted back window
0.1710 s	Solar panel bracket began to shatter back window
0.1920 s	Top of post began to penetrate through back window

7.4. TEST ACTUAL IMPACT CONDITIONS

Table 7.4 lists the details of the *MASH* impact conditions for this test and Table 7.5 lists the exit parameters.

Table 7.4. Impact Conditions for *MASH TEST 3-61,* Crash Test 619541-01-2.

Test Parameter	Specification	Tolerance	Measured
Impact Speed	62 mi/h	±2.5 mi/h	62.4 mi/h
Impact Angle	0°	±1.5°	0°
Kinetic Energy	288 kip-ft	≥288 kip-ft	316.7 kip-ft
Impact Location	Centerline of the post aligned 13 inches off the centerline of the vehicle toward the driver's side	±6 inches	Centerline of the post impacted 13 inches off the centerline of the vehicle toward the driver's side

Table 7.5. Exit Parameters for *MASH TEST 3-61,* Crash Test 619541-01-2.

Exit Parameter	Measured
Speed	61.5 mi/h
Brakes applied post impact	2.0 seconds
Vehicle at rest position	356 ft downstream of impact point 2 ft to the right side
Comments:	Vehicle remained upright and stable

7.5. DAMAGE TO TEST INSTALLATION

The support post landed 107’ d/s and 5’ left. The signal and solar panel landed 127’ d/s and 8’ left of impact. The signal and support post were deformed.

Figure 7.6 and Figure 7.7 show the damage to the Sign Posts with Flashing Beacon.

Figure 7.6. Breakaway Sign Support System with Flashing Equipment at Impact Location after Test 619541-01-2.

Figure 7.7. Breakaway Sign Support System with Flashing Equipment at Resting Location after Test 619541-01-2.

7.6. DAMAGE TO TEST VEHICLE

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

Figure 7.8. Roof of Test Vehicle after Test 619541-01-2.

Figure 7.9. Rear of Test Vehicle after Test 619541-01-2.

Figure 7.10. Overall Interior of Test Vehicle after Test 619541-01-2.

Table 7.6. Occupant Compartment Deformation for Test 619541-01-2.

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 lateral inches	0 inches
Foot Well/Toe Pan	≤9.0 inches	0 inches
Floor Pan/Transmission Tunnel	≤12.0 inches	0 inches
Side Front Panel	≤12.0 inches	0 inches
Front Door (above Seat)	≤9.0 inches	0 inches
Front Door (below Seat)	≤12.0 inches	0 inches

Table 7.7. Exterior Vehicle Damage for Test 619541-01-2.

Test Parameter	Details
Side Windows	Side windows remained intact
Maximum Exterior Deformation	0.3 inches at front bumper
VDS	12FC1
CDC	12FCHN1
Fuel Tank Damage	None
Description of Damage to Vehicle:	The bumper cover was dislodged and the grill was fractured. The bumper was deformed in by 0.3 inches with a collapsed rail frame of the bumper on the driver's side. The back glass was shattered due to penetration by the support post. This also caused a 0.8 inch long by 0.8 inch wide laceration in the carpet on the driver's side of the package tray. The trunk lid had a 5 inch wide by 5 inch long by 0.3 inch deep deformation on the driver's side, and there were abrasions on the spoiler.

7.7. OCCUPANT RISK FACTORS

Data from the accelerometers were digitized for evaluation of occupant risk, and the results are shown in Table 7.8. 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 7.8. Occupant Risk Factors for Test 619541-01-2.

Test Parameter	Specification [a]	Measured	Time
OIV, Longitudinal	≤16.0 ft/s *10.0* ft/s	2.8 ft/s	0.7452 seconds on right side of interior
OIV, Lateral	N/A	2.2 ft/s	0.7452 seconds on right side of interior
Ridedown, Longitudinal	≤20.49 g *15.0* g	0.5 g	0.9363 - 0.9463 seconds
Ridedown, Lateral	≤20.49 g *15.0* g	0.6 g	1.2892 - 1.2992 seconds
Theoretical Head Impact Velocity (THIV)	N/A	1.1 m/s	0.7643 seconds on right side of interior
Acceleration Severity Index	N/A	0.1	0.0071 - 0.0571 seconds
50-ms Moving Avg. Accelerations (MA) Longitudinal	N/A	-0.9 g	0.0000 - 0.0500 seconds
50-ms MA Lateral	N/A	-0.4 g	0.0131 - 0.0631 seconds
50-ms MA Vertical	N/A	-1.2 g	0.0136 - 0.0636 seconds
Roll	≤75°	2.6°	1.4999 seconds
Pitch	≤75°	2.8°	1.4411 seconds
Yaw	N/A	1.7°	1.4801 seconds

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

Note: N/A = Not Applicable

7.8. TEST SUMMARY

Figure 7.11 summarizes the results of *MASH* Test 3-61, crash test 619541-01-2.

0.000 s

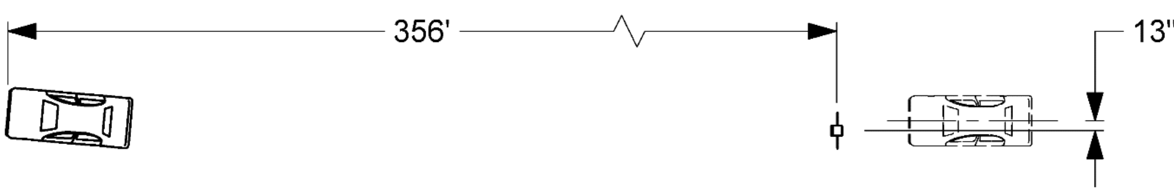
0.1000 s

0.2000 s

0.3000s

GENERAL INFORMATION	
Test Agency:	Texas A&M Transportation Institute (TTI)
Test Standard/Test No.:	*MASH* 2016, Test 3-61
Project No.:	619541-01-2
Test Date:	8/22/2024
TEST ARTICLE	
Type:	Support Structures
Name:	Breakaway Sign Support System with Flashing Equipment
Length:	14 feet 3.5 inches
Key Materials:	Perforated square post, flashing beacon, solar panel, slip base
Soil Type and Condition:	Existing soil, dry
TEST VEHICLE	
Type/Designation:	1100C
Year, Make and Model:	2019 Nissan Versa
Inertial Mass:	2433 lb
Dummy Mass:	165 lb
Gross Static Mass:	2598 lb
IMPACT CONDITIONS	
Impact Speed:	62.4 mi/h
Impact Angle:	0°
Impact Location:	Centerline of the post impacted 13 inches off the centerline of the vehicle toward the driver's side
Kinetic Energy:	316.7 kip-ft

EXIT CONDITIONS	
Exit Speed:	61.5 mi/h
Stopping Distance:	356 ft downstream 2 ft to the right side
VEHICLE DAMAGE	
VDS:	12FC1
CDC:	12FCHN1
Max Exterior Deformation:	0.25 inch at front bumper
Max Occupant Compartment Deformation:	No occupant compartment deformation, but the sign support penetrated through the back glass of the vehicle.
OCCUPANT RISK VALUES	
Longitudinal OIV:	2.8 ft/s
Lateral OIV:	2.2 ft/s
Longitudinal Ridedown:	0.5 g
Lateral Ridedown:	0.6 g
THIV:	1.1 m/s
ASI:	0.1
Max 50ms Longitudinal:	-0.9 g
Max 50ms Lateral:	-0.4 g
Max 50ms Vertical:	-1.2 g
Max Roll:	2.6°
Max Pitch:	2.8°
Max Yaw:	1.7°



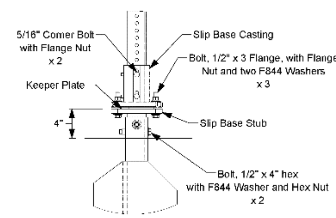


Figure 7.11. Summary of Results for *MASH* Test 3-61 on Breakaway Sign Support System with Flashing Equipment.

CHAPTER 8.

SUMMARY AND CONCLUSIONS

8.1. ASSESSMENT OF TEST RESULTS

The crash tests reported herein were performed in accordance with *MASH* TL-3, which involves three tests, on the breakaway sign support system with flashing equipment.

Table 8.1 shows that the breakaway sign support system with flashing equipment did not meet the performance criteria for *MASH* TL-3 Support Structures. The test installation penetrated the rear window during MASH Test 3-61 and did not meet the occupant compartment evaluation criterion D. MASH Test 3-62 was not performed after MASH Test 3-61 failed to meet all MASH performance criteria for support structures.

Table 8.1. Assessment Summary for *MASH* TL-3 Tests on Breakaway Sign Support System with Flashing Equipment.

Evaluation Criteria	Description	Test 619541-01-1 (*MASH* Test 3-60)	Test 619541-01-2 (*MASH* Test 3-61)
B	Test Article Broke Away, Fractured, Yielded	S	S
D	No Penetration into Occupant Compartment	S	FAIL
F	Roll and Pitch Limit	S	S
H	OIV Threshold	S	S
I	Ridedown Threshold	S	S
N	Vehicle Trajectory Behind Test Article Acceptable	S	S
Overall	Evaluation	Pass	Fail

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

8.2. CONCLUSIONS

State DOT agencies encounter situations where flashing equipment is mounted to a roadside sign support installation to improve communication with the travelling public. Standard roadside sign supports have been evaluated and shown to be crashworthy for MASH TL-3. It was necessary to evaluate the addition of flashing equipment to the top of the sign support installation and its effect on the system crashworthiness.

A literature review and state DOT survey was performed to understand previous research on this topic and current state of practice for DOTs. It was found that a common installation for state DOTs when using flashing equipment is a 4-inch sch. 40 aluminum pole with flashing beacons and solar panels. This type of system has had several configurations evaluated with previous full-scale crash testing (*2,3*). Thus, this type of system was not considered for further evaluation under this research study. Another common installation for state DOTs when using flashing equipment is a PSST post with a slip base assembly. This system was selected for additional consideration and full-scale crash testing under this research study.

An analysis of common PSST post types, post sizes, and equipment attachment was performed based on the state DOT survey results. In addition, wind loading requirements were considered in the design of the breakaway support system.

It was found that a 2.5-inch x 2.5-inch 10-gauge PSST with a sign panel and integrated flashing beacon and solar panel represented a configuration that met the wind loading requirements. It also represented the critical worst-case in terms of the flashing equipment selection as it resulted in the lowest system center of gravity.

Full-scale crash testing was performed to evaluate a test installation consisting of a 2.5-inch PSST, sign panel, and integrated flashing beacon and solar panel assembly. The system was evaluated according to MASH TL-3. The system indicated satisfactory performance for MASH Test 3-60. The system indicated unsatisfactory performance for MASH Test 3-61 and failed the occupant compartment deformation due to penetration of the rear windshield. MASH Test 3-62 was not performed due to the aforementioned failure. Thus, the breakaway sign support system with a 2.5-inch PSST post and flashing equipment did not meet the MASH TL-3 evaluation criteria. Future research is needed to evaluate alternative designs with flashing equipment attached to a PSST support. Alternative designs could include increased mounting height of the sign panel and/or increased mounting height of the integrated flashing beacon and solar panel. Consideration could also be given towards other flashing equipment configurations such as a separate flashing beacon and solar panel or a flashing beacon with A/C power box.

It should be noted that a MASH-compliant design for attaching flashing equipment is available for a 4-inch sch. 40 aluminum pole with a pedestal base. If other post types and configuration such as a PSST are desired, then additional research and testing will be needed to develop and evaluate such a design.

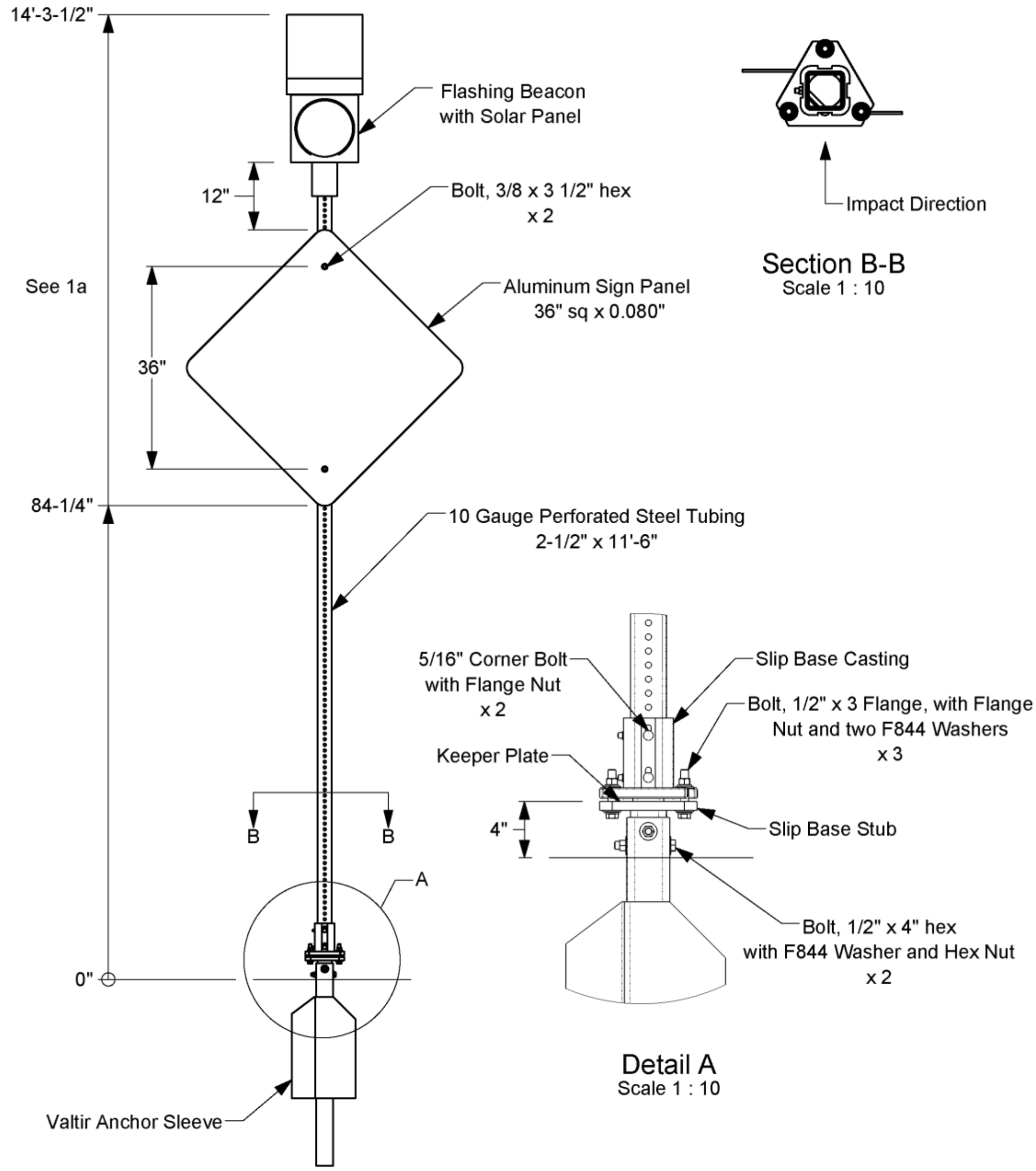
REFERENCES

1. AASHTO. *Manual for Assessing Safety Hardware*, Second Edition. American Association of State Highway and Transportation Officials, Washington, DC, 2016.
2. Bligh, R. P., Menges, W.L., and Kuhn, D.L. *MASH Evaluation of TxDOT Roadside Safety Features – Phase I.* Test Report No. 0-6946-1. Texas A&M Transportation Institute, College Station, TX, 2018.
3. Kiani, M., Schroeder, W., and Kuhn, D.L. *Evaluation of Crashworthy Enhanced Highway Sign Assemblies.* Test Report No. 616161-01. Texas A&M Transportation Institute, College Station, TX, 2018.

APPENDIX A.

DETAILS OF BREAKAWAY SIGN SUPPORT SYSTEM WITH FLASHING EQUIPMENT

Test Installation



1a. Sign and flashing beacon heights are ±1/2", due to hole locations in the Steel Tubing.
1b. Torque the three slip base bolts to 60 lb/fts.

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

Project #619541 Sign with Flashing Light | 2024-08-07

Drawn by GES | Scale 1:25 | Sheet 1 of 1 / Test Installation

S:\Accreditation-17025-2017\EIR-000 Project Files\619541 - Sign Support with Flasher - Schulz\Drafting, 619541\2024-08-07\619541 Drawing

APPENDIX B.

SUPPORTING CERTIFICATION DOCUMENTS

Certificate of Analysis

VALTIR

Valtir, LLC 2548 N.E. 28th Street Fort Worth TX 76111 United States	Order Number: SO67279	Prod LN Grp: Crash Cushion
	Customer PO: 619541	
Customer: TEXAS A&M TRANSPORTATION INSTITUTE	BOL Number 1016-00600	Ship Date: 8/5/2024
	Document #: 1016-00600_1	1016-00600
Shipped To: 3100 HWY 47 SOUTH BLDG 7091 Bryan, Texas 77807		
	Use State: Texas	
Project STOCK, , ,		

Qty	Part #	Description	Spec-CL-TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Va

UPON DELIVERY, ALL MATERIALS SUBJECT TO VALTIR, LLC STORAGE STAIN POLICY QMS-LQ-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT, 23 CFR 635.410.

ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.

ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.

ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 US DOMESTIC SHIPMENTS.

ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 INTERNATIONAL SHIPMENTS.

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B, P, OR S, ARE UNCOATED.

BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

WASHERS COMPLY WITH ASTM F-436 SPECIFICATION AND/OR F-844 AND ARE GALVANIZED IN ACCORDANCE WITH ASTM F-2329, UNLESS OTHERWISE STATED.

1016-00600

Certificate of Analysis

VALTIR

3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH - 46,000 LBS.

PURSUANT TO THE INFRASTRUCTURE INVESTMENT AND JOBS ACT IIJA, PUB. L. NO. 117-58, WHICH INCLUDES THE BUILD AMERICA, BUY AMERICA ACT BABA. IIJA DIV. G §§ 70901-27, THE IRON, STEEL, MANUFACTURED PRODUCTS, AND CONSTRUCTION MATERIALS SOLD BY VALTIR, LLC AND LISTED ON THE ATTACHED WERE PRODUCED IN THE UNITED STATES AND COMPLIES WITH BUILD AMERICA, BUY AMERICA ACT BABA.

Notary Public:

Commission Expires:

CHRISTINE EMILY HARRIS
Notary ID #134494894
My Commission Expires
August 4, 2027

Christine Harris

Certified By:

Quality Assurance:

Luis Ortiz

1016-00600

Certificate of Analysis

VALTIR

Valtir, LLC
2548 N.E. 28th Street
Fort Worth TX 76111
United States

Order Number: SO67279

Prod LN Grp: Small Signs

Customer PO: 619541

Customer: TEXAS A&M TRANSPORTATION INSTITUTE

BOL Number 1016-00600

Ship Date: 8/5/2024

Document #: 1016-00600_1

1016-00600

Shipped To: 3100 HWY 47 SOUTH
BLDG 7091
Bryan, Texas 77807

Use State: Texas

Project STOCK, , ,

Qty	Part #	Description	Spec-CL-TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Va
3	720776G	2.500PS10@144														
			COC Only	9322 09 36												
3	720989G	8 SQ SLIPBSE STUB INS														
			COC Only	2044503597-3												
			A-36 P	CA8750	43,000	68,800	35	0.19		0.008	0.001	0.03				
			MISC	384343												
3	840052G	3/8X3.5 HXFLNGOBLSHL DRBLT														
			COC with Full Traceability	B35275-1												
3	721336G	8 SQ SLIPBSE INS ANCH PLT														
			COC Only	2044503597-3												
			A-500-B	24068142	64,275	75,553	31	0.2	0.75	0.013	0.003					
			A-36 FB up to 1 inch	24061992	54,000	77,000	31	0.21		0.007	0.003	0.02				
3	721018G	SLPBSE 8SQ ABOVEGND COMP														
			MISC	129622												
			COC with Full Traceability	135104												

1016-00600

3 of 5

VALTIR

Certificate of Analysis

Qty	Part #	Description	Spec-CL-TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Va
			COC with Full Traceability	124832												
			COC with Full Traceability	0255649												
			A-536	5GB	49,221	76,636	18									
			MISC	THTX0431												

UPON DELIVERY, ALL MATERIALS SUBJECT TO VALTIR, LLC STORAGE STAIN POLICY QMS-LQ-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT, 23 CFR 635.410.

ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.

ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.

ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 US DOMESTIC SHIPMENTS.

ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 INTERNATIONAL SHIPMENTS.

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B, P, OR S, ARE UNCOATED.

BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

WASHERS COMPLY WITH ASTM F-436 SPECIFICATION AND/OR F-844 AND ARE GALVANIZED IN ACCORDANCE WITH ASTM F-2329, UNLESS OTHERWISE STATED.

3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH - 46,000 LBS.

PURSUANT TO THE INFRASTRUCTURE INVESTMENT AND JOBS ACT IIJA, PUB. L. NO. 117-58, WHICH INCLUDES THE BUILD AMERICA, BUY AMERICA ACT BABA. IIJA DIV. G §§ 70901-27, THE IRON, STEEL, MANUFACTURED PRODUCTS, AND CONSTRUCTION MATERIALS SOLD BY VALTIR, LLC AND LISTED ON THE ATTACHED WERE PRODUCED IN THE UNITED STATES AND COMPLIES WITH BUILD AMERICA, BUY AMERICA ACT BABA.

1016-00600

4 of 5

Certificate of Analysis

VALTIR

Notary Public:

Commission Expires:

CHRISTINE EMILY HARRIS
Notary ID #134494894
My Commission Expires
August 4, 2027

Certified By:

Quality Assurance:

1016-00600

5 of 5

Certificate of Compliance

VALTIR

Valtir, LLC 2548 N.E. 28th Street Fort Worth TX 76111 United States	Order Number: SO67279		
	Customer PO: 619541		
Customer: TEXAS A&M TRANSPORTATION INSTITUTE	BOL Number 1016-00600	Ship Date: 8/5/2024	
	Document #: 1016-00600_1	1016-00600	
Shipped To: 3100 HWY 47 SOUTH BLDG 7091 Bryan, Texas 77807			
	Use State: Texas		
Project STOCK, , ,			

Certificate of Compliance for Valtir, LLC

Pieces		Description	Part Number
3		2.500PS10@144	00720776G
	3	2.500PS10@144	720776G
3		SLPBSE 8SQ ABOVEGND COMP	00721018G
	3	SLPBSE 8SQ ABOVEGND COMP	721018G
3		8 SQ SLIPBSE INS ANCH PLT	00721336G
	3	8 SQ SLIPBSE INS ANCH PLT	721336G
3		8 SQ SLIPBSE STUB INS	00720989G
	3	8 SQ SLIPBSE STUB INS	720989G
3		3/8X3.5 HXFLNGOBLSHLDRBLT	00840052G
	3	3/8X3.5 HXFLNGOBLSHLDRBLT	840052G
3		TRACC 3/8" HEX FLANGE NUT	003256G
	3	3/8" HEX FLANGE NUT	3256G
1		LTL CHARGE	00FREIGHTLTL

UPON DELIVERY, ALL MATERIALS SUBJECT TO VALTIR, LLC STORAGE STAIN POLICY QMS-LQ-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT, 23 CFR 635.410.

ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.

ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.

ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 US DOMESTIC SHIPMENTS.

ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 INTERNATIONAL SHIPMENTS.

1016-00600

1 of 2

Certificate of Compliance

VALTIR

FINISHED GOOD PART NUMBERS ENDING IN SUFFIX B, P, OR S, ARE UNCOATED.

BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

WASHERS COMPLY WITH ASTM F-436 SPECIFICATION AND/OR F-844 AND ARE GALVANIZED IN ACCORDANCE WITH ASTM F-2329, UNLESS OTHERWISE STATED.

3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH - 46,000 LBS.

PURSUANT TO THE INFRASTRUCTURE INVESTMENT AND JOBS ACT IIJA, PUB. L. NO. 117-58, WHICH INCLUDES THE BUILD AMERICA, BUY AMERICA ACT BABA. IIJA DIV. G §§ 70901-27, THE IRON, STEEL, MANUFACTURED PRODUCTS, AND CONSTRUCTION MATERIALS SOLD BY VALTIR, LLC AND LISTED ON THE ATTACHED WERE PRODUCED IN THE UNITED STATES AND COMPLIES WITH BUILD AMERICA, BUY AMERICA ACT BABA.

Notary Public: CHRISTINE EMILY HARRIS Notary ID #134494894

Commission Expires: My Commission Expires August 4, 2027

Christine Harris

Certified By:

Quality Assurance:

1016-00600

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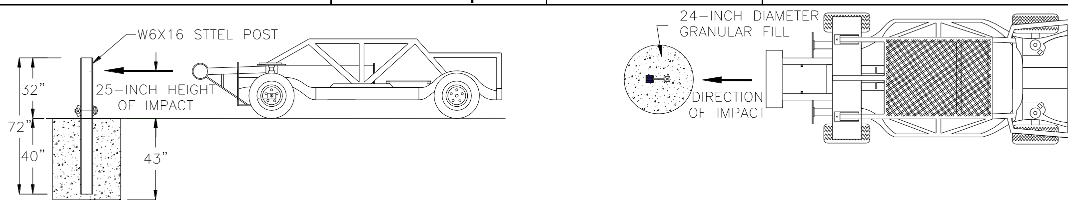
Dynamic Test Setup

Post-Test
Photo of post

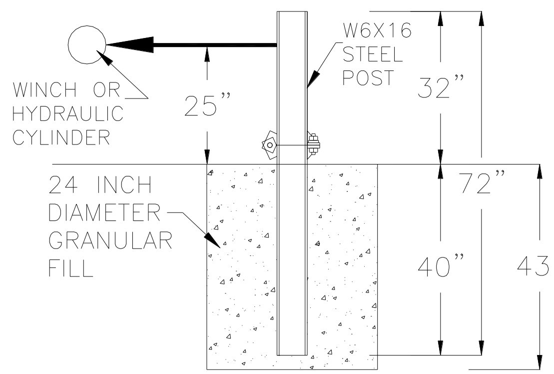
Static
Load Test

Post-Test
Photo



Dynamic Test Installation Details

Comparison of Load vs. Displacement



Static Load Test Installation Details

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

APPENDIX C.

MASH TEST 3-60 (CRASH TEST 619541-01-1)

C.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2024-08-07 Test No.: 619541-01-1 VIN No.: 3N1CN7APJK414819

Year: 2018 Make: Nissan Model: Versa

Tire Inflation Pressure: 36 PSI Odometer: 155730 Tire Size: P185/65R15

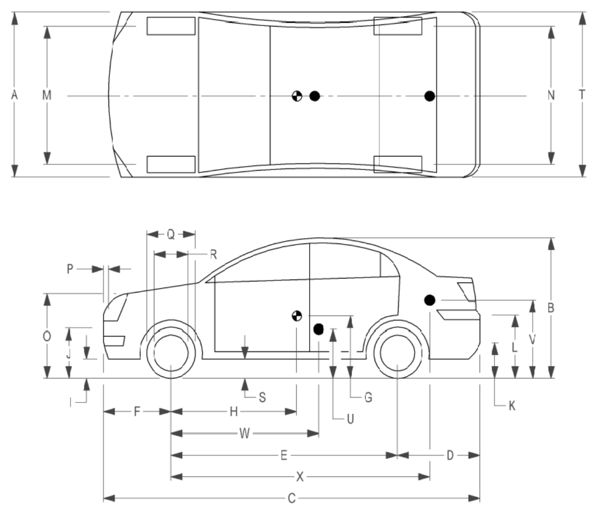
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES: None

Engine Type: 4 CYL
Engine CID: 1.6 L
Transmission Type:
☑ Auto or ☐ Manual
☑ FWD ☐ RWD ☐ 4WD
Optional Equipment:
None

Dummy Data:
Type: 50th Percentile Male
Mass: 165 lb
Seat Position: PASSENGER SIDE



Geometry: inches

A	66.70	F	32.50	K	12.50	P	4.50	U	15.50
B	59.60	G	0.00	L	26.00	Q	24.00	V	21.25
C	175.40	H	40.90	M	58.30	R	16.25	W	
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 -40.90

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}	1425	1456	1541
Back	1687	M_{rear}	1010	968	1048
Total	3389	M_{Total}	2435	2424	2589

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

Mass Distribution:
lb LF: 780 RF: 676 LR: 499 RR: 469

Figure C.1. Vehicle Properties for Test 619541-01-1.

Date: 2024-08-07	Test No.: 619541-01-1	VIN No.: 3N1CN7AP6JK414819
Year: 2018	Make: Nissan	Model: Versa

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

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

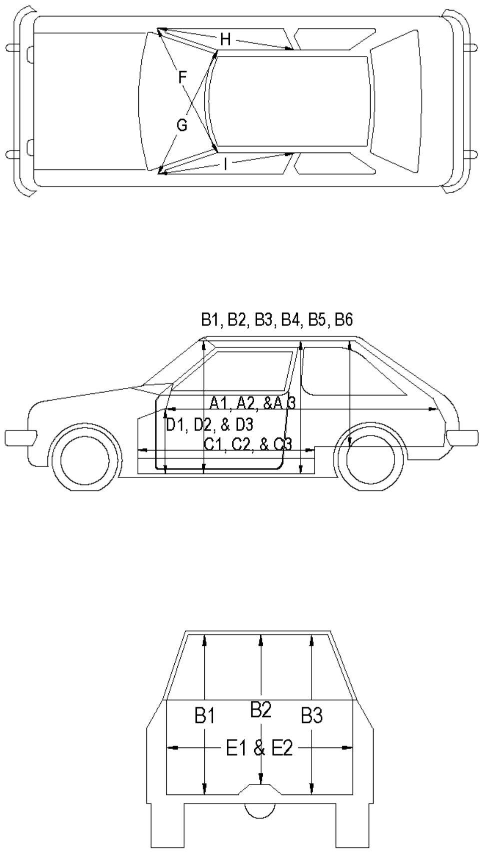
***Measure and document on the vehicle diagram the location of the maximum crush.

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

Figure C.2. Exterior Crush Measurements for Test 619541-01-1.

Date: 2024-08-07 Test No.: 619541-01-1 VIN No.: 3N1CN7AP6JK414819

Year: 2018 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	33.25	-3.00
B5	36.00	33.25	-2.75
B6	36.25	36.00	-0.25
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 619541-01-1.

C.2. SEQUENTIAL PHOTOGRAPHS

(a) 0.000 s (b) 0.1000 s

(c) 0.2000 s (d) 0.3000 s

(e) 0.4000 s (f) 0.5000 s

(g) 0.6000 s (h) 0.7000 s

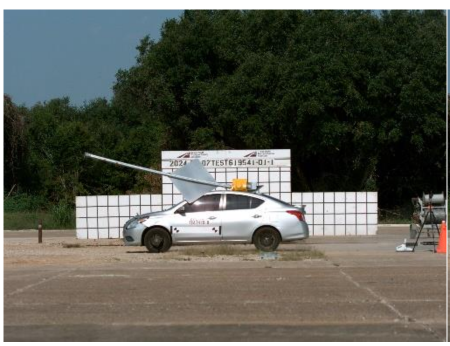
Figure C.4. Sequential Photographs for Test 619541-01-1 (Downstream Oblique Views).

(a) 0.000 s

(b) 0.1000 s

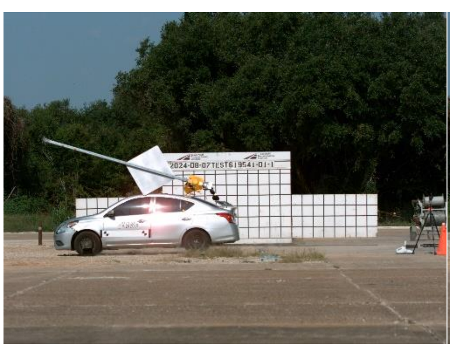
(c) 0.2000 s

(d) 0.3000 s



(e) 0.4000 s

(f) 0.5000 s

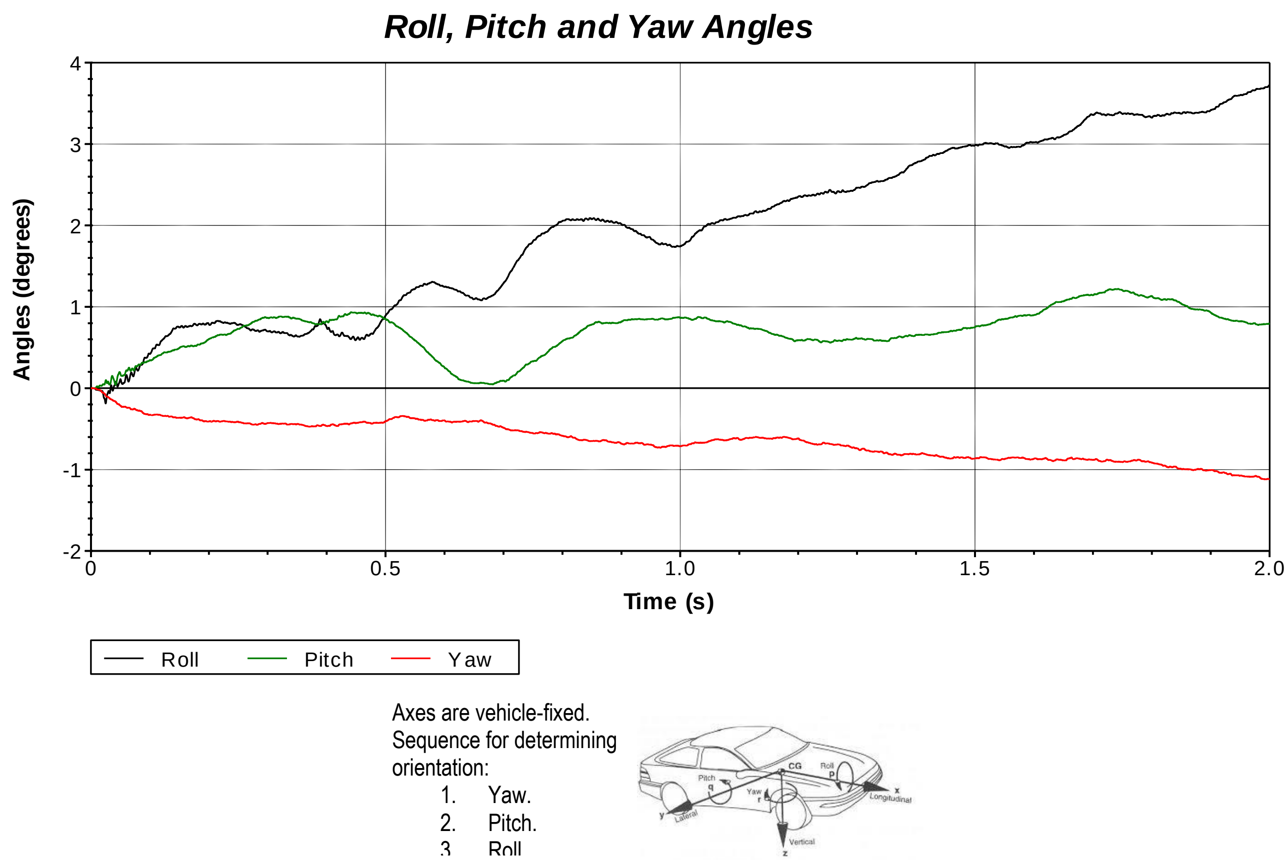


(g) 0.6000 s

(h) 0.7000 s

Figure C.5. Sequential Photographs for Test 619541-01-1 (Right Angle Views).

C.3. VEHICLE ANGULAR DISPLACEMENTS



Test Number: 619541-01-1
Test Standard Test Number: *MASH* Test 3-60
Test Article: Sign Posts with Flashing Beacon
Test Vehicle: 2018 Nissan Versa
Inertial Mass: 2424 lbs
Gross Mass: 2589 lbs
Impact Speed: 19.4 mi/h
Impact Angle: 0°

Figure C.7. Vehicle Angular Displacements for Test 619541-01-1.

C.4. VEHICLE ACCELERATIONS

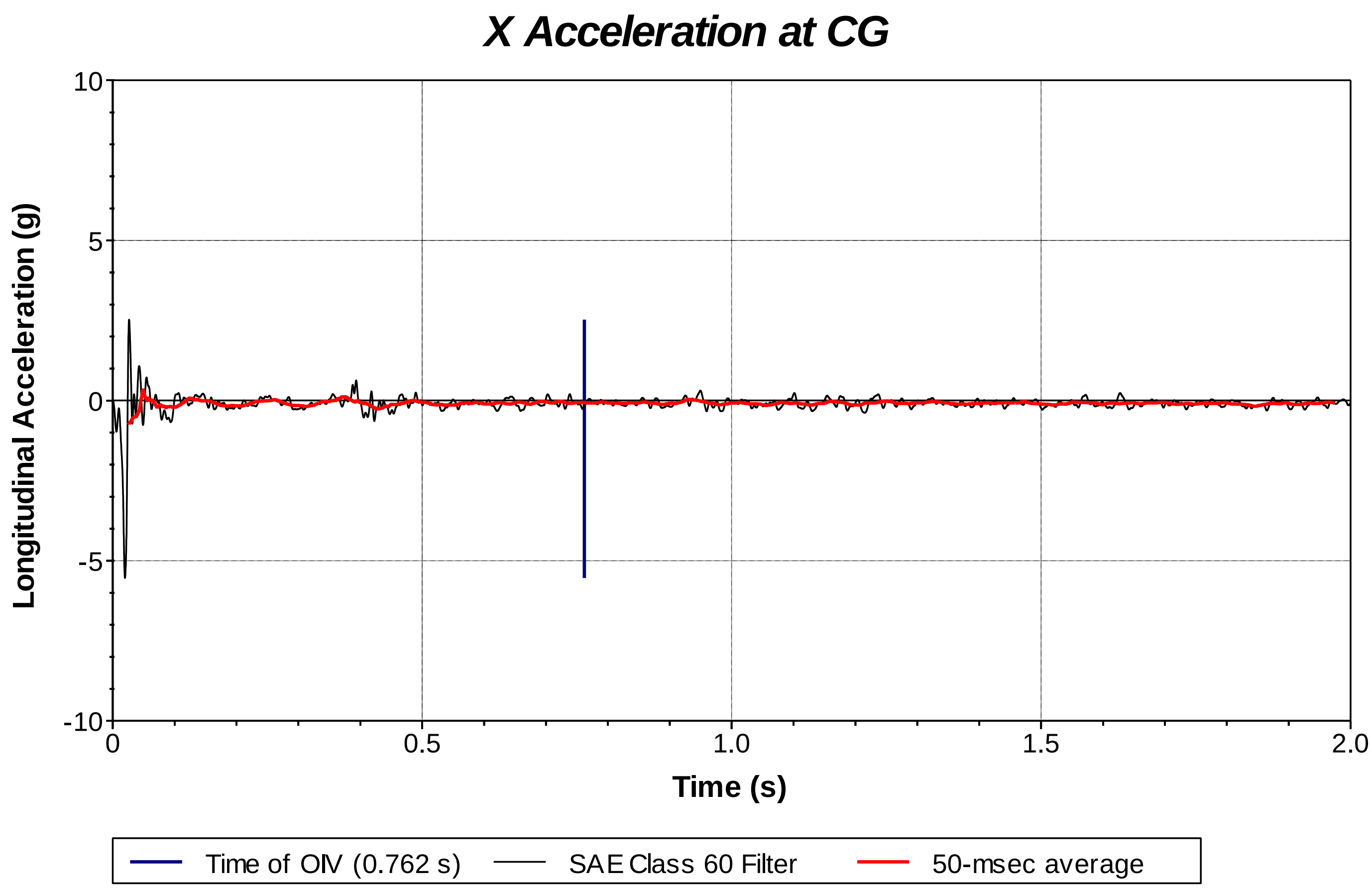


Figure C.8. Vehicle Longitudinal Accelerometer Trace for Test 619541-01-1 (Accelerometer Located at Center of Gravity).

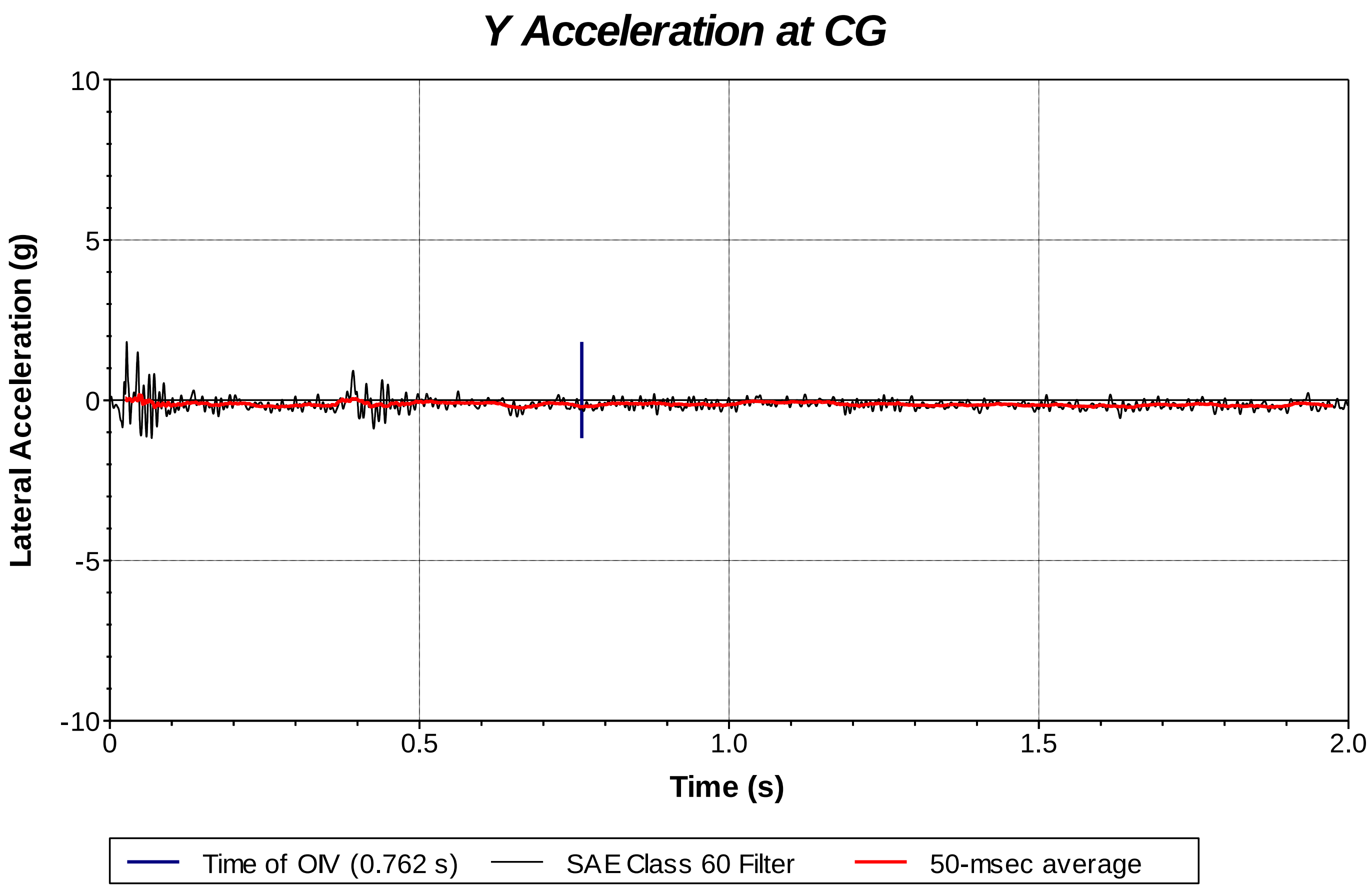


Figure C.9. Vehicle Lateral Accelerometer Trace for Test 619541-01-1
(Accelerometer Located at Center of Gravity).

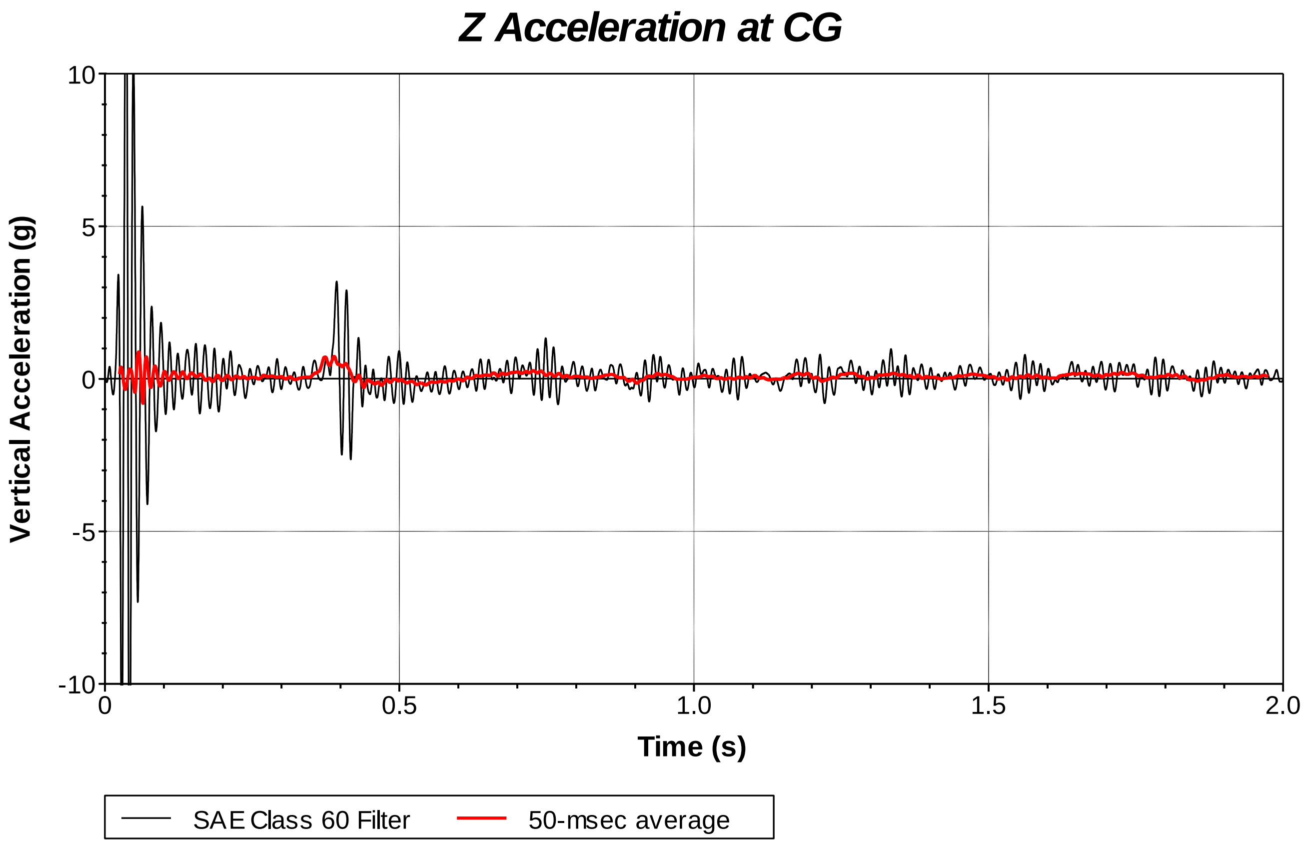


Figure C.10. Vehicle Vertical Accelerometer Trace for Test 619541-01-1 (Accelerometer Located at Center of Gravity).

APPENDIX D.

MASH TEST 3-61 (CRASH TEST 619541-01-2)

D.1. VEHICLE PROPERTIES AND INFORMATION

Date: 2024-08-22 Test No.: 619541-01-2 VIN No.: 3N1CN7AP1KL802178

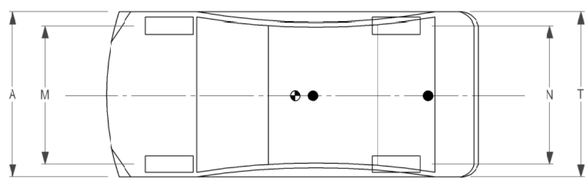
Year: 2019 Make: Nissan Model: Versa

Tire Inflation Pressure: 36 PSI Odometer: 66173 Tire Size: P185/65R15

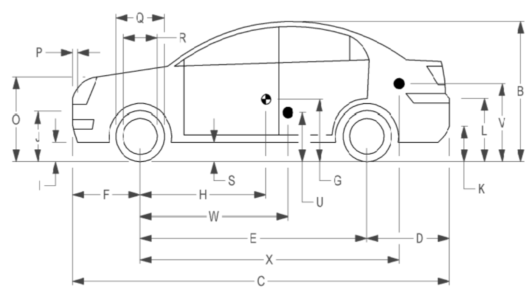
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES: None



Engine Type: 4 CYL
Engine CID: 1.6 L
Transmission Type:
☑ Auto or ☐ Manual
☑ FWD ☐ RWD ☐ 4WD
Optional Equipment:
None



Dummy Data:
Type: 50th Percentile Male
Mass: 165 lb
Seat Position: PASSENGER SIDE

Geometry: inches

A	66.70	F	32.50	K	12.50	P	4.50	U	15.50
B	59.60	G	0.00	L	26.00	Q	24.00	V	21.25
C	175.40	H	41.50	M	58.30	R	16.25	W	41.50
D	40.50	I	7.00	N	58.50	S	7.50	X	79.75
E	102.40	J	22.50	O	30.50	T	64.50		

Wheel Center Ht Front 11.50 Wheel Center Ht Rear 11.50 W-H 0.00

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}	1438	1448	1533
Back	1687	M_{rear}	947	985	1065
Total	3389	M_{Total}	2385	2433	2598

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

Mass Distribution:
lb LF: 732 RF: 716 LR: 469 RR: 516

Figure D.1. Vehicle Properties for Test 619541-01-2.

Date:	2024-08-22	Test No.:	619541-01-2	VIN No.:	3N1CN7AP1KL802178
Year:	2019	Make:	Nissan	Model:	Versa

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FRONT BUMPER	18	.25	2	-	-	-	-	-	-	-12
	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.

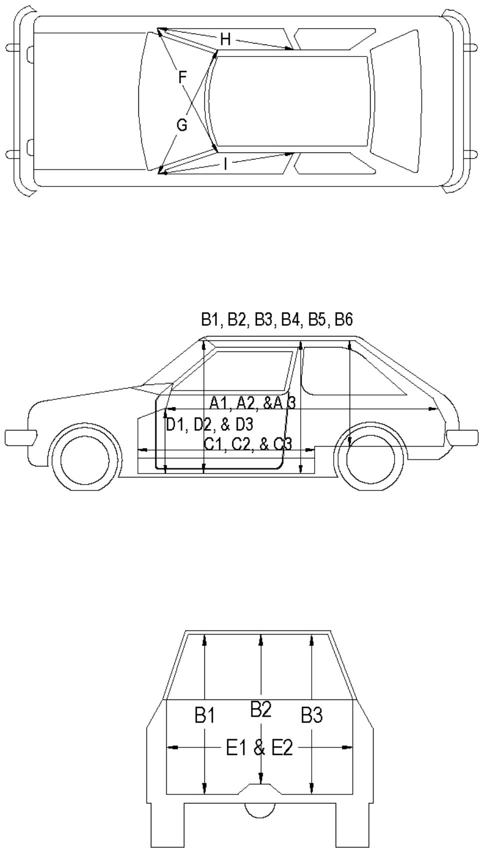
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***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 619541-01-2.

Date:	2024-08-22	Test No.:	619541-01-2	VIN No.:	3N1CN7AP1KL802178
Year:	2019	Make:	Nissan	Model:	Versa



OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	67.50	67.50	0.00
A2	67.25	67.25	0.00
A3	67.75	67.75	0.00
B1	40.50	40.50	0.00
B2	39.00	39.00	0.00
B3	40.50	40.50	0.00
B4	36.25	36.25	0.00
B5	36.00	36.00	0.00
B6	36.25	36.25	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	9.50	9.50	0.00
D2	0.00	0.00	0.00
D3	9.50	9.50	0.00
E1	51.50	51.50	0.00
E2	51.00	51.00	0.00
F	51.00	51.00	0.00
G	51.00	51.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	51.00	51.00	0.00

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

Figure D.3. Occupant Compartment Measurements for Test 619541-01-2.

D.2. SEQUENTIAL PHOTOGRAPHS

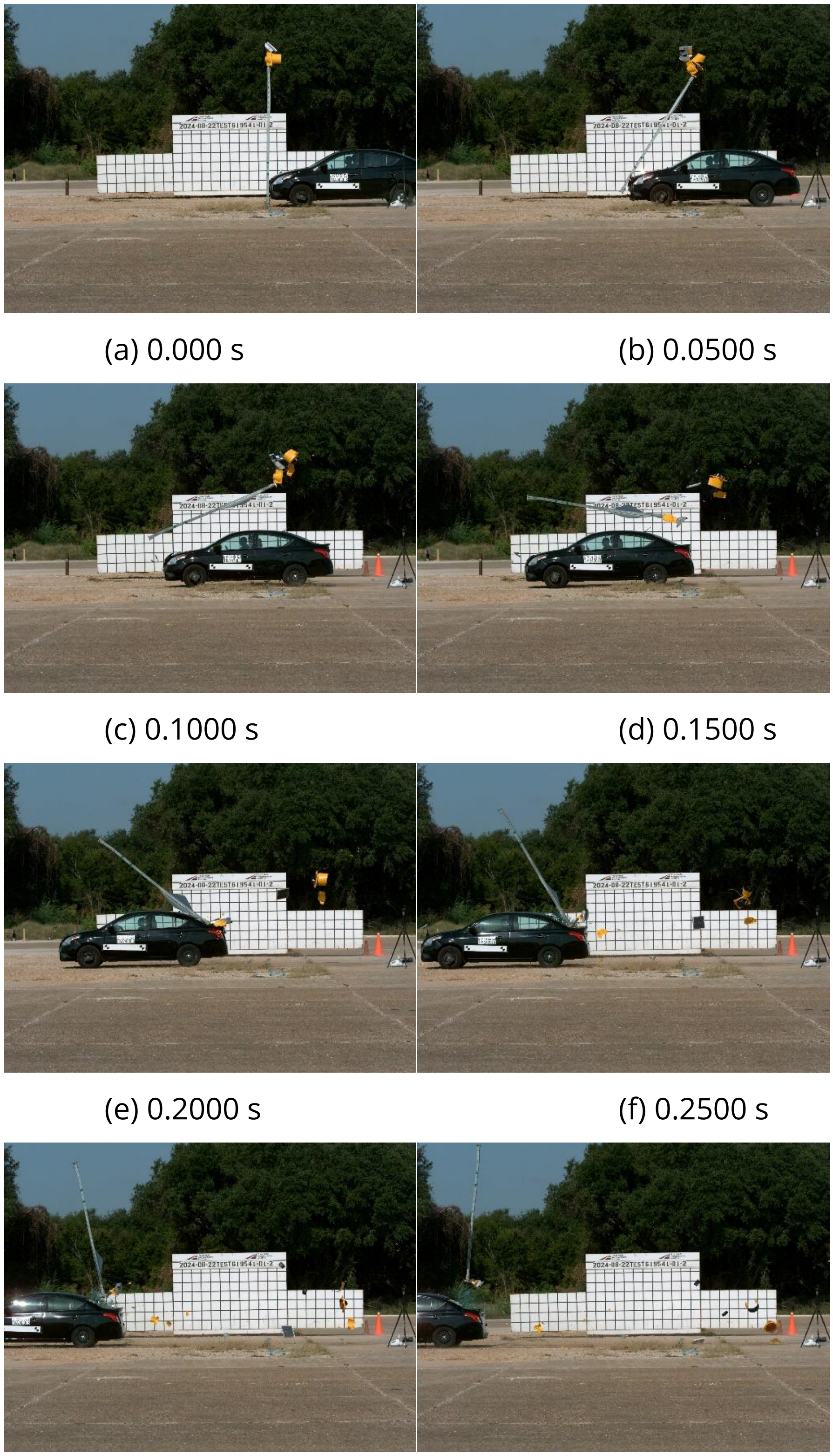
(a) 0.000 s (b) 0.0500 s

(c) 0.1000 s (d) 0.1500 s

(e) 0.2000 s (f) 0.2500 s

(g) 0.3000 s (h) 0.3500 s

Figure D.4. Sequential Photographs for Test 619541-01-2 (Downstream Oblique Views).



(a) 0.000 s (b) 0.0500 s

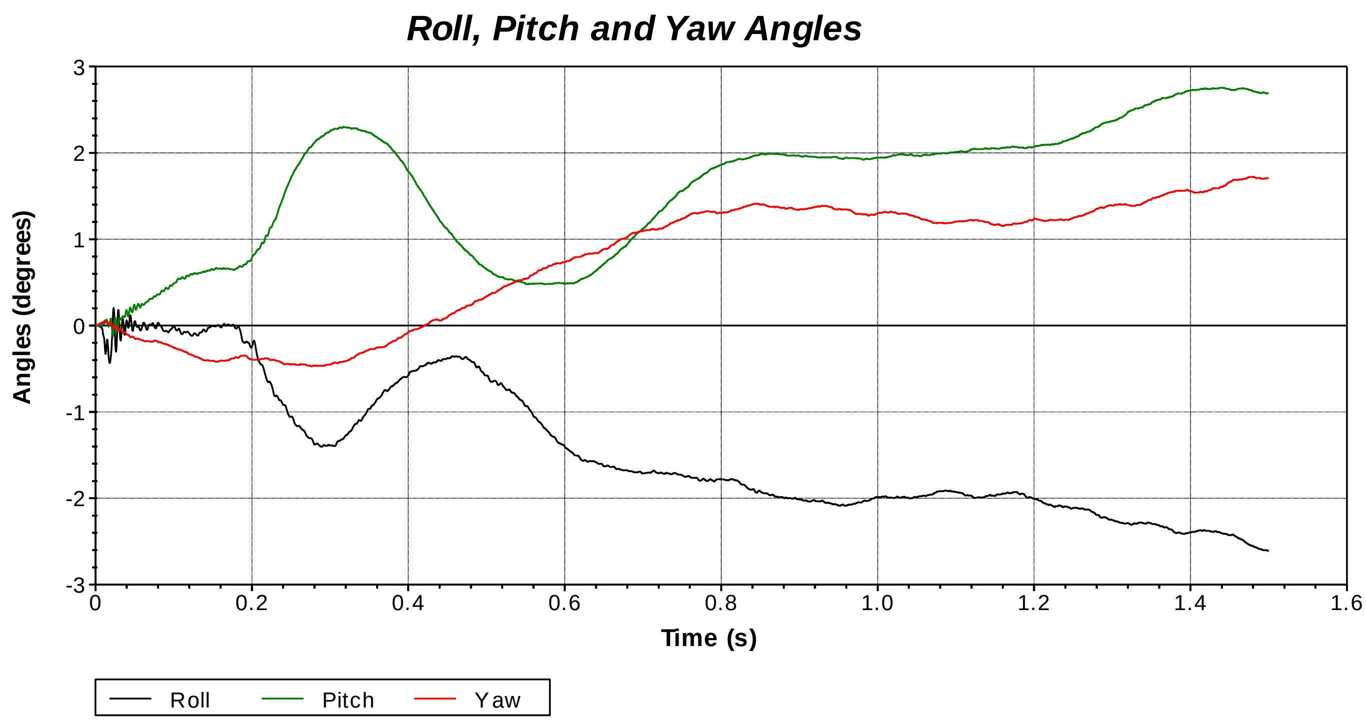
(c) 0.1000 s (d) 0.1500 s

(e) 0.2000 s (f) 0.2500 s

(g) 0.3000 s (h) 0.3500 s

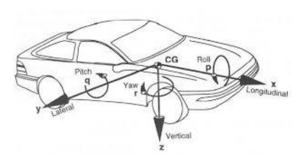
Figure D.5. Sequential Photographs for Test 619541-01-2 (Right Angle Views).

D.3. VEHICLE ANGULAR DISPLACEMENTS



Axes are vehicle-fixed.
Sequence for determining orientation:

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



Test Number: 619541-01-2
Test Standard Test Number: *MASH* Test 3-61
Test Article: Sign Posts with Flashing Beacon
Test Vehicle: 2019 Nissan Versa
Inertial Mass: 2433 lbs
Gross Mass: 2598 lbs
Impact Speed: 62.4 mi/h
Impact Angle: 0°

Figure D.7. Vehicle Angular Displacements for Test 619541-01-2.

D.4. VEHICLE ACCELERATIONS

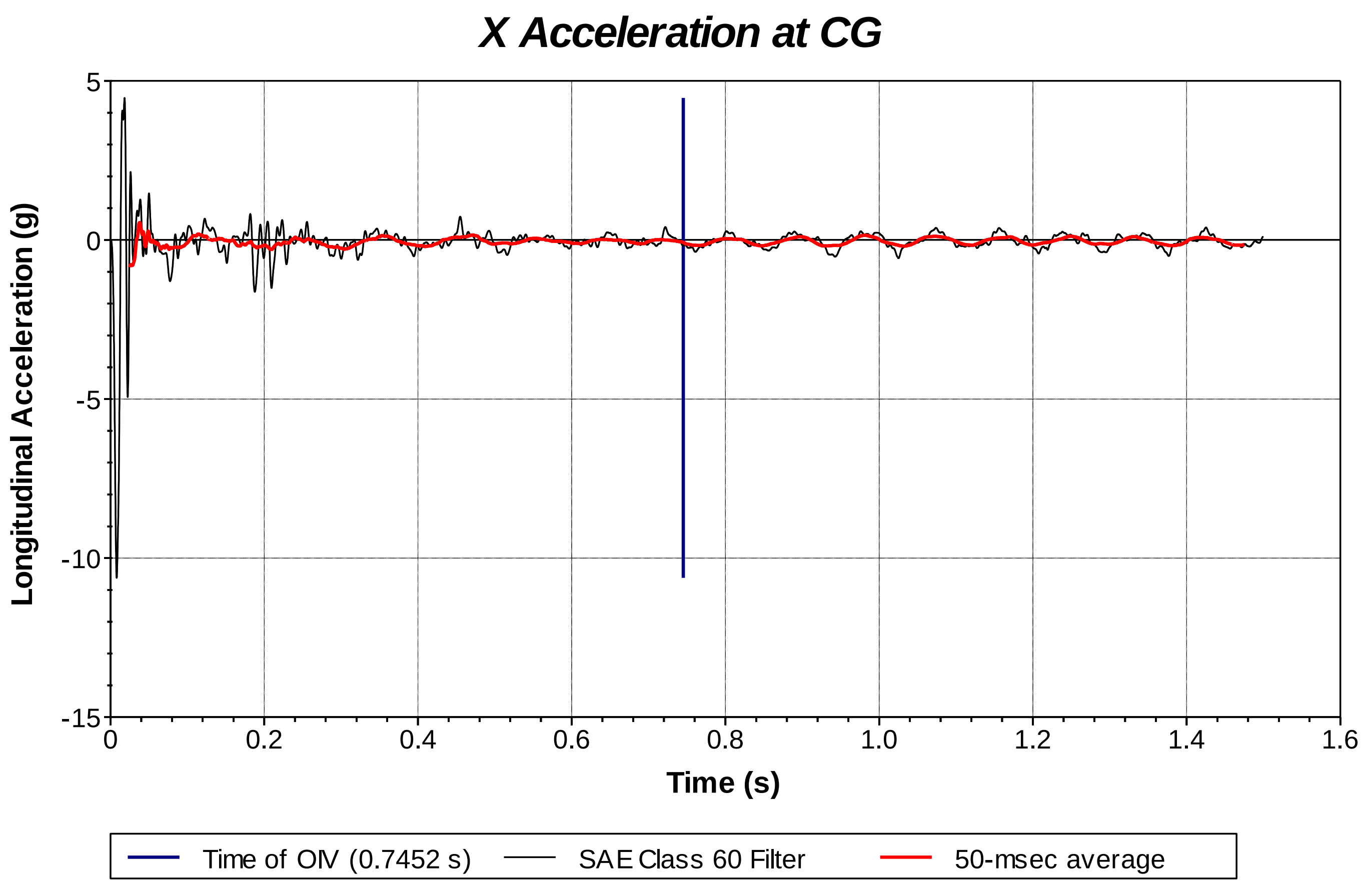


Figure D.8. Vehicle Longitudinal Accelerometer Trace for Test 619541-01-2 (Accelerometer Located at Center of Gravity).

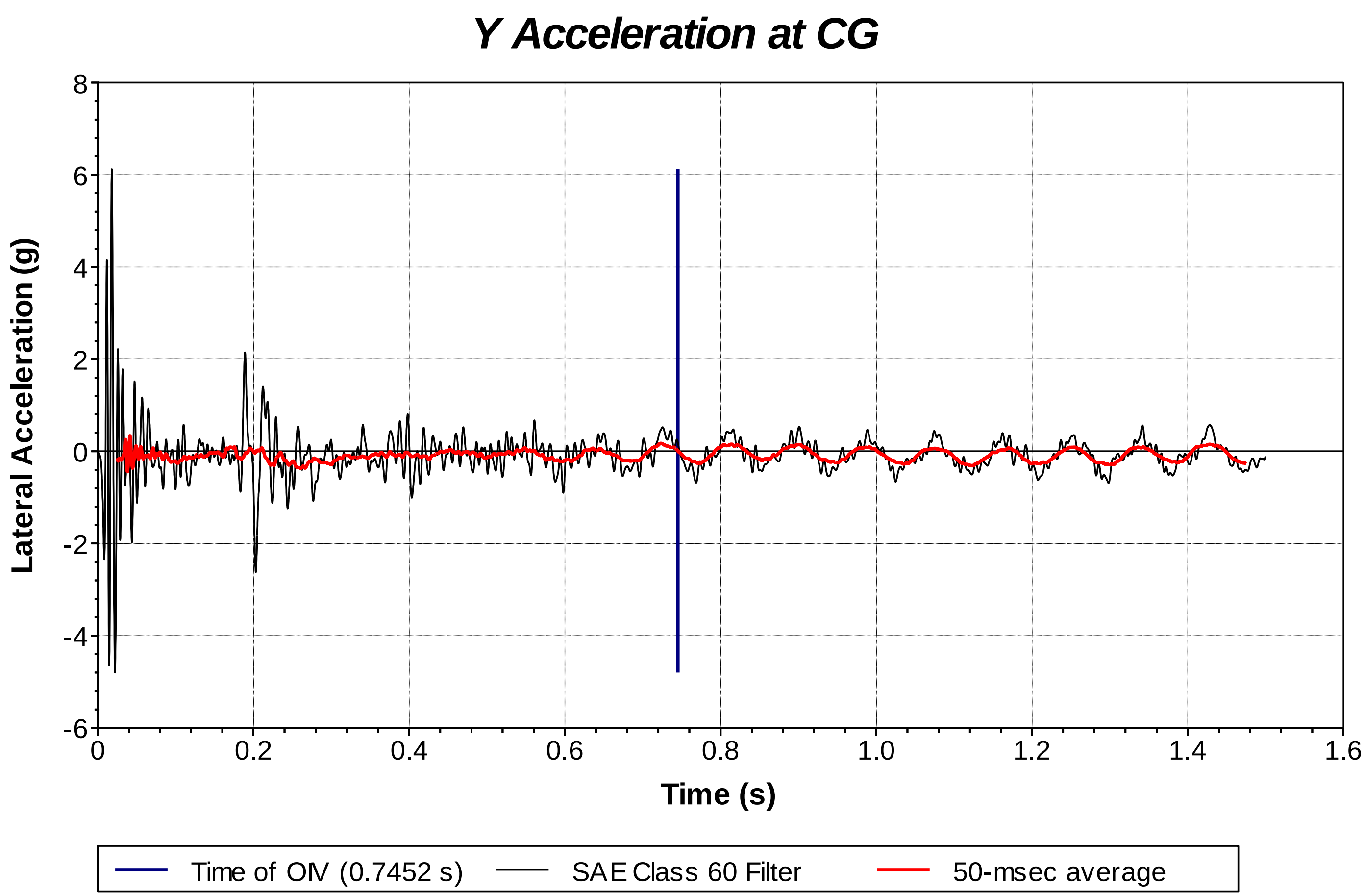


Figure D.9. Vehicle Lateral Accelerometer Trace for Test 619541-01-2 (Accelerometer Located at Center of Gravity).

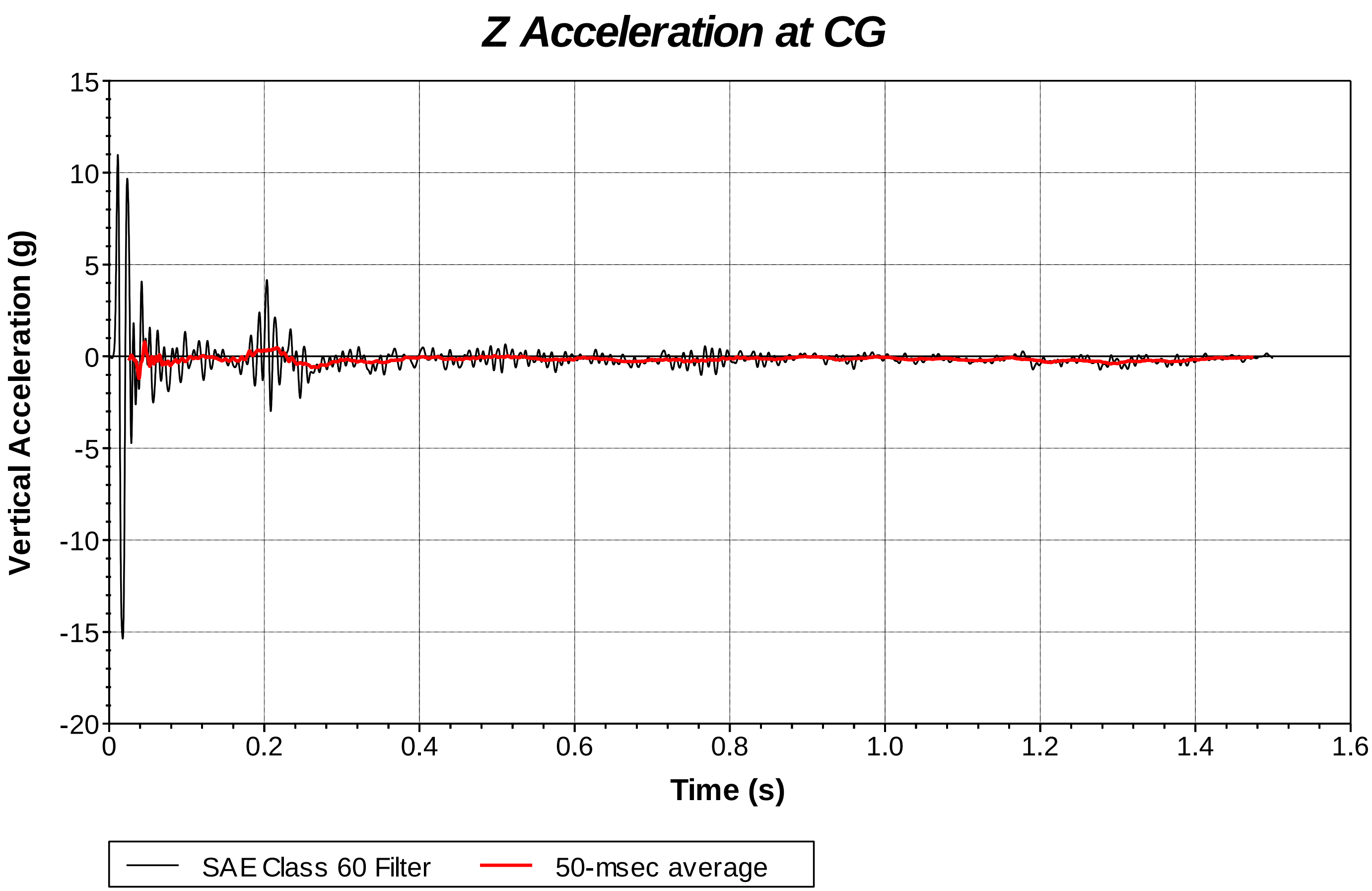


Figure D.10. Vehicle Vertical Accelerometer Trace for Test 619541-01-2 (Accelerometer Located at Center of Gravity).

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