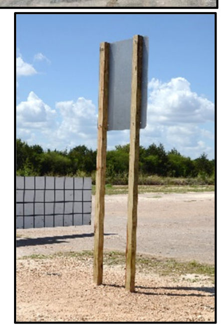
TTI: 0-6946

Texas A&M Transportation Institute

MASH EVALUATION OF TxDOT ROADSIDE SAFETY FEATURES – PHASE I









ACCREDITED
ISO 17025 Laboratory
Testing Certificate # 2821.01
Crash testing performed at:
TTI Proving Ground
3100 SH 47, Building 7091
Bryan, TX 77807

Test Report 0-6946-1

Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the
Federal Highway Administration and the
Texas Department of Transportation
http://tti.tamu.edu/documents/0-6946-1.pdf

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-17/0-6946-1		

4. Title and Subtitle	5. Report Date
MASH EVALUATION OF TXDOT ROADSIDE SAFETY FEATURES – PHASE I	Published: January 2018
	6. Performing Organization Code
7. Author(s) Roger P. Bligh, Wanda L. Menges, and Darrell L. Kuhn	8. Performing Organization Report No. Report 0-6946-1
9. Performing Organization Name and Address Texas A&M Transportation Institute College Station, Texas 77843-3135	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. Project 0-6946
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office 125 E. 11th Street Austin, Texas 78701-2483	13. Type of Report and Period Covered Technical Report: May 2017–December 2019
	14. Sponsoring Agency Code

15. Supplementary Notes
Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.
Project Title: Establishing Comprehensive *Manual on Assessing Safety Hardware* (*MASH*) Compliance for Roadside Safety Systems in Texas
URL: http://tti.tamu.edu/documents/0-6946-1.pdf

16. Abstract

In 2009, the American Association of State Highway and Transportation Officials (AASHTO) published the *Manual for Assessing Safety Hardware* (*MASH*), which supersedes the previous crash test and evaluation guidelines (*1*). A *MASH* implementation agreement was jointly developed and adopted by the Federal Highway Administration (FHWA) and AASHTO. It establishes implementation dates for different categories of roadside safety features.

Texas Department of Transportation (TxDOT), Bridge, Design, Maintenance, and Traffic Operations Divisions reviewed their standards for roadside safety devices and identified those devices that require testing and evaluation to assess *MASH* compliance. Under this project, a total of 33 roadside safety systems will be crash tested in accordance with *MASH* criteria in three phases over a three-year period. In Phase I, the following devices were crash tested: 36-inch vertical parapet bridge rail, 1-inch asphalt concrete pavement lateral support for concrete median barrier, pinning pattern for precast concrete barrier on concrete, single and dual embedded wood post sign support systems, pedestal poles with flashing beacons with and without solar assembly, double mailbox system on TxDOT Type 3 foundation and winged channel support, double mailbox system on TxDOT Type 2 foundation and thin walled galvanized tube support, and multi-mailbox system on TxDOT Type 1 foundation and thin walled galvanized tube support.

This report documents the crash testing and evaluation of these devices in accordance with *MASH* criteria. The critical tests were identified and performed to assess *MASH* compliance.

17. Key Words	18. Distribution Statement
Roadside Safety Systems, Concrete Barrier, Pinned Barrier, Flashing Beacon, Pedestal Base, Sign Support, Mailbox, Crash Testing	No restrictions. This document is available to the public through NTIS: National Technical Information Service, Alexandria, Virginia http://www.ntis.gov

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	350	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

MASH EVALUATION OF TXDOT ROADSIDE SAFETY FEATURES – PHASE I

by

Roger P. Bligh, P.E., Ph.D.
Senior Research Engineer
Texas A&M Transportation Institute

Wanda L. Menges
Research Specialist
Texas A&M Transportation Institute

and

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

Report 0-6946-1
Project 0-6946
Project Title: Establishing Comprehensive *Manual on Assessing Safety Hardware* (*MASH*) Compliance for Roadside Safety Systems in Texas

Performed in cooperation with the
Texas Department of Transportation
and the
Federal Highway Administration

Published: January 2018

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

DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation. The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report. This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Roger P. Bligh, P.E. #78550.

TTI PROVING GROUND DISCLAIMER

The results of the crash testing reported herein apply only to the article being tested.

ACCREDITED
ISO 17025 Laboratory
Testing Certificate # 2821.01

Crash testing performed at:
TTI Proving Ground
3100 SH 47, Building 7091
Bryan, TX 77807

Wanda L. Menges, Research Specialist
Deputy Quality Manager

Darrell L. Kuhn, Research Specialist
Quality Manager

Matthew N. Robinson, Senior Research Specialist
Technical Manager

ACKNOWLEDGMENTS

This project was conducted in cooperation with TxDOT and FHWA. The project team would like to thank Mr. Wade Odell, P.E. (TxDOT Project Manager), Mr. Ken Mora, P.E., and Mr. Chris Lindsey, P.E., with the TxDOT Design Division, Ms. Taya Retterer, P.E., and Mr. Jon Ries with the TxDOT Bridge Division, Mr. Doug Skowronek, P.E., and Mr. Mark Johnson, P.E., with the Traffic Operations Division, and Mr. Phillip Hempel, P.E., with the Maintenance Division for their valuable assistance and input on this project. Their contributions were instrumental to the success of the project.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (CONTINUED)

Page

TABLE OF CONTENTS (CONTINUED)

Page

TABLE OF CONTENTS (CONTINUED)

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

Page

LIST OF FIGURES (CONTINUED)

Page

LIST OF FIGURES (CONTINUED)

Page

LIST OF TABLES

LIST OF TABLES (CONTINUED)

Page

CHAPTER 1: INTRODUCTION

Since the 1940s, the United States has been crash testing highway safety appurtenances. National guidelines for testing roadside appurtenances originated in 1962. Guidelines for testing and evaluating the impact performance of roadside safety features are periodically updated to stay current with improvements in technology and changes in the vehicle fleet and impact conditions. In 2009, the American Association of State Highway and Transportation Officials (AASHTO) published the *Manual for Assessing Safety Hardware* (*MASH*), which supersedes the previous crash test and evaluation guidelines (*1*). Changes incorporated into *MASH* include new design test vehicles, revised test matrices, and revised impact conditions.

A *MASH* implementation agreement was jointly developed and adopted by the Federal Highway Administration (FHWA) and AASHTO. It establishes various implementation dates for different categories of roadside safety features. On projects let after the specified dates, only *MASH* compliant hardware is eligible for new installations on the National Highway System.

In response to the implementation requirements, Texas Department of Transportation (TxDOT) Bridge, Design, Maintenance, and Traffic Operations Divisions reviewed their standards for roadside safety devices and identified those devices that require testing and evaluation to assess *MASH* compliance. Under this project, a total of 33 roadside safety systems will be crash tested in accordance with *MASH* criteria in three phases over a three-year period.

Texas A&M Transportation Institute (TTI) crash tested and evaluated 10 devices in Phase I. These include:

- 36-inch vertical parapet bridge rail.
- 1-inch asphalt concrete pavement (ACP) lateral support for concrete median barrier.
- Pinning pattern for precast concrete barrier on concrete.
- Single and dual embedded wood post sign support systems.
- Pedestal pole with flashing beacons with and without solar assembly.
- Multimailbox system on TxDOT Type 1 foundation and thin walled galvanized tube support.
- Double mailbox system on TxDOT Type 2 foundation and thin walled galvanized tubing.
- Double mailbox system on TxDOT Type 3 foundation and winged channel support.

A summary of the recommended testing to achieve *MASH* compliance for each device is presented in Table 1.1. This table indicates the test level and test designations recommended for the *MASH* evaluation. TTI performed 15 full-scale crash tests in Phase I. These represent the critical tests considered necessary to demonstrate *MASH* compliance of each device.

Table 1.1. Phase I Full-Scale Crash Testing.

Device	Standard	Test Level	Recommended Tests	Comments
36-inch vertical parapet	N.A.	TL-4	4-12	Modify 32-inch T221 rail by increasing height adding additional reinforcement. Test at a joint in deck and rail.
1-inch ACP lateral support for concrete median barrier	SSCB(1F)-10	TL-4	4-12	TL-4 loading more critical than TL-3 for evaluation of barrier anchorage.
Pinning pattern for precast concrete barrier in concrete	CSB(7)-10	TL-3	3-11	JJ Hooks connection used for portable concrete barrier segments.
Embedded wood post sign support system	BC(5)-14 (single)	TL-3	3-62 @ 0°	4×4-inch support more critical than 4×6-inch support.
			3-61, 3-62 @ 90°	*MASH* requires testing of signs at 90° if they are used at intersections.
	BC(5)-14 (dual)	TL-3	3-61, 3-62 (impact one post @ 0°)	
			3-62 (impact two posts @ 0°)	Impacting two of two supports will evaluate secondary contact between sign assembly and vehicle.
Pedestal pole with flashing beacons	RFBA-13 (without solar assembly)	TL-3	3-62	Concrete foundation option used.
	SPRFBA-13 (with solar assembly)	TL-3	3-62	Concrete foundation option used.
Mailbox Type 1 foundation (multi) 56-inch hanger	MB-15(1)	TL-3	3-61	
Mailbox Type 2 foundation (double)-thin walled galvanized tubing	MB-15(1)	TL-3	3-61	
Mailbox Type 3 foundation (double)-winged channel post	MB-15(1)	TL-3	3-61	

TxDOT standards may include multiple configurations or variations of a device to accommodate different design considerations or needs. TTI researchers developed the recommended test plan based on consideration of critical or worst case configuration. If a critical configuration is successfully crash tested, a less critical configuration of the device would also be considered *MASH* compliant. This approach reduces the required number of tests to achieve *MASH* compliance.

The following chapters of this report provide details of the *MASH* testing and evaluation of the different roadside safety systems.

CHAPTER 2:
TXDOT 36-INCH VERTICAL WALL

2.1 BACKGROUND

TxDOT does not currently have a standard detail for a 36-inch vertical concrete bridge rail. The current T221 bridge rail is a 32-inch vertical parapet. The recommended minimum rail height for a Test Level 4 (TL-4) rail has increased from 32 inches under *National Cooperative Highway Research Program (NCHRP) Report 350* to 36 inches under *MASH* (*1,2*). This was previously determined through finite element impact simulations and full-scale crash testing performed by TTI (*3*). In order to maintain TL-4 impact performance under *MASH*, the height of the vertical parapet was increased from 32 inches to 36 inches. TTI researchers added two additional longitudinal bars ("R" bars) and extended the length of the vertical stirrups ("S1" bars) 4 inches.

Because a variation of the T221 on top of a mechanically stabilized earth (MSE) retaining wall has been successfully tested with the 2270P (5000-lb) *MASH* pickup truck under NCHRP Project 22-20, *Design of Roadside Barrier Systems Placed on MSE Retaining Walls*, *MASH* test designation 4-11 was not considered necessary (*4*). Similarly, because the 1100C (2420-lb) *MASH* passenger car was successfully tested with the more critical vertical profile of the 42-inch tall T224 bridge rail (*5*), TTI researchers did not consider *MASH* test designation 4-10 necessary to achieve *MASH* compliance for a 36-inch vertical parapet. Thus, only *MASH* test designation 4-12 was performed to establish *MASH* TL-4 compliance.

2.2 TEST INSTALLATION

2.2.1 Overall Details

The test installation was comprised of a 120 ft long, 36-inch tall vertical concrete bridge parapet. The steel reinforced parapet was cast in place on top of a cantilever deck that extended from a foundation wall. The bridge parapet and deck was constructed with a 2-inch wide expansion control joint, which represented the critical section for evaluation of rail strength.

Figure 2.1 presents overall information on the TxDOT 36-inch vertical concrete bridge rail, and Figure 2.2 provides photographs of the completed test installation. Appendix A.1 provides further details of the TxDOT 36-inch vertical concrete bridge rail.

2.2.2 Parapet

The parapet was 36 inches tall × 12 inches wide at the top and 10½ inches wide at the base. The traffic side profile was a smooth, vertical face, and the field side was offset 1½ inches inboard to create a 12-inch tall upper and a 22½-inch lower vertical face. The parapet and deck were continuous except for the single 2-inch wide expansion control joint located 24 ft from the upstream end of the installation

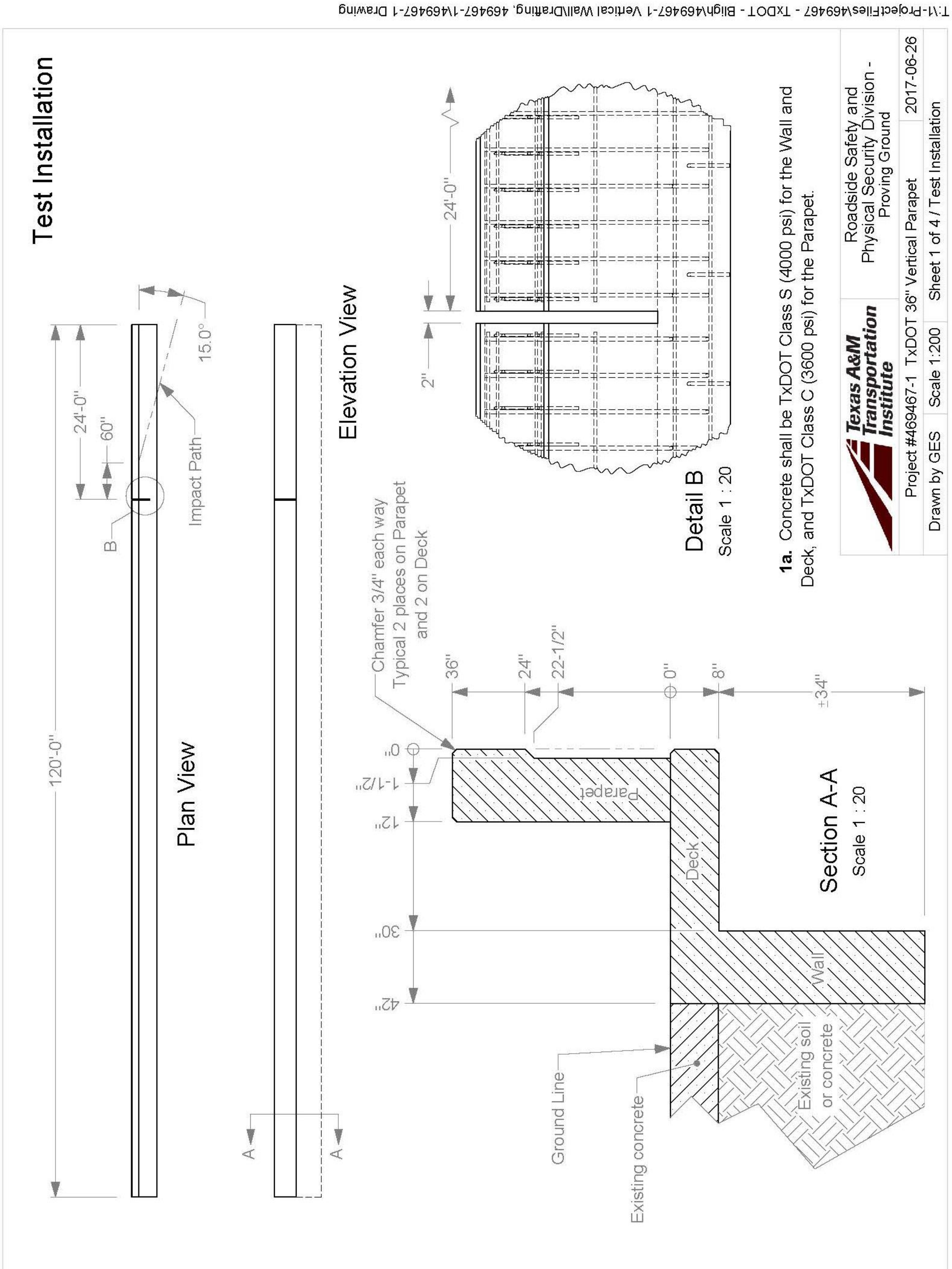


Figure 2.1. Overall Details of the TxDOT 36-inch Vertical Concrete Bridge Rail.

Figure 2.2. TxDOT 36-inch Vertical Concrete Bridge Rail prior to Testing.

2.2.3 Bridge Deck and Support Wall

The constructed cantilever bridge deck that supported the parapet was 42 inches wide × 8 inches thick and extended for the entire 120 ft length of the test installation. The bridge deck support wall was 12 inches thick × 34 inches tall and extended for the length of the installation. The bridge deck and support wall were steel reinforced. The cantilever deck and wall were integrally cast.

2.2.4 Material Properties

The specified minimum unconfined compressive strength of the concrete was 4000 psi TxDOT Class S for the bridge deck and wall, and 3600 psi TxDOT Class C for the parapet. The compressive strengths of the concrete comprising the test installation on the day of testing was 4620 psi and 5203 psi for the deck and parapet, respectively.

Steel reinforcement used in the construction of the parapet, bridge deck, and foundation wall was ASTM A615 Grade 60 rebar with specified minimum yield strength of 60 ksi. Material certification documents are provided in Appendix A.2.

2.3 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 4-12 involves a 10000S vehicle weighing 22,000 lb ±660 lb impacting the critical impact point (CIP) of the 36-inch vertical concrete bridge rail at an impact speed of 56 mi/h ±2.5 mi/h and an angle of 15° ±1.5°. The target CIP selected for the test was determined according to information provided in *MASH* Section 2.3.2.2 and *MASH* Table 2-8. Figure 2.3 shows the target CIP, which was 5 ft ±1 ft upstream of the expansion control joint.

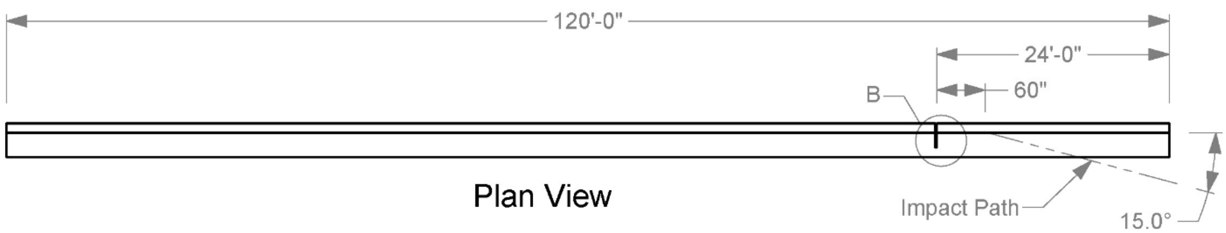


Figure 2.3. Target CIP for *MASH* Test 4-12 on 36-inch Vertical Concrete Bridge Rail.

The 2003 International 4200 single-unit box-van truck used in the test weighed 22,320 lb, and the actual impact speed and angle were 55.5 mi/h and 15.0°, respectively. The actual impact point was 5 ft upstream of the expansion control joint. Minimum target impact severity (IS) is 142 kip-ft, and actual IS was 154 kip-ft.

2.4 TEST VEHICLE

The 2003 International 4200 single-unit box-van truck, shown in Figures 2.4 and 2.5, was used for the crash test. The vehicle's test inertia weight was 22,320 lb, and its gross static weight was 22,320 lb. The height to the lower edge of the vehicle bumper was 19.25 inches, and the height to the upper edge of the bumper was 34.5 inches. The height to the center of gravity of the vehicle ballast was 62.0 inches. Table A.1 in Appendix A.3 gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

Figure 2.4. 36-inch Vertical Concrete Bridge Rail /Test Vehicle Geometrics for Test No. 469467-1-1.

Figure 2.5. Test Vehicle before Test No. 469467-1-1.

2.5 WEATHER CONDITIONS

The test was performed on the morning of August 15, 2017. Weather conditions at the time of testing were as follows: wind speed: 13 mi/h; wind direction: 180° (vehicle was traveling in a northerly direction); temperature: 90°F; relative humidity: 60 percent.

2.6 TEST DESCRIPTION

The test vehicle, traveling at an impact speed of 55.5 mi/h, contacted the bridge rail 5 ft upstream of the expansion control joint at an impact angle of 15.0°. Table 2.1 lists times and events that occurred during Test No. 469467-1-1. Figure A.1 in Appendix A.4 presents sequential photographs during the test.

Table 2.1. Events during Test No. 469467-1-1.

TIME (s)	EVENT
0.010	Right front tire impacts rail; rail begins to deflect toward field side
0.045	Left front wheel begins to toe in
0.050	Cab begins to twist counterclockwise relative to box
0.090	Vehicle begins to redirect
0.112	Left front wheel lifts from pavement
0.220	Left rear wheels lift from pavement {approximate}
0.229	Right rear tire impacts rail; rail further deflects toward field side
0.257	Max dynamic deflection at joint at downstream end of first section
0.299	Right rear corner of box impacts top of rail ~18 inches before joint
0.350	Vehicle traveling parallel with barrier
0.381	Vehicle/box pass beyond expansion joint
0.921	Working width at front top right corner of box
1.307	Left front wheel lands back on pavement
1.350	Left rear wheels land back on pavement {approximate}
1.412	Right front fender/hood begins to lose contact with top of rail
	Vehicle rode off end of barrier

For longitudinal barriers, it is desirable that the vehicle redirects and exits the barrier within the exit box criteria. The 10000S vehicle exited within the exit box criteria defined in *MASH*. Brakes on the vehicle were not applied. After loss of contact with the barrier, the vehicle came to rest 213 ft downstream of the impact and 26 ft toward the field side.

2.7 DAMAGE TO TEST INSTALLATION

Figure 2.6 shows damage to the 36-inch vertical wall. Slight cracking of the concrete parapet occurred in the impact region near the expansion joint. Working width was 67 inches at a height of 104.6 inches. Maximum dynamic deflection during the test was 2.2 inches, and permanent deformation was approximately 1 inch at the top of the first section.

2.8 DAMAGE TO TEST VEHICLE

Figure 2.7 shows the damage sustained by the test vehicle. The front bumper, hood, right front springs and U-bolts, right front tire and rim, right fuel tank, right side steps, right front door, right rear outer tire and rim, right front corner of the box, and right frame rail. Damage due to the vehicle roll included the cab, windshield, left door, left side of the box, left front springs and U-bolts, hood, and rear door of the box. Maximum exterior crush to the vehicle was 18.0 inches in the side plane at the right front corner at bumper height. No occupant compartment deformation or intrusion occurred. Figure 2.8 shows the interior of the vehicle.

Figure 2.6. 36-inch Vertical Concrete Bridge Rail after Test No. 469467-1-1.

Figure 2.7. Test Vehicle after Test No. 469467-1-1.

Before Test After Test

Figure 2.8. Interior of Test Vehicle for Test No. 469467-1-1.

2.9 OCCUPANT RISK FACTORS

Data from the accelerometer, located at the vehicle center of gravity, were digitized for information purposes, and the results are shown in Table 2.2. Figure 2.9 summarizes these data and other pertinent information from the test. Figure A.2 in Appendix A.5 shows the vehicle angular displacements, and Figures A.3 through A.8 in Appendix A.6 show vehicle accelerations versus time traces.

Table 2.2. Occupant Risk Factors for Test No. 469467-1-1.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)		
Longitudinal	**6.6 ft/s**	at 0.2317 s on right side of interior
Lateral	**8.9 ft/s**	
Occupant Ridedown Accelerations		
Longitudinal	**4.6 g**	0.2902–0.3002 s
Lateral	**6.3 g**	0.2517–0.2617 s
Theoretical Head Impact Velocity (THIV)	**12.4 km/h** **3.4 m/s**	at 0.2220 s on right side of interior
Post Head Deceleration (PHD)	**6.3 g**	0.2517–0.2617 s
Acceleration Severity Index (ASI)	**0.44**	0.3461–0.3961 s
Maximum 50-ms Moving Average		
Longitudinal	**−1.6 g**	0.2558–0.3058 s
Lateral	**−3.7 g**	0.3247–0.3747 s
Vertical	**−3.1 g**	0.2911–0.3411 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	**37.5°**	3.0000 s
Pitch	**16.7°**	2.8678 s
Yaw	**14.9°**	0.8372 s

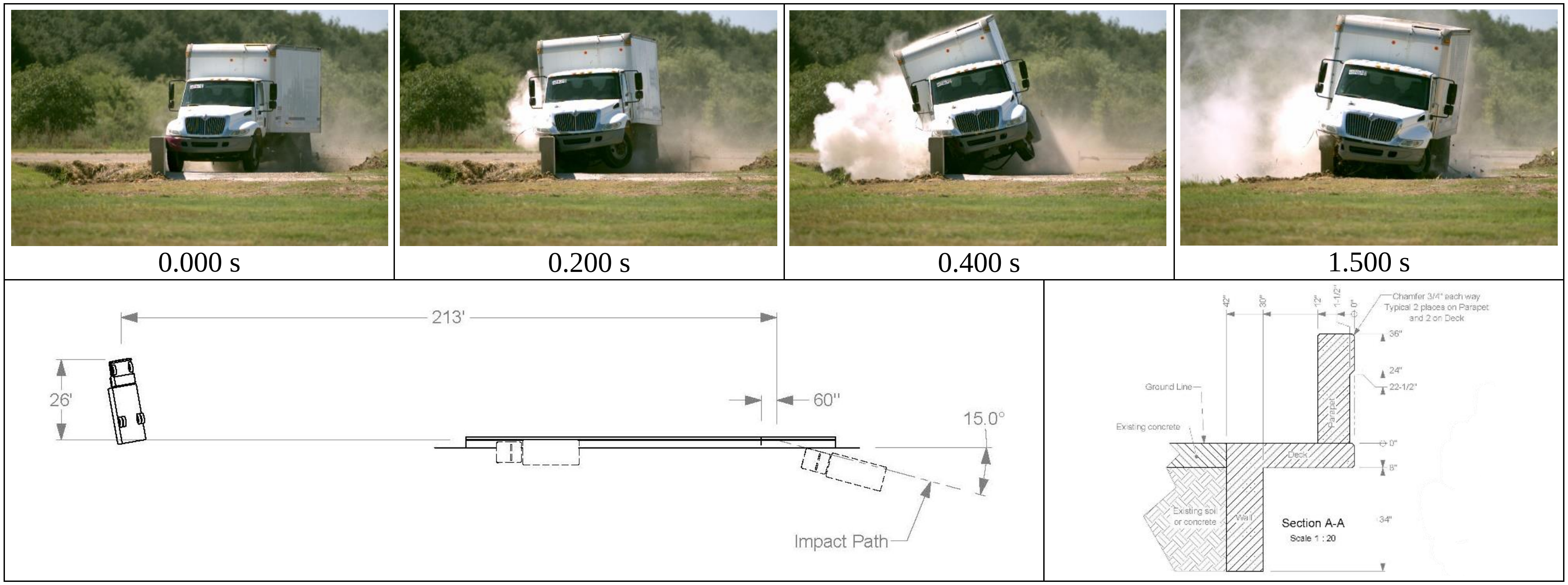
2.10 ASSESSMENT OF RESULTS

An assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 4-12 is provided in Table 2.3.

2.11 CONCLUSIONS

The 36-inch vertical wall contained and redirected the 10000S vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 2.2 inches. Slight cracking of the concrete parapet occurred in the impact region near the expansion joint in the rail. No detached elements, fragments, or other debris from the test article were present to penetrate or show potential for penetrating the occupant compartment or present hazard to others in the area. No occupant compartment deformation or intrusion occurred. The 10000S vehicle rolled onto its left side and roof after exiting the barrier and traversing unpaved terrain.

The 36-inch Vertical Concrete Bridge Rail performed acceptably for *MASH* Test 4-12.



General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 4-12
TTI Test No.	469467-1-1
Test Date	2017-08-15

Test Article

Type	Bridge Rail
Name	TxDOT 36-inch Vertical Wall
Installation Length	120 ft
Material or Key Elements	36 inches tall × 12 inches wide at the top × 10½ inches wide base
Soil Type and Condition	Concrete bridge deck, damp

Test Vehicle

Type/Designation	10000S
Make and Model	2003 International 4200 Box Van
Curb	12,610 lb
Test Inertial	22,320 lb
Dummy	No dummy
Gross Static	22,320 lb

Impact Conditions

Speed	55.5 mi/h
Angle	15.0°
Location/Orientation	5.0 ft upstream of joint
Impact Severity	154 kip-ft

Exit Conditions

Speed	Rode off end
Angle	of bridge rail

Occupant Risk Values

Longitudinal OIV	6.6 ft/s
Lateral OIV	8.9 ft/s
Longitudinal Ridedown	4.6 g
Lateral Ridedown	6.3 g
THIV	12.4 km/h
PHD	6.3 g
ASI	0.44
Max. 0.050-s Average	
Longitudinal	-1.6 g
Lateral	-3.7 g
Vertical	-3.1 g

Post-Impact Trajectory

Stopping Distance	213 ft downstream 26 ft twd field side

Vehicle Stability

Maximum Yaw Angle	15°
Maximum Pitch Angle	17°
Maximum Roll Angle	180°
Vehicle Snagging	No
Vehicle Pocketing	No

Test Article Deflections

Dynamic	2.2 inches
Permanent	1.0 inches
Working Width	67.0 inches
Height of Working Width	104.6 inches

Vehicle Damage

VDS	NA
CDC	01FDEW5
Max. Exterior Deformation	18.0 inches
OCDI	NA
Max. Occupant Compartment Deformation	None

Figure 2.9. Summary of Results for *MASH* Test 4-12 on the 36-inch Vertical Concrete Bridge Rail.

Table 2.3. Performance Evaluation Summary for *MASH* Test 4-12 on the 36-inch Vertical Concrete Bridge Rail.

Test Agency: Texas A&M Transportation Institute | Test No.: 469467-1-1 | Test Date: 2017-08-15

***MASH* Test 4-12 Evaluation Criteria**	**Test Results**	**Assessment**
Structural Adequacy *A.* *Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable*	The 36-inch vertical concrete bridge rail contained and redirected the 10000S vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 2.2 inches.	Pass
Occupant Risk *D.* *Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	No detached elements, fragments, or other debris from the test article were present to penetrate or show potential for penetrating the occupant compartment or present hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	No occupant compartment deformation or intrusion occurred.	
G. *It is preferable, although not essential, that the vehicle remain upright during and after collision.*	The 10000S vehicle rolled onto its roof after exiting the barrier and traversing unpaved terrain.	NA

CHAPTER 3:
TXDOT 42-INCH TALL SINGLE SLOPE CONCRETE BARRIER WITH 1-INCH ACP OVERLAY

3.1 BACKGROUND

Concrete median barriers can be cast in place or slip formed. One means of anchoring the concrete median barrier to a rigid or flexible pavement is to key it in to the pavement using an ACP overlay on each side of the barrier. TxDOT has a standard detail sheet for this practice for both a 32-inch F-shape concrete barrier (CSB(2)-13) and a 42-inch single slope concrete barrier (SSCB(1F)-10).

The 32-inch F-shape barrier does not meet the minimum 36-inch height requirement for a *MASH* TL-4 barrier; therefore, it would only be suitable to test this system to *MASH* TL-3. The 42-inch single slope barrier will accommodate *MASH* TL-4 if proper anchorage or lateral support is provided to the barrier. A TL-4 impact into a barrier of this height generates an impact force that is greater in magnitude and has a higher resultant height than a TL-3 impact. Therefore, this was considered the critical evaluation of the 1-inch ACP lateral support. If the 42-inch single slope barrier with 1-inch ACP lateral support is found to comply with *MASH* TL-4, then the less critical 32-inch F-shape with 1-inch ACP lateral support would be considered compliant with *MASH* TL-3.

TTI researchers recommended evaluating a 42-inch SSCB with 1-inch ACP lateral support to *MASH* TL-4. The structural adequacy test for *MASH* TL-4 is test designation 4-12 with a single unit truck. The other tests in the TL-4 barrier matrix would apply less lateral load, and therefore, will not be required to achieve *MASH* compliance for this barrier anchorage system.

It was necessary to establish a minimum segment length for the evaluation of the 1-inch ACP overlay. Longer barrier segments will provide more resistance to sliding and rotation. A segment length of 75 ft was selected in consultation with TxDOT. Cast-in-place segment lengths greater than or equal to 75 ft would be verified by a successful crash test. Shorter segments lengths would require additional lateral resistance (e.g., dowels across the joint to the longer segment length) unless further evaluated.

3.2 SYSTEM DETAILS

3.2.1 Test Article Design and Construction

The test installation was comprised of two sections of 42-inch tall SSCB: one 75-ft long and the other 44 ft-10¼ inches long with a 1¾-inch wide expansion control joint between the sections. Thus, the overall length of the test installation was 120 ft-0 inches. The barrier was cast-in-place directly on top an existing concrete apron. There were no pins, anchors, rebar, or bolts securing the barrier to the apron.

The barrier was keyed in place with a 1-inch thick layer of TxDOT Type D asphalt installed on the apron on each side of the barrier. The asphalt layer was 9 ft wide on each side of the barrier. The top of the barrier was 41 inches above the surrounding asphalt.

The SSCB was 24 inches wide at the base and 8 inches wide at the top. The barrier had a slope of 10.8° on both the traffic side and the field side faces. The barrier was reinforced using steel welded wire mesh comprised of D9.4 (0.346-inch diameter) welded wire reinforcement (WWR) lateral stirrup bars spaced at 8-inch centers along the length of the barrier. The stirrup bars were bent to conform to the profile of the barrier and provide a minimum 1¾-inch concrete cover. Longitudinal reinforcement of the SSCB was comprised of seven D19.7 bars (0.501-inch diameter) equally spaced (approximately 6-inches) along the slope of each face and located inside the lateral stirrups.

Figure 3.1 presents overall information on the TxDOT 42-inch tall SSCB with 1-inch ACP overlay. Figure 3.2 provides photographs of the completed test installation. Appendix B.1 provides further details of the TxDOT 42-inch tall SSCB with 1-inch ACP overlay.

3.2.2 Material Specifications

The compressive strength of the concrete for the single slope barrier was specified as 3600 psi. The compressive strength on the day of the test was 5241 psi for the 75-ft portion of the single slope barrier at 16 days of age, and 4700 psi for the 45-ft portion at 10 days of age. Results of the tests performed to determine the concrete compressive strength are shown in Appendix B.2. The steel reinforcing welded wire was grade 70 material. Certifications for the materials used are included in Appendix B.2.

3.3 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 4-12 involves a 10000S vehicle weighing 22,046 lb ±660 lb impacting the CIP of the TxDOT 42-inch SSCB at an impact speed of 56 mi/h ±2.5 mi/h and an angle of 15° ±1.5°. In order to ensure that the lateral impact load was fully applied to the 75-ft segment, the impact point was selected to be 25 ft ±1 ft downstream from the upstream end of the 75 ft barrier section.

The 2005 International 4300 single-unit truck used in the test weighed 22,210 lb, and the actual impact speed and angle were 56.5 mi/h and 15.8°, respectively. The actual impact point was 25 ft-2 inches downstream of the end of the barrier. Minimum target IS was 142 kip-ft, and actual IS was 175 kip-ft.

3.4 TEST VEHICLE

The 2005 International 4300 single-unit truck, shown in Figures 3.3 and 3.4, was used for the crash test. The vehicle's test inertia weight was 22,210 lb, and its gross static weight was 22,210 lb. The height to the lower edge of the vehicle bumper was 19.25 inches, and height to the upper edge of the bumper was 33.50 inches. Table B.1 in Appendix B.3 gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

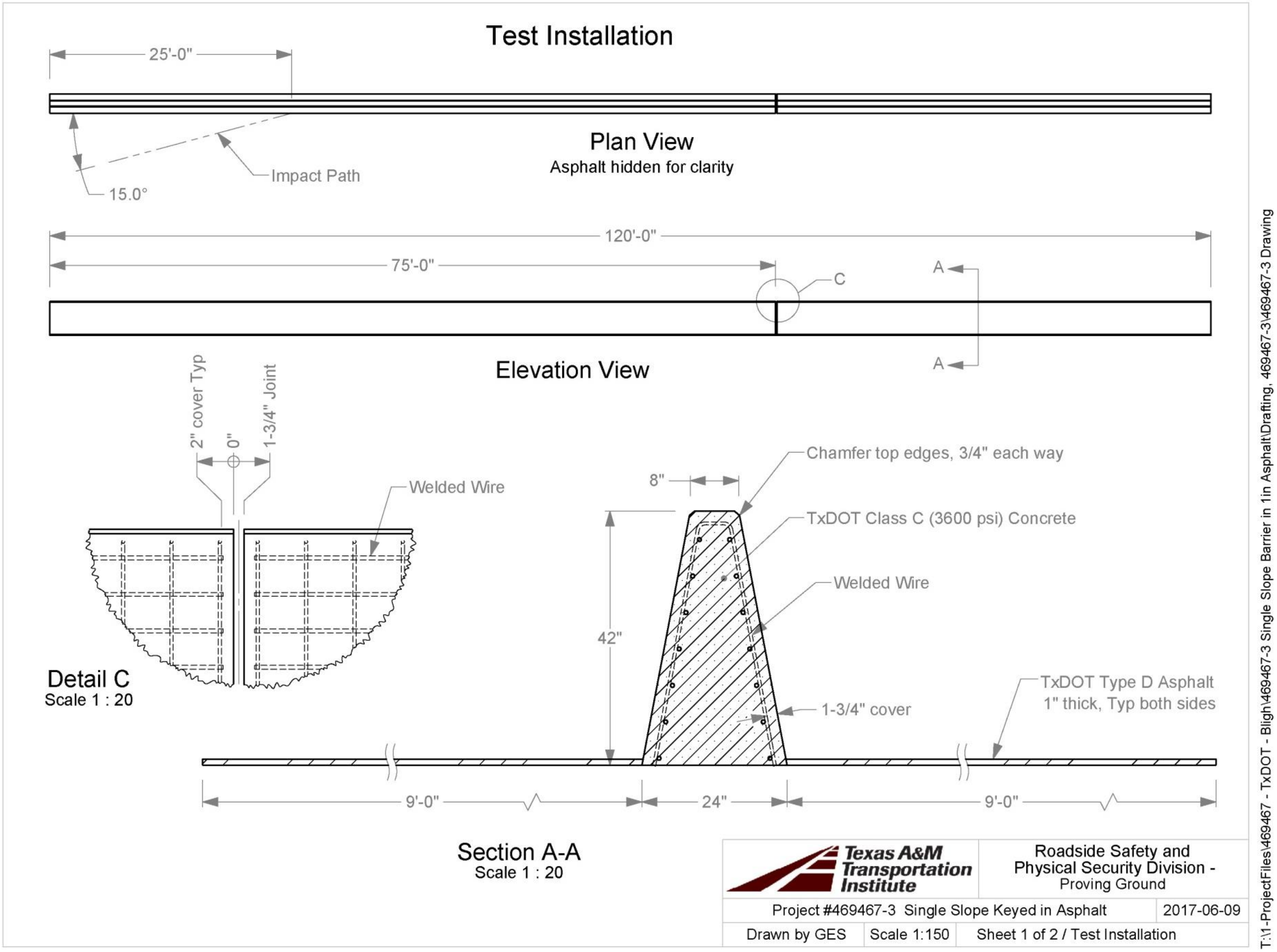


Figure 3.1. Overall Details of the TxDOT 42-inch Tall SSCB with 1-inch ACP Overlay.

Figure 3.2. TxDOT 42-inch Tall SSCB with 1-inch ACP Overlay prior to Testing.

Figure 3.3. TxDOT 42-inch Tall SSCB with 1-inch ACP Overlay/Test Vehicle Geometrics for Test No. 469467-3-1.

Figure 3.4. Test Vehicle before Test No. 469467-3-1.

3.5 WEATHER CONDITIONS

The test was performed on the morning of July 7, 2017. Weather conditions at the time of testing were as follows: wind speed: 3 mi/h; wind direction: 229° (vehicle was traveling in a northwesterly direction); temperature: 88°F; relative humidity: 68 percent.

3.6 TEST DESCRIPTION

The test vehicle, traveling at an impact speed of 56.5 mi/h, contacted the TxDOT 42-inch tall SSCB with 1-inch ACP overlay 25 ft-2 inches downstream of the upstream end of the barrier at an impact angle of 15.8°. Table 5.1 lists times and events that occurred during Test No. 469467-3-1. Figures B.1 and B.2 in Appendix B.4 present sequential photographs during the test.

Table 3.1. Events during Test No. 469467-3-1.

TIME (s)	EVENT
−0.004	Left front tire contacts barrier and begins to ride up the face of the barrier
0.027	Cab of vehicle pitches upward
0.030	Vehicle begins to redirect
0.090	Left front corner of box overrides barrier
0.255	Vehicle begins to redirect
0.266	Lower left rear of box impacts barrier
1.380	Left front tire (on pavement) skids off of end of barrier
1.634	Vehicle loses contact with barrier traveling at 52.5 mi/h and 0°

For longitudinal barriers, it is desirable that the vehicle redirects and exits the barrier within the exit box criteria (not less than 65.6 ft downstream from impact for the 10000S vehicle). The 10000S vehicle exited within the exit box criteria defined in *MASH*. After loss of contact with the barrier, the vehicle came to rest 247 ft downstream of the impact location and 19 ft toward the field side.

3.7 DAMAGE TO TEST INSTALLATION

Figures 3.5 and 3.6 show the damage to the TxDOT 42-inch tall SSCB with 1-inch ACP Overlay. Cosmetic damage and surface gouging was evident on the traffic face in the impact area and where the vehicle rode off the end of the barrier. Working width was 72.8 inches at a height of 12.9 ft. Dynamic deflection was not measureable during the test due to the vehicle obstructing the view. No measureable permanent deformation was noted.

3.8 DAMAGE TO TEST VEHICLE

Figure 3.7 shows the damage sustained by the test vehicle. The front bumper, hood, left front fender, left front tire and rim, left axle, left front springs, left front U-bolts, left door, left fuel tank and side steps, left front corner of the box, left side of lower box, left outer tire and rim, drive shaft, left battery box, and rear air bags were damaged. Maximum exterior crush to the vehicle was 14.0 inches in the front plane at the left front corner at bumper height. No occupant compartment deformation or intrusion was noted. Figure 3.8 shows the interior of the vehicle.

3.9 OCCUPANT RISK FACTORS

Data from the accelerometer, located at the vehicle center of gravity, were digitized for informational purposes only and are shown in Table 3.2. Figure 3.9 summarizes these data and other pertinent information from the test. Figure B.3 in Appendix B.5 shows the vehicle angular displacements, and Figures B.4 through B.9 in Appendix B.6 show vehicle acceleration versus time traces.

Figure 3.5. TxDOT 42-inch Tall SSCB with 1-inch ACP and Test Vehicle after Test No. 469467-3-1.

Figure 3.6. TxDOT 42-inch Tall SSCB with 1-inch ACP Overlay after Test No. 469467-3-1.

Figure 3.7. Test Vehicle after Test No. 469467-3-1.

Before Test After Test

Figure 3.8. Interior of Test Vehicle for Test No. 469467-3-1.

Table 3.2. Occupant Risk Factors for Test No. 469467-3-1.

Occupant Risk Factor	Value	Time
OIV		
Longitudinal	**7.2 ft/s**	at 0.2327 s on left side of interior
Lateral	**13.4 ft/s**	
Occupant Ridedown Accelerations		
Longitudinal	**3.6 g**	0.2327–0.2427 s
Lateral	**6.4 g**	0.2999–0.3099 s
THIV	**17.1 km/h** **4.7 m/s**	at 0.2235 s on left side of interior
PHD	**6.6 g**	0.2999–0.3099 s
ASI	**0.43**	0.3403–0.3903 s
Maximum 50-ms Moving Average		
Longitudinal	**−1.9 g**	0.2067–0.2567 s
Lateral	**3.7 g**	0.1289–0.1789 s
Vertical	**−3.9 g**	0.3151–0.3651 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	**24.3**	0.5338 s
Pitch	**7.5**	0.8803 s
Yaw	**21.7**	0.6395 s

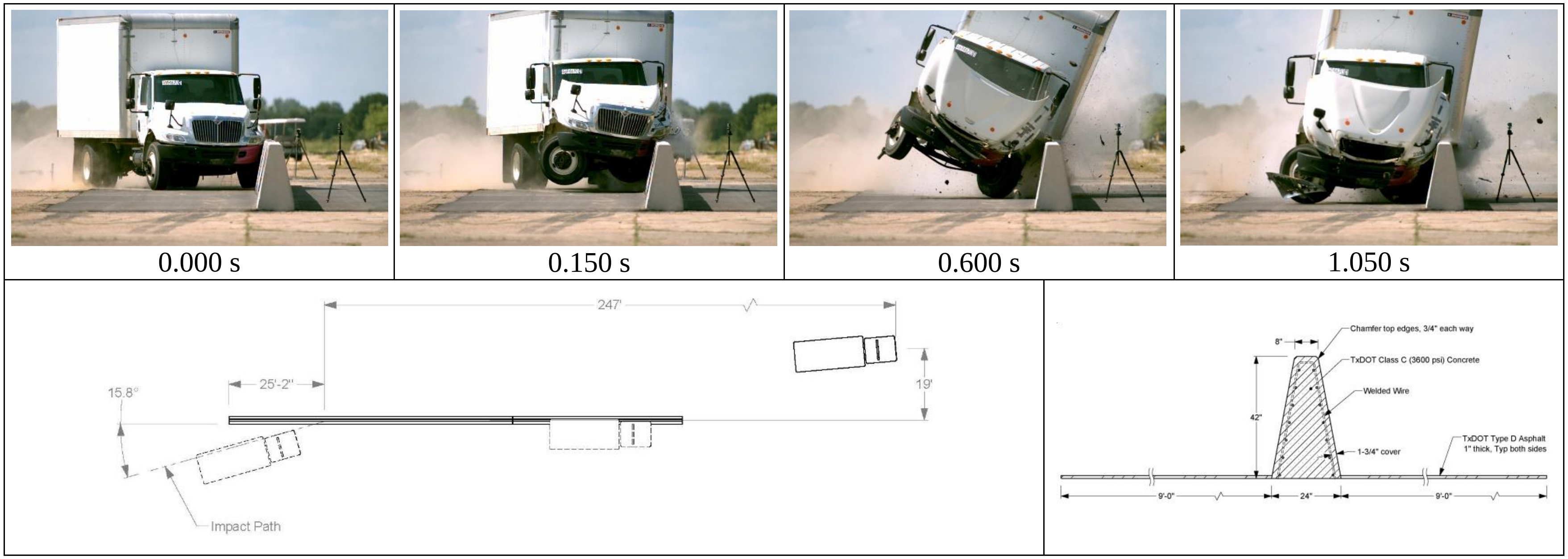
3.10 ASSESSMENT OF RESULTS

An assessment of the test on the TxDOT 42-inch tall SSCB with 1-inch ACP overlay based on the applicable safety evaluation criteria for *MASH* Test 4-12 is provided in Table 3.3.

3.11 CONCLUSIONS

The TxDOT 42-inch SSCB with 1-inch ACP overlay contained and redirected the 10000S vehicle. The vehicle did not penetrate, underride, or override the installation. No lateral deflection was noted during the test. No detached elements, fragments, or other debris was present to penetrate or show potential for penetrating the occupant compartment or to present hazard to others in the area. The 10000S vehicle remained upright during and after the collision event.

The TxDOT 42-inch tall SSCB with 1-inch ACP overlay performed acceptably for *MASH* Test 4-12.



General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 4-12
TTI Test No.	469467-3-1
Test Date	2017-07-07
Test Article	
Type	Median Barrier
Name	TxDOT 42-inch SSCB with 1-inch ACP overlay
Installation Length	120 ft
Material or Key Elements	42-inch tall SSCB, 24 inches wide at the base, and 8 inches wide at the top; 1-inch ACP overlay
Soil Type and Condition	Cast in place on existing concrete surface with no anchorage; damp
Test Vehicle	
Type/Designation	10000S
Make and Model	2005 International 4300
Curb	13,570 lb
Test Inertial	22,210 lb
Dummy	No dummy
Gross Static	22,210 lb

Impact Conditions	
Speed	56.5 mi/h
Angle	15.8°
Location/Orientation	25 ft-2 inches downstream of end
Impact Severity	175 kip-ft
Exit Conditions	
Speed	52.5 mi/h
Angle	0°
Occupant Risk Values	
Longitudinal OIV	7.2 ft/s
Lateral OIV	13.4 ft/s
Longitudinal Ridedown	3.6 g
Lateral Ridedown	6.4 g
THIV	17.1 km/h
PHD	6.6g
ASI	0.43
Max. 0.050-s Average	
Longitudinal	-1.9 g
Lateral	3.7 g
Vertical	-3.9 g

Post-Impact Trajectory	
Stopping Distance	247 ft downstream 19 ft twd field side
Vehicle Stability	
Maximum Yaw Angle	22°
Maximum Pitch Angle	8°
Maximum Roll Angle	24°
Vehicle Snagging	No
Vehicle Pocketing	No
Test Article Deflections	
Dynamic	1.0 inch
Permanent	None
Working Width	72.85 inches
Vehicle Intrusion	12.9 ft
Vehicle Damage	
VDS	NA
CDC	11LFEW5
Max. Exterior Deformation	14.0 inches
OCDI	NA
Max. Occupant Compartment Deformation	None

Figure 3.9. Summary of Results for *MASH* Test 4-12 on the TxDOT 42-inch Tall SSCB with 1-inch ACP Overlay.

Table 3.3. Performance Evaluation Summary for *MASH* Test 4-12 on the TxDOT 42-inch Tall SSCB with 1-inch ACP Overlay.

Test Agency: Texas A&M Transportation Institute | Test No.: 469467-3-1 | Test Date: 2017-07-07

MASH Test 4-12 Evaluation Criteria	Test Results	Assessment
Structural Adequacy *A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.*	The TxDOT 42-inch SSCB with 1-inch ACP lateral support contained and redirected the 10000S vehicle. The vehicle did not penetrate, underride, or override the installation. Dynamic deflection was not measureable during the test due to the vehicle obstructing the view. No measureable permanent deformation was noted.	Pass
Occupant Risk *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	No detached elements, fragments, or other debris was present to penetrate or show potential for penetrating the occupant compartment or to present hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	No occupant compartment deformation or intrusion occurred.	
G. It is preferable, although not essential, that the vehicle remain upright during and after collision.	The 10000S vehicle remained upright during and after the collision event.	Pass

CHAPTER 4: TXDOT 32-INCH CSB(7)-10 PINNED TO CONCRETE PAVEMENT

4.1 BACKGROUND

Precast concrete barrier is used to provide positive protection in work zones. A buffer area must be maintained behind the precast concrete barrier to accommodate dynamic deflection of the barrier during a vehicle impact. If available space is restricted, the lateral barrier deflection is often reduced by pinning the barrier to the underlying concrete pavement or deck structure. TxDOT's standard detail for this practice includes the use of 1¼-inch steel pins placed on the traffic side of the barrier. The pins are installed at an angle through the toe of the precast barrier and 6 inches into the concrete pavement.

TxDOT maintains standard details for pinning both the 32-inch CSB(7)-10 and the 42-inch SSCB(5)-10 to concrete pavement. The 32-inch F-shape barrier is considered the more critical of the two barriers for a TL-3 impact. Its lower height and mass give it a greater propensity to deflect and rotate, thus potentially aggravating the stability of the impacting vehicle. If the testing of the 32-inch pinned F-shape barrier is successful, the taller, heavier, 42-inch single-slope barrier pinned to concrete could also be considered *MASH* TL-3 compliant.

TTI researchers recommended evaluating a 32-inch precast F-shape barrier pinned to concrete pavement to *MASH* TL-3. The structural adequacy test for *MASH* TL-3 is test designation 3-11 with the 2270P pickup truck. The IS of test designation 3-10 is approximately half that of test 3-11. Consequently, since the pinned barrier shall behave essentially rigidly when impacted by the small passenger car, test designation 3-10 is not considered necessary for demonstrating *MASH* compliance for this anchorage system.

TxDOT standards permit the use of several different connection systems to attach the precast concrete barrier segments to each other. Thus, it was necessary to select a barrier connection system for the evaluation of the pinning system. The J-J Hooks® connection was selected in consultation with TxDOT. The J-J Hooks® connection is commonly used and represents a more critical connection type than the X-bolt connection system for evaluating the pinning of the barrier to concrete pavement. The X-bolt connection is stronger and allows less barrier deflection. Therefore, if the test of the pinning system with the J-J Hooks® barrier connections is successful, the same pinning system used with similar F-shape barriers with the less critical X-bolt barrier connections would also be considered *MASH* TL-3 compliant.

4.2 SYSTEM DETAILS

4.2.1 Test Article Design and Construction

The test installation consisted of four 32-inch tall, F-Shape concrete median barrier sections pinned at the edge of an unreinforced concrete pavement. Each precast barrier segment was nominally 30 ft in length and were connected to each other using J-J Hooks® end hook. The barriers were installed with all slack removed from the connections, which maximizes the space between adjacent barrier sections. The total length of the barrier installation was approximately 120 ft-3 inches, including a 1-inch gap between the ends of the adjacent barrier segments.

The barrier segments were manufactured by Tricon Precast Ltd. in Houston, Texas. Each barrier segment was 30 ft long (end-to-end) and 32-inches tall. The F-shape median barrier was 24-inches wide at the base and 9½-inches wide at the top with symmetrical 54½° lower and 83½° upper slopes on both faces. The ends were chamfered 1 inch at 45° as cast. Two drainage reliefs/forklift slots (each 35-inches long × 3½-inches high) were precast in the bottom of each barrier segment and were symmetrically centered 90 inches from each end. Two cast-in-place 2½-inch diameter PVC pipes located 77-inches from each end served as lifting holes. Each of the barrier segments was precast with reinforcing steel, wire mesh fabric, and 12-inch "J-J Hooks®" connections in each end. See TxDOT standard drawing CSB (1)-10 in Appendix C.1 for details.

The field side edge of the barriers was placed at the edge of a 6-inch thick, unreinforced concrete pavement. The soil behind the concrete pavement section was excavated to a depth of 8 inches to simulate a deck condition. Each barrier segment was secured to the concrete pavement using four drop anchor pins on the traffic side. The anchor pins were 1¼-inch diameter × 20-inches long with a 3-inch diameter × ¼-inch thick plate on the top and a ¼-inch chamfer on the bottom. The pins were inserted through the barrier via cast-in-place 2-inch PVC pipe guides and extended 5½ inches into the deck through 1⅜-inch diameter drilled holes. Other than the anchor pins, there were no additional bolts, plates, or adhesives securing the barriers to the concrete apron.

Figure 4.1 shows overall details TxDOT 32-inch CSB pinned to concrete pavement. Figure 4.2 shows photographs of the completed test installation. Further details of the TxDOT 32-inch CSB pinned to concrete pavement can be found in Appendix C.1.

4.2.2 Material Specifications

The anchor pins and steel top plate met ASTM A-36 specifications. Reinforcing steel met ASTM A706 grade 60 or A615 grade 60 dual specifications. Welded wire mesh met ASTM A185 grade 65 specifications. Appendix C.2 provides material certification documents for the materials used to install and construct the TxDOT 32-inch CSB pinned to concrete pavement.

4.3 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

MASH Test 3-11 involves a 2270P vehicle weighing 5000 lb ±110 lb impacting the CIP of the barrier at an impact speed of 62 mi/h ±2.5 mi/h and an impact angle of 25° ±1.5°. With reference to *MASH* Section 2.3.2 and Table 2-7, the CIP for *MASH* Test 3-11 on the TxDOT 32-inch CSB(7)-10 pinned to concrete pavement was determined to be 4.3 ft ±1 ft upstream of the joint between segments 2 and 3.

The 2012 Dodge RAM 1500 pickup truck used in the test weighed 5034 lb, and the actual impact speed and angle were 63.5 mi/h and 24.8°, respectively. The actual impact point was 4.4 ft upstream of the joint between segments 2 and 3. Minimum target IS was 106 kip-ft, and actual IS was 119 kip-ft.

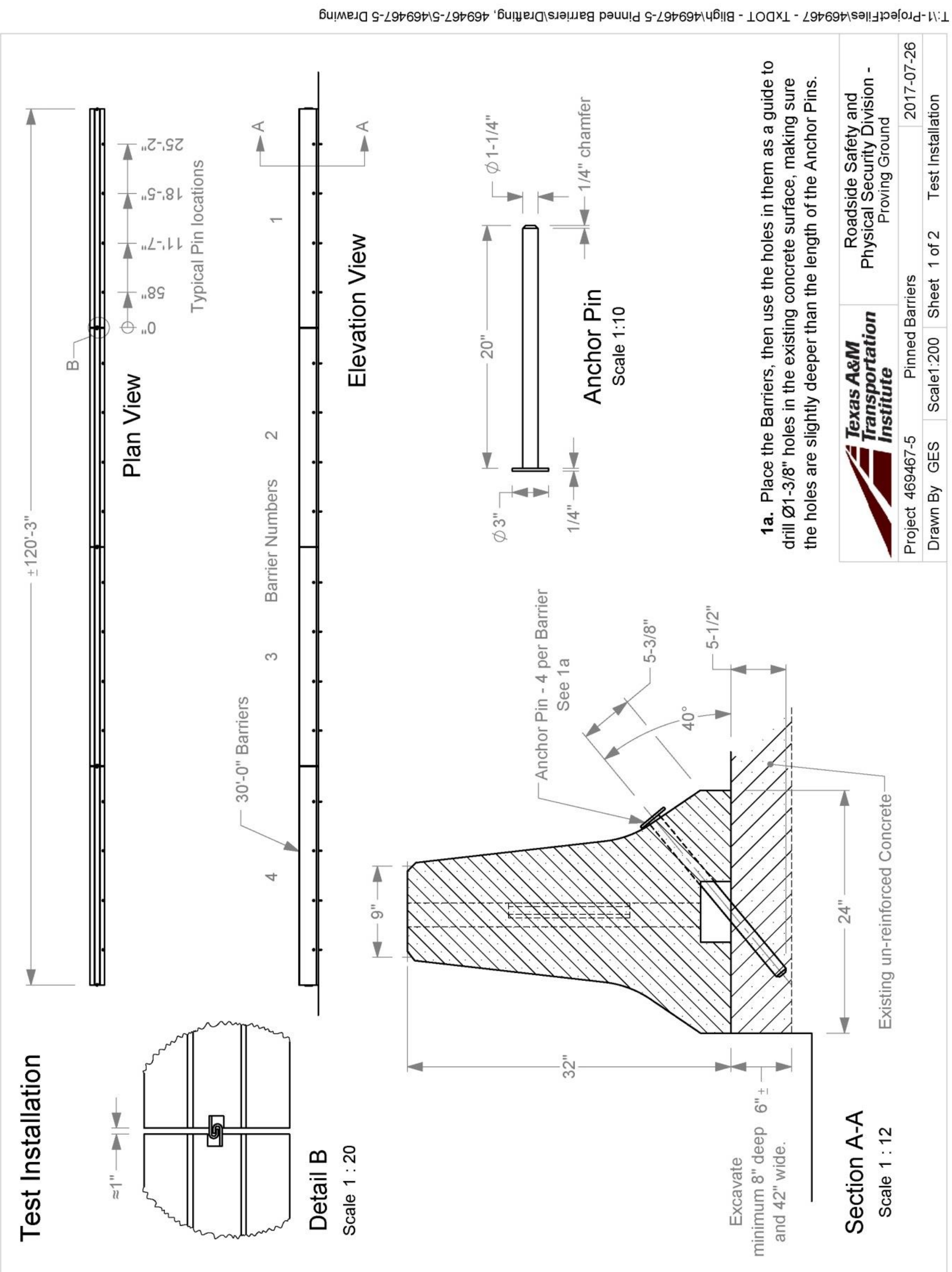


Figure 4.1. Overall Details of the TxDOT 32-inch CSB(7)-10 Pinned to Concrete Pavement.

Figure 4.2. TxDOT 32-inch CSB(7)-10 Pinned to Concrete Pavement prior to Testing.

4.4 TEST VEHICLE

The 2012 Dodge RAM 1500 pickup truck, shown in Figures 4.3 and 4.4, was used for the crash test. The vehicle's test inertia weight was 5034 lb, and its gross static weight was 5034 lb. The height to the lower edge of the vehicle bumper was 11.75 inches, and height to the upper edge of the bumper was 27.00 inches. The height to the vehicle's center of gravity was 28.25 inches. Tables C.1 and C.2 in Appendix C.3 give additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

Figure 4.3. TxDOT 32-inch CSB(7)-10 Pinned to Concrete Pavement/Test Vehicle Geometrics for Test No. 469467-5-1.

Figure 4.4. Test Vehicle before Test No. 469467-5-1.

4.5 WEATHER CONDITIONS

The test was performed on the morning of July 26, 2017. Weather conditions at the time of testing were as follows: wind speed: 8 mi/h; wind direction: 204° (vehicle was traveling in a southwesterly direction); temperature: 90°F; relative humidity: 64 percent.

4.6 TEST DESCRIPTION

The test vehicle, traveling at an impact speed of 63.5 mi/h, contacted the barrier 4.4 ft upstream of the joint between segments 2 and 3 at an impact angle of 24.8°. Table 4.1 lists times and events that occurred during Test No. 469467-5-1. Figures C.1 and C.2 in Appendix C.3 present sequential photographs during the test.

Table 4.1. Events during Test No. 469467-5-1.

TIME (s)	EVENT
0.002	Right front tire impacts toe of barrier
0.012	Barrier at joint #2-3 begins to displace to field side
0.013	Right front tire begins to climb toe of barrier
0.022	Right front tire deflates
0.040	Vehicle begins to redirect
0.043	Downstream end of barrier #3 begins to displace to traffic side
0.066	Downstream traffic toe of barrier #3 begins to lift & displace to traffic side
0.087	Left front tire lifts from pavement
0.117	Left rear tire lifts from pavement
0.133	Concrete begins to fracture at next-to-last pin on downstream end of barrier #2
0.187	Downstream traffic toe of barrier #4 begins to lift
0.194	Vehicle traveling parallel with barrier
0.195	Barrier concrete already broken at last pin on downstream end of barrier #2 (revealed under vehicle)
0.195	Right rear taillight impacts downstream end of barrier #2 near joint
0.270	Tailgate detaches from bed
0.300	Barrier at maximum lean ~13.3° from vertical to field side
0.300	Barrier at maximum lift ~4 inches at toe on traffic side of barrier #2
0.407	Right front tire lands back on pavement
0.500	Bumper impacts pavement
0.510	Vehicle loses contact with barrier while traveling at 53.9 mi/h and 2.9°
0.778	Left front tire lands back on pavement
0.991	Right rear tire lands back on pavement

For longitudinal barriers, it is desirable that the vehicle redirects and exits the barrier within the exit box criteria (not less than 32.8 ft downstream from impact for cars and pickups). The 2270P vehicle exited within the exit box criteria defined in *MASH*. Brakes on the vehicle were applied 4.6 s after impact. The vehicle subsequently came to rest 286 ft downstream of the impact and 40 ft toward traffic lanes.

4.7 DAMAGE TO TEST INSTALLATION

Figures 4.5 through 4.8 show the damage to the TxDOT 32-inch CSB(7)-10 pinned to concrete pavement. The upstream end of barrier segment 1 was pushed toward the field side 0.5 inch, and the downstream end was pushed toward traffic lanes 1.0 inch. The upstream end of barrier segment 2 was pushed toward traffic lanes 2.0 inches and was lifted upward from ground level 1.5 inches. The downstream end of barrier segment 2 was pushed 12.0 inches toward the field side and was lifted upward from ground level 0.5 inches. In barrier segment 2, pin 1 was pulled upward 0.5 inch, pin 2 was pulled up 1.0 inch, pin 3 was pulled up 3.0 inches, and pin 4 was pulled upward 4.0 inches and was deformed.

Figure 4.5. TxDOT 32-inch CSB(7)-10 Pinned to Concrete Pavement after Test No. 469467-5-1.

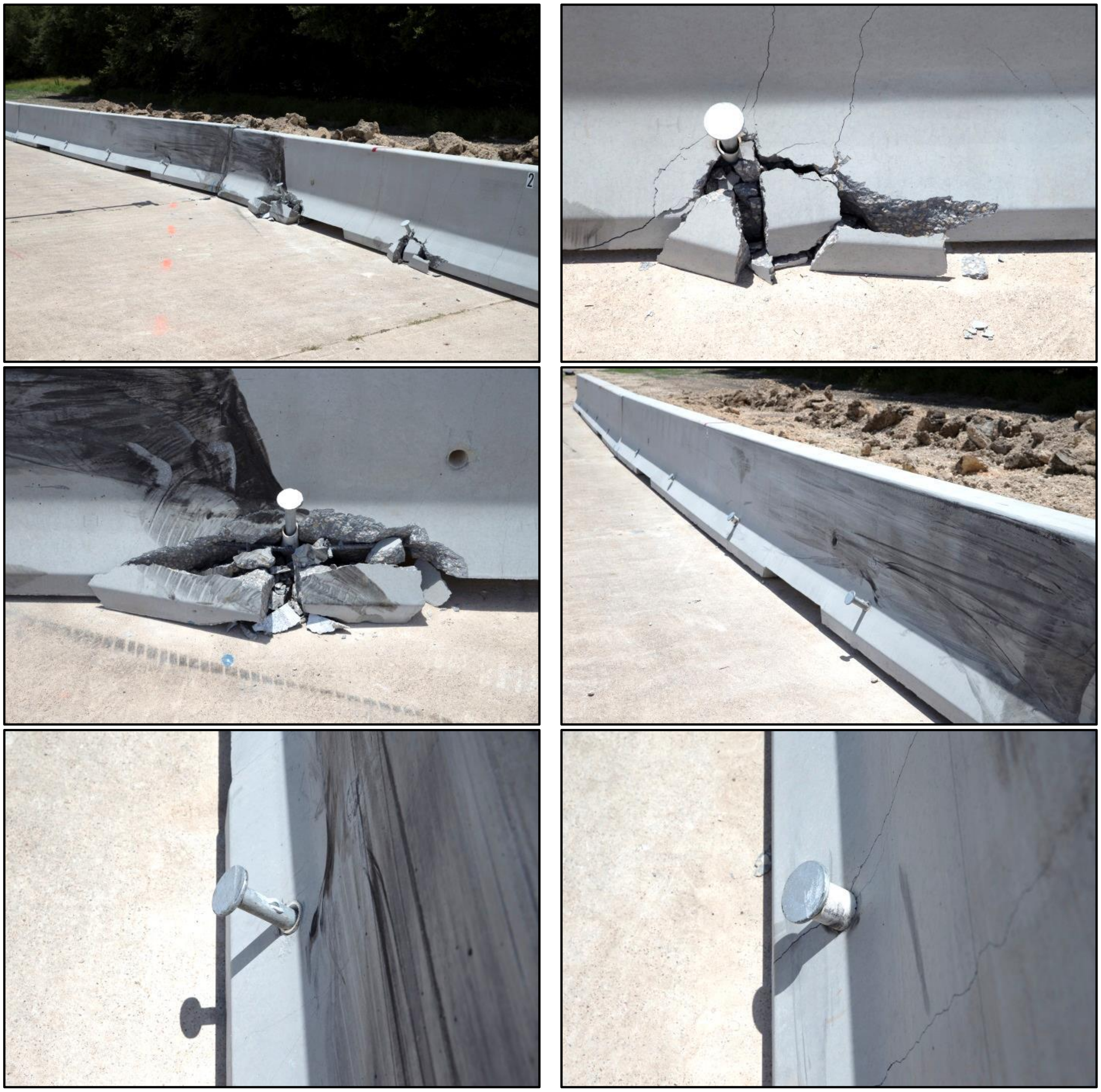


Figure 4.6. Damage at Pin Locations after Test No. 469467-5-1.

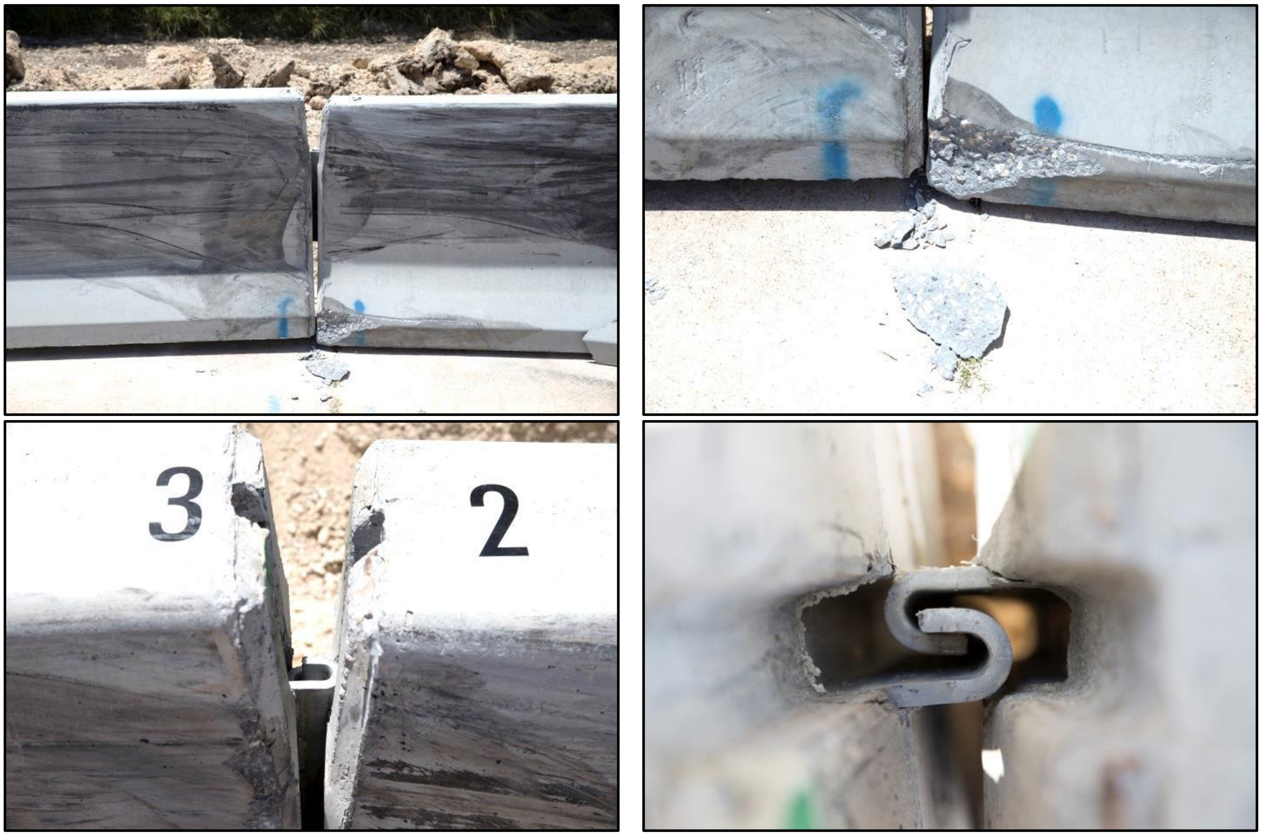


Figure 4.7. Damage at Joint 2-3 after Test No. 469467-5-1.

Figure 4.8. Field Side of Barrier after Test No. 469467-5-1.

Numerous vertical cracks were noted in barrier segment 2 starting 90 inches from the upstream end to 63 inches from the downstream end, and the concrete around the third and fourth pins was broken out. The upstream end of barrier segment 3 was pushed toward field side 12.0 inches, the downstream end was pushed toward traffic lanes 1.5 inches, and the entire front edge of the barrier was lifted 1.5 inches above ground. In barrier segment 3, pin 1 was pulled up

4.0 inches, pin 2 was pulled up 2.25 inches, and pin 3 was pulled up 1.25 inches. Barrier segment 3 had similar cracking to that noted in barrier segment 2. The upstream end of barrier segment 4 was pushed toward traffic lanes 0.5 inch with no pin movement.

Working width was 42.5 inches at a height of 29.4 inches. Maximum dynamic deflection was 24.6 inches, and maximum permanent deformation was 12.0 inches.

4.8 DAMAGE TO TEST VEHICLE

Figure 4.9 shows the damage sustained by the test vehicle. The front bumper, grill, radiator and support, right front fender, right front tire and rim, right front and rear doors, right lower cab corner, right rear exterior bed, right rear tire and rim, right axle, rear bumper, and tailgate were damaged. Maximum exterior crush to the vehicle was 15.0 inches in the side plane at the right front corner at bumper height. No occupant compartment deformation or intrusion was noted. Figure 4.10 shows the interior of the vehicle. Tables C.3 and C.4 in Appendix C.3 provide exterior crush and occupant compartment measurements.

Figure 4.9. Test Vehicle after Test No. 469467-5-1.

Before Test

After Test

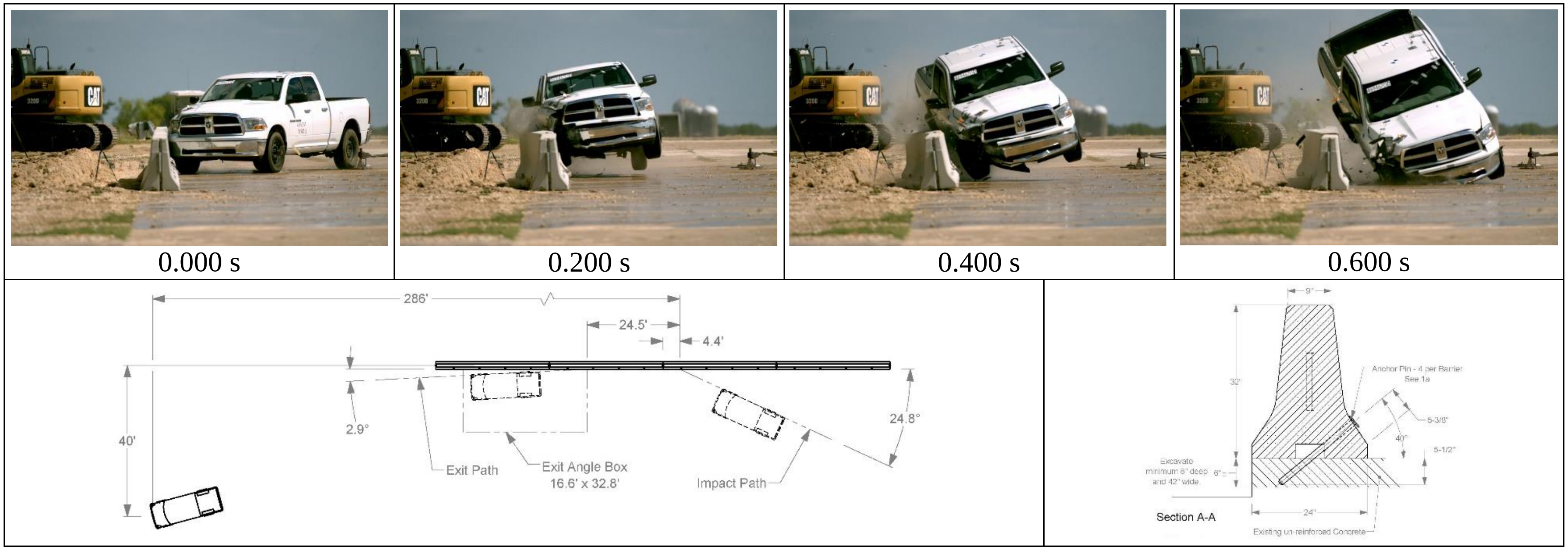
Figure 4.10. Interior of Test Vehicle for Test No. 469467-5-1.

4.9 OCCUPANT RISK FACTORS

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk. Results are shown in Table 4.2. Figure 4.11 summarizes these data and other pertinent information from the test. Figure C.3 in Appendix C.5 shows the vehicle angular displacements, and Figures C.4 through C.9 in Appendix C.6 show vehicle acceleration versus time traces.

Table 4.2. Occupant Risk Factors for Test No. 469467-5-1.

Occupant Risk Factor	Value	Time
OIV		
Longitudinal	**12.5 ft/s**	at 0.1017 s on right side of interior
Lateral	**22.3 ft/s**	
Occupant Ridedown Accelerations		
Longitudinal	**4.3 g**	0.2044–0.2144 s
Lateral	**13.1 g**	0.1999–0.2099 s
THIV	**28.0 km/h** **7.8 m/s**	at 0.0989 s on right side of interior
PHD	**13.7 g**	0.2000–0.2100 s
ASI	**1.46**	0.0579–0.1079 s
Maximum 50-ms Moving Average		
Longitudinal	**−6.1 g**	0.0244–0.0744 s
Lateral	**−11.3 g**	0.0315–0.0815 s
Vertical	**−2.9 g**	0.1661–0.2161 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	**17.2°**	0.5408 s
Pitch	**16.8°**	0.5773 s
Yaw	**40.3°**	1.0000 s



General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-11
TTI Test No.	469467-5-1
Test Date	2017-07-26
Test Article	
Type	Pinned Precast Concrete Barrier
Name	TxDOT CSB(7)-10 Pinned to Concrete
Installation Length	120 ft 3 inches
Material or Key Elements	Four 32-inch tall × 30 ft long CSB Segments Pinned to Un-Reinforced Concrete Pavement; 1 ¼-inch diameter angled drop pins
Soil Type and Condition	Pinned to Existing Concrete Pavement, Damp
Test Vehicle	
Type/Designation	2270P
Make and Model	2012 Dodge RAM 1500 Pickup
Curb	4881 lb
Test Inertial	5034 lb
Dummy	No dummy
Gross Static	5034 lb

Impact Conditions	
Speed	63.5 mi/h
Angle	24.8°
Location/Orientation	4.4 ft upstream of the joint 2-3
Impact Severity	176 kip-ft
Exit Conditions	
Speed	53.9 mi/h
Angle	2.9°
Occupant Risk Values	
Longitudinal OIV	12.5 ft/s
Lateral OIV	22.3 ft/s
Longitudinal Ridedown	4.3 g
Lateral Ridedown	13.1 g
THIV	28.0 km/h
PHD	13.7 g
ASI	1.46
Max. 0.050-s Average	
Longitudinal	-6.1 g
Lateral	-11.3 g
Vertical	-2.9 g

Post-Impact Trajectory	
Stopping Distance	286 ft downstream 40 ft toward traffic
Vehicle Stability	
Maximum Yaw Angle	40°
Maximum Pitch Angle	17°
Maximum Roll Angle	17°
Vehicle Snagging	No
Vehicle Pocketing	No
Test Article Deflections	
Dynamic	24.6 inches
Permanent	12.0 inches
Working Width	42.5 inches
Height of Working Width	29.4 inches
Vehicle Damage	
VDS	01RFQ4
CDC	01FREW4
Max. Exterior Deformation	15.0 inches
OCDI	FL0000000
Max. Occupant Compartment Deformation	None

Figure 4.11. Summary of Results for *MASH* Test 3-11 on the TxDOT 32-inch CSB(7)-10 Pinned to Concrete Pavement.

4.10 SUMMARY OF RESULTS

An assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-11 is provided in Table 4.3.

4.11 CONCLUSIONS

The TxDOT 32-inch CSB(7)-10 pinned to concrete pavement contained and redirected the 2270P vehicle. Maximum dynamic deflection was 24.6 inches. No detached elements, fragments, or other debris from the test article were present to penetrate or show potential for penetrating the occupant compartment, or to present undue hazard to others in the area. No occupant compartment deformation or intrusion occurred. The 2270P vehicle remained upright during and after the collision period. Maximum roll and pitch angles were both 17°. Occupant risk values were within the preferred limits.

The TxDOT 32-inch CSB(7)-10 pinned to concrete pavement performed acceptably for *MASH* Test 3-11.

Table 4.3. Performance Evaluation Summary for *MASH* Test 3-11 on the TxDOT 32-inch CSB(7)-10 Pinned to Concrete Pavement.

Test Agency: Texas A&M Transportation Institute | Test No.: 469467-5-1 | Test Date: 2017-07-26

***MASH* Test 3-11 Evaluation Criteria**	**Test Results**	**Assessment**
Structural Adequacy *A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable*	The TxDOT 32-inch CSB(7)-10 pinned to concrete pavement contained and redirected the 2270P vehicle. Maximum dynamic deflection during the test was 24.6 inches.	Pass
Occupant Risk *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	No detached elements, fragments, or other debris from the test article were present to penetrate or show potential for penetrating the occupant compartment, or to present undue hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	No occupant compartment deformation or intrusion occurred.	
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 2270P vehicle remained upright during and after the collision period. Maximum roll and pitch angles were both 17°.	Pass
H. Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 30 ft/s, or maximum allowable value of 40 ft/s.	Longitudinal OIV was 12.5 ft/s, and lateral OIV was 22.3 ft/s.	Pass
I. The occupant ridedown accelerations should satisfy the following: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	Maximum longitudinal occupant ridedown was 4.3 g, and maximum lateral occupant ridedown was 13.1 g.	Pass

CHAPTER 5:
TXDOT SINGLE AND DUAL EMBEDDED WOOD POST SIGN SYSTEMS

5.1 BACKGROUND

TxDOT uses single and dual embedded wood posts for ground-mounted temporary sign supports. The support posts can be either 4-inch × 4-inch or 4-inch × 6-inch in size depending on the sign area. The 4-inch × 6-inch supports incorporate 1½-inch diameter weakening holes near the ground line and at bumper height to facilitate fracture and breakaway of the support post when impacted. There are numerous configurations associated with these temporary support posts. TTI researchers worked with TxDOT to develop a plan to limit the number of tests required by testing to the most critical configurations. If the critical tests are successful, the less critical configurations can also be considered *MASH* compliant.

MASH Section 2.2.4.1 recognizes that sign support systems that are used near an intersection can be struck from virtually any direction. This section of *MASH* recommends that: "In this case, testing should be conducted at both 90° from the normal direction and at any orientation between 0° and 25° that is deemed to represent the highest risk for the system to fail any of the recommended evaluation criteria. Features designed to be used along the outside of divided highways need only be evaluated for impact angles of 0° to 25°."

The single support configuration has been previously tested with a small passenger car. Although the *MASH* small passenger car has changed, its performance in frontal impacts with ground-mounted breakaway sign support systems is not expected to vary appreciably; therefore, only test designation 3-62 with the 2270P pickup truck is necessary for the 0° impact scenario. Since the single wood support has not been previously tested at 90°, both test designation 3-61 (passenger car) and test designation 3-62 (pickup truck) are recommended to evaluate impact performance in this direction. A 4-inch × 4-inch support with a small sign is considered the worst case scenario for testing and evaluation. The smaller sign lowers the center of mass of the sign support system and reduces its mass moment of inertia; therefore, after the support fractures, the smaller sign should rotate about a lower point and with more rotational velocity than a system with a larger sign. This increases the opportunity for secondary interaction of the support system with the windshield and roof of the impacting vehicle. Such behavior has been observed with slip base small sign supports, and this behavior is expected to similar with other frangible small sign support systems (*6*).

Researchers consulted with TxDOT to identify minimum sign areas used on single support systems and which of these signs are commonly used at or near intersections. It was determined that a 12-inch × 18-inch DO NOT PASS sign (R4-1) is the smallest sign commonly used along roadways outside of intersection areas, and that the 24-inch × 18-inch END DETOUR sign (M4-8a) is the smallest sign that might be deployed at or near an intersection.

Researchers consulted with TxDOT on the applications and types of signs used in conjunction with the dual support configurations. It was determined that the maximum spacing of the two supports for the sign sizes typically utilized in temporary work zone applications is only 24 inches. With this close post spacing, it is highly probable that both supports will be impacted by an errant vehicle. Also, the review determined that the signs typically used on dual support configurations are not deployed at or near intersections. Therefore, impacting the dual support system at 90° is not necessary.

The most critical configuration will be dual 4-inch × 4-inch supports with a small sign area. As with the single support system, a dual support system with a small sign panel will have a greater probability of secondary contact with the windshield or roof of the impacting vehicle due to a lower center of mass and mass moment of inertia. Additionally, the 4-inch × 4-inch support is more likely to fracture into multiple sections during impact, which can increase the opportunity for a section of the support to interact with the vehicle windshield. TxDOT informed the researchers that a 36-inch × 48-inch SPEED LIMIT sign (R2-1) was the smallest commonly used sign supported by dual wood posts. Because a previous successful small car test with a dual support system with small sign panel could not be identified, both test designation 3-61 (passenger car) and test designation 3-62 (pickup truck) were recommended for evaluation of the impact performance of the dual support system.

5.2 SINGLE EMBEDDED WOOD POST SIGN SYSTEM

5.2.1 *MASH* Test 3-62 at 0°

5.2.2.1 System Details

The test installation consisted of a single aluminum sign mounted on a single dimensional lumber 4×4 pressure treated Southern Yellow Pine post. The test sign panel measured 18 inches tall × 12 inches wide and was fabricated from 0.080-inch thick aluminum. This represented a DO NOT PASS sign (R4-1). The sign was installed with a mounting height of 7 ft from the ground to the bottom edge of the sign panel.

The sign was attached to the post with two F3125/A325 Grade 5 steel ⅜-inch diameter, 4½-inch long hex bolts with flat washers, lock washers, and nuts through two $^{7}/_{16}$-inch diameter holes drilled in the post a distance of 1½ inches from the top and bottom edges of the sign panel.

The overall length of the wooden support post was 11 ft-6 inches. The post was embedded 36 inches deep in soil that met grading B of AASHTO standard specifications M147-65(2004) for “Materials for Aggregate and Soil Aggregate Subbase, Base and Surface Courses.”

Figure 5.1 presents details of the TxDOT single embedded wood post sign system for 90° impact, and Figure 5.2 provides photographs of the completed test installation.

5.2.2.2 Test Designation and Actual Impact Conditions

MASH Test 3-62 involves a 2270P vehicle weighing 5000 lb ±110 lb impacting the TxDOT single embedded wood post sign system at an impact speed of 62 mi/h ±2.5 mi/h. For this test, the target impact angle was 0° ±1.5°. The centerline of the support system was aligned with the left quarter point of the vehicle.

The 2011 Dodge RAM 1500 pickup truck used in the test weighed 5025 lb, and the actual impact speed and angle were 63.1 mi/h and 0°, respectively. The actual impact point was the centerline of the support aligned with the left quarter point of the vehicle. Minimum target kinetic energy (KE) was 594 kip-ft, and actual KE was 669 kip-ft.

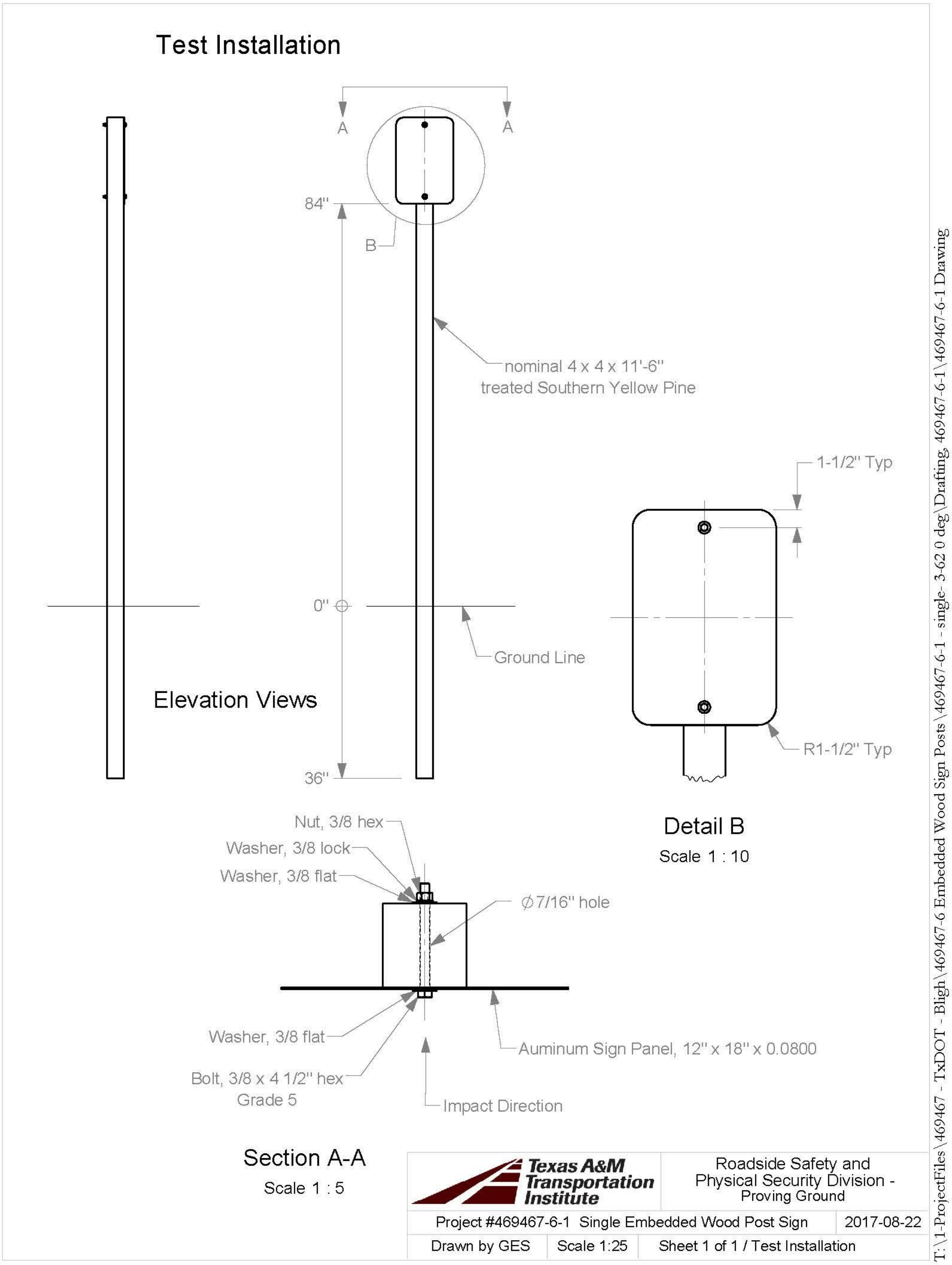


Figure 5.1. Overall Details of the TxDOT Single Embedded Wood Post Installation for 0° Impact.

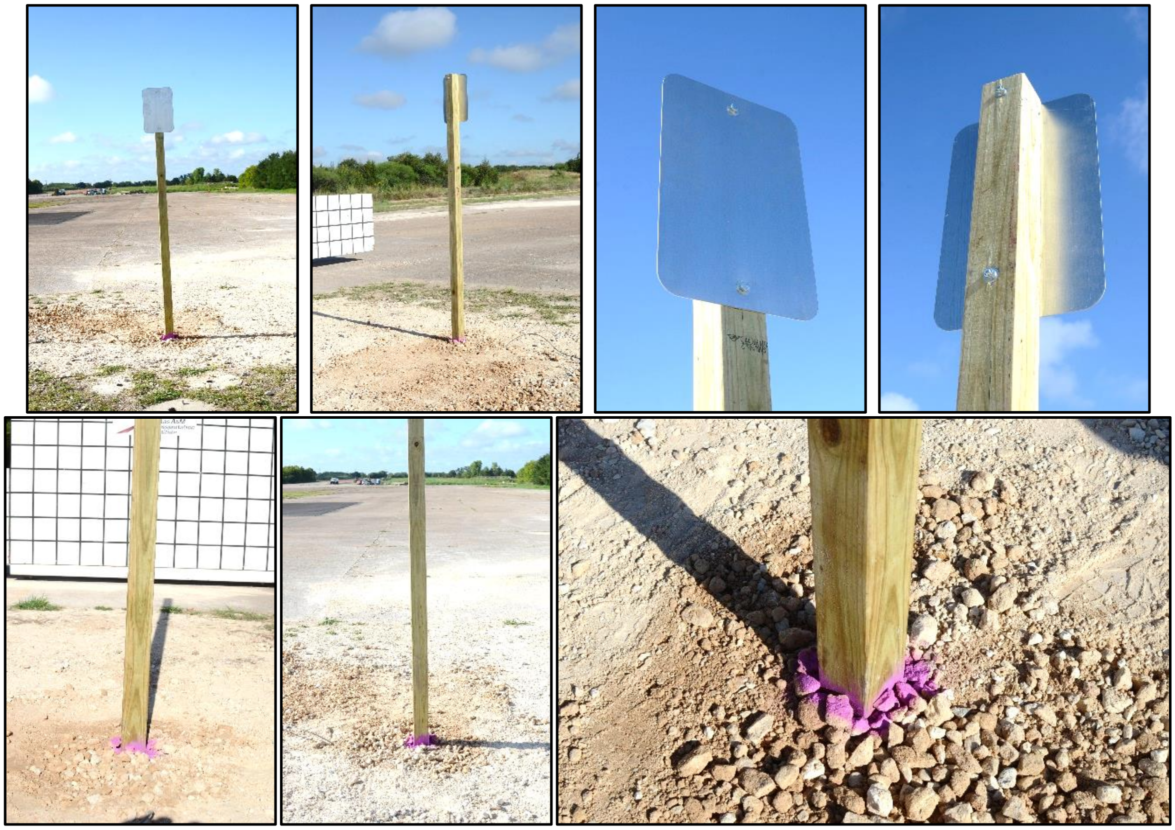


Figure 5.2. TxDOT Single Embedded Wood Post Sign System for 0° Impact prior to Testing.

5.2.2.3 Test Vehicle

The 2011 Dodge RAM 1500 pickup truck, shown in Figures 5.3 and 5.4, was used for the crash test. The vehicle's test inertia weight was 5025 lb, and its gross static weight was 5025 lb. The height to the lower edge of the vehicle bumper was 11.00 inches, and height to the upper edge of the bumper was 26.50 inches. The height to the vehicle's center of gravity was 28.0 inches. Table D.1 and D.2 in Appendix D.1 give additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

5.2.2.4 Weather Conditions

The test was performed on the morning of August 22, 2017. Weather conditions at the time of testing were as follows: wind speed: 4 mi/h; wind direction: 232° (vehicle was traveling in a southerly direction); temperature: 84°F; relative humidity: 78 percent.

5.2.2.5 Test Description

The test vehicle, traveling at an impact speed of 63.1 mi/h, contacted the TxDOT single embedded wood post system with the centerline of the support aligned with the left quarter point of the vehicle at an impact angle of 0°. Table 5.1 lists times and events that occurred during Test No. 469467-6-1. Figure D.1 in Appendix D.1 present sequential photographs during the test.

Figure 5.3. Test Installation/Test Vehicle Geometrics for Test No. 469467-6-1.

Figure 5.4. Test Vehicle before Test No. 469467-6-1.

Table 5.1. Events during Test No. 469467-6-1.

TIME (s)	EVENT
0.001	Post begins to deflect at bumper
0.002	Support post begins to fracture at top of bumper
0.003	Post impacts hood
0.004	Post begins to fracture approximately 2 ft above hood
0.012	Post fully fractured at bumper height
0.015	Post fully fractured above hood
0.019	Post fully fractured at grade level
0.037	Middle section of fractured post impacts top of hood
0.061	Vehicle loses contact with support while traveling 62.9 mi/h
0.075	Middle section of fractured post disengages from hood
0.083	Upper section of fractured post begins to scrape along roof for ~12 inches
0.090	Upper section of fractured post disengages from roof

Brakes on the vehicle were applied 1.1 s after impact. The vehicle subsequently came to rest 300 ft downstream of the impact.

5.2.2.6 Damage to Test Installation

Figure 5.5 shows the damage to the TxDOT single embedded wood sign system for 0° impact. The wood post fractured in three places. A 35-inch long section with the sign panel attached was resting 7 ft upstream of impact and 3 ft to the right of centerline. A 30-inch long section was resting 23 ft downstream and 3 ft to the left of centerline. A 50-inch section came to rest 173 ft downstream of impact and 3 ft to the left of centerline.

5.2.2.7 Damage to Test Vehicle

Figure 5.6 shows damage sustained by the vehicle. The front bumper and hood had a small dent at the quarter point. Maximum exterior crush to the vehicle was not measureable in the front plane at the left quarter point at bumper height. No occupant compartment deformation or intrusion was noted. Figure 5.7 shows the interior of the vehicle. Table D.3 in Appendix D.1 provides occupant compartment measurements.

5.2.2.8 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk and are shown in Table 5.2. Figure 5.8 summarizes these data and other pertinent information from the test. Figure D.2 in Appendix D.1 shows the vehicle angular displacements, and Figures D.3 through D.8 in Appendix D.1 show vehicle acceleration versus time traces.

5.2.2.9 Assessment of Results

An assessment of the test on the TxDOT single embedded wood post sign system based on the applicable safety evaluation criteria for *MASH* Test 3-62 is provided in Table 5.3.

5.2.2.10 Conclusions

The TxDOT single embedded wood post sign system fractured as designed. None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area. No occupant compartment deformation or intrusion occurred. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 2.0° and 0.6°, respectively. No occupant contact occurred. The 2270P vehicle came to rest 300 ft downstream of impact.

The support post fractured at three locations. The fracture above the vehicle hood may have been influenced by the presence of a knot on the impact face of the post. The sign panel and remaining post segment did not contact the windshield and had only minor (if any) contact with the roof. The influence of the knot on the fracture of the post may affect repeatability of the test. However, wood is a variable product with knots occurring randomly throughout. The TxDOT single embedded wood post sign system performed acceptably for *MASH* Test 3-62 at 0°.

Figure 5.5. TxDOT Single Embedded Wood Post System for 0° Impact after Test No. 469467-6-1.

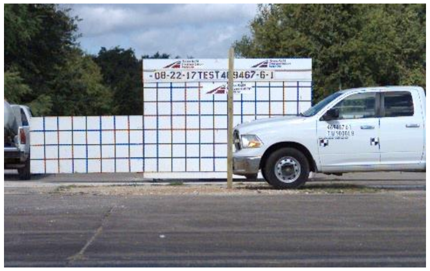
Figure 5.6. Test Vehicle after Test No. 469467-6-1.

Before Test　　　　After Test

Figure 5.7. Interior of Test Vehicle for Test No. 469467-6-1.

Table 5.2. Occupant Risk Factors for Test No. 469467-6-1.

Occupant Risk Factor	Value	Time
OIV	**No Contact**	
Occupant Ridedown Accelerations	**NA**	
THIV	**NA**	
PHD	**NA**	
ASI	**0.08**	0.3139–0.3639 s
Maximum 50-ms Moving Average		
Longitudinal	**−0.2 g**	0.3273–0.3773 s
Lateral	**−0.6 g**	0.2935–0.3435 s
Vertical	**0.4 g**	0.1666–0.2166 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	**2.0**	0.3656 s
Pitch	**0.6**	0.6052 s
Yaw	**3.0**	0.7500 s

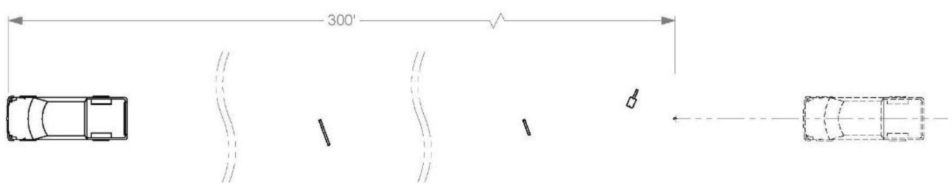


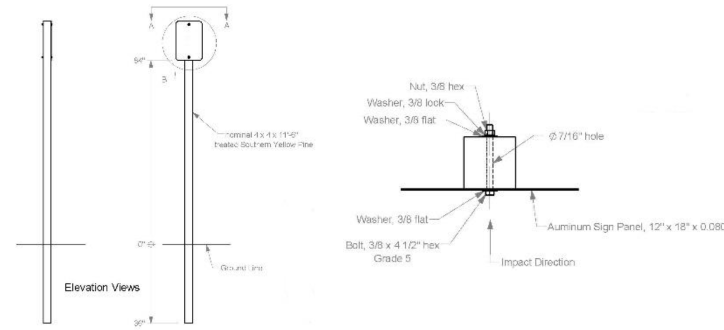
0.000 s

0.060 s

0.120 s

0.180 s





General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-62
TTI Test No.	469467-6-1
Test Date	2017-08-22
Test Article	
Type	Sign Support
Name	TxDOT Single Embedded Wood Post
Installation Height	7 ft to bottom of sign panel
Material or Key Elements	11 ft-6 inch long 4×4 pressure treated post with 18-inch tall × 12-inch wide × 0.08-inch thick aluminum sign panel
Soil Type and Condition	Embedded 36 inches in AASHTO M147-65(2004), grading B Soil (crushed limestone)
Test Vehicle	
Type/Designation	2270P
Make and Model	2011 Dodge RAM 1500
Curb	4749 lb
Test Inertial	5025 lb
Dummy	No dummy
Gross Static	5025 lb

Impact Conditions	
Speed	63.1 mi/h
Angle	0°
Location/Orientation	Left qtr-pt aligned with centerline
Kinetic Energy	669 kip-ft
Exit Conditions	
Speed	62.6 mi/h
Angle	0°
Occupant Risk Values	
Longitudinal OIV	No contact
Lateral OIV	No Contact
Longitudinal Ridedown	NA
Lateral Ridedown	NA
THIV	NA
PHD	NA
ASI	0.08
Max. 0.050-s Average	
Longitudinal	-0.2 g
Lateral	-0.6 g
Vertical	0.4 g

Post-Impact Trajectory	
Stopping Distance	300 ft
Vehicle Stability	
Maximum Yaw Angle	3.0°
Maximum Pitch Angle	0.6°
Maximum Roll Angle	2.0°
Debris Scatter	300 ft x 6 ft
Vehicle Damage	
VDS	12FL1
CDC	12FLEN1
Max. Exterior Deformation	Not measureable
OCDI	FS0000000
Max. Occupant Compartment Deformation	None

Figure 5.8. Summary of Results for *MASH* Test 3-62 at 0° on the TxDOT Single Embedded Wood Post Sign System.

Table 5.3. Performance Evaluation Summary for *MASH* Test 3-62 at 0° on the TxDOT Single Embedded Wood Sign System.

Test Agency: Texas A&M Transportation Institute | Test No.: 469467-6-1 | Test Date: 2017-08-22

***MASH* Test 3-62 Evaluation Criteria**	**Test Results**	**Assessment**
Structural Adequacy *B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*	The TxDOT single embedded wood post sign system fractured as designed.	Pass
Occupant Risk *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	No occupant compartment deformation or intrusion occurred.	
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 2.0° and 0.6°, respectively.	Pass
H. Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s, or maximum allowable value of 16 ft/s.	No occupant contact occurred.	Pass
I. The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	No occupant contact occurred.	Pass
Vehicle Trajectory *N. Vehicle trajectory behind the test article is acceptable.*	The 2270P vehicle came to rest 300 ft downstream of impact.	Pass

5.2.3 *MASH* Test 3-62 at 90°

5.2.3.1 System Details

The test installation consisted of a single aluminum sign mounted on a single dimensional lumber 4×4 pressure treated Southern Yellow Pine post. The test sign panel measured 18 inches tall × 24 inches wide and was fabricated from 0.080-inch thick aluminum. This represented an END DETOUR sign (M4-8a). The sign was installed with a mounting height of 7 ft from the ground to the bottom edge of the sign panel.

The sign was attached to the post with two F3125/A325 Grade 5 steel ⅜-inch diameter, 4½-inch long hex bolts with flat washers, lock washers, and nuts through two $^{7}/_{16}$-inch diameter holes drilled in the post a distance of 3 inches from the top and bottom edges of the sign panel.

The overall length of the wooden support post was 11 ft-6 inches. The post was embedded 36 inches deep in soil that met grading B of AASHTO standard specifications M147-65(2004) for "Materials for Aggregate and Soil Aggregate Subbase, Base and Surface Courses."

Figure 5.9 presents details of the TxDOT single embedded wood post sign system for 0° impact, and Figure 5.10 provides photographs of the completed test installation.

5.2.3.2 Test Designation and Actual Impact Conditions

MASH Test 3-62 involves a 2270P vehicle weighing 5000 lb ±110 lb impacting the TxDOT single embedded wood post sign system at an impact speed of 62 mi/h ±2.5 mi/h. For this test, the target impact angle was 90° ±1.5°. The centerline of the support system was aligned with the right quarter point of the vehicle.

The 2011 Dodge RAM 1500 pickup truck used in the test weighed 5025 lb, and the actual impact speed and angle were 63.2 mi/h and 90°, respectively. The actual impact point was the centerline of the support aligned with the left quarter point of the vehicle. Minimum target KE was 594 kip-ft, and actual KE was 671 kip-ft.

5.2.3.3 Test Vehicle

The 2011 Dodge RAM 1500 pickup truck shown in Figures 5.11 and 5.12, and used in the previous test, was used for the crash test. The vehicle's test inertia weight was 5025 lb, and its gross static weight was 5025 lb. The height to the lower edge of the vehicle bumper was 11.0 inches, and height to the upper edge of the bumper was 26.50 inches. The height to the vehicle's center of gravity was 28.0 inches. Table D.4 and D.5 in Appendix D.2 give additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

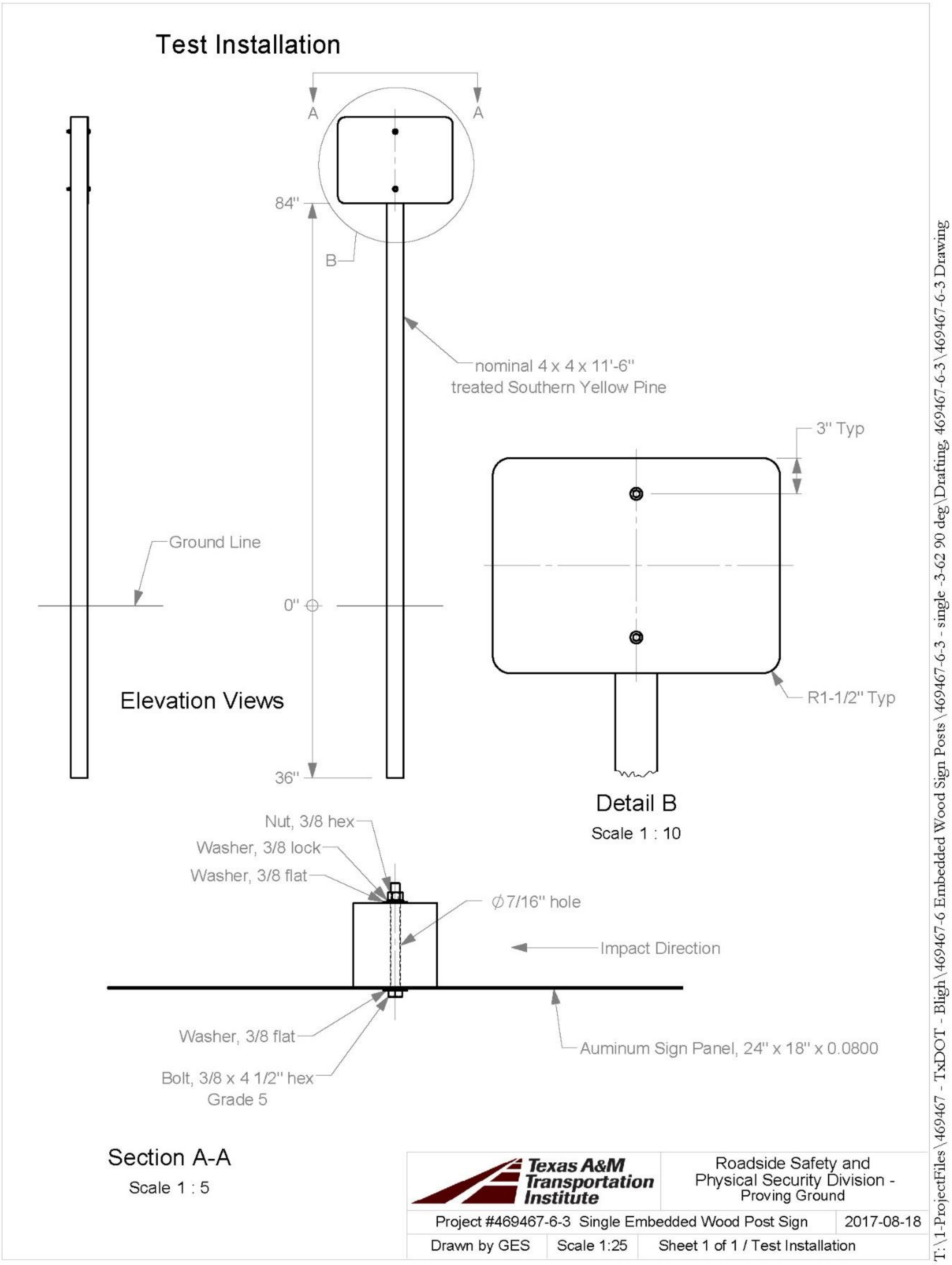


Figure 5.9. Overall Details of the TxDOT Single Embedded Wood Post Installation for 90° Impact.

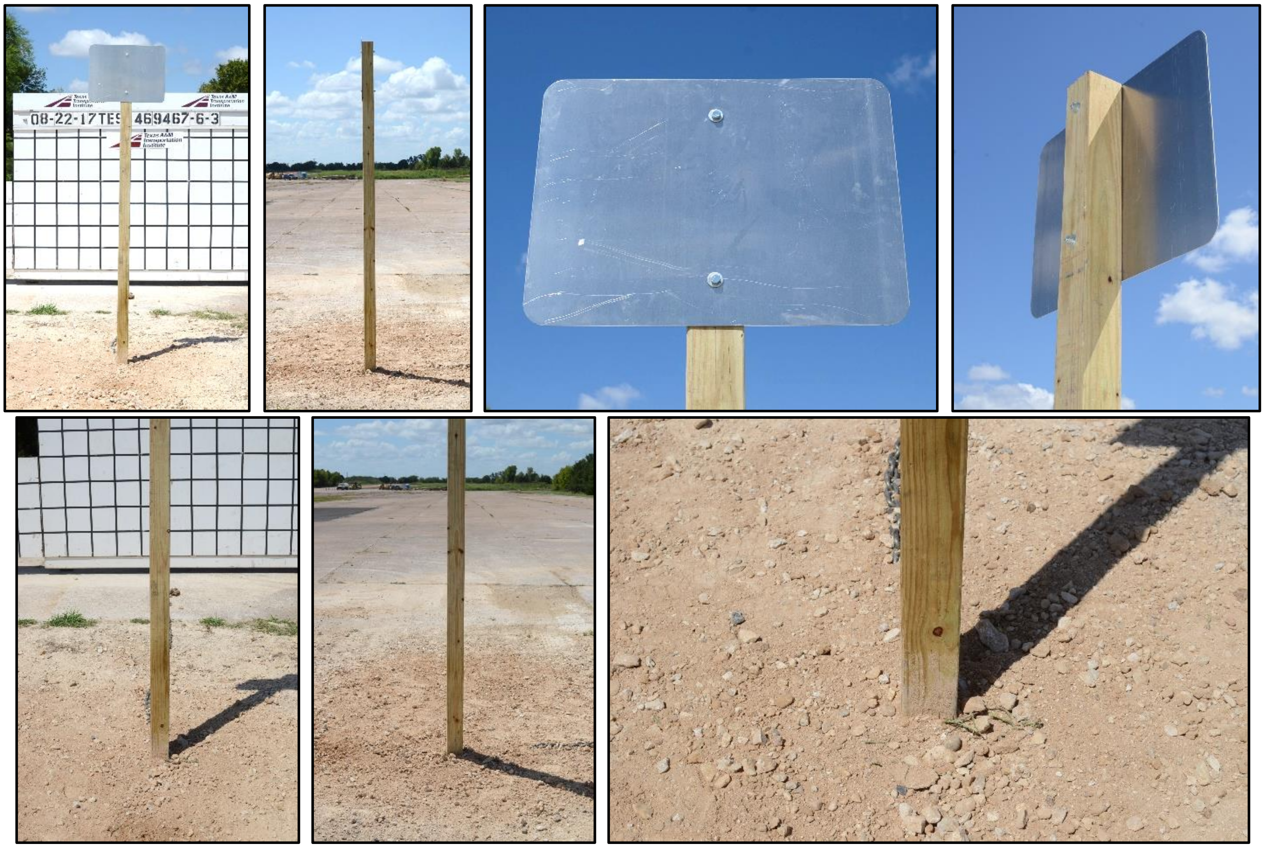


Figure 5.10. TxDOT Single Embedded Wood Post Sign System for 0° Impact prior to Testing.

Figure 5.11. Test Installation/Test Vehicle Geometrics for Test No. 469467-6-3.

Figure 5.12. Test Vehicle before Test No. 469467-6-3.

5.2.3.4 Weather Conditions

The test was performed on the afternoon of August 22, 2017. Weather conditions at the time of testing were as follows: wind speed: 3 mi/h; wind direction: 304° (vehicle was traveling in a southerly direction); temperature: 90°F; relative humidity: 60 percent.

5.2.3.5 Test Description

The test vehicle, traveling at an impact speed of 63.2 mi/h, contacted the TxDOT single embedded wood post system with the centerline of the support aligned with the right quarter point of the vehicle at an impact angle of 90°. Table 5.4 lists times and events that occurred during Test No. 469467-6-3. Figure D.9 in Appendix D.2 presents sequential photographs during the test.

Table 5.4. Events during Test No. 469467-6-3.

TIME (s)	EVENT
0.002	Post begins to deflect at bumper
0.003	Post impacts hood
0.004	Post begins to fracture at top of bumper
0.008	Sign panel begins to rotate toward vehicle
0.012	Post fully fractured at bumper height
0.026	Lower section of post fractured at ground
0.034	Vehicle loses contact with post while traveling at 63.2 mi/h
0.052	Corner of sign panel contacts windshield
0.056	Windshield begins to shatter
0.079	Sign panel completely inside vehicle while the bottom post continues to rotate upward/clockwise

Brakes on the vehicle were applied at 1.2 s after impact. The vehicle subsequently came to rest 355 ft downstream of the impact.

4.2.3.6 Damage to Test Installation

Figure 5.13 shows the damage to the TxDOT single embedded wood sign system. The wood post fractured in two places. A 32-inch long section was resting 155 ft upstream of impact and 11 ft to the left of centerline. An 80-inch section with the sign panel attached was embedded in the windshield of the vehicle.

Figure 5.13. TxDOT Single Embedded Wood Post System for 90° Impact after Test No. 469467-6-3.

4.2.3.7 Damage to Test Vehicle

Figure 5.14 shows damage sustained by the vehicle. The front bumper and hood had a small dent at the quarter point. The sign panel and support tore a 20 × 20-inch hole in the windshield just left of centerline. The sign panel and support also caused damage to the instrument panel, glove box, and roof. Maximum exterior crush to the vehicle was not measureable in the front plane at the left quarter point at bumper height. Penetration of the windshield occurred. Figure 5.15 shows the interior of the vehicle. Table D.6 in Appendix D.2 provides occupant compartment measurements.

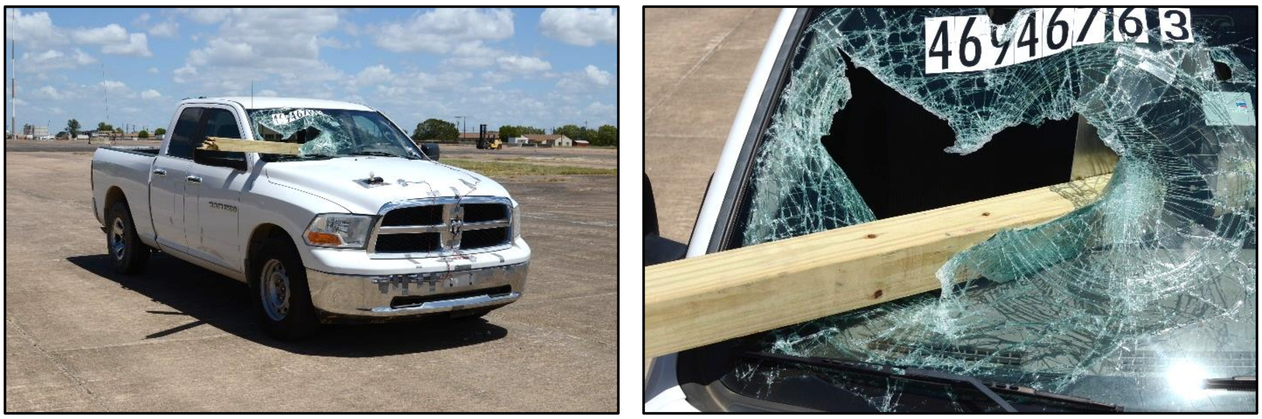


Figure 5.14. Test Vehicle after Test No. 469467-6-3.

Before Test After Test

Figure 5.15. Interior of Test Vehicle for Test No. 469467-6-3.

5.2.3.8 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk and are shown in Table 5.5. Figure 5.16 summarizes these data and other pertinent information from the test. Figure D.10 in Appendix D.2 shows the vehicle angular displacements, and Figures D.11 through D.16 in Appendix D.2 show vehicle acceleration versus time traces.

Table 5.5. Occupant Risk Factors for Test No. 469467-6-3.

Occupant Risk Factor	Value	Time
OIV	**No Contact**	
Occupant Ridedown Accelerations	**NA**	
THIV	**NA**	
PHD	**NA**	
ASI	**0.05**	0.1146–0.1646 s
Maximum 50-ms Moving Average		
Longitudinal	**−0.3 g**	0.1102–0.1602 s
Lateral	**0.3 g**	0.1521–0.2021 s
Vertical	**0.7 g**	0.1006–0.1506 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	**2.8**	0.8847 s
Pitch	**3.2**	0.1875 s
Yaw	**2.6**	0.7212 s

5.2.3.9 Assessment of Results

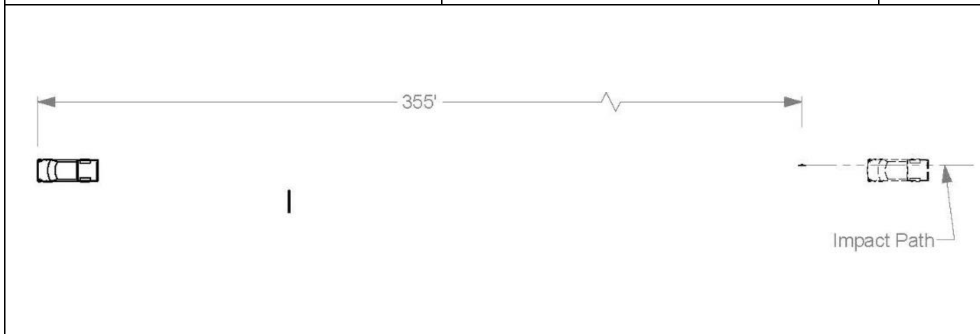
An assessment of the test on the TxDOT single embedded wood post sign system for 90° impact based on the applicable safety evaluation criteria for *MASH* Test 3-62 is provided in Table 5.6.

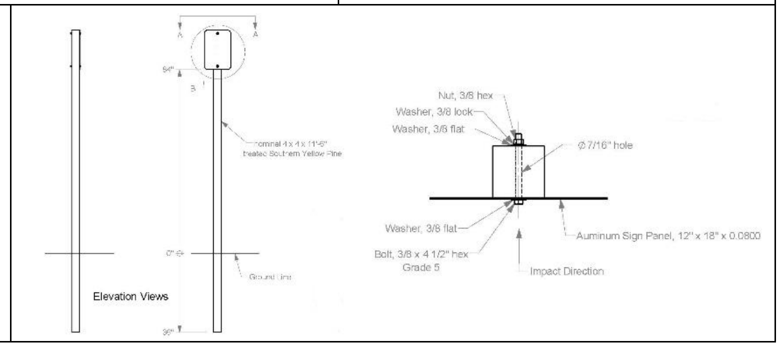
5.2.3.10 Conclusions

The TxDOT single embedded wood post sign system for 90° impact fractured as designed. An 80-inch section of wood post and the sign panel penetrated through the windshield. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 2.8° and 3.2°, respectively. No occupant contact occurred. The 2270P vehicle came to rest 355 ft downstream of impact.

The support post fractured near ground line and at bumper height. The fractured support and sign panel then rotated into the vehicle windshield, resulting in penetration of the windshield. The TxDOT single embedded wood post sign system did not perform acceptably for *MASH* Test 3-62 at 90° due to penetration of the windshield.

0.000 s | 0.025 s | 0.050 s | 0.100 s





General Information
- Test Agency: Texas A&M Transportation Institute (TTI)
- Test Standard Test No.: *MASH* Test 3-62
- TTI Test No.: 469467-6-3
- Test Date: 2017-08-22

Test Article
- Type: Sign Support
- Name: TxDOT Single Embedded Wood Post
- Installation Height: 7 ft to bottom of sign panel
- Material or Key Elements: 11 ft-6 inch long 4×4 pressure treated post with 18-inch tall × 24-inch wide × 0.08-inch thick aluminum sign panel

Soil Type and Condition: Embedded 36 inches in AASHTO M147-65(2004), grading B Soil (crushed limestone)

Test Vehicle
- Type/Designation: 2270P
- Make and Model: 2011 Dodge RAM 1500
- Curb: 4749 lb
- Test Inertial: 5025 lb
- Dummy: No dummy
- Gross Static: 5025 lb

Impact Conditions
- Speed: 63.2 mi/h
- Angle: 90°
- Location/Orientation: Right qtr-pt aligned with centerline

Kinetic Energy: 671 kip-ft

Exit Conditions
- Speed: 63.2 mi/h
- Angle: 90°

Occupant Risk Values
- Longitudinal OIV: No contact
- Lateral OIV: No Contact
- Longitudinal Ridedown: NA
- Lateral Ridedown: NA
- THIV: NA
- PHD: NA
- ASI: 0.05
- Max. 0.050-s Average
  - Longitudinal: -0.3 g
  - Lateral: 0.3 g
  - Vertical: 0.7 g

Post-Impact Trajectory
- Stopping Distance: 355 ft

Vehicle Stability
- Maximum Yaw Angle: 2.6°
- Maximum Pitch Angle: 3.2°
- Maximum Roll Angle: 2.8°

Debris Scatter: 355 ft x 11 ft

Vehicle Damage
- VDS: 12FR1
- CDC: 12FREN1
- Max. Exterior Deformation: Not measureable
- OCDI: NA
- Max. Occupant Compartment Deformation: Windshield penetration

Figure 5.16. Summary of Results for *MASH* Test 3-62 at 90° on the TxDOT Single Embedded Wood Post Sign System.

Table 5.6. Performance Evaluation Summary for *MASH* Test 3-62 at 90° on the TxDOT Single Embedded Wood Post Sign System.

Test Agency: Texas A&M Transportation Institute | Test No.: 469467-6-3 | Test Date: 2017-08-22

MASH Test 3-62 Evaluation Criteria	Test Results	Assessment
Structural Adequacy *B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*	The TxDOT single embedded wood post sign system fractured as designed.	Pass
Occupant Risk *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	An 80-inch section of wood post and the sign panel penetrated through the windshield.	Fail
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	Penetration of the windshield by wood post and sign panel.	
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 2.8° and 3.2°, respectively.	Pass
H. Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s, or maximum allowable value of 16 ft/s.	No occupant contact occurred.	Pass
I. The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	No occupant contact occurred.	Pass
Vehicle Trajectory *N. Vehicle trajectory behind the test article is acceptable.*	The 2270P vehicle came to rest 355 ft downstream of impact.	Pass

5.3 DUAL EMBEDDED WOOD POST SYSTEM

5.3.1 System Details

The test installation consisted of a single aluminum sign mounted on two-dimensional lumber 4×4 pressure treated Southern Yellow Pine posts that were spaced 24 inches apart. The sign panel measured 48 inches tall × 36 inches wide and was fabricated from 0.100-inch thick aluminum. This represented a SPEED LIMIT sign (R2-1). The sign was mounted at a height of 7 ft from the ground to the bottom of the sign.

The sign was attached to each post with two F3125/A325 Grade 5 steel ⅜-inch diameter, 4½-inch long hex bolts with flat washers, lock washers, and nuts through two $^{7}/_{16}$-inch diameter holes located 3 inches from the top and bottom edges of the sign panel.

The overall length of each wooden support post was 14 ft. The posts were installed 36 inches deep in soil that met grading B of AASHTO standard specifications M147-65(2004) for "Materials for Aggregate and Soil Aggregate Subbase, Base and Surface Courses."

Figure 5.17 presents details of the TxDOT dual embedded wood post sign system, and Figure 5.18 provides photographs of the completed test installation.

5.3.2 *MASH* Test 3-62 at 0°

5.3.2.1 Test Designation and Actual Impact Conditions

MASH Test 3-62 involves a 2270P vehicle weighing 5000 lb ±110 lb impacting the TxDOT single embedded wood post sign system at an impact speed of 62 mi/h ±2.5 mi/h. For this test, the target impact angle was 0° ±1.5°, which enabled the vehicle to impact both posts simultaneously and maximize the potential for secondary contact between the vehicle windshield and components of the sign support system. The centerline of the supports was aligned with the centerline of the vehicle.

The 2011 Dodge RAM 1500 pickup truck used in the test weighed 5025 lb, and the actual impact speed and angle were 62.7 mi/h and 0°, respectively. The actual impact point was the centerline of the support aligned with the centerline of the vehicle. Minimum target KE was 594 kip-ft, and actual KE was 660 kip-ft.

5.3.2.2 Test Vehicle

The 2011 Dodge RAM 1500 pickup truck shown in Figures 5.19 and 5.20, and used in the previous two tests, was used for the crash test. The windshield was replaced. The vehicle's test inertia weight was 5025 lb, and its gross static weight was 5025 lb. The height to the lower edge of the vehicle bumper was 11.00 inches, and height to the upper edge of the bumper was 26.50 inches. The height to the vehicle's center of gravity was 28.0 inches. Tables D.7 and D.8 in Appendix D.3 give additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

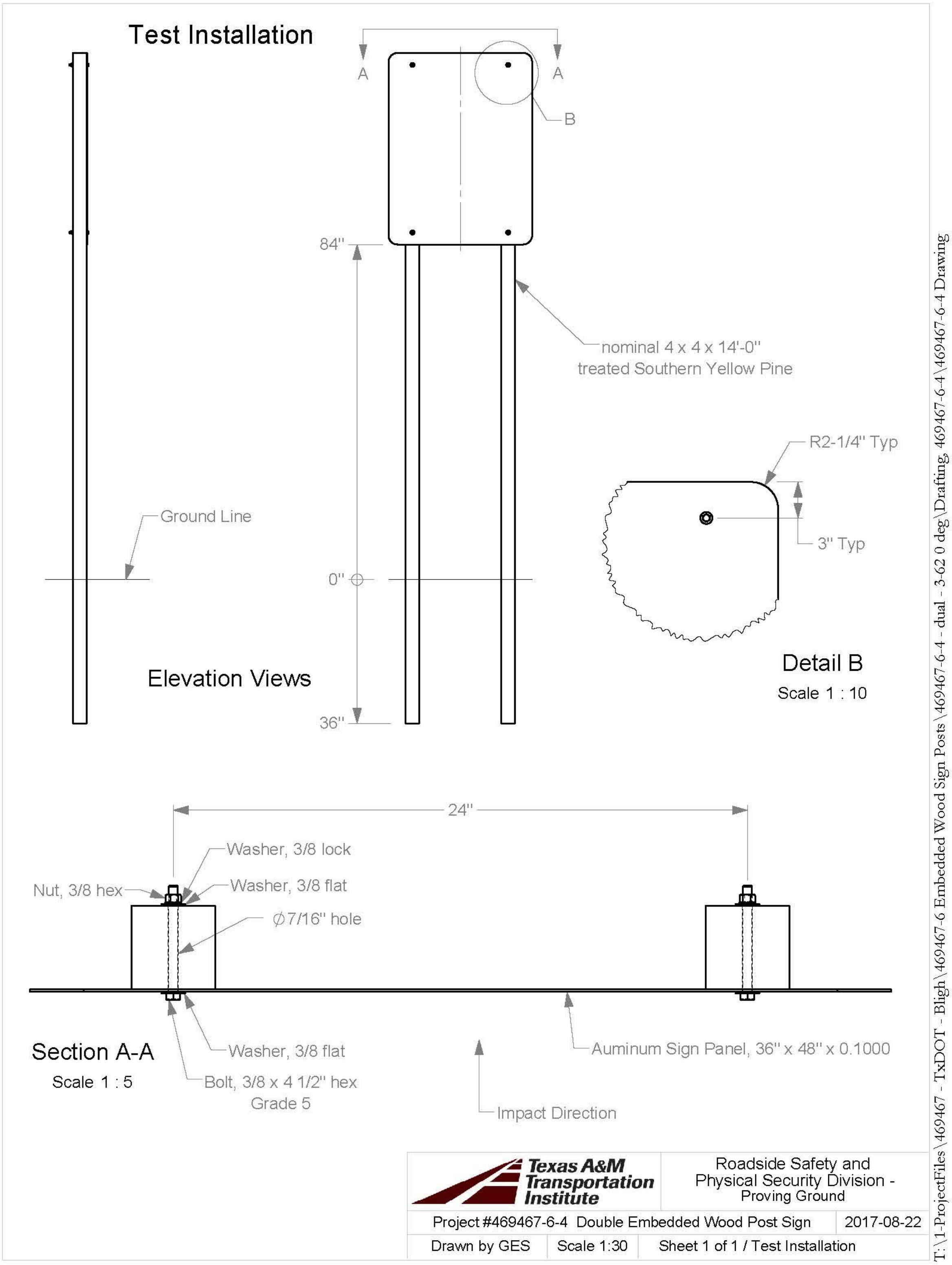


Figure 5.17. Overall Details of the TxDOT Dual Embedded Wood Post Installation.

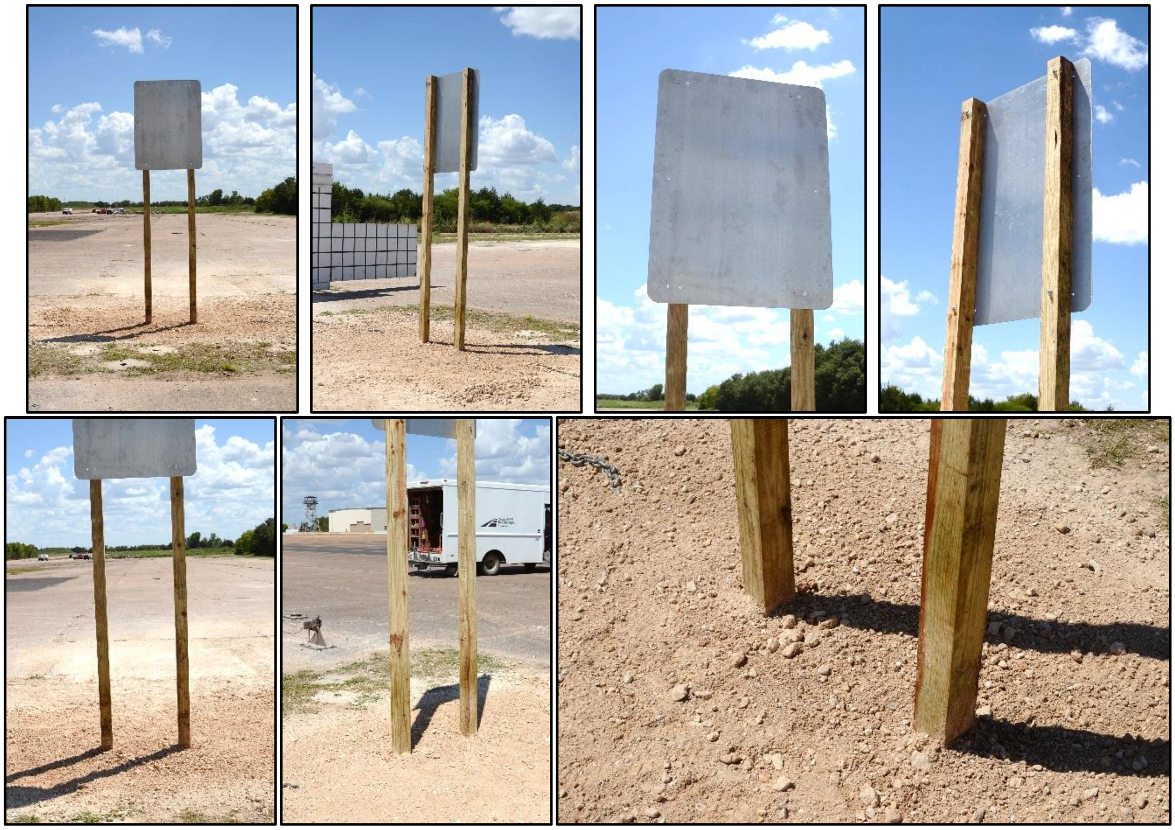


Figure 5.18. TxDOT Dual Embedded Wood Post Sign System prior to Testing.

Figure 5.19. TxDOT Dual Embedded Wood Post System/Test Vehicle Geometrics for Test No. 469467-6-4.

Figure 5.20. Test Vehicle before Test No. 469467-6-4.

5.3.2.3 Weather Conditions

The test was performed on the afternoon of August 22, 2017. Weather conditions at the time of testing were as follows: wind speed: 5 mi/h; wind direction: 103° (vehicle was traveling in a southerly direction); temperature: 98°F; relative humidity: 40 percent.

5.3.2.4 Test Description

The test vehicle, traveling at an impact speed of 62.7 mi/h, contacted the TxDOT dual embedded wood post system with the centerline of the supports aligned with the centerline of the vehicle at an impact angle of 0°. Table 5.7 lists times and events that occurred during Test No. 469467-6-4. Figure D.17 in Appendix D.3 presents sequential photographs during the test.

Table 5.7. Events during Test No. 469467-6-4.

TIME (s)	EVENT
0.0020	Posts begin to deflect at bumper
0.0040	Posts impacts hood
0.0050	Posts fractures just above bumper
0.0100	Top of posts begins to rotate toward vehicle
0.0170	Lower sections of posts fracture just below grade
0.0340	Vehicle loses contact with supports while traveling at 61.75 mi/h
0.0830	Sign panel and upper supports contact roof
0.1290	Sign panel and upper supports lose contact with roof

Brakes on the vehicle were applied at 1.6 s after impact. The vehicle subsequently came to rest 370 ft downstream of the impact.

5.3.2.5 Damage to Test Installation

Figure 5.21 shows the damage to the TxDOT dual embedded wood sign system. Both posts fractured at ground level. The stubs appeared to have displaced 0.38 inch downstream of the original location. A 32-inch long section of the right post was resting 42 ft downstream of impact. The remaining sections of both posts still attached to the sign panel were resting 115 ft downstream and 12 ft to the right of centerline.

Figure 5.21. TxDOT Single Embedded Wood Post System after Test No. 469467-6-4.

5.3.2.6 Damage to Test Vehicle

Figures 5.22 and 5.23 show damage sustained by the vehicle. The front bumper and hood had small dents at the left quarter point and to the right of centerline. The exterior roof was depressed over an area of 50 inches × 50 inches had a maximum depth of 3.0 inches. Maximum occupant compartment deformation was 3.0 inches in the center of the roof. Figure 5.24 shows the interior of the vehicle. Table D.9 in Appendix D.3 provides occupant compartment measurements.

Figure 5.22. Test Vehicle after Test No. 469467-6-4.

Figure 5.23. Test Vehicle Roof Damage after Test No. 469467-6-4.

Figure 5.24. Interior of Test Vehicle after Test No. 469467-6-4.

5.3.2.7 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk and are shown in Table 5.8. Figure 5.25 summarizes these data and other pertinent information from the test. Figure D.18 in Appendix D.3 shows the vehicle angular displacements, and Figures D.19 through D.24 in Appendix D.3 show vehicle acceleration versus time traces.

Table 5.8. Occupant Risk Factors for Test No. 469467-6-4.

Occupant Risk Factor	Value	Time
OIV	**No Contact**	
Occupant Ridedown Accelerations	**NA**	
THIV	**NA**	
PHD	**NA**	
ASI	**0.13**	0.0878–0.1378 s
Maximum 50-ms Moving Average		
Longitudinal	**−0.6 g**	0.0749–0.1249 s
Lateral	**0.8 g**	0.6850–0.7350 s
Vertical	**−1.6 g**	0.1010–0.1510 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	**2.5**	0.7594 s
Pitch	**1.3**	0.8867 s
Yaw	**1.3**	1.0000 s

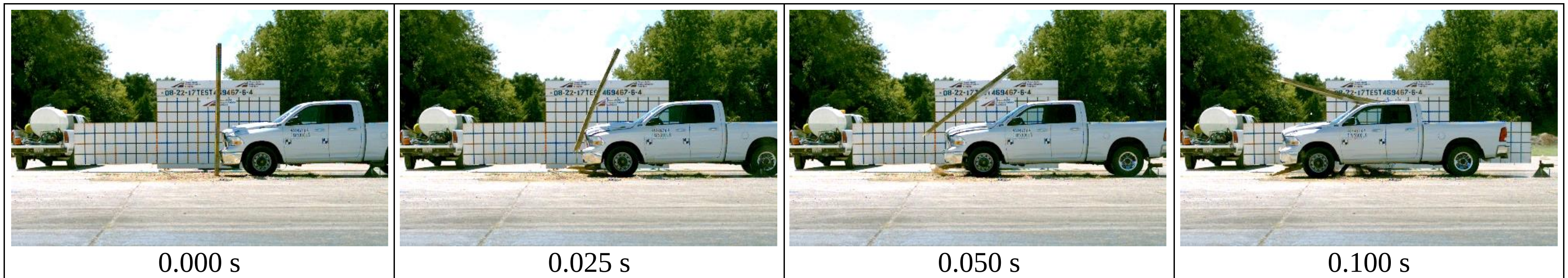
5.3.8 Assessment of Results

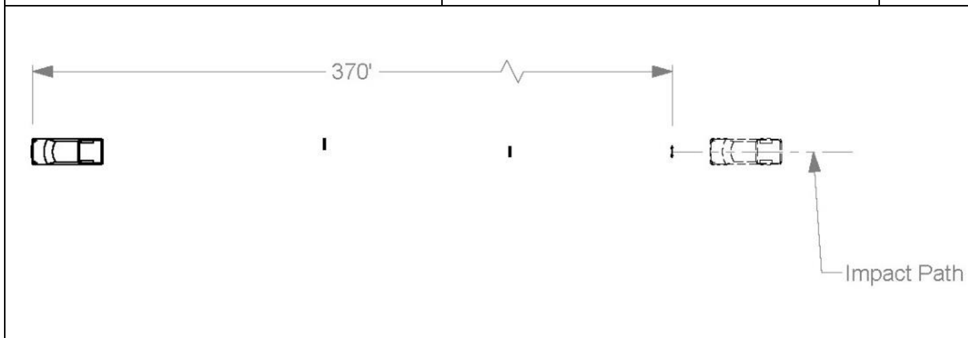
An assessment of the test on the TxDOT dual embedded wood post sign system based on the applicable safety evaluation criteria for *MASH* Test 3-62 is provided in Table 5.9.

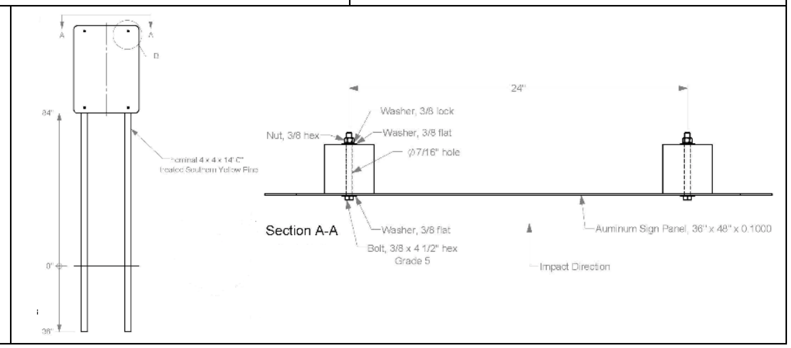
5.3.2.9 Conclusions

The TxDOT dual embedded wood post sign system fractured as designed. None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area. Maximum occupant compartment deformation was 3.0 inches in the center roof area. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 2.5° and 1.3°, respectively. No occupant contact occurred. The 2270P vehicle came to rest 370 ft downstream of impact.

The supports fractured in two locations (near ground level and at bumper height). The sign panel and fractured support posts rotated toward the vehicle and impacted the roof. Roof deformation was within the limits recommended in *MASH*. The TxDOT dual embedded wood post sign system performed acceptably for *MASH* Test 3-62 at 0°.







General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-62
TTI Test No.	469467-6-4
Test Date	2017-08-22

Test Article

Type	Sign Support
Name	TxDOT Dual Embedded Wood Post
Installation Height	7 ft to bottom of sign panel
Material or Key Elements	Two 14-ft long 4×4 pressure treated post spaced 24 inches apart with 48-inch tall × 36-inch wide × 0.10-inch thick aluminum sign panel

Soil Type and Condition	Embedded 36 inches in AASHTO M147-65(2004), grading B Soil (crushed limestone)

Test Vehicle

Type/Designation	2270P
Make and Model	2011 Dodge RAM 1500
Curb	4749 lb
Test Inertial	5025 lb
Dummy	No dummy
Gross Static	5025 lb

Impact Conditions

Speed	62.7 mi/h
Angle	0°
Location/Orientation	Centerline aligned w/centerline supports

Kinetic Energy	660 kip-ft

Exit Conditions

Speed	61.8 mi/h
Angle	0°

Occupant Risk Values

Longitudinal OIV	No contact
Lateral OIV	No Contact
Longitudinal Ridedown	NA
Lateral Ridedown	NA
THIV	NA
PHD	NA
ASI	0.13
Max. 0.050-s Average	
Longitudinal	-0.6 g
Lateral	0.8 g
Vertical	-1.6 g

Post-Impact Trajectory

Stopping Distance	370 ft

Vehicle Stability

Maximum Yaw Angle	1.3°
Maximum Pitch Angle	1.3°
Maximum Roll Angle	2.5°

Debris Scatter	370 ft x 16 ft

Vehicle Damage

VDS	12FD2
CDC	12FDEW1
Max. Exterior Deformation	3.0 inches
OCDI	FS0100000
Max. Occupant Compartment Deformation	3.0 inches

Figure 5.25. Summary of Results for *MASH* Test 3-62 at 0° on the TxDOT Dual Embedded Wood Post Sign System.

Table 5.9. Performance Evaluation Summary for *MASH* Test 3-62 at 0° on the TxDOT Dual Embedded Wood Sign System.

Test Agency: Texas A&M Transportation Institute | Test No.: 469467-6-4 | Test Date: 2017-08-22

***MASH* Test 3-62 Evaluation Criteria**	**Test Results**	**Assessment**
Structural Adequacy *B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*	The TxDOT dual embedded wood post sign system fractured as designed.	Pass
Occupant Risk *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	Maximum occupant compartment deformation was 3.0 inches in the center roof area.	
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 2.5° and 1.3°, respectively.	Pass
H. Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s, or maximum allowable value of 16 ft/s.	No occupant contact occurred.	Pass
I. The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	No occupant contact occurred.	Pass
Vehicle Trajectory *N. Vehicle trajectory behind the test article is acceptable.*	The 2270P vehicle came to rest 370 ft downstream of impact.	Pass

5.3.3 *MASH* Test 3-61 at 0°

5.3.3.1 Test Designation and Actual Impact Conditions

MASH Test 3-61 involves an 1100C vehicle weighing 2420 lb ±55 lb impacting the TxDOT single embedded wood post sign system at an impact speed of 62 mi/h ±2.5 mi/h. For this test, the target impact angle was 0° ±1.5°, which enabled the vehicle to impact both posts simultaneously and maximize the potential for secondary contact between the vehicle windshield and components of the sign support system. The centerline of the support system was aligned with the right quarter point of the vehicle.

The 2011 Kia Rio used in the test weighed 2429 lb, and the actual impact speed and angle were 63.6 mi/h and 0°, respectively. The actual impact point was the centerline of the support aligned with the right quarter point of the vehicle. Minimum KE was 288 kip-ft, and actual KE was 328 kip-ft.

5.3.3.2 Test Vehicle

The 2011 Kia Rio, shown in Figures 5.26 and 5.27, was used for the crash test. The vehicle's test inertia weight was 2429 lb, and its gross static weight was 2594 lb. The height to the lower edge of the vehicle bumper was 7.75 inches, and height to the upper edge of the bumper was 21.0 inches. Table D.10 in Appendix D.4 gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

Figure 5.26. Test Installation/Test Vehicle Geometrics for Test No. 469467-6-2.

Figure 5.27. Test Vehicle before Test No. 469467-6-2.

5.3.3.3 Weather Conditions

The test was performed on the afternoon of August 23, 2017. Weather conditions at the time of testing were as follows: wind speed: 4 mi/h; wind direction: 350° (vehicle was traveling in a southerly direction); temperature: 97°F; relative humidity: 44 percent.

5.3.3.4 Test Description

The test vehicle, traveling at an impact speed of 63.6 mi/h, contacted the TxDOT dual embedded wood post system with the centerline of the right support aligned with the right quarter point of the vehicle at an impact angle of 0°. Table 5.10 lists times and events that occurred during Test No. 469467-6-2. Figure D.25 in Appendix D.4 presents sequential photographs during the test.

Table 5.10. Events during Test No. 469467-6-2.

TIME (s)	EVENT
0.003	Left post fractures midway up/right post fractures at bumper height
0.005	Left post fractures at bumper height/right post fractures midway up
0.032	Top of lower section of left post contacts hood
0.058	Bottom of upper sections with sign panel contacts windshield
0.061	Top of lower section of right post contacts hood
0.068	Right post fractures below sign panel
0.070	Bottom of upper segments with sign panel contact roof
0.104	Supports lose contact with roof while vehicle traveling @ 63.0 mi/h

Brakes on the vehicle were applied at 1.1 s after impact. The vehicle subsequently came to rest 284 ft downstream of the impact.

5.3.3.5 Damage to Test Installation

Figure 5.28 shows the damage to the TxDOT dual embedded wood sign system. The sign panel attached to an 80-inch section of the left post and a 54-inch section of the right post came to rest near impact. The left support post fractured into three pieces. An upper 80-inch long section remained attached the sign panel. A lower 24-inch long section, which included 6-inches below grade and 18 inches above grade, came to rest 25 ft downstream and 8 ft to the left of centerline. The middle 34-inch long section came to rest 121 ft downstream and 3 ft to the left of centerline. The right support post fractured into four sections. The uppermost 54-inch long section remained attached to the sign panel. The bottom 21-inch section, which included 3 inches below grade and 18 inches above grade, came to rest 55 ft downstream and 7 ft to the left of centerline. A 32-inch long section of the right post came to rest 95 ft downstream and 2 ft to the left of centerline. A 25-inch long section of the right post came to rest 175 ft downstream and 3 ft to the right of centerline.

Figure 5.28. TxDOT Dual Embedded Wood Post System after Test No. 469467-6-2.

5.3.3.6 Damage to Test Vehicle

Figure 5.29 shows damage sustained by the vehicle. The front bumper and hood had a small dent at the right quarter point and just to the left of centerline. The sign panel and supports contacted the windshield and punctured a 2-inch × 4-inch hole in the windshield adjacent to the roof on the right side. The windshield was pushed inward toward the occupant compartment 1.5 inches. Maximum exterior crush to the vehicle was not measureable in the front plane at the left quarter point at bumper height. Penetration of the windshield occurred. Figure 5.30 shows the interior of the vehicle. Table D.11 in Appendix D.4 provides occupant compartment measurements.

Figure 5.29. Test Vehicle after Test No. 469467-6-2.

Before Test After Test

Figure 5.30. Interior of Test Vehicle for Test No. 469467-6-2.

5.2.3.7 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk and are shown in Table 5.11. Figure 5.31 summarizes these data and other pertinent information from the test. Figure D.26 in Appendix D.4 shows the vehicle angular displacements, and Figures D.27 through D.32 in Appendix D.4 show vehicle acceleration versus time traces.

Table 5.11. Occupant Risk Factors for Test No. 469467-6-2.

Occupant Risk Factor	Value	Time
OIV		
Longitudinal	**1.0 ft/s**	at 0.9324 s on left side of interior
Lateral	**2.0 ft/s**	
Occupant Ridedown Accelerations		
Longitudinal	**0.2 g**	0.9352–0.9452 s
Lateral	**0.3 g**	0.9412–0.9512 s
THIV	**2.4 km/h** **0.7 m/s**	at 0.9314 s on left side of interior
PHD	**0.3 g**	0.9414–0.9514 s
ASI	**0.06**	0.0015–0.0515 s
Maximum 50-ms Moving Average		
Longitudinal	**−0.5 g**	0.0012–0.0512 s
Lateral	**−0.3 g**	0.0083–0.0583 s
Vertical	**0.5 g**	0.0152–0.0652 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	**1.7°**	0.6511 s
Pitch	**2.8°**	1.0000 s
Yaw	**3.4°**	0.1131 s

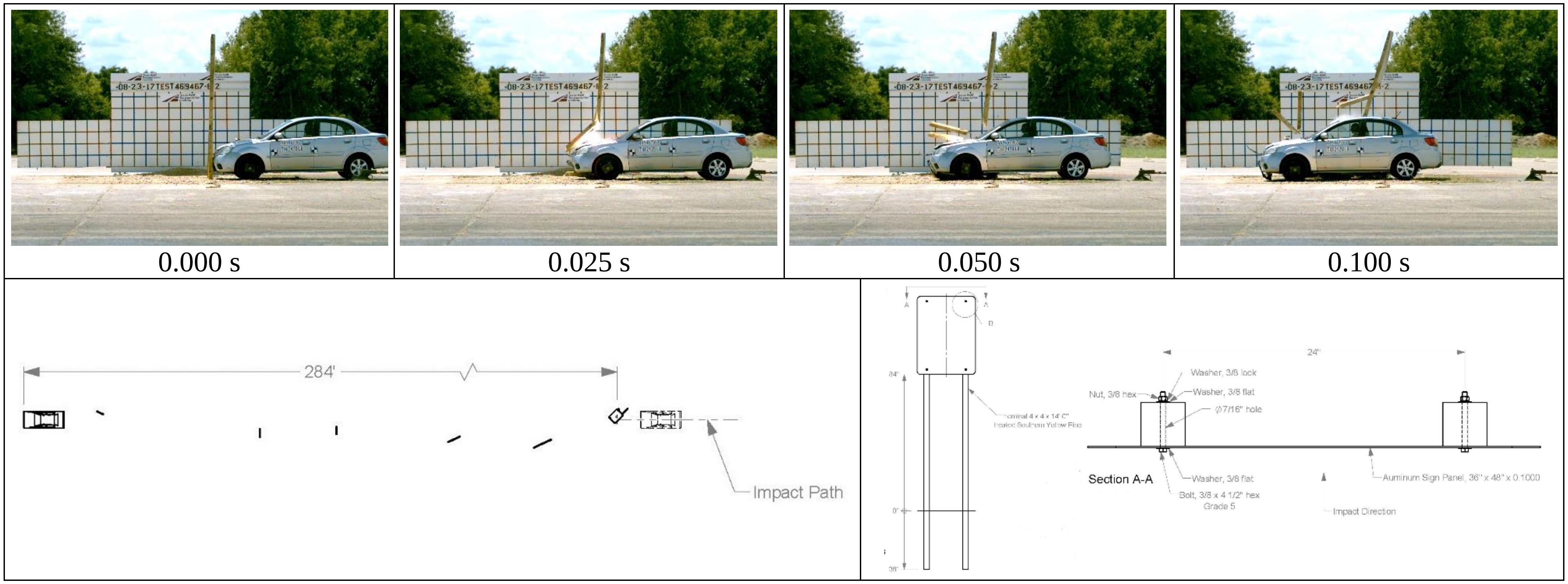
5.2.8 Assessment of Results

An assessment of the test on the TxDOT dual embedded wood post sign system based on the applicable safety evaluation criteria for *MASH* Test 3-61 is provided in Table 5.12.

5.3.2.9 Conclusions

The TxDOT dual embedded wood post sign system fractured as designed. The sign panel and portions of the wood post contacted the windshield and punctured a hole adjacent to the roof line. The windshield was shattered, depressed inward toward the occupant compartment 1.5 inches, and punctured near the roof line on the right side. The 1100V vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.7° and 2.8°, respectively. Occupant risk factors were within the preferable limits specified in *MASH*. The 1100C vehicle came to rest 284 ft downstream of impact.

Both support posts fractured at bumper height, and as the vehicle continued to move forward, the fractured end of the right support contacted and punctured the windshield. The TxDOT dual embedded wood post sign system did not perform acceptably for *MASH* Test 3-61 at 0° due to puncture of the windshield.



General Information
Test Agency .... Texas A&M Transportation Institute (TTI)
Test Standard Test No. .... *MASH* Test 3-62
TTI Test No. 469467-6-2
Test Date 2017-08-22

Test Article
Type .... Sign Support
Name .... TxDOT Dual Embedded Wood Post
Installation Height .... 7 ft to bottom of sign panel
Material or Key Elements .... Two 14-ft long 4×4 pressure treated post spaced 24 inches apart with 48-inch tall × 36-inch wide × 0.10-inch thick aluminum sign panel

Soil Type and Condition .... Embedded 36 inches in AASHTO M147-65(2004), grading B Soil (crushed limestone)

Test Vehicle
Type/Designation 1100C
Make and Model .... 2011 Kia Rio
Curb .... 2460 lb
Test Inertial .... 2429 lb
Dummy .... 165 lg
Gross Static .... 2594 lb

Impact Conditions
Speed .... 63.6 mi/h
Angle .... 0°
Location/Orientation .... Right qtr-pt aligned with right support

Kinetic Energy .... 328 kip-ft

Exit Conditions
Speed .... 63.0 mi/h
Angle .... 0°

Occupant Risk Values
Longitudinal OIV .... 1.0 ft/s
Lateral OIV .... 2.0 ft/s
Longitudinal Ridedown .... 0.2 g
Lateral Ridedown .... 0.3 g
THIV .... 2.4 km/h
PHD .... 0.3 g
ASI 0.06
Max. 0.050-s Average
Longitudinal .... -0.5 g
Lateral .... -0.3 g
Vertical .... 0.5 g

Post-Impact Trajectory
Stopping Distance .... 284 ft

Vehicle Stability
Maximum Yaw Angle .... 3.4°
Maximum Pitch Angle .... 2.8°
Maximum Roll Angle .... 1.7°

Debris Scatter .... 284 ft x 11 ft

Vehicle Damage
VDS 12FD2
CDC 12FDEW2
Max. Exterior Deformation .... 1.5 inches
OCDI .... Penetrated
Max. Occupant Compartment Deformation .... 1.5 inches

Figure 5.31. Summary of Results for *MASH* Test 3-61 at 0° on the TxDOT Dual Embedded Wood Post Sign System.

Table 5.12. Performance Evaluation Summary for *MASH* Test 3-61 at 0° on the TxDOT Dual Embedded Wood Post Sign System.

Test Agency: Texas A&M Transportation Institute | Test No.: 469467-6-2 | Test Date: 2017-08-23

***MASH* Test 3-61 Evaluation Criteria**	**Test Results**	**Assessment**
Structural Adequacy *B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*	The TxDOT single embedded wood post sign system fractured as designed.	Pass
Occupant Risk *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	The sign panel and portions of the wood post contacted the windshield and punctured a hole adjacent to the roof line.	Fail
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	The windshield was shattered, depressed inward toward the occupant compartment 1.5 inches, and punctured near the roof line on the right side.	
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.7° and 2.8°, respectively.	Pass
H. Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s, or maximum allowable value of 16 ft/s.	Longitudinal OIV was 1.0 ft/s, and lateral OIV was 2.0 ft/s.	Pass
I. The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	Maximum longitudinal occupant ridedown acceleration was 0.2 g, and maximum lateral ridedown acceleration was 0.3 g.	Pass
Vehicle Trajectory *N. Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest 284 ft downstream of impact.	Pass

CHAPTER 6:
TXDOT PEDESTAL POLE WITH BEACONS

6.1 BACKGROUND

TxDOT standards for pedestal poles with beacons contain options for use with (SPRFBA(2)-13) and without (RFBA-13) a solar assembly attached to the support post. Both of these options were previously tested under *NCHRP Report 350* with a small passenger car at low and high speeds. Although the *MASH* small passenger car design has changed, its performance in frontal impacts with ground-mounted breakaway sign support systems is not expected to differ appreciably from the previous small car test vehicle. Therefore, only test designation 3-62 with the 2270P pickup truck was considered necessary for the evaluation of the pedestal pole with beacons. TTI performed a separate test for each configuration (i.e., with and without solar assembly attached to the support post). Each installation was installed on an existing concrete apron.

6.2 *MASH* TEST 3-62 ON THE PEDESTAL POLE WITH BEACONS WITHOUT SOLAR ASSEMBLY

6.2.1 Test Article and Installation Details

The 19 ft-4 inch–tall test article was comprised of a single 4-inch aluminum pole, two 12-inch beacon lights, a 48-inch diamond shaped sign panel, and a pedestal-style breakaway base. The total mass of the test article was approximately 145 lb including the base.

The test pole was an 18 ft long 4-inch Schedule 40 (4.5 inch outside diameter; 0.237 inch wall thickness) 6061-T6 aluminum pipe that was fitted with a pipe cap at the top. The sign panel measured 48-inches square and was manufactured of 0.125-inch thick aluminum sheet. Each of the two beacons (McCain) measured 13½ × 13½ × 6½ inches deep and contained a 12-inch diameter lens and associated sun shield. The sign panel and beacons were attached to the pole with 4½-inch wide U-bolts and aluminum brackets

The 16-inch tall breakaway base (Component Products, Inc. model CPI-BAS-1-P) was manufactured of cast aluminum and measured 14-inches square at the base, tapering to 12 inches square at the top. A 5¾-inch diameter collar at the top of the base accommodated the base-to-pole connection. The bottom of the base was set approximately 1½-inches above the concrete apron to which it was mounted.

Four ¾-inch diameter 10 national coarse (UNC) thread, 9-inch long threaded anchor rods (ASTM A193 grade B7) connected the breakaway base to the concrete apron. These rods were embedded 5 inches in the apron on a 9-inch square pattern (12¾-inch bolt circle diameter) and secured using Hilti HIT-HY-200-R epoxy per Hilti's installation instructions. The base was attached using two sets of ¾-inch heavy hex nuts, lock washers, and USS flat washers per anchor rod.

Figure 6.1 provides details of the pedestal pole with beacons without solar assembly. Figure 6.2 provides photographs of the completed test installation. Appendix E.1 provides material certification documents.

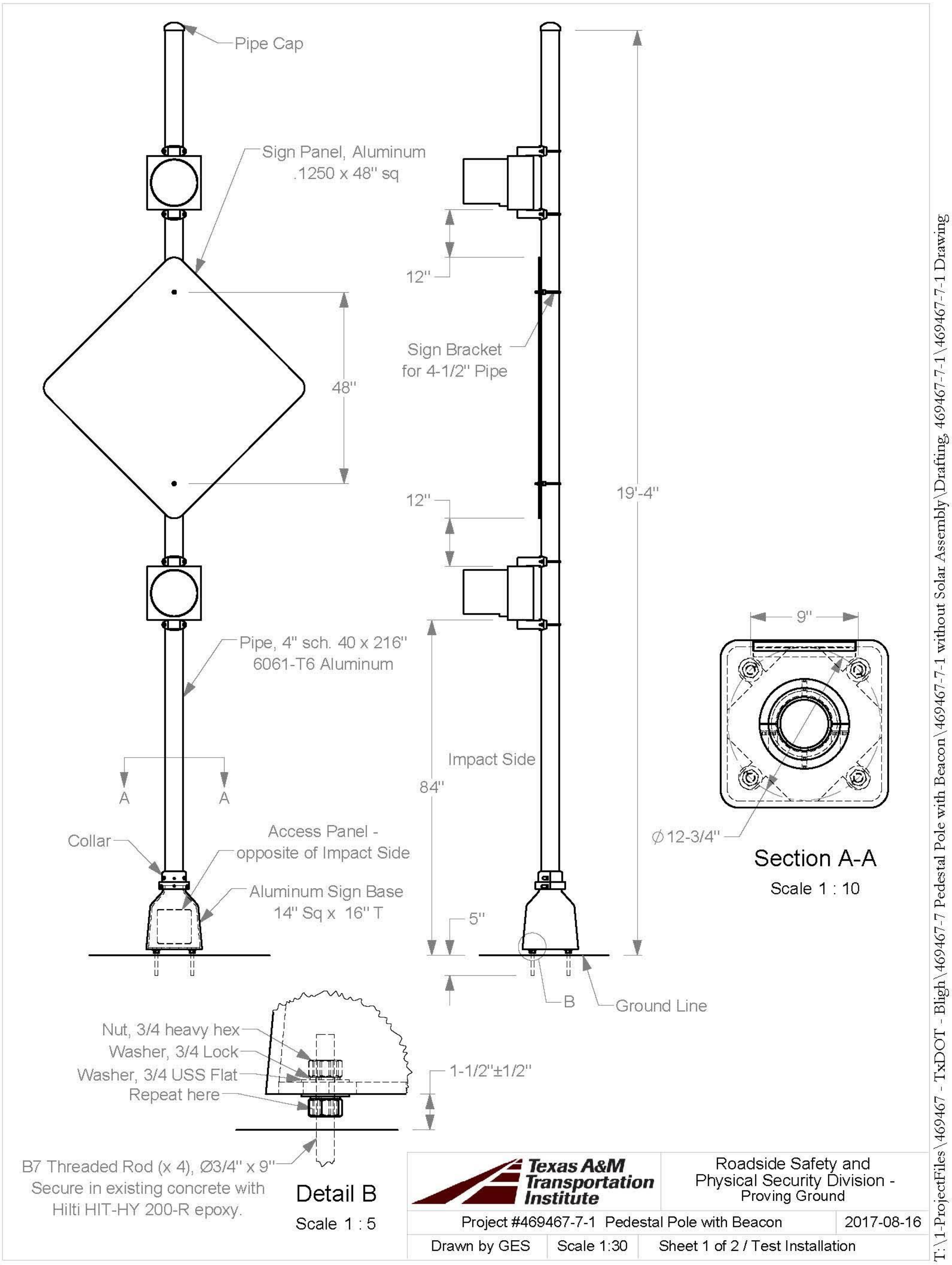


Figure 6.1. TxDOT Pedestal Pole with Beacons without Solar Assembly.

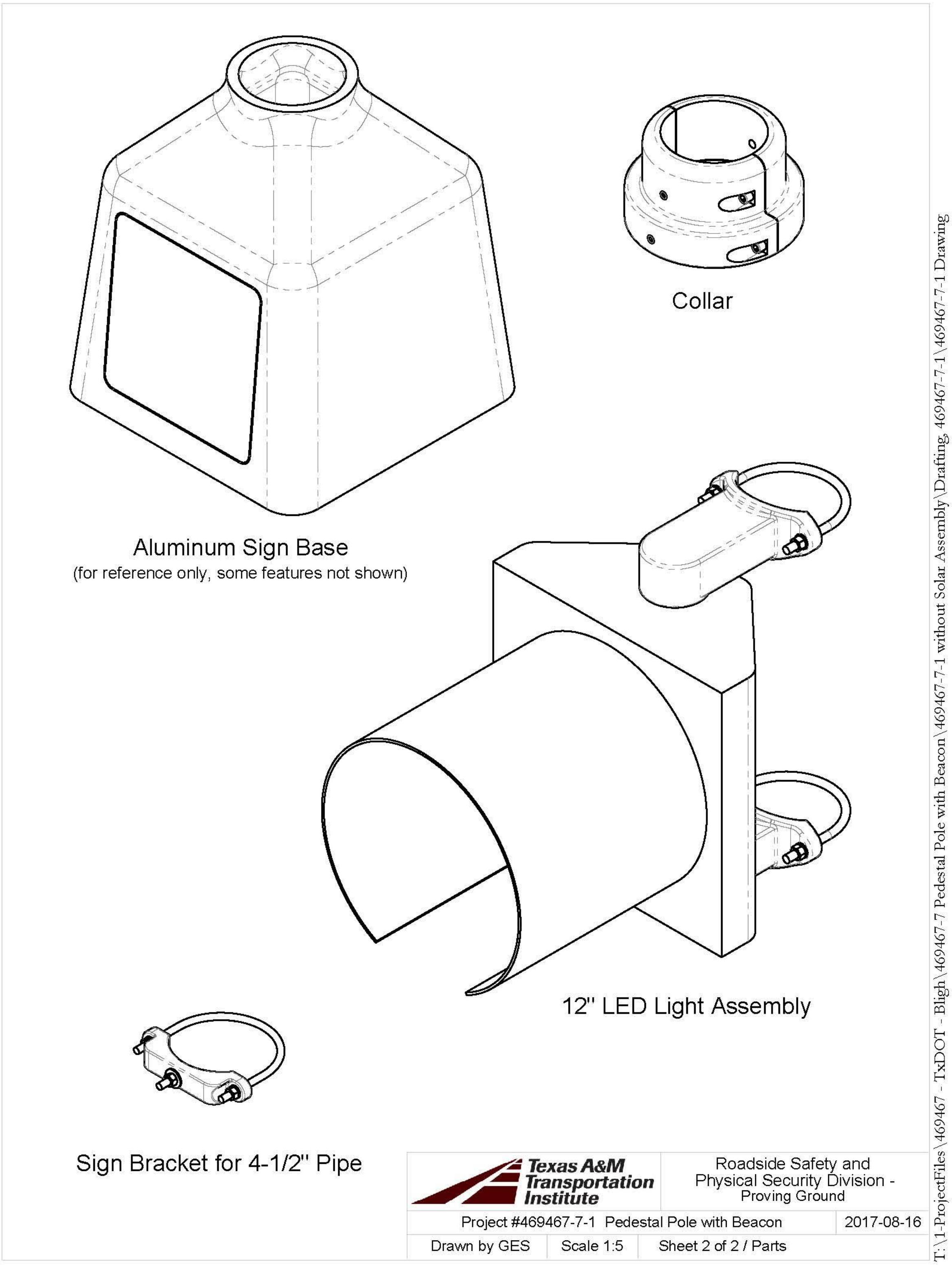


Figure 6.1. TxDOT Pedestal Pole with Beacons without Solar Assembly (Continued).

Figure 6.2. TxDOT Pedestal Pole with Beacons without Solar Assembly prior to Test No. 469467-7-1.

6.2.2 Test Designation and Actual Impact Conditions

MASH Test 3-62 involves a 2270P vehicle weighing 5000 lb ±110 lb impacting the TxDOT pedestal pole with beacon at an impact speed of 62 mi/h ±2.5 mi/h and a critical impact angle (CIA) ±1.5°. The CIA for *MASH* Test 3-62 on the TxDOT pedestal pole with beacon was 0° ±1.5°, which aligns the beacons and lens hoods along the axis of the vehicle to maximize potential interaction with the vehicle. The right quarter point of the vehicle was aligned with the centerline of the TxDOT pedestal pole.

The 2012 Dodge RAM 1500 pickup truck used in the test weighed 5034 lb, and the actual impact speed and angle were 62.8 mi/h and 0°, respectively. The right quarter point of the vehicle was aligned with the centerline of the TxDOT pedestal pole. Minimum target KE was 594 kip-ft, and actual KE was 664 kip-ft.

6.2.3 Test Vehicle

The 2012 Dodge RAM 1500 pickup truck, shown in Figure 6.3 and 6.4, was used for the crash test. The vehicle's test inertia weight was 5034 lb, and its gross static weight was 5034 lb. The height to the lower edge of the vehicle bumper was 11.0 inches, and height to the upper edge of the bumper was 26.5 inches. The height to the vehicle's center of gravity was 28.5 inches. Tables E.1 and E.2 in Appendix E.2 give additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

Figure 6.3. TxDOT Pedestal Pole with Beacons without Solar Assembly/Test Vehicle Geometrics for Test No. 469467-7-1.

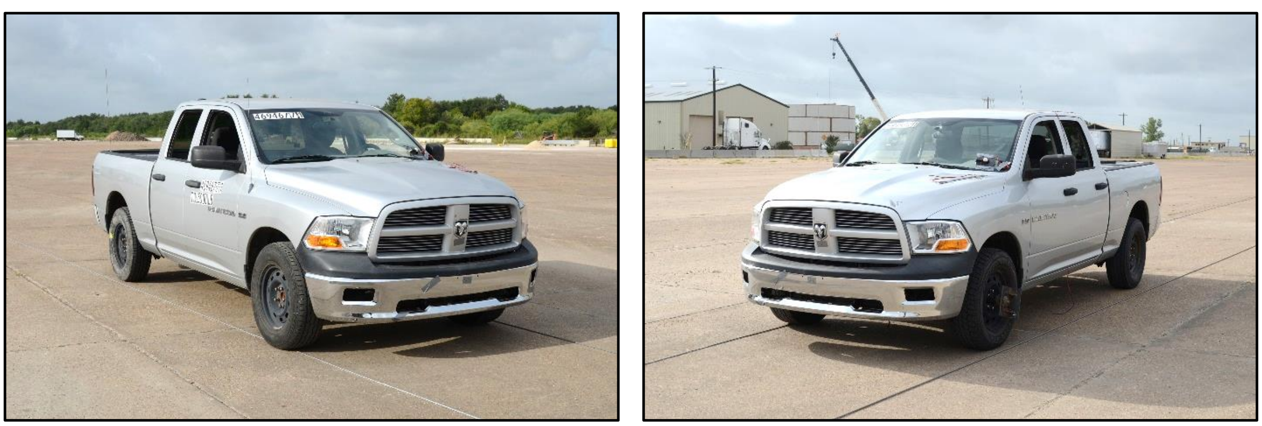


Figure 6.4. Test Vehicle before Test No. 469467-7-1.

6.2.4 Weather Conditions

The test was performed on the morning of August 17, 2017. Weather conditions at the time of testing were as follows: wind speed: 13 mi/h; wind direction: 204° (vehicle was traveling in a southerly direction); temperature: 88°F; relative humidity: 73 percent.

6.2.5 Test Description

The test vehicle, traveling at an impact speed of 62.8 mi/h, contacted the TxDOT pedestal pole with beacons at an impact angle of 0°. Table 6.1 lists times and events that occurred during Test No. 469467-7-1. Figure E.1 in Appendix E.2 presents sequential photographs during the test.

Table 6.1. Events during Test No. 469467-7-1.

TIME (s)	EVENT
0.007	Upper right grill and hood impact pole
0.007	Base begins to separate from pole
0.011	Downstream lower edge of sign base impacts pavement
0.020	Pole and base fully separated
0.020	Lower beacon shield and door begin to detach from beacon
0.032	Base horizontal and under vehicle bumper
0.079	Collar separates from pole
0.090	Lower beacon shield impacts roof on pass side just beyond windshield
0.150	Vehicle loss of contact with pole while traveling at 61.5 mi/h
0.184	Pole is horizontal approx. 65 inches above vehicle roof
0.214	Sign base lodged beneath right front "A" frame of vehicle
0.376	Pole is vertical and inverted approx. 73 inches behind vehicle
0.486	Sign panel impacts pavement
0.729	Bottom of pole impacts pavement

6.2.6 Damage to Test Installation

Figure 6.5 shows the damage to the TxDOT pedestal pole with beacons without solar assembly. The breakaway base fractured and released from the anchor bolts and pole. The anchor bolts on the impact side were deformed. The pole was resting 20 ft downstream of impact and 5 ft to the left of centerline. The sign panel detached from the pole after contact with the ground and was resting 51 ft downstream of impact and 6 ft to the left. One of the beacons was resting 58 ft downstream of impact, and the other was resting 150 ft downstream of impact and 10 ft to the left.

6.2.7 Damage to Test Vehicle

Figure 6.6 shows the damage sustained by the vehicle. The front bumper, right bumper bracket, hood, and grill were deformed. Maximum exterior crush to the vehicle was 6.5 inches in the front plane at the right front quarter point at bumper height. No occupant compartment deformation or intrusion occurred. Figure 6.7 shows the interior of the vehicle. Tables E.3 and E.4 in Appendix E.2 provide exterior crush and occupant compartment measurements.

Figure 6.5. TxDOT Pedestal Pole with Beacons without Solar Assembly after Test No. 469467-7-1.

Figure 6.6. Test Vehicle after Test No. 469467-7-1.

Before Test After Test

Figure 6.7. Interior of Test Vehicle for Test No. 469467-7-1.

6.2.8 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk and are shown in Table 6.2. Figure 6.8 summarizes these data and other pertinent information from the test. Figure E.2 in Appendix E.2 shows the vehicle angular displacements, and Figures E.3 through E.8 in Appendix E.2 show vehicle acceleration versus time traces.

6.2.9 Summary of Results

An assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-62 is provided in Table 6.3.

6.2.10 Conclusions

The TxDOT Pedestal Pole with Beacons without Solar Assembly yielded to the 2270P vehicle as designed by fracturing at the base. None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area. No occupant compartment deformation or intrusion occurred. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 3° and 2°, respectively. Occupant risk factors were within the preferred limits of *MASH*. The 2270P vehicle came to rest 308 ft downstream of impact.

The TxDOT Pedestal Pole with Beacons without Solar Assembly performed acceptably for *MASH* Test 3-62.

Table 6.2. Occupant Risk Factors for Test No. 469467-7-1.

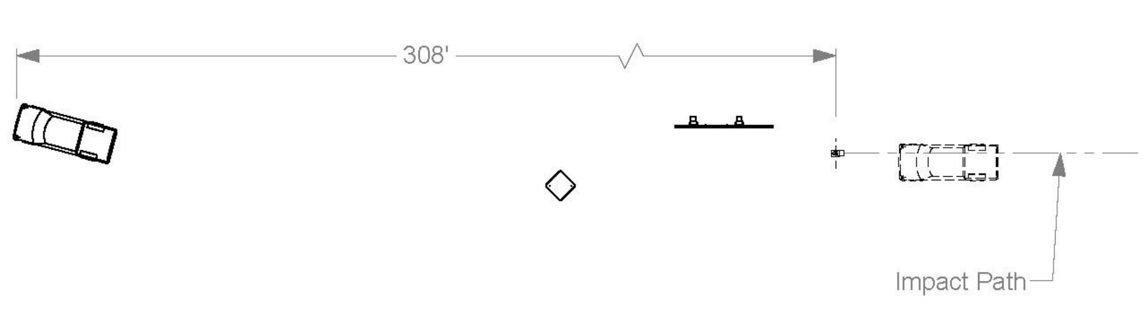
Occupant Risk Factor	Value	Time
OIV		
Longitudinal	**2.6 ft/s**	at 0.9178 s on front of interior
Lateral	**0 ft/s**	
Occupant Ridedown Accelerations		
Longitudinal	**0.8 g**	1.4013–1.4113 s
Lateral	**0.6 g**	1.3923–1.4023 s
THIV	**2.8 km/h** **0.8 m/s**	at 0.9185 s on front of interior
PHD	**0.9 g**	1.4011–1.4111 s
ASI	**0.14**	0.0162–0.0662 s
Maximum 50-ms Moving Average		
Longitudinal	**−1.1 g**	0.0017–0.0517 s
Lateral	**0.6 g**	0.0747–0.1247 s
Vertical	**−1.3 g**	0.0234–0.0734 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	**3.2°**	4.9988 s
Pitch	**1.8°**	0.1838 s
Yaw	**40.5°**	5.0000 s

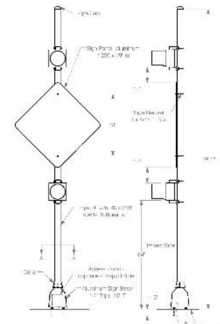
0.000 s

0.070 s

0.140 s

0.280 s





General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-62
TTI Test No.	469467-7-1
Test Date	2017-08-17

Test Article

Type	Sign Support
Name	Pedestal Pole with Beacons
Installation Height	19 ft-4 inches (to top of support)
Material or Key Elements	Single 4-inch aluminum pole, two 12-inch beacon lights, 48-inch diamond shaped sign panel, breakaway pedestal base
Soil Type and Condition	Anchor bolts embedded 5 inches in concrete on a 9-inch square (12¾-inch bolt circle dia.) secured with Hilti HIT-HY-200-R epoxy

Test Vehicle

Type/Designation	2270P
Make and Model	2012 Dodge RAM 1500
Curb	4957 lb
Test Inertial	5034 lb
Dummy	No dummy
Gross Static	5034 lb

Impact Conditions

Speed	62.8 mi/h
Angle	0°
Location/Orientation	Right Quarter Point w/centerline
Impact Severity	664 kip-ft

Exit Conditions

Speed	61.5 mi/h
Angle	0°

Occupant Risk Values

Longitudinal OIV	2.6 ft/s
Lateral OIV	0 ft/s
Longitudinal Ridedown	0.8 g
Lateral Ridedown	0.6 g
THIV	2.8 km/h
PHD	0.9 g
ASI	0.14
Max. 0.050-s Average	
Longitudinal	-1.1 g
Lateral	0.6 g
Vertical	-1.3 g

Post-Impact Trajectory

Stopping Distance	308 ft downstream 6 ft right

Vehicle Stability

Maximum Yaw Angle	41°
Maximum Pitch Angle	2°
Maximum Roll Angle	3°
Test Article Debris Scatter	150 ft x 15 ft

Vehicle Damage

VDS	12FR2
CDC	12FREN2
Max. Exterior Deformation	6.5 inches
OCDI	None
Max. Occupant Compartment Deformation	FS0000000

Figure 6.8. Summary of Results for *MASH* Test 3-62 on the TxDOT Pedestal Pole with Beacons without Solar Assembly.

Table 6.3. Performance Evaluation Summary for *MASH* Test 3-62 on the TxDOT Pedestal Pole with Beacons without Solar Assembly.

Test Agency: Texas A&M Transportation Institute | Test No.: 469467-7-1 | Test Date: 2017-08-17

MASH Test 3-62 Evaluation Criteria	Test Results	Assessment
Structural Adequacy *B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*	The TxDOT Pedestal Pole with Beacons without Solar Assembly yielded to the 2270P vehicle as designed by fracturing at the base.	Pass
Occupant Risk *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	No occupant compartment deformation or intrusion occurred.	Pass
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 3° and 2°, respectively.	Pass
H. Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s, or maximum allowable value of 16.4 ft/s.	Maximum longitudinal OIV was 2.6 ft/s, and no lateral contact was made.	Pass
I. The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	Longitudinal occupant ridedown acceleration was 0.8 g, and lateral occupant ridedown acceleration was 0.6 g.	Pass
Vehicle Trajectory *N. Vehicle trajectory behind the test article is acceptable.*	The 2270P vehicle came to rest 308 ft downstream of impact.	Pass

6.3 *MASH* TEST 3-62 ON THE PEDESTAL POLE WITH BEACONS AND SOLAR ASSEMBLY

6.3.1 Test Article and Installation Details

The 19 ft-4 inch–tall test article was comprised of a single 4-inch aluminum pole, two 12-inch beacon lights, a 48-inch diamond shaped sign panel, a solar panel, a battery box that includes two batteries, and a breakaway pedestal-style base. The total mass of the test article was approximately 332 lb, including the base.

The test pole was an 18 ft long 4-inch Schedule 40 (4.500-inch outside diameter; 0.237-inch wall thickness) 6061-T6 aluminum pipe that was fitted with a pipe cap at the top. The sign panel measured 48-inches square and was manufactured of 0.125-inch thick aluminum sheet. Each of the two beacons (McCain) measured 13½ × 13½ × 6½ inches deep and contained a 12-inch diameter lens and associated sun shield. The sign panel and beacons were attached to the pole with 4½-inch wide U-bolts and aluminum brackets.

The solar panel (Ameresco Solar model BSP-9012) was attached to the top of the pole and measured 48 × 21 × 1½ inches thick. The battery box measured 15½-inches wide × 17 inches deep × 26 inches tall and contained two 12-volt GEL batteries. The battery cabinet was located behind and toward the top of the sign panel.

The 16-inch tall pedestal base (Component Products, Inc. model CPI-BAS-1-P) was manufactured of cast aluminum and measured 14-inches square at the base, tapering to 12 inches square at the top. A 5¾-inch diameter collar at the top of the base accommodated the base-to-pole connection. The bottom of the base was set approximately 1½-inches above the concrete apron to which it was mounted.

Four ¾-inch diameter 10 UNC thread, 9-inch long threaded anchor rods (ASTM A193 grade B7) connected the breakaway base to the concrete apron. These rods were embedded 5 inches in the apron on a 9-inch square pattern (12¾-inch bolt circle diameter) and secured using Hilti HIT-HY-200-R epoxy per Hilti's installation instructions. The base was attached using two sets of ¾-inch heavy hex nuts, lock washers, and USS flat washers per anchor rod.

Details of the pedestal pole with beacons and solar assembly are provided in Figure 6.9. Figure 6.10 provides photographs of the completed test installation. Appendix E.1 provides material certification documents.

6.3.2 Test Designation and Actual Impact Conditions

MASH Test 3-62 involves a 2270P vehicle weighing 5000 lb ±110 lb impacting the TxDOT pedestal pole with beacon and solar assembly at an impact speed of 62 mi/h ±2.5 mi/h and a CIA ±1.5°. The CIA for *MASH* Test 3-62 on the TxDOT pedestal pole with beacon and solar assembly was 0° ±1.5°, which aligns the beacons and lens hoods along the axis of the vehicle to maximize potential interaction with the vehicle. The left quarter point of the vehicle was aligned with the centerline of the TxDOT pedestal pole.

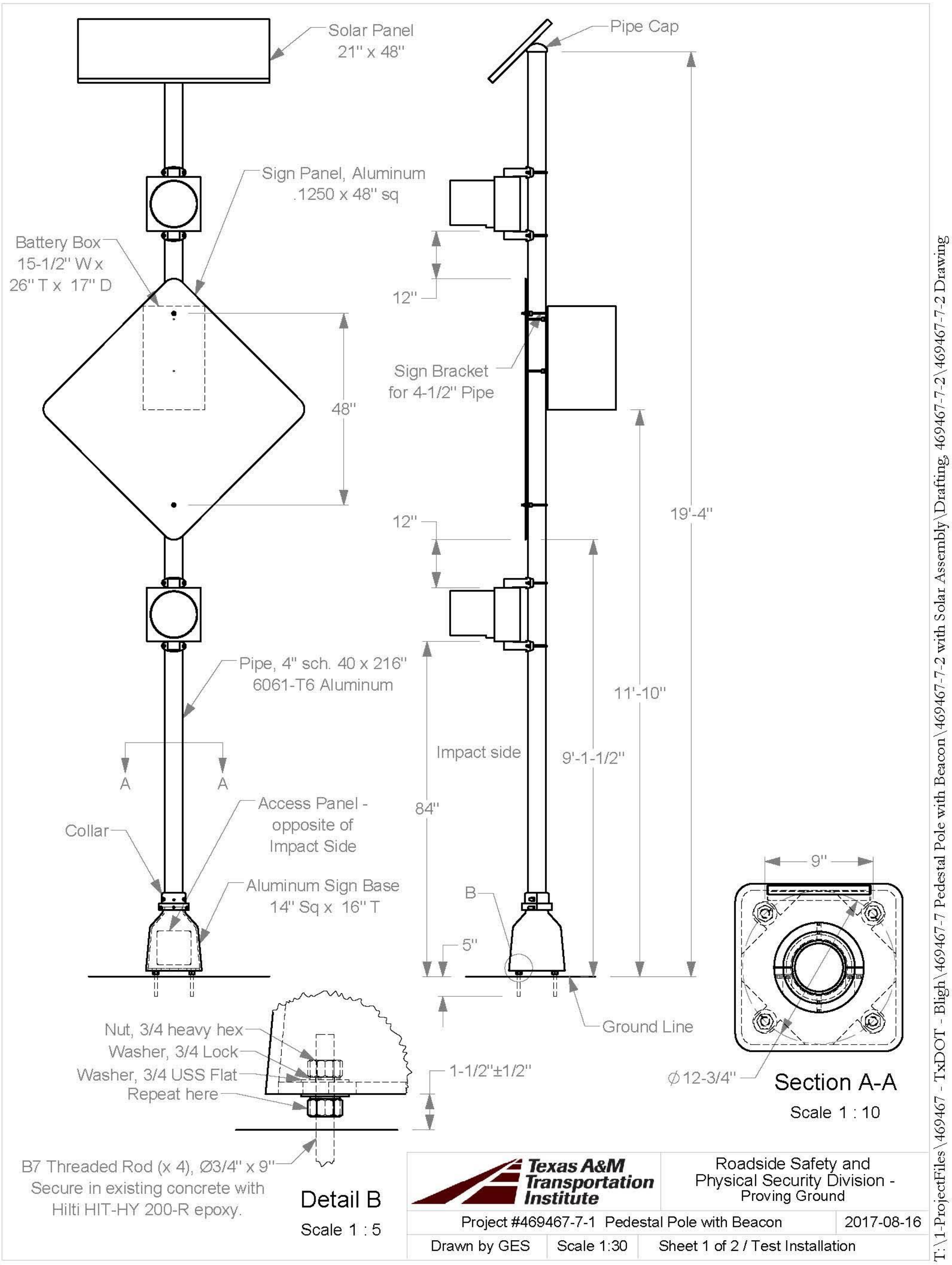


Figure 6.9. TxDOT Pedestal Pole with Beacons and Solar Assembly.

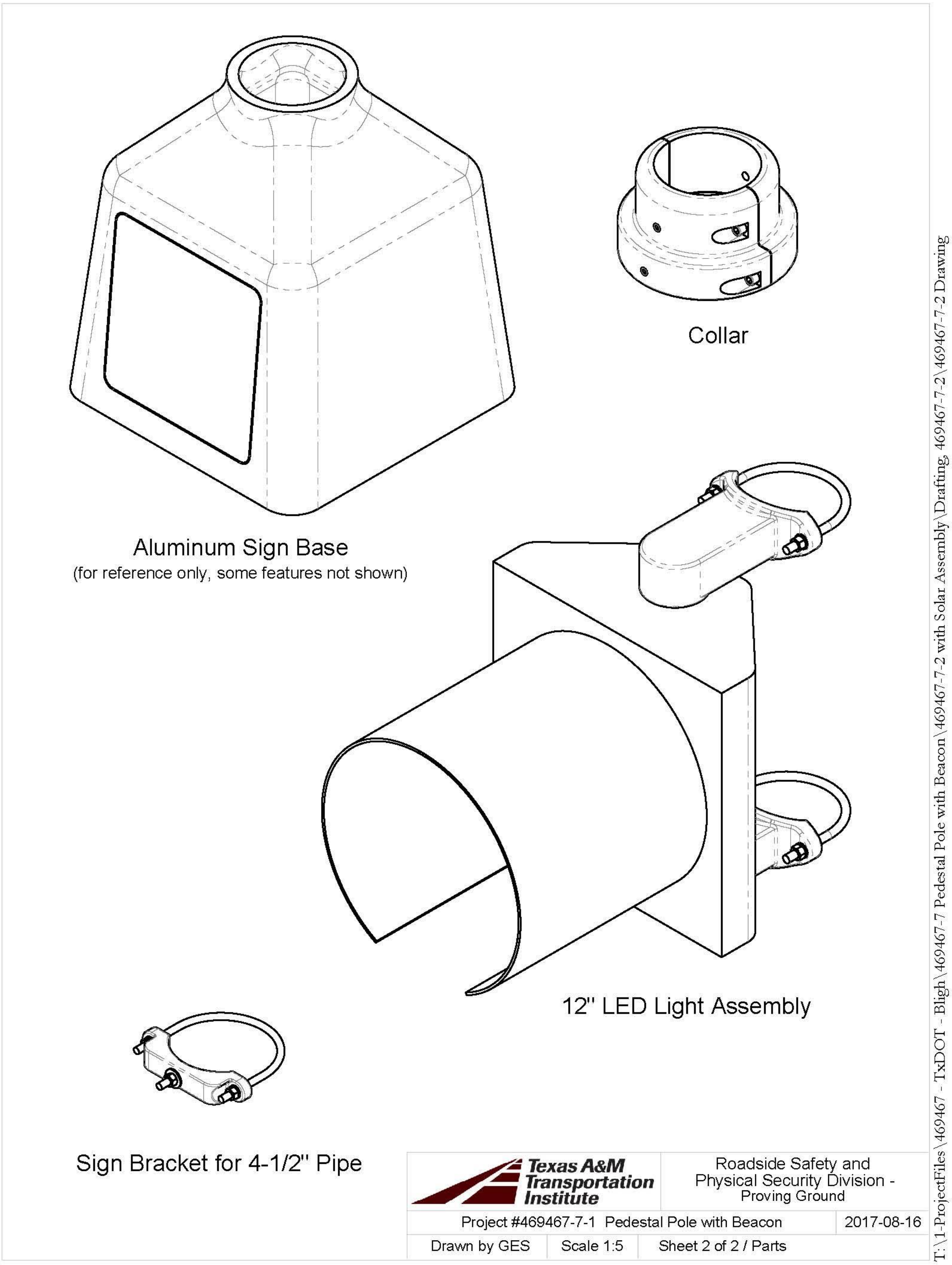


Figure 6.9. TxDOT Pedestal Pole with Beacons and Solar Assembly (Continued).

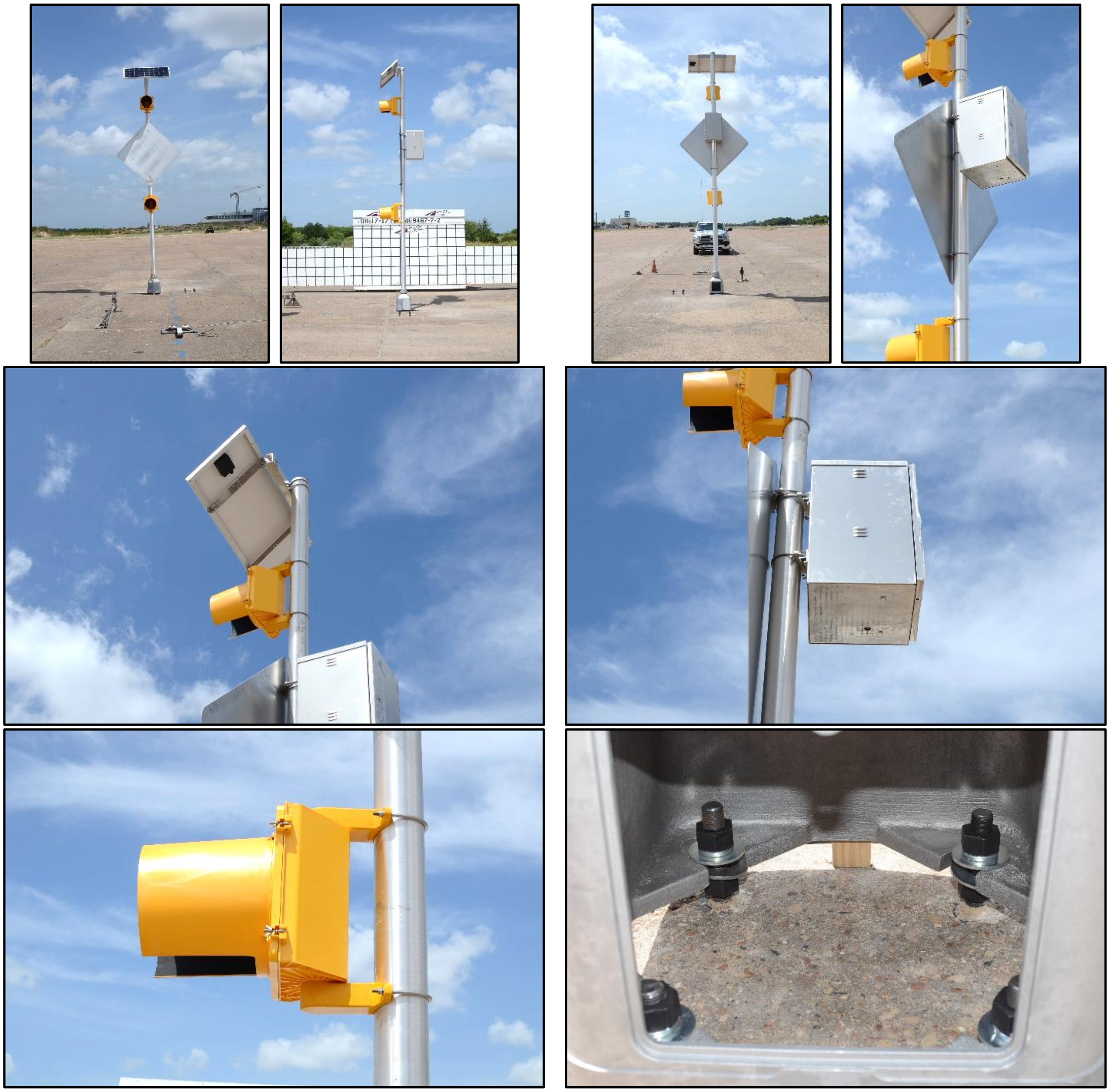


Figure 6.10. TxDOT Pedestal Pole with Beacon and Solar Assembly prior to Test No. 469467-7-2.

The 2012 Dodge RAM 1500 pickup truck used in the test weighed 5034 lb, and the actual impact speed and angle were 62.5 mi/h and 0°, respectively. The right quarter point of the vehicle was aligned with the centerline of the TxDOT pedestal pole. Minimum target KE was 594 kip-ft, and actual KE was 657 kip-ft.

6.3.3 Test Vehicle

The 2012 Dodge RAM 1500 pickup truck, shown in Figure 6.11 and 6.12, used in the first test was reused for this crash test. The impact was aligned with the opposite ¼-point along the front of the vehicle. The vehicle's test inertia weight was 5034 lb, and its gross static weight was 5034 lb. The height to the lower edge of the vehicle bumper was 11.0 inches, and height to the upper edge of the bumper was 26.5 inches. The height to the vehicle's center of gravity was 28.5 inches. Tables E.5 and E.6 in Appendix E.3 give additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

Figure 6.11. TxDOT Pedestal Pole with Beacons and Solar Assembly/Test Vehicle Geometrics for Test No. 469467-7-2.

Figure 6.12. Test Vehicle before Test No. 469467-7-2.

6.3.4 Weather Conditions

The test was performed on the afternoon of August 17, 2017. Weather conditions at the time of testing were as follows: wind speed: 12 mi/h; wind direction: 184° (vehicle was traveling in a southerly direction); temperature: 94°F; relative humidity: 59 percent.

6.3.5 Test Description

The test vehicle, traveling at an impact speed of 62.5 mi/h, contacted the TxDOT pedestal pole with beacons and solar assembly at an impact angle of 0°. Table 6.4 lists times and events that occurred during Test No. 469467-7-2. Figure E.9 in Appendix E.3 presents sequential photographs during the test.

Table 6.4. Events during Test No. 469467-7-2.

TIME (s)	EVENT
0.009	Upper left grill and hood impact pole, base begins to separate from pole
0.011	Downstream lower edge of sign base impacts pavement
0.016	Lower beacon shield and door begin to detach from beacon
0.019	Pole and base fully separated
0.032	Base horizontal and under vehicle bumper
0.040	Top of sign separates from bracket
0.045	Base lodged beneath left front "A" frame of vehicle
0.080	Collar separates from pole
0.085	Battery box door begins to open
0.150	Vehicle loss of contact with pole while traveling at 60.7 mi/h
0.188	Pole is horizontal approx. 64 inches above vehicle roof
0.284	Battery #1 exits box
0.373	Solar panel lands on pavement at anchor bolts.
0.407	Pole is vertical and inverted approx. 126 inches behind vehicle
0.648	Battery #2 exits box
0.820	Bottom of pole impacts pavement
0.874	Battery #1 impacts pavement
1.145	Battery #2 impacts pavement
1.306	Top of pole impacts pavement

6.3.6 Damage to Test Installation

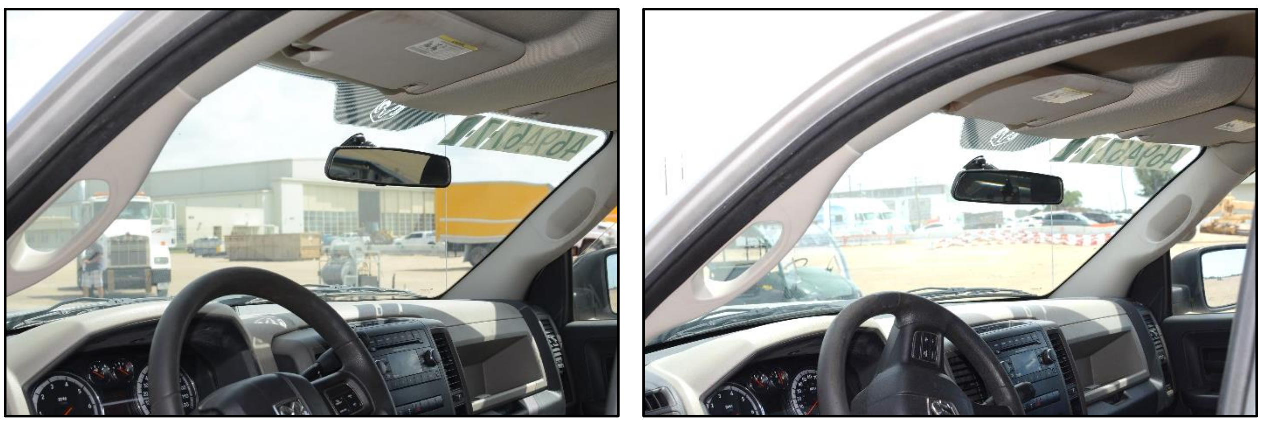
Figure 6.13 shows the damage to the TxDOT pedestal pole with beacon and solar assembly. The base of the pole fractured and released from the anchor bolts and pole. The anchor bolts on the impact side were deformed. The solar panel released from the pole and came to rest near the point of impact. The pole with top beacon, battery box, sign panel, and part of the lower beacon still attached was resting 10 ft downstream of impact. Both batteries released from the battery box; one was resting 5 ft downstream of impact and one was resting 36 ft downstream and 7 ft to the left of centerline. The broken lower beacon was resting 265 ft downstream and 26 ft to the right of centerline. The base lodged beneath the left front A-frame of the vehicle and rode along with the vehicle where it came to rest 377 ft downstream and 7 ft to the left of centerline.

6.3.7 Damage to Test Vehicle

Figure 6.14 shows the damage sustained by the vehicle. The front bumper, left bumper bracket, hood, and grill were deformed. Maximum exterior crush to the vehicle was 6.5 inches in the front plane at the left front quarter point at bumper height. No occupant compartment deformation or intrusion occurred. Figure 6.15 shows the interior of the vehicle. Tables E.7 and E.8 in Appendix E.3 provide exterior crush and occupant compartment measurements.

Figure 6.13. TxDOT Pedestal Pole with Beacons and Solar Assembly after Test No. 469467-7-2.

Figure 6.14. Test Vehicle after Test No. 469467-7-2.



Before Test After Test

Figure 6.15. Interior of Test Vehicle for Test No. 469467-7-2.

6.2.8 Occupant Risk Factors

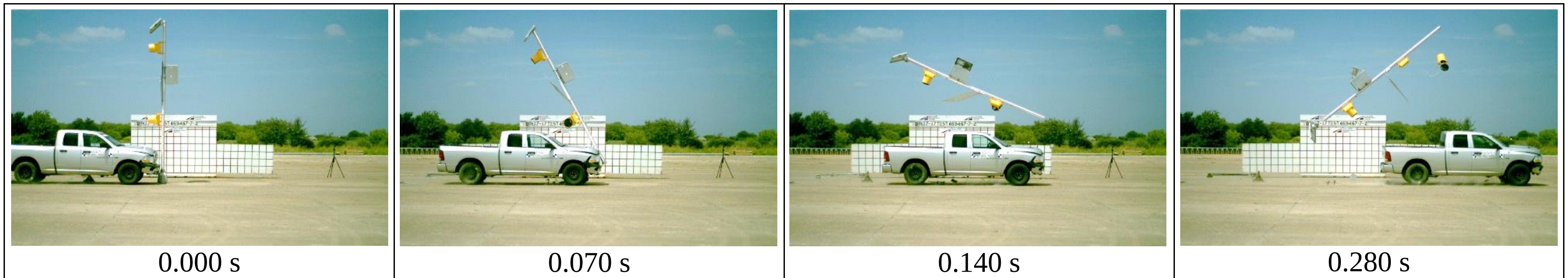
Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk and are shown in Table 6.5. Figure 6.16 summarizes these data and other pertinent information from the test. Figure E.3 in Appendix E.10 shows the vehicle angular displacements, and Figures E.11 through E.16 in Appendix E.3 show vehicle acceleration versus time traces.

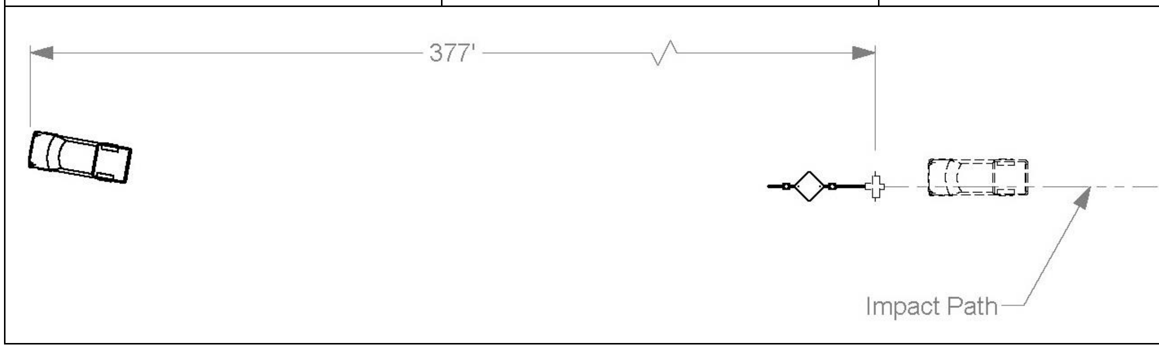
6.2.9 Summary of Results

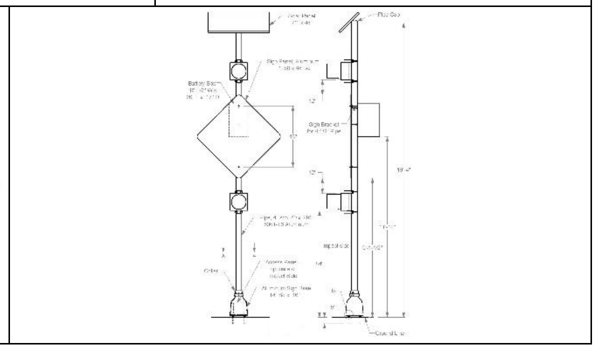
An assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-62 is provided in Table 6.6.

Table 6.5. Occupant Risk Factors for Test No. 469467-7-2.

Occupant Risk Factor	Value	Time
OIV		
Longitudinal	**2.6 ft/s**	at 0.7212 s on right side of interior
Lateral	**2.0 ft/s**	
Occupant Ridedown Accelerations		
Longitudinal	**0.9 g**	1.0767–1.0867 s
Lateral	**2.5 g**	1.0383–1.0483 s
THIV	**3.5 km/h** **1.0 m/s**	at 0.7150 s on right side of interior
PHD	**2.5 g**	1.0383–1.0483 s
ASI	**0.14**	0.0163–0.0663 s
Maximum 50-ms Moving Average		
Longitudinal	**−1.2 g**	0.0045–0.0545 s
Lateral	**−0.6 g**	0.1920–0.2420 s
Vertical	**1.3 g**	0.9985–1.0485 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	**2.2°**	1.3594 s
Pitch	**1.7°**	0.9045 s
Yaw	**1.0°**	0.2952 s







General Information
- Test Agency: Texas A&M Transportation Institute (TTI)
- Test Standard Test No.: *MASH* Test 3-62
- TTI Test No.: 469467-7-2
- Test Date: 2017-08-17

Test Article
- Type: Sign Support
- Name: Pedestal Pole with Beacons & Solar Panel
- Installation Height: 19 ft-4 inches (to top of support)
- Material or Key Elements: Single 4-inch aluminum pole, two 12-inch beacon lights, 48-inch diamond shaped sign panel, pedestal base, solar panel, battery box

Soil Type and Condition: Anchor bolts embedded 5 inches in concrete on a 9-inch square (12¾-inch bolt circle dia.) secured with Hilti HIT-HY-200-R epoxy

Test Vehicle
- Type/Designation: 2270P
- Make and Model: 2012 Dodge RAM 1500
- Curb: 4957 lb
- Test Inertial: 5034 lb
- Dummy: No dummy
- Gross Static: 5034 lb

Impact Conditions
- Speed: 62.5 mi/h
- Angle: 0°
- Location/Orientation: Left Quarter Point w/centerline

Impact Severity: 657 kip-ft

Exit Conditions
- Speed: 60.7 mi/h
- Angle: 0°

Occupant Risk Values
- Longitudinal OIV: 2.6 ft/s
- Lateral OIV: 2.0 ft/s
- Longitudinal Ridedown: 0.9 g
- Lateral Ridedown: 2.5 g
- THIV: 3.5 km/h
- PHD: 2.5 g
- ASI: 0.14

Max. 0.050-s Average
- Longitudinal: -1.2 g
- Lateral: -0.6 g
- Vertical: 1.3 g

Post-Impact Trajectory
- Stopping Distance: 377 ft downstream 6 ft right

Vehicle Stability
- Maximum Yaw Angle: 1°
- Maximum Pitch Angle: 2°
- Maximum Roll Angle: 2°

Test Article Debris Scatter: 377 ft x 33 ft

Vehicle Damage
- VDS: 12FL2
- CDC: 12FLEN2
- Max. Exterior Deformation: 6.5 inches
- OCDI: None
- Max. Occupant Compartment Deformation: FS0000000

Figure 6.16. Summary of Results for *MASH* Test 3-62 on the TxDOT Pedestal Pole with Beacons and Solar Assembly.

Table 6.6. Performance Evaluation Summary for *MASH* Test 3-62 on the TxDOT Pedestal Pole with Beacons and Solar Assembly.

Test Agency: Texas A&M Transportation Institute | Test No.: 469467-7-2 | Test Date: 2017-08-17

***MASH* Test 3-62 Evaluation Criteria**	**Test Results**	**Assessment**
Structural Adequacy *B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*	The TxDOT Pedestal Pole with Beacons and Solar Assembly yielded to the 2270P vehicle as designed by fracturing at the base.	Pass
Occupant Risk *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	No occupant compartment deformation or intrusion occurred.	Pass
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were both 2°.	Pass
H. Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s, or maximum allowable value of 16.4 ft/s.	Maximum longitudinal OIV was 2.6 ft/s, and maximum lateral OIV was 2.0 ft/s.	Pass
I. The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	Longitudinal occupant ridedown acceleration was 0.9 g, and lateral occupant ridedown acceleration was 2.5 g.	Pass
Vehicle Trajectory *N. Vehicle trajectory behind the test article is acceptable.*	The 2270P vehicle came to rest 377 ft downstream of impact.	Pass

6.2.10 Conclusions

The TxDOT Pedestal Pole with Beacons and Solar Assembly yielded to the 2270P vehicle as designed by fracturing at the base. None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area. No occupant compartment deformation or intrusion occurred. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were both 2°. Occupant risk factors were within the preferred limits of *MASH*. The 2270P vehicle came to rest 377 ft downstream of impact.

The TxDOT pedestal pole with beacons and solar assembly performed acceptably for *MASH* Test 3-62.

CHAPTER 7:
TXDOT MAILBOX SYSTEMS

7.1 BACKGROUND

The small passenger car is considered the critical design vehicle for evaluation of mailbox support systems based on the required mailbox mounting height. As shown in Figure 7.1, the 42-inch mounting height regulated for mailboxes by the United States Postal Service places mailboxes at a height that makes interaction with the windshield of the pickup truck design vehicle improbable. The taller hood height and longer wrap-around distance (i.e., the distance from the ground, around the front end, and across the hood to the base of the windshield) of the 2270P pickup truck significantly decreases the probability of windshield impact and occupant compartment intrusion. Therefore, Test 3-62 with the pickup truck was considered unnecessary for the *MASH* evaluation of the TxDOT mailbox systems.

Figure 7.1. Mailbox Geometrics with 2270P Pickup Truck (*7*).

The *MASH* test matrix for breakaway supports includes two tests with the 1100C small passenger car: a low-speed test at 19 mi/h (Test 3-60) and a high-speed test at 62 mi/h (Test 3-61). In the low speed small car test, *MASH* testing has shown that the mailbox support assembly will be pushed forward by the impacting vehicle (*8*). Under the lower IS, it is unlikely that the mailbox will separate from the support or that the support assembly will interact with the vehicle windshield.

TTI researchers consider the most critical test for evaluation of mailbox systems to be *MASH* test designation 3-61, which involves the 1100C small passenger car impacting at high speed. This test evaluates both the structural adequacy of the mailbox connection hardware and the interaction of the mailbox support assembly with the vehicle windshield. If the mailbox remains attached during this high-speed test, it is not expected to detach in the low-speed test.

Three different mailbox support systems were selected for *MASH* testing and evaluation during Phase I of the project. The details of these systems and the results of the crash testing are provided below.

7.2 DOUBLE MAILBOX SYSTEM ON WINGED CHANNEL POST WITH TYPE 3 FOUNDATION

7.2.1 System Details

This mailbox system consists of two mailboxes attached to a 2 lb/ft winged channel post directly embedded in soil. Each mailbox was empty, and the bottom of each mailbox was mounted 42 inches above grade. Details of this system are described in Maintenance Division standard MB-15(1).

Two *Elite* No. 1-A standard arched-top mailboxes from Solar Group, Inc., a division of Gibraltar Industries Model #E1600B00 were attached to the top of the support post. Each *Elite* mailbox was delivered as a fabricated steel unit with approximate dimensions of 11 inches tall × 8¾ inches wide × 21½ inches deep and weighed 7 lb. Attachment of each *Elite* mailbox to the post was accomplished using a mailbox bracket (DHT #148939), one extension bracket (DHT #148938), and associated SAE Grade 5 bolts, nuts, and washers. The mailboxes, located 10¼-inches center to center, were secured to a bracket plate (DHT #3789) that was attached to the support post using a two-part angle bracket. Angle bracket Part "A" (DHT # 159489) was located on the outside of the rib of the wing channel post and angle bracket Part "B" (DHT # 159490) was positioned inside the wing channel post on the opposite side. The angle bracket parts were connected to the post using two $^{5}/_{16}$-inch diameter × 2¾-inch long SAE Grade 5 hex bolts, flat and lock washers, and nuts. The two mailboxes with brackets and hardware weighed 21.0 lb.

The two mailboxes were supported on a TxDOT 2 lb/ft steel perforated winged-channel post (DHT #4289) fabricated from ASTM A1011 structural Grade 50 steel. The winged-channel post had an overall length of 71½ inches and weighed 12.2 lb. The support post was inserted 30½ inches into a drilled hole that measured approximately 12 inches in diameter × 30½ inches deep, which was then backfilled and compacted at the test site. The total mass of the two mailboxes, connection hardware, and support post assembly was 33.2 lb.

Figure 7.2 presents details of the TxDOT double mailbox system on winged channel post with type 3 foundation, and Figure 7.3 provides photographs of the completed test installation.

7.2.2 *MASH* Test 3-61

7.2.2.1 Test Designation and Actual Impact Conditions

MASH Test 3-61 involves an 1100C vehicle weighing 2420 lb ±55 lb impacting the TxDOT mailbox system at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 0° ±1.5°. The centerline of the mailbox support was aligned with the quarter point of the vehicle.

The 2011 Kia Rio used in the test weighed 2439 lb, and the actual impact speed and angle were 63.3 mi/h and 0°, respectively. The actual impact point was the centerline of the mailbox support aligned with the left quarter point of the vehicle. Minimum target KE was 288 kip-ft, and actual KE was 327 kip-ft.

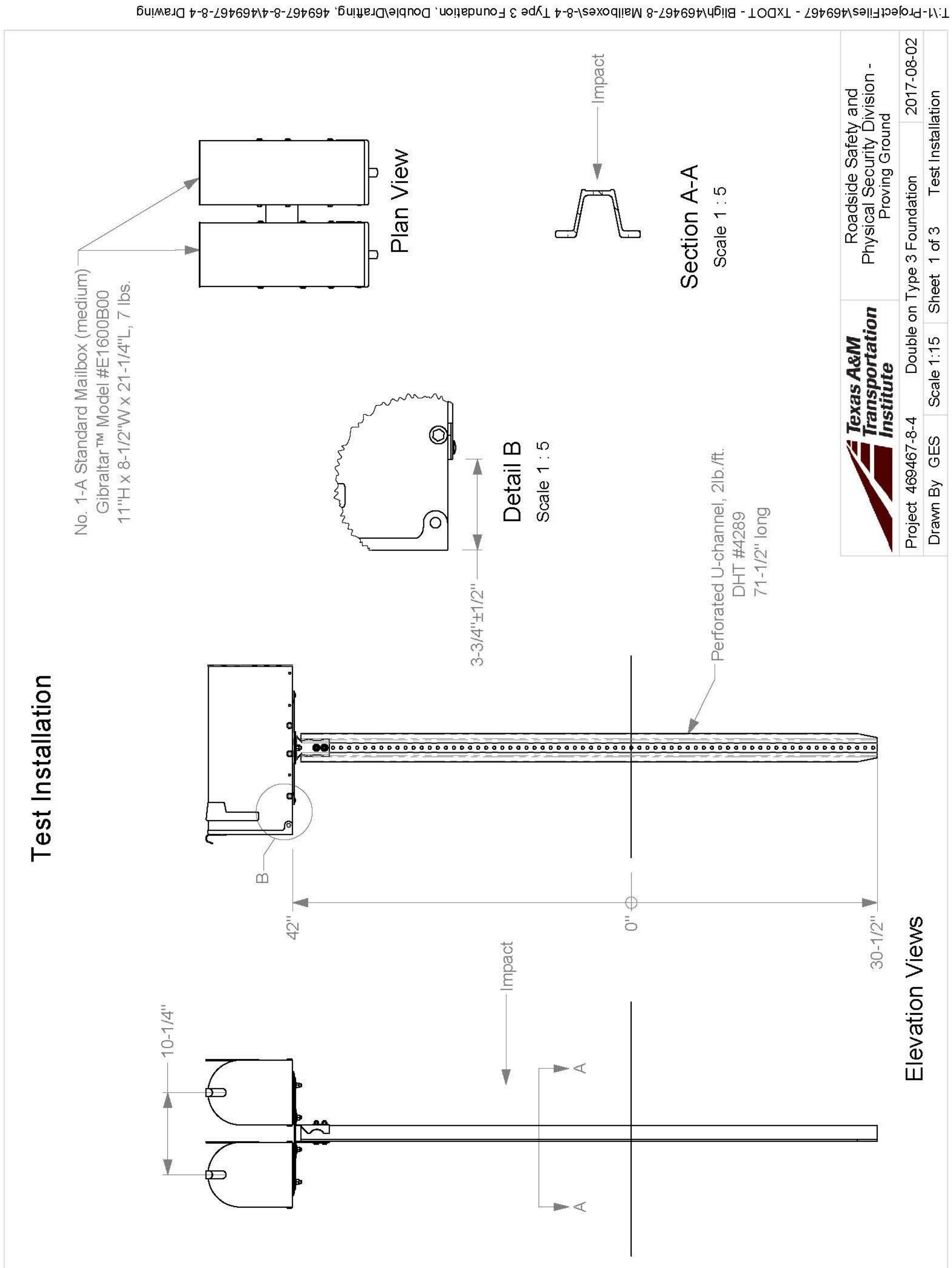


Figure 7.2. Details of the TxDOT Double Mailbox System on Winged Channel Post with Type 3 Foundation.

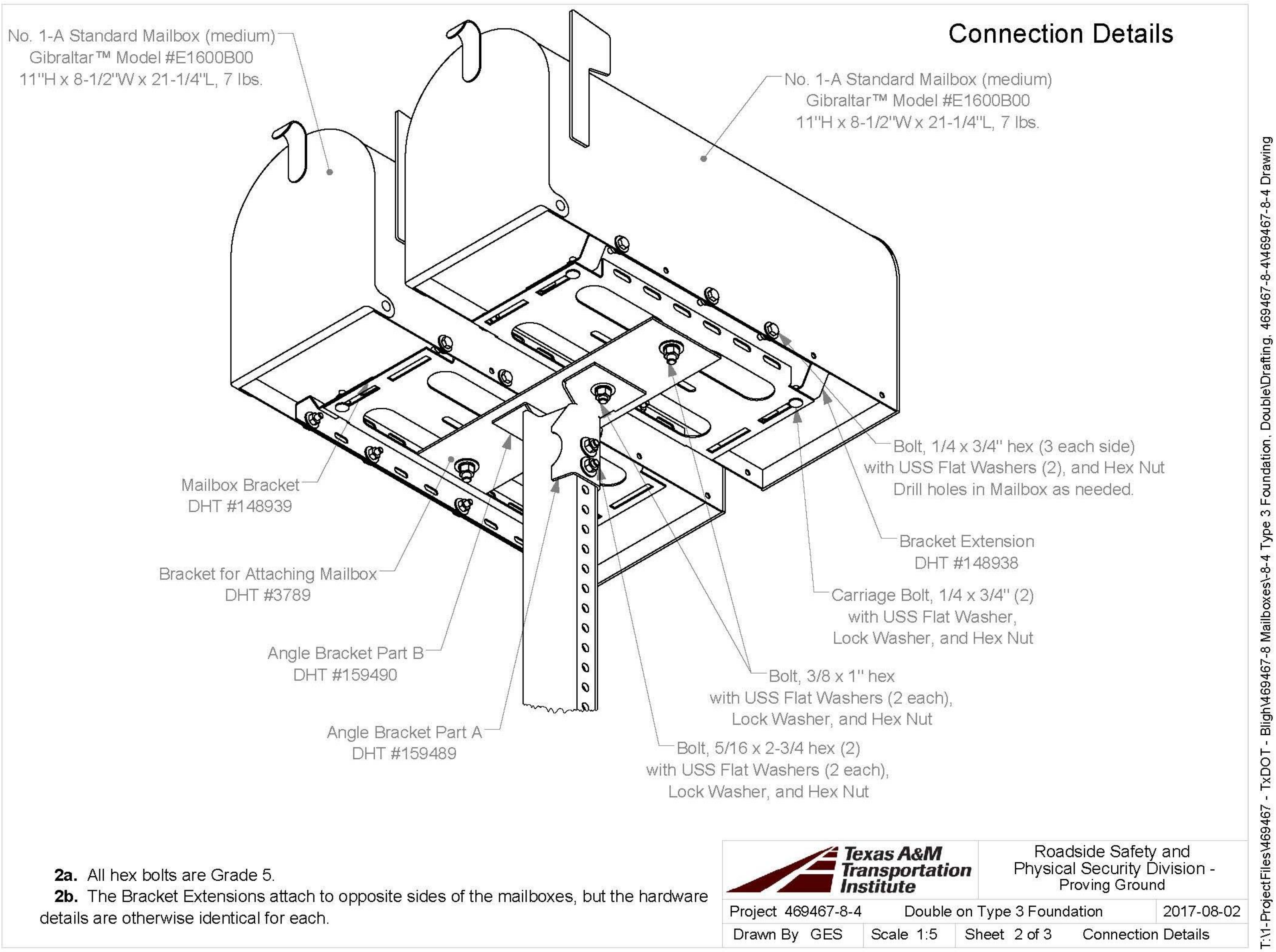


Figure 7.2. Details of the TxDOT Double Mailbox System on Winged Channel Post with Type 3 Foundation (Continued).

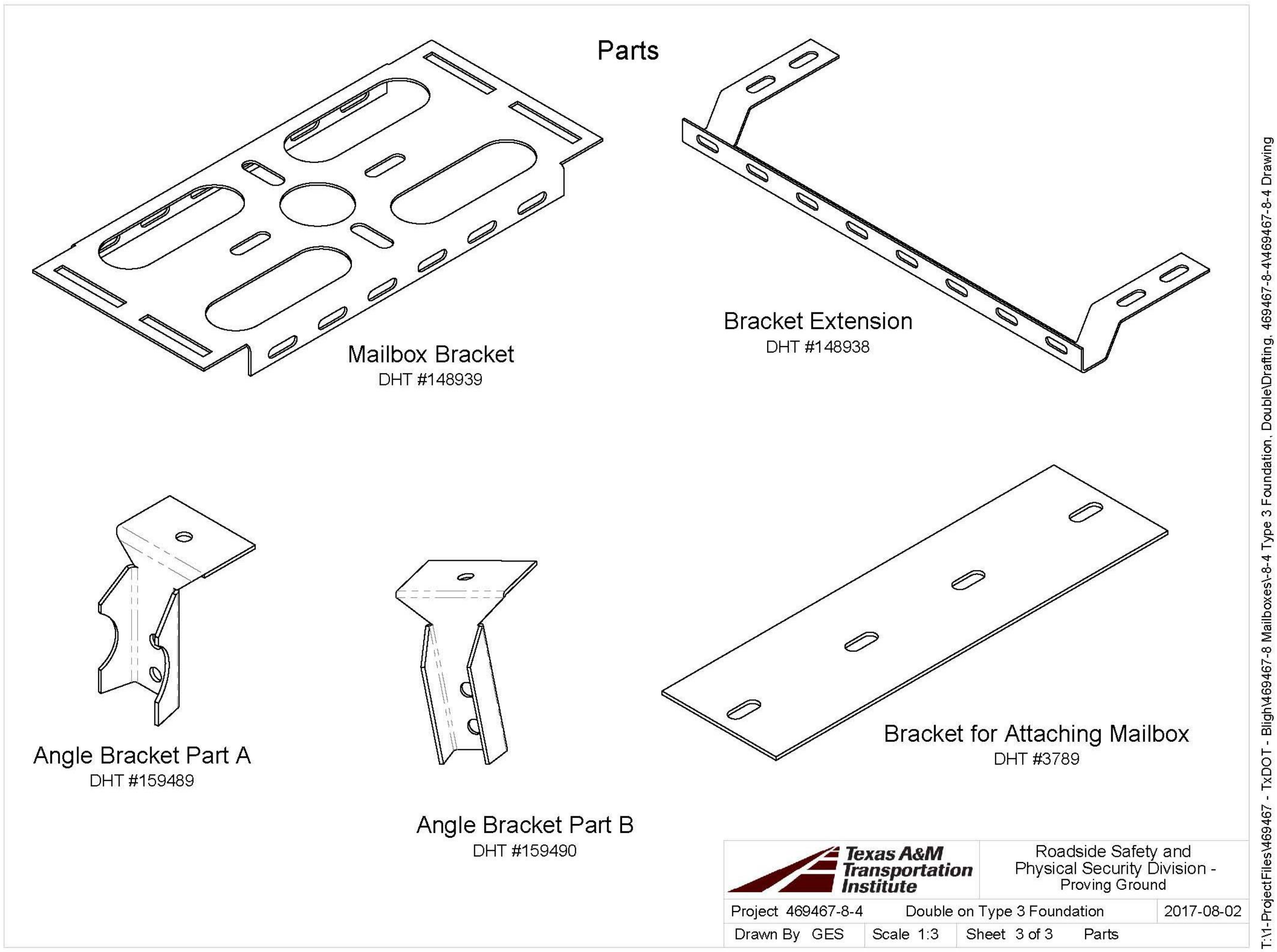


Figure 7.2. Details of the TxDOT Double Mailbox System on Winged Channel Post with Type 3 Foundation (Continued).

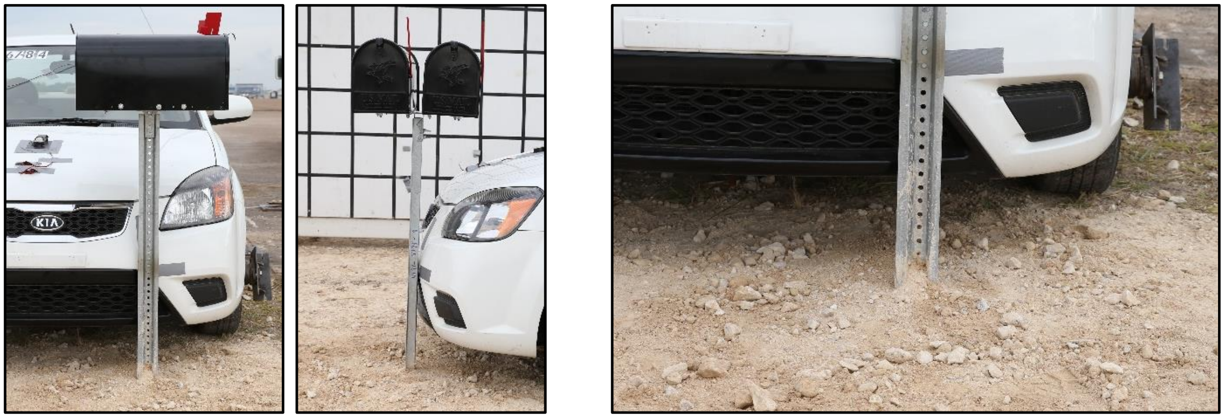


Figure 7.3. TxDOT Double Mailbox System on Winged Channel Post with Type 3 Foundation prior to Testing.

7.2.2.2 Test Vehicle

The 2011 Kia Rio, shown in Figures 7.4 and 7.5, was used for the crash test. The vehicle's test inertia weight was 2439 lb, and its gross static weight was 2604 lb. The height to the lower edge of the vehicle bumper was 7.75 inches, and height to the upper edge of the bumper was 21.0 inches. Table F.1 in Appendix F.1 gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

7.2.2.3 Weather Conditions

The test was performed on the morning of August 3, 2017. Weather conditions at the time of testing were as follows: wind speed: 2 mi/h; wind direction: 40° (vehicle was traveling in a southerly direction); temperature: 81°F; relative humidity: 80 percent.

Figure 7.4. TxDOT Double Mailbox System on Winged Channel Post with Type 3 Foundation/Test Vehicle Geometrics for Test No. 469467-8-4.

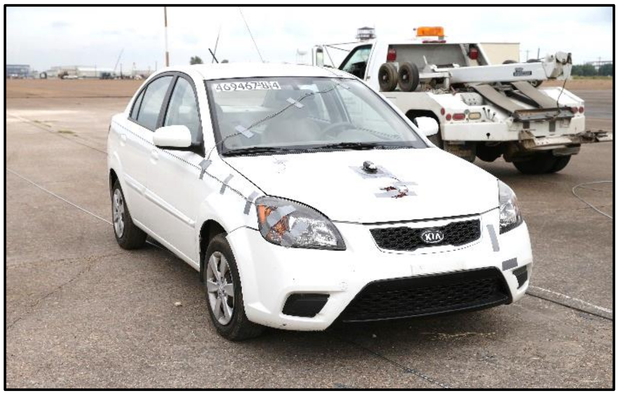
 

Figure 7.5. Test Vehicle before Test No. 469467-8-4.

7.2.2.4 Test Description

The test vehicle, traveling at an impact speed of 63.3 mi/h, contacted the mailbox system with the centerline of the support aligned with the left quarter point of the vehicle at an impact angle of 0°. Table 7.1 lists times and events that occurred during Test No. 469467-8-4. Figure F.1 in Appendix F.1 presents sequential photographs during the test.

Brakes on the vehicle were applied 1.8 s after impact. The vehicle subsequently came to rest 270 ft downstream of the impact.

Table 7.1. Events during Test No. 469467-8-4.

TIME (s)	EVENT
0.003	Support post begins to bend in socket
0.005	Horizontal mailbox support plate deflects downward from bottom of boxes
0.009	Mailboxes begin to be pulled vertically downward by support; Support post fully out of socket and begins to drag along ground
0.010	Post impacts hood
0.015	Mailboxes contact each other
0.025	Upstream mailbox impacts vehicle hood
0.026	Bottom of support post lifts off ground
0.042	Support post disengages from hood and bumper
0.060	Red flag on mailbox impacts windshield; windshield does not break
0.068	Entire mailbox and post assembly lifts, rotates, and displaces vertically
0.069	Mailboxes lose contact with hood without any windshield contact

7.2.2.5 Damage to Test Installation

Figure 7.6 shows the damage to the TxDOT mailbox system on winged channel post with type 3 foundation. The mailbox support fractured 3 inches below grade. The mailboxes (minus the doors) remained attached to the mailbox support and came to rest 188 ft downstream of impact.

Figure 7.6. TxDOT Double Mailbox System on Winged Channel Post with Type 3 Foundation after Test No. 469467-8-4.

7.2.2.6 Damage to Test Vehicle

Figure 7.7 shows damage sustained by the vehicle. The front bumper and hood had a small dent at the left quarter point. The left side of the hood was depressed downward 1.25 inches over an area 24 inches wide × 20 inches long. Maximum exterior crush to the vehicle was 1.25 inches on the hood. No occupant compartment deformation or intrusion was noted. Figure 7.8 shows the interior of the vehicle. Table F.2 in Appendix F.2 provides occupant compartment measurements.

7.2.2.7 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for informational purposes only and are shown in Table 7.2. Figure 7.9 summarizes these data and other pertinent information from the test. Figure F.2 in Appendix F.1 shows the vehicle angular displacements, and Figures F.3 through F.8 in Appendix F.1 show vehicle acceleration versus time traces.

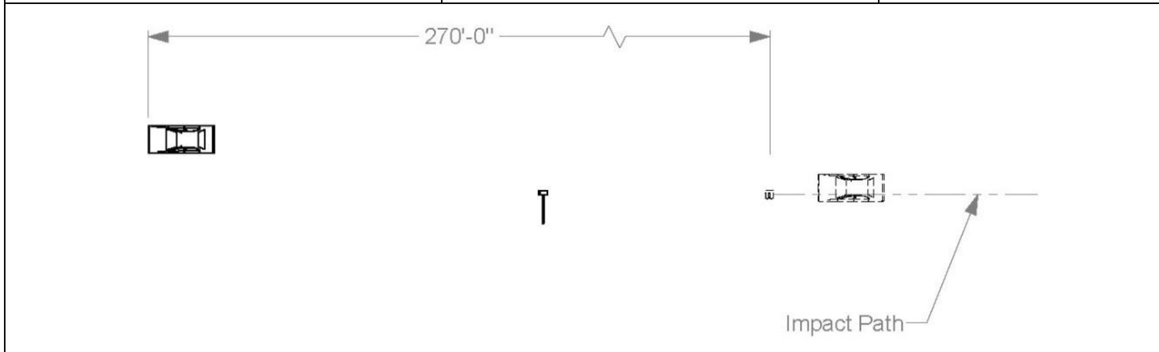
Figure 7.7. Test Vehicle after Test No. 469467-8-4.

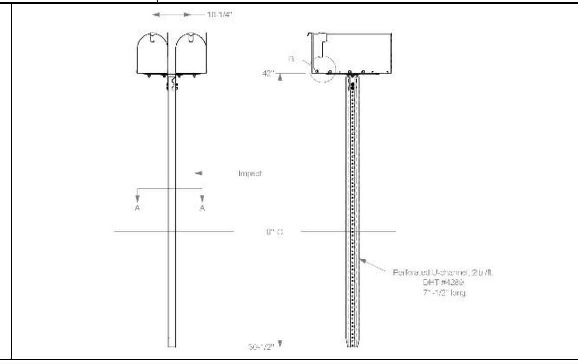
Before Test After Test

Figure 7.8. Windshield of Test Vehicle for Test No. 469467-8-4.

Table 7.2. Occupant Risk Factors for Test No. 469467-8-4.

Occupant Risk Factor	Value	Time
OIV	**No Contact**	
Occupant Ridedown Accelerations	**NA**	
THIV	**NA**	
PHD	**NA**	
ASI	**0.06**	0.0349–0.0849 s
Maximum 50-ms Moving Average		
Longitudinal	**−0.6 g**	0.0007–0.0507 s
Lateral	**−0.2 g**	0.0582–0.1082 s
Vertical	**0.7 g**	0.0259–0.0759 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	**1.2°**	0.3132 s
Pitch	**2.0°**	1.0000 s
Yaw	**1.3°**	0.3091 s





General Information		**Impact Conditions**		**Post-Impact Trajectory**	
Test Agency	Texas A&M Transportation Institute (TTI)	Speed	63.3 mi/h	Stopping Distance	270 ft 10 ft twd right
Test Standard Test No.	*MASH* Test 3-62	Angle	0°	**Vehicle Stability**	
TTI Test No.	469467-8-4	Location/Orientation	Left qtr-pt aligned w/centerline support	Maximum Yaw Angle	1.3°
Test Date	2017-08-03	**Kinetic Energy**	327 kip-ft	Maximum Pitch Angle	2.0°
Test Article		**Exit Conditions**		Maximum Roll Angle	1.2°
Type	Mailbox Support	Speed	61.9 mi/h	**Debris Scatter**	188 ft x 6 ft
Name	TxDOT Double Mailbox System on Winged Channel Post with Type 3 Foundation	Angle	0°	**Vehicle Damage**	
Installation Height	42 inches to bottom of mailbox	**Occupant Risk Values**		VDS	12FL1
Material or Key Elements	2 standard mailboxes mounted on a single winged-channel steel post	Longitudinal OIV	No contact	CDC	12FLEN1
Soil Type and Condition	Compacted road base; Damp	Lateral OIV	No Contact	Max. Exterior Deformation	1.25 inches
Test Vehicle		Longitudinal Ridedown	NA	OCDI	FS0000000
Type/Designation	1100C	Lateral Ridedown	NA	Max. Occupant Compartment Deformation	None
Make and Model	2011 Kia Rio	THIV	NA		
Curb	2469 lb	PHD	NA		
Test Inertial	2439 lb	ASI	0.06		
Dummy	165 lb	Max. 0.050-s Average			
Gross Static	2604 lb	Longitudinal	-0.2 g		
		Lateral	-0.6 g		
		Vertical	0.4 g		

Figure 7.9. Summary of Results for *MASH* Test 3-62 at 0° on the TxDOT Double Mailbox System on Winged Channel Post with Type 3 Foundation.

Table 7.3. Performance Evaluation Summary for *MASH* Test 3-62 at 0° on the TxDOT Double Mailbox System on Winged Channel Post with Type 3 Foundation.

Test Agency: Texas A&M Transportation Institute | Test No.: 469467-8-4 | Test Date: 2017-08-03

***MASH* Test 3-61 Evaluation Criteria**	**Test Results**	**Assessment**
<u>Structural Adequacy</u> *B.* *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*	The TxDOT double mailbox system on winged channel post with type 3 foundation fractured and released as designed.	Pass
<u>Occupant Risk</u> *D.* *Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	The mailboxes and support contacted the hood of the vehicle and then rotated up and over the vehicle without any secondary contact with the windshield. None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	No occupant compartment deformation or intrusion occurred.	
F. *The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.*	The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.2° and 2.0°, respectively.	Pass
H. *Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s, or maximum allowable value of 16 ft/s.*	No occupant contact occurred.	Pass
I. *The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.*	No occupant contact occurred.	Pass
<u>Vehicle Trajectory</u> *N.* *Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest 270 ft downstream of impact.	Pass

7.2.2.8 Assessment of Results

An assessment of the test on the TxDOT double mailbox system on winged channel post with type 3 foundation based on the applicable safety evaluation criteria for *MASH* Test 3-61 is provided in Table 7.3.

7.2.2.9 Conclusions

The TxDOT double mailbox system on winged channel post with type 3 foundation fractured and released as designed. The mailboxes and support contacted the hood of the vehicle and then rotated up and over the vehicle without any secondary contact with the windshield. None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area. No occupant compartment deformation or intrusion occurred. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.2° and 2.0°, respectively. No occupant contact occurred. The 1100C vehicle came to rest 270 ft downstream of impact.

The TxDOT double mailbox system on winged channel post with type 3 foundation performed acceptably for *MASH* Test 3-61.

7.3 DOUBLE MAILBOX SYSTEM ON THIN-WALLED GALVANIZED TUBE WITH TYPE 2 FOUNDATION

7.3.1 System Details

This system consists of a two mailboxes attached to a galvanized thin-wall steel tube support secured inside a 12-gauge galvanized anchor socket embedded in a concrete footing with a curved steel plate wedge. Each mailbox was empty, and the bottom of each mailbox was mounted 42 inches above grade. Details of this system are described in Maintenance Division standard MB-15(1).

Two *Elite* No. 1-A standard arched-top mailboxes from Solar Group, Inc., a division of Gibraltar Industries Model #E1600B00 were attached to the top of the support post. Each *Elite* mailbox was delivered as a fabricated steel unit with approximate dimensions of 11 inches tall by 8¾ inches wide by 21½ inches deep and weighed 7 lb. Attachment of each *Elite* mailbox to the post was accomplished using a mailbox bracket (DHT #148939), one extension bracket (DHT #148938), and associated SAE Grade 5 bolts, nuts, and washers. The mailboxes, located 10-inches center to center, were secured plate and collar bracket (DHT #162323) that was attached to the support post using a ⅜-inch diameter × 3½-inch long SAE Grade 5 hex bolt, flat and lock washers, and nut. The two boxes with brackets and hardware weighed 20 lb.

The two mailboxes were supported on a nominal 2-inch diameter x 16 gauge thick (2⅜ inches outside diameter by 0.065 inch wall thickness) galvanized thin-wall steel tube (DHT #143426) formed from ASTM A513 Type 5 DOM steel tubing. The overall length of the support post was 57 inches and it weighed 7.5 lb.

The support post was inserted approximately 15 inches into a socket (DHT #143434) and secured with a wedge (DHT #143433) on the impact side. The socket was embedded 27 inches deep, and installed flush with the top of a TxDOT Type 2 non-reinforced concrete footer that measured approximately 12 inches in diameter × 30 inches deep. The total mass of the two mailboxes, connection hardware, and support post assembly was 27.5 lb.

Figure 7.10 presents details of the TxDOT double mailbox system on thin-walled galvanized tube with type 2 foundation, and Figure 7.11 provides photographs of the completed test installation.

7.3.2 *MASH* Test 3-61

7.3.2.1 Test Designation and Actual Impact Conditions

MASH Test 3-61 involves an 1100C vehicle weighing 2420 lb ±55 lb impacting the TxDOT mailbox system at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 0° ±1.5°. The centerline of the support system was aligned with the quarter point of the vehicle.

The 2011 Kia Rio used in the test weighed 2439 lb, and the actual impact speed and angle were 62.5 mi/h and 0°, respectively. The actual impact point was the centerline of the support aligned with the right quarter point of the vehicle. Minimum target KE was 288 kip-ft, and actual KE was 318 kip-ft.

7.3.2.2 Test Vehicle

The 2011 Kia Rio shown in Figures 7.12 and 7.13, and used in the previous test, was used for the crash test. The vehicle's test inertia weight was 2439 lb, and its gross static weight was 2604 lb. The height to the lower edge of the vehicle bumper was 7.75 inches, and height to the upper edge of the bumper was 21.0 inches. Table F.3 in Appendix F.2 gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

7.3.2.3 Weather Conditions

The test was performed on the afternoon of August 3, 2017. Weather conditions at the time of testing were as follows: wind speed: 3 mi/h; wind direction: 12° (vehicle was traveling in a southerly direction); temperature: 86°F; relative humidity: 69 percent.

7.3.2.4 Test Description

The test vehicle, traveling at an impact speed of 62.5 mi/h, contacted the TxDOT mailbox with the centerline of the support aligned with the right quarter point of the vehicle at an impact angle of 0°. Table 7.4 lists times and events that occurred during Test No. 469467-8-3. Figure F.9 in Appendix F.3 presents sequential photographs during the test.

Brakes on the vehicle were applied 1.4 s after impact. The vehicle subsequently came to rest 283 ft downstream of the impact and 4 ft to the right of centerline.

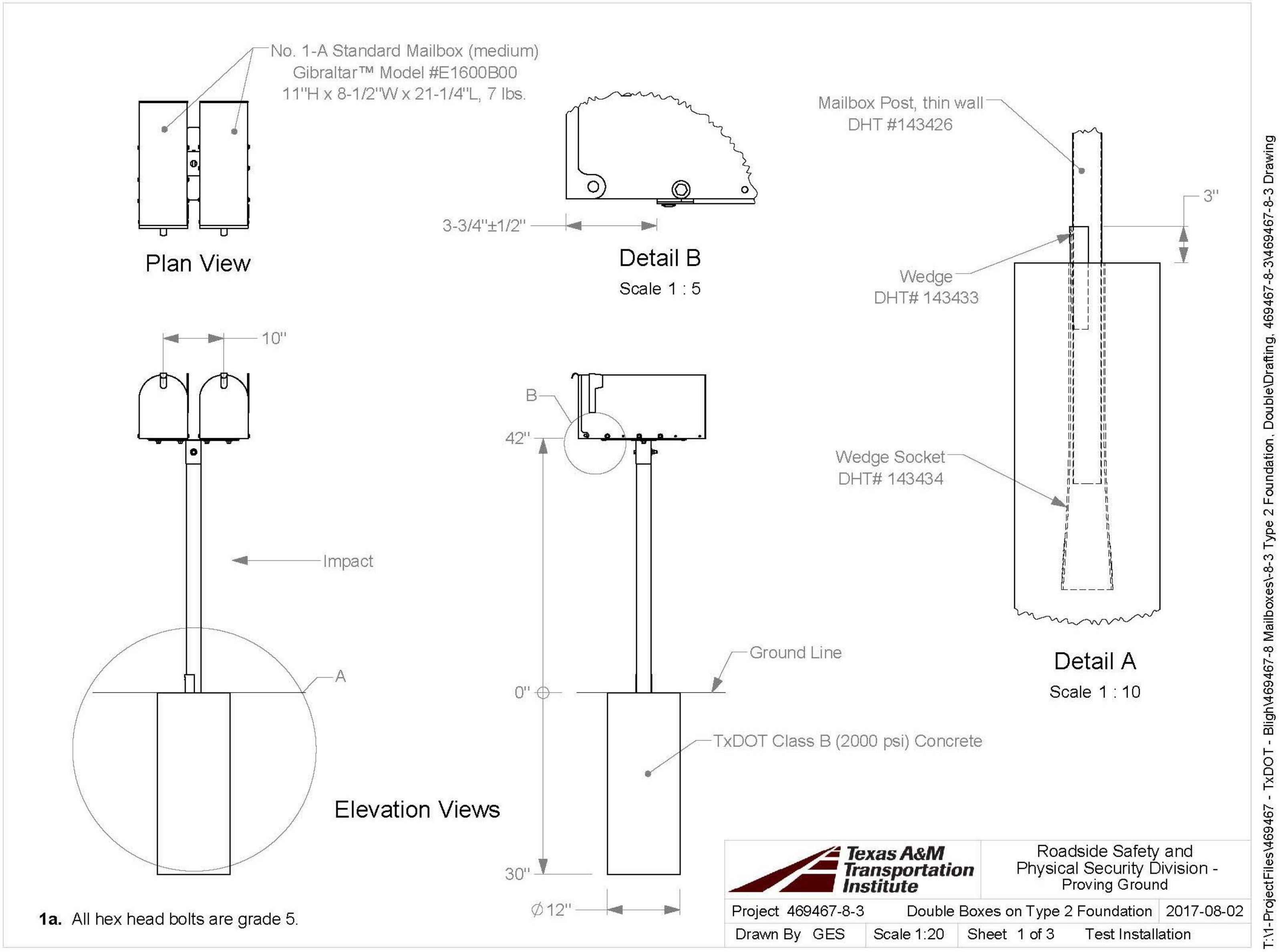


Figure 7.10. Details of the TxDOT Double Mailbox System on Thin-Walled Galvanized Tube with Type 2 Foundation.

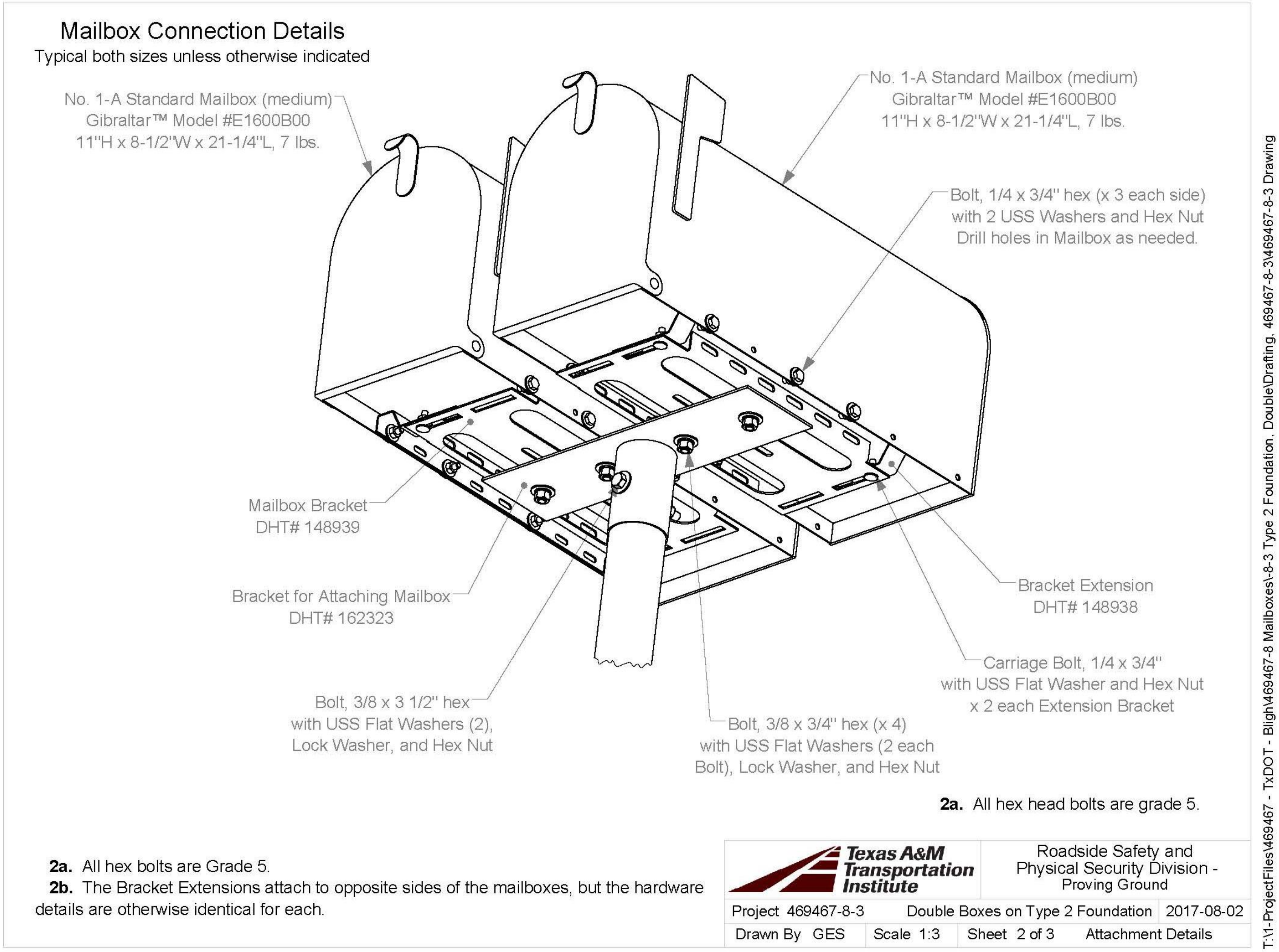


Figure 7.10. Details of the TxDOT Double Mailbox System on Thin-Walled Galvanized Tube with Type 2 Foundation (Continued).

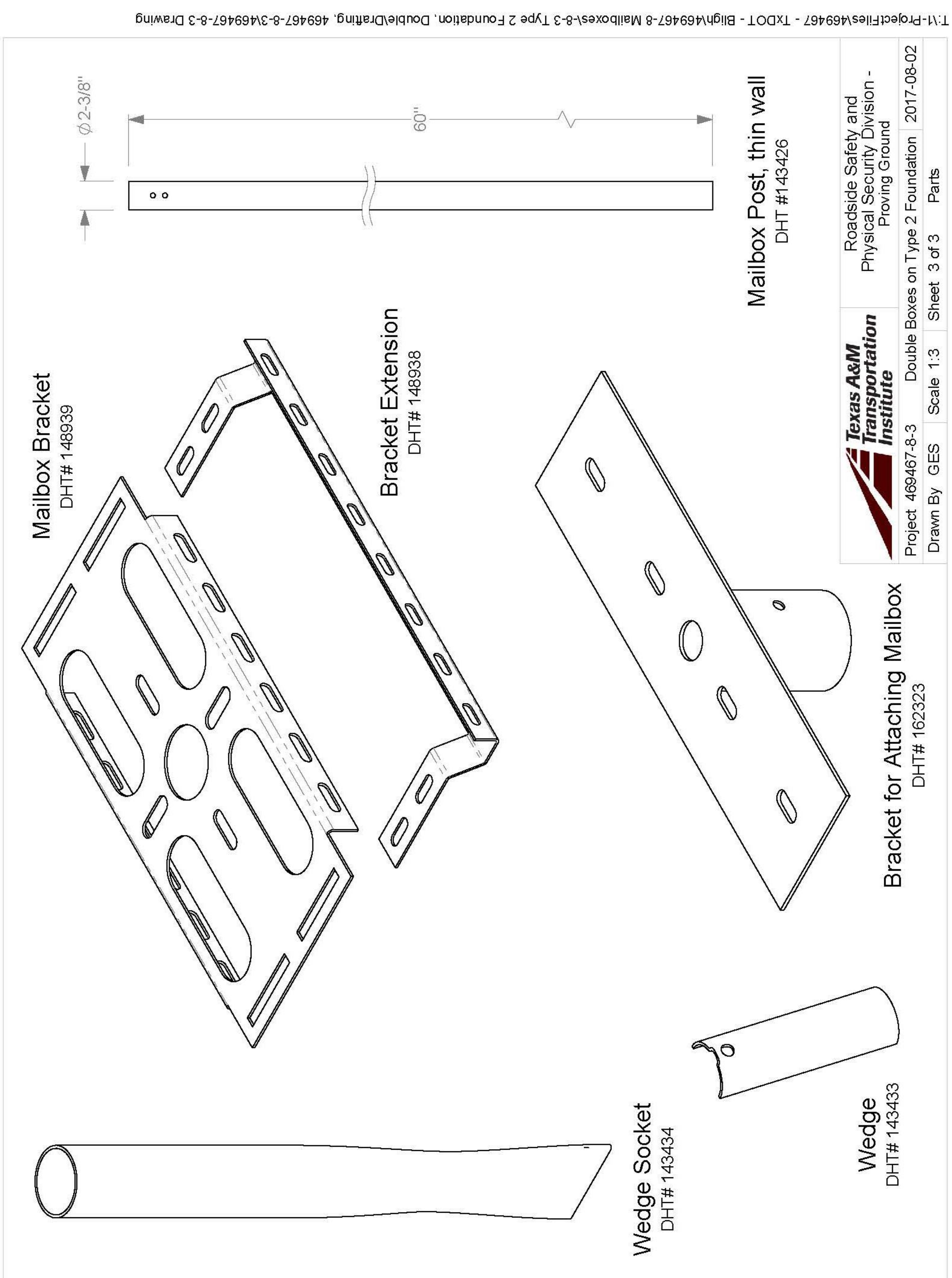


Figure 7.10. Details of the TxDOT Double Mailbox System on Thin-Walled Galvanized Tube with Type 2 Foundation (Continued).

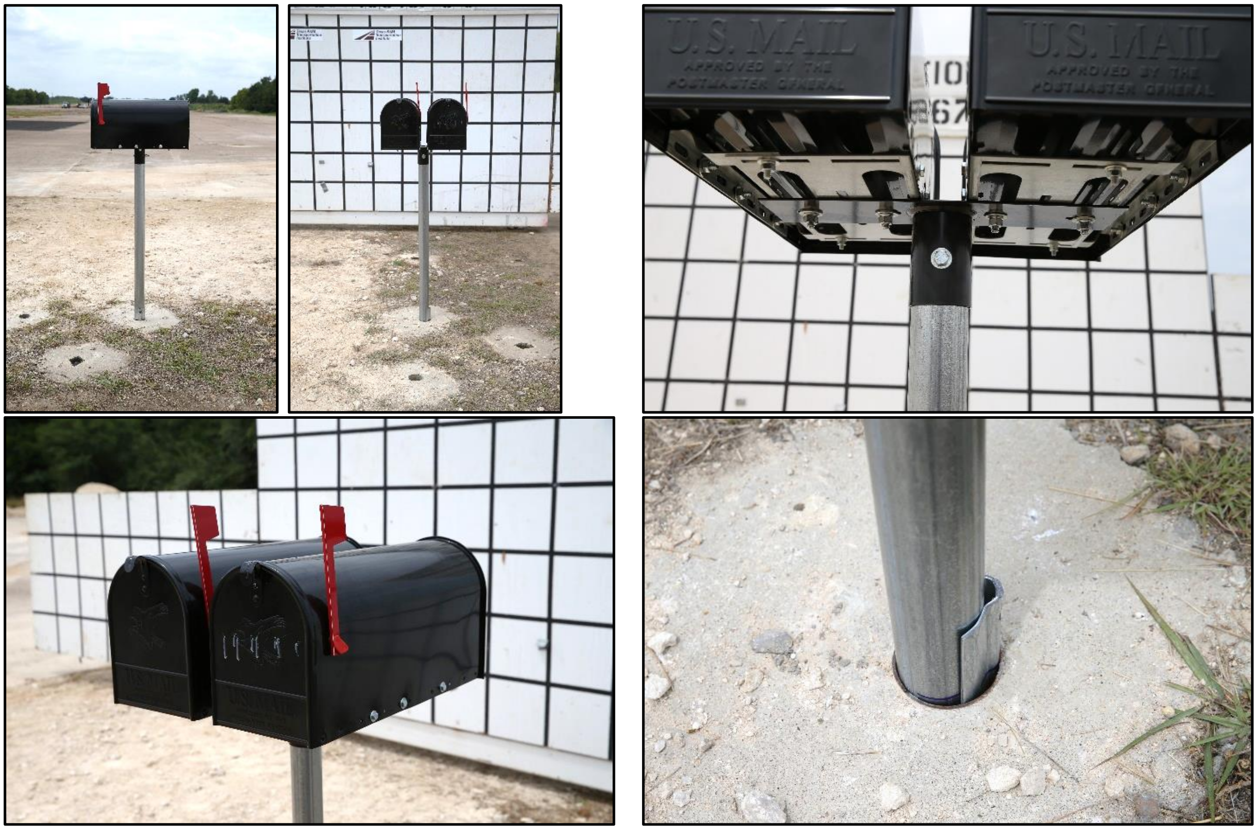


Figure 7.11. TxDOT Double Mailbox System on Thin-Walled Galvanized Tube with Type 2 Foundation prior to Testing.

Figure 7.12. TxDOT Double Mailbox System on Thin-Walled Galvanized Tube with Type 2 Foundation/Test Vehicle Geometrics for Test No. 469467-8-3.

Figure 7.13. Test Vehicle before Test No. 469467-8-3.

Table 7.4. Events during Test No. 469467-8-3.

TIME (s)	EVENT
0.003	Support tube begins to bend in socket
0.004	Horizontal mailbox support plate deflects downward from bottom of boxes
0.006	Mailboxes begin to be pulled vertically downward by support
0.007	Support impacts hood
0.012	Mailboxes contact each other
0.022	Upstream mailbox impacts vehicle hood
0.023	Support tube fully out of socket and begins to drag along ground
0.061	Support tube disengages from hood and bumper
0.068	Bottom of support tube lifts off of ground
0.069	Entire mailbox and support tube assembly lifts and displaces vertically

7.3.2.5 Damage to Test Installation

Figure 7.14 shows the damage to the TxDOT double mailbox system on thin-walled galvanized tube with type 2 foundation. The mailbox support pulled out of the ground socket. The mailboxes (minus one door) came to rest 206 ft downstream and 8 ft to the right of centerline.

7.3.2.6 Damage to Test Vehicle

Figure 7.15 shows damage sustained by the vehicle. The front bumper and hood had a small dent at the right quarter point. The right side of the hood was depressed downward 2.25 inches over an area 30 inches × 30 inches. Maximum exterior crush to the vehicle was 2.25 inches on the hood. A 0.5-inch cut was also noted in the depressed area. No occupant compartment deformation or intrusion was noted. Figure 7.16 shows the interior of the vehicle. Table F.4 in Appendix F.2 provides occupant compartment measurements.

Figure 7.14. TxDOT Double Mailbox System on Thin-Walled Galvanized Tube with Type 2 Foundation after Test No. 469467-8-3.

Figure 7.15. Test Vehicle after Test No. 469467-8-3.

Before Test After Test

Figure 7.16. Windshield of Test Vehicle for Test No. 469467-8-3.

7.3.2.7 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for informational purposes only and are shown in Table 7.5. Figure 7.17 summarizes these data and other pertinent information from the test. Figure F.10 in Appendix F.2 shows the vehicle angular displacements, and Figures F.11 through F.16 in Appendix F.2 show vehicle acceleration versus time traces.

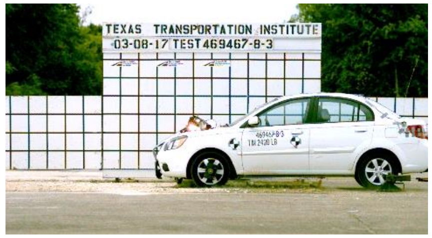
7.3.2.8 Assessment of Results

An assessment of the test on the TxDOT double mailbox system on thin-walled galvanized tube with type 2 foundation based on the applicable safety evaluation criteria for *MASH* Test 3-61 is provided in Table 7.6.

Table 7.5. Occupant Risk Factors for Test No. 469467-8-3.

Occupant Risk Factor	Value	Time
OIV	**No Contact**	
Occupant Ridedown Accelerations	**NA**	
THIV	**NA**	
PHD	**NA**	
ASI	**0.11**	0.0124–0.0624 s
Maximum 50-ms Moving Average		
Longitudinal	**−1.0 g**	0.0004–0.0504 s
Lateral	**−0.2 g**	0.0255–0.0755 s
Vertical	**0.7 g**	0.0149–0.0649 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	**1.3°**	0.9887 s
Pitch	**2.9°**	1.0000 s
Yaw	**1.5°**	0.7142 s

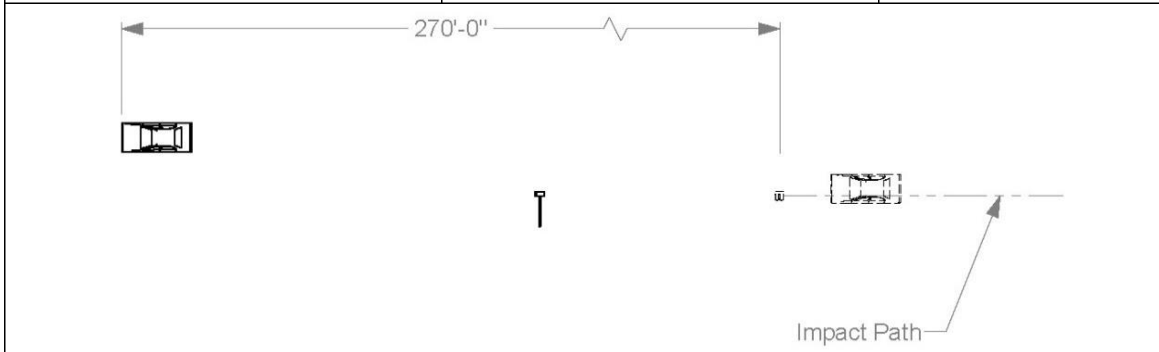
0.000 s

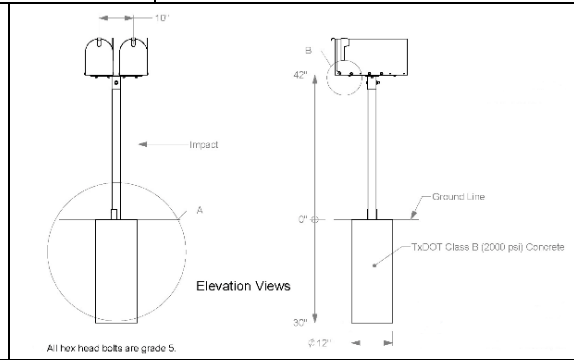


0.050 s

0.100 s

0.150 s





General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-61
TTI Test No.	469467-8-3
Test Date	2017-08-22
Test Article	
Type	Mailbox Support
Name	Double Mailbox System on Thin-Walled Galvanized Tube with Type 2 Foundation
Installation Height	42 inches to bottom of mailbox
Material or Key Elements	2 standard mailboxes mounted on single 2-inch thin wall steel post; wedge and socket foundation
Soil Type and Condition	Concrete Footing, Damp
Test Vehicle	
Type/Designation	1100C
Make and Model	2011 Kia Rio
Curb	2469 lb
Test Inertial	2439 lb
Dummy	165 lb
Gross Static	2604 lb

Impact Conditions	
Speed	62.5 mi/h
Angle	90°
Location/Orientation	Right qtr-pt aligned with centerline
Kinetic Energy	318 kip-ft
Exit Conditions	
Speed	61.1 mi/h
Angle	90°
Occupant Risk Values	
Longitudinal OIV	No contact
Lateral OIV	No Contact
Longitudinal Ridedown	NA
Lateral Ridedown	NA
THIV	NA
PHD	NA
ASI	0.11
Max. 0.050-s Average	
Longitudinal	-1.0 g
Lateral	-0.2 g
Vertical	0.7 g

Post-Impact Trajectory	
Stopping Distance	283 ft
Vehicle Stability	
Maximum Yaw Angle	1.5°
Maximum Pitch Angle	2.9°
Maximum Roll Angle	1.3°
Debris Scatter	206 ft x 8 ft
Vehicle Damage	
VDS	12FR1
CDC	12FREN1
Max. Exterior Deformation	1.25 inches
OCDI	FS0000000
Max. Occupant Compartment Deformation	None

Figure 7.17. Summary of Results for *MASH* Test 3-61 on the TxDOT Double Mailbox System on Thin-Walled Galvanized Tube with Type 2 Foundation.

Table 7.6. Performance Evaluation Summary for *MASH* Test 3-61 on the TxDOT Double Mailbox System on Thin-Walled Galvanized Tube with Type 2 Foundation.

Test Agency: Texas A&M Transportation Institute | Test No.: 469467-8-3 | Test Date: 2017-08-03

***MASH* Test 3-61 Evaluation Criteria**	**Test Results**	**Assessment**
Structural Adequacy *B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*	The TxDOT double mailbox system on thin-walled galvanized tube with type 2 foundation yielded around the front of the vehicle and pulled out of the ground socket as designed.	Pass
Occupant Risk *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	The mailboxes and support contacted the hood of the vehicle and then rotated up and over the vehicle without any secondary contact with the windshield. None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	No occupant compartment deformation or intrusion occurred.	
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.3° and 2.9°, respectively.	Pass
H. Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s, or maximum allowable value of 16 ft/s.	No occupant contact occurred.	Pass
I. The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	No occupant contact occurred.	Pass
Vehicle Trajectory *N. Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest 283 ft downstream of impact.	Pass

7.3.2.9 Conclusions

The TxDOT double mailbox system on thin-walled galvanized tube with type 2 foundation yielded around the front of the vehicle and pulled out of the ground socket as designed. The mailboxes and support contacted the hood of the vehicle and then rotated up and over the vehicle without any secondary contact with the windshield. None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area. No occupant compartment deformation or intrusion occurred. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.3° and 2.9°, respectively. No occupant contact occurred. The 1100C vehicle came to rest 283 ft downstream of impact.

The TxDOT double mailbox system on thin-walled galvanized tube with type 2 foundation performed acceptably for *MASH* Test 3-61.

7.4 MULTIPLE MAILBOX SYSTEM ON 56-INCH HANGER-TYPE THIN-WALLED GALVANIZED TUBE WITH TYPE 1 FOUNDATION

7.4.1 System Details

The mailbox configuration used for this test consists of four mailboxes (two large and two standard) attached to a galvanized thin-wall steel tube support formed in the shape of a hanger secured inside a V-wing socket embedded in a concrete footing using a triangular wedge. Each mailbox was empty, and the bottom of each mailbox was mounted 42 inches above grade. Details of this system are described in Maintenance Division standard MB-15(1). TTI recommend testing this system with two large and two standard mailboxes, which is more critical in terms of weight and size than four standard mailboxes (30 lb versus 20 lb). This is considered the most critical configuration that can be practically accommodated along the 56-inch width of the hanger-style support.

Two *Stanley* No. 2 large arched-top mailboxes from Solar Group, Inc., a division of Gibraltar Industries, Model #ST200B00, were attached at the second and third (middle two) of the four mounting positions located 7½ inches from the centerline of the support post. Each *Stanley* mailbox was delivered as a fabricated steel unit with approximate dimensions of 15 inches tall × 11½ inches wide × 24¾ inches deep and weighed 11 lb. Attachment of each *Stanley* mailbox to the horizontal segment of the thin-wall steel mounting post was accomplished using a mailbox bracket (DHT #148939), two extension brackets (DHT #148938), a pair of Part “A” angle brackets (DHT # 159489), and associated SAE Grade 5 bolts, nuts, and washers.

Two *Elite* No. 1-A standard arched-top mailboxes from Solar Group, Inc., a division of Gibraltar Industries Model #E1600B00, were attached at the first and fourth of the four mounting positions located 21 inches from the centerline of the support post. Each *Elite* mailbox was delivered as a fabricated steel unit with approximate dimensions of 11 inches tall × 8¾ inches wide × 21½ inches deep and weighed 7 lb. Attachment of each *Elite* mailbox to the horizontal segment of the thin-wall steel mounting post was accomplished using a mailbox bracket (DHT #148939), one extension bracket (DHT #148938), a pair of Part “A” angle brackets (DHT # 159489), and associated SAE Grade 5 bolts, nuts, and washers.

The four mailboxes were supported on a galvanized thin-wall steel tube support (DHT #149339) formed in the shape of a hanger from 2-inch nominal diameter × 16 gauge thick (2 inches outside diameter × 0.065 inch wall thickness) thin wall ASTM A513 Type 5 DOM steel tubing. The support post had outwardly sloping sides and a horizontal section on top to which the mailboxes were attached. The support post had an overall width of 56 inches and weighed 18 lb. The post's shorter leg was secured to the longer, supporting leg using two ⅜-inch diameter × 4½-inch long SAE Grade 5 bolts, flat washers, and nuts.

The longer leg of the support post was inserted approximately 9 inches into a V-wing Socket (DHT #149340) and secured with a V-wing Wedge (DHT #46625) on the side opposite the impact. The socket was embedded 24 inches deep and installed flush with the top of a TxDOT Type 1 non-reinforced concrete foundation that measured approximately 12 inches in diameter × 30 inches deep. The total mass of the four mailboxes, connection hardware, and support post assembly was 66 lb.

Figure 7.18 presents details of the TxDOT multiple mailbox system on 56-inch hanger-type thin-walled galvanized tube with Type 1 foundation, and Figure 7.19 provides photographs of the completed test installation.

7.4.2 *MASH* Test 3-61

7.4.2.1 Test Designation and Actual Impact Conditions

MASH Test 3-61 involves an 1100C vehicle weighing 2420 lb ±55 lb impacting the TxDOT mailbox system at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 0° ±1.5°. The centerline of the support system was aligned with the quarter point of the vehicle.

The 2011 Kia Rio used in the test weighed 2439 lb, and the actual impact speed and angle were 63.0 mi/h and 0°, respectively. The actual impact point was the centerline of the support aligned with the left quarter point of the vehicle. Minimum target KE was 288 kip-ft, and actual KE was 324 kip-ft.

7.4.2.2 Test Vehicle

The 2011 Kia Rio shown in Figures 7.20 and 7.21, and used in the previous two tests, was used for the crash test. The hood of the vehicle was replaced. The vehicle's test inertia weight was 2439 lb, and its gross static weight was 2604 lb. The height to the lower edge of the vehicle bumper was 7.75 inches, and height to the upper edge of the bumper was 21.0 inches. Table F.5 in Appendix F.3 gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

7.4.2.3 Weather Conditions

The test was performed on the afternoon of August 31, 2017. Weather conditions at the time of testing were as follows: wind speed: 9 mi/h; wind direction: 36° (vehicle was traveling in a southerly direction); temperature: 92°F; relative humidity: 44 percent.

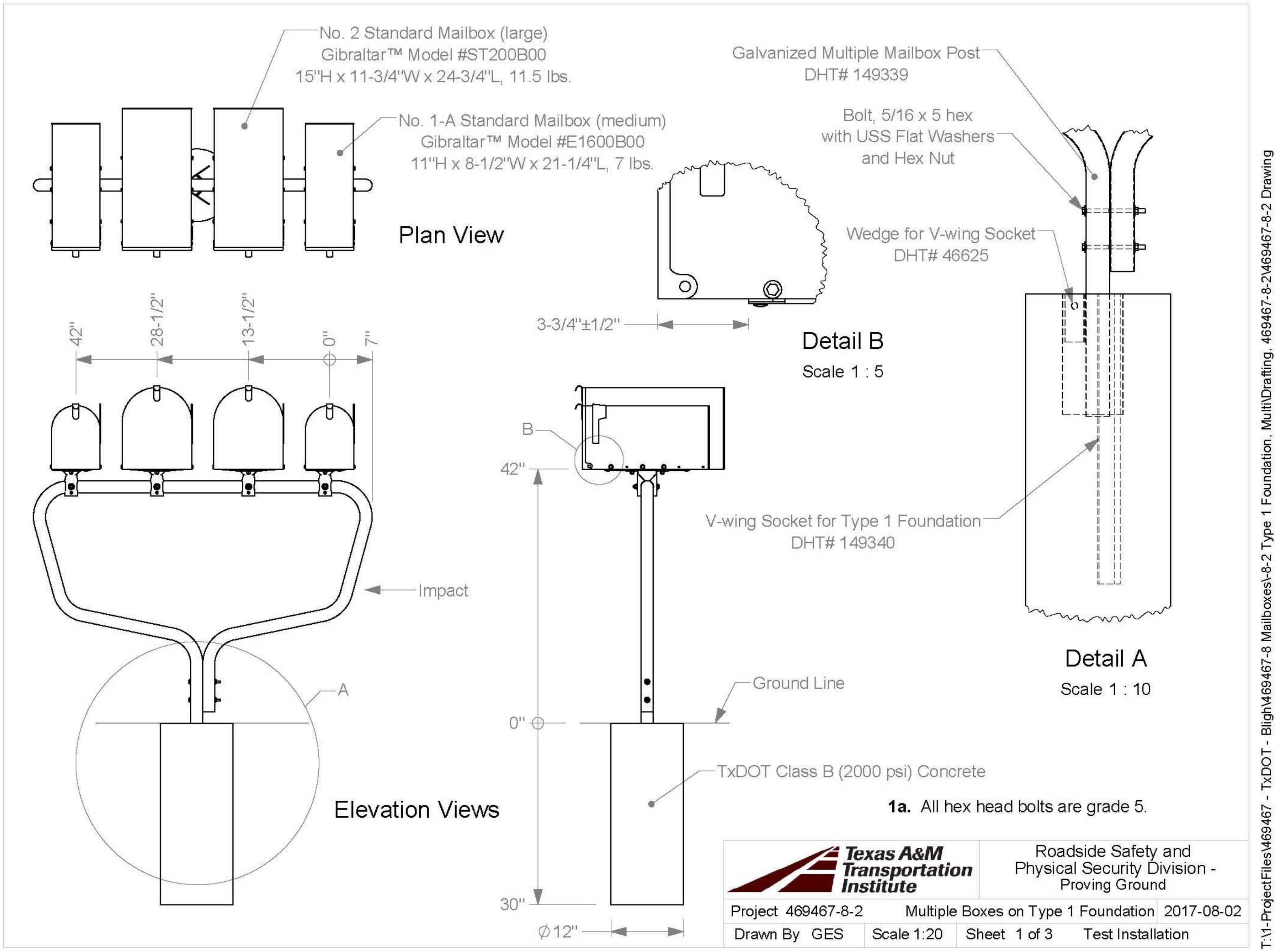


Figure 7.18. Details of the TxDOT Multiple Mailbox System on 56-inch Hanger-Type Thin-Walled Galvanized Tube with Type 1 Foundation.

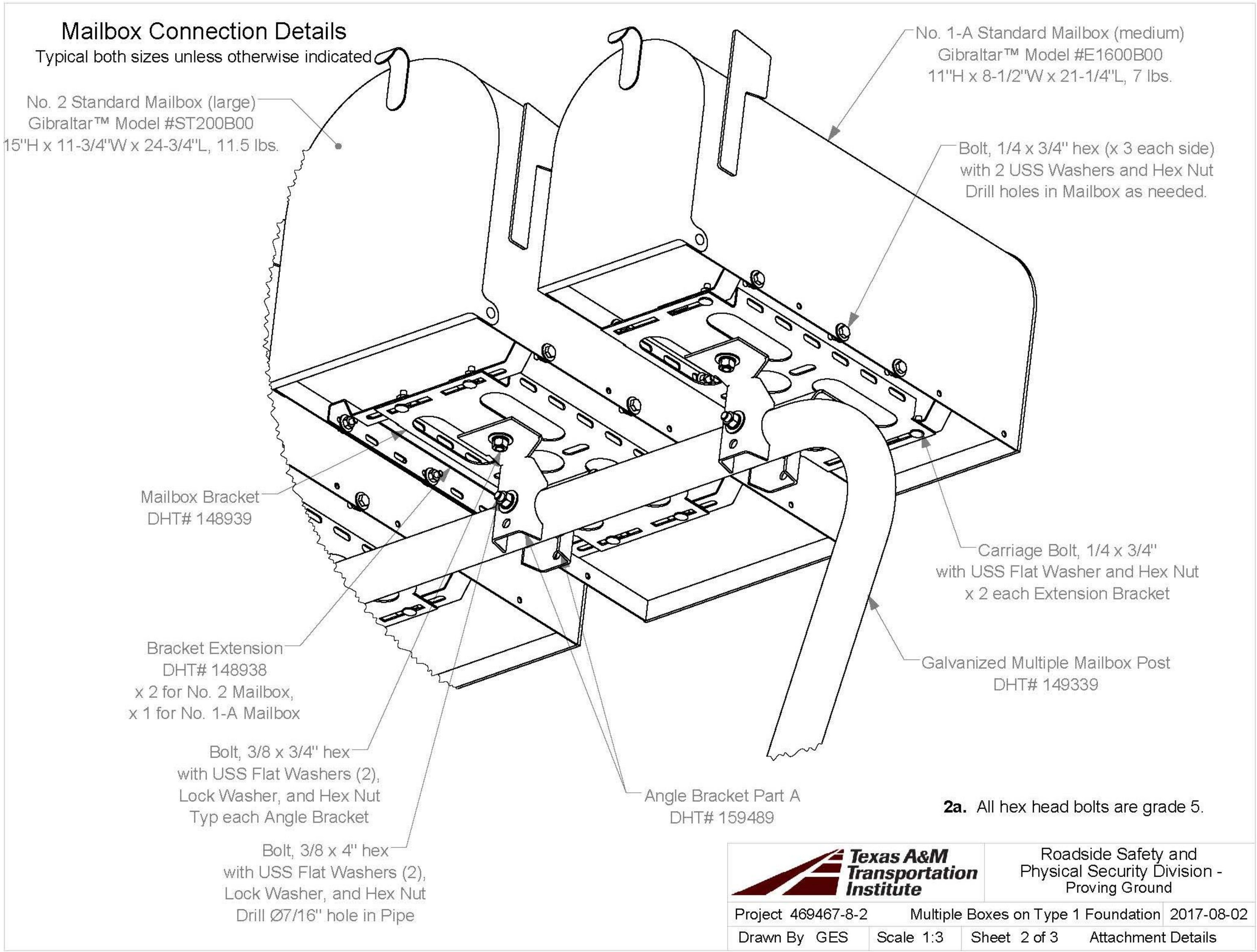


Figure 7.18. Details of the TxDOT Multiple Mailbox System on 56-inch Hanger-Type Thin-Walled Galvanized Tube with Type 1 Foundation (Continued).

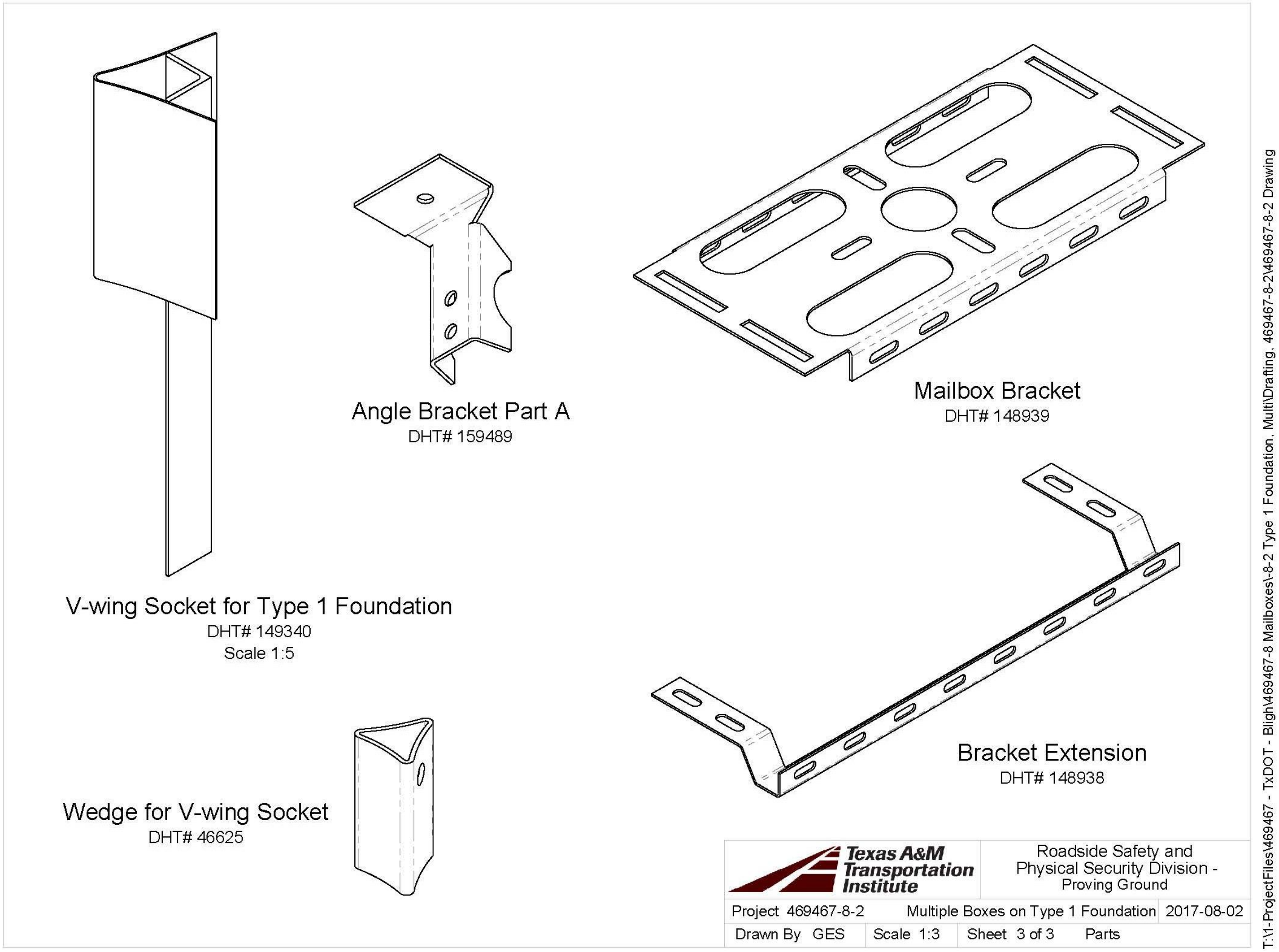


Figure 7.18. Details of the TxDOT Multiple Mailbox System on 56-inch Hanger-Type Thin-Walled Galvanized Tube with Type 1 Foundation (Continued).

Figure 7.19. TxDOT Multiple Mailbox System on 56-inch Hanger-Type Thin-Walled Galvanized Tube with Type 1 Foundation prior to Testing.

Figure 7.20. TxDOT Multiple Mailbox System on 56-inch Hanger-Type Thin-Walled Galvanized Tube with Type 1 Foundation/Test Vehicle Geometrics for Test No. 469467-8-2.

Figure 7.21. Test Vehicle before Test No. 469467-8-2.

7.4.2.4 Test Description

The test vehicle, traveling at an impact speed of 63.0 mi/h, contacted the TxDOT mailbox system with the centerline of the support aligned with the left quarter point of the vehicle at an impact angle of 0°. Table 7.7 lists times and events that occurred during Test No. 469467-8-2. Figure F.17 in Appendix F.3 presents sequential photographs during the test.

Table 7.7. Events during Test No. 469467-8-2.

TIME (s)	EVENT
0.0020	Support begins to deflect toward field side
0.0040	Ground support begins to deform
0.0060	Mailbox nearest vehicle begins to rise upward
0.0090	Remaining mailboxes begin to rise
0.0200	Support begins to pull out of socket and mailboxes rotate clockwise
0.0310	Support entirely lifted out of socket
0.0380	Elbow of support contacts hood near windshield
0.0490	Mailbox contacts windshield wiper
0.0510	Corner of mailbox contacts windshield
0.1460	Mailboxes lose contact with the vehicle

Brakes on the vehicle were applied at 1.4 s after impact. The vehicle subsequently came to rest 297 ft downstream of the impact.

7.4.2.5 Damage to Test Installation

Figure 7.22 shows the damage to the TxDOT multiple mailbox system on 56-inch hanger-type thin-walled galvanized tube with type 1 foundation. The mailbox assembly remained intact and the support post pulled out of the socket. The mailbox assembly came to rest 164 ft downstream of impact and 9 ft to the right of centerline.

Figure 7.22. TxDOT Multiple Mailbox System on 56-inch Hanger-Type Thin-Walled Galvanized Tube with Type 1 Foundation after Test No. 469467-8-2.

7.4.2.6 Damage to Test Vehicle

Figures 7.23 and 7.24 show damage sustained by the vehicle. The front bumper and hood had small dents at the left quarter point. The top of the hood was depressed over an area 19 inches wide × 22 inches long with a maximum depth of 2.1 inches. The windshield was shattered over an area 24 inches wide × 15 inches long with a maximum depth of 1.7 inches. No evidence of a puncture or hole in the windshield was noted. Maximum occupant compartment deformation was 1.7 inches in the windshield area. Figure 7.25 shows the interior of the vehicle. Table F.6 in Appendix F.3 provides occupant compartment measurements.

Figure 7.23. Test Vehicle after Test No. 469467-8-2.

Figure 7.24. Test Vehicle Exterior Windshield Damage after Test No. 469467-8-2.

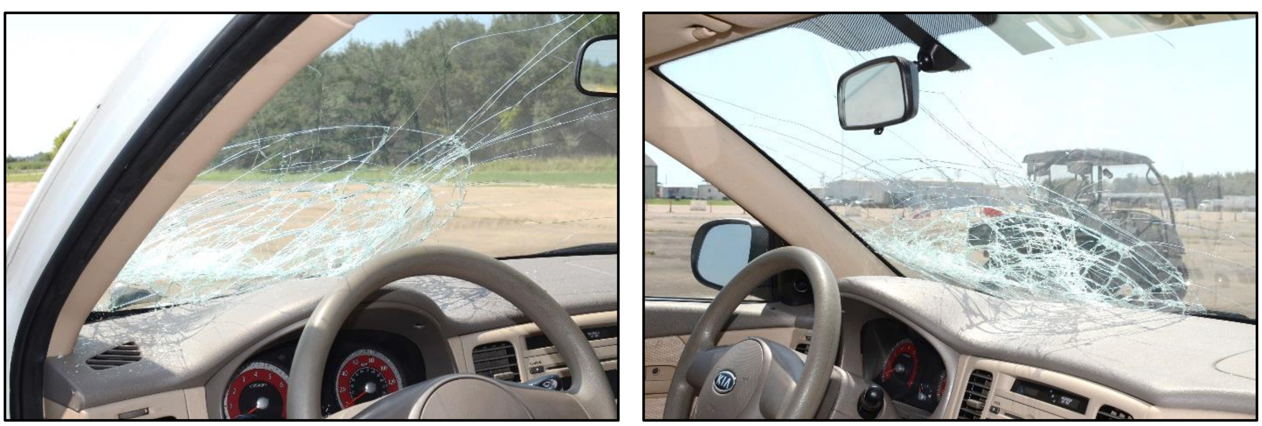


Figure 7.25. Interior Windshield Damage after Test No. 469467-8-2.

7.4.2.7 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for informational purposes only and are shown in Table 7.8. Figure 7.26 summarizes these data and other pertinent information from the test. Figure F.18 in Appendix F.3 shows the vehicle angular displacements, and Figures F.19 through F.24 in Appendix F.3 show vehicle acceleration versus time traces.

Table 7.8. Occupant Risk Factors for Test No. 469467-8.2.

Occupant Risk Factor	Value	Time
OIV		
Longitudinal	**2.3 ft/s**	at 0.8877 s on front of interior
Lateral	**0.3 ft/s**	
Occupant Ridedown Accelerations		
Longitudinal	**0.1 g**	0.9900–1.0000 s
Lateral	**0.3 g**	0.9753–0.9853 s
THIV	**2.6 km/h** **0.7 m/s**	at 0.8805 s on front of interior
PHD	**0.3 g**	0.9752–0.9852 s
ASI	**0.09**	0.0157–0.0657 s
Maximum 50-ms Moving Average		
Longitudinal	**−1.0 g**	0.0110–0.0610 s
Lateral	**−0.3 g**	0.0276–0.0776 s
Vertical	**0.9 g**	0.0452–0.0952 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	**1.2°**	0.7305 s
Pitch	**0.7°**	0.5212 s
Yaw	**1.6°**	0.3215 s

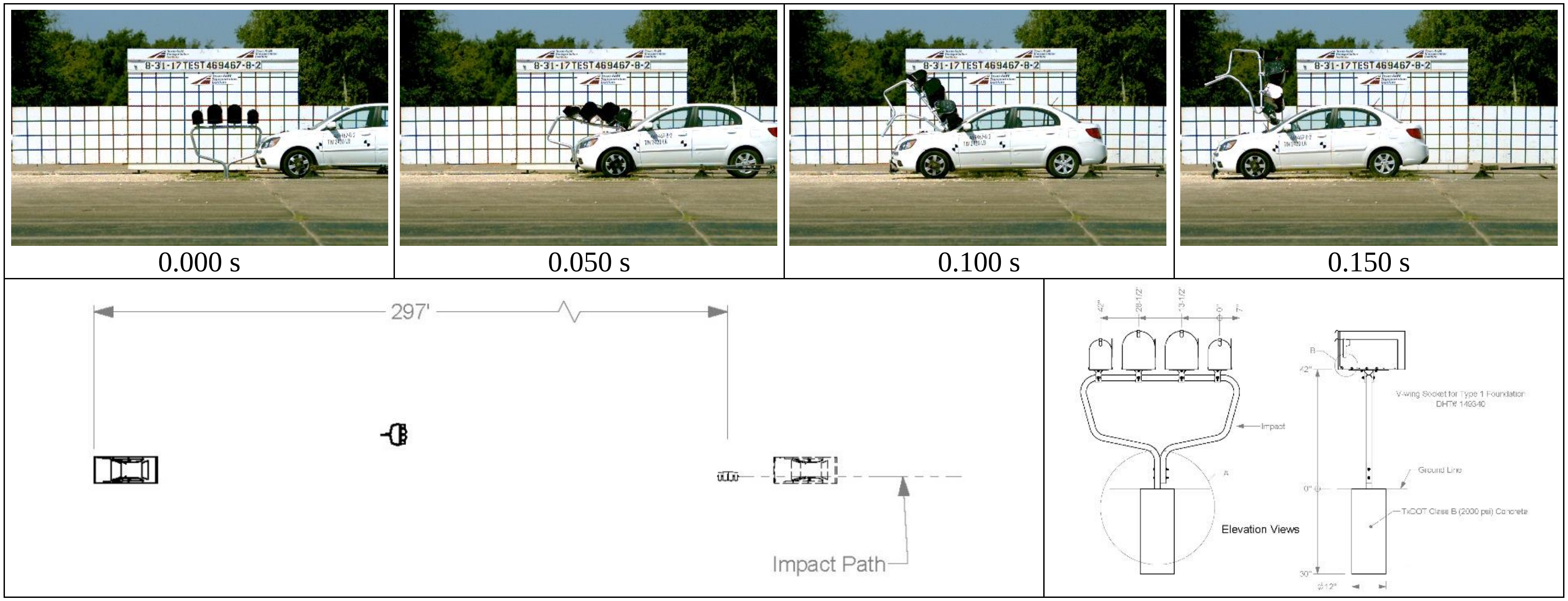
7.4.2.8 Assessment of Results

An assessment of the test on the TxDOT multiple mailbox system on 56-inch hanger-type thin-walled galvanized tube with type 1 foundation based on the applicable safety evaluation criteria for *MASH* Test 3-61 is provided in Table 7.9.

7.4.2.9 Conclusions

The TxDOT multiple mailbox system on 56-inch hanger-type thin-walled galvanized tube with type 1 foundation yielded to the vehicle by pulling out of the foundation socket as designed. None of the detached pieces penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area. Maximum occupant compartment deformation was 1.7 inches in the left windshield area. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.2° and 0.7°, respectively. No occupant contact occurred. The 1100C vehicle came to rest 297 ft downstream of impact.

The TxDOT multiple mailbox system on 56-inch hanger-type thin-walled galvanized tube with type 1 foundation performed acceptably for *MASH* Test 3-61.



General Information
Test Agency .... Texas A&M Transportation Institute (TTI)
Test Standard Test No. ...... *MASH* Test 3-61
TTI Test No. 469467-8-2
Test Date 2017-08-31
Test Article
Type .... Mailbox Support
Name .... TxDOT Multiple Mailbox System on 56-inch Hanger-Type Thin-Walled Galvanized Tube with Type 1 Foundation
Installation Height .... 42 inches to bottom of mailbox
Material or Key Elements ... 4 mailboxes (2 large/2 standard) attached to 2-inch steel thin wall tube in socket
Soil Type and Condition ..... Concrete Footing, Damp
Test Vehicle
Type/Designation 1100C
Make and Model .... 2011 Kia Rio
Curb .... 2469 lb
Test Inertial .... 2439 lb
Dummy .... 165 lb
Gross Static .... 2604 lb

Impact Conditions
Speed .... 63.0 mi/h
Angle .... 0°
Location/Orientation .... Left qtr-pt aligned with support
Kinetic Energy .... 324 kip-ft
Exit Conditions
Speed ....
Angle ....
Occupant Risk Values
Longitudinal OIV .... 2.3 ft/s
Lateral OIV .... 0.3 ft/s
Longitudinal Ridedown .... 0.1 g
Lateral Ridedown .... 0.3 g
THIV .... 2.6 km/h
PHD .... 0.3 g
ASI 0.09
Max. 0.050-s Average
Longitudinal .... -1.0 g
Lateral .... -0.3 g
Vertical .... 0.9 g

Post-Impact Trajectory
Stopping Distance .... 297 ft
Vehicle Stability
Maximum Yaw Angle .... 1.6°
Maximum Pitch Angle .... 0.7°
Maximum Roll Angle .... 1.2°
Debris Scatter .... 164 ft x 9 ft
Vehicle Damage
VDS ....
CDC ....
Max. Exterior Deformation......... 2.1 inches
OCDI FL0000000
Max. Occupant Compartment Deformation .... 1.7 inches

Figure 7.26. Summary of Results for *MASH* Test 3-62 at 0° on the TxDOT Multiple Mailbox System on 56-inch Hanger-Type Thin-Walled Galvanized Tube with Type 1 Foundation.

Table 7.9. Performance Evaluation Summary for *MASH* Test 3-62 at 0° on the TxDOT Multiple Mailbox System on 56-inch Hanger-Type Thin-Walled Galvanized Tube with Type 1 Foundation.

Test Agency: Texas A&M Transportation Institute | Test No.: 469467-8-2 | Test Date: 2017-08-31

***MASH* Test 3-61 Evaluation Criteria**	**Test Results**	**Assessment**
Structural Adequacy *B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*	The TxDOT multiple mailbox system on 56-inch hanger-type thin-walled galvanized tube with type 1 foundation yielded to the vehicle by pulling out of the foundation socket as designed.	Pass
Occupant Risk *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	None of the detached pieces penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	Maximum occupant compartment deformation was 1.7 inches in the left windshield area.	
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.2° and 0.7°, respectively.	Pass
H. Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s, or maximum allowable value of 16 ft/s.	No occupant contact occurred.	Pass
I. The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	No occupant contact occurred.	Pass
Vehicle Trajectory *N. Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest 297 ft downstream of impact.	Pass

CHAPTER 8: SUMMARY AND CONCLUSIONS

A *MASH* implementation agreement was jointly developed and adopted by FHWA and AASHTO. It establishes various implementation dates for different categories of roadside safety features. In response to the implementation requirements, TxDOT Bridge, Design, Maintenance, and Traffic Operations Divisions reviewed their standards for roadside safety devices and identified those devices that require testing and evaluation to assess *MASH* compliance. These systems will be crash tested in accordance with *MASH* criteria in three phases over a three-year period.

This report documents the Phase I testing and evaluation effort. Test results and assessment of *MASH* compliance for each device are summarized below.

8.1 *MASH* TEST 4-12 ON THE TXDOT 36-INCH VERTICAL WALL

The 36-inch vertical wall contained and redirected the 10000S vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 2.2 inches. Slight cracking of the concrete parapet occurred in the impact region near the expansion joint in the rail. No detached elements, fragments, or other debris from the test article were present to penetrate or show potential for penetrating the occupant compartment or present hazard to others in the area. No occupant compartment deformation or intrusion occurred. The 10000S vehicle rolled onto its left side and roof after exiting the barrier and traversing onto unpaved terrain.

The 36-inch vertical wall performed acceptably for *MASH* Test 4-12.

8.2 *MASH* TEST 4-12 ON THE TXDOT 42-INCH TALL SSCB

The TxDOT 42-inch SSCB with 1-inch ACP lateral support contained and redirected the 10000S vehicle. The vehicle did not penetrate, underride, or override the installation. No lateral deflection was noted during the test. No detached elements, fragments, or other debris was present to penetrate or show potential for penetrating the occupant compartment or to present hazard to others in the area. The 10000S vehicle remained upright during and after the collision event.

The TxDOT 42-inch tall SSCB with 1-inch ACP lateral support performed acceptably for *MASH* Test 4-12.

8.3 *MASH* TEST 3-11 ON THE TXDOT 32-INCH CSB(7)-10 PINNED TO CONCRETE PAVEMENT

The TxDOT 32-inch CSB(7)-10 pinned to concrete pavement contained and redirected the 2270P vehicle. Maximum dynamic deflection during the test was 24.6 inches. No detached elements, fragments, or other debris from the test article were present to penetrate or show potential for penetrating the occupant compartment, or to present undue hazard to others in the area. No occupant compartment deformation or intrusion occurred. The 2270P vehicle remained upright during and after the collision period. Maximum roll and pitch angles were 17° for both. Occupant risk values were within the preferred limits.

The TxDOT 32-inch CSB(7)-10 pinned to concrete pavement performed acceptably for *MASH* Test 3-11.

8.4 *MASH* TESTING OF TXDOT SINGLE AND DUAL EMBEDDED WOOD POST SIGN SYSTEMS

8.4.1 *MASH* Test 3-62 at 0° on the Single Embedded Wood Post Sign System

The TxDOT single embedded wood post sign system fractured as designed. None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area. No occupant compartment deformation or intrusion occurred. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 2.0° and 0.6°, respectively. No occupant contact occurred. The 2270P vehicle came to rest 300 ft downstream of impact.

The support post fractured at three locations, but the upper fracture (above the hood) may have been influenced by the presence of a knot on the impact face of the post. The sign panel and remaining post segment did not contact the windshield and had only minor (if any) contact with the roof. The influence of the knot on the fracture of the post may affect repeatability of the test. The TxDOT single embedded wood post sign system performed acceptably for *MASH* Test 3-62 at 0°.

8.4.2 *MASH* Test 3-62 at 90° on the Single Embedded Wood Post Sign System

The TxDOT single embedded wood post sign system fractured as designed. An 80-inch section of wood post and the sign panel penetrated through the windshield. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 2.8° and 3.2°, respectively. No occupant contact occurred. The 2270P vehicle came to rest 355 ft downstream of impact.

The support post fractured near ground line and at bumper height. The fractured support and sign panel then rotated into the vehicle windshield, resulting in penetration of the windshield. The TxDOT single embedded wood post sign system did not perform acceptably for *MASH* Test 3-62 at 90° due to penetration of the windshield.

8.4.3 *MASH* Test 3-62 at 0° on the Dual Embedded Wood Post Sign System

The TxDOT dual embedded wood post sign system fractured as designed. None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area. Maximum occupant compartment deformation was 3.0 inches in the center roof area. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 2.5° and 1.3°, respectively. No occupant contact occurred. The 2270P vehicle came to rest 370 ft downstream of impact.

The support fractured in two locations (near ground level and at bumper height). The sign panel and fractured support posts rotated toward the vehicle and impacted the roof. Roof deformation was within the limits set in *MASH*. The TxDOT dual embedded wood post sign system performed acceptably for *MASH* Test 3-62 at 0°.

8.4.4 *MASH* Test 3-61 at 0° on the Dual Embedded Wood Post Sign System

The TxDOT dual embedded wood post sign system fractured as designed. The sign panel and portions of the wood post contacted the windshield and punctured a hole adjacent to the roof line. The windshield was shattered, depressed inward toward the occupant compartment 1.5 inches, and punctured near the roof line on the right side. The 1100V vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.7° and 2.8°, respectively. Occupant risk factors were within the preferable limits specified in *MASH*. The 1100C vehicle came to rest 284 ft downstream of impact.

Both support posts fractured at bumper height, and as the vehicle continued to move forward, the fractured end of the right support contacted and punctured the windshield. The TxDOT dual embedded wood post sign system did not perform acceptably for *MASH* Test 3-61 at 0° due to puncture of the windshield.

8.5 *MASH* TEST 3-62 ON THE TXDOT PEDESTAL POLE WITH BEACON

8.5.1 *MASH* Test 3-62 on the TxDOT Pedestal Pole with Beacon without Solar Assembly

The TxDOT pedestal pole with beacon without solar assembly yielded to the 2270P vehicle as designed by fracturing at the base. None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area. No occupant compartment deformation or intrusion occurred. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 3° and 2°, respectively. Occupant risk factors were within the preferred limits of *MASH*. The 2270P vehicle came to rest 308 ft downstream of impact.

The TxDOT pedestal pole with beacon without solar assembly performed acceptably for *MASH* Test 3-62.

8.5.2 *MASH* Test 3-62 on the TxDOT Pedestal Pole with Beacon and Solar Assembly

The TxDOT pedestal pole with beacon and solar assembly yielded to the 2270P vehicle as designed by fracturing at the base. None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area. No occupant compartment deformation or intrusion occurred. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were both 2° each. Occupant risk factors were within the preferred limits of *MASH*. The 2270P vehicle came to rest 377 ft downstream of impact.

The TxDOT pedestal pole with beacon with solar assembly performed acceptably for *MASH* Test 3-62.

8.6 *MASH* TESTING OF TXDOT MAILBOX SYSTEMS

8.6.1 *MASH* Test 3-61 on the Double Mailbox System on Winged Channel Post with Type 3 Foundation

The TxDOT double mailbox system on winged channel post with type 3 foundation fractured and released as designed. The mailboxes and support contacted the hood of the vehicle and then rotated up and over the vehicle without any secondary contact with the windshield. None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area. No occupant compartment deformation or intrusion occurred. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.2° and 2.0°, respectively. No occupant contact occurred. The 1100C vehicle came to rest 270 ft downstream of impact.

The TxDOT double mailbox system on winged channel post with type 3 foundation performed acceptably for *MASH* Test 3-61.

8.6.2 *MASH* Test 3-61 on the Double Mailbox System on Thin-Walled Galvanized Tube with Type 2 Foundation

The TxDOT double mailbox system on thin-walled galvanized tube with type 2 foundation yielded around the front of the vehicle and pulled out of the foundation socket as designed. The mailboxes and support contacted the hood of the vehicle and then rotated up and over the vehicle without any secondary contact with the windshield. None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area. No occupant compartment deformation or intrusion occurred. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.3° and 2.9°, respectively. No occupant contact occurred. The 1100C vehicle came to rest 283 ft downstream of impact.

The TxDOT double mailbox system on thin-walled galvanized tube with type 2 foundation performed acceptably for *MASH* Test 3-61.

8.6.3 *MASH* Test 3-61 on the Double Mailbox System on 56-inch Hanger-Type Thin-Walled Galvanized Tube with Type 1 Foundation

The TxDOT multiple mailbox system on 56-inch hanger-type thin-walled galvanized tube with type 1 foundation yielded around the front of the vehicle and pulled out of the foundation socket as designed. None of the detached pieces penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area. Maximum occupant compartment deformation was 1.7 inches on the left windshield area. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.2° and 0.7°, respectively. No occupant contact occurred. The 1100C vehicle came to rest 297 ft downstream of impact.

The TxDOT multiple mailbox system on 56-inch hanger-type thin-walled galvanized tube with type 1 foundation performed acceptably for *MASH* Test 3-61.

CHAPTER 9:
IMPLEMENTATION

A total of 15 full-scale crash tests were performed under Phase I of this project to evaluate 10 different roadside safety devices. These tests represent the critical tests considered necessary to demonstrate *MASH* compliance of each device. Therefore, systems that met *MASH* requirements for the critical test conditions are considered *MASH* compliant and suitable for continued implementation beyond the *MASH* implementation deadline.

TxDOT standards include multiple configurations or variations for many of these devices to accommodate different design considerations. In such instances, the critical or worst case configuration was selected and tested. If the critical configuration met *MASH* requirements, other less critical configurations of the device are also considered *MASH* compliant. The implementation recommendations for each system tested and evaluated in accordance with *MASH* are described in the sections below.

9.1 TXDOT 36-INCH VERTICAL WALL

TxDOT does not have an existing standard detail for a 36-inch vertical concrete bridge rail. The current T221 bridge rail is a 32-inch vertical parapet. The recommended minimum rail height for *MASH* Test Level 4 (TL-4) rigid barrier systems is 36 inches (*3*). Therefore, in order to maintain TL-4 impact performance under *MASH*, the height of the vertical parapet was increased from 32 inches to 36 inches and additional reinforcement was incorporated.

Because a variation of the T221 on top of a MSE retaining wall has been successfully tested with the 2270P (5000-lb) *MASH* pickup truck under NCHRP Project 22-20, *Design of Roadside Barrier Systems Placed on MSE Retaining Walls*, *MASH* test designation 4-11 was not considered necessary (*4*). Similarly, because the 1100C (2420-lb) *MASH* passenger car was successfully tested with the more critical vertical profile of the 42-inch tall T224 bridge rail (*5*), TTI researchers did not consider *MASH* test designation 4-10 necessary to achieve *MASH* compliance for a 36-inch vertical parapet. Thus, only *MASH* test designation 4-12 was performed to establish *MASH* TL-4 compliance.

When tested in accordance with *MASH* Test 4-12, the 36-inch vertical concrete bridge rail met all required *MASH* criteria. Consequently, the 36-inch vertical concrete bridge rail is considered *MASH* compliant and suitable for implementation at locations where a *MASH* TL-4 bridge rail is desired. Implementation of the 36-inch vertical concrete bridge rail can be achieved by the Bridge Division through development of a new standard sheet based on details presented in Appendix A.1.

9.2 TXDOT 42-INCH TALL SSCB

A 42-inch SSCB(1F)-10 keyed into the pavement using a 1-inch ACP overlay on each side of the barrier was successfully tested with a single unit truck using *MASH* Test 4-12 impact conditions. This is the structural adequacy test for *MASH* TL-4. The other tests in the TL-4 test matrix apply less lateral load to the barrier and, therefore, were not considered necessary to evaluate *MASH* compliance for this barrier anchorage system.

TxDOT standards for this anchorage practice also include a 32-inch CSB(2)-13. The 42-inch single slope barrier is considered the more critical of the two applications. The 42-inch single slope barrier will accommodate *MASH* TL-4 if proper anchorage is provided. A TL-4 impact into a barrier of this height generates an impact force that is greater in magnitude and has a higher resultant height than a TL-3 impact. Therefore, since the 42-inch single slope barrier with 1-inch ACP lateral support complies with *MASH* TL-4, the less critical 32-inch F-shape with 1-inch ACP lateral support is considered compliant with *MASH* TL-3.

As part of the testing program, it was necessary to establish a minimum segment length for the evaluation of the 1-inch ACP overlay. A minimum segment length of 75 ft was selected in consultation with TxDOT and is the length that was successfully tested. Cast-in-place segment lengths greater than or equal to 75 ft will provide more resistance to sliding and rotation and are, therefore, considered acceptable. Shorter segments lengths will require additional lateral resistance (e.g., dowels across the joint to the longer segment length) unless further testing and evaluation is performed.

When keyed into pavement with a 1-inch ACP overlay on both sides of the barrier, both the 42-inch SSCB(1F)-10 and 32-inch CSB(2)-13 are considered *MASH* compliant for TL-4 and TL-3, respectively, provided the segment length is 75 ft or greater. Implementation of this anchorage system for these barrier systems can be achieved by the Design Division through revision of their respective standard sheets to reflect the details presented in Appendix B.1.

9.3 TXDOT 32-INCH CSB(7)-10 PINNED TO CONCRETE PAVEMENT

When available space for barrier deflection is restricted, one practice to reduce the lateral barrier deflection is pinning the barrier to the underlying concrete pavement or deck structure. TxDOT standard practice includes the use of 1¼-inch steel pins placed on the traffic side of the barrier. The pins are installed at an angle through the toe of the precast barrier and 6 inches into the concrete pavement.

To evaluate *MASH* compliance of TxDOT practice, a 32-inch precast F-shape barrier pinned to concrete pavement was tested to *MASH* TL-3. *MASH* Test 3-11 with the 2270P pickup truck was successfully performed on this system. This is the structural adequacy test for *MASH* TL-3. The IS of test designation 3-10 is approximately half that of test 3-11. Consequently, since the pinned 30-ft barrier segments behave more rigidly when impacted by the small passenger car and the small passenger vehicle is more stable than the pickup truck, test designation 3-10 was not considered necessary for demonstrating *MASH* compliance for this anchorage system.

TxDOT standards permit the use of several different connection systems to attach the precast concrete barrier segments to each other. As part of the testing program, it was necessary to select a barrier connection system for the evaluation of the pinning system. The J-J Hooks® connection was selected in consultation with TxDOT. The J-J Hooks® connection is commonly used and represents a more critical connection type than the X-bolt connection system because the X-bolt connection is stronger and allows less barrier deflection. Thus, the successful test of the pinning system with the J-J Hooks® barrier connections indicates that the same pinning system used with similar F-shape barriers with the less critical X-bolt barrier connections is also *MASH* TL-3 compliant.

TxDOT also maintains a standard for pinning both the 42-inch SSCB(5)-10 to concrete pavement. The 32-inch F-shape barrier is considered the more critical of the two barriers for a TL-3 impact. Its lower height and mass give it a greater propensity to deflect and rotate, thus potentially aggravating the stability of the impacting vehicle. Therefore, the successful testing of the 32-inch pinned F-shape barrier indicates that the taller, heavier, 42-inch single-slope barrier pinned to concrete is also *MASH* TL-3 compliant.

Implementation of this pinning system for these barrier systems can be achieved by the Design Division through revision of their respective standard sheets to reflect the details presented in Appendix C.1.

9.4 TXDOT SINGLE AND DUAL EMBEDDED WOOD POST SIGN SYSTEMS

TxDOT uses single and dual embedded wood posts for ground-mounted temporary sign supports. The support posts can be either 4-inch × 4-inch or 4-inch × 6-inch in size depending on the sign area. The 4-inch × 6-inch supports incorporate 1½-inch diameter weakening holes near the ground line and at bumper height to facilitate fracture and breakaway of the support post when impacted. A 4-inch × 4-inch support with a small sign is considered the worst case scenario for testing and evaluation. The smaller sign lowers the center of mass of the sign support system and reduces its mass moment of inertia; therefore, after the support fractures, the smaller sign should rotate about a lower point and with more rotational velocity than a system with a larger sign. This increases the opportunity for secondary interaction of the support system with the windshield and roof of the impacting vehicle. Such behavior has been observed with slip base small sign supports, and this behavior is expected to similar with other frangible small sign support systems (*5*).

9.4.1 Single Sign Support System

The single support configuration has been previously tested with a small passenger car. Although the *MASH* small passenger car has changed, its performance in frontal impacts with ground-mounted breakaway sign support systems is not expected to vary appreciably; therefore, only test designation 3-62 with the 2270P pickup truck was considered necessary for the 0° impact scenario. The single support configuration met all *MASH* criteria for Test 3-62 at 0°.

MASH recognizes that sign support systems used near an intersection can be struck from virtually any direction. It recommends evaluating impact performance 90° from the normal direction when a sign support system is used near intersections. Since the single wood support has not been previously tested at 90°, both test designation 3-61 (passenger car) and test designation 3-62 (pickup truck) were considered necessary to evaluate impact performance of this system. When *MASH* test 3-62 was performed on the single sign support system at 90°, the sign and support penetrated the windshield of the pickup truck. Thus, the single embedded wood sign support system does not meet *MASH* criteria when deployed at or near an intersection where it can be impacted at 90°. Further research is required to develop a modification to this system that will comply with *MASH* requirements.

9.4.2 Dual Sign Support System

Researchers consulted with TxDOT regarding the applications and types of signs used in conjunction with the dual support configurations. It was determined that the maximum spacing of the two supports for the sign sizes typically utilized in temporary work zone applications is only 24 inches. With this close post spacing, it is highly probable that both supports will be impacted by an errant vehicle. Also, the review determined that the signs typically used on dual support configurations are not typically deployed at or near intersections. Therefore, impacting the dual support system at 90° is not necessary.

The most critical configuration for the dual sign support system was considered to be dual 4-inch × 4-inch supports with a small sign panel. As with the single support system, a dual support system with a small sign panel will have a greater probability of secondary contact with the windshield or roof of the impacting vehicle due to a lower center of mass and mass moment of inertia. Additionally, the 4-inch × 4-inch support is more likely to fracture into multiple sections during impact, which can increase the opportunity for a section of the support to interact with the vehicle windshield. TxDOT informed the researchers that a 36-inch × 48-inch SPEED LIMIT sign (R2-1) was the smallest commonly used sign supported by dual wood posts. Because a previous successful small car test with a dual support system with small sign panel could not be identified, both test designation 3-61 (passenger car) and test designation 3-62 (pickup truck) were recommended for evaluation of the impact performance of the dual support system.

The dual support configuration met all *MASH* criteria for Test 3-62 at 0°. When *MASH* test 3-61 was performed on the single sign support system at 0°, one of the fractured supports damaged and created a hole in the windshield of the small passenger car. Thus, the dual embedded wood sign support system does not meet *MASH* criteria. Further research is required to develop a modification to this system that will comply with *MASH* requirements.

9.5 TXDOT PEDESTAL POLE WITH BEACON

TxDOT standards for pedestal poles with beacons contain options for use with (SPRFBA(2)-13) and without (RFBA-13) a solar assembly attached to the support post. Both of these options were previously tested under *NCHRP Report 350* with a small passenger car at low and high speeds. Although the *MASH* small passenger car design has changed, its performance in frontal impacts with ground-mounted breakaway sign support systems is not expected to differ appreciably from the previous small car test vehicle. Therefore, only test designation 3-62 with the 2270P pickup truck was considered necessary for the evaluation of the pedestal pole with beacons.

Separate tests were performed for each configuration (i.e., with and without solar assembly attached to the support post). Both systems met *MASH* requirements and are considered suitable for continued implementation. Implementation of the pedestal poles with beacons with and without attached solar assemblies can be achieved by the Traffic Operations Division through revision of their respective standard sheets to reflect the details presented in Figure 6.1 and Figure 6.9, respectively.

9.6 TXDOT MAILBOX SYSTEMS

The small passenger car is considered the critical design vehicle for evaluation of mailbox support systems based on the 42-inch mounting height regulated for mailboxes by the United States Postal Service. At this height, any interaction between the mailbox and the windshield of the pickup truck design vehicle is improbable. The taller hood height and longer wrap-around distance (i.e., the distance from the ground, around the front end, and across the hood to the base of the windshield) of the 2270P pickup truck significantly decreases the probability of windshield impact and occupant compartment intrusion. Therefore, Test 3-62 with the pickup truck was considered unnecessary for the *MASH* evaluation of the TxDOT mailbox systems.

The *MASH* test matrix for breakaway supports includes two tests with the 1100C small passenger car: a low-speed test at 19 mi/h (Test 3-60) and a high-speed test at 62 mi/h (Test 3-61). In the low speed small car test, *MASH* testing has shown that the mailbox support assembly will be pushed forward by the impacting vehicle (*6*). Under the lower IS, it is unlikely that the mailbox will separate from the support or that the support assembly will interact with the vehicle windshield.

The most critical test for evaluation of mailbox systems is *MASH* test designation 3-61. This test evaluates both the structural adequacy of the mailbox connection hardware and the interaction of the mailbox support assembly with the vehicle windshield. If the mailbox remains attached during this high-speed test, it is not expected to detach in the low-speed test.

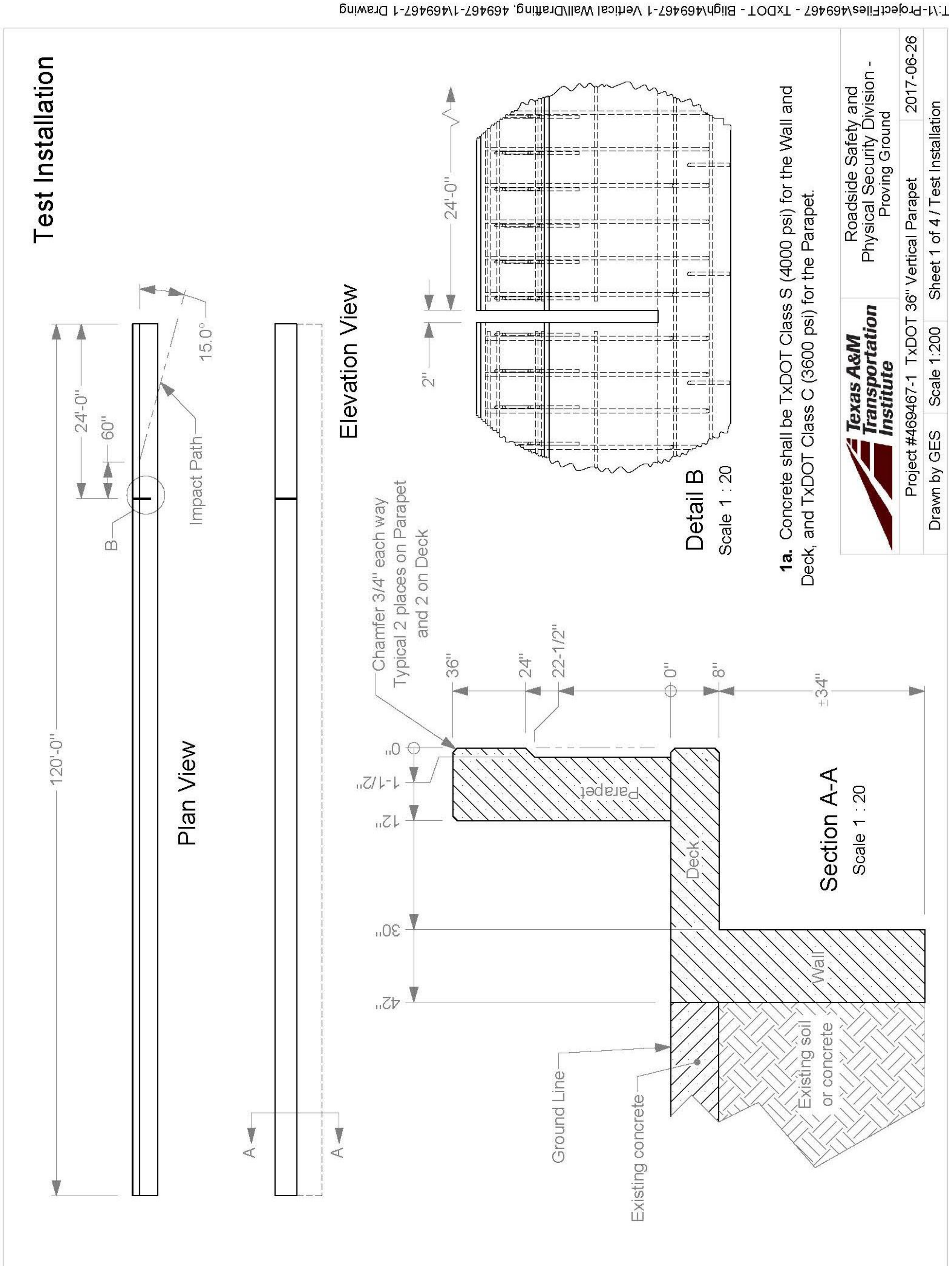
Three different mailbox support systems were selected for *MASH* testing and evaluation during Phase I of the project. Separate tests were successfully performed for each system. These include: a double mailbox system on winged channel post with Type 3 foundation, a double mailbox system on thin-walled galvanized tube with Type 2 foundation, and a multiple mailbox system on 56-inch hanger-type thin-walled galvanized tube with Type 1 foundation. Each of these systems are considered *MASH* compliant and suitable for continued implementation. Implementation of the mailbox systems can be achieved by the Maintenance Division through revision of mailbox standard MB-15(1) to reflect the details presented in Chapter 7.

REFERENCES

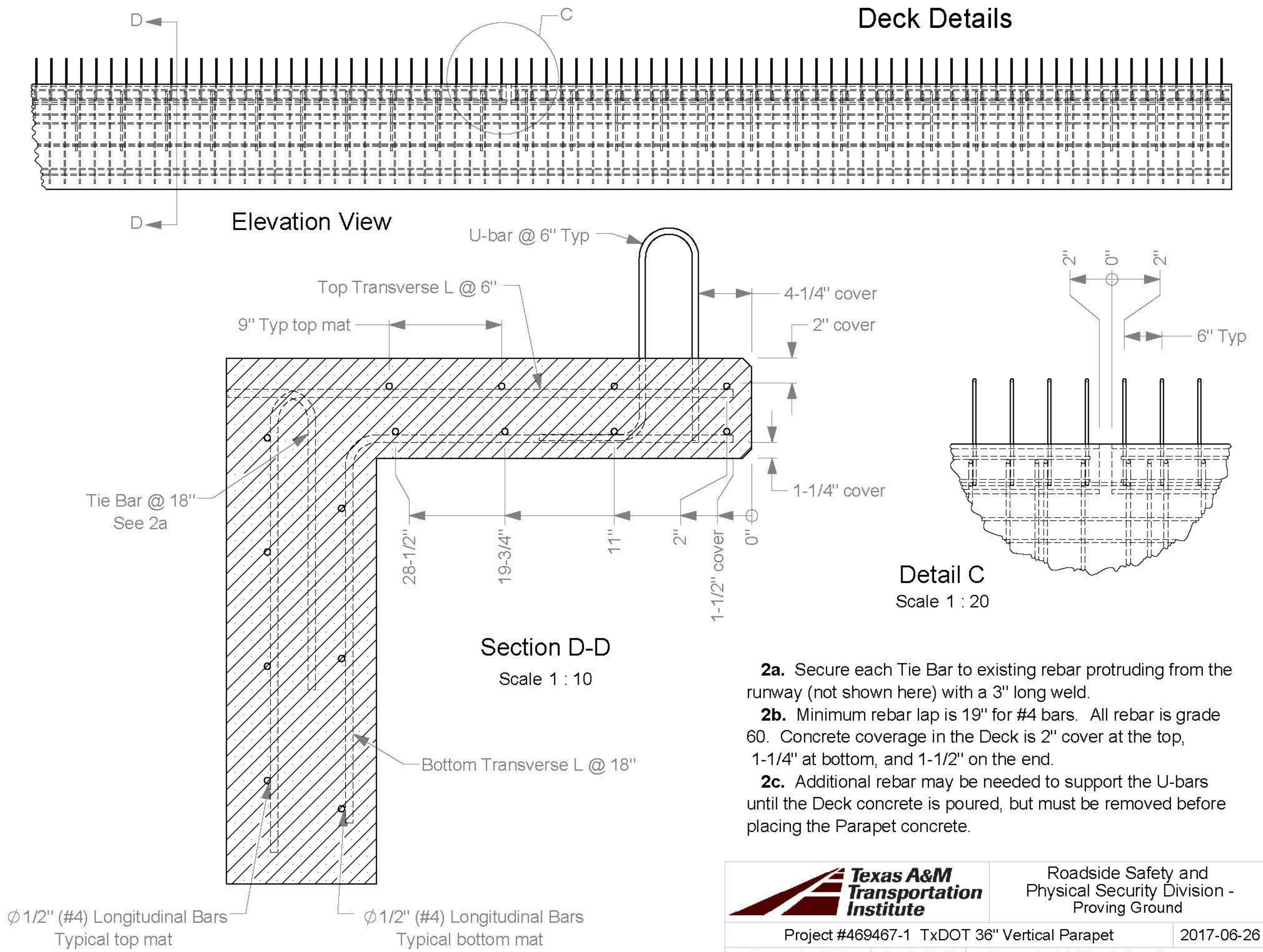
1. AASHTO. *Manual for Assessing Roadside Safety Hardware.* Second Edition, 2016, American Association of State Highway and Transportation Officials: Washington, D.C.
2. H.E. Ross, Jr., D.L. Sicking, R.A. Zimmer and J.D. Michie, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, National Cooperative Highway Research Program Report 350, Transportation Research Board, National Research Council, Washington, D.C., 1993.
3. N.M. Sheikh, R.P. Bligh, and W.L. Menges, *Determination of Minimum Height and Lateral Design Load for MASH Test Level 4 Bridge Rails*, Report No. 9-1002-5, Texas A&M Transportation Institute, College Station, TX, December 2011.
4. R.P. Bligh, J.L. Briaud, K.M. Kim, and A. Abu-Odeh, *Design of Roadside Barrier Systems Placed on MSE Retaining Walls*, National Cooperative Highway Research Program Report 663, Transportation Research Board, National Research Council, Washington, D.C., 2010.
5. W.F. Williams, R.P. Bligh, W.L. Menges, and D.L. Kuhn, *Crash Test and Evaluation of the TxDOT T224 Bridge Rail*, Report No. 9-1002-15-5, Texas A&M Transportation Institute, College Station, TX, December 2015.
6. C. Silvestri, D.R. Arrington, R.P. Bligh, and W.L. Menges, *Development Guidance for Sign Design Standards*, Report No. 0-6363-1, Texas A&M Transportation Institute, College Station, TX, February 2012.
7. C. Dobrovolny, R.P. Bligh, and W.L. Menges, *Crash Testing and Evaluation of Multiple Mailbox Supports for Use with Locking Architectural Mailboxes*, Report No. 9-1002-15-7, Texas A&M Transportation Institute, College Station, TX, February 2017.
8. R.P. Bligh, W.L. Menges, and D.L. Kuhn, *Crash Test and Evaluation of Locking Architectural Mailboxes*, Report No. 9-1002-12-9, Texas A&M Transportation Institute, College Station, TX, September 2014.

APPENDIX A. MASH TEST 4-12 ON THE 36-INCH VERTICAL WALL

A.1 DETAILS OF THE 36-INCH VERTICAL WALL



Deck Details



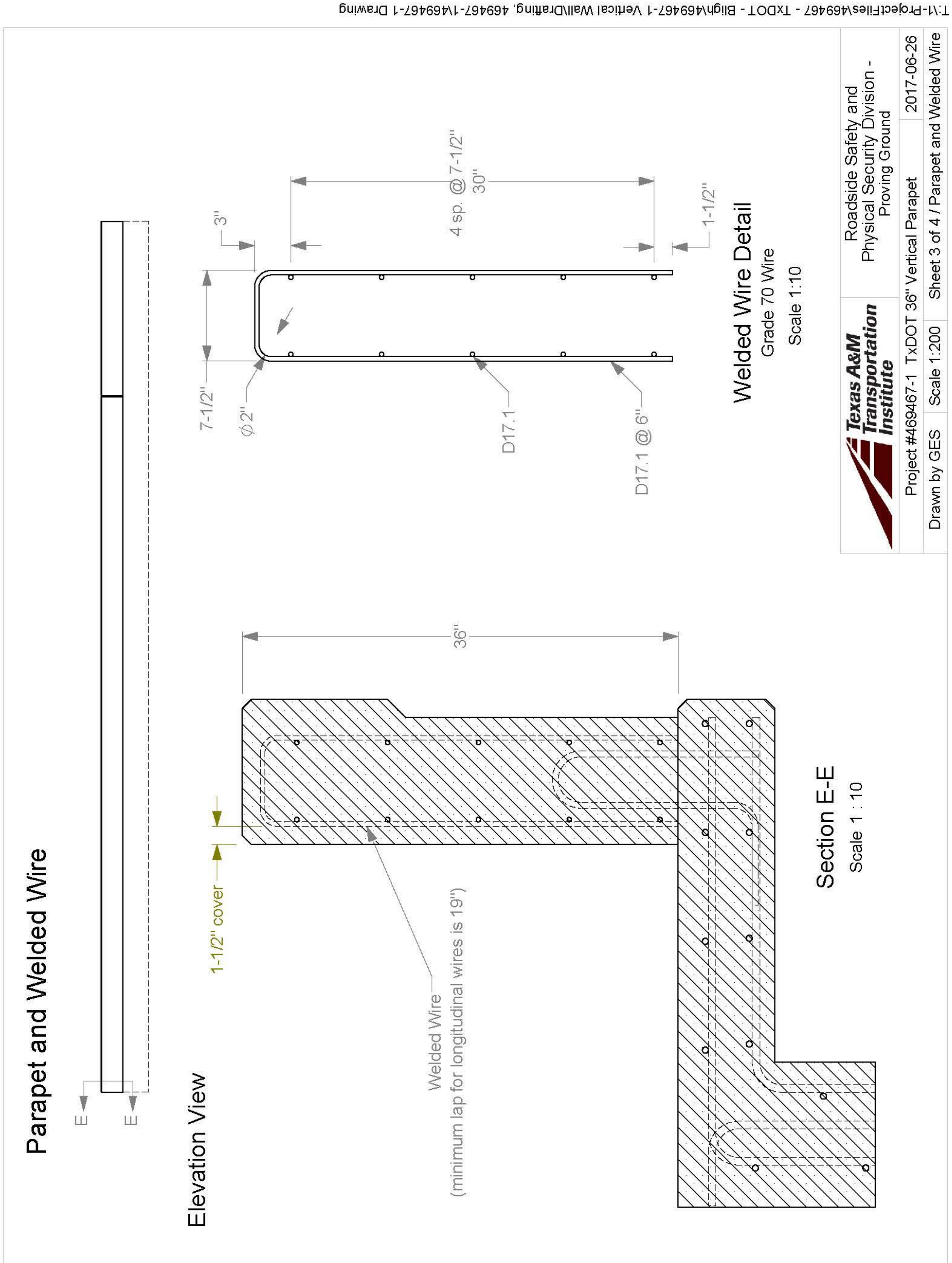
2a. Secure each Tie Bar to existing rebar protruding from the runway (not shown here) with a 3'' long weld.

2b. Minimum rebar lap is 19'' for #4 bars. All rebar is grade 60. Concrete coverage in the Deck is 2'' cover at the top, 1-1/4'' at bottom, and 1-1/2'' on the end.

2c. Additional rebar may be needed to support the U-bars until the Deck concrete is poured, but must be removed before placing the Parapet concrete.

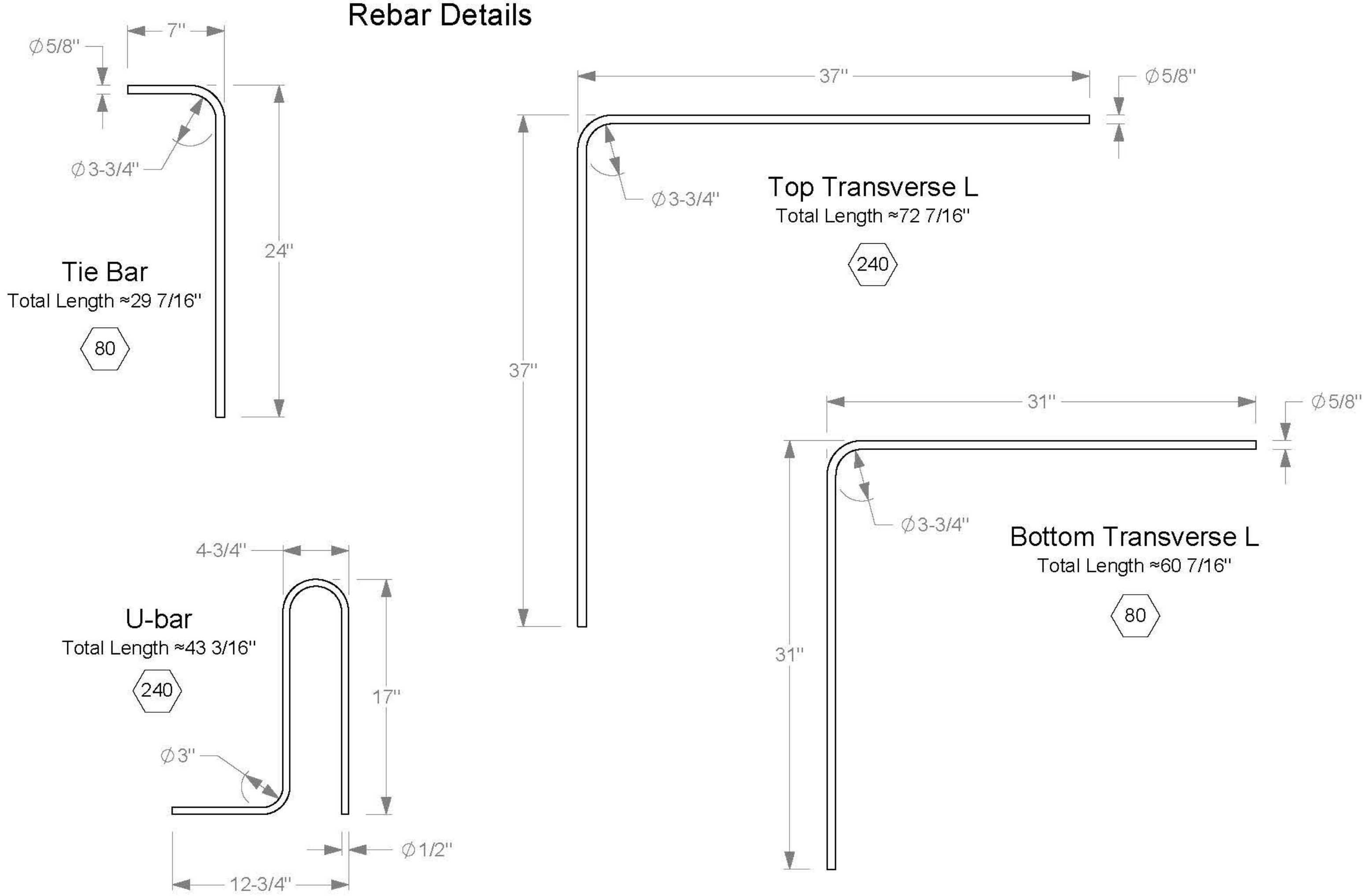
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #469467-1 TxDOT 36'' Vertical Parapet		2017-06-26
Drawn by GES	Scale 1:50	Sheet 2 of 4 / Deck Details

T:\1-ProjectFiles\469467 - TxDOT - Bligh\469467-1 Vertical Wall\Drafting, 469467-1\469467-1 Drawing



Parapet and Welded Wire
E
E
Elevation View
1-1/2" cover
Welded Wire
(minimum lap for longitudinal wires is 19")
36"
Section E-E
Scale 1 : 10
3"
4 sp. @ 7-1/2"
30"
1-1/2"
7-1/2"
ϕ2"
D17.1
D17.1 @ 6"
Welded Wire Detail
Grade 70 Wire
Scale 1:10
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #469467-1
TxDOT 36" Vertical Parapet
2017-06-26
Drawn by GES
Scale 1:200
Sheet 3 of 4 / Parapet and Welded Wire
T:\1-ProjectFiles\469467 - TxDOT - Bligh\469467-1 Vertical Wall\Drafting, 469467-1\469467-1 Drawing

Rebar Details



4a. The numerals in hexagons indicate the quantity needed for each. The length dimensions are given as a reference only. The individual dimensions take precedence in the event of a conflict.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #469467-1 TxDOT 36" Vertical Parapet		2017-06-26
Drawn by GES	Scale 1:10	Sheet 4 of 4 / Rebar Details

T:\1-ProjectFiles\469467 - TxDOT - Bligh\469467-1 Vertical Wall\Drafting, 469467-1\469467-1 Drawing

A.2 SUPPORTING CERTIFICATION DOCUMENTS

CMC

STRAIGHT BILL OF LADING-SHORT FORM
ORIGINAL-NON NEGOTIABLE

72106680

SHIPMENT NO.(BOL) : 72106680	**CARRIER'S NAME:** Mauricio Junco	**SEAL NUMBER :**
DATE AND TIME : 07/05/2017 12:58:00	**TRUCK/UNIT No:**	**TRAILER/RAILCAR No:**
SHIP FROM :	**CMC INCO TERMS:** CPT Bryan	**SOLD TO:** 3078525
CMC Sterling Steel Truck	**SHIP TO:** 3097711	BXB Group Inc
2001 Brittmoore Road	Texas A&M Tti - 36" Vertical	3936 S Hwy 287, Ste 6
Houston, TX 77043-2208	3100 TX 47	Decatur, TX 76234-5076
USA	Bryan, TX 77807 USA	USA
Contact Phone No. :713-690-0347	Contact Phone No. :8175271292	Contact Phone No. :8175271292
Fax No. :	Fax No. :	Fax No. :9999999999

Subject to Section 7: Subject to Section 7 of Conditions of applicable bill of lading, if this shipment is to be delivered to the consignee without recourse on the consignor, the consignor shall sign the following statement. The carrier shall not make delivery of this shipment without payment of freight and all other lawful charges.

Consignor's Signature : ______________________________

BOL INSTRUCTIONS:

NOTES/SPECIAL INSTRUCTIONS: Gerald 817-602-2637

Additional Instructions :

Material Details

Delivery	Cust PO	Ctrl Cd	Rel No.	Release Description	Dwg #	Material Description	PCS	Weight LB
PROJECT: R/1723300730	UP							
2816906	42949	0BDX	01	Parapet Wall-Transverse Bars.	ST	Rebar Black 60/420		3,915
2816906	42949	0BDX	01	Parapet Wall-Transverse Bars.	ST	Rebar Black A706		218
						Total Weight		4,133

MTR'S INCLUDED

RECEIVED, subject to the classifications in effect on the date of the issue of the Bill of Lading, the property described above, in apparent good order, except as noted (contents of packages unknown), marked, consigned, and destined as indicated below, which said carrier (the word carrier being understood throughout this contract as meaning any person or corporation in possession of the property under the contract) agrees to carry to its usual place of delivery at said destination, if on its route, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed, as to each carrier of all or any said property over all or any said property over all or any portion of said route to destination, and as to each party at any time interested in all or any of said property, that every service to be performed hereunder shall be subject to all the terms and conditions of the Uniform Domestic Straight Bill of Lading set forth (1) in Official, Southern, Western and Illinois Freight Classifications in effect on the date hereof, if this is a rail or a rail-water shipment, or (2) in the applicable motor carrier classification or tariff if this is a motor carrier shipment. Shipper hereby certifies that he is familiar with all the terms and conditions of the said bill of lading, including those on the back thereof, set forth in the classification or tariff which governs the transportation of this shipment and the said terms and conditions are hereby agreed to by the shipper and accepted for himself and his assigns. This is to certify that the above articles are properly describe by name and are packed and marked and are in proper condition for transportation according to regulations by the Interstate Commerce Commission. * If the shipment moves between two ports by a carrier by water, the law requires that the bill of lading shall state whether it is "carriers or shipper's weight." * Shipper's imprints in lieu of stamp; not a part of Bill of Lading approved by the Interstate Commerce Commission. NOTE: Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of property. The agreed or declared value of the property is hereby specifically state by the shipper to be not exceeding.

DRIVER'S SIGNATURE/AGENT : ______________________________

NOTICE TO RECEIVERS :Please check each item on this shipping bill carefully. CMC will not be responsible for any exceptions to goods unless notified within twenty four hours and noted on this document.

RECEIVED BY : ____________ DATE: ____________ TIME: ____________,

DELIVERED BY: MRM DATE: 7/6/17 TIME IN: ____________,TIME OUT____________

Page 1 of 1

CMC Sterling Steel
2001 Britmoore
Houston, TX 77043-
Phone: (713) 690-0347 FAX: (713) 690-5758

JOB NUMBER	RELEASE NUMBER	REQ. DELIVERY DATE	PAGE
1723300730	01		1 of 1

JOB NAME: TX A&M TTI-36 VERTICAL PARA(DW
CC: 0BDX
CUSTOMER: BXB Group Inc
BY: JML

MATERIAL TYPE	REFERENCE	DRAWING ID	DESCRIPTION
Multiple		ST	Parapet Wall-Transverse Bars.

Itm	Qty	Size	Length	Mark	Shape	Lbs	A	B	C	D	E	F/R	G	H	J	K	O	BC
	Rebar, Grade A706, Black																	
1	81	5	2-07	TB	2	218	0-07	2-00										103
	81.					218.												
	Rebar, Grade 60, Black																	
2	241	5	6-02	TT	2	1551	3-01	3-01										103
3	81	5	5-02	BT	2	437	2-07	2-07										103
	322.					1988.												
4	241	4	3-08	UB	S12	591	0-08	2-113						1-05		1-05	0-043	C402
5	100	4	20-00			1336												ST
	341.					1927.												

Total Weight: 4,133 Lbs

Longest Length: 20-00

WEIGHT SUMMARY

SIZE	TOTAL ITEMS	TOTAL PIECES	TOTAL LBS	STRAIGHT ITEMS	STRAIGHT PIECES	STRAIGHT LBS	LIGHT BENDING ITEMS	LIGHT BENDING PIECES	LIGHT BENDING LBS	HEAVY BENDING ITEMS	HEAVY BENDING PIECES	HEAVY BENDING LBS
Rebar, Grade A706, Black												
5	1	81	218	0	0	0	0	0	0	1	81	218
	1	81	218	0	0	0	0	0	0	1	81	218
Rebar, Grade 60, Black												
4	2	341	1,927	1	100	1,336	1	241	591	0	0	0
5	2	322	1,988	0	0	0	0	0	0	2	322	1,988
	4	663	3,915	1	100	1,336	1	241	591	2	322	1,988

Total Weight: 4,133 Lbs

Longest Length: 20-00

v14.02.101 (T) (HOW) Wednesday, June 28, 2017 10:37 AM

MATERIAL TEST REPORT

Date Printed: 06/22/2017

Mid American Steel & Wire
Madill, Oklahoma

Bill to:
CMC REBAR
P O BOX 139094
DALLAS, TX 75313

Ship to:
CMC REBAR
2001 BRITTMOORE
HOUSTON, TX 77043

Customer No: 000000006015
PO Number: 4501073845
Ship Date: 06/22/2017
Order Number: 86308
Load Number: 110609

Item Number	Description
D0#50CMC_60S	#5 CMC_60 REBAR

CHEMICAL ANALYSIS

Heat Number	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	V	Al	N	B
3070348	0.2500	1.0000	0.0150	0.0430	0.2100	0.2700	0.0800	0.2600	0.0540	0.0100	0.0400	0.0000	0.0000	0.0000

MECHANICAL PROPERTIES

Heat Number	Yield (Psi)	Tensile (Psi)	Elongation (%)	Reduction (%)	Bend Test Pass/ Fail
3070348	70645 psi /	142812 psi /	14.27	0.00	Pass

The melting and rolling processes used to manufacture the above described material took place in the United States of America. The material was produced and tested in accordance with ASTM A-510.

Quality Assurance: ______

CMC STEEL TEXAS
1 STEEL MILL DRIVE
SEGUIN TX 78155-7510

CERTIFIED MILL TEST REPORT
For additional copies call
830-372-8771

We hereby certify that the test results presented here are accurate and conform to the reported grade specification

TOMMY HEWITT
Quality Assurance Manager

HEAT NO.:3065785 SECTION: REBAR 16MM (#5) 40'0" A706 GRADE: ASTM A706-16 Grade 420 (60) ROLL DATE: 09/14/2016 MELT DATE: 09/08/2016	S O L D T O	CMC Rebar Houston-West BRITTMOORE RD. HOUSTON TX US 77043-2208 713-690-0347	S H I P T O	CMC Sterling Steel 2001 Brittmoore Rd Houston TX US 77043-2208 7136900347 7136905758	Delivery#: 81899287 BOL#: 71779845 CUST PO#: CUST P/N: DLVRY LBS / HEAT: 24030.000 LB DLVRY PCS / HEAT: 576 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.28%	Bend Test 1	Passed		
Mn	1.23%				
P	0.015%				
S	0.040%				
Si	0.32%				
Cu	0.30%				
Cr	0.16%				
Ni	0.10%				
Mo	0.026%				
V	0.034%				
Cb	0.001%				
Sn	0.010%				
Al	0.000%				
Carbon Eq A706	0.51%				
Yield Strength test 1	76.8ksi				
Tensile Strength test 1	104.1ksi				
Elongation test 1	15%				
Elongation Gage Lgth test 1	8IN				
Bend Test Diameter	1.875IN				

THIS MATERIAL IS FULLY KILLED, 100% MELTED AND MANUFACTURED IN THE USA, WITH NO WELD REPAIR OR MERCURY CONTAMINATION IN THE PROCESS.

REMARKS :

09/23/2016 11:00:47
Page 1 OF 1

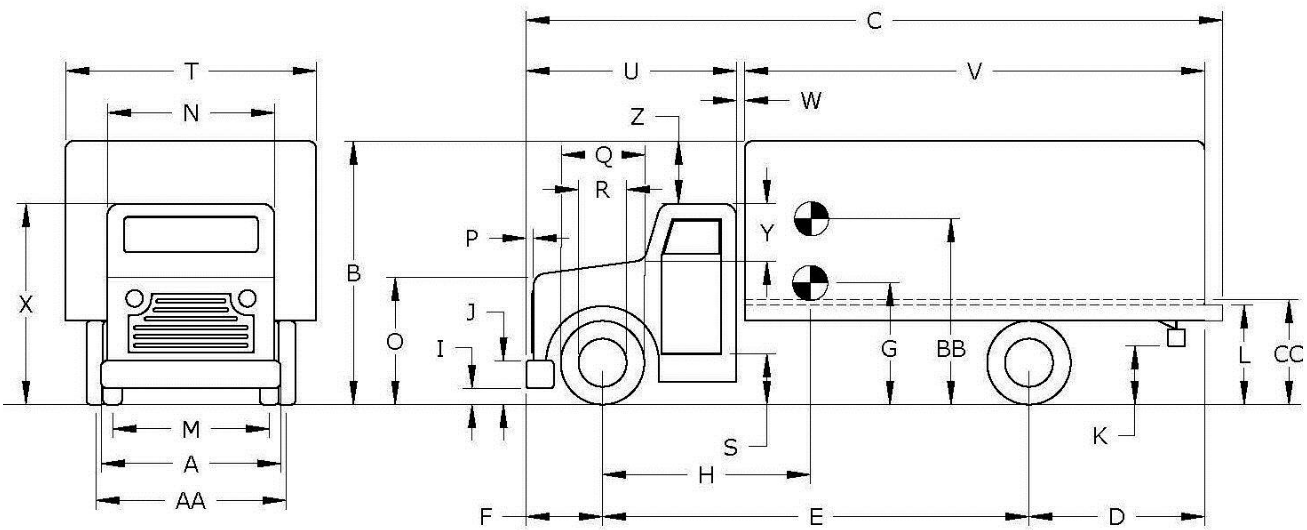
A.3 VEHICE PROPERTIES AND INFORMATION

Table A.1. Vehicle Properties for Test No. 469467-1-1.

Date: 2017-08-15 Test No.: 467469-1-1 VIN No.: 1HTMPAFN73H564911

Year: 2003 Make: International Model: 4200

Odometer: 128225 Tire Size Front: 295/75R22.5 Tire Size Rear: 295/75R22.5



Vehicle Geometry: inches

A	Front Bumper Width:	95.00	K	Rear Bumper Bottom:	-----	U	Cab Length:	106.00
B	Overall Height:	134.00	L	Rear Frame Top:	37.50	V	Trailer/Box Length:	223.00
C	Overall Length:	332.00	M	Front Track Width:	80.00	W	Gap Width:	5.00
D	Rear Overhang:	90.00	N	Roof Width:	71.00	X	Overall Front Height:	98.50
E	Wheel Base:	206.00	O	Hood Height:	59.50	Y	Roof-Hood Distance:	30.00
F	Front Overhang:	36.00	P	Bumper Extension:	1.00	Z	Roof-Box Height Difference:	32.75
G	C.G. Height:	-----	Q	Front Tire Width:	39.00	AA	Rear Track Width:	73.00
H	C.G. Horizontal Dist. w/Ballast:	139.08	R	Front Wheel Width:	23.50	BB	Ballast Center of Mass:	62.00
I	Front Bumper Bottom:	19.25	S	Bottom Door Height:	37.50	CC	Cargo Bed Height:	49.00
J	Front Bumper Top:	34.50	T	Overall Width:	96.00			

Wheel Center Height Front	19.00	Wheel Well Clearance (Front)	14.00	Bottom Frame Height (Front)	26.50
Wheel Center Height Rear	19.00	Wheel Well Clearance (Rear)	4.00	Bottom Frame Height (Rear)	27.50

Table A.1. Vehicle Properties for Test No. 469467-1-1 (Continued).

Date: 2017-08-15 Test No.: 467469-1-1 VIN No.: 1HTMPAFN73H564911

Year: 2003 Make: International Model: 4200

WEIGHTS (lb)	CURB	TEST INERTIAL
$W_{front\ axle}$	6060	7250
$W_{rear\ axle}$	6550	15070
W_{TOTAL}	12610	22320

Ballast: 10282 (lb) **(as-needed)** **(See *MASH* Section 4.2.1.2 for recommended ballasting)**

Mass Distribution
(lb): **LF:** 3650 **RF:** 3600 **LR:** 7570 **RR:** 7500

Engine Type: UT

Engine Size: 365

Transmission Type:

x Auto or ____ Manual

____ FWD x RWD ____ 4WD

Accelerometer Locations (inches)

	x[1]	y	z[2]
Front:			
Center:	139.00	0	49.00
Rear:	239.00	0	49.00

Describe any damage to the vehicle prior to test: None

Other notes to include ballast type, dimensions, mass, location, center of mass, and method of attachment:

Block; height 30 inches x width 60 inches x length 30 inches; weight 4612 lb

Block; height 30 inches x width 60 inches x length 30 inches; weight 5670 lb

Centered in middle of bed

62 inches to center of block to ground

Four 5/16 cables per block

[1] Referenced to the front axle
[2] Above ground

A.4 SEQUENTIAL PHOTOGRAPHS

0.000 s

0.100 s

0.200 s

0.300 s

Figure A.1. Sequential Photographs for Test No. 469467-1-1 (Frontal and Rear Views).

0.400 s

0.500 s

1.000 s

1.500 s

Figure A.1. Sequential Photographs for Test No. 469467-1-1 (Frontal and Rear Views) (Continued).

A.5 VEHICLE ANGULAR DISPLACEMENT

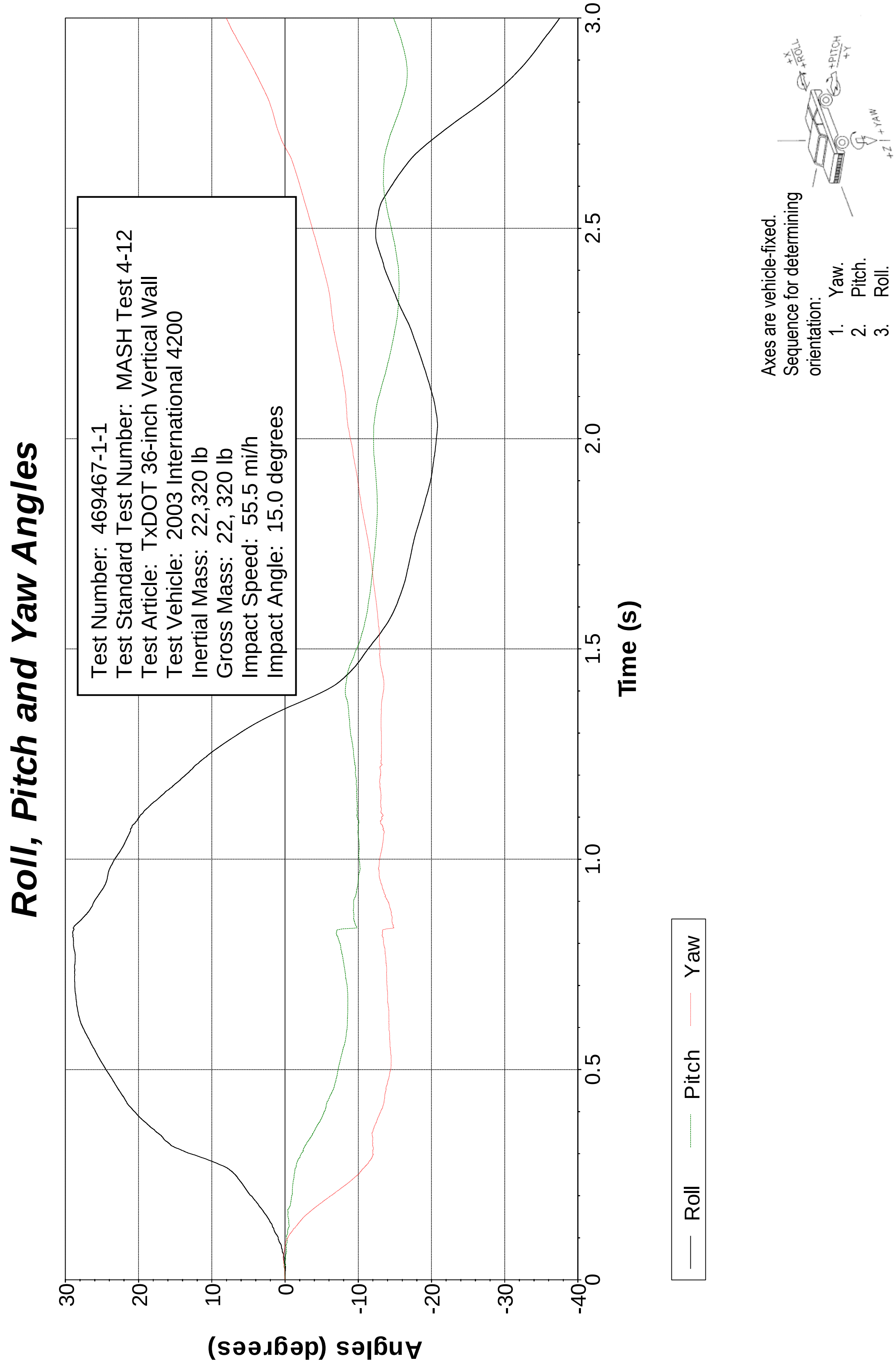


Figure A.2. Vehicle Angular Displacements for Test No. 469467-1-1.

A.6 VEHICLE ACCELERATIONS

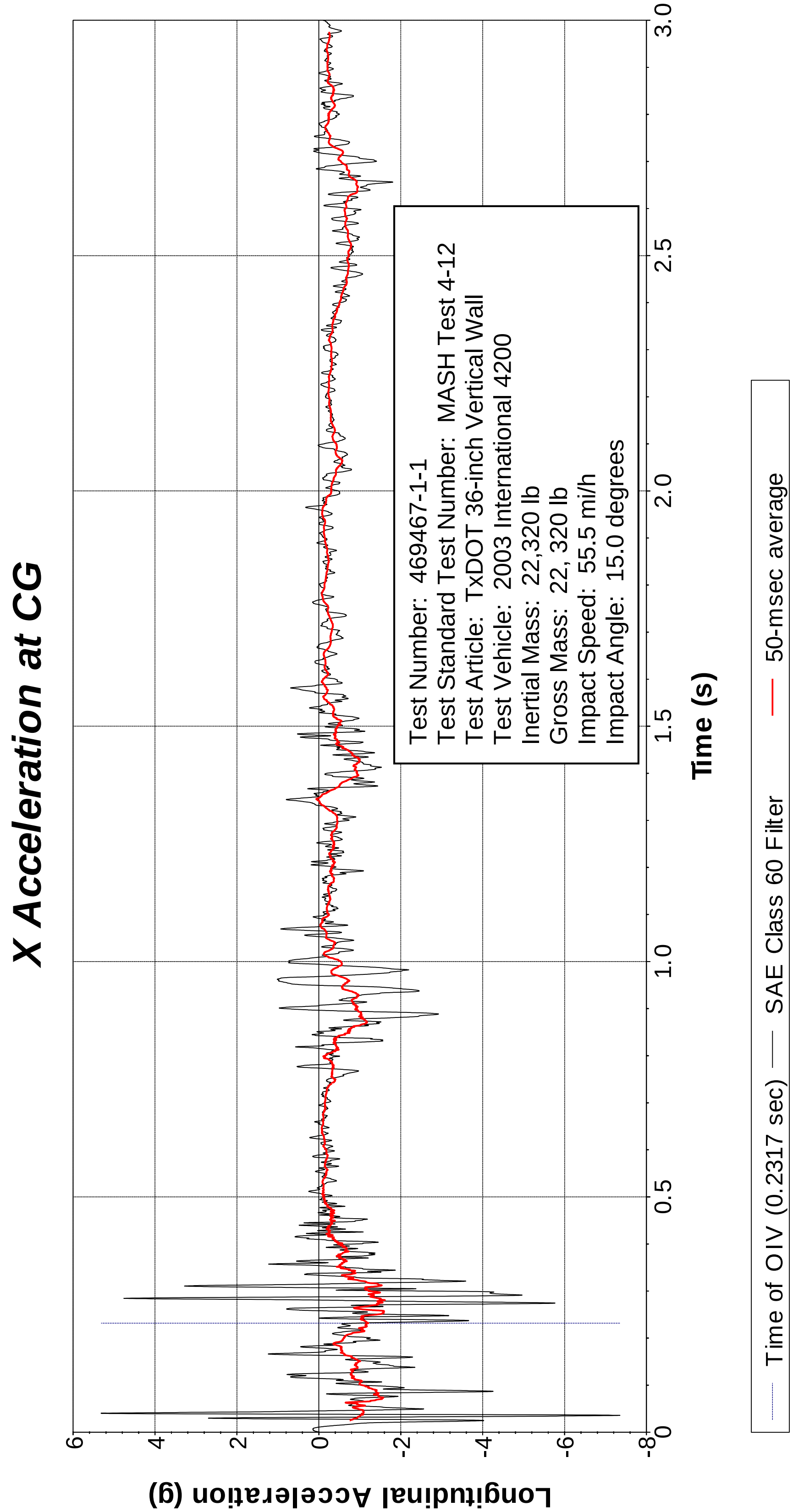


Figure A.3. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-1-1 (Accelerometer Located at Center of Gravity).

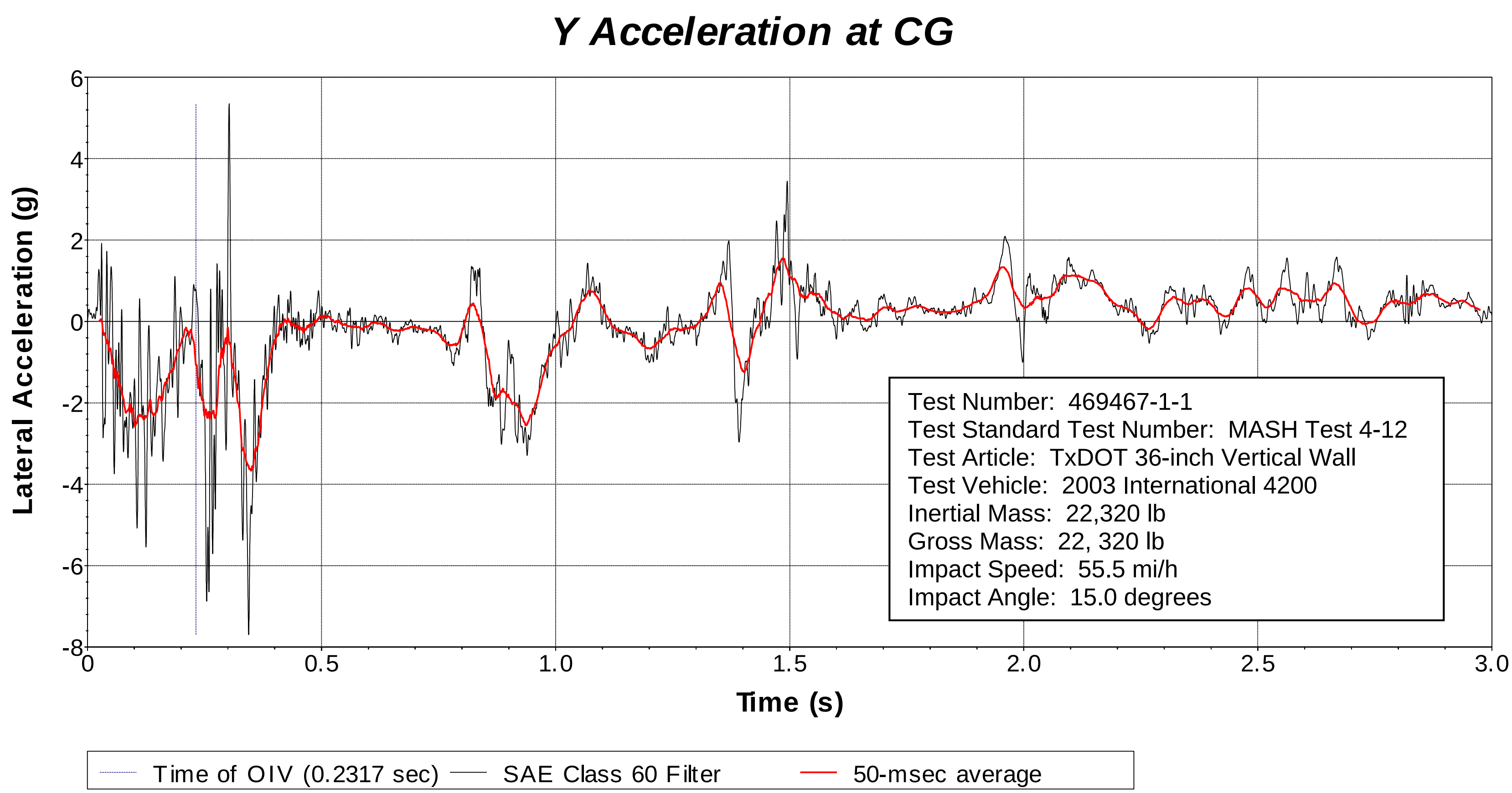


Figure A.4. Vehicle Lateral Accelerometer Trace for Test No. 469467-1-1 (Accelerometer Located at Center of Gravity).

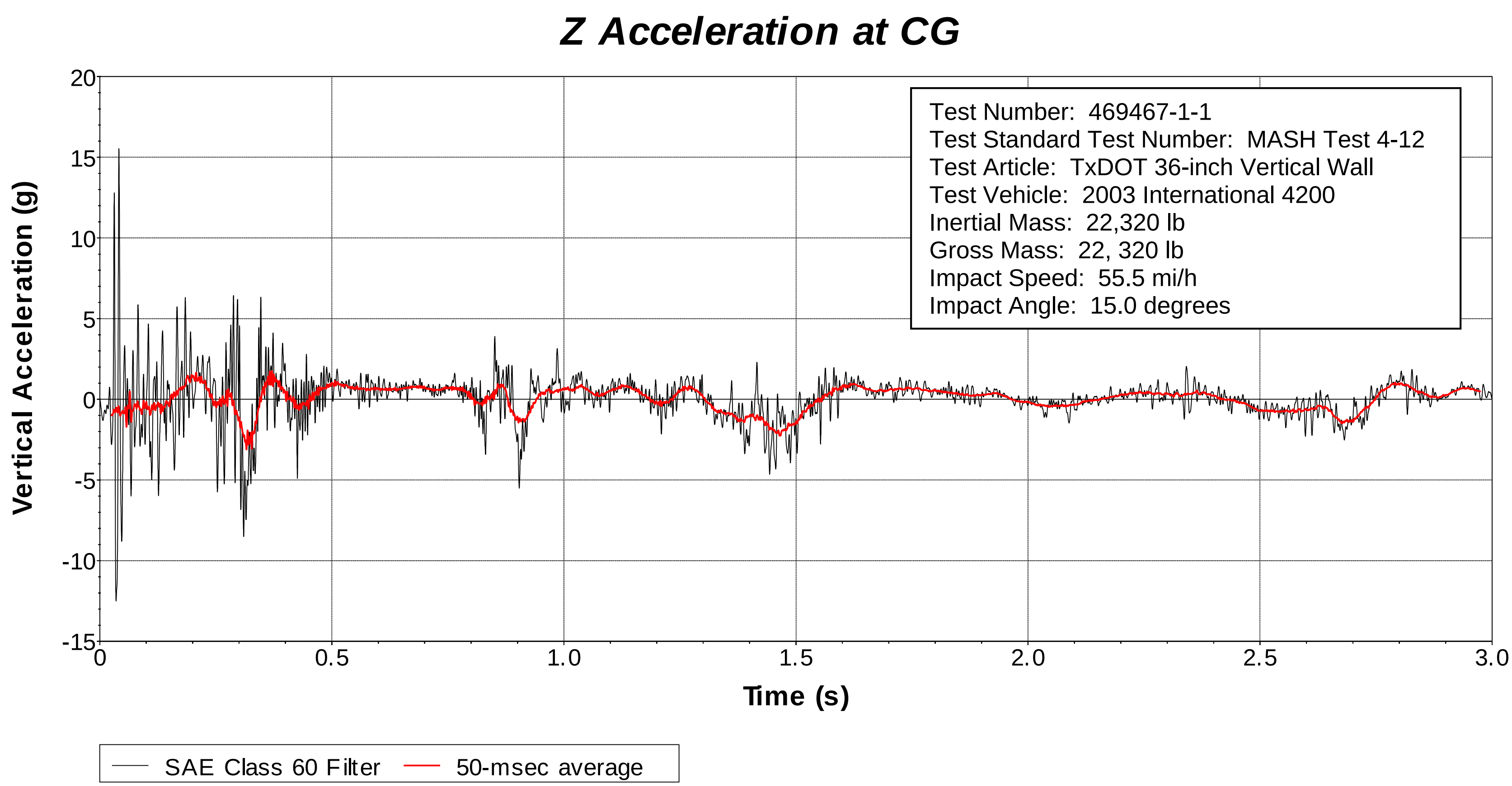


Figure A.5. Vehicle Vertical Accelerometer Trace for Test No. 469467-1-1 (Accelerometer Located at Center of Gravity).

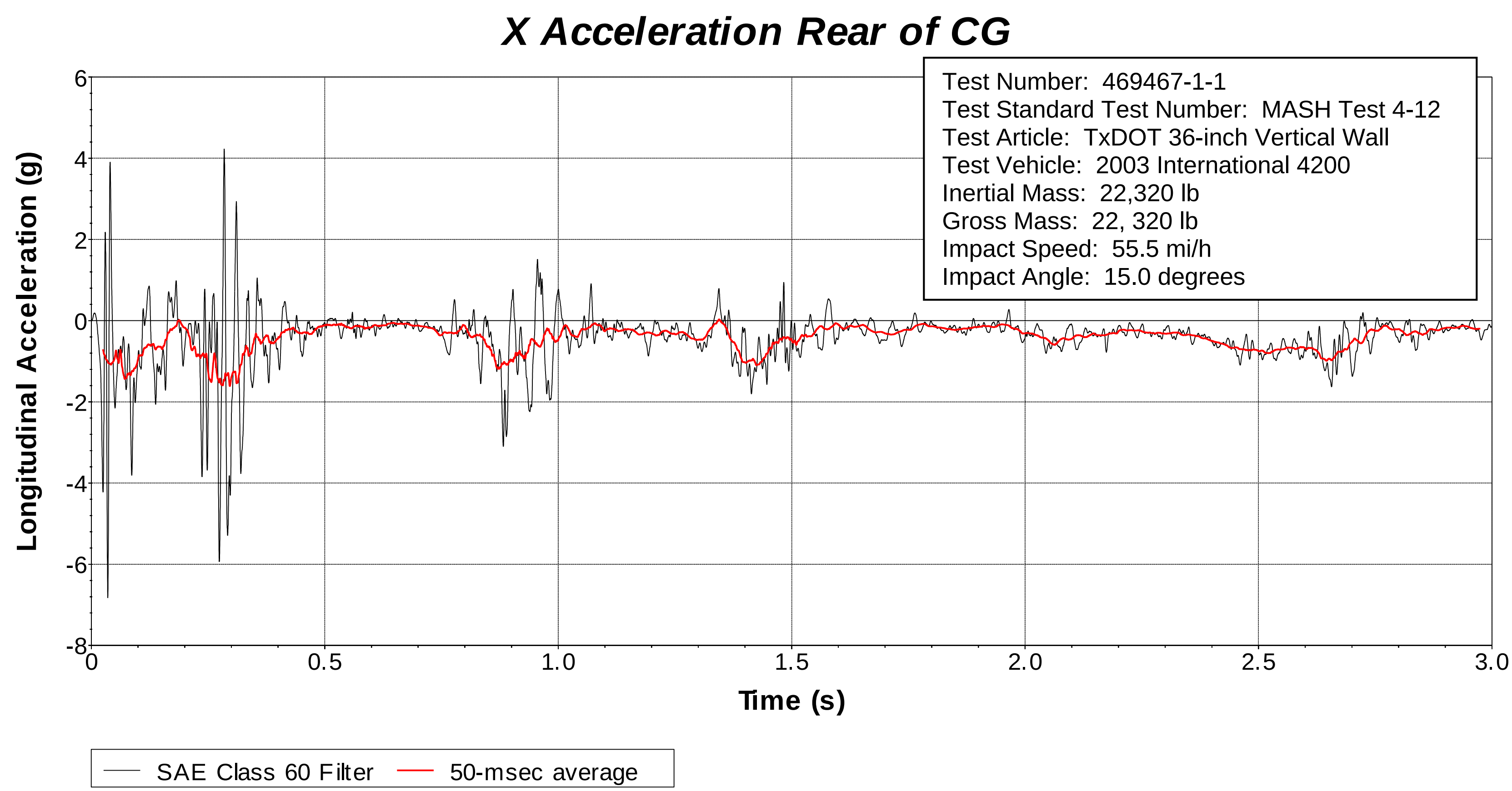


Figure A.6. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-1-1 (Accelerometer Located Rear of Center of Gravity).

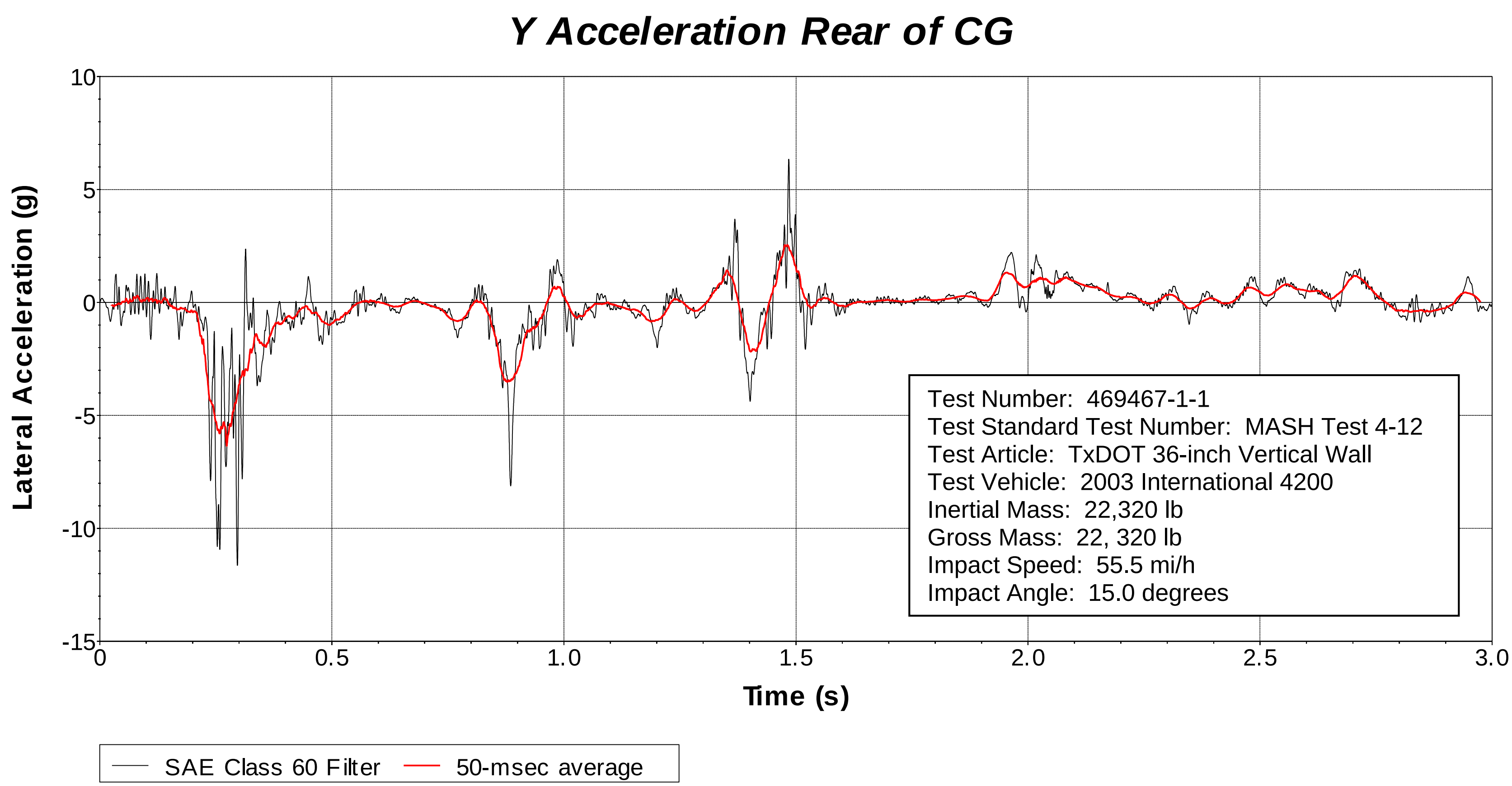


Figure A.7. Vehicle Lateral Accelerometer Trace for Test No. 469467-1-1 (Accelerometer Located Rear of Center of Gravity).

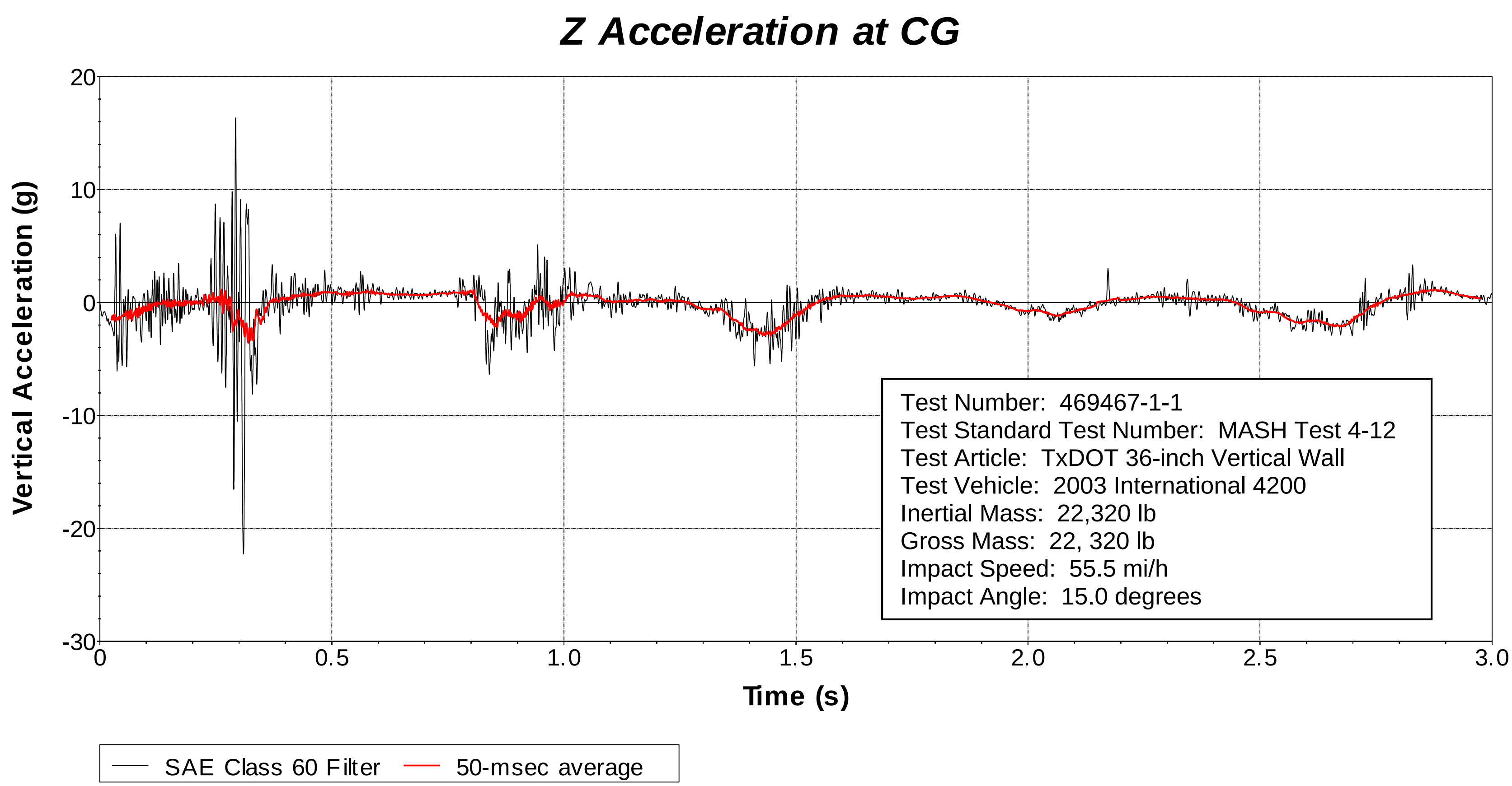
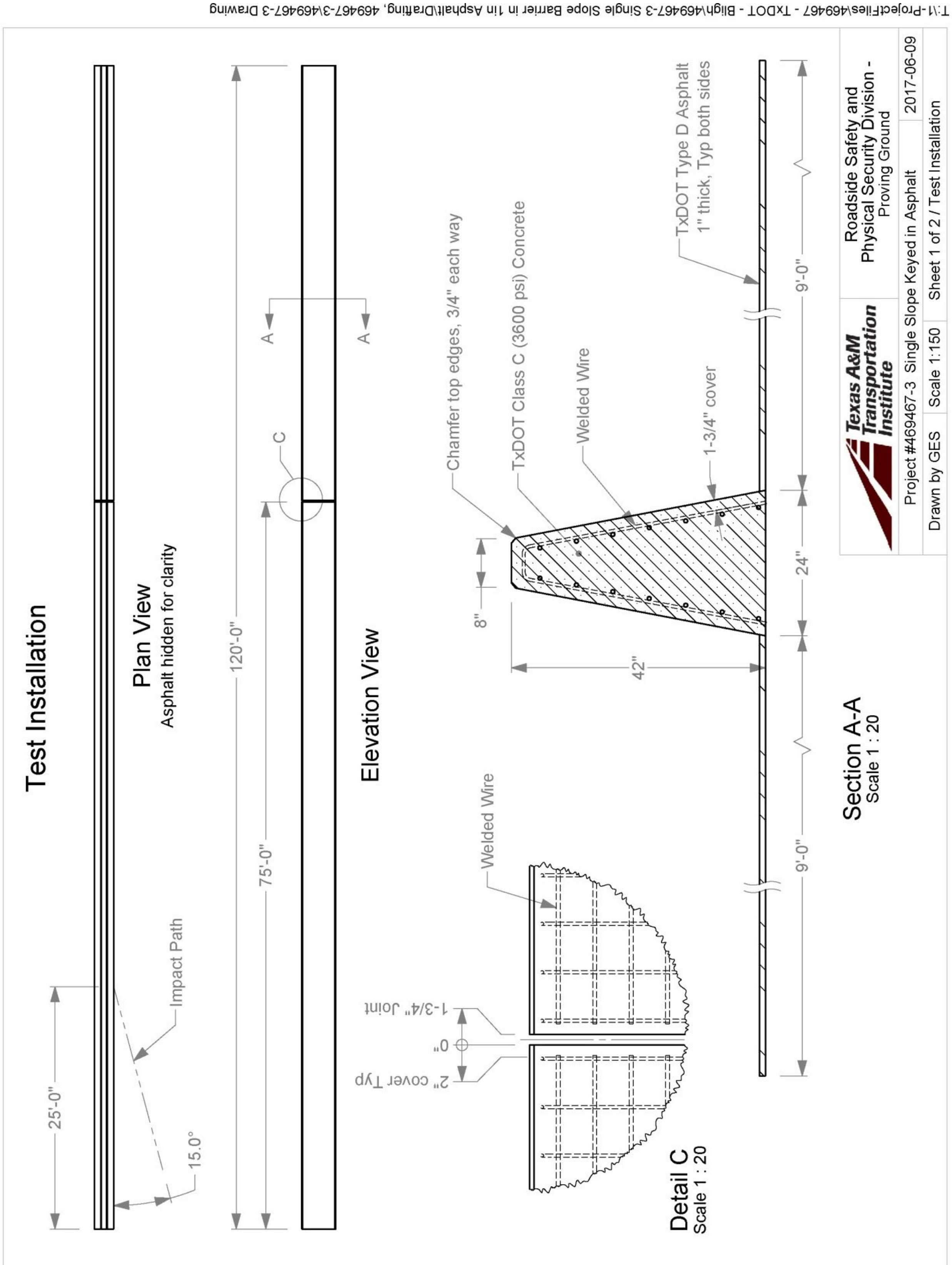


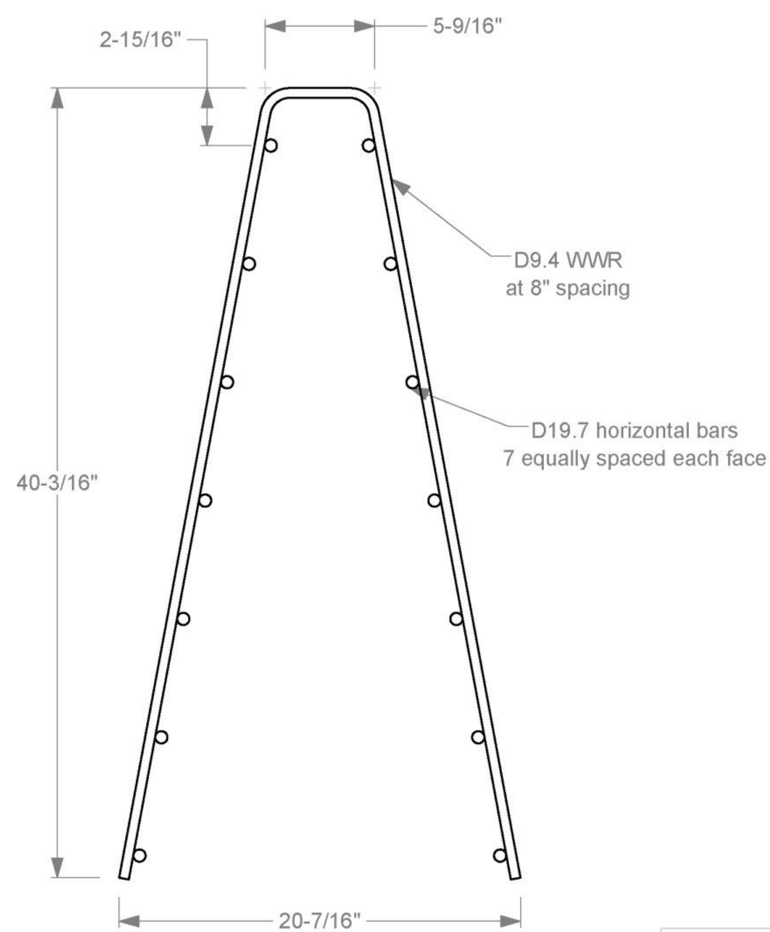
Figure A.8. Vehicle Vertical Accelerometer Trace for Test No. 469467-1-1 (Accelerometer Located Rear of Center of Gravity).

APPENDIX B. MASH TEST 4-12 ON THE TXDOT 42-INCH TALL SSCB WITH 1-INCH ACP

B.1 DETAILS OF THE TXDOT 42-INCH TALL SSCB WITH 1-INCH ACP



Welded Wire



Welded Wire
Grade 70

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #469467-3 Single Slope Keyed in Asphalt		2017-06-09
Drawn by GES	Scale 1:8	Sheet 2 of 2 / Welded Wire

T:\1-ProjectFiles\469467 - TxDOT - Bligh\469467-3 Single Slope Barrier in 1in Asphalt\Drafting, 469467-3\469467-3 Drawing

B2. SUPPORTING CERTIFICATION DOCUMENTS

Texas A&M Transportation Institute Proving Ground, 3100 SH 47, Bldg 7091, Bryan, TX 77807 Texas A&M University, College Station, TX 77843, Phone 979-845-6375	5.7.2 Concrete Break	Doc. No. QPF 5.7.2	Revision Date: 2012-09-17
Quality Policy Form	Revised by: G. E. Schroeder Approved by: C. E. But	Revision: 5	Page: 1 of 1

Project No.: 469467-3   **Casting Date:** 2017-6-21

Placement: 75 ft SSCB   **Mix Design P.S.I.:** Class C

Truck No.	Batch Ticket	Yards
1		10
2		5

Printed name of Technician taking sample: GREG FRITZ

Signature of Technician taking sample:

Printed name of Technician breaking sample: GREG FRITZ

Signature of Technician breaking sample:

Break Date	Cylinder Age	Truck No.	Total Load (Pounds)	PSI Break	Average
2017-7-6	15 Days	1	133,500	4720	
2017-7-6	15 Days	2	150,000	5305	
2017-7-7	16 Days	1	135,000	4775	
2017-7-7	16 Days	1	151,500	5360	5230
2017-7-7	16 Days	1	157,000	5555	
2017-7-7	16 Days	2	145,500	5150	
2017-7-7	16 Days	2	150,000	5305	5255
2017-7-7	16 Days	2	150,000	5305	

Texas A&M Transportation Institute Proving Ground, 3100 SH 47, Bldg 7091, Bryan, TX 77807 Texas A&M University, College Station, TX 77843, Phone 979-845-6375	5.7.2 Concrete Break	Doc. No. QPF 5.7.2	Revision Date: 2012-09-17
Quality Policy Form	Revised by: G. E. Schroeder Approved by: C. E. But	Revision: 5	Page: 1 of 1

Project No.: 469467-3
Casting Date: 2017-6-27
Placement: 45 ft SSCB
Mix Design P.S.I.: Class C

Truck No.	Batch Ticket	Yards
1		

Printed name of Technician taking sample: Greg Fritz
Signature of Technician taking sample:
Printed name of Technician breaking sample: Greg Fritz
Signature of Technician breaking sample:

Break Date	Cylinder Age	Truck No.	Total Load (Pounds)	PSI Break	Average
2017-7-7	10 Days	1	125,000	4420	
2017-7-7	10 Days	1	138,500	4900	4700
2017-7-7	10 Days	1	142,000	5025	
2017-7-7	10 Days	1	126,000	4460	

Tricon
Precast Limited™
15055 Henry Road, Houston TX 77060
P: 281-931-9832 F: 281-931-0061
www.triconprecast.com

PROPOSAL

TRICON PRECAST CONCRETE TRAFFIC BARRIER

November 17, 2016

Texas Transportation Institute
P.O # 468957-5

Re: F Shape Barrier for Crash Testing
Texas A&M Transportation Institute
Bryan, Texas
Brazos County, Texas

TPL # 1611026

We are pleased to offer for your consideration, the following quotation prepared in accordance with specifications and drawings / information provided to us:

ITEM	DESC	TPL PART	ITEM DESCRIPTION	QTY	UNIT	UNIT PRICE	EXTENSION
512	6005		Port CTB 30' - 32" F Shape JJ Connections	120	LF	$57.80	$6,936.00
			To be anchored to concrete paving				
			4 each f shape barrier for crash testing				
			w/ diagonal holes and pins on one side only:				
			1.25' x 20.5" anchor pins ASTM A36 w/ 2.25"				
			washer all galvanized. Certified papers for				
			reinforcing, JJ Hooks, Batch Tickets, and				
			break test results on all barrier.				

INCLUSIONS /EXCLUSIONS

Drain Slots	X	included		excluded
Diag Anchor Holes / Pins 4	X	Included		excluded
Connecting Hardware	X	Included		excluded
Freight	X	Included		excluded
Offloading / Installation		included	X	excluded
8.25% Sales Tax		included	X	excluded
Lifting Hardware		Included	X	excluded
Epoxy Coated Reinforcing		Included	X	excluded
Galvanized Reinforcing		Included	X	excluded

Page 1 of 3

190193

June 16, 2017

K-T Bolt Manufacturing Company, Inc.®
1150 Katy Fort-Bend Road
Katy, Texas 77494
Ph: 281-391-2196 Fax: 281-391-2673
certs@k-tbolt.com

Original Mill Test Report

Company: Tricon Precast, LTD
Part Description: 100 pcs 1 ¼" x 20 ½" Washer Head Drive Pin
Material Specification: ASTM A36 – '12
Coating Specification: Galvanized per ASTM F2329 / A153
Purchase Order Number: 8291
Lot Number: 46590-3
Comments: None
Material Heat Number: 3064788

Chemical Analysis

C	Cb	Cr	Cu	Mn	Mo	V	Ni
.19%	.001%	.11%	.23%	.75%	.019%	.015%	.07%
P	S	Si	Sn	Al	-	-	-
.016%	.041%	.22%	.009%	.002%	-	-	-

100% Melted and Manufactured in the USA - Values reflect original mill test report

Tensile and Hardness Test Results

Property	#1 ksi
Tensile:	79.3
Proof/Yield:	54.3
Elongation %:	27%
ROA %:	56%
Hardness:	183BHN

Comments
Test results reflect the original mill test report

K-T Bolt Manufacturing Co., Inc.

Linda Isgot

Quality Representative

FS R.

GERDAU

US-ML-MIDLOTHIAN
300 WARD ROAD
MIDLOTHIAN, TX 76065
USA

CERTIFIED MATERIAL TEST REPORT

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
REGAL METALS INTERNATIONAL INC 207 SENTRY DR MANSFIELD,TX 76063-3609 USA	REGAL METALS INTERNATIONAL INC 207 SENTRY DR MANSFIELD,TX 76063-3609 USA	60 (420)	Rebar / #5 (16MM)	0000000000

LENGTH	WEIGHT	HEAT / BATCH
40'00"	24,282 LB	**58027631/02**

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
4416559/000010		ASTM A615/A615M-15 E1

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
14488	1327-0000215334	11/07/2016

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %	Al %
0.42	0.98	0.016	0.028	0.24	0.27	0.12	0.27	0.032	0.013	0.003	0.000	0.003

CHEMICAL COMPOSITION

CEqyA706 %
0.62

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
67215	463	105845	730	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
18.20	OK

COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

TOM HARRINGTON
QUALITY ASSURANCE MGR.

FS.R.

GERDAU

US-ML-MIDLOTHIAN
300 WARD ROAD
MIDLOTHIAN, TX 76065
USA

CERTIFIED MATERIAL TEST REPORT

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
REGAL METALS INTERNATIONAL INC 207 SENTRY DR MANSFIELD,TX 76063-3609 USA	REGAL METALS INTERNATIONAL INC 207 SENTRY DR MANSFIELD,TX 76063-3609 USA	60 (420)	Rebar / #5 (16MM)	0000000000

LENGTH	WEIGHT	HEAT / BATCH
40'00"	6,008 LB	58027888/02

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
4543455/000010		ASTM A615/A615M-15 E1

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
350221	1327-0000218247	12/07/2016

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %	Al %
0.42	0.72	0.011	0.039	0.21	0.22	0.13	0.30	0.021	0.006	0.001	0.000	0.003

CHEMICAL COMPOSITION

CEqyA706 %
0.58

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
64501	445	99487	686	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
16.00	OK

COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 769-1014 Email: Bhaskar.Yalamanchili@gerdau.com

TOM HARRINGTON
QUALITY ASSURANCE MGR.
Phone: 972-779-1872 Email: Tommy.Harrington@gerdau.com

FSR.

GERDAU

US-ML-MIDLOTHIAN
300 WARD ROAD
MIDLOTHIAN, TX 76065
USA

CERTIFIED MATERIAL TEST REPORT

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
REGAL METALS INTERNATIONAL INC 207 SENTRY DR MANSFIELD,TX 76063-3609 USA	REGAL METALS INTERNATIONAL INC 207 SENTRY DR MANSFIELD,TX 76063-3609 USA	60 (420)	Rebar / #5 (16MM)	0000000000

LENGTH	WEIGHT	HEAT / BATCH
40'00"	24,032 LB	58027889/03

SALES ORDER	CUSTOMER MATERIAL Nº	SPECIFICATION / DATE or REVISION
4538466/000010		ASTM A615/A615M-15 E1

CUSTOMER PURCHASE ORDER NUMBER.	BILL OF LADING	DATE
YARD 53	1327-0000218461	12/09/2016

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %	Al %
0.42	0.76	0.012	0.026	0.27	0.27	0.16	0.24	0.035	0.007	0.003	0.000	0.003

CHEMICAL COMPOSITION

CEqyA706 %
0.58

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
65467	451	100277	691	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
15.00	OK

COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 769-1014 Email: Bhaskar.Yalamanchili@gerdau.com

TOM HARRINGTON
QUALITY ASSURANCE MGR.
Phone: 972-779-1872 Email: Tommy.Harrington@gerdau.com

FS.2

GERDAU

US-ML-MIDLOTHIAN
300 WARD ROAD
MIDLOTHIAN, TX 76065
USA

CERTIFIED MATERIAL TEST REPORT

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
REGAL METALS INTERNATIONAL INC 207 SENTRY DR MANSFIELD,TX 76063-3609 USA	REGAL METALS INTERNATIONAL INC 207 SENTRY DR MANSFIELD,TX 76063-3609 USA	60 (420)	Rebar / #4 (13MM)	0000000000

LENGTH	WEIGHT	HEAT / BATCH
60'00"	12,024 LB	58028862/02

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
4938978/000010		ASTM A615/A615M-15 E1

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
RL3/28	1327-0000230265	03/29/2017

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %	Al %
0.47	0.86	0.016	0.029	0.23	0.33	0.11	0.19	0.021	0.006	0.002	0.000	0.004

CHEMICAL COMPOSITION

CEqyA706 %
0.64

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
66970	462	105260	726	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
13.60	OK

COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 769-1014 Email: Bhaskar.Yalamanchili@gerdau.com

TOM HARRINGTON
QUALITY ASSURANCE MGR.
Phone: 972-779-1872 Email: Tommy.Harrington@gerdau.com

FSR

GERDAU

US-ML-MIDLOTHIAN
300 WARD ROAD
MIDLOTHIAN, TX 76065
USA

CERTIFIED MATERIAL TEST REPORT

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
REGAL METALS INTERNATIONAL INC 207 SENTRY DR MANSFIELD,TX 76063-3609 USA	REGAL METALS INTERNATIONAL INC 207 SENTRY DR MANSFIELD,TX 76063-3609 USA	60 (420)	Rebar / #5 (16MM)	0000000000

LENGTH	WEIGHT	HEAT / BATCH
40'00"	10,514 LB	58027890/03

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
4564328/000010		ASTM A615/A615M-15 E1

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
709567	1327-0000218889	12/14/2016

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	Nb %	Al %
0.42	0.80	0.017	0.035	0.21	0.32	0.16	0.29	0.034	0.007	0.002	0.000	0.003

CHEMICAL COMPOSITION

CEqyA706 %
0.59

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
65456	451	99907	689	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
15.40	OK

COMMENTS / NOTES

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 769-1014 Email: Bhaskar.Yalamanchili@gerdau.com

TOM HARRINGTON
QUALITY ASSURANCE MGR.
Phone: 972-779-1872 Email: Tommy.Harrington@gerdau.com

JJE w/24" Rebar

Rebar Ref.#74084
A706 #5 Heat #2055671

JJE Ref.# 74320
Plate 3/8" x 12" Heat # 55045644/02
Ang. 2x2x 3/16" Heat # 54153180/05

02/21/17

GERDAU

US-ML-CHARLOTTE
6601 LAKEVIEW ROAD
CHARLOTTE, NC 28269
USA

CERTIFIED MATERIAL TEST REPORT

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID.
ALLIED CRAWFORD LAKELAND INC 1500 FISH HATCHERY RD LAKELAND,FL 33801-9543 USA	ALLIED CRAWFORD LAKELAND INC 1500 FISH HATCHERY RD LAKELAND,FL 33801-9543 USA	GGMULTI	Angle / 2X2X3/16	0000015922

LENGTH	WEIGHT	HEAT / BATCH
20'00"	9,564 LB	54153180/05

SALES ORDER	CUSTOMER MATERIAL N°
4293759/000060	

SPECIFICATION / DATE or REVISION
ASTM A529-14, A572-15 ASTM A6-14,A36-14, ASME SA-36 ASTM A709-15, AASHTO M270-12 CSA G40.20-13 G40.21-13

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
114320	1321-0000044063	01/05/2017

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	V %	Nb %	Sn %
0.14	0.77	0.016	0.029	0.21	0.34	0.09	0.11	0.020	0.016	0.003	0.024

MECHANICAL PROPERTIES

Elong. %	G/L Inch	UTS PSI	UTS MPa	YS PSI	YS MPa
25.00	8.000	74861	516	54200	374

GEOMETRIC CHARACTERISTICS

R:R
35.00

COMMENTS / NOTES

This grade meets the requirements for the following grades:
ASTM Grades: A36; A529-50; A572-50; A709-36; A709-50
CSA Grades: 44W; 50W
AASHTO Grades: M270-36; M270-50
ASME Grades: SA36

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1

BHASKAR YALAMANCHILI
QUALITY DIRECTOR
Phone: (409) 769-1014 Email: Bhaskar.Yalamanchili@gerdau.com

JORDAN FOSTER
QUALITY ASSURANCE MGR.
Phone: (704) 596-0361 EX3708 Email: Jordan.Foster@gerdau.com

GERDAU

US-ML-CARTERSVILLE
384 OLD GRASSDALE ROAD NE
CARTERSVILLE, GA 30121
USA

CERTIFIED MATERIAL TEST REPORT

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
ALLIED CRAWFORD LAKELAND INC 1500 FISH HATCHERY RD LAKELAND,FL 33801-9543 USA	ALLIED CRAWFORD LAKELAND INC 1500 FISH HATCHERY RD LAKELAND,FL 33801-9543 USA	GGMULTI	Flat Bar / 3/8 X 12	0000035337
		LENGTH 20'00"	WEIGHT 4,590 LB	HEAT / BATCH 55045644/02

SALES ORDER	CUSTOMER MATERIAL Nº	SPECIFICATION / DATE or REVISION
37S0634/001220		ASTM A529-14, A572-15 ASTM A6-14,A36-14, ASME SA-36 ASTM A709-15, AASHTO M270-12 CSA G40.20-13/G40.21-13

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
113610-11	1323-0000074939	08/12/2016

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	V %	Nb %	N %	Pb %
0.17	0.89	0.017	0.018	0.19	0.29	0.08	0.14	0.027	0.016	0.000	0.0068	0.0030

CHEMICAL COMPOSITION

Sn %
0.010

MECHANICAL PROPERTIES

Elong. %	G/L Inch	UTS PSI	UTS MPa	YS 0.2% PSI	YS MPa
23.10	8.000	75900	523	54700	377
24.90	8.000	75000	517	53700	370

COMMENTS / NOTES

This grade meets the requirements for the following grades:
ASTM Grades: A36; A529-50; A572-50; A709-36; A709-50
CSA Grades. 44W; 50W
AASHTO Grades: M270-36; M270-50
ASME Grades: SA36

The above figures are certified chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with specified requirements. This material, including the billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1.

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

YAN WANG
QUALITY ASSURANCE MGR.

Tricon

CONCRETE SUMMARY

Cast Date:	6-15-17	Tested By:	K. Mahaffee
Break Date:	6-16-17	Days:	1
Time:	5:56 AM		

Mix #	Load	Cyl #	PSI	Avg.	Cone Temp	Amb. Temp	Flow
	MSE						
	53,490	1	4,260				
	53,940	2	4,290				
	SW/Columns/Caps						
	62,100	1	4,940				
	61,510	2	4,900				
	Coping						
	76,400	1	6080.				
	73,310	2	5,840				
	MSE-Exposed						
	SW-Exposed						
	MSE-Color						
	Coping-Color						
F-Shape	CTB						
	86,970	1	6,920				
	86,680	2	6,900				
	Bridge						

51115

****

Job: BARRIER1 Date: Jun 15, 2017 Start:11:29 Disch:11:36 Ref#: 7092
Operator: JULIO Duration/Wait: 8:05/0:05 Batch#:153633 Mixer#: 1
Mix: H-70135GCPT Mix Name: TRUCK
Required: 999999.00 Batched: 55350.85
Amount: 3.50 CY
PreWet: 70%

Material	Bin	Moist/ABS%	Design	Target	Actual		%Err	*Note	Jogs
3/4	2	1.38/0.00	1620	5691:5806	5752	Lb	0.1	-P---	2
Liberty	3	4.86/0.00	1483	5388:5497	5410	Lb	-0.6	-P---	5
HOLCIM	1		455	1577:1624	1584	Lb	-0.6	-----	5
POZZO	4		245	849:870	854	Lb	-0.5	-----	2
ADVA575	2		7.75	184.18:195.57	192.00	Oz	1.1	-----	
RECOVER	1		3.00	71.30:75.70	74.00	Oz	0.7	-----	
VMAR-3	5		3.00	63.50:83.50	75.00	Oz	2.0	-----	
Prewet				36.5:37.1	36.9	Ga	0.5	-----	
Water				15.5:15.7	16.1	Ga	3.2	-----	
Dry Mixing			0:30		0:30	s			
Wet Mixing			1:45		1:51	s			
Total Mixing			3:13		3:13	s			
Total Moisture:			26.3	92.0	92.4	Ga	0.4		
Water/Cement:			0.313	0.316					

CONCRETE SUMMARY

Cast Date:	6-16-17	Tested By:	DM
Break Date:	6-17-17	Days:	1
Time:	6:00 Am		

Mix #	Load	Cyl #	PSI	Avg.	Cone Temp	Amb. Temp	Flow
	MSE	1	67070	5340	56	10	
		2	73780	5870			
	SW/Columns/Caps						
		1	71090	5660	56	70	
		2	71340	5680			
	Coping						
		1	67080	5340	56	70	
		2	75260	5990			
	MSE-Exposed						
	SW-Exposed						
	MSE-Color						
	Coping-Color						
	CTB						
F-Shape		1	66920	5330	53	40	
		2	67160	5350			
	Bridge						

51115

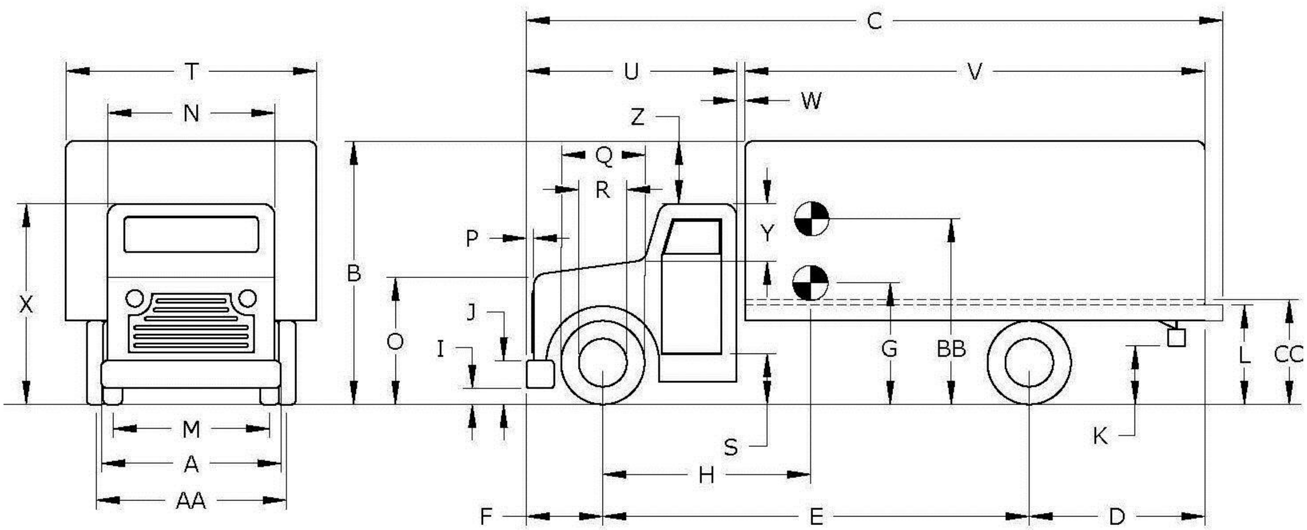
```
****************************************************************************
Job:        BARRIER1    Date: Jun 16, 2017    Start:11:24 Disch:11:34 Ref#: 7139
Operator:   TRICON      Duration/Wait: 10:42/1:55   Batch#:153680    Mixer#: 2
Mix:        H-70135GCPT Mix Name: TRUCK
Required:   999999.00    Batched: 55395.85
Amount:     3.50 CY
PreWet: 70%

Material       Bin Moist/ABS% Design      Target        Actual      %Err *Note Jogs
3/4              2 1.38/0.00   1620     5691:5806         5784 Lb    0.6 -P---   3
Liberty          3 3.92/0.00   1483     5340:5448         5366 Lb   -0.5 -P---   5
HOLCIM         1                455     1577:1624         1598 Lb    0.3 -----   3
POZZO          4                245      849:870           862 Lb    0.5 -----   1
ADVA575        2               7.75   184.18:195.57     192.00 Oz    1.1 -----
RECOVER        1               3.00    71.30:75.70       74.00 Oz    0.7 -----
VMAR-3         5               3.00    63.50:83.50       74.00 Oz    0.7 -----
Prewet                                 40.6:41.2          40.9 Ga    0.2 -----
Water                                  17.3:17.6          18.1 Ga    4.0 -----
Dry Mixing                     0:30                       0:30 s
Wet Mixing                     1:45                       3:44 s
Total Mixing                   5:13                       5:13 s
Total Moisture:                26.3        92.0           92.7 Ga    0.7
Water/Cement:                 0.313       0.314
```

B.3 VEHICLE PROPERTIES AND INFORMATION

Table B.1. Vehicle Properties for Test No. 469467-3-1.

Date:	2017-07-07	Test No.:	469467-3-1	VIN No.:	1HTMMAAL05H105654
Year:	2005	Make:	International	Model:	4300
Odometer:	411757	Tire Size Front:	295/75R22.5	Tire Size Rear:	295/75R22.5



Vehicle Geometry: inches

A	Front Bumper Width:	95.00	K	Rear Bumper Bottom:	-----	U	Cab Length:	106.00
B	Overall Height:	145.00	L	Rear Frame Top:	37.00	V	Trailer/Box Length:	221.00
C	Overall Length:	330.50	M	Front Track Width:	80.00	W	Gap Width:	5.00
D	Rear Overhang:	87.00	N	Roof Width:	71.00	X	Overall Front Height:	98.50
E	Wheel Base:	207.50	O	Hood Height:	59.00	Y	Roof-Hood Distance:	30.00
F	Front Overhang:	36.00	P	Bumper Extension:	1.00	Z	Roof-Box Height Difference:	46.125
G	C.G. Height:	-----	Q	Front Tire Width:	39.00	AA	Rear Track Width:	73.00
H	C.G. Horizontal Dist. w/Ballast:	132.40	R	Front Wheel Width:	23.50	BB	Ballast Center of Mass:	62.00
I	Front Bumper Bottom:	19.25	S	Bottom Door Height:	36.50	CC	Cargo Bed Height:	50.00
J	Front Bumper Top:	33.50	T	Overall Width:	102.00			
	Wheel Center Height Front	19.00		Wheel Well Clearance (Front)	14.00		Bottom Frame Height (Front)	25.00
	Wheel Center Height Rear	19.00		Wheel Well Clearance (Rear)	5.00		Bottom Frame Height (Rear)	27.50

Table B.1. Vehicle Properties for Test No. 469467-3-1 (Continued).

Date: 2017-07-07 Test No.: 469467-3-1 VIN No.: 1HTMMAAL05H105654

Year: 2005 Make: International Model: 4300

WEIGHTS (lb)	CURB	TEST INERTIAL
$W_{front\ axle}$	6930	8060
$W_{rear\ axle}$	6640	14210
W_{TOTAL}	13570	22210

Ballast: 8700 (lb) **(See *MASH* Section 4.2.1.2 for recommended ballasting)**

Mass Distribution
(lb): **LF:** 4140 **RF:** 3920 **LR:** 7300 **RR:** 6910

Engine Type: DT

Engine Size: 466

Transmission Type:

x Auto or ____ Manual

____ FWD x RWD ____ 4WD

Accelerometer Locations (inches)

	x^1	y	z^2
Front:	---	---	---
Center:	132.4	0	47.25
Rear:	232.40	0	47.25

Describe any damage to the vehicle prior to test: None

Other notes to include ballast type, dimensions, mass, location, center of mass, and method of attachment:

Ballast block 30 inches high, 60 inches wide, and 30 inches long

Ballast block 24 inches high, 60 inches wide, 30 inches long up on 3-inch tube

Centered in middle of bed

62 inches to center of block to ground

Four $^5/_{16}$-inch cables per block

[1] Referenced to the front axle
[2] Above ground

B.4 SEQUENTIAL PHOTOGRAPHS

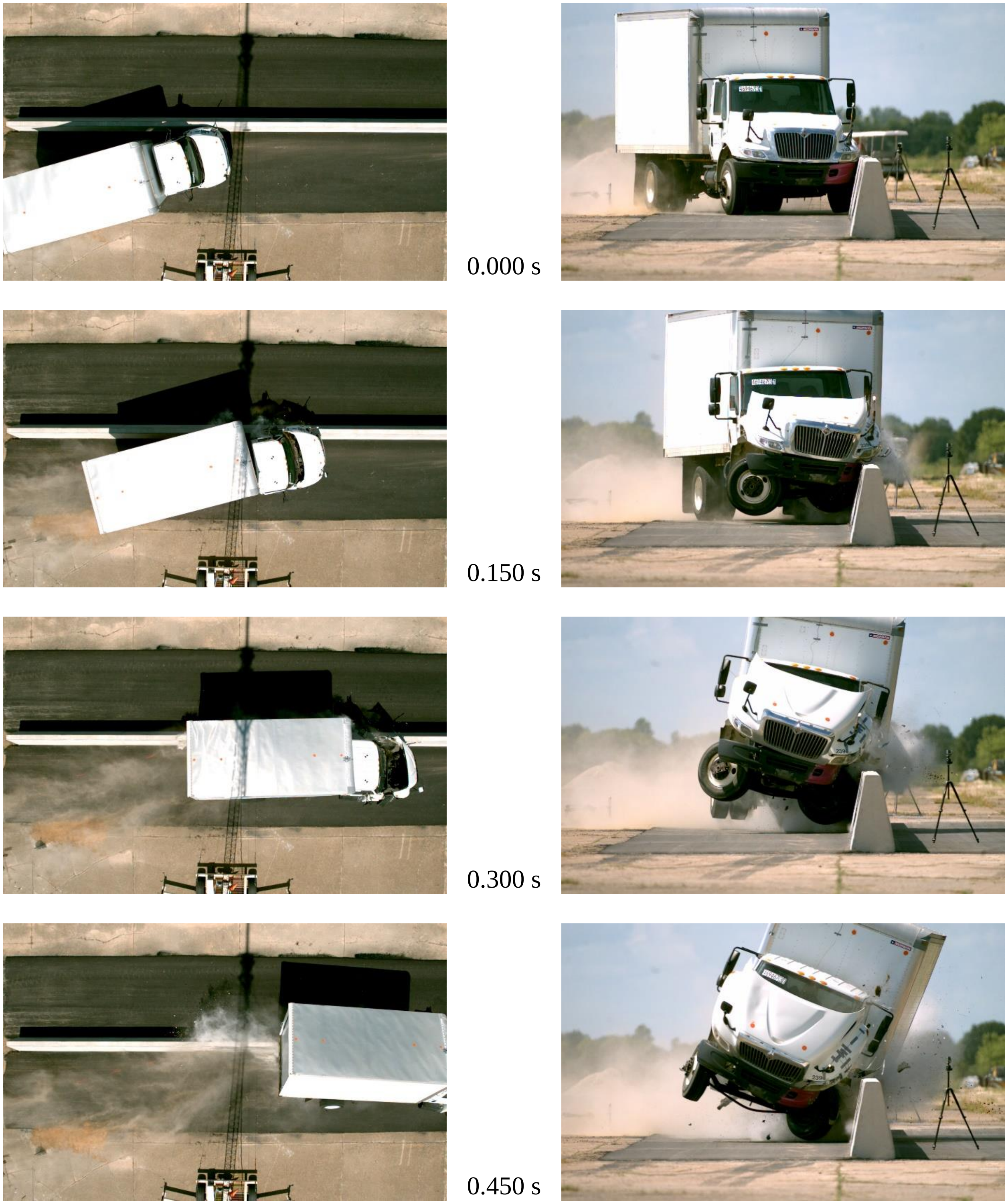


Figure B.1. Sequential Photographs for Test No. 469467-3-1 (Overhead and Frontal Views).

0.600 s

0.750 s

Out of View

0.900 s

Out of View

1.050 s

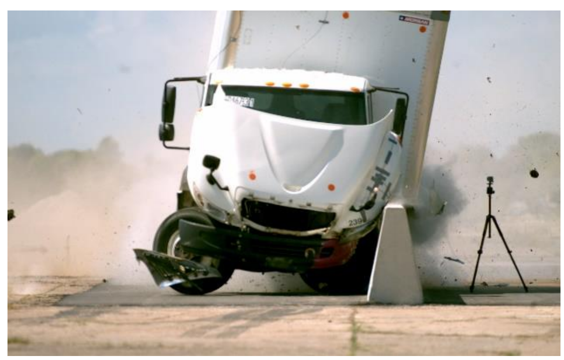


Figure B.1. Sequential Photographs for Test No. 469467-3-1 (Overhead and Frontal Views) (Continued).

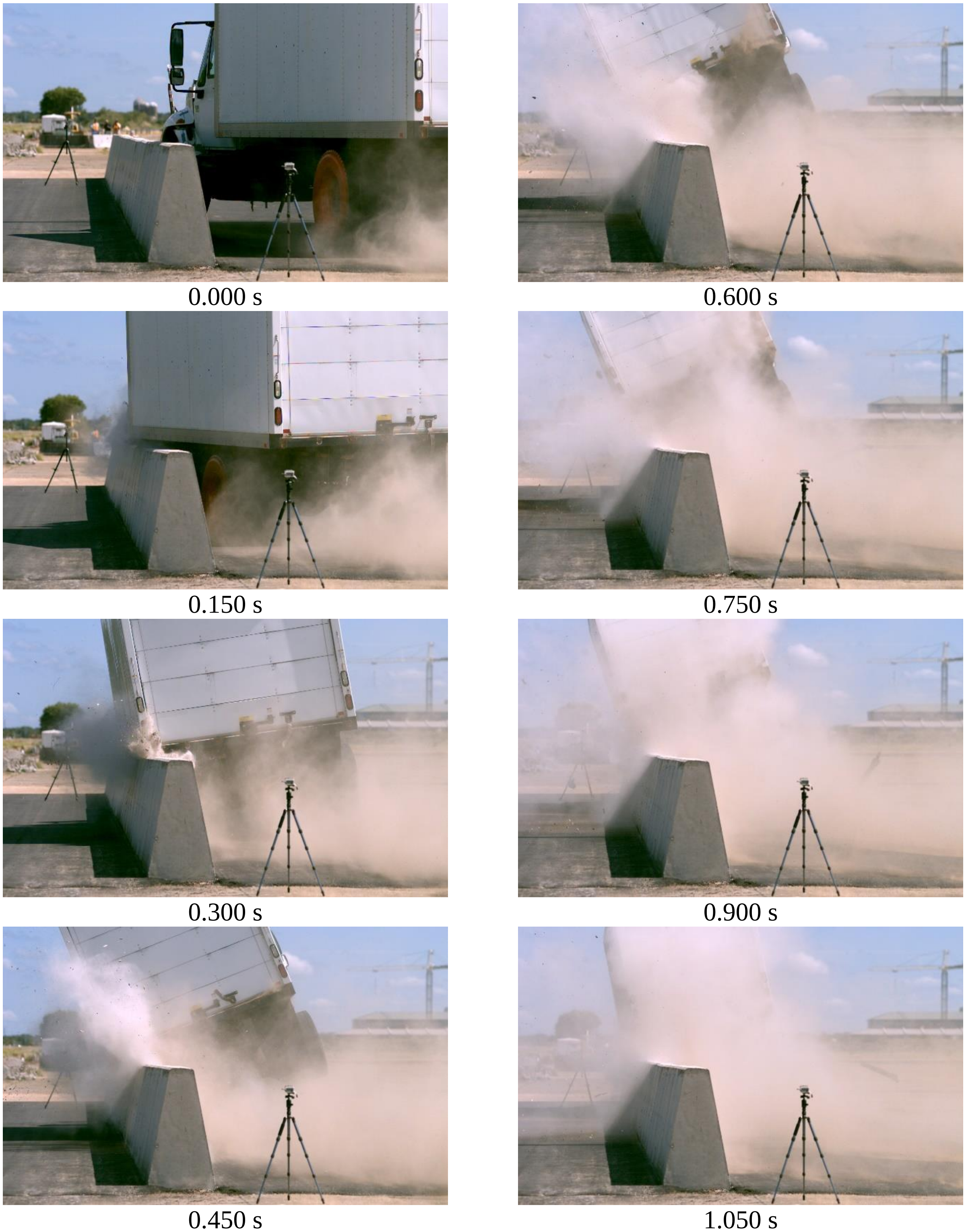


Figure B.2. Sequential Photographs for Test No. 469467-3-1 (Rear View).

B.5 VEHICLE ANGULAR DISPLACEMENT

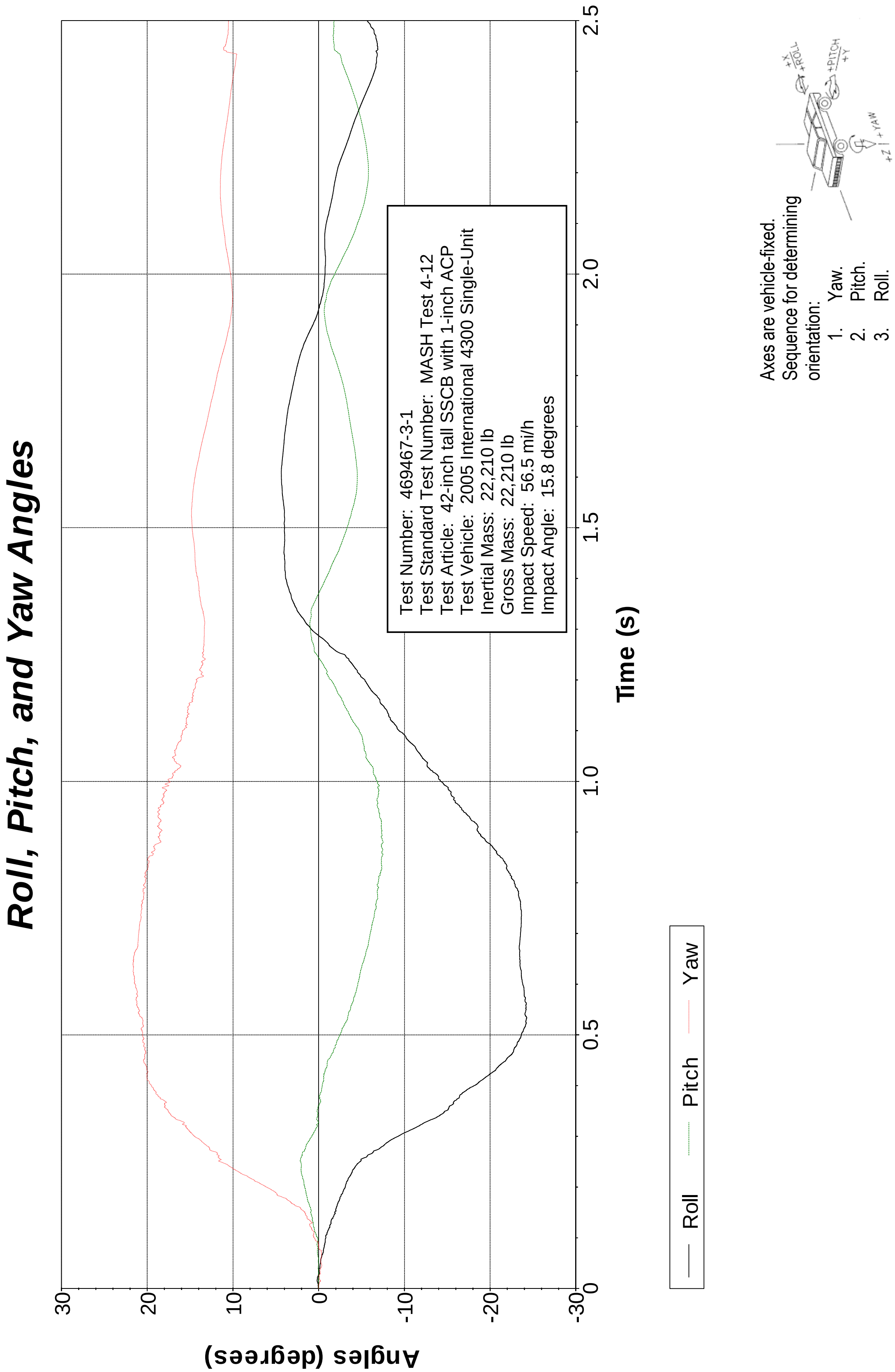


Figure B.3. Vehicle Angular Displacements for Test No. 469467-3-1.

B.6 VEHICLE ACCELERATIONS

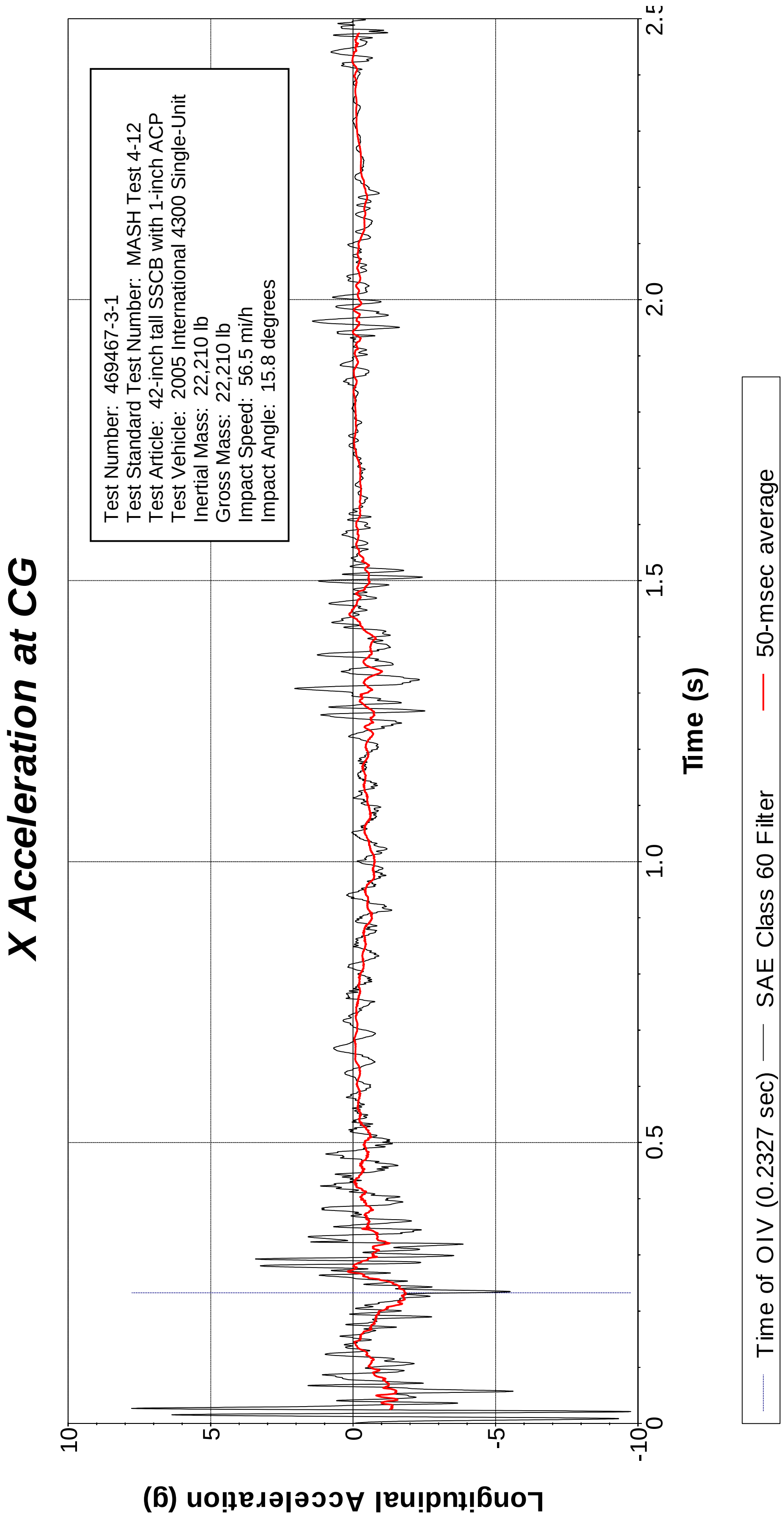


Figure B.4. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-3-1 (Accelerometer Located at Center of Gravity).

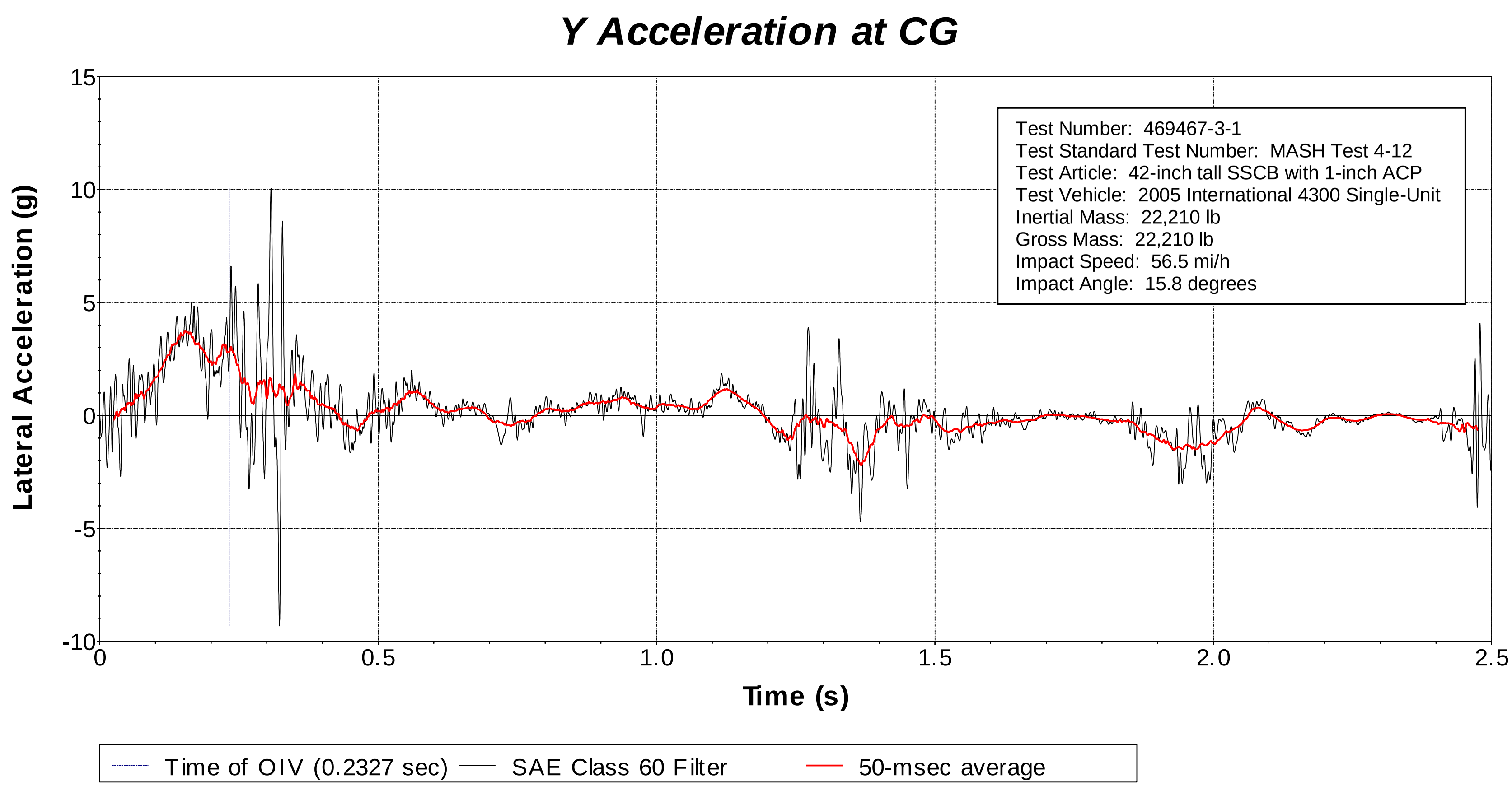


Figure B.5. Vehicle Lateral Accelerometer Trace for Test No. 469467-3-1 (Accelerometer Located at Center of Gravity).

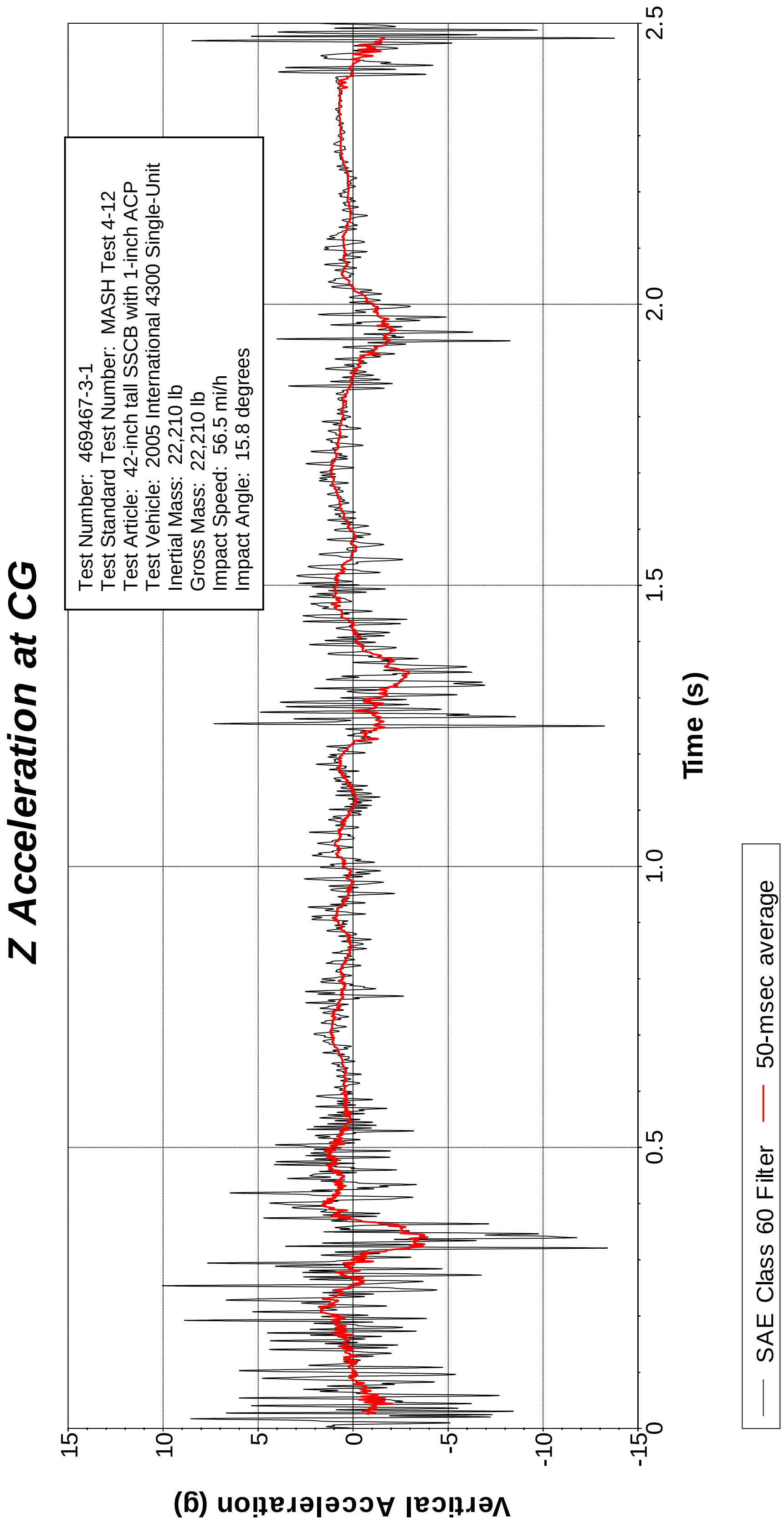


Figure B.6. Vehicle Vertical Accelerometer Trace for Test No. 469467-3-1 (Accelerometer Located at Center of Gravity).

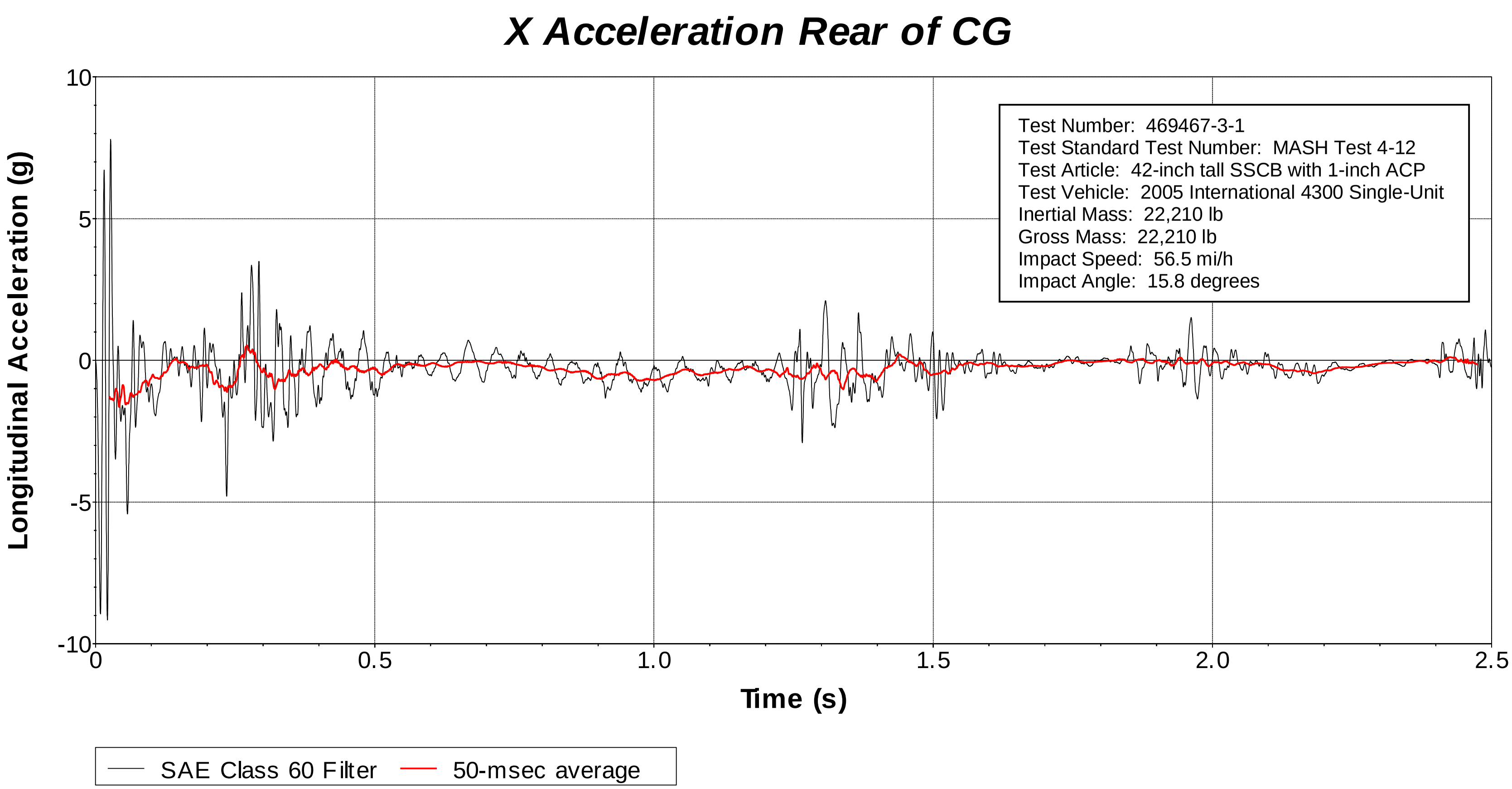


Figure B.7. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-3-1 (Accelerometer Located Rear of Center of Gravity).

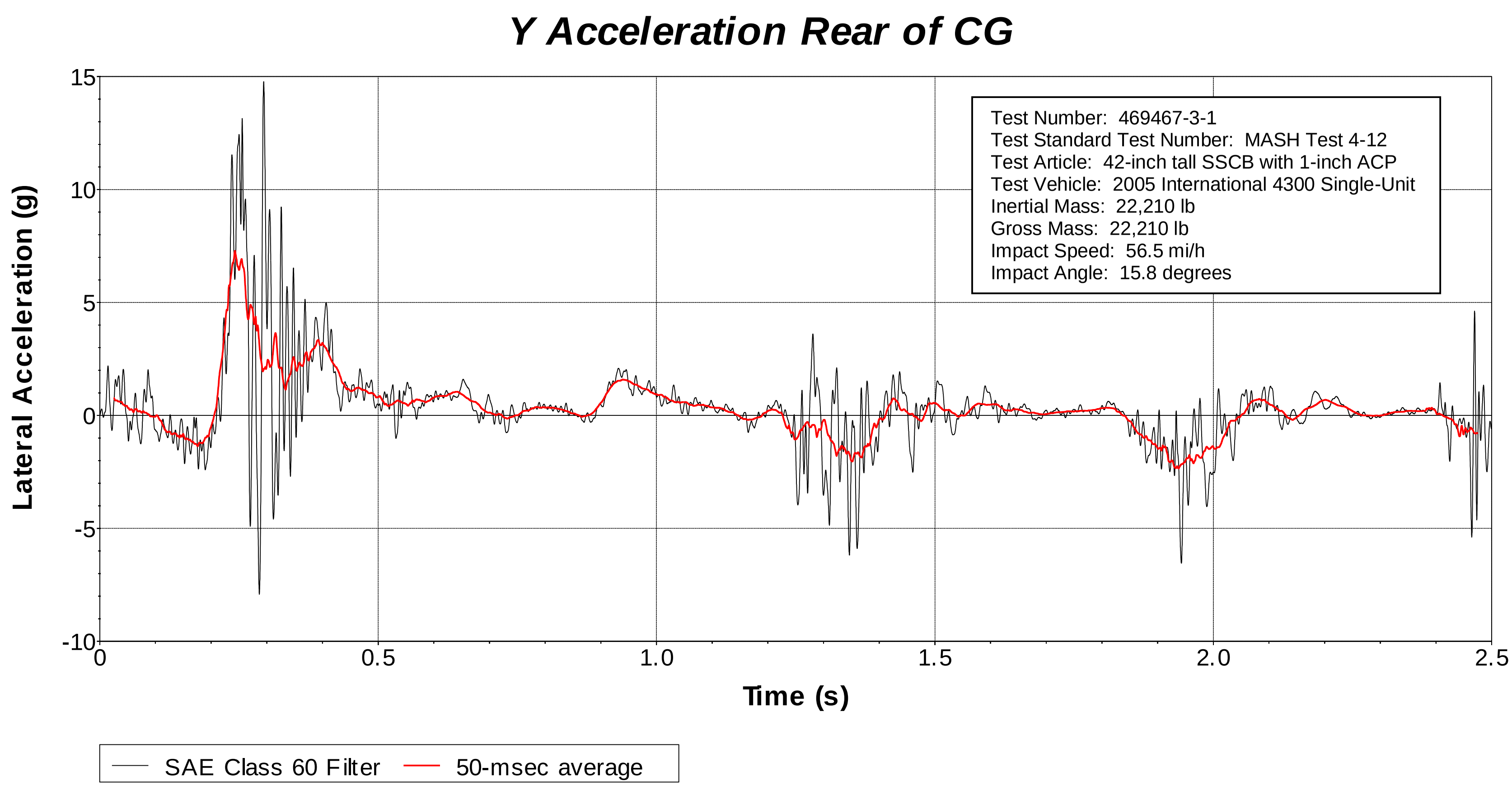


Figure B.8. Vehicle Lateral Accelerometer Trace for Test No. 469467-3-1 (Accelerometer Located Rear of Center of Gravity).

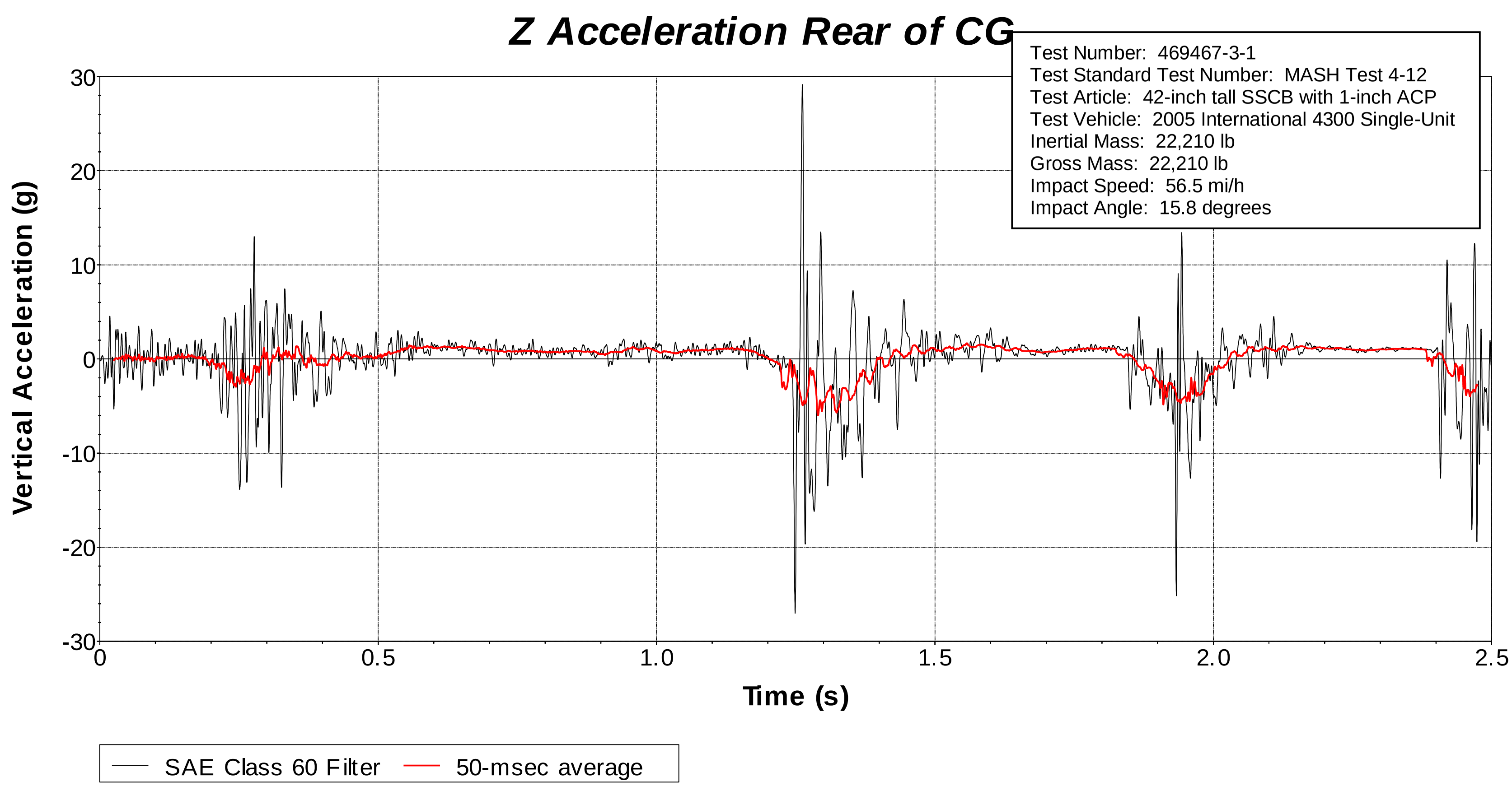
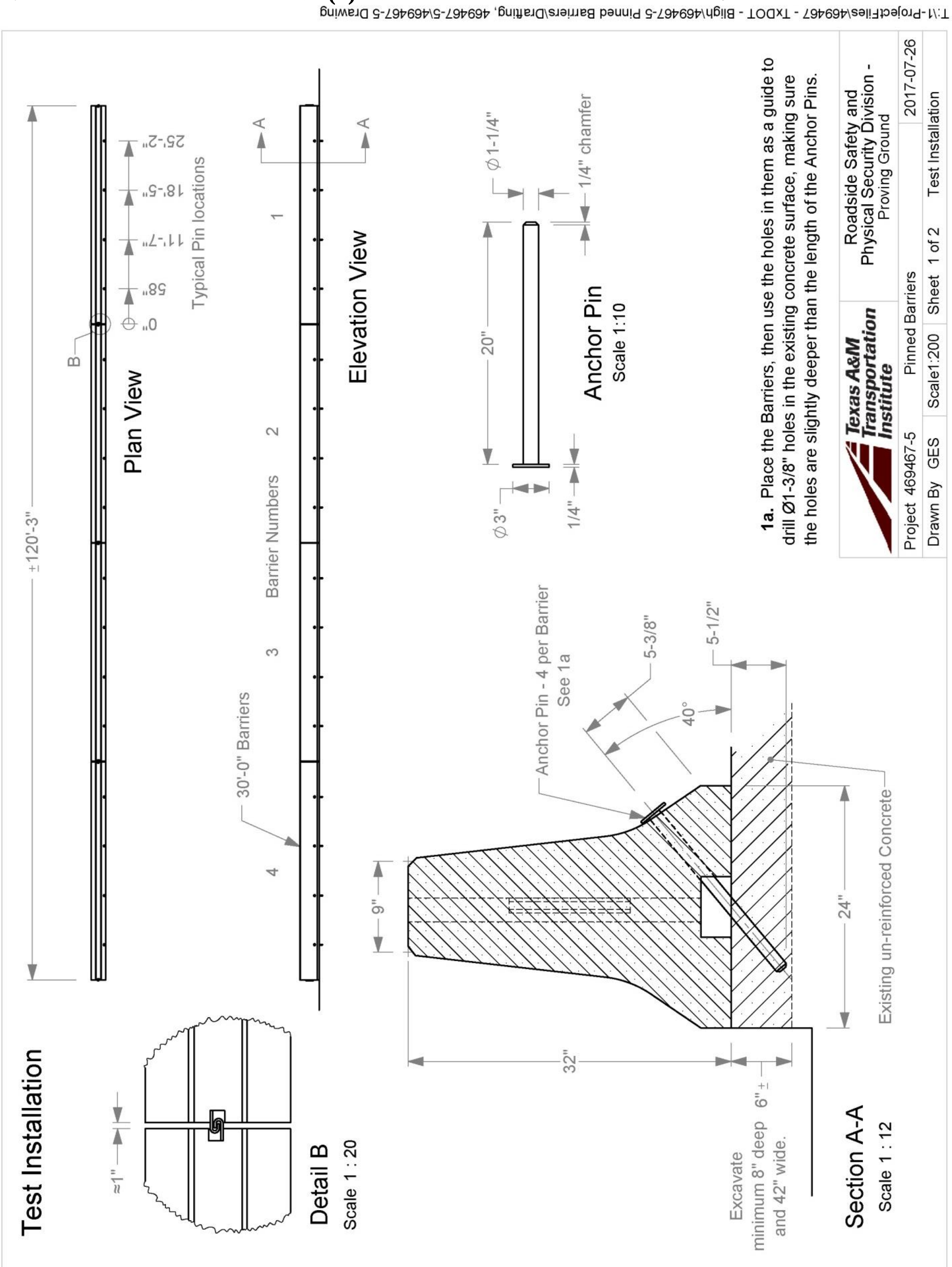
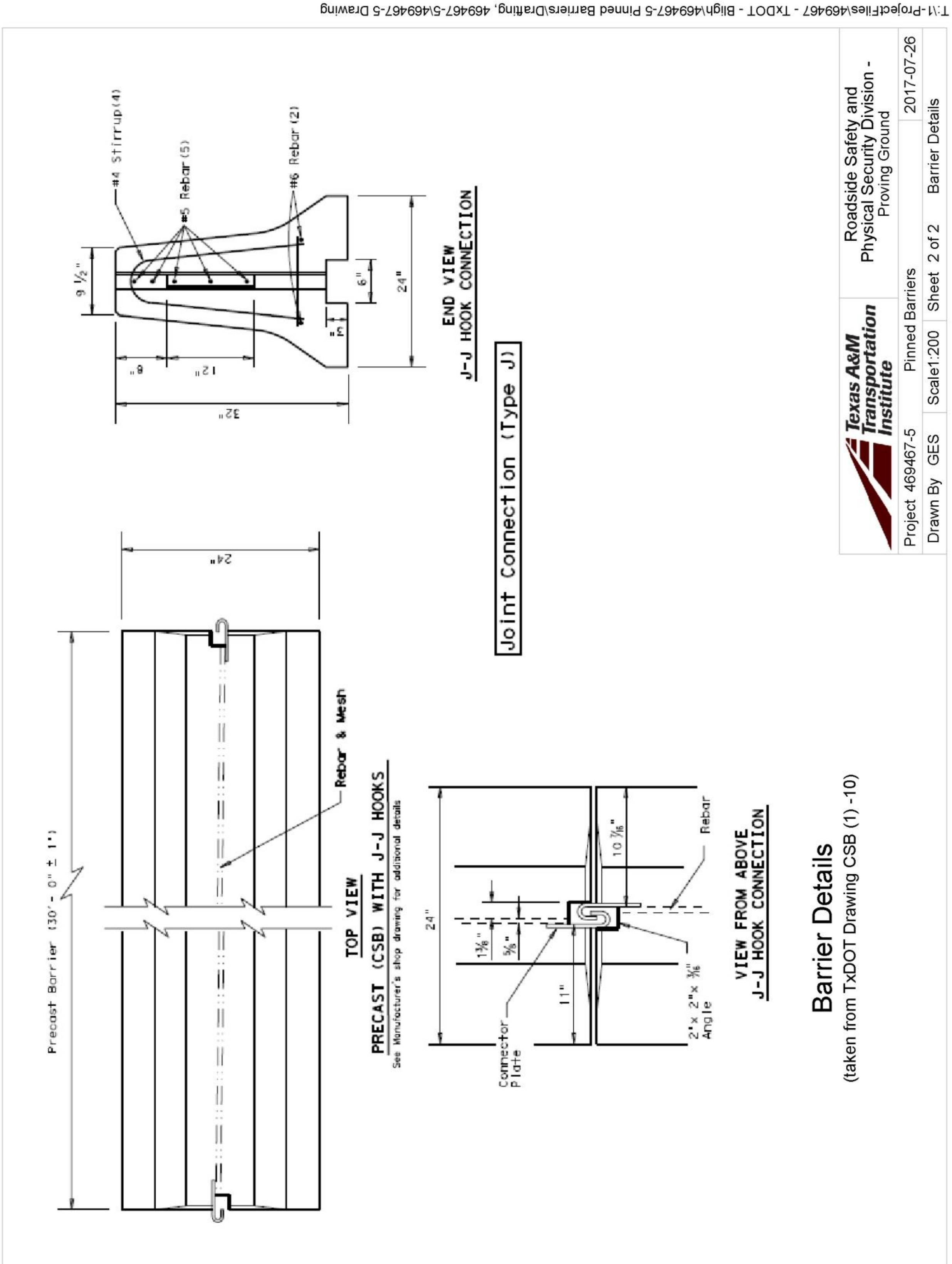


Figure B.9. Vehicle Vertical Accelerometer Trace for Test No. 469467-3-1 (Accelerometer Located Rear of Center of Gravity).

APPENDIX C. *MASH* TEST 3-11 ON THE 32-INCH F-SHAPE CONCRETE BARRIER (CSB(7)-10) PINNED TO CONCRETE PAVEMENT

C.1 DETAILS OF THE CSB(7)-10 PINNED TO CONCRETE PAVEMENT




T:\1-ProjectFiles\469467 - TxDOT - Bligh\469467-5 Pinned Barriers\Drafting, 469467-5\469467-5 Drawing
Roadside Safety and Physical Security Division - Proving Ground
Texas A&M Transportation Institute
Project 469467-5
Pinned Barriers
2017-07-26
Drawn By GES
Scale1:200
Sheet 2 of 2
Barrier Details
#4 Stirrup(4)
#5 Rebar(5)
#6 Rebar(2)
9 1/2"
6"
24"
3"
8"
12"
32"
END VIEW
J-J HOOK CONNECTION
Joint Connection (Type J)
Precast Barrier (30' - 0" ± 1')
24"
Rebar & Mesh
TOP VIEW
PRECAST (CSB) WITH J-J HOOKS
See Manufacturer's shop drawing for additional details
24"
1 3/8"
5/8"
11"
10 7/16"
Rebar
Connector Plate
2" x 2" x 3/16" Angle
VIEW FROM ABOVE
J-J HOOK CONNECTION
Barrier Details
(taken from TxDOT Drawing CSB (1) -10)

C.2 SUPPORTING CERTIFICATION DOCUMENTS


469 467-5-1
TxDOT

Tricon Precast Ltd.

32 F-Shape (JJ) 4 Pins Other

Form # 30FS-01-801

Texas Transportation Institute

132611

6/15/2017 1611026

C.3 VEHICLE PROPERTIES AND INFORMATION

Table C.1. Vehicle Properties for Test No. 469467-5-1.

Date: 2017-07-26 Test No.: 467469-5-1 VIN No.: 1C6RDC6GP2C5193320

Year: 2012 Make: Dodge Model: RAM 1500

Tire Size: 265/70R17 Tire Inflation Pressure: 40 psi

Tread Type: Highway Odometer: 207579

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

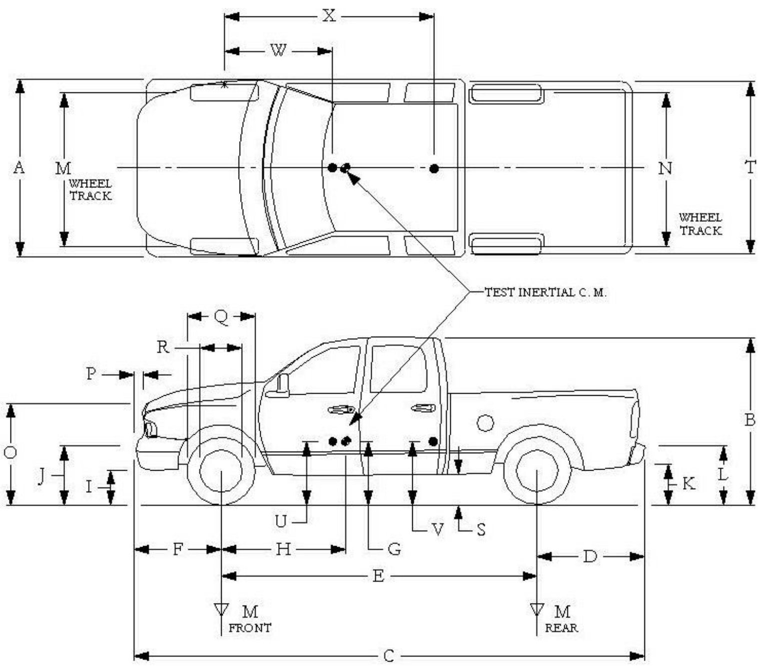
NOTES: None

Engine Type: V-8
Engine CID: 4.7 liter gas

Transmission Type:
x Auto or ____ Manual
____ FWD x RWD ____ 4WD

Optional Equipment:
None

Dummy Data:
Type: No dummy
Mass: NA
Seat Position: NA



Geometry: inches

A	78.50	F	40.00	K	19.75	P	3.00	U	27.50
B	74.00	G	28.25	L	29.50	Q	30.50	V	29.75
C	225.50	H	61.99	M	68.50	R	18.00	W	62.00
D	47.00	I	11.75	N	68.00	S	13.25	X	78.25
E	140.50	J	27.00	O	45.50	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	17.00
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	25.50

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2851	2813	----
Back	3900	M_{rear}	2030	2221	----
Total	6700	M_{Total}	4881	5034	----

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

Mass Distribution:
lb LF: 1404 RF: 1401 LR: 1101 RR: 1120

Table C.2. Measurements of Vehicle Vertical CG for Test No. 469467-5-1.

Date: 2017-07-26 Test No.: 469467-5-1 VIN: 1C6RDC6GP2C5193320

Year: 2012 Make: Dodge Model: RAM 1500

Body Style: Quad Cab Mileage: 207579

Engine: 4.7 liter V-8 gas Transmission: Automatic

Fuel Level: Empty Ballast: 232 lb (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70R17

Measured Vehicle Weights: (lb)							
LF:	1404		RF:	1409		Front Axle:	2813
LR:	1101		RR:	1120		Rear Axle:	2221
Left:	2505		Right:	2529		Total:	5034
						5000 ±110 lb allowed	
Wheel Base:	140.5	inches	Track: F:	68.5	inches	R:	68 inches
	148 ±12 inches allowed			Track = (F+R)/2 = 67 ±1.5 inches allowed			
Center of Gravity, SAE J874 Suspension Method							
X:	61.99	inches	Rear of Front Axle	(63 ±4 inches allowed)			
Y:	0.16	inches	Left - Right +	of Vehicle Centerline			
Z:	28.25	inches	Above Ground	(minumum 28.0 inches allowed)			

Hood Height: 45.50 inches
43 ±4 inches allowed

Front Bumper Height: 27.00 inches

Front Overhang: 40.00 inches
39 ±3 inches allowed

Rear Bumper Height: 29.50 inches

Overall Length: 225.50 inches
237 ±13 inches allowed

Table C.3. Exterior Crush Measurements of Vehicle for Test No. 469467-5-1.

Date: 2017-07-26 Test No.: 467469-5-1 VIN No.: 1C6RDC6GP2C5193320

Year: 2012 Make: Dodge Model: RAM 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	Front plane at bumper ht	16	14	36	1	3	4.5	8	12	14	+8
2	Side plane at bumper ht	16	15	53	0	2	--	--	14	15	+75
	Measurements recorded										
	in inches										

[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).

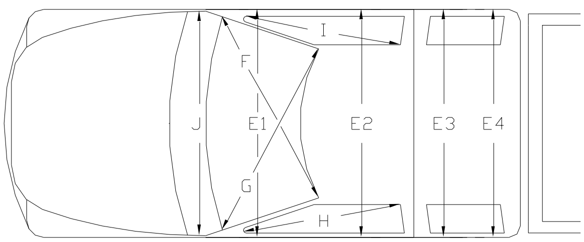
***Measure and document on the vehicle diagram the location of the maximum crush.

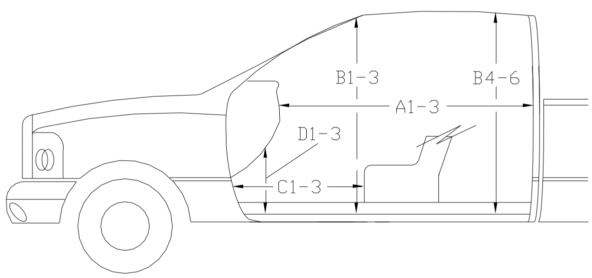
Note: Use as many lines/columns as necessary to describe each damage profile.

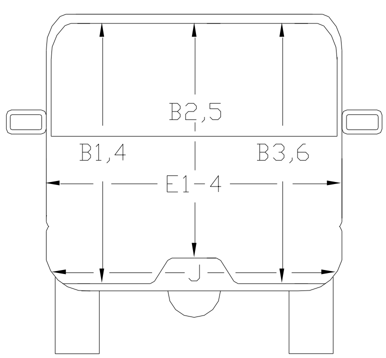
Table C.4. Occupant Compartment Measurements of Vehicle for Test No. 469467-5-1.

Date: 2017-07-26 Test No.: 467469-5-1 VIN No.: 1C6RDC6GP2C5193320

Year: 2012 Make: Dodge Model: RAM 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
A2	63.00	63.00	0
A3	65.50	65.50	0
B1	44.00	44.00	0
B2	37.75	37.75	0
B3	44.00	44.00	0
B4	39.50	39.50	0
B5	43.25	43.25	0
B6	39.50	39.50	0
C1	27.00	27.00	0
C2	-----	-----	--
C3	26.50	26.50	0
D1	11.50	11.50	0
D2	-----	-----	--
D3	11.50	11.50	0
E1	62.00	62.00	0
E2	62.50	62.50	0
E3	62.50	62.50	0
E4	62.50	62.50	0
F	59.00	59.00	0
G	59.00	59.00	0
H	38.00	38.00	0
I	38.00	38.00	0
J*	22.50	22.50	0

C.4 SEQUENTIAL PHOTOGRAPHS

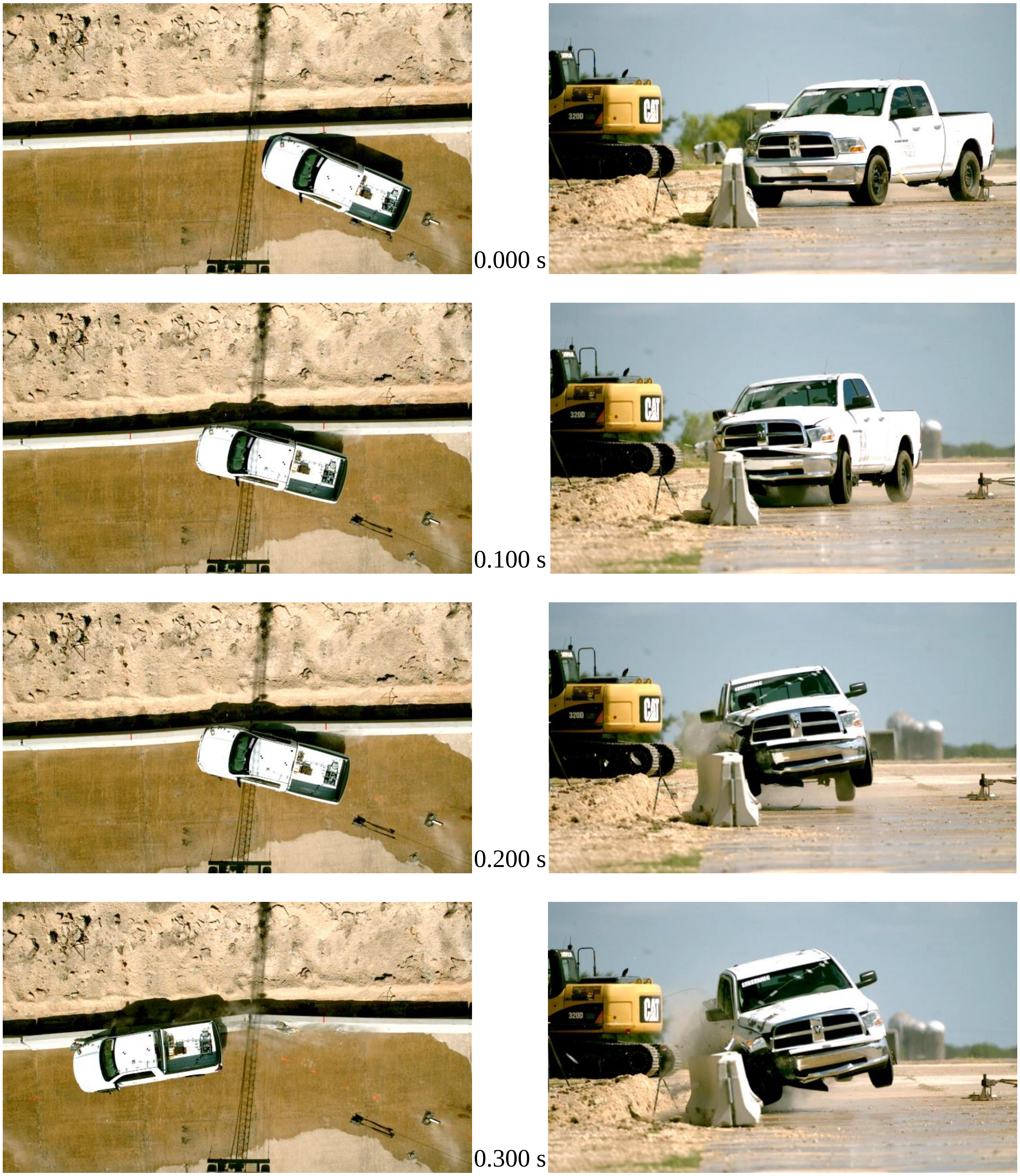


Figure C.1. Sequential Photographs for Test No. 469467-5-1 (Overhead and Frontal Views).

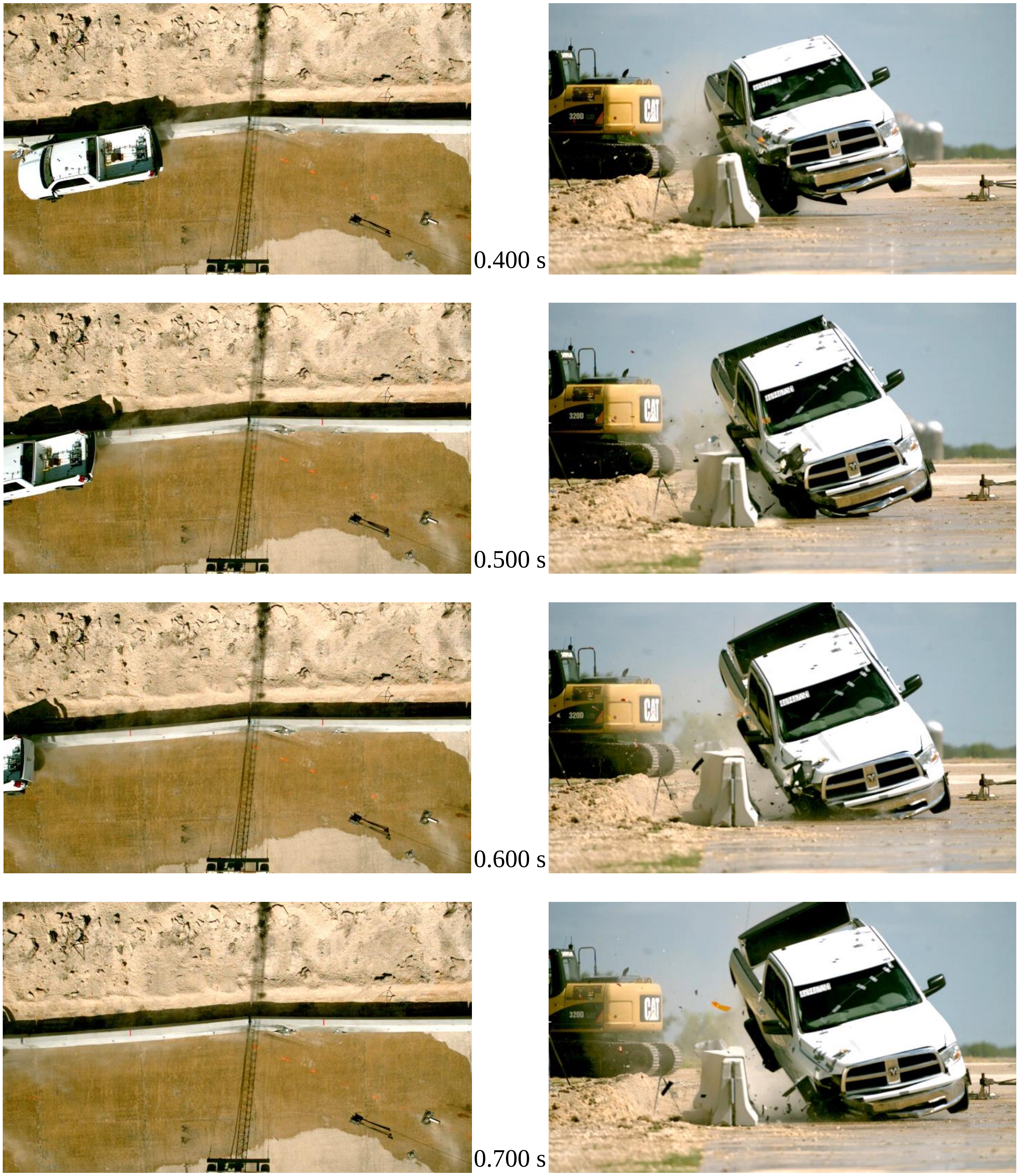
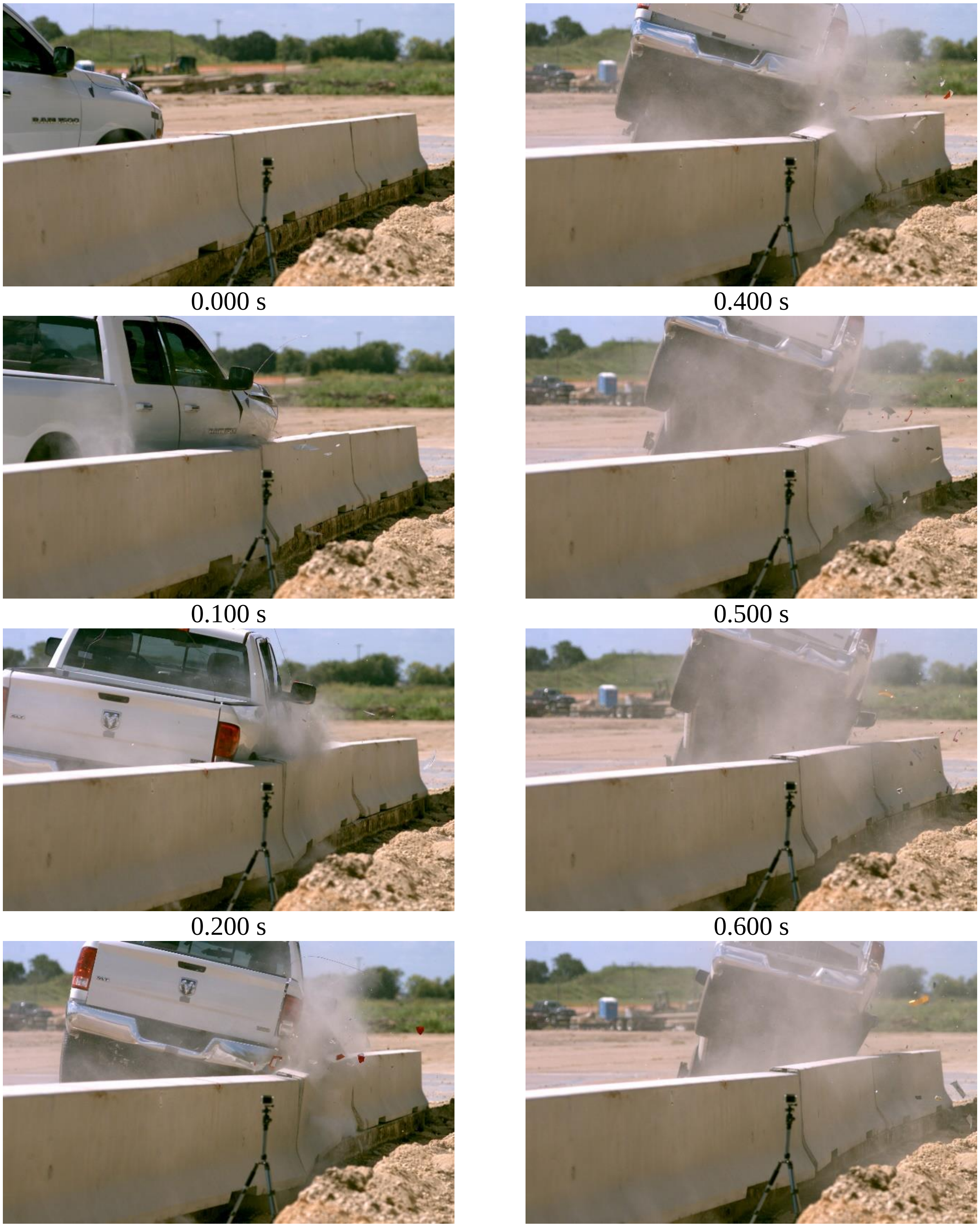


Figure C.1. Sequential Photographs for Test No. 469467-5-1 (Overhead and Frontal Views) (Continued).



0.000 s | 0.400 s
0.100 s | 0.500 s
0.200 s | 0.600 s
0.300 s | 0.700 s

Figure C.2. Sequential Photographs for Test No. 469467-5-1 (Rear View).

C.5 VEHICLE ANGULAR DISPLACEMENT

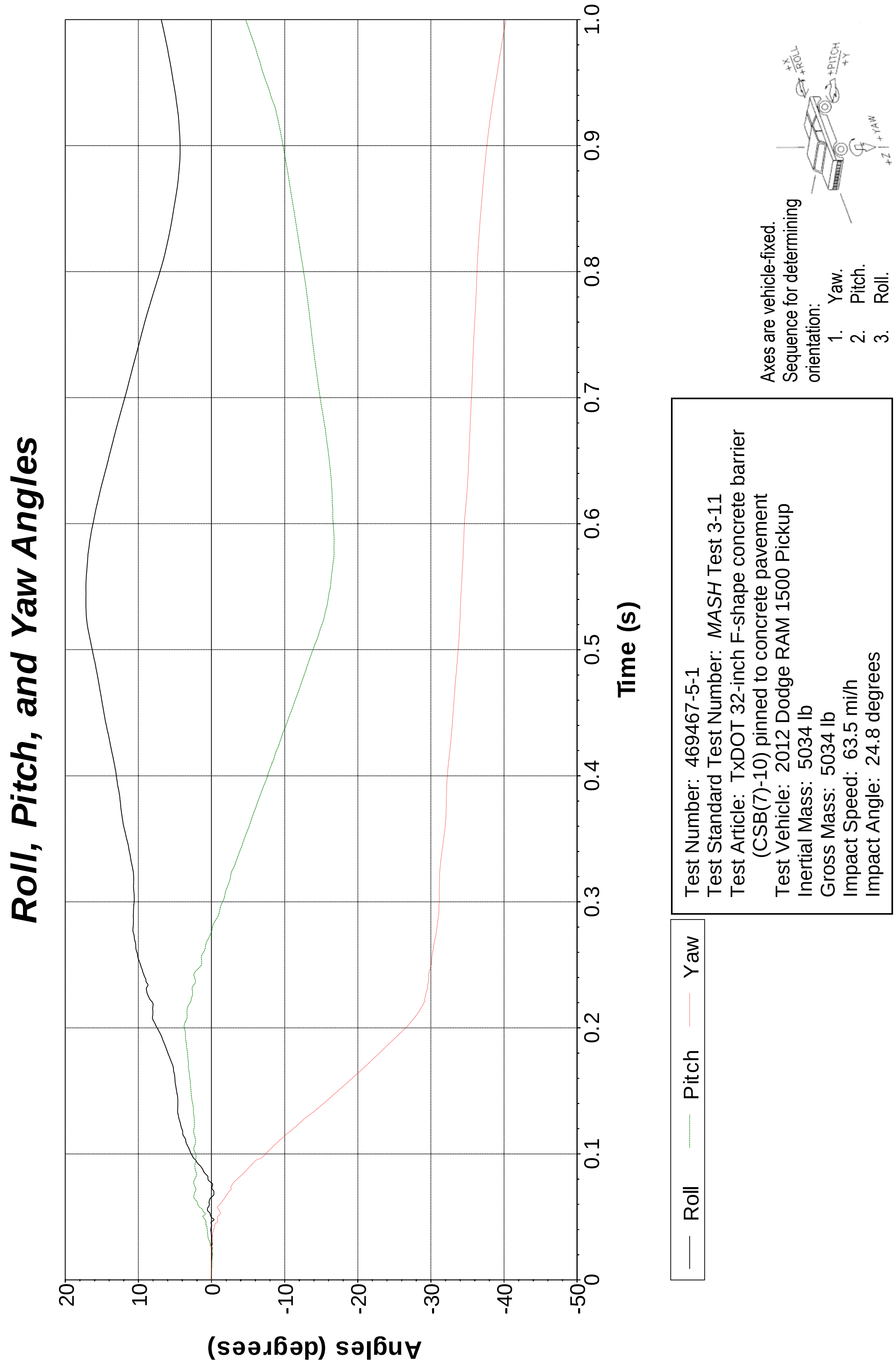


Figure C.3. Vehicle Angular Displacements for Test No. 469467-5-1.

C.6 VEHICLE ACCELERATIONS

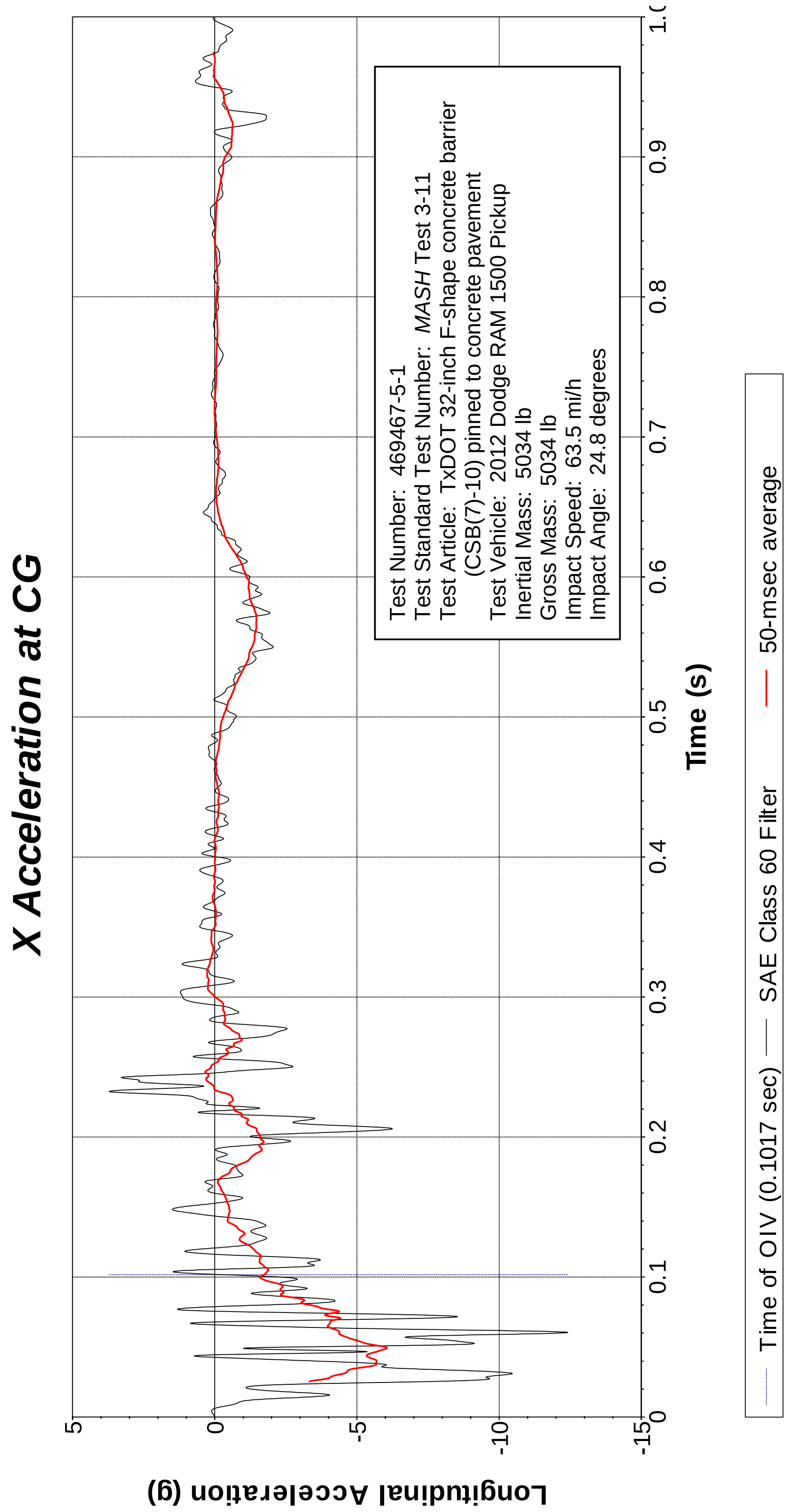


Figure C.4. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-5-1 (Accelerometer Located at Center of Gravity).

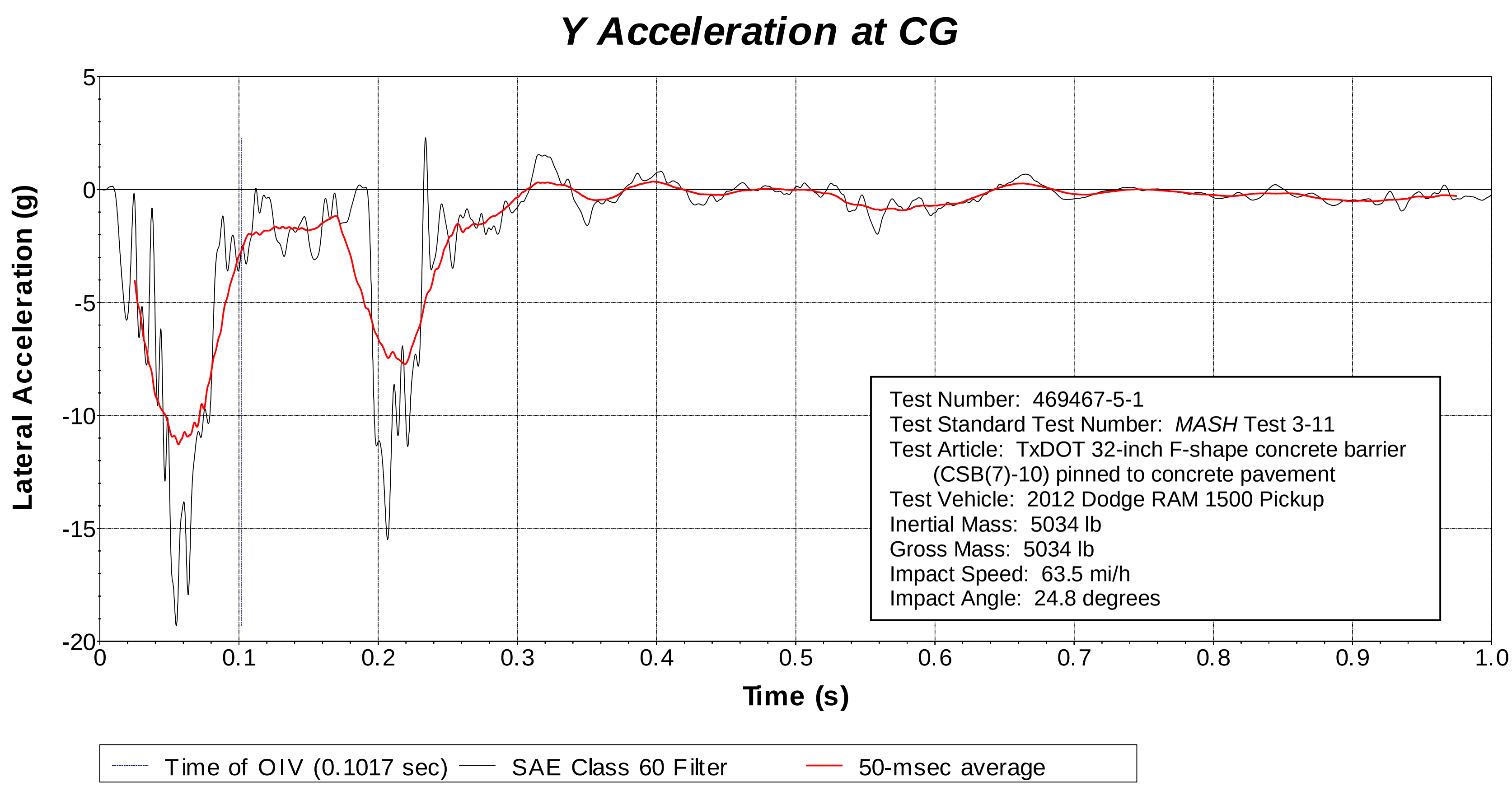


Figure C.5. Vehicle Lateral Accelerometer Trace for Test No. 469467-5-1 (Accelerometer Located at Center of Gravity).

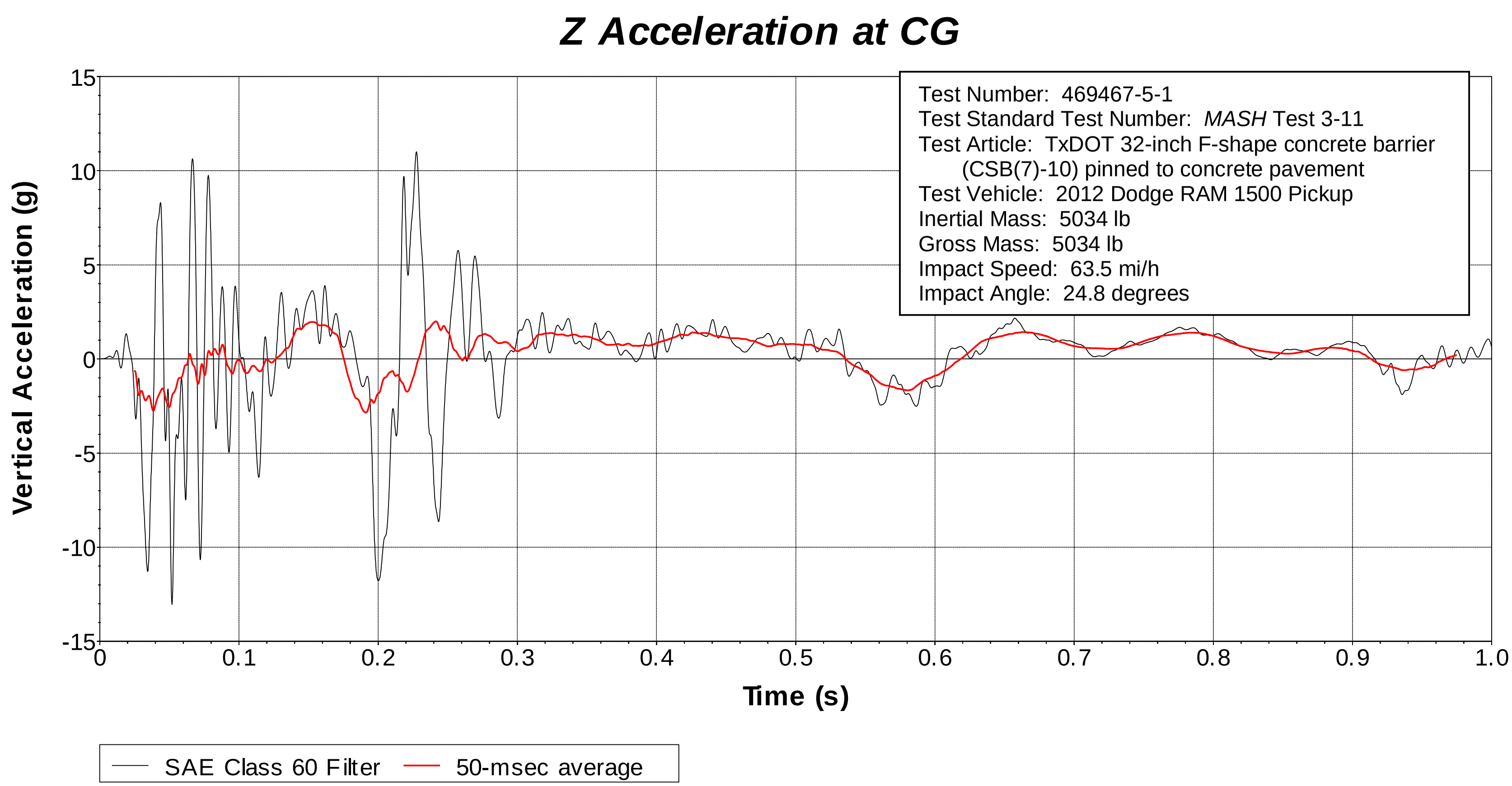


Figure C.6. Vehicle Vertical Accelerometer Trace for Test No. 469467-5-1 (Accelerometer Located at Center of Gravity).

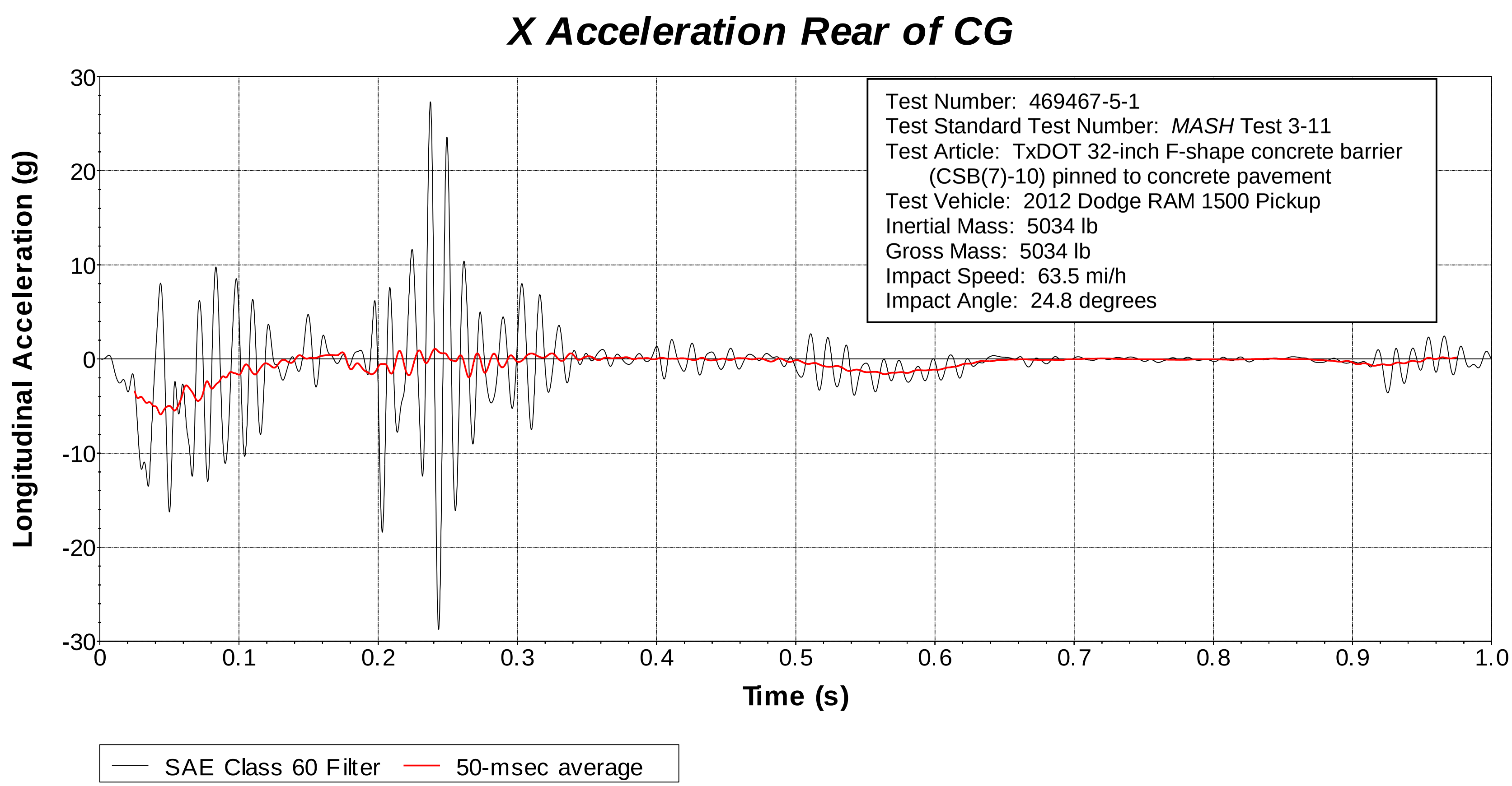


Figure C.7. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-5-1 (Accelerometer Located Rear of Center of Gravity).

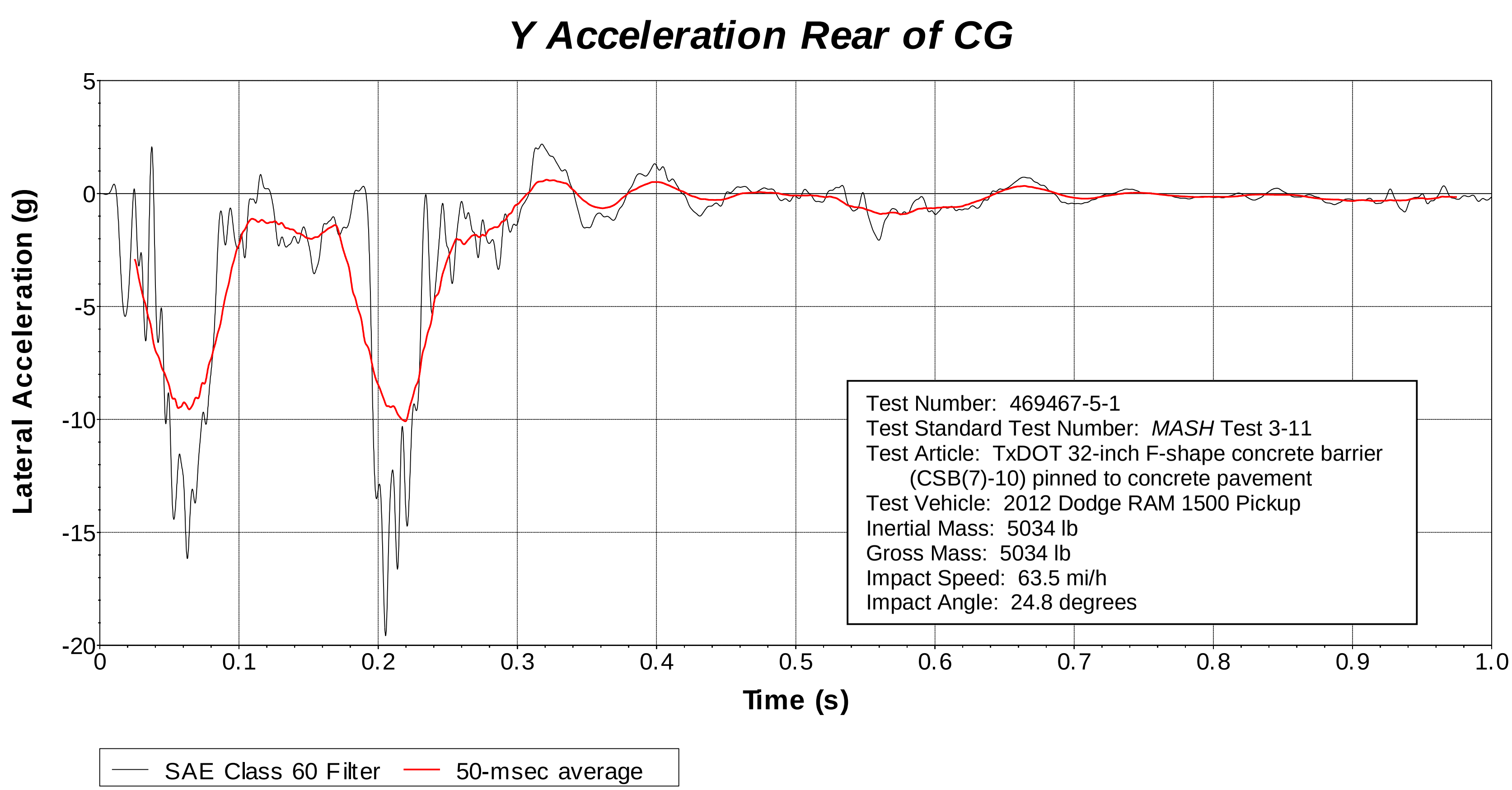


Figure C.8. Vehicle Lateral Accelerometer Trace for Test No. 469467-5-1 (Accelerometer Located Rear of Center of Gravity).

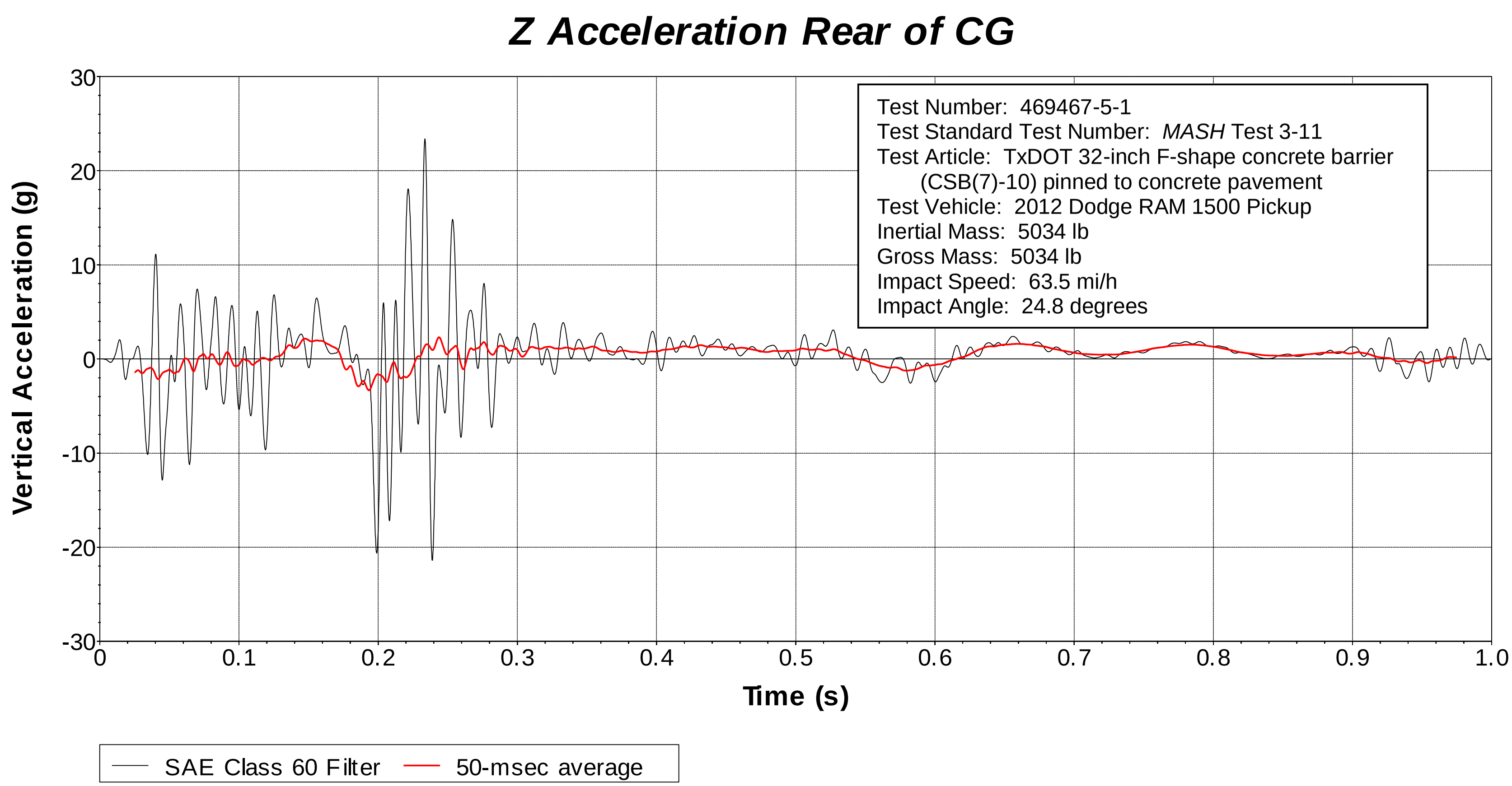


Figure C.9. Vehicle Vertical Accelerometer Trace for Test No. 469467-5-1 (Accelerometer Located Rear of Center of Gravity).

APPENDIX D. *MASH* TESTING ON EMBEDDED WOOD SIGN SUPPORTS

D.1 *MASH* TEST 3-62 ON SINGLE EMBEDDED WOOD SIGN SUPPORT AT 0°

Table D.1. Vehicle Properties for Test No. 469467-6-1.

Date: 2017-08-22 Test No.: 469467-6-1 VIN No.: 1D7RB16P4BS692707

Year: 2011 Make: Dodge Model: RAM 1500

Tire Size: 265/70R17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 151312

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

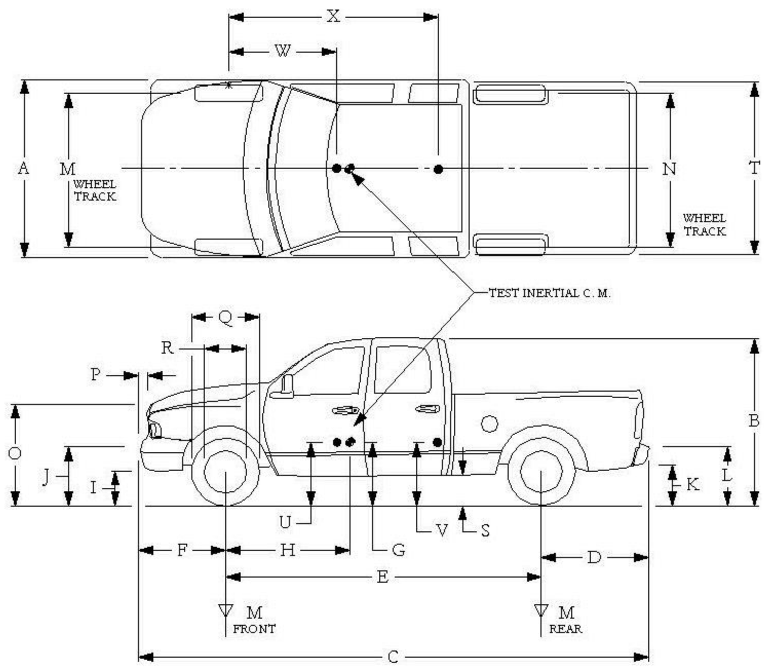
NOTES: None

Engine Type: V-8
Engine CID: 4.7 liter

Transmission Type:
x Auto or ___ Manual
___ FWD x RWD ___ 4WD

Optional Equipment:
None

Dummy Data:
Type: No dummy
Mass: NA
Seat Position: NA



Geometry: inches

A	78.50	F	40.00	K	20.75	P	3.00	U	27.50
B	75.00	G	28.00	L	29.50	Q	30.50	V	30.50
C	227.50	H	62.63	M	68.50	R	18.00	W	62.63
D	47.00	I	11.00	N	68.00	S	13.25	X	78.63
E	140.50	J	26.50	O	46.00	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	17.00
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	25.50

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2827	2785	
Back	3900	M_{rear}	1922	2240	
Total	6700	M_{Total}	4749	5025	

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

Mass Distribution:
lb LF: 1390 RF: 1395 LR: 1115 RR: 1125

Table D.2. Measurements of Vehicle Vertical CG for Test No. 469467-6-1.

Date: 2017-08-22 Test No.: 469467-6-1 VIN: 1D7RB16P4BS692707

Year: 2011 Make: Dodge Model: RAM 1500

Body Style: Quad-Cab Mileage: 151312

Engine: 4.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 207 lb (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70R17

Measured Vehicle Weights: (lb)							
LF:	1390		RF:	1395		Front Axle:	2785
LR:	1115		RR:	1125		Rear Axle:	2240
Left:	2505		Right:	2520		Total:	5025
							5000 ±110 lb allowed
Wheel Base:	140.50	inches	Track: F:	68.50	inches	R:	68.00 inches
	148 ±12 inches allowed			Track = (F+R)/2 = 67 ±1.5 inches allowed			
Center of Gravity, SAE J874 Suspension Method							
X:	62.63	inches	Rear of Front Axle	(63 ±4 inches allowed)			
Y:	0.10	inches	Left - Right +	of Vehicle Centerline			
Z:	28.00	inches	Above Ground	(minumum 28.0 inches allowed)			

Hood Height: 46.00 inches
43 ±4 inches allowed

Front Bumper Height: 26.50 inches

Front Overhang: 40.00 inches
39 ±3 inches allowed

Rear Bumper Height: 29.50 inches

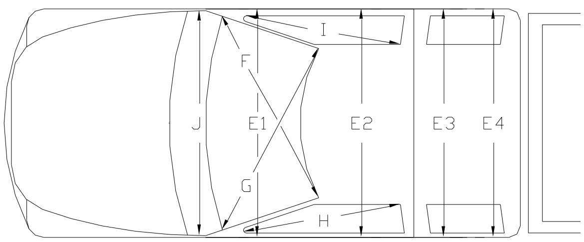
Overall Length: 227.50 inches
237 ±13 inches allowed

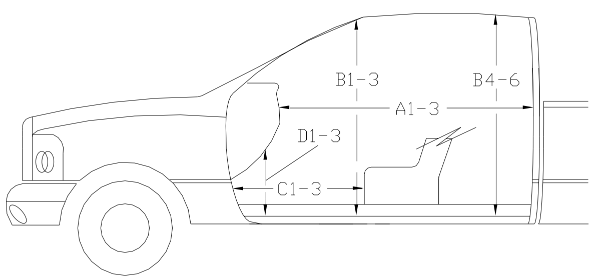
Test Conductor(s): ______________________

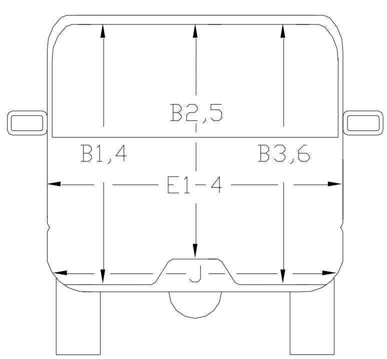
Table D.3. Occupant Compartment Measurements for Test No. 469467-6-1.

Date: 2017-08-22 Test No.: 469467-6-1 VIN No.: 1D7RB16P4BS692707

Year: 2011 Make: Dodge Model: RAM 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
A2	62.50	62.50	0
A3	65.25	65.25	0
B1	44.75	44.75	0
B2	38.00	38.00	0
B3	44.75	44.75	0
B4	39.50	39.50	0
B5	43.00	43.00	0
B6	39.50	39.50	0
C1	26.50	26.50	0
C2	-----	-----	-
C3	26.50	26.50	0
D1	11.25	11.25	0
D2	-----	-----	-
D3	11.25	11.25	0
E1	58.50	58.50	0
E2	63.50	63.50	0
E3	63.50	63.50	0
E4	63.50	63.50	0
F	59.00	59.00	0
G	59.00	59.00	0
H	37.50	37.50	0
I	37.50	37.50	0
J*	23.50	23.50	0

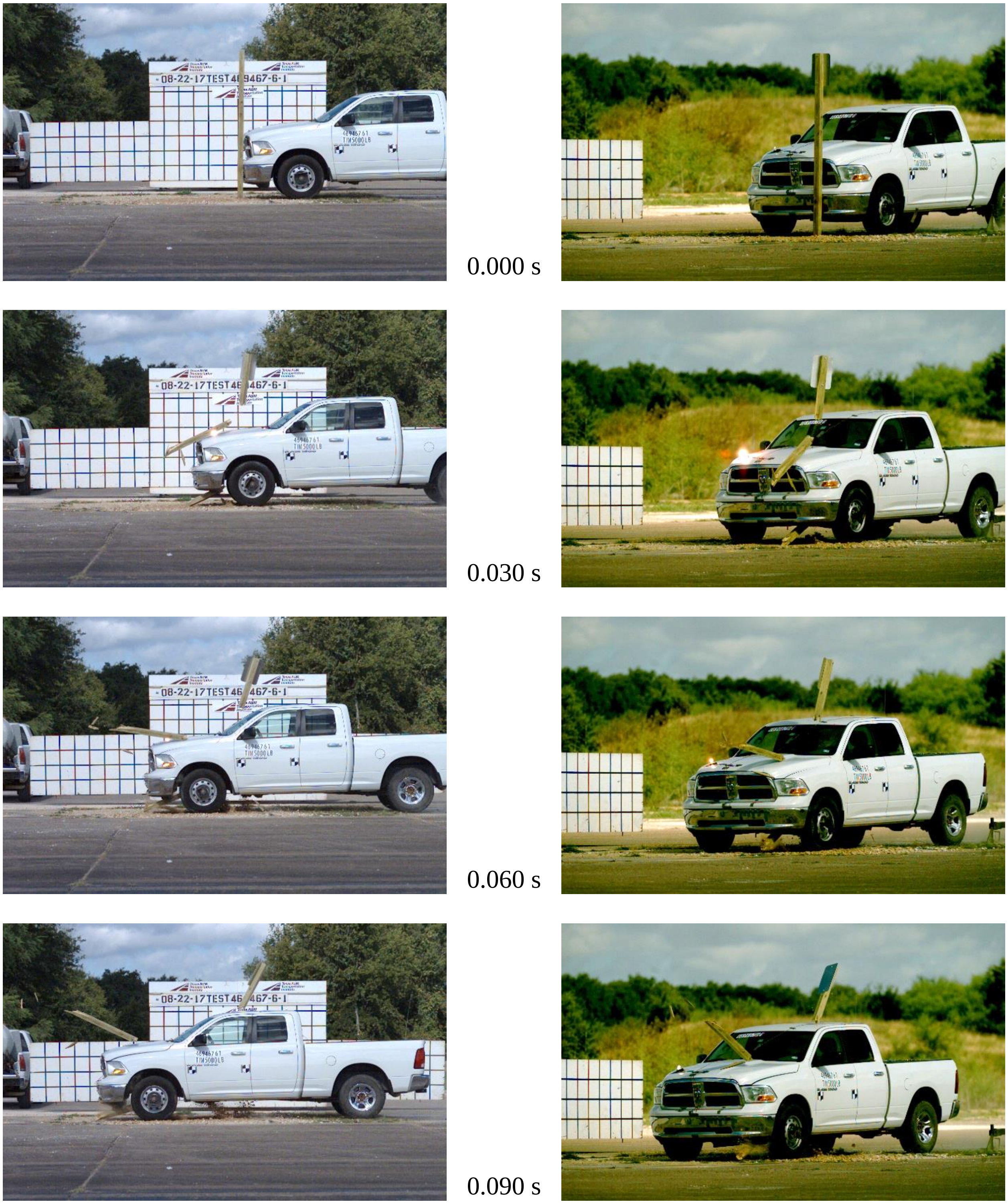


Figure D.1. Sequential Photographs for Test No. 469467-6-1 (Perpendicular and Oblique Views).

0.120 s

0.150 s

0.180 s

0.210 s

Figure D.1. Sequential Photographs for Test No. 469467-6-1 (Perpendicular and Oblique Views) (Continued).

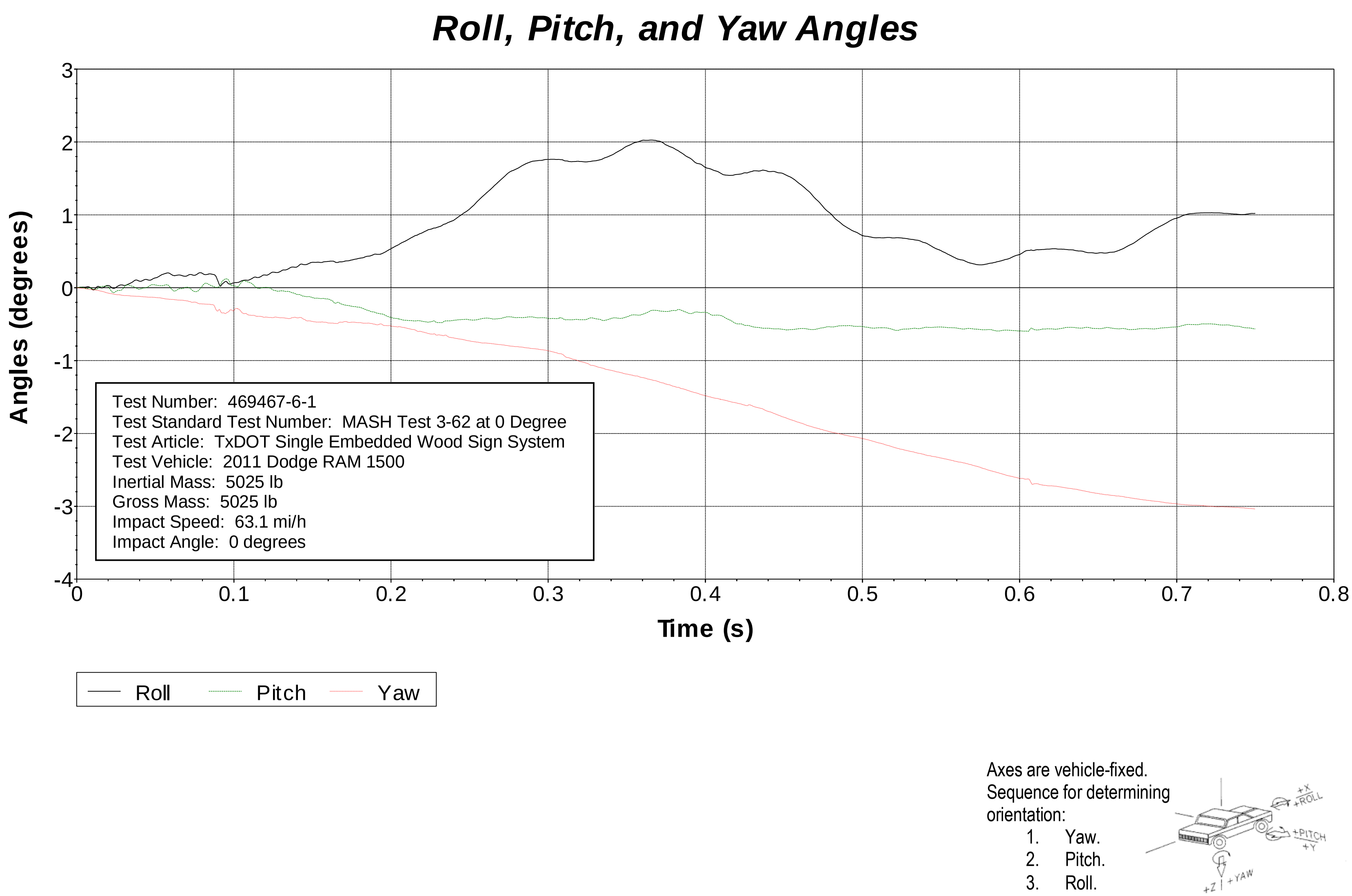


Figure D.2. Vehicle Angular Displacements for Test No. 469467-6-1.

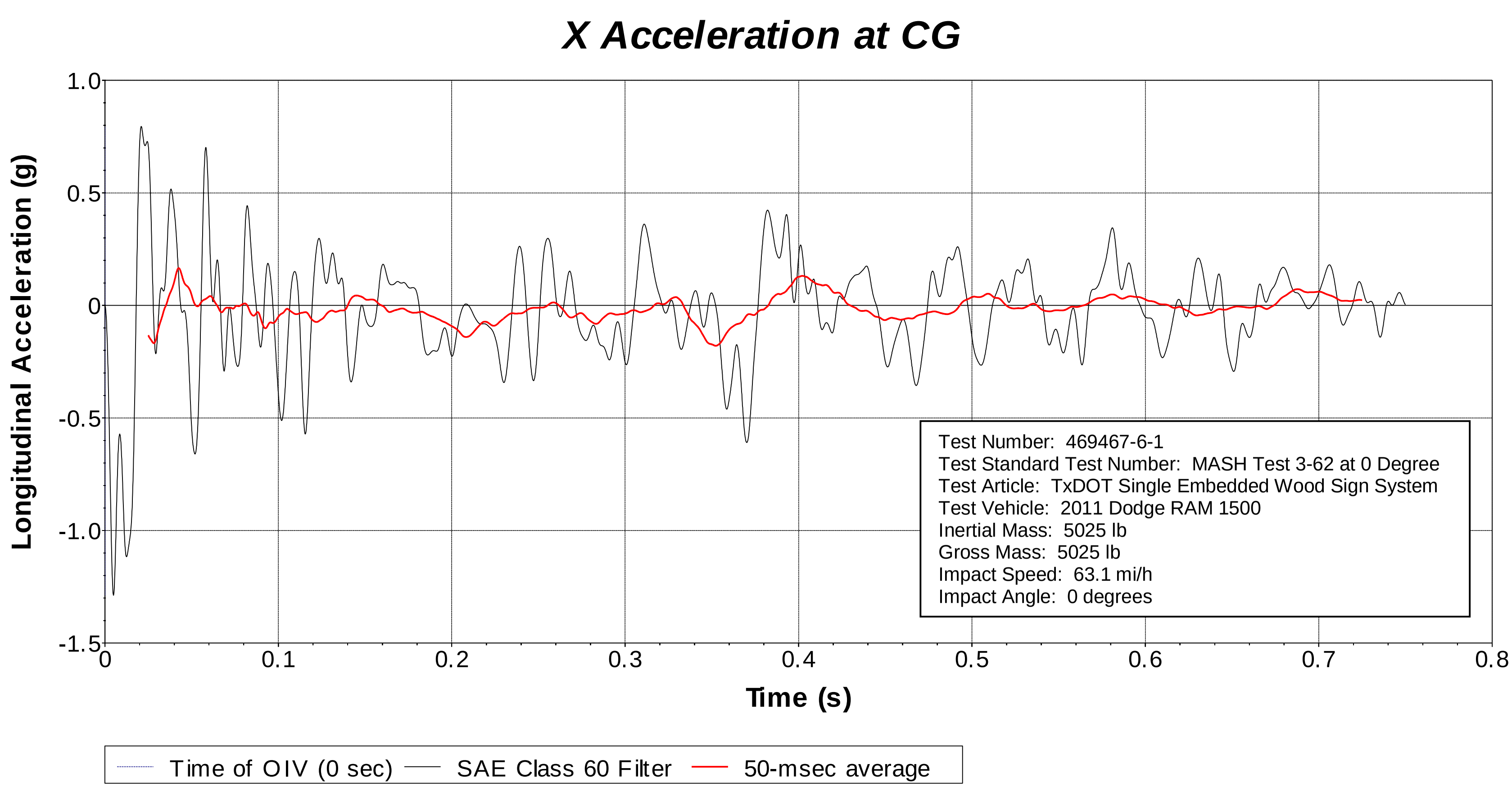


Figure D.3. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-6-1 (Accelerometer Located at Center of Gravity).

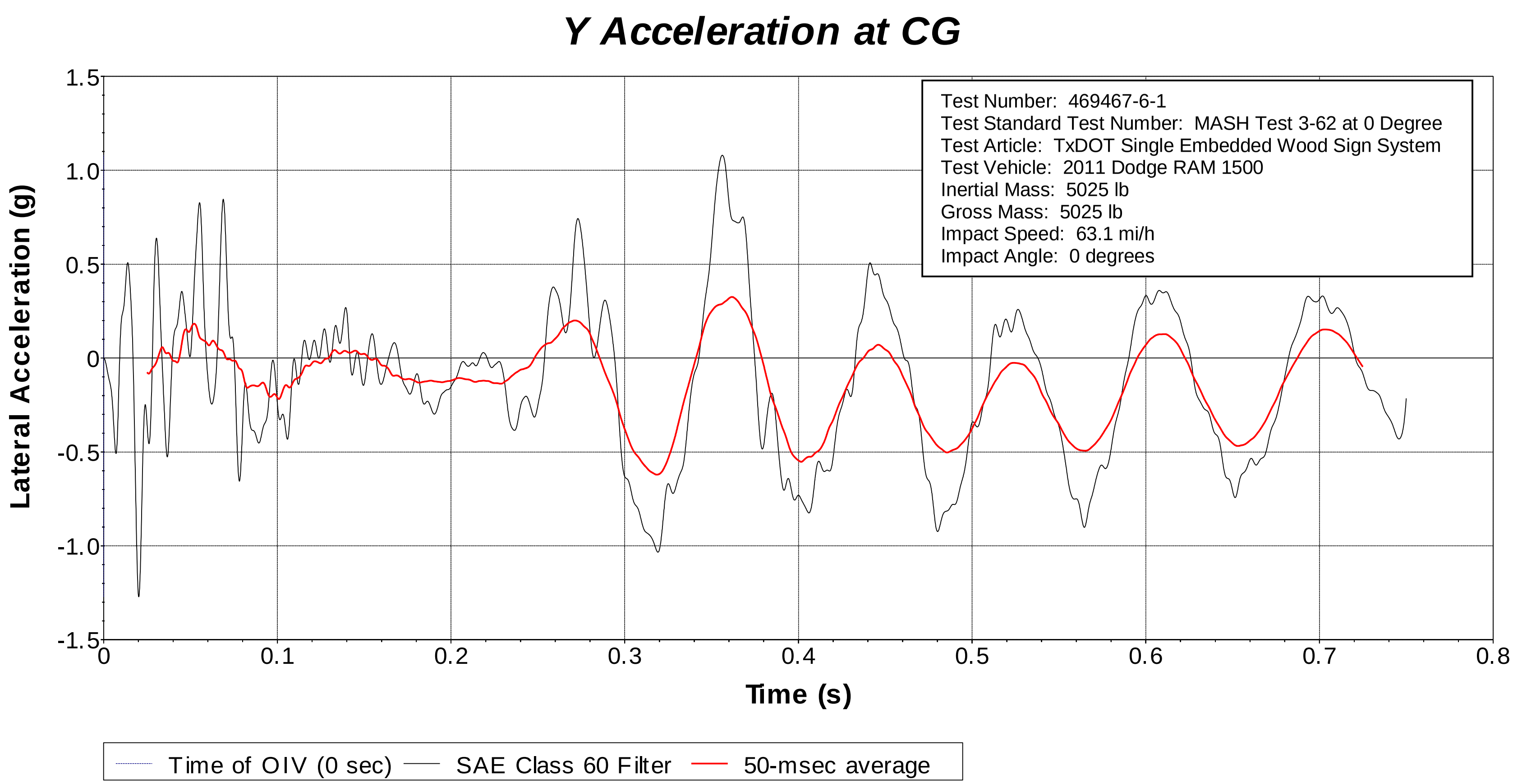


Figure D.4. Vehicle Lateral Accelerometer Trace for Test No. 469467-6-1 (Accelerometer Located at Center of Gravity).

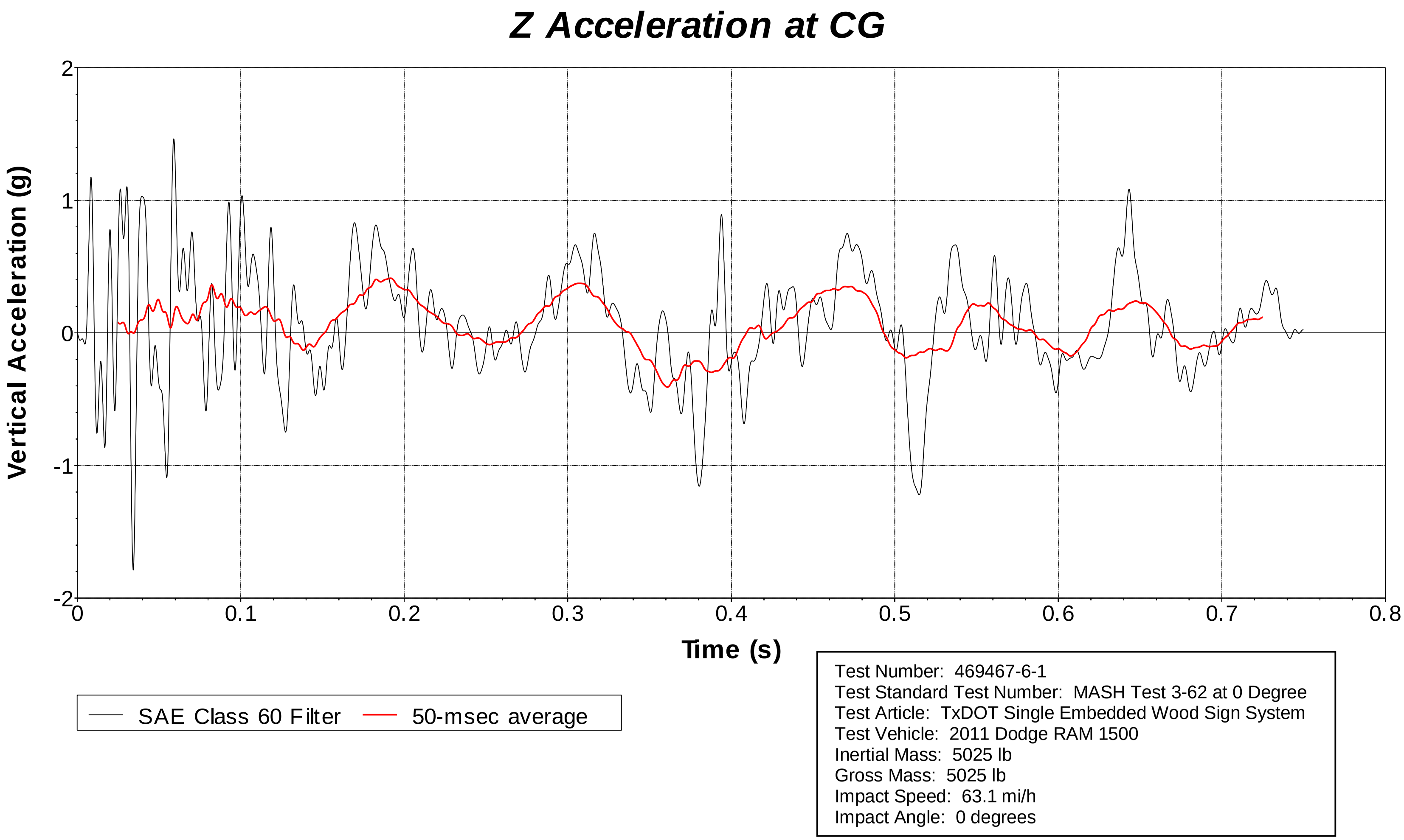


Figure D.5. Vehicle Vertical Accelerometer Trace for Test No. 469467-6-1 (Accelerometer Located at Center of Gravity).

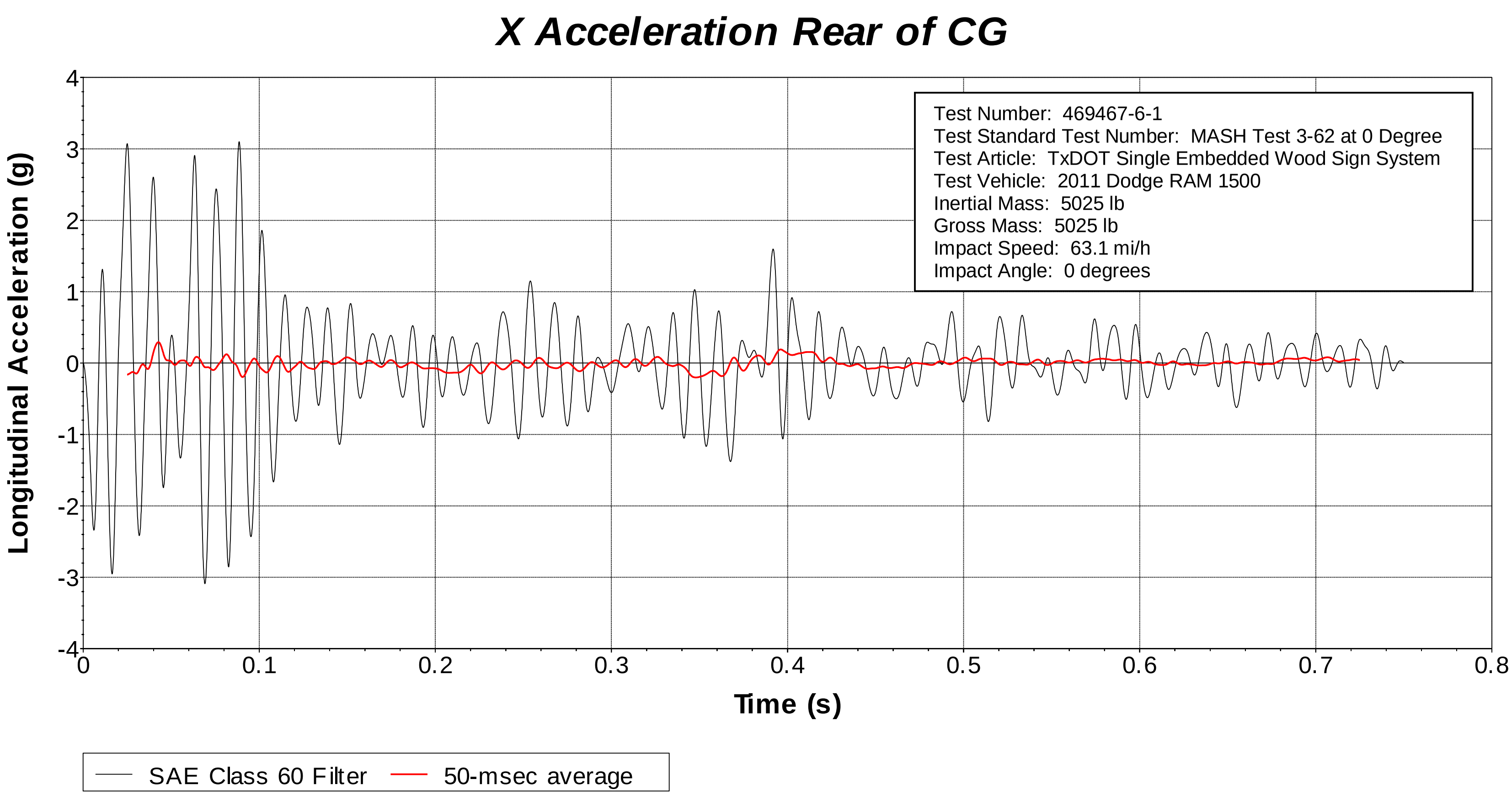


Figure D.6. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-6-1 (Accelerometer Located Rear of Center of Gravity).

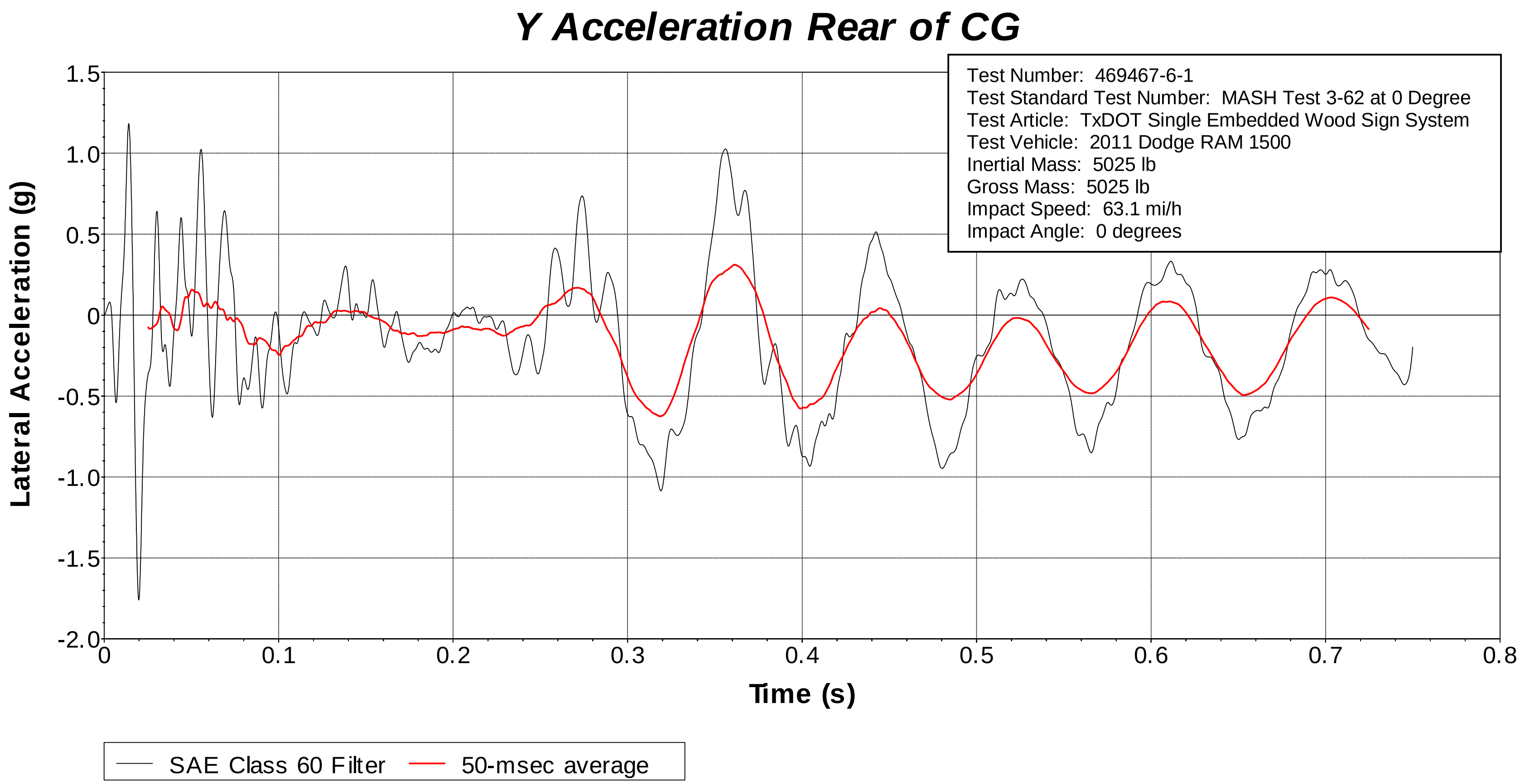


Figure D.7. Vehicle Lateral Accelerometer Trace for Test No. 469467-6-1 (Accelerometer Located Rear of Center of Gravity).

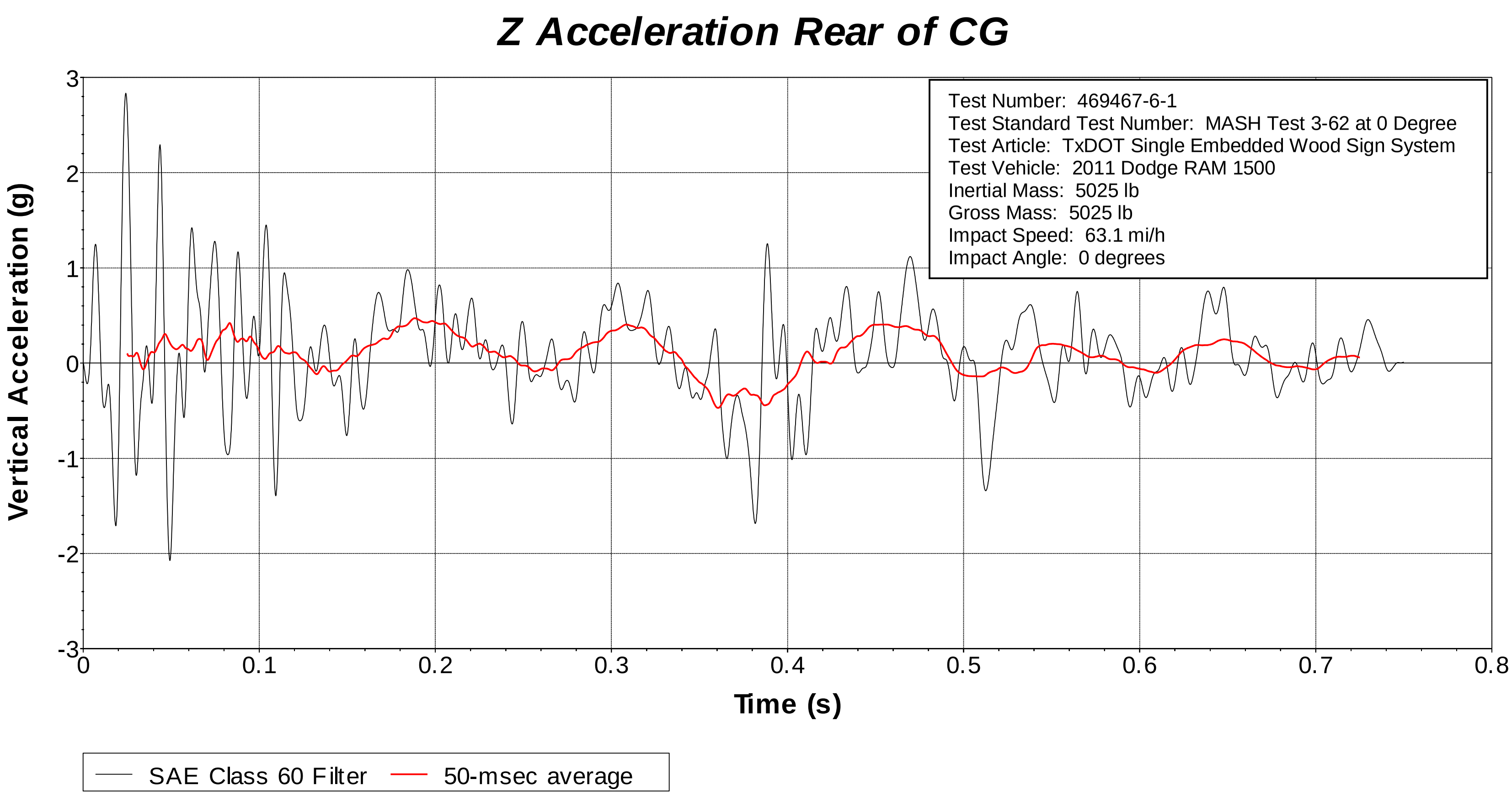


Figure D.8. Vehicle Vertical Accelerometer Trace for Test No. 469467-6-1 (Accelerometer Located Rear of Center of Gravity).

D.2 *MASH* TEST 3-62 ON SINGLE EMBEDDED SIGN SUPPORT AT 90°

Table D.4. Vehicle Properties for Test No. 469467-6-3.

Date: 2017-08-22 Test No.: 469467-6-3 VIN No.: 1D7RB16P4BS692707

Year: 2011 Make: Dodge Model: RAM 1500

Tire Size: 265/70R17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 151312

Note any damage to the vehicle prior to test: Small dent at right quarter point of bumper and hood

● Denotes accelerometer location.

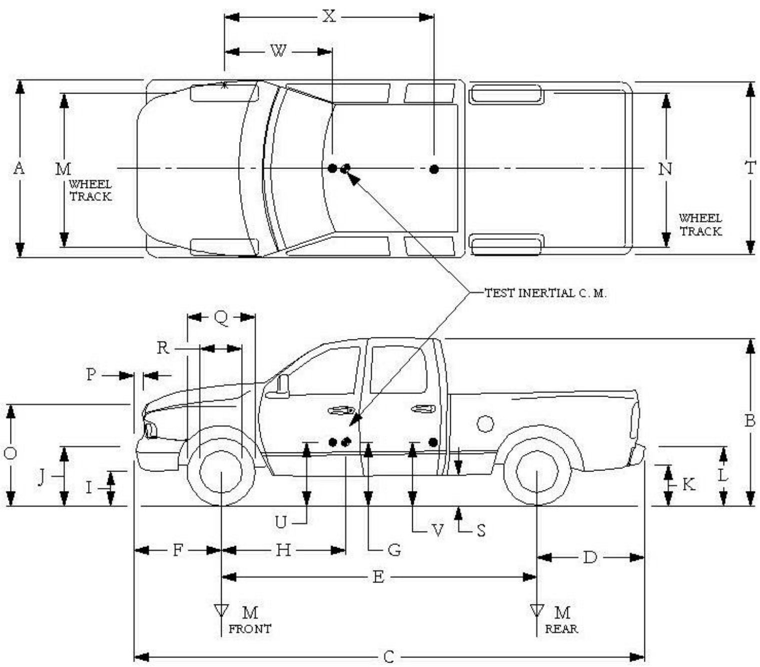
NOTES: Previously used in Test No. 469467-6-1

Engine Type: V-8
Engine CID: 4.7 liter

Transmission Type:
x Auto or ___ Manual
___ FWD x RWD ___ 4WD

Optional Equipment:
None

Dummy Data:
Type: No dummy
Mass: NA
Seat Position: NA



Geometry: inches

A	78.50	F	40.00	K	20.75	P	3.00	U	27.50
B	75.00	G	28.00	L	29.50	Q	30.50	V	30.50
C	227.50	H	62.63	M	68.50	R	18.00	W	62.63
D	47.00	I	11.00	N	68.00	S	13.25	X	78.63
E	140.50	J	26.50	O	46.00	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	17.00
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	25.50

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2827	2785	
Back	3900	M_{rear}	1922	2240	
Total	6700	M_{Total}	4749	5025	

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

Mass Distribution:
lb LF: 1390 RF: 1395 LR: 1115 RR: 1125

Table D.5. Measurements of Vehicle Vertical CG for Test No. 469467-6-3.

Date: 2017-08-22 Test No.: 469467-6-3 VIN: 1D7RB16P4BS692707

Year: 2011 Make: Dodge Model: RAM 1500

Body Style: Quad-Cab Mileage: 151312

Engine: 4.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 207 lb (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70R17

Measured Vehicle Weights: (lb)						
LF:	1390	RF:	1395	Front Axle:	2785	
LR:	1115	RR:	1125	Rear Axle:	2240	
Left:	2505	Right:	2520	Total:	5025	
					5000 ±110 lb allowed	
Wheel Base:	140.50 inches	Track: F:	68.50 inches	R:	68.00	inches
	148 ±12 inches allowed		Track = (F+R)/2 = 67 ±1.5 inches allowed			
Center of Gravity, SAE J874 Suspension Method						
X:	62.63 inches	Rear of Front Axle	(63 ±4 inches allowed)			
Y:	0.10 inches	Left - Right +	of Vehicle Centerline			
Z:	28.00 inches	Above Ground	(minumum 28.0 inches allowed)			

Hood Height: 46.00 inches
43 ±4 inches allowed

Front Bumper Height: 26.50 inches

Front Overhang: 40.00 inches
39 ±3 inches allowed

Rear Bumper Height: 29.50 inches

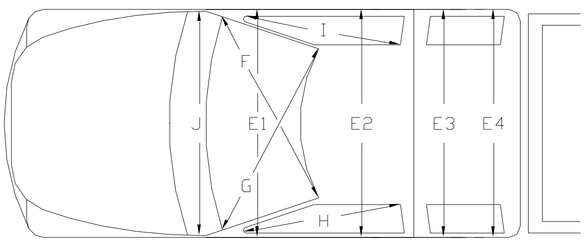
Overall Length: 227.50 inches
237 ±13 inches allowed

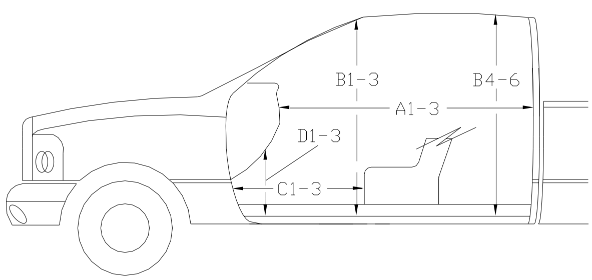
Test Conductor(s): ______________________

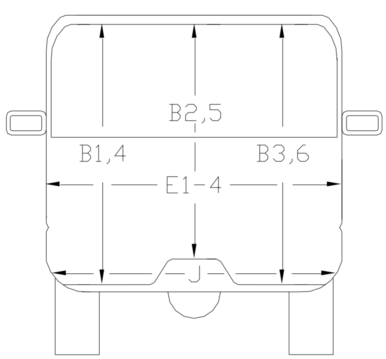
Table D.6. Occupant Compartment Measurements for Test No. 469467-6-3.

Date: 2017-08-22 Test No.: 469467-6-3 VIN No.: 1D7RB16P4BS692707

Year: 2011 Make: Dodge Model: RAM 1500



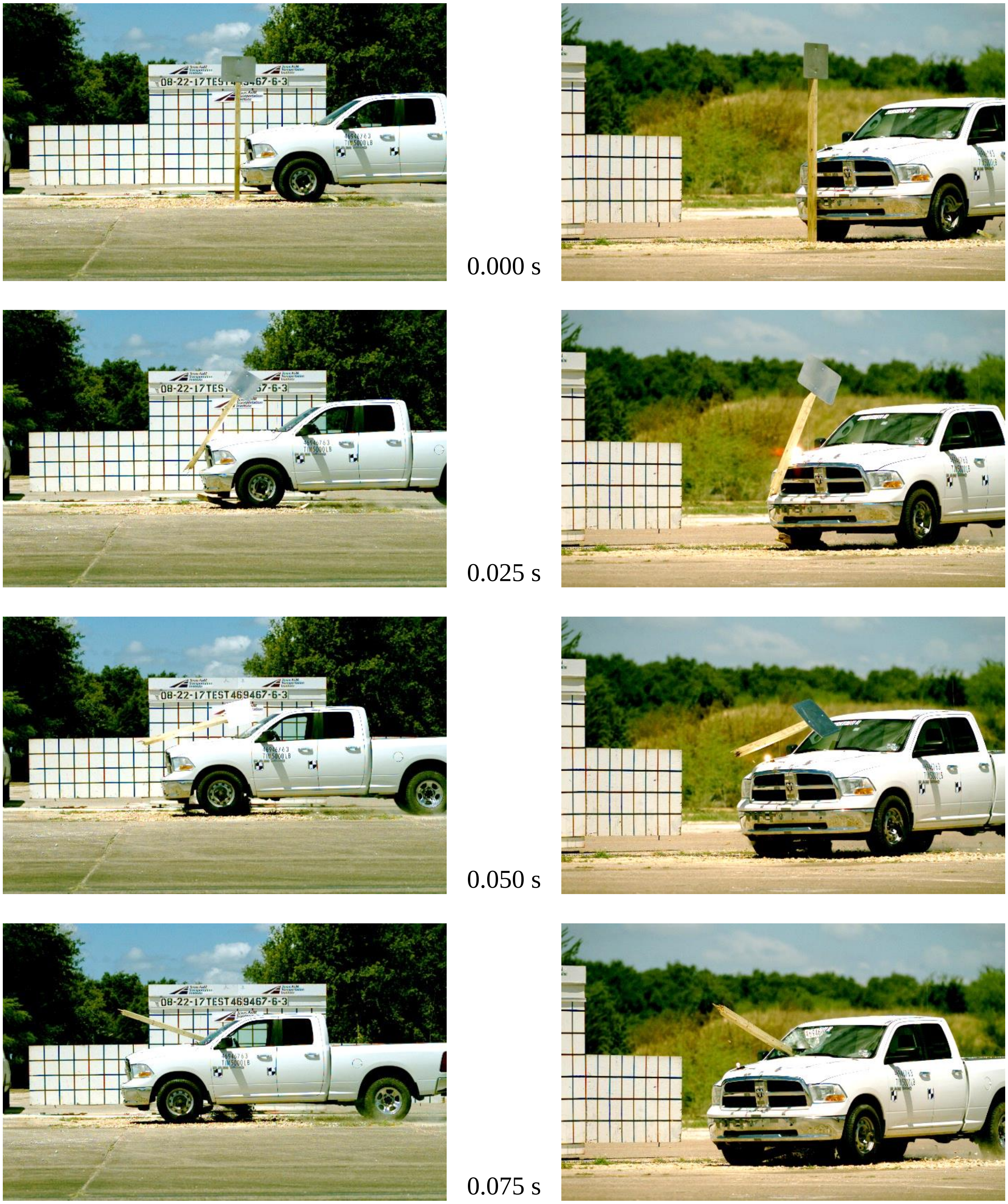




*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	**After** (inches)	**Differ.**
A1	65.00	65.00	0
A2	62.50	62.50	0
A3	65.25	65.25	0
B1	44.75	44.75	0
B2	38.00	38.00	0
B3	44.75	44.75	0
B4	39.50	39.50	0
B5	43.00	43.00	0
B6	39.50	39.50	0
C1	26.50	26.50	0
C2	-----	-----	-
C3	26.50	26.50	0
D1	11.25	11.25	0
D2	-----	-----	-
D3	11.25	11.25	0
E1	58.50	58.50	0
E2	63.50	63.50	0
E3	63.50	63.50	0
E4	63.50	63.50	0
F	59.00	59.00	0
G	59.00	59.00	0
H	37.50	37.50	0
I	37.50	37.50	0
J*	23.50	23.50	0



0.000 s

0.025 s

0.050 s

0.075 s

Figure D.9. Sequential Photographs for Test No. 469467-6-3 (Perpendicular and Oblique Views).

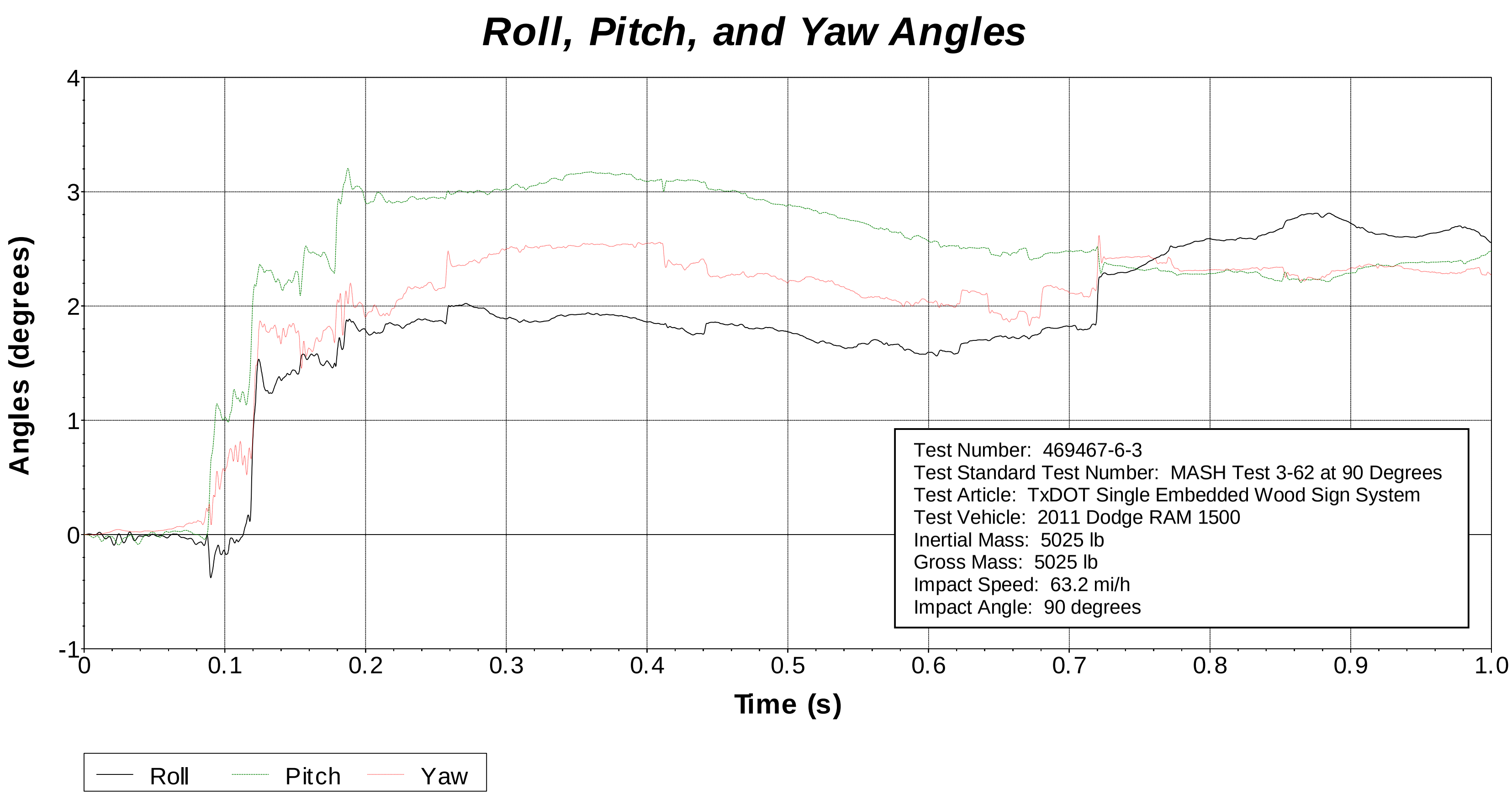
0.100 s

0.125 s

0.150 s

0.175 s

Figure D.9. Sequential Photographs for Test No. 469467-6-3 (Perpendicular and Oblique Views) (Continued).



Axes are vehicle-fixed.
Sequence for determining orientation:
1. Yaw.
2. Pitch.
3. Roll.

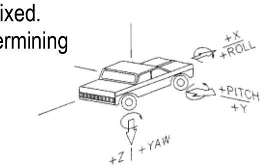


Figure D.10. Vehicle Angular Displacements for Test No. 469467-6-3.

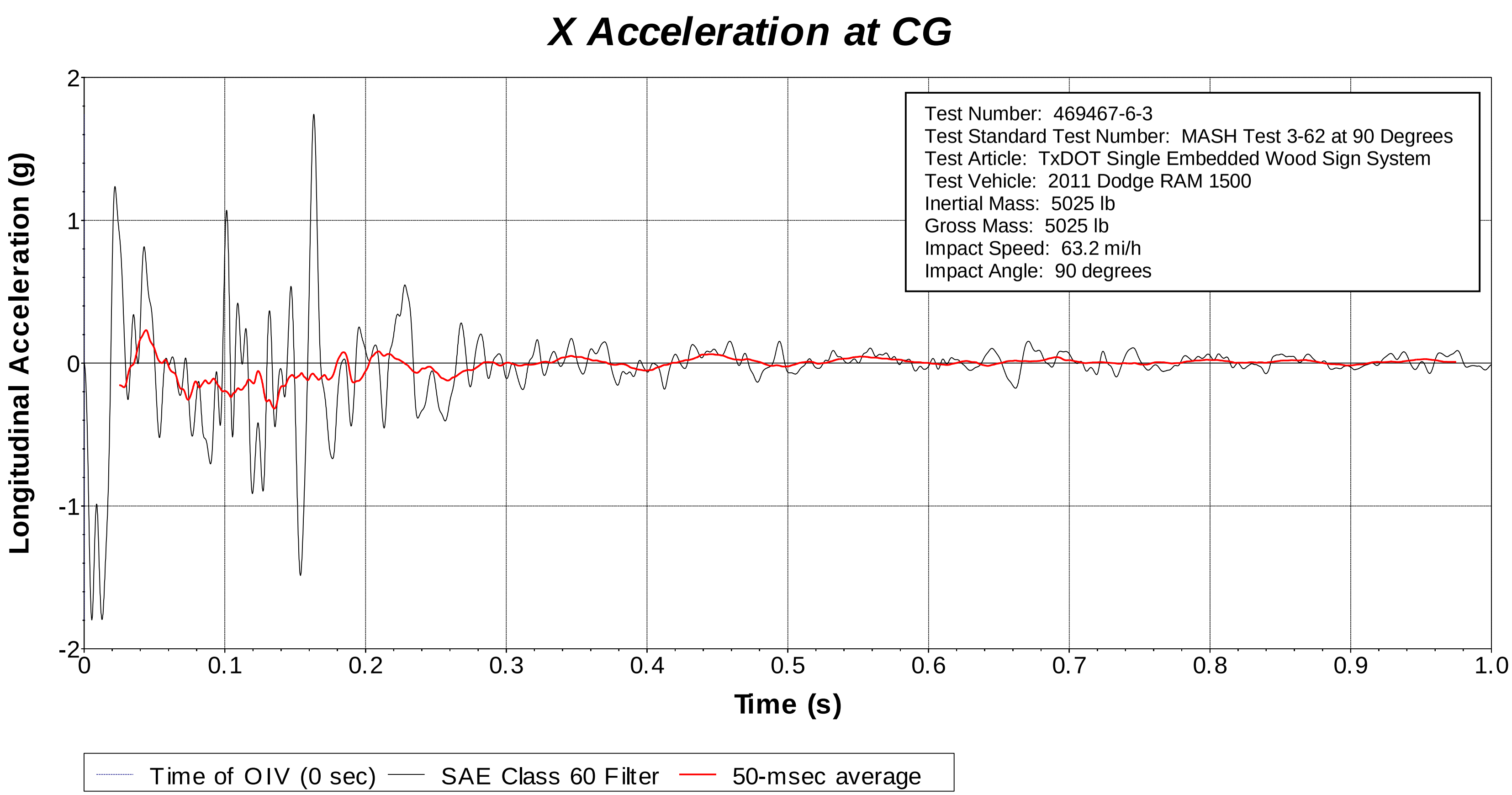


Figure D.11. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-6-3 (Accelerometer Located at Center of Gravity).

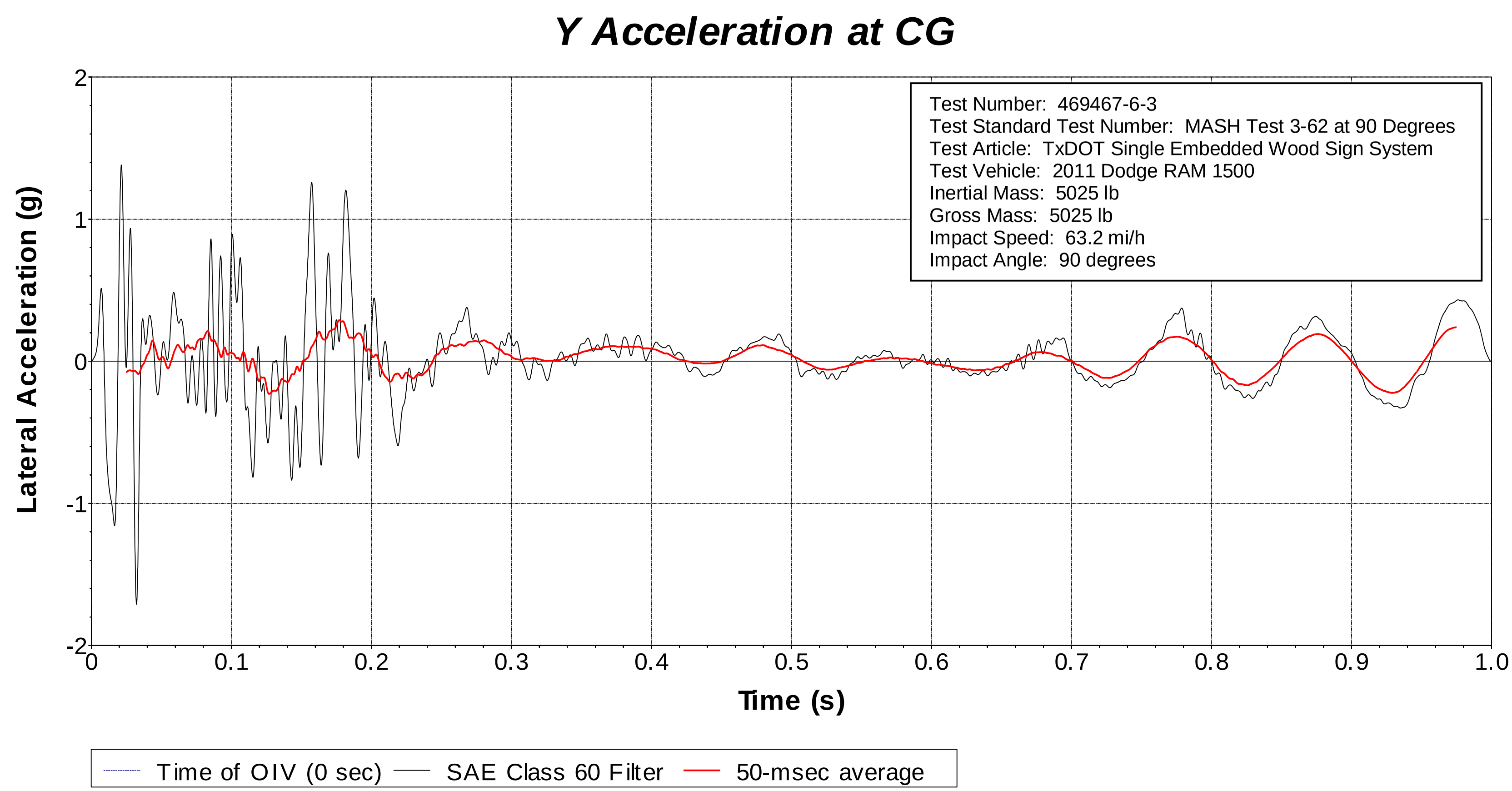


Figure D.12. Vehicle Lateral Accelerometer Trace for Test No. 469467-6-3 (Accelerometer Located at Center of Gravity).

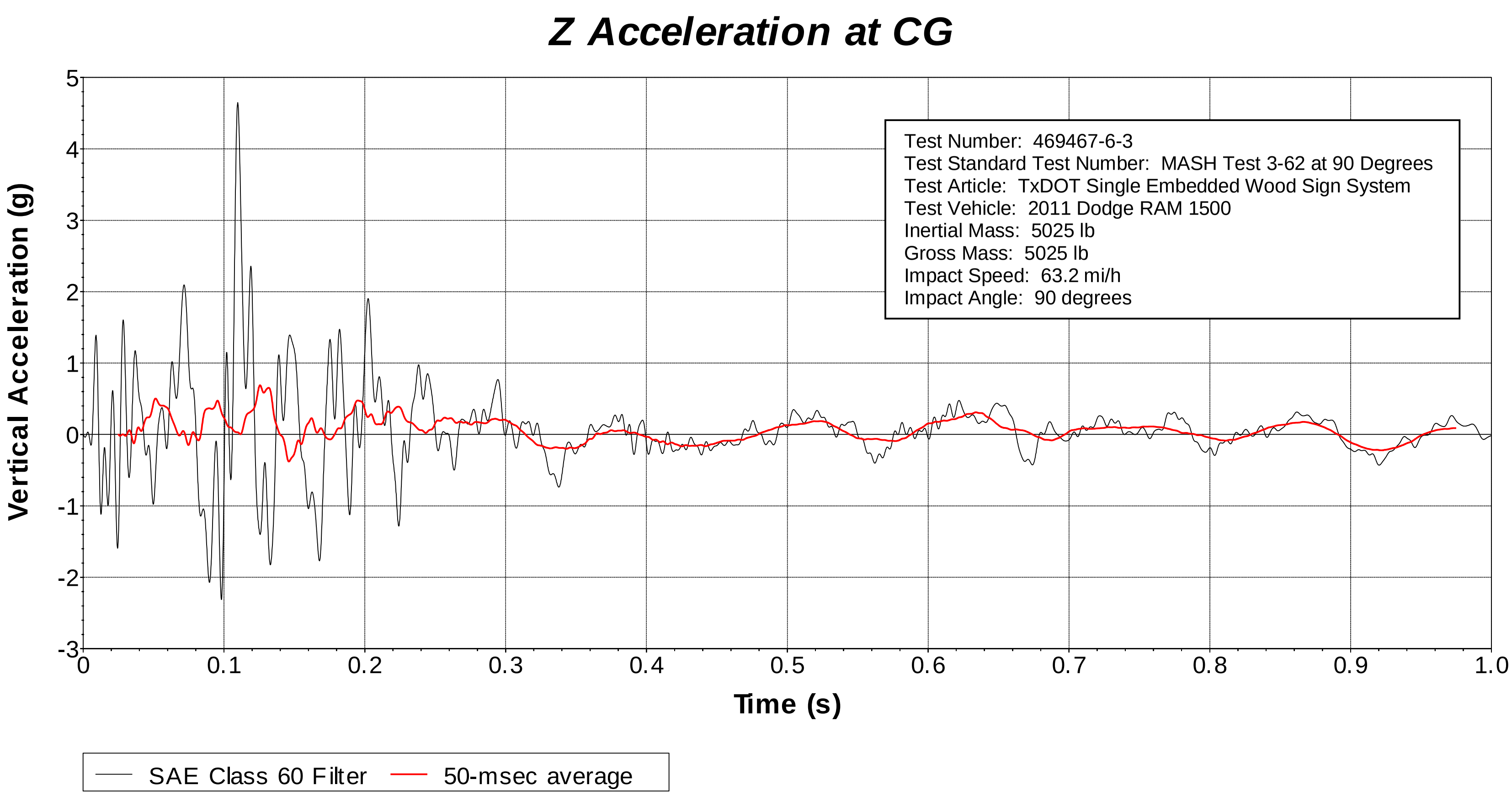


Figure D.13. Vehicle Vertical Accelerometer Trace for Test No. 469467-6-3 (Accelerometer Located at Center of Gravity).

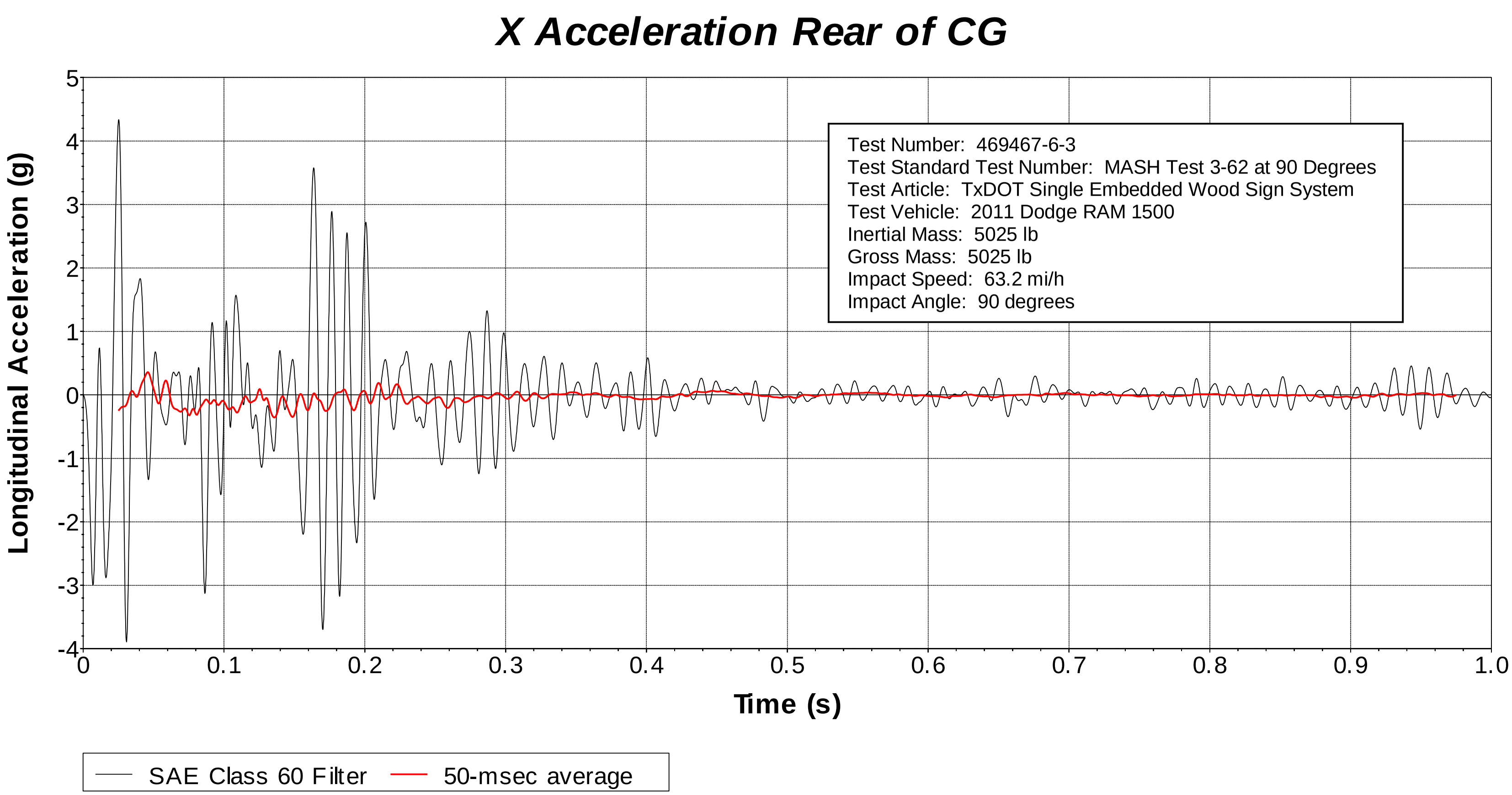


Figure D.14. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-6-3 (Accelerometer Located Rear of Center of Gravity).

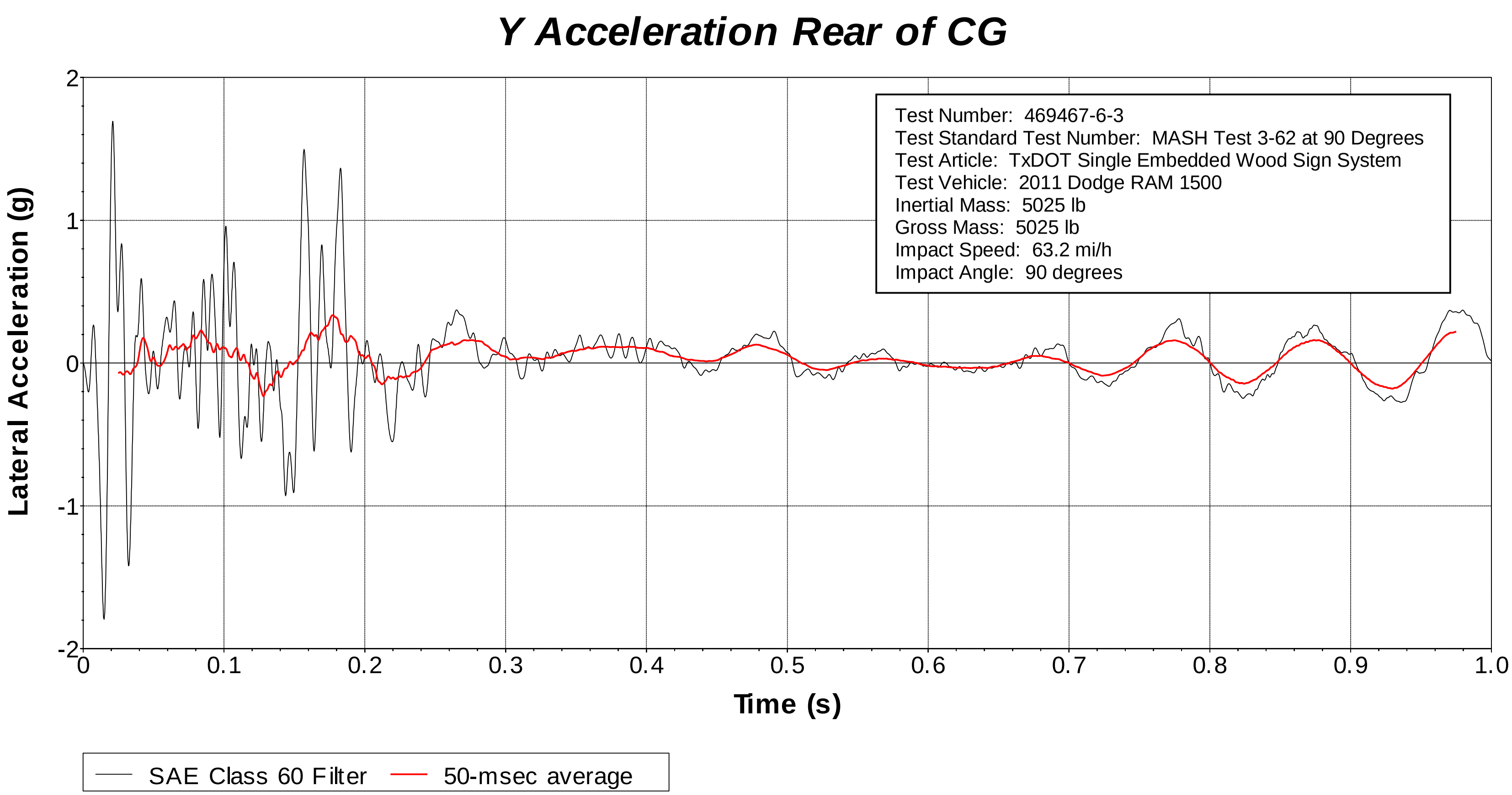


Figure D.15. Vehicle Lateral Accelerometer Trace for Test No. 469467-6-3 (Accelerometer Located Rear of Center of Gravity).

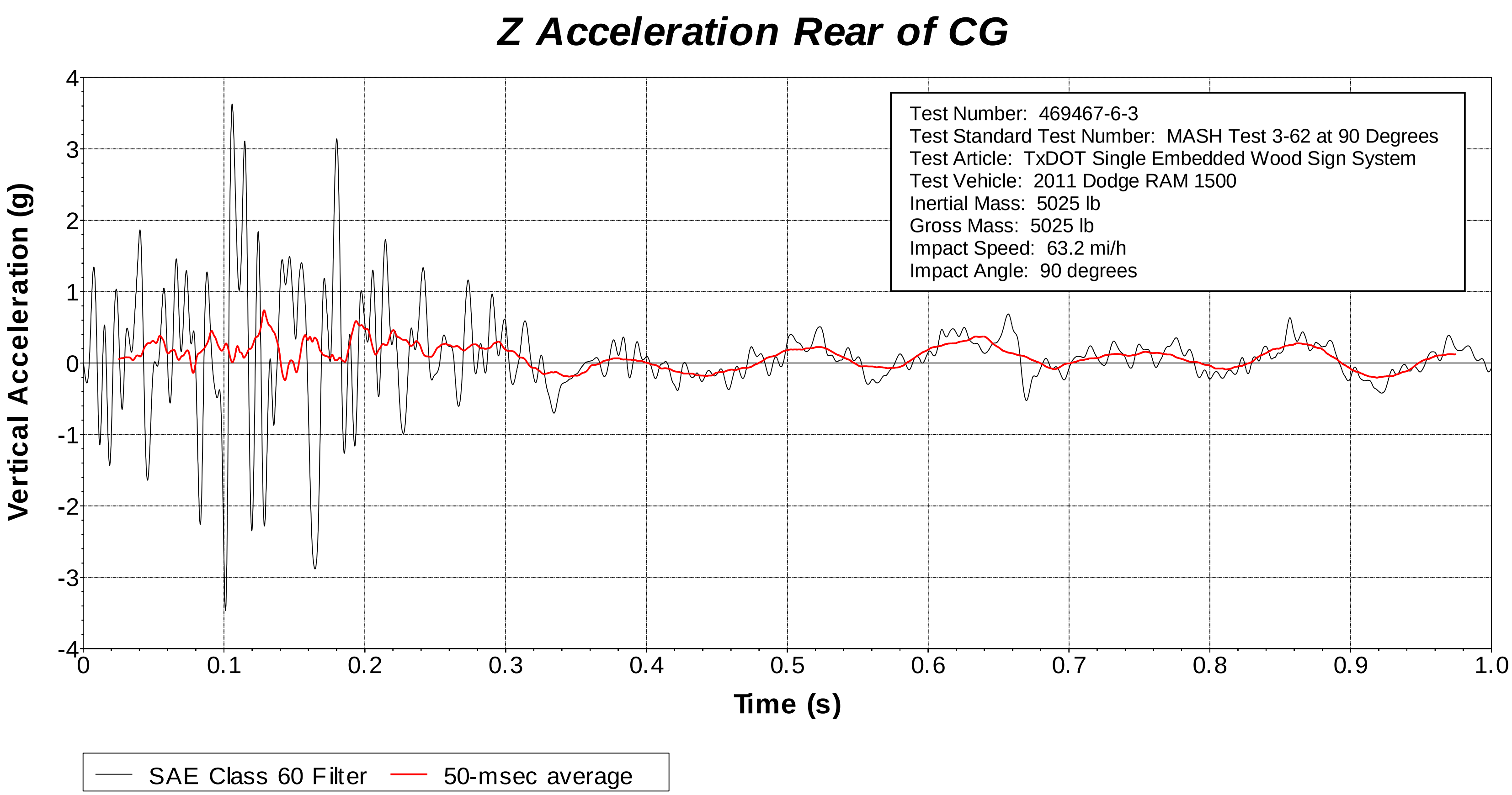


Figure D.16. Vehicle Vertical Accelerometer Trace for Test No. 469467-6-3 (Accelerometer Located Rear of Center of Gravity).

D.3 *MASH* TEST 3-62 ON DUAL EMBEDDED SIGN SUPPORT AT 0°

Table D.7. Vehicle Properties for Test No. 469467-6-4.

Date: 2017-08-22 Test No.: 469467-6-4 VIN No.: 1D7RB16P4BS692707

Year: 2011 Make: Dodge Model: RAM 1500

Tire Size: 265/70R17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 151312

Note any damage to the vehicle prior to test: Small dents at right and left qtr pt of bumper and hood

● Denotes accelerometer location.

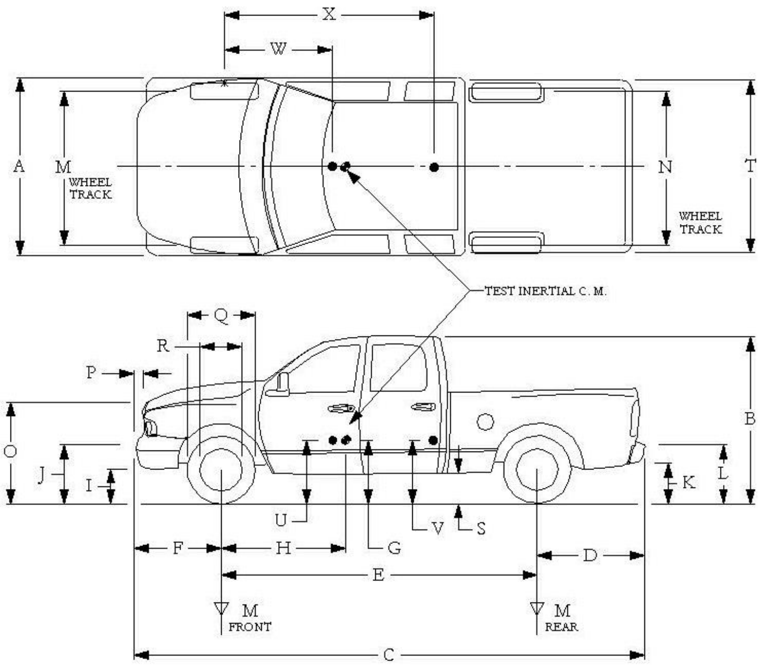
NOTES: Previously used in Test No. 469467-6-1 and 469467-6-3

Engine Type: V-8
Engine CID: 4.7 liter

Transmission Type:
x Auto or ____ Manual
____ FWD x RWD ____ 4WD

Optional Equipment:
None

Dummy Data:
Type: No dummy
Mass: NA
Seat Position: NA



Geometry: inches

A	78.50	F	40.00	K	20.75	P	3.00	U	27.50
B	75.00	G	28.00	L	29.50	Q	30.50	V	30.50
C	227.50	H	62.63	M	68.50	R	18.00	W	62.63
D	47.00	I	11.00	N	68.00	S	13.25	X	78.63
E	140.50	J	26.50	O	46.00	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	17.00
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	25.50

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2827	2785	
Back	3900	M_{rear}	1922	2240	
Total	6700	M_{Total}	4749	5025	

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

Mass Distribution:
lb LF: 1390 RF: 1395 LR: 1115 RR: 1125

Table D.8. Measurements of Vehicle Vertical CG for Test No. 469467-6-4.

Date: 2017-08-22 Test No.: 469467-6-4 VIN: 1D7RB16P4BS692707

Year: 2011 Make: Dodge Model: RAM 1500

Body Style: Quad-Cab Mileage: 151312

Engine: 4.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 207 lb (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70R17

Measured Vehicle Weights: (lb)							
LF:	1390		RF:	1395		Front Axle:	2785
LR:	1115		RR:	1125		Rear Axle:	2240
Left:	2505		Right:	2520		Total:	5025
							5000 ±110 lb allowed
Wheel Base:	140.50	inches	Track: F:	68.50	inches	R:	68.00 inches
	148 ±12 inches allowed			Track = (F+R)/2 = 67 ±1.5 inches allowed			
Center of Gravity, SAE J874 Suspension Method							
X:	62.63	inches	Rear of Front Axle	(63 ±4 inches allowed)			
Y:	0.10	inches	Left -	Right +	of Vehicle Centerline		
Z:	28.00	inches	Above Ground	(minumum 28.0 inches allowed)			

Hood Height: 46.00 inches
43 ±4 inches allowed

Front Bumper Height: 26.50 inches

Front Overhang: 40.00 inches
39 ±3 inches allowed

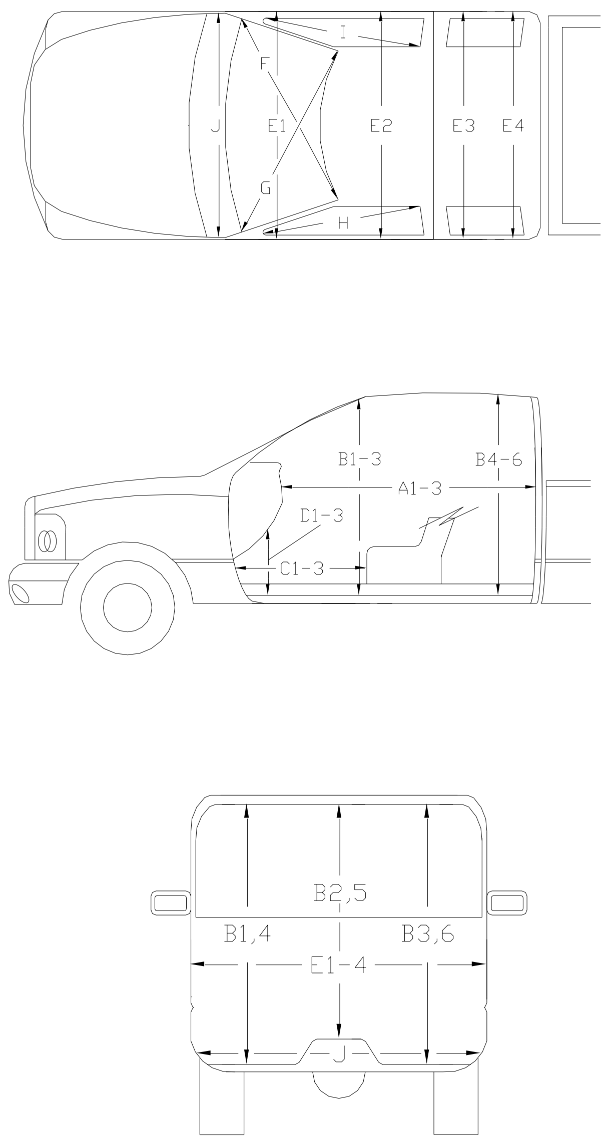
Rear Bumper Height: 29.50 inches

Overall Length: 227.50 inches
237 ±13 inches allowed

Test Conductor(s): ______________________

Table D.9. Occupant Compartment Measurements for Test No. 469467-6-4.

Date:	2017-08-22	Test No.:	469467-6-4	VIN No.:	1D7RB16P4BS692707
Year:	2011	Make:	Dodge	Model:	RAM 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
A2	62.50	62.50	0
A3	65.25	65.25	0
B1	44.75	43.75	-1.00
B2	38.00	35.00	-3.00
B3	44.75	43.75	-1.00
B4	39.50	38.50	-1.00
B5	43.00	40.00	-3.00
B6	39.50	38.50	-1.00
C1	26.50	26.50	0
C2	-----	-----	-
C3	26.50	26.50	0
D1	11.25	11.25	0
D2	-----	-----	-
D3	11.25	11.25	0
E1	58.50	58.50	0
E2	63.50	63.50	0
E3	63.50	63.50	0
E4	63.50	63.50	0
F	59.00	59.00	0
G	59.00	59.00	0
H	37.50	37.50	0
I	37.50	37.50	0
J*	23.50	23.50	0

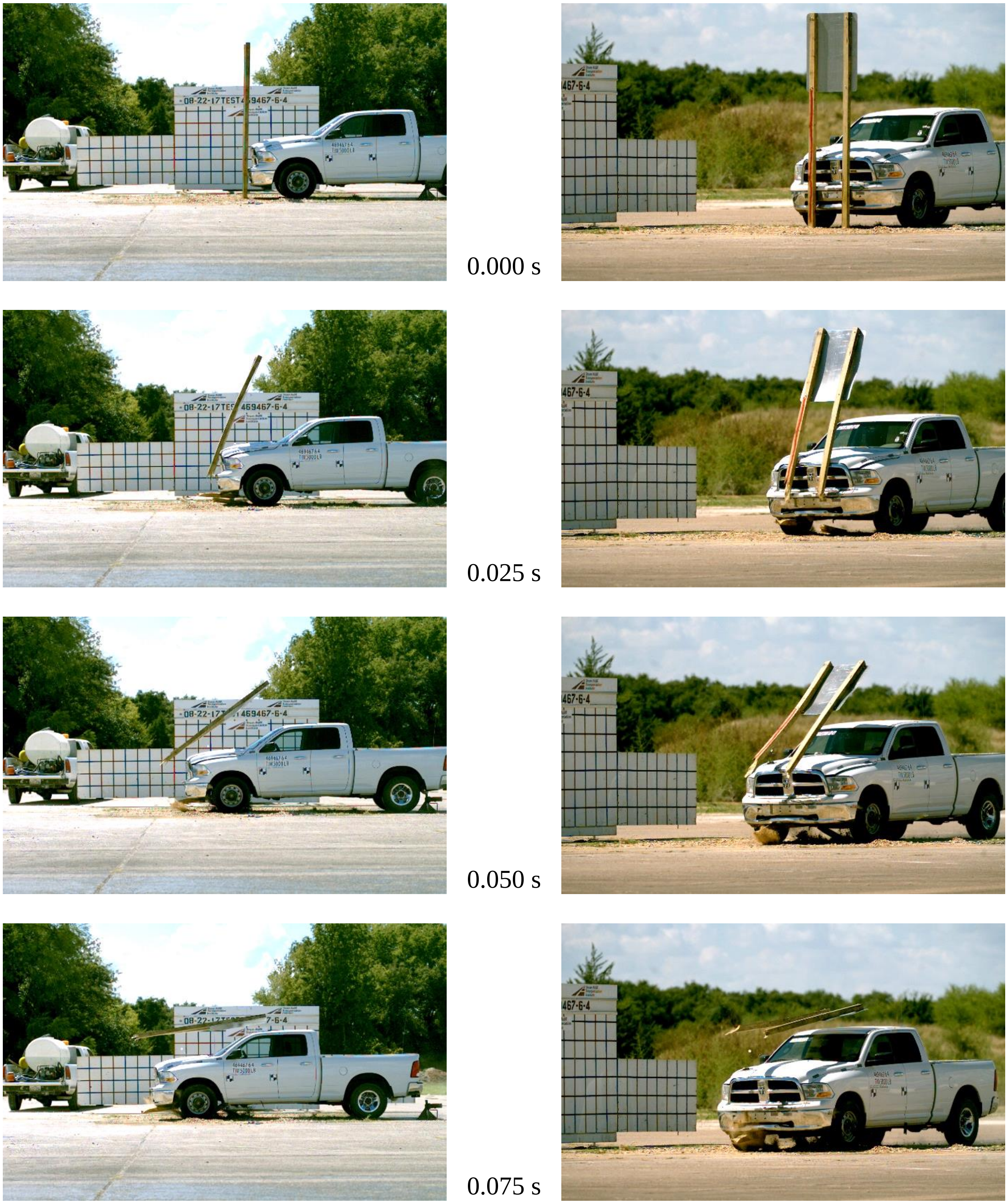


Figure D.17. Sequential Photographs for Test No. 469467-6-4 Perpendicular and Oblique Views).

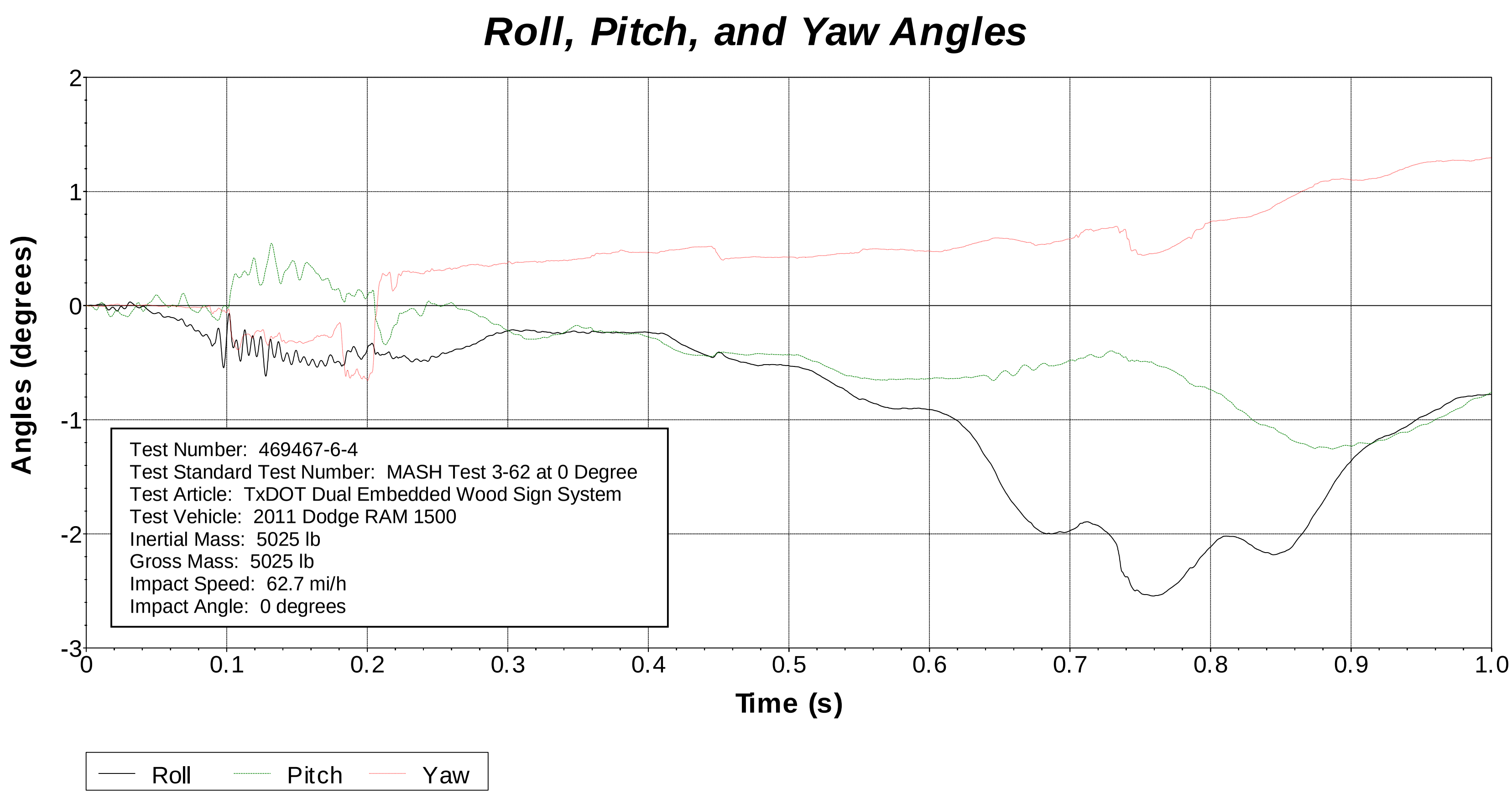
0.100 s

0.125 s

0.150 s

0.175 s

Figure D.17. Sequential Photographs for Test No. 469467-6-4 Perpendicular and Oblique Views) (Continued).



Axes are vehicle-fixed.
Sequence for determining orientation:
1. Yaw.
2. Pitch.
3. Roll.

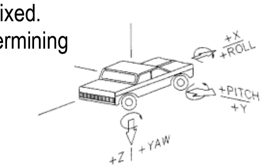


Figure D.18. Vehicle Angular Displacements for Test No. 469467-6-4.

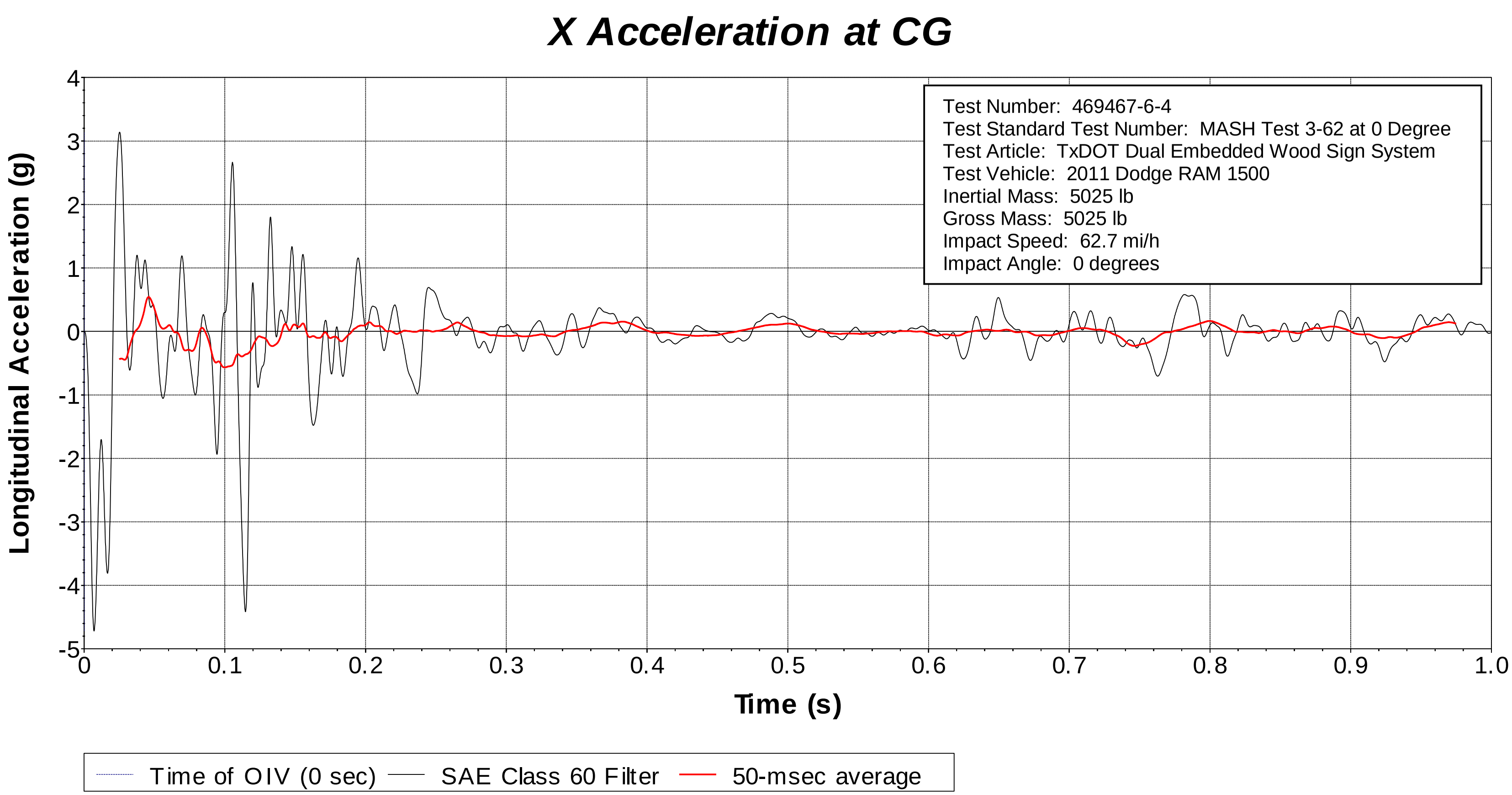


Figure D.19. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-6-4 (Accelerometer Located at Center of Gravity).

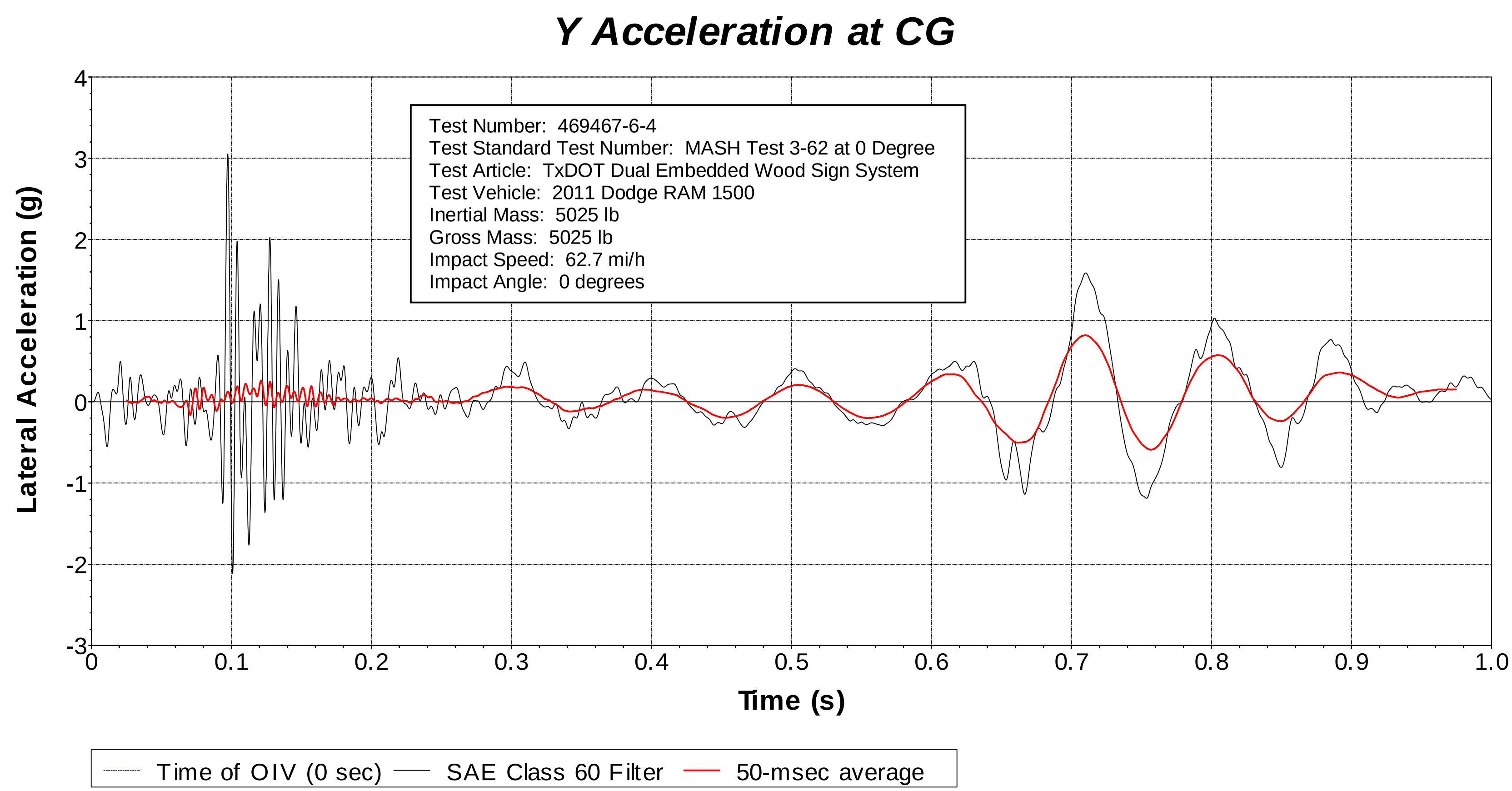


Figure D.20. Vehicle Lateral Accelerometer Trace for Test No. 469467-6-4 (Accelerometer Located at Center of Gravity).

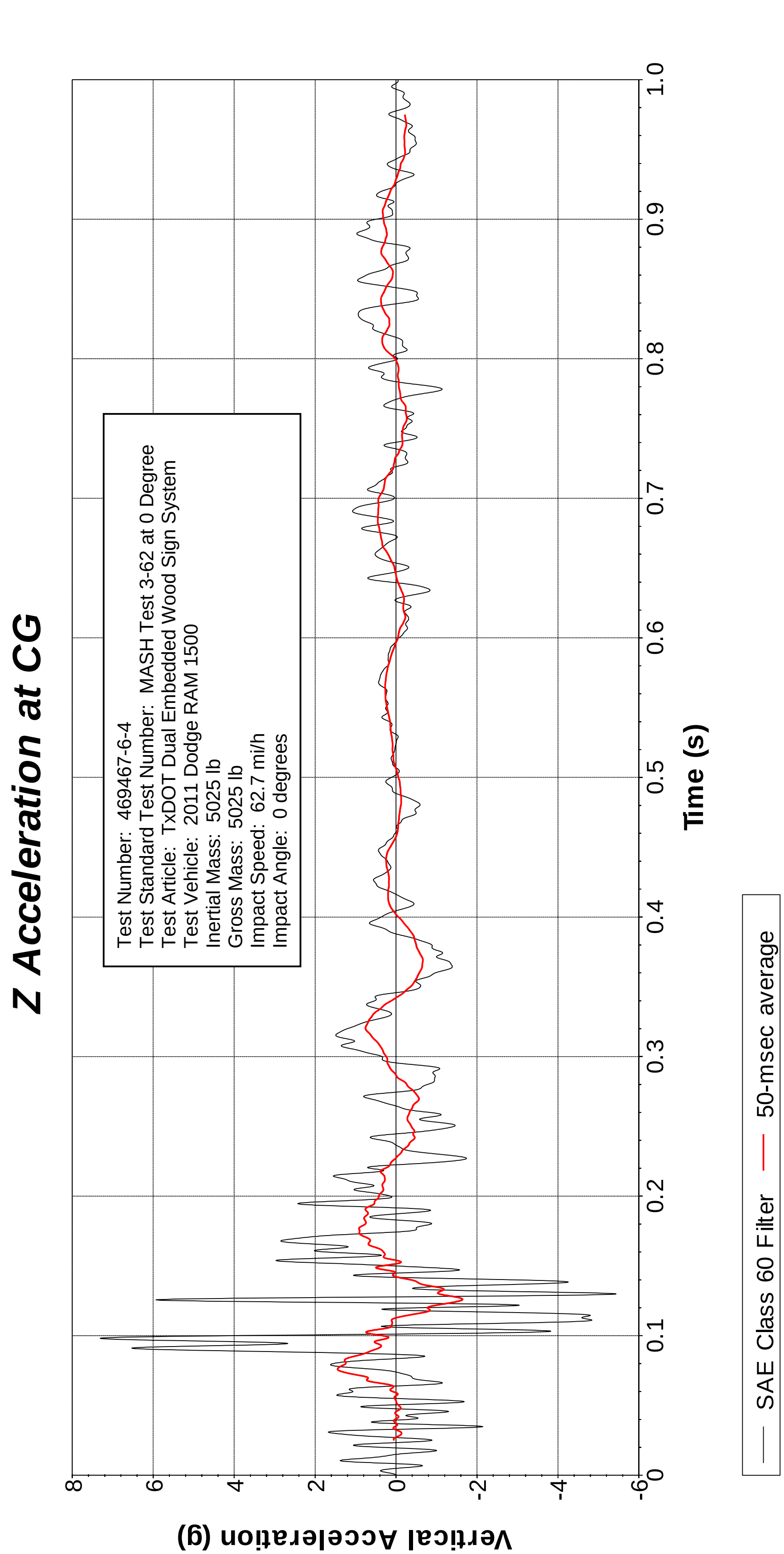


Figure D.21. Vehicle Vertical Accelerometer Trace for Test No. 469467-6-4 (Accelerometer Located at Center of Gravity).

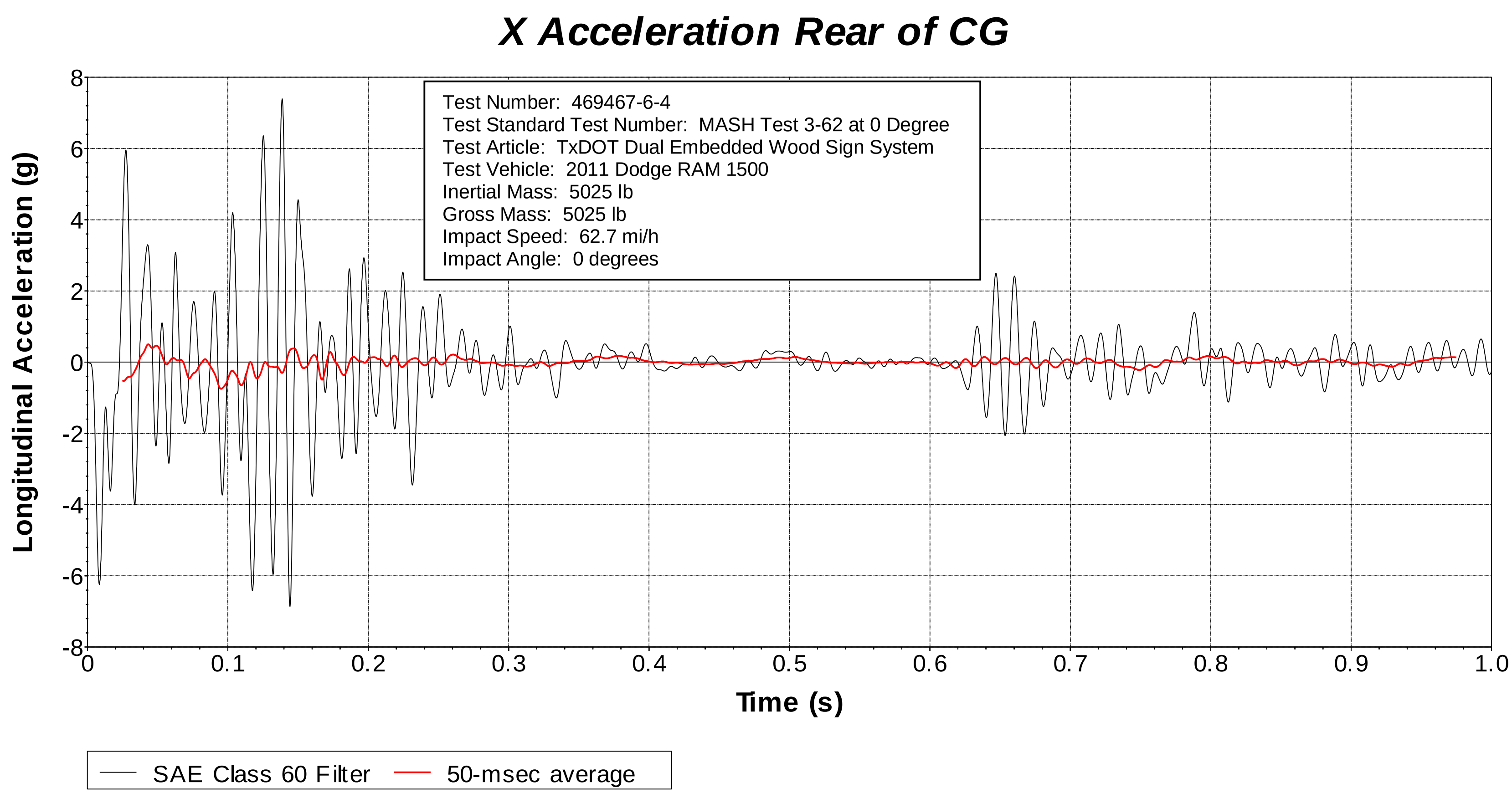


Figure D.22. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-6-4 (Accelerometer Located Rear of Center of Gravity).

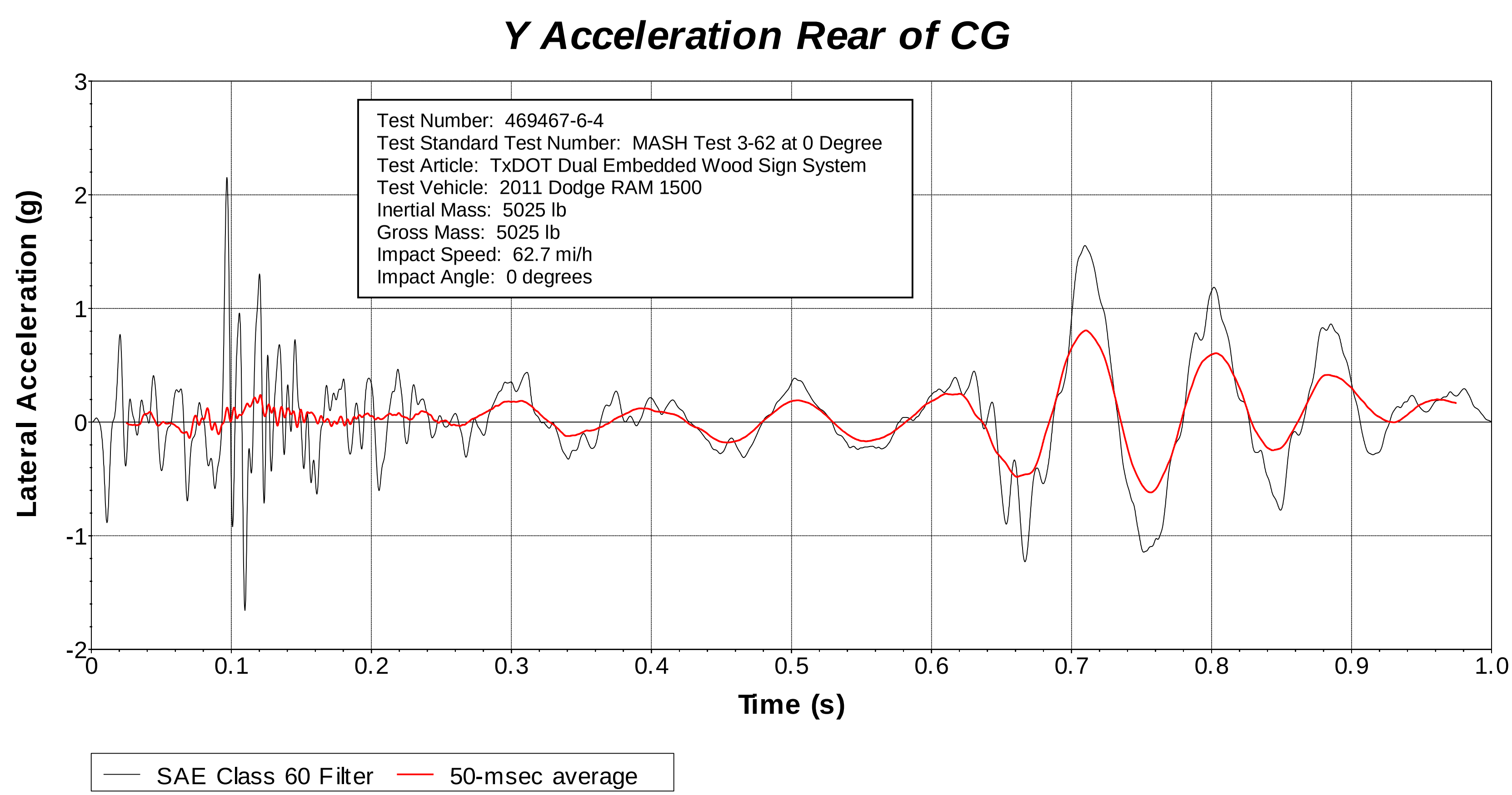


Figure D.23. Vehicle Lateral Accelerometer Trace for Test No. 469467-6-4 (Accelerometer Located Rear of Center of Gravity).

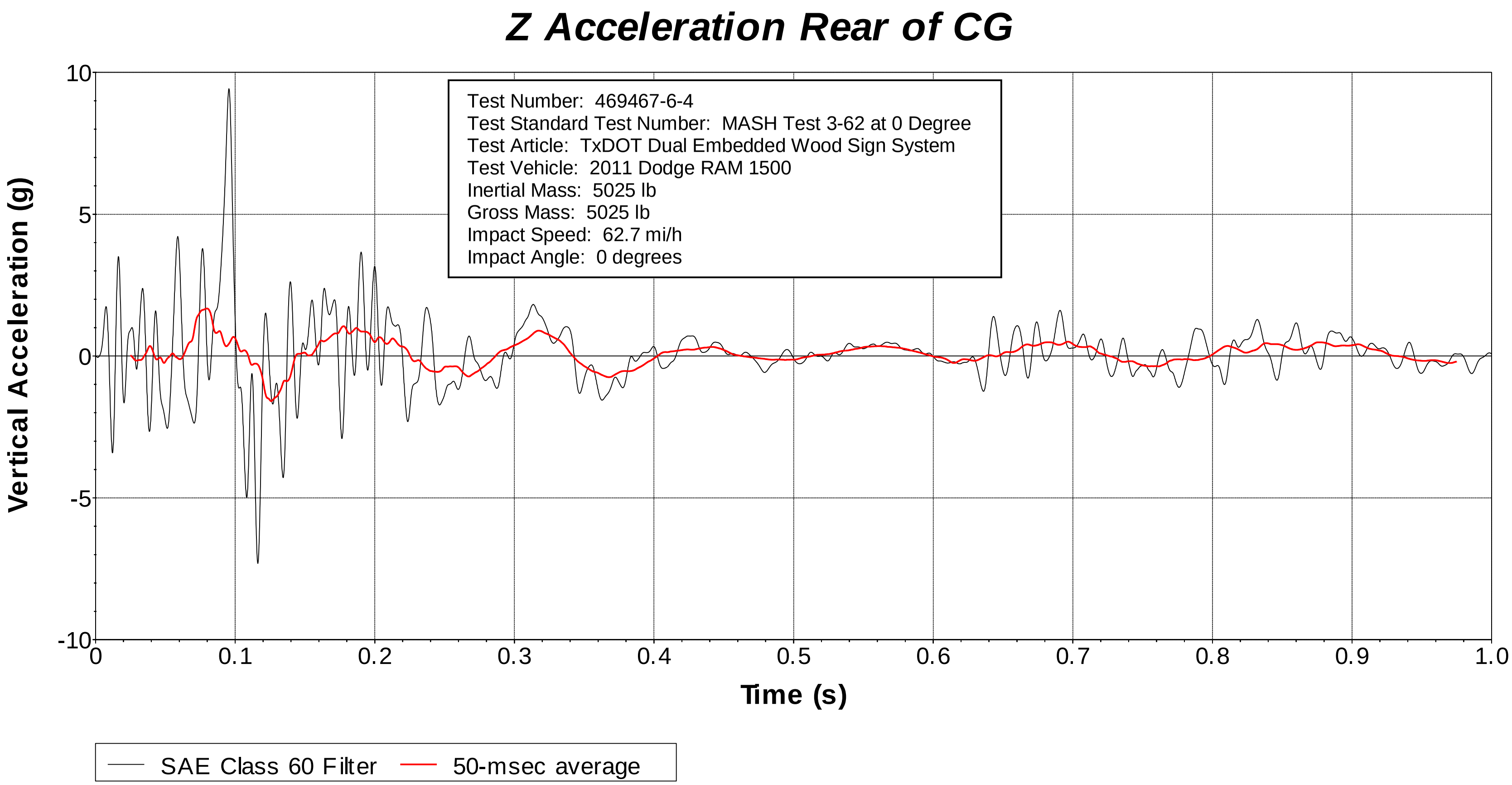


Figure D.24. Vehicle Vertical Accelerometer Trace for Test No. 469467-6-4 (Accelerometer Located Rear of Center of Gravity).

D.4 *MASH* TEST 3-61 ON DUAL EMBEDDED SIGN SUPPORT AT 0°

Table D.10. Vehicle Properties for Test No. 469467-6-2.

Date: 2017-08-23 Test No.: 469467-6-2 VIN No.: KNADH4A30B6872976

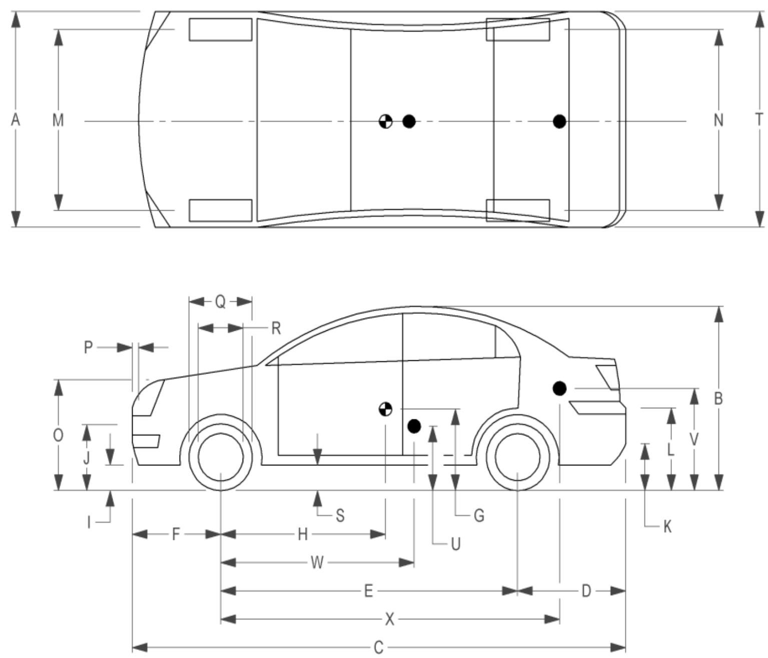
Year: 2011 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 107379 Tire Size: 18565R14

Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES: None



Engine Type: 4 cylinder
Engine CID: 1.6 liter
Transmission Type:
x Auto or ____ Manual
x FWD ____ RWD ____ 4WD
Optional Equipment:
None

Dummy Data:
Type: 50th percentile male
Mass: 165 lb
Seat Position: Driver

Geometry: inches

A	66.38	F	33.00	K	10.50	P	4.12	U	15.00
B	58.00	G	-----	L	24.50	Q	22.50	V	19.50
C	165.75	H	35.89	M	57.75	R	15.50	W	35.89
D	34.00	I	7.75	N	57.70	S	9.00	X	105.60
E	98.75	J	21.00	O	28.00	T	33.20		
	Wheel Center Ht Front		11.00		Wheel Center Ht Rear		11.00	W-H	0

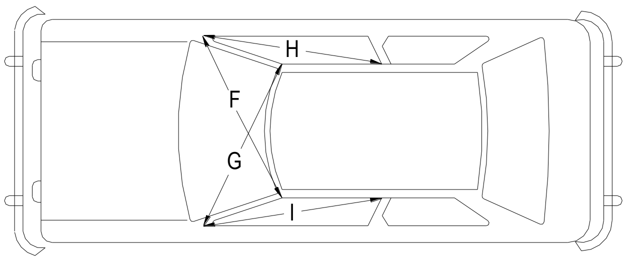
GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1570	1546	1631
Back	1874	M_{rear}	890	883	963
Total	3638	M_{Total}	2460	2429	2594

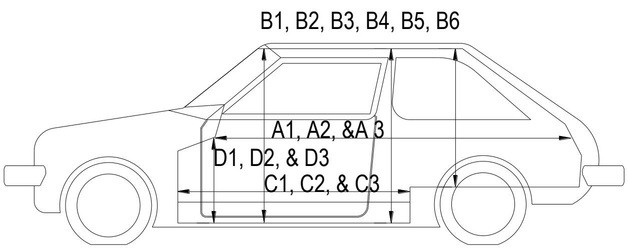
Allowable TIM = 2420 lb ±55 lb | Allowable GSM = 2585 lb ± 55 lb

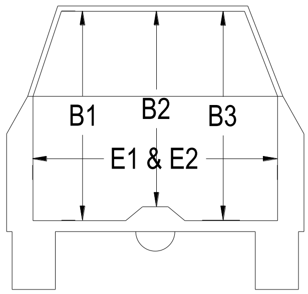
Mass Distribution:
lb LF: 761 RF: 785 LR: 472 RR: 411

Table D.11. Occupant Compartment Measurements for Test No. 469467-6-2.

Date:	2017-08-23	Test No.:	469467-6-2	VIN No.:	KNADH4A30B6872976
Year:	2011	Make:	Kia	Model:	Rio







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	67.50	67.50	0
A2	67.50	67.50	0
A3	67.75	67.75	0
B1	40.50	40.50	0
B2	36.75	36.75	0
B3	40.50	40.50	0
B4	36.25	36.25	0
B5	35.75	35.75	0
B6	36.25	36.25	0
C1	26.00	26.00	0
C2	-----	-----	-
C3	26.00	26.00	0
D1	9.50	9.50	0
D2	-----	-----	-
D3	9.75	9.75	0
E1	51.50	51.50	0
E2	51.00	51.00	0
F	51.00	51.00	0
G	51.00	51.00	0
H	38.00	38.00	0
I	38.00	38.00	0
J*	51.00	51.00	0

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

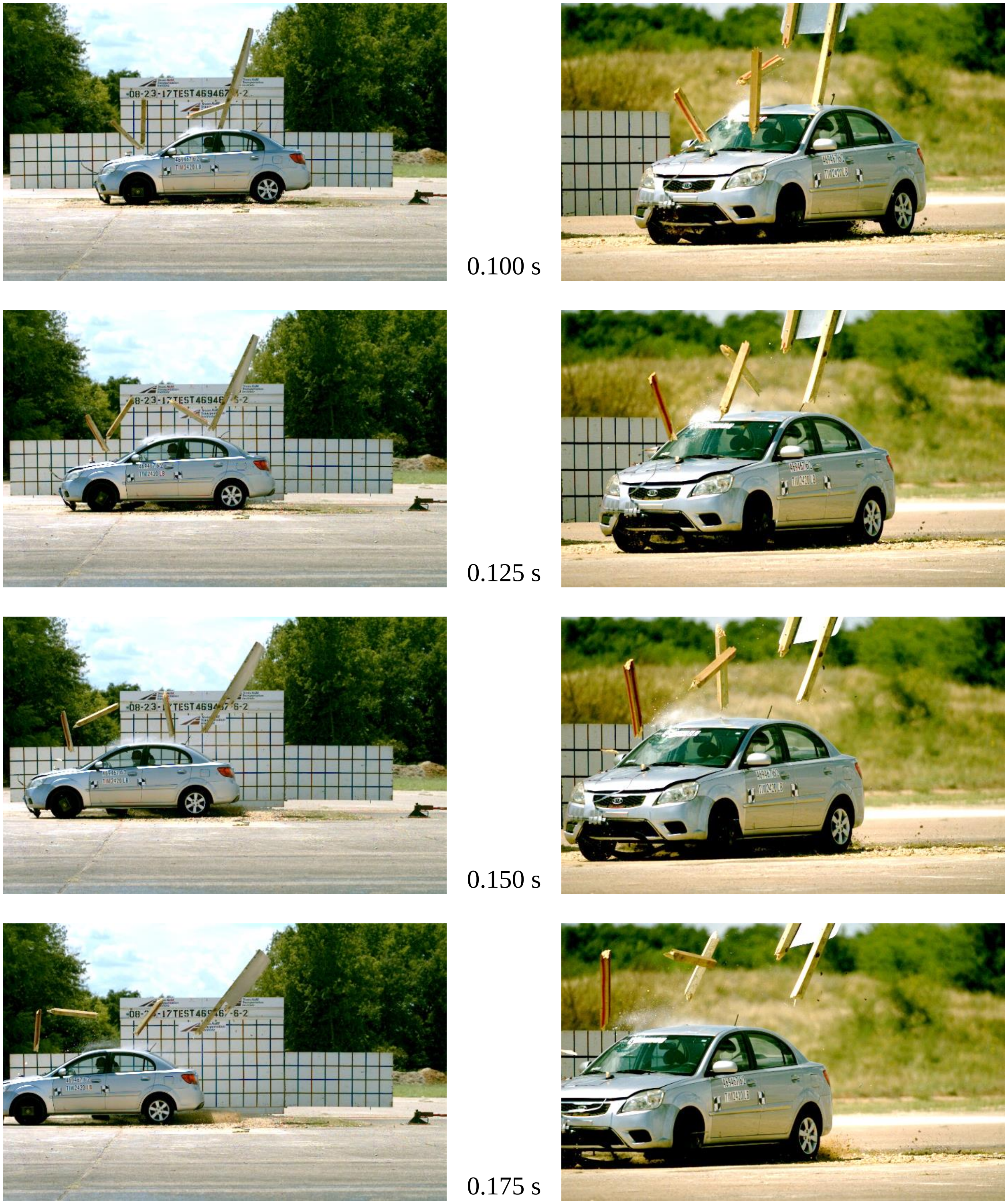
0.000 s

0.025 s

0.050 s

0.075 s

Figure D.25. Sequential Photographs for Test No. 469467-6-2 (Perpendicular and Oblique Views).



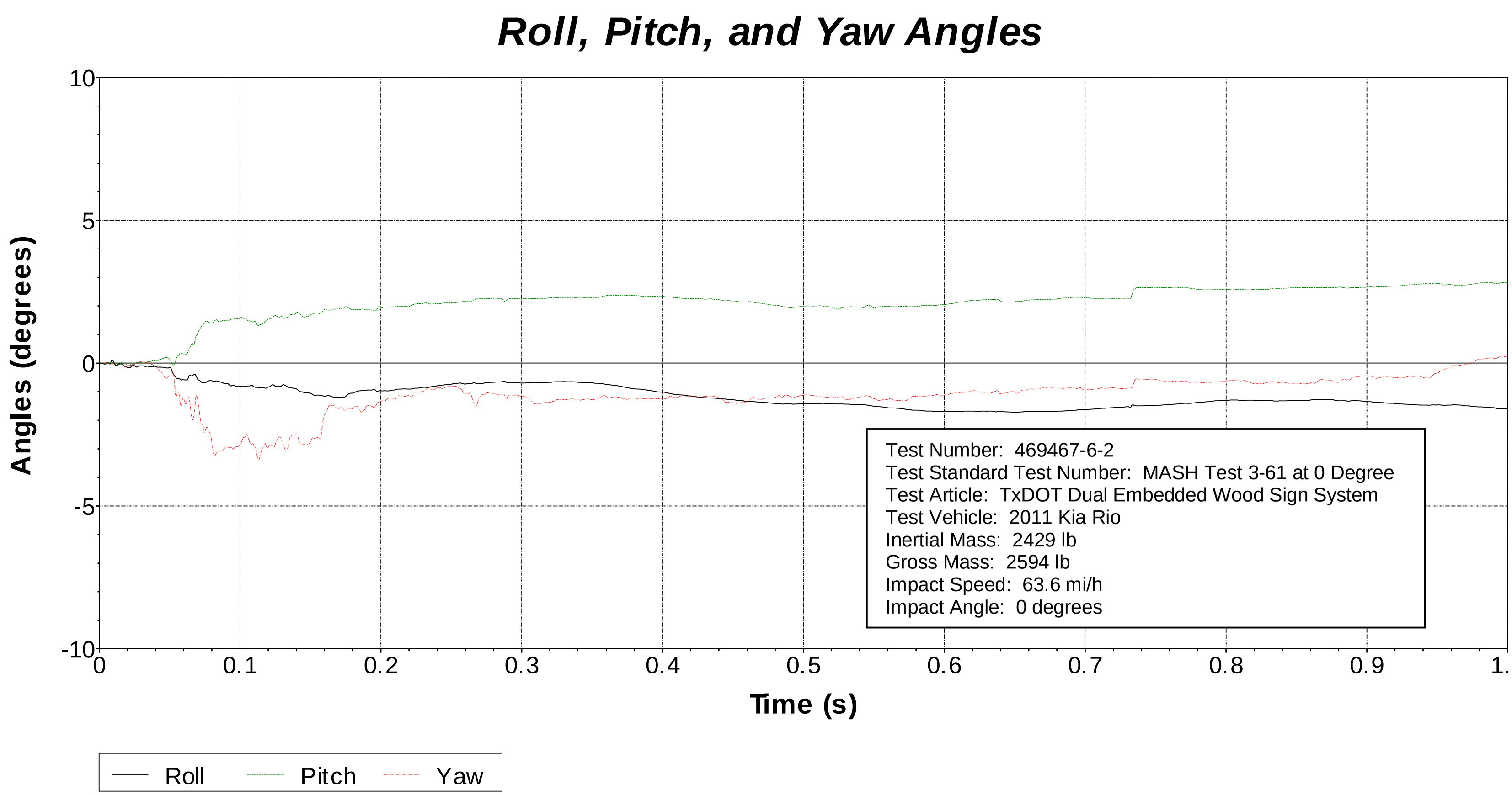
0.100 s

0.125 s

0.150 s

0.175 s

Figure D.25. Sequential Photographs for Test No. 469467-6-2 (Perpendicular and Oblique Views) (Continued).



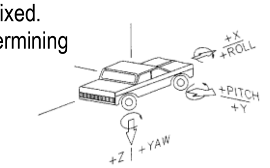


Figure D.26. Vehicle Angular Displacements for Test No. 469467-6-2.

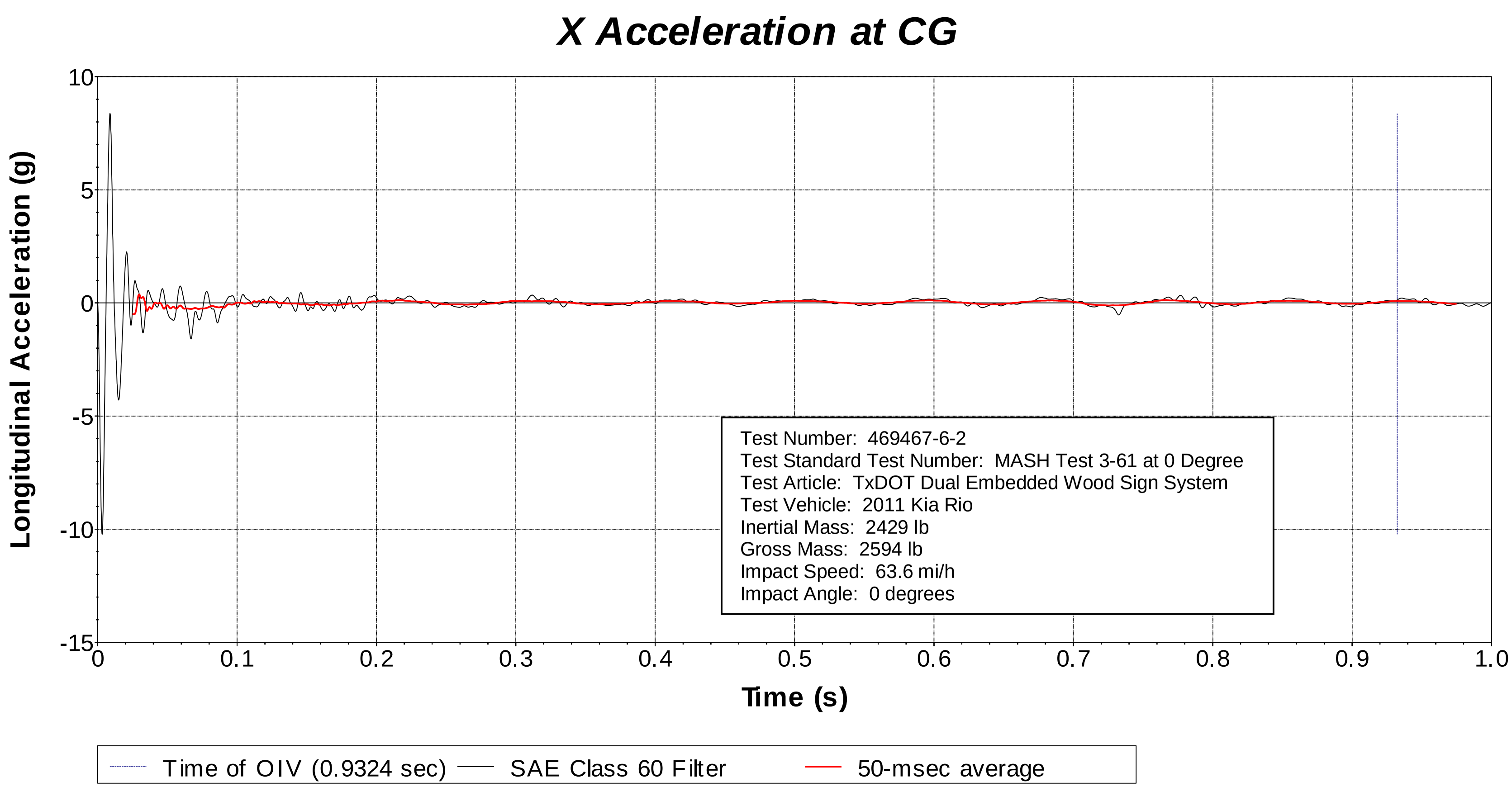


Figure D.27. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-6-2 (Accelerometer Located at Center of Gravity).

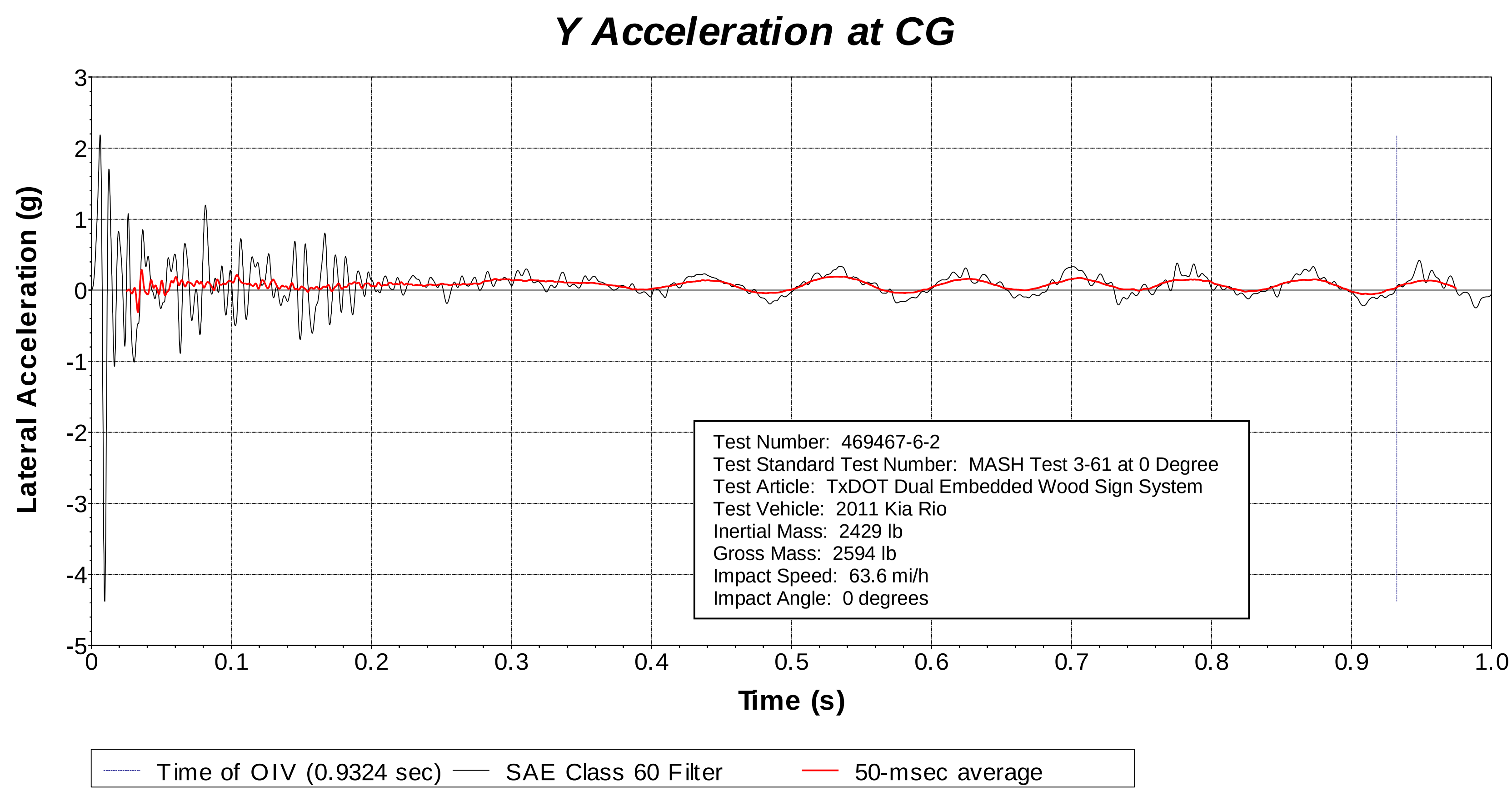


Figure D.28. Vehicle Lateral Accelerometer Trace for Test No. 469467-6-2 (Accelerometer Located at Center of Gravity).

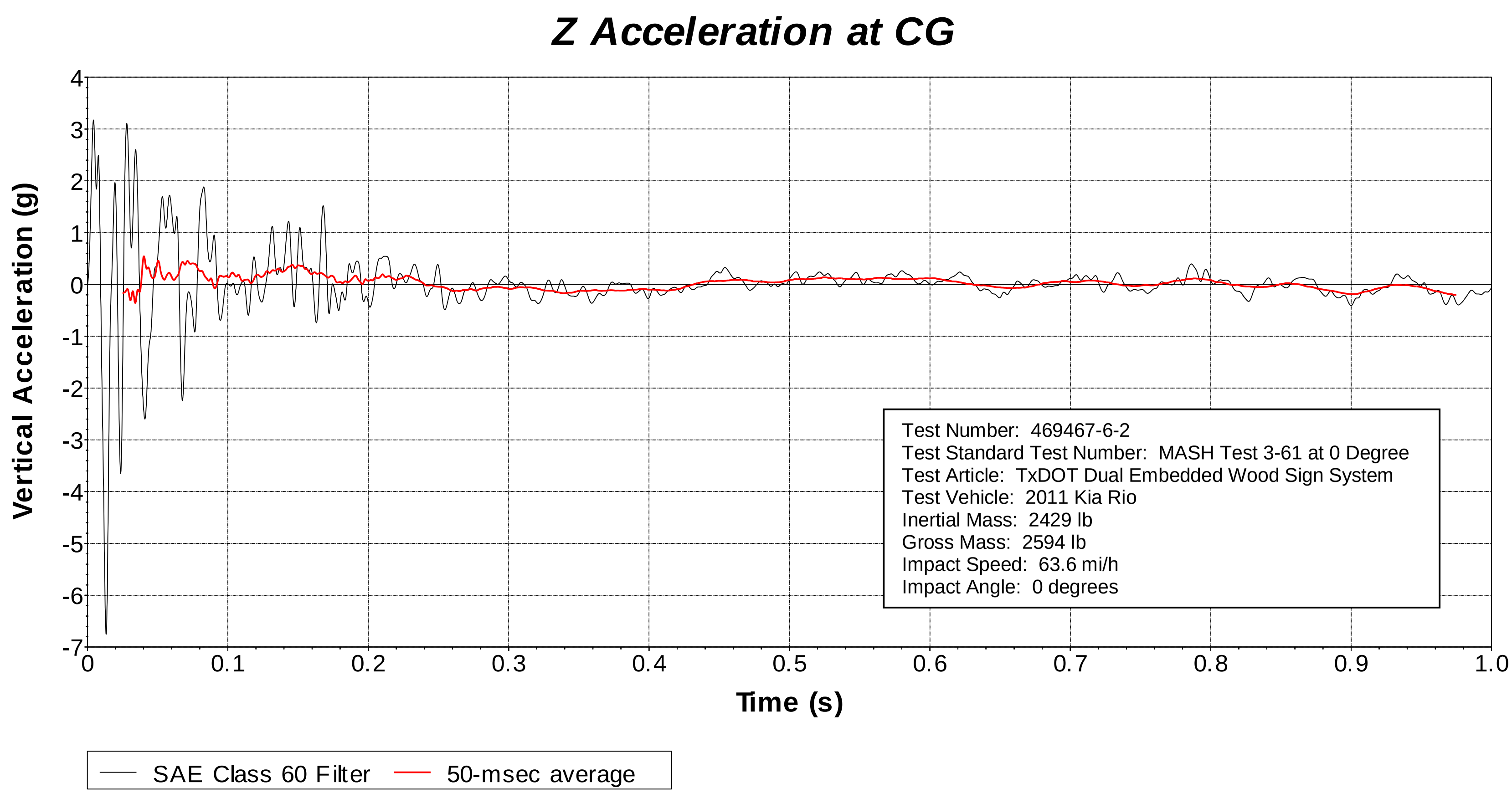


Figure D.29. Vehicle Vertical Accelerometer Trace for Test No. 469467-6-2 (Accelerometer Located at Center of Gravity).

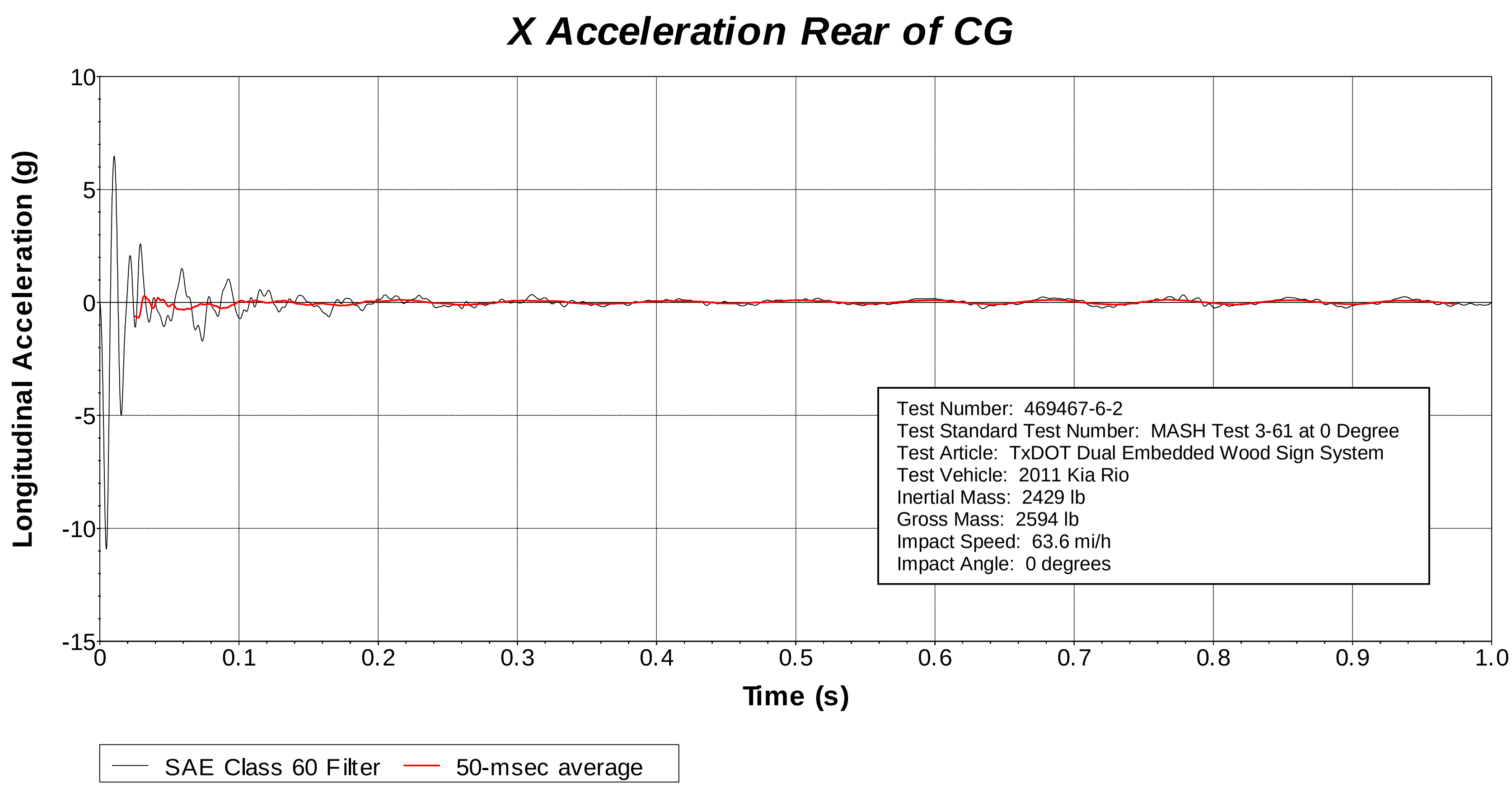


Figure D.30. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-6-2 (Accelerometer Located Rear of Center of Gravity).

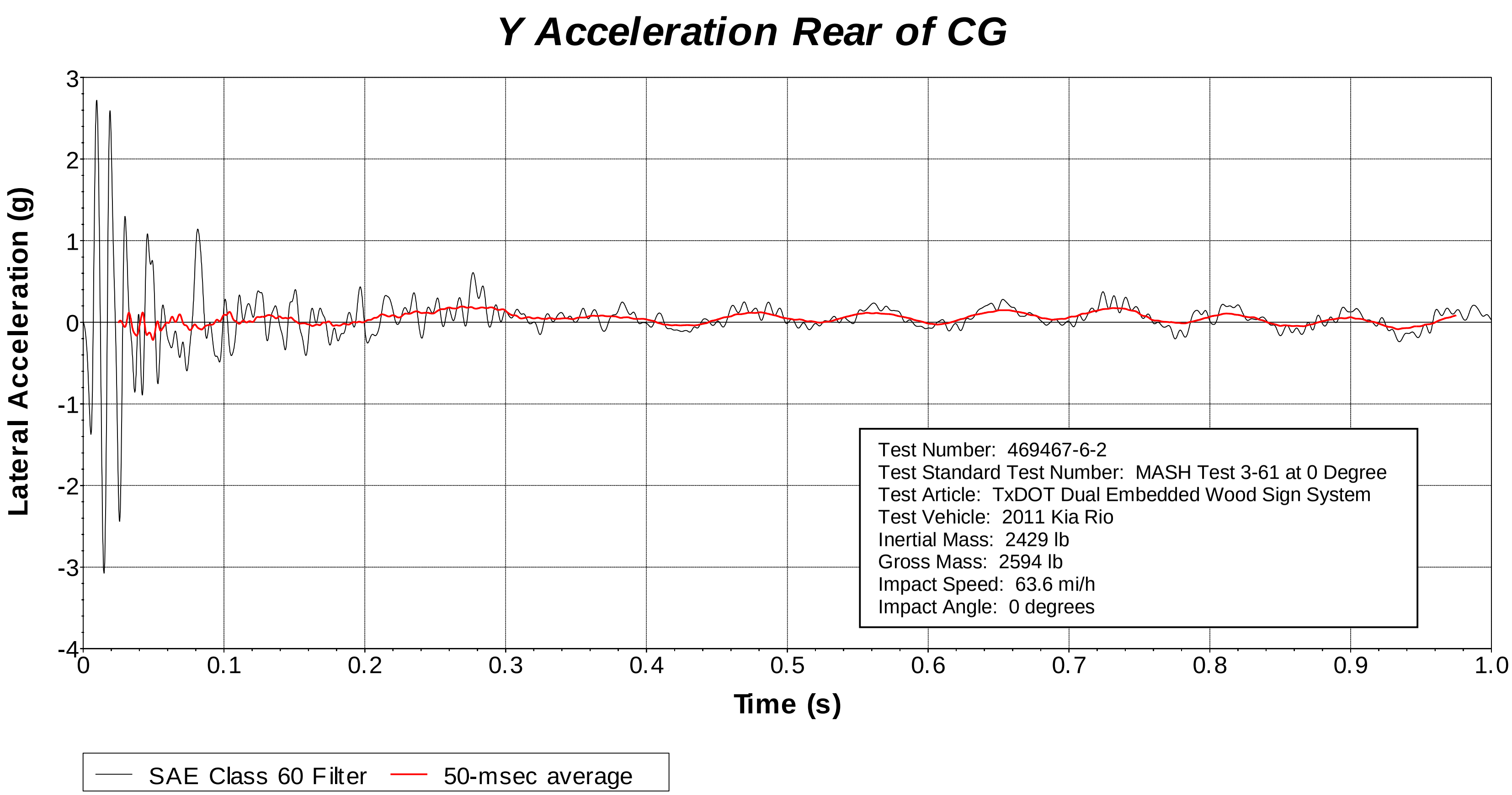


Figure D.31. Vehicle Lateral Accelerometer Trace for Test No. 469467-6-2 (Accelerometer Located Rear of Center of Gravity).

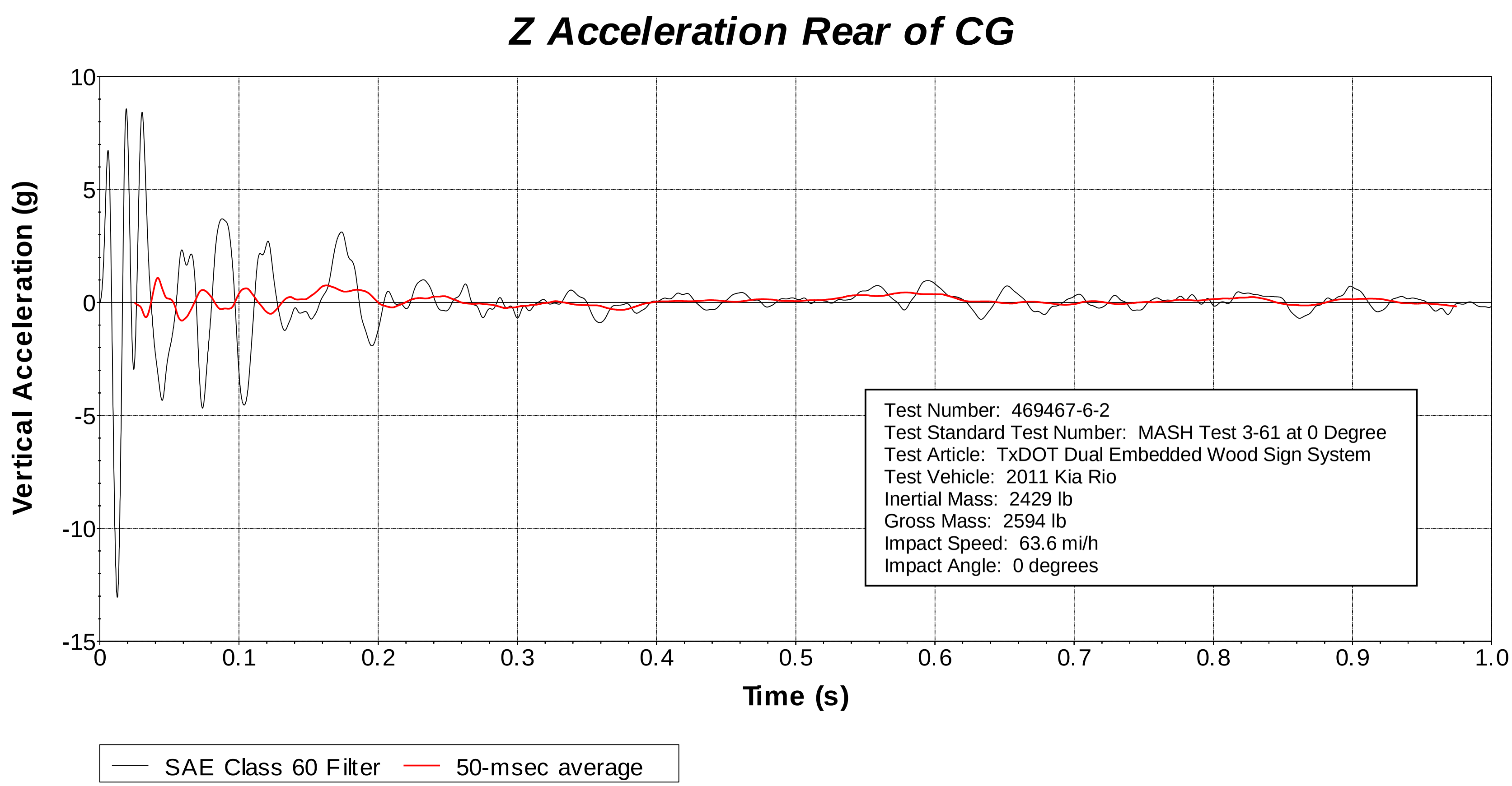


Figure D.32. Vehicle Vertical Accelerometer Trace for Test No. 469467-6-2 (Accelerometer Located Rear of Center of Gravity).

APPENDIX E. *MASH* TESTING OF THE PEDESTAL POLE BEACON

E.1 MATERIAL CERTIFICATION DOCUMENTS

Texas Highway Products, LTD **PACKING TICKET**

1309 Clark St., Round Rock, TX 78681
Phone: (512) 255-7633 Fax: (512) 255-7634
www.trafficsignals.com

17 - SO-002792

DATE: 07-07-2017

BILL TO: N-Line Traffic Maintenance
2620 Clarks Lane
Bryan, TX 77898

SHIP TO: N-Line Traffic Maintenance
Texas Transportation Institute
3100 SH 47 BLDG 7090
ATTN: Gary Gerke 936-825-4661
Byran, TX 77807

Attn:
Phone:

Shipping Instructions: None

CUSTOMER PO #	JOB	SHIPPING METHOD	SHIPPING TERMS
999830	N-LINE (SOLAR FLASHER ASSEMBLIES)		FOB Destination

ITEM	PRODUCT NAME	DESCRIPTION	LOT	QTY ORDERED	QTY SHIPPED	DATE SHIPPED	QTY BACK-ORDERED
1	M66156	12" Beacon Yellow Poly Signal	THP Main	4	4	07/14/17	0
2	M19275	12" Poly Yel Tunnel Visor	THP Main	4	4	07/14/17	0
3	DI-433-3230-905XL	12vDC 12 Watt Yellow Full Ball Led	THP Main	4	4	07/14/17	0
4	SE-0567-P29	Side-of-Pole Assy, 1-Way Tri-Stud For 8" Or 12" Signal & 4-1/2" Od Pole, Alum (Yellow)	THP Main	4	4	07/14/17	0
5	SE-3054-P01	Signal Closure Kit-(Yellow)	THP Main	4	4	07/14/17	0
6	2-Battery-Cabinet	2 Battery Cabinet--24 Hour Or School Zone	THP Main	2	2	07/14/17	0
7	SM-1012-2SK-BRS	Lock With 2 Short Keys, Police Type Brass	THP Main	2	2	07/14/17	0
8	SP-5293-PNC	Cabinet Mounting Bracket Assy(Set of 2) (Unpainted)	THP Main	2	2	07/14/17	0
9	MK-E-27SLDG	Deka Solar 8g27 Battery - Includes Hardware.	THP Main	4	4	07/14/17	0
10	Cabinet-Backpanel---1CP	Solar Cabinet Backpanel Cardinal 1cp - 1st Design	THP Main	2	2	07/14/17	0
11	DPC2000-24hr-DUAL	24hr Controller - Calibrated For Double 12" Yellow LEDs, Deka 8g27 Batteries (NON DIMMING)	THP Main	2	2	07/14/17	0
12	CPI-AP-18-40	18' ALUMINUM POLE SCH 40 SPUN AND TOE	THP Main	2	2	07/14/17	0
13	CPI-APC-1	4" Aluminum Pole Cap	THP Main	2	2	07/14/17	0
14	CPI-BAS-1-PDP	SQUARE ALUMINUM BASE W/ NATURAL FINISH W/ PLASTIC DOOR, 1/2-13 NC female threaded hole near the bottom of the base for grounding	THP Main	2	2	07/14/17	0

Page 1 of 2

15	CPI-GRDLUG-.50-COP	1/2" Copper Ground Lug	THP Main	2	2	07/14/17	0
16	CPI-RBC-1	POLE AND BASE RE-ENFORCING COLLAR	THP Main	2	2	07/14/17	0
17	SH-0206-4-PNC	Sign Clamp, U-Bolt, 4" (4-1/2" Od) Pipe, Set of 2, Alum	THP Main	2	2	07/14/17	0
18	Sunbelt-Hardware-RD	Includes: (1) 3/8"X4 1/2"X6 Ubolt, (2) 3/8-16x3hhb, (4) 3/8 16 Nylon Lock Nut, (6) 3/8 F/W, (2) 3/8 L/W	THP Main	2	2	07/14/17	0
19	Solar-Harness	12-2C Tray Cable, 600v 90c	THP Main	2	2	07/14/17	0
20	PowerUP-HPMH50-90	Side of Pole solar panel mount	THP Main	2	2	07/14/17	0
21	PowerUP-BSP90-12	90 Watt Solar Panel	THP Main	2	2	07/14/17	0
22	Chance-Stretlight-Found	C11242ng4vp - 8" Diameter X 60" Shaft, 1" Thick X 15.75" Square Base.	THP Main	2	2	07/14/17	0

MARK PACKAGES AS: PO 999830

E.2 *MASH* TEST 3-62 ON PEDESTAL BASE WITH BEACON WITHOUT SOLAR PANEL

Table E.1. Vehicle Properties for Test No. 469467-7-1.

Date: 2017-08-17   Test No.: 469467-7-1   VIN No.: 1C6RD6FT5CS289859

Year: 2012   Make: Dodge   Model: RAM 1500

Tire Size: 265/70R17   Tire Inflation Pressure: 35 psi

Tread Type: Highway   Odometer: 217274

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

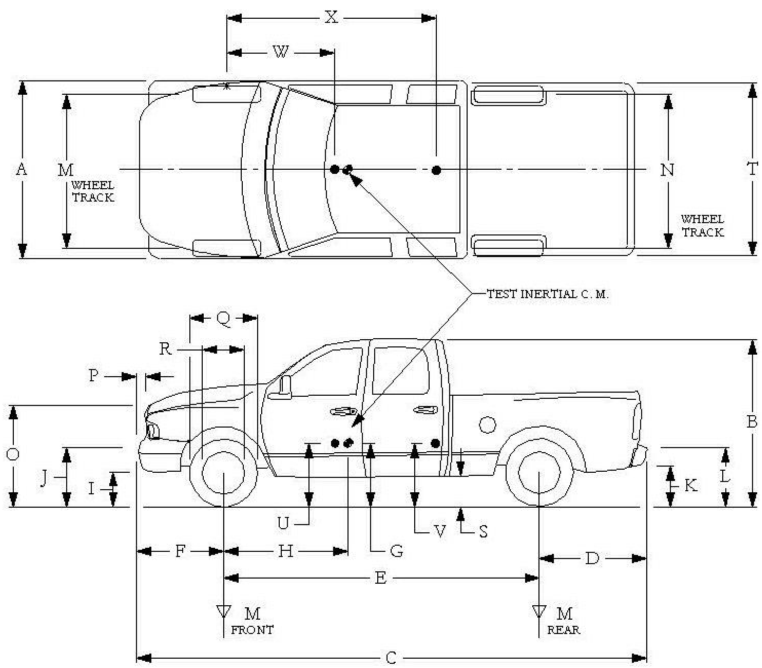
NOTES: None

Engine Type: v-8
Engine CID: 5.7 liter

Transmission Type:
x Auto or ___ Manual
___ FWD x RWD ___ 4WD

Optional Equipment:
None

Dummy Data:
Type: No dummy
Mass: NA
Seat Position: NA



Geometry: inches

A	78.50	F	40.00	K	20.75	P	3.00	U	27.50
B	75.00	G	28.50	L	29.50	Q	30.50	V	30.75
C	227.50	H	61.90	M	68.50	R	18.00	W	61.90
D	47.00	I	11.00	N	68.00	S	13.25	X	77.40
E	140.50	J	26.50	O	46.00	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	17.00
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	25.50

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2871	2816	----
Back	3900	M_{rear}	2086	2218	----
Total	6700	M_{Total}	4957	5037	----

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

Mass Distribution:
lb   LF: 1411   RF: 1405   LR: 1105   RR: 1113

Table E.2. Measurements of Vehicle Vertical CG for Test No. 469467-7-1.

Date: 2017-08-17 Test No.: 469467-7-1 VIN: 1C6RD6FT5CS289859

Year: 2012 Make: Dodge Model: RAM 1500

Body Style: Quad Cab Mileage: 217274

Engine: 5.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 190 lb (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70R17

Measured Vehicle Weights: (lb)								
LF:	1411		RF:	1405		Front Axle:	2816	
LR:	1105		RR:	1113		Rear Axle:	2218	
Left:	2516		Right:	2518		Total:	5034	
						5000 ±110 lb allowed		
Wheel Base:	140.50	inches	Track: F:	68.50	inches	R:	68.00	inches
	148 ±12 inches allowed			Track = (F+R)/2 = 67 ±1.5 inches allowed				
Center of Gravity, SAE J874 Suspension Method								
X:	61.90	inches	Rear of Front Axle	(63 ±4 inches allowed)				
Y:	0.01	inches	Left -	Right +	of Vehicle Centerline			
Z:	28.50	inches	Above Ground	(minumum 28.0 inches allowed)				

Hood Height: 46.00 inches
43 ±4 inches allowed

Front Bumper Height: 26.50 inches

Front Overhang: 40.00 inches
39 ±3 inches allowed

Rear Bumper Height: 29.50 inches

Overall Length: 227.50 inches
237 ±13 inches allowed

Table E.3. Exterior Crush Measurements of Vehicle for Test No. 469467-7-1.

Date:	2017-08-17	Test No.:	469467-7-1	VIN No.:	1C6RD6FT5CS289859
Year:	2012	Make:	Dodge	Model:	RAM 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	Front plane at bumper ht	14	6.5	38	0	0	4	6.5	4	4	+19
	Measurements recorded										
	in inches										

[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).

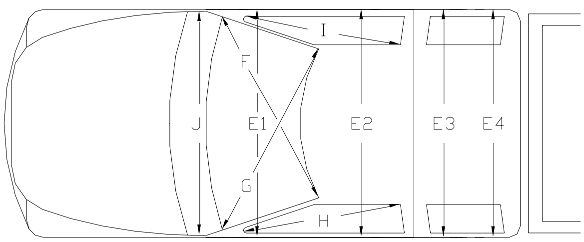
***Measure and document on the vehicle diagram the location of the maximum crush.

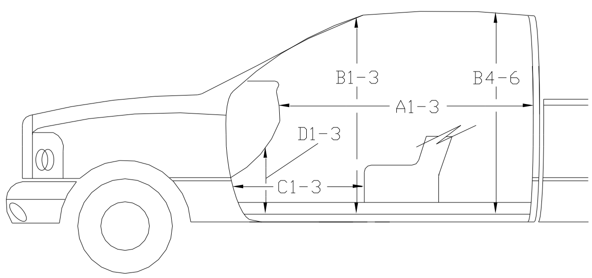
Note: Use as many lines/columns as necessary to describe each damage profile.

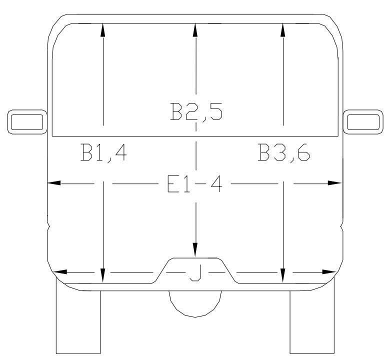
Table E.4. Occupant Compartment Measurements of Vehicle for Test No. 469467-7-1.

Date: 2017-08-17 Test No.: 469467-7-1 VIN No.: 1C6RD6FT5CS289859

Year: 2012 Make: Dodge Model: RAM 1500







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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After	Differ.
	(inches or mm)		
A1	65.25	65.25	0
A2	63.25	63.25	0
A3	65.50	65.50	0
B1	44.50	44.50	0
B2	38.00	38.00	0
B3	44.50	44.50	0
B4	39.50	39.50	0
B5	43.00	43.00	0
B6	39.50	39.50	0
C1	26.00	26.00	0
C2	-----	-----	-
C3	26.00	26.00	0
D1	11.50	11.50	0
D2	-----	-----	-
D3	11.50	11.50	0
E1	58.75	58.75	0
E2	63.50	63.50	0
E3	63.50	63.50	0
E4	63.50	63.50	0
F	59.00	59.00	0
G	59.00	59.00	0
H	37.50	37.50	0
I	37.50	37.50	0
J*	23.25	23.25	0

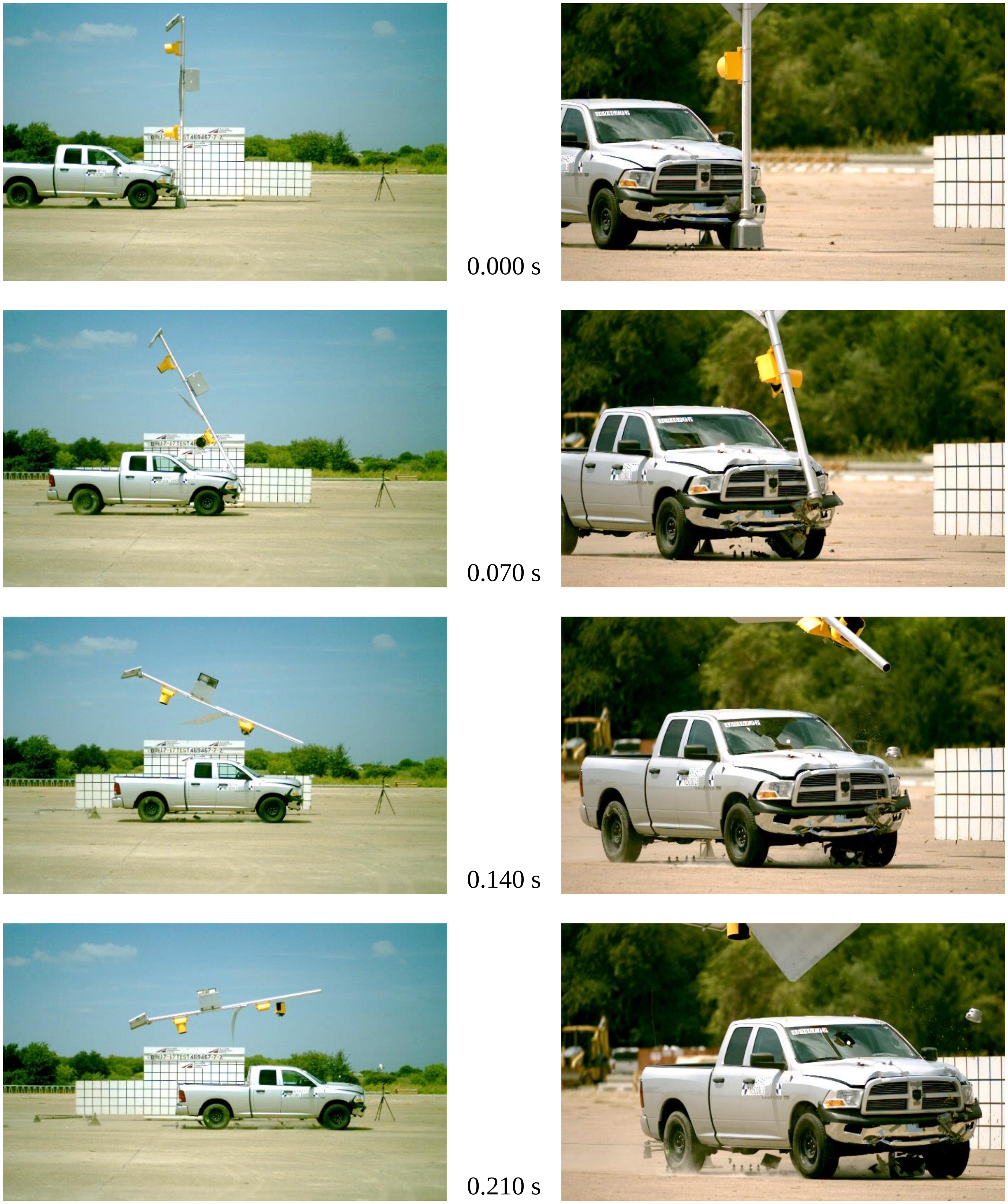


Figure E.1. Sequential Photographs for Test No. 469467-7-1 (Perpendicular and Oblique Views).

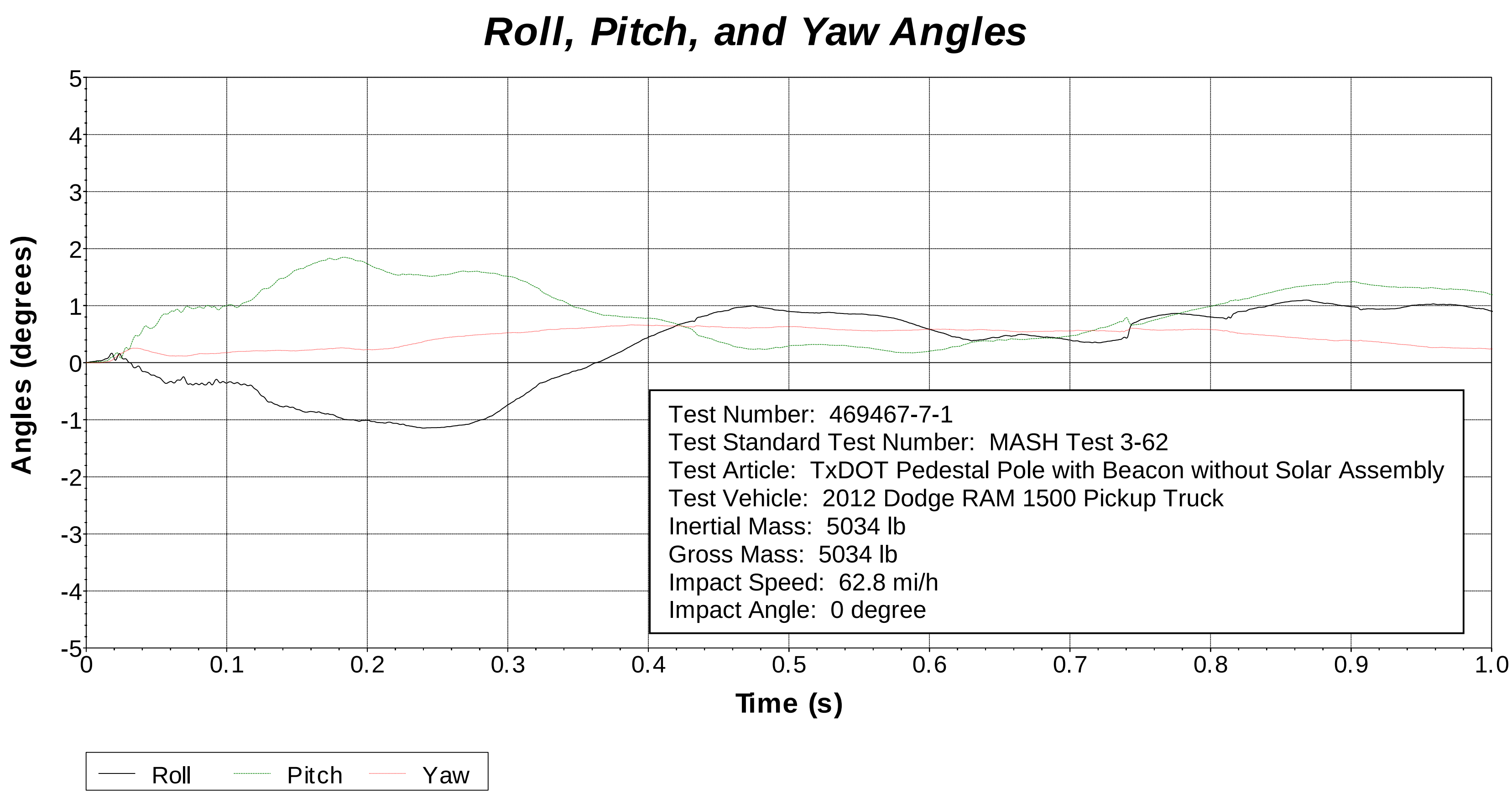
0.280 s

0.350 s

0.420 s

0.490 s

Figure E.1. Sequential Photographs for Test No. 469467-7-1 (Perpendicular and Oblique Views) (Continued).



Axes are vehicle-fixed.
Sequence for determining orientation:

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

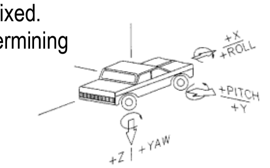


Figure E.2. Vehicle Angular Displacements for Test No. 469467-7-1.

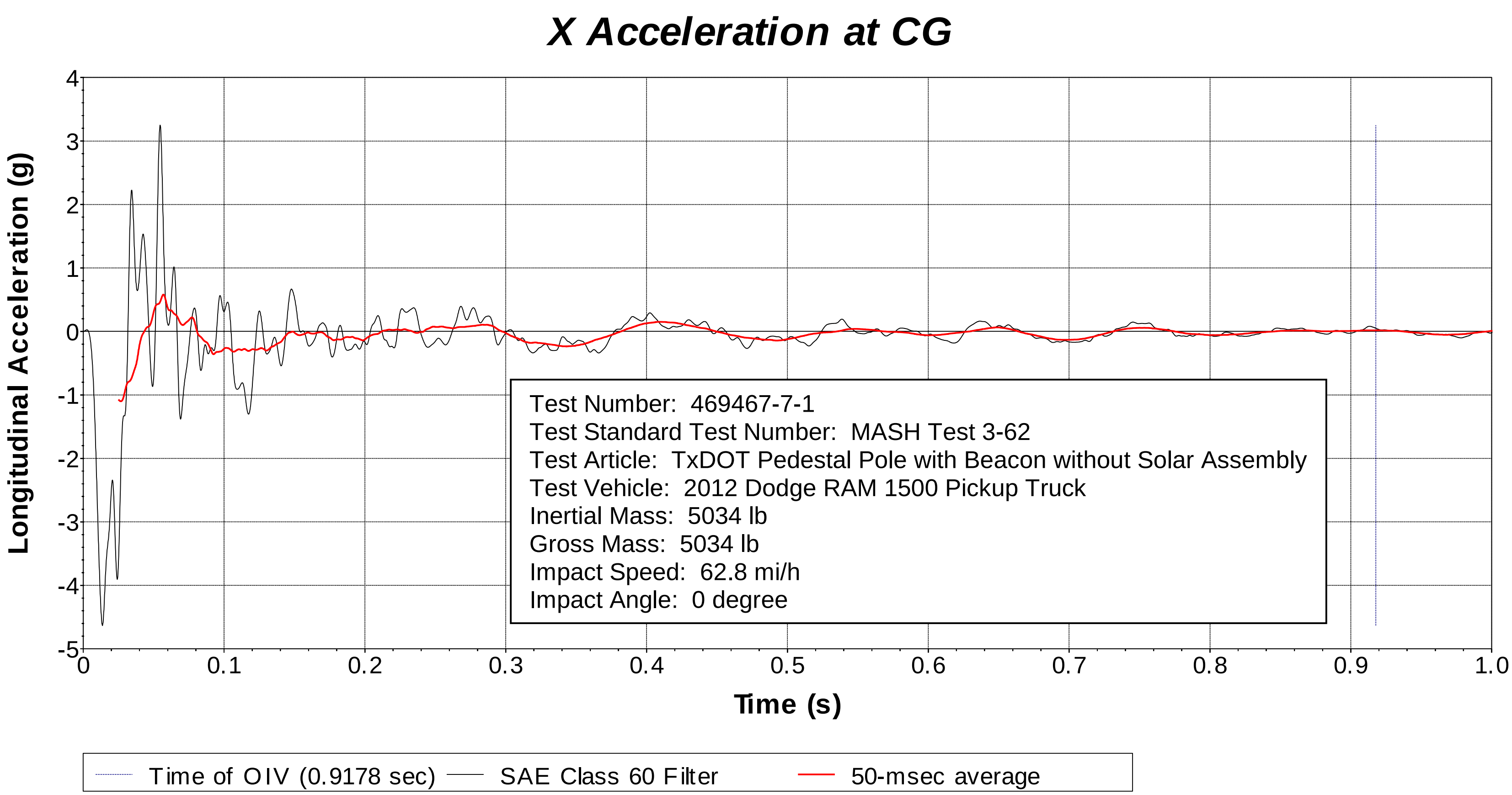


Figure E.3. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-7-1 (Accelerometer Located at Center of Gravity).

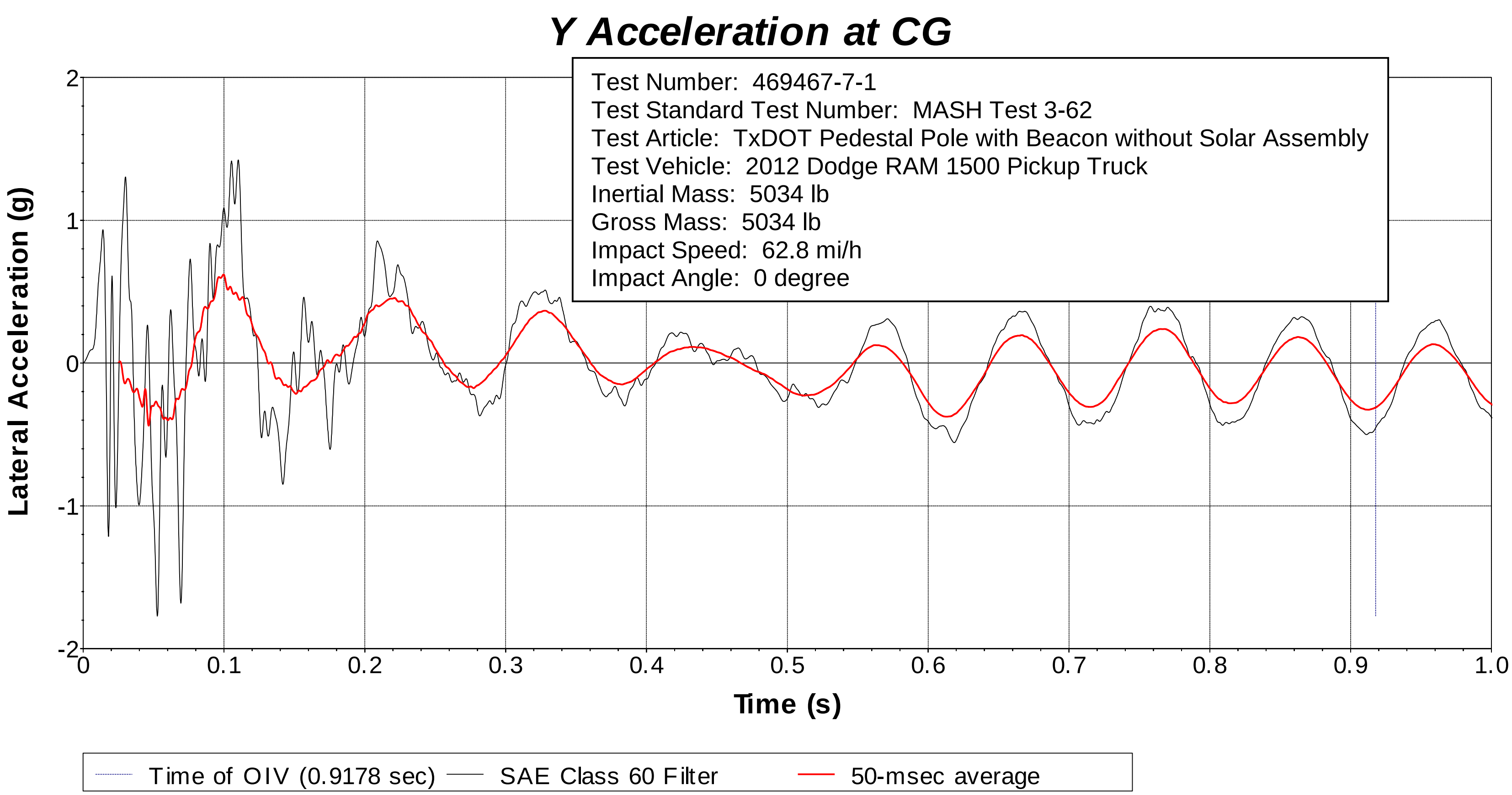


Figure E.4. Vehicle Lateral Accelerometer Trace for Test No. 469467-7-1 (Accelerometer Located at Center of Gravity).

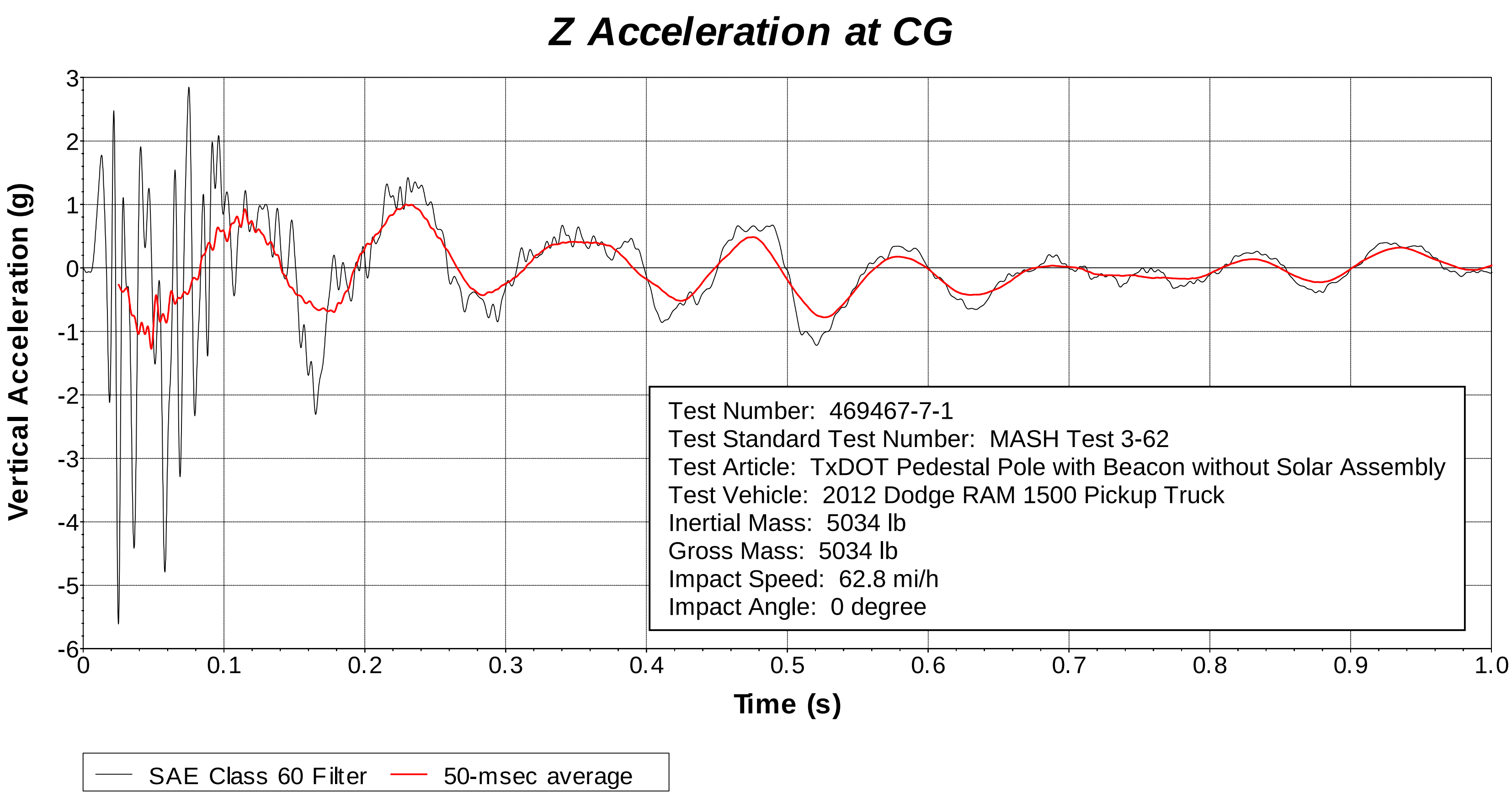


Figure E.5. Vehicle Vertical Accelerometer Trace for Test No. 469467-7-1 (Accelerometer Located at Center of Gravity).

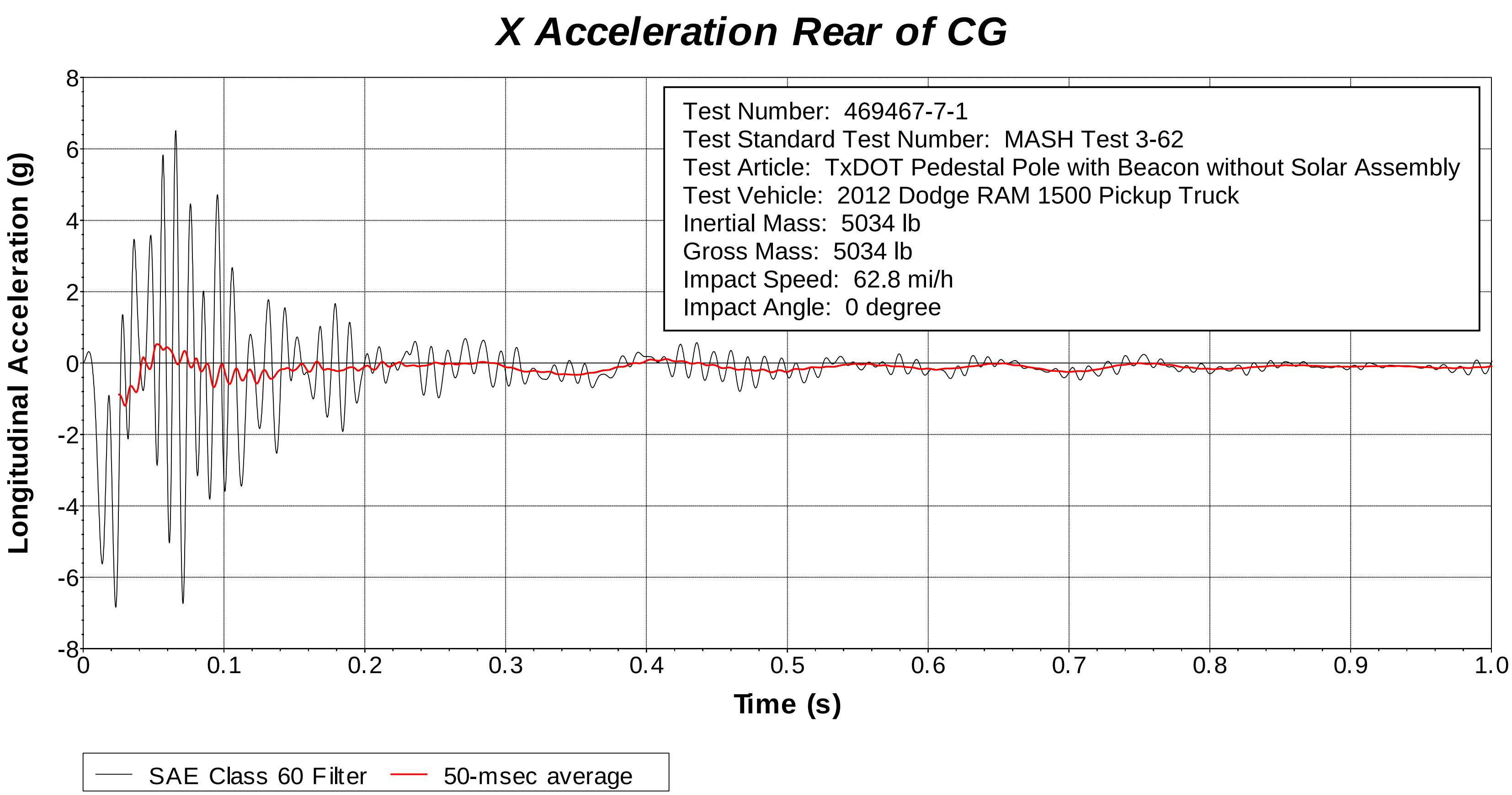


Figure E.6. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-7-1 (Accelerometer Located Rear of Center of Gravity).

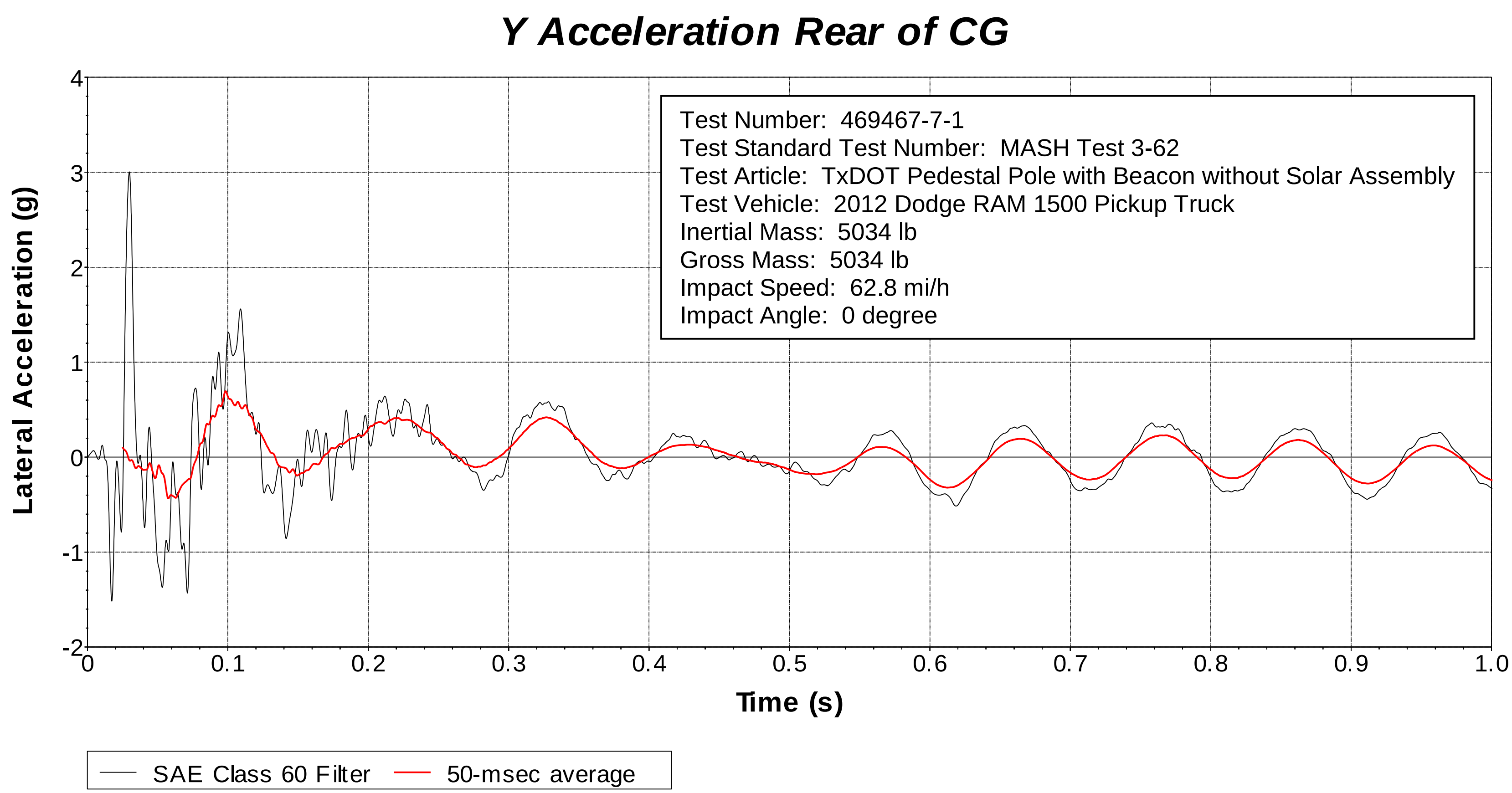


Figure E.7. Vehicle Lateral Accelerometer Trace for Test No. 469467-7-1 (Accelerometer Located Rear of Center of Gravity).

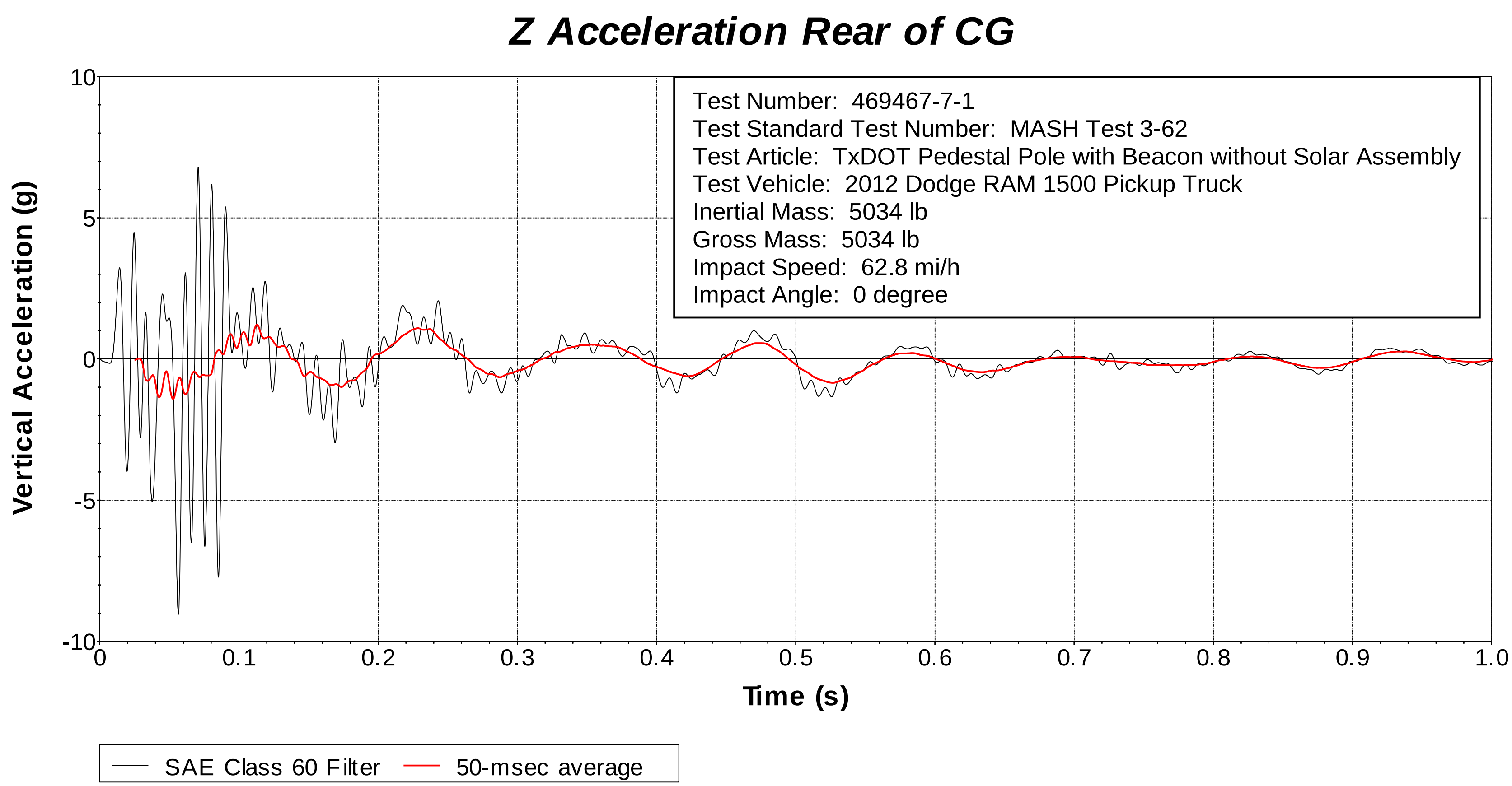


Figure E.8. Vehicle Vertical Accelerometer Trace for Test No. 469467-7-1 (Accelerometer Located Rear of Center of Gravity).

E.3 *MASH* TEST 3-62 ON THE PEDESTAL POLE WITH BEACONS AND SOLAR ASSEMBLY

Table E.5. Vehicle Properties for Test No. 469467-7-2.

Date: 2017-08-17 Test No.: 469467-7-2 VIN No.: 1C6RD6FT5CS289859

Year: 2012 Make: Dodge Model: RAM 1500

Tire Size: 265/70R17 Tire Inflation Pressure: 35 psi

Tread Type: Highway Odometer: 217274

Note any damage to the vehicle prior to test: 6.5 inch dent at right qtr pt of bumper, grill, hood

● Denotes accelerometer location.

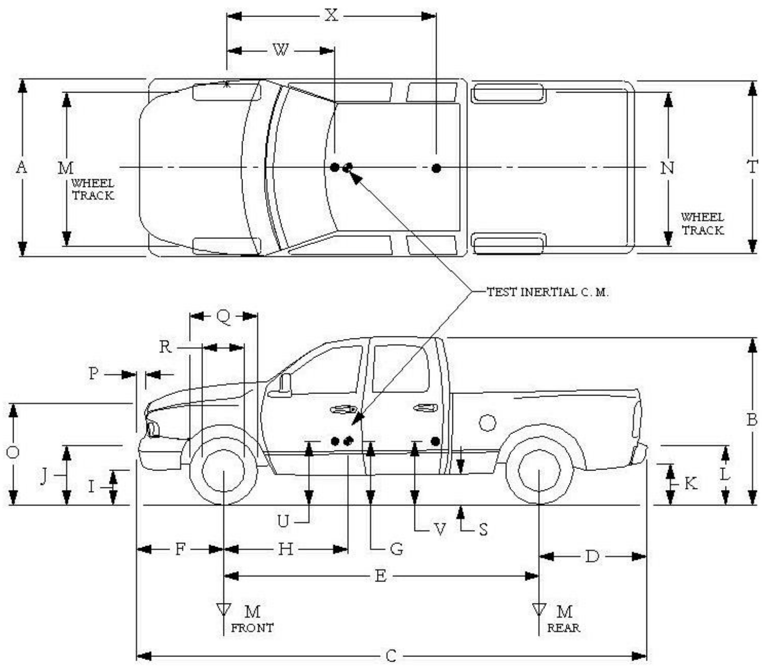
NOTES: Previously used in Test No. 469467-7-1

Engine Type: v-8
Engine CID: 5.7 liter

Transmission Type:
x Auto or ___ Manual
___ FWD x RWD ___ 4WD

Optional Equipment:
None

Dummy Data:
Type: No dummy
Mass: NA
Seat Position: NA



Geometry: inches

A	78.50	F	40.00	K	20.75	P	3.00	U	27.50
B	75.00	G	28.50	L	29.50	Q	30.50	V	30.75
C	227.50	H	61.90	M	68.50	R	18.00	W	61.90
D	47.00	I	11.00	N	68.00	S	13.25	X	77.40
E	140.50	J	26.50	O	46.00	T	77.00		

Wheel Center Height Front	14.75	Wheel Well Clearance (Front)	6.00	Bottom Frame Height - Front	17.00
Wheel Center Height Rear	14.75	Wheel Well Clearance (Rear)	9.25	Bottom Frame Height - Rear	25.50

GVWR Ratings:		Mass: lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2871	2816	----
Back	3900	M_{rear}	2086	2218	----
Total	6700	M_{Total}	4957	5037	----

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

Mass Distribution:
lb LF: 1411 RF: 1405 LR: 1105 RR: 1113

Table E.6. Measurements of Vehicle Vertical CG for Test No. 469467-7-2.

Date: 2017-08-17 Test No.: 469467-7-2 VIN: 1C6RD6FT5CS289859

Year: 2012 Make: Dodge Model: RAM 1500

Body Style: Quad Cab Mileage: 217274

Engine: 5.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 190 lb (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70R17

Measured Vehicle Weights: (lb)							
LF:	1411		RF:	1405		Front Axle:	2816
LR:	1105		RR:	1113		Rear Axle:	2218
Left:	2516		Right:	2518		Total:	5034
						5000 ±110 lb allowed	
Wheel Base:	140.50	inches	Track: F:	68.50	inches R:	68.00	inches
	148 ±12 inches allowed			Track = (F+R)/2 = 67 ±1.5 inches allowed			
Center of Gravity, SAE J874 Suspension Method							
X:	61.90	inches	Rear of Front Axle	(63 ±4 inches allowed)			
Y:	0.01	inches	Left - Right +	of Vehicle Centerline			
Z:	28.50	inches	Above Ground	(minumum 28.0 inches allowed)			

Hood Height: 46.00 inches Front Bumper Height: 26.50 inches

43 ±4 inches allowed

Front Overhang: 40.00 inches Rear Bumper Height: 29.50 inches

39 ±3 inches allowed

Overall Length: 227.50 inches

237 ±13 inches allowed

Table E.7. Exterior Crush Measurements of Vehicle for Test No. 469467-7-2.

Date: 2017-08-17 Test No.: 469467-7-2 VIN No.: 1C6RD6FT5CS289859

Year: 2012 Make: Dodge Model: RAM 1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
1	Front plane at bumper ht	14	6.5	38	4	4	6.5	4	0	0	-19
	Measurements recorded										
	in inches										

[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.

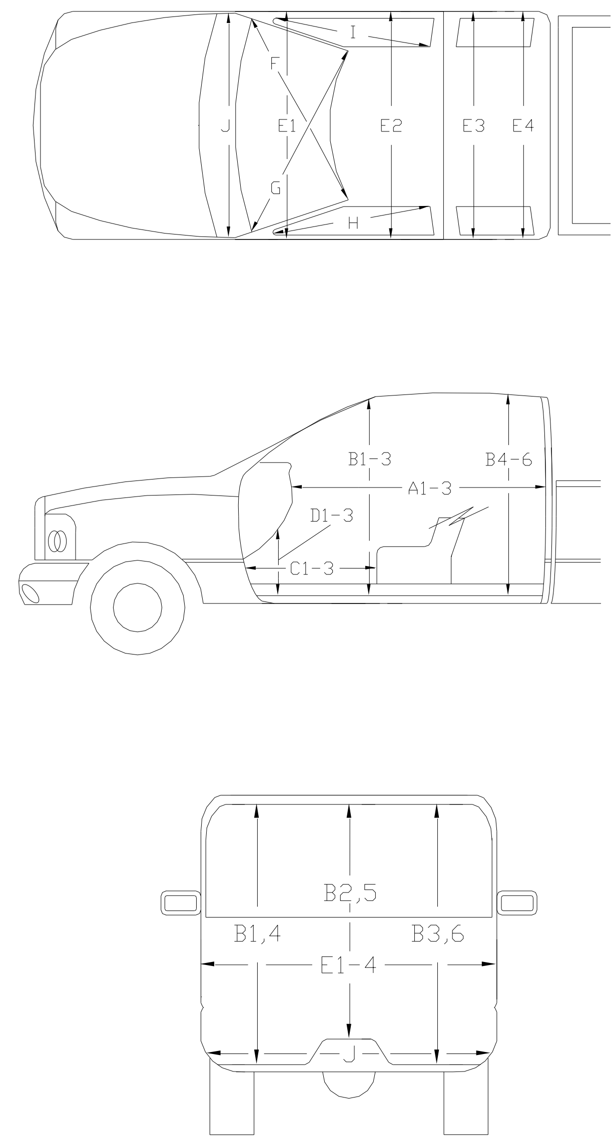
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***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.

Table E.8. Occupant Compartment Measurements of Vehicle for Test No. 469467-7-2.

Date:	2017-08-17	Test No.:	469467-7-2	VIN No.:	1C6RD6FT5CS289859
Year:	2012	Make:	Dodge	Model:	RAM 1500



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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After	Differ.
	(inches or mm)		
A1	65.25	65.25	0
A2	63.25	63.25	0
A3	65.50	65.50	0
B1	44.50	44.50	0
B2	38.00	38.00	0
B3	44.50	44.50	0
B4	39.50	39.50	0
B5	43.00	43.00	0
B6	39.50	39.50	0
C1	26.00	26.00	0
C2	-----	-----	-
C3	26.00	26.00	0
D1	11.50	11.50	0
D2	-----	-----	-
D3	11.50	11.50	0
E1	58.75	58.75	0
E2	63.50	63.50	0
E3	63.50	63.50	0
E4	63.50	63.50	0
F	59.00	59.00	0
G	59.00	59.00	0
H	37.50	37.50	0
I	37.50	37.50	0
J*	23.25	23.25	0

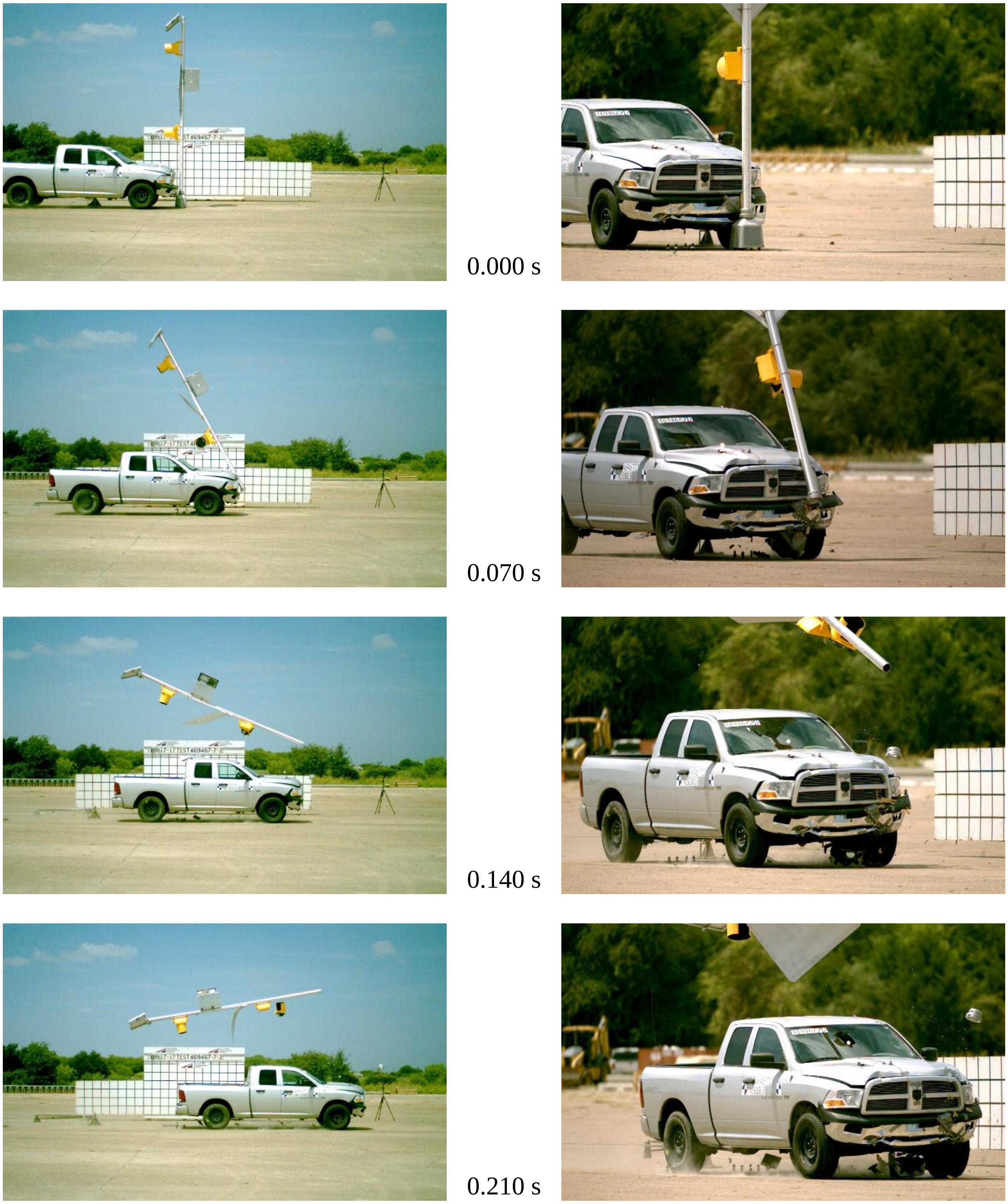


Figure E.9. Sequential Photographs for Test No. 469467-7-2 (Perpendicular and Oblique Views).

0.280 s

0.350 s

0.420 s

0.490 s

Figure E.9. Sequential Photographs for Test No. 469467-7-2 (Perpendicular and Oblique Views) (Continued).

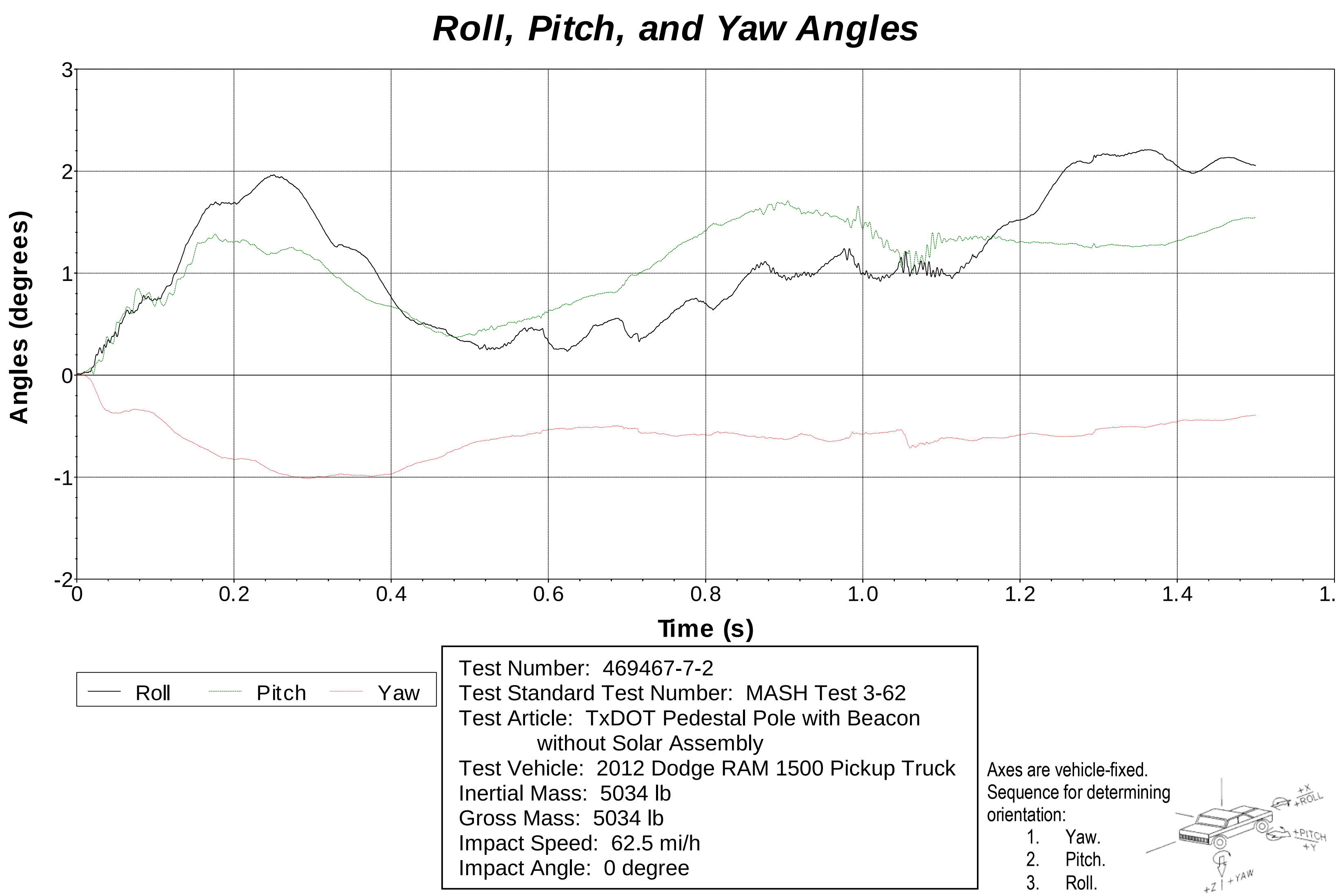


Figure E.10. Vehicle Angular Displacements for Test No. 469467-7-1.

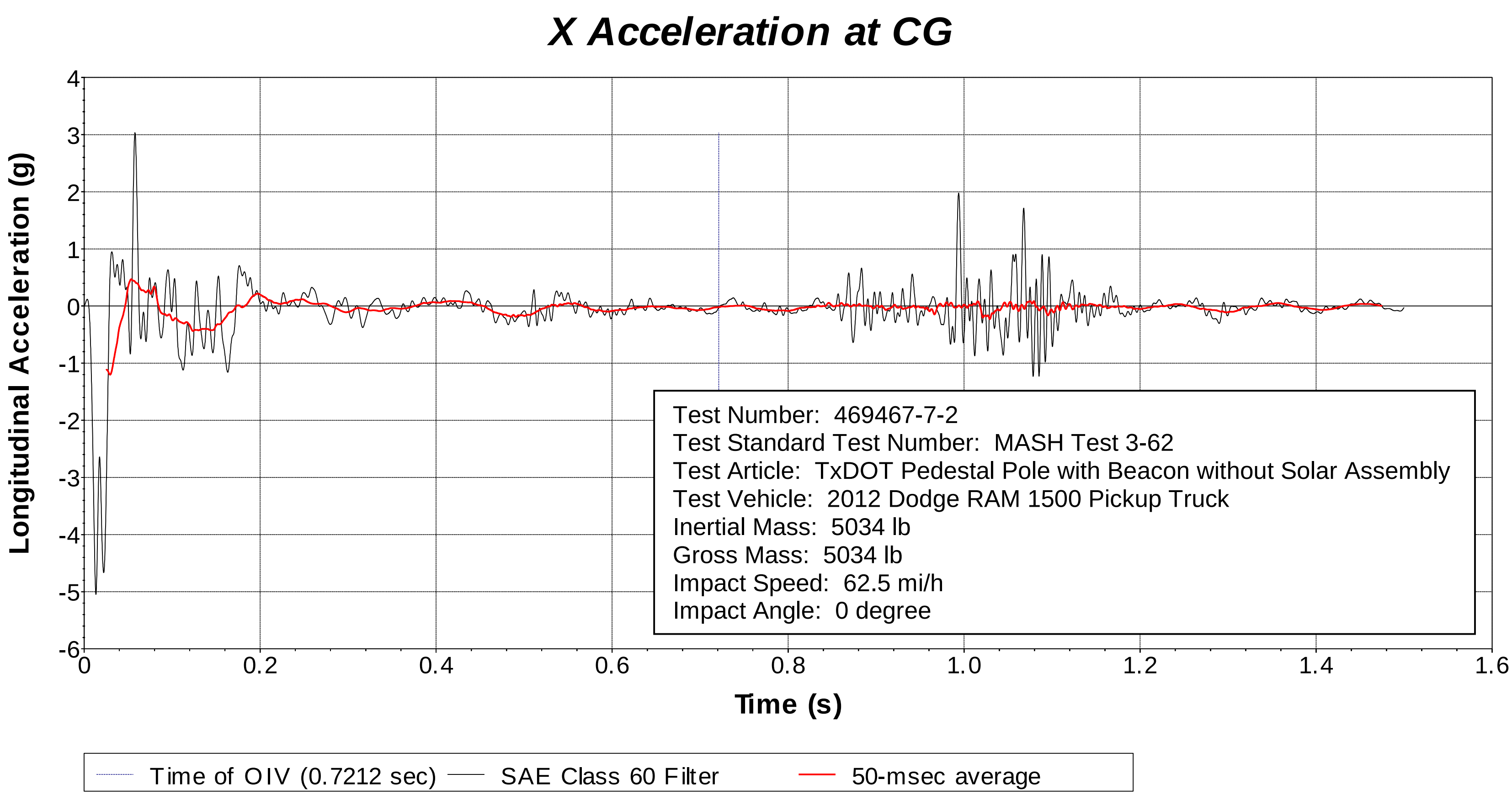


Figure E.11. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-7-2 (Accelerometer Located at Center of Gravity).

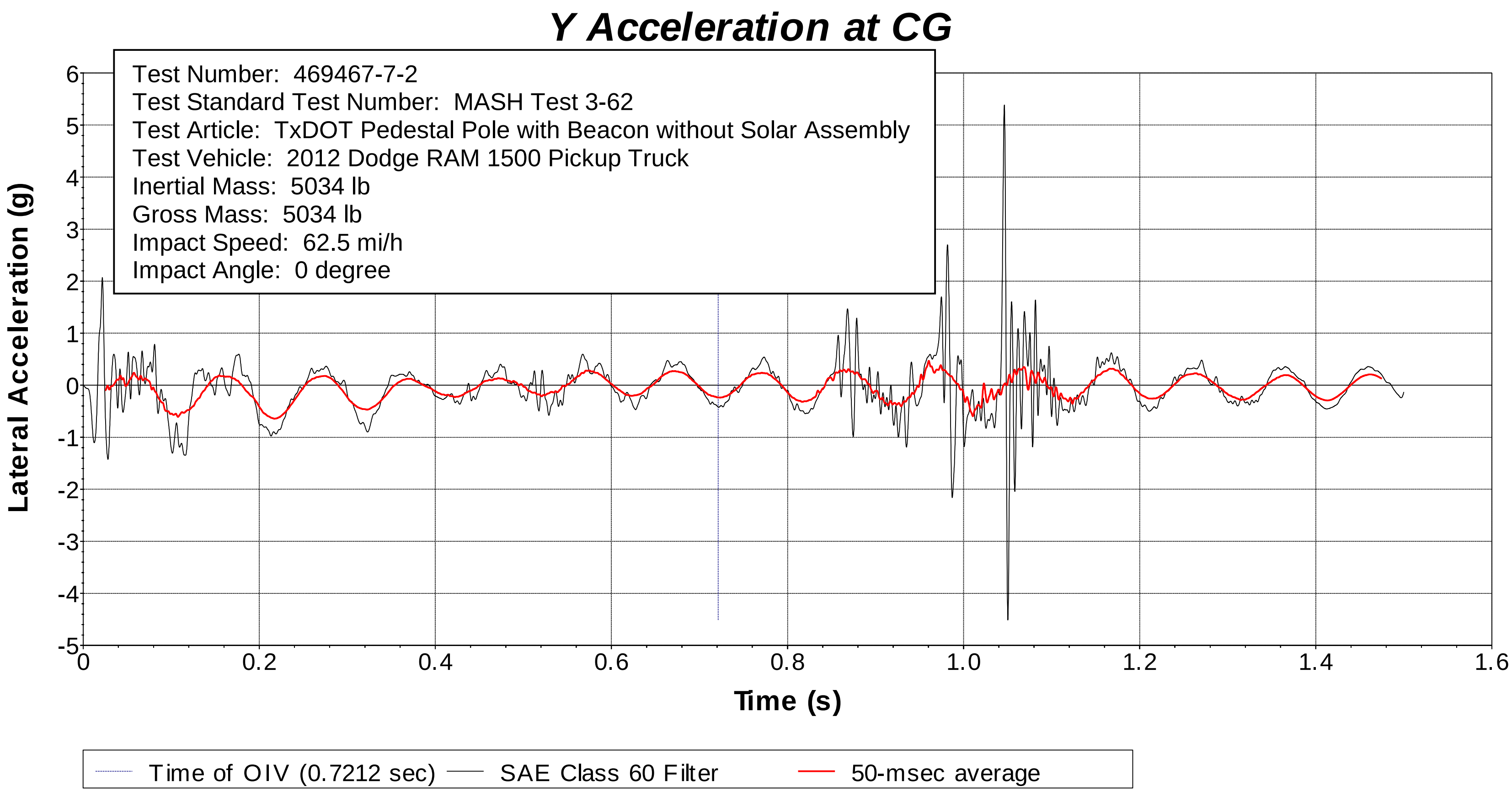


Figure E.12. Vehicle Lateral Accelerometer Trace for Test No. 469467-7-2 (Accelerometer Located at Center of Gravity).

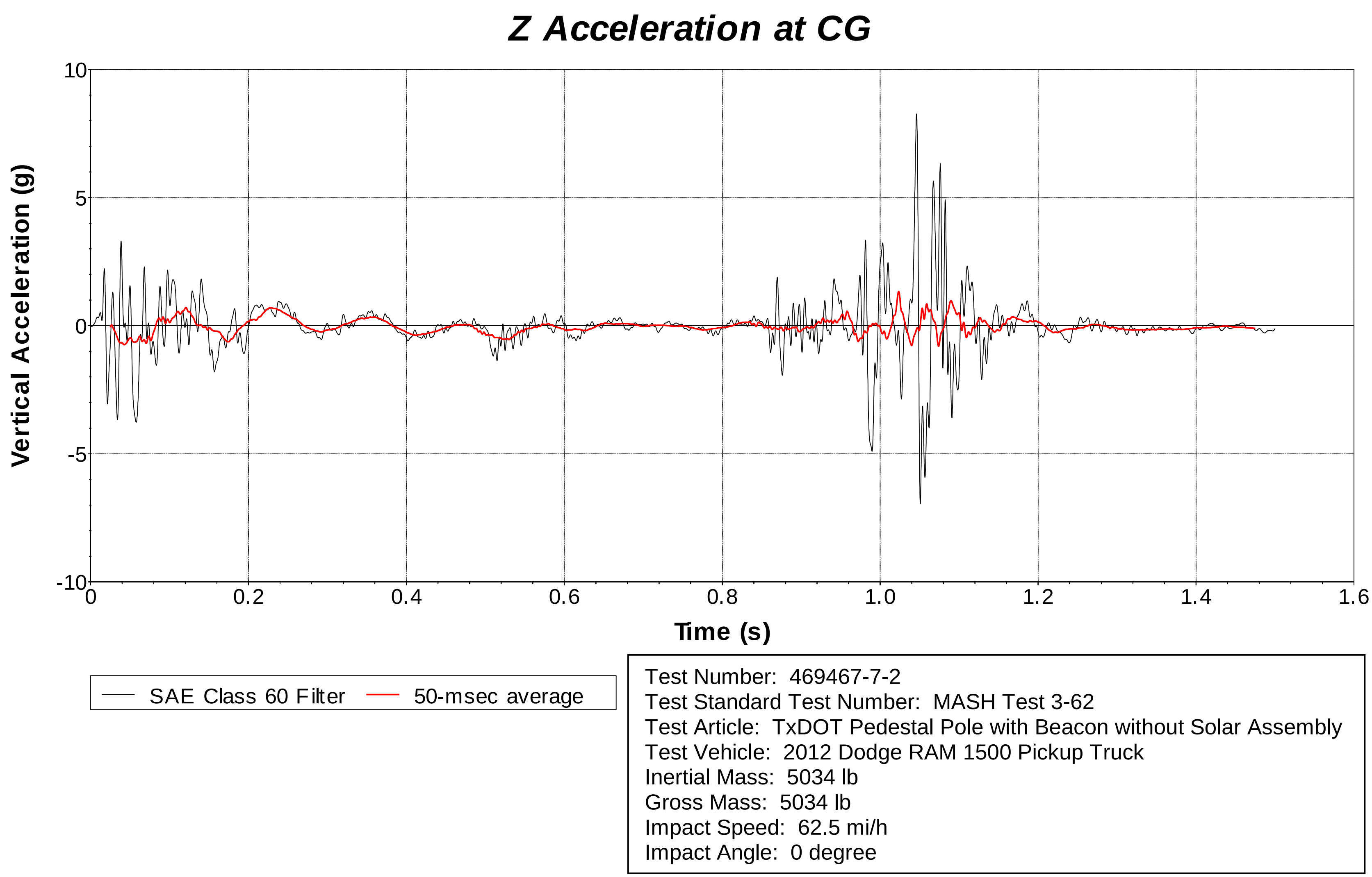


Figure E.13. Vehicle Vertical Accelerometer Trace for Test No. 469467-7-2 (Accelerometer Located at Center of Gravity).

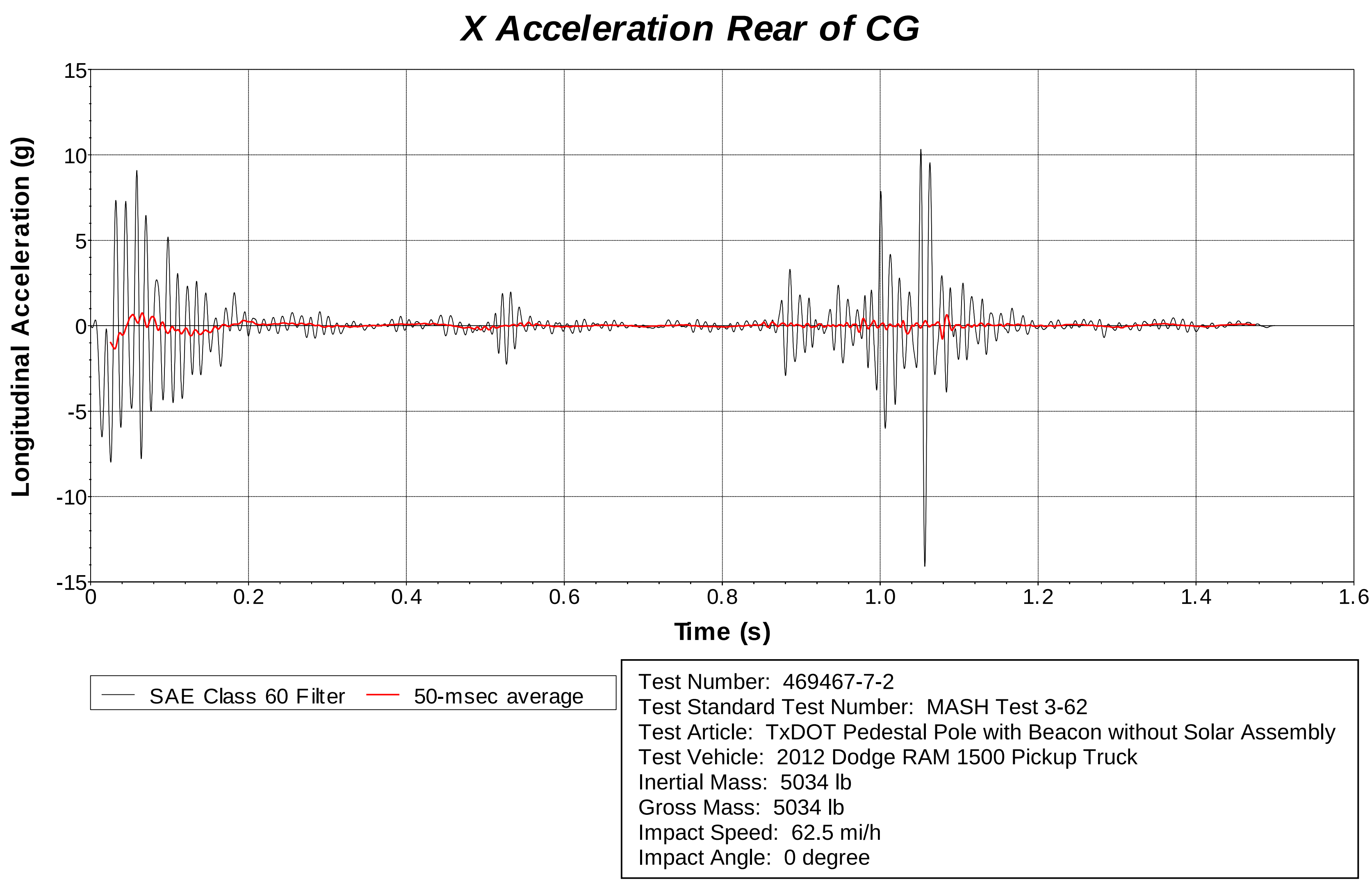
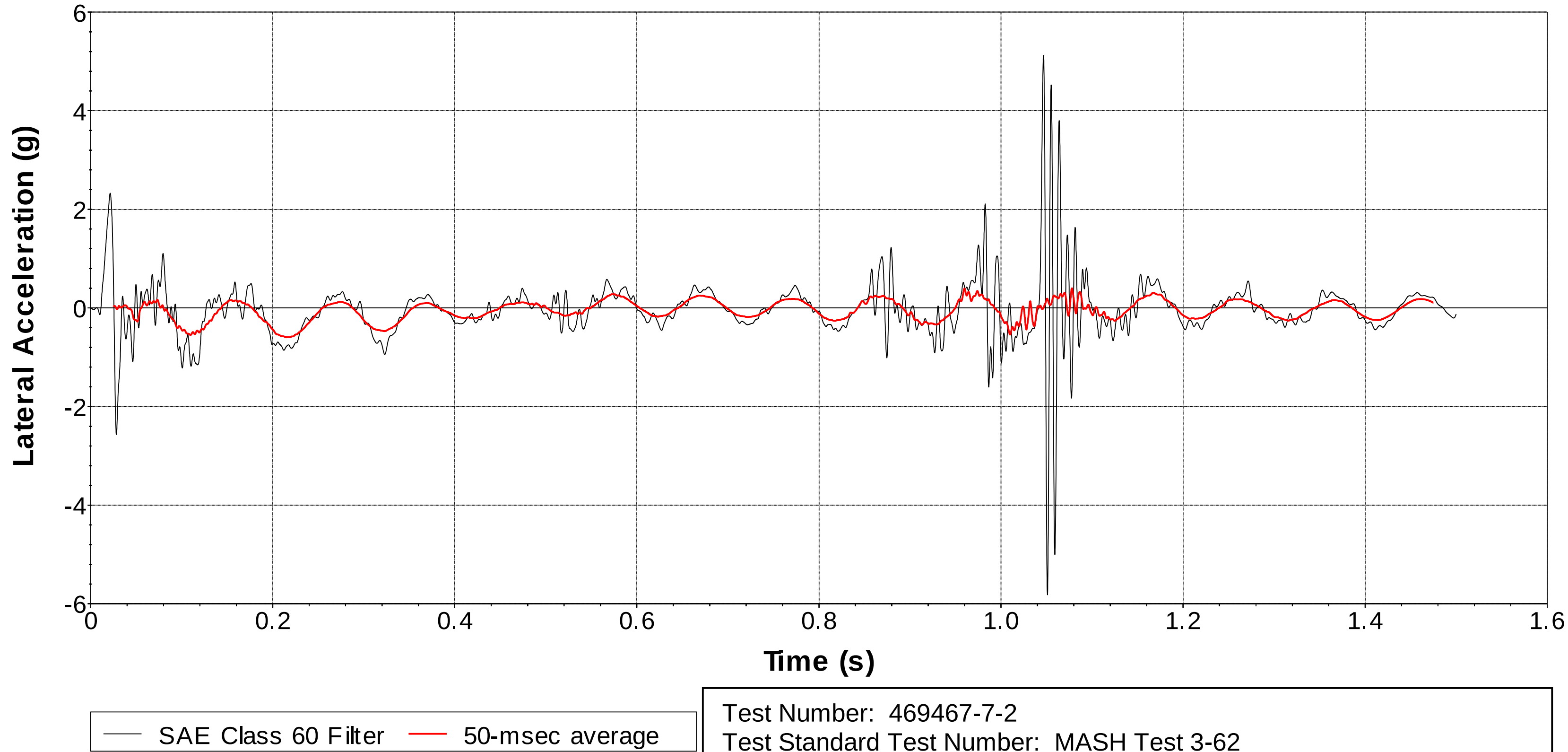


Figure E.14. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-7-2 (Accelerometer Located Rear of Center of Gravity).

Y Acceleration Rear of CG



Test Number: 469467-7-2
Test Standard Test Number: MASH Test 3-62
Test Article: TxDOT Pedestal Pole with Beacon without Solar Assembly
Test Vehicle: 2012 Dodge RAM 1500 Pickup Truck
Inertial Mass: 5034 lb
Gross Mass: 5034 lb
Impact Speed: 62.5 mi/h
Impact Angle: 0 degree

Figure E.15. Vehicle Lateral Accelerometer Trace for Test No. 469467-7-2 (Accelerometer Located Rear of Center of Gravity).

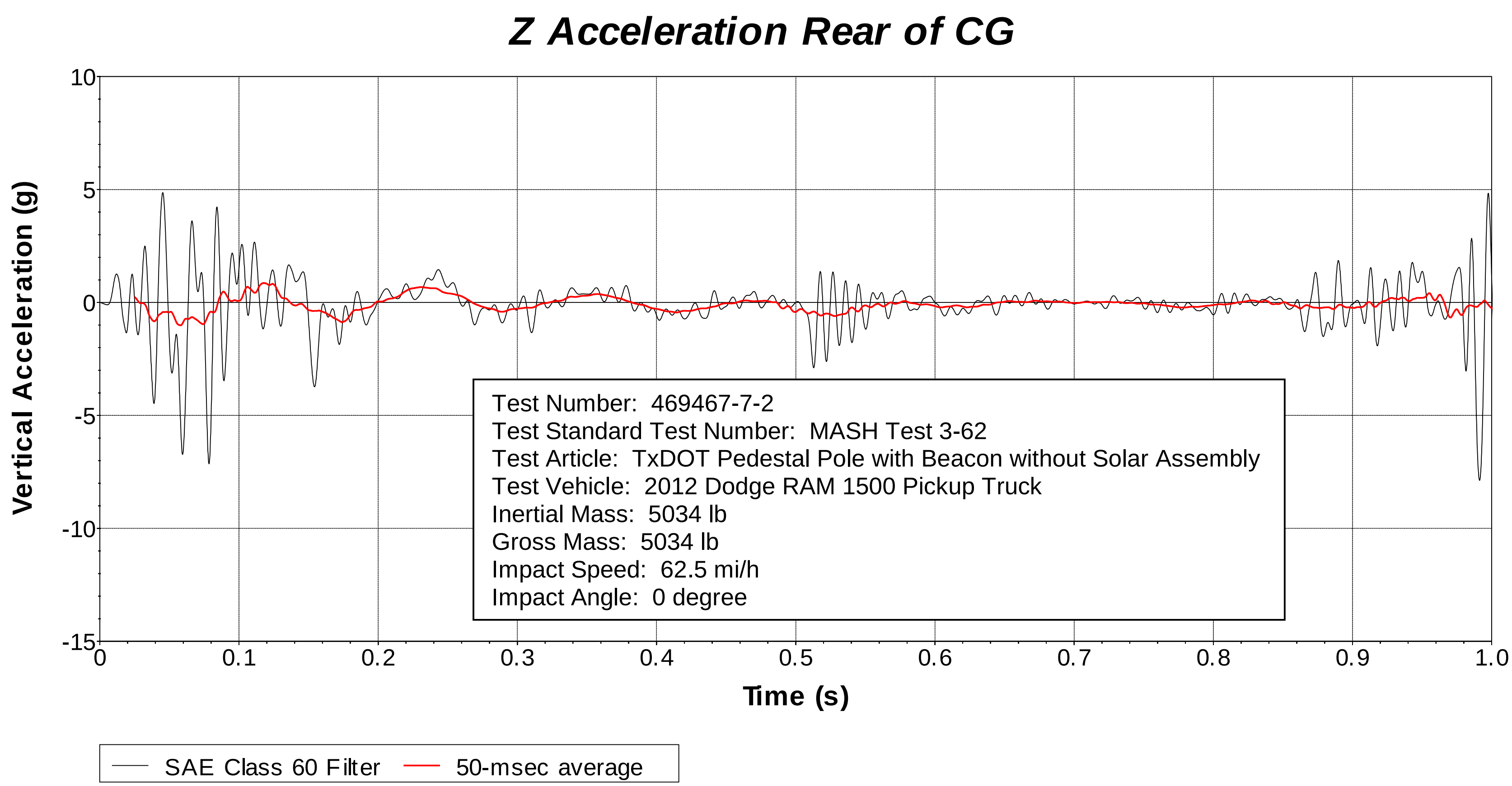


Figure E.16. Vehicle Vertical Accelerometer Trace for Test No. 469467-7-2 (Accelerometer Located Rear of Center of Gravity).

APPENDIX F. *MASH* TESTING OF TXDOT MAILBOX SYSTEMS

F.1 *MASH* TEST 3-61 AT 0 DEGREES ON DOUBLE MAILBOX SYSTEM ON WINGED CHANNEL POST WITH TYPE 3 FOUNDATION

Table F.1. Vehicle Properties for Test No. 469467-8-4.

Date: 2017-08-03 Test No.: 469467-8-4 VIN No.: KNADH4A30B6857166

Year: 2011 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 111224 Tire Size: 185/65R14

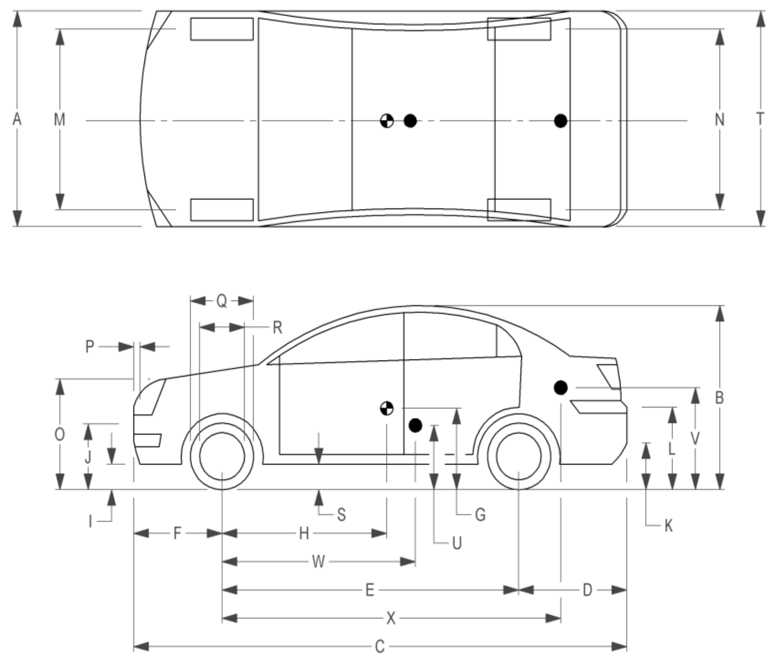
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES: None

Engine Type: 4 cylinder
Engine CID: 1.6 liter
Transmission Type:
x Auto or ____ Manual
x FWD ____ RWD ____ 4WD
Optional Equipment:
None

Dummy Data:
Type: 50th percentile male
Mass: 165 lb
Seat Position: Front Passenger



Geometry: inches

A	66.385	F	33.00	K	10.50	P	4.12	U	15.25
B	58.00	G	-----	L	24.50	Q	22.50	V	20.50
C	165.75	H	35.22	M	57.75	R	15.50	W	35.00
D	34.00	I	7.75	N	57.75	S	9.00	X	107.00
E	98.75	J	21.00	O	28.00	T	66.25		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00 W-H 0

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1570	1569	1654
Back	1874	M_{rear}	899	870	950
Total	3592	M_{Total}	2469	2439	2604

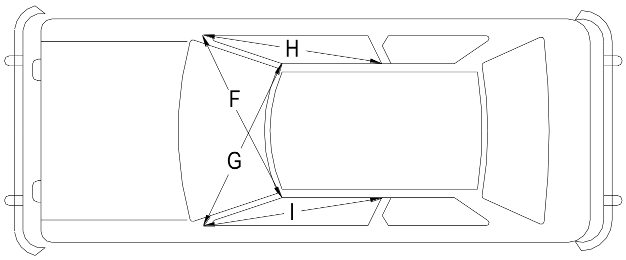
Allowable TIM = 2420 lb ±55 lb | Allowable GSM = 2585 lb ± 55 lb

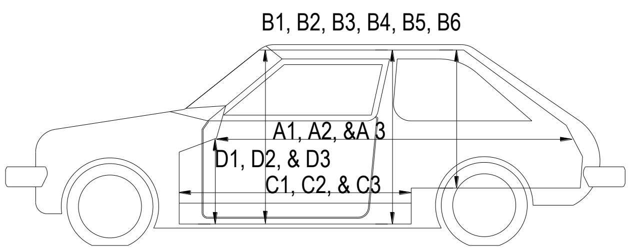
Mass Distribution:
lb LF: 771 RF: 798 LR: 446 RR: 424

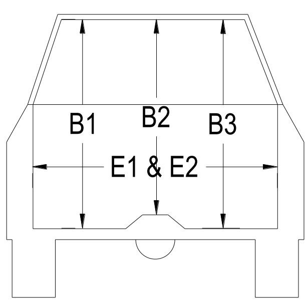
Table F.2. Occupant Compartment Measurements for Test No. 469467-6-1.

Date: 2017-08-03 Test No.: 469467-8-4 VIN No.: KNADH4A30B6857166

Year: 2011 Make: Kia Model: Rio







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	67.50	67.50	0
A2	67.00	67.00	0
A3	67.50	67.50	0
B1	40.50	40.50	0
B2	37.00	37.00	0
B3	40.50	40.50	0
B4	36.25	36.25	0
B5	35.25	35.25	0
B6	36.25	36.25	0
C1	27.75	27.75	0
C2	-----	-----	-
C3	27.00	27.00	0
D1	9.50	9.50	0
D2	-----	-----	-
D3	9.50	9.50	0
E1	51.50	51.50	0
E2	51.00	51.00	0
F	51.00	51.00	0
G	51.00	51.00	0
H	37.25	37.25	0
I	37.25	37.25	0
J*	51.00	51.00	0

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

0.000 s

0.025 s

0.050 s

0.0750 s

Figure F.1. Sequential Photographs for Test No. 469467-8-4 (Perpendicular and Oblique Views).

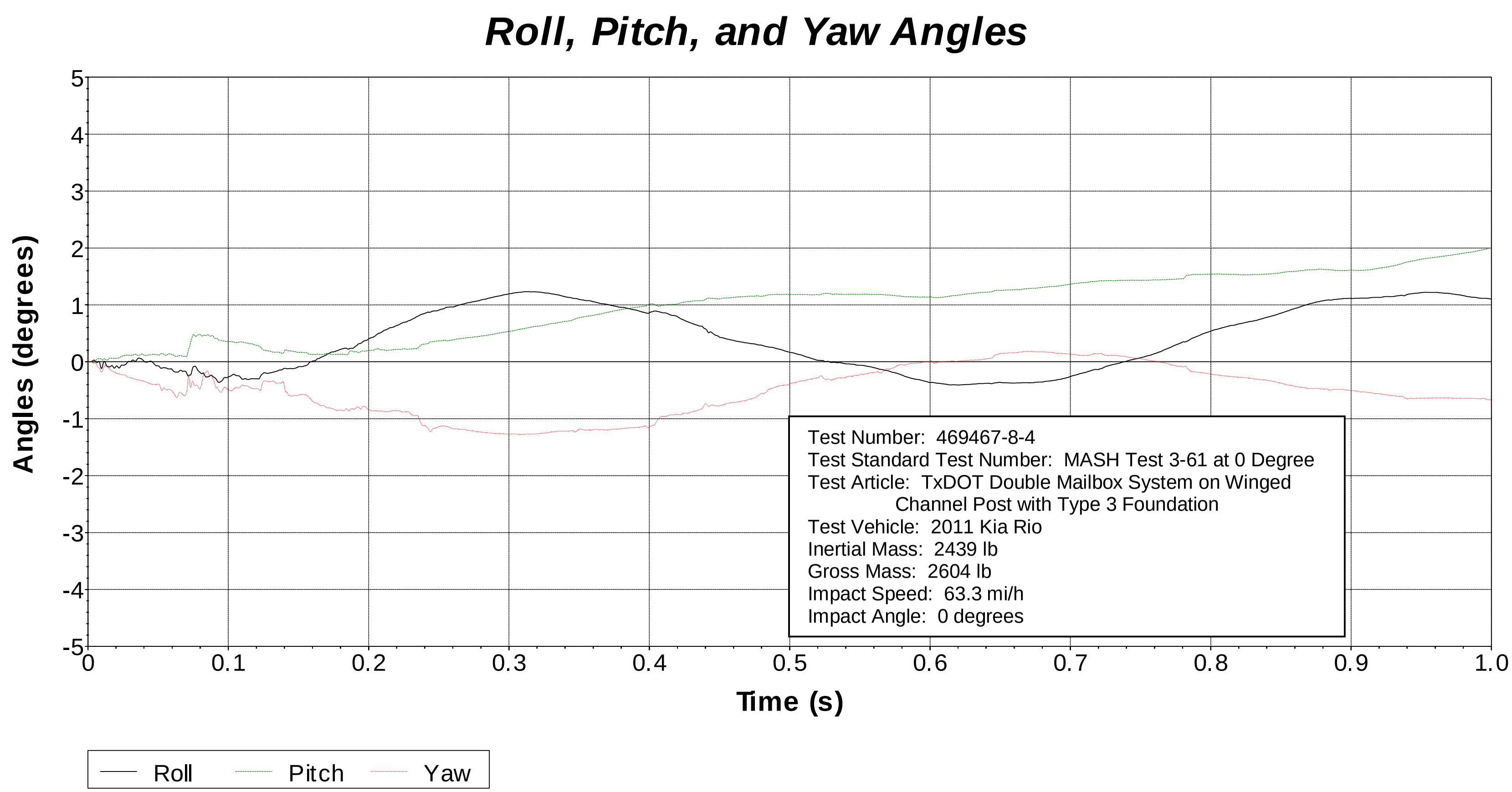
0.100 s

0.125 s

0.150 s

0.175 s

Figure F.1. Sequential Photographs for Test No. 469467-8-4 (Perpendicular and Oblique Views) (Continued).



Axes are vehicle-fixed.
Sequence for determining orientation:

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

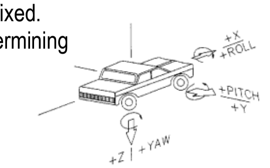


Figure F.2. Vehicle Angular Displacements for Test No. 469467-8-4.

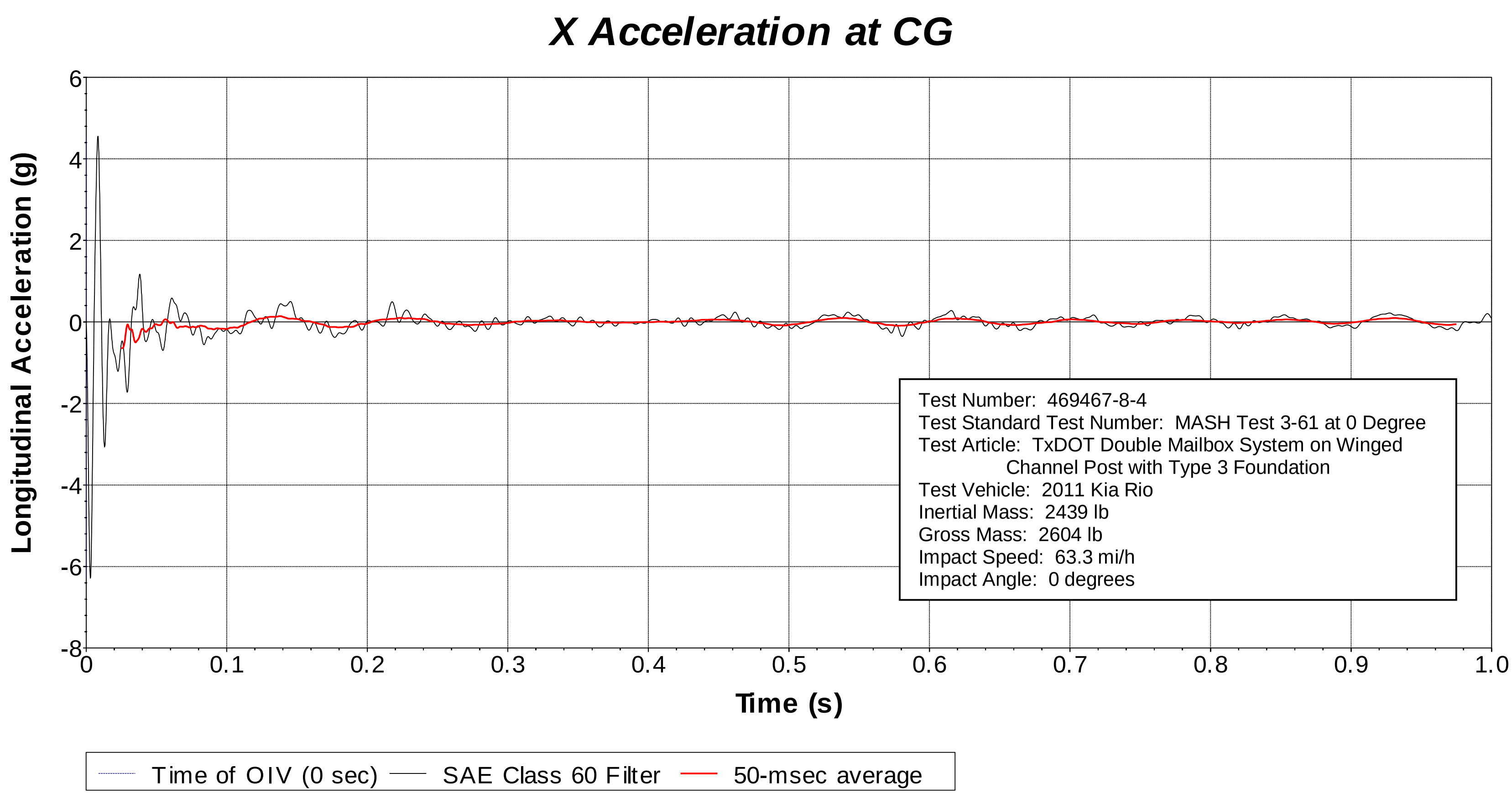


Figure F.3. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-8-4 (Accelerometer Located at Center of Gravity).

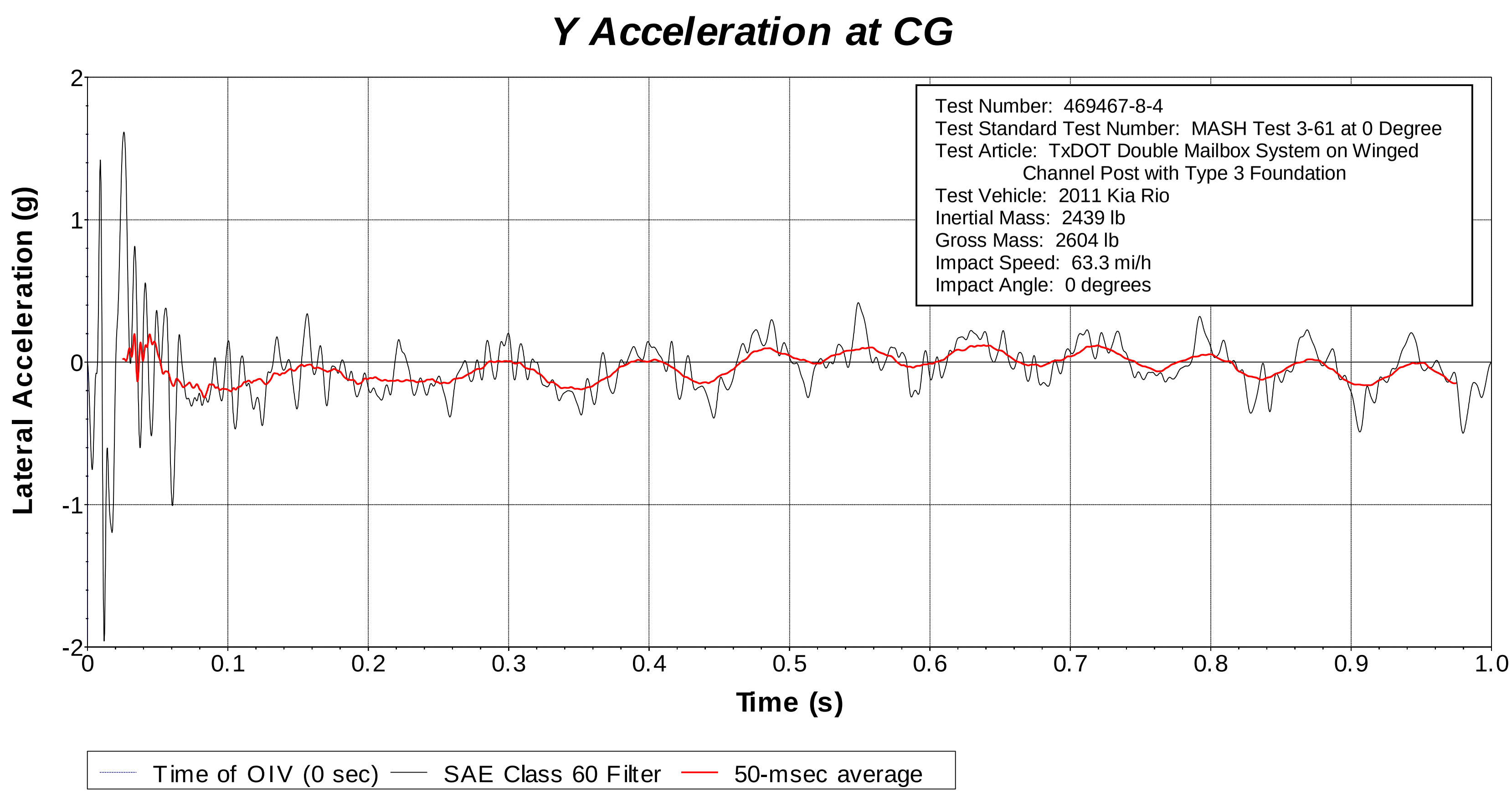


Figure F.4. Vehicle Lateral Accelerometer Trace for Test No. 469467-8-4 (Accelerometer Located at Center of Gravity).

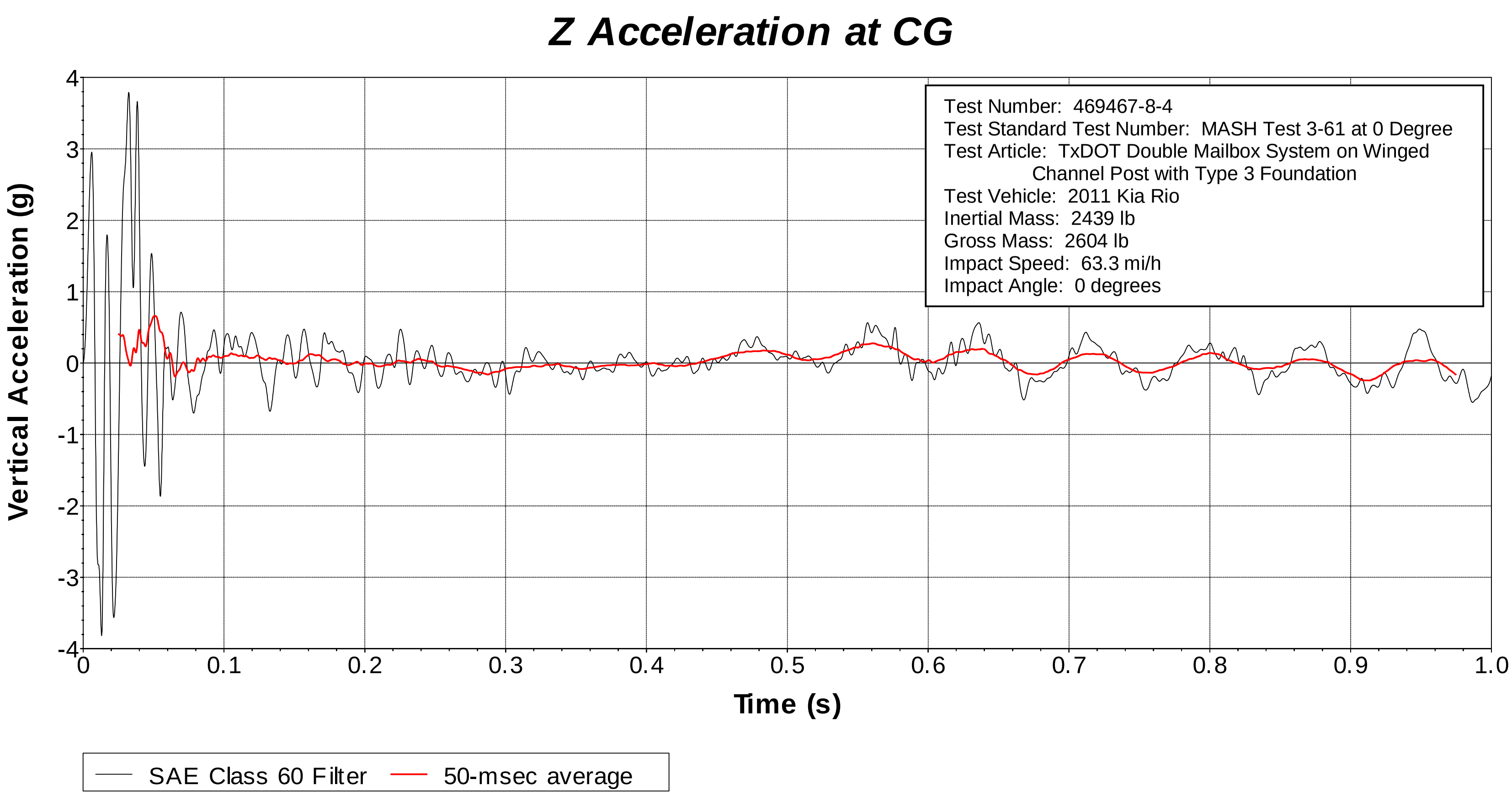


Figure F.5. Vehicle Vertical Accelerometer Trace for Test No. 469467-8-4 (Accelerometer Located at Center of Gravity).

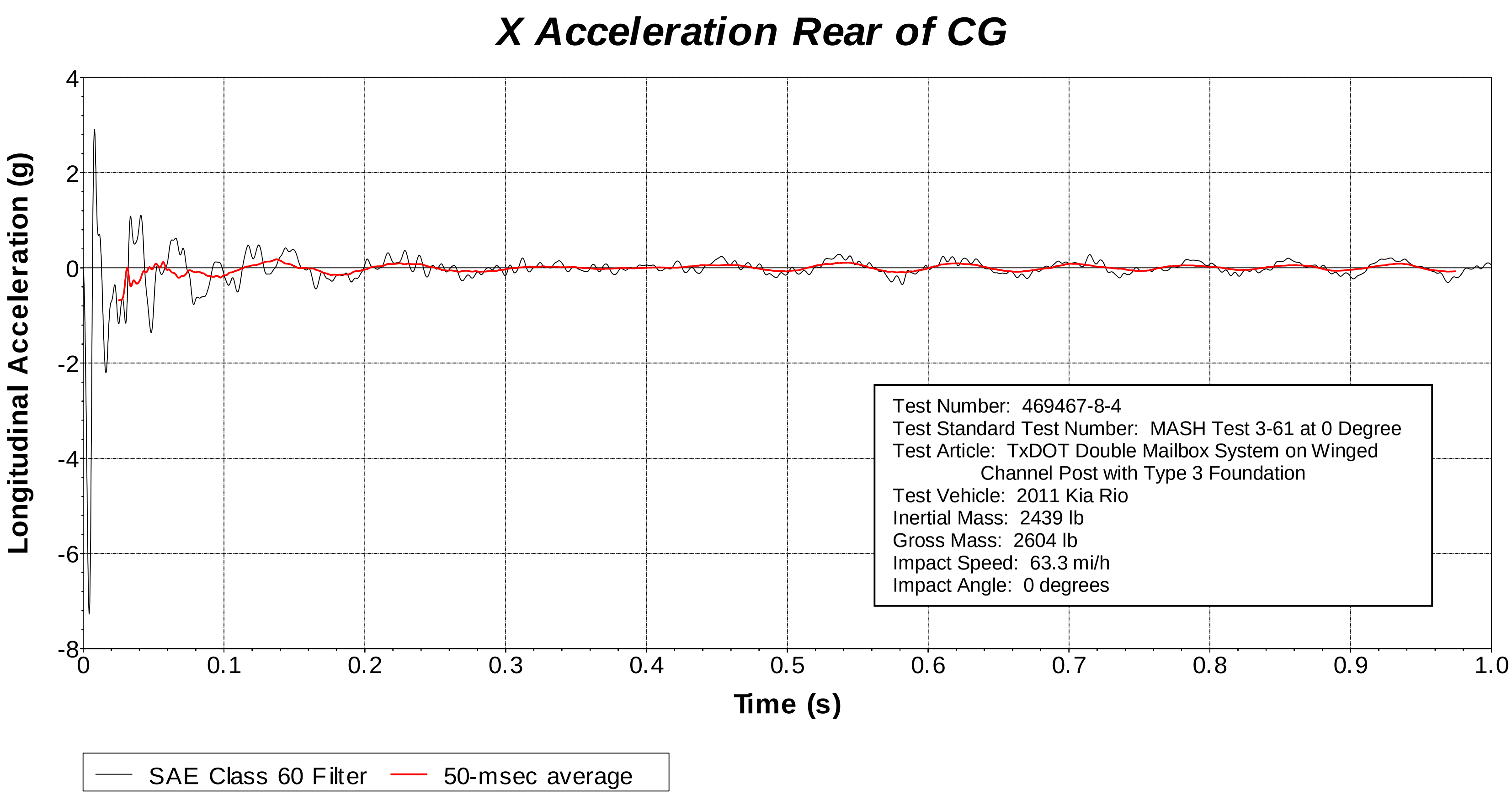


Figure F.6. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-8-4 (Accelerometer Located Rear of Center of Gravity).

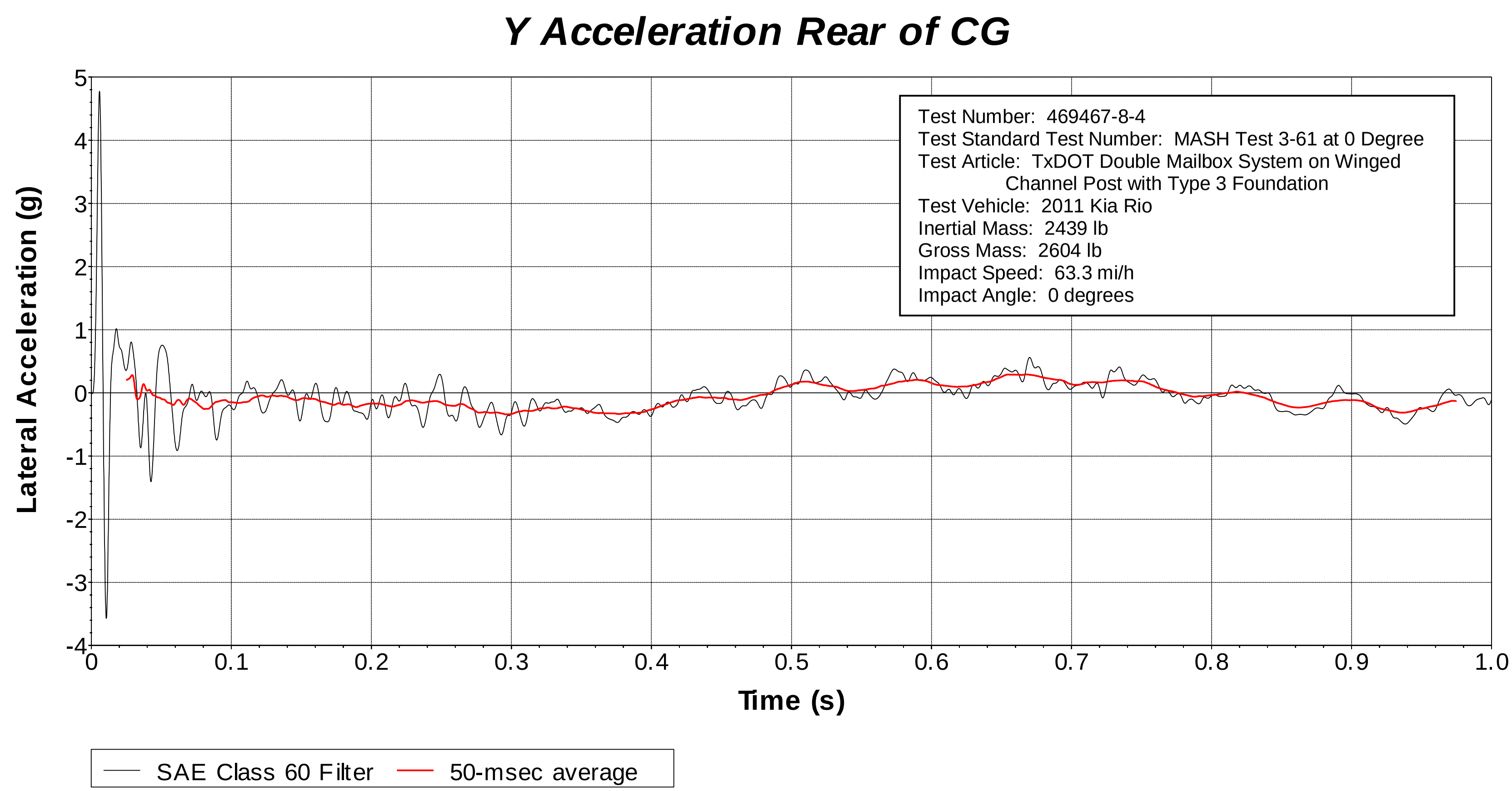


Figure F.7. Vehicle Lateral Accelerometer Trace for Test No. 469467-8-4 (Accelerometer Located Rear of Center of Gravity).

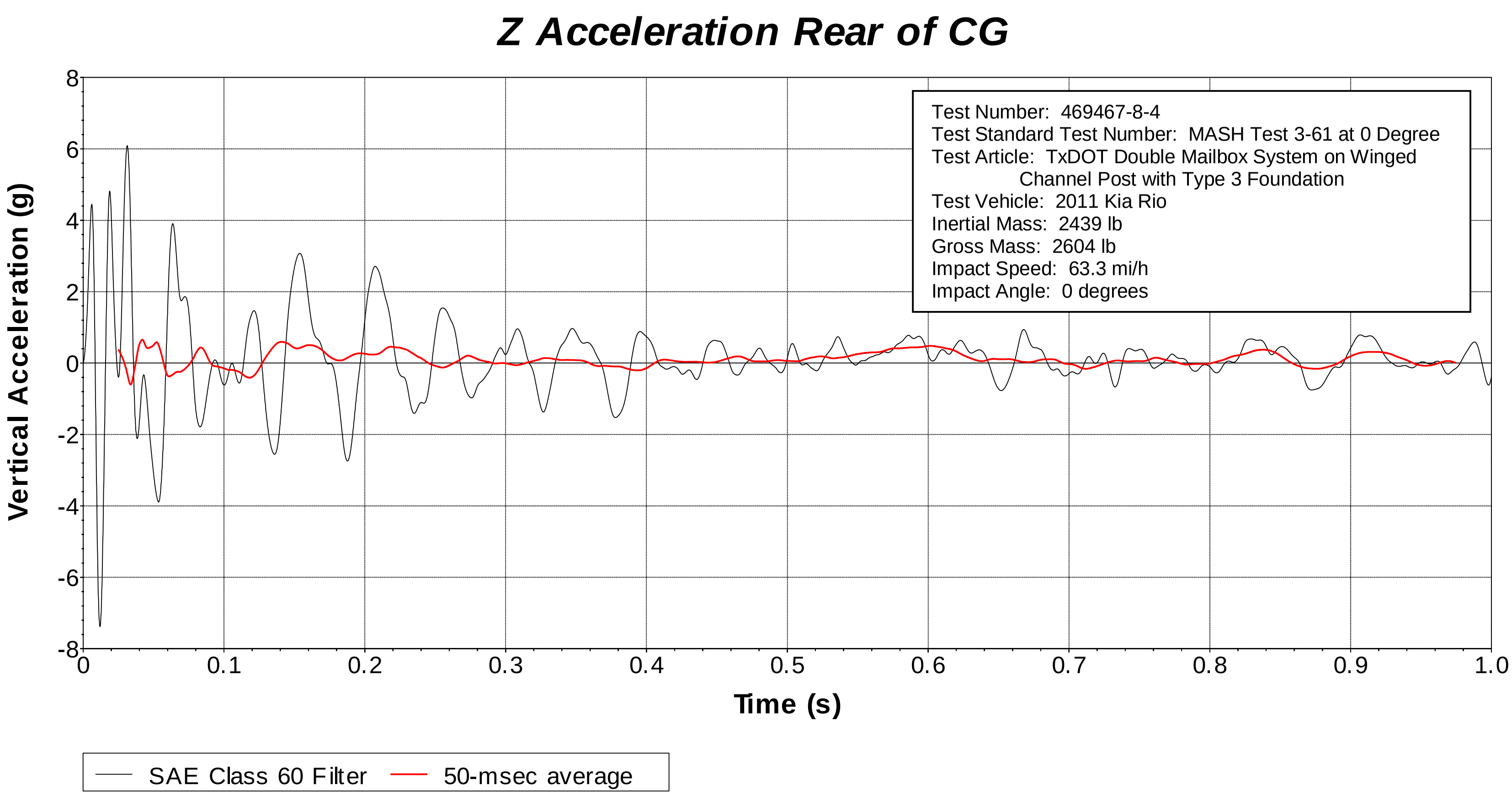


Figure F.8. Vehicle Vertical Accelerometer Trace for Test No. 469467-8-4 (Accelerometer Located Rear of Center of Gravity).

F.2 *MASH* TEST 3-61 AT 0 DEGREES OF DOUBLE MAILBOX SYSTEM ON THIN-WALLED GALVANIZED TUBE WITH TYPE 2 FOUNDATION

Table F.3. Vehicle Properties for Test No. 469467-8-3.

Date: 2017-08-03 Test No.: 469467-8-3 VIN No.: KNADH4A30B6857166

Year: 2011 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 111224 Tire Size: 185/65R14

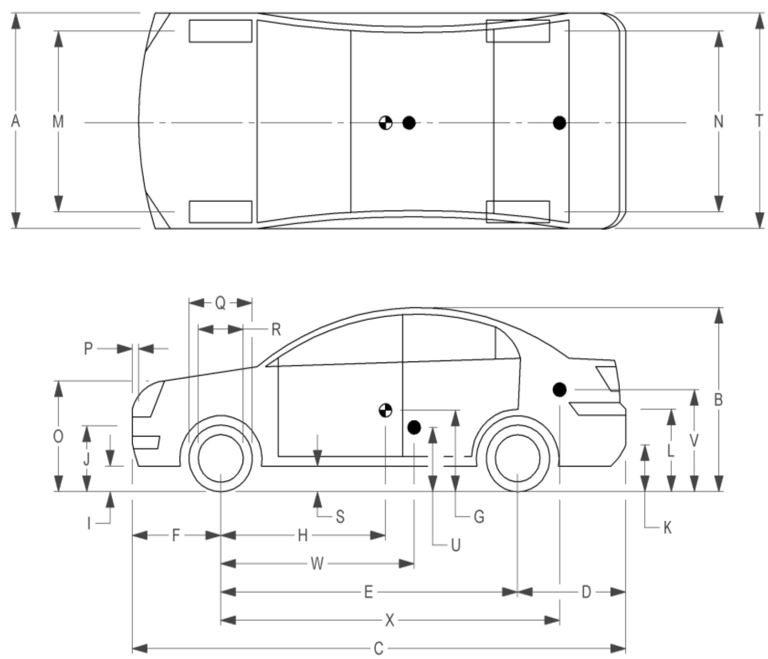
Describe any damage to the vehicle prior to test: Small dents at left qtr pt bumper and hood with hood depression of 1.25 on left side

● Denotes accelerometer location.

NOTES: Previously used in Test No. 469467-8-4

Engine Type: 4 cylinder
Engine CID: 1.6 liter
Transmission Type:
x Auto or ____ Manual
x FWD ____ RWD ____ 4WD
Optional Equipment:
None

Dummy Data:
Type: 50th percentile male
Mass: 165 lb
Seat Position: Front Passenger



Geometry: inches

A	66.385	F	33.00	K	10.50	P	4.12	U	15.25
B	58.00	G	-----	L	24.50	Q	22.50	V	20.50
C	165.75	H	35.22	M	57.75	R	15.50	W	35.00
D	34.00	I	7.75	N	57.75	S	9.00	X	107.00
E	98.75	J	21.00	O	28.00	T	66.25		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00 W-H 0

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1570	1569	1654
Back	1874	M_{rear}	899	870	950
Total	3592	M_{Total}	2469	2439	2604

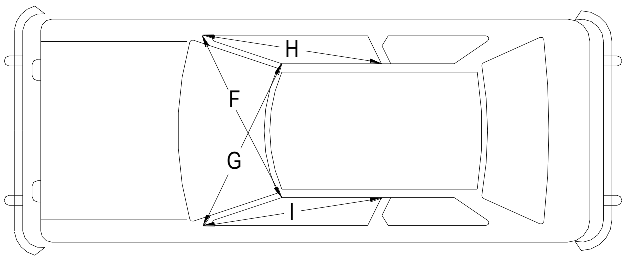
Allowable TIM = 2420 lb ±55 lb | Allowable GSM = 2585 lb ± 55 lb

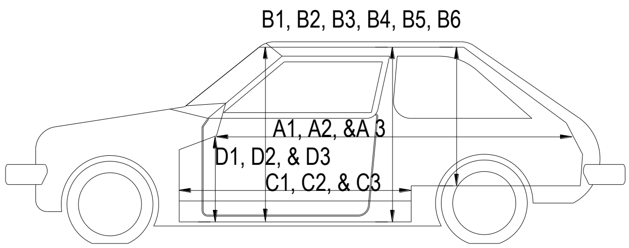
Mass Distribution:
lb LF: 771 RF: 798 LR: 446 RR: 424

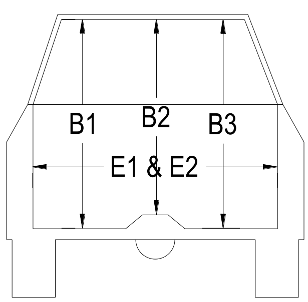
Table F.4. Occupant Compartment Measurements for Test No. 469467-8-3.

Date: 2017-08-03 Test No.: 469467-8-3 VIN No.: KNADH4A30B6857166

Year: 2011 Make: Kia Model: Rio







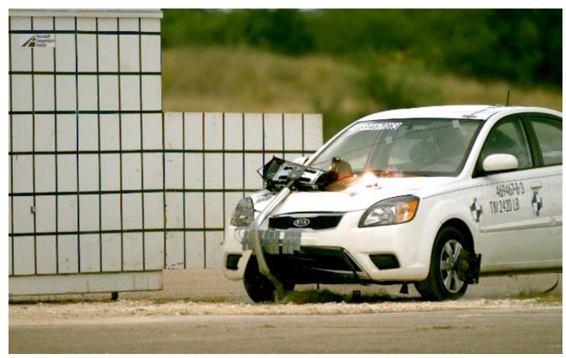
OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	67.50	67.50	0
A2	67.00	67.00	0
A3	67.50	67.50	0
B1	40.50	40.50	0
B2	37.00	37.00	0
B3	40.50	40.50	0
B4	36.25	36.25	0
B5	35.25	35.25	0
B6	36.25	36.25	0
C1	27.75	27.75	0
C2	-----	-----	-
C3	27.00	27.00	0
D1	9.50	9.50	0
D2	-----	-----	-
D3	9.50	9.50	0
E1	51.50	51.50	0
E2	51.00	51.00	0
F	51.00	51.00	0
G	51.00	51.00	0
H	37.25	37.25	0
I	37.25	37.25	0
J*	51.00	51.00	0

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

0.000 s

0.025 s



0.050 s

0.075 s

Figure F.9. Sequential Photographs for Test No. 469467-8-3 (Perpendicular and Oblique Views).

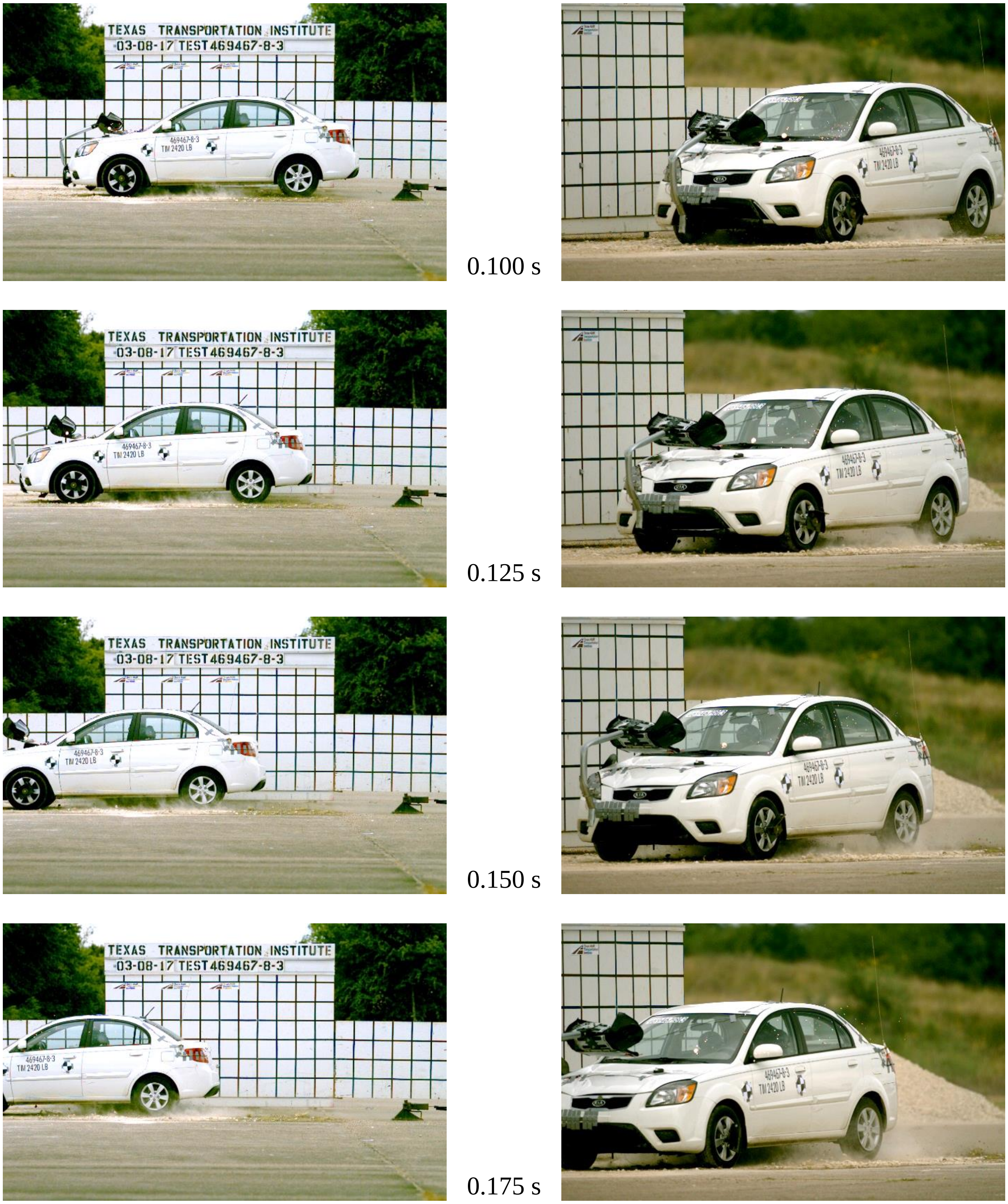


Figure F.9. Sequential Photographs for Test No. 469467-8-3 (Perpendicular and Oblique Views) (Continued).

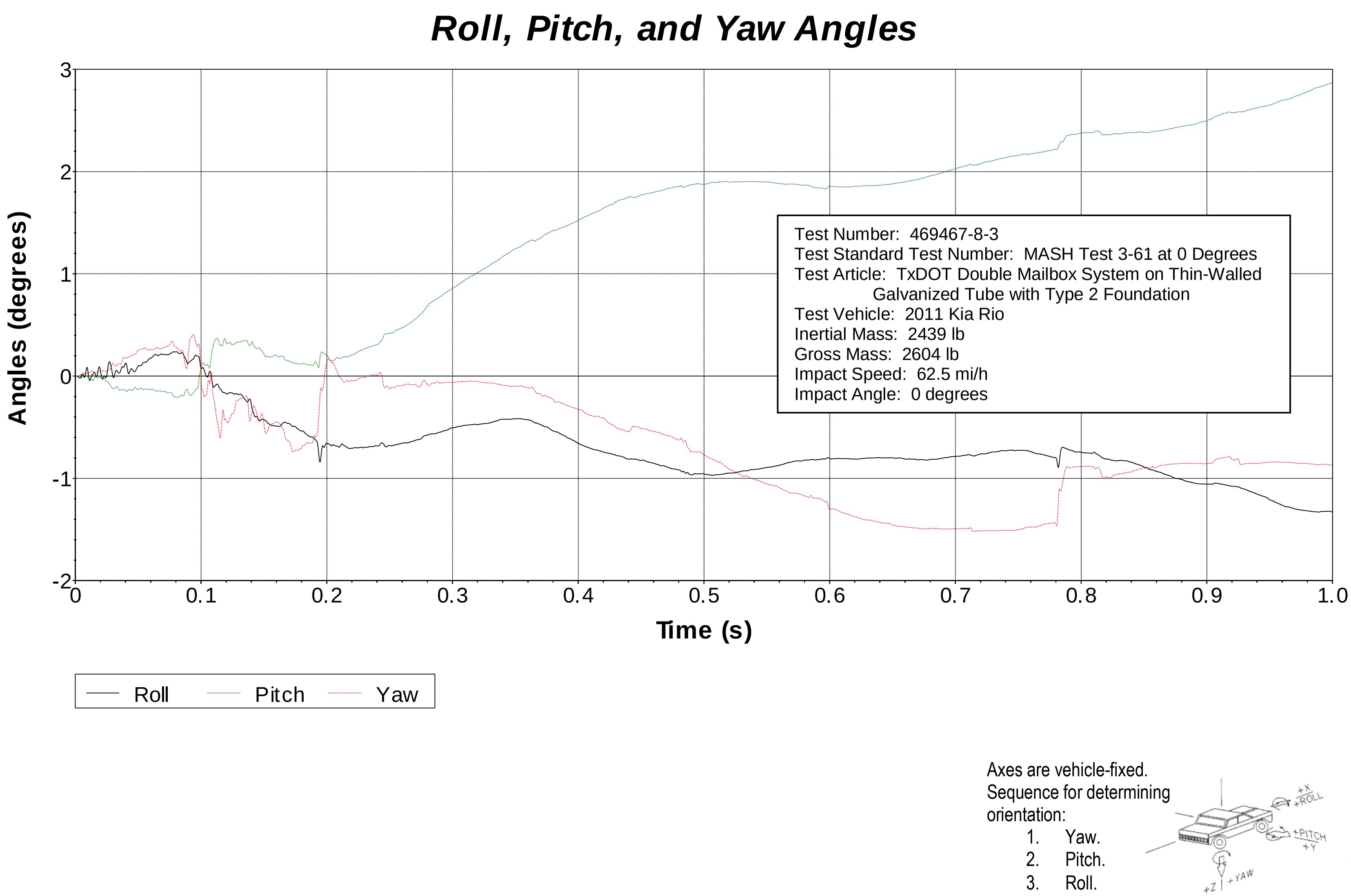


Figure F.10. Vehicle Angular Displacements for Test No. 469467-8-3.

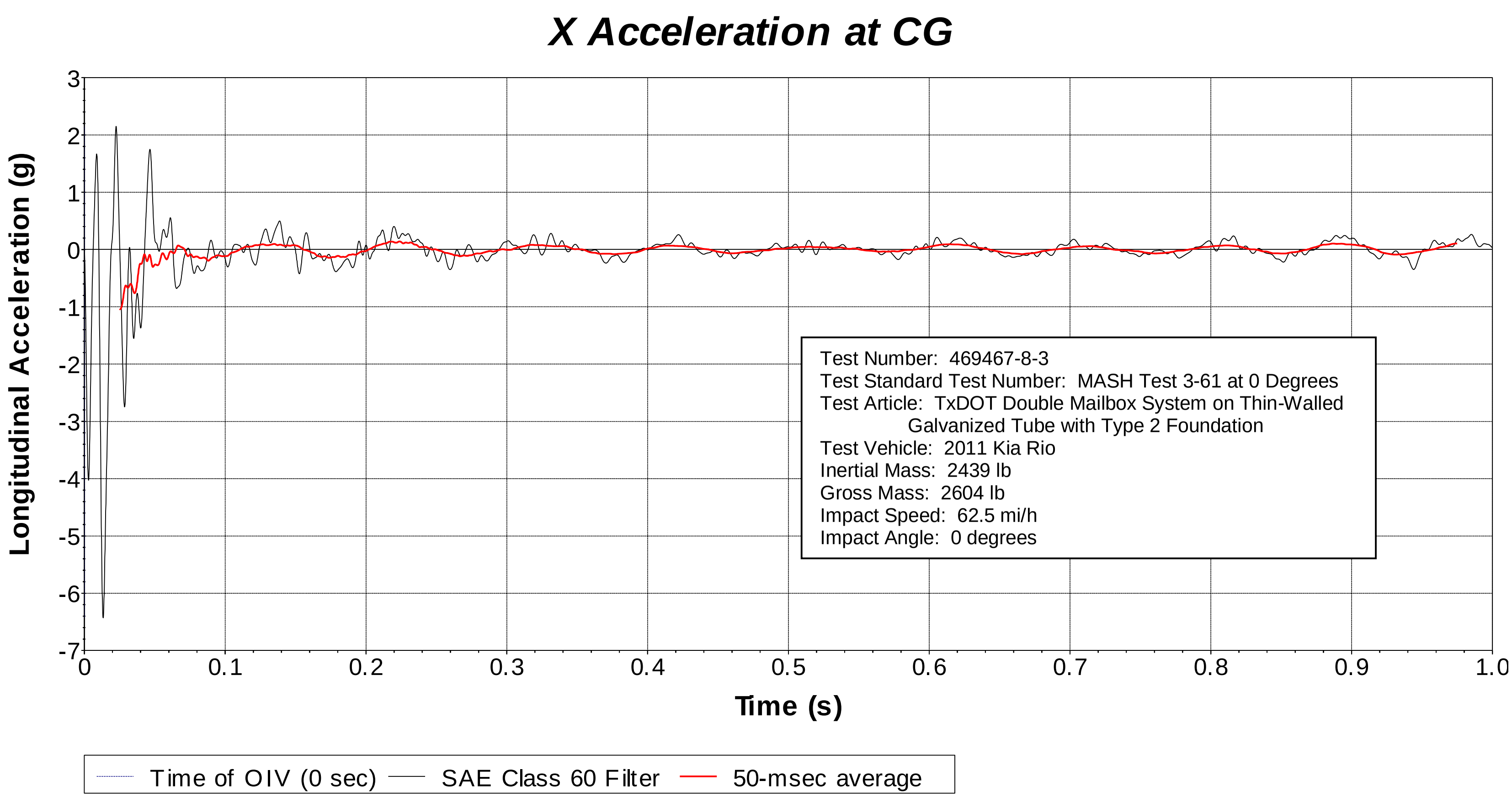


Figure F.11. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-8-3 (Accelerometer Located at Center of Gravity).

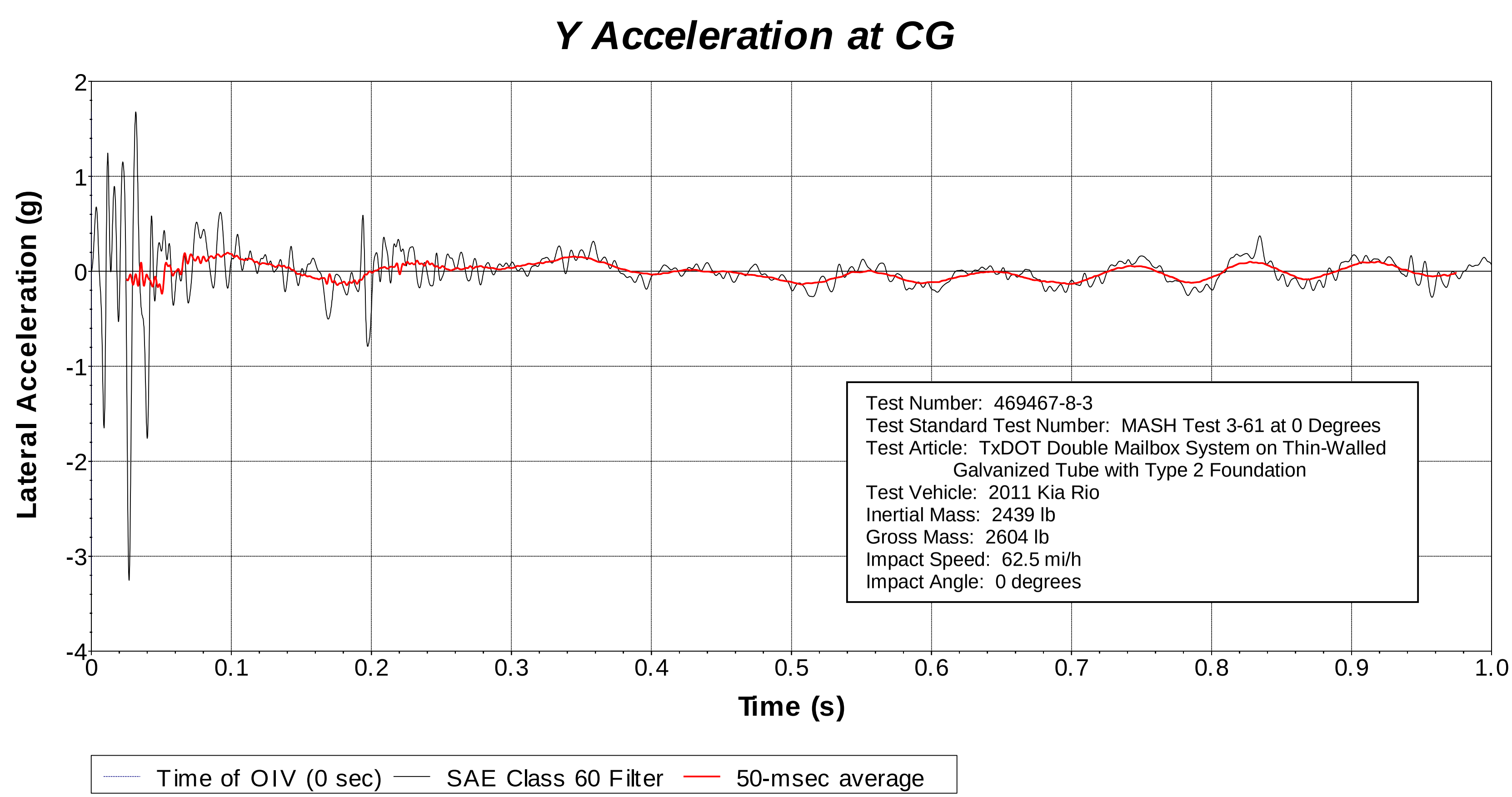


Figure F.12. Vehicle Lateral Accelerometer Trace for Test No. 469467-8-3 (Accelerometer Located at Center of Gravity).

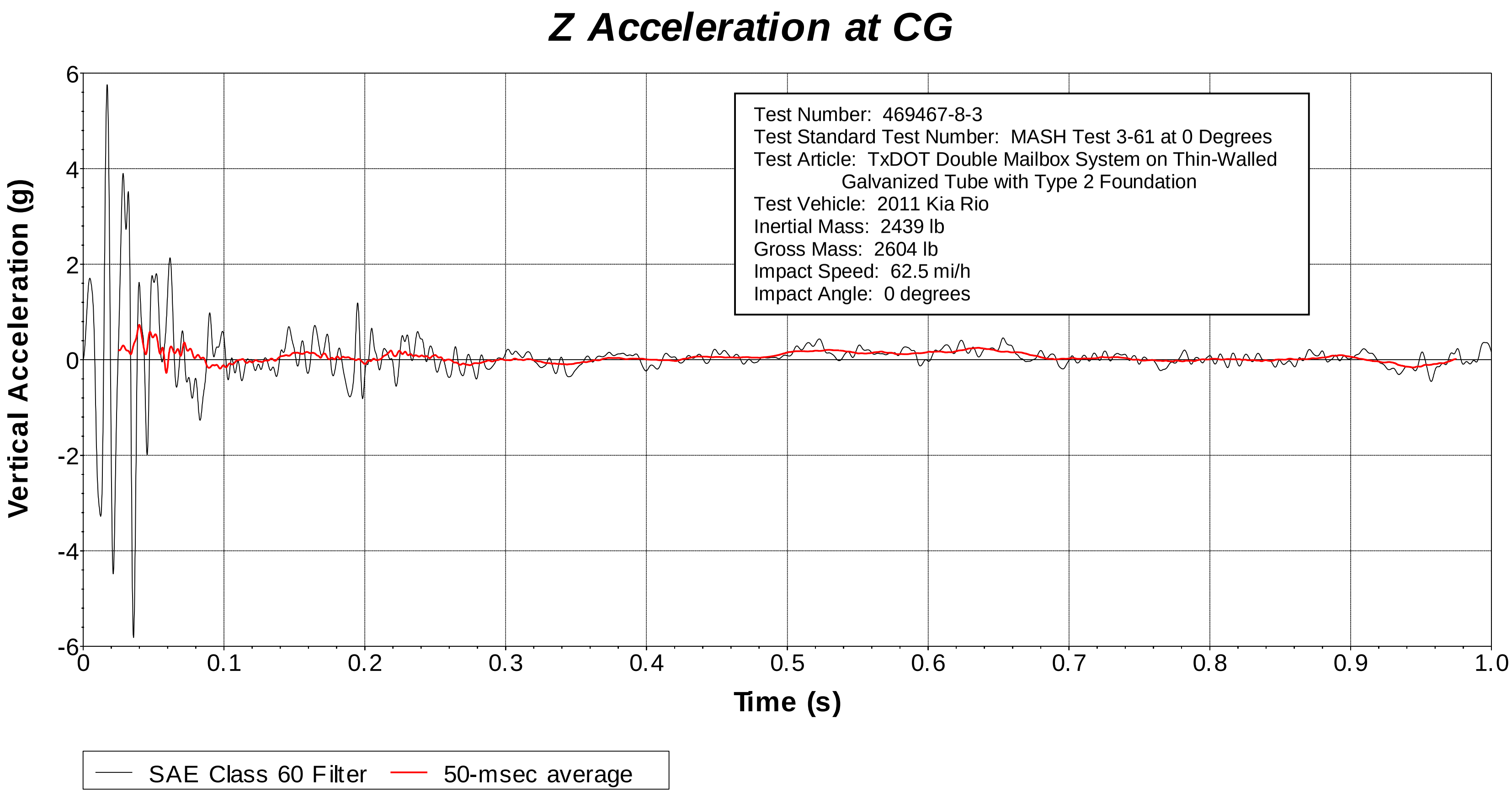


Figure F.13. Vehicle Vertical Accelerometer Trace for Test No. 469467-8-3 (Accelerometer Located at Center of Gravity).

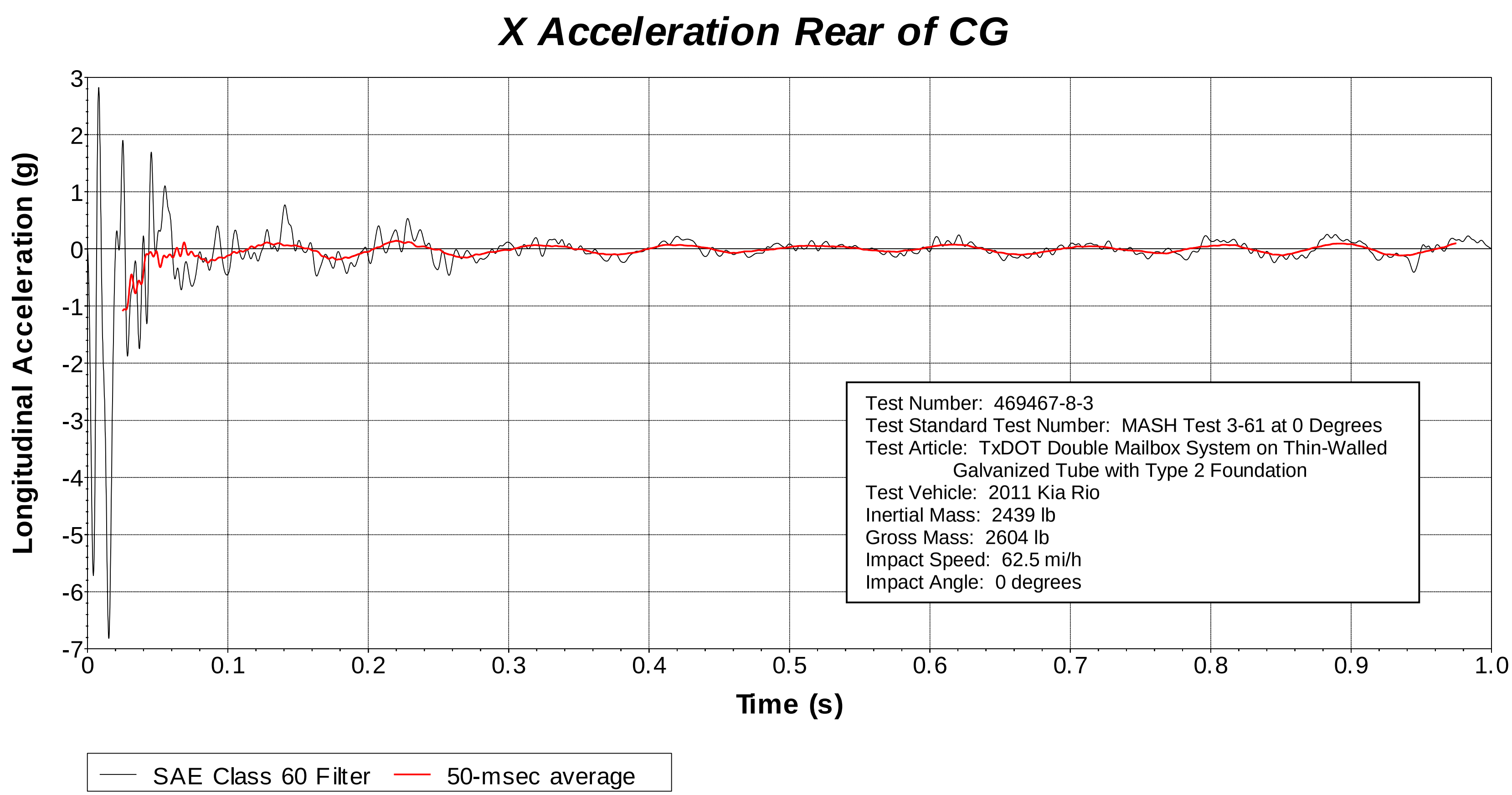


Figure F.14. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-8-3 (Accelerometer Located Rear of Center of Gravity).

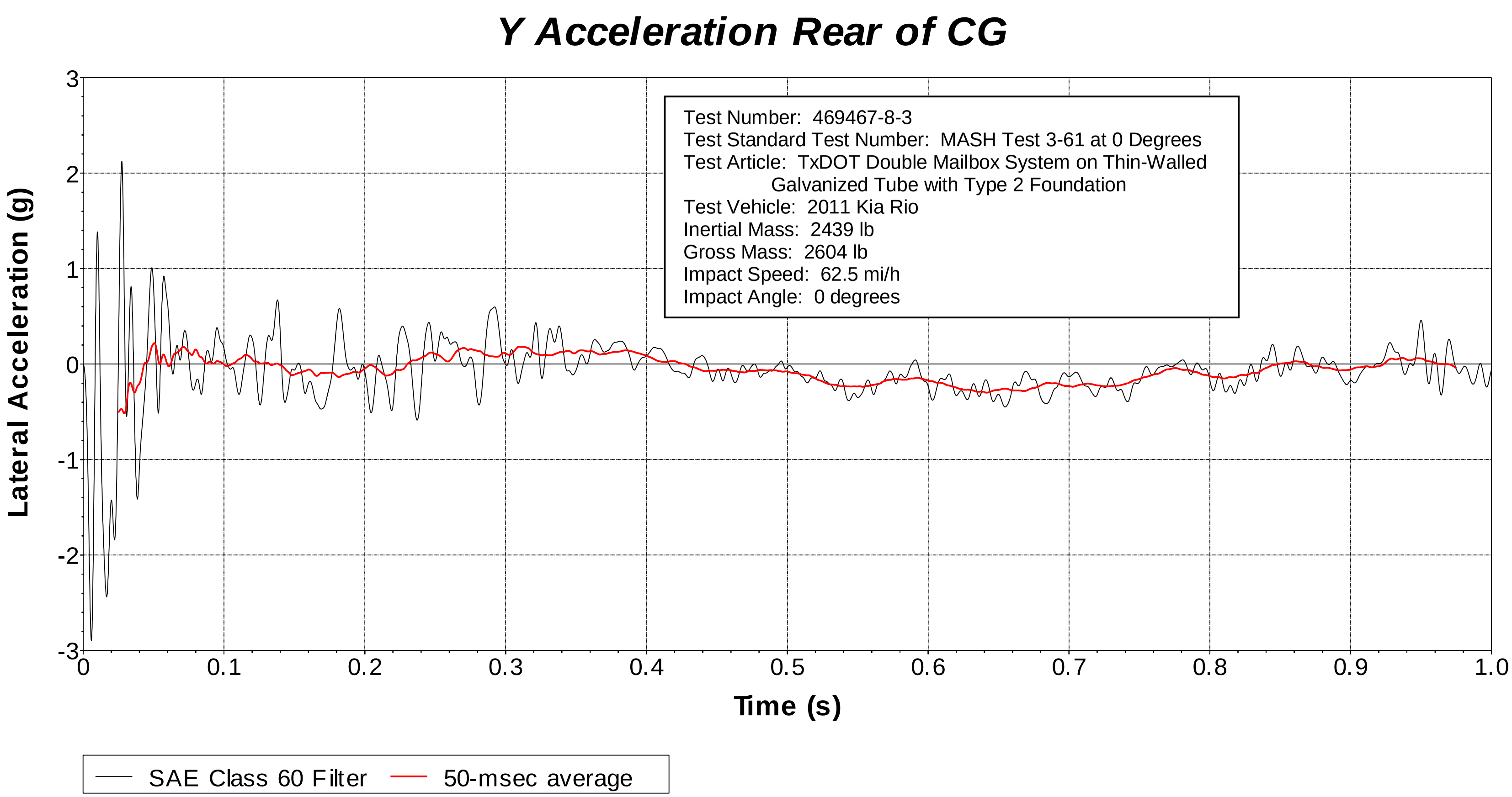


Figure F.15. Vehicle Lateral Accelerometer Trace for Test No. 469467-8-3 (Accelerometer Located Rear of Center of Gravity).

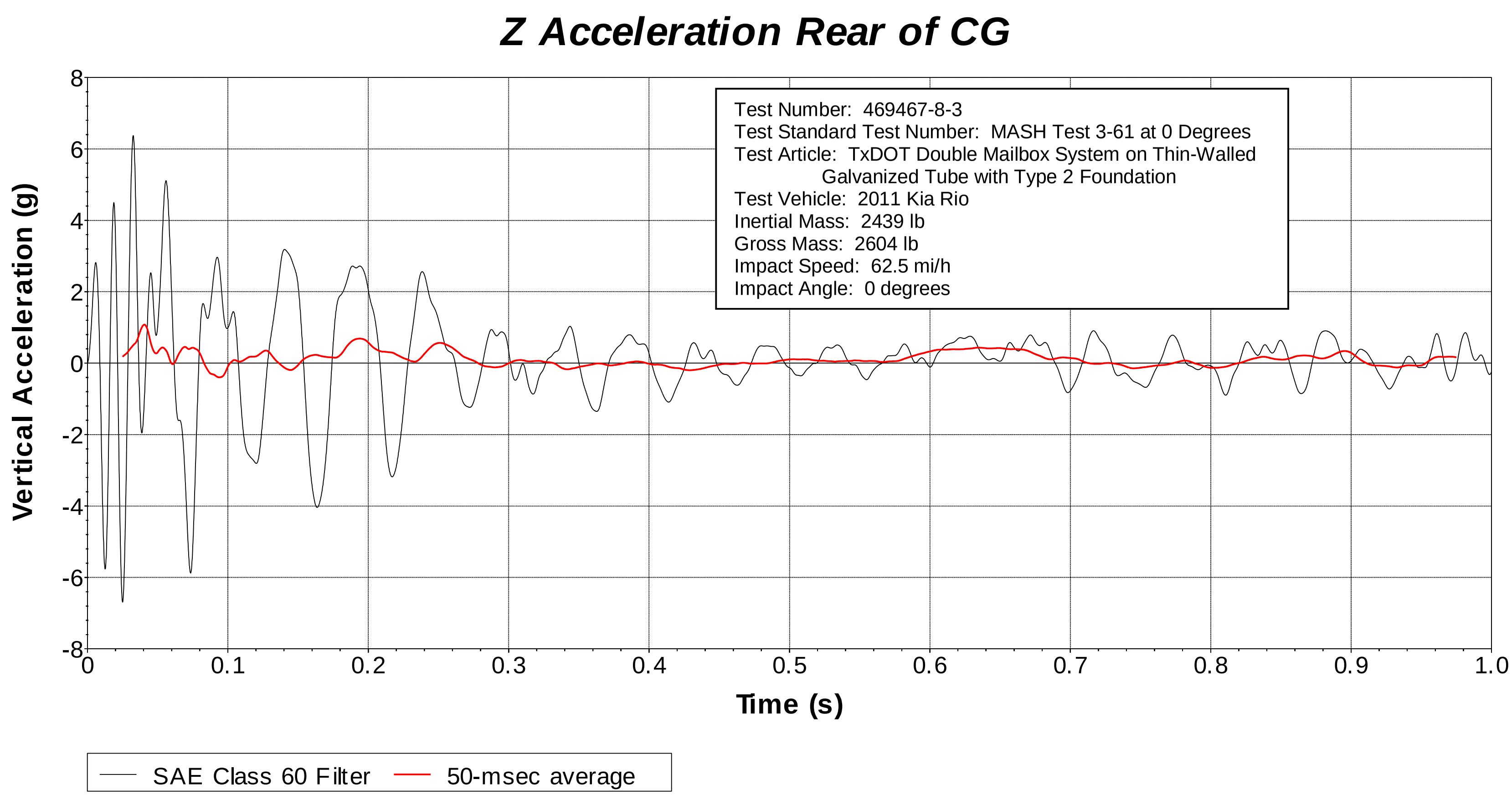


Figure F.16. Vehicle Vertical Accelerometer Trace for Test No. 469467-8-3 (Accelerometer Located Rear of Center of Gravity).

F.3 MASH TEST 3-61 AT 0 DEGREES OF MULTIPLE MAILBOXES ON 56-INCH HANGER-TYPE THIN-WALLED GALVANIZED TUBE WITH TYPE 1 FOUNDATION

Table F.5. Vehicle Properties for Test No. 469467-8-2.

Date: 2017-08-03 Test No.: 469467-8-2 VIN No.: KNADH4A30B6857166

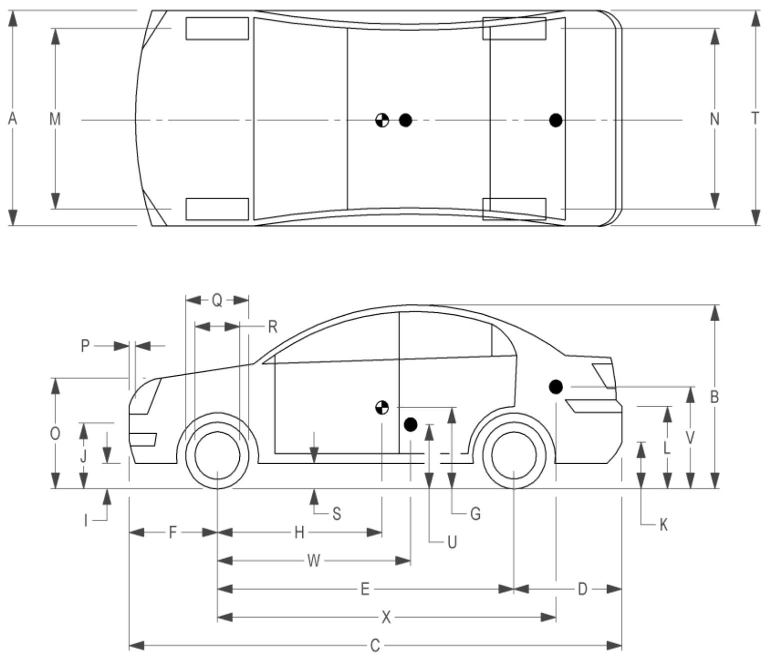
Year: 2011 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 111224 Tire Size: 185/65R14

Describe any damage to the vehicle prior to test: Two very small dents at the right and left qtr points. Hood was replaced

● Denotes accelerometer location.

NOTES: Previously used in Test No. 469467-8-4 and 8-3



Engine Type: 4 cylinder
Engine CID: 1.6 liter
Transmission Type:
x Auto or ____ Manual
x FWD ____ RWD ____ 4WD
Optional Equipment:
None

Dummy Data:
Type: 50th percentile male
Mass: 165 lb
Seat Position: Front Passenger

Geometry: inches

A	66.385	F	33.00	K	10.50	P	4.12	U	15.25
B	58.00	G	-----	L	24.50	Q	22.50	V	20.50
C	165.75	H	35.22	M	57.75	R	15.50	W	35.00
D	34.00	I	7.75	N	57.75	S	9.00	X	107.00
E	98.75	J	21.00	O	28.00	T	66.25		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00 W-H 0

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1570	1569	1654
Back	1874	M_{rear}	899	870	950
Total	3592	M_{Total}	2469	2439	2604

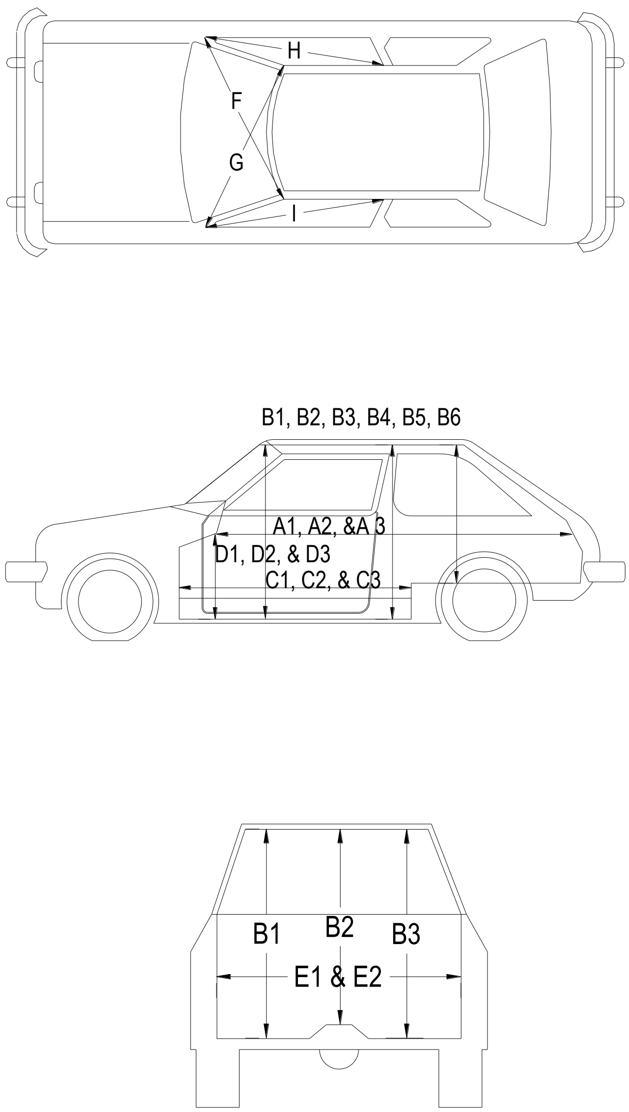
Allowable TIM = 2420 lb ±55 lb | Allowable GSM = 2585 lb ± 55 lb

Mass Distribution:
lb LF: 771 RF: 798 LR: 446 RR: 424

Table F.6. Occupant Compartment Measurements for Test No. 469467-8-3.

Date: 2017-08-03 Test No.: 469467-8-3 VIN No.: KNADH4A30B6857166

Year: 2011 Make: Kia Model: Rio

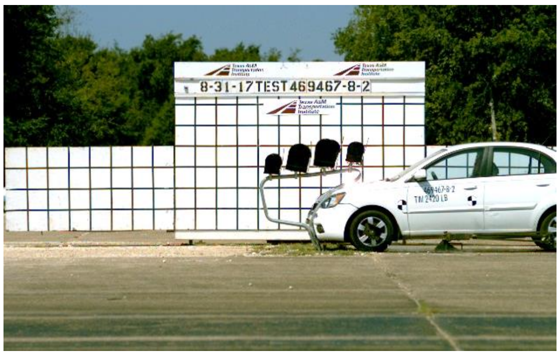


OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

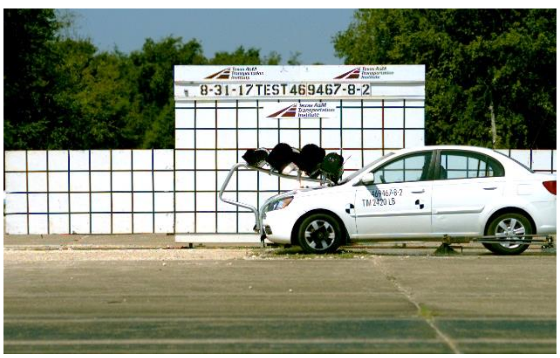
	Before	After (inches)	Differ.
A1	67.50	67.50	0
A2	67.00	67.00	0
A3	67.50	67.50	0
B1	40.50	40.50	0
B2	37.00	37.00	0
B3	40.50	40.50	0
B4	36.25	36.25	0
B5	35.25	35.25	0
B6	36.25	36.25	0
C1	27.75	27.75	0
C2	-----	-----	-
C3	27.00	27.00	0
D1	9.50	9.50	0
D2	-----	-----	-
D3	9.50	9.50	0
E1	51.50	51.50	0
E2	51.00	51.00	0
F	51.00	51.00	0
G	51.00	51.00	0
H	37.25	37.25	0
I	37.25	37.25	0
J*	51.00	51.00	0

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

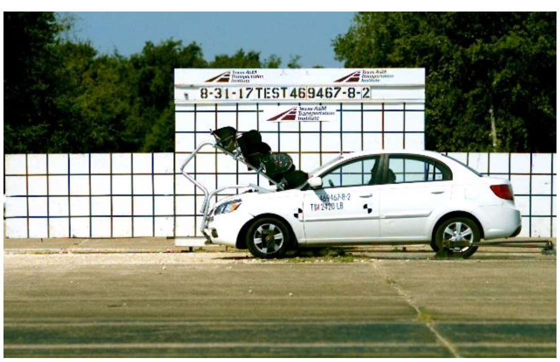
0.000 s



0.025 s

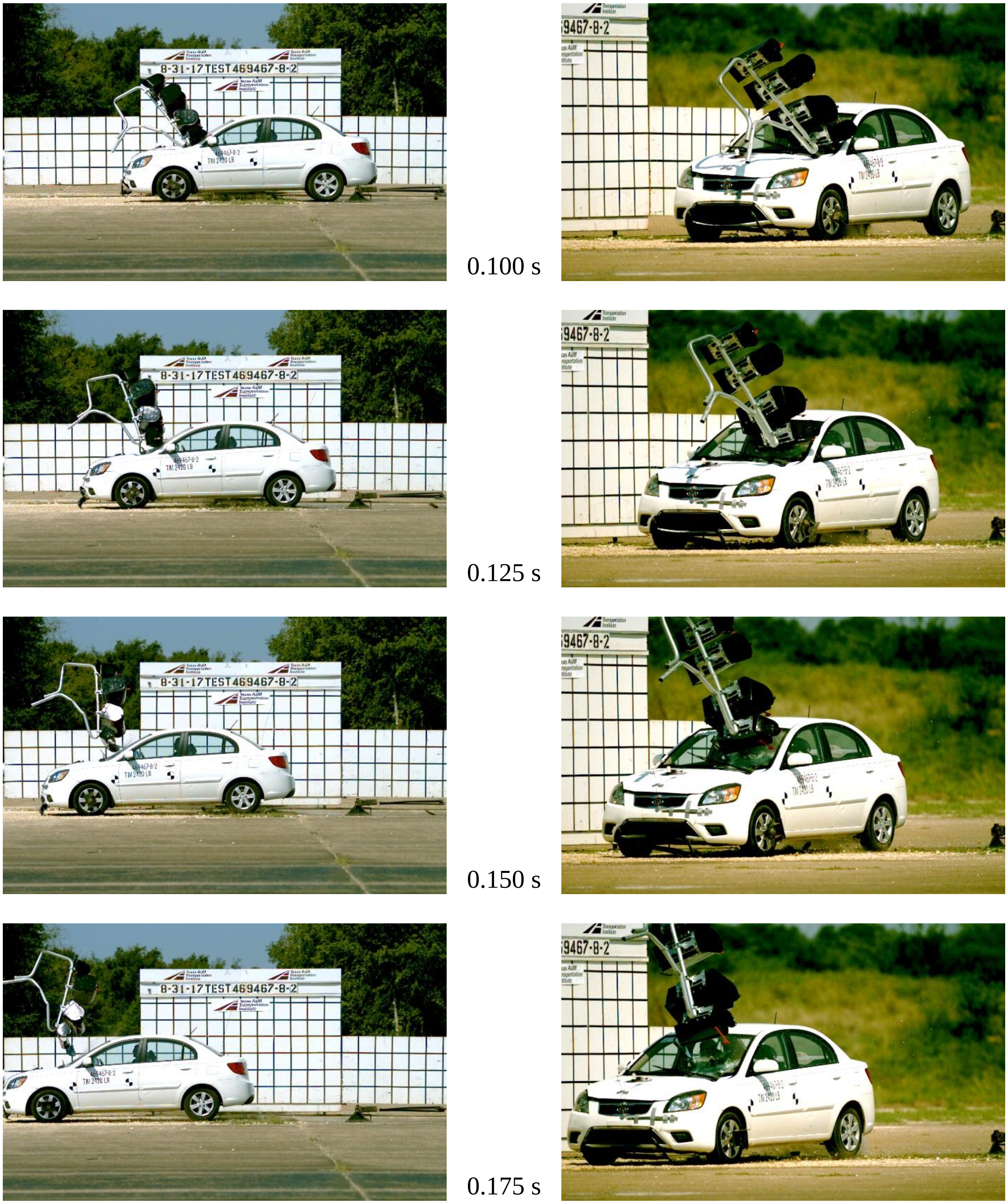


0.050 s



0.075 s

Figure F.9. Sequential Photographs for Test No. 469467-8-2 (Perpendicular and Oblique Views).



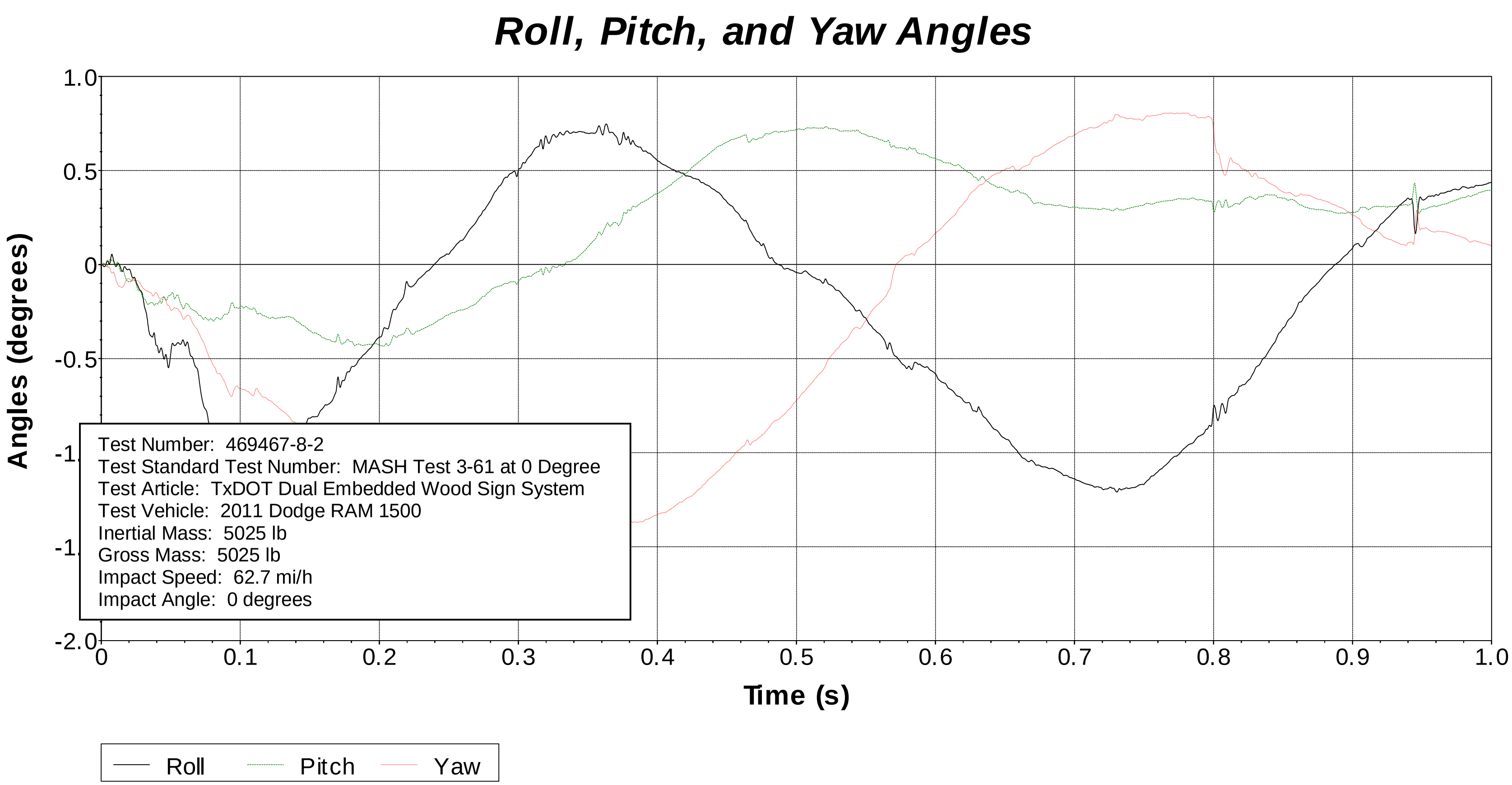
0.100 s

0.125 s

0.150 s

0.175 s

Figure F.9. Sequential Photographs for Test No. 469467-8-2 (Perpendicular and Oblique Views) (Continued).



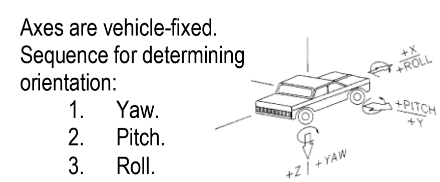


Figure F.18. Vehicle Angular Displacements for Test No. 469467-8-2.

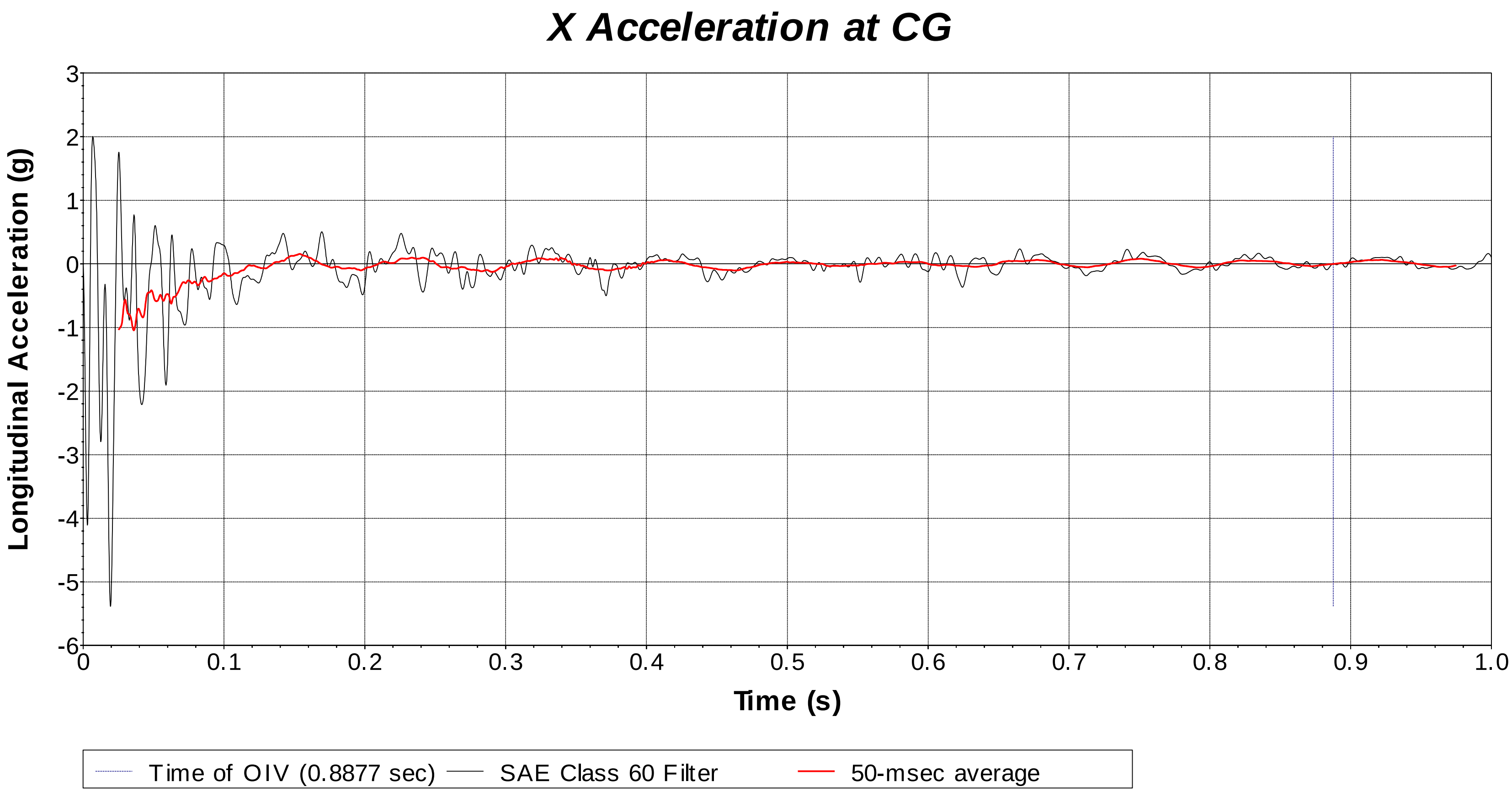


Figure F.19. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-8-2 (Accelerometer Located at Center of Gravity).

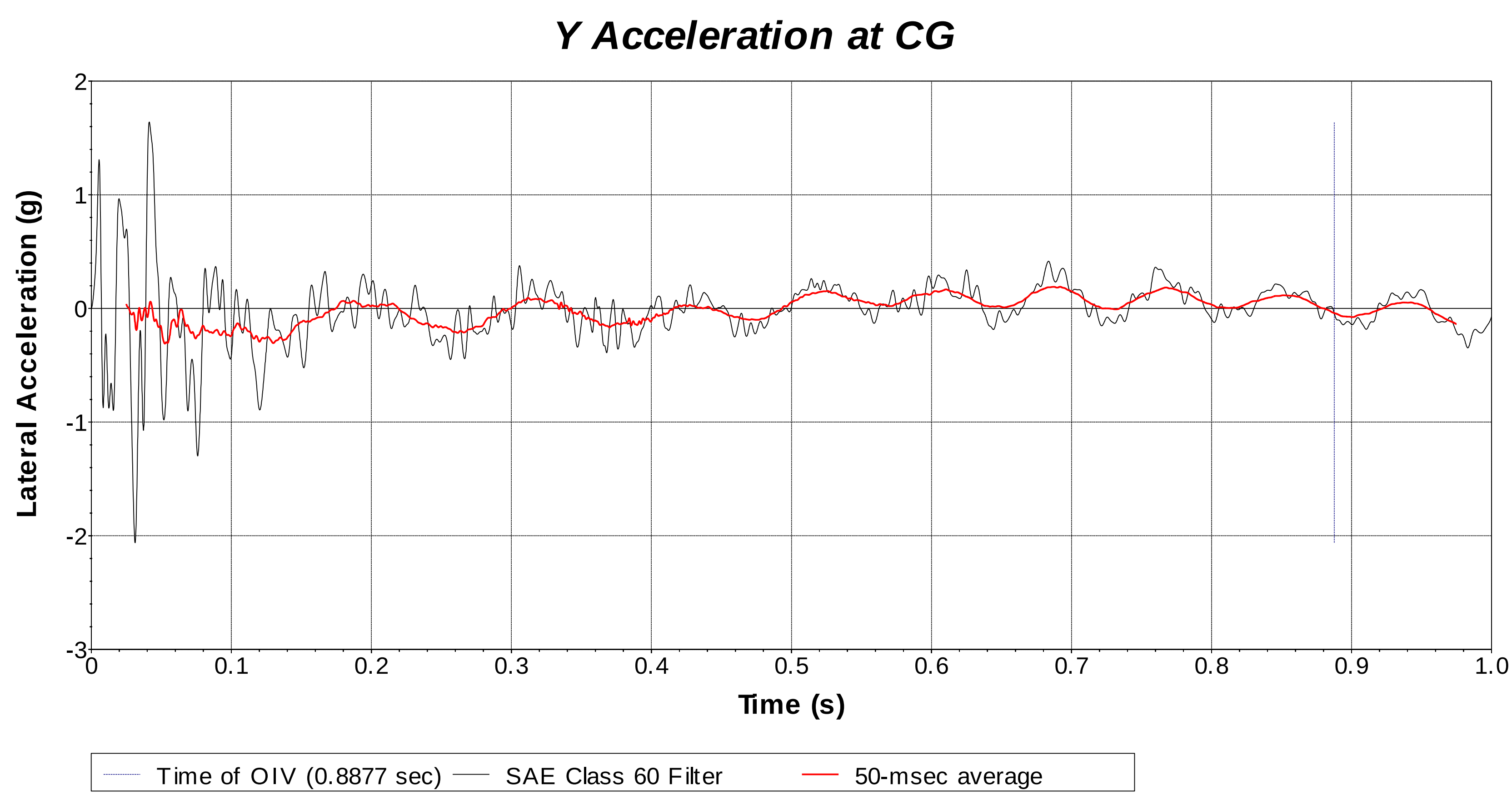


Figure F.20. Vehicle Lateral Accelerometer Trace for Test No. 469467-8-2 (Accelerometer Located at Center of Gravity).

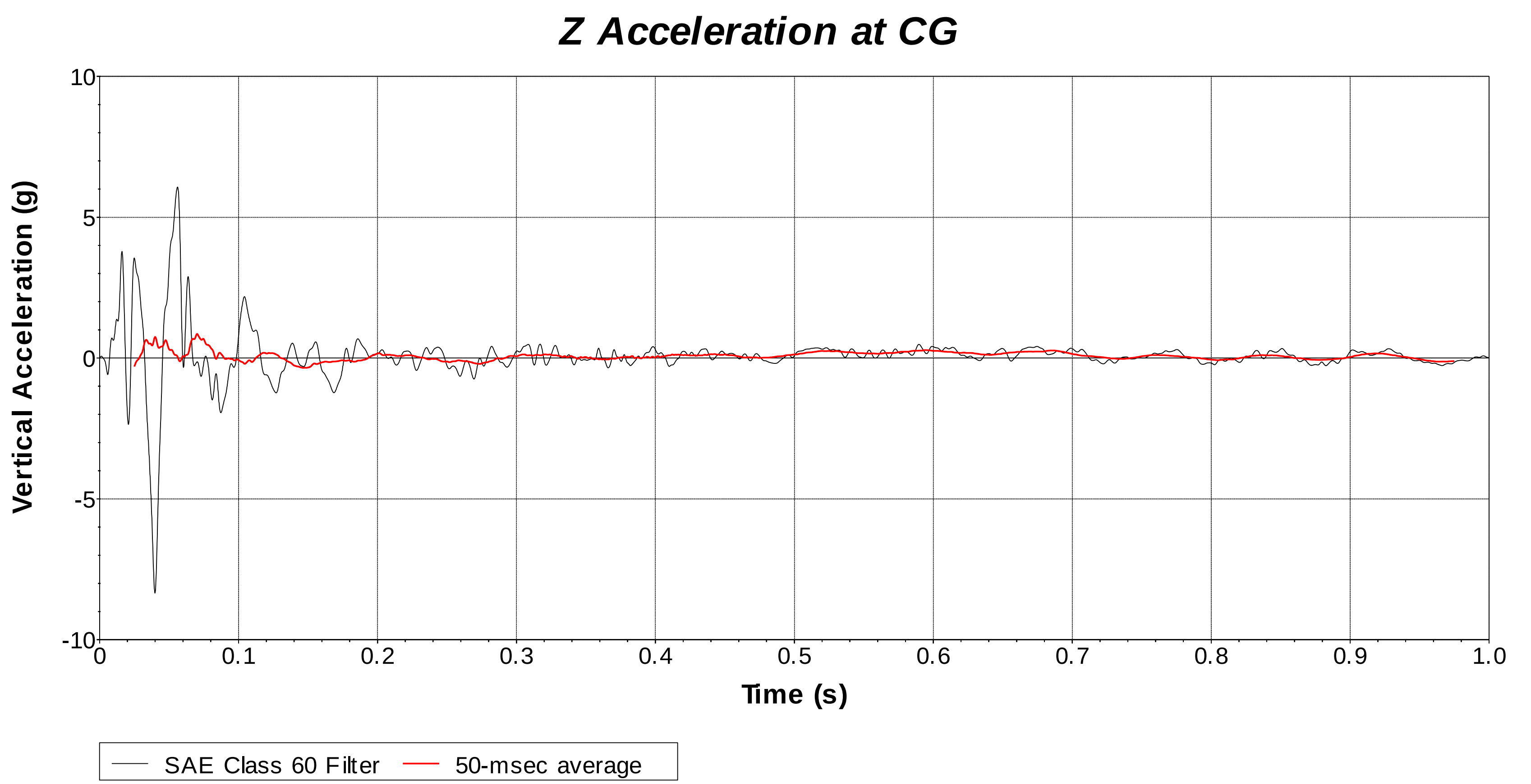


Figure F.21. Vehicle Vertical Accelerometer Trace for Test No. 469467-8-2 (Accelerometer Located at Center of Gravity).

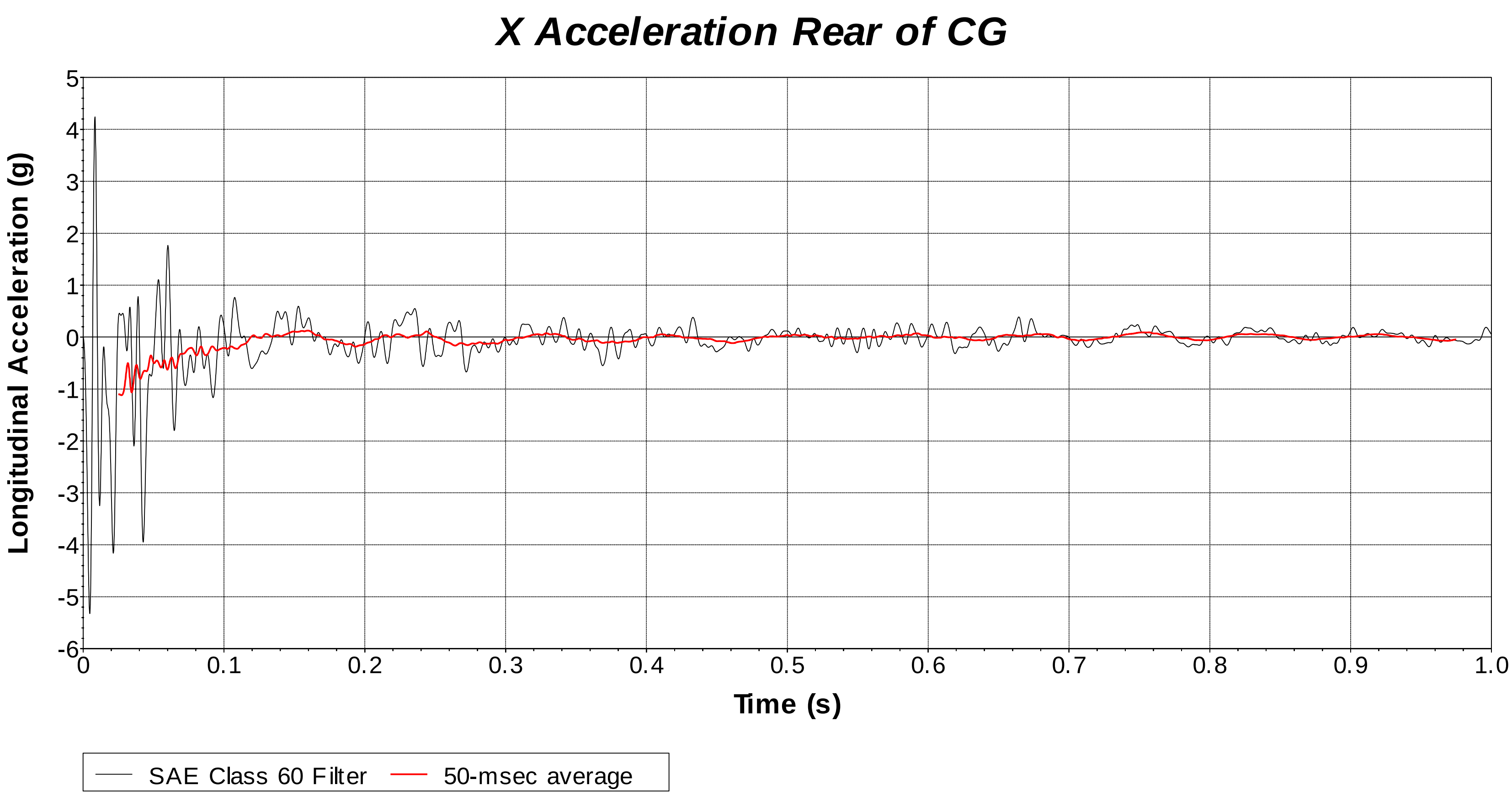


Figure F.22. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-8-2 (Accelerometer Located Rear of Center of Gravity).

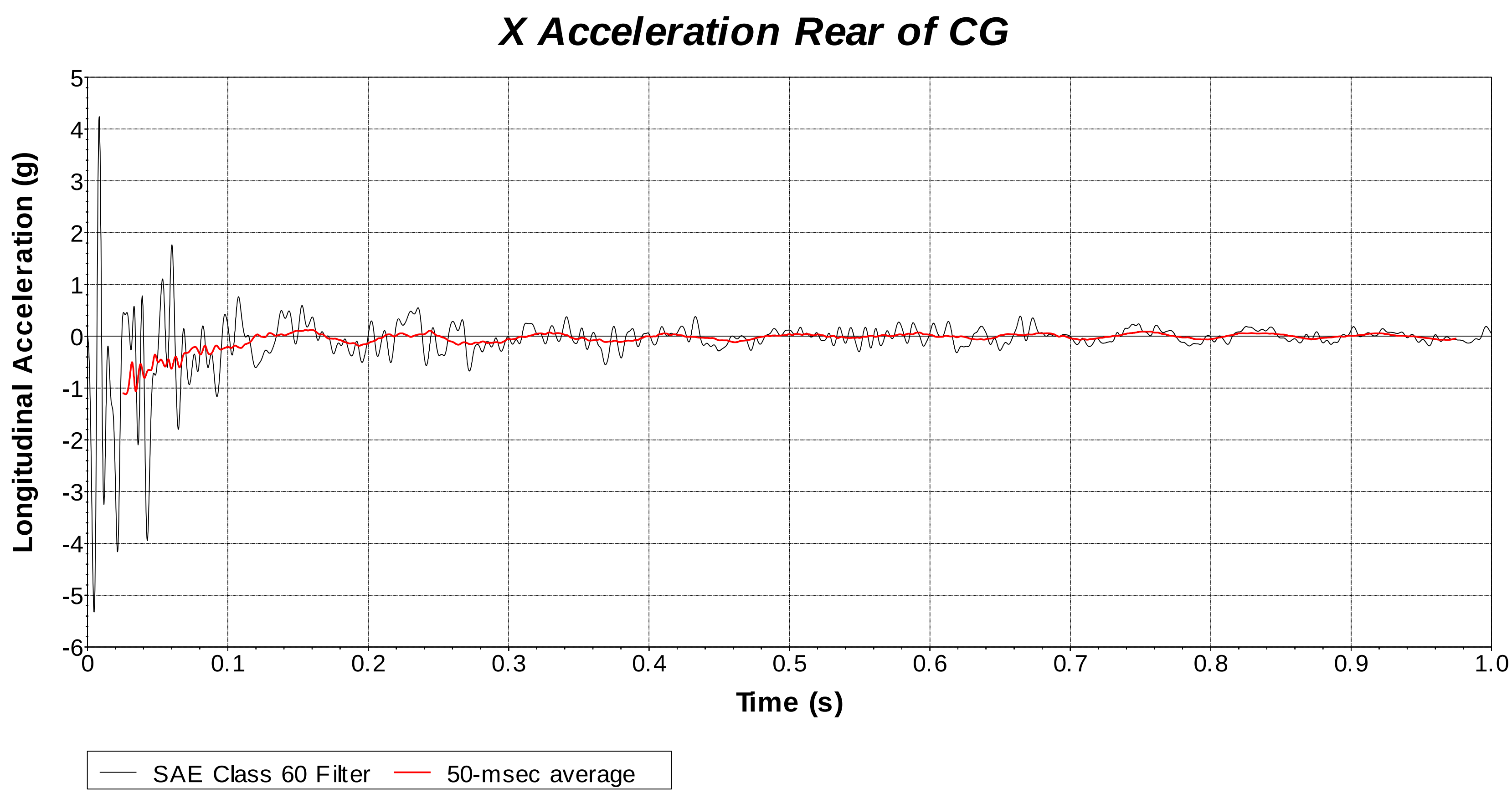


Figure F.23. Vehicle Lateral Accelerometer Trace for Test No. 469467-8-2 (Accelerometer Located Rear of Center of Gravity).

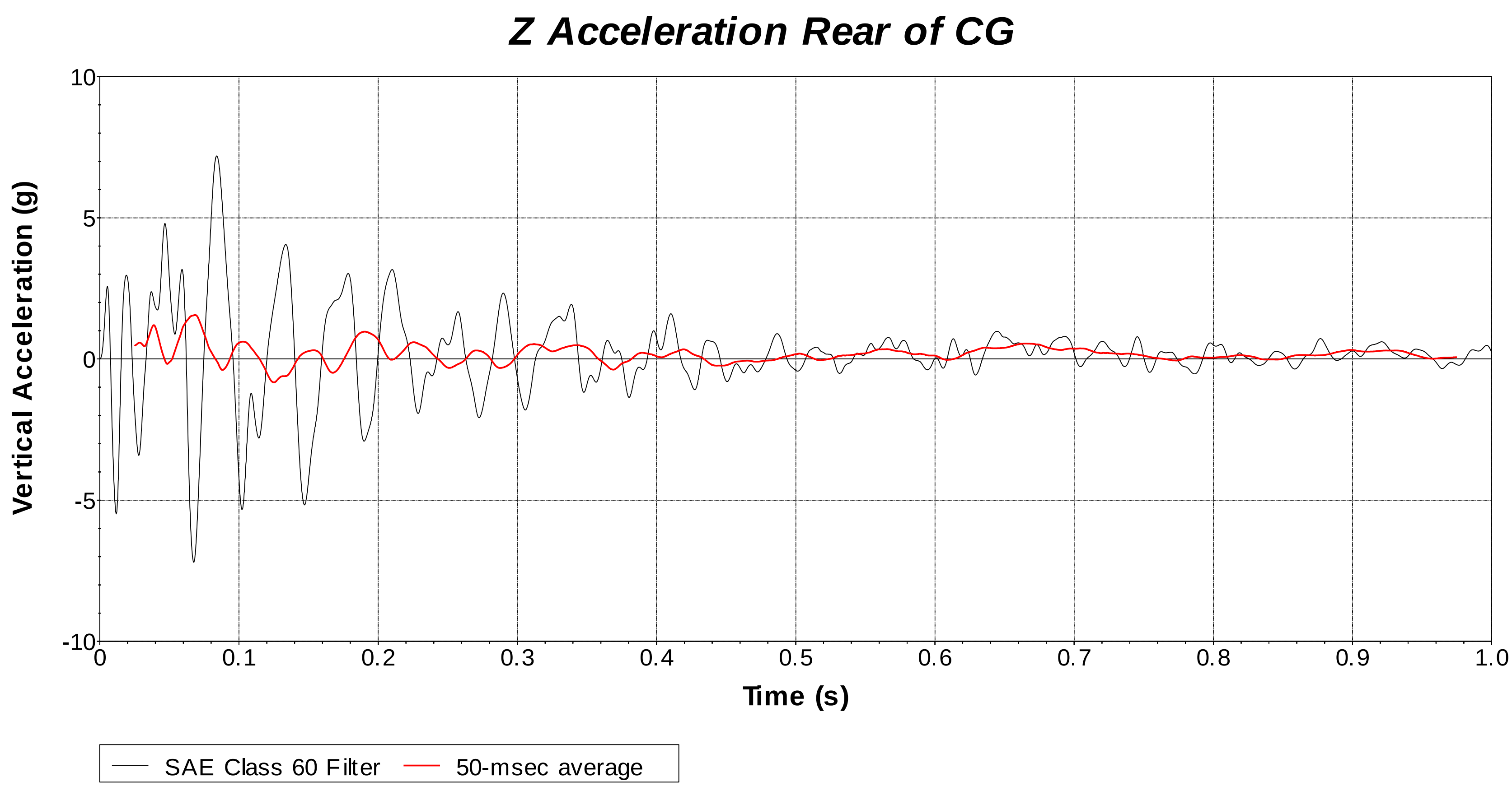


Figure F.24. Vehicle Vertical Accelerometer Trace for Test No. 469467-8-2 (Accelerometer Located Rear of Center of Gravity).