TTI: 0-6946-R3

Texas A&M Transportation Institute

MASH EVALUATION OF TxDOT ROADSIDE SAFETY FEATURES— PHASE III

Test Report 0-6946-R3

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
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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. A *MASH* implementation agreement was jointly developed and adopted by the Federal Highway Administration and AASHTO. It establishes implementation dates for different categories of roadside safety features.

Texas Department of Transportation 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, roadside safety systems used in Texas will be crash-tested in accordance with *MASH* criteria in three phases over a 3-year period.

A total of 10 devices were tested and evaluated during Phase I. In Phase II, an additional 14 devices were tested and evaluated. In Phase III, which is the subject of this report, an additional 14 devices were tested and evaluated.

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

17. Key Words	18. Distribution Statement
Bridge Rail, Low-Profile Barrier, Guardrail, F-Shape Barrier, Transition, Sign Support, Mailbox, Skid-Mounted, Mow Strip, Round Posts, Wood Posts, Steel Posts, Type III Barricade, Crash Test, *MASH*, Roadside Safety	No restrictions. This document is available to the public through NTIS: National Technical Information Service Alexandria, Virginia http://www.ntis.gov

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and the
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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 FHWA or TxDOT.

This report does not constitute a standard, specification, or regulation. 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.

The United States Government and the State of Texas do not endorse products or manufacturers. Trade of manufacturers' names appear herein solely because they are considered essential to the object of this report.

TTI PROVING GROUND DISCLAIMER

ACCREDITED
ISO 17025 Laboratory
Testing Certificate # 2821.01

Crash testing performed at:
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The full-scale crash tests reported herein were performed at the Texas A&M Transportation Institute (TTI) Proving Ground, an International Standards Organization (ISO)/International Electrotechnical Commission (IEC) 17025-accredited laboratory with American Association for Laboratory Accreditation (A2LA) Mechanical Testing Certificate 2821.01. The full-scale crash tests were performed according to TTI Proving Ground quality procedures, and according to the *MASH* guidelines and standards. The results reported herein apply only to the articles being tested.

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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5(F-32)/9 or (F-32)/1.8	Celsius	°C
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	Square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lb/in^2

*SI is the symbol for the International System of Units

ACKNOWLEDGMENTS

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TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

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. The agreement 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, the 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, 33 roadside safety systems will be crash-tested in accordance with *MASH* criteria in three phases over a 3-year period.

The Texas A&M Transportation Institute (TTI) crash-tested and evaluated 10 devices in Phase I, which included the following:

- 36-inch vertical parapet bridge rail.
- 1-inch asphalt concrete pavement lateral support for concrete median barrier.
- Pinning pattern for precast concrete barriers on concrete.
- Single and dual embedded wood post sign support systems.
- Pedestal pole with flashing beacons with and without solar assembly.
- Multi-mailbox 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.

In Phase II, 14 devices were crash-tested and evaluated. These included the following:

- C402 bridge rail.
- C412 bridge rail.
- C411 bridge rail.
- T1W bridge rail.
- Guardrail with round wood posts.

- Concrete barrier at light post.
- Single-post perforated square metal tube skid.
- Mailbox Type 4 foundation (single)—recycled rubber post.
- Mailbox Type 4 foundation (double)—thin-walled white post.
- Mailbox Type 4 foundation (multi)—Shurtite Multi Hanger.
- Mailbox Type 5 foundation (single)—wood post.
- Dual post wood skid.
- Guardrail steel posts in rocky terrain.
- Round wood posts in rocky terrain.

An additional 14 devices were crash-tested and evaluated in Phase III. These included the following:

- C1W bridge rail.
- Modified C66 bridge rail.
- Low-profile barrier.
- Low-profile-to-F-shape transition.
- Thrie-beam transition.
- Wood skid sign.
- Embedded Unistrut® sign.
- Burn ban slip base sign.
- Burn ban socket sign.
- Mailbox Type 6 foundation (single) on a plastic drum.
- Mailbox Type 2 foundation (single)—extra-large.
- Mailbox Type 2 foundation (single)—lockable
- Mow strip with wood posts.
- Type III barricade.

TxDOT standards may include multiple configurations or variations of a device to accommodate different design considerations or needs. TTI researchers developed the test plan for each device 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 of the different roadside safety systems evaluated under Phase III.

CHAPTER 2: TXDOT C1W BRIDGE RAIL

2.1 BACKGROUND

The C1W bridge rail is a variation of a rail initially developed by the Wyoming Department of Transportation. The bridge rail is a 42-inch-tall combination rail that consists of four rectangular tubular steel rail elements attached to fabricated steel posts mounted on a 9-inch-tall concrete curb. The bridge rail is designed to accommodate both vehicle and pedestrian traffic. TxDOT elected to evaluate the impact performance of the C1W bridge rail for *MASH* TL-4.

Under Phase II of this project, the impact performance of the T1W bridge rail was evaluated using the full *MASH* TL-3 test matrix (*2*). The T1W bridge rail is a 32-inch-tall rail that consists of two rectangular tubular steel rail elements attached to fabricated steel posts mounted on a 9-inch-tall concrete curb. The rail geometrics of the T1W bridge rail are considered more critical than the C1W. The rail elements, post details, and curb details used in the T1W are similar to those in the C1W bridge rail. The curb height and post setback distance are equivalent between the two systems. The upper rail element in the T1W is at the same mounting height as the third rail of the C1W. The lower rail element of the T1W, which is mounted at a height of 20 inches to the top of the rail, is replaced by two rail elements at mounting heights of 16¾ inches and 24½ inches in the C1W. Thus, the C1W provides additional rail contact surface area and reduced clear opening between rail elements, both of which reduce the potential for vehicle snagging or high vehicle decelerations. Further, review of the T1W tests did not indicate potential for head contact on the taller C1W bridge rail. Therefore, based on the successful testing of the T1W bridge rail, *MASH* Test 4-10 with the passenger car and Test 4-11 with the pickup truck were considered unnecessary for evaluation of the C1W. Only the structural adequacy test (*MASH* Test 4-12) was performed to evaluate the *MASH* compliance of the C1W bridge rail.

2.2 SYSTEM DETAILS

2.2.1 Test Article and Installation Details

The TxDOT C1W test installation consisted of four rectangular tubular steel rail elements attached to fabricated steel posts mounted on a concrete curb that was cast on an 8-inch-thick reinforced cantilevered concrete deck. The curb was 9 inches tall and 14 inches wide, and had embedded anchor bolts for attachment of the steel posts. The posts were spaced on 9-ft centers. The total height of the rail was 42 inches above the deck.

Two joints extended through both the curb and deck, and a third joint extended only through the curb. The most upstream of the three joints, which extended through the curb and deck, was used for *MASH* Test 4-12 to evaluate the structural adequacy of the C1W bridge rail. The second joint that extended through both the parapet and deck and the third joint that extended through the curb only were used in the previous evaluation of the T1W bridge rail for *MASH* Test 3-11 and Test 3-10, respectively (*1*).

Figure 2.1 presents overall information on the C1W bridge rail, and Figure 2.2 provides photographs of the installation. Appendix A.1 provides further details of the C1W bridge rail.

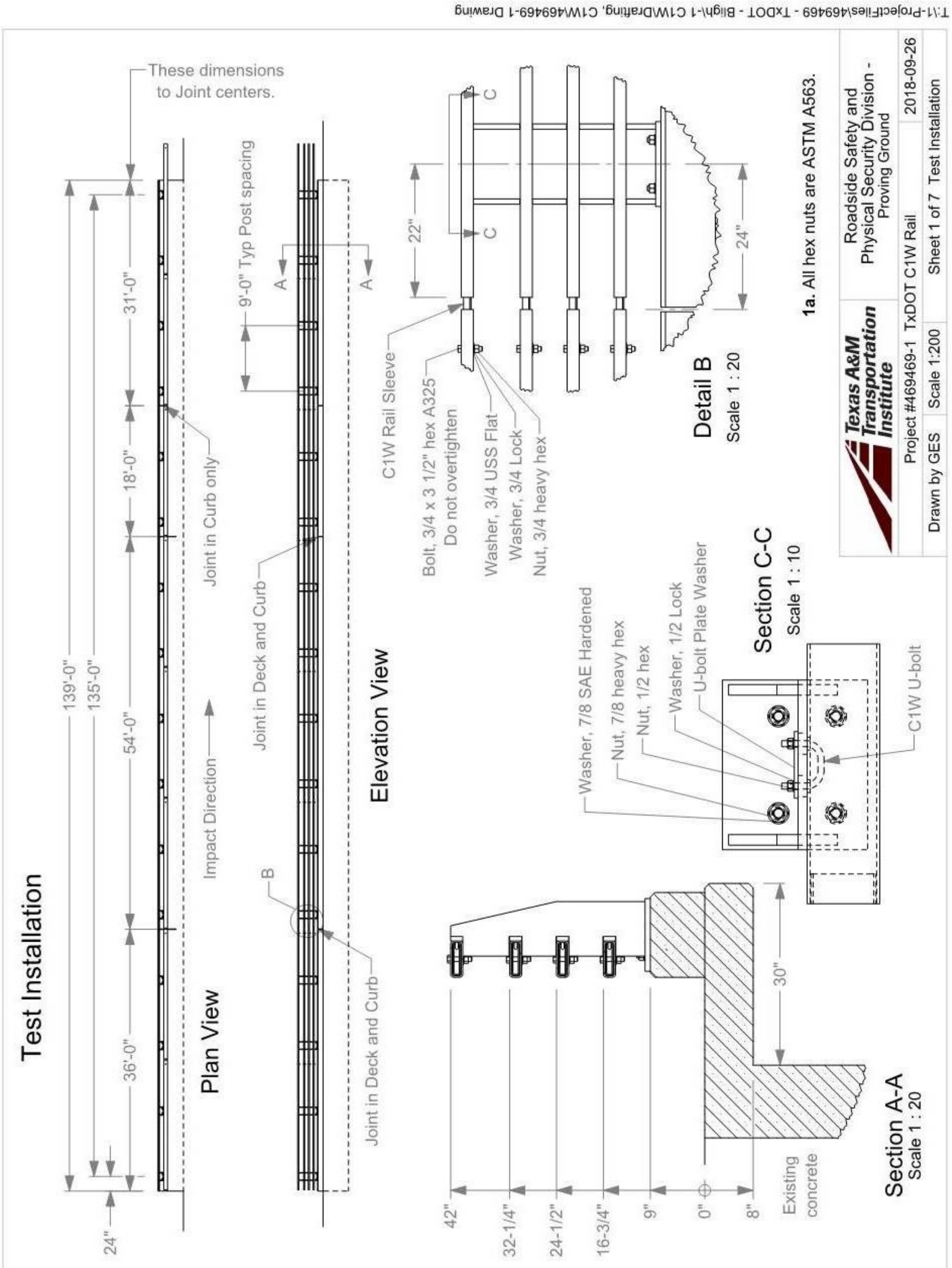


Figure 2.1. Overall Details of the C1W Bridge Rail.

Figure 2.2. C1W Bridge Rail prior to Testing.

2.2.2 Material Specifications

Appendix A.2 provides material certification documents for the materials used to install/construct the C1W bridge rail.

The specified minimum unconfined compressive strength of the concrete was 4000 psi for TxDOT Class S concrete. The compressive strength of all of the concrete used in the curb and bridge deck measured an average of 6469 psi on October 1, 2018.

2.3 MASH TEST 4-12 (TEST NO. 469469-1)

2.3.1 Test Designation and Actual Impact Conditions

MASH Test 4-12 involves a 10000S vehicle weighing 22,046 lb ±660 lb impacting the critical impact points (CIPs) of the C1W bridge rail at an impact speed of 56 mi/h ±2.5 mi/h and an angle of 15° ±1.5°. The CIP for *MASH* Test 4-12 on the C1W bridge rail was 5.0 ft ±1 ft upstream of the joint in the deck and curb between posts 4 and 5.

The 2011 International 4300 box truck used in the test weighed 22,220 lb, and the actual impact speed and angle were 56 mi/h and 14°, respectively. The actual impact point was 5.3 ft upstream of the joint in the deck and curb between posts 4 and 5. Minimum target impact severity (IS) was 142 kip-ft, and actual IS was 136 kip-ft. Although the IS was 4% below the recommended value, the speed and impact angle were individually within their tolerance ranges recommended in *MASH*. Further, the Single Unit Truck (SUT) was contained by the test article in a very stable manner with a maximum roll angle of only 23°, and the resulting occupant compartment deformation was only 45% of the maximum allowed intrusion (at the floor pan). Based on the observed impact performance of the barrier, the behavior of the SUT, and the amount of room left within the *MASH* evaluation criteria, a retest was not deemed necessary.

2.3.2 Weather Conditions

The test was performed on the morning of October 17, 2018. Weather conditions at the time of testing were as follows: wind speed: 5 mi/h; wind direction: 30° with respect to the vehicle (vehicle was traveling in a north, northwesterly direction); temperature: 61°F; relative humidity: 94 percent.

2.3.3 Test Vehicle

Figure 2.3 and Figure 2.4 show the 2011 International 4300 box truck that was used for the crash test. The vehicle's test inertia weight was 22,220 lb, and its gross static weight was 22,220 lb. The height to the lower edge of the vehicle bumper was 19 inches, and height to the upper edge of the bumper was 34 inches. Table A.1 and Table A.2 in Appendix A.3.1 give 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 2.3. C1W Bridge Rail/Test Vehicle Geometrics for Test No. 469469-1.

Figure 2.4. Test Vehicle before Test No. 469469-1.

2.3.4 Test Description

Table 2.1 lists events that occurred during Test No. 469469-1. Figure A.1 and Figure A.2 in Appendix A.3.2 present sequential photographs during the test.

Table 2.1. Events during Test No. 469469-1.

Time	Events
0.000	Vehicle contacts barrier
0.076	Vehicle begins to redirect and deflect away from barrier
0.116	Front right tire leaves pavement
0.237	Rear left side of box frame contacts top rail
0.241	Rear right tires leave pavement
0.248	Vehicle is parallel with barrier
0.300	Barrier is at maximum dynamic deflection
0.454	Vehicle exits barrier
0.715	Right front tire makes contact with pavement
1.234	Left front tire makes secondary contact with curb and bottom three rails

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 heavy vehicles). The 10000S vehicle exited within the exit box criteria defined in *MASH*. After loss of contact with the barrier, the vehicle yawed counterclockwise and came to rest 213 ft downstream of the impact.

2.3.5 Damage to Test Installation

Figure 2.5 shows the damage to the C1W bridge rail. The bridge rails were deformed at the location of impact. The concrete was fractured around posts 4, 5, and 6. Post 5 was leaning back 3.1° from vertical. Post 4 was leaning back toward the protected side 5.9° from vertical and was fractured at the weld where the vertical plates are connected to the base plate. There was a secondary contact at post 14 to the end of the bridge rail. No damage was noticed, other than black marks from the tire. Working width was 4 ft, and the height of the working width was 13.1 ft. Maximum dynamic deflection during the test was 0.9 ft, and maximum permanent deformation was 0.3 ft.

Figure 2.5. C1W Bridge Rail after Test No. 469469-1.

2.3.6 Damage to Test Vehicle

Figure 2.6 and Figure 2.7 show the damage sustained by the vehicle. The front bumper, hood, left head light, left front tire and rim, left front spring and U-bolts, left side step, left corner of floor pan, left front corner of box, and left rear outer tire and rim were damaged. Maximum exterior crush to the vehicle was 14.0 inches in the front left corner. Maximum occupant compartment deformation was 5.5 inches in the front left corner of the floor pan. Table A.3 in Appendix A.3.1 provides details on the damage to the test vehicle.

Figure 2.6. Test Vehicle after Test No. 469469-1.

Figure 2.7. Interior of Test Vehicle for Test No. 469469-1.

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 2.2. Figure 2.8 summarizes these data and other pertinent information from the test. Figure A.3 in Appendix A.3.3 shows the vehicle angular displacements, and Figure A.4 through Figure A.6 in Appendix A.3.4 show accelerations versus time traces.

Table 2.2. Occupant Risk Factors for Test No. 469469-1.

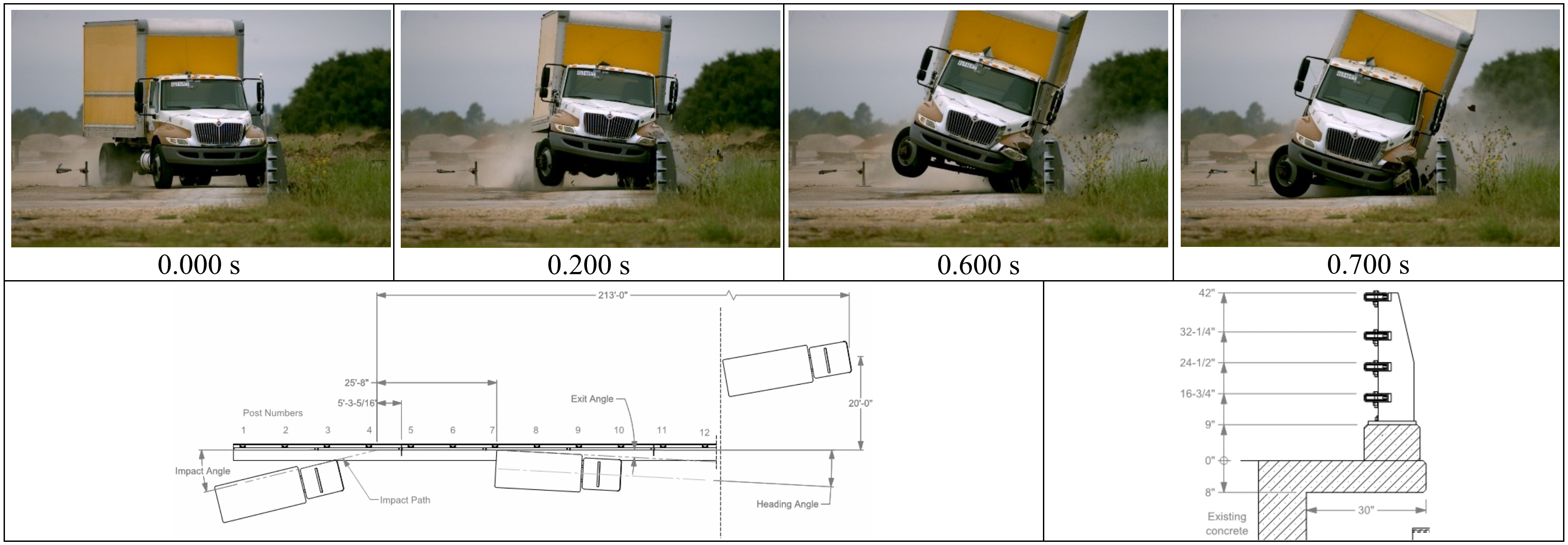
Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)	ft/s	at 0.1962 seconds on left side of interior
Longitudinal	**6.2**	
Lateral	**13.1**	
Occupant Ridedown Accelerations	**g**	
Longitudinal	**1.6**	(0.3084–0.3184 seconds)
Lateral	**9.6**	(0.2454–0.2554 seconds)
Theoretical Head Impact Velocity (THIV)	m/s	at 0.1908 seconds on left side of interior
	4.5	
Acceleration Severity Index (ASI)	**0.68**	(0.3254–0.3754 seconds)
Maximum 50-ms Moving Average	**g**	
Longitudinal	**−1.4**	(0.0764–0.1264 seconds)
Lateral	**5.6**	(0.2958–0.3458 seconds)
Vertical	**1.8**	(0.4217–0.4717 seconds)
Maximum Roll, Pitch, and Yaw Angles	**Degrees**	
Roll	**23**	(0.7419 seconds)
Pitch	**7**	(0.7398 seconds)
Yaw	**18**	(0.4755 seconds)

2.3.8 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.

2.4 CONCLUSIONS

The C1W 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............... 469469-1
Test Date................. 2018-10-17

Test Article
Type......................... Longitudinal barrier—bridge rail
Name....................... TxDOT C1W bridge rail
Installation Length..... 139 ft
Material or Key Elements Concrete deck 8 inches thick with curb 9 inches tall × 14 inches wide with fabricated steel posts spaced at 9 ft supporting four steel rails. Top at 42 inches.

Soil Type and Condition Concrete deck, damp

Test Vehicle
Type/Designation...... 10000S
Make and Model....... 2011 International 4300, box truck
Curb......................... 14,190 lb
Test Inertial.............. 22,220 lb
Dummy..................... No dummy
Gross Static............. 22,220 lb

Impact Conditions
Speed..................... 56 mi/h
Angle...................... 14°
Location/Orientation 5.3 ft upstream of the joint in the deck/curb between posts 4 and 5

Impact Severity......... 136.3 kip-ft

Exit Conditions
Speed..................... 53 mi/h
Exit Trajectory/Heading 3.4°/3.1°

Occupant Risk Values
Longitudinal OIV...... 6.2 ft/s
Lateral OIV.............. 13.1 ft/s
Longitudinal Ridedown 1.6 g
Lateral Ridedown..... 9.6 g
THIV....................... 4.5 m/s
ASI.......................... 0.68
Max. 0.050-s Average
Longitudinal............. −1.4 g
Lateral..................... 5.6 g
Vertical.................... 1.8 g

Post-Impact Trajectory
Stopping Distance......... 213 ft downstream 20 ft to field side

Vehicle Stability
Maximum Yaw Angle..... 18°
Maximum Pitch Angle.... 7°
Maximum Roll Angle..... 23°
Vehicle Snagging.......... Slight
Vehicle Pocketing.......... No

Test Article Deflections
Dynamic....................... 11.1 inches
Permanent.................... 3.8 inches
Working Width.............. 48.1 inches
Working Width Height.... 157 inches

Vehicle Damage
VDS............................. NA
CDC............................. 11FLEW4
Max. Exterior Deformation 14.0 inches
OCDI............................ NA
Max. Occupant Compartment Deformation................ 5.5 inches

Figure 2.8. Summary of Results for *MASH* Test 4-12 on the C1W Bridge Rail.

Table 2.3. Performance Evaluation Summary for *MASH* Test 4-12 on the C1W Bridge Rail.

Test Agency: Texas A&M Transportation Institute | Test No.: 469469-1 | Test Date: 2018-10-17

***MASH* Test 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 C1W bridge rail redirected the 10000S vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 11.1 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 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 5.5 inches at the front left floor pan.	Pass
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. Maximum roll was 23°.	Pass
Vehicle Trajectory For redirective devices, it is preferable that the vehicle be smoothly redirected and leave the barrier within the "exit box" criteria (not less than 65.6 ft for the 10000S vehicle), and should be documented.	The 10000S vehicle exited within the exit box criteria.	Documentation only

CHAPTER 3: TXDOT MODIFIED C66 BRIDGE RAIL

3.1 BACKGROUND

The T66 bridge rail is a variation of a rail initially developed by the California Department of Transportation. The bridge rail is a concrete beam-and-post system mounted on a 9-inch curb. The 15-inch-wide concrete posts are spaced at 6 ft 6 inches center to center. A 12-inch by 12-inch concrete beam is mounted at a height of 32 inches and offset 4 inches from the traffic face of the posts in line with the curb.

The C66 rail is a combination version of the T66 rail that is designed to accommodate both vehicle and pedestrian traffic. The C66 rail differs from the T66 rail in two ways. First, a 8-inch-tall steel rail element is attached to the top of the posts to achieve a total overall height of 42 inches to meet pedestrian requirements. The lateral position of the steel rail element is 10 inches from the traffic face of the concrete beam. The second variation is the addition of a steel pipe between posts centered in the clear opening between the bottom of the concrete beam and top of the curb. This pipe is also set back 10 inches from the traffic face of the concrete beam and curb.

The test installation was constructed in a manner to evaluate the *MASH* compliance of both the T66 and C66 bridge rail systems. The C66 steel rail element was incorporated into the test installation to evaluate any potential occupant or vehicle interaction. Since the lower pipe section could potentially reduce the severity of wheel snagging on the concrete posts, the lower pipe was removed from the test installation. If the testing of the Modified C66 rail (with the lower pipe removed) is successful, both the C66 and T66 bridge rail systems would be considered *MASH* compliant.

The Modified C66 bridge rail was tested and evaluated in accordance with *MASH* TL-3 requirements. The full *MASH* TL-3 test matrix was conducted on this rail system to fully evaluate vehicle-snagging potential on the concrete posts or any occupant or vehicle contact with the steel steel rail element. This shall consist of test designations 3-10 (small passenger car) and 3-11 (pickup truck).

3.2 SYSTEM DETAILS

3.2.1 Test Article and Installation Details

The Modified C66 bridge rail test installation was 74 ft 4½ inches long and consisted of a reinforced cantilevered concrete deck supporting a reinforced concrete beam-and-post bridge rail mounted on a 9-inch-tall reinforced concrete curb. The concrete deck was 30 inches wide by 8 inches thick. The curb was 9 inches tall and 17½ inches wide. Reinforced concrete posts measuring 12 inches by 15 inches were spaced on 6-ft-6-inch centers. A 12-inch by 12-inch longitudinal reinforced concrete beam was integrally cast with the posts such that the traffic face of the beam was flush with the traffic side face of the curb. The traffic face of the concrete posts was inset 4 inches from the traffic face of the beam and curb, and the top of the concrete posts extended 2 inches above the top of the beam. The top of the rail was 32 inches above the deck surface. A 2⅞-inch-diameter steel steel rail element pipe assembly was attached to the top of each post, and the top of the steel rail element was 42 inches above the deck. Two ¾-inch-wide joints were placed through the concrete beam, curb, and deck. A concrete post was placed on each side of the joints.

Figure 3.1 presents the overall information on the Modified C66 bridge rail, and Figure 3.2 provides photographs of the installation. Appendix B.1 provides further details of the Modified C66 bridge rail.

3.2.2 Material Specifications

The minimum compressive strength of the TxDOT Class S concrete specified for the bridge deck, curb, posts, and beam was 4000 psi. The bridge deck and support wall were cast on September 27, 2018. The average compressive strength of the two batches of concrete used in the deck and wall measured 5900 psi on October 31, 2018 (at 34 days). The entire curb was cast on October 2, 2018, and its average compressive strength measured 4695 psi on October 31, 2018 (at 29 days). The posts and beam were cast on October 4, 2018, and their average compressive strength measured 5185 psi on October 31, 2018 (at 27 days). Appendix B.2 provides the concrete strength test results for the bridge rail test installation.

Reinforcement of the bridge deck was comprised of ASTM A615 Grade 60 rebar with a specified minimum yield strength of 60 ksi. Appendix B.2 contains mill certification sheets and other certification documents for the materials used in the bridge deck test installation.

3.3 MASH TEST 3-11 (TEST NO. 469469-2-1)

3.3.1 Test Designation and Actual Impact Conditions

MASH Test 3-11 involves a 2700P vehicle weighing 5000 lb ±110 lb impacting the CIP of the Modified C66 bridge rail at a speed of 62 mi/h ±2.5 mi/h and an angle of 25° ±1.5°. The CIP for *MASH* Test 3-11 on the Modified C66 bridge rail was 4.3 ft upstream of the joint in the deck, curb, and beam between posts 4 and 5.

The 2012 RAM 1500 used in the test weighed 5014 lb, and the actual impact speed and angle were 61.8 mi/h and 24.3°, respectively. The actual impact point was 4.1 ft upstream of the joint in the deck, curb, and beam between posts 4 and 5. Minimum target IS was 106 kip-ft, and actual IS was 108.4 kip-ft.

3.3.2 Weather Conditions

The test was performed on the morning of October 31, 2018. Weather conditions at the time of testing were as follows: wind speed: 10 mi/h; wind direction: 163° with respect to the vehicle (vehicle was traveling in a northwesterly direction); temperature: 76°F; relative humidity: 93 percent.

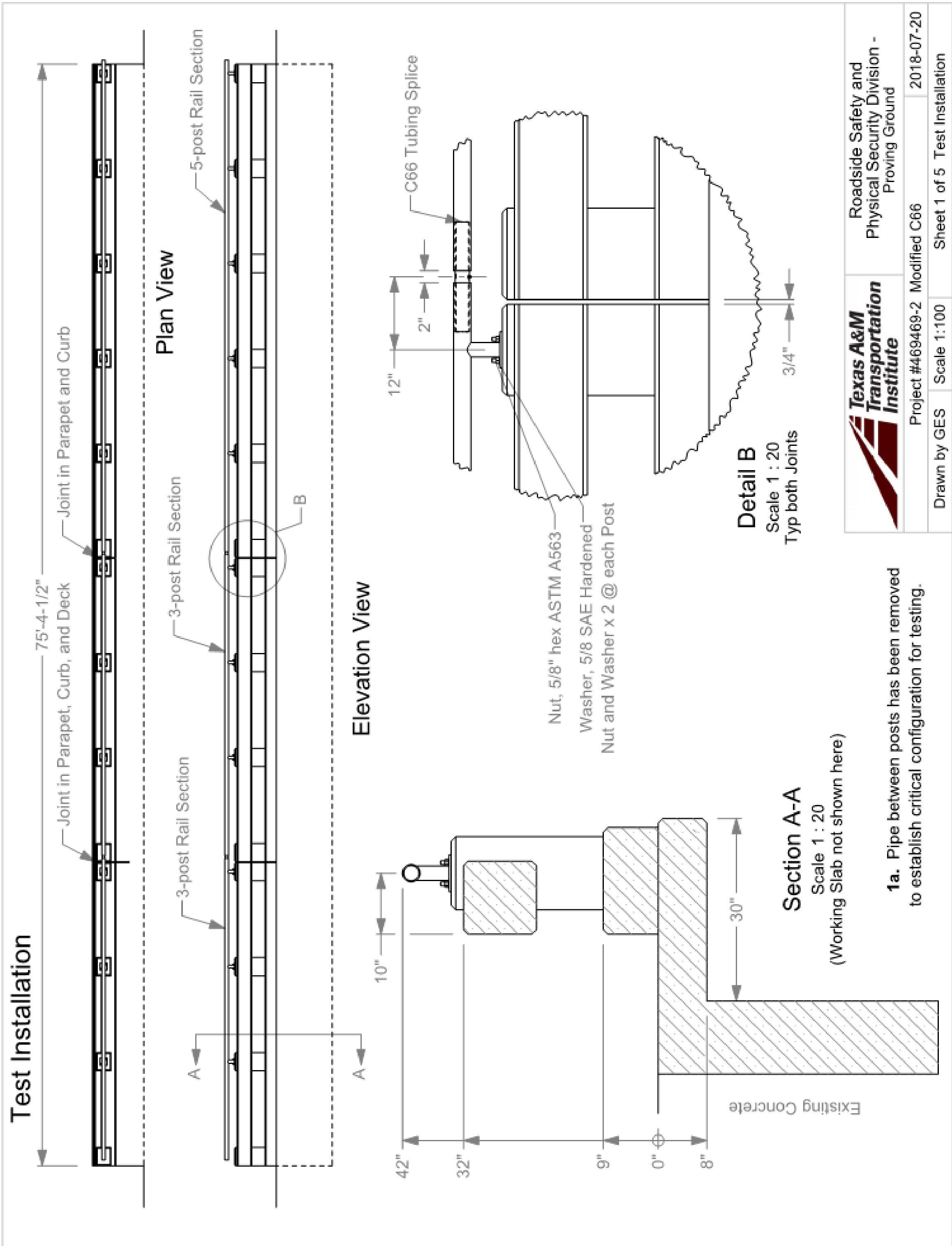


Figure 3.1. Overall Details of the Modified C66 Bridge Rail.

Figure 3.2. Modified C66 Bridge Rail prior to Testing.

3.3.3 Test Vehicle

Figure 3.3 and Figure 3.4 show the 2012 RAM 1500 that was used for the crash test. The vehicle's test inertia weight was 5014 lb, and its gross static weight was 5179 lb. The height to the lower edge of the vehicle bumper was 11.8 inches, and the height to the upper edge of the bumper was 27 inches. The height to the vehicle's center of gravity was 28 inches. Table B.1 and Table B.2 in Appendix B.3.1 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.

Figure 3.3. Modified C66 Bridge Rail/Test Vehicle Geometrics for Test No. 469469-2-1.

Figure 3.4. Test Vehicle before Test No. 469469-2-1.

3.3.4 Test Description

Table 3.1 lists events that occurred during Test No. 469469-2-1. Figure B.1 and Figure B.2 in Appendix B.3.2 present sequential photographs during the test.

Table 3.1. Events during Test No. 469469-2-1.

Time	Events
0.000	Vehicle contacts barrier
0.044	Vehicle begins to redirect
0.146	Left front tire lifts off pavement
0.157	Left rear tire lifts off pavement
0.208	Vehicle is parallel with barrier
0.245	Right rear bumper contacts barrier
0.392	Left front tire makes contact with pavement
0.416	Vehicle exits the barrier at 46.3 mi/h, heading 8.7° from barrier with a trajectory of 3.4° from barrier

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*. After loss of contact with the barrier, the vehicle yawed counterclockwise and came to rest 185 ft downstream of the impact point and 5 ft toward traffic lanes.

3.3.5 Damage to Test Installation

Figure 3.5 shows the damage to the Modified C66 bridge rail. Some of the edges of the concrete at the joint between posts 4 and 5 were damaged and missing a small amount of material. No further damage to the bridge rail was noted. Working width was 20.5 inches, and the height of the working width was 58 inches. Maximum dynamic deflection during the test was 1.1 inches for the steel rail element on top of the concrete parapet. There was no measurable dynamic deflection of the concrete parapet. There was no measurable permanent deflection in either the concrete parapet or the steel rail element.

Figure 3.5. Modified C66 Bridge Rail after Test No. 469469-2-1.

3.3.6 Damage to Test Vehicle

Figure 3.6 and Figure 3.7 show the damage sustained by the vehicle. The front bumper, hood, radiator and support, left front fender, left front tire and rim, left frame rail, left upper and lower A-arms, left front floor pan and kick panel, left front door and glass and left rear door, left cab corner, left rear fender, and left rear tire and rim were damaged. Maximum exterior crush to the vehicle was 14.0 inches in the side plane at the left front corner at bumper height. Maximum occupant compartment deformation was 2.0 inches in the left side firewall area. Table B.3 and Table B.4 in Appendix B.3.1 provide the exterior crush and occupant compartment measurements of the vehicle.

Figure 3.6. Test Vehicle after Test No. 469469-2-1.

Figure 3.7. Interior of Test Vehicle for Test No. 469469-2-1
(before Test on Left; after Test on Right).

3.3.7 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk, and results are shown in Table 3.2. Figure 3.8 summarizes these data and other pertinent information from the test. Figure B.3 in Appendix B.3.3 shows the vehicle angular displacements, and Figure B.4 through Figure B.6 in Appendix B.3.4 show acceleration versus time traces.

Table 3.2. Occupant Risk Factors for Test No. 469469-2-1.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)	ft/s	at 0.1029 seconds on left side of interior
Longitudinal	**22.3**	
Lateral	**23.6**	
Occupant Ridedown Accelerations (g's)		
Longitudinal	**4.1**	(0.2233–0.2333 seconds)
Lateral	**7.8**	(0.2236–0.2336 seconds)
Theoretical Head Impact Velocity (THIV)	m/s	at 0.0997 seconds on left side of interior
	10	
Acceleration Severity Index (ASI)	**1.81**	(0.0594–0.1094 seconds)
Maximum 50-ms Moving Average (g's)		
Longitudinal	**−11.8**	(0.0340–0.0840 seconds)
Lateral	**13.3**	(0.0367–0.0867 seconds)
Vertical	**4**	(0.0787–0.1287 seconds)
Maximum Roll, Pitch, and Yaw Angles		
Roll (degrees)	**12**	(0.4178 seconds)
Pitch (degrees)	**7**	(0.4409 seconds)
Yaw (degrees)	**39**	(0.7687 seconds)

3.3.8 Assessment of Results

An assessment of the tests based on the applicable safety evaluation criteria for *MASH* Test 3-11 is provided in Table 3.3.

3.4 MASH TEST 3-10 (TEST NO. 469469-2-2)

3.4.1 Test Designation and Actual Impact Conditions

MASH Test 3-10 involves an 1100C vehicle weighing 2420 lb ±55 lb impacting the CIP of the Modified C66 bridge rail at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25° ±1.5°. The CIP for *MASH* Test 3-10 on the Modified C66 bridge rail was 3.6 ft upstream of the joint in the deck, curb, and beam between posts 8 and 9.

The 2011 Kia Rio[1] used in the test weighed 2448 lb, and the actual impact speed and angle were 63.0 mi/h and 24.9°, respectively. The actual impact point was 4.0 ft upstream of the joint in the deck, curb, and beam between posts 8 and 9. Minimum target impact severity was 51 kip-ft, and actual IS was 57.6 kip-ft.

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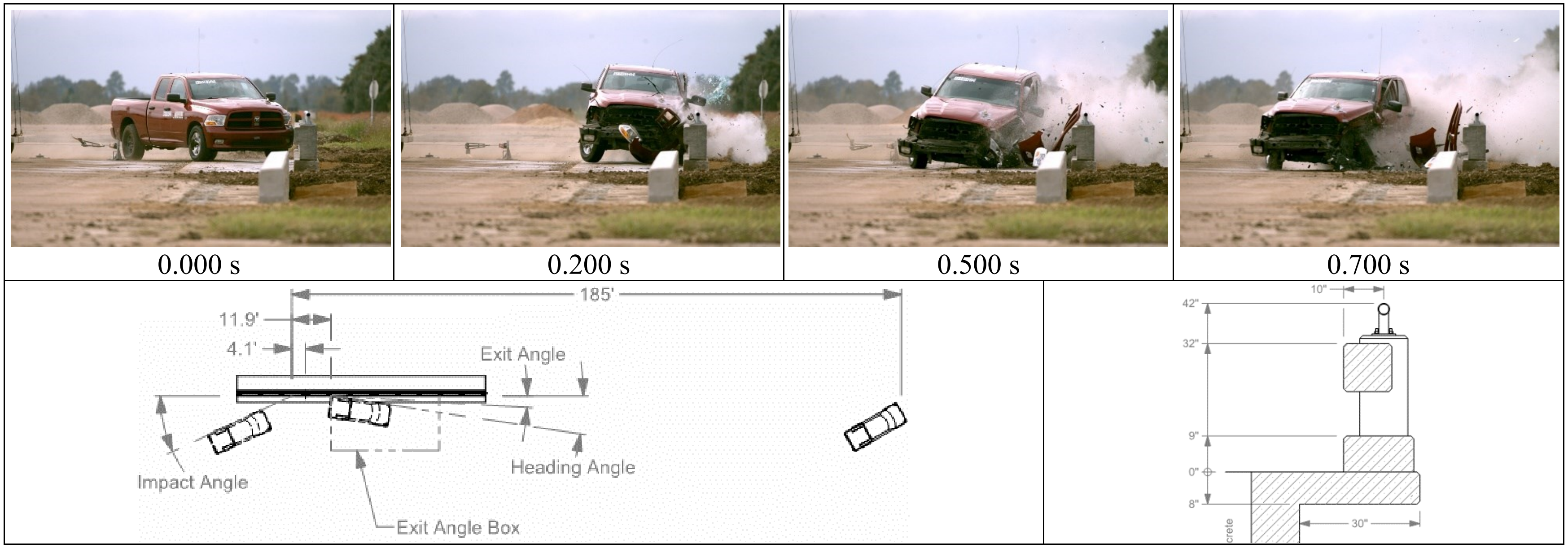
[1] The 2009 model vehicle used is older than the 6-year age noted in *MASH*, and was selected based upon availability. An older model vehicle is permitted by AASHTO as long as it is otherwise *MASH* compliant. Other than the vehicle's year model, this 2009 model vehicle met the *MASH* requirements.



General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-11
TTI Test No.	469469-2-1
Test Date	2018-10-31
Test Article	
Type	Longitudinal barrier—bridge rail
Name	TxDOT Modified C66 bridge rail
Installation Length	75 ft 4-1/2 inches
Material or Key Elements	32-inch-tall concrete beam-and-post rail mounted on 9-inch-tall curb attached to 8-inch-thick cantilever deck; concrete posts spaced at 6.5 ft; metal steel rail element attached to concrete posts at height of 42 inches
Soil Type and Condition	Concrete deck, damp
Test Vehicle	
Type/Designation	2270P
Make and Model	2012 RAM 1500
Curb	5025 lb
Test Inertial	5014 lb
Dummy	165 lb
Gross Static	5179 lb

Impact Conditions	
Speed	61.8 mi/h
Angle	24.3°
Location/Orientation	4.1 ft upstream of the joint in the deck/curb between posts 4 and 5
Impact Severity	108.4 kip-ft
Exit Conditions	
Speed	46.3 mi/h
Exit Trajectory/Heading	3.4°/8.7°
Occupant Risk Values	
Longitudinal OIV	22.3 ft/s
Lateral OIV	23.6 ft/s
Longitudinal Ridedown	4.1 g
Lateral Ridedown	7.8 g
THIV	10 m/s
ASI	1.81
Max. 0.050-s Average	
Longitudinal	−11.8 g
Lateral	13.3 g
Vertical	4 g

Post-Impact Trajectory	
Stopping Distance	185 ft
Vehicle Stability	
Maximum Yaw Angle	39°
Maximum Pitch Angle	7°
Maximum Roll Angle	12°
Vehicle Snagging	Slight
Vehicle Pocketing	No
Test Article Deflections	
Dynamic	1.1 inches
Permanent	None
Working Width	20.5 inches
Working Width Height	58 inches
Vehicle Damage	
VDS	10-LFQ-5
CDC	10FLEW4
Max. Exterior Deformation	14 inches
OCDI	LF0011000
Max. Occupant Compartment Deformation	2 inches

Figure 3.8. Summary of Results for *MASH* Test 3-11 on the Modified C66 Bridge Rail.

Table 3.3. Performance Evaluation Summary for *MASH* Test 3-11 on the Modified C66 Bridge Rail.

Test Agency: Texas A&M Transportation Institute | Test No.: 469469-2-1 | Test Date: 2018-10-31

***MASH* Test 3-11 Evaluation Criteria**	**Test Results**	**Assessment**
<u>Structural Adequacy</u> *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 Modified C66 bridge rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 1.1 inches in the metal steel rail element.	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.*	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 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 reduction of space in the occupant compartment was 2.0 inch in the driver side floor pan and kick panel areas.	
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 was 12°, and maximum pitch was 7°.	Pass
H. Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.	Longitudinal OIV was 22.3 ft/s, and lateral OIV was 23.6 ft/s.	Pass
I. Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 g, or at least below the maximum allowable value of 20.49 g.	Maximum longitudinal 10-ms occupant ridedown acceleration was 4.1 g, and maximum lateral 10-ms occupant ridedown acceleration was 7.8 g.	Pass
<u>Vehicle Trajectory</u> For redirective devices, it is preferable that the vehicle be smoothly redirected and leave the barrier within the “exit box” criteria (not less than 32.8 ft for the 1100C and 2270P vehicles), and should be documented.	The 2270P vehicle exited within the exit box criteria.	Documentation only

3.4.2 Weather Conditions

The test was performed on the morning of November 28, 2018. Weather conditions at the time of testing were as follows: wind speed: 9 mi/h; wind direction: 176° with respect to the vehicle (vehicle was traveling in a northwesterly direction); temperature: 62°F; relative humidity: 75 percent.

3.4.3 Test Vehicle

Figure 3.9 and Figure 3.10 show the 2011 Kia Rio that was used for the crash test. The vehicle's test inertia weight was 2448 lb, and its gross static weight was 2613 lb. The height to the lower edge of the vehicle bumper was 7.8 inches, and the height to the upper edge of the bumper was 21.5 inches. Table B.5. and Table B.6. in Appendix B.4.1 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.

Figure 3.9. Modified C66 Bridge Rail/Test Vehicle Geometrics for Test No. 469469-2-2.

Figure 3.10. Test Vehicle before Test No. 469469-2-2.

3.4.4 Test Description

Table 3.4 lists events that occurred during Test No. 469469-2-2. Figure B.7 and Figure B.8 in Appendix B.4.2 present sequential photographs during the test.

Table 3.4. Events during Test No. 469469-2-2.

Time	Events
0.000	Vehicle contacts barrier
0.031	Vehicle begins to redirect
0.076	Right rear tire lifts off pavement
0.179	Vehicle is parallel with barrier
0.191	Left rear bumper contacts barrier
0.293	Vehicle exits the barrier at 49.4 mi/h, heading 10.1° from barrier and a trajectory of 4.7° from barrier

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 1100C vehicle exited within the exit box criteria defined in *MASH*. After loss of contact with the barrier, the vehicle yawed counterclockwise and came to rest 184 ft downstream of the impact point and 4 ft behind the barrier.

3.4.5 Damage to Test Installation

Figure 3.11 shows the damage to the Modified C66 bridge rail. Some of the edges of the concrete at the joint between posts 8 and 9 were damaged and missing a small amount of material. No further damage to the bridge rail was noted. Working width was 16 inches, and the height of the working width was 32 inches. There was no measurable dynamic or permanent deflection in either the concrete parapet or the steel rail element.

Figure 3.11. Modified C66 Bridge Rail after Test No. 469469-2-2.

3.4.6 Damage to Test Vehicle

Figure 3.12 and Figure 3.13 show the damage sustained by the vehicle. The front bumper, hood, radiator and support, left front head light, left front fender, left front strut and tower, left front tire and rim, left A post, windshield, left front floor pan, left front and rear door, left rear fender, rear bumper, and roof were damaged. Maximum exterior crush to the vehicle was 12.0 inches in the side plane at the left front corner above front bumper height. Maximum occupant compartment deformation was 2.0 inches for the interior height. Table B.6 and Table B.7 in Appendix B.4.1 provide exterior crush and occupant compartment measurements.

Figure 3.12. Test Vehicle after Test No. 469469-2-2.

Figure 3.13. Interior of Test Vehicle after Test No. 469469-2-2.

3.4.7 Occupant Risk Factors

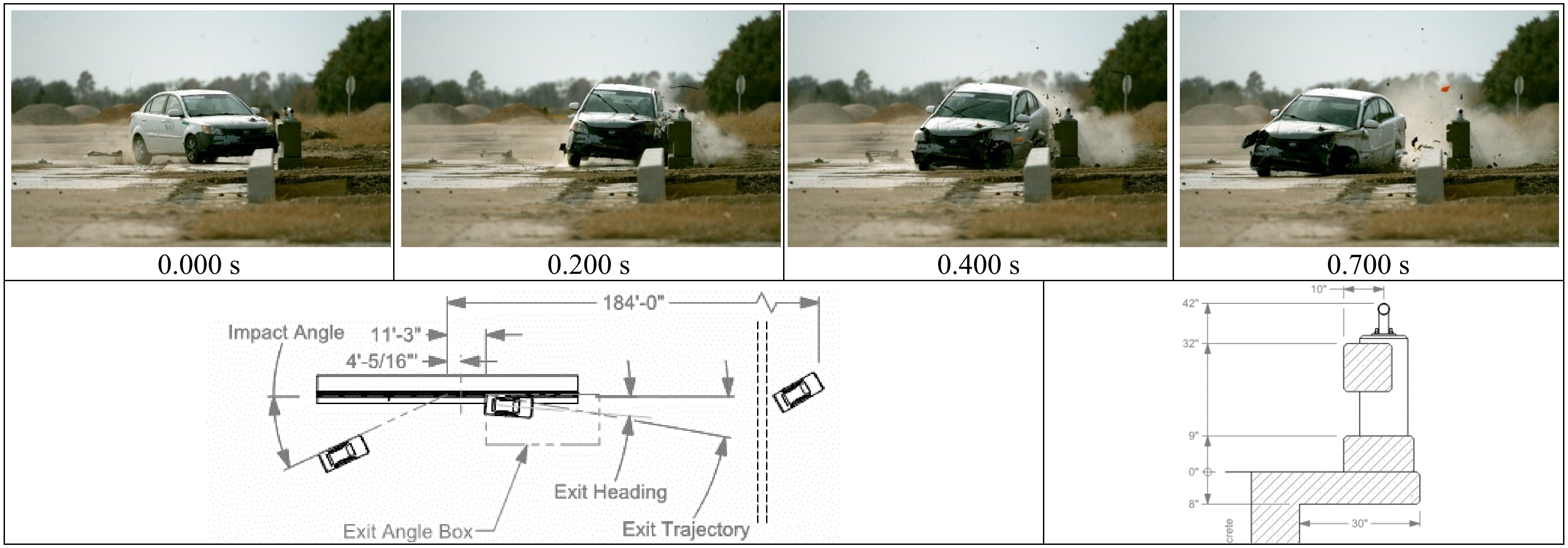
Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk, and results are shown in Table 3.5. Figure 3.14 summarizes these data and other pertinent information from the test. Figure B.9 in Appendix B.4.3 shows the vehicle angular displacements, and Figure B.10 through Figure B.12 in Appendix B.4.4 show acceleration versus time traces.

Table 3.5. Occupant Risk Factors for Test No. 469469-2-2.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)	ft/s	at 0.0703 seconds on left side of interior
Longitudinal	**28.5**	
Lateral	**33.1**	
Occupant Ridedown Accelerations (g's)		
Longitudinal	**3.7**	(0.5879–0.5979 seconds)
Lateral	**6.7**	(0.2163–0.2263 seconds)
Theoretical Head Impact Velocity (THIV)	m/s **13.2**	at 0.0686 seconds on left side of interior
Acceleration Severity Index (ASI)	**2.92**	(0.0433–0.0933 seconds)
Maximum 50-ms Moving Average (g's)		
Longitudinal	**−16.2**	(0.0127–0.0627 seconds)
Lateral	**20.2**	(0.0118–0.0618 seconds)
Vertical	**−3.4**	(0.0081–0.0581 seconds)
Maximum Roll, Pitch, and Yaw Angles	**Degrees**	
Roll	**18**	(1.5000 seconds)
Pitch	**14**	(1.5000 seconds)
Yaw	**43**	(0.5956 seconds)

3.4.8 Assessment of Results

An assessment of the tests based on the applicable safety evaluation criteria for *MASH* Test 3-10 is provided in Table 3.6.



General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-10
TTI Test No.	469469-2-2
Test Date	2018-11-28
Test Article	
Type	Longitudinal barrier—bridge rail
Name	TxDOT Modified C66 bridge rail
Installation Length	75 ft 4-1/2 inches
Material or Key Elements	32-inch-tall concrete beam-and-post rail mounted on 9-inch-tall curb attached to 8-inch-thick cantilever deck; concrete posts spaced at 6.5 ft; metal steel rail element attached to concrete posts at height of 42 inches
Soil Type and Condition	Concrete deck, damp
Test Vehicle	
Type/Designation	1100C
Make and Model	2011 Kia Rio
Curb	2458 lb
Test Inertial	2448 lb
Dummy	165 lb
Gross Static	2613 lb

Impact Conditions	
Speed	63.0 mi/h
Angle	24.9°
Location/Orientation	4.0 ft upstream of the joint in the deck/curb between posts 8 and 9
Impact Severity	57.6 kip*ft
Exit Conditions	
Speed	49.4 mi/h
Exit Trajectory/Heading	4.7°/10.1°
Occupant Risk Values	
Longitudinal OIV	28.5 ft/s
Lateral OIV	33.1 ft/s
Longitudinal Ridedown	3.7 g
Lateral Ridedown	6.7 g
THIV	13.2 m/s
ASI	2.92
Max. 0.050-s Average	
Longitudinal	−16.2 g
Lateral	20.2 g
Vertical	−3.4 g

Post-Impact Trajectory	
Stopping Distance	184 ft and 4 ft toward field
Vehicle Stability	
Maximum Yaw Angle	43°
Maximum Pitch Angle	14°
Maximum Roll Angle	18°
Vehicle Snagging	Slight
Vehicle Pocketing	No
Test Article Deflections	
Dynamic	None detected
Permanent	none
Working Width	16 inches
Working Width Height	32 inches
Vehicle Damage	
VDS	NA
CDC	11FLEW4
Max. Exterior Deformation	12.0 inches
OCDI	NA
Max. Occupant Compartment Deformation	2.0 inches

Figure 3.14. Summary of Results for *MASH* Test 3-10 on the Modified C66 Bridge Rail.

Table 3.6. Performance Evaluation Summary for *MASH* Test 3-10 on the Modified C66 Bridge Rail.

Test Agency: Texas A&M Transportation Institute | Test No.: 469469-2-2 | Test Date: 2018-11-28

***MASH* Test 3-10 Evaluation Criteria**	**Test Results**	**Assessment**
<u>Structural Adequacy</u> *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 Modified C66 bridge rail contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. There was no measurable dynamic deflection during the test.	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.*	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 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 reduction of space in the occupant compartment was 2.0 inches between the floor and roof.	
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 was 18°, and maximum pitch was 14°.	Pass
H. Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.	Longitudinal OIV was 28.5 ft/s, and lateral OIV was 33.1 ft/s.	Pass
I. Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 g, or at least below the maximum allowable value of 20.49 g.	Maximum longitudinal 10-ms occupant ridedown acceleration was 3.7 g, and maximum lateral 10-ms occupant ridedown acceleration was 6.7 g.	Pass
<u>Vehicle Trajectory</u> For redirective devices, it is preferable that the vehicle be smoothly redirected and leave the barrier within the "exit box" criteria (not less than 32.8 ft for the 1100C and 2270P vehicles), and should be documented.	The 1100C vehicle exited within the exit box criteria.	Documentation only

3.5 CONCLUSIONS

The TxDOT Modified C66 bridge rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 1.1 inches at the steel rail element, and there was no measurable permanent deformation. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. Maximum occupant compartment deformation was 2.0 inches in the driver side floor pan and kick panel areas. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 12° and 7°, respectively. Occupant risk factors were within the preferred limits specified in *MASH*. The 2270P vehicle exited within the exit box criteria.

The TxDOT Modified C66 bridge rail contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. There was no measurable dynamic or permanent deformation. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. Maximum occupant compartment deformation was 2 inches between the floor and roof. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 18° and 14°, respectively. Occupant risk factors were within the acceptable limits specified in *MASH*. The 1100C vehicle exited within the exit box criteria.

The TxDOT Modified C66 bridge rail performed acceptably according to *MASH* TL-3 evaluation criteria as shown in Table 3.7.

Table 3.7. Assessment Summary for *MASH* TL-3 Tests on TxDOT Modified C66 Bridge Rail.

Evaluation Factors	**Evaluation Criteria**	**Test No. 469469-2-1**	**Test No. 469469-2-2**
Structural Adequacy	A	S	S
Occupant Risk	D	S	S
	F	S	S
	H	S	S
	I	S	S
	Test No.	***MASH* Test 3-11**	***MASH* Test 3-10**
	Pass/Fail	Pass	Pass

S = Satisfactory
U = Unsatisfactory

CHAPTER 4: TXDOT LOW-PROFILE BARRIER

4.1 BACKGROUND

Details of the low-profile precast concrete barrier are found in TxDOT standard detail LCPB-13. This 20-inch-tall barrier provides improved sight distance for turning maneuvers within low-speed work zone areas. A negative slope on the face of the barrier helps improve vehicle stability during a vehicle impact.

The full *MASH* test matrix was performed on the low-profile barrier to assess vehicle stability, occupant risk, and dynamic deflection. The TL-2 matrix included Test 2-10 with the small passenger car and Test 2-11 with the pickup truck. The target CIPs selected for the tests were determined according to information provided in *MASH* Section 2.3.2, Table 2-7.

4.2 SYSTEM DETAILS

4.2.1 Test Article and Installation Details

The low-profile barrier test installation was approximately 200 ft long. It consisted of 10 precast reinforced concrete barriers that were each 20 ft long and 20 inches tall. The width at the base of the barrier sections was 26 inches and flared out to 28 inches at the top. Adjacent segments were connected with two threaded rods that were inserted into a trough and passed through holes cast into the ends of each segment. Each threaded rod was secured with a plate washer, flat washer, and nut on each end.

Eight of the barriers (numbers 2 through 9) were newly constructed for these tests by a TxDOT-approved contractor. The two end segments (numbers 1 and 10) used to complete the installation were taken from existing TTI inventory.

Figure 4.1 presents overall information on the low-profile barrier, and Figure 4.2 provides photographs of the installation. Appendix C.1 provides further details of the low-profile barrier.

4.2.2 Material Specifications

Appendix C.2 provides material certification documents and information on the concrete used to install/construct the low-profile barrier.

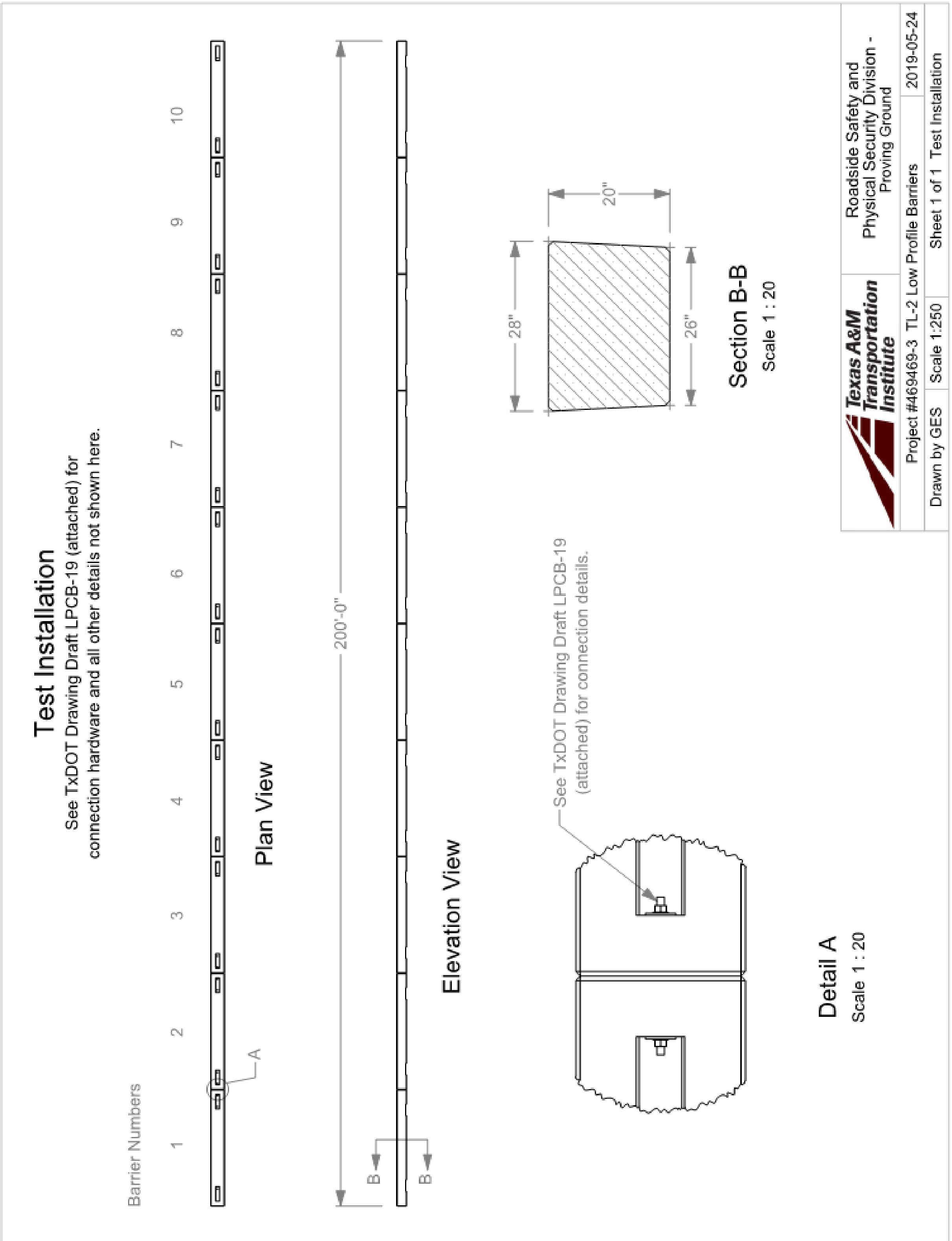


Figure 4.1. Overall Details of the Low-Profile Barrier.

Figure 4.2. Low-Profile Barrier prior to Testing.

4.3 MASH TEST 2-11 (TEST NO. 469469-3-2)

4.3.1 Test Designation and Actual Impact Conditions

MASH Test 2-11 involves a 2700P vehicle weighing 5000 lb ±110 lb impacting the CIP of the low-profile barrier at an impact speed of 44 mi/h ±2.5 mi/h and an angle of 25° ±1.5°. The CIP for *MASH* Test 2-11 on the low-profile barrier was 2.6 ft upstream of the joint between segments 5 and 6.

The 2015 RAM 1500 used in the test weighed 5011 lb, and the actual impact speed and angle were 44.4 mi/h and 25.1°, respectively. The actual impact point was 2.9 ft upstream of the joint between segments 5 and 6. Minimum target impact severity was 52 kip-ft, and actual IS was 59.4 kip-ft.

4.3.2 Weather Conditions

The test was performed on the morning of June 6, 2019. Weather conditions at the time of testing were as follows: wind speed: 5 mi/h; wind direction: 315° with respect to the vehicle (vehicle was traveling at a magnetic heading of 0°); temperature: 79°F; relative humidity: 82 percent.

4.3.3 Test Vehicle

Figure 4.3 and Figure 4.4 show the 2015 RAM 1500 that was used for the crash test. The vehicle's test inertia weight was 5011 lb, and its gross static weight was 5011 lb. The height to the lower edge of the vehicle bumper was 11.8 inches, and height to the upper edge of the bumper was 27 inches. The height to the vehicle's center of gravity was 28.4 inches. Table C.1 and Table C.2 in Appendix C.3.1 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.

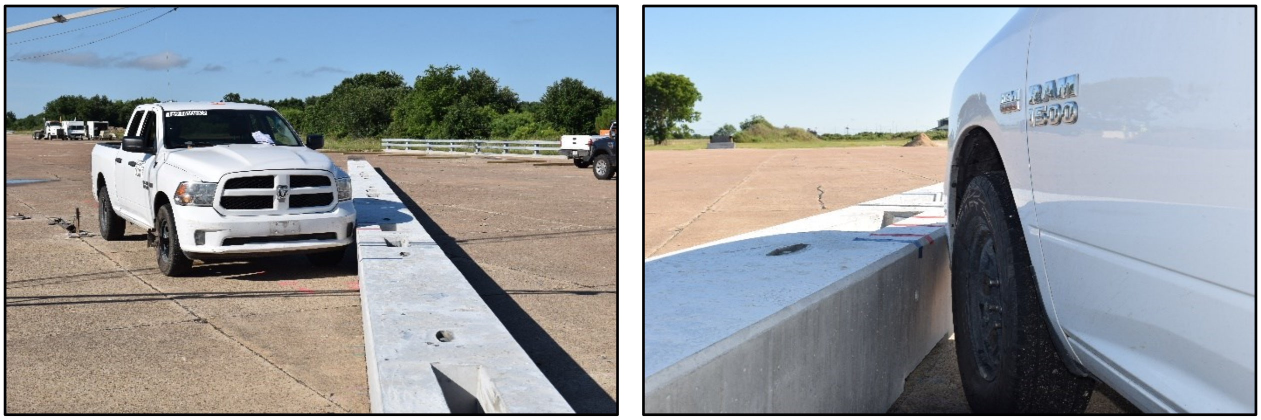


Figure 4.3. Low-Profile Barrier/Test Vehicle Geometrics for Test No. 469469-3-2.

Figure 4.4. Test Vehicle before Test No. 469469-3-2.

4.3.4 Test Description

Table 4.1 lists events that occurred during Test No. 469469-3-2. Figure C.1 and Figure C.2 in Appendix C.3.2 present sequential photographs during the test.

Table 4.1. Events during Test No. 469469-3-2.

Time	Events
0.000	Vehicle contacts barrier
0.080	Vehicle begins to redirect
0.100	Right front tire leaves pavement
0.138	Right rear tire leaves pavement
0.301	Vehicle is parallel with barrier
0.333	Rear left bumper corner makes contact with barrier
0.578	Vehicle exits barrier at 34.4 mi/h at a trajectory angle of 10.6° and a heading angle of 3.2°
0.684	Right front makes contact with pavement
1.455	Secondary impact with front left bumper of vehicle and low-profile barrier

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*. After loss of contact with the barrier, the vehicle yawed counterclockwise and came to rest 120 ft downstream of the point of impact and 2 ft behind the traffic side of the barrier facing approximately 2° to the left. Brakes were not applied.

4.3.5 Damage to Test Installation

Figure 4.5 shows the damage to the low-profile barrier. The field side top corners were broken for a distance ranging from 10 to 18 inches on the downstream end of barrier segments 4, 5, and 7. There was minor cosmetic damage on the traffic side of barrier segments 5 and 6 near the joint. Table 4.2 shows the permanent field side displacement measured at the joints between segments.

Working width[2] was 36.6 inches, and the height of maximum working width was 20 inches. Maximum dynamic deflection during the test was 8.6 inches, and the maximum permanent deflection was 8.5 inches.

[2] Working width is defined as the distance between the traffic face of the barrier before impact and the maximum lateral position of any major part of the barrier or the vehicle after impact.

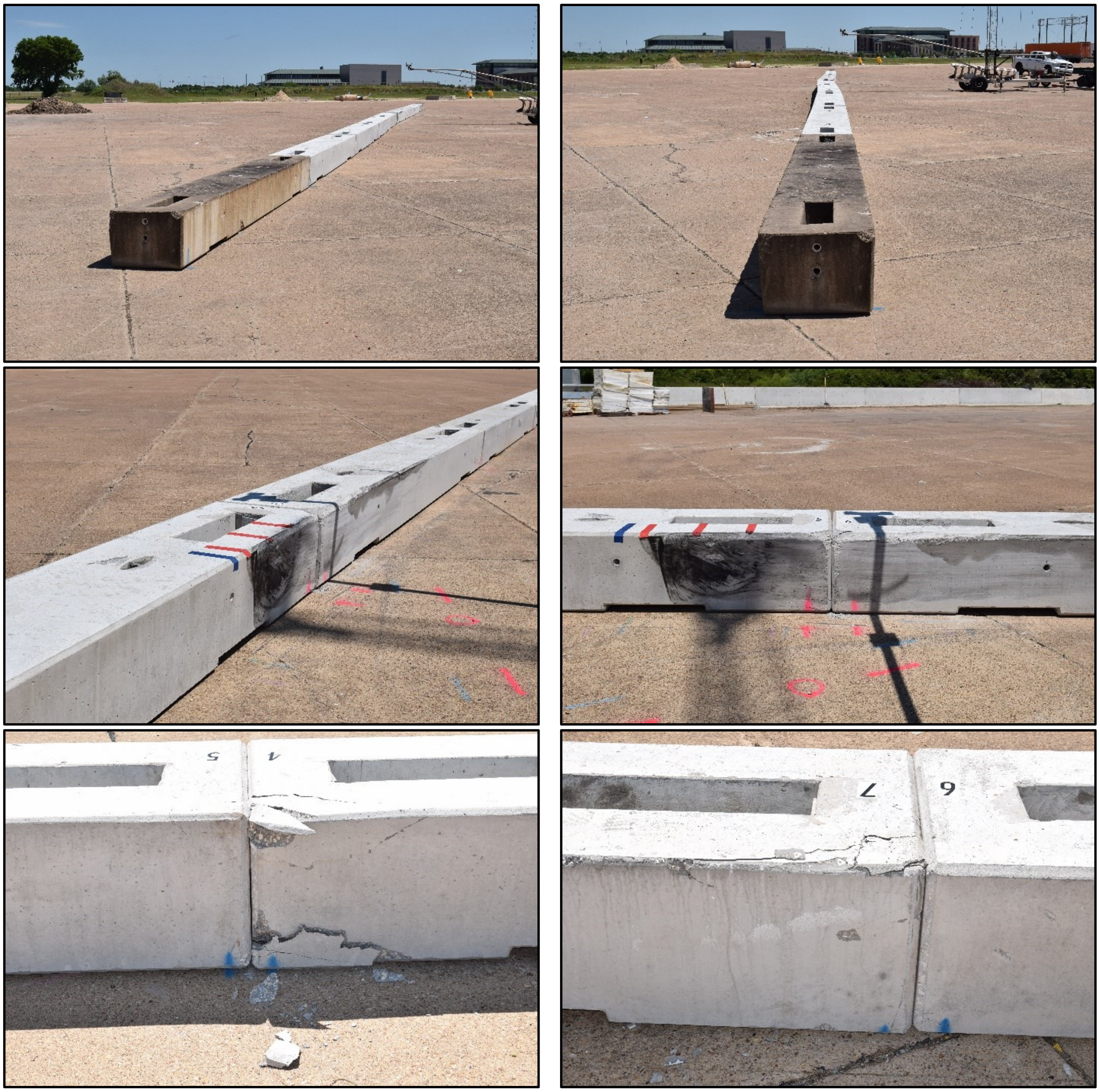


Figure 4.5. Low-Profile Barrier after Test No. 469469-3-2.

Table 4.2. Measured Displacement of Barrier, Test No. 469469-3-2.

Location	Displacement (Inches)
Joint 4-5	4
Joint 5-6	8.5
Joint 6-7	5.5
Joint 7-8	1

4.3.6 Damage to Test Vehicle

Figure 4.6 and Figure 4.7 show the damage sustained by the vehicle. The front bumper, left front fender, left front tire and rim, left front door, left rear door, left rear door, left cab corner, left rear fender, left rear rim, and rear bumper were damaged. Maximum exterior crush to the vehicle was 2 inches in the side plane at the left front corner at bumper height. There was no observed occupant compartment deformation. Table C.3 and Table C.4 in Appendix C.3.1 provide exterior crush and occupant compartment measurements.

Figure 4.6. Test Vehicle after Test No. 469469-3-2.

Figure 4.7. Interior of Test Vehicle for Test No. 469469-3-2 (before Test on Left; after Test on Right).

4.3.7 Occupant Risk Factors

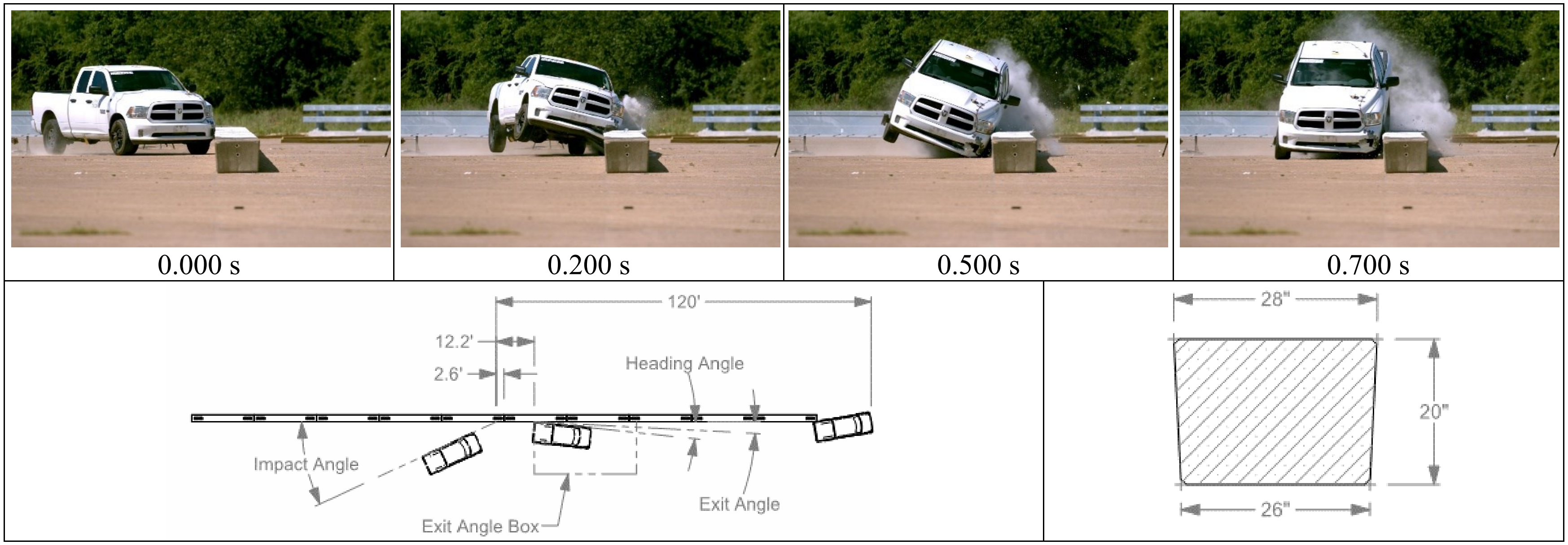
Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk, and results are shown in Table 4.3. Figure 4.8 summarizes these data and other pertinent information from the test. Figure C.3 in Appendix C.3.3 shows the vehicle angular displacements, and Figure C.4 through Figure C.6 in Appendix C.3.4 show acceleration versus time traces.

Table 4.3. Occupant Risk Factors for Test No. 469469-3-2.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)	**ft/s**	at 0.1298 seconds on left side of interior
Longitudinal	**15.1**	
Lateral	**16.1**	
Occupant Ridedown Accelerations (g's)		
Longitudinal	**2.6**	(0.8807–0.8907 seconds)
Lateral	**5.6**	(0.3473–0.3573 seconds)
Theoretical Head Impact Velocity (THIV)	**m/s**	at 0.1252 seconds on left side of interior
	6.7	
Acceleration Severity Index (ASI)	**1.1**	(0.0690–0.1190 seconds)
Maximum 50-ms Moving Average (g's)		
Longitudinal	**−7.3**	(0.0405–0.0905 seconds)
Lateral	**7.9**	(0.0446–0.0946 seconds)
Vertical	**−2**	(0.0301–0.0801 seconds)
Maximum Roll, Pitch, and Yaw Angles	**Degrees**	
Roll	**22**	(0.4391 seconds)
Pitch	**10**	(0.7849 seconds)
Yaw	**31**	(0.4870 seconds)

4.3.8 Assessment of Results

An assessment of the tests based on the applicable safety evaluation criteria for *MASH* Test 2-11 is provided in Table 4.4.



General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 2-11
TTI Test No.	469469-3-2
Test Date	2019-06-06
Test Article	
Type..........................	Longitudinal barrier—low profile
Name	TxDOT low-profile barrier
Installation Length.....	200 ft
Material or Key Elements	Precast concrete barrier segments connected with two threaded rods
Soil Type and Condition	Concrete deck, damp
Test Vehicle	
Type/Designation	2270P
Make and Model	2015 RAM 1500
Curb..........................	4967 lb
Test Inertial	5011 lb
Dummy	No dummy
Gross Static	5011 lb

Impact Conditions	
Speed	44.4 mi/h
Angle	25.1°
Location/Orientation	2.9 ft upstream of the joint between segments 5 and 6
Impact Severity.........	59.4 kip-ft
Exit Conditions	
Speed	34.4 mi/h
Exit Trajectory/Heading	10.6°/3.2°
Occupant Risk Values	
Longitudinal OIV.......	15.1 ft/s
Lateral OIV...............	16.1 ft/s
Longitudinal Ridedown	2.6 g
Lateral Ridedown	5.6 g
THIV	6.7 m/s
ASI...........................	1.1
Max. 0.050-s Average	
Longitudinal.............	−7.3 g
Lateral......................	7.9 g
Vertical.....................	−2 g

Post-Impact Trajectory	
Stopping Distance	120 ft downstrm; 2 ft twd field side
Vehicle Stability	
Maximum Yaw Angle.....	31°
Maximum Pitch Angle....	10°
Maximum Roll Angle	22°
Vehicle Snagging	No
Vehicle Pocketing..........	No
Test Article Deflections	
Dynamic........................	8.6 inches
Permanent	8.5
Working Width...............	36.6 inches
Working Width Height....	20 inches
Vehicle Damage	
VDS	10-LFQ-2
CDC	10FLEW2
Max. Exterior Deformation	2 inches
OCDI.............................	LF0000000
Max. Occupant Compartment Deformation	0 inches

Figure 4.8. Summary of Results for *MASH* Test 2-11 on the Low-Profile Barrier.

Table 4.4. Performance Evaluation Summary for *MASH* Test 2-11 on the Low-Profile Barrier.

Test Agency: Texas A&M Transportation Institute | Test No.: 469469-3-2 | Test Date: 2019-06-06

***MASH* Test 2-11 Evaluation Criteria**	**Test Results**	**Assessment**
<u>Structural Adequacy</u> *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 low-profile barrier contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 8.6 inches.	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.*	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 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 was observed.	
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 was 22°, and maximum pitch was 10°.	Pass
H. *Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.*	Longitudinal OIV was 15.1 ft/s, and lateral OIV was 16.1 ft/s.	Pass
I. *Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 g, or at least below the maximum allowable value of 20.49 g.*	Maximum longitudinal 10-ms occupant ridedown acceleration was 2.6 g, and maximum lateral 10-ms occupant ridedown acceleration was 5.6 g.	Pass

4.4 MASH TEST 2-10 (TEST NO. 469469-3-1)

4.4.1 Test Designation and Actual Impact Conditions

MASH Test 2-10 involves a 1100C vehicle weighing 2420 lb ±55 lb impacting the CIP of the low-profile barrier at an impact speed of 44 mi/h ±2.5 mi/h and an angle of 25° ±1.5°. The CIP for *MASH* Test 2-10 on the low-profile barrier was 3.3 ft upstream of the joint between segments 5 and 6.

The 2009 Kia Rio[3] used in the test weighed 2440 lb, and the actual impact speed and angle were 44.0 mi/h and 25.1°, respectively. The actual impact point was 3.6 ft upstream of the joint between segments 5 and 6. Minimum target impact severity was 25 kip-ft, and actual IS was 29 kip-ft.

4.4.2 Weather Conditions

The test was performed on the morning of June 14, 2019. Weather conditions at the time of testing were as follows: wind speed: 11 mi/h; wind direction: 187° with respect to the vehicle (vehicle was traveling at a magnetic heading of 0°); temperature: 84°F; relative humidity: 73 percent.

4.4.3 Test Vehicle

Figure 4.9 and Figure 4.10 show the 2009 Kia Rio that was used for the crash test. The vehicle's test inertia weight was 2440 lb, and its gross static weight was 2605 lb. The height to the lower edge of the vehicle bumper was 7.8 inches, and height to the upper edge of the bumper was 21.5 inches. Table C.5 in Appendix C.4.1 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.

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[3] The 2009 model vehicle used is older than the 6-year age noted in *MASH* and was selected based upon availability. An older model vehicle is permitted by AASHTO as long as it is otherwise *MASH* compliant. Other than the vehicle's year model, this 2009 model vehicle met the *MASH* requirements.

Figure 4.9. Low-Profile Barrier/Test Vehicle Geometrics for Test No. 469469-3-1.

Figure 4.10. Test Vehicle before Test No. 469469-3-1.

4.4.4 Test Description

Table 4.5 lists events that occurred during Test No. 469469-3-1. Figure C.7 and Figure C.8 in Appendix C.4.2 present sequential photographs during the test.

Table 4.5. Events during Test No. 469469-3-1.

Time	Events
0.000	Vehicle contacts barrier
0.051	Vehicle begins to redirect
0.231	Vehicle is parallel with barrier
0.253	Left rear bumper makes contact with barrier
0.263	Maximum dynamic barrier deflection of 4.9 inches
0.455	Vehicle exits barrier at 30.6 mi/h at a trajectory angle of 9.4° and a heading angle of 7.2°

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 1100C vehicle exited within the exit box criteria defined in *MASH*. After loss of contact with the barrier, the vehicle yawed counterclockwise and came to rest 128 ft downstream of the point of impact and 13 ft on the traffic side of the barrier. Brakes were not applied.

4.4.5 Damage to Test Installation

Figure 4.11 shows the damage to the low-profile barrier. There was concrete spalling, approximately 1½ inches wide and 16 inches long, and cracks on the traffic face upstream end top edge of barrier 6. Table 4.6 shows the permanent field side displacement measured at the joints between segments.

Table 4.6. Measured Displacement of Barrier, Test No. 469469-3-1.

Location	Displacement (Inches)
Joint 4-5	2
Joint 5-6	4.3
Joint 6-7	1

Working width[4] was 32.9 inches, and the height of maximum working width was 20 inches. Maximum dynamic deflection during the test was 4.9 inches, and maximum permanent deflection was 4.3 inches.

[4] Working width is defined as the distance between the traffic face of the barrier before impact and the maximum lateral position of any major part of the barrier or the vehicle after impact.

Figure 4.11. Low-Profile Barrier after Test No. 469469-3-1.

4.4.6 Damage to Test Vehicle

Figure 4.12 and Figure 4.13 show the damage sustained by the vehicle. The front bumper, left front tire and rim, left rear door, left front fender, rear bumper, and left rear fender were damaged. Maximum exterior crush to the vehicle was 6 inches in the side plane at the left front corner at bumper height. There was no observed occupant compartment deformation. Table C.6 and Table C.7 in Appendix C.4.1 provide exterior crush and occupant compartment measurements.

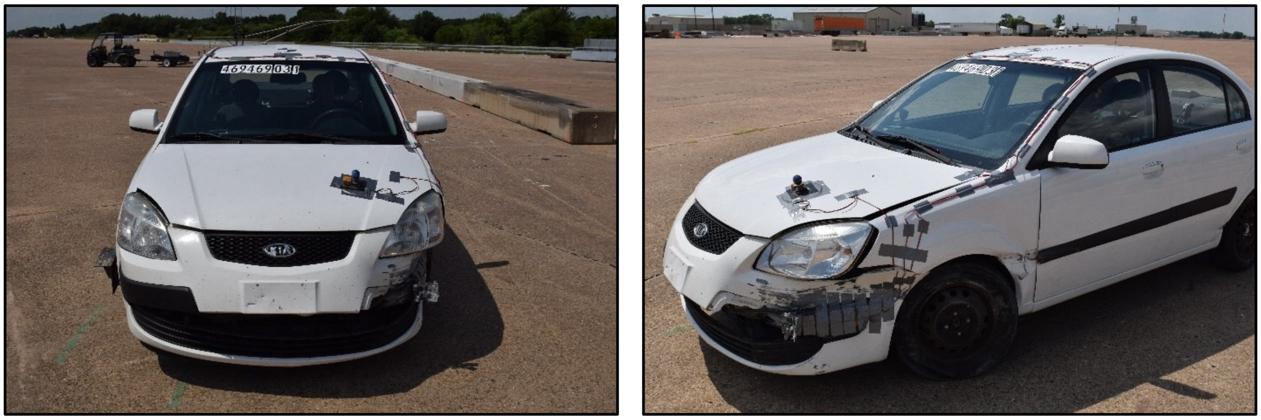


Figure 4.12. Test Vehicle after Test No. 469469-3-1.

Figure 4.13. Interior of Test Vehicle for Test No. 469469-3-1 (before Test on Left; after Test on Right).

4.4.7 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk, and results are shown in Table 4.7. Figure 4.14 summarizes these data and other pertinent information from the test. Figure C.9 in Appendix C.4.3 shows the vehicle angular displacements, and Figure C.10 through Figure C.12 in Appendix C.4.4 show acceleration versus time traces.

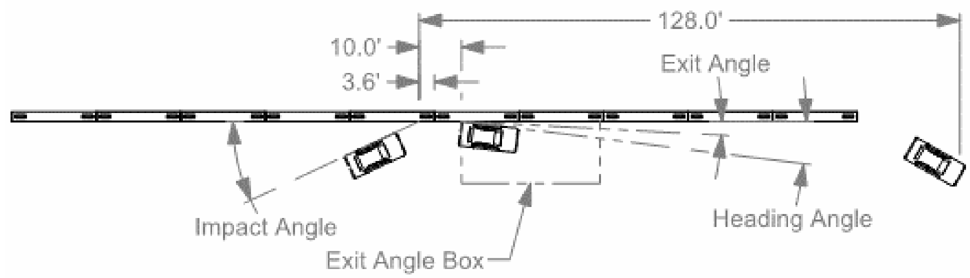
Table 4.7. Occupant Risk Factors for Test No. 469469-3-1.

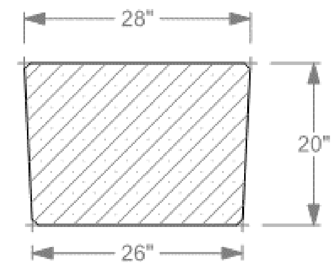
Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)	**ft/s**	at 0.0993 seconds on left side of interior
Longitudinal	**14.4**	
Lateral	**17.4**	
Occupant Ridedown Accelerations (g's)		
Longitudinal	**2.9**	(0.1044–0.1144 seconds)
Lateral	**7.9**	(0.2652–0.2752 seconds)
Theoretical Head Impact Velocity (THIV)	**m/s**	at 0.0958 seconds on left side of interior
	6.8	
Acceleration Severity Index (ASI)	**1.4**	(0.0433–0.0933 seconds)
Maximum 50-ms Moving Average (g's)		
Longitudinal	**−6.9**	(0.0239–0.0739 seconds)
Lateral	**10.3**	(0.0136–0.0636 seconds)
Vertical	**−1.9**	(0.0447–0.0947 seconds)
Maximum Roll, Pitch, and Yaw Angles	**Degrees**	
Roll	**6**	(1.9864 seconds)
Pitch	**3**	(0.3690 seconds)
Yaw	**32**	(0.8730 seconds)

4.4.8 Assessment of Results

An assessment of the tests based on the applicable safety evaluation criteria for *MASH* Test 2-10 is provided in Table 4.8.

0.000 s | 0.200 s | 0.400 s | 0.700 s





General Information	
Test Agency.............	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 2-10
TTI Test No.	469469-3-2
Test Date	2019-06-14
Test Article	
Type.........................	Longitudinal barrier—low profile
Name	TxDOT low-profile barrier
Installation Length.....	200 ft
Material or Key Elements	Precast concrete barrier segments connected with two threaded rods
Soil Type and Condition	Concrete deck, damp
Test Vehicle	
Type/Designation	1100C
Make and Model	2009 Kia Rio
Curb.........................	2451 lb
Test Inertial	2440 lb
Dummy	165 lb
Gross Static	2605 lb

Impact Conditions	
Speed	44 mi/h
Angle	25.1°
Location/Orientation	3.6 ft upstream of the joint between segments 5 and 6
Impact Severity.........	29 kip*ft
Exit Conditions	
Speed	30.6 mi/h
Exit Trajectory/Heading	9.4°/7.2°
Occupant Risk Values	
Longitudinal OIV......	14.4 ft/s
Lateral OIV..............	17.4 ft/s
Longitudinal Ridedown	2.9 g
Lateral Ridedown	7.9 g
THIV	6.8 m/s
ASI..........................	1.4
Max. 0.050-s Average	
Longitudinal.............	−6.9 g
Lateral.....................	10.3 g
Vertical....................	−1.9 g

Post-Impact Trajectory	
Stopping Distance	128 ft downstrm; 13 ft twd traffic
Vehicle Stability	
Maximum Yaw Angle.....	32°
Maximum Pitch Angle....	3°
Maximum Roll Angle	6°
Vehicle Snagging	No
Vehicle Pocketing..........	No
Test Article Deflections	
Dynamic	4.9 inches
Permanent	4.3 inches
Working Width..............	32.9 inches
Working Width Height....	20 inches
Vehicle Damage	
VDS	10-LFQ-2
CDC	10FLEW2
Max. Exterior Deformation	6 inches
OCDI	LF0000000
Max. Occupant Compartment Deformation	0 inches

Figure 4.14. Summary of Results for *MASH* Test 2-10 on the Low-Profile Barrier.

Table 4.8. Performance Evaluation Summary for *MASH* Test 2-10 on the Low-Profile Barrier.

Test Agency: Texas A&M Transportation Institute | Test No.: 469469-3-1 | Test Date: 2019-06-14

MASH Test 2-10 Evaluation Criteria	Test Results	Assessment
<u>Structural Adequacy</u> 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 low-profile barrier contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 4.9 inches.	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.*	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 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 was observed.	
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 was 6°, and maximum pitch was 3°.	Pass
H. *Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.*	Longitudinal OIV was 14.4 ft/s, and lateral OIV was 17.4 ft/s.	Pass
I. *Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 g, or at least below the maximum allowable value of 20.49 g.*	Maximum longitudinal 10-ms occupant ridedown acceleration was 2.9 g, and maximum lateral 10-ms occupant ridedown acceleration was 7.9 g.	Pass

4.5 CONCLUSIONS

The TxDOT low-profile barrier contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 8.6 inches, and maximum permanent deformation was 8.5 inches. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. There was no observed occupant compartment deformation. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 22° and 10°, respectively. Occupant risk factors were within the preferred limits specified in *MASH*. The 2270P vehicle exited within the exit box criteria.

The TxDOT low-profile barrier contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 4.9 inches, and maximum permanent deformation was 4.3 inches. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. There was no observed occupant compartment deformation. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 6° and 3°, respectively. Occupant risk factors were within the allowable limits specified in *MASH*. The 1100C vehicle exited within the exit box criteria.

The TxDOT low-profile barrier performed acceptably according to *MASH* TL-2 evaluation criteria as shown in Table 4.9.

Table 4.9. Assessment Summary for *MASH* TL-2 Tests on TxDOT Low-Profile Barrier.

Evaluation Factors	Evaluation Criteria	Test No. 469469-3-2	Test No. 469469-3-1
Structural Adequacy	A	S	S
Occupant Risk	D	S	S
	F	S	S
	H	S	S
	I	S	S
	Test No.	***MASH* Test 2-11**	***MASH* Test 2-10**
	Pass/Fail	Pass	Pass

S = Satisfactory
U = Unsatisfactory
N/A = Not applicable

CHAPTER 5: TXDOT LOW-PROFILE-TO-F-SHAPE TRANSITION

5.1 BACKGROUND

This transition barrier segment is used to connect the 20-inch-tall low-profile barrier (LPCB-13) to the 32-inch-tall F-shape portable concrete barrier (CSB[1]-10). The low-profile barrier is a TL-2 system intended for use on lower-speed roadways, whereas the F-shape barrier is a TL-3 system suitable for use on high-speed roadways.

The transition is used when a segment of highway is transitioning from a low-speed to a high-speed section. Since the transition barrier segment is attached to the low-profile barrier on one end, it was considered appropriate to test and evaluate the transition segment using the same test level used for the low-profile barrier. This is analogous to testing a guardrail-to-bridge-rail transition to the same level as the approach guardrail, as opposed to the higher level of the bridge rail. Once the transition to a standard barrier height has been made, the roadway speed limits can be adjusted to those that are consistent with the taller TL-3 F-shape barrier.

Previous research under which the low-profile-to-F-shape transition was developed and tested was reviewed to help determine recommended tests for establishing *MASH* compliance and the critical impact points for those tests (*3*). Travel from both directions (i.e., F-shape to low profile and low profile to F-shape) was considered. The previous testing under National Cooperative Highway Research Program (NCHRP) Report 350 demonstrated that the pickup truck was much more stable traveling from the F-shape barrier to the low-profile barrier than in the opposite direction (*3*). Additionally, previous impact simulations with the 820C passenger car under NCHRP Report 350 impact conditions showed that the small car was very stable when impacting from both directions of the transition section, but traveling from the F-shape barrier toward the low-profile barrier was more critical.

It was determined that two tests should be performed to verify the impact performance of the low-profile-to-F-shape transition under *MASH* criteria. Test 2-20 with the small passenger car was performed with the vehicle traveling from the F-shape barrier toward the low-profile barrier. Although previous simulations indicated stable performance, the impact angle for Test 2-20 increased from 20° under NCHRP Report 350 to 25° under *MASH*. Therefore, since the increase in impact angle could aggravate vehicle stability, Test 2-20 was performed in the critical direction of travel. Test 2-21 with the pickup truck was performed with the vehicle traveling from the low-profile barrier toward the F-shape barrier. This was the critical direction of travel based on the previous crash testing.

5.2 SYSTEM DETAILS

5.2.1 Test Article and Installation Details

Low-profile-to-F-shape transition installation consisted of five 20-ft-long low-profile barriers, one 10-ft-long transition section, and three 30-ft-long F-shape precast reinforced concrete barrier segments set end to end. The barriers were placed freestanding (not attached or anchored) on a concrete surface.

The low-profile barrier segments were 20 inches tall, 28 inches wide at the top, and 26 inches wide at the bottom. They were connected to each other and to the transition section using two 1¼-inch-diameter steel rods with a plate washer, flat washer, and nut on each end. These steel rods were inserted into a trough and passed through holes cast into the ends of the low-profile barrier and transition sections.

The F-shape barrier segments were 32 inches tall, 9½ inches wide at the top, and 24 inches wide at the bottom. The F-shape barrier segment placed adjacent to the transition section was connected to the transition section using a cross-bolt connection consisting of two 7/8-inch-diameter rods with a plate washer, flat washer, and nut on each end. The rods passed through holes cast in the ends of the barrier segments at two different elevations forming an X in plan view and terminated in recesses cast into the sides of the barriers. This F-shape barrier section had a bent plate connection on the other end opposite the transition section. The portion of the plate that protruded from the end of the barrier had a J-shape that interlocked with a corresponding J-shaped bent plate on the adjacent F-shape barrier. The other two F-shape barriers had the J-shaped bent plate connection on each end.

The transition barrier segment transitioned from a 20-inch-tall low-profile barrier section on one end to a 32-inch-tall F-shape profile on the other end. The height and shape transitioned to the F-shape profile over a distance of 7.5 ft. The last 2.5 ft of the transition section had an F-shape profile to accommodate the cross-bolt connection to the adjacent F-shape barrier segment. The transition section had two 3-inch-tall by 24-inch-long drainage scuppers cast into the bottom 2 ft from each end.

Figure 5.1 presents overall information on the low-profile-to-F-shape transition, and Figure 5.2 provides photographs of the installation. Appendix D.1 provides further details of the low-profile-to-F-shape transition.

5.2.2 Material Specifications

The minimum compressive strength of the TxDOT Class C concrete specified for the transition section was 3600 psi. The transition barrier segment was cast on June 28, 2019. The average compressive strength of the single batch of concrete used in the transition measured 6213 psi on July 29, 2019 (at 31 days). An existing low-profile barrier segment was cored on August 2, 2019, and its compressive strength measured 8170 psi.

Reinforcement of the transition barrier segment was comprised of Grade 60 rebar with a specified minimum yield strength of 60 ksi.

Appendix D.2 provides material certification documents and information on the concrete used to install/construct a low-profile-to-F-shape transition.

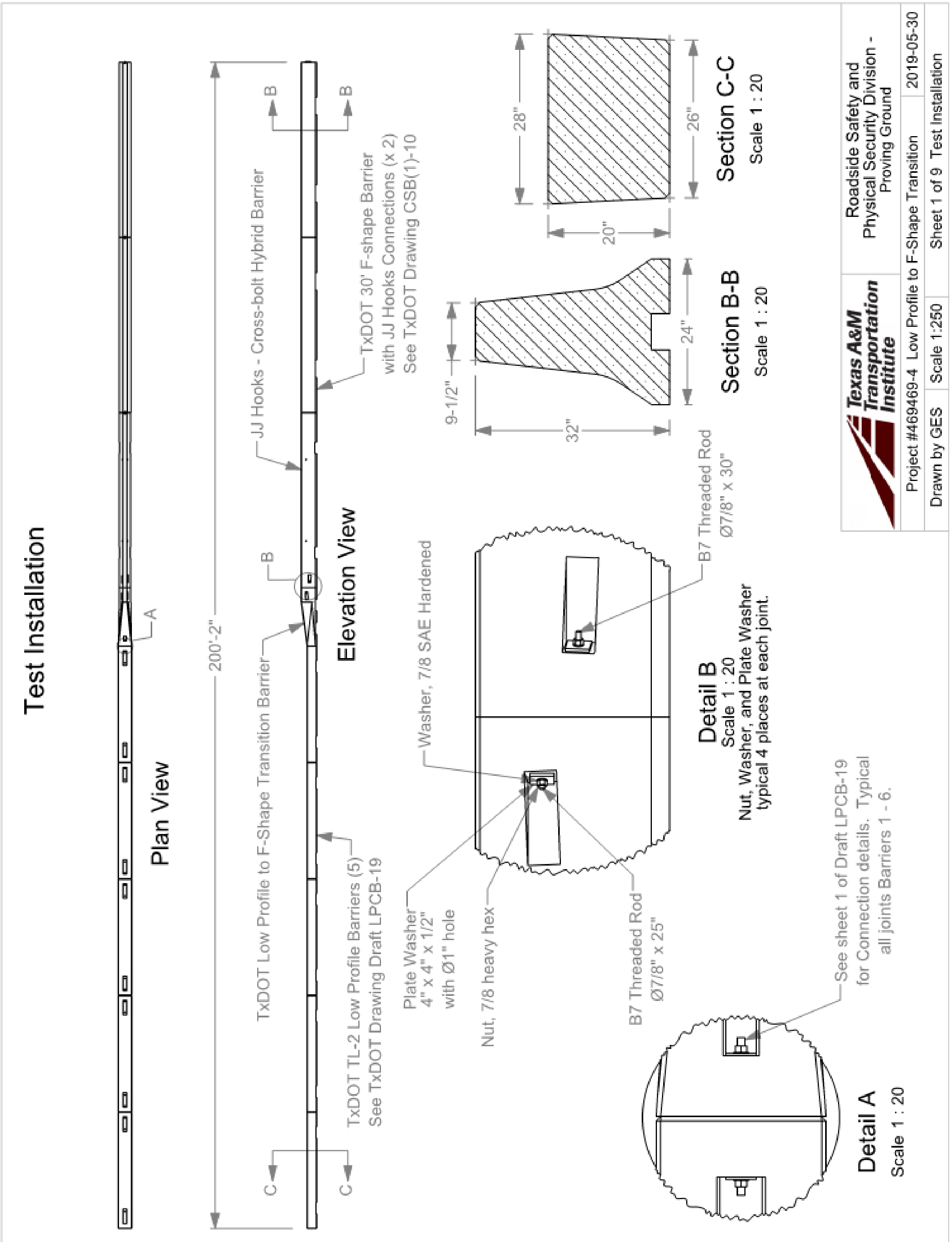


Figure 5.1. Overall Details of Low-Profile-to-F-Shape Transition.

Figure 5.2. Low-Profile-to-F-Shape Transition prior to Testing.

5.3 MASH TEST 2-20 (TEST NO. 469469-4-1)

5.3.1 Test Designation and Actual Impact Conditions

MASH Test 2-20 involves a 1100C vehicle weighing 2420 lb ±55 lb impacting the CIP of a low-profile-to-F-shape transition at an impact speed of 44 mi/h ±2.5 mi/h and an angle of 25° ±1.5°. The CIP for *MASH* Test 2-20 on a low-profile-to-F-shape transition was 30 inches downstream of joint 3-4 (between the transition and F-shape barriers) as determined through previous finite element impact simulations (*3*).

The 2008 Kia Rio[5] used in the test weighed 2420 lb, and the actual impact speed and angle were 45.3 mi/h and 24.6°, respectively. The actual impact point was 27.9 inches

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[5] The 2008 model vehicle used is older than the 6-year age noted in *MASH* and was selected based upon availability. An older model vehicle is permitted by AASHTO as long as it is otherwise *MASH* compliant. Other than the vehicle's year model, this 2008 model vehicle met the *MASH* requirements.

downstream of joint 3-4. Minimum target impact severity was 25 kip-ft, and actual IS was 28.8 kip-ft.

5.3.2 Weather Conditions

The test was performed on the morning of July 29, 2019. Weather conditions at the time of testing were as follows: wind speed: 10 mi/h; wind direction: 18° with respect to the vehicle (vehicle was traveling at a magnetic heading of 205°); temperature: 88°F; relative humidity: 70 percent.

5.3.3 Test Vehicle

The 2008 Kia Rio shown in Figure 5.3 and Figure 5.4 was used for the crash test. The vehicle's test inertia weight was 2420 lb, and its gross static weight was 2585 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 21.5 inches. Table D.1 in Appendix D.3.1 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.

Figure 5.3. Low-Profile-to-F-Shape Transition/Test Vehicle Geometrics for Test No. 469469-4-1.

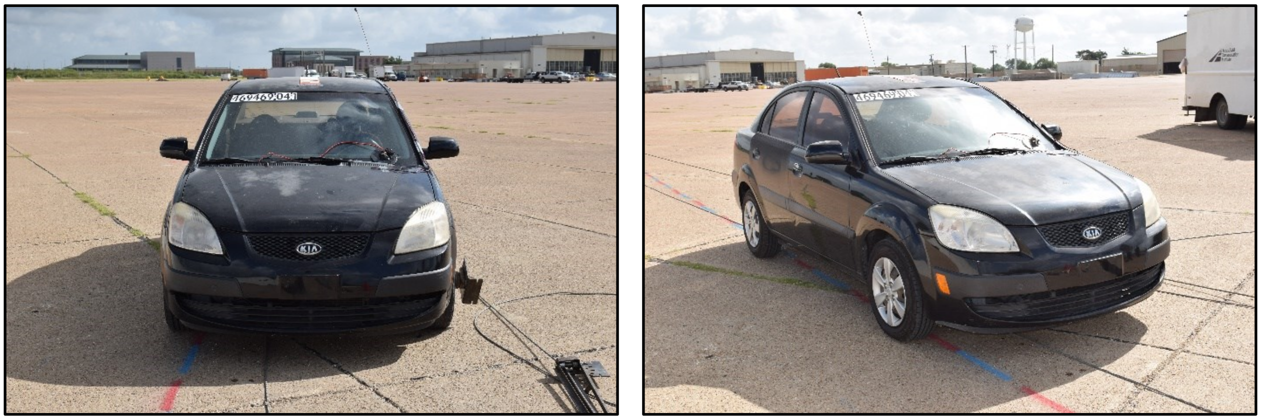


Figure 5.4. Test Vehicle before Test No. 469469-4-1.

5.3.4 Test Description

Table 5.1 lists events that occurred during Test No. 469469-4-1. Figure D.1 and Figure D.2 in Appendix D.3.2 present sequential photographs during the test.

Table 5.1. Events during Test No. 469469-4-1.

Time	Events
0.000	Vehicle contacts barrier
0.022	Vehicle begins to redirect
0.024	Transition barrier begins to displace toward field side
0.039	Transition barrier No. 4 begins to displace toward field side
0.062	Low-profile barrier No. 5 begins to displace toward field side
0.127	Front left tire leaves pavement
0.174	Vehicle is parallel with barrier
0.237	Right rear corner of vehicle impacts transition barrier
0.263	Rear left tire leaves pavement
0.383	Vehicle loses contact with barrier. Vehicle exits barrier at 37.1 mi/h at a trajectory angle of 9.8° and a heading angle of 15.3° from the barrier.
0.385	Right front tire makes contact with pavement
0.532	Left front tire makes contact with 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 1100C vehicle exited within the exit box criteria defined in *MASH*. After loss of contact with the barrier, the vehicle yawed counterclockwise and came to rest 150 ft downstream of the point of impact and 75 ft behind the traffic side of the barrier facing approximately 45° to the left of downstream. Brakes were applied 3.1 second after impact.

5.3.5 Damage to Test Installation

Figure 5.5 shows the damage to the low-profile-to-F-shape transition system. The barriers were pushed toward the field side 8 inches at the joint between barriers 3 and 4, 6 inches at the joint between barriers 4 and 5, and 2 inches at the joint between barriers 5 and 6. There was an area of concrete damage 18 inches up from the bottom and 48 inches long on the traffic-side downstream end of barrier 3.

Working width[6] was 36 inches, and the height of maximum working width was 0 inches (toe of the barrier). Maximum dynamic deflection during the test was 8 inches, and maximum permanent deflection was 8 inches.

[6] Working width is defined as the distance between the traffic face of the barrier before impact and the maximum lateral position of any major part of the barrier or the vehicle after impact.

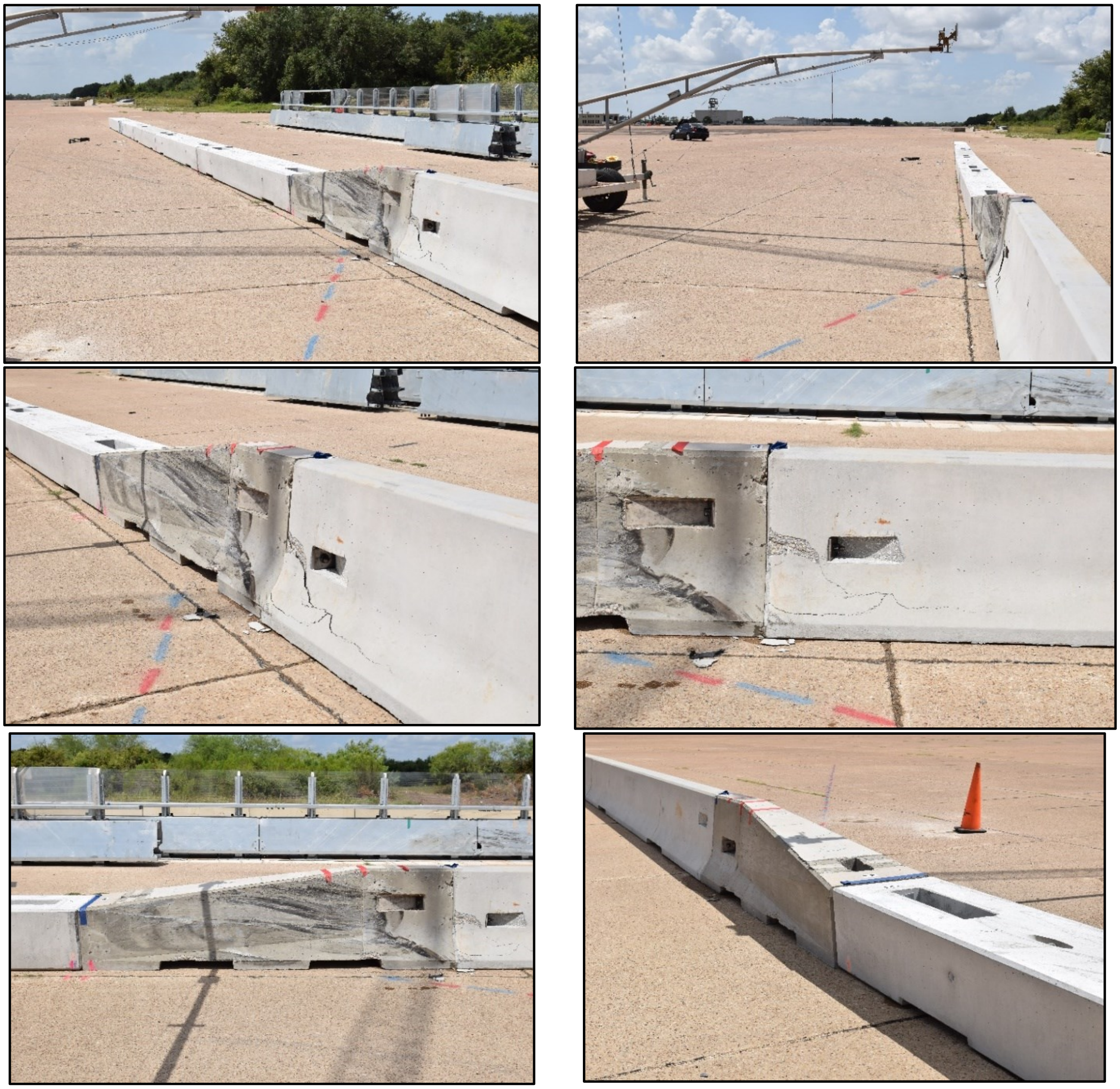


Figure 5.5. Low-Profile-to-F-Shape Transition after Test No. 469469-4-1.

5.3.6 Damage to Test Vehicle

Figure 5.6 and Figure 5.7 show the damage sustained by the vehicle. The front bumper, right front fender, right front tire and rim, right strut tower, right rear door, right head light, hood, right rear fender, right rear tire and rim, and rear bumper were damaged. Maximum exterior crush to the vehicle was 7 inches in the side plane at the right front corner at bumper height. There was no measurable occupant compartment deformation. Table D.2 and Table D.3 in Appendix D.3.1 provide exterior crush and occupant compartment measurements.

Figure 5.6. Test Vehicle after Test No. 469469-4-1.

Figure 5.7. Interior of Test Vehicle for Test No. 469469-4-1 (before Test on Left; after Test on Right).

5.3.7 Occupant Risk Factors

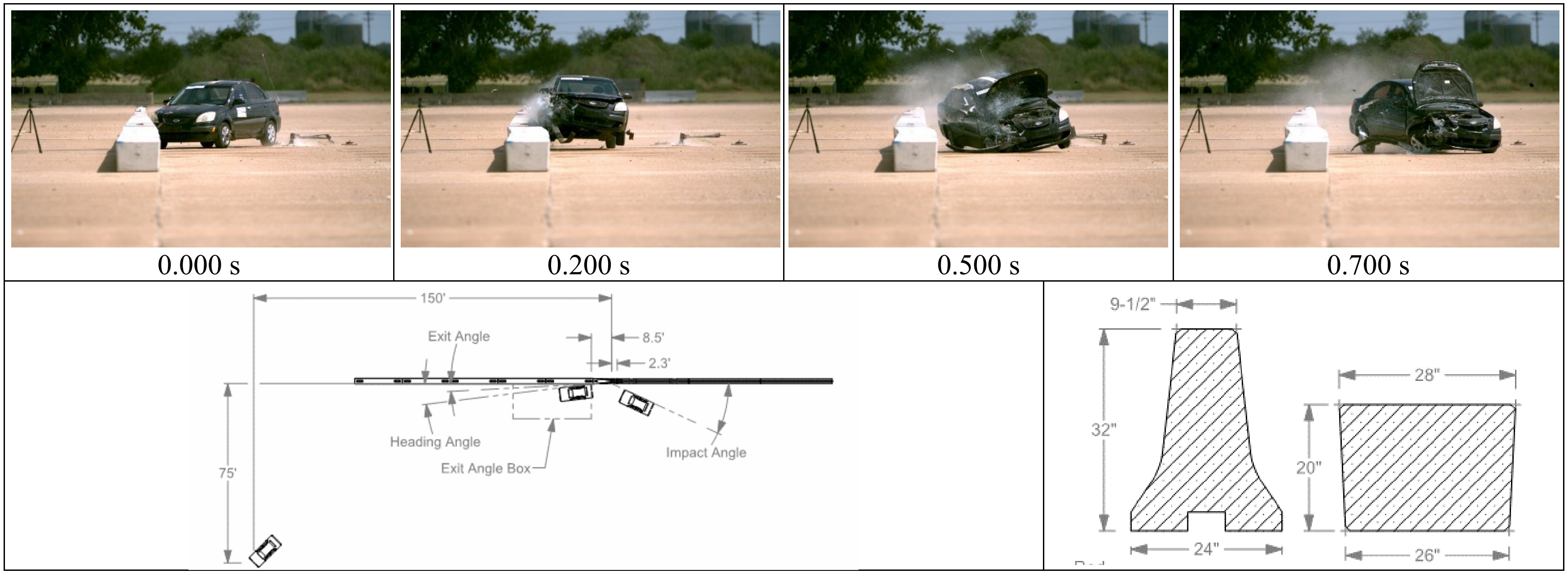
Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk, and results are shown in Table 5.2. Figure 5.8 summarizes these data and other pertinent information from the test. Figure D.3 in Appendix D.3.3 shows the vehicle angular displacements, and Figure D.4 through Figure D.6 in Appendix D.3.4 show acceleration versus time traces.

Table 5.2. Occupant Risk Factors for Test No. 469469-4-1.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)	**ft/s**	at 0.0882 seconds on right side of interior
Longitudinal	**15.4**	
Lateral	**23.6**	
Occupant Ridedown Accelerations (g's)	**ft/s²**	
Longitudinal	**2.1**	(0.2382–0.2482 seconds)
Lateral	**7.8**	(0.2308–0.2408 seconds)
Theoretical Head Impact Velocity (THIV)	**m/s**	at 0.0855 seconds on right side of interior
	8.6	
Acceleration Severity Index (ASI)	**1.7**	(0.0477–0.0977 seconds)
Maximum 50-ms Moving Average (g's)	**ft/s²**	
Longitudinal	**−7.1**	(0.0319–0.0819 seconds)
Lateral	**−12.8**	(0.0303–0.0803 seconds)
Vertical	**−2.5**	(0.0182–0.0682 seconds)
Maximum Roll, Pitch, and Yaw Angles	**Degrees**	
Roll	**17**	(0.4889 seconds)
Pitch	**8**	(1.1183 seconds)
Yaw	**59**	(2.0000 seconds)

5.3.8 Assessment of Results

An assessment of the tests based on the applicable safety evaluation criteria for *MASH* Test 2-20 is provided in Table 5.3.



General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 2-20
TTI Test No.	469469-4-1
Test Date	2019-07-29

Test Article

Type	Longitudinal barrier—transition
Name	TxDOT low-profile-to-F-shape transition
Installation Length	200 ft 2 inches
Material or Key Elements	10 ft concrete shape transition section between 5 low-profile barrier segments and 3 F-shape barrier segments
Soil Type and Condition	Concrete deck, damp

Test Vehicle

Type/Designation	1100C
Make and Model	2008 Kia Rio
Curb	2461 lb
Test Inertial	2420 lb
Dummy	165 lb, on impact side
Gross Static	2585 lb

Impact Conditions

Speed	45.3 mi/h
Angle	24.6°
Location/Orientation	27.9 inches downstream of joint 3-4
Impact Severity	28.8 kip-ft

Exit Conditions

Speed	37.1 mi/h
Exit Trajectory/Heading	9.8°/15.3°

Occupant Risk Values

Longitudinal OIV	15.4 ft/s
Lateral OIV	23.6 ft/s
Longitudinal Ridedown	2.1 g
Lateral Ridedown	7.8 g
THIV	8.6 m/s
PHD	7.9 g
ASI	1.7
Max. 0.050-s Average	
Longitudinal	−7.1 g
Lateral	−12.8 g
Vertical	−2.5 g

Post-Impact Trajectory

Stopping Distance	150 ft downstrm; 75 ft toward traffic side

Vehicle Stability

Maximum Yaw Angle	59°
Maximum Pitch Angle	8°
Maximum Roll Angle	17°
Vehicle Snagging	No
Vehicle Pocketing	No

Test Article Deflections

Dynamic	8 inches
Permanent	8 inches
Working Width	36 inches
Working Width Height	0 inches

Vehicle Damage

VDS	10-RFQ-2
CDC	10RLEW2
Max. Exterior Deformation	7 inches
OCDI	LF0000000
Max. Occupant Compartment Deformation	0 inches

Figure 5.8. Summary of Results for *MASH* Test 2-20 on Low-Profile-to-F-Shape Transition.

Table 5.3. Performance Evaluation Summary for *MASH* Test 2-20 on Low-Profile-to-F-Shape Transition.

Test Agency: Texas A&M Transportation Institute | Test No.: 469469-04-1 | Test Date: 2019-07-29

***MASH* Test 2-10 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 low-profile-to-F-shape transition contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 8 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 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 was observed.	
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 was 17°, and maximum pitch was 8°.	Pass
H. Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.	Longitudinal OIV was 15.4 ft/s, and lateral OIV was 23.6 ft/s.	Pass
I. Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 g, or at least below the maximum allowable value of 20.49 g.	Maximum longitudinal 10-ms occupant ridedown acceleration was 2.1 g, and maximum lateral 10-ms occupant ridedown acceleration was 7.8 g.	Pass
Vehicle Trajectory For redirective devices, it is preferable that the vehicle be smoothly redirected and leave the barrier within the “exit box” criteria (not less than 32.8 ft for the 1100C and 2270P vehicles), and should be documented.	The 1100C vehicle exited within the exit box criteria.	Documentation only

5.4 MASH TEST 2-21 (TEST NO. 469469-4-2)

5.4.1 Test Designation and Actual Impact Conditions

MASH Test 2-21 involves a 2270P vehicle weighing 5000 lb ±110 lb impacting the CIP of a low-profile-to-F-shape transition at an impact speed of 44 mi/h ±2.5 mi/h and an angle of 25° ±1.5°. The CIP for *MASH* Test 2-11 on the low-profile-to-F-shape transition was at the joint between segments 5 and 6 (between the low-profile barriers and the transition) as determined by previous finite element impact simulations (*3*).

The 2015 RAM 1500 used in the test weighed 5030 lb, and the actual impact speed and angle were 44.3 mi/h and 24.4°, respectively. The actual impact point was at the joint between segments 5 and 6. Minimum target impact severity was 52 kip-ft, and actual IS was 56.3 kip-ft.

5.4.2 Weather Conditions

The test was performed on the morning of August 1, 2019. Weather conditions at the time of testing were as follows: wind speed: 1 mi/h; wind direction: 155° with respect to the vehicle (vehicle was traveling at a magnetic heading of 335°); temperature: 89°F; relative humidity: 68 percent.

5.4.3 Test Vehicle

The 2015 RAM 1500 shown in Figure 5.9 and Figure 5.10 was used for the crash test. The vehicle's test inertia weight was 5030 lb, and its gross static weight was 5030 lb. The height to the lower edge of the vehicle bumper was 11.8 inches, and height to the upper edge of the bumper was 27 inches. The height to the vehicle's center of gravity was 28.9 inches. Table D.4 and Table D.5 in Appendix D.4.1 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.

Figure 5.9. Low-Profile-to-F-Shape Transition/Test Vehicle Geometrics for Test No. 469469-4-2.

Figure 5.10. Test Vehicle before Test No. 469469-4-2.

5.4.4 Test Description

The 2015 RAM 1500, traveling at an impact speed of 56 mi/h, contacted the low-profile-to-F-shape transition at an impact angle of 24.4°. Table 5.4 lists events that occurred during Test No. 469469-4-2. Figure D.7 and Figure D.8 in Appendix D.4.2 present sequential photographs during the test.

Table 5.4. Events during Test No. 469469-4-2.

Time	Events
0.000	Vehicle contacts barrier
0.048	Vehicle begins to redirect
0.342	Vehicle is parallel with barrier
0.052	Transition and low-profile barrier begins to displace toward field side
0.075	F-shape barrier No. 7 begins to displace toward field side
0.101	Right front tire lifts off pavement
0.346	Left rear bumper impacts transition barrier
0.376	Right rear tire lifts off pavement
0.549	Vehicle loses contact with barrier. Vehicle exits at a speed of 35.5 mi/h, with a trajectory angle of 6.4° and a heading angle of 0.4° toward the barrier.
0.680	Right front tire makes contact with pavement
0.883	Right rear tire makes contact with 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*. After loss of contact with the barrier, the vehicle yawed counterclockwise and came to rest 150 ft downstream of the point of impact and 27 ft on the field side of the barrier. Brakes were applied 4.2 s after impact.

5.4.5 Damage to Test Installation

Figure 5.11 shows the damage to the low-profile-to-F-shape transition system. The barriers were pushed toward the field side 1 inch at the joint between barriers 4 and 5, 9 inches at the joint between barriers 5 and 6, and 14 inches at the joint between barriers 6 and 7. There was concrete damage to the upstream traffic faces of barriers 6 and 7, and the concrete face was spalled on the upstream end of the field side of barrier 5. Working width[7] was 38.5 inches, and the height of maximum working width was 0 inches (at the toe of the barrier). Maximum dynamic deflection during the test was 14.5 inches, and the maximum permanent deflection was 14.0 inches.

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[7] Working width is defined as the distance between the traffic face of the barrier before impact and the maximum lateral position of any major part of the barrier or the vehicle after impact.

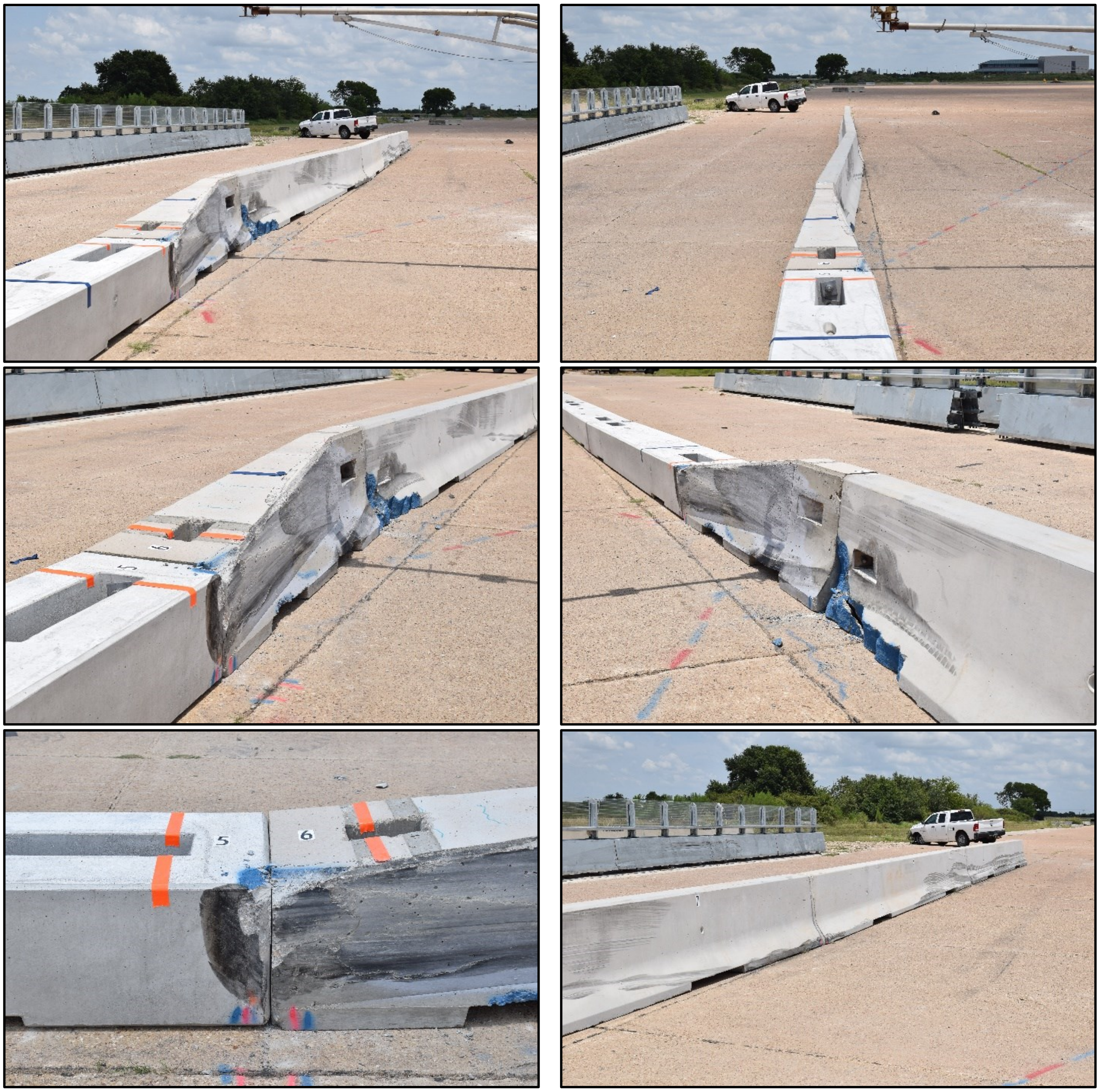


Figure 5.11. Low-Profile-to-F-Shape Transition after Test No. 469469-4-2.

5.4.6 Damage to Test Vehicle

Figure 5.12 and Figure 5.13 show the damage sustained by the vehicle. The front left bumper, left front tire and rim, left front door, left front fender, left headlight, and left front A-arm were damaged. Maximum exterior crush to the vehicle was 13 inches in the side plane at the left front corner at bumper height. There was no measurable occupant compartment deformation. Table D.6 and Table D.7 in Appendix D.4.1 provide exterior crush and occupant compartment measurements.

Figure 5.12. Test Vehicle after Test No. 469469-4-2.

Figure 5.13. Interior of Test Vehicle for Test No. 469469-4-2 (before Test on Left; after Test on Right).

5.4.7 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk, and results are shown in Table 5.5. Figure 5.14 summarizes these data and other pertinent information from the test. Figure D.9 in Appendix D.4.3 shows the vehicle angular displacements, and Figure D.10 through Figure D.12 in Appendix D.4.4 show acceleration versus time traces.

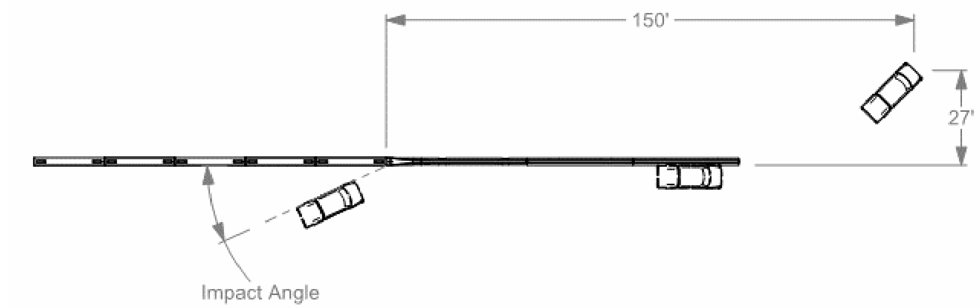
Table 5.5. Occupant Risk Factors for Test No. 469469-4-2.

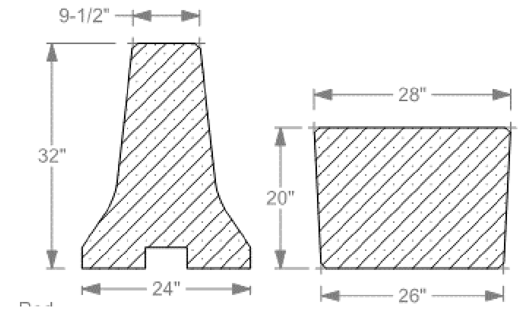
Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)	**ft/s**	at 0.1332 seconds on left side of interior
Longitudinal	**12.8**	
Lateral	**14.1**	
Occupant Ridedown Accelerations (g's)	**ft/s²**	
Longitudinal	**2.0**	(0.7312–0.7412 seconds)
Lateral	**6.8**	(0.3773–0.3873 seconds)
Theoretical Head Impact Velocity (THIV)	**m/s**	at 0.1285 seconds on left side of interior
	5.8	
Acceleration Severity Index (ASI)	**1.03**	(0.0636–0.1136 seconds)
Maximum 50-ms Moving Average (g's)	**ft/s²**	
Longitudinal	**−5.6**	(0.0354–0.0854 seconds)
Lateral	**7.2**	(0.0441–0.0941 seconds)
Vertical	**−3.5**	(0.0499–0.0999 seconds)
Maximum Roll, Pitch, and Yaw Angles	**Degrees**	
Roll	**7**	(0.5262 seconds)
Pitch	**7**	(0.7546 seconds)
Yaw	**26**	(0.3909 seconds)

5.4.8 Assessment of Results

An assessment of the tests based on the applicable safety evaluation criteria for *MASH* Test 2-21 is provided in Table 5.6.

0.000 s | 0.200 s | 0.400 s | 0.700 s





General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 2-21
TTI Test No.	469469-4-2
Test Date	2019-08-01
Test Article	
Type	Longitudinal barrier—low profile
Name	TxDOT low-profile-to-F-shape transition
Installation Length	200 ft
Material or Key Elements	10 ft concrete shape transition section between 5 low-profile barrier segments and 3 F-shape barrier segments
Soil Type and Condition	Concrete deck, damp
Test Vehicle	
Type/Designation	2270P
Make and Model	2015 RAM 1500
Curb	4944 lb
Test Inertial	5030 lb
Dummy	No dummy
Gross Static	5030 lb

Impact Conditions	
Speed	44.3 mi/h
Angle	24.4°
Location/Orientation	At the center of joints 5 and 6
Impact Severity	56.3 kip*ft
Exit Conditions	
Speed	35.5 mi/h
Exit Trajectory/Heading	6.3°/0.4°
Occupant Risk Values	
Longitudinal OIV	12.8 ft/s
Lateral OIV	14.1 ft/s
Longitudinal Ridedown	2.0 g
Lateral Ridedown	6.8 g
THIV	5.8 km/h
PHD	6.8 g
ASI	1.03
Max. 0.050-s Average	
Longitudinal	−5.6 g
Lateral	7.2 g
Vertical	−3.5 g

Post-Impact Trajectory	
Stopping Distance	150 ft downstrm; 27 ft on field side of barrier
Vehicle Stability	
Maximum Yaw Angle	26°
Maximum Pitch Angle	7°
Maximum Roll Angle	7°
Vehicle Snagging	No
Vehicle Pocketing	No
Test Article Deflections	
Dynamic	14.5 inches
Permanent	14 inches
Working Width	38.5 inches
Working Width Height	0 inches
Vehicle Damage	
VDS	10-LFQ-2
CDC	10FLEW2
Max. Exterior Deformation	6 inches
OCDI	LF0000000
Max. Occupant Compartment Deformation	0 inches

Figure 5.14. Summary of Results for *MASH* Test 2-11 on Low-Profile-to-F-Shape Transition.

Table 5.6. Performance Evaluation Summary for *MASH* Test 2-21 on Low-Profile-to-F-Shape Transition.

Test Agency: Texas A&M Transportation Institute — Test No.: 469469-04-2 — Test Date: 2019-08-01

MASH Test 2-11 Evaluation Criteria	Test Results	Assessment
<u>Structural Adequacy</u> 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 low-profile-to-F-shape transition contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 14.5 inches.	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.*	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 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 was observed.	
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 was 7°, and maximum pitch was 7°.	Pass
H. *Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.*	Longitudinal OIV was 12.8 ft/s, and lateral OIV was 14.1 ft/s.	Pass
I. *Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 g, or at least below the maximum allowable value of 20.49 g.*	Maximum longitudinal 10-ms occupant ridedown acceleration was 2.0 g, and maximum lateral 10-ms occupant ridedown acceleration was 6.8 g.	Pass
<u>Vehicle Trajectory</u> For redirective devices, it is preferable that the vehicle be smoothly redirected and leave the barrier within the “exit box” criteria (not less than 32.8 ft for the 1100C and 2270P vehicles), and should be documented.	The 2270P vehicle exited within the exit box criteria.	Documentation only

5.5 CONCLUSIONS

In Test 2-20, the TxDOT low-profile-to-F-shape transition contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 8 inches, and permanent deformation was 8 inches. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. There was no observed occupant compartment deformation. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 17° and 8°, respectively. Occupant risk factors were within the preferred limits specified in *MASH*. The 1100C vehicle exited within the exit box criteria.

In Test 2-21, the TxDOT low-profile-to-F-shape transition contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 14.5 inches, and permanent deformation was 14 inches. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. There was no observed occupant compartment deformation. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 7° and 7°, respectively. Occupant risk factors were within the preferred limits specified in *MASH*. The 2270P vehicle exited within the exit box criteria.

The TxDOT low-profile-to-F-shape transition performed acceptably according to *MASH* TL-2 evaluation criteria as shown in Table 5.7.

Table 5.7. Assessment Summary for *MASH* TL-2 Tests on TxDOT Low-Profile-to-F-Shape Transition.

Evaluation Factors	Evaluation Criteria	Test No. 469469-4-1	Test No. 469469-4-2
Structural Adequacy	A	S	S
Occupant Risk	D	S	S
	F	S	S
	H	S	S
	I	S	S
	Test No.	***MASH* Test 2-20**	***MASH* Test 2-21**
	Pass/Fail	Pass	Pass

S = Satisfactory
U = Unsatisfactory
N/A = Not applicable

CHAPTER 6: TXDOT THRIE-BEAM TRANSITION TO CONCRETE BARRIER WITHOUT END SHOE BLOCK

6.1 BACKGROUND

When guardrail is used at a bridge approach, the stiffness of the more flexible metal beam guard fence is transitioned to the rigid concrete bridge parapet using a nested thrie-beam transition section with reduced post spacing. This thrie-beam transition section has been previously tested to *MASH* at both the upstream and downstream ends (*4, 5*). When the transition system was tested at the downstream end near its connection to a safety-shaped concrete parapet, a tapered steel block was positioned under the end shoe to keep it in a vertical plane.

The TxDOT variation of this transition, which is detailed in standard GF(31)TR, does not use the tapered blockout but rather twists the nested thrie beam and end shoe into the sloped barrier face. It was decided to test the downstream transition without the tapered end shoe block to determine if this configuration is *MASH* compliant.

The critical test for evaluating the need for the tapered end shoe block is *MASH* test designation 3-21 with the 2270P pickup truck. The stability of the pickup truck is most likely to be affected by the sloping thrie-beam rail adjacent to the bridge rail parapet. The standard detail sheet for the thrie-beam transition permits the use of three different post types: W6×8.5 steel posts, 7-inch-diameter round wood posts, and 6-inch by 8-inch rectangular wood posts. Researchers consider the W6×8.5 steel post to be the most critical condition for post snagging. Therefore, the steel post option was used in the full-scale crash test. By using the most critical post type, a successful result would also be applicable to the other post types permitted in the standard.

TxDOT bridge rail standards include two systems that have sloped faces that attach to the TL-3 thrie-beam transition. These are a 32-inch F-shape parapet (Type T551) and a 36-inch single slope traffic rail (SSTR). The SSTR has an 11° slope on the traffic face compared to a 6.5° slope on the upper face of the F-shape parapet. The greater slope of the SSTR made it the more critical profile for evaluating the thrie-beam transition without end shoe block. A successful result with the more critical SSTR would also be applicable to the T551 F-shape bridge rail.

6.2 SYSTEM DETAILS

6.2.1 Test Article and Installation Details

The bridge parapet constructed for the test was a 36-inch-tall SSTR. A 12.5-ft-long section of nested, 12-gauge thrie-beam rail was attached to the face of the SSTR using a 10-gauge thrie-beam terminal connector. The nested thrie-beam rail was twisted toward the sloped traffic face of the SSTR such that the terminal connector lay approximately flush with the surface of the parapet. The terminal connector was then attached to the parapet using five 7/8-inch A325 hex head through bolts.

The first post supporting the nested thrie-beam transition section was located 12¼ inches upstream from the end of the bridge rail end. The next five posts were spaced 18¾ inches center to center. Each of these first six posts were 7-ft-long W6×8.5 steel posts embedded 52 inches below grade.

The nested thrie-beam rail was transitioned to a single 12-gauge W-beam rail over a distance of 6 ft 3 inches, using a 10-gauge, asymmetrically tapered transition section. The three posts positioned along this section of the transition were 6-ft-long W6×8.5 posts spaced at 37½ inches on center, which resulted in a post on each end and at midspan of the thrie-beam-to-W-beam transition piece. Routered wood blockouts nominally measuring 6 inches by 8 inches by 18 inches were used along the length of the thrie beam and the first two posts of the asymmetric transition section to offset the rail from the posts.

A 50-ft length of 31-inch-tall W-beam guardrail was attached to the upstream end of the asymmetric transition section. The guardrail consisted of a 12-gauge W-beam rail supported on 6-ft-long W6×8.5 steel posts spaced at 6 ft 3 inches. The W-beam rail was offset from the posts using routered wood blockouts nominally measuring 6 inches by 8 inches by 14 inches. The upstream end of the installation terminated with a TxDOT downstream anchor terminal.

A 12-foot-long section of 5¾-inch-tall reinforced concrete curb was constructed beneath the nested thrie-beam transition rail beginning at the end of the concrete parapet. The back of the curb was ½ inch from the traffic side face of the posts.

Figure 6.1 presents overall information on the thrie-beam transition without end shoe block, and Figure 6.2 provides photographs of the installation. Appendix E.1 provides further details of the thrie-beam transition without end shoe block.

6.2.2 Material Specifications

The minimum compressive strength of the TxDOT Class C concrete specified for the curb was 3600 psi. Part base of curb was cast on May 24, 2019. The average compressive strength of the single batch of concrete used in the base of thecurb was 4091 psi on August 8, 2019 (at 76 days).

The minimum compressive strength of the TxDOT Class A concrete specified for the curb was 3000 psi. The curb segment was cast on May 29, 2019. The average compressive strength of the single batch of concrete used in the curb was 5601 psi on August 8, 2019 (at 71 days).

Appendix E.2 provides material certification documents and information on the materials used to install/construct the thrie-beam transition without end shoe block.

6.2.3 Soil Conditions

The test installation was installed in standard soil meeting Grading B of AASHTO standard specification M147-65(2004), “Materials for Aggregate and Soil Aggregate Subbase, Base and Surface Courses.”

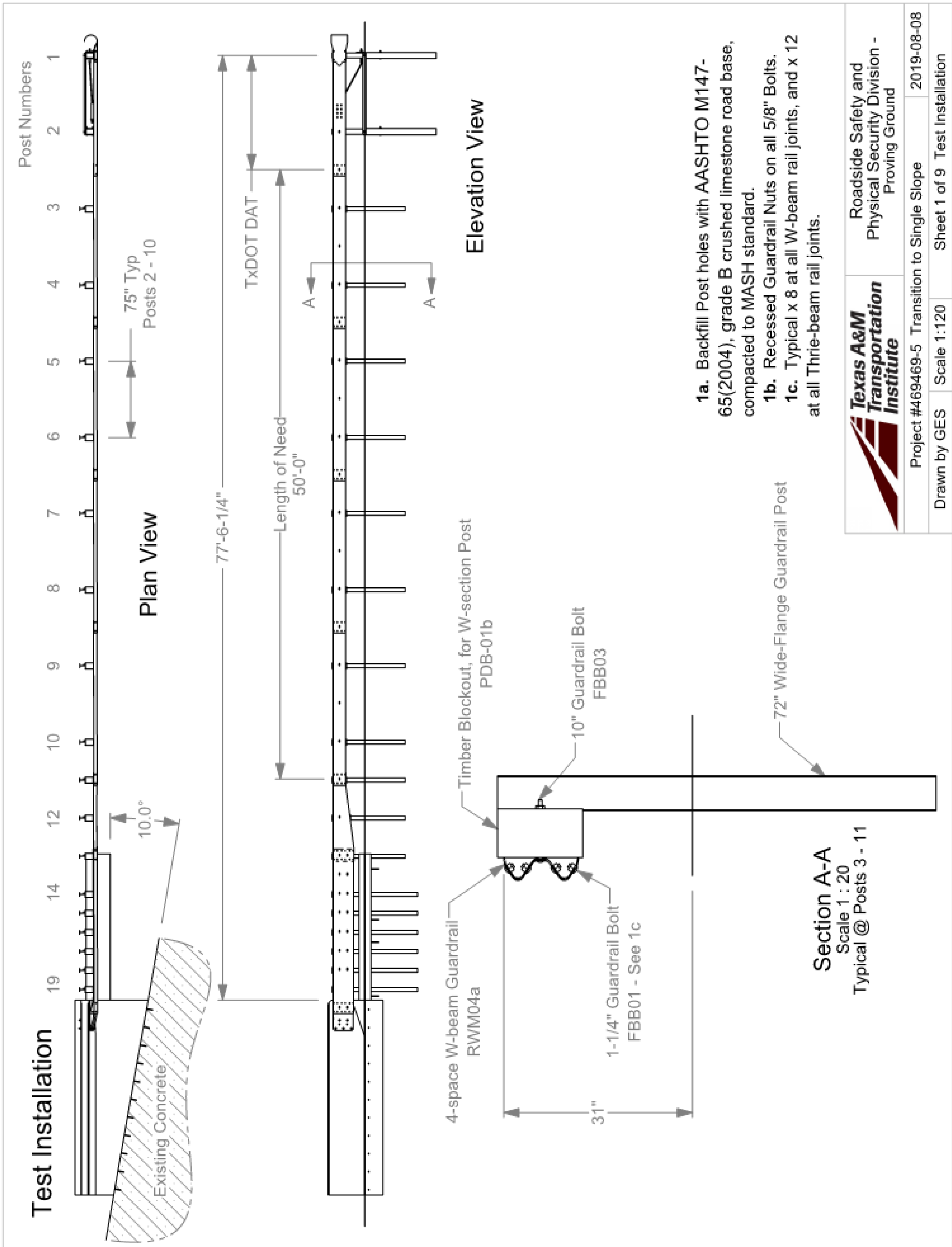


Figure 6.1. Overall Details of the Thrie-Beam Transition without End Shoe Block.

Figure 6.2. Thrie-Beam Transition without End Shoe Block prior to Testing.

In accordance with Appendix B of *MASH*, soil strength was measured the day of the crash test. During installation of the guardrail system for full-scale crash testing, two 6-ft-long W6×16 posts were installed in the immediate vicinity of the guardrail system using the same fill materials and installation procedures used in the test installation and the standard dynamic test. Table E.1 in Appendix E.2 presents minimum soil strength properties established through the dynamic testing performed in accordance with *MASH* Appendix B.

As determined by the tests summarized in Appendix E.2, Table E.2, the minimum post loads required for deflections at 5 inches, 10 inches, and 15 inches, measured at a height of 25 inches, are 3940 lb, 5500 lb, and 6540 lb, respectively (90 percent of static load for the initial standard installation).

On the day of the first test, August 8, 2019, loads on the post at deflections of 5 inches, 10 inches, and 15 inches were 4040 lbf, 11627 lbf, and 13047 lbf, respectively. Table E.2 in Appendix E.2 shows that the strength of the backfill material in which the guardrail system was installed met the minimum *MASH* requirements.

6.3 MASH TEST 3-21 (TEST NO. 469469-5)

6.3.1 Test Designation and Actual Impact Conditions

MASH Test 3-21 involves a 2270P vehicle weighing 5000 lb ±110 lb impacting the CIP of the thrie-beam transition without end shoe block at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25° ±1.5°. The CIP for *MASH* Test 3-21 on the thrie-beam transition without end shoe block was 93 inches upstream of the end of the concrete barrier.

The 2013 RAM 1500 used in the test weighed 5038 lb, and the actual impact speed and angle were 62.3 mi/h and 25.1°. The actual impact point was 97.7 inches upstream of the end of the concrete barrier. Minimum target impact severity was 106 kip-ft, and actual IS was 118 kip-ft.

6.3.2 Weather Conditions

The test was performed on the morning of August 8, 2019. Weather conditions at the time of testing were as follows: wind speed: 6 mi/h; wind direction: 200° with respect to the vehicle (vehicle was traveling at a magnetic heading of 205°); temperature: 95°F; relative humidity: 56 percent.

6.3.3 Test Vehicle

The 2013 RAM 1500 shown in Figure 6.3 and Figure 6.4 was used for the crash test. The vehicle's test inertia weight was 5038 lb, and its gross static weight was 5038 lb. The height to the lower edge of the vehicle bumper was 11.8 inches, and height to the upper edge of the bumper was 27 inches. The height to the vehicle's center of gravity was 28.4 inches. Table E.3 and Table E.4 in Appendix E.3.1 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.

Figure 6.3. Thrie-Beam Transition without End Shoe Block/Test Vehicle Geometrics for Test No. 469469-5.

Figure 6.4. Test Vehicle before Test No. 469469-5.

6.3.4 Test Description

Table 6.1 lists events that occurred during Test No. 469469-5. Figure E.1 and Figure E.2 in Appendix E.3.2 present sequential photographs during the test.

Table 6.1. Events during Test No. 469469-5.

Time	Events
0.000	Vehicle contacts rail
0.046	Vehicle begins to redirect
0.010	Post 14, 15, 16 and 17 begin to deflect toward field side
0.022	Post 18 and 19 begin to deflect toward field side
0.119	Front left tire leaves pavement
0.148	Rear left tire leaves pavement
0.193	Rear right bumper of truck impacts rail. Vehicle is parallel with rail.
0.288	Vehicle loses contact with the barrier; vehicle is traveling at 48.8 mi/h at a trajectory angle of 8.2° and a heading angle of 10.1°

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*. After loss of contact with the barrier, the vehicle yawed counterclockwise and came to rest 241 ft downstream of the point of impact and 23 ft from the traffic side of the barrier. Brakes were applied at 2.1 seconds after impact.

6.3.5 Damage to Test Installation

Figure 6.5 shows the damage to the thrie-beam transition without end shoe block. There was a ½-inch gap between the curb and soil on the field side, and the rail was scuffed and deformed.

Working width[8] was 18.5 inches, and the height of maximum working width was 48.8 inches (side mirror). Maximum dynamic deflection was 4.0 inches in the nested thrie-beam section. Maximum permanent deflection was ½ inch between posts 16 and 17.

[8] Working width is defined as the distance between the traffic face of the barrier before impact and the maximum lateral position of any major part of the barrier or the vehicle after impact.

Figure 6.5. Thrie-Beam Transition without End Shoe Block after Test No. 469469-5.

6.3.6 Damage to Test Vehicle

Figure 6.6 and Figure 6.7 show the damage sustained by the vehicle. The front right bumper, hood, grill, radiator and supports, right front tire and rim, right front fender, right frame rail, right front upper and lower ball joints, right front upper and lower A-arms, front sway bar, right front door (8-inch gap at top), right front floor pan, right rear door, right cab corner, right rear fender, right rear rim, rear bumper, and right tail light were damaged. The windshield sustained stress cracks originating at the lower right and lower left corners. Maximum exterior crush to the vehicle was 10 inches at the front bumper at bumper height. The maximum occupant compartment deformation was 4 inches at the lower right floor pan. Table E.5 and Table E.6 in Appendix E.3.1 provide exterior crush and occupant compartment measurements.

Figure 6.6. Test Vehicle after Test No. 469469-5.

Figure 6.7. Interior of Test Vehicle for Test No. 469469-5
(before Test on Left; after Test on Right).

6.3.7 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk, and results are shown in Table 6.2. Figure 6.8 summarizes these data and other pertinent information from the test. Figure E.3 in Appendix E.3.3 shows the vehicle angular displacements, and Figure E.4 through Figure E.6 in Appendix E.3.4 show acceleration versus time traces.

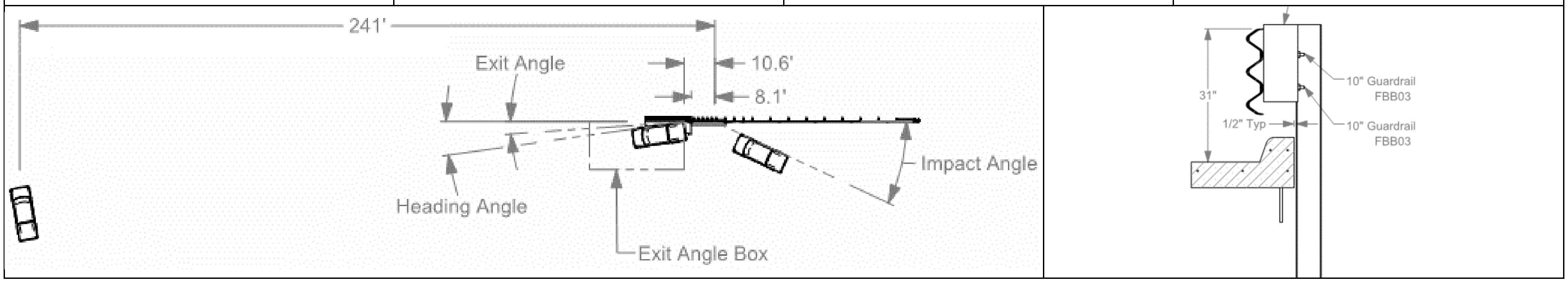
Table 6.2. Occupant Risk Factors for Test No. 469469-5.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)	ft/s	at 0.1057 seconds on right side of interior
Longitudinal	**20.3**	
Lateral	**26.2**	
Occupant Ridedown Accelerations (g's)		
Longitudinal	**6.6**	(0.1057–0.1157 seconds)
Lateral	**14.4**	(0.2392–0.2492 seconds)
Theoretical Head Impact Velocity (THIV)	m/s	at 0.1027 seconds on right side of interior
	9.9	
Post Head Deceleration (PHD) (g's)	**14.6**	(0.2391–0.2491 seconds)
Acceleration Severity Index (ASI)	**1.4**	(0.0811–0.1311 seconds)
Maximum 50-ms Moving Average (g's)		
Longitudinal	**−8.7**	(0.0357–0.0857 seconds)
Lateral	**−11.2**	(0.0569–0.1069 seconds)
Vertical	**−3.8**	(0.0204–0.0704 seconds)
Maximum Roll, Pitch, and Yaw Angles	**Degrees**	
Roll	**24**	(0.4866 seconds)
Pitch	**7**	(1.9988 seconds)
Yaw	**47**	(1.0026 seconds)

6.3.8 Assessment of Results

An assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-21 is provided in Table 6.3.

0.000 s | 0.200 s | 0.400 s | 0.700 s



General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-21
TTI Test No.	469469-5
Test Date	2019-08-08
Test Article	
Type	Thrie-beam transition
Name	TxDOT thrie-beam transition without end shoe block
Installation Length	93.5 ft
Material or Key Elements	36-inch single slope concrete barrier, 12-ga. nested thrie-beam, 5¾-inch curb, 10-ga. asymmetric transition section, W6×8.5 steel posts
Soil Type and Condition	AASHTO M147-65(2004), Grading B soil (crushed limestone), damp
Test Vehicle	
Type/Designation	2270P
Make and Model	2013 RAM 1500
Curb	5011 lb
Test Inertial	5038 lb
Dummy	No dummy
Gross Static	5038 lb

Impact Conditions	
Speed	62.3 mi/h
Angle	25.1°
Location/Orientation	At the center of joints 5 and 6
Impact Severity	118 kip*ft
Exit Conditions	
Speed	48.8 mi/h
Exit Trajectory/Heading	8.2°/10.1°
Occupant Risk Values	
Longitudinal OIV	20.3 ft/s
Lateral OIV	26.2 ft/s
Longitudinal Ridedown	6.6 g
Lateral Ridedown	14.4 g
THIV	35.6 km/h
PHD	14.6 g
ASI	1.38
Max. 0.050-s Average	
Longitudinal	−8.7 g
Lateral	−11.2 g
Vertical	−3.8 g

Post-Impact Trajectory	
Stopping Distance	241 ft downstrm; 23 ft on traffic side of barrier
Vehicle Stability	
Maximum Yaw Angle	47°
Maximum Pitch Angle	7°
Maximum Roll Angle	24°
Vehicle Snagging	No
Vehicle Pocketing	No
Test Article Deflections	
Dynamic	4.0 inches
Permanent	0.5 inches
Working Width	18.5 inches
Working Width Height	48.8 inches
Vehicle Damage	
VDS	10-RFQ-3
CDC	10FREW3
Max. Exterior Deformation	10 inches
OCDI	LF0121100
Max. Occupant Compartment Deformation	4 inches

Figure 6.8. Summary of Results for *MASH* Test 3-21 on the Thrie-Beam Transition without End Shoe Block.

Table 6.3. Performance Evaluation Summary for *MASH* Test 3-21 on the Thrie-Beam Transition without End Shoe Block.

Test Agency: Texas A&M Transportation Institute | Test No.: 469469-05 | Test Date: 2019-08-08

MASH Test 3-21 Evaluation Criteria	Test Results	Assessment
<u>Structural Adequacy</u> 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 thrie-beam transition without end shoe block contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 4.0 inches.	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.*	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 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.	4 inches of deformation in the floor pan.	
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 was 24°, and maximum pitch was 7°.	Pass
H. *Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.*	Longitudinal OIV was 20.3 ft/s, and lateral OIV was 26.2 ft/s.	Pass
I. *Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 g, or at least below the maximum allowable value of 20.49 g.*	Maximum longitudinal 10-ms occupant ridedown acceleration was 6.6 g, and maximum lateral 10-ms occupant ridedown acceleration was 14.4 g.	Pass
<u>Vehicle Trajectory</u> For redirective devices, it is preferable that the vehicle be smoothly redirected and leave the barrier within the "exit box" criteria (not less than 32.8 ft for the 1100C and 2270P vehicles), and should be documented.	The 2270P vehicle exited within the exit box criteria.	Documentation only

6.4 CONCLUSIONS

The TxDOT thrie-beam transition without end shoe block contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 4.0 inches, and permanent deformation was ½ inch. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. The maximum occupant compartment deformation was 4 inches. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 24° and 7°, respectively. Occupant risk factors were within the preferred limits specified in *MASH*. The 2270P vehicle exited within the exit box criteria.

The TxDOT thrie-beam transition without end shoe block performed acceptably according to *MASH* Test 3-21 evaluation criteria as shown in Table 6.4.

Table 6.4. Assessment Summary for *MASH* Test 3-21 on TxDOT Thrie-Beam Transition without End Shoe Block.

Evaluation Factors	Evaluation Criteria	Test No. 469469-5
Structural Adequacy	A	S
Occupant Risk	D	S
	F	S
	H	S
	I	S
	Test No.	*MASH* Test 3-21
	Pass/Fail	Pass

S = Satisfactory
U = Unsatisfactory
N/A = Not applicable

CHAPTER 7: TXDOT SINGLE WOOD POST SKID-MOUNTED SIGN SUPPORT SYSTEM

7.1 BACKGROUND

The single wood post skid-mounted temporary sign support system uses a nominal 4-inch by 4-inch post and is designed for use with a maximum 12-sq-ft sign panel. Details can be found on TxDOT Barricade and Construction sheet BC(5)-14.

The *MASH* test matrix for work zone traffic control devices includes a high-speed test with a passenger car (Test 3-71) and pickup truck (Test 3-72) at both 0° and 90° impact orientations. The single wood post skid-mounted sign support system was previously tested with a small passenger car at high speed under NCHRP Report 350. Although the small passenger car design test vehicle has changed under *MASH*, its performance in frontal impacts with large skid-mounted sign support systems is not expected to differ appreciably. Therefore, only test designation 3-72 with the 2270P pickup truck is considered necessary for both the 0° and 90° impact orientations to assess *MASH* compliance.

MASH states that "lightweight free-standing features cannot cause sufficient velocity change to result in failure of the test under occupant risk criteria. Therefore, Tests 3-71 and 3-72 can be conducted without the instrumentation necessary for determining occupant risk whenever the test article has a total weight of 220 lb (100 kg) or less."

7.2 SYSTEM DETAILS

7.2.1 Test Article and Installation Details

This test installation consisted of a 36-inch-square by 0.10-inch-thick aluminum sign panel secured to a nominal 4-inch by 4-inch wood support with two ⅜-inch-diameter through bolts. The panel had rounded corners and was mounted in a diamond orientation, with the bottom corner 84 inches above grade. The wood frame consisted of nominal 4-inch by 4-inch, 2-inch by 6-inch, and 2-inch by 4-inch lumber and assorted hardware. All lumber was treated southern yellow pine. All hex bolts were grade 5, and each had two USS flat washers, one lock washer, and one hex nut. Each lag screw had a USS flat washer under the head.

The installation was placed on an existing concrete apron but was not secured to it. The single wood post skid-mounted temporary sign support system was placed with the sign panel at 90° (parallel to the vehicle path). A 40-pound sandbag was placed on each end of the wood frame skid.

Figure 7.1 presents overall information on the single wood post skid-mounted sign, and Figure 7.2 provides photographs of the installation. Appendix F.1 provides further details of the single wood post skid-mounted sign.

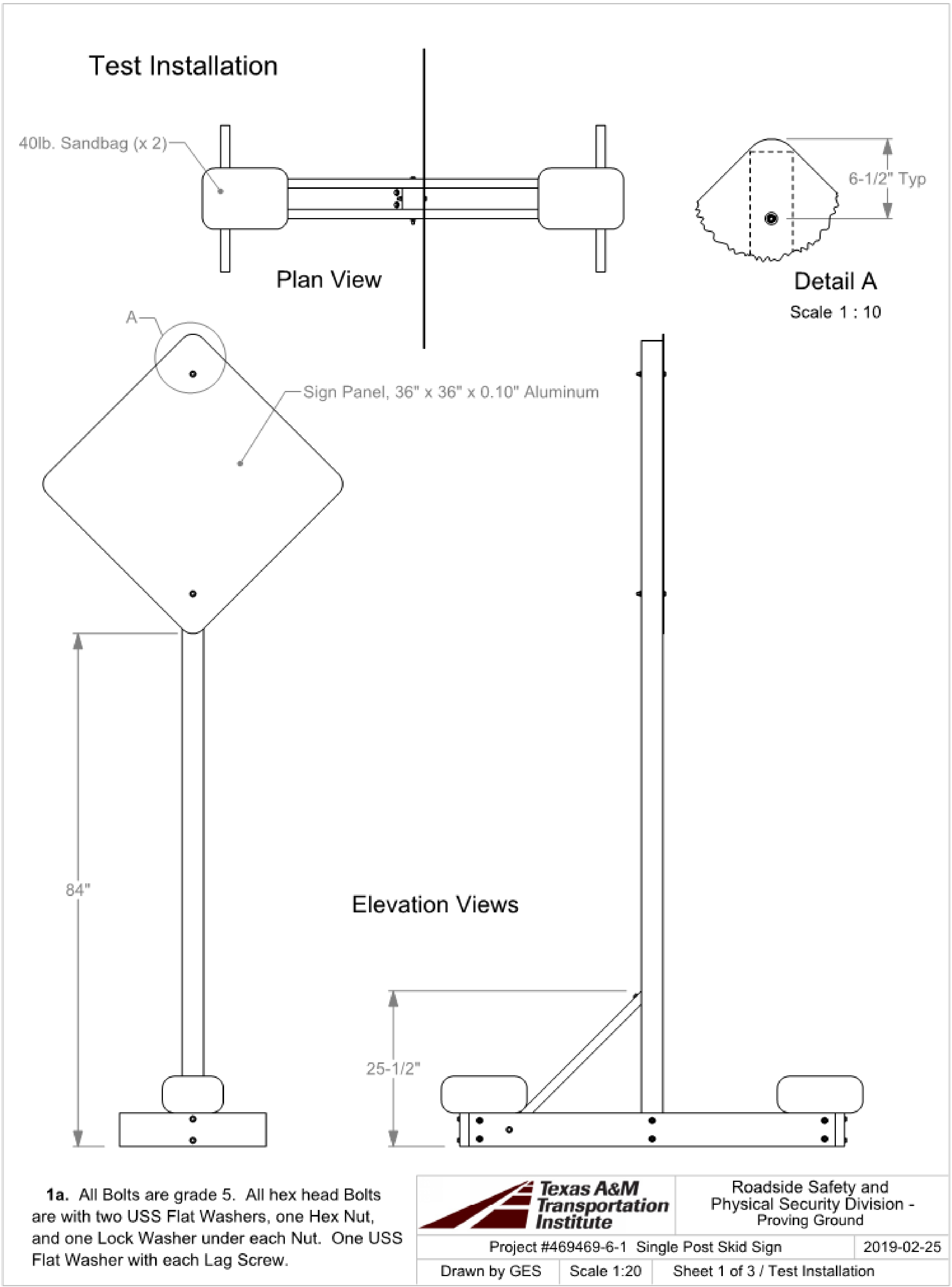


Figure 7.1. Overall Details of the Single Wood Post Skid-Mounted Sign.

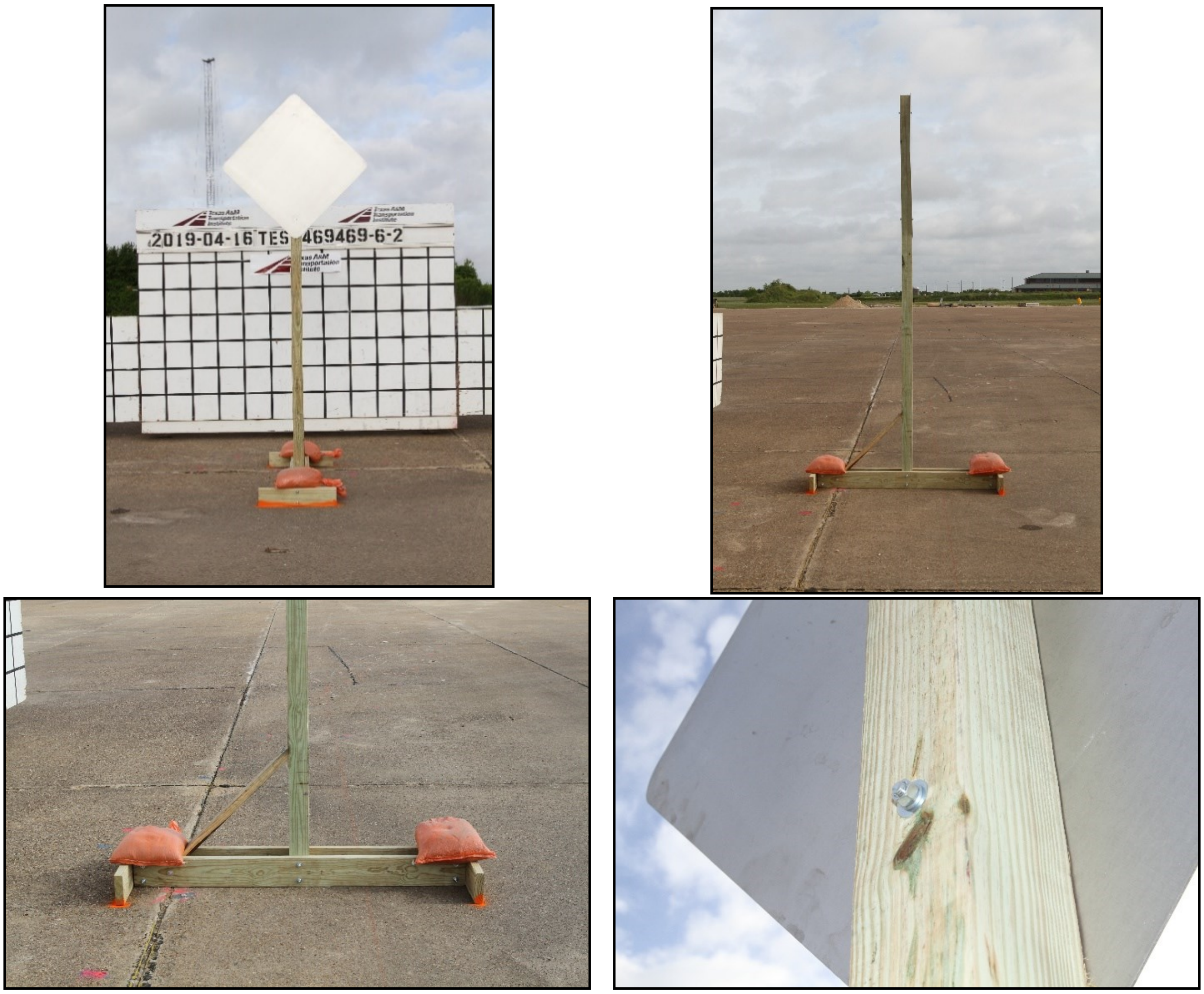


Figure 7.2. Single Wood Post Skid-Mounted Sign prior to Test No. 469469-06-02.

7.2.2 Material Specifications

Appendix F.2 provides material certification documents for the materials used to install/construct the single wood post skid-mounted sign.

7.3 MASH TEST 3-72 (TEST NO. 469469-06-02)

7.3.1 Test Designation and Actual Impact Conditions

MASH Test 3-72 involves a 2270P vehicle weighing 5000 lb ±110 lb impacting the CIP of the single wood post skid-mounted sign at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 90° ±1.5°. The CIP for *MASH* Test 3-72 was the centerline of the support post aligned 12 inches off the centerline of the vehicle toward the driver's side.

The 2015 RAM 1500 used in the test weighed 5026 lb, and the actual impact speed and angle were 62.2 mi/h and 90°, respectively. Minimum target impact severity was 594 kip-ft, and actual IS was 650 kip-ft.

7.3.2 Weather Conditions

The test was performed on the morning of April 16, 2019. Weather conditions at the time of testing were as follows: wind speed: 10 mi/h; wind direction: 205° with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 70°F; relative humidity: 86 percent.

7.3.3 Test Vehicle

The 2015 RAM 1500 shown in Figure 7.3 and Figure 7.4 was used for the crash test. The vehicle's test inertia weight was 5026 lb, and its gross static weight was 5026 lb. The height to the lower edge of the vehicle bumper was 11.8 inches, and height to the upper edge of the bumper was 27 inches. The height to the vehicle's center of gravity was 28 inches. Table F.1 and Table F.2 in Appendix F.2.1 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.

Figure 7.3. Single Wood Post Skid-Mounted Sign/Test Vehicle Geometrics for Test No. 469469-06-02.

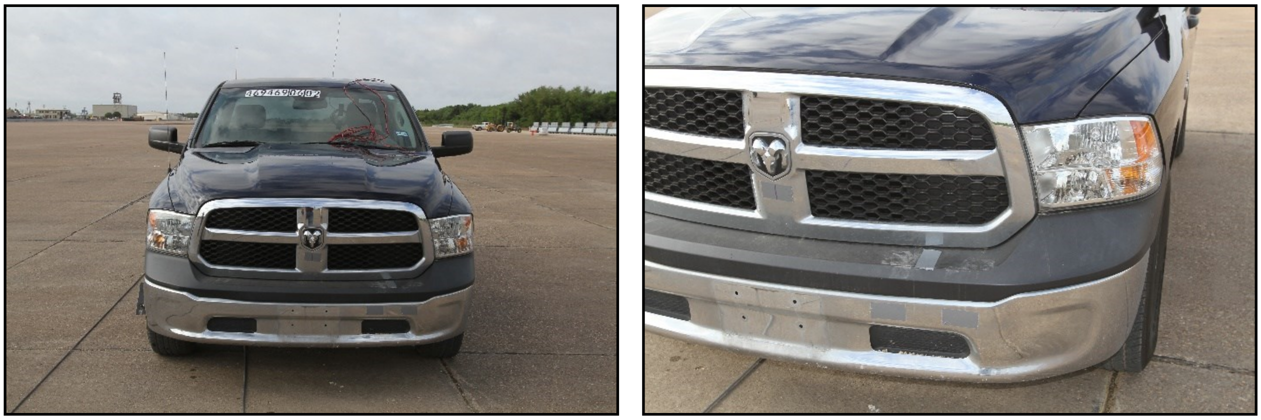


Figure 7.4. Test Vehicle before Test No. 469469-06-02.

7.3.4 Test Description

The 2015 RAM 1500 was traveling at an impact speed of 62.2 mi/h when it contacted the support post 12 inches off centerline of the vehicle on the driver's side, at an impact angle of 90°. Table 7.1 lists events that occurred during Test No. 469469-06-02. Figure F.1 and Figure F.2 in Appendix F.2.2 present sequential photographs during the test.

Table 7.1. Events during Test No. 469469-06-02.

Time	Events
0.000	Vehicle contacts sign support
0.002	Wood support post begins to fracture
0.015	Wood support post completely fractured and separated
0.031	Released wood support post and attached sign loses contact with vehicle
0.070	Corner of sign panel impacts upper windshield area near roof
0.134	Sign rotates off of vehicle roof

The 2270P vehicle came to rest 360 ft downstream and 10 ft to the left of the original impact position.

7.3.5 Damage to Test Installation

Figure 7.5 shows the damage to the single wood post skid-mounted sign. Components of the wood base fractured into multiple pieces that were scattered from the impact point to 50 ft downstream. The 4×4 wood support post fractured 24 inches above grade. The sign remained attached to the upper section of the fractured wood support post and came to rest 245 ft downstream and 50 ft to the left of the original impact position.

Figure 7.5. Single Wood Post Skid-Mounted Sign after Test No. 469469-06-02.

7.3.6 Damage to Test Vehicle

Figure 7.6 and Figure 7.7 show the damage sustained by the vehicle. There was a 7-inch by 12-inch by 1-inch-deep dent in the front bumper, a 4-inch by 2.5-inch by 0.3-inch-deep dent in the hood, and a 33-inch by 48-inch by 3.3-inch-deep dent in the roof. The windshield had a 48-inch by 8-inch by 2.8-inch-deep area of damage, and there was a 4-inch-long tear in the windshield laminate. The maximum exterior crush of the vehicle was 1 inch. Maximum occupant compartment deformation was 3.5 inches at the center of the roof. Table F.3 and Table F.4 in Appendix F.2.1 provide exterior crush and occupant compartment measurements.

Figure 7.6. Test Vehicle after Test No. 469469-06-02.

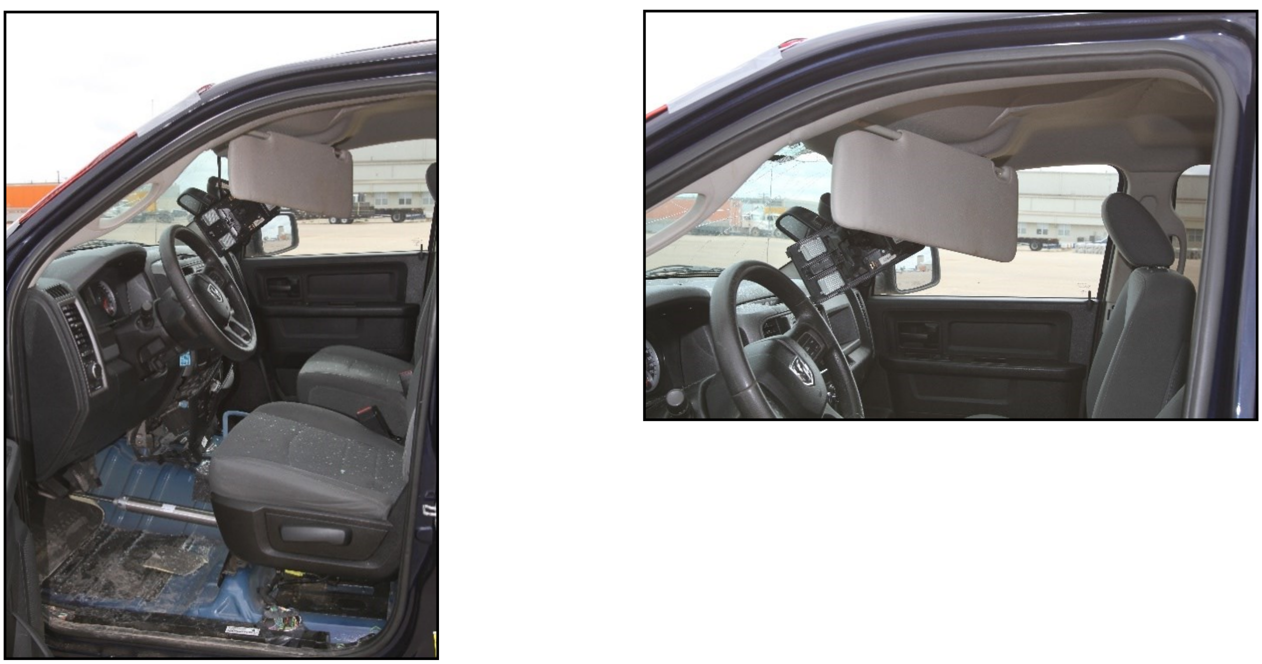


Figure 7.7. Interior of Test Vehicle after Test No. 469469-06-02.

7.3.7 Occupant Risk Factors

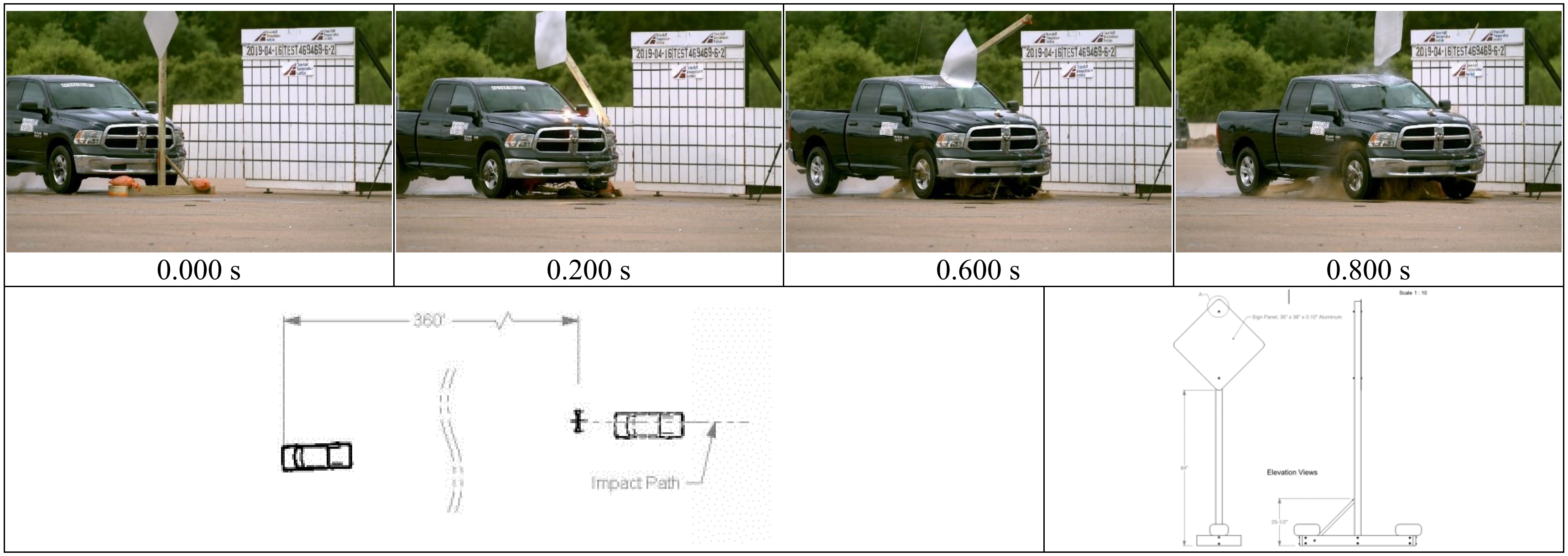
Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk, and results are shown in Table 7.2. Figure 7.8 summarizes these data and other pertinent information from the test. Figure F.3 in Appendix F.2.3 shows the vehicle angular displacements, and Figure F.4 through Figure F.6 in Appendix F.2.4 show acceleration versus time traces.

Table 7.2. Occupant Risk Factors for Test No. 469469-06-02.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)	ft/s	at 0.8294 seconds on right side of interior
Longitudinal	**2.6**	
Lateral	**2.0**	
Occupant Ridedown Accelerations (g's)		
Longitudinal	**0.1**	(1.4034–1.4134 seconds)
Lateral	**0.3**	(1.0431–1.0531 seconds)
Theoretical Head Impact Velocity (THIV)	m/s **1**	at 0.8062 seconds on right side of interior
Post Head Deceleration (PHD) (g's)	**0.3**	(1.0430–1.0530 seconds)
Acceleration Severity Index (ASI)	**0.1**	(0.0963–0.1463 seconds)
Maximum 50-ms Moving Average (g's)		
Longitudinal	**−1**	(0.0016–0.0516 seconds)
Lateral	**−1**	(0.1228–0.1728 seconds)
Vertical	**1.1**	(0.1463–0.1963 seconds)
Maximum Roll, Pitch, and Yaw Angles	Degrees	
Roll	**2**	(0.1963 seconds)
Pitch	**1**	(1.4978 seconds)
Yaw	**3**	(1.4989 seconds)

7.3.8 Assessment of Results

An assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-72 is provided in Table 7.3.



General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-72
TTI Test No.	469469-06-02
Test Date	2019-4-16
Test Article	
Type	Work zone sign
Name	TxDOT single wood post skid-mounted sign support
Installation Length	n/a
Material or Key Elements	36-inch-square × 0.10-inch-thick aluminum sign mounted on 4×4 wood support at height of 84 inches: support attached to wood frame skid
Soil Type and Condition	Placed on dry concrete
Test Vehicle	
Type/Designation	2270P
Make and Model	2015 RAM 1500
Curb	5026 lb
Test Inertial	5026 lb
Dummy	No dummy
Gross Static	5026 lb

Impact Conditions	
Speed	62.2 mi/h
Angle	90°
Location/Orientation	Center of post aligned 12 inches off center of the vehicle toward the driver's side
Impact Severity	650 kip*ft
Exit Conditions	
Speed	61.4 mi/h
Exit Trajectory/Heading	n/a
Occupant Risk Values	
Longitudinal OIV	2.6 ft/s
Lateral OIV	2.0 ft/s
Longitudinal Ridedown	0.1 g
Lateral Ridedown	0.3 g
THIV	1.0 m/s
PHD	0.3 g
ASI	0.13
Max. 0.050-s Average	
Longitudinal	−1.0 g
Lateral	−1.0 g
Vertical	1.1 g

Post-Impact Trajectory	
Stopping Distance	360 ft downstrm; 10 ft left
Vehicle Stability	
Maximum Yaw Angle	3°
Maximum Pitch Angle	1°
Maximum Roll Angle	2°
Vehicle Snagging	No
Vehicle Pocketing	n/a
Test Article Deflections	
Dynamic	n/a
Permanent	n/a
Working Width	n/a
Working Width Height	n/a
Vehicle Damage	
VDS	12TRGN2
CDC	12FR1
Max. Exterior Deformation	1 inch
OCDI	FS0100000
Max. Occupant Compartment Deformation	3.5 inches (roof)

Figure 7.8. Summary of Results for *MASH* Test 3-72 on the Single Wood Post Skid-Mounted Sign.

Table 7.3. Performance Evaluation Summary for *MASH* Test 3-72 on the Single Wood Post Skid-Mounted Sign.

Test Agency: Texas A&M Transportation Institute | Test No.: 469469-06-02 | Test Date: 2019-04-16

MASH Test 3-72 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 wood support post fractured and yielded to the 2270P vehicle 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 edge of the aluminum sign panel contacted and penetrated the top of the windshield, resulting in a 4-inch-long tear in its laminate.	Fail
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	The occupant compartment deformation was 3.5 inches in the roof.	Pass
E. Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle	No detached elements, fragments, or other debris from the test article or vehicle blocked the driver's vision	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 2° and 1°, 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 2.6 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.	Longitudinal occupant ridedown acceleration was 0.1 g, and lateral occupant ridedown was 0.3 g.	Pass
Vehicle Trajectory		
N. Vehicle trajectory behind the test article is acceptable.	The 2270P vehicle came to rest 360 ft behind and 10 ft left of the original position of the installation.	Pass

7.4 CONCLUSIONS

Upon impact, the wood support post fractured near bumper height. The upper portion of the fractured support with attached aluminum sign panel rotated toward the vehicle, and the corner of the sign panel contacted the windshield and caused a 4-inch-long tear in the laminate. Consequently, the single wood post skid-mounted sign support system failed to comply with *MASH* Test 3-72 criteria.

The TxDOT single wood post skid-mounted temporary sign support system did not perform acceptably according to *MASH* Test 3-72 evaluation criteria as shown in Table 7.4.

Table 7.4. Assessment Summary for *MASH* Test 3-72 on TxDOT Single Wood Post Skid-Mounted Temporary Sign Support System.

Evaluation Factors	Evaluation Criteria	Test No. 469469-5
Structural Adequacy	B	S
Occupant Risk	D	F
	E	S
	F	S
	H	S
	I	S
	N	S
	Test No.	***MASH* Test 3-72**
	Pass/Fail	Pass

S = Satisfactory
U = Unsatisfactory
N/A = Not applicable

CHAPTER 8: TXDOT PERFORATED SQUARE STEEL TUBE SIGN SUPPORT

8.1 BACKGROUND

TxDOT uses perforated square steel tube (PSST) supports for ground-mounted temporary signs. Barricade and construction sheet BC(5)-14 and Section J "Signs and Sign Supports" of the Compliant Work Zone Traffic Control Device List provide three foundation options:

- Option 1 is direct embedment of the sign support.
- Option 2 involves insertion of the sign post into a larger size PSST anchor stub.
- Option 3 incorporates an 18-inch PSST reinforcing sleeve over the PSST anchor stub.

The PSST support functions by fracturing the post through the perforated holes that exist on each face of the square cross section. The most critical foundation option is Option 1, direct embedment. Option 2 and Option 3 both provide additional stiffening of the support post at the ground line, which helps facilitate fracture during an impact. However, field use of Option 2 is much more common than Option 1 because it permits the short anchor stub to be readily driven into the ground for installation of the PSST support. Therefore, efforts focused on evaluation of the anchor stub foundation options. If the testing demonstrates that the single PSST sign support in anchor stub (Option 2) meets *MASH* criteria, the less critical Option 3 foundation configuration with reinforced anchor stub 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. *MASH* Section 2.2.4.1 recommends that "In this case, testing should be conducted at both 90 degrees from the normal direction and at any orientation between 0 and 25 degrees 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 degrees." Consequently, since these temporary signs are used at or near intersections, the recommended test matrix for evaluating the ground-mounted PSST sign support system includes *MASH* Test 3-61 with the 1100C passenger car and Test 3-62 with the 2270P pickup truck at both 0° and 90°.

The TxDOT standards permit the use of both 14-gauge and 12-gauge PSST supports of different sizes to accommodate different sign sizes. A single 2-inch by 14-gauge PSST support in an anchor stub was successfully tested in accordance with *MASH* criteria. Therefore, efforts under the current project focused on evaluation of 12-gauge PSST supports. Both foundation Option 2 (PSST support in anchor stub) and Option 3 (PSST support in reinforced anchor stub) were evaluated for a 2-inch, 12-gauge PSST support.

8.2 PSST SIGN SUPPORT IN ANCHOR STUB

8.2.1 Test Article and Installation Details

The PSST sign support in anchor stub system test assembly consisted of a 2-inch by 12-gauge PSST support post inserted 9 inches into a 2¼-inch by 12-gauge perforated square steel anchor stub. The anchor tube was 34 inches long and embedded such that it protruded 2 inches above grade. The PSST support was secured inside the anchor stub using a ⅜-inch-diameter hex head bolt and hardware. The PSST support and anchor stub contained 7/16-inch-diameter holes spaced on 1-inch centers on all four faces. The anchor stub was installed in AASHTO M147-65(2004), Grading B soil (crushed limestone) that was compacted to meet *MASH* performance standards as demonstrated by a static post pull test (Appendix G.1.1).

A 36-inch by 36-inch by 0.100-inch-thick aluminum sign panel was mounted to the support post in a diamond orientation using two ⅜-inch-diameter hex head bolts and hardware, with the bottom corner located 84 inches above grade.

Figure 8.1 presents overall information on the PSST sign support in anchor stub system, and Figure 8.2 provides photographs of the test installation. Appendix G.1 provides further details of the PSST sign support in anchor stub system.

8.2.2 MASH Test 3-61 (Test No. 469469-07-02)

8.2.2.1 Test Designation and Actual Impact Conditions

MASH Test 3-61 involves a 1100C vehicle weighing 2420 lb ±55 lb impacting the PSST sign support in anchor stub system at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 90° ±1.5°. The selected point of impact was the centerline of the PSST sign support in anchor stub system aligned 14 inches off the centerline of the vehicle toward the driver's side.

The 2011 Kia Rio[9] used in the test weighed 2443 lb, and the actual impact speed and angle were 62.7 mi/h and 90°, respectively. Minimum target impact severity was 288 kip-ft, and actual IS was 321 kip-ft.

8.2.2.2 Weather Conditions

The test was performed on the afternoon of August 23, 2019. Weather conditions at the time of testing were as follows: wind speed: 3 mi/h; wind direction: 157° with respect to the vehicle (vehicle was traveling at a magnetic heading of 180°); temperature: 97°F; relative humidity: 52 percent.

[9] The 2011 model vehicle used is older than the 6-year age noted in *MASH* and was selected based upon availability. An older model vehicle is permitted by AASHTO as long as it is otherwise *MASH* compliant. Other than the vehicle's year model, this 2011 model vehicle met the *MASH* requirements.

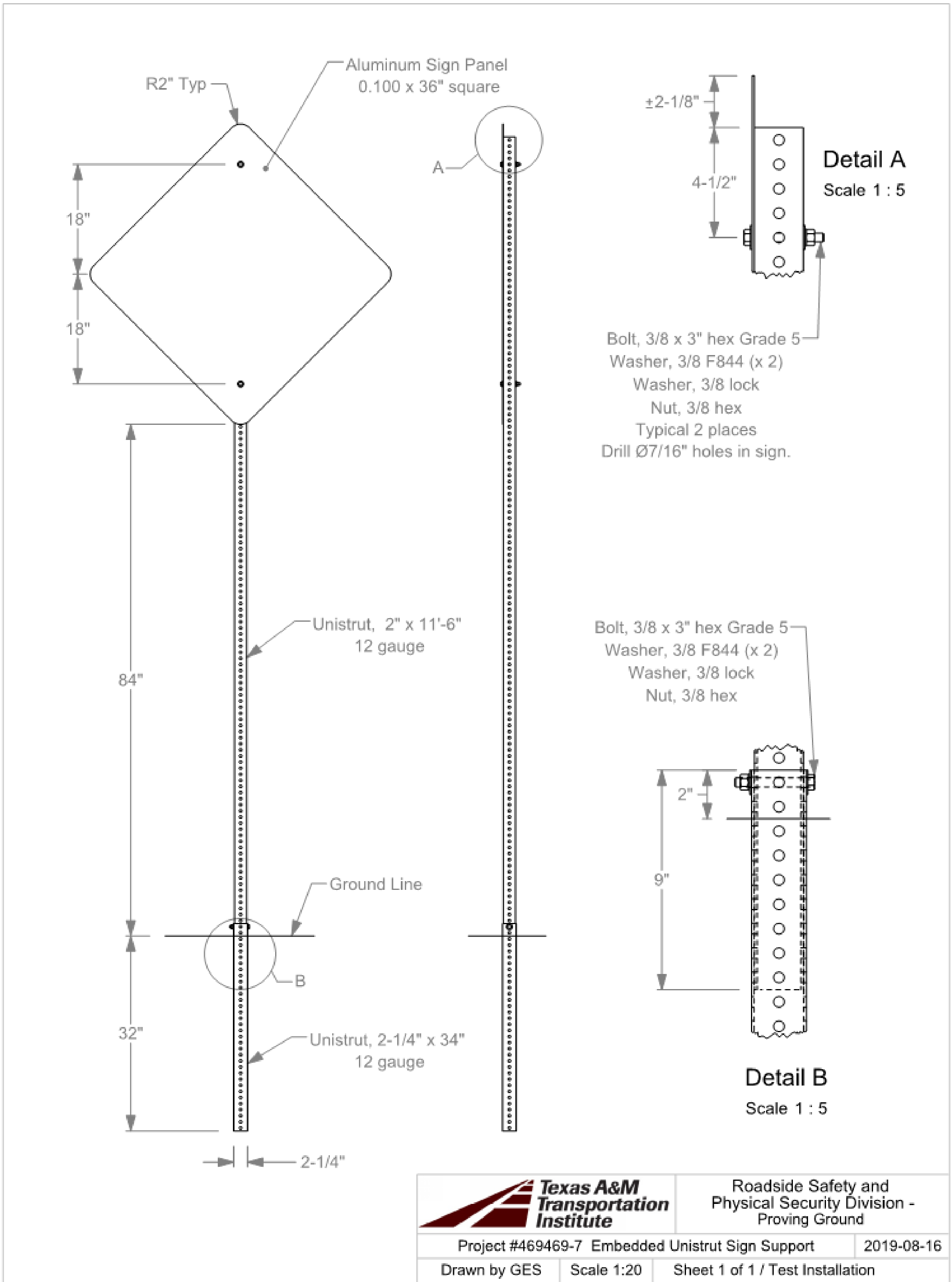


Figure 8.1. Overall Details of the PSST Sign Support in Anchor Stub System for Text No. 469469-7-2.

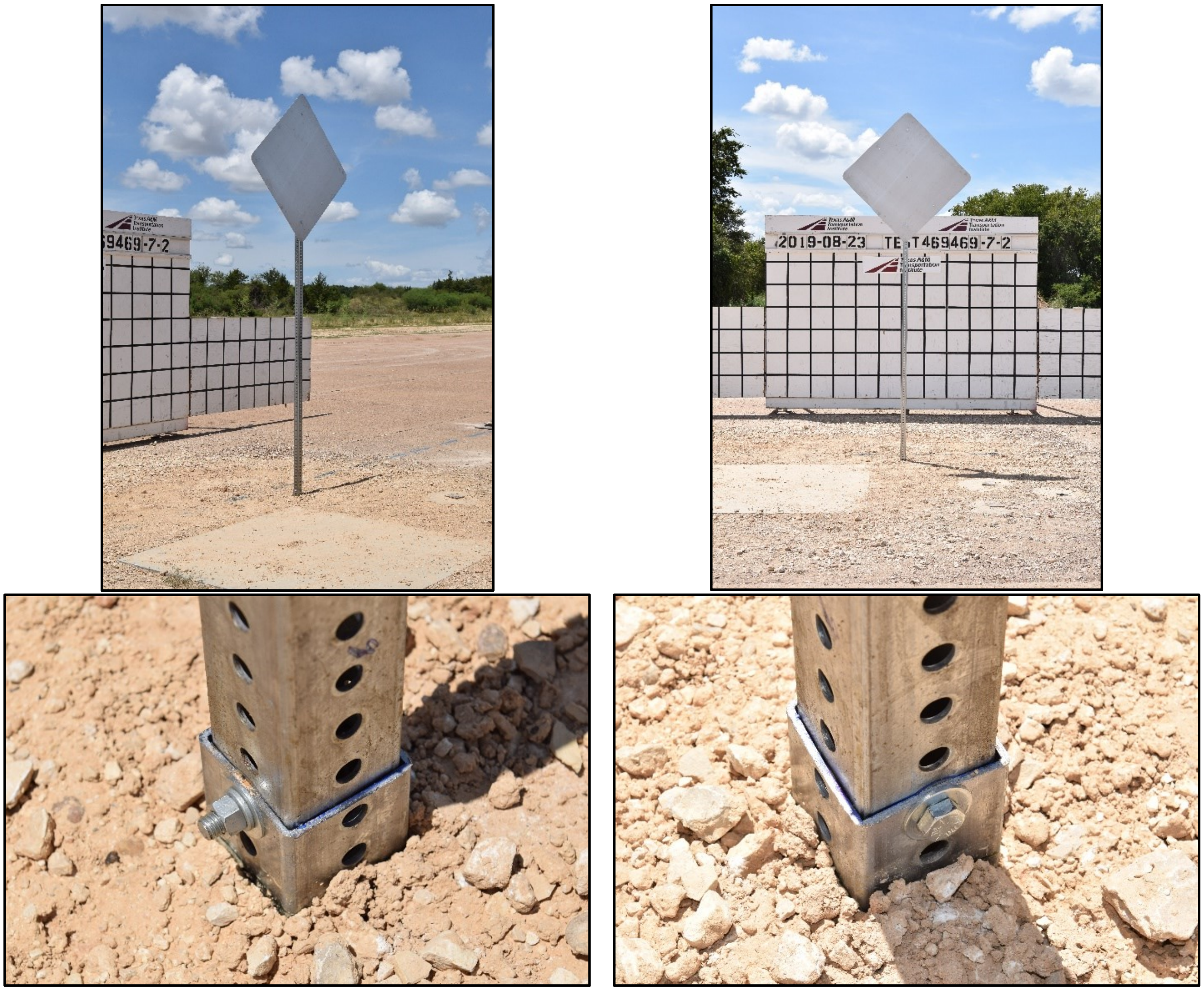


Figure 8.2. PSST Sign Support in Anchor Stub System prior to Test No. 469469-07-02.

8.2.2.3 Test Vehicle

The 2011 Kia Rio shown in Figure 8.3 and Figure 8.4 was used for the crash test. The vehicle's test inertia weight was 2443 lb, and its gross static weight was 2608 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 21.5 inches. Table G.3 in Appendix G.1.2 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 8.3. PSST Sign Support in Anchor Stub System Test Vehicle Geometrics for Test No. 469469-07-02.

Figure 8.4. Test Vehicle before Test No. 469469-07-02.

8.2.2.4 Test Description

Table 8.1 lists events that occurred during Test No. 469469-07-02. Figure G.1 in Appendix G.1.3 presents sequential photographs during the test.

Table 8.1. Events during Test No. 469469-07-02.

Time	Events
0.000	Vehicle contacts support post
0.011	Anchor stub begins to pull out of soil
0.043	Anchor stub fractures
0.059	Corner of sign makes contact with vehicle at roof and windshield interface
0.065	Corner of sign penetrates into occupant compartment
0.095	Sign at max penetration into occupant compartment

Brakes were applied 3.3 seconds after impact, and the vehicle came to rest 450 ft downstream of the initial point of impact and in line of the impact path.

8.2.2.5 Damage to Test Installation

Figure 8.5 shows the damage to the PSST sign support in anchor stub system. The anchor stub displaced 2½ inches rearward in the soil and fractured 9 inches below the top end as it was pulled out of the ground. The support post was bent 90° approximately 18 inches above grade. The sign panel remained attached to the post, and the assembly landed 240 ft downstream of the point of impact and in line with the impact path.

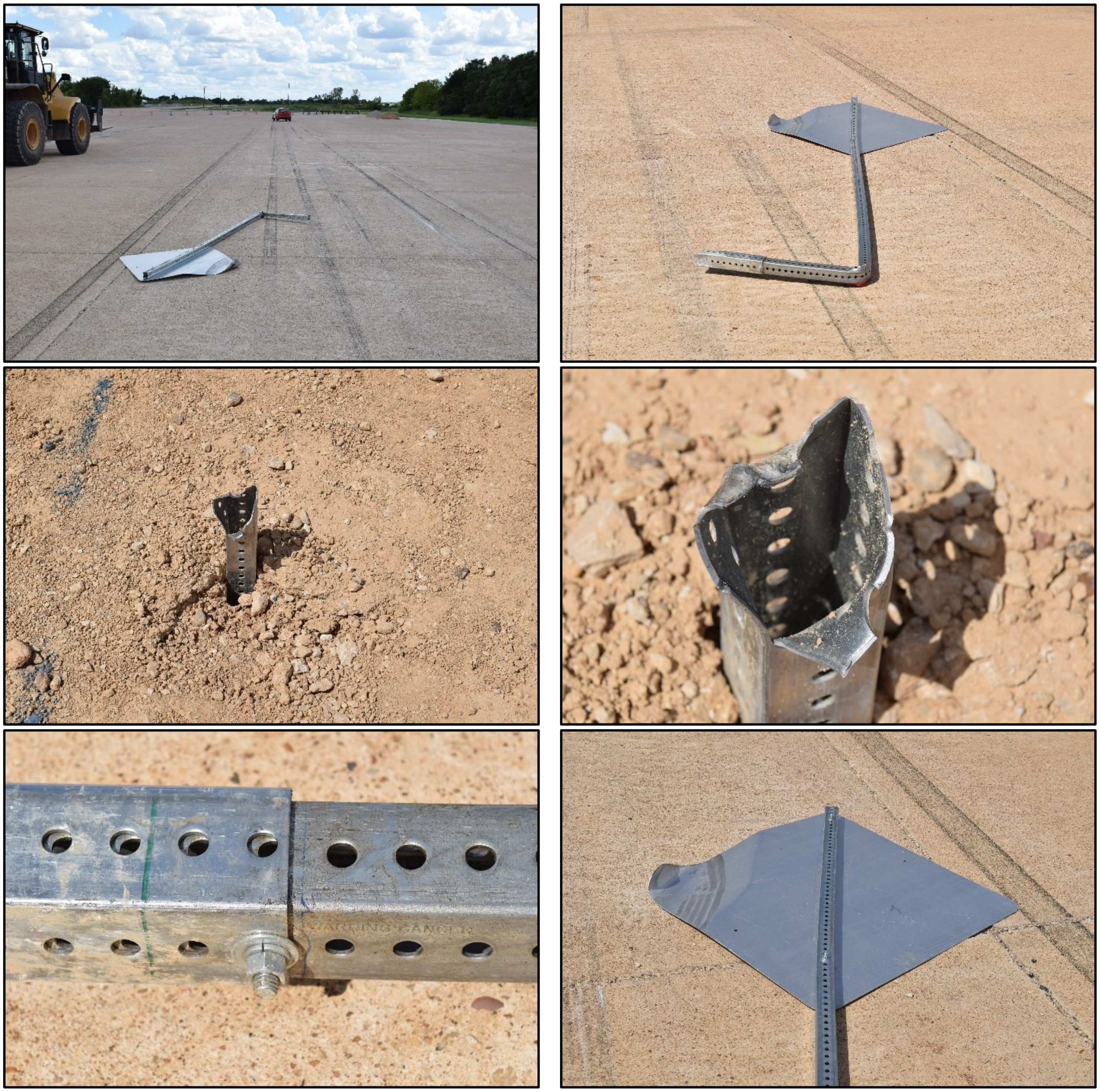


Figure 8.5. PSST Sign Support in Anchor Stub System after Test No. 469469-07-02.

8.2.2.6 Damage to Test Vehicle

Figure 8.6 and Figure 8.7 show the damage sustained by the vehicle. There was a dent 14 inches to the left of the vehicle centerline in the front bumper and hood. The windshield had a 44-inch by 31-inch by 13-inch-deep dent with a 6-inch by 24-inch cut in the laminate. The roof sustained a 41-inch by 27-inch by 12-inch-deep dent. There was also a 16-inch-long tear in the roof along the left seam line. There was no measurable exterior crush of the vehicle. The roof was pushed 11½ inches into the occupant compartment. Table G.4 and Table G.5 in Appendix G.1.2 provide exterior crush and occupant compartment measurements.

Figure 8.6. Test Vehicle after Test No. 469469-07-02.

Figure 8.7. Interior of Test Vehicle after Test No. 469469-07-02.

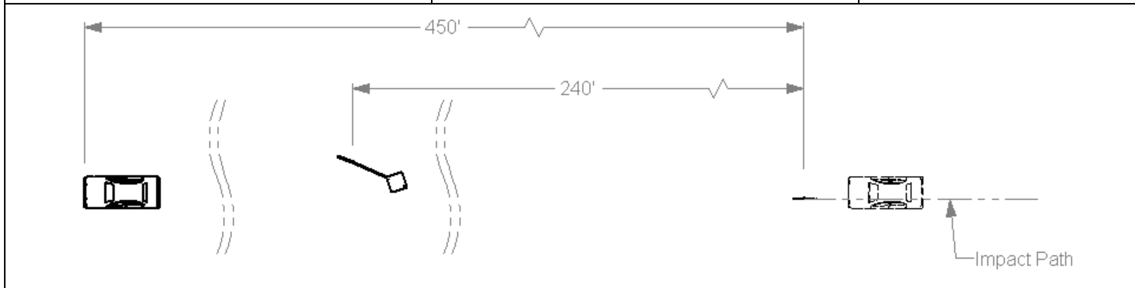
8.2.2.7 Occupant Risk Factors

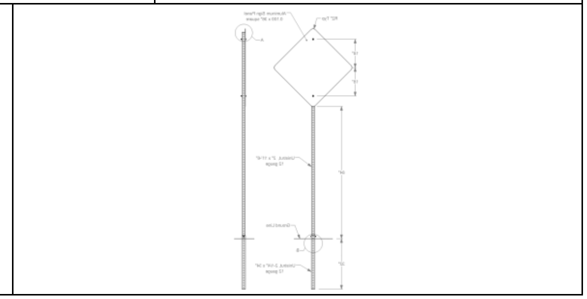
Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk, and results are shown in Table 8.2. Figure 8.8 summarizes these data and other pertinent information from the test. Figure G.3 in Appendix G.1.4 shows the vehicle angular displacements, and Figure G.4 through Figure G.6 in Appendix G.1.5 show acceleration versus time traces.

Table 8.2. Occupant Risk Factors for Test No. 469469-07-02.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)	ft/s	at 0.7037 seconds on front of interior
Longitudinal	**3.0**	
Lateral	**0.0**	
Occupant Ridedown Accelerations (g's)		
Longitudinal	**0.8**	(1.8902–1.9002 seconds)
Lateral	**0.5**	(0.8154–0.8254 seconds)
Theoretical Head Impact Velocity (THIV)	m/s **0.9**	at 0.6964 seconds on front of interior
Acceleration Severity Index (ASI)	**0.1**	(0.0133–0.0633 seconds)
Maximum 50-ms Moving Average (g's)		
Longitudinal	**−1.4**	(0.0016–0.0516 seconds)
Lateral	**0.3**	(0.6392–0.6892 seconds)
Vertical	**0.9**	(0.0476–0.0976 seconds)
Maximum Roll, Pitch, and Yaw Angles	**Degrees**	
Roll	**2**	(0.3695 seconds)
Pitch	**2**	(1.8772 seconds)
Yaw	**2**	(0.3055 seconds)

0.000 s	0.050 s	0.100 s	0.200 s





General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-61
TTI Test No.	469469-07-02
Test Date	2019-08-23

Test Article

Type	Sign support structure
Name	PSST sign support in anchor stub
Installation Length	n/a
Material or Key Elements	2-inch × 12-ga. PSST support inserted into 2¼ -inch × 12-ga. PSST anchor stub, 36-inch-square × 0.100-inch-thick aluminum sign at 84 inches above grade

Soil Type and Condition Embedded in AASHTO M147-65(2004), Grading B soil (crushed limestone)

Test Vehicle

Type/Designation	1100C
Make and Model	2011 Kia Rio
Curb	2544 lb
Test Inertial	2443 lb
Dummy	165 lb
Gross Static	2608 lb

Impact Conditions

Speed	62.7 mi/h
Angle	0°
Location/Orientation	Center of post aligned 14 inches off center of the vehicle toward the driver's side

Impact Severity 321 kip*ft

Exit Conditions

Speed	n/a
Exit Trajectory/Heading	n/a

Occupant Risk Values

Longitudinal OIV	3.0 ft/s
Lateral OIV	0.0 ft/s
Longitudinal Ridedown	0.8 g
Lateral Ridedown	0.5 g
THIV	0.9 m/s
ASI	0.13
Max. 0.050-s Average	
Longitudinal	−1.4 g
Lateral	0.3 g
Vertical	0.9 g

Post-Impact Trajectory

Stopping Distance	450 ft, in line

Vehicle Stability

Maximum Yaw Angle	2°
Maximum Pitch Angle	2°
Maximum Roll Angle	2°
Vehicle Snagging	No
Vehicle Pocketing	n/a

Test Article Deflections

Dynamic	n/a
Permanent	n/a
Working Width	n/a
Working Width Height	n/a

Vehicle Damage

VDS	12FL2
CDC	12TLGN3
Max. Exterior Deformation	Non-measurable
OCDI	LF0300000
Max. Occupant Compartment Deformation	11.5 inches at roof

Figure 8.8. Summary of Results for *MASH* Test 3-61 on the PSST Sign Support in Anchor Stub System.

8.2.2.8 Assessment of Results

An assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-61 is provided in Table 8.3.

8.2.3 Conclusions

The anchor stub fractured as it was pulled out of the ground. After the anchor stub fractured, the sign panel and support rotated toward the vehicle and impacted the windshield and roof. The sign penetrated into the occupant compartment through the windshield and roof. Consequently, the PSST sign support in anchor stub system did not satisfy *MASH* criteria for breakaway support structures.

After the unsuccessful test of the PSST sign support in anchor stub system, it was decided to evaluate the impact performance of a 2-inch by 12-gauge PSST support post in a reinforced anchor stub. The reinforcing sleeve provides additional stiffening of the support post at the ground line, which should help facilitate fracture of the support post during an impact. Quicker fracture of the support post may change the trajectory of the released sign support system. The crash test performed on the PSST sign support in reinforced anchor stub system is described in the next section.

Table 8.3. Performance Evaluation Summary for *MASH* Test 3-61 on the PSST Sign Support in Anchor Stub System.

Test Agency: Texas A&M Transportation Institute | Test No.: 469469-07-02 | Test Date: 2019-08-23

***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 embedded Unistrut sign post support system yielded to the 1100C vehicle and fractured.	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.*	After fracture of the anchor stub, the released sign support system rotated toward the vehicle and impacted the windshield and roof of the vehicle. The sign panel penetrated through the windshield and roof into the occupant compartment.	Fail
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	There was a 24-inch-long cut in the windshield that connected to a 16-inch-long cut in the roof.	Fail
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 2° 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 ft/s.*	Longitudinal OIV was 3.0 ft/s, and lateral OIV was 0.0 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 0.8 g, and lateral occupant ridedown was 0.5 g.	Pass
Vehicle Trajectory		
N. *Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest 450 ft behind the original position of the installation.	Documentation only

8.3 PSST SIGN SUPPORT IN REINFORCED ANCHOR STUB

8.3.1 Test Article and Installation Details

The PSST sign support in reinforced anchor stub system test assembly consisted of a 2-inch by 12-gauge PSST support post inserted 12 inches into a reinforced anchor stub. The 2¼-inch by 12-gauge by 42-inch-long PSST anchor stub was embedded such that it protruded 2 inches above grade. A 2½-inch by 12-gauge by 18-inch-long PSST reinforcing sleeve was placed over and flush with the top of the anchor stub. The PSST support was secured inside the anchor stub using a 5/16-inch-diameter corner bolt and hardware. The PSST support, anchor stub, and reinforcing sleeve contained 7/16-inch-diameter holes spaced on 1-inch centers on all four faces. The anchor stub and reinforcing sleeve were installed in AASHTO M147-65(2004), Grading B soil (crushed limestone) that was compacted to meet *MASH* performance standards as demonstrated by a static post pull test (Appendix G.2.1).

A 36-inch by 36-inch by 0.100-inch-thick aluminum sign panel was mounted to the support post in a diamond orientation using two ⅜-inch-diameter hex head bolts and hardware, with the bottom corner located 84 inches above grade.

Figure 8.9 presents overall information on the PSST sign support in reinforced anchor stub system, and Figure 8.10 provides photographs of the test installation. Appendix G.2 provides further details of the PSST sign support in reinforced anchor stub system.

8.3.2 MASH Test 3-61 (Test No. 469469-07-05)

8.3.2.1 Test Designation and Actual Impact Conditions

MASH Test 3-61 involves a 1100C vehicle weighing 2420 lb ±55 lb impacting the PSST sign support in anchor stub system at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 90° ±1.5°. The selected impact point was the centerline of the PSST sign support in anchor stub system aligned 14 inches off the centerline of the vehicle toward the driver's side.

The 2007 Kia Rio[10] used in the test weighed 2450 lb, and the actual impact speed and angle were 61.3 mi/h and 90°, respectively. Minimum target impact severity was 288 kip-ft, and actual IS was 308 kip-ft.

8.3.2.2 Weather Conditions

The test was performed on the morning of August 29, 2019. Weather conditions at the time of testing were as follows: wind speed: 2 mi/h; wind direction: 225° with respect to the vehicle (vehicle was traveling at a magnetic heading of 180°); temperature: 86°F; relative humidity: 81 percent.

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[10] The 2007 model vehicle used is older than the 6-year age noted in *MASH* and was selected based upon availability. An older model vehicle is permitted by AASHTO as long as it is otherwise *MASH* compliant. Other than the vehicle's year model, this 2007 model vehicle met the *MASH* requirements.

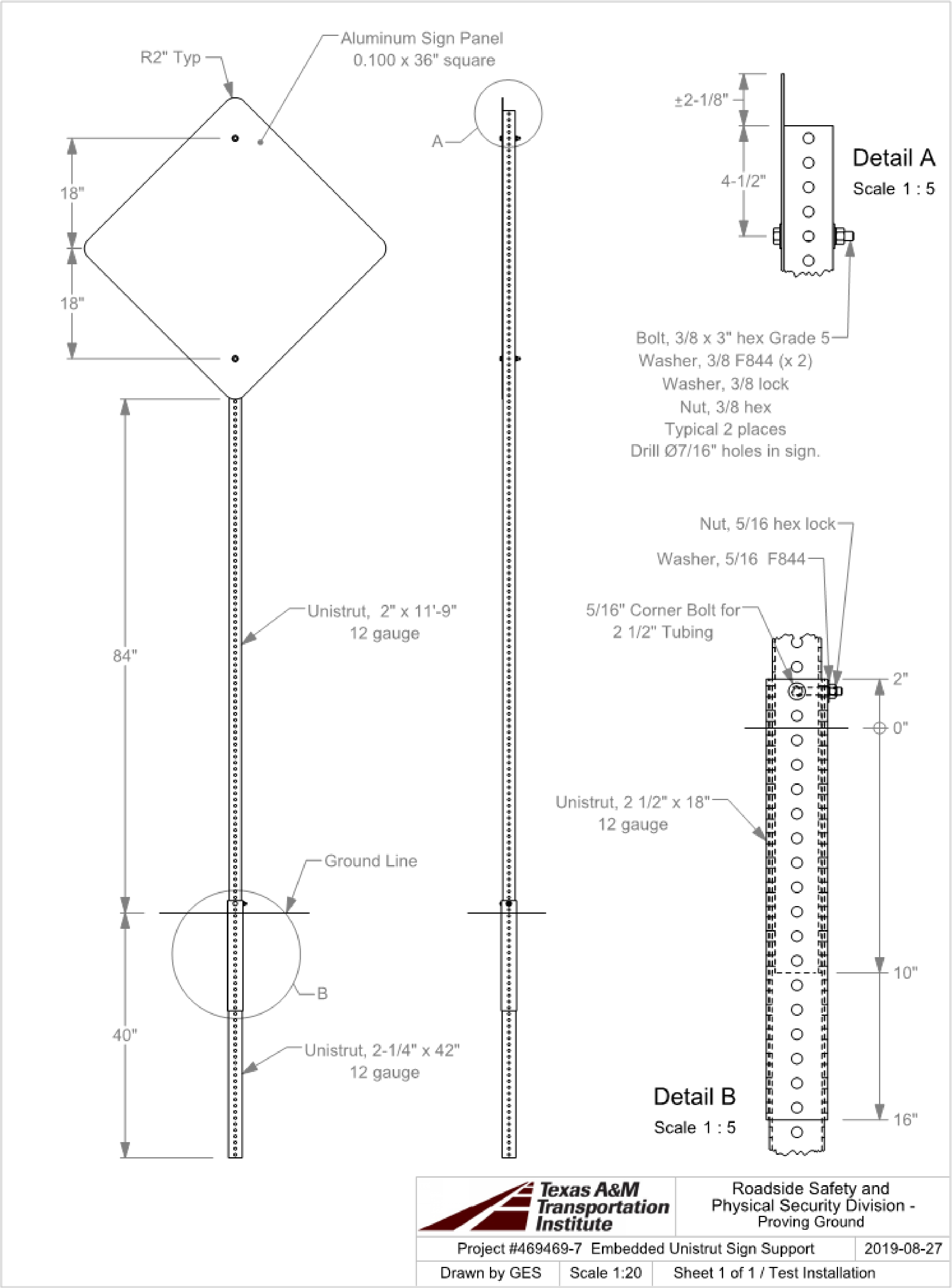


Figure 8.9. Overall Details of the PSST Sign Support in Anchor Stub System for Test No. 469469-7-5.

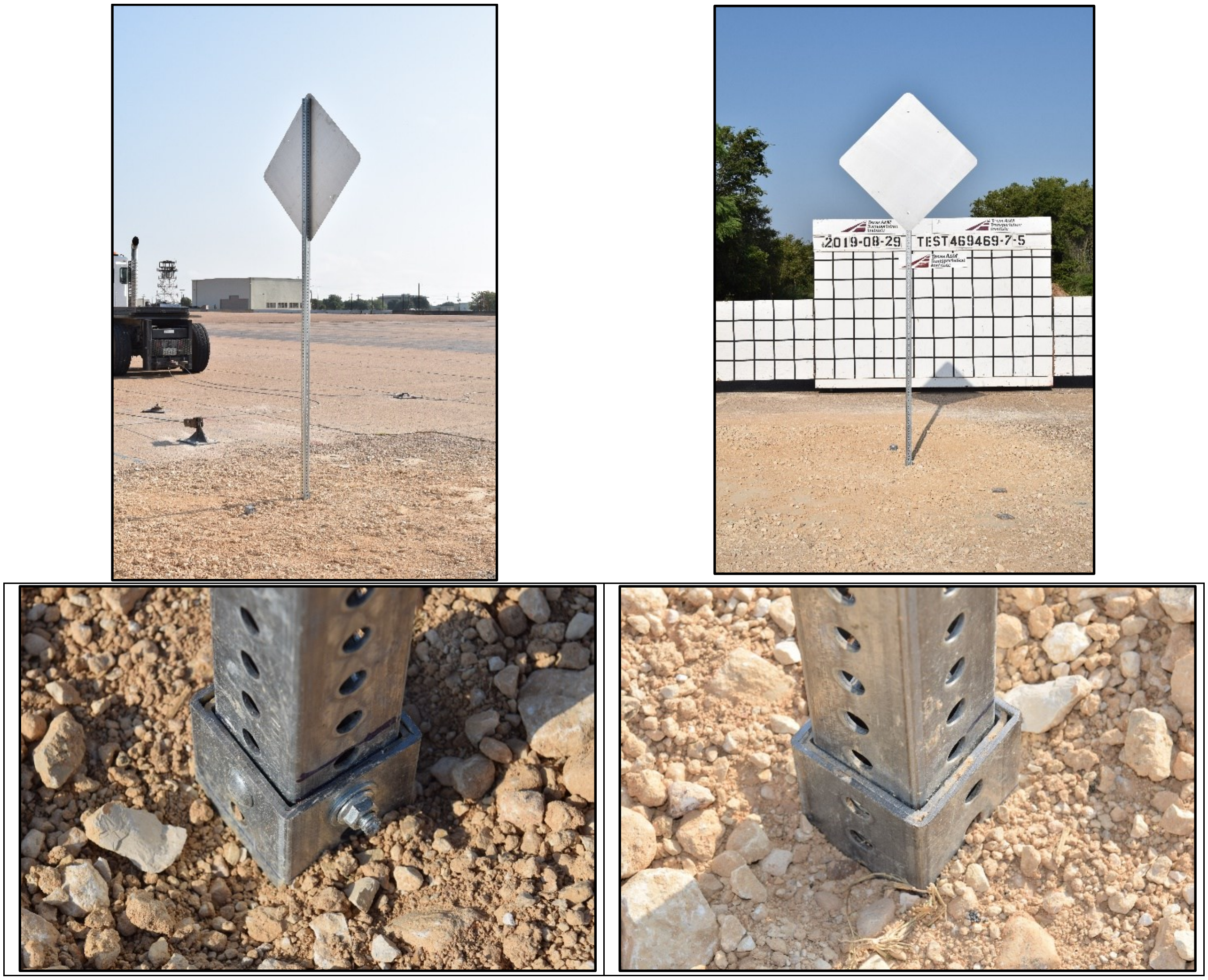


Figure 8.10. PSST Sign Support in Anchor Stub System prior to Test No. 469469-07-05.

8.3.2.3 Test Vehicle

The 2007 Kia Rio shown in Figure 8.11 and Figure 8.12 was used for the crash test. The vehicle's test inertia weight was 2450 lb, and its gross static weight was 2615 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 21.5 inches. Table G.8 in Appendix G.2.1 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.

Figure 8.11. PSST Sign Support in Anchor Stub System Test Vehicle Geometrics for Test No. 469469-07-05.

Figure 8.12. Test Vehicle before Test No. 469469-07-05.

8.3.2.4 Test Description

Table 8.4 lists events that occurred during Test No. 469469-07-05. Figure G.7 in Appendix G.2.3 present sequential photographs during the test.

Table 8.4. Events during Test No. 469469-07-05.

Time	Events
0.000	Vehicle contacts support post
0.010	Support post begins to pull out of anchor stub
0.015	Support post fractures near grade
0.067	Corner of sign makes contact with roof
0.071	Corner of sign penetrates into occupant compartment
0.125	Sign at maximum penetration into occupant compartment

Brakes were applied 2.3 seconds after impact, and the vehicle came to rest 420 ft downstream of the point of impact and in line of the impact path.

8.3.2.5 Damage to Test Installation

Figure 8.13 shows the damage to the PSST sign support in anchor stub system. The soil was disturbed around the anchor stub and reinforcing sleeve. The corner bolt was fractured. The support post lifted about 2 inches out of the anchor stub and fractured approximately 4 inches above grade. The sign panel remained attached to the post, and the assembly landed 150 ft downstream of the point of impact and 13 ft to the left of the impact path.

Figure 8.13. PSST Sign Support in Anchor Stub System after Test No. 469469-07-05.

8.3.2.6 Damage to Test Vehicle

Figure 8.14 and Figure 8.15 show the damage sustained by the vehicle. There was a dent located 14 inches to the left of the vehicle centerline in the front bumper and hood. The windshield was shattered in an area measuring 34 inches by 16 inches by 1 inch deep. The roof sustained a 4-inch-wide by 46½-inch-long cut. The was no measurable exterior crush of the vehicle. The deformation of the roof extended 11¼ inches into the occupant compartment. Table G.9 and Table G.10 in Appendix G.2.2 provide exterior crush and occupant compartment measurements.

Figure 8.14. Test Vehicle after Test No. 469469-07-05.

Figure 8.15. Interior of Test Vehicle after Test No. 469469-07-05.

8.3.2.7 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk, and results are shown in Table 8.5. Figure 8.16 summarizes these data and other pertinent information from the test. Figure G.8 in Appendix G.2.4 shows the vehicle angular displacements, and Figure G.9 through Figure G.11 in Appendix G.2.5 show acceleration versus time traces.

Table 8.5. Occupant Risk Factors for Test No. 469469-07-05.

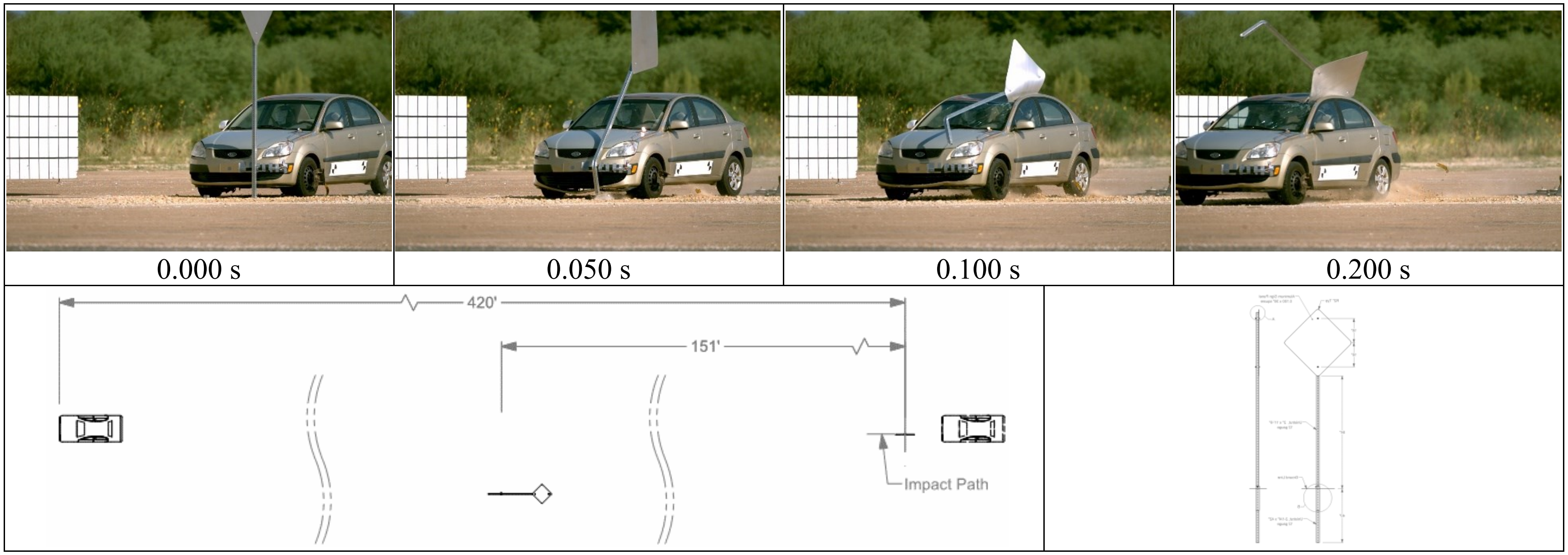
Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)	ft/s	at 0.6523 seconds on right side of interior
Longitudinal	**2.6**	
Lateral	**2.6**	
Occupant Ridedown Accelerations (g's)		
Longitudinal	**0.3**	(0.7642–0.7742 seconds)
Lateral	**0.4**	(1.0180–1.0280 seconds)
Theoretical Head Impact Velocity (THIV)	m/s	at 0.6539 seconds on right side of interior
	1.1	
Post Head Deceleration (PHD) (g's)	**0.4**	(1.0179–1.0279 seconds)
Acceleration Severity Index (ASI)	**0.1**	(0.0077–0.0577 seconds)
Maximum 50-ms Moving Average (g's)		
Longitudinal	**−0.7**	(0.0016–0.0516 seconds)
Lateral	**−0.4**	(0.1773–0.2273 seconds)
Vertical	**0.8**	(0.0383–0.0883 seconds)
Maximum Roll, Pitch, and Yaw Angles	**Degrees**	
Roll	**2**	(1.9996 seconds)
Pitch	**1**	(0.2145 seconds)
Yaw	**2**	(0.3164 seconds)

8.3.2.8 Assessment of Results

An assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-61 is provided in Table 8.6.

8.3.3 Conclusions

The sign support fractured near the ground line as designed. After the support post fractured, the sign panel and support rotated toward the vehicle and impacted the windshield and roof. The sign penetrated through the roof into the occupant compartment, and the roof sustained 11¼ inches of deformation into the occupant compartment. Consequently, the PSST sign support in reinforced anchor stub system did not satisfy *MASH* criteria for breakaway support structures.



General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-61
TTI Test No.	469469-07-05
Test Date	2019-08-29
Test Article	
Type	Sign support structure
Name	PSST sign support in reinforced anchor stub
Installation Length	n/a
Material or Key Elements	2-inch × 12-ga. PSST support inserted into 2¼ -inch × 12-ga. PSST anchor stub with 2¼ -inch × 12-ga. PSST reinforcing sleeve, 36-inch-square × 0.100-inch-thick aluminum sign at 84 inches above grade
Soil Type and Condition	Embedded in AASHTO M147-65(2004), Grading B soil (crushed limestone)
Test Vehicle	
Type/Designation	1100C
Make and Model	2007 Kia Rio
Curb	2453 lb
Test Inertial	2450 lb
Dummy	165 lb
Gross Static	2615 lb

Impact Conditions	
Speed	61.3 mi/h
Angle	0°
Location/Orientation	Center of post aligned 14 inches off center of the vehicle toward the driver's side
Impact Severity	308 kip*ft
Exit Conditions	
Speed	n/a
Exit Trajectory/Heading	n/a
Occupant Risk Values	
Longitudinal OIV	2.6 ft/s
Lateral OIV	2.6 ft/s
Longitudinal Ridedown	0.3 g
Lateral Ridedown	0.4 g
THIV	1.1 m/s
PHD	0.4 g
ASI	0.1
Max. 0.050-s Average	
Longitudinal	−0.7 g
Lateral	−0.4g
Vertical	0.8 g

Post-Impact Trajectory	
Stopping Distance	420 ft, in line
Vehicle Stability	
Maximum Yaw Angle	2°
Maximum Pitch Angle	1°
Maximum Roll Angle	2°
Vehicle Snagging	No
Vehicle Pocketing	n/a
Test Article Deflections	
Dynamic	n/a
Permanent	n/a
Working Width	n/a
Working Width Height	n/a
Vehicle Damage	
VDS	12FL2
CDC	12TLGN3
Max. Exterior Deformation	Non-measurable
OCDI	LF0300000
Max. Occupant Compartment Deformation	11¼ inches at roof

Figure 8.16. Summary of Results for *MASH* Test 3-61 on the PSST Sign Support in Anchor Stub System.

Table 8.6. Performance Evaluation Summary for *MASH* Test 3-61 on the PSST Sign Support in Anchor Stub System.

Test Agency: Texas A&M Transportation Institute | Test No.: 469469-07-05 | Test Date: 2019-08-29

***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 embedded Unistrut sign post support yielded to the 1100C vehicle and 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.*	After fracture of the support post, the released sign support system rotated toward the vehicle and impacted the windshield and roof of the vehicle. The sign panel penetrated through the roof into the occupant compartment.	Fail
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	There was a 4-inch wide by 46½-inch-long cut in the roof and 11¼ inches of roof deformation.	Fail
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 2° and 1°, 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 2.6 ft/s, and lateral OIV was 2.6 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 0.3 g, and lateral occupant ridedown was 0.4 g.	Pass
Vehicle Trajectory		
N. *Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest 420 ft behind and 13 ft to left of the original position of the installation.	Pass

CHAPTER 9: TXDOT BURN BAN SIGN ON SLIP BASE SUPPORT

9.1 BACKGROUND

TxDOT permits counties to post advisory signs on the roadside to alert motorists when a burn ban is in effect. The current practice is to append the burn ban notification signs to existing sign support structures.

Two different sizes of burn ban signs fabricated from lightweight composite sheeting were appended to slip base sign supports and evaluated through full-scale crash testing under NCHRP Report 350 with the 820C vehicle (*6*). In the full-scale tests, secondary contact of the released sign support system with the roof of the impacting vehicle resulted in roof deformation ranging from 4.8 inches to 5.6 inches (*7*). Although these deformations were considered acceptable under NCHRP Report 350, they exceed the permissible roof deformation criteria of 4 inches in *MASH*. Additional testing of burn ban signs on slip base supports was therefore needed with both the 1100C passenger car and the 2270P pickup truck design vehicle that was added to the *MASH* test matrix for breakaway support structures. Since burn ban signs are deployed on support structures along the roadside and not at or near intersections, only evaluation at 0° was considered necessary.

The previous testing of the burn ban signs under NCHRP Report 350 showed that the observed roof deformation was largely attributed to the practice of using small signs on slip base supports rather than the appended lightweight burn ban signs (*7*). This led to further research that concluded the minimum sign area that should be used on a slip base support to meet *MASH* requirements for 0° impacts is 14 sq ft (*8*). Therefore, it was recommended to append the burn ban sign to a slip base sign support system that has a primary sign panel area of at least 14 sq ft.

Two different sizes of burn ban signs are used. The smaller 24-inch by 24-inch sign is intended to simply communicate that a burn ban is in effect. The larger 30-inch by 36-inch sign additionally indicates the name of the county when needed. The larger sign is the more critical of the two sizes. If testing of the 30-inch by 36-inch burn ban sign is satisfactory, the smaller 24-inch by 24-inch burn ban sign will also be considered *MASH* compliant.

9.2 SYSTEM DETAILS

9.2.1 Test Article and Installation Details

The test installation for evaluation of a burn ban sign on slip base support consisted of a 45-inch-square by 0.10-inch-thick aluminum sign mounted on a 2½-inch 10 BWG pipe support, with the lower edge of the primary sign located 84 inches above grade. A T-bracket was attached to the top of the 10 BWG pipe to help support the aluminum sign panel.

A second 30-inch-wide by 36-inch-tall by 0.080-inch-thick lightweight composite burn ban sign was mounted 3 inches below the primary sign. The composite burn ban sign panel was comprised of a thin sheet of high-density polyethylene plastic between aluminum sheets. This smaller sign was attached directly to the pipe support.

The bottom end of the 10 BWG pipe support was secured inside a cast slip base assembly using three set screws. The upper triangular slip base plate was secured to a matching lower plate using three slip bolts tightened to a torque of 60 ft-lb. A keeper plate was positioned between the upper and lower slip plates. The lower triangular slip plate was attached to a pipe stub that was embedded in a 12-inch-diameter by 42-inch-deep unreinforced concrete footing.

Figure 9.1 presents overall information on the burn ban sign on slip base support, and Figure 9.2 provides photographs of the installation. Appendix H.1 provides further details of the burn ban sign on slip base support.

9.2.2 Material Specifications

Appendix H.2 provides material certification documents for the materials used to install/construct the burn ban sign on slip base support.

9.3 MASH TEST 3-61 (TEST NO. 469469-08-01)

9.3.1 Test Designation and Actual Impact Conditions

MASH Test 3-61 involves a 1100C vehicle weighing 2420 lb ±55 lb impacting the CIP of the burn ban sign with slip base at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 0° ±1.5°. The centerline of the support post was aligned 13 inches off the centerline of the vehicle toward the driver's side.

The 2007 Kia Rio used in the test weighed 2418 lb, and the actual impact speed and angle were 62.9 mi/h and 0°, respectively. Minimum target IS was 288 kip-ft, and actual IS was 320 kip-ft.

9.3.2 Weather Conditions

The test was performed on the morning of April 26, 2019. Weather conditions at the time of testing were as follows: wind speed: 4 mi/h; wind direction: 30° with respect to the vehicle (vehicle was traveling in a southerly direction); temperature: 73°F; relative humidity: 71 percent.

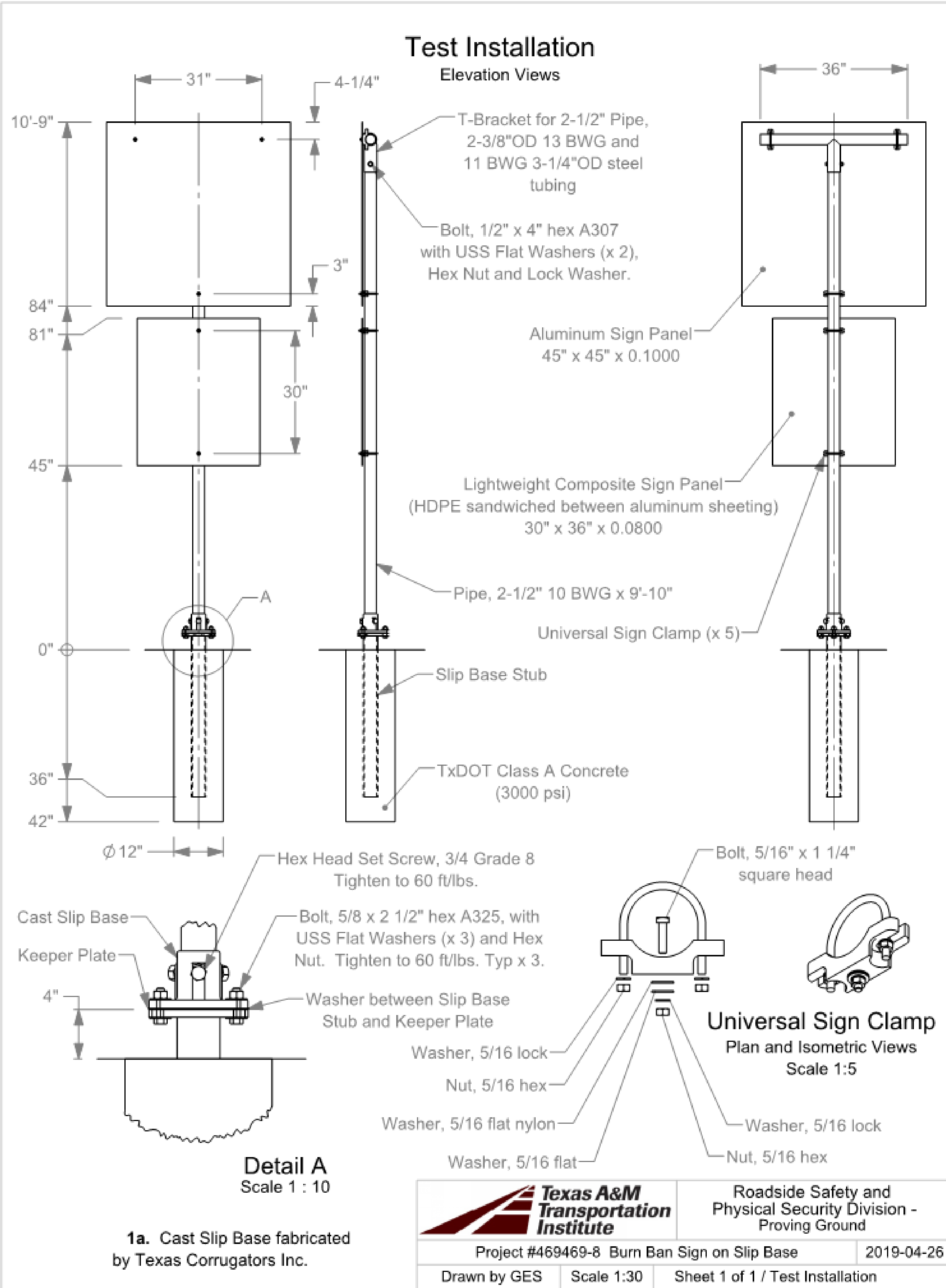


Figure 9.1. Overall Details of the Burn Ban Sign on Slip Base Support.

Figure 9.2. Burn Ban Sign on Slip Base Support prior to Test No. 469469-08-01.

9.3.3 Test Vehicle

The 2007 Kia Rio shown in Figure 9.3 and Figure 9.4 was used for the crash test. The vehicle's test inertia weight was 2418 lb, and its gross static weight was 2583 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 21.5 inches. Table H.1. and Table H.2. in Appendix H.3.1 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.

Figure 9.3. Burn Ban Sign with Slip Base Test Vehicle Geometrics for Test No. 469469-08-01.

Figure 9.4. Test Vehicle before Test No. 469469-08-01.

9.3.4 Test Description

Table 9.1 lists events that occurred during Test No. 469469-08-01. Figure H.1 in Appendix H.3.2 presents sequential photographs during the test.

Table 9.1. Events during Test No. 469469-08-01.

Time	Events
0.000	Vehicle contacts support
0.003	Slip base begins to move
0.007	Slip base completely released
0.015	Composite burn ban sign released from support
0.040	Released sign support loses contact with bumper
0.067	Composite burn ban sign impacts windshield
0.157	Sign and support contact rear window and trunk of vehicle
0.199	Sign and support rotates off of vehicle

The sign support installation rotated over the 1100C vehicle, and the vehicle came to rest 400 ft downstream of the impact point and in line with the initial impact path.

9.3.5 Damage to Test Installation

Figure 9.5 shows the damage to the burn ban sign on slip base support. The slip base system activated as designed, and the stub and foundation were undisturbed. The lower burn ban sign released from the pipe support and came to rest 105 ft downstream and 20 ft right of the original location. The remaining components of the sign support system stayed together and came to rest 120 ft downstream and 8 ft right of the original location.

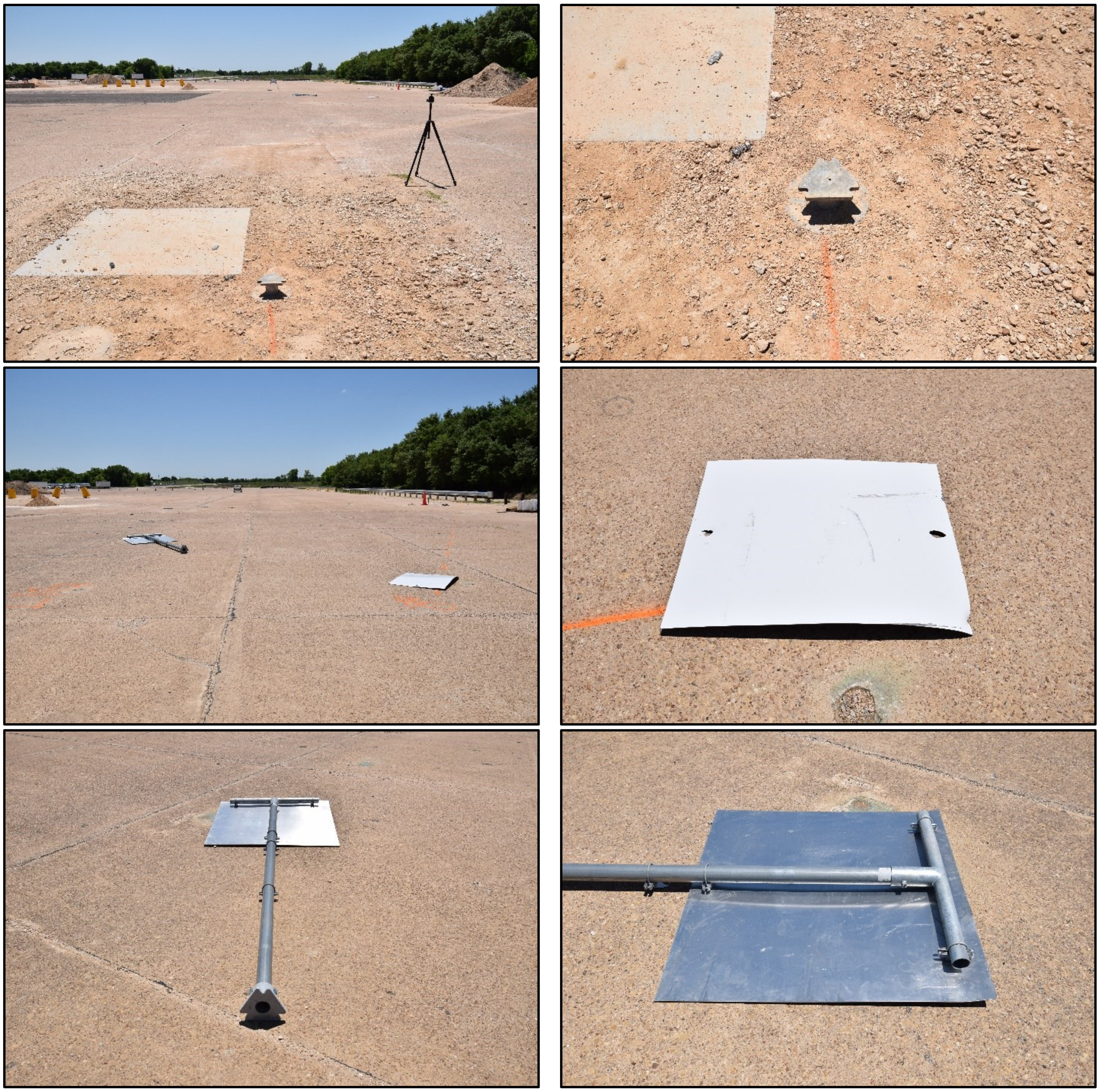


Figure 9.5. Burn Ban Sign with Slip Base Support after Test No. 469469-08-01.

9.3.6 Damage to Test Vehicle

Figure 9.6 and Figure 9.7 show the damage sustained by the vehicle. There was a 4-inch by 6-inch by 2.5-inch-deep dent in the front bumper and a 3-inch by 4-inch by 1-inch-deep dent in the hood, the trunk lid was dented, and the rear window was ejected. The maximum exterior crush of the vehicle was 2.5 inches at the front bumper. There was no measurable occupant compartment deformation. The package deck (shelf) under the rear window showed signs of penetration by the hardware that attached the sign to the support (Figure 9.6). Table H.2 and Table H.3 in Appendix H.3.1 provide exterior crush and occupant compartment measurements.

Figure 9.6. Test Vehicle after Test No. 469469-08-01.

Figure 9.7. Interior of Test Vehicle after Test No. 469469-08-01.

9.3.7 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk, and results are shown in Table 9.2. Figure 9.8 summarizes these data and other pertinent information from the test. Figure H.2 in Appendix H.3.3 shows the vehicle angular displacements, and Figure H.3 through Figure H.5 in Appendix H.3.4 show acceleration versus time traces.

Table 9.2. Occupant Risk Factors for Test No. 469469-08-01.

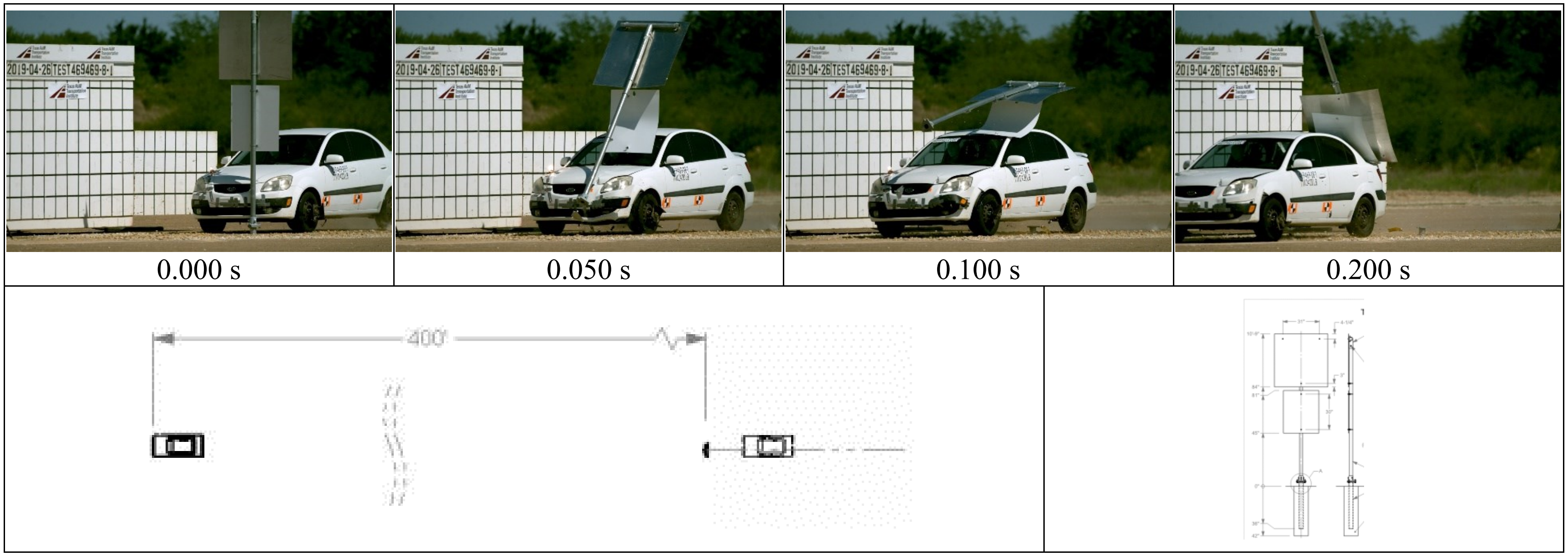
Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)	ft/s	at 0.7746 seconds on right side of interior
Longitudinal	**2.0**	
Lateral	**1.6**	
Occupant Ridedown Accelerations (g's)		
Longitudinal	**0.2**	(1.2171–1.2271 seconds)
Lateral	**0.4**	(1.2025–1.2125 seconds)
Theoretical Head Impact Velocity (THIV)	m/s	at 0.7744 seconds on right side of interior
	0.8	
Acceleration Severity Index (ASI)	**0.1**	(0.0033–0.0533 seconds)
Maximum 50-ms Moving Average (g's)		
Longitudinal	**−0.8**	(0.0011–0.0511 seconds)
Lateral	**−0.4**	(0.2527–0.3027 seconds)
Vertical	**0.8**	(0.1533–0.2033 seconds)
Maximum Roll, Pitch, and Yaw Angles	Degrees	
Roll	**1**	(0.5983 seconds)
Pitch	**3**	(1.5000 seconds)
Yaw	**2**	(0.3072 seconds)

9.3.8 Assessment of Results

An assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-61 is provided in Table 9.3.

9.4 CONCLUSIONS

The burn ban sign on slip base support did not comply with *MASH* criteria. After release from the slip base, the sign support system rotated over the impacting vehicle, and the top of the sign panel and support contacted and penetrated the rear window.



General Information	
Test Agency.............	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-61
TTI Test No.	469469-08-01
Test Date..................	2019-4-26
Test Article	
Type..........................	Sign support structure
Name........................	Burn ban sign on slip base support
Installation Length.....	n/a
Material or Key Elements	Triangular, 3-bolt slip base, 10 BWG support pipe, 45-inch-square aluminum sign, 30×36-inch composite sign
Soil Type and Condition	Concrete footing in compacted road base
Test Vehicle	
Type/Designation......	1100C
Make and Model.......	2007 Kia Rio
Curb..........................	2467 lb
Test Inertial...............	2418 lb
Dummy.....................	165 lb
Gross Static..............	2583 lb

Impact Conditions	
Speed......................	62.9 mi/h
Angle.......................	0°
Location/Orientation	Center of post aligned 13 inches off center of the vehicle toward the driver's side
Impact Severity.........	320 kip*ft
Exit Conditions	
Speed......................	62.9 mi/h
Exit Trajectory/Heading	n/a
Occupant Risk Values	
Longitudinal OIV.......	2.0 ft/s
Lateral OIV..............	1.6 ft/s
Longitudinal Ridedown	0.2 g
Lateral Ridedown.....	0.4 g
THIV........................	0.8 m/s
PHD.........................	0.4 g
ASI...........................	0.11
Max. 0.050-s Average	
Longitudinal.............	−0.8 g
Lateral......................	−0.4 g
Vertical.....................	0.8 g

Post-Impact Trajectory	
Stopping Distance.........	400 ft
Vehicle Stability	
Maximum Yaw Angle.....	2°
Maximum Pitch Angle....	3°
Maximum Roll Angle.....	1°
Vehicle Snagging..........	No
Vehicle Pocketing..........	n/a
Test Article Deflections	
Dynamic........................	n/a
Permanent....................	n/a
Working Width..............	n/a
Working Width Height....	n/a
Vehicle Damage	
VDS..............................	12TRGN2
CDC..............................	12FR1
Max. Exterior Deformation	2.5 inches (bumper)
OCDI.............................	FS0100000
Max. Occupant Compartment Deformation................	None measurable

Figure 9.8. Summary of Results for *MASH* Test 3-61 on the Burn Ban Sign with Slip Base.

Table 9.3. Performance Evaluation Summary for *MASH* Test 3-61 on the Burn Ban Sign with Slip Base.

Test Agency: Texas A&M Transportation Institute | Test No.: 469469-08-01 | Test Date: 2019-04-16

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 slip base activated 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 released sign support system rotated over the vehicle and contacted the rear window and trunk. The top portion of the aluminum sign panel penetrated beyond the rear window, leaving marks on the package deck (shelf) inside the occupant compartment. Thus, the sign panel penetrated the occupant compartment.	Fail
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	There was no measurable occupant compartment deformation.	Pass
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° and 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.*	Longitudinal OIV was 2.0 ft/s, and lateral OIV was 1.6 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 0.2 g, and lateral occupant ridedown was 0.4 g.	Pass
<u>Vehicle Trajectory</u>		
N. *Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest 400 ft behind the original position of the installation.	Pass

CHAPTER 10: TXDOT BURN BAN SIGN ON WEDGE AND SOCKET SUPPORT

10.1 BACKGROUND

TxDOT permits counties to post advisory signs on the roadside to alert motorists when a burn ban is in effect. The current practice is to append the burn ban notification signs to existing sign support structures.

The initial implementation of this practice was limited to slip base sign support systems (*7*). TxDOT desires to expand this implementation to include thin-wall steel tubing supports secured in a wedge and socket foundation. Since burn ban signs are deployed on support structures along the roadside and not at or near intersections, only evaluation at 0° was considered necessary. Therefore, the recommendation was to evaluate the burn ban sign with both the 1100C passenger car and 2270P pickup truck at 0°.

Two different sizes of burn ban signs are used. The smaller 24-inch by 24-inch sign is intended to simply communicate that a burn ban is in effect. The larger 30-inch by 36-inch sign additionally indicates the name of the county when needed. Due to the capacity of the thin-wall steel tube support, the smaller 24-inch by 24-inch burn ban sign was evaluated.

10.2 SYSTEM DETAILS

10.2.1 Test Article and Installation Details

The TxDOT burn ban sign on wedge and socket support test installation consisted of two sign panels mounted on a nominal 2⅜-inch outer diameter by 0.095-inch wall galvanized steel tube support post (13 BWG pipe). The support post was inserted 12 inches into a steel tube socket that was embedded in a 12-inch-diameter by 30-inch-deep unreinforced concrete footer. The support post was secured inside the socket using a driven steel wedge.

The upper primary sign was a 38-inch-square by 0.100-inch-thick aluminum panel mounted with its bottom edge 84 inches above grade. A T-bracket was attached to the top of the 13 BWG pipe to help support the aluminum sign panel. The lower burn ban sign was a 24-inch-square by ⅛-inch (3-mm) thick composite panel that was mounted 3 inches below the primary sign. The composite burn ban sign panel was comprised of a thin sheet of high-density polyethylene plastic between thin aluminum sheets. The support post, two signs, and associated hardware weighed 53 lbs.

Figure 10.1 presents overall information on the burn ban sign on wedge and socket support, and Figure 10.2 provides photographs of the installation. Appendix I.1 provides further details of the burn ban sign on wedge and socket support.

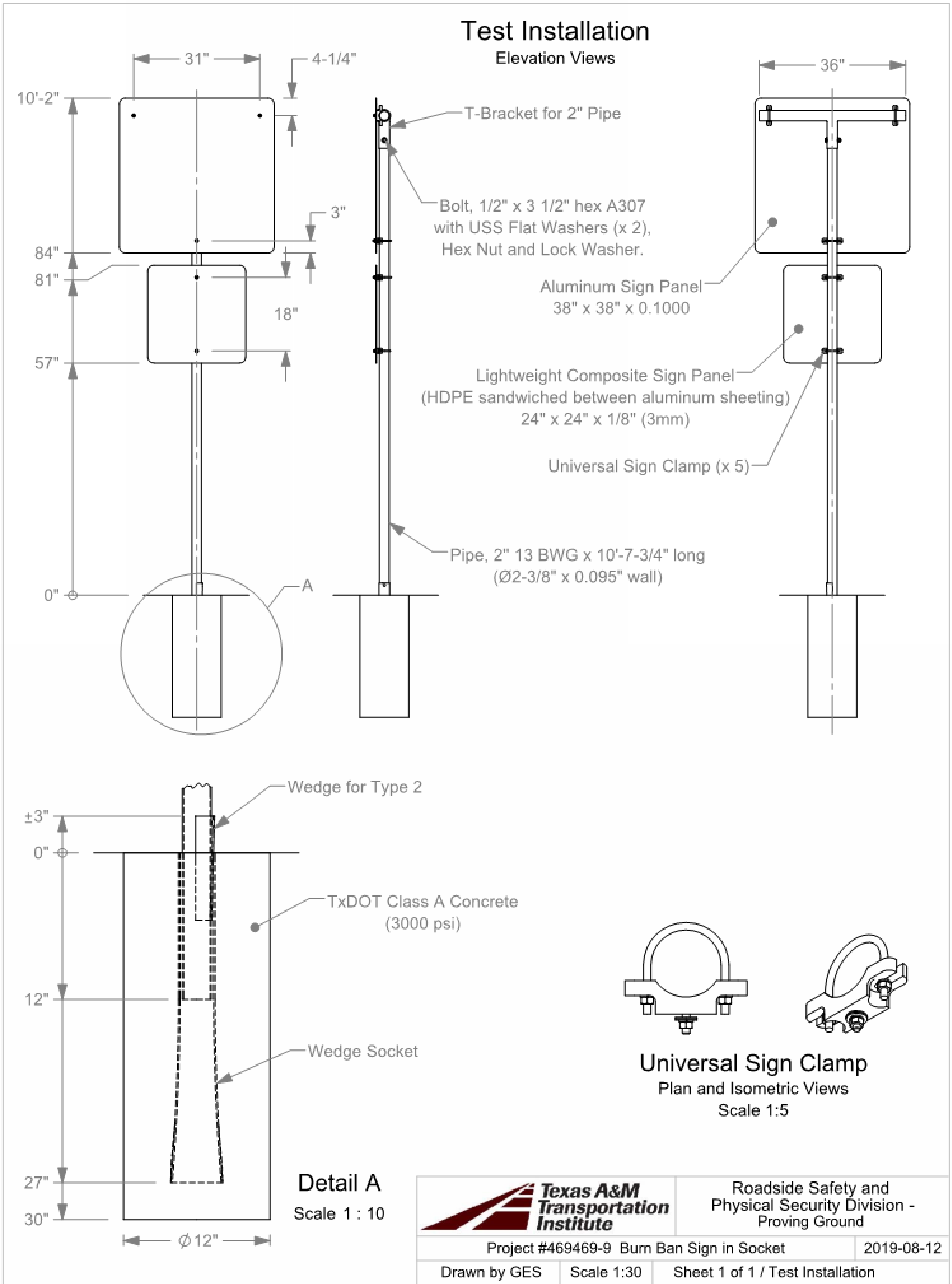


Figure 10.1. Overall Details of the Burn Ban Sign on Wedge and Socket Support.

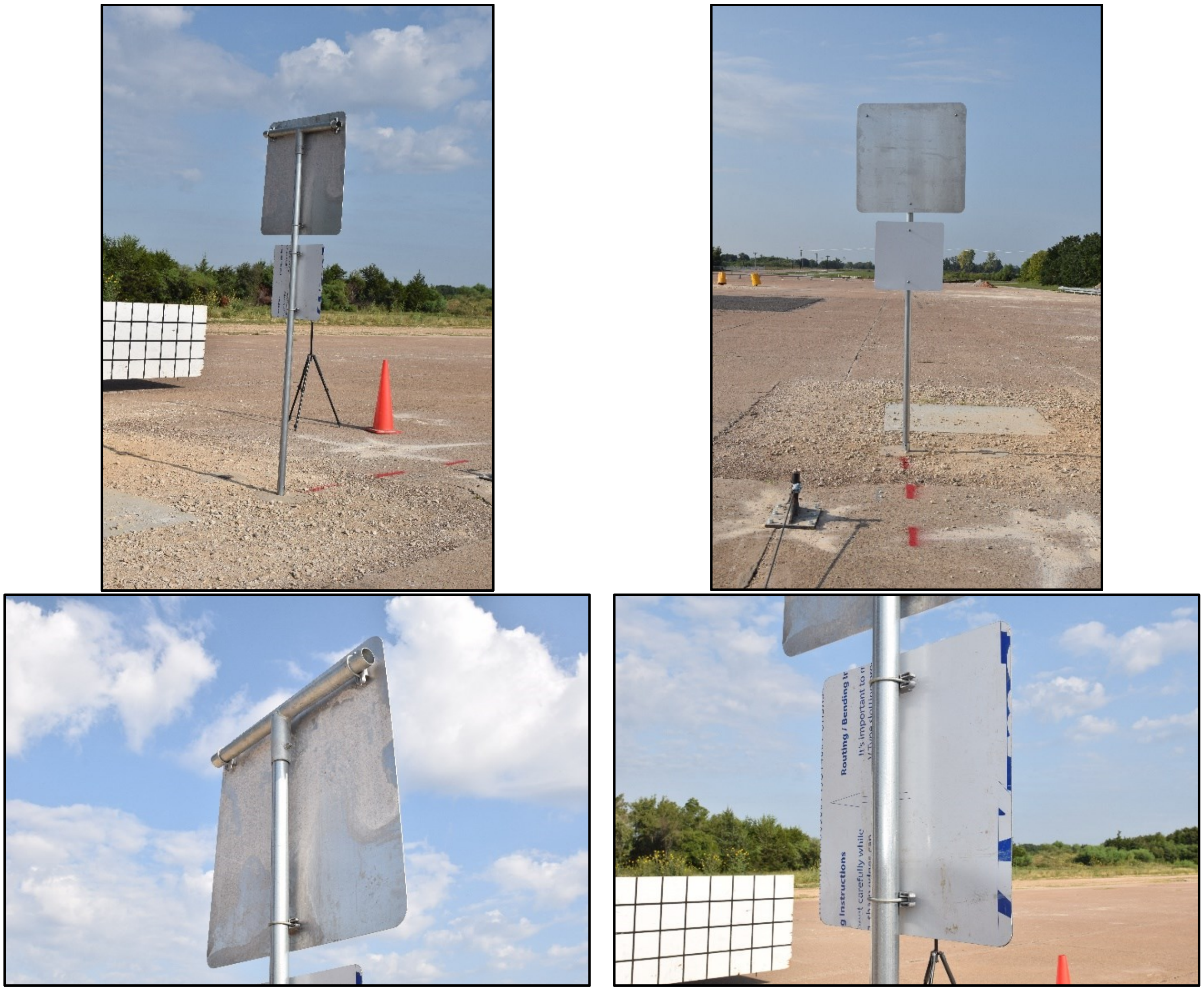


Figure 10.2. Burn Ban Sign on Wedge and Socket Support prior to Test No. 469469-09-01.

10.3 MASH TEST 3-61 (TEST NO. 469469-09-01)

10.3.1 Test Designation and Actual Impact Conditions

MASH Test 3-61 involves a 1100C vehicle weighing 2420 lb ±55 lb impacting the CIP of the burn ban sign on wedge and socket support at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 0° ±1.5°. The selected impact point was the centerline of the burn ban sign on wedge and socket support aligned 14 inches off the centerline of the vehicle toward the driver's side.

The 2008 Kia Rio used in the test weighed 2435 lb, and the actual impact speed and angle were 63.7 mi/h and 0°, respectively. Minimum target impact severity was 288 kip-ft, and actual IS was 330 kip-ft.

10.3.2 Weather Conditions

The test was performed on the morning of August 14, 2019. Weather conditions at the time of testing were as follows: wind speed: 4 mi/h; wind direction: 265° with respect to the vehicle (vehicle was traveling at a magnetic heading of 180°); temperature: 88°F; relative humidity: 76 percent.

10.3.3 Test Vehicle

Figure 10.3 and Figure 10.4 show the 2008 Kia Rio[11] that was used for the crash test. The vehicle's test inertia weight was 2435 lb, and its gross static weight was 2600 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 21.5 inches. Table I.1 in Appendix I.2.1 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.

Figure 10.3. Burn Ban Sign on Wedge and Socket Support Test Vehicle Geometrics for Test No. 469469-09-01.

[11] The 2008 model vehicle used is older than the 6-year age noted in *MASH* and was selected based upon availability. An older model vehicle is permitted by AASHTO as long as it is otherwise *MASH* compliant. Other than the vehicle's year model, this 2008 model vehicle met the *MASH* requirements.

Figure 10.4. Test Vehicle before Test No. 469469-09-01.

10.3.4 Test Description

Table 10.1 lists events that occurred during Test No. 469469-09-01. Figure I.1 in Appendix I.2.2 presents sequential photographs during the test.

Table 10.1. Events during Test No. 469469-09-01.

Time	Events
0.000	Vehicle contacts sign support
0.008	Sign support begins to pull out of socket
0.039	Lower burn ban sign on support makes contact with vehicle hood
0.062	Top primary sign on support impacts windshield

Brakes were applied 1.6 seconds after impact, and the vehicle came to rest 303 ft downstream and 4 ft left of the origin point of impact with the sign support system still in contact.

10.3.5 Damage to Test Installation

Figure 10.5 shows the damage to the burn ban sign on wedge and socket support. The support post partially pulled out of the socket and fractured 24 inches above the ground line. The lower portion remaining in the socket was bent over approximately 85° such that it was nearly parallel with the ground. Both sign panels remained attached to the upper portion of the fractured support post, and this assembly wrapped around the front of the test vehicle and remained intact with the vehicle until it came to a stop.

Figure 10.5. Burn Ban Sign on Wedge and Socket Support after Test No. 469469-09-01.

10.3.6 Damage to Test Vehicle

Figure 10.6 and Figure 10.7 show the damage sustained by the vehicle. There was a dent in the front bumper and a 24-inch by 34-inch by 4.25-inch-deep dent in the hood including two 0.25-inch round holes that were 7 inches apart. The left headlight, left side mirror, left A-pillar, and radiator support were damaged. The windshield had a 37-inch by 32-inch by 6-inch-deep indentation and two cuts/tears in the laminate, one 16 inches long and one 3 inches long. There was no measurable exterior crush of the vehicle. The windshield deformed 6 inches into the occupant compartment and had a large cut in it as explained previously. Table I.2 and Table I.3 in Appendix I.2.1 provide exterior crush and occupant compartment measurements.

Figure 10.6. Test Vehicle after Test No. 469469-09-01.

Figure 10.7. Interior of Test Vehicle after Test No. 469469-09-01.

10.3.7 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk, and results are shown in Table 10.2. Figure 10.8 summarizes these data and other pertinent information from the test. Figure I.2 in Appendix I.2.3 shows the vehicle angular displacements, and Figure I.3 through Figure I.5 in Appendix I.2.4 show acceleration versus time traces.

Table 10.2. Occupant Risk Factors for Test No. 469469-09-01.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)	ft/s	at 0.2671 seconds on front of interior
Longitudinal	**8.5**	
Lateral	**1.0**	
Occupant Ridedown Accelerations (g's)		
Longitudinal	**0.4**	(0.4735–0.4835 seconds)
Lateral	**0.9**	(0.3533–0.3633 seconds)
Theoretical Head Impact Velocity (THIV)	m/s	at 0.2680 seconds on front of interior
	2.7	
Acceleration Severity Index (ASI)	**0.35**	(0.0408–0.0908 seconds)
Maximum 50-ms Moving Average (g's)		
Longitudinal	**−4.4**	(0.0123–0.0623 seconds)
Lateral	**−1.1**	(0.0710–0.1210 seconds)
Vertical	**3.4**	(0.0288–0.0788 seconds)
Maximum Roll, Pitch, and Yaw Angles	**Degrees**	
Roll	**5**	(0.2870 seconds)
Pitch	**2**	(0.1800 seconds)
Yaw	**9**	(0.4507 seconds)

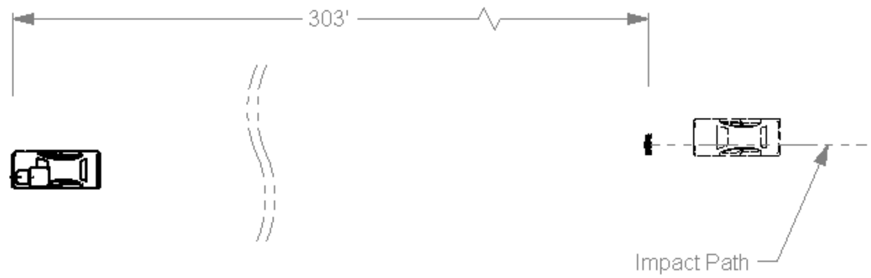
10.3.8 Assessment of Results

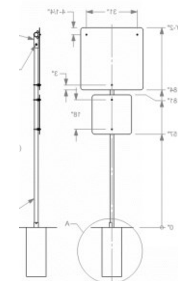
An assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-61 is provided in Table 10.3.

10.4 CONCLUSIONS

Upon impact with the burn ban sign on wedge and socket support, the support post initially began to pull out of its socket, but it subsequently fractured about 24 inches above grade. After fracture of the support post, the upper portion wrapped around the front of the vehicle, and the upper sign panel and support contacted and penetrated the windshield. Consequently, the burn ban sign on wedge and socket support did not meet *MASH* criteria.

0.000 s | 0.050 s | 0.100 s | 0.200 s





General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-61
TTI Test No.	469469-09-01
Test Date	2019-8-14

Test Article

Type	Sign support structure
Name	Burn ban sign on wedge and socket support
Installation Length	n/a
Material or Key Elements	13 BWG steel pipe support secured in socket with steel wedge, 38-inch-square aluminum primary sign, 24-inch-square composite burn ban sign, steel hardware

Soil Type and Condition Unreinforced concrete footer in compacted road base

Test Vehicle

Type/Designation	1100C
Make and Model	2008 Kia Rio
Curb	2459 lb
Test Inertial	2435 lb
Dummy	165 lb
Gross Static	2600 lb

Impact Conditions

Speed	63.7 mi/h
Angle	0°
Location/Orientation	Center of post aligned 14 inches off center of the vehicle toward the driver's side

Impact Severity 330 kip*ft

Exit Conditions

Speed	n/a
Exit Trajectory/Heading	n/a

Occupant Risk Values

Longitudinal OIV	8.5 ft/s
Lateral OIV	1.0 ft/s
Longitudinal Ridedown	0.4 g
Lateral Ridedown	0.9 g
THIV	2.7 m/s
PHD	0.9 g
ASI	0.35

Max. 0.050-s Average

Longitudinal	−4.4 g
Lateral	−1.1 g
Vertical	3.4 g

Post-Impact Trajectory

Stopping Distance	303 ft, 4 ft left

Vehicle Stability

Maximum Yaw Angle	9°
Maximum Pitch Angle	2°
Maximum Roll Angle	5°
Vehicle Snagging	No
Vehicle Pocketing	n/a

Test Article Deflections

Dynamic	n/a
Permanent	n/a
Working Width	n/a
Working Width Height	n/a

Vehicle Damage

VDS	12TLGN2
CDC	12FL1
Max. Exterior Deformation	Non-measurable
OCDI	FS0000000
Max. Occupant Compartment Deformation	6 inches at windshield

Figure 10.8. Summary of Results for *MASH* Test 3-61 on the Burn Ban Sign on Wedge and Socket Support.

Table 10.3. Performance Evaluation Summary for *MASH* Test 3-61 on the Burn Ban Sign on Wedge and Socket Support.

Test Agency: Texas A&M Transportation Institute | Test No.: 469469-09-01 | Test Date: 2019-04-16

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 burn ban sign on wedge and socket support yielded to the 1100C vehicle and fractured.	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.*	After fracture of the support post, the upper portion wrapped around the front of the vehicle, and the upper sign panel and support contacted and penetrated the windshield. The sign panel penetrated the occupant compartment.	Fail
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	There was a 6-inch-deep area of deformation and 16-inch-long tear in the windshield laminate.	Fail
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 5° 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 ft/s.*	Longitudinal OIV was 8.5 ft/s, and lateral OIV was 1.0 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 0.4 g, and lateral occupant ridedown was 0.9 g.	Pass
Vehicle Trajectory		
N. *Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest 303 ft behind the original position of the installation.	Pass

CHAPTER 11: TXDOT SINGLE TEMPORARY MAILBOX ON PLASTIC DRUM

11.1 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 11.1, the 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 11.1. Mailbox Geometrics with 2270P Pickup Truck (*9*).

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 (*10*). It is unlikely that the mailbox will separate from the support or that the support assembly will interact with the vehicle windshield during this lower impact severity test.

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 any secondary contact and interaction between the mailbox support assembly and the vehicle, particularly the 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 III of the project. The details of these systems and the results of the crash testing are provided as follows.

11.2 SINGLE TEMPORARY MAILBOX ON PLASTIC DRUM (TYPE 6 FOUNDATION)

11.2.1 System Details

The test installation consisted of a No. 1-A medium size mailbox (Gibraltar Model #E1600B00) attached to the top of a "Lane Changer" plastic construction drum (Work Area Protection Corp Model# B500LC) using two 14-gauge steel angle brackets (DHT 2917). The bottom of the mailbox was mounted 42 inches above grade. The single temporary mailbox on a plastic drum was placed freestanding on compacted AASHTO M147-65(2004) Grade B crushed limestone road base. Details of this system are described in Maintenance Division standard MB-15(1) and Section K of the TxDOT Compliant Work Zone Traffic Control Device List.

Figure 11.2 presents overall information on the single temporary mailbox on a plastic drum, and Figure 11.3 provides photographs of the test installation. Further details are provided in Appendix J.1.1.

11.2.2 MASH Test 3-61 (Crash Test No. 469469-10-1)

11.2.2.1 Test Designation and Actual Impact Conditions

MASH Test 3-61 involves an 1100C vehicle weighing 2420 lb ±55 lb impacting the CIP of the single temporary mailbox on a plastic drum at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 0° ±1.5°. The target impact point was the centerline of the mailbox aligned 14 inches toward the driver's side from the centerline of the vehicle.

The 2011 Kia Rio used in the test weighed 2440 lb, and the actual impact speed and angle were 62.9 mi/h and 0°, respectively. The actual impact point on the vehicle was the centerline of the mailbox aligned with a point 14 inches toward the driver's side from the centerline of the vehicle. Minimum target impact severity was 288 kip-ft, and actual IS was 323 kip-ft.

11.2.2.2 Weather Conditions

The test was performed on the morning of April 11, 2019. Weather conditions at the time of testing were as follows: wind speed: 8 mi/h; wind direction: 229° with respect to the vehicle (vehicle was traveling at a magnetic heading of 180°); temperature: 76°F; relative humidity: 75 percent.

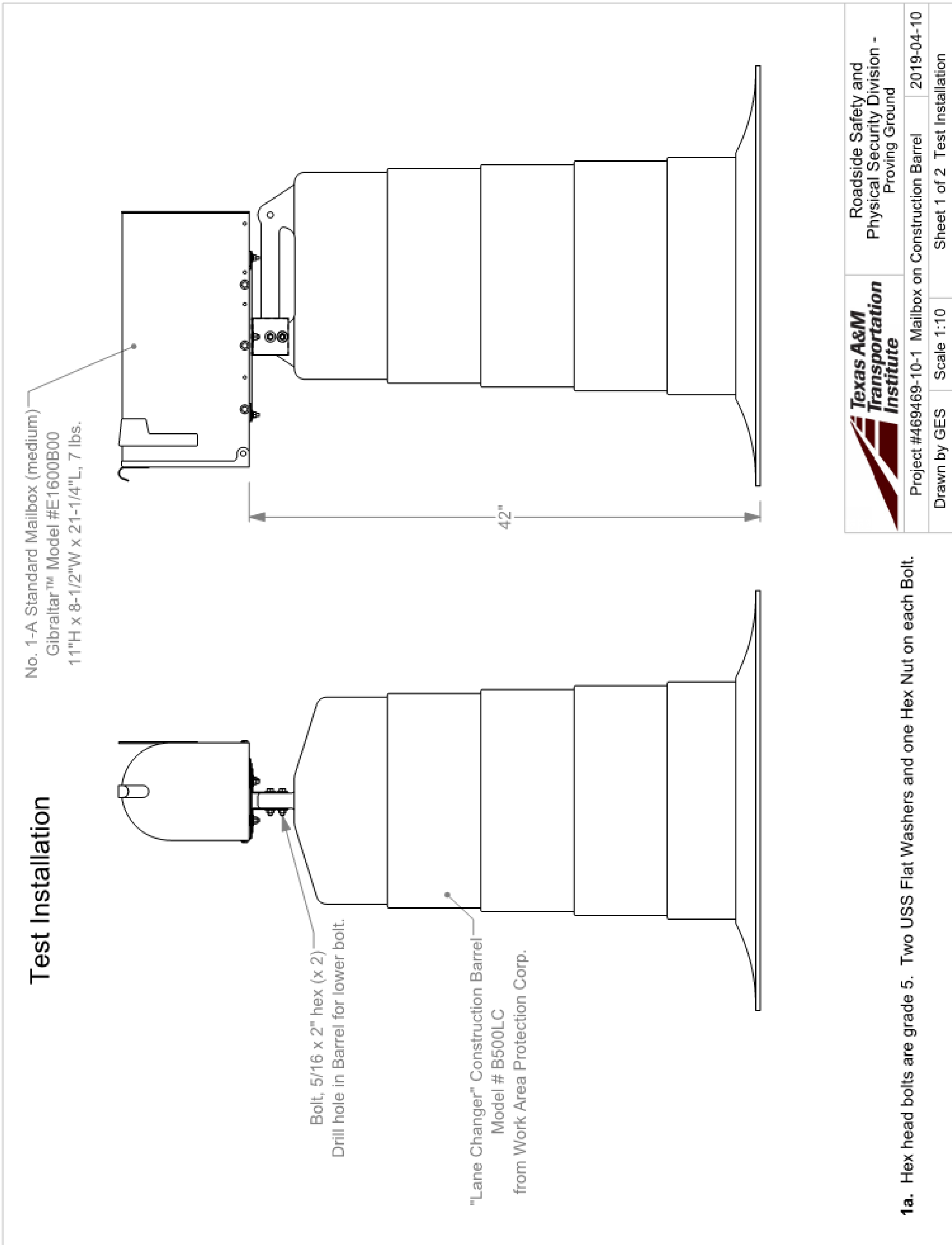


Figure 11.2. Overall Details of the Single Temporary Mailbox on Plastic Drum.

Figure 11.3. Single Temporary Mailbox on Plastic Drum prior to Testing.

11.2.2.3 Test Vehicle

The 2011 Kia Rio,[12] shown in Figure 11.4 and Figure 11.5, was used for the crash test. The vehicle's test inertia weight was 2440 lb, and its gross static weight was 2605 lb. The height to the lower edge of the vehicle bumper was 7.8 inches, and height to the upper edge of the bumper was 21.5 inches. Table J.1 in Appendix J.1.2 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.

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[12] The 2011 model vehicle used is older than the 6-year age noted in *MASH* and was selected based upon availability. An older model vehicle is permitted by AASHTO as long as it is otherwise *MASH* compliant. Other than the vehicle's year model, this 2011 model vehicle met the *MASH* requirements.

Figure 11.4. Single Temporary Mailbox on Plastic Drum/Test Vehicle Geometrics for Test No. 469469-10-1.

Figure 11.5. Test Vehicle before Test No. 469469-10-1 (prior to Placement of the Dummy).

11.2.2.4 Test Description

The 2011 Kia Rio, traveling at an impact speed of 62.9 mi/h, contacted the single temporary mailbox on a plastic drum 14 inches toward the driver's side from the centerline of the vehicle (CIP) at an impact angle of 0°. Table 11.1 lists events that occurred during Test No. 469469-10-1. Figure J.1 in Appendix J.1.3 presents sequential photographs during the test.

Table 11.1. Events during Test No. 469469-10-1.

Time	Events
0.000	Vehicle contacts drum
0.025	Drum released from rubber ring base
0.034	Mailbox begins to impact vehicle hood
0.097	Drum and mailbox have rebounded off vehicle

Brakes were applied at 1.8 seconds after loss of contact with the single temporary mailbox on a plastic drum, and the vehicle came to rest 325 ft downstream and in line of the point of impact.

11.2.2.5 Damage to Test Installation

Figure 11.6 shows the damage to the single temporary mailbox on a plastic drum. The mailbox was deformed but still attached to the drum. The single temporary mailbox on a plastic drum assembly came to rest 90 ft downstream and 10 ft to the left of its original location.

Figure 11.6. Single Temporary Mailbox on Plastic Drum after Test No. 469469-10-1.

11.2.2.6 Damage to Test Vehicle

Figure 11.7 and Figure 11.8 show the damage sustained by the vehicle. The hood of the vehicle suffered an 8-inch by 20-inch by ¾-inch-deep dent, and there were minor scuff marks on the bumper at the point of impact. There was neither measurable exterior crush nor interior deformation to the vehicle. Table J.2 and Table J.3 in Appendix J.1.2 provide further details.

Figure 11.7. Test Vehicle after Test No. 469469-10-1.

Figure 11.8. Interior of Test Vehicle for Test No. 469469-10-1.

11.2.2.7 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk, and results are shown in Table 11.2. Figure 11.9 summarizes these data and other pertinent information from the test. Figure J.2 in Appendix J.1.4 shows the vehicle angular displacements, and Figure J.3 through Figure J.5 in Appendix J.1.5 show acceleration versus time traces.

Table 11.2. Occupant Risk Factors for Test No. 469469-10-1.

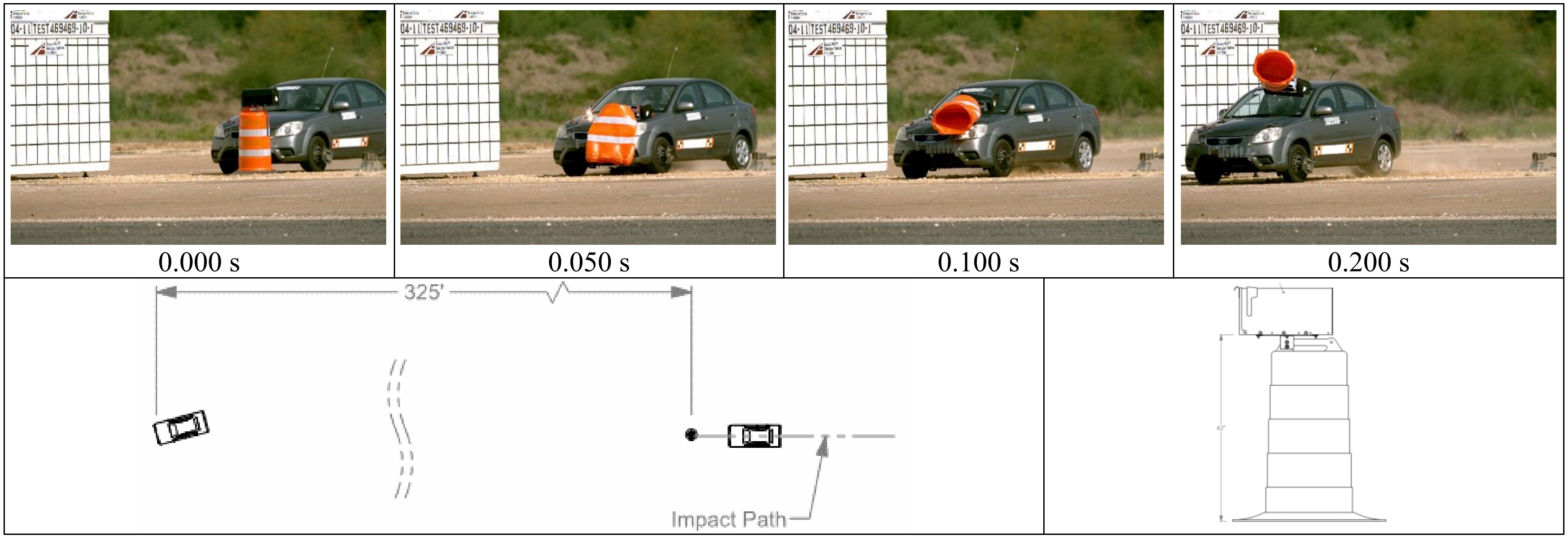
Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)	ft/s	at 0.7988 seconds on left side of interior
Longitudinal	**0.3**	
Lateral	**3.0**	
Occupant Ridedown Accelerations (g's)		
Longitudinal	**0.2**	(1.3974–1.4074 seconds)
Lateral	**0.4**	(1.3319–1.3419 seconds)
Theoretical Head Impact Velocity (THIV)	m/s	at 0.7940 seconds on left side of interior
	0.9	
Post Head Deceleration (PHD) (g's)	**0.5**	(1.3319–1.3419 seconds)
Acceleration Severity Index (ASI)	**0.06**	(0.0464–0.0964 seconds)
Maximum 50-ms Moving Average (g's)		
Longitudinal	**−0.5**	(0.0012–0.0512 seconds)
Lateral	**0.3**	(0.0186–0.0686 seconds)
Vertical	**0.5**	(0.0312–0.0812 seconds)
Maximum Roll, Pitch, and Yaw Angles	Degrees	
Roll	**2**	(1.4519 seconds)
Pitch	**1**	(0.2792 seconds)
Yaw	**3**	(1.4725 seconds)

11.2.2.8 Assessment of Results

An assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-61 is provided in Table 11.3.

11.2.3 Conclusions

The TxDOT mailbox support and foundation (MB-15[1]) Type 6 temporary mailbox support on a plastic drum (single temporary mailbox on a plastic drum) 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.	469469-10-1
Test Date	2019-04-11

Test Article

Type	Temporary mailbox
Name	Mailbox on "Lane Changer" construction drum
Installation Length	n/a
Material or Key Elements	Metal medium-size mailbox bolted to plastic drum

Soil Type and Condition AASHTO M147-65(2004) Grade B crushed limestone road base

Test Vehicle

Type/Designation	1100C
Make and Model	2011 Kia Rio
Curb	2455 lb
Test Inertial	2440 lb
Dummy	165 lb
Gross Static	2605 lb

Impact Conditions

Speed	62.9 mi/h
Angle	0°
Location/Orientation	14 inches off center of vehicle on driver's side with center of mailbox

Impact Severity 323 kip*ft

Exit Conditions

Speed	60.0 mi/h
Exit Trajectory/Heading	0°

Occupant Risk Values

Longitudinal OIV	0.3 ft/s
Lateral OIV	3.0 ft/s
Longitudinal Ridedown	0.2 g
Lateral Ridedown	0.4 g
THIV	3.3 km.h
PHD	0.5 g
ASI	0.06
Max. 0.050-s Average	
Longitudinal	−0.5g
Lateral	0.3 g
Vertical	0.5 g

Post-Impact Trajectory

Stopping Distance	325 ft

Vehicle Stability

Maximum Yaw Angle	3°
Maximum Pitch Angle	1°
Maximum Roll Angle	2°
Vehicle Snagging	No
Vehicle Pocketing	n/a

Test Article Deflections

Dynamic	n/a
Permanent	n/a
Working Width	n/a
Working Width Height	n/a

Vehicle Damage

VDS	n/a
CDC	n/a
Max. Exterior Deformation	None measurable
OCDI	n/a
Max. Occupant Compartment Deformation	None measurable

Figure 11.9. Summary of Results for *MASH* Test 3-61 on the Single Temporary Mailbox on Plastic Drum.

Table 11.3. Performance Evaluation Summary for *MASH* Test 3-61 on the Single Temporary Mailbox on Plastic Drum.

Test Agency: Texas A&M Transportation Institute — Test No.: 469469-10-1 — Test Date: 2019-04-11

***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 single temporary mailbox on a plastic drum yielded to the 1100C vehicle.	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 were 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 5.2.2 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 2° and 1°, 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 0.3 ft/s, and lateral OIV was 3.0 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 occupant ridedown acceleration was 0.4 g.	Pass
Vehicle Trajectory N. *Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest 325 ft behind the installation.	Pass

11.3 SINGLE CENTENNIAL MODEL MAILBOX ON TYPE 2 FOUNDATION

11.3.1 System Details

This system consisted of a single extra-large mailbox attached to a galvanized thin-wall steel tube support secured inside a 12-gauge galvanized anchor socket embedded in a concrete footing. The bottom (floor) of the mailbox was mounted 42 inches above grade. Details of this system are described in Maintenance Division standard MB-15(1).

The Centennial extra-large mailbox (Model #950020B) from Architectural Mailboxes had approximate dimensions of 11.9 inches tall by 14.2 inches wide by 18.3 inches deep and weighed 11.8 lb. Attachment of the mailbox to the post was accomplished using a mailbox bracket with an integral collar (DHT #161443). The bracket was secured to the bottom of the mailbox using four 5/16-inch-diameter by 1-inch-long SAE Grade 5 hex bolts, two 2-inch by 5½-inch by ⅛-inch ASTM A36 plate washers, and associated hardware. The collar on the mailbox bracket was positioned over and secured to the top of the support post using a 5/16-inch-diameter by 3-inch-long SAE Grade 5 hex bolt with associated hardware.

The support post was a 2⅜-inch-outside-diameter by 0.095-inch-thick galvanized thin-wall steel tube (DHT #143426). The support post was inserted approximately 8 inches into a 2⅜-inch-outside-diameter by 0.095-inch-thick galvanized thin-wall steel tube socket (DHT #143434) and secured with a curved steel wedge plate (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 by 30 inches deep.

Figure 11.10 presents overall information on the extra-large mailbox on thin-wall galvanized tube with Type 2 foundation, and Figure 11.11 provides photographs of the test installation. Further details are provided in Appendix J.2.1.

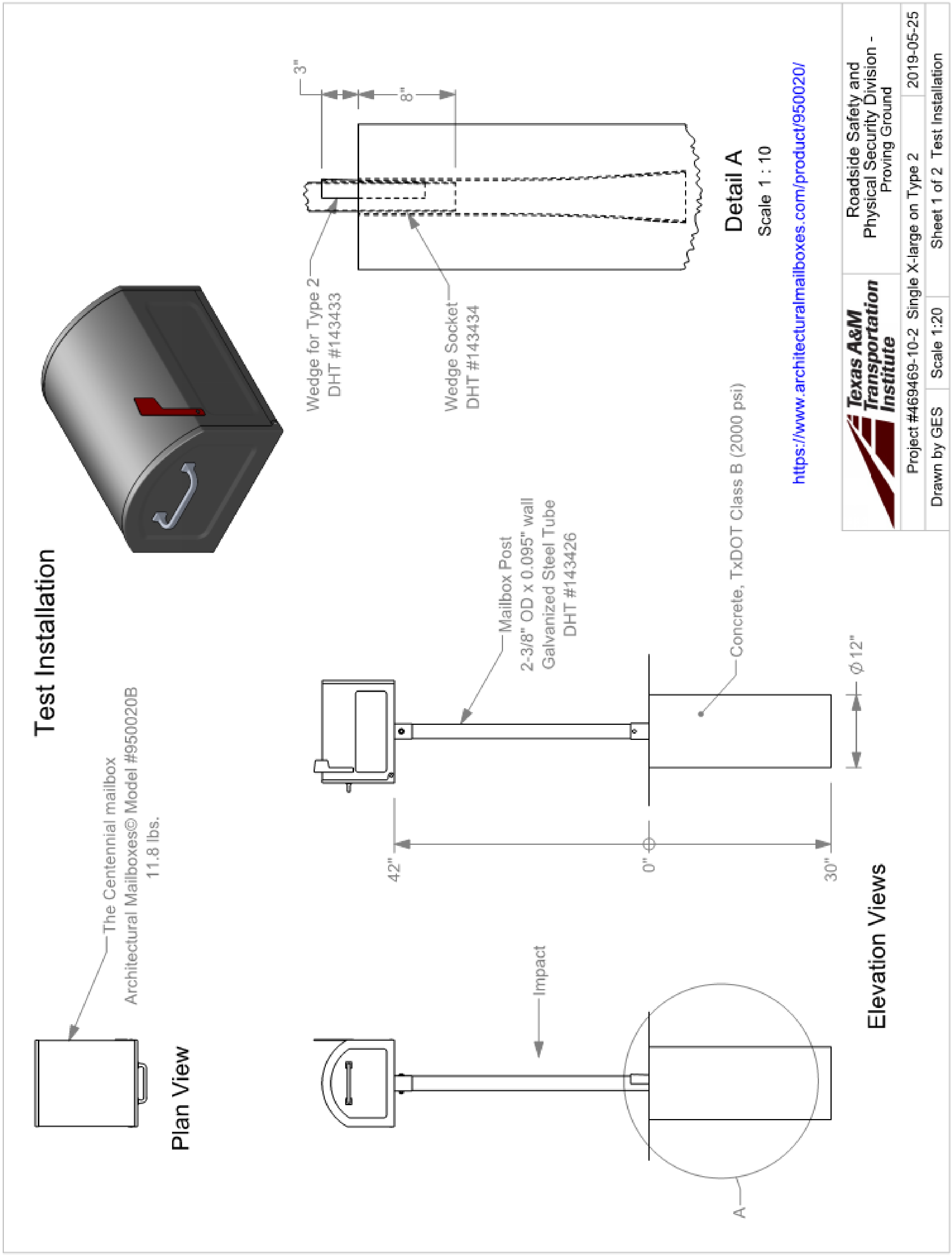


Figure 11.10. Overall Details of the Centennial Mailbox on Steel Tube Post.

Figure 11.11. Centennial Mailbox on Steel Tube Post prior to Testing.

11.3.2 MASH Test 3-61 (Crash Test No. 469469-10-2)

11.3.2.1 Test Designation and Actual Impact Conditions

MASH Test 3-61 involves a 1100C vehicle weighing 2420 lb ±55 lb impacting the Centennial model mailbox on Type 2 foundation at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 0° ±1.5°. The target impact point was the centerline of the mailbox support aligned 14 inches toward the driver's side from the centerline of the vehicle.

The 2011 Kia Rio used in the test weighed 2440 lb, and the actual impact speed and angle were 63.0 mi/h and 0°, respectively. The actual impact point of the mailbox support on the vehicle was 14 inches toward the driver's side from the centerline of the vehicle. Minimum target impact severity was 288 kip-ft, and actual IS was 324 kip-ft.

11.3.2.2 Weather Conditions

The test was performed on the morning of June 25, 2019. Weather conditions at the time of testing were as follows: wind speed: 3 mi/h; wind direction: 144° with respect to the vehicle (vehicle was traveling at a magnetic heading of 180°); temperature: 85°F; relative humidity: 79 percent.

11.3.2.3 Test Vehicle

The 2011 Kia Rio,[13] shown in Figure 11.12 and Figure 11.13, was used for the crash test. The vehicle's test inertia weight was 2440 lb, and its gross static weight was 2605 lb. The height to the lower edge of the vehicle bumper was 7.8 inches, and height to the upper edge of the bumper was 21.5 inches. Table J.5 in Appendix J.2.2 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 11.12. Extra-Large Mailbox on Thin-Wall Galvanized Tube with Type 2 Foundation/Test Vehicle Geometrics for Test No. 469469-10-2.

Figure 11.13. Test Vehicle before Test No. 469469-10-2 (prior to Installation of the Dummy).

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[13] The 2011 model vehicle used is older than the 6-year age noted in *MASH* and was selected based upon availability. An older model vehicle is permitted by AASHTO as long as it is otherwise *MASH* compliant. Other than the vehicle's year model, this 2011 model vehicle met the *MASH* requirements.

11.3.2.4 Test Description

Table 11.4 lists events that occurred during Test No. 469469-10-2. Figure J.6 in Appendix J.2.3 present sequential photographs during the test.

Table 11.4. Events during Test No. 469469-10-2.

Time	Events
0.000	Vehicle contacts mailbox support
0.008	Mailbox support begins to pull out of base
0.015	Top of mailbox separates from bottom panel of mailbox
0.059	Mailbox support is still in base under car and flat on ground
0.028	Top of mailbox impacts hood of vehicle
0.144	Mailbox has rebounded off of windshield and post is under car

Brakes on the vehicle were applied 1.25 seconds after impact. The vehicle came to rest 265 ft downstream of and in line with the point of impact with the vehicle facing 45° counterclockwise.

11.3.2.5 Damage to Test Installation

Figure 11.14 shows the damage to the Centennial model mailbox on Type 2 foundation. The post pulled out of the socket 5 inches and then bent over flat against the soil/concrete. The mailbox was detached from the bracket and separated into four pieces that came to rest in an area ranging from 55 to 95 ft downstream of the point of impact and 5 ft left to 31 ft right of the travel path of the vehicle.

Figure 11.14. Extra-Large Mailbox on Thin-Wall Galvanized Tube with Type 2 Foundation after Test No. 469469-10-2.

11.3.2.6 Damage to Test Vehicle

Figure 11.15 and Figure 11.16 show the damage sustained by the vehicle. The right side of the bumper had a 3-inch dent, and the right side of the hood of the vehicle had a 29-inch by 31-inch by 1.3-inch-deep dent with 2.5-inch by 2-inch cuts. There was a small dent in the right A-pillar, and the bottom right of the windshield was fractured over an 8-inch by 8-inch area; however, there was no penetration of the windshield. There was a 3-inch dent in the bumper and no interior deformation to the vehicle. Table J.6 and Table J.7 in Appendix J.2.2 provide further details.

Figure 11.15. Test Vehicle after Test No. 469469-10-2.

Figure 11.16. Interior of Test Vehicle for Test No. 469469-10-2.

11.3.2.7 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk, and results are shown in Table 11.5. Figure 11.17 summarizes these data and other pertinent information from the test. Figure J.7 in Appendix J.2.4 shows the vehicle angular displacements, and Figure J.8 through Figure J.10 in Appendix J.2.5 show acceleration versus time traces.

Table 11.5. Occupant Risk Factors for Test No. 469469-10-2.

Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)	ft/s	at 0.6071 seconds on left side of interior
Longitudinal	**3.0**	
Lateral	**2.6**	
Occupant Ridedown Accelerations (g's)		
Longitudinal	**0.2**	(0.7029–0.7129 seconds)
Lateral	**0.4**	(0.9324–0.9424 seconds)
Theoretical Head Impact Velocity (THIV)	m/s	at 0.5996 seconds on left side of interior
	1.3	
Post Head Deceleration (PHD) (g's)	**0.4**	(0.9324–0.9424 seconds)
Acceleration Severity Index (ASI)	**0.2**	(0.0154–0.0654 seconds)
Maximum 50-ms Moving Average (g's)		
Longitudinal	**−1.9**	(0.0006–0.0506 seconds)
Lateral	**0.5**	(0.0606–0.1106 seconds)
Vertical	**0.7**	(0.0309–0.0809 seconds)
Maximum Roll, Pitch, and Yaw Angles	**Degrees**	
Roll	**3**	(1.0000 seconds)
Pitch	**1**	(0.1126 seconds)
Yaw	**3**	(0.3505 seconds)

11.3.2.8 Assessment of Results

An assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-61 is provided in Table 11.6.

11.3.3 Conclusions

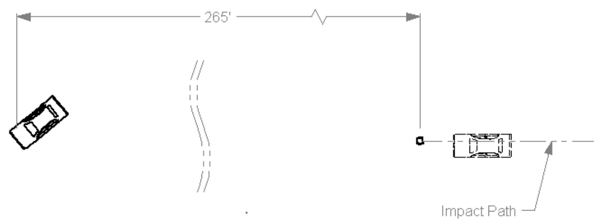
The Centennial model mailbox mounted on a 2⅜-inch OD by 0.095-inch wall galvanized steel tube post performed acceptably for *MASH* Test 3-61.

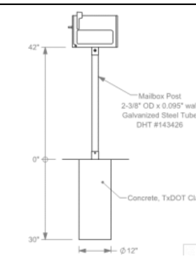
0.000 s

0.050 s

0.100 s

0.200 s





General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-61
TTI Test No.	469469-10-2
Test Date	2019-06-25
Test Article	
Type	Mailbox support
Name	Extra-large mailbox on thin-wall tube with Type 2 foundation
Installation Length	n/a
Material or Key Elements	Extra-large mailbox attached to 2⅜-inch OD steel tube inserted into a steel anchor tube embedded in concrete footing and secured by a curved steel wedge
Soil Type and Condition	AASHTO M147-65(2004) Grade B crushed limestone road base
Test Vehicle	
Type/Designation	1100C
Make and Model	2011 Kia Rio
Curb	2455 lb
Test Inertial	2440 lb
Dummy	165 lb
Gross Static	2605 lb

Impact Conditions	
Speed	63.0 mi/h
Angle	0°
Location/Orientation	Center of mailbox post aligned 14 inches off center of vehicle on driver's side
Impact Severity	324 kip*ft
Exit Conditions	
Speed	61.3 mi/h
Exit Trajectory/Heading	0°
Occupant Risk Values	
Longitudinal OIV	3.0 ft/s
Lateral OIV	2.6 ft/s
Longitudinal Ridedown	0.2 g
Lateral Ridedown	0.4 g
THIV	1.3 m/s
PHD	0.4 g
ASI	0.2
Max. 0.050-s Average	
Longitudinal	−1.9g
Lateral	0.5 g
Vertical	0.7 g

Post-Impact Trajectory	
Stopping Distance	265 ft
Vehicle Stability	
Maximum Yaw Angle	3°
Maximum Pitch Angle	1°
Maximum Roll Angle	3°
Vehicle Snagging	No
Vehicle Pocketing	n/a
Test Article Deflections	
Dynamic	n/a
Permanent	n/a
Working Width	n/a
Working Width Height	n/a
Vehicle Damage	
VDS	n/a
CDC	n/a
Max. Exterior Deformation	None measurable
OCDI	n/a
Max. Occupant Compartment Deformation	None measurable

Figure 11.17. Summary of Results for *MASH* Test 3-61 on the Extra-Large Mailbox on Thin-Wall Galvanized Tube with Type 2 Foundation.

Table 11.6. Performance Evaluation Summary for *MASH* Test 3-61 on the Centennial Model Mailbox on Type 2 Foundation.

Test Agency: Texas A&M Transportation Institute   Test No.: 469469-10-2   Test Date: 2019-06-25

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 Centennial model mailbox on a Type 2 foundation yielded to the 1100C vehicle.	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 were 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 5.2.2 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 3° and 1°, 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 3.0 ft/s, and lateral OIV was 2.6 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 occupant ridedown acceleration was 0.4 g.	Pass
Vehicle Trajectory		
N. *Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest 265 ft behind the installation.	Pass

11.4 LOCKABLE MAILBOX ON THIN-WALL GALVANIZED TUBE WITH TYPE 2 FOUNDATION

11.4.1 System Details

This system consisted of a lockable mailbox attached to a galvanized thin-wall steel tube support secured inside a 12-gauge galvanized anchor socket embedded in a concrete footing. The bottom (floor) of the mailbox was mounted 42 inches above grade. Details of this system are described in Maintenance Division standard MB-15(1).

The Oasis Jr. Elite lockable mailbox (Model #620010B-10) had approximate dimensions of 15 inches tall by 12 inches wide by 18.1 inches deep and weighed 23 lb. Attachment of the mailbox to the post was accomplished using a mailbox bracket with an integral collar (DHT #161443). The bracket was secured to the bottom of the mailbox using four ⅜-inch-diameter by 1¼-inch-long SAE Grade 5 hex bolts, two 2-inch by 5½-inch by ⅛-inch ASTM A36 plate washers, and associated hardware. The collar on the mailbox bracket was positioned over and secured to the top of the support post using a 5/16-inch-diameter by 3-inch-long SAE Grade 5 hex bolt with associated hardware.

The support post was a 2⅜-inch-outside-diameter by 0.095-inch-thick galvanized thin-wall steel tube (DHT #143426). The support post was inserted approximately 8 inches into a 2⅜-inch-outside-diameter by 0.125-inch-thick galvanized thin-wall steel tube socket (DHT #143434) and secured with a curved steel wedge plate (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 by 30 inches deep.

Figure 11.18 presents overall information on the lockable mailbox on thin-wall galvanized tube with Type 2 foundation, and Figure 11.19 provides photographs of the test installation. Further details are provided in Appendix J.3.1.

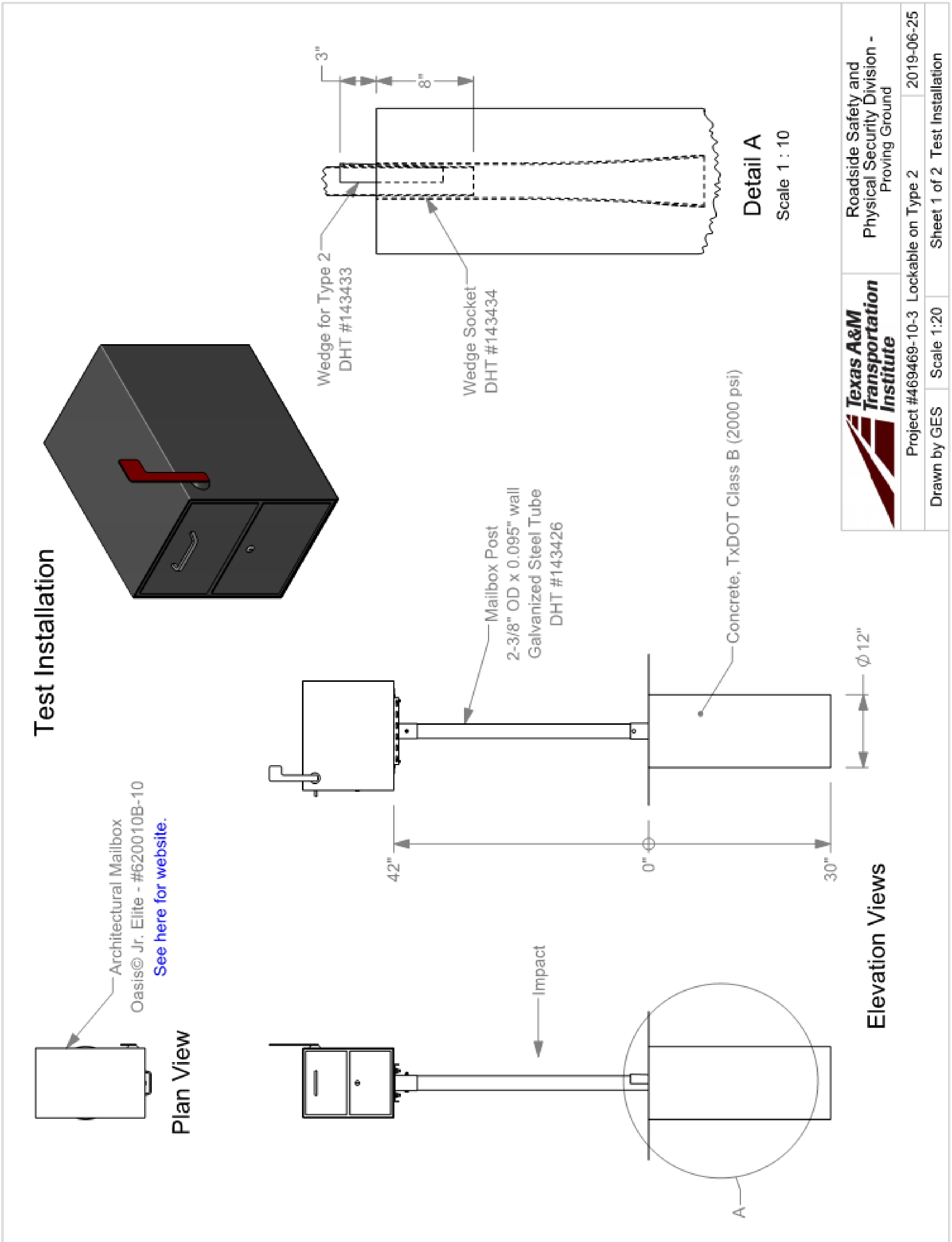


Figure 11.18. Overall Details of the Lockable Mailbox on Steel Tube Post.

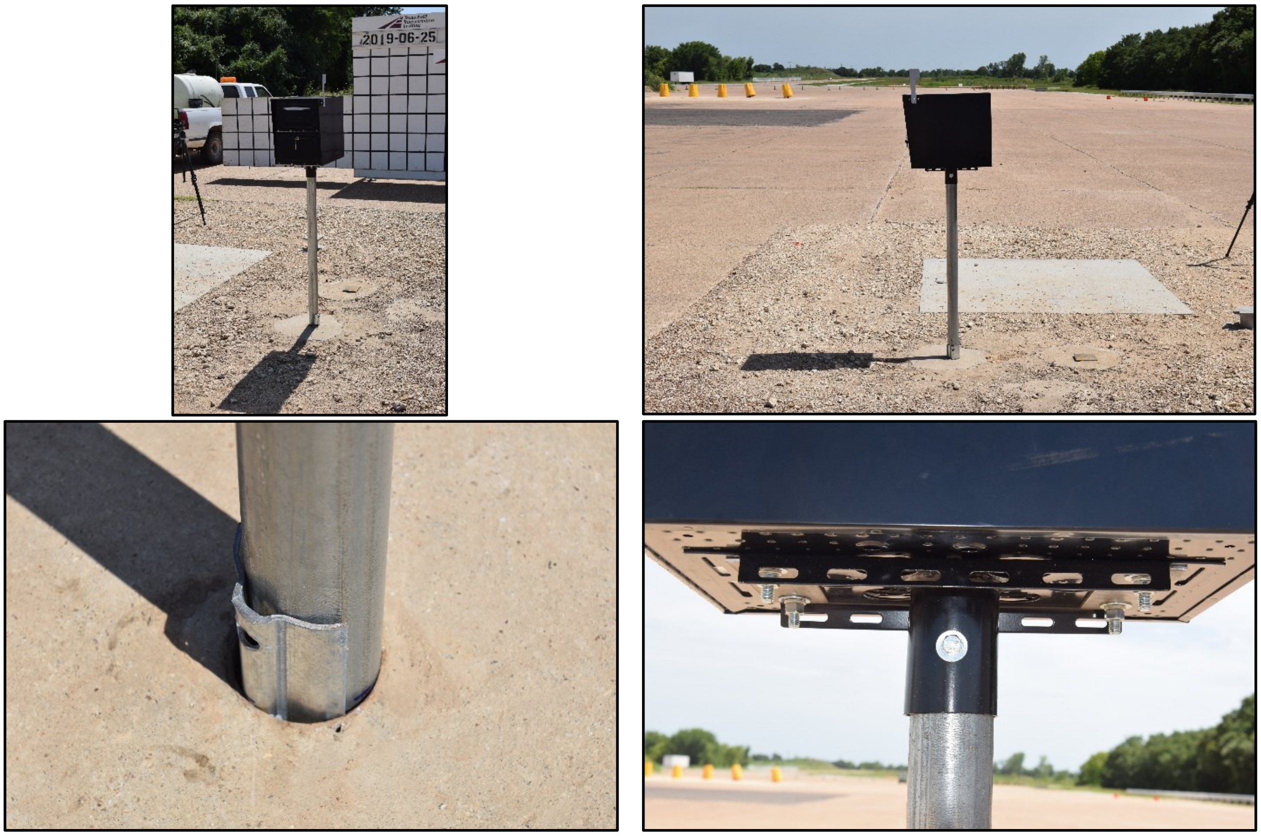


Figure 11.19. Lockable Mailbox on Steel Tube Post prior to Testing.

11.4.2 MASH Test 3-61 (Crash Test No. 469469-10-3)

11.4.2.1 Test Designation and Actual Impact Conditions

MASH Test 3-61 involves a 1100C vehicle weighing 2420 lb ±55 lb impacting the lockable mailbox on thin-wall galvanized tube with Type 2 Foundation at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 0° ±1.5°. The target impact point was the centerline of the mailbox support aligned 14 inches toward the driver's side from the centerline of the vehicle.

The 2011 Kia Rio used in the test weighed 2440 lb, and the actual impact speed and angle were 62.6 mi/h and 0°, respectively. The actual impact point on the vehicle was 14 inches toward the driver's side from the centerline of the vehicle. Minimum target impact severity was 288 kip-ft, and actual IS was 320 kip-ft.

11.4.2.2 Weather Conditions

The test was performed on the afternoon of June 25, 2019. Weather conditions at the time of testing were as follows: wind speed: 10 mi/h; wind direction: 158° with respect to the vehicle (vehicle was traveling at a magnetic heading of 180°); temperature: 88°F; relative humidity: 66 percent.

11.4.2.3 Test Vehicle

The 2011 Kia Rio,[14] shown in Figure 11.20 and Figure 11.21, was used for the crash test. The vehicle's test inertia weight was 2440 lb, and its gross static weight was 2605 lb. The height to the lower edge of the vehicle bumper was 7.8 inches, and height to the upper edge of the bumper was 21.5 inches. Table J.9 in Appendix J.3.2 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.

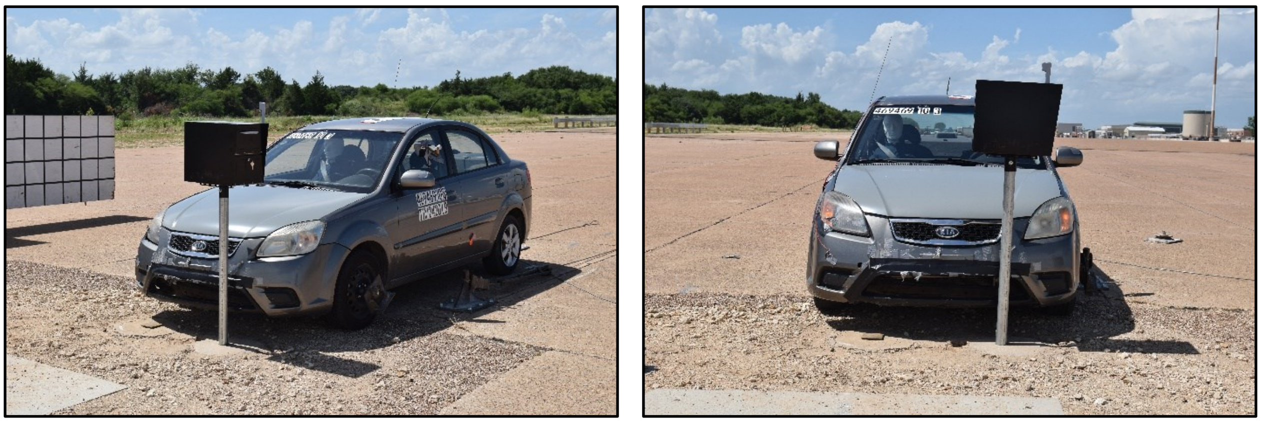


Figure 11.20. Lockable Mailbox on Thin-Wall Galvanized Tube with Type 2 Foundation/Test Vehicle Geometrics for Test No. 469469-10-3.

Figure 11.21. Test Vehicle before Test No. 469469-10-3.

11.4.2.4 Test Description

Table 11.7 lists events that occurred during Test No. 469469-10-3. Figure J.1.1 in Appendix J.3.3 presents sequential photographs during the test.

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[14] The 2011 model vehicle used is older than the 6-year age noted in *MASH* and was selected based upon availability. An older model vehicle is permitted by AASHTO as long as it is otherwise *MASH* compliant. Other than the vehicle's year model, this 2011 model vehicle met the *MASH* requirements.

Table 11.7. Events during Test No. 469469-10-3.

Time	Events
0.000	Vehicle contacts mailbox support
0.011	Mailbox support begins to pull out of base
0.024	Mailbox support is fully released from base socket
0.025	Mailbox on support impacts hood of vehicle
0.104	Mailbox on support rebounds off hood

The brakes were applied 1.5 seconds after impact, and the vehicle came to rest 296 ft downstream of and in line of the point of impact.

11.4.2.5 Damage to Test Installation

Figure 11.22 shows the damage to the lockable mailbox on thin-wall galvanized tube with Type 2 foundation. The mailbox-post assembly remained intact. The mailbox, bracket, and support post were deformed. The lockable mailbox on thin-wall galvanized tube with Type 2 foundation assembly came to rest 311 ft downstream of its original location.

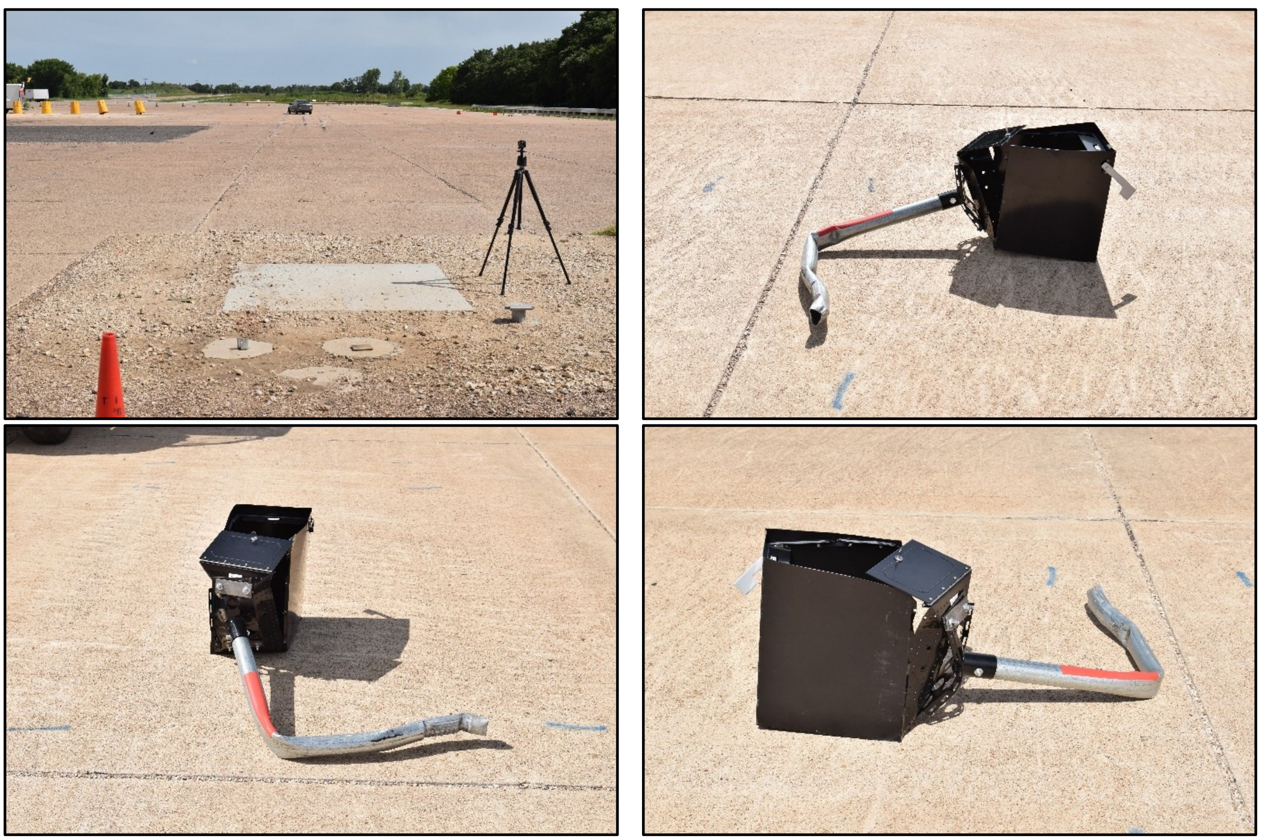


Figure 11.22. Lockable Mailbox on Thin-Wall Galvanized Tube with Type 2 Foundation after Test No. 469469-10-3.

11.4.2.6 Damage to Test Vehicle

Figure 11.23 and Figure 11.24 show the damage sustained by the vehicle. The front bumper sustained a 3-inch-deep dent, 14 inches from the centerline of the vehicle. The left side hood of the vehicle had a 26-inch by 33-inch by 1.5-inch-deep dent with a ¼-inch by ½-inch cut. The lower left area of the windshield was cracked over an area approximately 8 inches by 8 inches. There was no measurable exterior crush or interior deformation to the vehicle. Table J.10 and Table J.11 in Appendix J.3.2 provide further details.

Figure 11.23. Test Vehicle after Test No. 469469-10-3.

Figure 11.24. Interior of Test Vehicle for Test No. 469469-10-3.

11.4.2.7 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk, and results are shown in Table 11.8. Figure 11.25 summarizes these data and other pertinent information from the test. Figure J.12 in Appendix J.3.4 shows the vehicle angular displacements, and Figure J.13 through Figure J.15 in Appendix J.3.5 show acceleration versus time traces.

Table 11.8. Occupant Risk Factors for Test No. 469469-10-3.

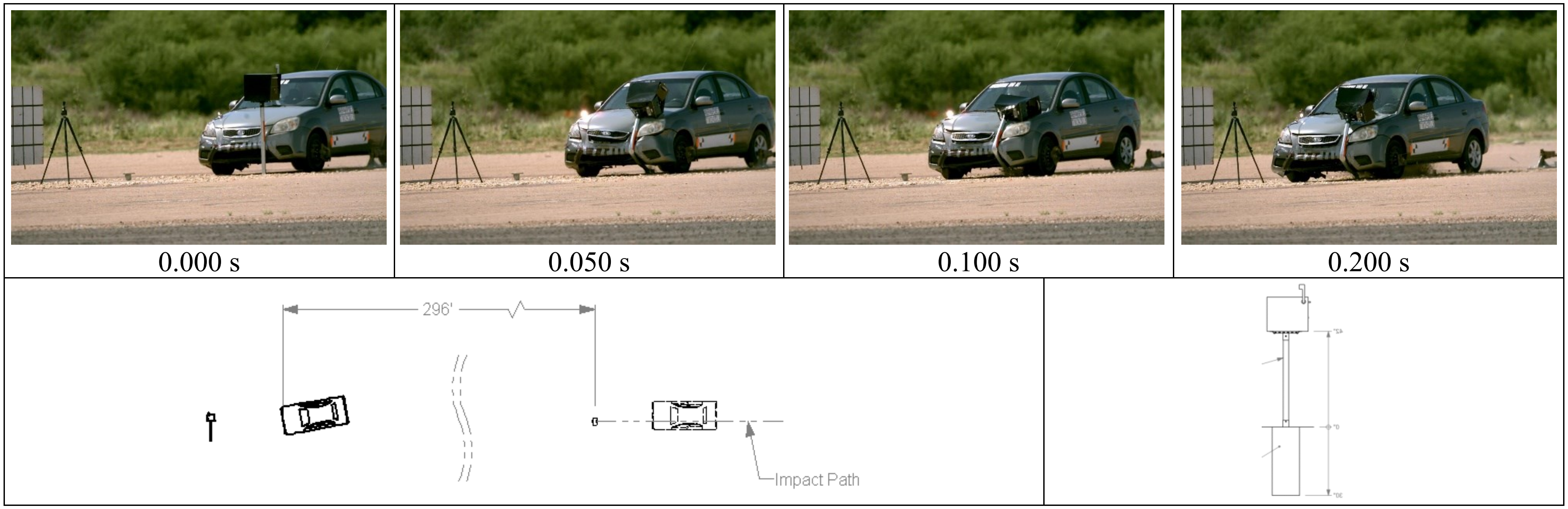
Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)	ft/s	at 0.7785 seconds on front of interior
Longitudinal	**2.6**	
Lateral	**2.3**	
Occupant Ridedown Accelerations (g's)		
Longitudinal	**0.2**	(0.9327–0.9427 seconds)
Lateral	**0.5**	(0.7785–0.7885 seconds)
Theoretical Head Impact Velocity (THIV)	m/s	at 0.7808 seconds on front of interior
	1.0	
Post Head Deceleration (PHD) (g's)	**0.5**	(0.7808–0.7908 seconds)
Acceleration Severity Index (ASI)	**0.15**	(0.0124–0.0624 seconds)
Maximum 50-ms Moving Average (g's)		
Longitudinal	**−1.6**	(0.0018–0.0518 seconds)
Lateral	**0.4**	(0.0198–0.0698 seconds)
Vertical	**0.6**	(0.0302–0.0802 seconds)
Maximum Roll, Pitch, and Yaw Angles	**Degrees**	
Roll	**3**	(0.6426 seconds)
Pitch	**1**	(0.1101 seconds)
Yaw	**3**	(0.7270 seconds)

11.4.2.8 Assessment of Results

An assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-61 is provided in Table 11.9.

11.4.3 Conclusions

The lockable mailbox mounted on a 2⅜-inch OD by 0.095-inch wall galvanized steel tube post 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.	469469-10-3
Test Date	2019-06-25
Test Article	
Type	Mailbox support
Name	Lockable mailbox on thin-wall tube with Type 2 foundation
Installation Length	n/a
Material or Key Elements	Lockable mailbox attached to 2⅜-inch OD steel tube inserted into a steel anchor tube embedded in concrete footing and secured by a curved steel wedge
Soil Type and Condition	AASHTO M147-65(2004) Grade B crushed limestone road base
Test Vehicle	
Type/Designation	1100C
Make and Model	2011 Kia Rio
Curb	2455 lb
Test Inertial	2440 lb
Dummy	165 lb
Gross Static	2605 lb

Impact Conditions	
Speed	62.6 mi/h
Angle	0°
Location/Orientation	14 inches off center of vehicle on driver's side with center of mailbox
Impact Severity	320 kip*ft
Exit Conditions	
Speed	60.7 mi/h
Exit Trajectory/Heading	0°
Occupant Risk Values	
Longitudinal OIV	2.6 ft/s
Lateral OIV	2.3 ft/s
Longitudinal Ridedown	0.2 g
Lateral Ridedown	0.5 g
THIV	3.7 km.h
PHD	0.5 g
ASI	0.15
Max. 0.050-s Average	
Longitudinal	−1.6g
Lateral	0.4 g
Vertical	0.6 g

Post-Impact Trajectory	
Stopping Distance	296 ft
Vehicle Stability	
Maximum Yaw Angle	3°
Maximum Pitch Angle	1°
Maximum Roll Angle	3°
Vehicle Snagging	No
Vehicle Pocketing	n/a
Test Article Deflections	
Dynamic	n/a
Permanent	n/a
Working Width	n/a
Working Width Height	n/a
Vehicle Damage	
VDS	n/a
CDC	n/a
Max. Exterior Deformation	None measurable
OCDI	n/a
Max. Occupant Compartment Deformation	None measurable

Figure 11.25. Summary of Results for *MASH* Test 3-61 on the Lockable Mailbox on Thin-Wall Galvanized Tube with Type 2 Foundation.

Table 11.9. Performance Evaluation Summary for *MASH* Test 3-61 on the Lockable Mailbox on Type 2 Foundation.

Test Agency: Texas A&M Transportation Institute | Test No.: 469469-10-3 | Test Date: 2019-06.25

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 lockable mailbox on a Type 2 foundation yielded to the 1100C vehicle.	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 were 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 5.2.2 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 3° and 1°, 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 2.6 ft/s, and lateral OIV was 2.3 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 occupant ridedown acceleration was 0.5 g.	Pass
Vehicle Trajectory		
N. *Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest 296 ft behind the installation.	Pass

CHAPTER 12: TXDOT ROUND WOOD POST GUARDRAIL IN CONCRETE MOW STRIP

12.1 BACKGROUND

TxDOT frequently installs guardrail in a concrete mow strip. Pavement mow strips are used to combat vegetation growth around guardrail posts to avoid the use of herbicides, decrease maintenance costs, and reduce the safety risk to workers associated with hand mowing around guardrail. A sacrificial grout layer is used in a leave-out section formed in the mow strip around the guardrail posts. During an impact, the grout is crushed, and the post is able to rotate in the leave-out section and dissipate the energy of the impacting vehicle. After an impact, the damaged posts and grout can be replaced within the leave-out region without demolishing and reconstructing the surrounding mow strip.

The TxDOT round wood post guardrail system in soil with 36-inch post embedment performed acceptably in *MASH* Test 3-11 (*11*). Additional constraint on the round wood posts beyond the standard soil embedment can change the dynamic response of the guardrail system. *MASH* Test 3-11 is considered the critical test for evaluation of the round wood post guardrail system in a concrete mow strip. This test places more demand on the mow-strip-confined posts and, therefore, is more likely to result in fracture of the round wood posts and pocketing or rupture of the W-beam guardrail.

MASH Test 3-10 was not considered necessary on the round wood post guardrail in a concrete mow strip. *MASH* Test 3-10 was successfully performed on a guardrail in a concrete mow strip with both W6×8.5 steel posts and 6-inch by 8-inch rectangular wood posts (*12*). The geometries of the steel and rectangular wood posts are considered more critical in terms of the vehicle snagging and deceleration compared to the round wood post.

12.2 SYSTEM DETAILS

12.2.1 Test Article and Installation Details

The round wood post guardrail in a concrete mow strip test installation consisted of 162 ft 6 inches of 12-gauge W-beam guardrail attached to nominal 7¼-inch-diameter wood posts embedded 36 inches. A TxDOT downstream anchor terminal was installed on each end of the test installation for a total length of 181 ft 3 inches. The top of the W-beam rail was mounted 31 inches above grade, the posts were spaced 75 inches center to center, and the guardrail splices were located mid-span between every other post. The W-beam rail was offset from the posts using routered wood offset blocks.

A 4-inch-thick by 42-inch-wide by 100-ft-long concrete mow strip was placed in the central section of the test installation. The posts in this region were placed in 19-inch-square voids or leave-outs cast into the concrete mow strip. These posts were installed in 18-inch-diameter drilled holes and backfilled with compacted soil up to the bottom of the mow strip. The remaining 4-inch-deep voids corresponding to the thickness of the mow strip were filled with a low-strength grout after the posts were installed.

Figure 12.1 presents overall information on the round wood post guardrail in a concrete mow strip, and Figure 12.2 provides photographs of the installation. Appendix K.1 provides further details of the round wood post guardrail in a concrete mow strip.

12.2.2 Material Specifications

The specified concrete strength for the mow strip was 2000 psi. Concrete strength was taken on October 9, 2017, and at 17 days of age was 3040 psi.

The low-strength grout mix used in the leave-outs was comprised of 1 part Type 1A cement, 14 parts sand, and 5 parts water, by volume. Grout compressive strength was taken on November 27, 2018, and at 20 days of age was 100 psi.

Appendix K.2 provides material certification documents for the materials used to install/construct the round wood post guardrail in a concrete mow strip.

12.2.3 Soil Conditions

The test installation was installed in standard soil meeting Grading B of AASHTO standard specification M147-65(2004), "Materials for Aggregate and Soil Aggregate Subbase, Base and Surface Courses."

In accordance with Appendix B of *MASH*, soil strength was measured the day of the crash test. During installation of the guardrail system for full-scale crash testing, two 6-ft-long W6×16 posts were installed in the immediate vicinity of the guardrail system using the same fill materials and installation procedures used in the test installation and the standard dynamic test. Table K.1 in Appendix K.2 presents minimum soil strength properties established through the dynamic testing performed in accordance with *MASH* Appendix B.

As determined by the tests summarized in Appendix K.2, Table K.2, the minimum post loads required for deflections at 5 inches, 10 inches, and 15 inches, measured at a height of 25 inches, are 3940 lb, 5500 lb, and 6540 lb, respectively (90 percent of static load for the initial standard installation).

On the day of the first test, December 4, 2018, loads on the post at deflections of 5 inches, 10 inches, and 15 inches were 7525 lbf, 7878 lbf, and 7727 lbf, respectively. Tables K.2 in Appendix K.2 shows that the strength of the backfill material in which the guardrail system was installed met the minimum *MASH* requirements.

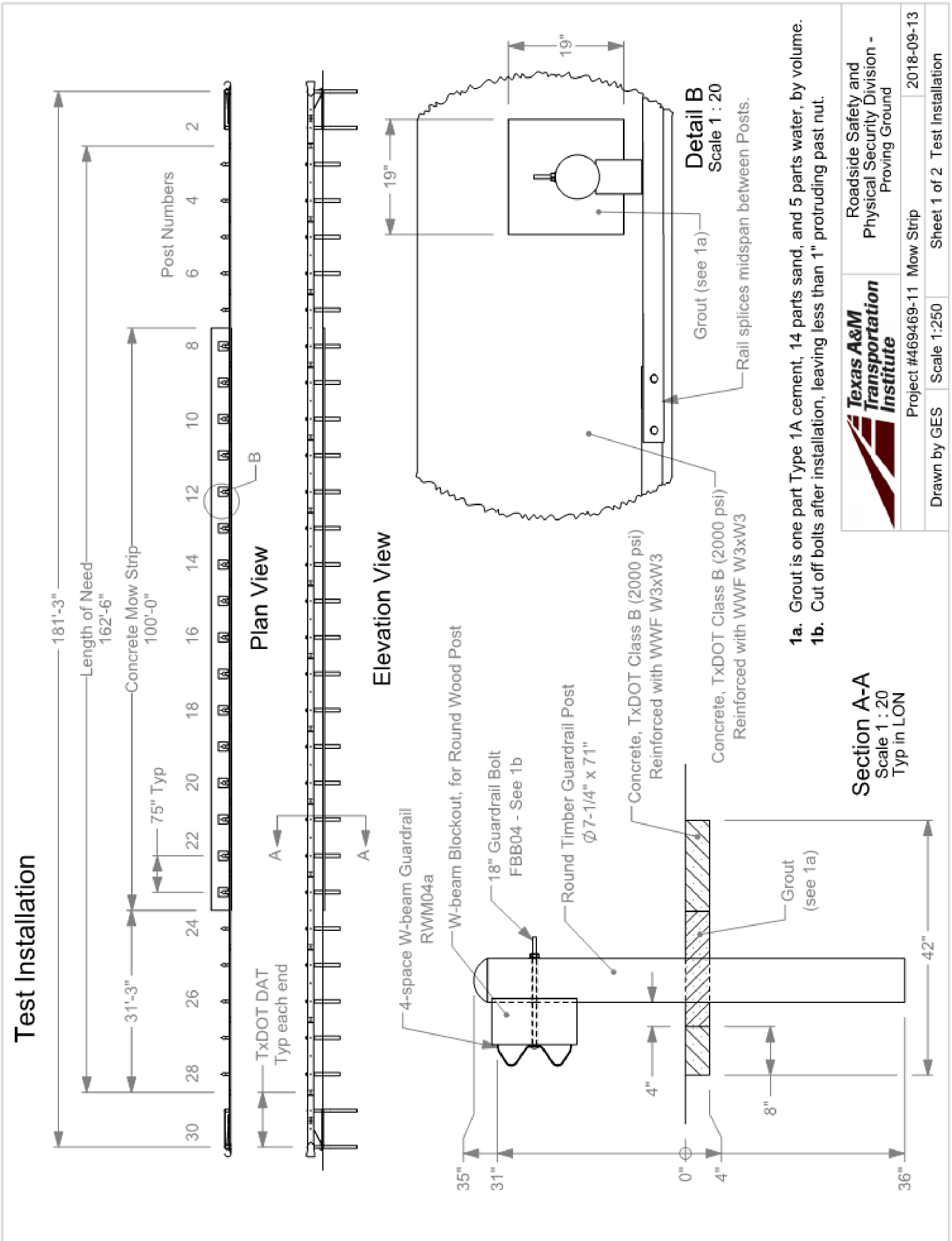


Figure 12.1. Overall Details of the Round Wood Post Guardrail in Concrete Mow Strip.

Figure 12.2. Round Wood Post Guardrail in a Concrete Mow Strip prior to Testing.

12.3 MASH TEST 3-11 (TEST NO. 469469-11)

12.3.1 Test Designation and Actual Impact Conditions

MASH Test 3-11 involves a 2270P vehicle weighing 5000 lb ±110 lb impacting the CIP of the round wood post guardrail in a concrete mow strip at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 25° ±1.5°. The CIP for *MASH* Test 3-11 on the round wood post guardrail in a concrete mow strip was 11.8 ft upstream of post 15.

The 2012 RAM 1500 used in the test weighed 5020 lb, and the actual impact speed and angle were 63.3 mi/h and 25.3°, respectively. The actual impact point was 12.1 ft upstream of the center of post 15. Minimum target impact severity was 106 kip-ft, and actual IS was 122.8 kip-ft.

12.3.2 Weather Conditions

The test was performed on the morning of December 4, 2018. Weather conditions at the time of testing were as follows: wind speed: 4 mi/h; wind direction: 48° with respect to the vehicle (vehicle was traveling in a southerly direction); temperature: 49°F; relative humidity: 63 percent.

12.3.3 Test Vehicle

The 2012 RAM 1500, shown in Figure 12.3 and Figure 12.4, was used for the crash test. The vehicle's test inertia weight was 5020 lb, and its gross static weight was 5020 lb. The height to the lower edge of the vehicle bumper was 11.8 inches, and height to the upper edge of the bumper was 27 inches. The height to the vehicle's center of gravity was 28 inches. Table K.3 and Table K.4 in Appendix K.3.1 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.

Figure 12.3. Round Wood Post Guardrail in Concrete Mow Strip/Test Vehicle Geometrics for Test No. 469469-11.

Figure 12.4. Test Vehicle before Test No. 469469-11.

12.3.4 Test Description

Table 12.1 lists events that occurred during Test No. 469469-11. Figure K.1 and Figure K.2 in Appendix K.3.2 present sequential photographs during the test.

Table 12.1. Events during Test No. 469469-11.

Time	Events
0.000	Vehicle contacts barrier
0.049	Vehicle begins to redirect
0.071	Guardrail begins to tear
0.076	Guardrail is fully torn. Vehicle continues to pass through rail.

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 went through the guardrail and came to rest 210 ft downstream of the impact and 80 ft on the field side of the guardrail.

12.3.5 Damage to Test Installation

Figure 12.5 shows the damage to the round wood post guardrail in a concrete mow strip. The rail released from posts 14 to 20 and ruptured at post 14. Post 13 was leaning 1.5° toward the field side, and posts 14, 15, and 16 broke off at grade. The vehicle passed through the barrier to the field side.

Figure 12.5. Round Wood Post Guardrail in a Concrete Mow Strip after Test No. 469469-11.

12.3.6 Damage to Test Vehicle

Figure 12.6 and Figure 12.7 show the vehicle after the test. The front bumper, hood, grill, radiator and support, right and left front fender, right front and rear door, right and left head lights, right rear fender, and right rear tire and rim were damaged. Maximum exterior crush to the vehicle was 17.0 inches at the front bumper. There was no measurable occupant compartment deformation. Table K.5 and Table K.6 in Appendix K.3.1 provide exterior crush and occupant compartment measurements.

Figure 12.6. Test Vehicle after Test No. 469469-11.

Figure 12.7. Interior of Test Vehicle for Test No. 469469-11.

12.3.7 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk, and results are shown in Table 12.2. Figure 12.8 summarizes these data and other pertinent information from the test. Figure K.3 in Appendix K.3.3 shows the vehicle angular displacements, and Figure K.4 through Figure K.6 in Appendix K.3.4 show acceleration versus time traces.

Table 12.2. Occupant Risk Factors for Test No. 469469-11.

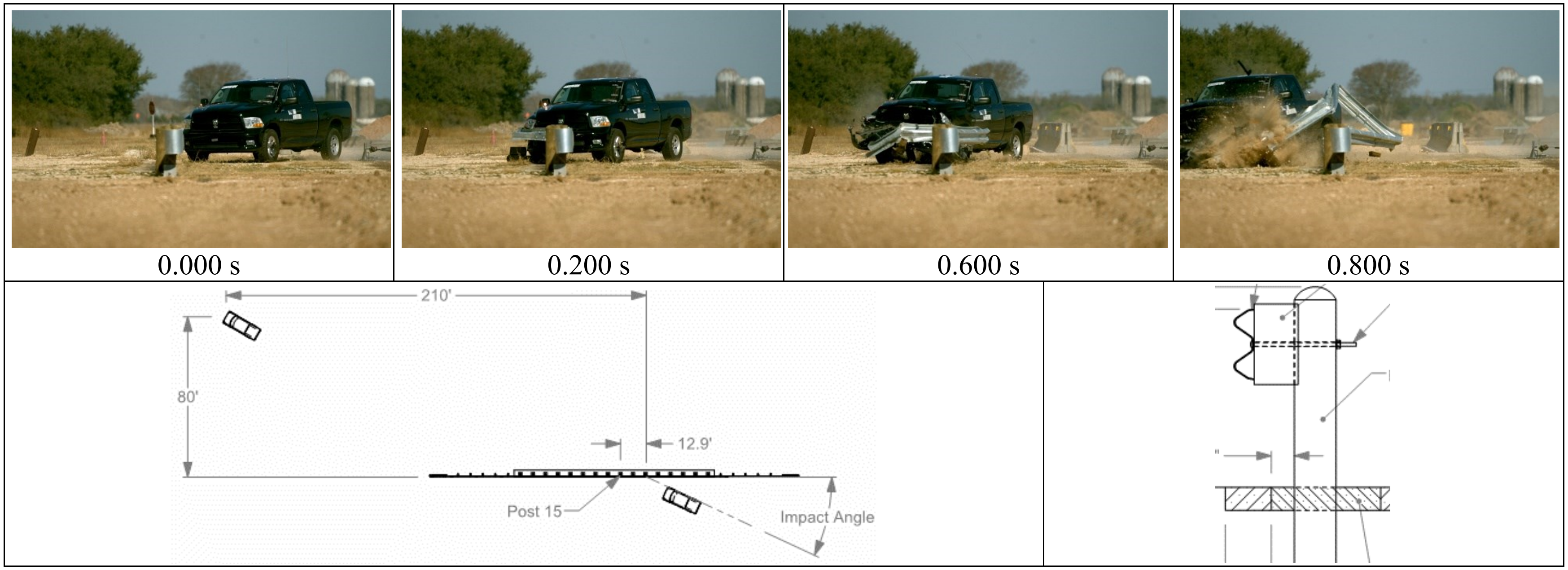
Occupant Risk Factor	Value	Time
Occupant Impact Velocity (OIV)	ft/s	at 0.2232 seconds on right side of interior
Longitudinal	**14.1**	
Lateral	**4.9**	
Occupant Ridedown Accelerations (g's)		
Longitudinal	**3.2**	(0.2378–0.2478 seconds)
Lateral	**2.3**	(0.2975–0.3075 seconds)
Theoretical Head Impact Velocity (THIV)	m/s	at 0.2048 seconds on right side of interior
	4.1	
Post Head Deceleration (PHD) (g's)	**3.5**	(0.2115–0.2215 seconds)
Acceleration Severity Index (ASI)	**0.42**	(0.0531–0.1031 seconds)
Maximum 50-ms Moving Average (g's)		
Longitudinal	**−3.6**	(0.0866–0.1366 seconds)
Lateral	**−3.3**	(0.0376–0.0876 seconds)
Vertical	**−1.5**	(0.0685–0.1185 seconds)
Maximum Roll, Pitch, and Yaw Angles	**Degrees**	
Roll	**5**	(0.2335 seconds)
Pitch	**2**	(0.6598 seconds)
Yaw	**5**	(0.2139 seconds)

12.3.8 Assessment of Results

An assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-11 is provided in Table 12.3.

12.4 CONCLUSIONS

The round wood post guardrail in a concrete mow strip did not meet *MASH* criteria. The 2270P vehicle penetrated through the guardrail and was not contained or redirected by the round wood post guardrail in a concrete mow strip.



General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-11
TTI Test No.	469469-11
Test Date	2018-12-04
Test Article	
Type	Guardrail
Name	W-beam guardrail with round wood posts in mow strip
Installation Length	181 ft 3 inches w/ 100-ft concrete mow strip incl.
Material or Key Elements	7¼-inch-diameter round wood posts, W-beam guardrail, concrete mow strip, grout-filled leave-outs
Soil Type and Condition	4-inch-thick concrete mow strip with grout-filled leave-outs
Test Vehicle	
Type/Designation	2270P
Make and Model	2012 RAM 1500
Curb	5020 lb
Test Inertial	5020 lb
Dummy	No dummy
Gross Static	5020 lb

Impact Conditions	
Speed	63.3 mi/h
Angle	25.3°
Location/Orientation	12.1 ft upstream of center of post 15
Impact Severity	122.8 kip*ft
Exit Conditions	
Speed	n/a
Exit Trajectory/Heading	n/a
Occupant Risk Values	
Longitudinal OIV	14.1 ft/s
Lateral OIV	4.9 ft/s
Longitudinal Ridedown	3.2 g
Lateral Ridedown	2.3 g
THIV	4.1 m/s
PHD	3.5 g
ASI	0.42
Max. 0.050-s Average	
Longitudinal	−3.6 g
Lateral	−3.3 g
Vertical	−1.5 g

Post-Impact Trajectory	
Stopping Distance	210 ft downstrm 80 ft twd field
Vehicle Stability	
Maximum Yaw Angle	5°
Maximum Pitch Angle	2°
Maximum Roll Angle	5°
Vehicle Snagging	No
Vehicle Pocketing	Yes
Test Article Deflections	
Dynamic	Guardrail ruptured
Permanent	and vehicle
Working Width	penetrated to field
Working Width Height	side
Vehicle Damage	
VDS	01FD4
CDC	01FLEL2
Max. Exterior Deformation	17.0 inches
OCDI	RF0000000
Max. Occupant Compartment Deformation	No measurable deformation

Figure 12.8. Summary of Results for *MASH* Test 3-11 on the Round Wood Post Guardrail in Concrete Mow Strip.

Table 12.3. Performance Evaluation Summary for *MASH* Test 3-11 on the Round Wood Post Guardrail in Concrete Mow Strip.

Test Agency: Texas A&M Transportation Institute — Test No.: 469469-11 — Test Date: 2018-12-04

***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 round wood post guardrail in a concrete mow strip failed to contain or redirect the 2270P vehicle.	Fail
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 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.	There was no measurable deformation of the occupant compartment.	
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 was 5°, and maximum pitch was 2°.	Pass
H. *Longitudinal and lateral occupant impact velocities should fall below the preferred value of 30 ft/s, or at least below the maximum allowable value of 40 ft/s.*	Longitudinal OIV was 14.1 ft/s, and lateral OIV was 4.9 ft/s.	Pass
I. *Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 g, or at least below the maximum allowable value of 20.49 g.*	Maximum longitudinal 10-ms occupant ridedown acceleration was 3.2 g, and maximum lateral 10-ms occupant ridedown acceleration was 2.3 g.	Pass
Vehicle Trajectory		
For redirective devices, it is preferable that the vehicle be smoothly redirected and leave the barrier within the "exit box" criteria (not less than 32.8 ft for the 1100C and 2270P vehicles), and should be documented.	The 2270P vehicle was not contained.	Documentation only

CHAPTER 13: TXDOT TYPE III BARRICADE

13.1 BACKGROUND

Acceptable design configurations for Type III barricades are provided on barricade and construction sheet BC(5)-14 and Section D "Type III Barricades" of the Compliant Work Zone Traffic Control Device List. Numerous material options and combinations are permitted. Evaluation under this project focused on systems with a support structure fabricated using PSST.

Type III barricades with PSST frames can be used with three different rail types: wood, hollow-profile plastic lumber (HPPL), and plastic I-beam rails. The wood and HPPL rails are directly bolted to the barricade uprights, while the plastic I-beam rails clip into brackets attached to the uprights. Because the I-beam rails are releasable, their evaluation requires separate testing. Of the two direct-bolted rail types, wood was considered more critical than HPPL. This is because the wood rails are heavier and can fracture into multiple pieces that can subsequently impact the windshield of the vehicle. Thus, if the Type III barricade with wood rails meets *MASH* requirements, a similar design with HPPL rails would also be considered *MASH* compliant.

The PSST frame consists of uprights and skids. The uprights insert into PSST sleeves that can be connected to the skids by welding or bolted steel hardware. Welded connections were considered the more critical of the two connection types because the small welds have an opportunity to fracture and release the barricade uprights, which could then potentially interact with the vehicle windshield. Therefore, if the Type III barricade with welded connections meets *MASH* requirements, a similar design with bolted hardware connections would also be considered *MASH* compliant.

A lower cross member between the two uprights is an optional feature for the Type III barricades that can be used when needed to provide additional structural support to the barricade frame. This cross member is typically only needed when the plastic I-beam rails are used because these clip-on rails do not provide the same structural rigidity of the direct-bolted rails. Additionally, the barricade system with direct-bolted rails would be considered more critical without the lower cross member because the cross member provides additional strength and rigidity that would make separation of the barricade components less likely during an impact. Consequently, the Type III barricade system evaluated under *MASH* did not include a lower cross member. However, if this system satisfies *MASH* criteria, a similar design with a bolted cross member would also be considered *MASH* compliant.

Finally, TxDOT standards permit Type III barricades to vary in length from 4 ft to 8 ft. A 4-ft length was considered most critical. This length permits both uprights to be impacted simultaneously, thus increasing the probability of the uprights releasing from their skids. In a longer configuration, if only one upright is impacted, the barricade may simply rotate out of the path of the vehicle. Therefore, if a 4-ft-long Type III barricade system satisfies *MASH* criteria, longer variations would also be considered *MASH* compliant.

The *MASH* test matrix for work zone traffic control devices consists of three tests: 3-70, 3-71, and 3-72. Test 3-70 is considered optional for free-standing devices weighing less than 220 lb because "velocity changes during low-speed impacts will be within acceptable limits…" Tests 3-71 and 3-72 evaluate the behavior of the device during high-speed impacts with the

1100C passenger car and 2270P pickup, respectively. *MASH* Section 2.2.4.2 states that "lightweight free-standing features cannot cause sufficient velocity change to result in failure of the test under occupant risk criteria. Therefore, Tests 71 and 72 can be conducted without the instrumentation necessary for determining occupant risk whenever the test article has a total weight of 220 lb (100 kg) or less." Consequently, the vehicles used for the tests on the Type III barricade reported herein were uninstrumented.

MASH Section 3.4.2.3 recognizes that a work-zone traffic control device such as a barricade may be placed in "out-of-service" orientations. A common practice with barricades is to turn the barricade rails parallel to and out of view of traffic until they are put back in use or picked up from the job site. *MASH* states that "If there is a reasonable expectation that a device will be commonly found adjacent to traffic in an 'out-of-service' orientation and this orientation poses a greater risk to the motorist than in the normal position, it should be tested in the alternate position. If it cannot be determined which position is more critical, tests in both the normal and 'out-of-service' orientations should be conducted." Both normal (perpendicular) and parallel orientations were evaluated for the Type III barricade.

13.2 SYSTEM DETAILS

13.2.1 Test Article and Installation Details

The Type III barricade consisted of three 1-inch by 8-inch (nominal) pine boards mounted to two vertical sections of 1½-inch PSST. The top edges of the boards were positioned 20, 40, and 60 inches above grade. The PSST uprights were laterally spaced 36 inches apart. The uprights were inserted into 4-inch-long vertical sleeves fabricated from 1¾-inch PSST. The sleeves were welded to 60-inch-long horizontal skids that were also fabricated from 1¾-inch PSST. The wood rails were attached to the uprights, and the uprights were secured inside the sleeves using ⅜-inch-diameter bolts and associated hardware. The total weight of the Type III barricade assembly was 57 lb. A 40-pound sand bag was placed on each end of both horizontal skids, and the assembly rested on concrete pavement with no anchoring.

Figure 13.1 presents overall information on the Type III barricade, and Figure 13.2 provides photographs of the installation. Appendix L.1 provides further details of the Type III barricade.

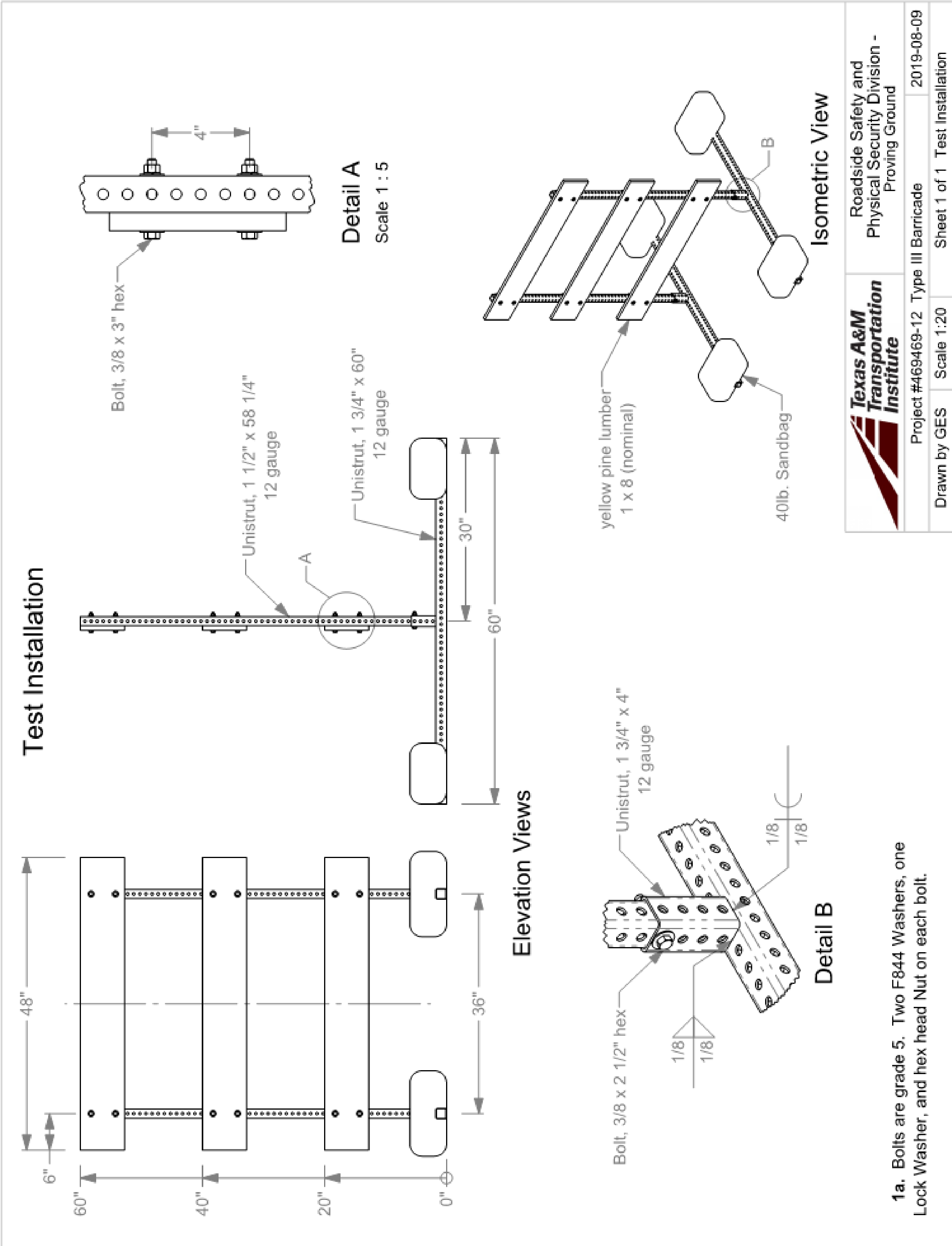


Figure 13.1. Overall Details of the Type III Barricade.

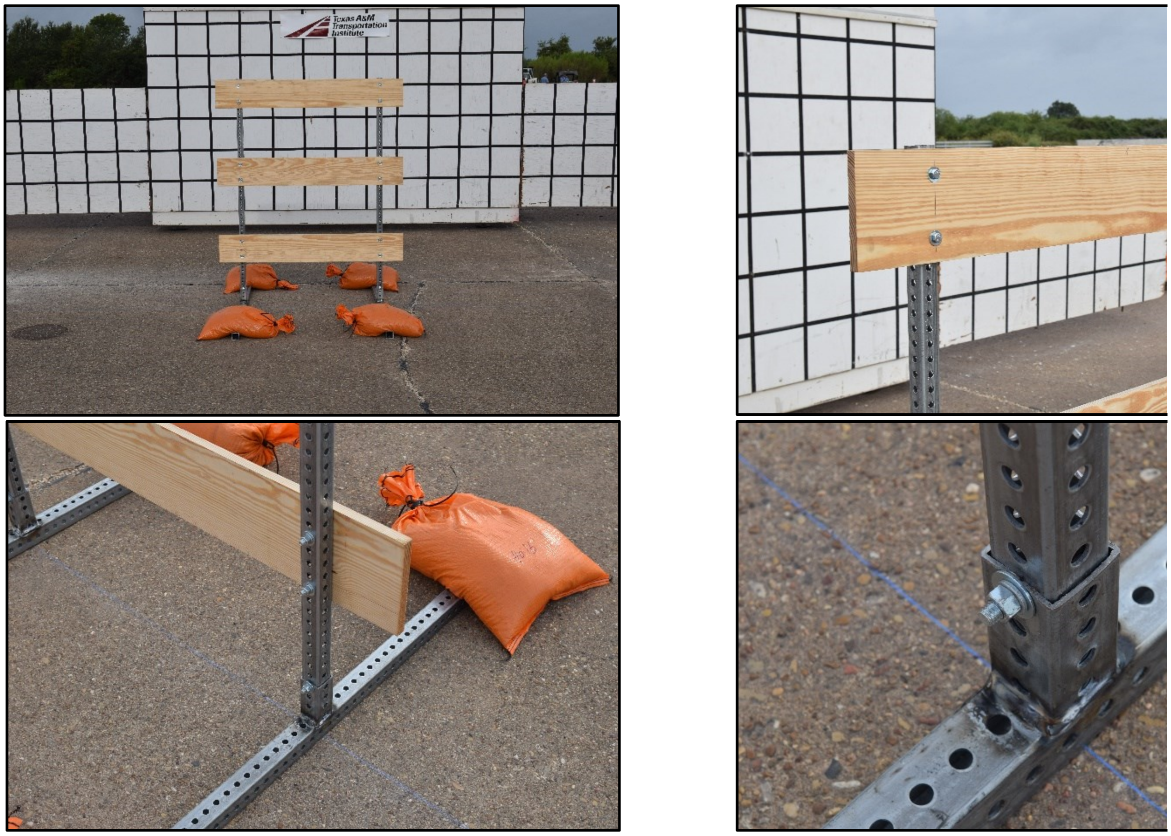


Figure 13.2. Type III Barricade prior to Test

13.3 MASH TEST 3-71 AT 90° (TEST NO. 469469-12-01)

13.3.1 Test Designation and Actual Impact Conditions

MASH Test 3-71 involves a 1100C vehicle weighing 2420 lb ±55 lb impacting the Type III barricade at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 90° ±1.5°. The selected impact point was the centerline of the Type III barricade aligned 14 inches off of the centerline of the vehicle toward the driver's side.

The 2009 Kia Rio used in the test weighed 2416 lb, and the actual impact speed and angle were 62.2 mi/h and 90°, respectively. Minimum target impact severity was 288 kip-ft, and actual IS was 312 kip-ft.

13.3.2 Weather Conditions

The test was performed on the morning of August 27, 2019. Weather conditions at the time of testing were as follows: wind speed: 4 mi/h; wind direction: 191° with respect to the vehicle (vehicle was traveling at a magnetic heading of 0°); temperature: 86°F; relative humidity: 82 percent.

13.3.3 Test Vehicle

The 2009 Kia Rio,[15] shown in Figure 13.3 and Figure 13.4, was used for the crash test. The vehicle's test inertia weight was 2416 lb, and its gross static weight was 2581 lb. The height to the lower edge of the vehicle bumper was 7.75 inches, and the height to the upper edge of the bumper was 21.5 inches. Table L.1 in Appendix L.2.1 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.

Figure 13.3. Type III Barricade/Test Vehicle Geometrics for Test No. 469469-12-01.

Figure 13.4. Test Vehicle before Test No. 469469-12-01.

[15] The 2009 model vehicle used is older than the 6-year age noted in *MASH* and was selected based upon availability. An older model vehicle is permitted by AASHTO as long as it is otherwise *MASH* compliant. Other than the vehicle's year model, this 2009 model vehicle met the *MASH* requirements.

13.3.4 Test Description

Table 13.1 lists events that occurred during Test No. 469469-12-01. Figure L.1 in Appendix L.2.2 presents sequential photographs during the test.

Table 13.1. Events during Test No. 469469-12-01.

Time	Events
0.000	Vehicle contacts barricade
0.004	Barricade uprights begin to bend
0.012	Downstream barricade skid lifts off pavement
0.051	Downstream upright fractures at location of bottom rail
0.078	Downstream skid makes contact with pavement

The 1100C vehicle came to rest 397 ft downstream and 6 ft left of the original impact point.

13.3.5 Damage to Test Installation

Figure 13.5 shows the damage to the Type III barricade. Components of the barricade fractured into multiple pieces that were scattered 165 ft downstream, 13 ft to the right and 43 ft to the left of the original position. The largest section of debris consisting of two wood rails and the fractured uprights came to rest 142 ft downstream and 43 ft to the left of the original impact location.

Figure 13.5. Type III Barricade after Test No. 469469-12-01.

13.3.6 Damage to Test Vehicle

Figure 13.6 and Figure 13.7 show the damage sustained by the vehicle. There was a 4-inch by 8-inch by 1.75-inch-deep dent in the front bumper and hood edge, and a 24-inch by 24-inch by 2.5-inch-deep dent in the top left side of the hood. There was no measurable occupant compartment deformation. Table L.2 and Table L.3 in Appendix L.2.1 provide exterior crush and occupant compartment measurements.

Figure 13.6. Test Vehicle after Test No. 469469-12-01.

Figure 13.7. Interior of Test Vehicle after Test No. 469469-12-01.

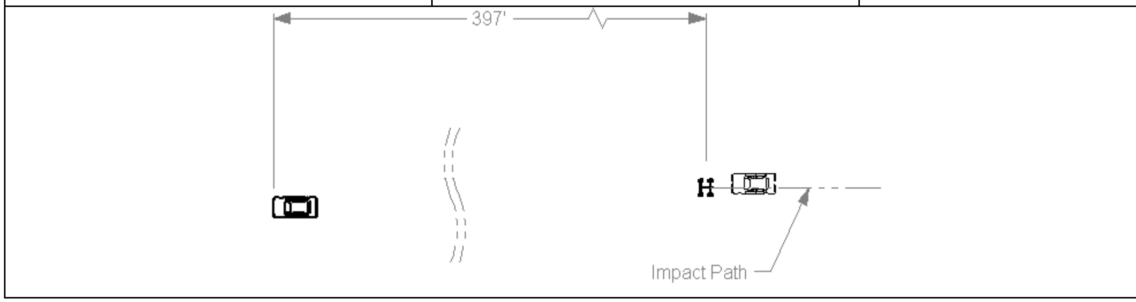
13.3.7 Occupant Risk Factors

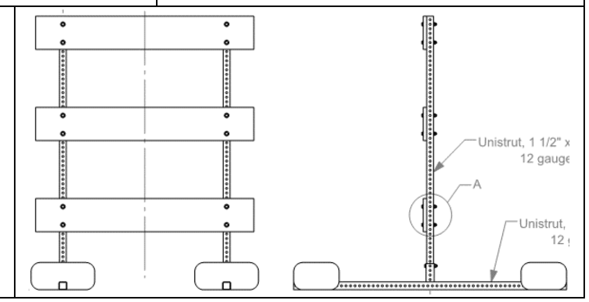
According to *MASH*, when the weight of the traffic control device is less than 220 lb, the test may be performed without vehicle instrumentation. The Type III barricade system weighed 57 lb. Therefore, the vehicle was not instrumented, and occupant risk factors were not obtained for this test.

13.3.8 Assessment of Results

The summary of test results can be found in Figure 13.8 and an assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-71 at 90° is provided in Table 13.2.

0.000 s | 0.100 s | 0.200 s | 0.300 s





General Information	
Test Agency.............	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-71
TTI Test No..............	469469-12-01
Test Date	2019-08-27
Test Article	
Type.........................	Work zone traffic control device
Name	TxDOT Type III barricade
Installation Length.....	n/a
Material or Key Elements	Wood boards and perforated square steel tube frame
Soil Type and Condition	Placed on dry concrete
Test Vehicle	
Type/Designation	1100C
Make and Model	2009 Kia Rio
Curb.........................	2527 lb
Test Inertial	2416 lb
Dummy	165 lb dummy on passenger side
Gross Static	2581 lb

Impact Conditions	
Speed	62.2 mi/h
Angle	90°
Location/Orientation	Center of barricade 14 inches off center of the vehicle toward the driver's side.
Impact Severity.........	312 kip*ft
Exit Conditions	58.5 mi/h
Speed	n/a
Exit Trajectory/Heading	n/a
Occupant Risk Values	
Longitudinal OIV.......	n/a
Lateral OIV..............	n/a
Longitudinal Ridedown	n/a
Lateral Ridedown	n/a
THIV	n/a
ASI..........................	n/a
Max. 0.050-s Average	
Longitudinal.............	n/a
Lateral.....................	n/a
Vertical....................	n/a

Post-Impact Trajectory	
Stopping Distance	397 ft downstrm; 6 ft left
Vehicle Stability	
Maximum Yaw Angle.....	n/a
Maximum Pitch Angle....	n/a
Maximum Roll Angle	n/a
Vehicle Snagging	n/a
Vehicle Pocketing..........	n/a
Test Article Deflections	
Dynamic	n/a
Permanent	n/a
Working Width..............	n/a
Working Width Height....	n/a
Vehicle Damage	
VDS	12FL1
CDC	12FLEN1
Max. Exterior Deformation	0 inches
OCDI............................	LF000000
Max. Occupant Compartment Deformation	0 inches

Figure 13.8. Summary of Results for *MASH* Test 3-71 on the Type III Barricade.

Table 13.2. Performance Evaluation Summary for *MASH* Test 3-71 on the Type III Barricade.

Test Agency: Texas A&M Transportation Institute — Test No.: 469469-12-01 — Test Date: 2019-08-27

MASH Test 3-60 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 Type III barricade support yielded to the 1100C vehicle 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.*	After impact, the barricade fragments did not penetrate or show any potential for penetration into the occupant compartment.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	There was no occupant compartment deformation	Pass
E. Detached elements, fragments, or other debris from the test article, of vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.	The detached elements did not obstruct the driver's vision or cause loss of control of the vehicle.	Pass
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The vehicle remained upright and stable during and after the impact	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.	According to *MASH*, when the weight of the traffic control device is less than 220 lb, the test may be performed without vehicle instrumentation.	n/a
I. The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	The Type III barricade system weighed 57 lb. Therefore, the vehicle was not instrumented, and occupant risk factors were not obtained for this test.	n/a
Post-Impact Vehicular Response *N. Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest 397 ft behind and 6 ft left of the original position of the installation.	Pass

13.4 MASH TEST 3-72 AT 90° (TEST NO. 469469-12-02)

13.4.1 Test Designation and Actual Impact Conditions

MASH Test 3-72 involves a 2270P vehicle weighing 5000 lb ±110 lb impacting the Type III barricade at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 90° ±1.5°. The selected impact point was the centerline of the Type III barricade post aligned 12 inches off the centerline of the vehicle toward the driver's side.

The 2013 RAM 1500 used in the test weighed 5044 lb, and the actual impact speed and angle were 63.5 mi/h and 90°, respectively. Minimum target impact severity was 594 kip-ft, and actual IS was 680 kip-ft.

13.4.2 Weather Conditions

The test was performed in the afternoon of August 27, 2019. Weather conditions at the time of testing were as follows: wind speed: 3 mi/h; wind direction: 327° with respect to the vehicle (vehicle was traveling at a magnetic heading of 0°); temperature: 93°F; relative humidity: 59 percent.

13.4.3 Test Vehicle

The 2013 RAM 1500, shown in Figure 13.9 and Figure 13.10, was used for the crash test. The vehicle's test inertia weight was 5044 lb, and its gross static weight was 5044 lb. The height to the lower edge of the vehicle bumper was 11.8 inches, and height to the upper edge of the bumper was 27 inches. The height to the vehicle's center of gravity was 28.4 inches. Table L.4 and Table L.5 in Appendix L.3.1 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.

Figure 13.9. Type III Barricade/Test Vehicle Geometrics for Test No. 469469-12-02.

Figure 13.10. Test Vehicle before Test No. 469469-12-02.

13.4.4 Test Description

Table 13.3 lists events that occurred during Test No. 469469-12-02. Figure L.2 in Appendix L.3.2 present sequential photographs during the test.

Table 13.3. Events during Test No. 469469-12-02.

Time	Events
0.000	Vehicle contacts barricade
0.009	Barricade uprights begin to bend from impact
0.016	Corner of top wood rail begins to impact the hood of the vehicle
0.018	Downstream barricade skid begins to lift off the pavement

The 2270P vehicle came to rest 330 ft downstream and 12 ft to the left of the original impact point.

13.4.5 Damage to Test Installation

Figure 13.11 shows the damage to the Type III barricade. The barricade separated into two pieces. One of the uprights fractured approximately 15 inches above grade. The lower portion of this upright and the attached skid came to rest 218 ft downstream and 40 ft to the left of the impact point. The remaining portion of the fracture upright, the other upright and skid, and the three rails remained together and came to rest 105 ft downstream of the impact point.

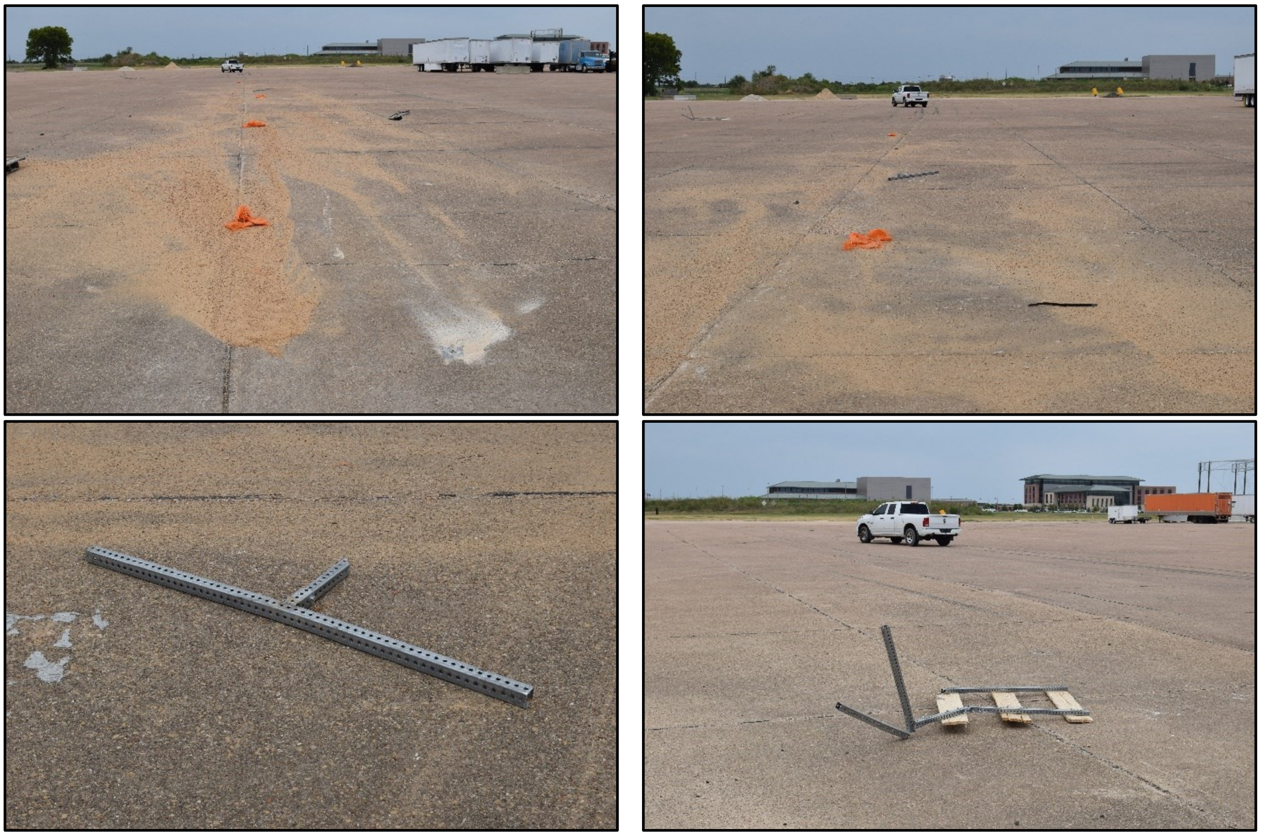


Figure 13.11. Type III Barricade after Test No. 469469-12-02.

13.4.6 Damage to Test Vehicle

Figure 13.12 and Figure 13.13 show the damage sustained by the vehicle. There was an 8-inch by 8-inch dent in the hood, including a 1-inch hole located 1 ft to the left of the centerline of the hood at the front. The front bumper and grill also sustained damage. There was no measurable occupant compartment deformation. Table L.6 and Table L.7 in Appendix L.3.1 provide exterior crush and occupant compartment measurements.

Figure 13.12. Test Vehicle after Test No. 469469-12-02.

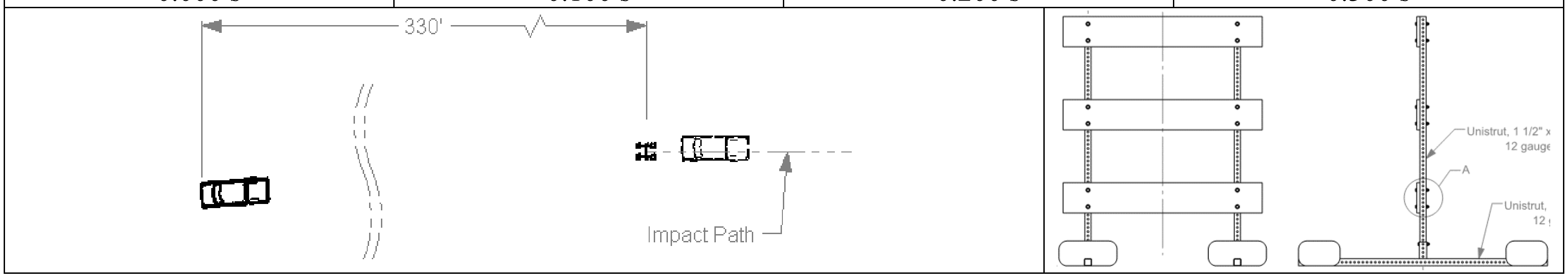
Figure 13.13. Interior of Test Vehicle after Test No. 469469-12-02.

13.4.7 Occupant Risk Factors

According to *MASH*, when the weight of the traffic control device is less than 220 lb, the test may be performed without vehicle instrumentation. The Type III barricade system weighed 57 lb. Therefore, the vehicle was not instrumented, and occupant risk factors were not obtained for this test.

13.4.8 Assessment of Results

The summary of test results can be found in Figure 13.14 and an assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-72 at 90° is provided in Table 13.4.



General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-72
TTI Test No.	469469-12-02
Test Date	2019-08-27
Test Article	
Type	Work zone traffic control device
Name	TxDOT Type III barricade
Installation Length	n/a
Material or Key Elements	Wood boards and perforated square steel tube frame
Soil Type and Condition	Placed on dry concrete
Test Vehicle	
Type/Designation	2270P
Make and Model	2013 RAM 1500
Curb	5022 lb
Test Inertial	5044 lb
Dummy	No dummy
Gross Static	5044 lb

Impact Conditions	
Speed	63.5 mi/h
Angle	90°
Location/Orientation	Center of barricade 14 inches off center of the vehicle toward the driver's side
Impact Severity	680 kip*ft
Exit Conditions	
Speed	60.3 mi/h
Exit Trajectory/Heading	n/a
Occupant Risk Values	
Longitudinal OIV	n/a
Lateral OIV	n/a
Longitudinal Ridedown	n/a
Lateral Ridedown	n/a
THIV	n/a
ASI	n/a
Max. 0.050-s Average	
Longitudinal	n/a
Lateral	n/a
Vertical	n/a

Post-Impact Trajectory	
Stopping Distance	330 ft downstrm; 12 ft left
Vehicle Stability	
Maximum Yaw Angle	n/a
Maximum Pitch Angle	n/a
Maximum Roll Angle	n/a
Vehicle Snagging	n/a
Vehicle Pocketing	n/a
Test Article Deflections	
Dynamic	n/a
Permanent	n/a
Working Width	n/a
Working Width Height	n/a
Vehicle Damage	
VDS	12FL1
CDC	12FLEN1
Max. Exterior Deformation	0 inches
OCDI	LF000000
Max. Occupant Compartment Deformation	0 inches

Figure 13.14. Summary of Results for *MASH* Test 3-72 on the Type III Barricade.

Table 13.4. Performance Evaluation Summary for *MASH* Test 3-72 on the Type III Barricade.

Test Agency: Texas A&M Transportation Institute — Test No.: 469469-12-02 — Test Date: 2019-08-27

MASH Test 3-60 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 Type III barricade support yielded to the 2270P vehicle 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.*	After impact, the barricade fragments did not penetrate or show any potential for penetration into the occupant compartment.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	There was no occupant compartment deformation	Pass
E. *Detached elements, fragments, or other debris from the test article, of vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*	The detached elements did not obstruct the driver's vision or cause loss of control of the vehicle.	Pass
F. *The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.*	The vehicle remained upright and stable during and after the impact	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.*	According to *MASH*, when the weight of the traffic control device is less than 220 lb, the test may be performed without vehicle instrumentation.	n/a
I. *The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.*	The Type III barricade system weighed 57 lb. Therefore, the vehicle was not instrumented, and occupant risk factors were not obtained for this test.	n/a
Post-Impact Vehicular Response N. *Vehicle trajectory behind the test article is acceptable.*	The 2270P vehicle came to rest 330 ft behind and 12 ft left of the original position of the installation.	Pass

13.5 MASH TEST 3-72 AT 0° (TEST NO. 469469-12-03)

13.5.1 Test Designation and Actual Impact Conditions

MASH Test 3-72 involves a 2270P vehicle weighing 5000 lb ±110 lb impacting the Type III barricade at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 0° ±1.5°. The selected point of impact was the centerline of the Type III barricade aligned with the centerline of the vehicle.

The 2013 RAM 1500 used in the test weighed 5044 lb, and the actual impact speed and angle were 61.3 mi/h and 0°, respectively. Minimum target impact severity was 594 kip-ft, and actual IS was 634 kip-ft.

13.5.2 Weather Conditions

The test was performed at noon on August 29, 2019. Weather conditions at the time of testing were as follows: wind speed: 3 mi/h; wind direction: 102° with respect to the vehicle (vehicle was traveling at a magnetic heading of 0°); temperature: 90°F; relative humidity: 67 percent.

13.5.3 Test Vehicle

The 2013 RAM 1500, shown in Figure 13.15 and Figure 13.16, was used for the crash test. The vehicle's test inertia weight was 5044 lb, and its gross static weight was 5044 lb. The height to the lower edge of the vehicle bumper was 11.8 inches, and the height to the upper edge of the bumper was 27 inches. The height to the vehicle's center of gravity was 28.4 inches. Table L.8 and Table L.9 in Appendix L.4.1 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.

Figure 13.15. Type III Barricade/Test Vehicle Geometrics for Test No. 469469-12-03.


Figure 13.16. Test Vehicle before Test No. 469469-12-03.

13.5.4 Test Description

Table 13.5 lists events that occurred during Test No. 469469-12-03. Figure L.3 in Appendix L.4.2 presents sequential photographs during the test.

Table 13.5. Events during Test No. 469469-12-03.

Time	Events
0.000	Vehicle contacts barricade
0.003	Barricade uprights begin to bend
0.008	Barricade begins to slide
0.012	Top rail of barricade contacts hood of vehicle
0.052	Barricade has slid through sand bags and continues to be pushed forward by vehicle

The 2270P came to rest 430 ft downstream and 14 ft to the left of the original impact point.

13.5.5 Damage to Test Installation

Figure 13.17 shows the damage to the Type III barricade. The barricade remained mostly intact and came to rest 462 ft downstream and 14 ft to the left of the impact location. The welds were cracked at the base, and the supports were bent at 18 inches up from the base.

Figure 13.17. Type III Barricade after Test No. 469469-12-03.

13.5.6 Damage to Test Vehicle

Figure 13.18 and Figure 13.19 show the damage sustained by the vehicle. There were scuffs marks on the bumper and grill. There was neither measurable exterior crush on the vehicle nor occupant compartment deformation. Table L.10 and Table L.11 in Appendix L.4.1 provide exterior crush and occupant compartment measurements.

Figure 13.18. Test Vehicle after Test No. 469469-12-03.

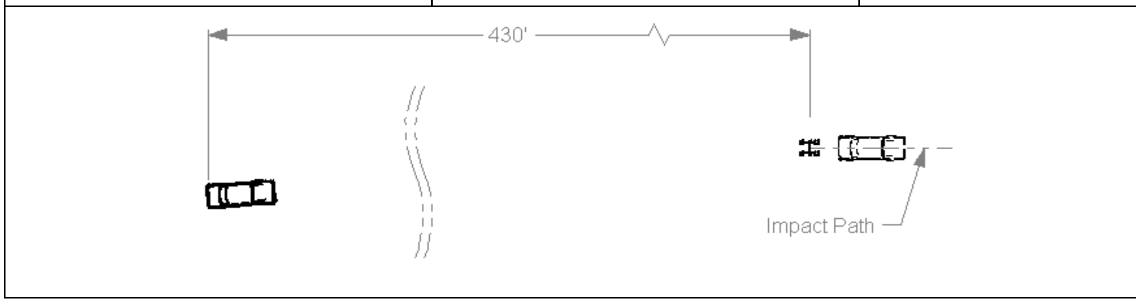
Figure 13.19. Interior of Test Vehicle after Test No. 469469-12-03.

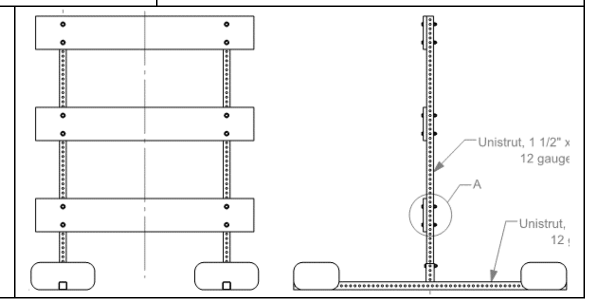
13.5.7 Occupant Risk Factors

According to *MASH*, when the weight of the traffic control device is less than 220 lb, the test may be performed without vehicle instrumentation. The Type III barricade system weighed 57 lb. Therefore, the vehicle was not instrumented, and occupant risk factors were not obtained for this test.

13.5.8 Assessment of Results

The summary of test results can be found in Figure 13.20 and an assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-72 at 0° is provided in Table 13.6.





General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-72
TTI Test No.	469469-12-03
Test Date	2019-08-29
Test Article	
Type	Work zone traffic control device
Name	TxDOT Type III barricade
Installation Length	n/a
Material or Key Elements	Wood boards and perforated square steel tube frame
Soil Type and Condition	Placed on dry concrete
Test Vehicle	
Type/Designation	2270P
Make and Model	2013 RAM 1500
Curb	50224 lb
Test Inertial	5044 lb
Dummy	No dummy
Gross Static	5044 lb

Impact Conditions	
Speed	61.3 mi/h
Angle	90°
Location/Orientation	Center of barricade 14 inches off center of the vehicle toward the driver's side
Impact Severity	634 kip*ft
Exit Conditions	
Speed	n/a
Exit Trajectory/Heading	n/a
Occupant Risk Values	
Longitudinal OIV	n/a
Lateral OIV	n/a
Longitudinal Ridedown	n/a
Lateral Ridedown	n/a
THIV	n/a
ASI	n/a
Max. 0.050-s Average	
Longitudinal	n/a
Lateral	n/a
Vertical	n/a

Post-Impact Trajectory	
Stopping Distance	430 ft downstrm; 14 ft left
Vehicle Stability	
Maximum Yaw Angle	n/a
Maximum Pitch Angle	n/a
Maximum Roll Angle	n/a
Vehicle Snagging	n/a
Vehicle Pocketing	n/a
Test Article Deflections	
Dynamic	n/a
Permanent	n/a
Working Width	n/a
Working Width Height	n/a
Vehicle Damage	
VDS	12FL1
CDC	12FLEN1
Max. Exterior Deformation	0 inches
OCDI	LF000000
Max. Occupant Compartment Deformation	0 inches

Figure 13.20. Summary of Results for *MASH* Test 3-72 on the Type III Barricade.

Table 13.6. Performance Evaluation Summary for *MASH* Test 3-72 on the Type III Barricade.

Test Agency: Texas A&M Transportation Institute | Test No.: 469469-12-03 | Test Date: 2019-08-29

***MASH* Test 3-60 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 Type III barricade yielded to the 2270P vehicle 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.*	After impact, the barricade fragments did not penetrate or show any potential for penetration into the occupant compartment.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	There was no occupant compartment deformation.	Pass
E. Detached elements, fragments, or other debris from the test article, of vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.	The detached elements did not obstruct the driver's vision or cause loss of control of the vehicle.	Pass
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The vehicle remained upright and stable during and after the impact	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.	According to *MASH*, when the weight of the traffic control device is less than 220 lb, the test may be performed without vehicle instrumentation.	n/a
I. The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	The Type III barricade system weighed 57 lb. Therefore, the vehicle was not instrumented, and occupant risk factors were not obtained for this test.	n/a
Post-Impact Vehicular Response *N. Vehicle trajectory behind the test article is acceptable.*	The 2270P vehicle came to rest 430 ft behind and 14 ft left of the original position of the installation.	Pass

13.6 MASH TEST 3-71 AT 0° (TEST NO. 469469-12-04)

13.6.1 Test Designation and Actual Impact Conditions

MASH Test 3-71 involves a 1100C vehicle weighing 2420 lb ±55 lb impacting the Type III barricade at an impact speed of 62 mi/h ±2.5 mi/h and an angle of 0° ±1.5°. The selected impact point was the centerline of the Type III barricade aligned with the centerline of the vehicle.

The 2007 Kia Rio used in the test weighed 2450 lb, and the actual impact speed and angle were 64.5 mi/h and 0°, respectively. Minimum target impact severity was 288 kip-ft, and actual IS was 341 kip-ft.

13.6.2 Weather Conditions

The test was performed late morning on August 27, 2019. Weather conditions at the time of testing were as follows: wind speed: 3 mi/h; wind direction: 182° with respect to the vehicle (vehicle was traveling at a magnetic heading of 0°); temperature: 90°F; relative humidity: 69 percent.

13.6.3 Test Vehicle

The 2007 Kia Rio,[16] shown in Figure 13.21 and Figure 13.22, was used for the crash test. The vehicle's test inertia weight was 2450 lb, and its gross static weight was 2615 lb. The height to the lower edge of the vehicle bumper was 7.75 inches, and the height to the upper edge of the bumper was 21.5 inches. Table L.12 in Appendix L.5.1 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.

[16] The 2007 model vehicle used is older than the 6-year age noted in *MASH* and was selected based upon availability. An older model vehicle is permitted by AASHTO as long as it is otherwise *MASH* compliant. Other than the vehicle's year model, this 2007 model vehicle met the *MASH* requirements.

Figure 13.21. Type III Barricade/Test Vehicle Geometrics for Test No. 469469-12-04.

Figure 13.22. Test Vehicle before Test No. 469469-12-04.

13.6.4 Test Description

Table 13.7 lists events that occurred during Test No. 469469-12-04. Figure L.4 in Appendix L.5.2 presents sequential photographs during the test.

Table 13.7. Events during Test No. 469469-12-04.

Time	Events
0.000	Vehicle lower bumper contacts sand bags on barricade
0.018	Vehicle bumper contacts lower rail on barricade
0.028	Bottom rail begins to split along its length
0.029	Barricade begins to move downstream
0.036	Middle board impacts hood of vehicle
0.061	Top board impacts hood of vehicle

The 1100C vehicle came to rest 367 ft downstream and in line of the original impact point.

13.6.5 Damage to Test Installation

Figure 13.23 shows the damage to the Type III barricade. The assembly separated into multiple pieces and came to rest in an area 105 to 262 ft downstream of the impact location and 24 ft right to 15 ft left of the impact path.

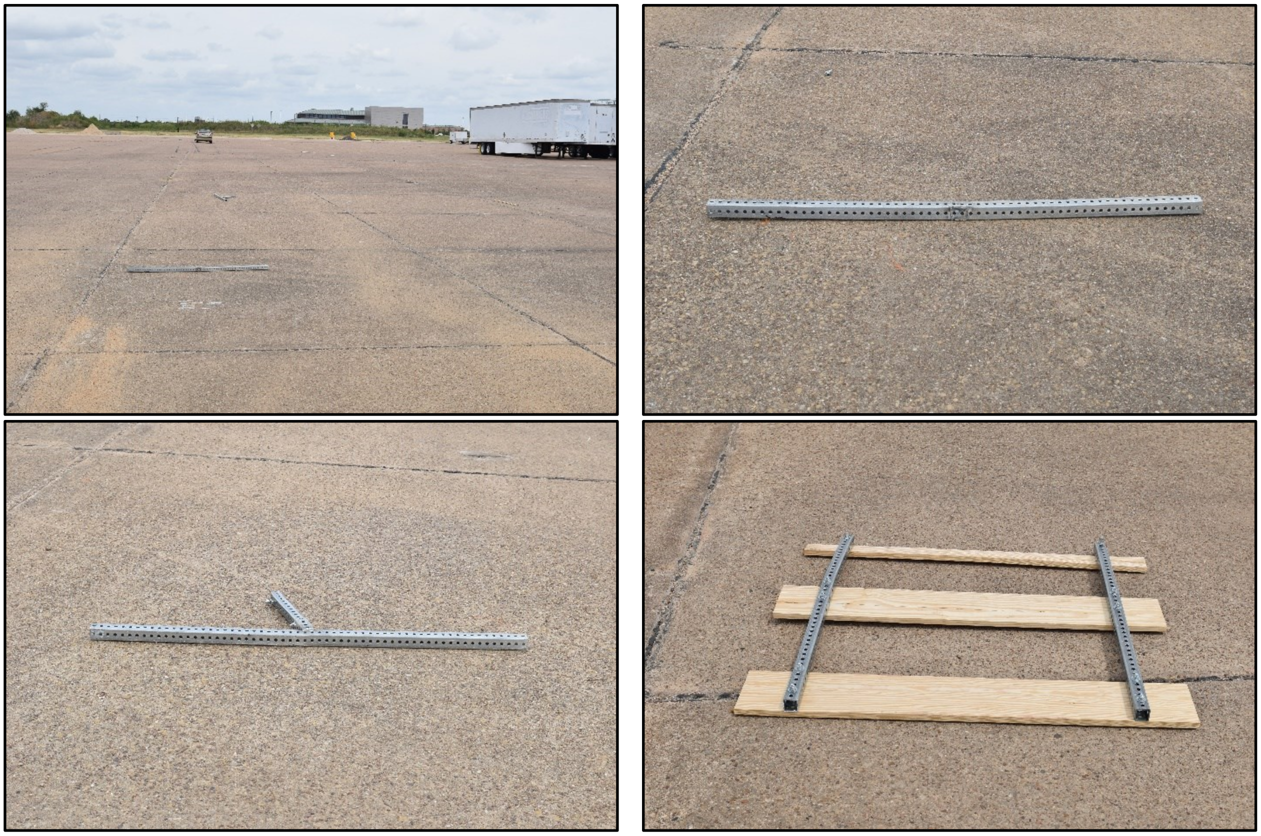


Figure 13.23. Type III Barricade after Test No. 469469-12-04.

13.6.6 Damage to Test Vehicle

Figure 13.24 and Figure 13.25 show the damage sustained by the vehicle. There was a 42-inch by 8-inch by 1.25-inch-deep dent along the front of the hood, and additional damage was sustained by the right head light. There was no measurable occupant compartment deformation. Table L.13 and Table L.14 in Appendix L.5.1 provide exterior crush and occupant compartment measurements.

Figure 13.24. Test Vehicle after Test No. 469469-12-04.

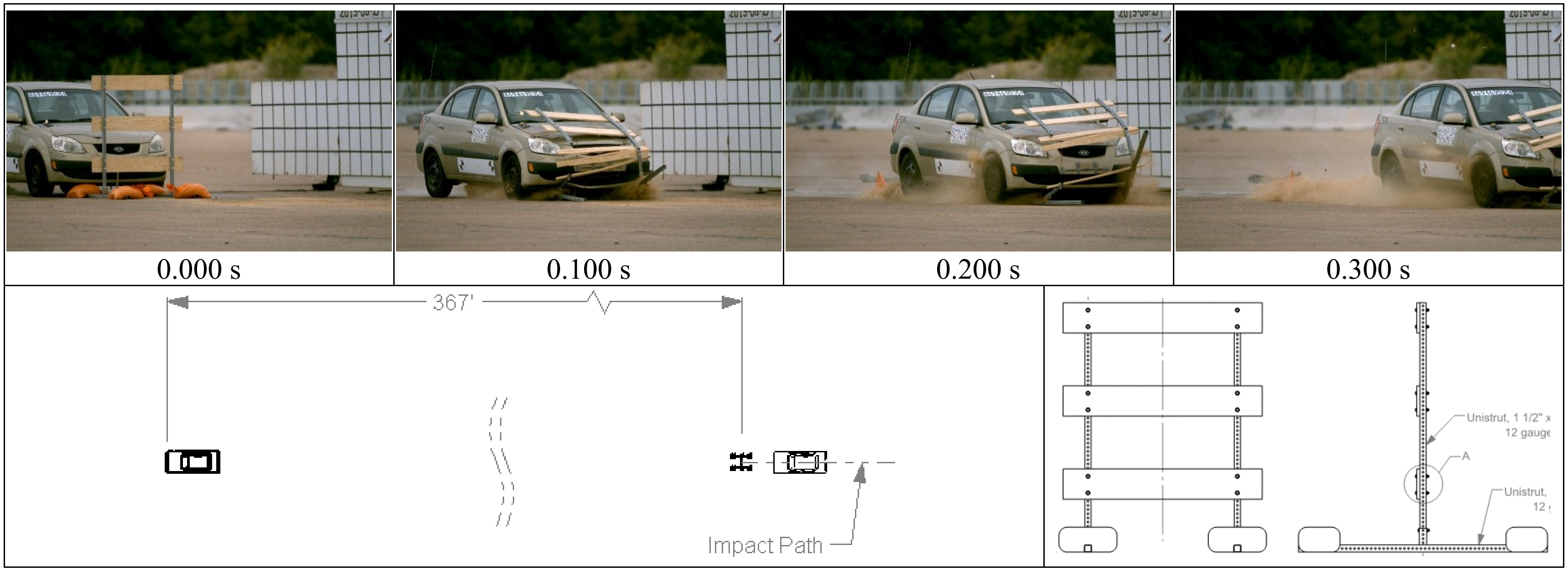
Figure 13.25. Interior of Test Vehicle after Test No. 469469-12-04.

13.6.7 Occupant Risk Factors

According to *MASH*, when the weight of the traffic control device is less than 220 lb, the test may be performed without vehicle instrumentation. The Type III barricade system weighed 57 lb. Therefore, the vehicle was not instrumented, and occupant risk factors were not obtained for this test.

13.6.8 Assessment of Results

The summary of test results can be found in Figure 13.26 and an assessment of the test based on the applicable safety evaluation criteria for *MASH* Test 3-71 at 0° is provided in Table 13.8.



General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	*MASH* Test 3-71
TTI Test No.	469469-12-04
Test Date	2019-08-27
Test Article	
Type	Work zone traffic control device
Name	TxDOT Type III barricade
Installation Length	n/a
Material or Key Elements	Wood boards and perforated square steel tube frame
Soil Type and Condition	Placed on dry concrete
Test Vehicle	
Type/Designation	1100C
Make and Model	2007 Kia Rio
Curb	2453 lb
Test Inertial	2450 lb
Dummy	165 lb dummy on passenger side
Gross Static	2615 lb

Impact Conditions	
Speed	64.5 mi/h
Angle	0°
Location/Orientation	Center of barricade 14 inches off center of the vehicle toward the driver's side
Impact Severity	341 kip*ft
Exit Conditions	
Speed	61.7 mi/h
Exit Trajectory/Heading	n/a
Occupant Risk Values	
Longitudinal OIV	n/a
Lateral OIV	n/a
Longitudinal Ridedown	n/a
Lateral Ridedown	n/a
THIV	n/a
ASI	n/a
Max. 0.050-s Average	
Longitudinal	n/a
Lateral	n/a
Vertical	n/a

Post-Impact Trajectory	
Stopping Distance	367 ft downstrm
Vehicle Stability	
Maximum Yaw Angle	n/a
Maximum Pitch Angle	n/a
Maximum Roll Angle	n/a
Vehicle Snagging	n/a
Vehicle Pocketing	n/a
Test Article Deflections	
Dynamic	n/a
Permanent	n/a
Working Width	n/a
Working Width Height	n/a
Vehicle Damage	
VDS	12FL1
CDC	12FLEN1
Max. Exterior Deformation	0 inches
OCDI	LF000000
Max. Occupant Compartment Deformation	0 inches

Figure 13.26. Summary of Results for *MASH* Test 3-71 on the Type III Barricade.

Table 13.8. Performance Evaluation Summary for *MASH* Test 3-71 on the Type III Barricade.

Test Agency: Texas A&M Transportation Institute | Test No.: 469469-12-04 | Test Date: 2019-08-27

MASH Test 3-60 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 Type III barricade yielded to the 1100C vehicle 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.	After impact, the barricade fragments did not penetrate or show any potential for penetration into the occupant compartment.	Pass
Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH.	There was no occupant compartment deformation	Pass
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The vehicle remained upright and stable during and after the impact	Pass
E. Detached elements, fragments, or other debris from the test article, of vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.	The detached elements did not obstruct the driver's vision or cause loss of control of the vehicle.	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.	According to *MASH*, when the weight of the traffic control device is less than 220 lb, the test may be performed without vehicle instrumentation.	n/a
I. The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	The Type III barricade system weighed 57 lb. Therefore, the vehicle was not instrumented, and occupant risk factors were not obtained for this test.	n/a
Post-Impact Vehicular Response		
N. Vehicle trajectory behind the test article is acceptable.	The 1100C vehicle came to rest 367 ft behind and in line of the original position of the installation.	Pass

13.7 CONCLUSIONS

The Type III barricade performed acceptably in all tests (Table 13.9). Although some of the barricades separated into multiple pieces, these pieces did not penetrate or show any potential for penetrating the occupant compartment. The vehicle remained upright and stable during and after the impact for each test. The Type III barricade performed as designed in all tests and is considered *MASH* compliant.

Table 13.9. Assessment Summary for *MASH* TL-3 Tests on TxDOT Type III Barricade.

Evaluation Factors	Evaluation Criteria	Test No. 469469-12-1	Test No. 469469-12-2	Test No. 469469-12-3	Test No. 469469-12-4
Structural Adequacy	B	S	S	S	S
Occupant Risk	D	S	S	S	S
	E	S	S	S	S
	F	S	S	S	S
	H	S	S	S	S
	I	S	S	S	S
	N	S	S	S	S
	Test No.	***MASH* Test 3-71**	***MASH* Test 3-72**	***MASH* Test 3-72**	***MASH* Test 3-71**
	Pass/Fail	Pass	Pass	Pass	Pass

S = Satisfactory
U = Unsatisfactory

CHAPTER 14: SUMMARY AND CONCLUSIONS

A *MASH* implementation agreement was jointly developed and adopted by FHWA and AASHTO. The agreement establishes various implementation dates for different categories of roadside safety features. In response to the implementation requirements, the TxDOT Bridge, Design, Maintenance, and Traffic Safety Divisions reviewed their standards for roadside safety devices and identified those devices that require testing and evaluation to assess *MASH* compliance. These systems are being crash-tested in accordance with *MASH* criteria in three phases over a 3-year period.

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

14.1 C1W BRIDGE RAIL

The TxDOT C1W 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 0.9 ft, and maximum permanent deformation was 0.3 ft. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. Maximum occupant compartment deformation was 5.5 inches in the front left corner of the floor pan. The 10000S vehicle remained upright during and after the collision event. Maximum roll and pitch was 23° and 7°, respectively. Occupant risk factors were within the preferred limits specified in *MASH*. The C1W bridge rail performed acceptably for according to *MASH* TL-4 evaluation criteria.

14.2 MODIFIED C66 BRIDGE RAIL

The TxDOT Modified C66 bridge rail contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 1.1 inches at the steel rail element, and there was no measurable permanent deformation. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. Maximum occupant compartment deformation was 2.0 inches in the driver side floor pan and kick panel areas. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 12° and 7°, respectively. Occupant risk factors were within the preferred limits specified in *MASH*. The 2270P vehicle exited within the exit box criteria.

The TxDOT Modified C66 bridge rail contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. There was no measurable dynamic or permanent deformation. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. Maximum occupant compartment deformation was 2 inches between the floor and roof. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 18° and 14°, respectively. Occupant risk factors were within the acceptable limits specified in *MASH*. The 1100C vehicle exited within the exit box criteria.

The TxDOT Modified C66 bridge rail performed acceptably according to *MASH* TL-3 evaluation criteria.

14.3 LOW-PROFILE BARRIER

The TxDOT low-profile barrier contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 8.6 inches, and maximum permanent deformation was 8.5 inches. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. There was no observed occupant compartment deformation. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 22° and 10°, respectively. Occupant risk factors were within the preferred limits specified in *MASH*. The 2270P vehicle exited within the exit box criteria.

The TxDOT low-profile barrier contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 4.9 inches, and maximum permanent deformation was 4.3 inches. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. There was no observed occupant compartment deformation. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 6° and 3°, respectively. Occupant risk factors were within the allowable limits specified in *MASH*. The 1100C vehicle exited within the exit box criteria.

The TxDOT low-profile barrier performed acceptably according to *MASH* TL-3 evaluation criteria.

14.4 LOW-PROFILE-TO-F-SHAPE TRANSITION

In Test 2-20, the TxDOT low-profile-to-F-shape transition contained and redirected the 1100C vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 8 inches, and permanent deformation was 8 inches. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. There was no observed occupant compartment deformation. The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 17° and 8°, respectively. Occupant risk factors were within the preferred limits specified in *MASH*. The 1100C vehicle exited within the exit box criteria.

In Test 2-21, the TxDOT low-profile-to-F-shape transition contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 14.5 inches, and permanent deformation was 14 inches. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. There was no observed occupant compartment deformation. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 7° and 7°, respectively. Occupant risk factors were within the preferred limits specified in *MASH*. The 2270P vehicle exited within the exit box criteria.

The TxDOT low-profile-to-F-shape transition performed acceptably according to *MASH* TL-2 evaluation criteria.

14.5 THRIE-BEAM TRANSITION

The TxDOT thrie-beam transition without end shoe block contained and redirected the 2270P vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 4.0 inches, and permanent deformation was ½ inch. No detached elements, fragments, or other debris were present to penetrate or show potential for penetrating the occupant compartment, or to present hazard to others in the area. The maximum occupant compartment deformation was 4 inches. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 24° and 7°, respectively. Occupant risk factors were within the preferred limits specified in *MASH*. The 2270P vehicle exited within the exit box criteria.

The TxDOT thrie-beam transition without end shoe block performed acceptably according to *MASH* Test 3-21 evaluation criteria.

14.6 SINGLE WOOD POST SKID-MOUNTED SIGN SUPPORT SYSTEM

Upon impact, the wood support post fractured near bumper height. The upper portion of the fractured support with attached aluminum sign panel rotated toward the vehicle, and the corner of the sign panel contacted the windshield and caused a 4-inch-long tear in the laminate. Consequently, the single wood post skid-mounted sign support system failed to comply with *MASH* Test 3-72 criteria.

The TxDOT single wood post skid-mounted sign support system did not perform acceptably according to *MASH* Test 3-72 evaluation criteria.

14.7 PERFORATED SQUARE STEEL TUBE SIGN SUPPORT

The sign support fractured near the ground line as designed. After the support post fractured, the sign panel and support rotated toward the vehicle and impacted the windshield and roof. The sign penetrated through the roof into the occupant compartment, and the roof sustained 11¼ inches of deformation into the occupant compartment. Consequently, the PSST sign support in reinforced anchor stub system did not satisfy *MASH* criteria for breakaway support structures.

The TxDOT PSST sign support did not perform acceptably according to *MASH* Test 3-61 evaluation criteria

14.8 BURN BAN SIGN ON SLIP BASE SUPPORT

The burn ban sign on slip base support did not comply with *MASH* criteria. After release from the slip base, the sign support system rotated over the impacting vehicle, and the top of the sign panel and support contacted and penetrated the rear window.

14.9 BURN BAN SIGN ON WEDGE AND SOCKET SUPPORT

Upon impact with the burn ban sign on wedge and socket support, the support post initially began to pull out of its socket but subsequently fractured about 24 inches above grade. After fracture of the support post, the upper portion wrapped around the front of the vehicle and the upper sign panel and support contacted and penetrated the windshield. Consequently, the burn ban sign on wedge and socket support did not meet *MASH* criteria.

14.10 MAILBOXES

14.10.1 Single Temporary Mailbox on Plastic Drum (Type 6 Foundation)

The mailbox on Type 6 foundation on a plastic drum performed acceptably in *MASH* Test 3-61 and is considered *MASH* compliant. The mailbox deformed but remained connected to the barrel. No part of the test article penetrated or showed any potential for penetrating the occupant compartment. The vehicle remained upright and stable during and after the impact.

14.10.2 Centennial Model Mailbox on Type 2 Foundation

The Centennial model mailbox on Type 2 foundation performed acceptably in *MASH* Test 3-61 and is considered *MASH* compliant. The mailbox deformed and disconnected from the post. The post remained attached to its anchor. No part of the test article penetrated or showed any potential for penetrating the occupant compartment. The vehicle remained upright and stable during and after the impact.

14.10.3 Lockable Mailbox on Thin-Wall Galvanized Tube with Type 2 Foundation

The lockable mailbox on thin-wall galvanized tube with Type 2 foundation performed acceptably in *MASH* Test 3-61 and is considered *MASH* compliant. The mailbox deformed but remained connected to the post, which disengaged from its ground support. No part of the test article penetrated or showed any potential for penetrating the occupant compartment. The vehicle remained upright and stable during and after the impact.

14.11 ROUND WOOD POST GUARDRAIL IN CONCRETE MOW STRIP

The round wood post guardrail in a concrete mow strip did not meet *MASH* criteria. The 2270P vehicle penetrated through the guardrail and was not contained or redirected by the round wood post guardrail in a concrete mow strip.

14.12 TYPE III BARRICADE

The Type III barricade performed acceptably in all tests. Although some of the barricades separated into multiple pieces, these pieces did not penetrate or show any potential for penetrating the occupant compartment. The vehicle remained upright and stable during and after the impact for each test. The Type III barricade performed as designed in all tests and is considered *MASH* compliant.

CHAPTER 15: IMPLEMENTATION

A total of 22 full-scale crash tests were performed under Phase III of this project to evaluate 14 different roadside safety devices or configurations. These tests represent the critical tests considered necessary to demonstrate *MASH* compliance of each device. The systems that met *MASH* requirements for these 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 as follows.

15.1 C1W BRIDGE RAIL

The C1W bridge rail is a 42-inch-tall combination rail that consists of four rectangular tubular steel rail elements attached to fabricated steel posts mounted on a 9-inch-tall concrete curb. The bridge rail is designed to accommodate both vehicle and pedestrian traffic. When tested in accordance with *MASH* Test 4-12 with a 24,200-lb single-unit truck, the C1W bridge rail met all required *MASH* criteria. Based on previous testing of the T1W to *MASH* TL-3 (*1*), test designations 4-10 and 4-11 were deemed unnecessary. Compared to the T1W, the C1W provides additional rail contact surface area and reduced clear opening between rail elements, both of which reduce potential for vehicle snagging.

Consequently, the C1W bridge rail is considered *MASH* TL-4 compliant. Continued implementation of this bridge rail system can be achieved by the Bridge Division through its respective standard sheets.

15.2 MODIFIED C66 BRIDGE RAIL

The C66 bridge rail is a concrete beam-and-post system mounted on a 9-inch curb. The C66 rail is a combination version of the T66 rail that is designed to accommodate both vehicle and pedestrian traffic. The additional features incorporated into the C66 rail include a 10-inch-tall steel rail element attached to the top of the system and a steel pipe positioned between posts in the clear opening between the bottom of the concrete beam and top of the curb.

The test installation was constructed in a manner to evaluate *MASH* compliance of both the T66 and C66 bridge rail systems. The C66 steel rail element was incorporated into the test installation to evaluate any potential occupant or vehicle interaction. Since the lower pipe section could potentially reduce the severity of wheel snagging on the concrete posts, the lower pipe was removed from the test installation.

The full *MASH* test matrix was successfully performed on the Modified C66 bridge rail system. The full-scale crash tests included *MASH* test designations 3-10 (small passenger car) and 3-11 (pickup truck). Therefore, both the T66 and the C66 bridge rail systems are considered *MASH* TL-3 compliant. Continued implementation of these bridge rail systems can be achieved by the Bridge Division through their respective standard sheets.

15.3 LOW-PROFILE BARRIER

The low-profile barrier is a 20-inch-tall, free-standing concrete barrier designed to improve sight distance for turning maneuvers within low-speed work zone areas. The low-profile barrier test installation followed a draft specification (Draft LPCB-19) that included some changes from the previous standard. Key among them was the use of two separate washer plates for the two connection bolts rather than a single plate, and polyvinyl chloride (PVC) pipe rather than steel pipe for the connection bolts at each end of the barrier segments.

The full *MASH* TL-2 test matrix was successfully performed on the low-profile barrier. The full-scale crash tests included *MASH* test designations 2-10 with the small passenger car and 2-11 with the pickup truck. Therefore, the low-profile barrier is considered *MASH* TL-2 compliant. Continued implementation of this bridge rail system can be achieved by the Design Division through revision of their respective standard sheets as necessary to reflect the details presented in Appendix C.1.

15.4 LOW-PROFILE-TO-F-SHAPE TRANSITION

This transition barrier segment is used to connect a 20-inch-tall low-profile concrete barrier to a 32-inch-tall F-shape portable concrete barrier. The low-profile barrier is a TL-2 system intended for use on lower-speed roadways, whereas the F-shape barrier is a TL-3 system suitable for use on high-speed roadways. The low-profile-to-F-shape transition section incorporated some changes from the previous standard. The tested transition section incorporated PVC pipe at each, rather than steel pipe for the connection bolts, and the X-bolt connection details on the F-shape end of the transition section were significantly simplified. Additionally, the steel reinforcement was simplified and reduced throughout.

Based on a review of previous analysis and testing of the low-profile-to-F-shape transition (*3*), it was determined that two tests should be performed to verify the impact performance of the low-profile-to-F-shape transition under *MASH* criteria. *MASH* Test 2-20 with the small passenger car was successfully performed with the vehicle traveling from the F-shape barrier toward the low-profile barrier, and *MASH* Test 2-21 with the pickup truck was successfully performed with the vehicle traveling from the low-profile barrier toward the F-shape barrier. These were the critical directions for these tests based on previous simulation and crash testing of the system. Test 2-20 from the low-profile barrier end and Test 2-21from the F-shape barrier end were not considered necessary because previous simulations showed them to be less critical (more stable) than the tests that were performed.

Therefore, the low-profile-to-F-shape transition is considered *MASH* TL-2 compliant. Continued implementation of the transition can be achieved by the Design Division through revision of the respective standard sheets as necessary to reflect the details presented in Appendix D.1

15.5 THRIE-BEAM TRANSITION

The TxDOT thrie-beam transition is used to connect an approach guardrail to a bridge rail system. Variations of this transition section have been previously tested to *MASH* at both the upstream and downstream ends (*4, 5*). When the transition system was tested at the downstream end near its connection to a safety-shaped concrete parapet, a tapered steel block was positioned under the end shoe to keep the thrie-beam rail in a vertical plane. The TxDOT variation of this transition twists the nested thrie beam and end shoe into the sloped barrier face in lieu of using the tapered steel blockout. It was decided to test the downstream transition without the tapered end shoe block to determine if this configuration is *MASH* compliant.

The critical test for evaluating the need for the tapered end shoe block is *MASH* test designation 3-21 with the 2270P pickup truck. The stability of the pickup truck is most likely to be affected by the sloping thrie-beam rail adjacent to the bridge rail parapet. This test was successfully performed and met all associated *MASH* evaluation criteria. Therefore, the thrie-beam transition without tapered steel block is considered *MASH* compliant. Continued implementation of this transition system can be achieved by the Design Division through their respective standard sheets.

The standard detail sheet for the TxDOT thrie-beam transition permits use of three different post types: W6×8.5 steel posts, 7-inch (178-mm) diameter round wood posts, and 6-inch by 8-inch (152-mm by 203-mm) rectangular wood posts. Researchers consider the W6×8.5 steel post to be the most critical condition in regard to post snagging; therefore, the steel post option was used in the full-scale crash test. Based on the successful impact performance with the steel posts, the transition is also considered *MASH* compliant with the less critical round and rectangular posts types.

TxDOT bridge rail standards include two systems that have sloped faces that attach to the TL-3 thrie-beam transition. These are a 32-inch F-shape parapet (Type T551) and a 36-inch SSTR. The greater slope of the SSTR made it the more critical profile for evaluating the thrie-beam transition without end shoe block. Based on the successful impact performance with the transition attached to the SSTR, the transition is also considered *MASH* compliant when attached to the less-critical T551 F-shape bridge rail.

15.6 SINGLE WOOD POST SKID-MOUNTED SIGN SUPPORT SYSTEM

The single wood post skid-mounted temporary sign support system uses a 4-inch by 4-inch post and is designed for use with a maximum 12-sq-ft sign panel. Details can be found on TxDOT Barricade and Construction sheet BC(5)-14. The *MASH* test matrix for work zone traffic control devices includes a high-speed test with a passenger car (Test 3-71) and pickup truck (Test 3-72) at both 0° and 90° impact orientations.

During Test 3-72 with the single wood post skid-mounted sign support system oriented at 90°, the edge of the aluminum sign panel contacted and penetrated the top of the windshield, resulting in a 4-inch-long tear in the laminate. Thus, the single wood post skid-mounted temporary sign support system did not perform acceptably for *MASH* Test 3-72, and the system is not *MASH* compliant. Further research is required to develop a modified system that will comply with *MASH* requirements.

15.7 PERFORATED SQUARE STEEL TUBE SIGN SUPPORT

TxDOT uses PSST supports for ground-mounted temporary signs. Barricade and construction sheet BC(5)-14 and Section J "Signs and Sign Supports" of the Compliant Work Zone Traffic Control Device List provide three foundation options:

- Option 1 is direct embedment of the sign support.
- Option 2 involves insertion of the sign post into a larger size PSST anchor stub.
- Option 3 incorporates an 18-inch PSST reinforcing sleeve over the PSST anchor stub.

Evaluation efforts under this project focused on the options with anchor stubs because they are much more common in the field.

The TxDOT standards permit the use of both 14-gauge and 12-gauge PSST supports of different sizes to accommodate different sign sizes. A single 2-inch by 14-gauge PSST support in an anchor stub was successfully tested in accordance with *MASH* criteria. Therefore, efforts under this project focused on evaluation of 12-gauge PSST supports. Both foundation Option 2 (PSST support in anchor stub) and Option 3 (PSST support in reinforced anchor stub) were evaluated for a 2-inch, 12-gauge PSST support.

MASH recognizes that sign support systems that are used near an intersection can be struck from virtually any direction. Consequently, *MASH* Section 2.2.4.1 recommends that testing of these systems 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. Since these temporary sign supports are used at or near intersections, the recommended test matrix for evaluating the ground-mounted PSST sign support system includes *MASH* Test 3-61 with the 1100C passenger car and Test 3-62 with the 2270P pickup truck at both 0° and 90°.

When Option 2 was evaluated in *MASH* Test 3-61 with the sign in a 90° orientation, the anchor stub fractured, and the sign panel and support rotated toward the vehicle and impacted the windshield and roof. The sign penetrated into the occupant compartment through the windshield and roof. Consequently, the PSST sign support in anchor stub system did not satisfy *MASH* criteria for breakaway support structures.

After the unsuccessful test of the PSST sign support in anchor stub system, it was decided to evaluate the impact performance of a 2-inch by 12-gauge PSST support post in a reinforced anchor stub. The reinforcing sleeve provides additional stiffening of the support post at the ground line, which should help facilitate fracture of the support post during an impact. Quicker fracture of the support post offered the possibility of changing the trajectory of the released sign support system.

When Option 3 was evaluated in *MASH* Test 3-61 with the sign in a 90° orientation, the sign support fractured near the ground line as designed. After the support post fractured, the sign panel and support rotated toward the vehicle and impacted the windshield and roof. The sign penetrated through the roof into the occupant compartment. Consequently, the PSST sign support in reinforced anchor stub system did not satisfy *MASH* criteria for breakaway support structures. Further research is required to develop a modification to this system that will comply with *MASH* requirements.

15.8 BURN BAN SIGN ON SLIP BASE SUPPORT

TxDOT permits counties to post advisory signs on the roadside to alert motorists when a burn ban is in effect. The current practice is to append the burn ban notification signs to existing sign support structures. Since burn ban signs are deployed on support structures along the roadside and not at or near intersections, only evaluation at 0° was considered necessary.

Previous research concluded that the minimum sign area that should be used on a slip base support to meet *MASH* requirements for 0° impacts is 14 sq ft (*8*). Therefore, it was recommended to append the burn ban sign to a slip base sign support system that has a primary sign panel area of at least 14 sq ft.

Two different sizes of burn ban signs are used. The smaller 24-inch by 24-inch sign is intended to simply communicate that a burn ban is in effect. The larger 30-inch by 36-inch sign additionally indicates the name of the county when needed. The larger sign is the more critical of the two sizes. If testing of the 30-inch by 36-inch burn ban sign is satisfactory, the smaller 24-inch by 24-inch burn ban sign would also be considered *MASH* compliant.

The burn ban sign on slip base support structure did not comply with *MASH* criteria. During *MASH* Test 3-61, the released sign support system rotated over the impacting vehicle, and the top of the sign panel and support contacted and penetrated the rear window. Further research is required to develop a modification to this system that will comply with *MASH* requirements.

15.9 BURN BAN SIGN ON WEDGE AND SOCKET SUPPORT

TxDOT desired to expand the implementation of burn ban signs to include thin-wall steel tubing supports secured in a wedge and socket foundation. Due to the capacity of the thin-wall steel tube support, the smaller 24-inch by 24-inch burn ban sign was evaluated.

During *MASH* Test 3-61, the thin-wall steel support post initially began to pull out of its socket, but it subsequently fractured about 24 inches above grade. After fracture of the support post, the upper portion wrapped around the front of the vehicle and the upper sign panel and support contacted and penetrated the windshield. Consequently, the burn ban sign on wedge and socket support did not meet *MASH* criteria. Further research is required to develop a modification to this system that will comply with *MASH* requirements.

15.10 MAILBOXES

The small passenger car is considered the critical design vehicle for evaluation of mailbox support systems based on the mounting height regulated for mailboxes by the United States Postal Service. At the required mounting 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 (*10*). Under the lower impact severity, 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 III of the project. Separate tests were successfully performed for each system. These include a single temporary mailbox on a plastic drum (Type 6 foundation), a single extra-large mailbox on thin-wall galvanized steel tube with Type 2 foundation, and a lockable mailbox on thin-wall galvanized steel tube support with a Type 2 foundation.

Each of these systems are considered *MASH* compliant and suitable for implementation. Systems that were tested with a single mailbox should be implemented with a single mailbox only. Smaller mailboxes with similar attachment hardware are less critical and are considered *MASH* compliant. Implementation of these mailbox systems can be achieved by the Maintenance Division through updating of mailbox standard MB-15(1) (as necessary) to reflect the tested details presented in Chapter 11.

15.11 ROUND WOOD POST GUARDRAIL IN CONCRETE MOW STRIP

TxDOT frequently installs guardrail in a concrete mow strip. Pavement mow strips are used to combat vegetation growth around guardrail posts to avoid the use of herbicides, decrease maintenance costs, and reduce the safety risk to workers associated with hand mowing around guardrail. A sacrificial grout layer is used in a leave-out section formed in the mow strip around the guardrail posts. During an impact, the grout is crushed, and the post is able to rotate in the leave-out section.

MASH Test 3-11 is considered the critical test for evaluation of the round wood post guardrail system in a concrete mow strip. This test places more demand on the mow-strip-confined posts. *MASH* Test 3-10 was not considered necessary on the round wood post guardrail in a concrete mow strip because *MASH* Test 3-10 was successfully performed on guardrail in a concrete mow strip with W6×8.5 steel posts and 6-inch by 8-inch rectangular wood posts (*12*). The geometries of the steel and rectangular wood posts are considered more critical in terms of the vehicle snagging and deceleration compared to the round wood post.

The test installation for the round wood post guardrail system in a concrete mow strip used nominal 7-inch-diameter posts with a 36-inch post embedment. During *MASH* Test 3-11, the 2270P pickup truck penetrated through the guardrail and was not contained or redirected by the round wood post guardrail in a concrete mow strip. Thus, this configuration of round wood post guardrail in a concrete mow strip does not meet *MASH* criteria. Further research is required to develop a modification to this system that will comply with *MASH* requirements. An options for future consideration is increasing the size (diameter) of the post to delay/prevent post fracture and permit more energy of the vehicle to be dissipated through post deflection.

15.12 TYPE III BARRICADE

Acceptable design configurations for Type III barricades are provided on barricade and construction sheet BC(5)-14 and Section D “Type III Barricades” of the Compliant Work Zone Traffic Control Device List. Numerous material options and combinations are permitted. Evaluation under this project focused on systems with a support structure fabricated using PSST.

Type III barricades with PSST frames can be used with three different rail types: wood, HPPL, and plastic I-beam rails. The wood and HPPL rails are directly bolted to the barricade uprights, while the plastic I-beam rails clip into brackets attached to the uprights. Because the I-beam rails are releasable, their evaluation will require separate testing. Of the two direct-bolted rail types, wood was considered more critical than HPPL. This is because the wood rails are heavier and can fracture into multiple pieces that can subsequently impact the windshield of the vehicle.

The *MASH* test matrix for work zone traffic control devices consists of three tests: 3-70, 3-71, and 3-72. Test 3-70 is considered optional for free-standing devices weighing less than 220 lb because “velocity changes during low-speed impacts will be within acceptable limits…” *MASH* Tests 3-71 and 3-72 were successfully performed with the barricade in both normal (perpendicular) and parallel orientations. Thus, the Type III barricade with PSST supports and wood rails meets *MASH* requirements. Additionally, the similar Type III barricade with PSST supports and less critical HPPL rails is also considered *MASH* compliant.

The PSST barricade frame consists of uprights and skids. The uprights insert into PSST sleeves that can be connected to the skids by welding or bolted steel hardware. Welded connections were considered the more critical of the two connection types because the small welds have an opportunity to fracture and release the barricade uprights, which could then potentially interact with the vehicle windshield. Therefore, given the successful *MASH* evaluation of the Type III barricade with welded connections, the similar design with bolted hardware connections is also considered *MASH* compliant.

A lower cross member between the two uprights is an optional feature for the Type III barricades that can be used when needed to provide additional structural support to the barricade frame. This cross member is typically only needed when the plastic I-beam rails are used because these clip-on rails do not provide the same structural rigidity of the direct-bolted rails. Additionally, the barricade system with direct-bolted rails would be considered more critical without the lower cross member because the cross member provides additional strength and rigidity that would make separation of the barricade components less likely during an impact. Consequently, the Type III barricade system evaluated under this project did not include a lower cross member. Given the successful *MASH* evaluation of the Type III barricade without the lower cross member, the similar design with bolted cross member is also considered *MASH* compliant.

Finally, TxDOT standards permit Type III barricades to vary in length from 4 ft to 8 ft. A 4-ft length was considered most critical. This length permits both uprights to be impacted simultaneously, thus increasing the probability of the uprights releasing from their skids. In a longer configuration, if only one upright is impacted, the barricade may simply rotate out of the path of the vehicle. Therefore, given the successful evaluation of the 4-ft-long Type III barricade system, longer variations are also considered *MASH* compliant.

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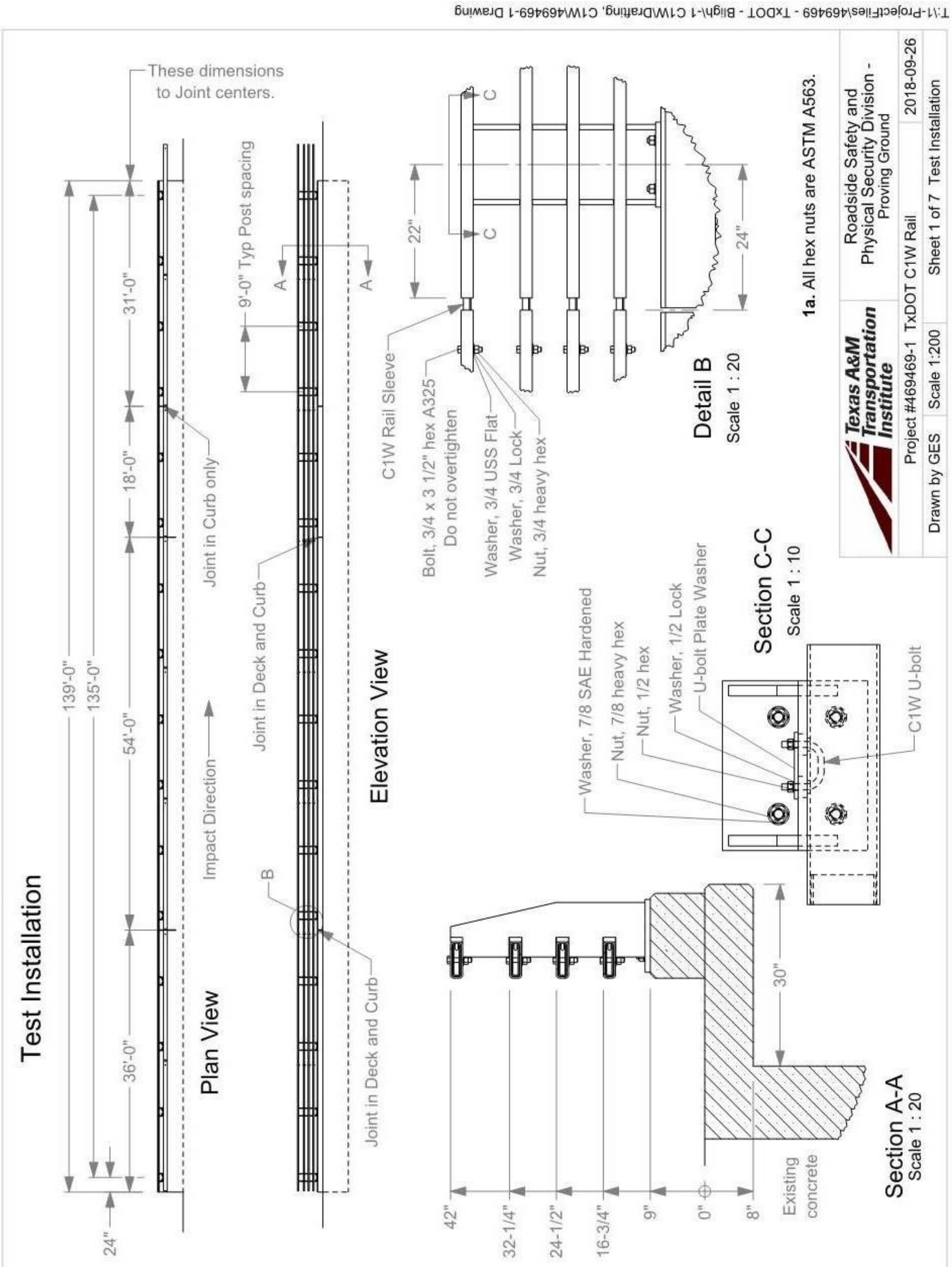
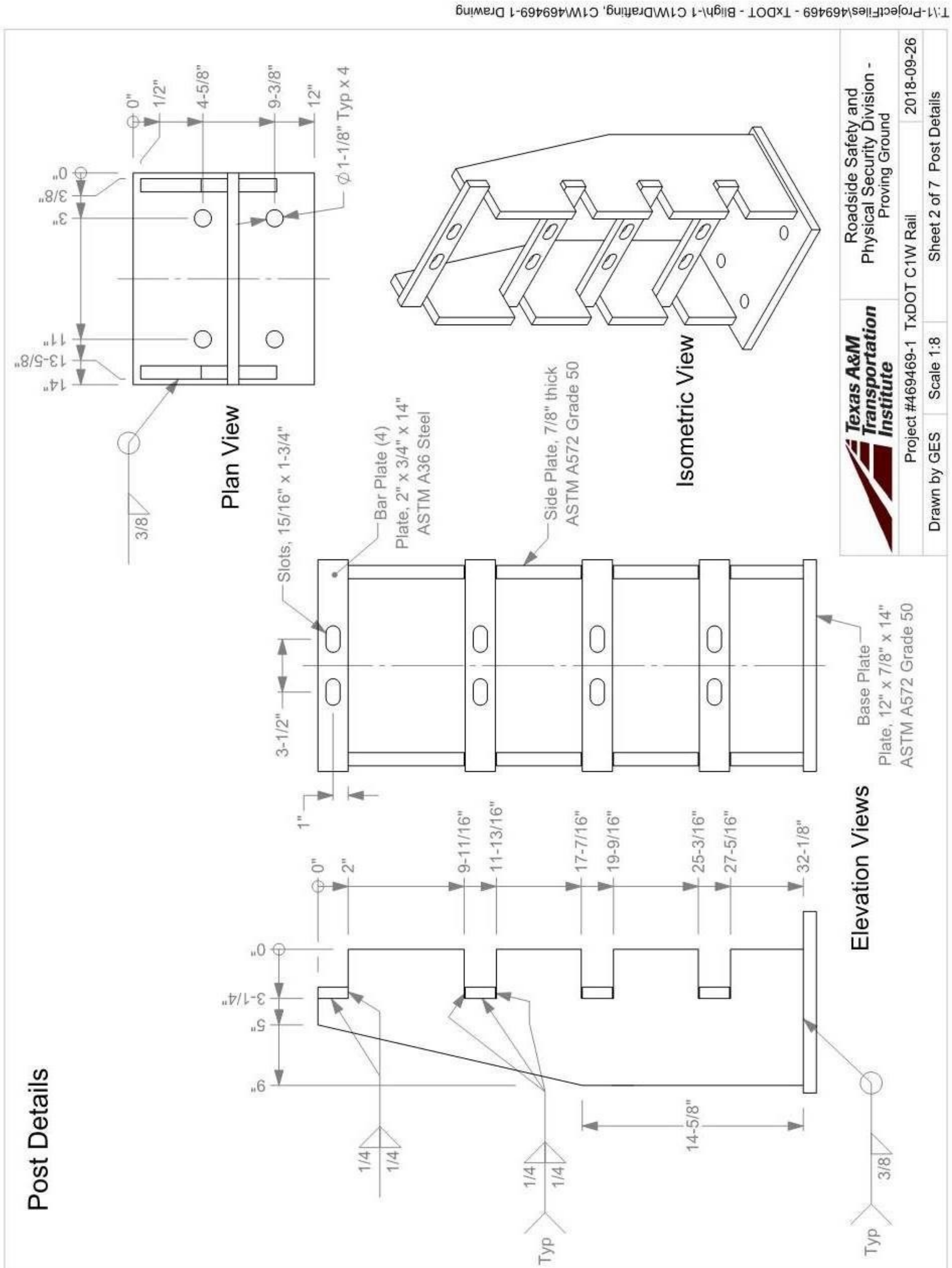
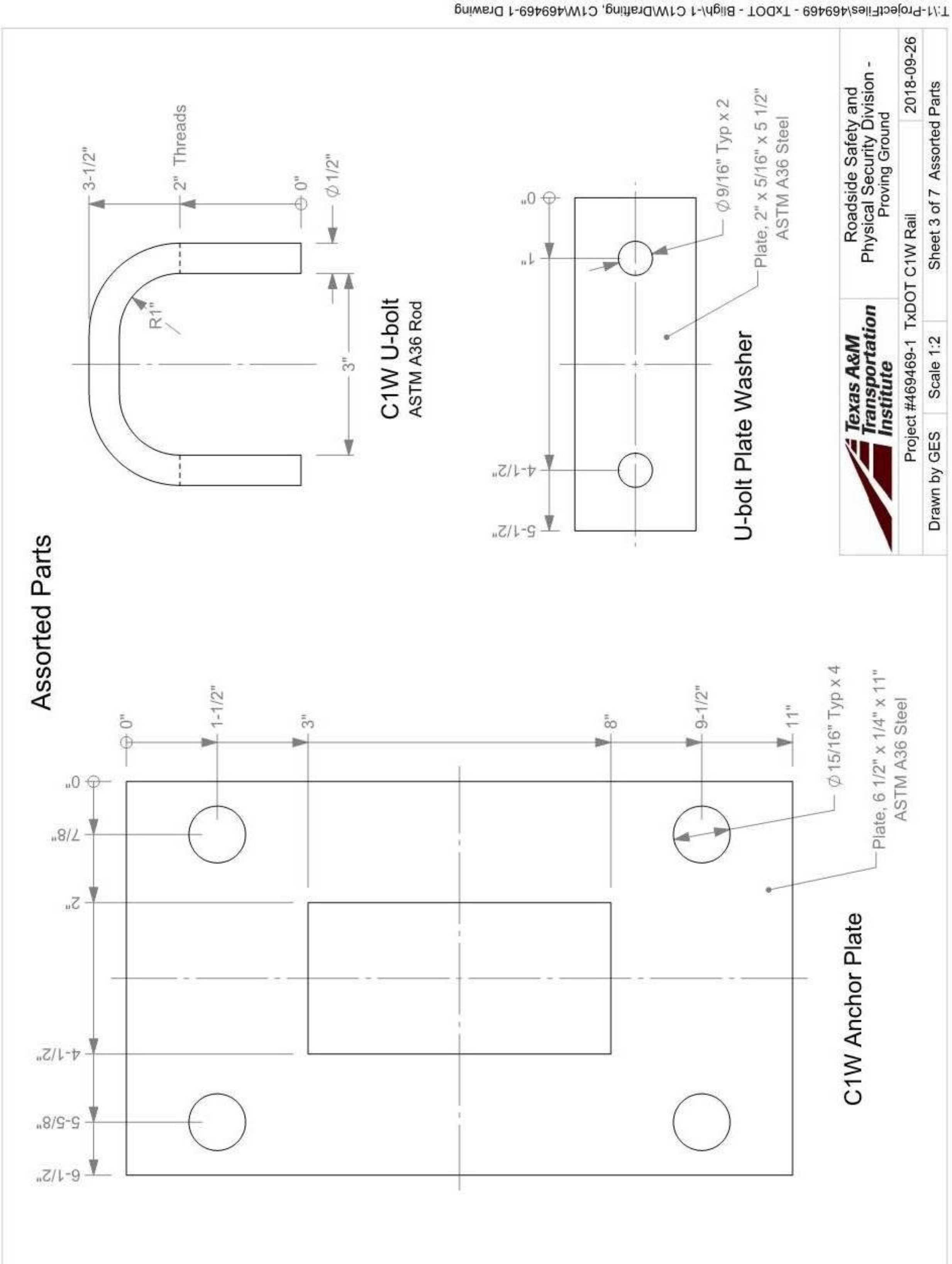
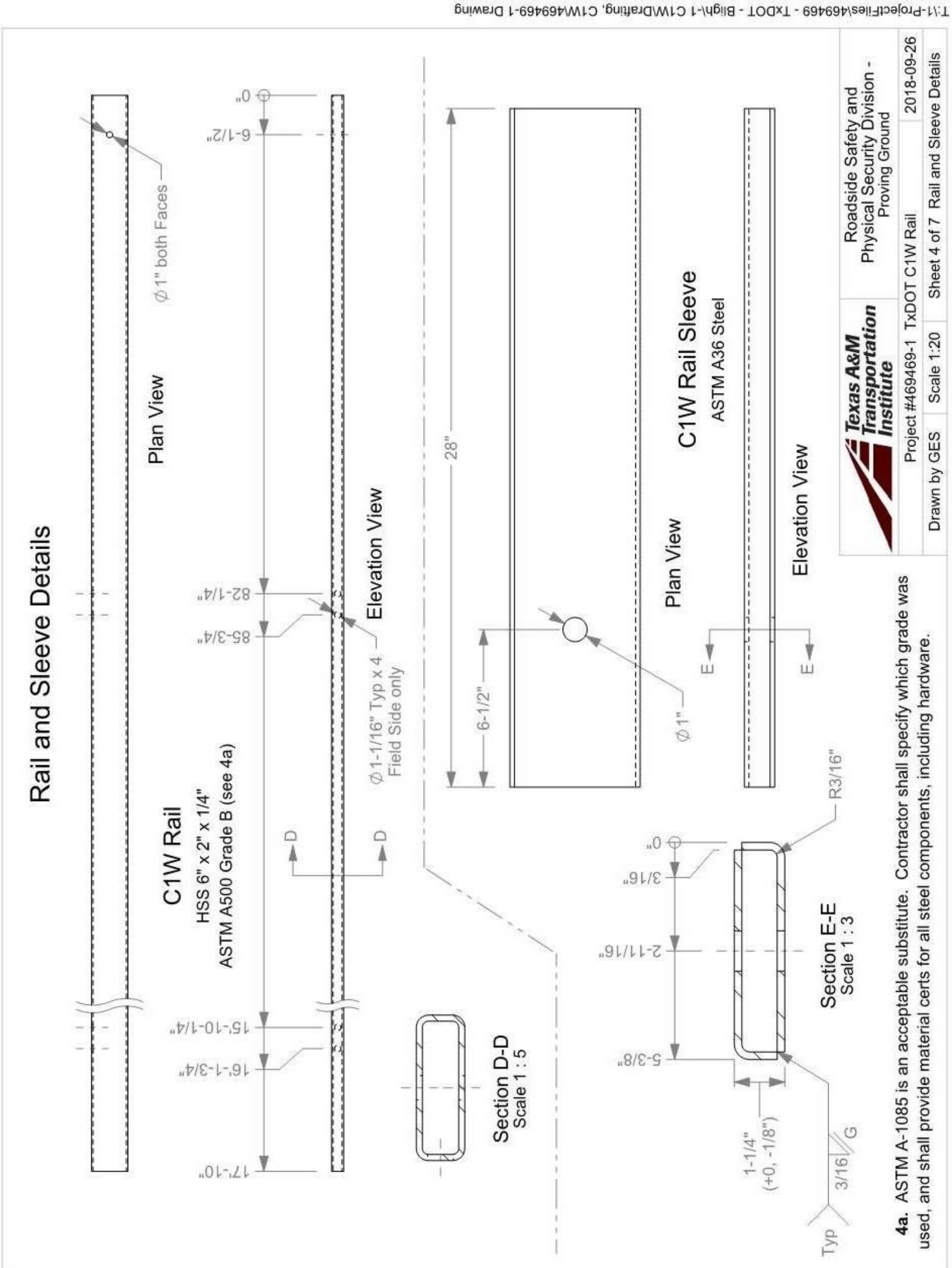
APPENDIX A: TXDOT C1W BRIDGE RAIL

A.1. DETAILS OF THE C1W BRIDGE RAIL




T:\1-ProjectFiles\469469 - TxDOT - Bligh\-1 C1W\Drafting, C1W\469469-1 Drawing
Post Details
Elevation Views
Plan View
Isometric View
Slots, 15/16" x 1-3/4"
Bar Plate (4)
Plate, 2" x 3/4" x 14"
ASTM A36 Steel
Side Plate, 7/8" thick
ASTM A572 Grade 50
Base Plate
Plate, 12" x 7/8" x 14"
ASTM A572 Grade 50
⌀1-1/8" Typ x 4
0"
2"
9-11/16"
11-13/16"
17-7/16"
19-9/16"
25-3/16"
27-5/16"
32-1/8"
3-1/4"
5"
9"
14-5/8"
3-1/2"
1"
1/2"
4-5/8"
9-3/8"
12"
3/8"
3"
11"
13-5/8"
14"
1/4
Typ
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #469469-1
TxDOT C1W Rail
2018-09-26
Drawn by GES
Scale 1:8
Sheet 2 of 7
Post Details


T:\1-ProjectFiles\469469 - TxDOT - Bligh\-1 C1W\Drafting, C1W\469469-1 Drawing
Assorted Parts
C1W U-bolt
ASTM A36 Rod
3-1/2"
2" Threads
0"
Ø 1/2"
R1"
3"
U-bolt Plate Washer
Ø 9/16" Typ x 2
Plate, 2" x 5/16" x 5 1/2"
ASTM A36 Steel
0"
1"
4-1/2"
5-1/2"
C1W Anchor Plate
Ø 15/16" Typ x 4
Plate, 6 1/2" x 1/4" x 11"
ASTM A36 Steel
0"
1-1/2"
3"
8"
9-1/2"
11"
7/8"
2"
4-1/2"
5-5/8"
6-1/2"
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #469469-1
TxDOT C1W Rail
2018-09-26
Drawn by GES
Scale 1:2
Sheet 3 of 7 Assorted Parts


T:\1-ProjectFiles\469469 - TxDOT - Bligh\-1 C1W\Drafting, C1W\469469-1 Drawing
Rail and Sleeve Details
C1W Rail
HSS 6" x 2" x 1/4"
ASTM A500 Grade B (see 4a)
Plan View
Ø 1" both Faces
Elevation View
Ø 1-1/16" Typ x 4
Field Side only
0"
6-1/2"
82-1/4"
85-3/4"
15'-10-1/4"
16'-1-3/4"
17'-10"
D
D
Section D-D
Scale 1 : 5
C1W Rail Sleeve
ASTM A36 Steel
Plan View
Elevation View
28"
6-1/2"
Ø 1"
E
E
Section E-E
Scale 1 : 3
0"
3/16"
2-11/16"
5-3/8"
R3/16"
1-1/4"
(+0, -1/8")
3/16
G
Typ
4a. ASTM A-1085 is an acceptable substitute. Contractor shall specify which grade was used, and shall provide material certs for all steel components, including hardware.
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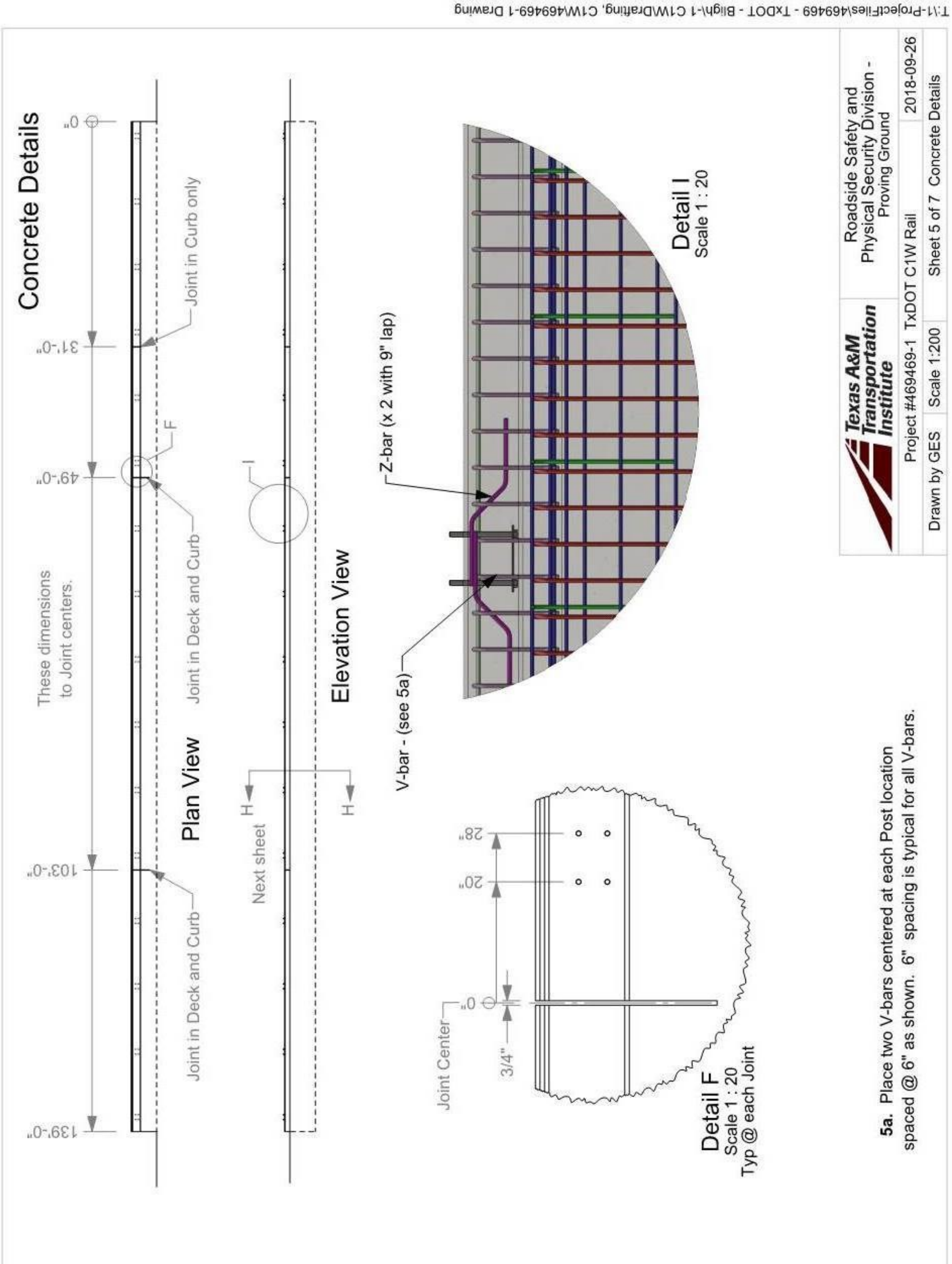
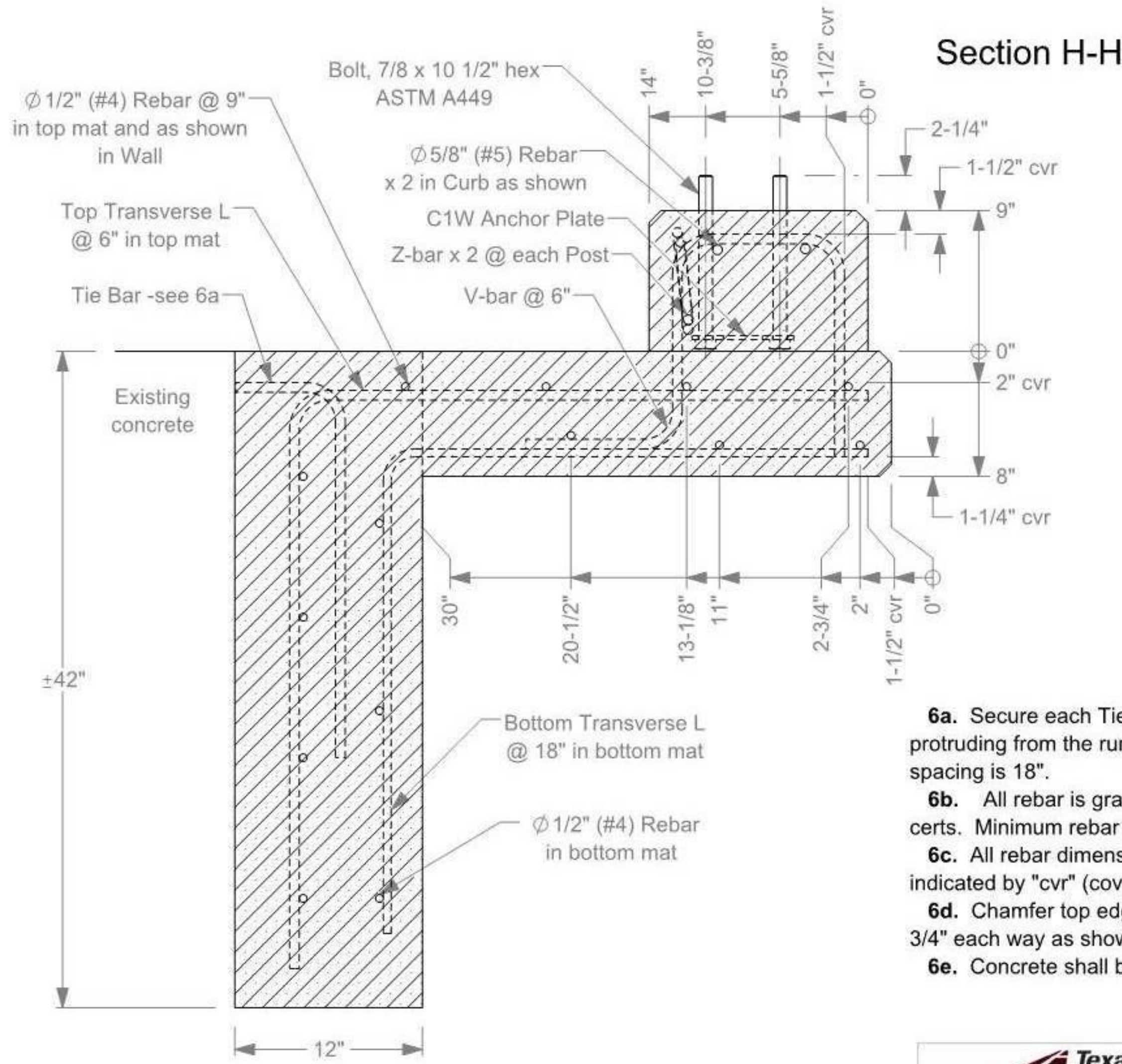
Project #469469-1
TxDOT C1W Rail
2018-09-26
Drawn by GES
Scale 1:20
Sheet 4 of 7
Rail and Sleeve Details


T:\1-ProjectFiles\469469 - TxDOT - Bligh\-1 C1W\Drafting, C1W\469469-1 Drawing
Concrete Details
0"
31'-0"
49'-0"
103'-0"
139'-0"
These dimensions to Joint centers.
Joint in Curb only
F
Joint in Deck and Curb
Joint in Deck and Curb
Plan View
I
Next sheet
H
H
Elevation View
Z-bar (x 2 with 9" lap)
V-bar - (see 5a)
Detail I
Scale 1 : 20
Joint Center
0"
3/4"
20"
28"
Detail F
Scale 1 : 20
Typ @ each Joint
5a. Place two V-bars centered at each Post location spaced @ 6" as shown. 6" spacing is typical for all V-bars.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #469469-1
TxDOT C1W Rail
2018-09-26
Drawn by GES
Scale 1:200
Sheet 5 of 7
Concrete Details

Section H-H



6a. Secure each Tie Bar to existing rebar (not shown here) protruding from the runway with a minimum 3" weld. Maximum spacing is 18".

6b. All rebar is grade 60, and contractor shall provide material certs. Minimum rebar lap is 19" for #4 bars and 24" for #5 bars.

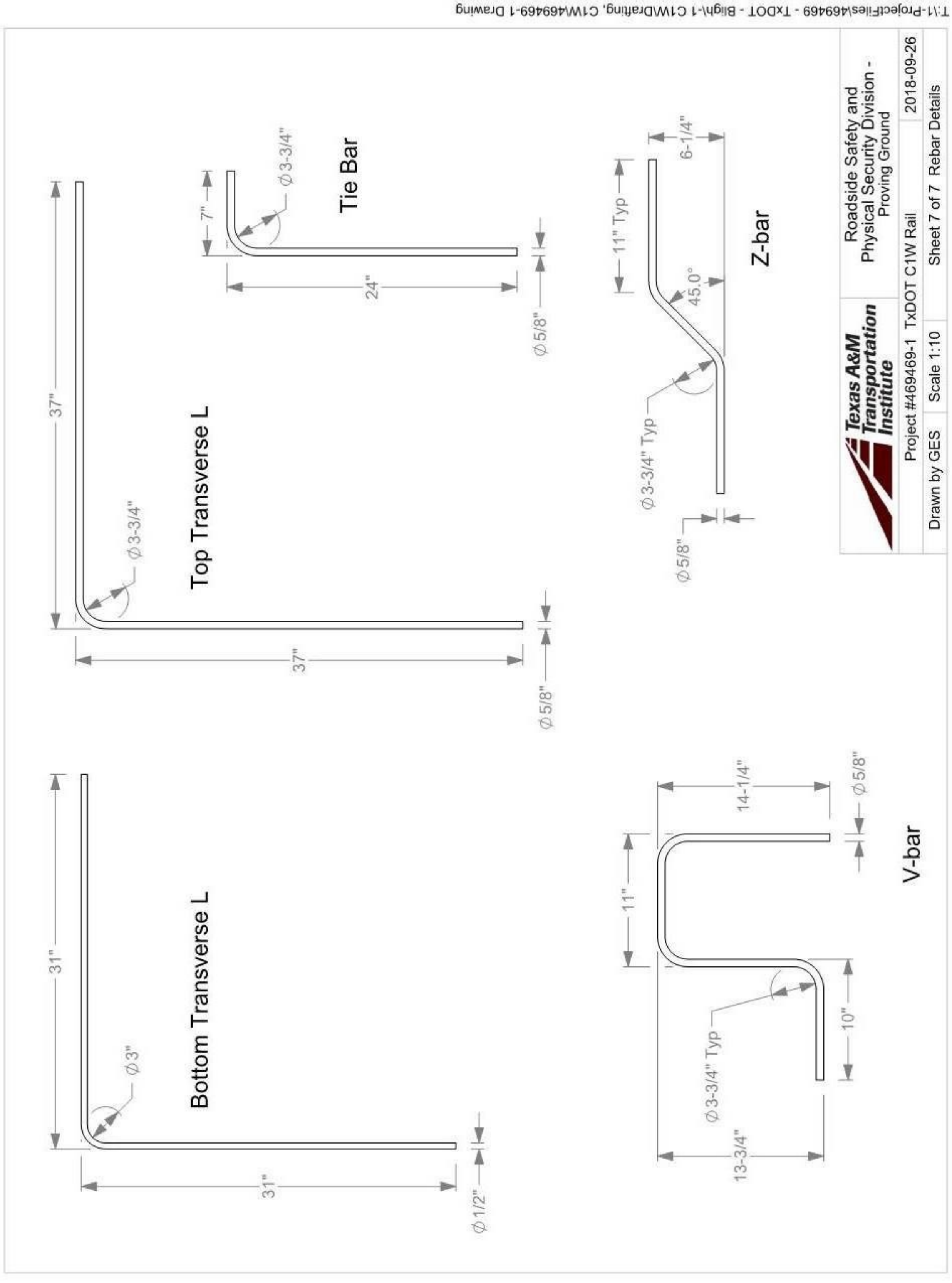
6c. All rebar dimensions are to center of bar unless otherwise indicated by "cvr" (cover).

6d. Chamfer top edges of Curb and field side edges of Deck 3/4" each way as shown.

6e. Concrete shall be TxDOT Class S (4000psi).

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #469469-1 TxDOT C1W Rail		2018-09-26
Drawn by GES	Scale 1:10	Sheet 6 of 7 Section View

T:\1-ProjectFiles\469469 - TxDOT - Bligh\-1 C1W\Drafting, C1W\469469-1 Drawing


T:\1-ProjectFiles\469469 - TxDOT - Bligh\-1 C1W\Drafting, C1W\469469-1 Drawing
Bottom Transverse L
31"
31"
Ø3"
Ø1/2"
Top Transverse L
37"
37"
Ø3-3/4"
Ø5/8"
Tie Bar
7"
24"
Ø3-3/4"
Ø5/8"
Z-bar
11" Typ
6-1/4"
45.0°
Ø3-3/4" Typ
Ø5/8"
V-bar
14-1/4"
11"
10"
13-3/4"
Ø3-3/4" Typ
Ø5/8"
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #469469-1 TxDOT C1W Rail
2018-09-26
Drawn by GES
Scale 1:10
Sheet 7 of 7 Rebar Details

A.2. 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 Sampling	Doc. No. QPF 5.7.2	Revision Date: 2018-04-17
Quality Policy Form	Revised by: B. L. Griffith Approved by: D. Kuhn	Revision: 6	Page: 1 of 1

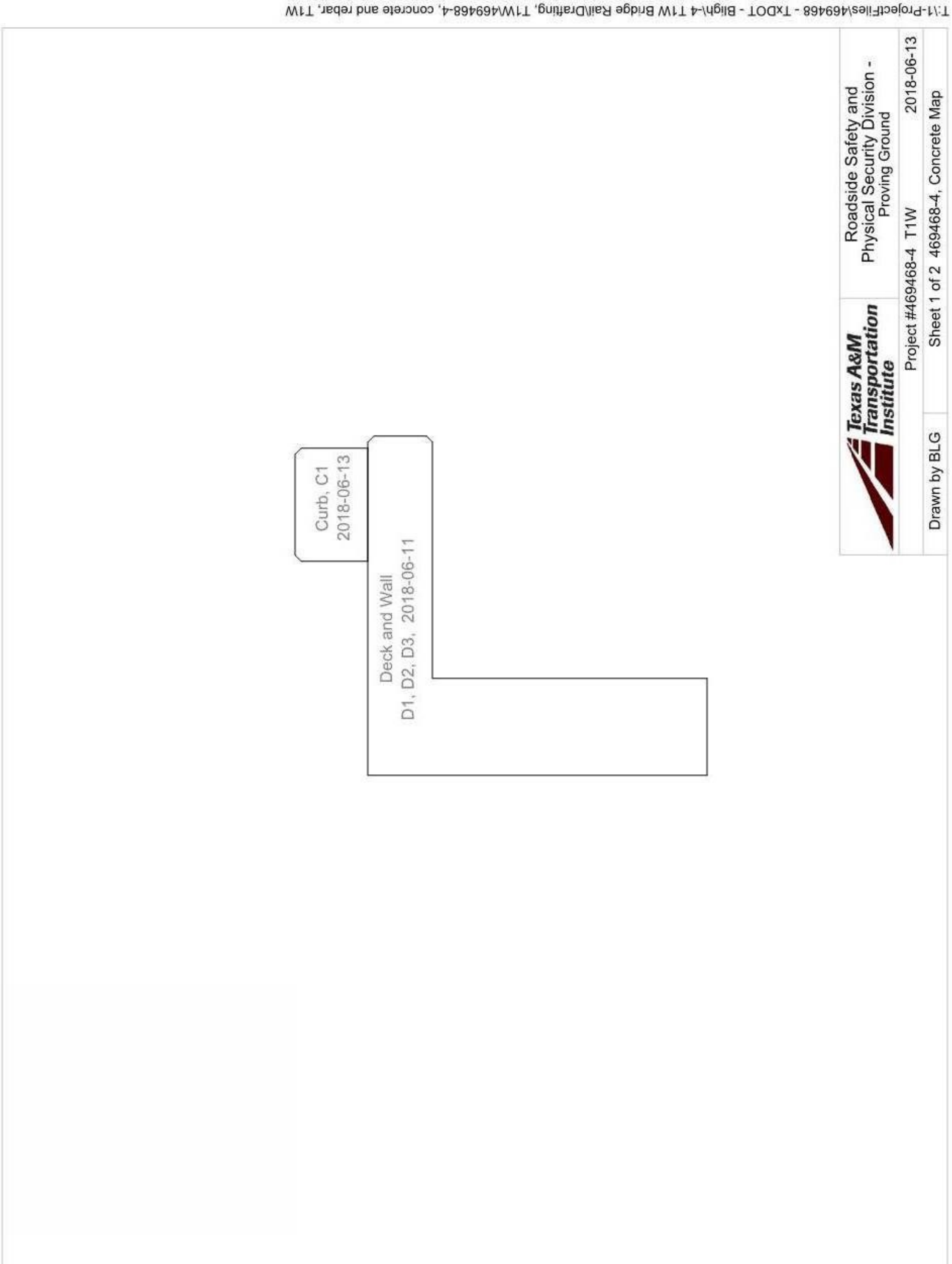
Project No: 469468-4 **Casting Date:** 2018/06/13 **Mix Design (psi):** 4000

Printed Name of Technician taking Sample: Matt Robinson
Printed Name of Technician breaking Sample: GREG FRITZ

Signed Name of Technician taking Sample:
Signed Name of Technician breaking Sample:

Load No.	Truck No.	Ticket No.	Location (from concrete map)
C/T1	390126	0621249	1 TRUCK 100% of curb

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
T1	2018-8-1	52 DAYS	193,000	6,825	
			182,000	6,435	6,600
			185,000	6,545	


T:\1-ProjectFiles\469468 - TxDOT - Bligh\-4 T1W Bridge Rail\Drafting, T1W\469468-4, concrete and rebar, T1W
Curb, C1
2018-06-13
Deck and Wall
D1, D2, D3, 2018-06-11
Texas A&M Transportation Institute
Roadside Safety and
Physical Security Division -
Proving Ground
Project #469468-4 T1W
2018-06-13
Drawn by BLG
Sheet 1 of 2 469468-4, Concrete Map

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 Sampling**	Doc. No. QPF 5.7.2	Revision Date: 2018-04-17
Quality Policy Form	Revised by: B. L. Griffith Approved by: D. Kuhn	Revision: 6	Page: 1 of 1

Project No: 469468-4 **Casting Date:** 2018-06-11 **Mix Design (psi):** 4000 psi

Printed Name of Technician taking Sample: GREG FRITZ
Printed Name of Technician breaking Sample: GREG FRITZ

Signed Name of Technician taking Sample: [signature]
Signed Name of Technician breaking Sample: [signature]

Load No.	Truck No.	Ticket No.	Location (from concrete map)
D1/T1	390100	0021700	Starting North End, Wall/Deck, 1/3 Length
D2/T2	390143	0042526	Middle 3rd of total wall/Deck
D3/T3	390127	0042528	Southern End, Final 1/3, wall/Deck

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
T1	2018-8-1	50 DAYS	175,000	6,190	
↓	↓	↓	175,000	6,190	6,035
↓			162,000	5,730	
T2			177,000	6,260	
↓			180,000	6,365	6,380
↓			184,000	6,510	
T3			198,000	7,005	
↓			189,000	6,685	6,860
↓	↓	↓	195,000	6,895	

SOUTH REGION/MAIN OFFICE
6310 State Highway 21 West
Bryan, TX 77807
PH: (979) 361-2900
FAX: (979) 361-2920

KNIFE RIVER
AN MDU RESOURCES COMPANY

RB 0021749

Riverbend

ELLIS-MCGINNIS CONSTRUC
P.O. BOX 40
EDDY

Disp Order#: 2020

TAMU TRANSPORTATION INSTITUTE
LF47 LF RELLIS CAMPUS RT AT THE
STOP SIGN 2ND STOP TAKE A LF 2ND
STOP TAKE A RT GO 2 STOP SIGN D
OWN TAKE A LF GO TO MORE STOP SI
GN DOWN TAKE RT GO THE NEXT STOP

TIME	FORMULA	LOAD SIZE	YARDS ORDERED		DRIVER/TRUCK		PLANT TRANSACTION #
8:41:32	CLSLS	6.50	6.50	2801	Louie FREDDIE R	390126	

DATE	PROJECT	LOAD #	YARDS DEL.	BATCH #	WATER TRIM	SLUMP	TICKET NUMBER
06/13/18	TAMUTRANS	1	6.50			5.00 in	20012869

WARNING
IRRITATING TO THE SKIN AND EYES

Contains Portland Cement. Wear Rubber Boots and Gloves, PROLONGED CONTACT MAY CAUSE BURNS. Avoid Contact With Eyes and Prolonged Contact With Skin. In Case of Contact With Skin or Eyes, Flush Thoroughly With Water. If Irritation Persists, Get Medical Attention. **KEEP CHILDREN AWAY.**

CONCRETE is a PERISHABLE COMMODITY and BECOMES THE PROPERTY of the PURCHASER UPON LEAVING the PLANT. ANY CHANGES or CANCELLATION of ORIGINAL INSTRUCTIONS MUST be TELEPHONED to the OFFICE BEFORE **LOADING** starts.

The undersigned promises to pay all costs, including reasonable attorney's fees, incurred in collecting any sums owed.

All accounts not paid within 30 days of delivery will bear interest at the rate of 18% per annum.

Not Responsible for Reactive Aggregate or Color Quality. No Claim Allowed Unless Made at Time Material is Delivered.

A $15.00 Service Charge and Loss of the Cash Discount will be Collected on all Returned Checks.

Excess Delay Time Charged @ $75.00/hr.

PROPERTY DAMAGE RELEASE
(TO BE SIGNED IF DELIVERY TO BE MADE INSIDE CURB LINE)

Dear Customer - The driver of this truck in presenting this RELEASE to you for your signature is of the opinion that the size and weight of this truck may possibly cause damage to the premises and/or adjacent property if he places the material in this load where you desire it. It is our wish to help you in every way that we can, but in order to do this the driver is requesting that you sign this RELEASE relieving him and this supplier from any responsibility from damage that may occur to the premises and or adjacent property, buildings, sidewalks, drive-ways, curbs, etc., by the delivery of this material, and that you also agree to help him remove mud from the wheels of his vehicle so that he will not litter the public street. Further, as additional consideration; the undersigned agrees to indemnify and hold harmless the driver of this truck and this supplier for any and all damage to the premises and/or adjacent property which may be claimed by anyone to have arisen out of delivery of this order.

SIGNED:

X ______________________

Excessive Water is Detrimental to Concrete Performance.
H_2O Added by Request / Authorized By:

______ GAL X ______________________

WEIGHMASTER

Thank you for your business

NOTICE: MY SIGNATURE BELOW INDICATES THAT I HAVE READ THE HEALTH WARNING NOTICE AND SUPPLIER WILL NOT BE RESPONSIBLE FOR ANY DAMAGE CAUSED WHEN DELIVERING INSIDE CURB LINE.

LOAD RECEIVED BY

x ______________________

QUANTITY	CODE	DESCRIPTION	OUR MIXES ARE DESIGNED TO ACHIEVE SPECIFICATIONS AT A MAX 4" SLUMP	UNIT PRICE	EXTENDED PRICE
6.50 yd	CLSLS	CLASS 5 4000 PSI			

RETURNED TO PLANT	LEFT JOB	FINISH UNLOADING	ON SITE TESTING		AIR TEMP
			TESTING LAB:		
LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP.	
8:55	9:12	9:15			
TOTAL ROUND TRIP	TOTAL AT JOB	UNLOADING TIME	AIR	CYLINDERS	

Tax
Prev. AMT
Ticket Total
Grand Total

ADDITIONAL CHARGE 1 ______
ADDITIONAL CHARGE 2 ______
GRAND TOTAL

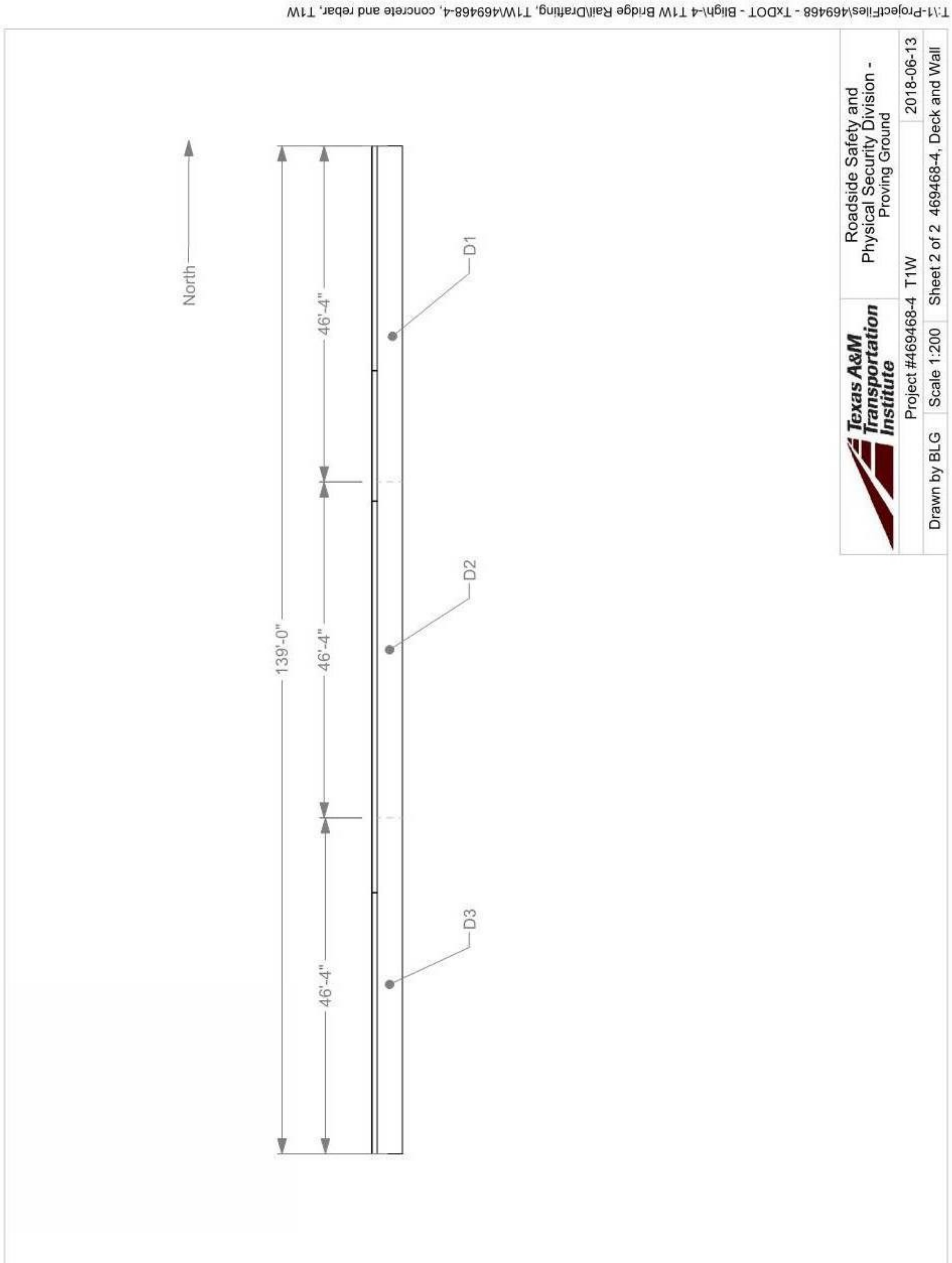
Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
390126	559579	user	20012869	12815	8:41	

RB 0021749

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
6.50 CYDS	CLSLS				D	9

Material	Design Qty	Required	Batched		% Var	% Moisture	Actual	Wat
CEMENT	417.00 lb	2710.50 lb	2706.00 lb		-0.17%			
FLYASH	143.00 lb	929.50 lb	932.00 lb		0.27%			
SAND	1223 lb	8287 lb	8340 lb		0.64%	4.25% M		41 gl
LMSTN1"	1380 lb	8992 lb	8930 lb		-0.69%	0.25% M		3 gl
GRAVEL3/8"	460 lb	3005 lb	3560 lb	>	18.47%	0.50% M		2 gl
WATER	252 lb	1154 lb	1157 lb		0.24%			139 gl
POZZ80	25.00 oz	162.50 oz	163.00 oz		0.31%			
AE-90	3.00 oz	19.50 oz	19.50 oz		0.00%			

Actual   Num Batches: 1
Load 25636 lb   Design W/C: 0.450   Water/Cement: 0.450 T   Design 196.3 gl   Actual 184.2 gl   To Add: 12.1 gl
Slump: 5.00 in   Water In Truck: 0.0 gl   Adjust Water: 0.0 gl / Load   Trim Water: -2.0 gl / CYD
Actual W/C Ratio: 0.423   Actual Water: 184 gl   Batched Cement: 3638 lb   Allowable Water: 100 gl


T:\1-ProjectFiles\469468 - TxDOT - Bligh\-4 T1W Bridge Rail\Drafting, T1W\469468-4, concrete and rebar, T1W
North
139'-0"
46'-4"
46'-4"
46'-4"
D1
D2
D3
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #469468-4 T1W
2018-06-13
Drawn by BLG
Scale 1:200
Sheet 2 of 2 469468-4, Deck and Wall

KNIFE RIVER

AN MDU RESOURCES COMPANY

SOUTH REGION/MAIN OFFICE
6310 State Highway 21 West
Bryan, TX 77807
PH: (979) 361-2900
FAX: (979) 361-2920

RB 0021700

Riverbend

ELLIS-MCGINNIS CONSTRUC
P.O. BOX 40
EDDY

Disp Order#: 2010

SHIP TO:

TAMU TRANSPORTATION INSTITUTE
LF47 LF RELLIS CAMPUS RT AT THE STOP SIGN 2ND STOP TAKE A LF 2ND STOP TAKE A RT GO 2 STOP SIGN DOWN TAKE A LF GO TO MORE STOP SIGN DOWN TAKE RT GO THE NEXT STOP

TIME	FORMULA	LOAD SIZE	YARDS ORDERED		DRIVER/TRUCK		PLANT TRANSACTION #
7:53:10	CLSLS	10.00	30.00	2801	MELVIN MA	390108	
DATE	**PROJECT**	**LOAD #**	**YARDS DEL**	**BATCH #**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
06/11/18	TAMUTRANS	1	10.00			5.00 in	20012820

WARNING

IRRITATING TO THE SKIN AND EYES

Contains Portland Cement. Wear Rubber Boots and Gloves. PROLONGED CONTACT MAY CAUSE BURNS. Avoid Contact With Eyes and Prolonged Contact With Skin. In Case of Contact With Skin or Eyes, Flush Thoroughly With Water. If Irritation Persists, Get Medical Attention. **KEEP CHILDREN AWAY.**

CONCRETE is a PERISHABLE COMMODITY and BECOMES THE PROPERTY of the PURCHASER UPON LEAVING the PLANT. ANY CHANGES or CANCELLATION of ORIGINAL INSTRUCTIONS MUST be TELEPHONED to the OFFICE BEFORE **LOADING** starts.

The undersigned promises to pay all costs, including reasonable attorney's fees, incurred in collecting any sums owed.

All accounts not paid within 30 days of delivery will bear interest at the rate of 18% per annum.

Not Responsible for Reactive Aggregate or Color Quality. No Claim Allowed Unless Made at Time Material is Delivered.

A $15.00 Service Charge and Loss of the Cash Discount will be Collected on all Returned Checks.

Excess Delay Time Charged @ $75.00/hr.

PROPERTY DAMAGE RELEASE

(TO BE SIGNED IF DELIVERY TO BE MADE INSIDE CURB LINE)

Dear Customer - The driver of this truck in presenting this RELEASE to you for your signature is of the opinion that the size and weight of this truck may possibly cause damage to the premises and/or adjacent property if he places the material in this load where you desire it. It is our wish to help you in every way that we can, but in order to do this the driver is requesting that you sign this RELEASE relieving him and this supplier from any responsibility from damage that may occur to the premises and or adjacent property, buildings, sidewalks, drive-ways, curbs, etc., by the delivery of this material, and that you also agree to help him remove mud from the wheels of his vehicle so that he will not litter the public street. Further, as additional consideration; the undersigned agrees to indemnify and hold harmless the driver of this truck and this supplier for any and all damage to the premises and/or adjacent property which may be claimed by anyone to have arisen out of delivery of this order.

SIGNED:

X ______________________

Excessive Water is Detrimental to Concrete Performance.
H_2O Added by Request / Authorized By:

_______ GAL X ______________________

WEIGHMASTER

Thank you for your business

NOTICE: MY SIGNATURE BELOW INDICATES THAT I HAVE READ THE HEALTH WARNING NOTICE AND SUPPLIER WILL NOT BE RESPONSIBLE FOR ANY DAMAGE CAUSED WHEN DELIVERING INSIDE CURB LINE.

LOAD RECEIVED BY

x ______________________

QUANTITY	CODE	DESCRIPTION	OUR MIXES ARE DESIGNED TO ACHIEVE SPECIFICATIONS AT A MAX 4" SLUMP	UNIT PRICE	EXTENDED PRICE
10.00 yc	CLSLS	CLASS S 4000 PSI			

RETURNED TO PLANT	LEFT JOB	FINISH UNLOADING	ON SITE TESTING		AIR TEMP
			TESTING LAB:		
LEFT PLANT	**ARRIVED JOB**	**START UNLOADING**	**SLUMP**	**CONCRETE TEMP.**	
8:00	8:05				
TOTAL ROUND TRIP	**TOTAL AT JOB**	**UNLOADING TIME**	**AIR**	**CYLINDERS**	

Tax
Prev. AMT
Ticket Total
Grand Total

ADDITIONAL CHARGE 1 ______

ADDITIONAL CHARGE 2 ______

GRAND TOTAL ▶

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
390108	569696	user	20012820	12766	7:53	6/11/18

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
10.00 CYDS	CLSLS				D	14

RB 0021700

Material	Design Qty	Required	Batched	% Var	% Moisture	Actual	Wat
CEMENT	417.00 lb	4170.00 lb	4144.00 lb	-0.62%			
FLYASH	143.00 lb	1430.00 lb	1418.00 lb	-0.84%			
SAND	1223 lb	12713 lb	12750 lb	0.30%	4.00% M		53 gl
LMSTN1"	1380 lb	13835 lb	13810 lb	-0.18%	0.25% M		4 gl
GRAVEL3/8"	460 lb	4623 lb	4600 lb	-0.50%	0.50% M		3 gl
WATER	252 lb	1806 lb	1805 lb	-0.08%			216 gl
POZZ80	25.00 oz	250.00 oz	250.00 oz	0.00%			
AE-90	3.00 oz	30.00 oz	30.00 oz	0.00%			

46 T46 8.4 N 1/3

Actual
Load 36685 lb   Num Batches: 1
Design W/C: 0.450   Water/Cement: 0.463 T   Design 302.0 gl   Actual 282.1 gl   To Add 19.9 gl
Slump: 5.00 in   Water In Truck: 0.0 gl   Adjust Water: 0.0 gl / Load   Trim Water: -2.0 gl / CYD
Actual W/C Ratio: 0.423   Actual Water: 282 gl   Batched Cement: 5562 lb   Allowable Water: 149 gl

KNIFE RIVER
AN MDU RESOURCES COMPANY

SOUTH REGION/MAIN OFFICE
6310 State Highway 21 West
Bryan, TX 77807
PH: (979) 361-2900
FAX: (979) 361-2920

BRYAN
6310 Hwy. 21 West
Bryan, TX 77807
DISPATCH: (979) 361-2931
FAX: (979) 361-2920

B 0042526

Bryan Plant #6

ELLIS-MCGINNIS CONSTRUC
P.O. BOX 40
EDDY

TAMU TRANSPORTATION INSTITUTE
LF47 LF RELLIS CAMPUS RT AT THE STOP SIGN 2ND STOP TAKE A LF 2ND STOP TAKE A RT GO 2 STOP SIGN DOWN TAKE A LF GO TO MORE STOP SIGN DOWN TAKE RT GO THE NEXT STOP

Disp Order#: 2010

TIME	FORMULA	LOAD SIZE	YARDS ORDERED		DRIVER/TRUCK		PLANT TRANSACTION #
8:25:02	CLSLS	10.00	30.00	2801	ROY DAVIS	390143	
DATE		**LOAD #**	**YARDS DEL.**	**BATCH #**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
06/11/18	TAMUTRANS	2	20.00			5.00 in	6141872

WARNING
IRRITATING TO THE SKIN AND EYES
Contains Portland Cement. Wear Rubber Boots and Gloves, PROLONGED CONTACT MAY CAUSE BURNS. Avoid Contact With Eyes and Prolonged Contact With Skin. In Case of Contact With Skin or Eyes, Flush Thoroughly With Water. If Irritation Persists, Get Medical Attention. **KEEP CHILDREN AWAY.**

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Not Responsible for Reactive Aggregate or Color Quality. No Claim Allowed Unless Made at Time Material is Delivered.
A $15.00 Service Charge and Loss of the Cash Discount will be Collected on all Returned Checks.
Excess Delay Time Charged @ $75.00/hr.

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SIGNED:
X

Excessive Water is Detrimental to Concrete Performance.
H_2O Added by Request / Authorized By:
GAL X
WEIGHMASTER
Thank you for your business

NOTICE: MY SIGNATURE BELOW INDICATES THAT I HAVE READ THE HEALTH WARNING NOTICE AND SUPPLIER WILL NOT BE RESPONSIBLE FOR ANY DAMAGE CAUSED WHEN DELIVERING INSIDE CURB LINE.
LOAD RECEIVED BY
x

QUANTITY	CODE	DESCRIPTION	UNIT PRICE	EXTENDED PRICE
10.00CY	CLSLS	CLASS S 4000 PSI		

OUR MIXES ARE DESIGNED TO ACHIEVE SPECIFICATIONS AT A MAX 4" SLUMP

RETURNED TO PLANT	LEFT JOB	FINISH UNLOADING	ON SITE TESTING		AIR TEMP
			TESTING LAB:		
LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP.	
8.38	8.47	9.05			
TOTAL ROUND TRIP	TOTAL AT JOB	UNLOADING TIME	AIR	CYLINDERS	

Tax
Prev. AMT
Ticket Tot
Grand Tota
ADDITIONAL CHARGE 1
ADDITIONAL CHARGE 2
GRAND TOTAL ▶

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
390143	554626	user	6141872	50317	8:25	06/11/18

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
10.00 CYDS	CLSLS				D	1

B 0042526

Material	Design Qty	Required	Batched	% Var	Moisture	Actual Wat
SAND	1223 lb	12903 lb	12900 lb	-0.02%	5.50% M	81 gl
LMSTN1"	1380 lb	13800 lb	13680 lb	-0.87%		
GRAVEL3/8"	460 lb	4669 lb	4700 lb	0.66%	1.50% M	8 gl
CEMENT	417.0 lb	4170.0 lb	4198.0 lb	0.67%		
FLYASH	143.0 lb	1430.0 lb	1444.0 lb	0.98%		
WATER	30.3 gl	194.1 gl	193.9 gl	-0.12%		193.9 gl
RE-90	3.00 oz	30.00 oz	30.00 oz	0.00%		
DZZ80	25.00 oz	250.00 oz	250.00 oz	0.00%		

Actual Num Batches: 1 Manual 8:25:02
Load Total: 38558 lb Design W/C: 0.452 Water/Cement: 0.448 T Design Water: 303.0 gl Actual Water: 282.8 gl To Add: 20.2 gl
Slump: 5.00 in Water in Truck: 0.0 gl Adjust Water: 0.0 gl/ Load Trim Water: -2.0 gl/ CYDS

46 T460.4 M1/3

KNIFE RIVER
AN MDU RESOURCES COMPANY

SOUTH REGION/MAIN OFFICE
6310 State Highway 21 West
Bryan, TX 77807
PH: (979) 361-2900
FAX: (979) 361-2920

BRYAN
6310 Hwy. 21 West
Bryan, TX 77807
DISPATCH: (979) 361-2931
FAX: (979) 361-2920

B 0042528

Bryan Plant #6

ELLIS-MCGINNIS CONSTRUC
P.O. BOX 40
EDDY

Disp Order#: 2010

TAMU TRANSPORTATION INSTITUTE
LF47 LF RELLIS CAMPUS RT AT THE STOP SIGN 2ND STOP TAKE A LF 2ND STOP TAKE A RT GO 2 STOP SIGN DOWN TAKE A LF GO TO MORE STOP SIGN DOWN TAKE RT GO THE NEXT STOP

TIME	FORMULA	LOAD SIZE	YARDS ORDERED		DRIVER/TRUCK		PLANT TRANSACTION #
9:19:11	CLSLS	10.00	30.00	2801	EDDIE SWE	390127	
DATE		**LOAD #**	**YARDS DEL.**	**BATCH #**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
06/11/18	TAMUTRANS	3	30.00			5.00in	6141875

WARNING
IRRITATING TO THE SKIN AND EYES

Contains Portland Cement. Wear Rubber Boots and Gloves, PROLONGED CONTACT MAY CAUSE BURNS. Avoid Contact With Eyes and Prolonged Contact With Skin. In Case of Contact With Skin or Eyes, Flush Thoroughly With Water. If Irritation Persists, Get Medical Attention. **KEEP CHILDREN AWAY.**

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SIGNED:

X

Excessive Water is Detrimental to Concrete Performance.
H_2O Added by Request / Authorized By:

10 GAL X

WEIGHMASTER

Thank you for your business

NOTICE: MY SIGNATURE BELOW INDICATES THAT I HAVE READ THE HEALTH WARNING NOTICE AND SUPPLIER WILL NOT BE RESPONSIBLE FOR ANY DAMAGE CAUSED WHEN DELIVERING INSIDE CURB LINE.

LOAD RECEIVED BY

x

QUANTITY	CODE	DESCRIPTION	OUR MIXES ARE DESIGNED TO ACHIEVE SPECIFICATIONS AT A MAX 4" SLUMP	UNIT PRICE	EXTENDED PRICE
10.00CY	CLSLS	CLASS S 4000 PSI			

RETURNED TO PLANT	LEFT JOB	FINISH UNLOADING	ON SITE TESTING		AIR TEMP
			TESTING LAB:		
LEFT PLANT	**ARRIVED JOB**	**START UNLOADING**	**SLUMP**	**CONCRETE TEMP.**	
9:35	9:58	10:01			
TOTAL ROUND TRIP	**TOTAL AT JOB**	**UNLOADING TIME**	**AIR**	**CYLINDERS**	

Tax
Prev. AMT
Ticket Tot
Grand Tota

ADDITIONAL CHARGE 1 ____________

ADDITIONAL CHARGE 2 ____________

GRAND TOTAL

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
390127	548949	user	6141875	50319	9:19	6/11/18

B 0042528

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
10.00 CYDS	CLSLS				D	3

Material	Design Qty	Required	Batched	% Var	Moisture	Actual Wat
SAND	1223 lb	12903 lb	12790 lb	-0.87%	5.50% M	80 gl
MSTN1"	1380 lb	13800 lb	13730 lb	-0.51%		
GRAVEL3/8"	460 lb	4669 lb	4640 lb	-0.62%	1.50% M	8 gl
CEMENT	417.0 lb	4170.0 lb	4198.0 lb	0.67%		
FLYASH	143.0 lb	1430.0 lb	1422.0 lb	-0.56%		
WATER	30.3 gl	194.1 gl	194.1 gl	0.00%		194.1 gl
E-90	3.00 oz	30.00 oz	30.00 oz	0.00%		
DZZ80	25.00 oz	250.00 oz	250.00 oz	0.00%		

Actual Num Batches: 1 Manual 9:19:11

Load Total: 38417 lb Design W/C: 0.452 Water/Cement: 0.450 T Design Water: 303.0 gl Actual Water: 282.2 gl To Add: 20.8 gl

Slump: 5.00 in Water in Truck: 0.0 gl Adjust Water: 0.0 gl/ Load Trim Water: -2.0 gl/ CYDS

~~5~~ 5 1/3

4(74/60 4

AMERICAN METAL GROUP

American Metal Group
290 Lower Bon Air Road
Sylacauga, AL 35150
Tel 205.433.6680

Material Certification

Customer PO No: 363758
American Metal Group Order No: 1435
Order Line: 2
American Metal Group Part No: IQR .445X240
Customer Part No: IQR .445X240
Shipped Qty: 19660
Heat: 1821262
Grade: 1008
Country of Origin: USA
Note:

Material Specification Type	Material Specification	Actual
Chemistry	Carbon (max)	0.06 %
	Manganese	0.4 %
	Phosphorus (max)	0.010 %
	Sulfur (max)	0.027 %

We hereby certify that chemical analysis and/or physical characteristics shown are a true copy of orignal test reports on file with us from the producing source covering the heat or lot from which this material was taken.

STELFAST® INC.

C1W

22979 Stelfast Parkway
Strongsville, Ohio 44149

CERTIFICATE OF CONFORMANCE

DESCRIPTION OF MATERIAL AND SPECIFICATIONS

- Sales Order #: 192453
- Part No: DUSZP07500
- Quantity (PCS): 200
- Description: 3/4 U.S.S Flat Washer ZP
- Specification: ASME B18.21.1
- Stelfast I.D. NO: 695797-O203501
- Customer PO: 33629
- Warehouse: HOU
- ROHS Compliant: Y

The data in this report is a true representation of the information provided by the material supplier certifying that the product meets the mechanical and material requirements of the listed specification. This certificate applies to the product shown on this document, as supplied by STELFAST INC. Alterations to the product by our customer or a third party shall render this certificate void.

This document may only be reproduced unaltered and only for certifying the same or lesser quantity of the product specified herein. Reproduction or alteration of this document for any other purpose is prohibited.

Stelfast certifies parts to the above description. The customer part number is only for reference purposes.

David Biss
Quality Manager

February 23, 2018

Page 1 of 1

Stelfast Inc.

22979 Stelfast Parkway
Strongsville, Ohio

44149

Report of Chemical and Physical Properties

C/W

Issued To: Mack Bolt, Steel & Machine
5875 Hwy 21 East
BRYAN, TX
77808

Purchase Order: 33998
Stelfast Order: SO 198097
Certificate #: 668,670

Quantity: 3,500
Part #: DMLAZY05000
Description: 1/2 Helical Med Split L/W Alloy ZY

Lot Number: 1701237
Heat Number: 6208770BB
Country of Origin: CN

Chemical Analysis

C	Mn	P	S	Si	Cr	Mo	V	B	Ni	Cu
0.4	0.68	0.015	0.003	0.16	0.99					

Mechanical Properties

Hardness (Core)	40.0 - 41.5 HRC

We hereby certify that the above data is a true copy of the data furnished to us by the producing mill or the data resulting from tests performed in approved laboratories. Stelfast does not certify to customer's part numbers.
This certificate applies to the product shown on this document, as supplied by Stelfast Inc. Alterations to the product by our customer or a third party will render this certificate void.

David Biss
Quality Manager

May 24, 2018

Page 1 of 1

GEM-YEAR TESTING LABORATORY
CERTIFICATE OF INSPECTION

MANUFACTURER GEM-YEAR INDUSTRIAL CO., LTD.
ADDRESS : NO.8 GEM-YEAR ROAD,E.D.Z.,JIASHAN,ZHEJIANG,P.R.CHINA

Tel: (0573)84185001(48Lines)
Fax: (0573)84184488 84184567
DATE : 2012/11/09

PURCHASER : PORTEOUS FASTENER COMPANY.
PO. NUMBER : 12051557
COMMODITY : A325 STRUCTURAL BOLT A325 TYPEI
SIZE : 3/4-10X3-1/2 NC
LOT NO : 1B1260886
SHIP QUANTITY : 1,800 PCS
HEADMARKS : A325 & GENIUS SYMBOL

COUNTRY OF ORIGINAL : CHINA

PACKING NO : GEM121024007
INVOICE NO : GEM/PFC-121105 DA-1
PART NO : 00152-3232-024
SAMPLING PLAN : ASME B18.18.2
HEAT NO : 331201962
MATERIAL : 10B33
FINISH : H.T. HOT DIP GAL PER ASTM A153/ASTM F2329

PERCENTAGE COMPOSITION OF CHEMISTRY :

Chemistry	B%	C%	Mn%	P%	S%	Si%
Spec. : MIN.	0.0008	0.2900	0.7000			
MAX.	0.0030	0.3800	1.0000	0.0300	0.0300	0.4000
Test Value	0.0020	0.3300	0.8200	0.0170	0.0070	0.2100

DIMENSIONAL INSPECTIONS :
TEST DATE : 2012/09/29 SAMPLED BY : WANG YUN SAMPLING DATE : 2012/09/29

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
THREAD LENGTH	13 PCS	MIL-STD-120	35.06		37.020-37.190 MM	13	0
MAJOR DIAMETER	3 PCS	MIL-STD-120		18.680-19.010 MM	18.700-18.710 MM	3	0
BODY DIAMETER	3 PCS	MIL-STD-120		18.520-19.500 MM	18.610-18.640 MM	3	0
WIDTH ACROSS CORNERS	3 PCS	MIL-STD-120		35.130-36.650 MM	36.120-36.170 MM	3	0
HEIGHT	3 PCS	MIL-STD-120		11.560-12.260 MM	12.010-12.020 MM	3	0
NOMINAL LENGTH	13 PCS	MIL-STD-120		84.080-88.900 MM	85.610-85.640 MM	13	0
WIDTH ACROSS FLATS	13 PCS	MIL-STD-120		30.790-31.750 MM	30.910-30.960 MM	13	0
SURFACE DISCONTINUITIES	18 PCS	ASTM F812			PASSED	18	0
THREAD	3 PCS	MIL-STD-120		nut	PASSED	3	0

MECHANICAL PROPERTIES : ACCORDING TO ASTM A325
TEST DATE : 2012/09/16 SAMPLED BY : ZHANG YA QIANG SAMPLING DATE : 2012/09/16

INSPECTIONS ITEM	SAMPLE	TEST METHOD	REF	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
CORE HARDNESS	18 PCS	ASTM F606/F606M		25-34 HRC	29-31 HRC	18	0
TENSILE STRENGTH	13 PCS	ASTM F606/F606M		Min. 120 KSI	122-129 KSI	13	0

ALL TESTS ARE IN ACCORDANCE WITH THE METHODS PRESCRIBED IN THE APPLICABLE ASTM/SAE/ASME/MIL-STD-120 SPECIFICATION. WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.

THIS CERTIFIED MATERIAL TEST REPORT APPLIES TO THE SAMPLES TESTED AND IT CANNOT BE REPRODUCED EXCEPT IN FULL.

SIGNATURE : Jerry

page 1 of 1

NINGBO DONGXIN HIGH-STRENGTH NUT CO.,LTD

TEST CERTIFICATE (EN 10204.3.1)

TEL:0086-574-86531750 FAX:0086-574-86531751 www.d-x.com.cn dongxin@d-x.com.cn

Customer: BRIGHTON-BEST INTERNATIONAL	P/O NO.: B16100374	QTY(MP): 33.75		INVOICE NO: 17075DX228-018	
	Product Description: ASTM A194 2H Heavy Hex Nuts				
	Specification: 3/4"-10		T/O:0.51	Lot#: 1610DX228-0242	
	Material: 45K	Surface Finish: HDG		Heat No.: J11604926	
	Mark: DX,2HZN		Part Number:	313200	

Chemical Composition

Specification:ASTM A194-16

Element	C	Mn	P	S	Si
Requirement	≥0.40	≤1.00	≤0.04	≤0.05	≤0.40
Result	0.44	0.69	0.019	0.004	0.15

Mechanical Properties

Specification:ASTM A194-16

Test Item	Standard	Results	Sampling	Test method
Hardness after Treatment (540℃ 24h HRB)	MIN89	92-94	5	ASTM E18-14
Hardness HRC	24 - 35	27 - 31	4	ASTM E18-14
Proof loading LBF	58450	58736	3	ASTMA962/A962M-09

Dimensions

Specification:ASTM/ANSI/ASME B18.2.2.10

Test Item	Spec.	Inspection Results	Sampling	Rej	Remark	Test method
Widthacrossflats(mm)	30.78 - 31.75	31.24-31.42	125	0	OK	--------
Widthacrossangle(mm)	35.10 - 36.65	35.80-35.97	125	0	OK	--------
Height(mm)	18.03 - 19.25	18.52-18.72	125	0	OK	--------
Go Gauge	GO	GO	125	0	OK	ASTM B1.1-02
No-Go	NO GO	NO GO	125	0	OK	ASTM B1.1-02
Appearance	OK	OK	125	0	OK	ASTM F812-07

MACROETCH

Division	Surface Condition	Random Condition	Center Segregation	Spec. Of test method
Spec.	S2	R2	C3	ASTM E381
Results	S2	R2	C3	

NOTE: Test Standards:ASTM A194/A194M-2016/ WAF TO DIN934-1987 H=D (HEIGHT=1 DIAMETER) Standard Specification for Carbon and
Alloy Steel nuts.
Quench at 830℃ about 80 minutes, Tempering at 550℃ about 80 minutes
We hereby certify that all the above results are original from our actual testing, and the products have proved to comply with the relevant standards.
Signed on Behalf of Ningbo Dongxin High- Strength Nut Co., Ltd. Date:2017.02.27

(2)

宁波东鑫高强度螺母有限公司
NINGBO DONGXIN HIGH-STRENGTH NUT CO LTD

NUCOR
NUCOR STEEL JACKSON, INC.

Mill Certification
7/13/2018

MTR #: M1-169180
NUCOR STEEL JACKSON, INC.
3630 Fourth Street
Flowood, MS 39232
(601) 939-1623
Fax: (601) 936-6202

Sold To: TRIPLE S STEEL
PO BOX 21119
HOUSTON, TX 77226
(713) 697-7105
Fax: (713) 697-5945

Ship To: TRIPLE S STEEL
6000 JENSEN DR
HOUSTON, TX 77026
(713) 697-7105
Fax: (713) 697-5945

Customer P.O.	HOU-181268	Sales Order	351653.4
Product Group	Merchant Bar Quality	Part Number	537502002400- V0
Grade	A36/A529GR50/CSA44W/50W	Lot #	JW1810486001
Size	3/4x2" Flat	Heat #	JW18104860
Product	3/4x2" Flat 20' A36/A529-50/44W/50W	B.L. Number	M1-451203
Description	A36/A529-50/44W/50W	Load Number	M1-169180
Customer Spec		Customer Part #	

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Roll Date: 5/26/2018 Melt Date: 5/21/2018 Qty Shipped LBS: 4,900 Qty Shipped Pcs: 48

ASTM A36/A36M-12, A709/709M-13 GR36, ASME SA36-10 Ed '11 Ad.
ASME SA36-2010 EDITION-2011 ADDENDA
ASTM A709/A709M-13 GR 36 [250]

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	C
0.12%	0.82%	0.010%	0.032%	0.21%	0.23%	0.12%	0.12%	0.047%	0.0398%	0.0[illegible]%

Yield 1: 54,600psi	Tensile 1: 71,900psi	Elongation: 21% in 8"(in 203.3mm)
Yield 2: 54,200psi	Tensile 2: 71,700psi	Elongation 23% in 8"(in 203.3mm)

Specification Comments: MEETS THE REQUIREMENTS OF: ASTM A36/36M, ASTM A529/A529 GR50 ASTM A709/709M GR36/GR50 CSA G40.21 GR44W(300W)/GR50W(350W) AASHTO M270/M270M GR36 ASME SA36/SA36M MEETS THE EN10204 SEC 3.1 REPORTING REQUIREMENTS

1. ALL MANUFACTURING PROCESSES OF THE STEEL MATERIALS IN THIS PRODUCT, INCLUDING MELTING, HAVE OCCURRED WITHIN THE UNITED STATES.
2. ALL PRODUCTS PRODUCED ARE WELD FREE.
3. MERCURY, IN ANY FORM, HAS NOT BEEN USED IN THE PRODUCTION OR TESTING OF THIS MATERIAL.

Grant Etheredge
Division Metallurgist

NBMG-10 October 1, 2017

Page 1 of 1

ArcelorMittal Burns Harbor Plate

QUALITY ASSURANCE
REPORT OF TEST AND ANAYLSES

SHIPMENT NO: 8GA-10830

DATE SHIPPED: 07-16-18

CAR OR VEHICLE NO.: T MYRE

PAGE 1

SOLD TO:
INTSEL STEEL DISTRIBUTORS L P
11310 W LITTLE YORK RD
PO BOX 41041
HOUSTON TX 77241-1041

SHIP TO:
INTSEL STEEL DISTRIBUTORS LP
HOUSTON PRIME STOCK
11310 W LITTLE YORK RD
HOUSTON TX 77041

SERIAL NUMBER	PAT NO.	HEAT NUMBER	NO. PCS	THICKNESS	WIDTH OR DIA.	LENGTH	WEIGHT	YIELD POINT	TENSILE STRENGTH	ELONG.	RED.
				INCHES	INCHES	INCHES	POUNDS	PSI	PSI	IN %	%

NOTE:
QUALITY STEEL MELTED & MANUFACTURED IN THE U. S. A.
PLATES - AASHTO M270-15 GR 50 KLD FINE GRAIN
PRAC NO IMPACTS REQUIRED TYPE 2,
ASTM A709-13A GR 50, ASTM A572-06
GR 50, ASME SA572 GR 50 2013
EDITION
MFST - MFST MILL SERIAL# & PATTERN# MFST PROC ON
GH820-4412A LIFT MAX 15 TON-SIZES & GRADES SEP
UNLDG FORK LIFT-SIDE FOR ULTIMATE DELIVERY
LATER
CO# WLY-21710

GH 353-2276A

SERIAL NUMBER	PAT NO.	HEAT NUMBER	NO. PCS	THICKNESS	WIDTH OR DIA.	LENGTH	WEIGHT	YIELD POINT	TENSILE STRENGTH	ELONG.	RED.
J06236601		823B61780	1	.875	96	240	5717	56400	83300	8	25
								56800	83600	8	25
J06236602		823B61780	1	.875	96	240	5717	56400	83300	8	25
								56800	83600	8	25
J06236604		823B61780	1	.875	96	240	5717	56400	83300	8	25
								56800	83600	8	25

Q-QUENCH TEMPERATURE T-TEMPER TEMPERATURE N-NORMALIZE TEMPERATURE

SERIAL NUMBER	PAT NO.	HEAT NUMBER	HARD BHN	BEND	THICKNESS INCHES	TYPE	SIZE	DIR	TEST TEMP F	CHARPY IMPACT ENERGY FT LBS 1	2	3	SHEAR(%) 1	2	3	LAT. EXP MILS 1	2	3

CHEMICAL ANALYSIS

HEAT NUMBER	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Ti	Al	B	Cb	N	Sn	MCQUAID GRAIN SIZE
823B61780	.17	1.21	.021	.004	.268	.018	.01	.03	.004	.057	.002	.036	.0002	.002	.005	.001	

I certify that the above results are a true and correct copy of actual results contained in records maintained by ArcelorMittal Burns Harbor and are in full compliance with the requirements of the specification cited above. This test report connot be altered and must be transmitted intact with any subsequent third party test reports, if required.

BHPLTRPT.TIF

SUPV. QUALITY ASSURANCE ANDREW SMITH PER ELJ

SSAB

13609 Industrial Road, Houston, TX 77015, US

Test Certificate

Form TC1: Revision 2: Date 23 Apr 2014

Customer:
DELTA STEEL, INC.
5599 SAN FELIPE-STE 600
P.O BOX 2289
HOUSTON
TX 77252

Customer P.O.No.: DHO-154402
Mill Order No. 41-534177-01
Shipping Manifest: HT115299

Product Description: ASTM A36(14)/A709(17)36/ASME SA36(17)
AASHTO M270(15)36, 0.80-1.20 MN

Ship Date: 05 Mar 18
Cert Date: 05 Mar18
Cert No: 031204093
(Page 1 of 1)

Size: 0.188 X 96.00 X 240.0 (IN)

Tested Pieces:				Tensiles:							Charpy Impact Tests					
Heat Id	Piece Id	Piece Dimensions	Tst Loc	YS (KSI)	UTS (KSI)	%RA	Elong % 2in	Elong % 8in	Tst Dir	Hardness	Abs. Energy(FTLB) 1 2 3 Avg	% Shear 1 2 3 Avg	Tst Tmp	Tst Dir	Tst Siz (mm)	BDWTT Tmp %Shr
W8A519	0168	0.188 (T.L.C)	L	48	67		31		T							
			C	48	68		29		T							
W8A519	0186	0.188 (T.L.C)	L	48	66		29		T							
			C	49	68		28		T							
W8A522	0169	0.501 (T.L.C)	L	46	66		33		T							
			C	45	66		35		T							
W8A522	0212	0.188 (T.L.C)	L	52	71		28		T							
			C	53	71		28		T							

Chemical Analysis

Heat Id	C	Mn	P	S	Si	Tot Al	Cu	Ni	Cr	Mo	Cb	V	Ti	B	N	IIW	ORGN
W8A519	.17	.83	.011	.002	.04	.041	.29	.14	.11	.03	.001	.004	.015	.0001	.0089	.37	USA
W8A522	.19	.85	.013	<.001	.06	.042	.28	.14	.13	.04	.001	.004	.014	.0001	.0093	.39	USA

KILLED STEEL
MERCURY IS NOT A METALLURGICAL COMPONENT OF THE STEEL AND NO MERCURY WAS INTENTIONALLY ADDED DURING THE MANUFACTURE OF THIS PRODUCT.
CEV (IIW) = C + MN/6 + (CR+MO+V)/5 + (NI+CU)/15
MTR EN 10204:2004 INSPECTION CERTIFICATE 3.1 COMPLIANT
100% MELTED AND MANUFACTURED IN THE USA.
MATERIAL MARKED BELOW WITH AN ASTERISK IS PRODUCED FROM COIL
PRODUCTS SHIPPED:

* W8A519	0164	PCES:	2, LBS:	2456	* W8A519	0165	PCES:	30, LBS:	36840		
* W8A522	0209	PCES:	6, LBS:	7368							

(P) Cust Part #:

WE HEREBY CERTIFY THAT THIS MATERIAL WAS TESTED IN ACCORDANCE WITH, AND MEETS THE REQUIREMENTS OF, THE APPROPRIATE SPECIFICATION

Justin Ward
SENIOR METALLURGIST - PRODUCT

Doc No. 212726 Indexed 5Mar18 by sholman

계 약 번 호
P/O No. : D-HOU-178825

발 행 일 자
Date of Issue : 2018. 05. 21.

증 명 서 번 호
Certificatate No. : K - 18 - 09 - 04 - 2

제 품 명
Commodity : ERW STEEL STRUCTURAL TUBING

제품 규격
Spec. & Type : ASTM A500 Gr.B/C (REV. 2013)

검 사 증 명 서

INSPECTION CERTIFICATE

수 요 가
Customer : DOSCO AMERICA, INC.

주 문 자
Shipper :

DOSCO DONG - A STEEL CO., LTD.

* Head Office :
BusanBank Sasang Industrial Complex on the 2nd floor 901, Nakdong-daero, Sasang-gu, Busan, Republic of Korea
* Seoul Office : 507-1, Sihwa Industrial Complex 2ma, Jungwang-dong, Siheung City, Gyeonggi, Korea
* Taegu Office : 1767, Sangyok-dong, Buk-gu, Taegu, Korea

* Gwangyang Factory : 1653-12, Taein-dong, Gwangyang City, jeonranam-do, korea

치 수 Size (inch)	두께 Thickness (inch)	길이 Length (ft)	제품번호 Product No. (Lot No.)	수량 Quantity	총 길이 Total Lengh (ft)	인장 시험 Tensile Test (Min.) Y.P (psi)	T.S (psi)	E.L (%)	굽힘시험 Bending Test	편평시험 Flattening Test	표면상태 Surface Treatment	화 학 성 분(%) Chemical Composition (Max.) C	Si	Mn	P	S	제강번호 Heat No. (Coil No.)	비 고 Remarks
						50000	62000	21				0.270	-	1.4	0.045	0.045		
3 x 3	0.250	24	JCC13P91DV001	25	600	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
5 x 3	0.250	20	JCC08P91DV001	20	400	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
5 x 3	0.250	20	JCC08P91DV002	20	400	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
5 x 3	0.250	20	JCC08P91DV003	20	400	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
5 x 3	0.250	20	JCC08P91DV004	20	400	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
5 x 3	0.250	20	JCC08P91DV005	20	400	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
6 x 2	0.250	24	JCC30P51EV008	15	360	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
6 x 2	0.250	24	JCC30P51EV009	15	360	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
6 x 2	0.250	24	JCC30P51EV010	15	360	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
6 x 2	0.250	24	JCC30P51EV011	15	360	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
6 x 2	0.250	24	JCC30P51EV012	15	360	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
6 x 2	0.250	24	JCC30P51EV013	15	360	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
6 x 2	0.250	24	JCC30P51EV014	15	360	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
6 x 2	0.250	24	JCC30P51EV015	15	360	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
6 x 2	0.250	24	JCC30P51EV016	15	360	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
6 x 2	0.250	24	JCC30P51EV017	15	360	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
6 x 2	0.250	40	JCC30P51EV019	12	480	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
6 x 2	0.250	40	JCC30P51EV020	12	480	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
6 x 2	0.250	40	JCC30P51EV021	12	480	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
6 x 2	0.250	40	JCC30P51EV022	12	480	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	
6 x 2	0.250	40	JCC30P51EV023	12	480	56812	71774	25	-	Good	Oiled	0.1830	0.014	0.440	0.0135	0.0035	SP98280	

Surveyor To:

본 제품은 관련 규격의 시험을 행하여 합격하였음을 증명합니다.

We hereby certify that the material has been made in accordance with the order and specification.

Test Certificate is issued according to EN10204 3.1.

Gyong

Manager of material testing section YEO G.Y.

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.:3079675 SECTION: REBAR 13MM (#4) 40'0" 420/60 GRADE: ASTM A615-16 Gr 420/60 ROLL DATE: 04/25/2018 MELT DATE: 04/25/2018 Cert. No.: 82374860 / 079675A371	SOLD TO	CMC Rebar Houston-West BRITTMOORE RD. HOUSTON TX US 77043-2208 713-690-0347	SHIP TO	CMC Sterling Steel 2001 Brittmoore Rd Houston TX US 77043-2208 7136900347 7136905758

Delivery#: 82374860
BOL#: 72461341
CUST PO#:
CUST P/N:
DLVRY LBS / HEAT: 13254.000 LB
DLVRY PCS / HEAT: 496 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.41%				
Mn	0.81%				
P	0.011%				
S	0.048%				
Si	0.18%				
Cu	0.32%				
Cr	0.16%				
Ni	0.16%				
Mo	0.056%				
V	0.000%				
Cb	0.002%				
Sn	0.011%				
Al	0.000%				
Yield Strength test 1	62.8ksi				
Tensile Strength test 1	99.4ksi				
Elongation test 1	13%				
Elongation Gage Lgth test 1	8IN				
Bend Test Diameter	1.750IN				
Bend Test 1	Passed				

The Following is true of the material represented by this MTR:
- *Material is fully killed*
- *100% melted and rolled in the USA*
- *EN10204:2004 3.1 compliant*
- *Contains no weld repair*
- *Contains no Mercury contamination*
- *Manufactured in accordance with the latest version of the plant quality manual*
- *Meets the "Buy America" requirements of 23 CFR635.410*

REMARKS :

04/27/2018 00:45:21
Page 1 OF 1

MATERIAL TEST REPORT

Date Printed: 05/02/2018

Mid American Steel & Wire

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: 4501221760
Ship Date: 05/02/2018
Order Number: 93623
Load Number: 117909

Item Number	Description
4REBAR	# 4 GRADE 60 COILED REBAR

CHEMICAL ANALYSIS

Heat Number	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	V	Al	N	Nb
1820634	0.4300	0.9000	0.0150	0.0220	0.2400	0.2400	0.1700	0.2500	0.0500	0.0130	0.0020	0.0040	0.0082	0.0003

MECHANICAL PROPERTIES

Heat Number	Yield (Psi/Mpa)	Tensile (Psi/Mpa)	Elongation (% 8" guage)	Bend Test Pass/Fail
1820634	68590 psi / 473 Mpa	116653 psi / 805 Mpa	13.27	Pass

I hereby certify that the above test results are correct as contained in the records of the company. All Manufacturing processes of the steel materials in this product, including melting have occurred in the United States. The material was produced and tested according to ASTM A615/A615M-065.

Quality Assurance:

MATERIAL TEST REPORT

Date Printed: 03/28/2018

Mid American Steel & Wire
Madill, Oklahoma

Customer No: 000000006015
PO Number: 4501201440
Ship Date: 03/28/2018
Order Number: 92187
Load Number: 116527

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

Ship to:
CMC REBAR
2001 BRITTMOORE
HOUSTON, TX 77043

Item Number	Description
5REBAR	# 5 GRADE 60 COILED REBAR

CHEMICAL ANALYSIS

Heat Number	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	Sn	V	Al	N	Nb
1723630	0.4600	0.8700	0.0170	0.0260	0.2000	0.2100	0.1100	0.1900	0.0300	0.0110	0.0030	0.0010	0.0067	0.0005

MECHANICAL PROPERTIES

Heat Number	Yield (Psi/Mpa)	Tensile (Psi/Mpa)	Elongation (% 8" guage)	Bend Test Pass/Fail
1723630	62474 psi / 431 Mpa	108254 psi / 747 Mpa	11.71	Pass

I hereby certify that the above test results are correct as contained in the records of the company. All Manufacturing processes of the steel materials in this product, including melting have occurred in the United States. The material was produced and tested according to ASTM A615/A615M-065.

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.:3079087 SECTION: REBAR 16MM (#5) 40'0" 420/60 B096 GRADE: ASTM A615-16 Gr 420/60 ROLL DATE: 04/06/2018 MELT DATE: 04/03/2018 Cert. No.: 82359116 / 079087A236	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#: 82359116 BOL#: 72437512 CUST PO#: CUST P/N: DLVRY LBS / HEAT: 48060.000 LB DLVRY PCS / HEAT: 1152 EA	

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.41%				
Mn	0.82%				
P	0.013%				
S	0.049%				
Si	0.19%				
Cu	0.34%				
Cr	0.20%				
Ni	0.20%				
Mo	0.088%				
V	0.000%				
Cb	0.002%				
Sn	0.012%				
Al	0.002%				
Yield Strength test 1	69.3ksi				
Tensile Strength test 1	106.4ksi				
Elongation test 1	14%				
Elongation Gage Lgth test 1	8IN				
Bend Test Diameter	2.188IN				
Bend Test 1	Passed				

The Following is true of the material represented by this MTR:

*Material is fully killed
*100% melted and rolled in the USA
*EN10204:2004 3.1 compliant
*Contains no weld repair
*Contains no Mercury contamination
*Manufactured in accordance with the latest version of the plant quality manual
*Meets the "Buy America" requirements of 23 CFR635.410

REMARKS :

04/09/2018 15:29:41
Page 1 OF 1

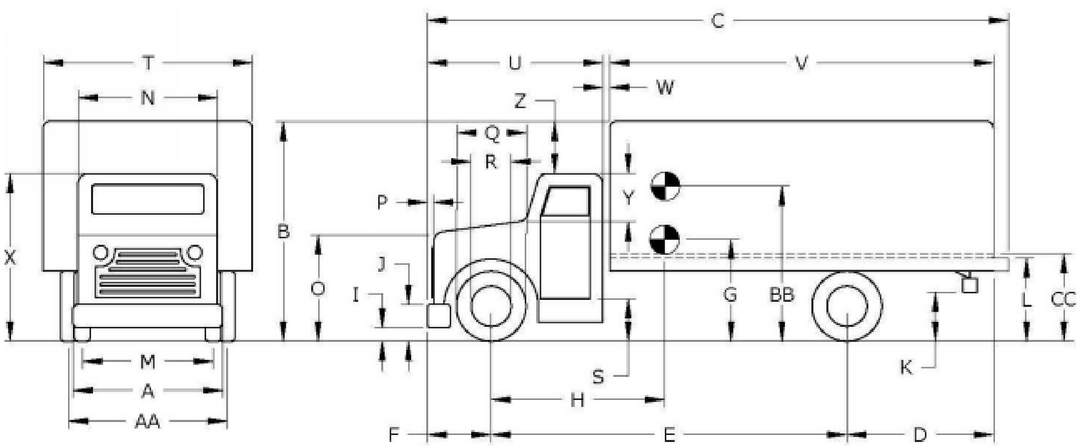
A.3. *MASH* TEST X-XX (CRASH TEST NO. 469469-1)

A.3.1. Sequential Photographs

Table A.1. Vehicle Properties for Test No. 469469-1.

Vehicle Inventory Number: 1355

Date:	2018-10-17	Test No.:	469469-1-1	VIN No.:	IHTMMAAXXBH388433
Year:	2011	Make:	INTERNATIONAL	Model:	4300
Odometer:	142106	Tire Size Front:	275/80R22.5	Tire Size Rear:	275/80R22.5



Vehicle Geometry: ☑ inches or ☐ mm

A	Front Bumper Width:	95.00	K	Rear Bumper Bottom:		U	Cab Length:	106.00
B	Overall Height:	146	L	Rear Frame Top:	37.00	V	Trailer/Box Length:	223.00
C	Overall Length:	328.25	M	Front Track Width:	80.00	W	Gap Width:	3.00
D	Rear Overhang:	87.50	N	Roof Width:	71.00	X	Overall Front Height:	98.50
E	Wheel Base:	204.75	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:	35.00
G	C.G. Height:		Q	Front Tire Width:	39.00	AA	Rear Track Width:	73.00
H	C.G. Horizontal Dist. w/Ballast:	127.07	R	Front Wheel Width:	23.50	BB	Ballast Center of Mass:	62.50
I	Front Bumper Bottom:	19.00	S	Bottom Door Height:	37.50	CC	Cargo Bed Height:	50.00
J	Front Bumper Top:	34.00	T	Overall Width:	96.00			

Allowable Range: C = 394 inches max.; E = 240 inches max.; CC = 51 ±2 inches; BB = 63 ±2 inches above ground;

Wheel Center Height Front	19.00	Wheel Well Clearance (Front)	9.00	Bottom Frame Height (Front)	25.50
Wheel Center Height Rear	19.00	Wheel Well Clearance (Rear)	5.25	Bottom Frame Height (Rear)	27.00

More information needed on next page

Table A.2. Measurements of Vehicle Vertical CG for Test No. 469469-1.

Vehicle Inventory Number: 1355

Date:	2018-10-17	Test No.:	469469-1-1	VIN No.:	IHTMMAAXXBH388433
Year:	2011	Make:	INTERNATIONAL	Model:	4300

WEIGHTS
(☑ lb or ☐ kg)

	CURB	TEST INERTIAL
$W_{front\ axle}$	7240	8430
$W_{rear\ axle}$	6950	13790
W_{TOTAL}	14190	22220

Allowable Range for CURB = 13,200 ±2200 lb | Allowable Range for TIM = 22,046 ±660 lb

Ballast: 8030 (☑ lb or ☐ kg) **(as-needed)** **(See *MASH* Section 4.2.1.2 for recommended ballasting)**

Mass Distribution
(☑ lb or ☐ kg): **LF:** 4110 **RF:** 4320 **LR:** 7110 **RR:** 6680

Engine Type: MAXX FORCE

Engine Size: 466

Transmission Type:

☑ Auto or ☐ Manual

☐ FWD ☑ RWD ☐ 4WD

Accelerometer Locations (☑ inches or ☐ mm)

	x[1]	y	z[2]
Front:			
Center:	127.00	0.00	50.00
Rear:	227.00	0.00	50.00

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 1 H30" W 60" L30"
BLOCK 2 H30" W 60" L30"
CENTERED IN MIDDLE OF BED
62.5 FROM CENTER OF BLOCK TO GROUND
4 5/16" CABLES PER BLOCK

Performed by: SCD Date: 2018-10-17

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

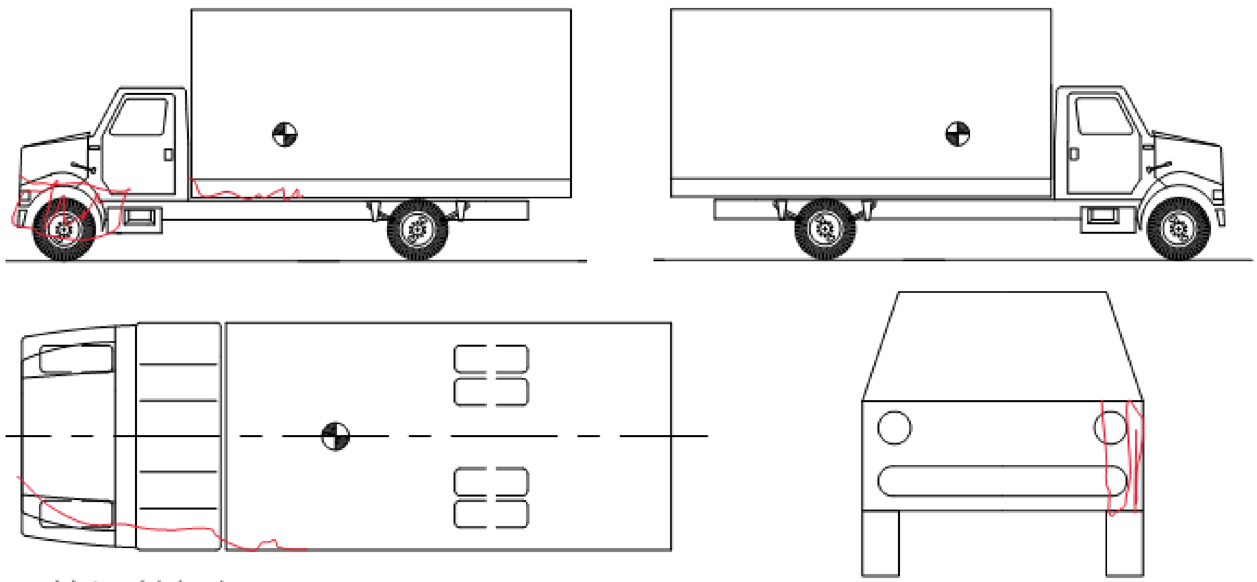
Table A.3. Exterior Crush Measurements of Vehicle for Test No. 469469-1.

		Vehicle Inventory Number:	1355		
Date:	2018-10-17	Test No.:	469469-1-1	VIN No.:	IHTMMAAXXBH388433
Year:	2011	Make:	INTERNATIONAL	Model:	4300
				Mileage:	142106

Please shade damage areas and note type of damage.

Driver's Side

Passenger Side



List vehicle damage:			
FT BUMPER	Max Exterior Crush:	14.00	inches
HOOD	Location:	FT LT CORNER	
LT HEAD LIGHT	Max Interior Deformation:	5.50	inches
LT FT TIRE & RIM	Location:	FT LT CORNER OF FLOOR PAN	
LT FT SPRING & U-BOLTS			
LT SIDE STEP			
LT FT CORNER OF FLOOR PAN			
LT FT CORNER OF BOX			
LT REAR OUTTER TIRE & RIM			

Performed by:	SCD	Date:	2018-10-17

A.3.2. Sequential Photographs

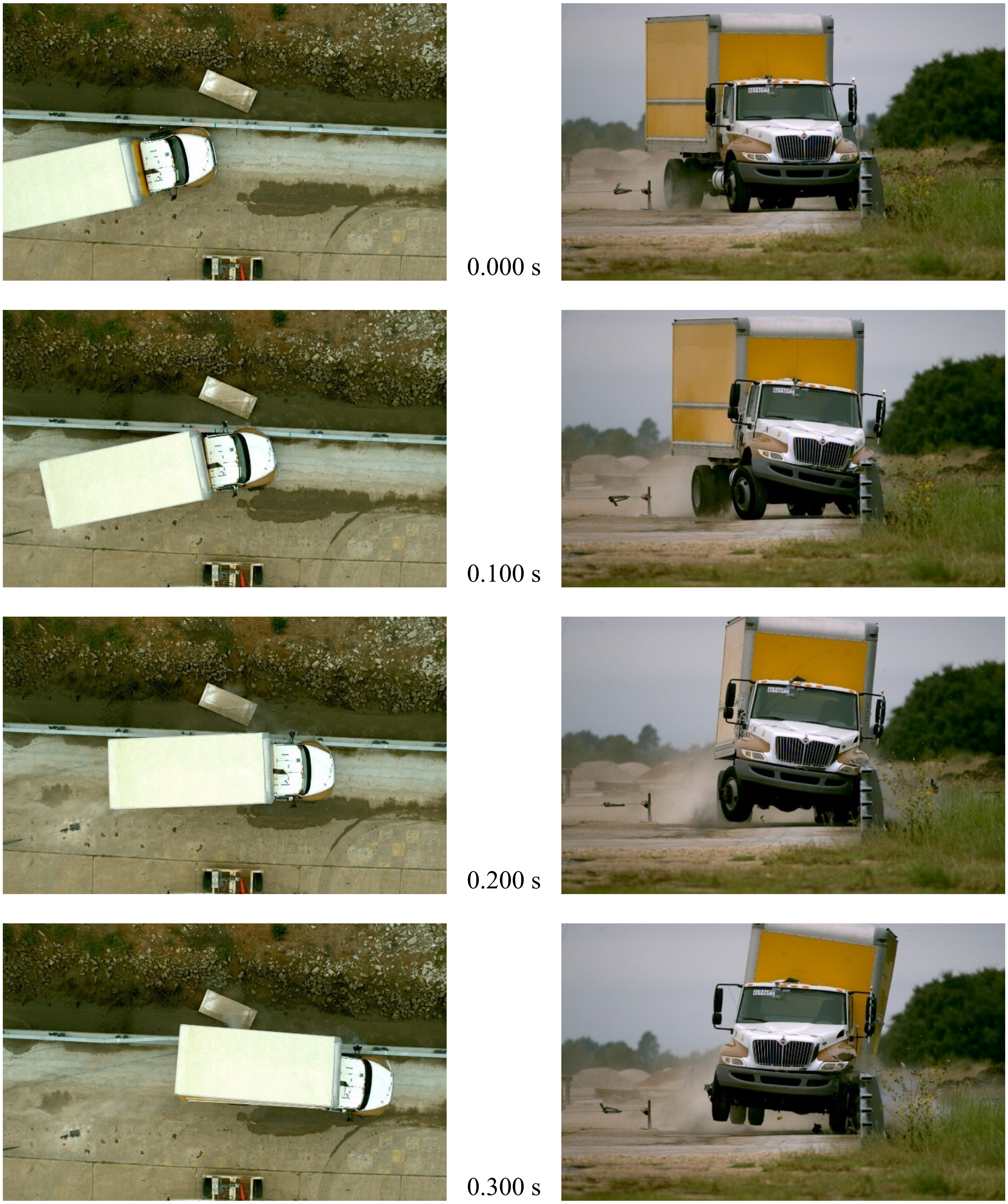


Figure A.1. Sequential Photographs for Test No. 469469-1 (Overhead and Gut Views).

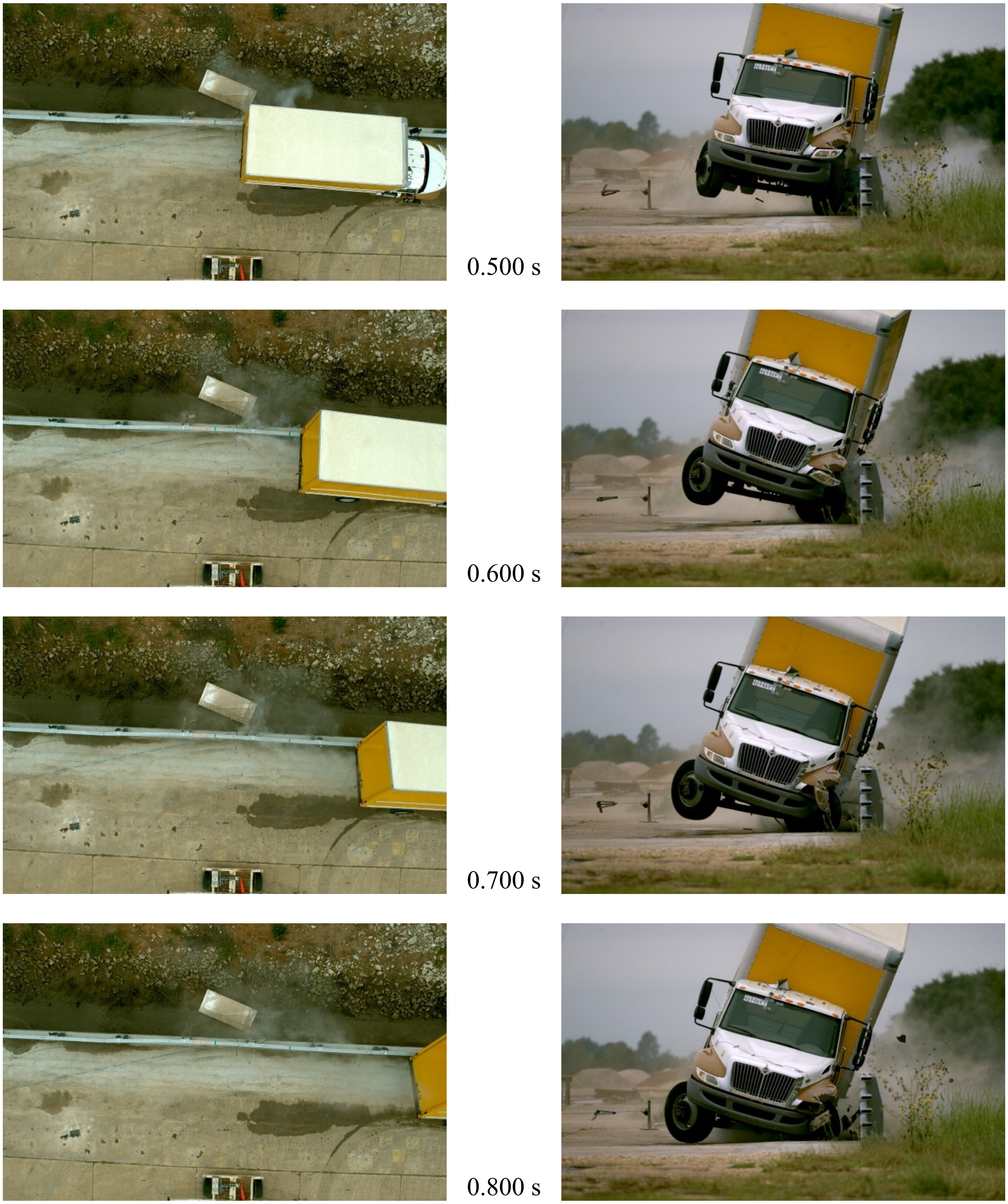


Figure A.1. Sequential Photographs for Test No. 469469-1 (Overhead and Gut Views) (Continued).


0.000 s


0.100 s


0.200 s


0.300 s


0.400 s

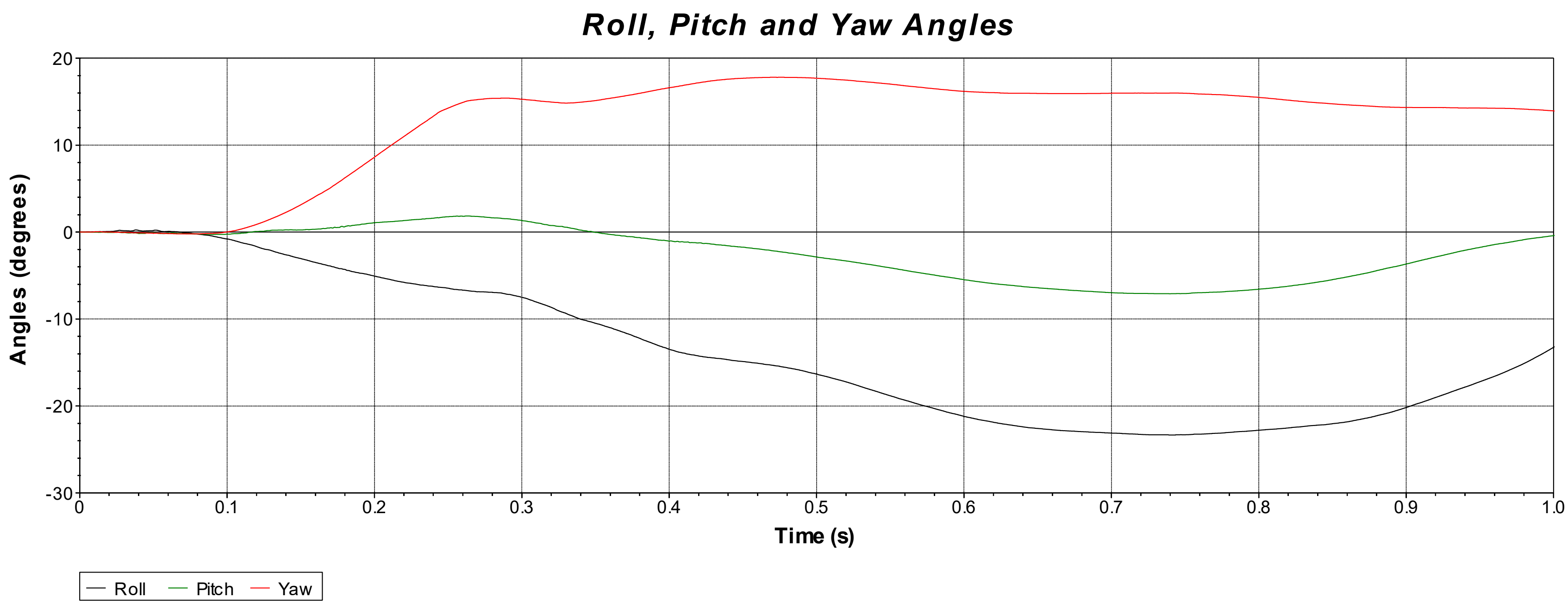

0.500 s


0.600 s


0.700 s

Figure A.2. Sequential Photographs for Test No. 469469-1 (Rear View).

A.3.3. Vehicle Angular Displacement



Test Number: 469469-1
Test Standard: 4-12
Test Article: C1W
Test Vehicle: 10000S Box Van
Inertial Mass: 22,220 lb
Gross Mass: 22,220 lb
Impact Speed: 56 mi/h
Impact Angle: 14.0 degrees

Axes are vehicle-fixed.
Sequence for determining orientation:

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

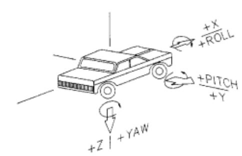
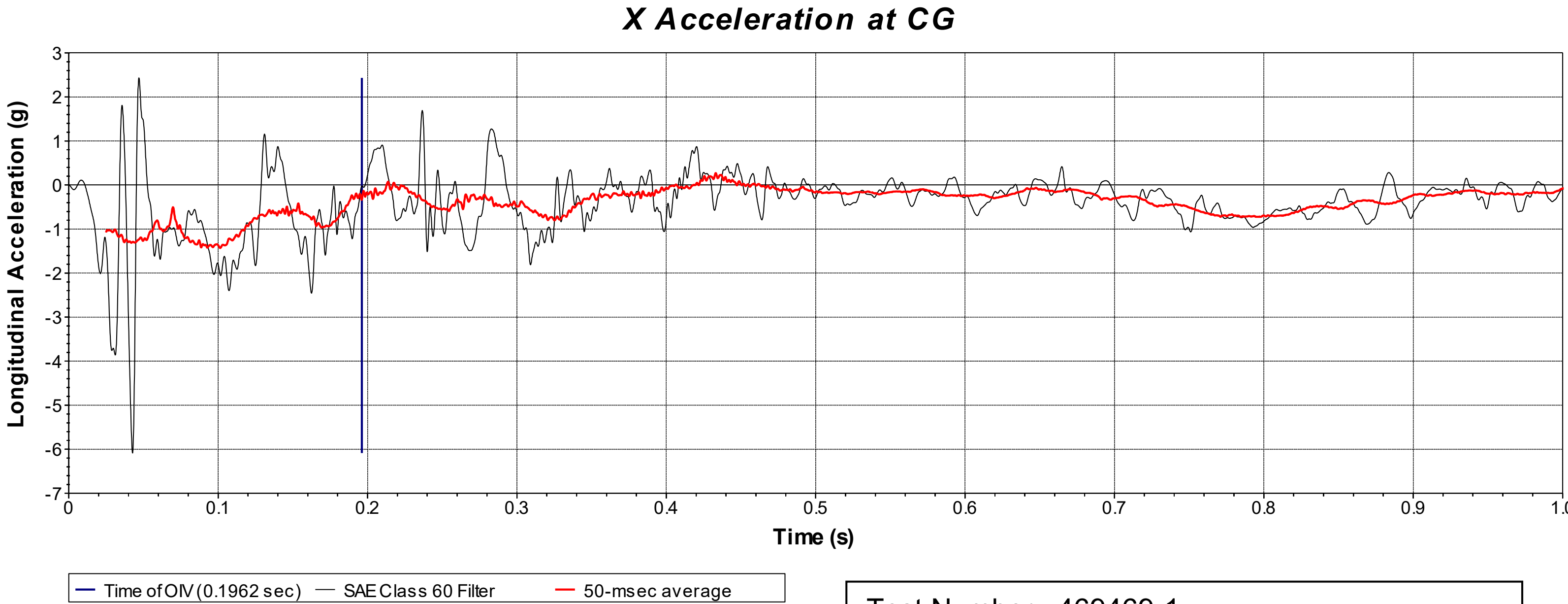


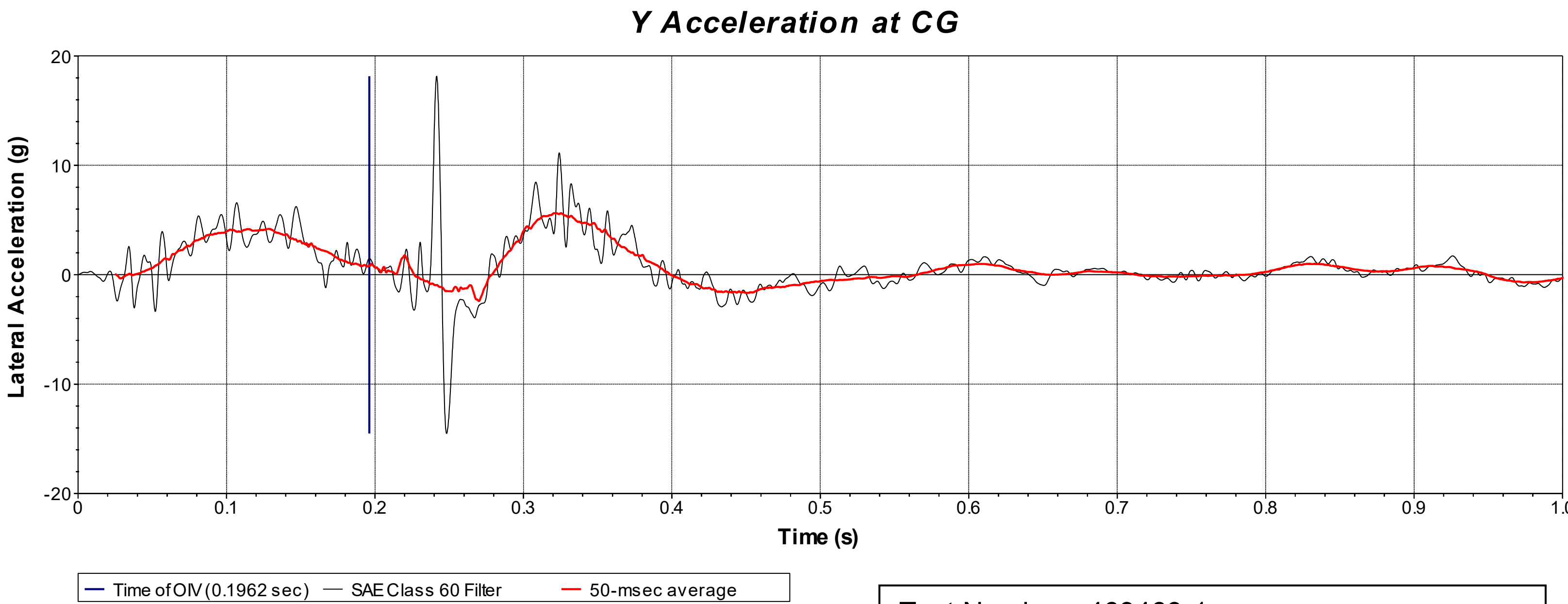
Figure A.3. Vehicle Angular Displacements for Test No. 469469-1.

A.3.4. Vehicle Acceleration



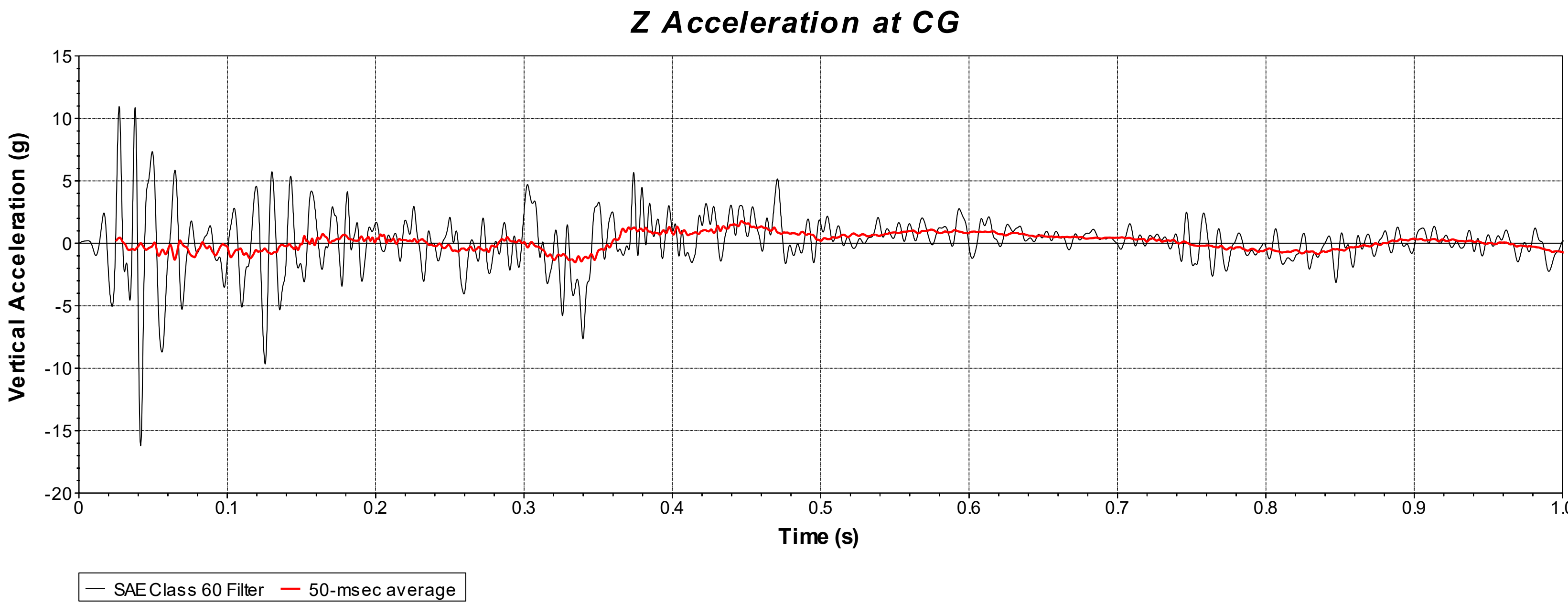
Test Number: 469469-1
Test Standard: 4-12
Test Article: C1W
Test Vehicle: 10000S Box Van
Inertial Mass: 22,220 lb
Gross Mass: 22,220 lb
Impact Speed: 56 mi/h
Impact Angle: 14.0 degrees

Figure A.4. Vehicle Longitudinal Accelerometer Trace for Test No. 469469-1 (Accelerometer Located at Center of Gravity).



Test Number: 469469-1
Test Standard: 4-12
Test Article: C1W
Test Vehicle: 10000S Box Van
Inertial Mass: 22,220 lb
Gross Mass: 22,220 lb
Impact Speed: 56 mi/h
Impact Angle: 14.0 degrees

Figure A.5. Vehicle Lateral Accelerometer Trace for Test No. 469469-1 (Accelerometer Located at Center of Gravity).

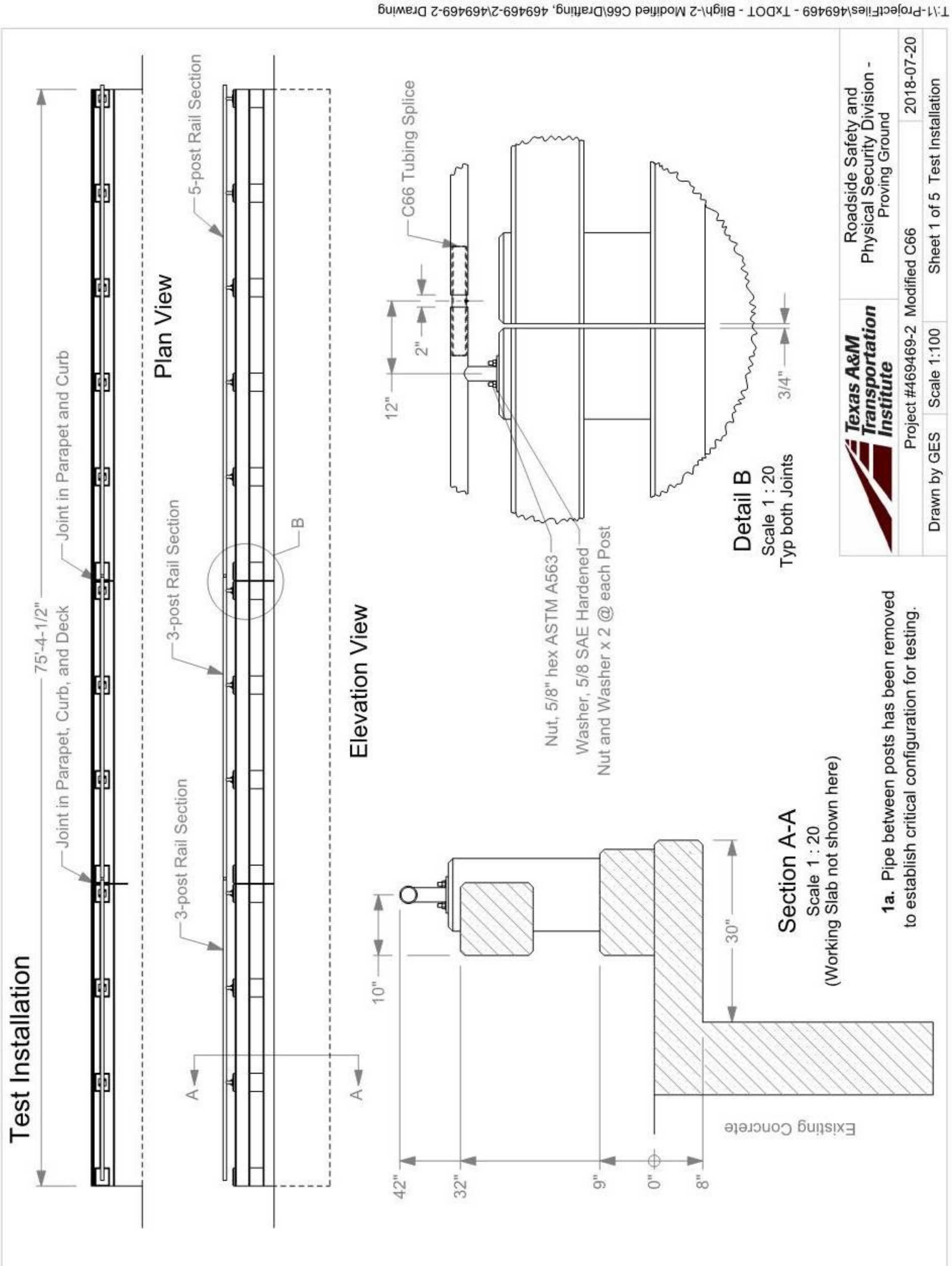


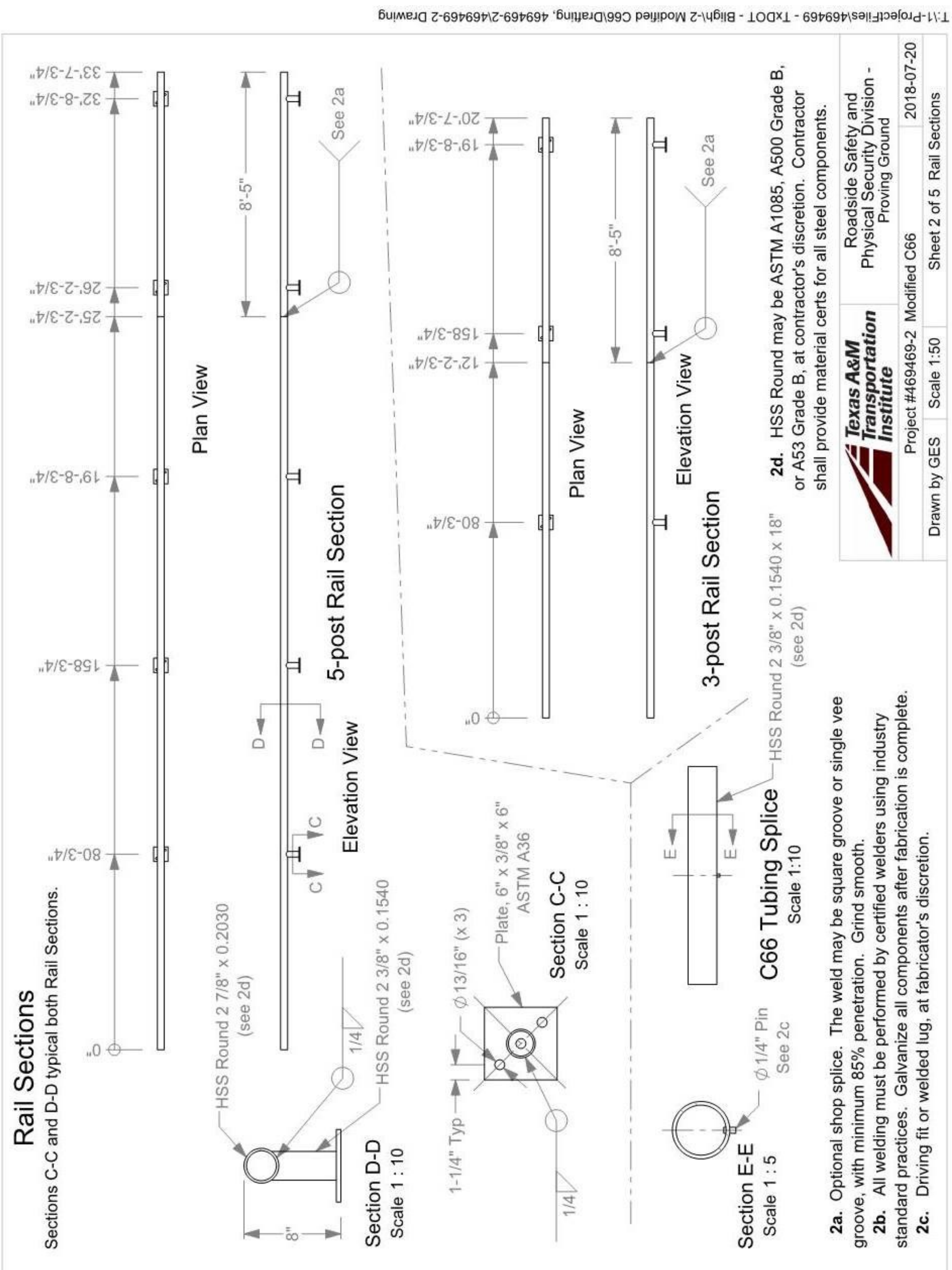
Test Number: 469469-1
Test Standard: 4-12
Test Article: C1W
Test Vehicle: 10000S Box Van
Inertial Mass: 22,220 lb
Gross Mass: 22,220 lb
Impact Speed: 56 mi/h
Impact Angle: 14.0 degrees

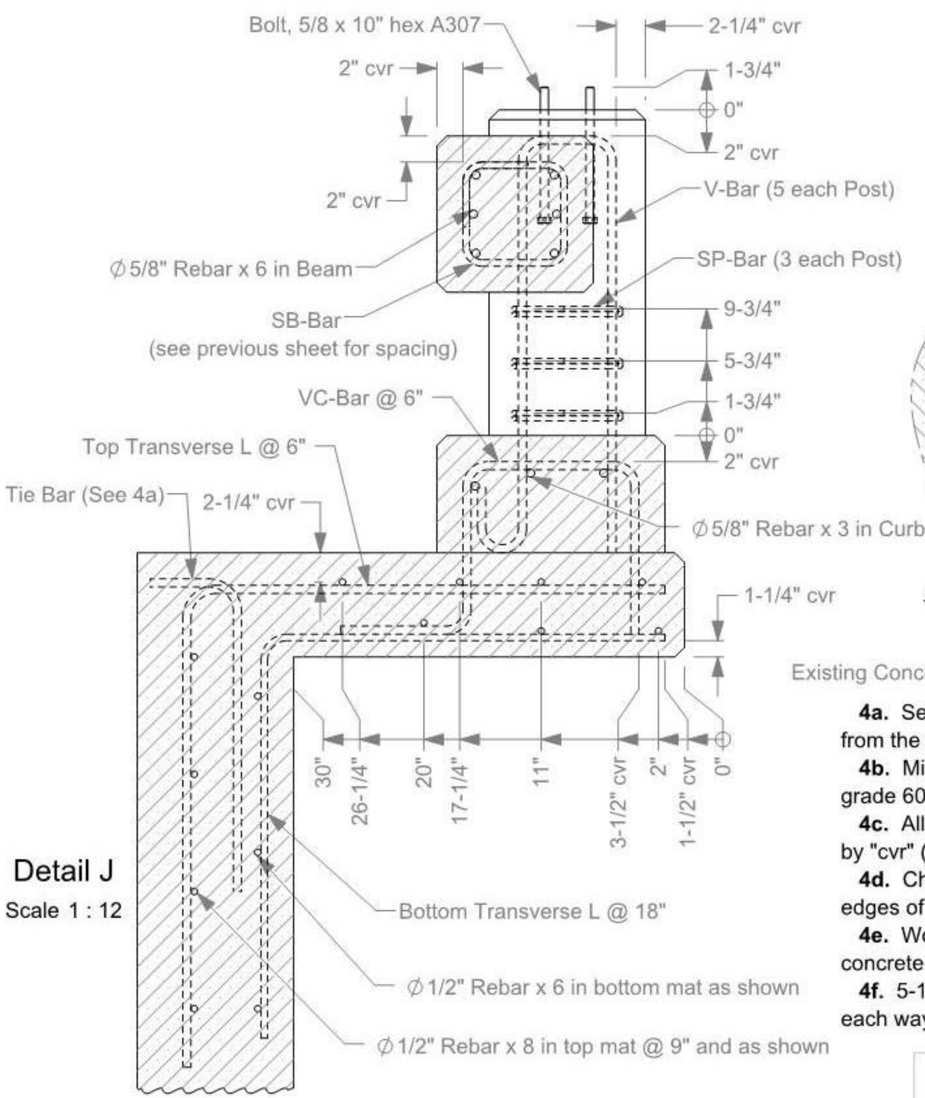
Figure A.6. Vehicle Vertical Accelerometer Trace for Test No. 469469-1 (Accelerometer Located at Center of Gravity).

APPENDIX B. TXDOT MODIFIED C66 BRIDGE RAIL

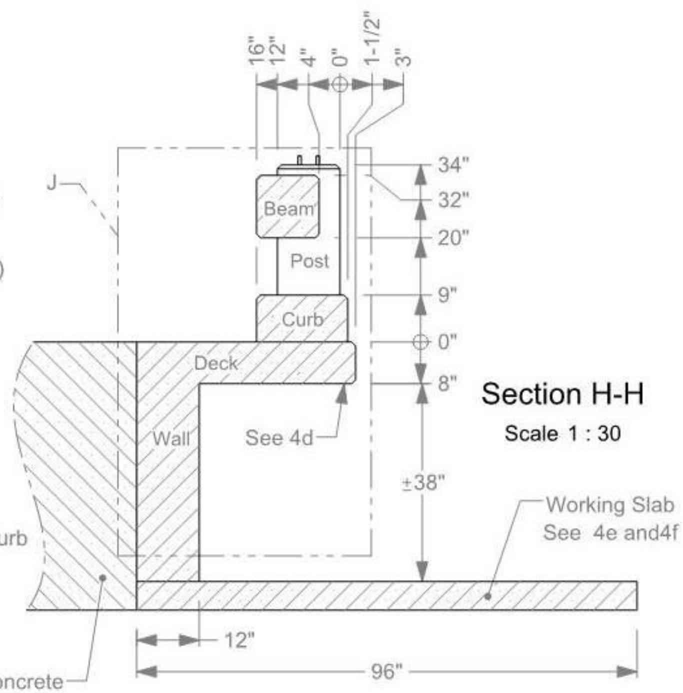
B.1. DETAILS OF THE MODIFIED C66 BRIDGE RAIL




T:\1-ProjectFiles\469469 - TxDOT - Bligh\-2 Modified C66\Drafting, 469469-2\469469-2 Drawing
Rail Sections
Sections C-C and D-D typical both Rail Sections.
0"
80-3/4"
158-3/4"
19'-8-3/4"
25'-2-3/4"
26'-2-3/4"
32'-8-3/4"
33'-7-3/4"
Plan View
8'-5"
See 2a
HSS Round 2 7/8" x 0.2030 (see 2d)
HSS Round 2 3/8" x 0.1540 (see 2d)
1/4
8"
Section D-D
Scale 1 : 10
Elevation View
5-post Rail Section
C
C
D
D
1-1/4" Typ
Ø 13/16" (x 3)
Plate, 6" x 3/8" x 6"
ASTM A36
1/4
Section C-C
Scale 1 : 10
Ø 1/4" Pin
See 2c
Section E-E
Scale 1 : 5
E
E
HSS Round 2 3/8" x 0.1540 x 18" (see 2d)
C66 Tubing Splice
Scale 1:10
0"
80-3/4"
12'-2-3/4"
158-3/4"
19'-8-3/4"
20'-7-3/4"
Plan View
8'-5"
See 2a
Elevation View
3-post Rail Section
2a. Optional shop splice. The weld may be square groove or single vee groove, with minimum 85% penetration. Grind smooth.
2b. All welding must be performed by certified welders using industry standard practices. Galvanize all components after fabrication is complete.
2c. Driving fit or welded lug, at fabricator's discretion.
2d. HSS Round may be ASTM A1085, A500 Grade B, or A53 Grade B, at contractor's discretion. Contractor shall provide material certs for all steel components.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #469469-2
Modified C66
2018-07-20
Drawn by GES
Scale 1:50
Sheet 2 of 5
Rail Sections



Detail J
Scale 1 : 12



Section H-H
Scale 1 : 30

4a. Secure each Tie Bar to existing rebar (not shown here) protruding from the runway with a minimum 3" weld. Maximum spacing is 18".

4b. Minimum rebar lap is 19" for #4 bars and 24" for #5 bars. All rebar is grade 60.

4c. All rebar dimensions are to center of bar unless otherwise indicated by "cvr" (cover).

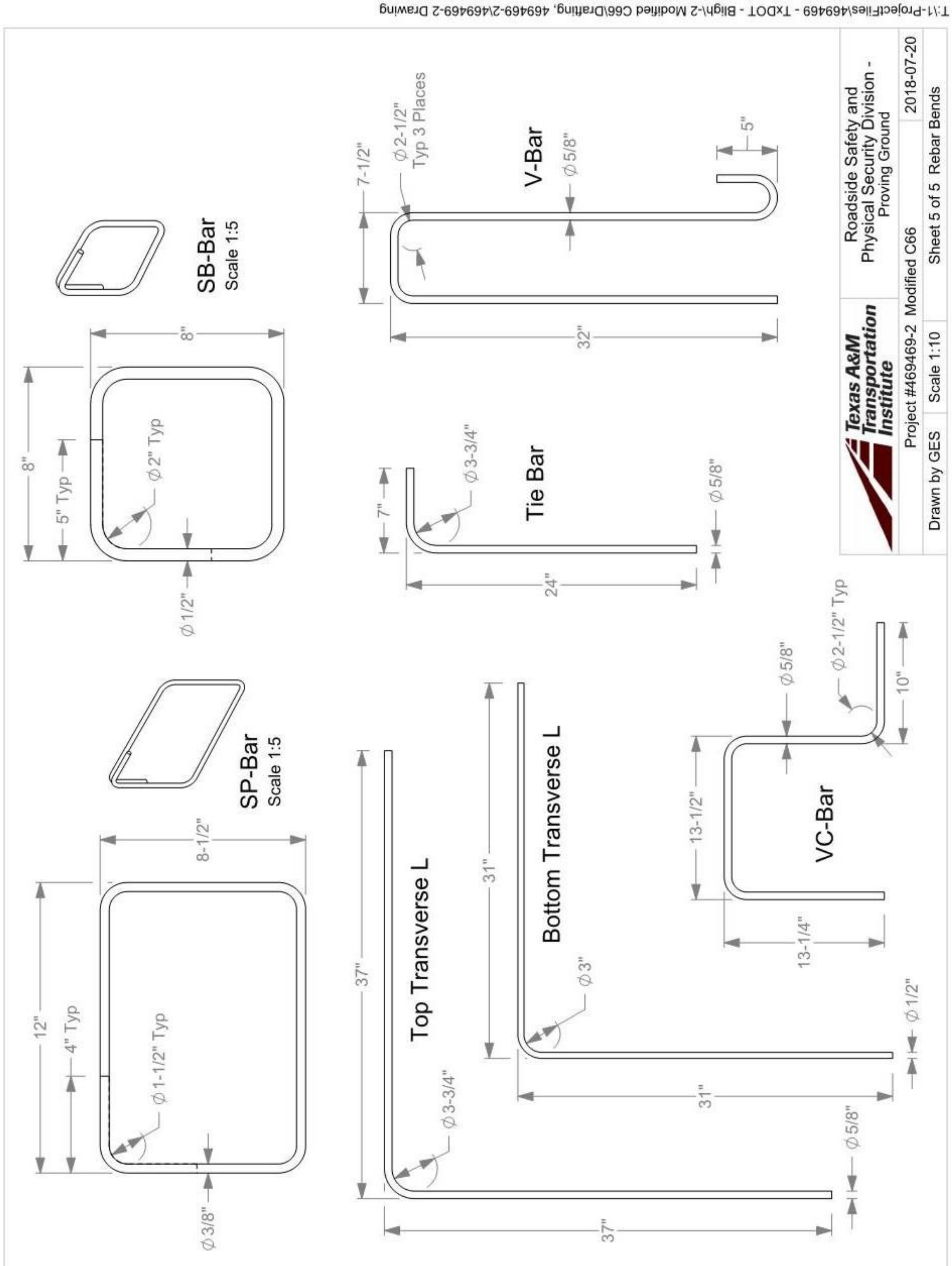
4d. Chamfer top edges of Posts, horizontal edges of Beam, and exposed edges of Curb and Deck 3/4" each way, as shown.

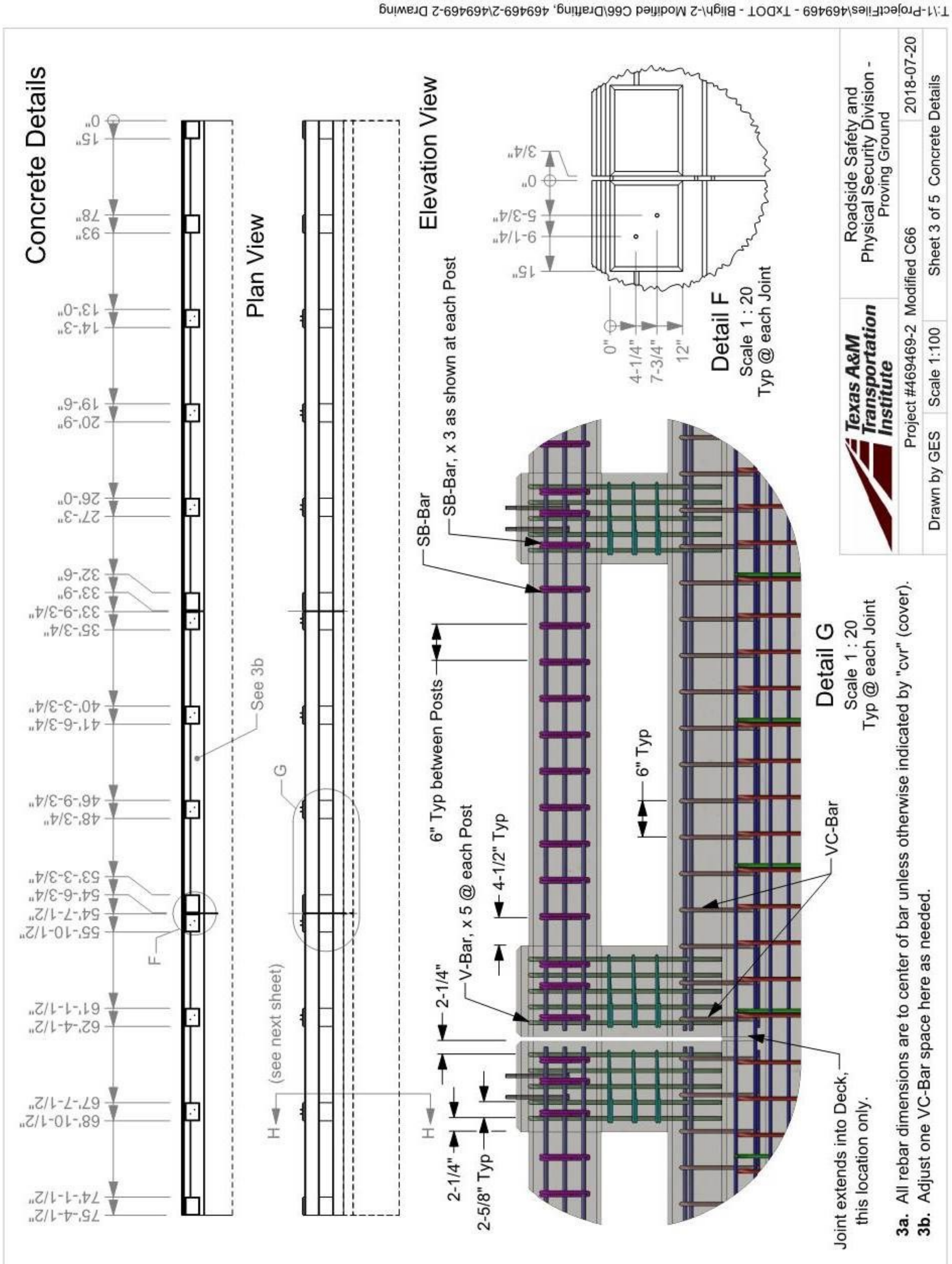
4e. Working Slab concrete stength is minimum 3000 psi. All other concrete (Deck, Wall, Curb, Posts, and Beam) is TxDOT Class S (4000 psi).

4f. 5-1/2" thick. One layer of #4 rebar (not shown here) spaced @ 12" each way, with 1-1/2" cover at top.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #469469-2 Modified C66		2018-07-20
Drawn by GES	Scale 1:30	Sheet 4 of 5 Section View

T:\1-ProjectFiles\469469 - TxDOT - Bligh\-2 Modified C66\Drafting, 469469-2\469469-2 Drawing


T:\1-ProjectFiles\469469 - TxDOT - Bligh\-2 Modified C66\Drafting, 469469-2\469469-2 Drawing
SB-Bar
Scale 1:5
SP-Bar
Scale 1:5
V-Bar
Tie Bar
Top Transverse L
Bottom Transverse L
VC-Bar
Roadside Safety and Physical Security Division - Proving Ground
Texas A&M Transportation Institute
Project #469469-2 Modified C66
2018-07-20
Drawn by GES
Scale 1:10
Sheet 5 of 5 Rebar Bends



T:\1-ProjectFiles\469469 - TxDOT - Bligh\-2 Modified C66\Drafting, 469469-2\469469-2 Drawing
Concrete Details
0"
15"
7'8"
9'3"
13'-0"
14'-3"
19'-6"
20'-9"
26'-0"
27'-3"
32'-6"
33'-9"
33'-9-3/4"
35'-3/4"
40'-3-3/4"
41'-6-3/4"
46'-9-3/4"
48'-3/4"
53'-3-3/4"
54'-6-3/4"
54'-7-1/2"
55'-10-1/2"
61'-1-1/2"
62'-4-1/2"
67'-7-1/2"
68'-10-1/2"
74'-1-1/2"
75'-4-1/2"
F
See 3b
Plan View
(see next sheet)
G
H
H
Elevation View
3/4"
0"
5-3/4"
9-1/4"
15"
0"
4-1/4"
7-3/4"
12"
Detail F
Scale 1 : 20
Typ @ each Joint
SB-Bar
SB-Bar, x 3 as shown at each Post
6" Typ between Posts
6" Typ
V-Bar, x 5 @ each Post
4-1/2" Typ
2-1/4"
2-1/4"
2-5/8" Typ
VC-Bar
Detail G
Scale 1 : 20
Typ @ each Joint
Joint extends into Deck, this location only.
3a. All rebar dimensions are to center of bar unless otherwise indicated by "cvr" (cover).
3b. Adjust one VC-Bar space here as needed.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #469469-2 Modified C66
2018-07-20
Drawn by GES
Scale 1:100
Sheet 3 of 5 Concrete Details

B.2. 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	QF 7.3-01 Concrete Sampling	Doc. No. QF 7.3-01	Issue Date: 2018-06-18
Quality Form	Prepared by: Wanda L. Menges Approved by: Darrell L. Kuhn	Revision: 6	Page: 1 of 1

The information contained in this document is confidential to TTI Proving Ground.

Project No: 469469-2 **Casting Date:** 2018-05-27 **Mix Design (psi):** 4000

Name of Technician Taking Sample: Greg Fritz

Name of Technician Breaking Sample: Greg Fritz

Signature of Technician Taking Sample: [signature]

Signature of Technician Breaking Sample: [signature]

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	35Rental2	0024184	North Wall & Deck (48' From North)
T2	350133	0045695	South Wall & Deck (28' From South)

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
T1	2018-10-31	34 DAYS	165,000	5835	
			172,000	6085	5990
			171,000	6,050	
T2			163,000	5765	
			166,000	5870	5810
			164,000	5,800	

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	QF 7.3-01 Concrete Sampling	Doc. No. QF 7.3-01	Issue Date: 2018-06-18
Quality Form	Prepared by: Wanda L. Menges Approved by: Darrell L. Kuhn	Revision: 6	Page: 1 of 1

The information contained in this document is confidential to TTI Proving Ground

Project No: 469469-2 **Casting Date:** 2018-10-2 **Mix Design (psi):** 4000

Name of Technician Taking Sample: Bill Griffith

Name of Technician Breaking Sample: GREG FRITZ

Signature of Technician Taking Sample:

Signature of Technician Breaking Sample:

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	350070	0024283	Full Curb

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
T1	2018-10-31	29 DAYS	137,000	4845	
↓	↓	↓	131,000	4635	4,695
			130,000	4,600	

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	QF-7.3-01 Concrete Sampling	Doc. No. QF-7.3-01	Issue Date: 2018-06-18
Quality Form	Prepared by: Wanda L. Menges Approved by: Darrell L. Kuhn	Revision: 6	Page: 1 of 1

The information contained in this document is confidential to TTI Proving Ground.

Project No: 465465-2 **Casting Date:** 2018-10-04 **Mix Design (psi):** 4000

Name of Technician Taking Sample: Bill Griffith

Name of Technician Breaking Sample: Greg Fritz

Signature of Technician Taking Sample: [signature]

Signature of Technician Breaking Sample:

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	350121	0024288	Columns + Parapet 100%

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
T1	2018-10-31	27 DAYS	147,000	5,200	
↓	↓	↓	138,000	4,880	5,185
			155,000	5,480	

KNIFE RIVER
AN MDU RESOURCES COMPANY

SOUTH REGION/MAIN OFFICE
6310 State Highway 21 West
Bryan, TX 77807
PH: (979) 361-2900
FAX: (979) 361-2920

RB 0024184

Riverbend

TUCKER CONSTRUCTION
7425 MIZE RD
BRYAN

Disp Order#: 2023

TTI C66 MODIFIED RAIL
LF 47 LF INTO RELIS CAMPUS STAY
RT AVE D TAKE A LF AND GO THRU
THE SECURITY GATE(CODE 17965#)
STRAIGHT TO JOB BY THE RUN WAY

PO#

TIME	FORMULA	LOAD SIZE	YARDS ORDERED		DRIVER/TRUCK		PLANT TRANSACTION #
9:11:28	39CLSCMT	10.00	50.00		B'S TRANS	39RENTAL2	
DATE	**PROJECT**	**LOAD #**	**YARDS DEL**	**BATCH #**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
09/27/18	TTIRAIL	2	20.00			5.00 in	20015312

WARNING
IRRITATING TO THE SKIN AND EYES

Contains Portland Cement. Wear Rubber Boots and Gloves, PROLONGED CONTACT MAY CAUSE BURNS. Avoid Contact With Eyes and Prolonged Contact With Skin. In Case of Contact With Skin or Eyes, Flush Thoroughly With Water. If Irritation Persists, Get Medical Attention. **KEEP CHILDREN AWAY.**

CONCRETE is a PERISHABLE COMMODITY and BECOMES THE PROPERTY of the PURCHASER UPON LEAVING the PLANT. ANY CHANGES or CANCELLATION of ORIGINAL INSTRUCTIONS MUST be TELEPHONED to the OFFICE BEFORE **LOADING** starts.

The undersigned promises to pay all costs, including reasonable attorney's fees, incurred in collecting any sums owed.

All accounts not paid within 30 days of delivery will bear interest at the rate of 18% per annum.

Not Responsible for Reactive Aggregate or Color Quality. No Claim Allowed Unless Made at Time Material is Delivered.

A $15.00 Service Charge and Loss of the Cash Discount will be Collected on all Returned Checks.

Excess Delay Time Charged @ $75.00/hr.

PROPERTY DAMAGE RELEASE
(TO BE SIGNED IF DELIVERY TO BE MADE INSIDE CURB LINE)

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SIGNED:

X ______________________

Excessive Water is Detrimental to Concrete Performance.
H_2O Added by Request / Authorized By:

________ GAL X ______________________

WEIGHMASTER

Thank you for your business

NOTICE: MY SIGNATURE BELOW INDICATES THAT I HAVE READ THE HEALTH WARNING NOTICE AND SUPPLIER WILL NOT BE RESPONSIBLE FOR ANY DAMAGE CAUSED WHEN DELIVERING INSIDE CURB LINE.

LOAD RECEIVED BY

X ______________________

QUANTITY	CODE	DESCRIPTION	OUR MIXES ARE DESIGNED TO ACHIEVE SPECIFICATIONS AT A MAX 4" SLUMP	UNIT PRICE	EXTENDED PRICE

RETURNED TO PLANT	LEFT JOB	FINISH UNLOADING	ON SITE TESTING		AIR TEMP
			TESTING LAB:		
LEFT PLANT	**ARRIVED JOB**	**START UNLOADING**	**SLUMP**	**CONCRETE TEMP.**	
TOTAL ROUND TRIP	**TOTAL AT JOB**	**UNLOADING TIME**	**AIR**	**CYLINDERS**	

Tax
Prev. AMT
Ticket Total
Grand Total

ADDITIONAL CHARGE 1 ____________
ADDITIONAL CHARGE 2 ____________
GRAND TOTAL

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
39RENTAL2	2	user	20015312	15246	9:11	9/27/18

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
10.00 CYDS	39CLSCMT				D	55

RB 0024184

Material	Design Qty	Required	Batched	% Var	% Moisture	Actual	Wat
CEMENT	560.00 lb	5600.00 lb	5578.00 lb	-0.39%			
SAND	1335 lb	14285 lb	14330 lb	0.32%	7.00% M		112 gl
LMSTN1"	1350 lb	13635 lb	13660 lb	0.18%	1.00% M		16 gl
GRAVEL3/8"	800 lb	8000 lb	8000 lb	-0.15%	1.75% M		40 gl
WATER	252 lb	1200 lb	1200 lb	-0.01%			144 gl
POZZ80	36.50 oz	365.00 oz	365.00 oz	0.00%			

Actual Num Batches: 1

Load 39871 lb Design W/C: 0.491 Water/Cement: 0.453 T Design 302.5 gl Actual 282.8 gl To Add: 19.6 gl

Slump: 5.00 in # Water in Truck: 0.0 gl Adjust Water: 0.0 gl / Load Trim Water: -2.0 gl / CYD

Actual W/C Ratio: 0.423 Actual Water: 283 gl Batched Cement: 5578 lb Allowable Water: 153 gl

KNIFE RIVER
AN MDU RESOURCES COMPANY

SOUTH REGION/MAIN OFFICE
6310 State Highway 21 West
Bryan, TX 77807
PH: (979) 361-2900
FAX: (979) 361-2920

BRYAN
6310 Hwy. 21 West
Bryan, TX 77807
DISPATCH: (979) 361-2931
FAX: (979) 361-2920

B 0045695

Bryan Plant #6

TUCKER CONSTRUCTION
7425 MIZE RD
BRYAN

Disp Order#: 2023

TTI C66 MODIFIED RAIL
LF 47 LF INTO RELIS CAMPUS STAY
RT AVE D TAKE A LF AND GO THRU
THE SECURITY GATE(CODE 17965#)
STRAIGHT TO JOB BY THE RUN WAY

TIME	FORMULA	LOAD SIZE	YARDS ORDERED		DRIVER/TRUCK		PLANT TRANSACTION #
9:06:25	39CLSCMT	10.00	50.00		LLOYD JON	390133	
DATE		**LOAD #**	**YARDS DEL.**	**BATCH #**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
09/27/18	TTIRAIL	1	10.00			5.00in	6145065

WARNING
IRRITATING TO THE SKIN AND EYES

Contains Portland Cement. Wear Rubber Boots and Gloves, PROLONGED CONTACT MAY CAUSE BURNS. Avoid Contact With Eyes and Prolonged Contact With Skin. In Case of Contact With Skin or Eyes, Flush Thoroughly With Water. If Irritation Persists, Get Medical Attention. **KEEP CHILDREN AWAY.**

CONCRETE is a PERISHABLE COMMODITY and BECOMES THE PROPERTY of the PURCHASER UPON LEAVING the PLANT. ANY CHANGES or CANCELLATION of ORIGINAL INSTRUCTIONS MUST be TELEPHONED to the OFFICE BEFORE **LOADING** starts.

The undersigned promises to pay all costs, including reasonable attorney's fees, incurred in collecting any sums owed.

All accounts not paid within 30 days of delivery will bear interest at the rate of 18% per annum.

Not Responsible for Reactive Aggregate or Color Quality. No Claim Allowed Unless Made at Time Material is Delivered.

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(TO BE SIGNED IF DELIVERY TO BE MADE INSIDE CURB LINE)

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SIGNED:

X

Excessive Water is Detrimental to Concrete Performance.
H_2O Added by Request / Authorized By:

_____ GAL X _____

WEIGHMASTER

Thank you for your business

NOTICE: MY SIGNATURE BELOW INDICATES THAT I HAVE READ THE HEALTH WARNING NOTICE AND SUPPLIER WILL NOT BE RESPONSIBLE FOR ANY DAMAGE CAUSED WHEN DELIVERING INSIDE CURB LINE.

LOAD RECEIVED BY

X

QUANTITY	CODE	DESCRIPTION	OUR MIXES ARE DESIGNED TO ACHIEVE SPECIFICATIONS AT A MAX 4" SLUMP	UNIT PRICE	EXTENDED PRICE
10.00CY	39CLSCMT	TXDOT CLASS S NO ASH			

RETURNED TO PLANT	LEFT JOB	FINISH UNLOADING	ON SITE TESTING		AIR TEMP
			TESTING LAB:		
LEFT PLANT	ARRIVED JOB	START UNLOADING	SLUMP	CONCRETE TEMP.	
9:20	9:44				
TOTAL ROUND TRIP	TOTAL AT JOB	UNLOADING TIME	AIR	CYLINDERS	

Tax
Prev. AMT
Ticket Tot
Grand Tota

ADDITIONAL CHARGE 1 _____
ADDITIONAL CHARGE 2 _____
GRAND TOTAL ▶

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
390133	490896	user	6145065	53477	9:06	

B 0045695

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
10.00 CYDS	39CLSCMT				D	73

Material	Design Qty	Required	Batched	% Var	Moisture	Actual Wat
SAND	1335 lb	14618 lb	14540 lb	-0.54%	9.50% M	151 gl
LMSTN1"	1350 lb	13601 lb	13460 lb	-1.04%	0.75% M	12 gl
GRAVEL3/8"	500 lb	5100 lb	5060 lb	-0.78%	2.00% M	12 gl
CEMENT	560.0 lb	5600.0 lb	5624.0 lb	0.43%		
WATER	30.3 gl	126.9 gl	126.5 gl	-0.29%		126.5 gl
07280	36.50 oz	365.00 oz	365.00 oz	0.00%		

Actual Num Batches: 1 Manual 9:06:25
Load Total: 39763 lb Design W/C: 0.452 Water/Cement: 0.450 T Design Water: 303.0 gl Actual Water: 301.6 gl To Add: 1.4 gl
Slump: 5.00 in # Water in Truck: 0.0 gl Adjust Water: 0.0 gl/ Load Trim Water: 0.0 gl/ CYDS

KNIFE RIVER
AN MDU RESOURCES COMPANY

SOUTH REGION/MAIN OFFICE
6310 State Highway 21 West
Bryan, TX 77807
PH: (979) 361-2900
FAX: (979) 361-2920

RB 0024283

Riverbend

TUCKER CONSTRUCTION
7425 MIZE RD
BRYAN

TTI C66 MODIFIED RAIL
LF 47 LF INTO RELIS CAMPUS STAY
RT AVE D TAKE A LF AND GO THRU
THE SECURITY GATE(CODE 17965#)
STRAIGHT TO JOB BY THE RUN WAY

Disp Order#: 2022

TIME	FORMULA	LOAD SIZE	YARDS ORDERED	PO#	DRIVER/TRUCK		PLANT TRANSACTION #
8:57:42	39CLSCMT	4.00	4.00		ALLEY, RA	390070	
DATE	**PROJECT**	**LOAD #**	**YARDS DEL.**	**BATCH #**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
10/02/18	TTIRAIL	1	4.00			5.00 in	20015412

WARNING
IRRITATING TO THE SKIN AND EYES
Contains Portland Cement. Wear Rubber Boots and Gloves, PROLONGED CONTACT MAY CAUSE BURNS. Avoid Contact With Eyes and Prolonged Contact With Skin. In Case of Contact With Skin or Eyes, Flush Thoroughly With Water. If Irritation Persists, Get Medical Attention. **KEEP CHILDREN AWAY.**

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SIGNED:
X

Excessive Water is Detrimental to Concrete Performance.
H_2O Added by Request / Authorized By:
GAL X

WEIGHMASTER

Thank you for your business

NOTICE: MY SIGNATURE BELOW INDICATES THAT I HAVE READ THE HEALTH WARNING NOTICE AND SUPPLIER WILL NOT BE RESPONSIBLE FOR ANY DAMAGE CAUSED WHEN DELIVERING INSIDE CURB LINE.

LOAD RECEIVED BY
x

QUANTITY	CODE	DESCRIPTION	OUR MIXES ARE DESIGNED TO ACHIEVE SPECIFICATIONS AT A MAX 4" SLUMP	UNIT PRICE	EXTENDED PRICE
4.00 CY	39CLSCMT	TXDOT CLASS S NO ASH			

RETURNED TO PLANT	LEFT JOB	FINISH UNLOADING	ON SITE TESTING		AIR TEMP
			TESTING LAB:		
LEFT PLANT	**ARRIVED JOB**	**START UNLOADING**	**SLUMP**	**CONCRETE TEMP.**	
9:15					
TOTAL ROUND TRIP	**TOTAL AT JOB**	**UNLOADING TIME**	**AIR**	**CYLINDERS**	

Tax
Prev. AMT
Ticket Total
Grand Total

ADDITIONAL CHARGE 1 ____________
ADDITIONAL CHARGE 2 ____________
GRAND TOTAL

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
390070	579258	user	20015412	15345	8:57	10/2/18

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
4.00 CYDS	39CLSCMT				D	7

RB 0024283

Material	Design Qty	Required	Batched	% Var	% Moisture	Actual Wat
CEMENT	560.00 lb	2240.00 lb	2222.00 lb	-0.80%		
SAND	1335 lb	5687 lb	5770 lb	1.46%	6.50% M	42 gl
LMSTN1"	1350 lb	5441 lb	5490 lb	0.91%	0.79% M	5 gl
GRAVEL3/8"	500 lb	2030 lb	1990 lb	-1.97%	1.50% M	4 gl
WATER	252 lb	425 lb	422 lb	-0.73%		51 gl
POZZ80	36.50 oz	146.00 oz	146.00 oz	0.00%		

Actual Num Batches: 1
Load 15903 lb Design W/C: 0.451 Water/Cement: 0.494 T Design 121.0 gl Actual 101.2 gl To Add 19.9 gl
Slump: 5.00 in # Water In Truck: 0.0 gl Adjust Water: 0.0 gl / Load Trim Water: -5.0 gl / CYD
Actual W/C Ratio: 0.380 Actual Water: 101 gl Batched Cement: 2222 lb Allowable Water: 157 gl

465469-2

KNIFE RIVER
AN MDU RESOURCES COMPANY

SOUTH REGION/MAIN OFFICE
6310 State Highway 21 West
Bryan, TX 77807
PH: (979) 361-2900
FAX: (979) 361-2920

RB 0024388

Riverbend

TUCKER CONSTRUCTION
7425 MIZE RD
BRYAN

TTI C66 MODIFIED RAIL
LF 47 LF INTO RELIS CAMPUS STAY
RT AVE D TAKE A LF AND GO THRU
THE SECURITY GATE(CODE 17965#)
STRAIGHT TO JOB BY THE RUN WAY

Disp Order#: 2024

TIME	FORMULA	LOAD SIZE	YARDS ORDERED		DRIVER/TRUCK		PLANT TRANSACTION #
11:01:14	39CLSCMT	4.50	4.50		AGUSTIN H	390121	
DATE	**PROJECT**	**LOAD #**	**YARDS DEL.**	**BATCH #**	**WATER TRIM**	**SLUMP**	**TICKET NUMBER**
10/04/18	TTIRAIL	1	4.50			5.00 in	20015519

WARNING
IRRITATING TO THE SKIN AND EYES

Contains Portland Cement. Wear Rubber Boots and Gloves, PROLONGED CONTACT MAY CAUSE BURNS. Avoid Contact With Eyes and Prolonged Contact With Skin. In Case of Contact With Skin or Eyes, Flush Thoroughly With Water. If Irritation Persists, Get Medical Attention. **KEEP CHILDREN AWAY.**

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SIGNED:

X ____________________

Excessive Water is Detrimental to Concrete Performance.
H_2O Added by Request / Authorized By:

________ GAL X ____________________

WEIGHMASTER

Thank you for your business

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LOAD RECEIVED BY

X ____________________

QUANTITY	CODE	DESCRIPTION	OUR MIXES ARE DESIGNED TO ACHIEVE SPECIFICATIONS AT A MAX 4" SLUMP	UNIT PRICE	EXTENDED PRICE
4.50 CY	39CLSCMT	TXDOT CLASS S NO ASH			

RETURNED TO PLANT	LEFT JOB	FINISH UNLOADING	ON SITE TESTING		AIR TEMP
			TESTING LAB:		
LEFT PLANT	**ARRIVED JOB**	**START UNLOADING**	**SLUMP**	**CONCRETE TEMP.**	
11:12	11:45	11:48			
TOTAL ROUND TRIP	**TOTAL AT JOB**	**UNLOADING TIME**	**AIR**	**CYLINDERS**	

Tax
Prev. AMT
Ticket Total
Grand Total

ADDITIONAL CHARGE 1 ________
ADDITIONAL CHARGE 2 ________
GRAND TOTAL ▶

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
390121	511322	user	20015519	15450	11:01	10/4/18

RB 0024388

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
4.50 CYDS	39CLSCMT				D	27

Material	Design Qty	Required	Batched		% Var	% Moisture	Actual Wat
CEMENT	560.00 lb	2520.00 lb	2580.00 lb	>	2.38%		
SAND	1335 lb	6467 lb	6590 lb		1.90%	7.69% M	56 gl
LMSTN"	1350 lb	6121 lb	6110 lb	-	-0.17%	0.75% M	5 gl
GRAVEL3/8"	500 lb	2284 lb	2300 lb		0.71%	1.50% M	4 gl
WATER	252 lb	522 lb	519 lb		-0.64%		62 gl
POZZ80	36.50 oz	164.25 oz	164.00 oz		-0.15%		

Actual Num Batches: 1
Load 18108 lb Design W/C: 0.461 Water/Cement: 0.440 T Design 136.1 gl Actual 127.8 gl To Add: 8.3 gl
Slump: 5.00 in # Water In Truck: 0.0 gl Adjust Water: 0.0 gl / Load Trim Water: -2.0 gl / CYD
Actual W/C Ratio: 0.414 Actual Water: 128 gl Batched Cement: 2580 lb Allowable Water: 96 gl

WO # 22632   2½" sch 40 st pipe 42'

09-19-2018 03:00   Load - 3143664   BL - 3850230   BLR466
Custom Fabricators   Heat - A803638
Cust. PO - PAULS ORDER   Order-Line - 16565801 / 1

EXLTUBE

1000 BURLINGTON STREET, NORTH KANSAS CITY, MO 64116 1-816-474-5210 TOLL FREE 1-800-892-TUBE

STEEL VENTURES, LLC dba EXLTUBE

Certified Test Report

Customer:	Size:	Customer Order No:	Date:
Kloeckner Metals Corp-Roswell mtr mtr 500 Colonial Center Parkway #500 ROSWELL GA 30076-8853	02.875	7288878	07/02/2018
	Gauge: .203	Delivery No: 83197174 Load No: 4043461	
	Specification: ASTM A500-13 Gr.B/C, ASTM A53-12 Gr.B BNT*, ASME SA53 Gr.B BNT*		

Heat No	Yield KSI	Tensile KSI	Elongation % 2 Inch
A803638	72.2	80.4	26.00

Heat No	C	MN	P	S	SI	CU	NI	CR	MO	V
A803638	0.0600	0.5500	0.0080	0.0040	0.0200	0.1400	0.0400	0.0600	0.0200	0.0010

This material was melted & manufactured in the U.S.A.
Coil Producing Mill: STEEL DYNAMICS COLUMBUS, COLUMBUS, MS

We hereby certify that all test results shown in this report are correct as contained in the records of our company. All testing and manufacturing is in accordance to A.S.T.M. parameters encompassed within the scope of the specifications denoted in the specification and grade tiles above. This product was manufactured in accordance with your purchase order requirements.
BNT=Grade B not pressure tested - meets tensile & chemical properties ONLY.

This material has not come into direct contact with mercury, any of its compounds, or any mercury bearing devices during our manufacturing process, testing, or inspections.

This material is in compliance with EN 10204 Section 4.1 Inspection Certificate Type 3.1

This material has passed NDE (eddy current, A309) testing. This material has passed flattening tests.

Tensile test completed using test specimen with 3/4" reduced area.

STEEL VENTURES, LLC dba EXLTUBE

Jonathan Wolfe

Jonathan Wolfe
Quality Assurance Manager

WO# 22632 2 1/2" sch 40 st pipe 21'

The TAPCO Tube Company

10748 South Water Street • Meadville, PA 16335

MATERIAL TEST RESULTS

Sold to:
Triple-S Steel Supply Co
6000 Jensen Drive
Houston, TX 77026

Ship to:
Triple-S Supply Co
8411 Irvington Blvd
Houston, TX 77022

TAPCO WO#	Ship Date	PO #
4699	5-8-18	HOU-179847

The below material meets or exceeds the ASTM standard for A500 Grade C– 2.875x.203 HRBK.

Heat#	Tensile	Yield	Elongation
213920	68300	56400	29

C	Mn	P	S	Si	Cu	Al	V	Cr	Ti	Mo
.19	.53	.012	.002	.03	.100	.020	.001	.05	.001	.01

Heat#	Tensile	Yield	Elongation
460380	67100	51600	32

C	Mn	P	S	Si	Cu	Al	V	Cr	Ti	Mo
.17	.46	.012	.006	.017	.050	.051	.002	.03	.002	.01

The below material meets or exceeds the ASTM standard for A500 Grade C– 3.50x.216-HRBK.

Heat#	Tensile	Yield	Elongation
225044	63632	57021	33

C	Mn	P	S	Si	Cu	Al	V	Cr	Ti	Mo
.045	.41	.010	.005	.014	.03	.048	.00	.02	.002	.00

Heat#	Tensile	Yield	Elongation
0660940	71032	56086	26

C	Mn	P	S	Si	Cu	Al	V	Cr	Ti	Mo
.21	.90	.012	.006	.159	.05	.048	.002	.13	.021	.01

9-13-18

Tapco Tube Company's purchasing procedure for raw material is from domestic sources.
All steel used to manufacture the above tube was Made & Melted in the USA.

Manufacturers of TAPCO Round, Square & Rectangular Tube Steel Stock

Phone: 1-814-724-4528
Fax: 1-814-333-6259

WO# 22652 2" sch 40 sl pipe 21'

Quality & Productivity Specialist
FEMCO®
SINCE 1949

出廠品質證明書
MILL TEST CERTIFICATE
ORIGINAL

遠東機械工業股份有限公司
FAR EAST MACHINERY CO., LTD
中華民國嘉義市 60080 忠孝路 752 號
No.752,CHUNG HSIAO ROAD CHIAYI 60080,TAIWAN
TEL: +886-5-2766171 FAX: +886-5-2718509

客戶名稱 CUSTOMER	OPTIMA STEEL INTERNATIONAL LLC	訂單編號 ORDER NO.	P.O. NO.PO-33748 CUST PO.HOU-178407	證明書編號 CERTIFICATE NO.	4011071366
		交運日期 SHIPPING DATE	MAY.17.2018	證明書日期 T/C ISSUE DATE	MAY.17.2018
規格名稱 SPEC.	ERW STEEL PIPE TO API 5LB PSL1/ASTM A53B/ASME SA53B	工程單位 CONSTRUCTION			
		工程名稱 PROJECT			

項次 ITEM NO.	尺寸及規格 MATERIAL DESCRIPTION 外徑 OD 公稱尺寸 NPD	最大 MAX	最小 MIN	長度 L	厚度 T.	直度 S	端口 END FACE	重量 W	數量 QTY	水壓試驗 H.T	化學成份 CHEMICAL ANALYSIS % C	Mn	P	S	Cu	Ni	Cr	Mo	V	Si	Al	Ti	Nb	B	機械性質 MECHANICAL PROPERTIES 拉伸試驗 TENSILE T. 降伏 Y.S.	抗拉 T.S.	伸長 EL	壓扁試驗 FLAT.T. 0°	90°	彎曲試驗 BEND.T. 90°	180°	爐號 HEAT NO.	非破壞檢驗 N.D.T. U.T.	R.T.	結果判定 DETERMINE
	in	mm	mm						PCS	PSI	×10²	×10²	×10³	×10³	×10²	×10²	×10²	×10²	×10²	×10²	×10³	×10³	×10³	×10⁴	PSI	PSI	%								
01	2"	61.9	59.9	21'	0.154"	OK	OK	OK	858	2500	14	80	15	3	1	1	2	1	1	1	32	1	1	1	51670	66470	40	—	—	OK	—	KB858	OK	—	OK
02	4"	115.9	113.9	42'	0.237"	OK	OK	OK	90	2240	13	79	17	4	1	1	1	1	1	1	29	1	1	1	56760	68220	36	OK	OK	—	—	PS135	OK	—	OK
03	8"	220.2	218.0	21'	0.322"	OK	OK	OK	75	1590	16	88	18	3	1	1	2	1	1	1	29	1	1	1	47890	69810	37	OK	OK	—	—	PQ529	OK	—	OK
04	8"	220.2	218.0	42'	0.322"	OK	OK	OK	38	1590	15	88	17	3	1	1	2	1	1	1	30	1	1	1	49780	69230	36	OK	OK	—	—	PQ529	OK	—	OK
05	10"	274.4	271.6	21'	0.365"	OK	OK	OK	26	1450	15	87	15	2	1	1	2	1	1	1	37	1	1	1	49930	71690	36	OK	OK	—	—	PN235	OK	—	OK
06	10"	274.4	271.6	42'	0.365"	OK	OK	OK	13	1450	15	87	15	2	1	1	2	1	1	1	37	1	1	1	50510	69670	36	OK	OK	—	—	PN235	OK	—	OK
07	12"	325.4	322.2	21'	0.375"	OK	OK	OK	21	1250	14	86	16	4	2	1	2	1	1	1	23	1	1	1	50220	66330	41	OK	OK	—	—	PS675	OK	—	OK
	END																																		

註釋 NOTES ※ HARDNESS 22RC MAX. ※ 1 kgf/mm2=9.80665Mpa=1422.33psi
※ EDITION YEAR ASTM A53B 2012/API 5L 2013 45TH

茲證明本表所列產品，均依鋼管規格製造及檢驗，並符合規範之要求。
WE HEREBY CERTIFY THAT MATERIAL DESCRIBED HEREIN HAS BEEN MANUFACTURED AND TESTED WITH SATISFACTORY RESULTS IN ACCORDANCE WITH THE REQUIREMENT OF THE ABOVE MATERIAL SPECIFICATION

Peter Chou
鋼鐵事業部品保課長
QA Chief Peter Chou

品質保證中心
Quality Assurance Center

遠東機械工業股份有限公司 品質保證中心 (05)2766171 嘉義市忠孝路752號

4P002QC-07

WU" XX0XX ... 78 X6 ST 76 @ 20

DEACERO
EXCELENCIA EN CALIDAD

Aceria Ramos Arizpe
CARRETERA MONCLOVA KM 4 NUMERO 2125
TRAMO SANTA CRUZ OJO CALIENTE
C.P./ZIP RAMOS ARIZPE, COAHUILA
Tel/Phone (+52) 01 818 368 1111
MX 01 800 021 3322, USA 1800 332 2376

/ CERTIFICATE OF TEST AN ANALYSIS

No. Certificado / Certificate No:	124792 - 21639433
Fecha / Date:	26/07/2018

P.O181456 UK3447

Hecho en México / Made in Mexico

DATOS DEL CLIENTE / SOLD TO	CLIENTE CONSIGNADO / SHIP TO	DATOS DEL EMBARQUE / SHIPPING INFORMATION
Cliente / Customer: DEACERO USA INC (HOUSTON DISTRIBUTION CENTER)	Cliente / Customer: DEACERO USA INC (HOUSTON DISTRIBUTION CENTER)	Núm. Viaje / Travel No: 124792
Dirección / Address: 8411 IRVINGTON BLVD	Dirección / Address: 1755 FEDERAL RD	
Ciudad / City: HOUSTON Estado / State: , TX	Ciudad / City: HOUSTON Estado / State: , TX	Núm. Factura / Invoice No: FQ69470
Teléfono / Phone: 332 2376 País / Country: U.S.A. C.P./ZIP 77022-3		Pedido / Customer Order No: 21639433
Correo Electrónico / eMail:		Núm. Plan / Shipping Plan: 133444
		Fecha Embarque / Date: 25/07/2018
		Orden de Compra / Purchase Order:

COMPOSICIÓN QUÍMICA / CHEMICAL COMPOSITION (% PESO / WEIGHT)

Colada / Heat	Secuencia / Sequence	Clave / Code	Producto / Description of Goods	% C	% Mn	% Si	% P	% S	% Cu	% Cr	% Ni	% Mo	% Sn	% Ti	% V	% Nb	% N	CE
				AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG
29454	36480	64169	FLAT BAR 6" x 3/8" A36/529-50 20' 2.0T	0.21	0.90	0.20	0.005	0.007	0.19	0.0360	0.0810	0.0140	0.0090	0.0084	0.0123	0.0080	0.0104	0.3776
29456	36479	64169	FLAT BAR 6" x 3/8" A36/529-50 20' 2.0T	0.21	0.94	0.21	0.003	0.014	0.17	0.0340	0.0770	0.0140	0.0080	0.0085	0.0136	0.0094	0.0096	0.3838
29462	36475	64169	FLAT BAR 6" x 3/8" A36/529-50 20' 2.0T	0.20	0.91	0.22	0.003	0.006	0.16	0.0630	0.0760	0.0140	0.0070	0.0120	0.0150	0.0089	0.0090	0.3645

PROPIEDADES MECÁNICAS / MECHANICAL PROPERTIES

Colada / Heat	Secuencia / Sequence	Clave / Code	Producto / Description of Goods	Calibre / Diameter	Cantidad / Bundle	RT kg/mm²	TS PSI	% Elong / Elong	LF kg/mm²	YS PSI	P. Doblez / Bend Test
						AVG	AVG	AVG	AVG	AVG	
29454	36480	64169	FLAT BAR 6" x 3/8" A36/529-50 20' 2.0T	6" x 3/8"	1	50.54	71918.42	31.59	36.99	52636.77	Cumple / Successfully
29456	36479	64169	FLAT BAR 6" x 3/8" A36/529-50 20' 2.0T	6" x 3/8"	4	52.41	74579.43	32.78	37.38	53191.74	Cumple / Successfully
29462	36475	64169	FLAT BAR 6" x 3/8" A36/529-50 20' 2.0T	6" x 3/8"	6	52.96	75362.08	32.42	37.64	53561.72	Cumple / Successfully

CE=[C]+([Cu]/40)+([Mn]/6)+([Ni]/20)+([Cr]/10)-([Mo]/50)-([V]/10)

DEACERO +VERDE

Certificamos que este material ha sido producido, inspeccionado y probado de acuerdo a las normas de fabricación del acero aplicables a la ASTM A36-2008, A529-2005 (re aprobada el 2009), A572-2012 y A992-2011 y a las normas dimensionales NMX B252, ASTM A6/A6M-2012. / We certify that this material has been produced hot-rolled carbon, inspected and tested according to standards applicable steelmaking to ASTM A36-2008, A529-2005 (Reapproved 2009), A572-2012 y A992-2011, and the dimensional standards NMX B252, ASTM A6/A6M-2012.

GUSTAVO GABRIEL MANCILLA GARZA
Gerente de Aseguramiento de Calidad / Quality Assurance Manager

WO#22632 5/8"-11 nut HDG

CERTIFIED MATERIAL TEST REPORT
FOR ASTM A194/A194M-10a GRADE 2H HVY HEX NUTS

FACTORY: NINGBO HAIXIN HARDWARE CO.,LTD.
DATE: AUG.08.2011
ADDRESS: XIJINGTANG,LUOTUO NINGBO ZHEJIANG 315205 CHINA
MFG LOT NUMBER: 1033130006
CUSTOMER: BRIGHTON-BEST INTERNATIONAL (TAIWAN) INC
PO NUMBER: U04584
QNTY SHIPPED: 28.800MPCS
PART NO: 313150
SAMPLE SIZE : ACC. TO ASME B18 . 18 . 1 - 02
SIZE & DESCRIPTION: 5/8-11+0.020"(HDG)

STEEL PROPERTIES:
STEEL GRADE: SWRCH45K SIZE: 25mm HEAT NO: 331105231
CHEMISTRY COMPOSITION:

CHEMIST	C %	Mn %	P %	S %	Si %	Cr %	Ni %	Cu %	Mo %	OTHERS
SPE:	MIN 0.40	MAX 1.00	MAX 0.04	MAX 0.05	MAX 0.40					
TEST:	0.45	0.73	0.009	0.01	0.21					

DIMENSIONAL INSPECTIONS — SPECIFICATION: ASME/ANSI B18 . 2 . 2 - 87(R1999)

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
********************	****************	**************	****************	******	********
APPEARANCE	ASTM F812-02		PASSED	100	0
WIDTH A/F	1.031 "-1.062"		1.042"-1.052"	32	0
WIDTH A/C	1.175"-1. 227 "		1.180"-1.221"	32	0
THREAD	ASME B1.1-02		PASSED	8	0
HEIGHT	0.587"-0.631"		0.597"-0.611"	32	0
MARK	2H* LM		PASSED	100	0

MECHANICAL PROPERTIES: TO 1-1/2" in — SPECIFICATION: ASTM A194-10a

CHARACTERISTICS	TEST METHOD	SPECIFIED	ACTUAL RESULT	ACC.	REJ.
********************	***************	***************	*****************	*******	*********
HARDNESS	ASTM E18-05	24-35HRC	HRC28-30	5	0
PROOF LOAD	ASTM F606-07	39550lbf	39550lbf	5	0
DECARBURIZATION	SAE J121		PASSED	1	0
HARDNESS AFTER 24H AT 540°C ASTM A194 MIN 89 HRB			HRB 92-94	5	0
TEMPERING TEMPERATURE Min455°C			PASSED(520°C)		
MACROETCH	ASTM E381	S1/R1/C1~S4/R4/C4	S2/R2/C2	5	0

PARTS ARE MANUFACTURED AND TESTED IN ACCORDANCE WITH ASTM A194/A194M-10a ALL TESTS IN ACCORDANCE WITH THE METHODS PRESCRIBED SPECIFICATION. WE CERTIFY THAT THIS DAIA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY.

All parts meet the requirements of FQA and records of compliance are on file.

Maker's ISO#00109Q10593R0M/3302

(SIGNATURE OF Q.A. LAB MGR.)
(NAME OF MANUFACTURER)

WO# 22632 5/8"-11 x10" hex head bolts HDG

ZHEJIANG LAIBAO PRECISION TECHNOLOGY CO.,LTD
NO.668 DONGHAI ROAD,XITANGQIAO TOWN,HAIYAN,ZHEJIANG,CHINA
TEL: +86-573-86813788 FAX:+86-573-86811201

QUALITY CERTIFICATE

Customer Name :	BRIGHTON - BEST INTERNATIONAL (TAIWAN), INC.	**Country of origin:**	China
INV.NO.:	BBT1343	**QUANTITY:**	2.475 MPcs
P.O.NO.:	U36323	**TEST DATE:**	07.08,2016
S/C NO.:	BBI16165	**ON BOARD:**	07.14,2016
PART NO.:	495106	**SIZE:**	5/8-11×10
LOT NO.:	1606825501	**DESCRIPTION:**	HEX HEAD BOLTS UNC HDG
PRODUCTION DATE:	06.08,2016		

Size: ASME B18.2.1 2012

Material and Mechanical properties: ASTM A307-2014 GR.A

Zinc Coatings: ASTM F2329-13

1.Chemical Composition Of Material (%)

STEEL GRADE /HEAT NO:	DIA. (mm)	C	Si	Mn	P	S	Cr	B	Ni	Al	Mo
Q195/183045	16	0.08	0.12	0.33	0.017	0.018					

2.Dimension

INSPECTION ITEM	SPECIFICATION	RESULT	SAMPLE SIZE
Head Marking	LB307A	LB307A	1
Width A/F (inch)	0.906-0.938	0.910-0.925	9
Width A/C (inch)	1.033-1.083	1.040-1.059	9
Head Height (inch)	0.378-0.444	0.384-0.405	9
Body Dia (inch)	0.605-0.642	0.615-0.622	3
Total Length (inch)	9.820-10.140	9.920-9.945	9
Thread Length (inch)	NOM 1.750	1.792-1.823	9
Major Dia (inch)	0.6112-0.6250	0.615-0.622	3
GO Ring Gauge	THE NUT OF UNC 5/8-11 $^{+0.40}$ 2B	OK	3
NO GO Ring Gauge	UNC 5/8-11 2A	OK	3
Tensile Strength (Psi)	MIN 60000	80380-83165	2
Hardness (HRB)	69-100	84-85	4
Visual	OK	OK	25
Salt Spray Test	/	/	/
Zinc Thickness (μm)	MIN53	58.6-59.1	9

We hereby certify that the material described herein has been manufactured and tested with satisfactory results in accordance with the requirement of the above material/dimensional specifications.

QIN YUE ZHU
Q.C Supervisor
品 管 部

WO# 22632 5/8" F436 Washer HDG

Stelfast Inc.

22979 Stelfast Parkway
Strongsville, Ohio

44149

Report of Chemical and Physical Properties

Winzer Corporation
4060 E Plano Pkwy
PLANO TX 75074

Purchase Order: F03328
Stelfast Order: SO 144926
Certificate #: 588,321

Cust Part No: 308.02.58
Lot Number: GTR15538262A-010
Heat Number: 2922
Country of Origin: CN

Quantity: 1,200
Part #: DHWGA06250
Description: 5/8 Hardened Washer F436 HDG

Chemical Analysis

C	Mn	P	S	Si	Cr
0.44	0.55	0.025	0.007	0.19	

Mechanical Properties

Core Hardness	32 - 34 HRC
Grade Marking	ASTM F436(93)-TYPE 1

We hereby certify that the above data is a true copy of the data furnished to us by the producing mill or the data resulting from tests performed in approved laboratories. Stelfast does not certify to customer's part numbers.
This certificate applies to the product shown on this document, as supplied by Stelfast Inc. Alterations to the product by our customer or a third party will render this certificate void.

David Biss
Quality Manager

September 13, 2018

Page 1 of 1

CMC

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

EAT NO.:3082086 ECTION: REBAR 10MM (#3) 40'0" 420/60 RADE: ASTM A615-16 Gr 420/60 OLL DATE: 07/30/2018 IELT DATE: 07/29/2018 ert. No.: 82463515 / 082086A127	S O L D T O	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	S H I P T O	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 82463515 BOL#: 72588853 CUST PO#: 789831 CUST P/N: DLVRY LBS / HEAT: 23100.000 LB DLVRY PCS / HEAT: 1536 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.42%				
Mn	0.58%				
P	0.008%				
S	0.050%				
Si	0.18%				
Cu	0.31%				
Cr	0.12%				
Ni	0.18%				
Mo	0.087%				
V	0.000%				
Cb	0.002%				
Sn	0.010%				
Al	0.001%				
Yield Strength test 1	67.5ksi				
Tensile Strength test 1	101.6ksi				
Elongation test 1	13%				
Elongation Gage Lgth test 1	8IN				
Bend Test Diameter	1.313IN				
Bend Test 1	Passed				

The Following is true of the material represented by this MTR:

Material is fully killed
100% melted and rolled in the USA
EN10204:2004 3.1 compliant
Contains no weld repair
Contains no Mercury contamination
Manufactured in accordance with the latest version of the plant quality manual
Meets the "Buy America" requirements of 23 CFR635.410

EMARKS :

08/03/2018 19:00:59
Page 1 OF 1

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

EAT NO.:3082431 ECTION: REBAR 13MM (#4) 20'0" 420/60 RADE: ASTM A615-16 Gr 420/60 OLL DATE: 08/13/2018 IELT DATE: 08/11/2018 ert. No.: 82493014 / 082431A130	SOLD TO: CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO: CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900

Delivery#: 82493014
BOL#: 72632953
CUST PO#: 793185
CUST P/N:
DLVRY LBS / HEAT: 13146.000 LB
DLVRY PCS / HEAT: 984 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.43%				
Mn	0.64%				
P	0.016%				
S	0.045%				
Si	0.20%				
Cu	0.38%				
Cr	0.22%				
Ni	0.14%				
Mo	0.064%				
V	0.001%				
Cb	0.001%				
Sn	0.018%				
Al	0.001%				
Yield Strength test 1	61.9ksi				
Tensile Strength test 1	99.0ksi				
Elongation test 1	14%				
Elongation Gage Lgth test 1	8IN				
Bend Test Diameter	1.750IN				
Bend Test 1	Passed				

The Following is true of the material represented by this MTR:

Material is fully killed
100% melted and rolled in the USA
EN10204:2004 3.1 compliant
Contains no weld repair
Contains no Mercury contamination
Manufactured in accordance with the latest version of the plant quality manual
Meets the "Buy America" requirements of 23 CFR635.410
Warning: This product can expose you to chemicals which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov

:MARKS :

09/10/2018 14:30:55
Page 1 OF 1

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

EAT NO.:3082743 ECTION: REBAR 16MM (#5) 20'0" 420/60 RADE: ASTM A615-16 Gr 420/60 OLL DATE: 08/26/2018 IELT DATE: 08/24/2018 ert. No.: 82483492 / 082743A371	SOLD TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	SHIP TO	CMC Construction Svcs College Stati 10650 State Hwy 30 College Station TX US 77845-7950 979 774 5900	Delivery#: 82483492 BOL#: 72619128 CUST PO#: 792190 CUST P/N: DLVRY LBS / HEAT: 6570.000 LB DLVRY PCS / HEAT: 315 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.44%				
Mn	0.82%				
P	0.013%				
S	0.047%				
Si	0.20%				
Cu	0.30%				
Cr	0.15%				
Ni	0.18%				
Mo	0.058%				
V	0.000%				
Cb	0.001%				
Sn	0.008%				
Al	0.001%				
Yield Strength test 1	65.4ksi				
Tensile Strength test 1	103.8ksi				
Elongation test 1	15%				
Elongation Gage Lgth test 1	8IN				
Bend Test Diameter	2.188IN				
Bend Test 1	Passed				

The Following is true of the material represented by this MTR:
*Material is fully killed
*100% melted and rolled in the USA
*EN10204:2004 3.1 compliant
*Contains no weld repair
*Contains no Mercury contamination
*Manufactured in accordance with the latest version of the plant quality manual
*Meets the "Buy America" requirements of 23 CFR635.410

EMARKS :

08/27/2018 18:02:04
Page 1 OF 1

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.:3005785 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

B.3. *MASH* TEST 3-11 (CRASH TEST NO. 469469-2-1)

B.3.1. Vehicle Properties and Information

Table B.1. Vehicle Properties for Test No. 469469-2-1.

Vehicle Inventory Number: 1360

Date:	2018-10-31	Test No.:	469469-2-1	VIN No.:	1C6RD6FTXCS211979
Year:	2012	Make:	RAM	Model:	1500

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

Tread Type: Highway Odometer: 244565

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

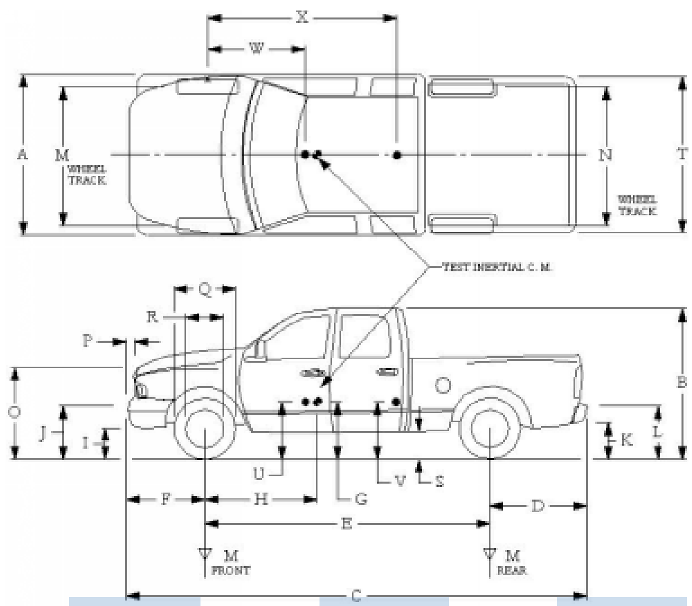
NOTES: None

Engine Type: V-8
Engine CID: 4.7 liter

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

Optional Equipment:
None

Dummy Data:
Type: 50 PERCENTILE
Mass: 165 lb
Seat Position: IMPACT SIDE



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	27.50
B	74.00	G	28.00	L	30.00	Q	30.50	V	31.25
C	227.50	H	62.26	M	68.50	R	18.00	W	62.26
D	44.00	I	11.75	N	68.00	S	13.00	X	77.75
E	140.50	J	27.00	O	46.00	T	77.00		

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

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

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2960	2792	2877
Back	3900	M_{rear}	2065	2222	2302
Total	6700	M_{Total}	5025	5014	5179

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

Mass Distribution:
lb LF: 1364 RF: 1428 LR: 1066 RR: 1156

Table B.2. Measurements of Vehicle Vertical CG for Test No. 469469-2-1.

Vehicle Inventory Number: 1360

Date: 2018-10-31 Test No.: 469469-2-1 VIN: 1C6RD6FTXCS211979

Year: 2012 Make: RAM Model: 1500

Body Style: Quad Cab Mileage: 244565

Engine: 4.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 171 (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70 R 17

Measured Vehicle Weights: (lb)

LF:	1364	RF:	1428	Front Axle:	2792
LR:	1066	RR:	1156	Rear Axle:	2222
Left:	2430	Right:	2584	Total:	5014
					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:	62.26	inches	Rear of Front Axle	(63 ±4 inches allowed)
Y:	1.05	inches	Left - Right +	of Vehicle Centerline
Z:	28.00	inches	Above Ground	(minumum 28.0 inches allowed)

Hood Height: 46.00 inches Front Bumper Height: 27.00 inches

43 ±4 inches allowed

Front Overhang: 40.00 inches Rear Bumper Height: 30.00 inches

39 ±3 inches allowed

Overall Length: 227.50 inches

237 ±13 inches allowed

Performed by: SCD Date: 2018-10-31

Table B.3. Exterior Crush Measurements of Vehicle for Test No. 469469-2-1.

Vehicle Inventory Number: 1360

Date:	2018-10-31	Test No.:	469469-2-1	VIN No.:	1C6RD6FTXCS211979
Year:	2012	Make:	RAM	Model:	1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FT BUMPER	16	14	24							
2	SAME	16	14	54							
	Measurements recorded										
	☐ **inches** **or** ☐ **mm**										

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

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

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

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

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

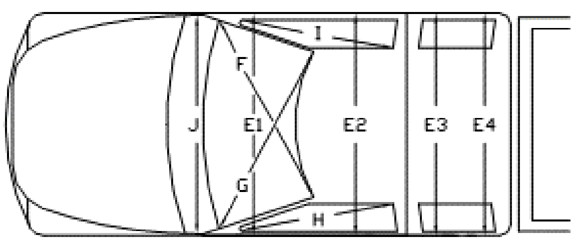
Note: Use as many lines/columns as necessary to describe each damage profile.

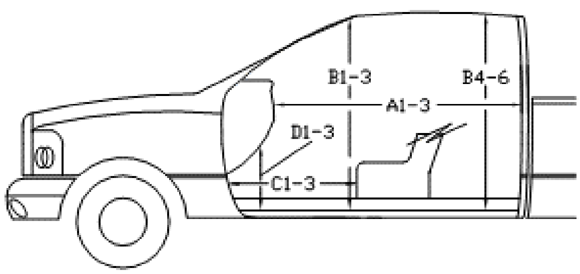
Performed by: SCD Date: 2018-10-31

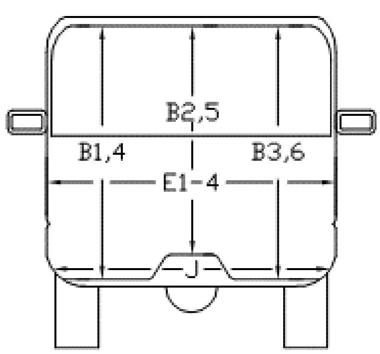
Table B.4. Occupant Compartment Measurements of Vehicle for Test No. 469469-2-1.

Vehicle Inventory Number: 1360

Date:	2018-10-31	Test No.:	469469-2-1	VIN No.:	1C6RD6FTXCS211979
Year:	2012	Make:	RAM	Model:	1500







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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	64.50	-0.50
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.50	0.50
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	24.00	-2.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	11.00	12.00	1.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	59.50	1.00
E2	63.50	64.50	1.00
E3	63.50	63.50	0.00
E4	63.50	64.00	0.50
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	23.50	-1.50

Performed by: SCD Date: 2018-10-31

B.3.2. Sequential Photographs

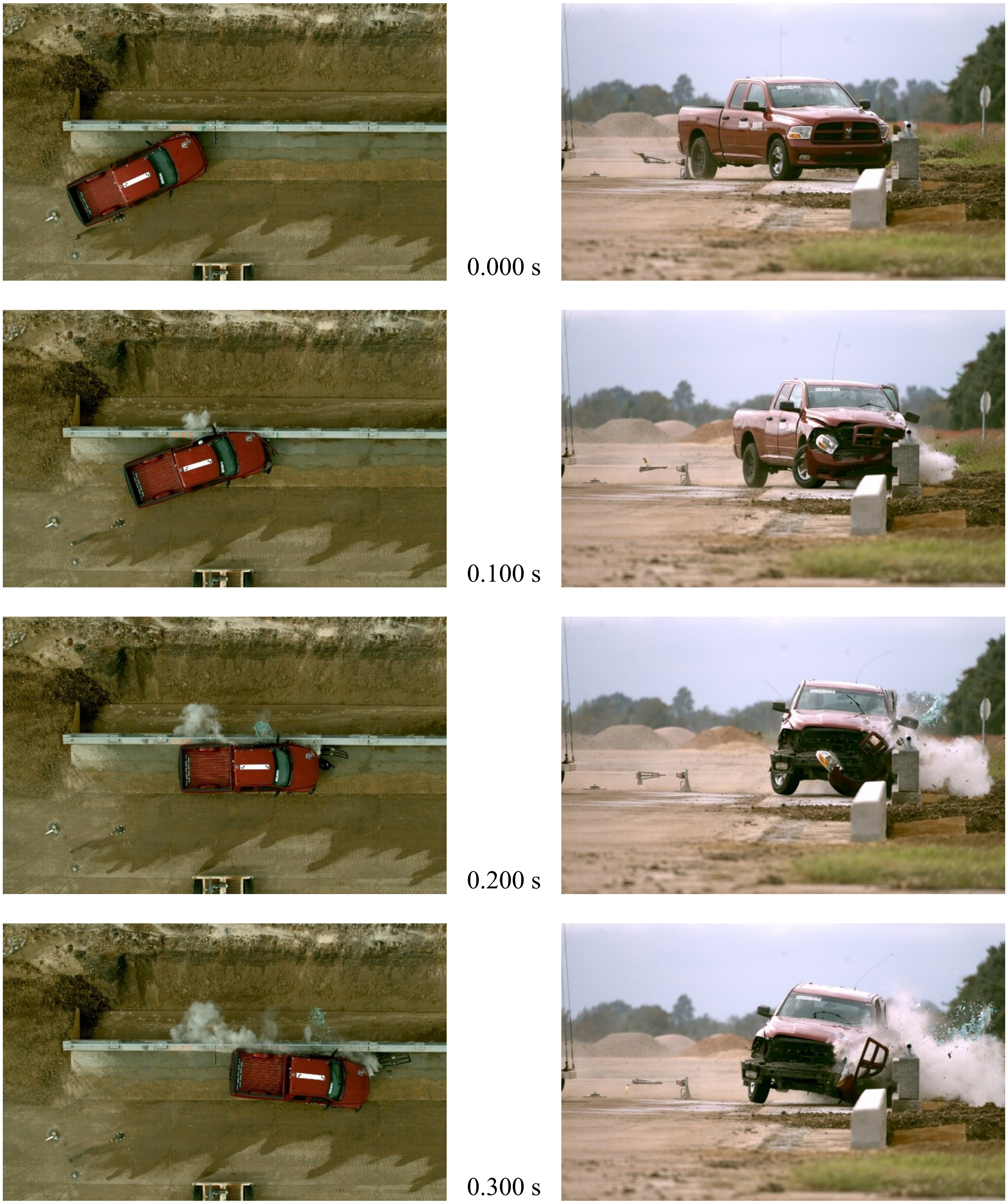


Figure B.1. Sequential Photographs for Test No. 469469-2-1 (Overhead and Gut Views).

0.400 s

0.500 s

0.600 s

0.700 s

Figure A.1. Sequential Photographs for Test No. 469469-2-1 (Overhead and Gut Views) (Continued).

0.000 s

0.100 s

0.200 s

0.300 s

0.400 s

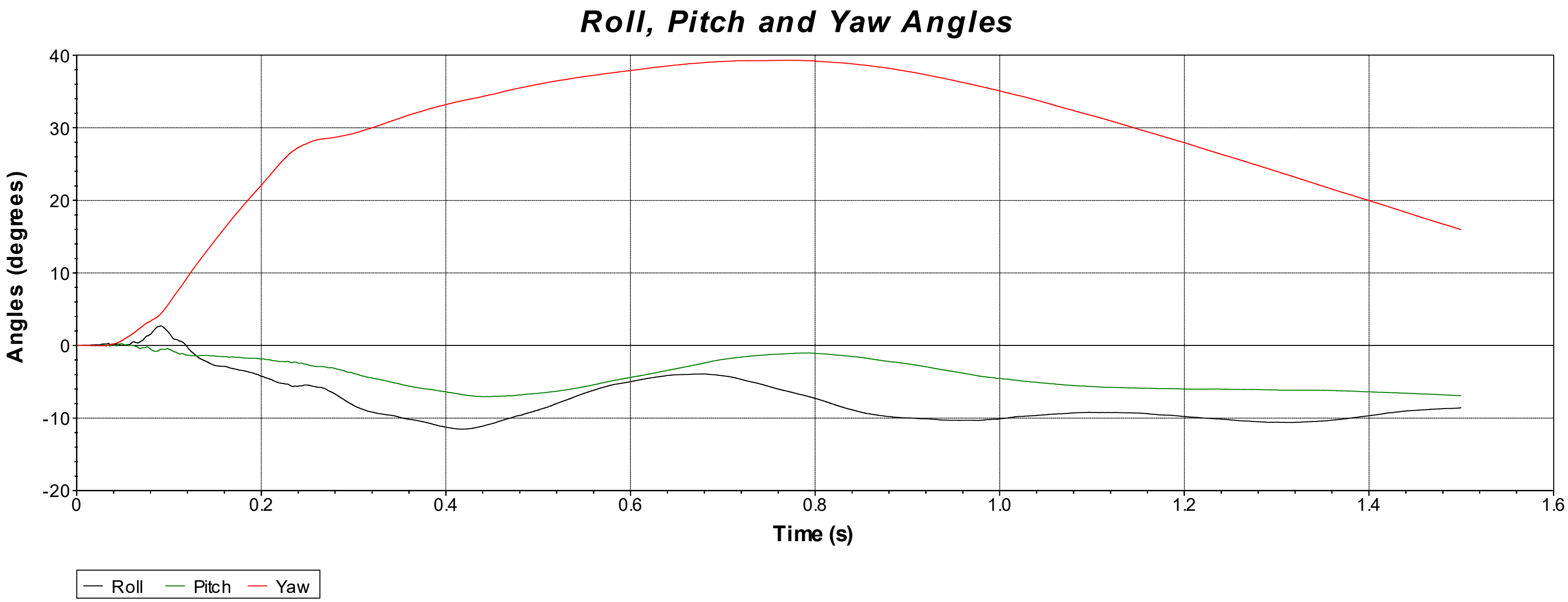
0.500 s

0.600 s

0.700 s

Figure B.2. Sequential Photographs for Test No. 469469-2-1 (Rear View).

B.3.3. Vehicle Angular Displacement



Test Number: 469469-2-1
Test Standard: *MASH* Test 3-11
Test Article: Modified C66 Bridge Rail
Test Vehicle: 2270P/ 2012 RAM 1500
Inertial Mass: 5014 lb
Gross Mass: 5179 lb
Impact Speed: 61.8 mi/h
Impact Angle: 24.3 degrees

Axes are vehicle-fixed.
Sequence for determining orientation:

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

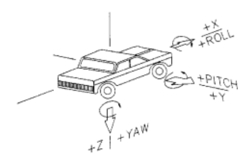
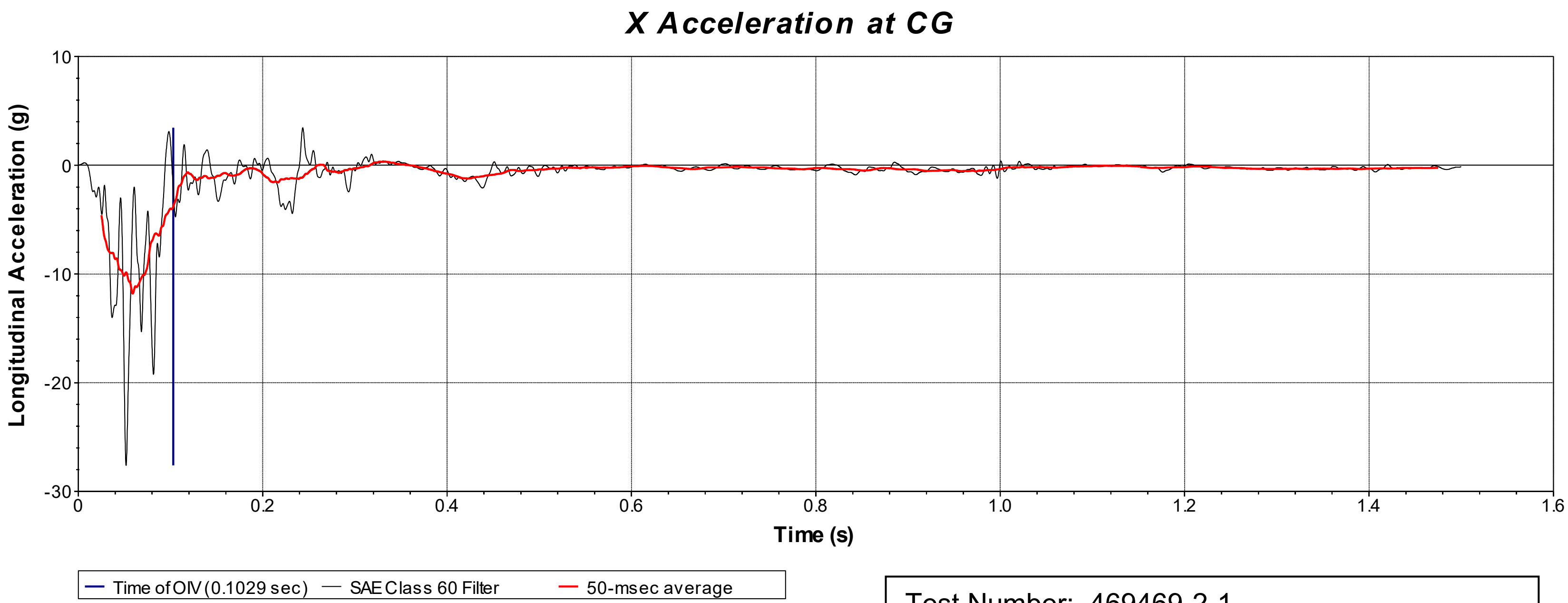


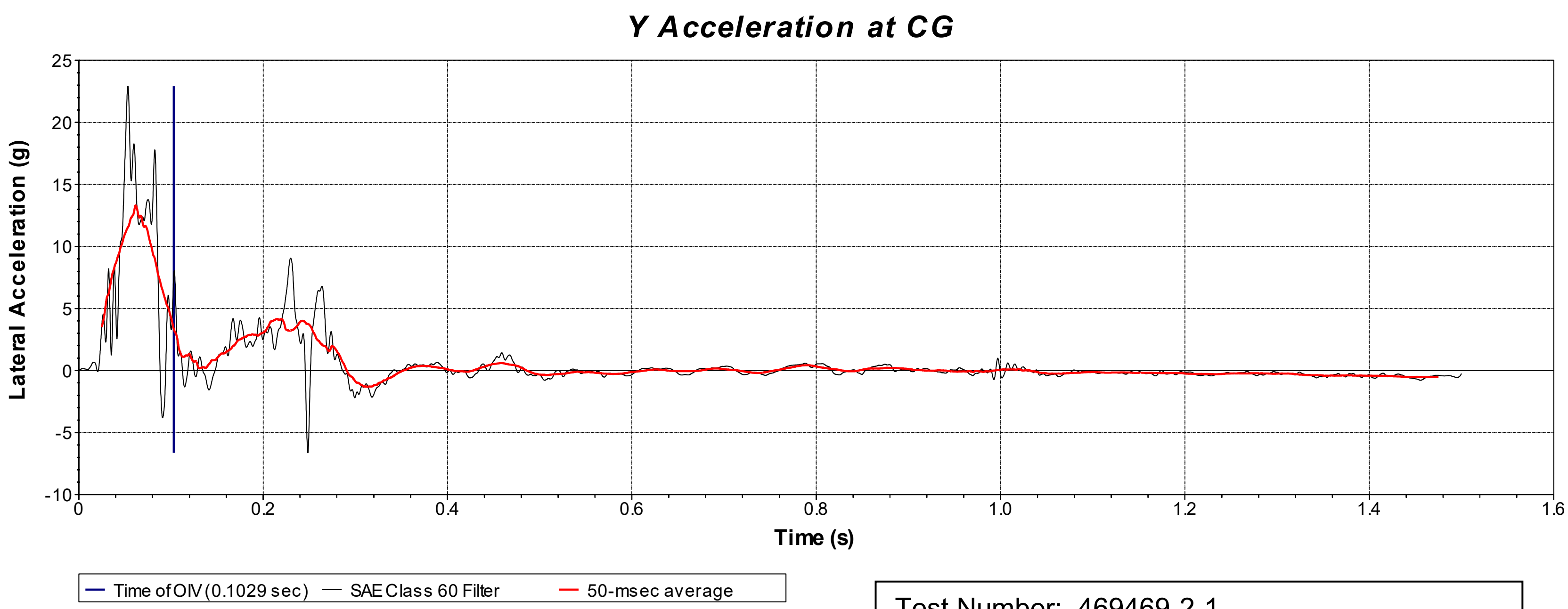
Figure B.3. Vehicle Angular Displacements for Test No. 469469-2-1.

B.3.4. Vehicle Acceleration



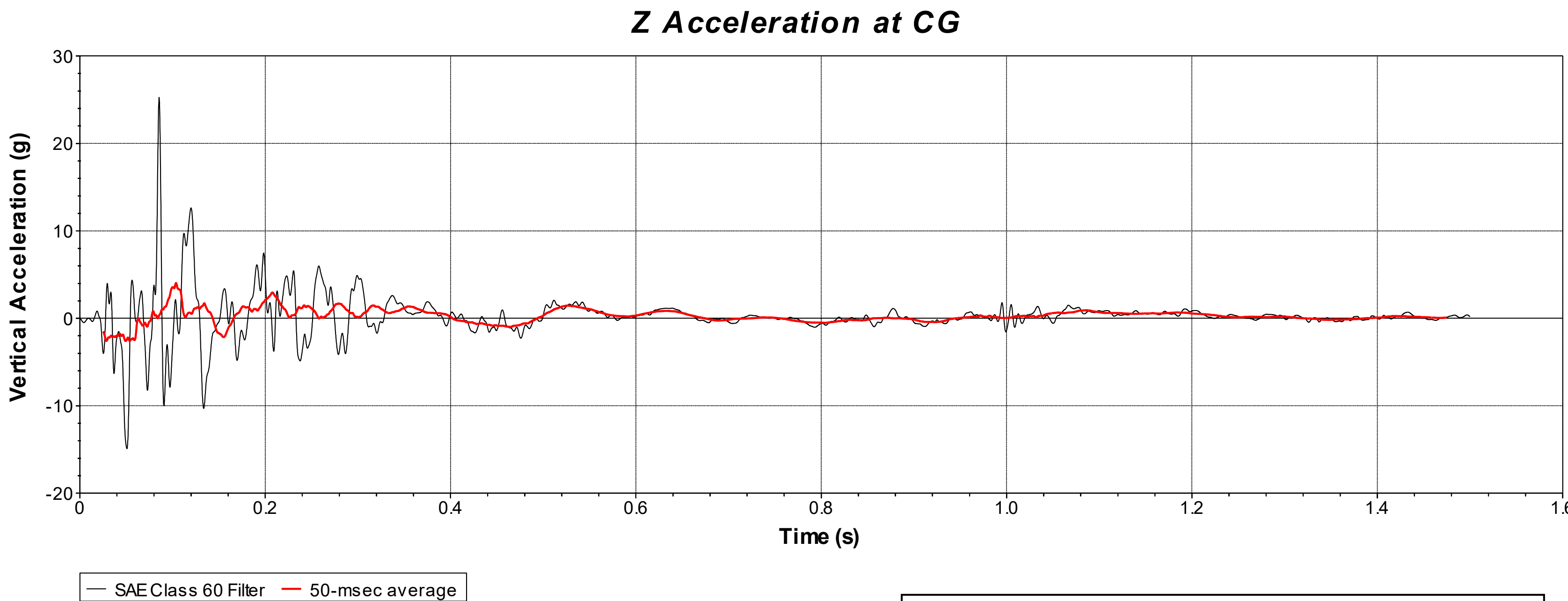
Test Number: 469469-2-1
Test Standard: *MASH* Test 3-11
Test Article: Modified C66 Bridge Rail
Test Vehicle: 2270P/ 2012 RAM 1500
Inertial Mass: 5014 lb
Gross Mass: 5179 lb
Impact Speed: 61.8 mi/h
Impact Angle: 24.3 degrees

Figure B.4. Vehicle Longitudinal Accelerometer Trace for Test No. 469469-2-1 (Accelerometer Located at Center of Gravity).



Test Number: 469469-2-1
Test Standard: *MASH* Test 3-11
Test Article: Modified C66 Bridge Rail
Test Vehicle: 2270P/ 2012 RAM 1500
Inertial Mass: 5014 lb
Gross Mass: 5179 lb
Impact Speed: 61.8 mi/h
Impact Angle: 24.3 degrees

Figure B.5. Vehicle Lateral Accelerometer Trace for Test No. 469469-2-1 (Accelerometer Located at Center of Gravity).



Test Number: 469469-2-1
Test Standard: *MASH* Test 3-11
Test Article: Modified C66 Bridge Rail
Test Vehicle: 2270P/ 2012 RAM 1500
Inertial Mass: 5014 lb
Gross Mass: 5179 lb
Impact Speed: 61.8 mi/h
Impact Angle: 24.3 degrees

Figure B.6. Vehicle Vertical Accelerometer Trace for Test No. 469469-2-1 (Accelerometer Located at Center of Gravity).

B.4. *MASH* TEST 3-10 (CRASH TEST NO. 469469-2-2)

B.4.1. Vehicle Properties and Information

Table B.5. Vehicle Properties for Test No. 469469-2-2.

Vehicle Inventory Number: 1338

Date:	2018-11-28	Test No.:	469469-2-2	VIN No.:	KNADH4A38B6736630
Year:	2011	Make:	Kia	Model:	Rio
Tire Inflation Pressure:	32 psi	Odometer:	123920	Tire Size:	185/65R14

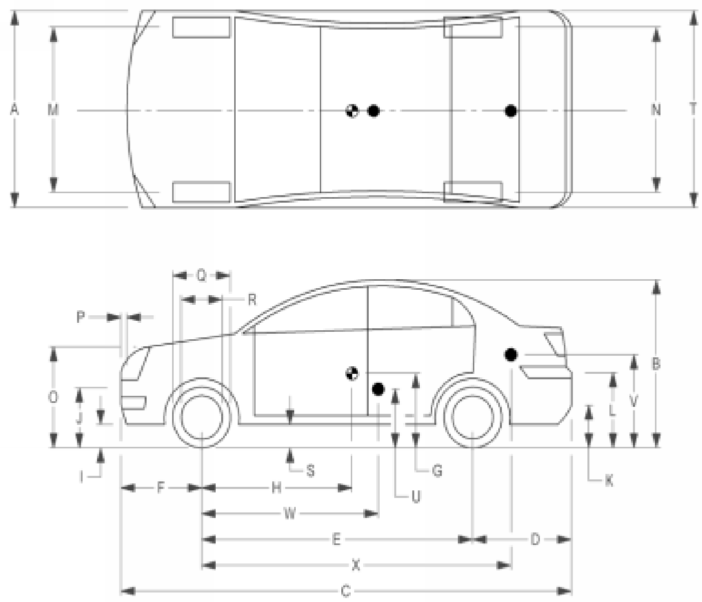
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES: None

Engine Type: 4 cylinder
Engine CID: 1.6 L
Transmission Type:
☑ Auto or ☐ Manual
☑ FWD ☐ RWD ☐ 4WD
Optional Equipment:

Dummy Data:
Type: 50th percentile male
Mass: 165 lb
Seat Position: IMPACT SIDE



Geometry: inches

A	66.38	F	33.00	K	12.25	P	4.12	U	15.00
B	51.50	G		L	25.25	Q	22.50	V	20.75
C	165.75	H	35.80	M	57.75	R	15.50	W	35.80
D	34.00	I	7.75	N	57.70	S	8.25	X	108.00
E	98.75	J	21.50	O	28.25	T	66.20		

Wheel Center Ht Front: 11.00 Wheel Center Ht Rear: 11.00 W-H: 0.00

RANGE LIMIT: A = 65 ±3 inches; C = 168 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; G = 39 ±4 inches; O(Bottom of Hood Lip) = 24 ±4 inch
(M+N)/2 = 56 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1581	1559	1644
Back	1874	M_{rear}	877	889	969
Total	3638	M_{Total}	2458	2448	2613

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

Mass Distribution:
lb

LF:	RF:	LR:	RR:
779	780	429	460

Table B.6. Exterior Crush Measurements of Vehicle for Test No. 469469-2-2.

Vehicle Inventory Number: 1338

Date:	2018-11-28	Test No.:	469469-2-2	VIN No.:	KNADH4A38B6736630
Year:	2011	Make:	Kia	Model:	Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FT BUMPER	17	10	22	0	1	2	3	6	10	-9
2	ABOVE FT BUMPER	17	12	46	2.5	5	8	9	10.5	12	+62
	Measurements recorded										
	☐ inches or ☐ mm										

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

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

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

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

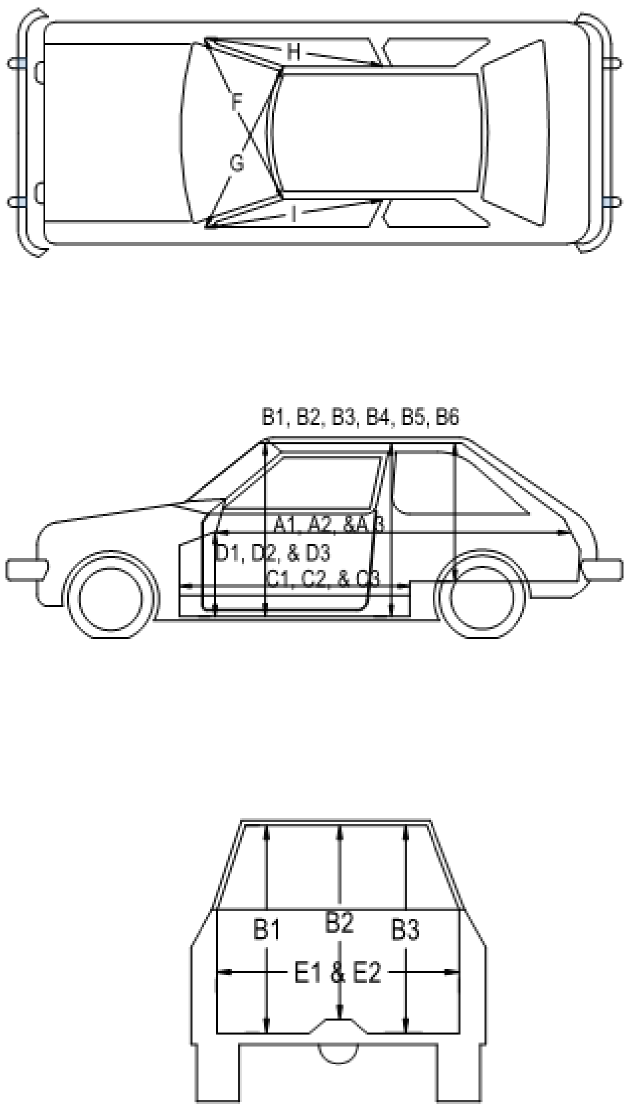
***Measure and document on the vehicle diagram the location of the maximum crush.

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

Table B.7. Occupant Compartment Measurements of Vehicle for Test No. 469469-2-2.

Vehicle Inventory Number: 1338

Date:	2018-11-28	Test No.:	469469-2-2	VIN No.:	KNADH4A38B6736630
Year:	2011	Make:	Kia	Model:	Rio

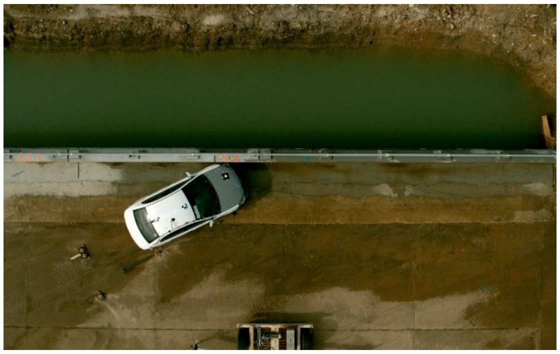


*Lateral area across the cab from driver's side kick panel to passenger's side kick panel.

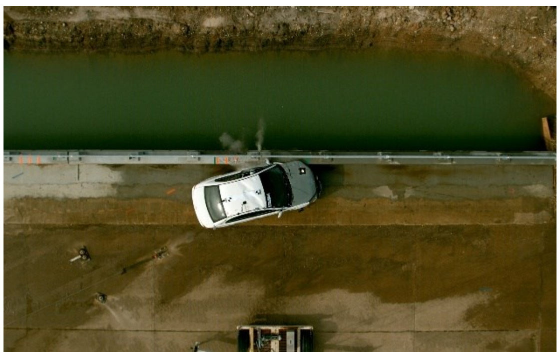
OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	67.50	67.00	-0.50
A2	67.25	67.25	0.00
A3	67.75	67.75	0.00
B1	40.50	38.50	-2.00
B2	39.00	39.00	0.00
B3	40.50	40.50	0.00
B4	36.25	36.25	0.00
B5	36.00	36.00	0.00
B6	36.25	35.25	-1.00
C1	26.00	24.50	-1.50
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	9.50	8.50	-1.00
D2	0.00	0.00	0.00
D3	9.50	9.50	0.00
E1	51.50	52.50	1.00
E2	51.00	53.00	2.00
F	51.00	51.00	0.00
G	51.00	50.50	-0.50
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	51.00	49.50	-1.50

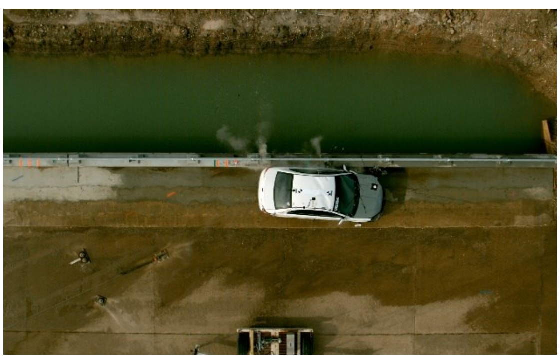
B.4.2. Sequential Photographs



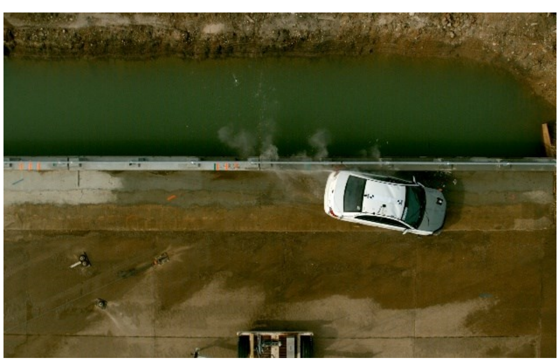
0.000 s



0.100 s



0.200 s



0.300 s

Figure B.7. Sequential Photographs for Test No. 469469-2-2 (Overhead and Gut Views).

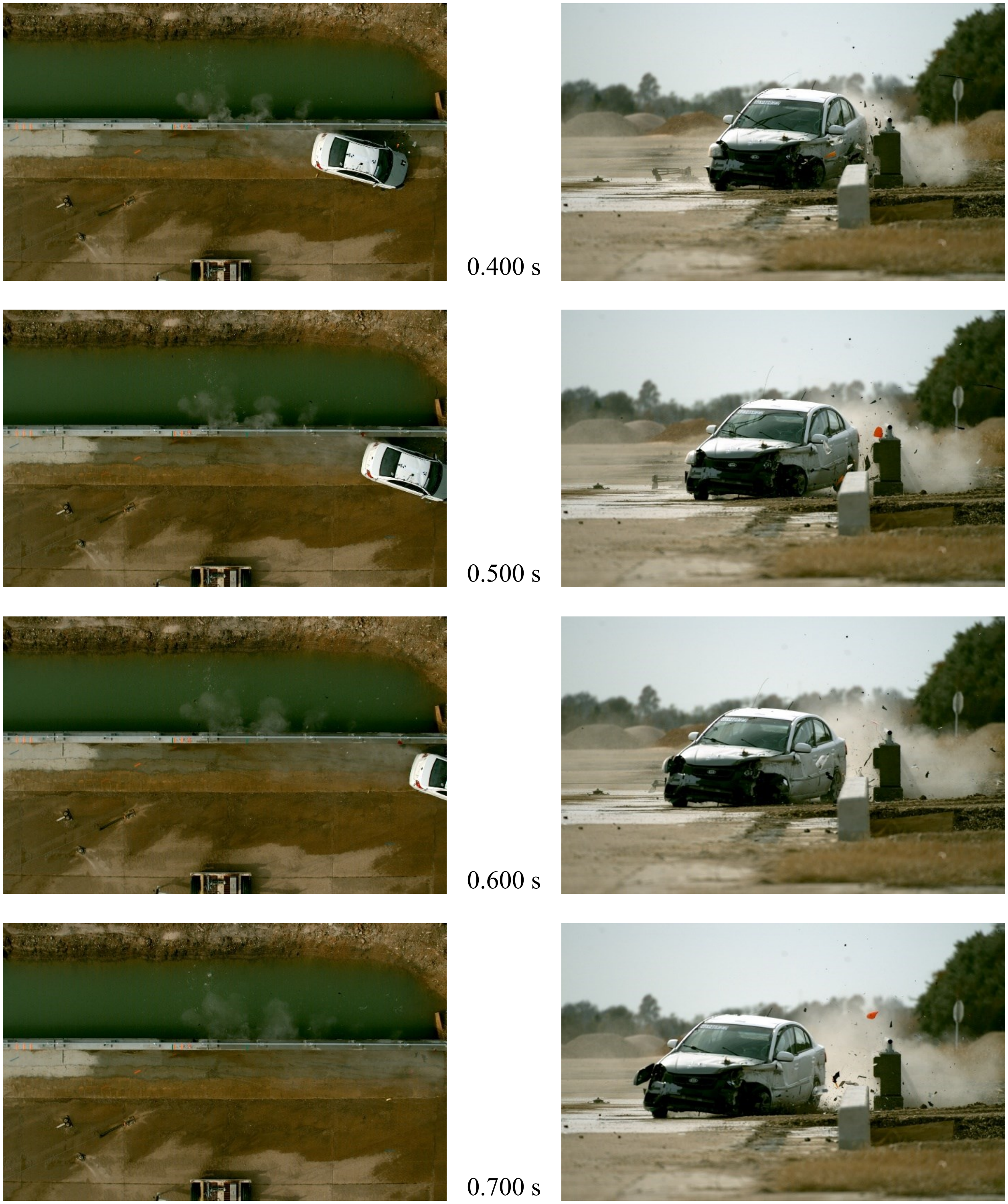


Figure A.1. Sequential Photographs for Test No. 469469-2-2 (Overhead and Gut Views) (Continued).

0.000 s

0.100 s

0.200 s

0.300 s

0.400 s

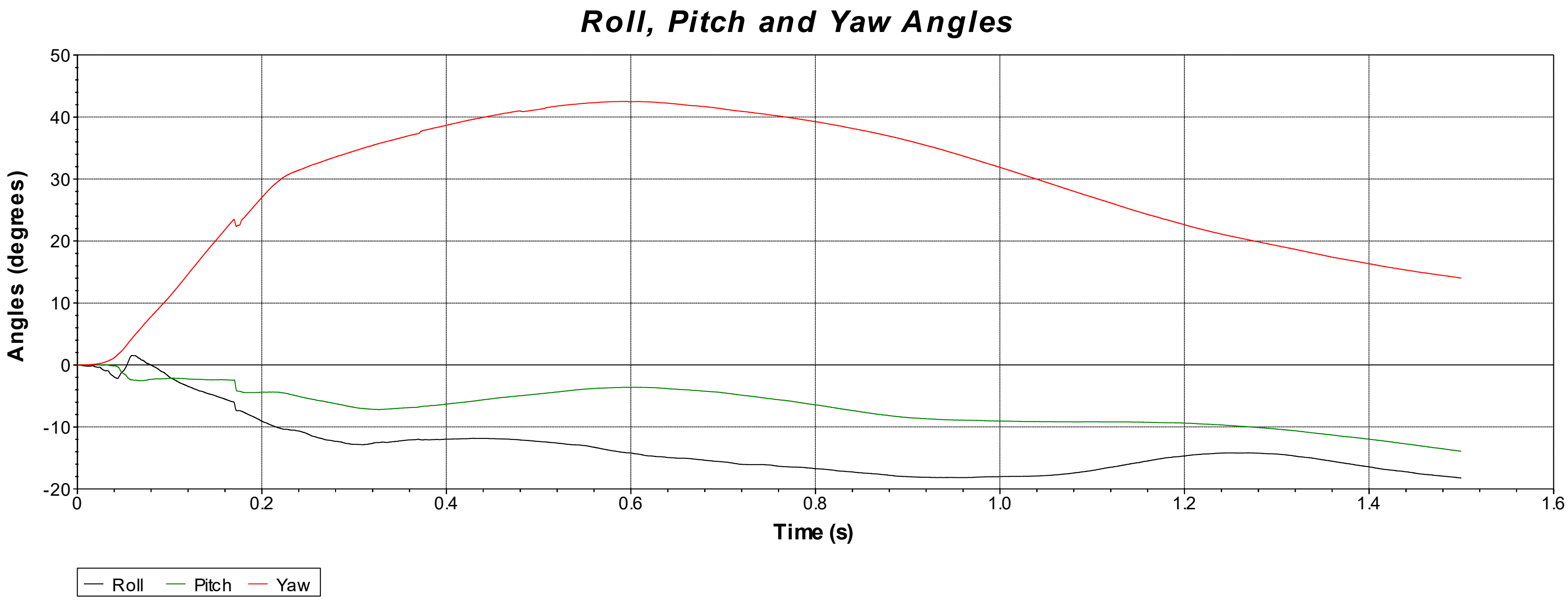
0.500 s

0.600 s

0.700 s

Figure B.8. Sequential Photographs for Test No. 469469-2-2 (Rear View).

B.4.3. Vehicle Angular Displacement



Test Number: 469469-2-2
Test Standard: *MASH* Test 3-10
Test Article: Modified C66 Bridge Rail
Test Vehicle: 1100C/ 2011 Kia Rio
Inertial Mass: 2448 lb
Gross Mass: 2613 lb
Impact Speed: 63.0 mi/h
Impact Angle: 24.9 degrees

Axes are vehicle-fixed.
Sequence for determining orientation:

7. Yaw.
8. Pitch.
9. Roll.

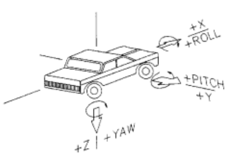
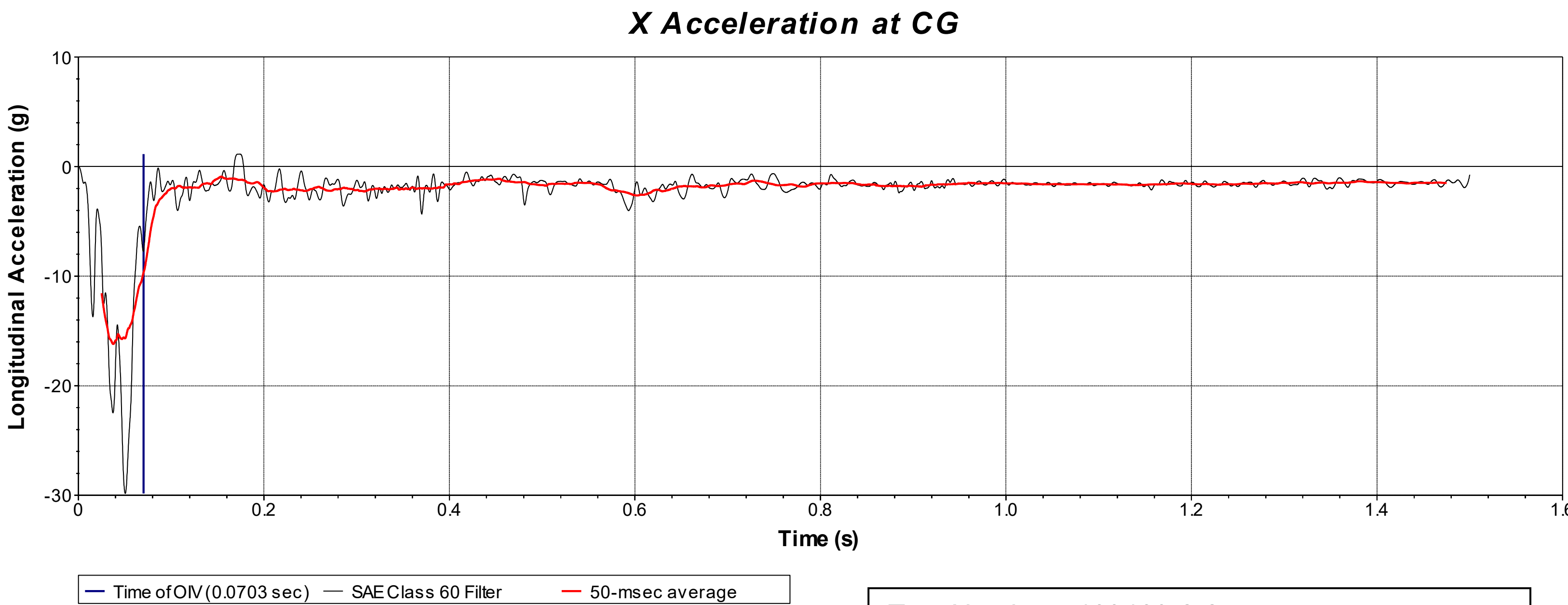


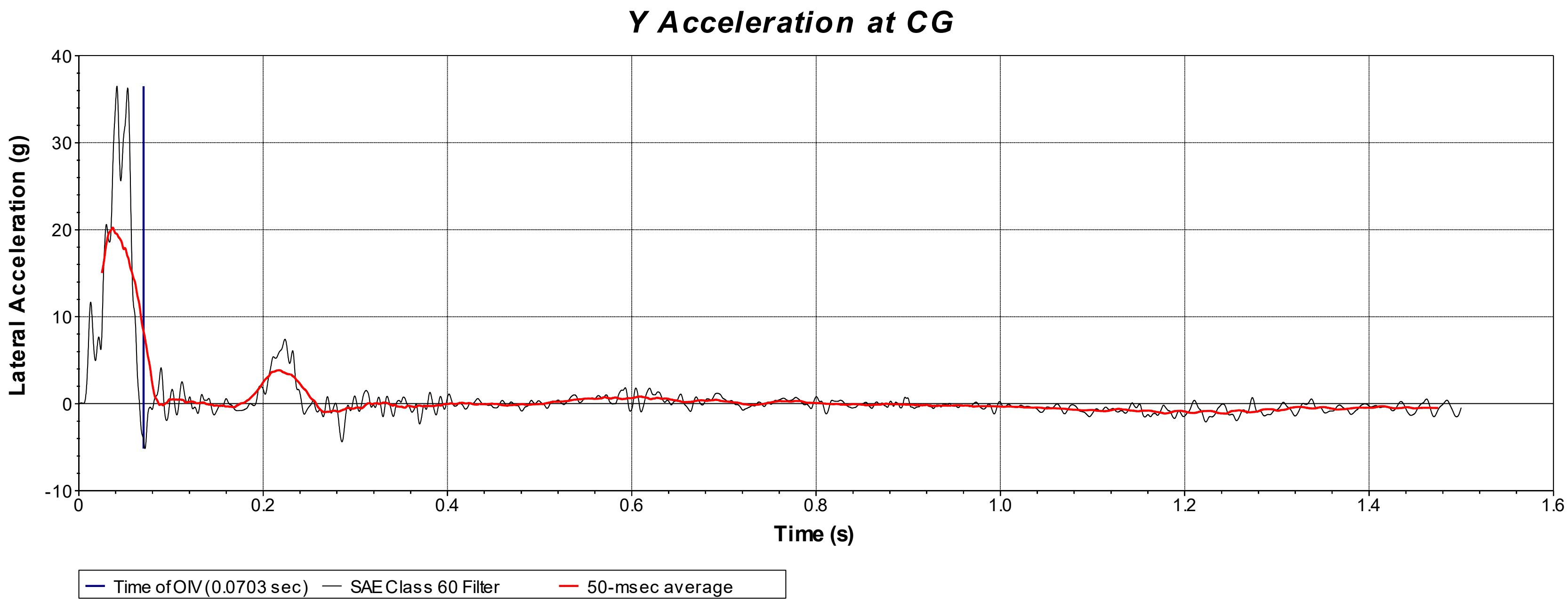
Figure B.9. Vehicle Angular Displacements for Test No. 469469-2-2.

B.4.4. Vehicle Acceleration



Test Number: 469469-2-2
Test Standard: *MASH* Test 3-10
Test Article: Modified C66 Bridge Rail
Test Vehicle: 1100C/ 2011 Kia Rio
Inertial Mass: 2448 lb
Gross Mass: 2613 lb
Impact Speed: 63.0 mi/h
Impact Angle: 24.9 degrees

Figure B.10. Vehicle Longitudinal Accelerometer Trace for Test No. 469469-2-2 (Accelerometer Located at Center of Gravity).



Test Number: 469469-2-2
Test Standard: *MASH* Test 3-10
Test Article: Modified C66 Bridge Rail
Test Vehicle: 1100C/ 2011 Kia Rio
Inertial Mass: 2448 lb
Gross Mass: 2613 lb
Impact Speed: 63.0 mi/h
Impact Angle: 24.9 degrees

Figure B.11. Vehicle Lateral Accelerometer Trace for Test No. 469469-2-2 (Accelerometer Located at Center of Gravity).

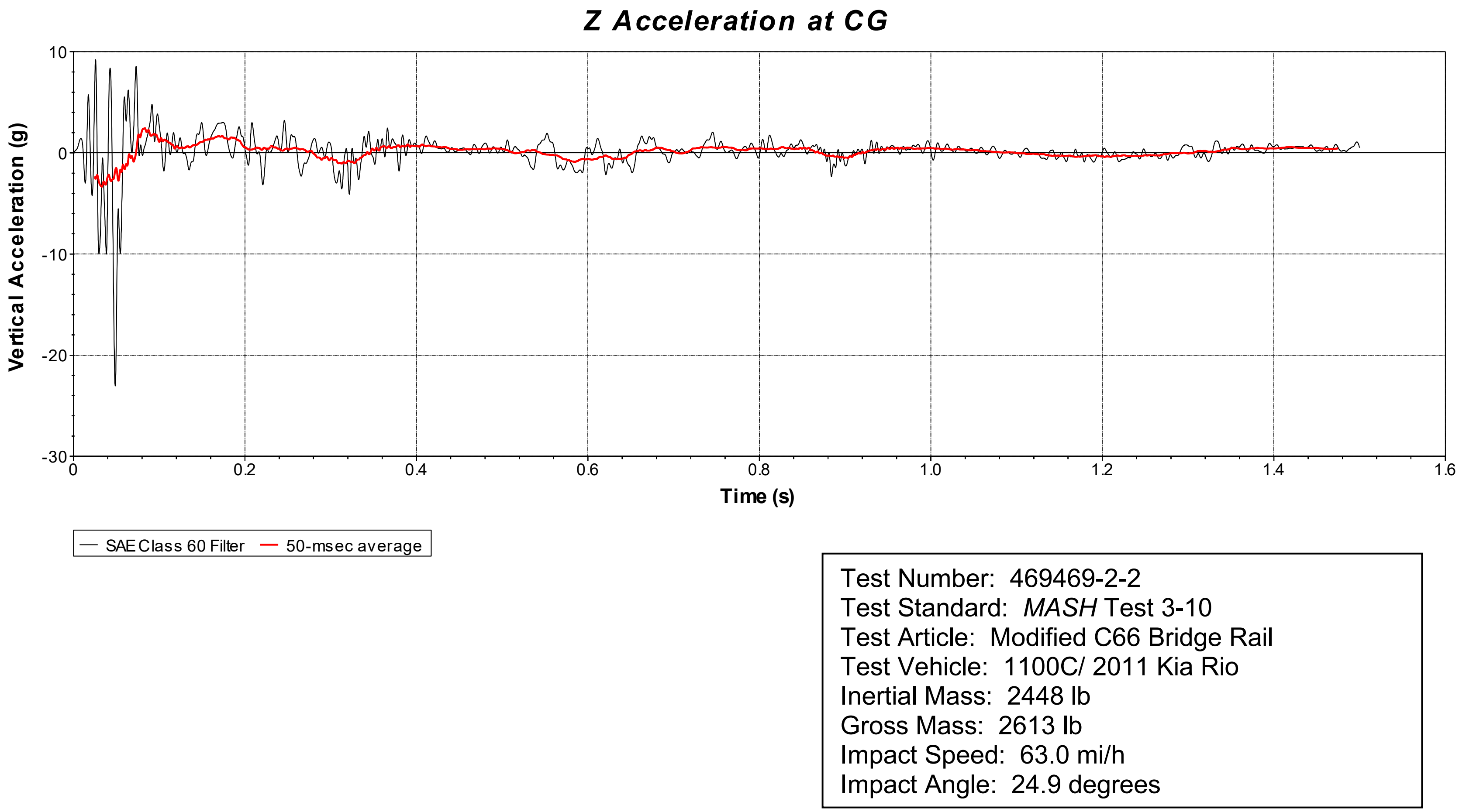
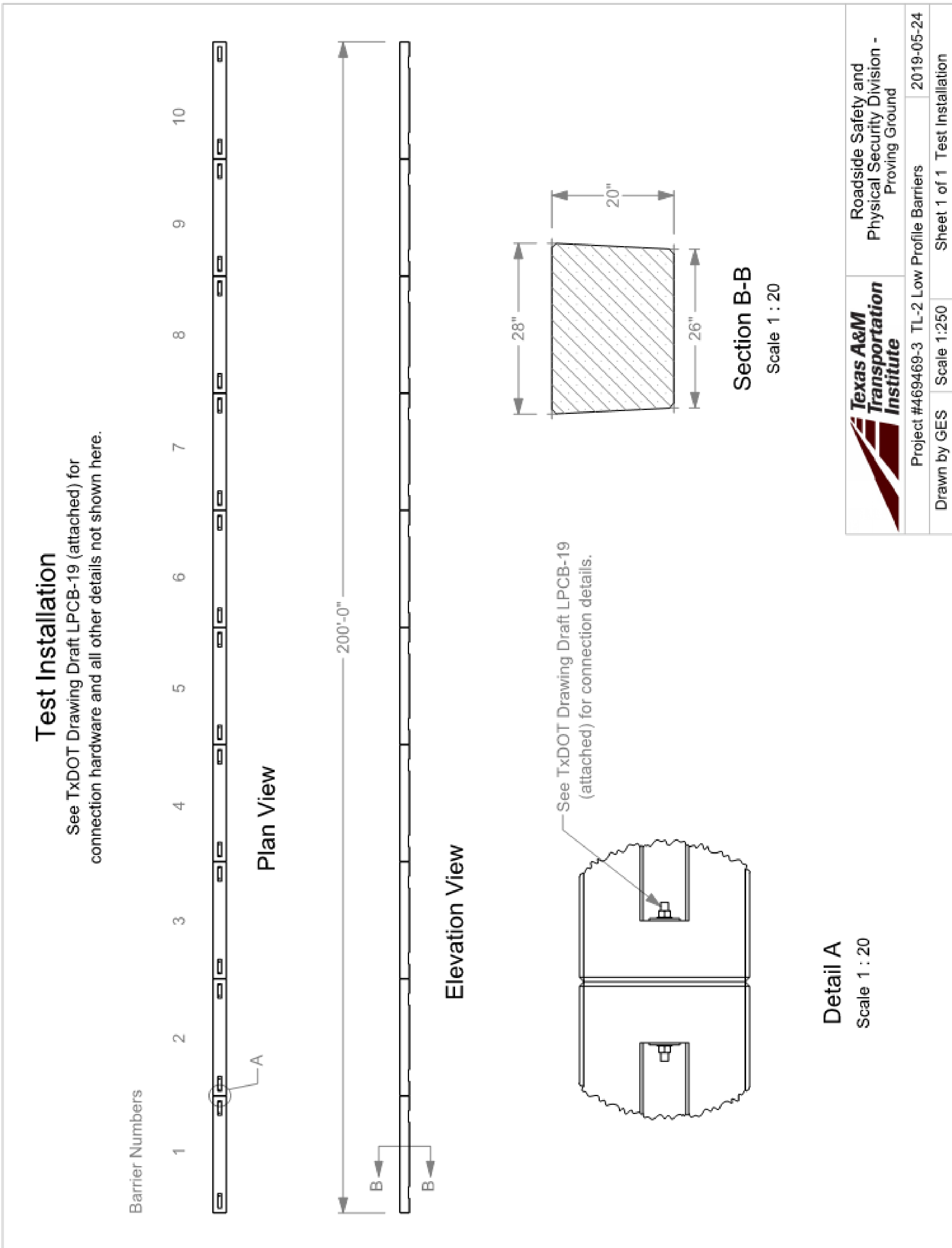
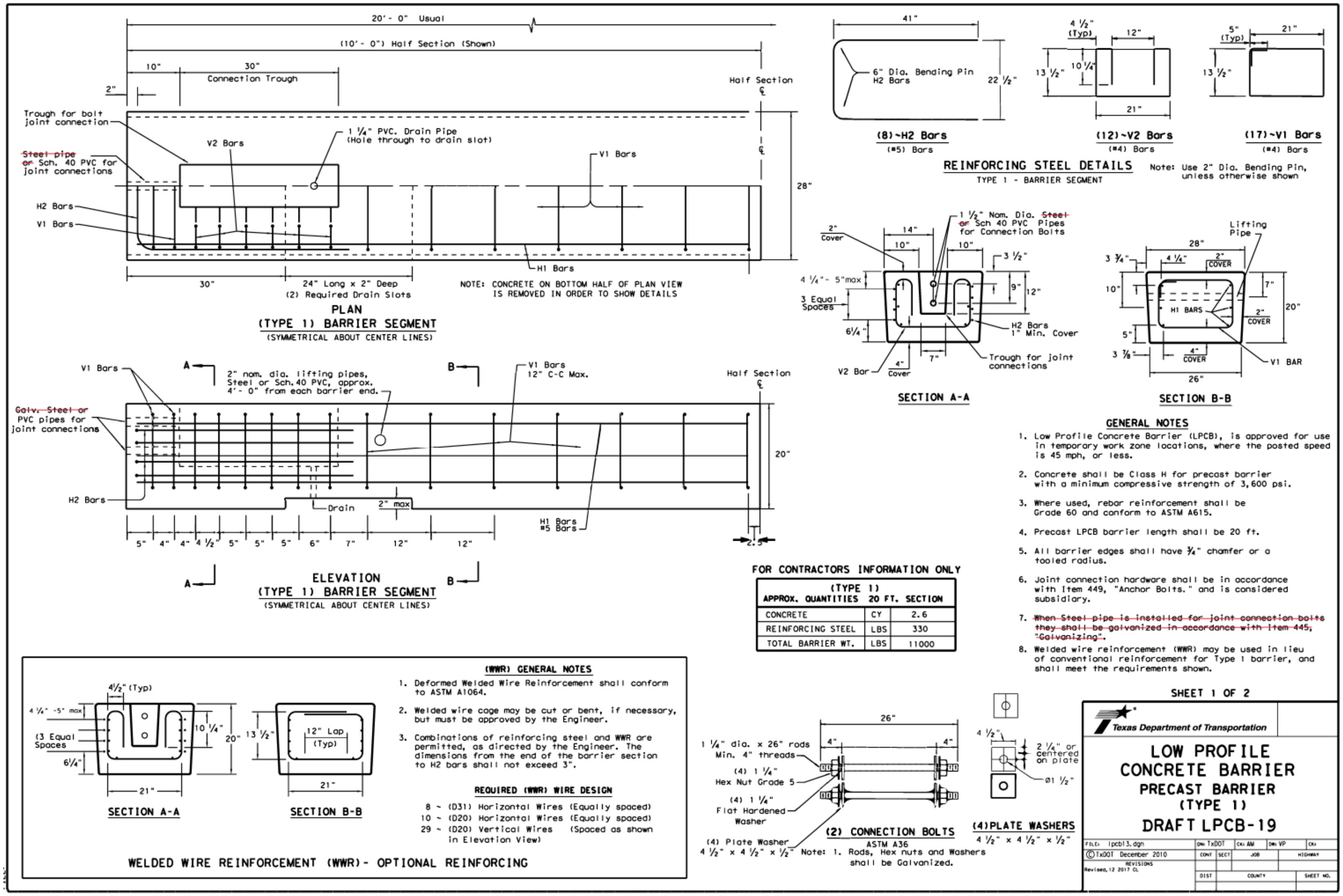


Figure B.12. Vehicle Vertical Accelerometer Trace for Test No. 469469-2-2 (Accelerometer Located at Center of Gravity).

APPENDIX C. TXDOT LOW-PROFILE BARRIER

C.1. DETAILS OF THE LOW-PROFILE BARRIER





(TYPE 1) APPROX. QUANTITIES		20 FT. SECTION
CONCRETE	CY	2.6
REINFORCING STEEL	LBS	330
TOTAL BARRIER WT.	LBS	11000

C.2. SUPPORTING CERTIFICATION DOCUMENTS

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Concrete Core Test Report

Report Number: A1171057.0056
Service Date: 06/24/19
Report Date: 06/26/19
Task: PO #469469-11

Client

Texas Transportation Institute
Attn: Gary Gerke
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project

Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information

Specified Strength:

Specified Length:
Mix ID:
Nominal Maximum Size Aggregate:

Sample Information

Placement Date:
Date Tested: 06/26/19 **Time:** 0000
Sampled By: Juan Vasquez
Drill Directions: Vertical
Date Core Obtained: 06/24/19 **Time:** 0000
Date Ends Trimmed: 06/26/19 **Time:** 0000
Moisture Conditioning History: According to ASTM C-42

Laboratory Test Data

Core ID		Location	Cored Length (in)	Trim Length (in)	Capped Length (in)	Diam. (in)	Area (sq in)	Length / Diam. Ratio	Max Load (lbs)	Corr. Factor	Comp. Strength (psi)	Fracture Type	Density (pcf)	Tested By
1	A	Low profile barrier 5	12.50	7.85	8.10	3.99	12.50	2.03	81470	1.000	6520	1		BJA
1	B	Low profile barrier 8	12.00	7.80	8.05	3.99	12.50	2.02	100810	1.000	8060	2		BJA

Comments:

Services:
Terracon Rep.: Juan Vasquez
Reported To:
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Gary Gerke (1) Terracon Consultants, Inc., Andrea Allen

Start/Stop: 0700-1100

Reviewed By:
Andrea Allen
Project Manager

Test Methods:

The tests were performed in general accordance with applicable ASTM, AASHTO, or DOT test methods. This report is exclusively for the use of the client indicated above and shall not be reproduced except in full without the written consent of our company. Test results transmitted herein are only applicable to the actual samples tested at the location(s) referenced and are not necessarily indicative of the properties of other apparently similar or identical materials.

C.3. *MASH* TEST 2-11 (CRASH TEST NO. 469469-3-2)

C.3.1. Vehicle Properties and Information

Table C.1. Vehicle Properties for Test No. 469469-3-2.

Vehicle Inventory Number: 1408

Date:	2019-06-06	Test No.:	469469-03-2	VIN No.:	1C6RR6FT5FS547450
Year:	2015	Make:	RAM	Model:	1500

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

Tread Type: Highway Odometer: 188757

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

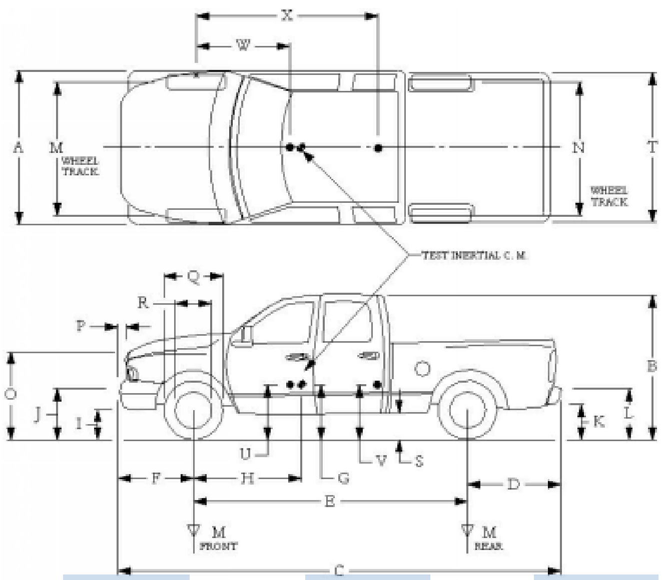
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

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

Optional Equipment:
None

Dummy Data:
Type:
Mass: 0 lb
Seat Position:



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.40	L	30.00	Q	30.50	V	30.25
C	227.50	H	60.36	M	68.50	R	18.00	W	60.30
D	44.00	I	11.75	N	68.00	S	13.00	X	79.00
E	140.50	J	27.00	O	46.00	T	77.00		

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

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

GVWR Ratings:		Mass: lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2910	2858	
Back	3900	M_{rear}	2057	2153	
Total	6700	M_{Total}	4967	5011	0

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

Mass Distribution:
lb LF: 1426 RF: 1432 LR: 1111 RR: 1042

Table C.2. Measurements of Vehicle Vertical CG for Test No. 469469-3-2.

Vehicle Inventory Number: 1408

Date: 2019-06-06 Test No.: 469469-03-2 VIN: 1C6RR6FT5FS547450

Year: 2015 Make: RAM Model: 1500

Body Style: Quad Cab Mileage: 188757

Engine: 5.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 100 (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70 R 17

Measured Vehicle Weights: (lb)

LF:	1426	RF:	1432	Front Axle:	2858
LR:	1111	RR:	1042	Rear Axle:	2153
Left:	2537	Right:	2474	Total:	5011
					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:	60.37	inches	Rear of Front Axle	(63 ±4 inches allowed)
Y:	-0.43	inches	Left - Right +	of Vehicle Centerline
Z:	28.40	inches	Above Ground	(minumum 28.0 inches allowed)

Hood Height: 46.00 inches Front Bumper Height: 27.00 inches

43 ±4 inches allowed

Front Overhang: 40.00 inches Rear Bumper Height: 30.00 inches

39 ±3 inches allowed

Overall Length: 227.50 inches

237 ±13 inches allowed

Table C.3. Exterior Crush Measurements of Vehicle for Test No. 469469-3-2.

Vehicle Inventory Number: 1408

Date:	2019-06-06	Test No.:	469469-03-2	VIN No.:	1C6RR6FT5FS547450
Year:	2015	Make:	RAM	Model:	1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FT BUMPER	22	2								
	Measurements recorded										
	☐ inches or ☐ mm										

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

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

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

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

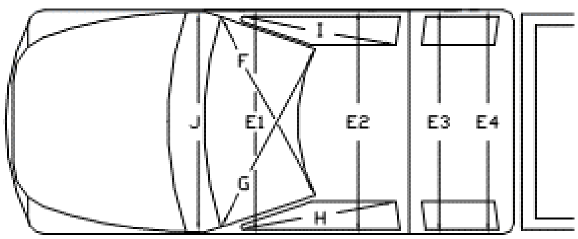
***Measure and document on the vehicle diagram the location of the maximum crush.

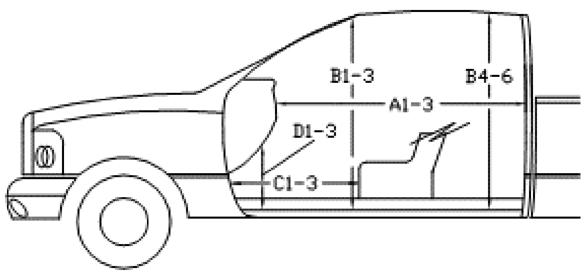
Note: Use as many lines/columns as necessary to describe each damage profile.

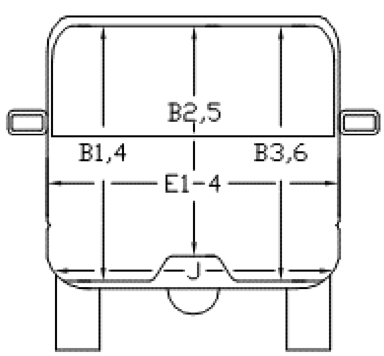
Table C.4. Occupant Compartment Measurements of Vehicle for Test No. 469469-3-2.

Vehicle Inventory Number: 1408

Date:	2019-06-06	Test No.:	469469-03-2	VIN No.:	1C6RR6FT5FS547450
Year:	2015	Make:	RAM	Model:	1500







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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	58.50	0.00
E2	63.50	63.50	0.00
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	25.00	0.00

C.3.2. Sequential Photographs

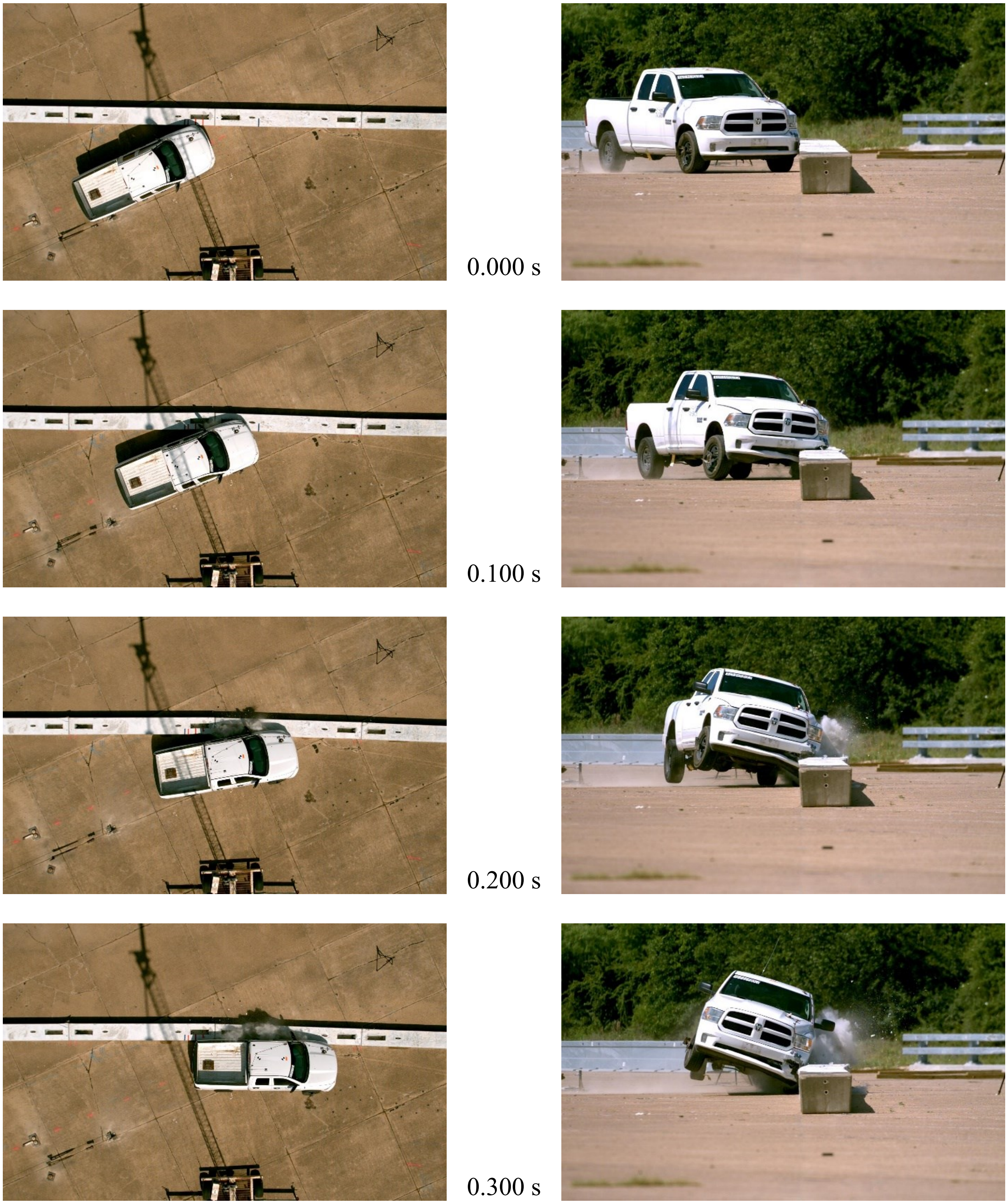


Figure C.1. Sequential Photographs for Test No. 469469-3-2 (Overhead and Gut Views).

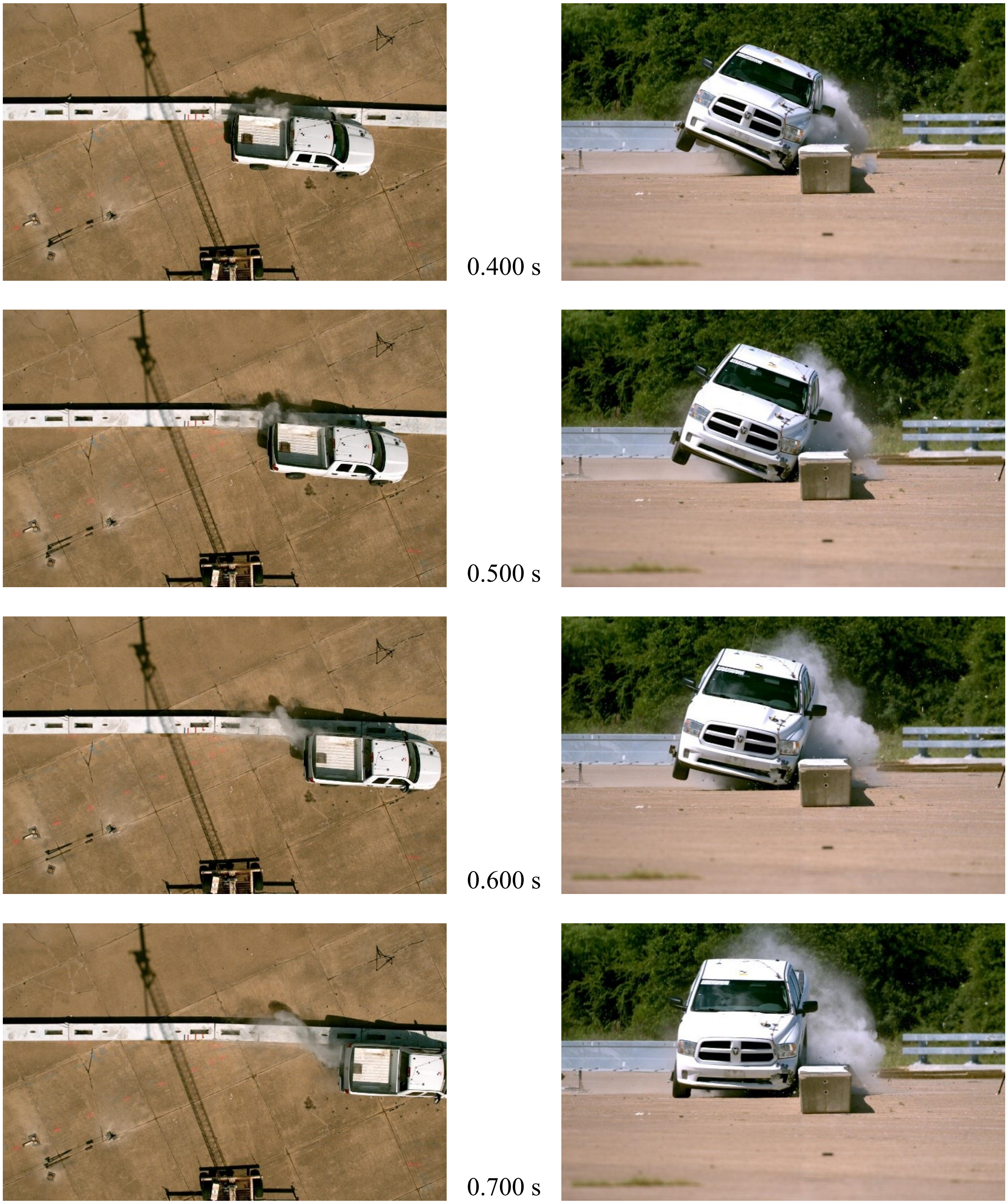


Figure A.1. Sequential Photographs for Test No. 469469-3-2 (Overhead and Gut Views) (Continued).

0.000 s

0.100 s

0.200 s

0.300 s

0.400 s

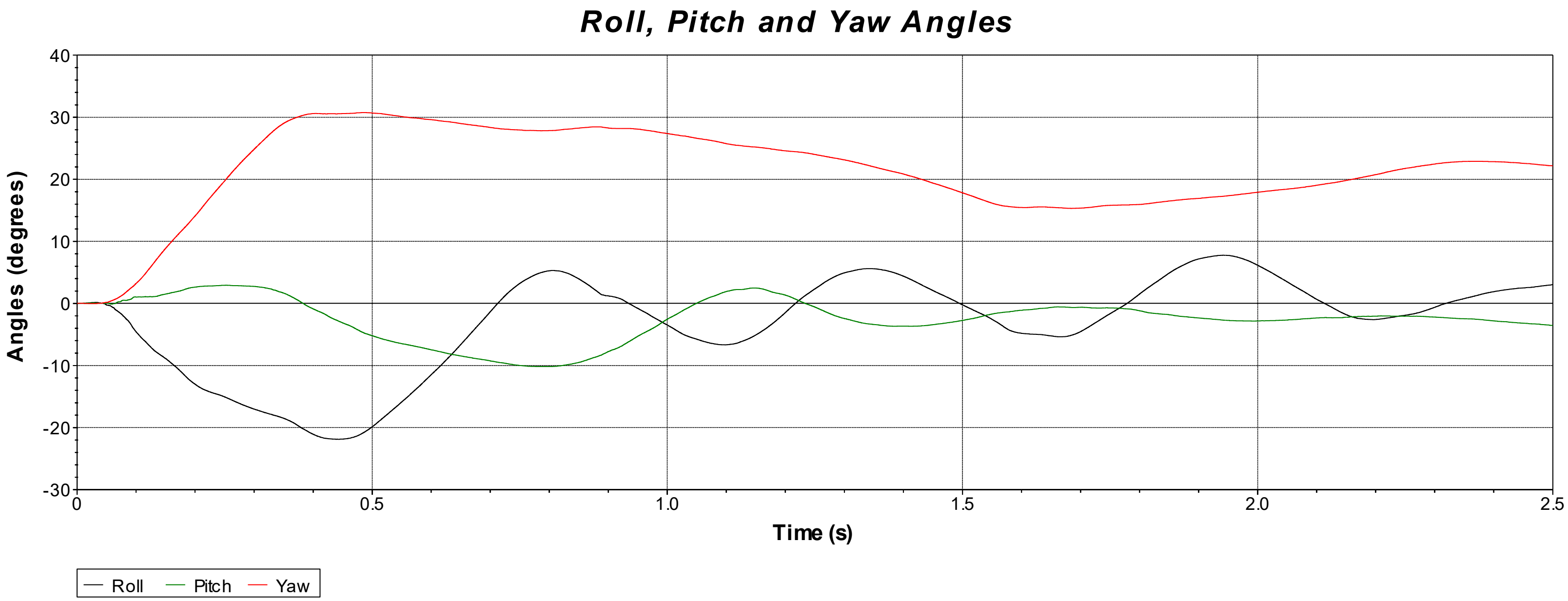
0.500 s

0.600 s

0.700 s

Figure C.2. Sequential Photographs for Test No. 469469-3-2 (Rear View).

C.3.3. Vehicle Angular Displacement



Test Number: 469469-3-2
Test Standard: 2-11
Test Article: Low-Profile Barrier
Test Vehicle: 2270P/ 2015 RAM 1500
Inertial Mass: 5011 lb
Gross Mass: 5011 lb
Impact Speed: 44.4 mi/h
Impact Angle: 25.1 degrees

Axes are vehicle-fixed.
Sequence for determining orientation:

10. Yaw.
11. Pitch.
12. Roll.

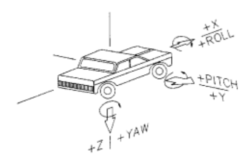


Figure C.3. Vehicle Angular Displacements for Test No. 469469-3-2.

C.3.4. Vehicle Acceleration

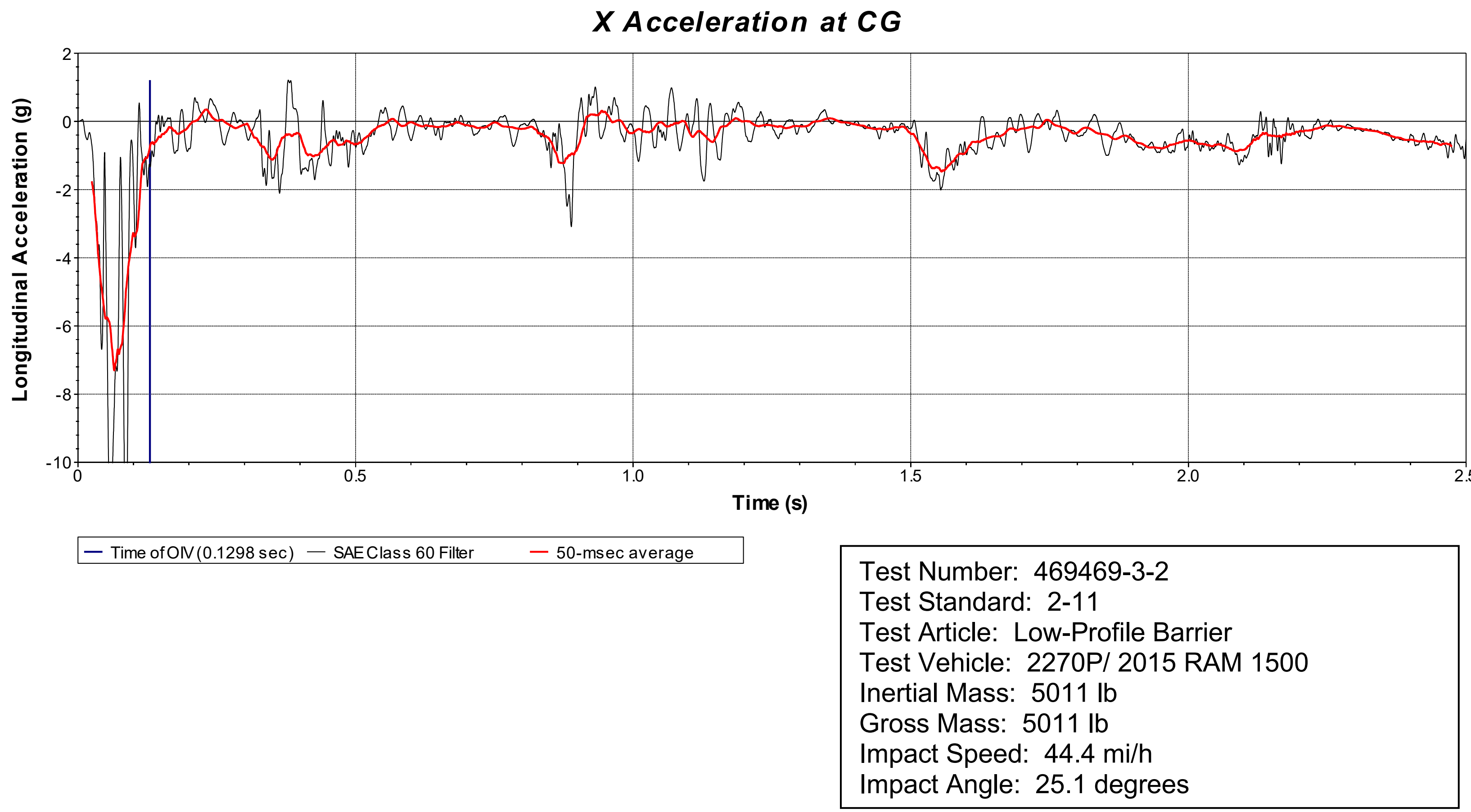
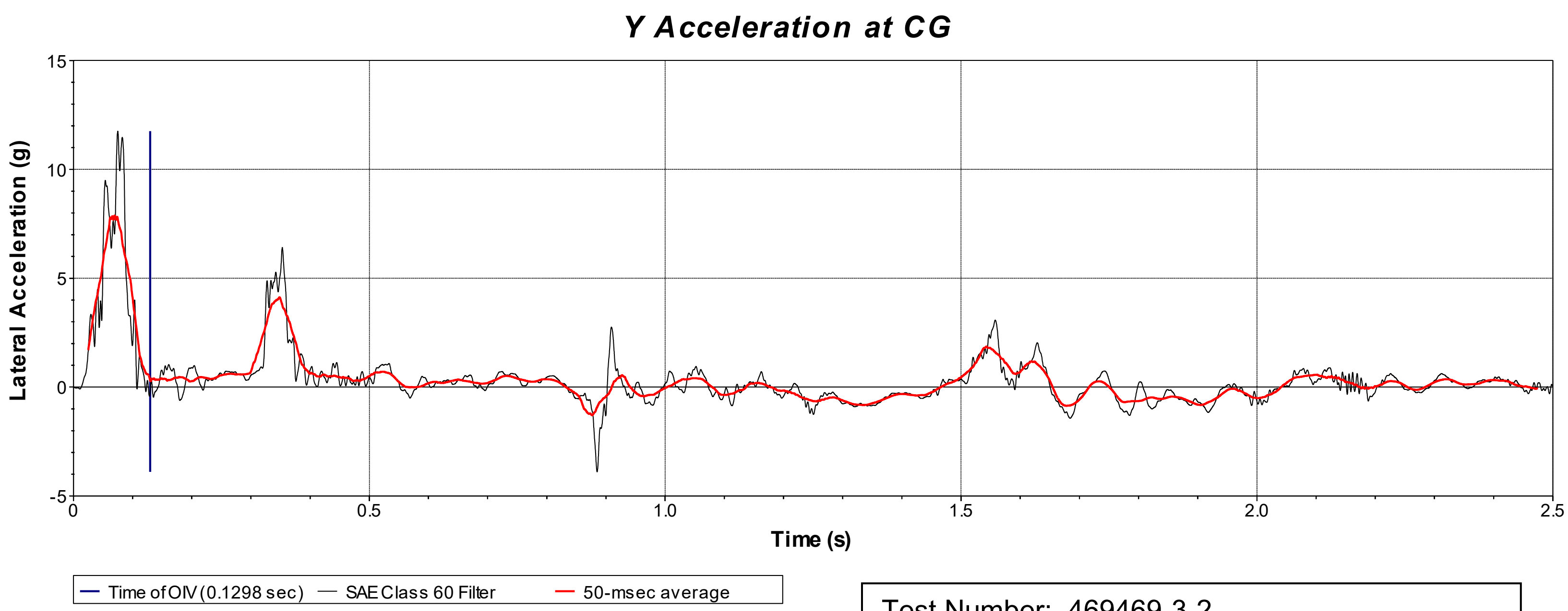
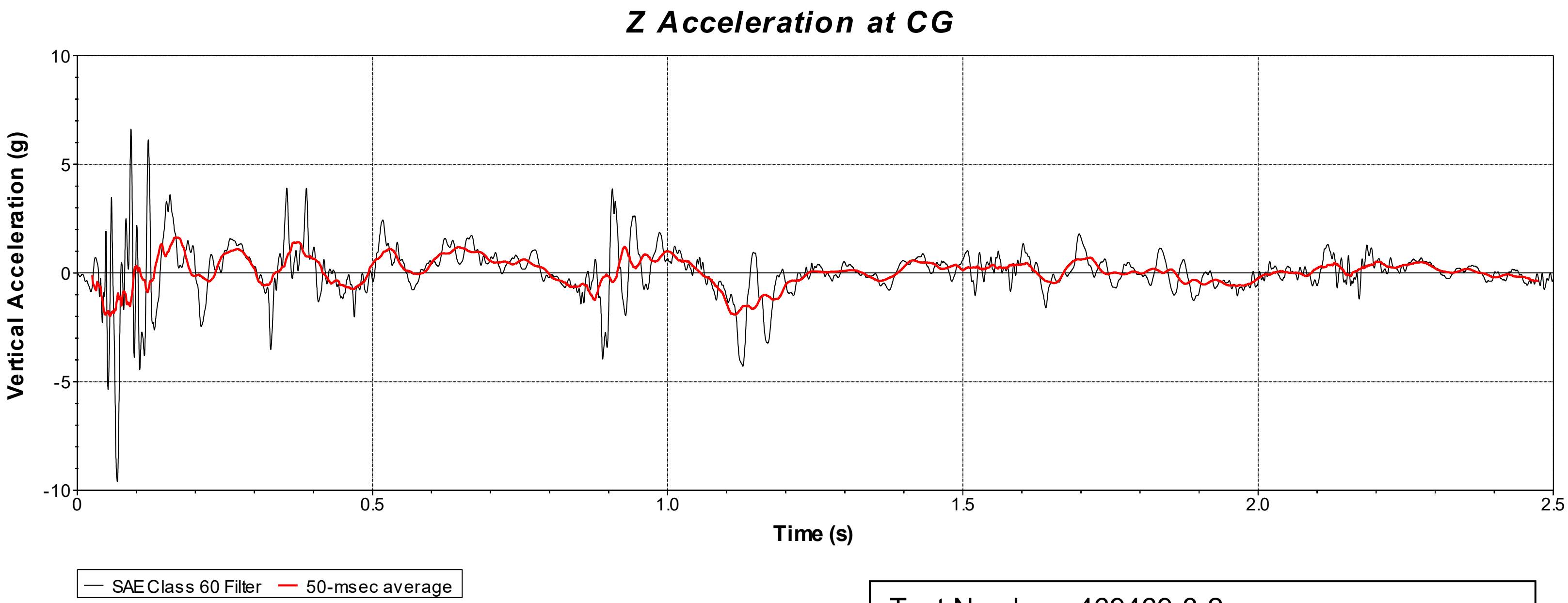


Figure C.4. Vehicle Longitudinal Accelerometer Trace for Test No. 469469-3-2 (Accelerometer Located at Center of Gravity).



Test Number: 469469-3-2
Test Standard: 2-11
Test Article: Low-Profile Barrier
Test Vehicle: 2270P/ 2015 RAM 1500
Inertial Mass: 5011 lb
Gross Mass: 5011 lb
Impact Speed: 44.4 mi/h
Impact Angle: 25.1 degrees

Figure C.5. Vehicle Lateral Accelerometer Trace for Test No. 469469-3-2 (Accelerometer Located at Center of Gravity).



Test Number: 469469-3-2
Test Standard: 2-11
Test Article: Low-Profile Barrier
Test Vehicle: 2270P/ 2015 RAM 1500
Inertial Mass: 5011 lb
Gross Mass: 5011 lb
Impact Speed: 44.4 mi/h
Impact Angle: 25.1 degrees

Figure C.6. Vehicle Vertical Accelerometer Trace for Test No. 469469-3-2 (Accelerometer Located at Center of Gravity).

C.4. *MASH* TEST 2-10 (CRASH TEST NO. 469469-3-1)

C.4.1. Vehicle Properties and Information

Table C.5. Vehicle Properties for Test No. 469469-3-1.

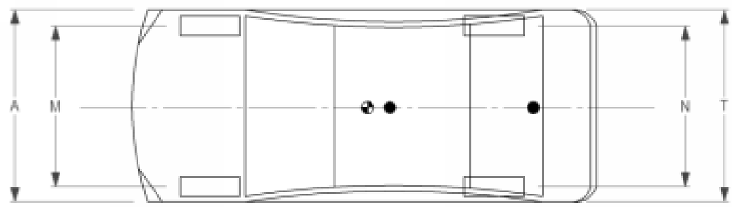
Vehicle Inventory Number: 1409

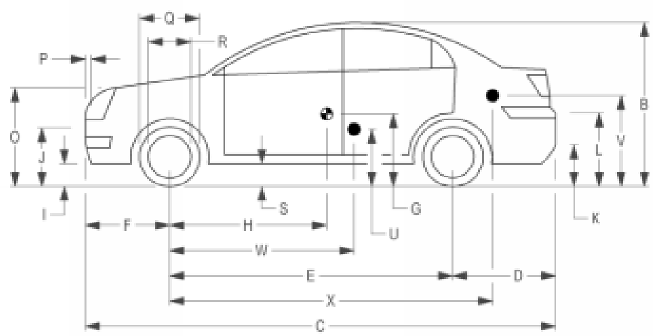
Date:	2019-06-14	Test No.:	469469-03-1	VIN No.:	KNADE223196504232
Year:	2009	Make:	Kia	Model:	Rio
Tire Inflation Pressure:	32 PSI	Odometer:	193992	Tire Size:	185/65R14

Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES:





Engine Type: 4 CYL
Engine CID: 1.6 L

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

Optional Equipment:
None

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

Geometry: inches

A	66.38	F	33.00	K	12.25	P	4.12	U	14.75
B	51.50	G		L	25.25	Q	22.50	V	20.75
C	165.75	H		M	57.75	R	15.50	W	35.20
D	34.00	I	7.75	N	57.70	S	8.25	X	71.50
E	98.75	J	21.50	O	27.00	T	66.20		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00 W-H 0.00

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Bottom of Hood Lip) = 24 ±4 inches
TOP OF RADIATOR SUPPORT = 28.25 inches; (M+N)/2 = 56 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1586	1570	1655
Back	1874	M_{rear}	865.00	870	950.00
Total	3638	M_{Total}	2451	2440	2605

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

Mass Distribution:
lb LF: 800 RF: 770 LR: 430 RR: 440

Table C.6. Exterior Crush Measurements of Vehicle for Test No. 469469-3-1.

Vehicle Inventory Number: 1409

Date:	2019-06-14	Test No.:	469469-03-1	VIN No.:	KNADE223196504232
Year:	2009	Make:	Kia	Model:	Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FT BUMPER	24	6								
	Measurements recorded										
	☐ inches or ☐ mm										

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

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

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

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

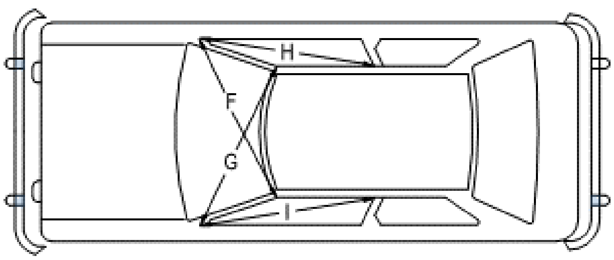
***Measure and document on the vehicle diagram the location of the maximum crush.

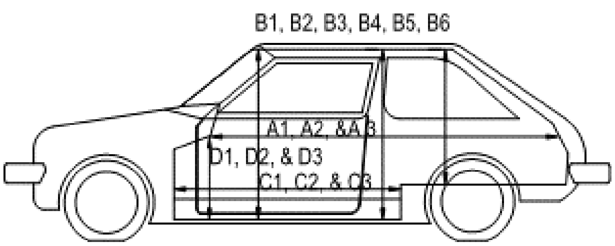
Note: Use as many lines/columns as necessary to describe each damage profile.

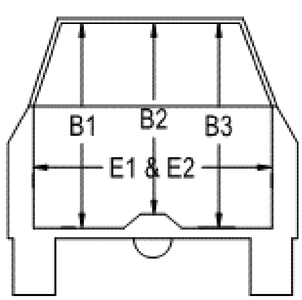
Table C.7. Occupant Compartment Measurements of Vehicle for Test No. 469469-3-1.

Vehicle Inventory Number: 1409

Date:	2019-06-14	Test No.:	469469-03-1	VIN No.:	KNADE223196504232
Year:	2009	Make:	Kia	Model:	Rio







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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

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

C.4.2. Sequential Photographs


0.000 s



0.100 s



0.200 s



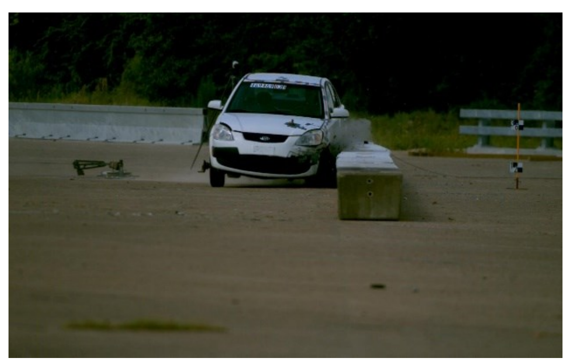
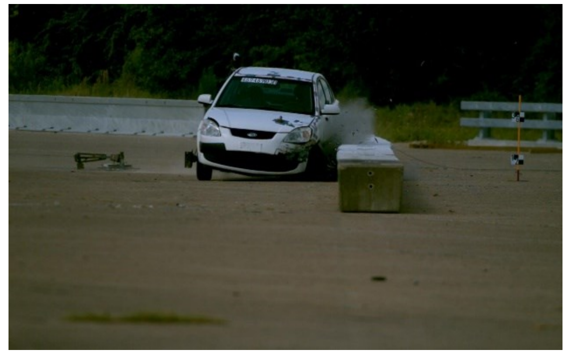
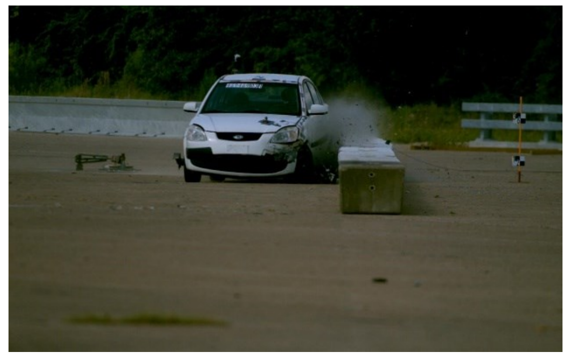
0.300 s


Figure C.7. Sequential Photographs for Test No. 469469-3-1 (Overhead and Gut Views).


0.400 s



0.500 s
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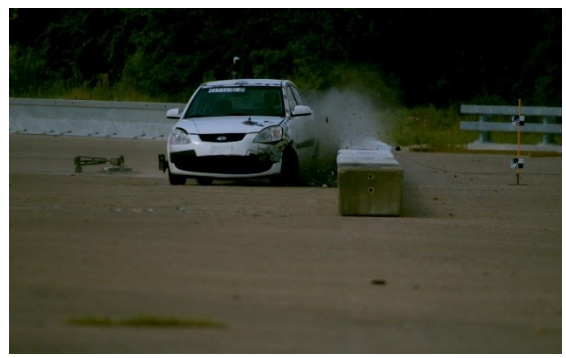


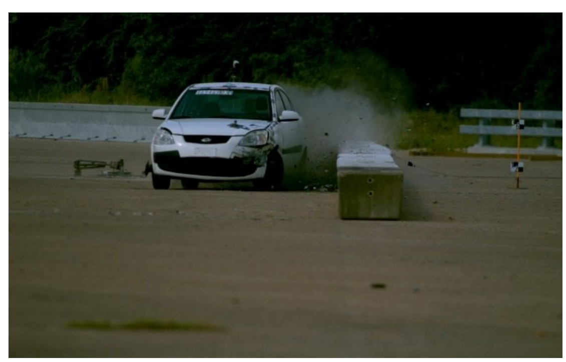

0.700 s


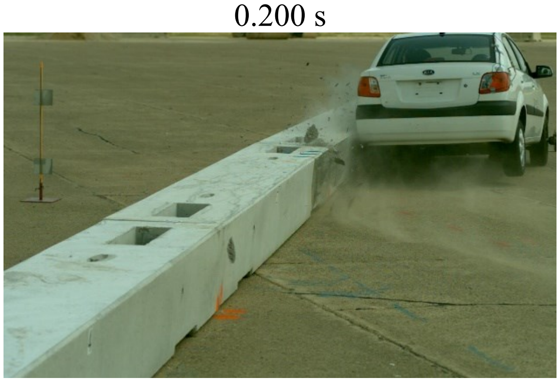
Figure C.7. Sequential Photographs for Test No. 469469-3-1 (Overhead and Gut Views) (Continued).

0.000 s

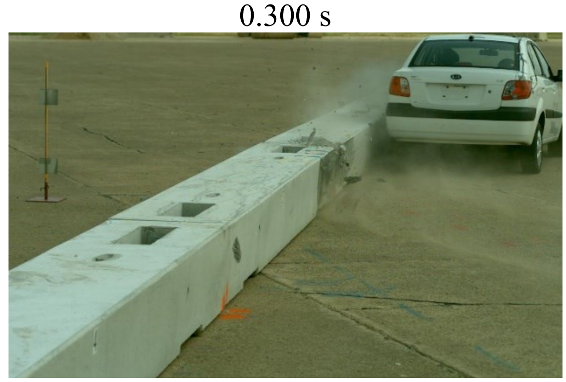
0.100 s

0.200 s

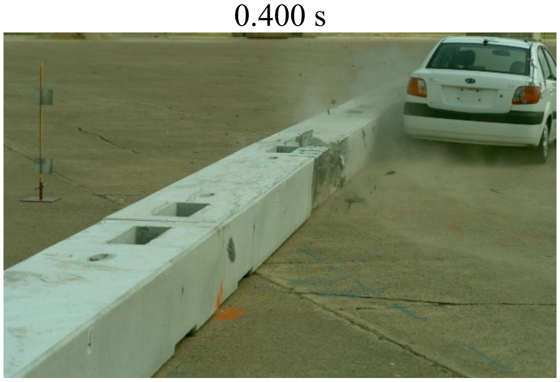
0.300 s



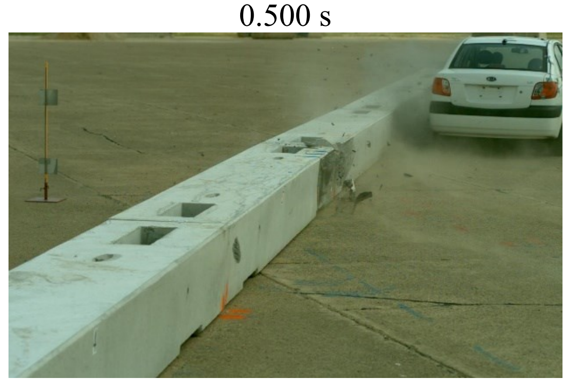
0.400 s



0.500 s



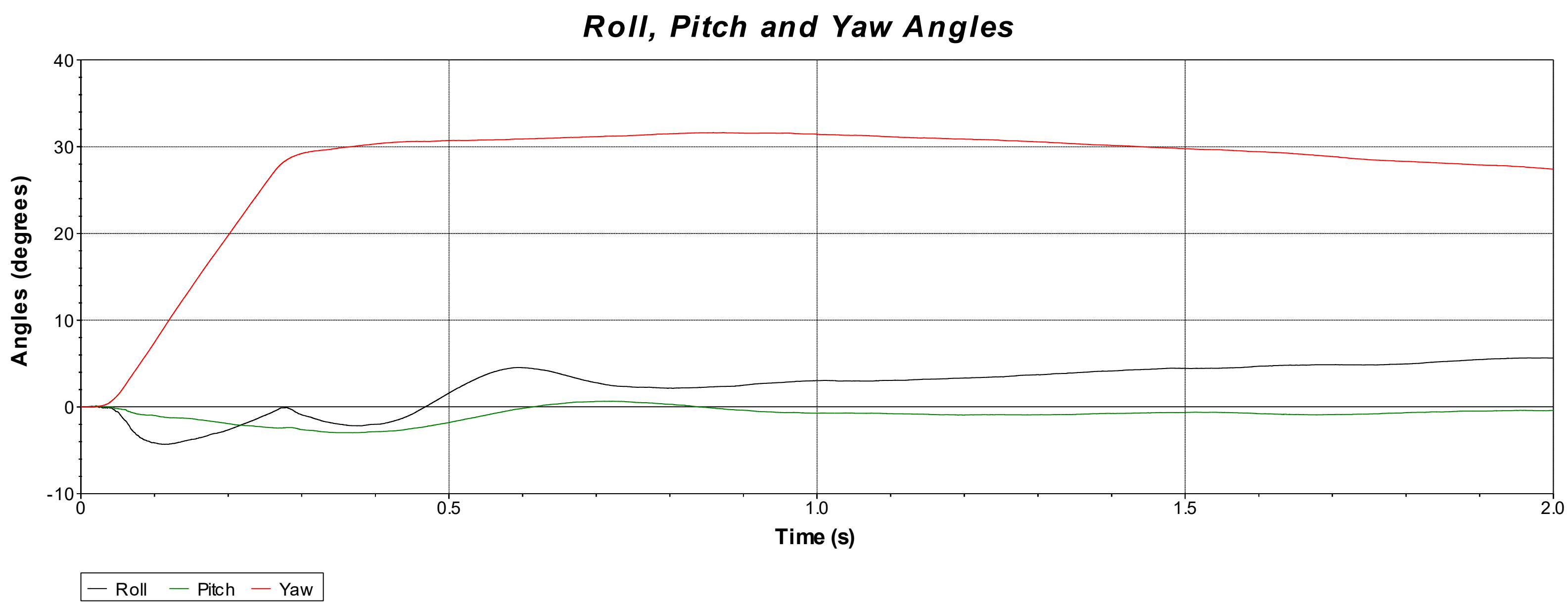
0.600 s



0.700 s

Figure C.8. Sequential Photographs for Test No. 469469-3-1 (Rear View).

C.4.3. Vehicle Angular Displacement



Test Number: 469469-3-1
Test Standard: 2-10
Test Article: Low Profile Barrier
Test Vehicle: 1100C/ 2009 Kia Rio
Inertial Mass: 2440 lb
Gross Mass: 2605 lb
Impact Speed: 44.0 mi/h
Impact Angle: 25.1 degrees

Axes are vehicle-fixed.
Sequence for determining orientation:

13. Yaw.
14. Pitch.
15. Roll.

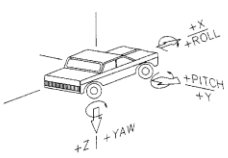


Figure C.9. Vehicle Angular Displacements for Test No. 469469-3-1.

C.4.4. Vehicle Acceleration

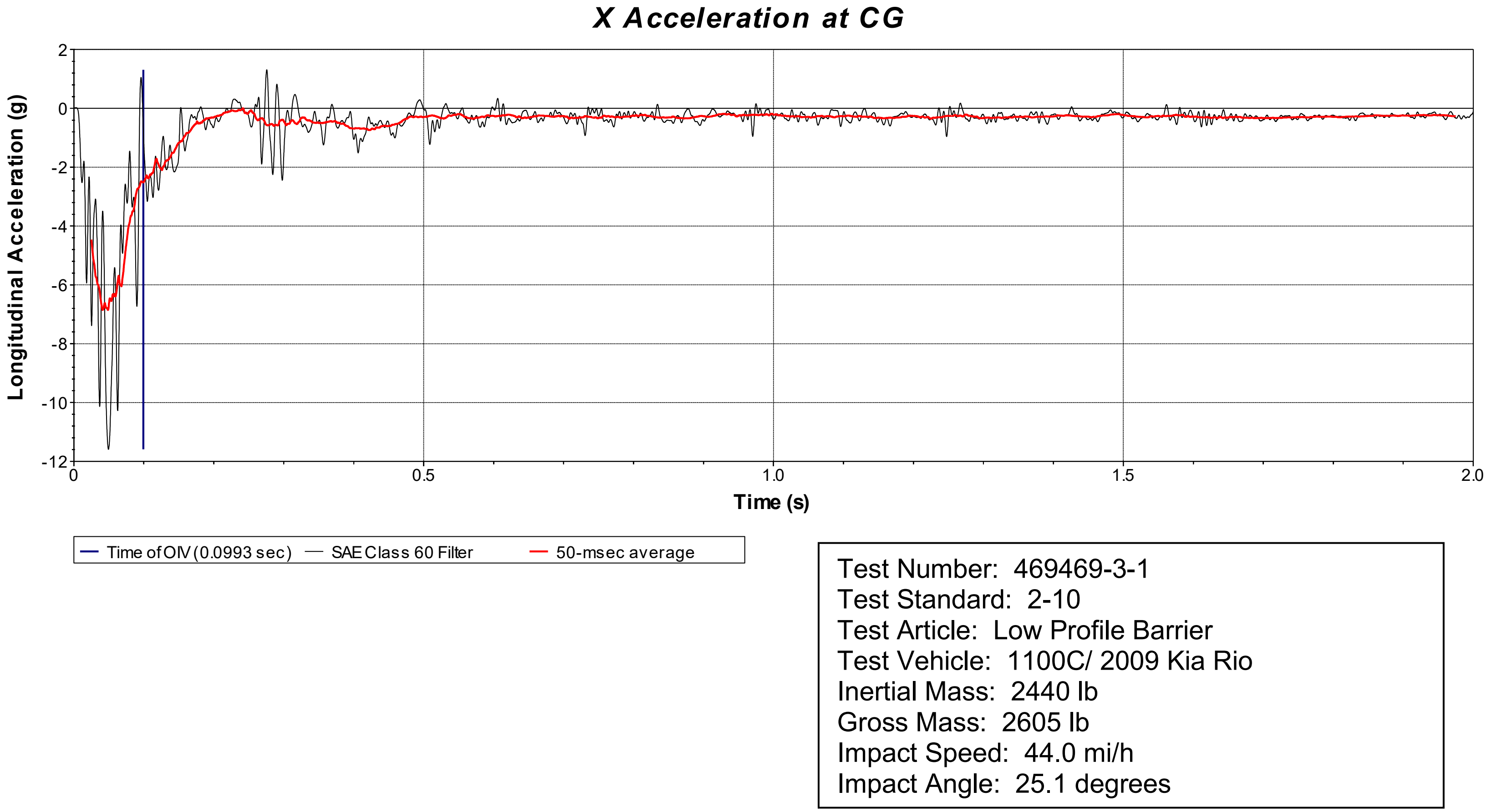
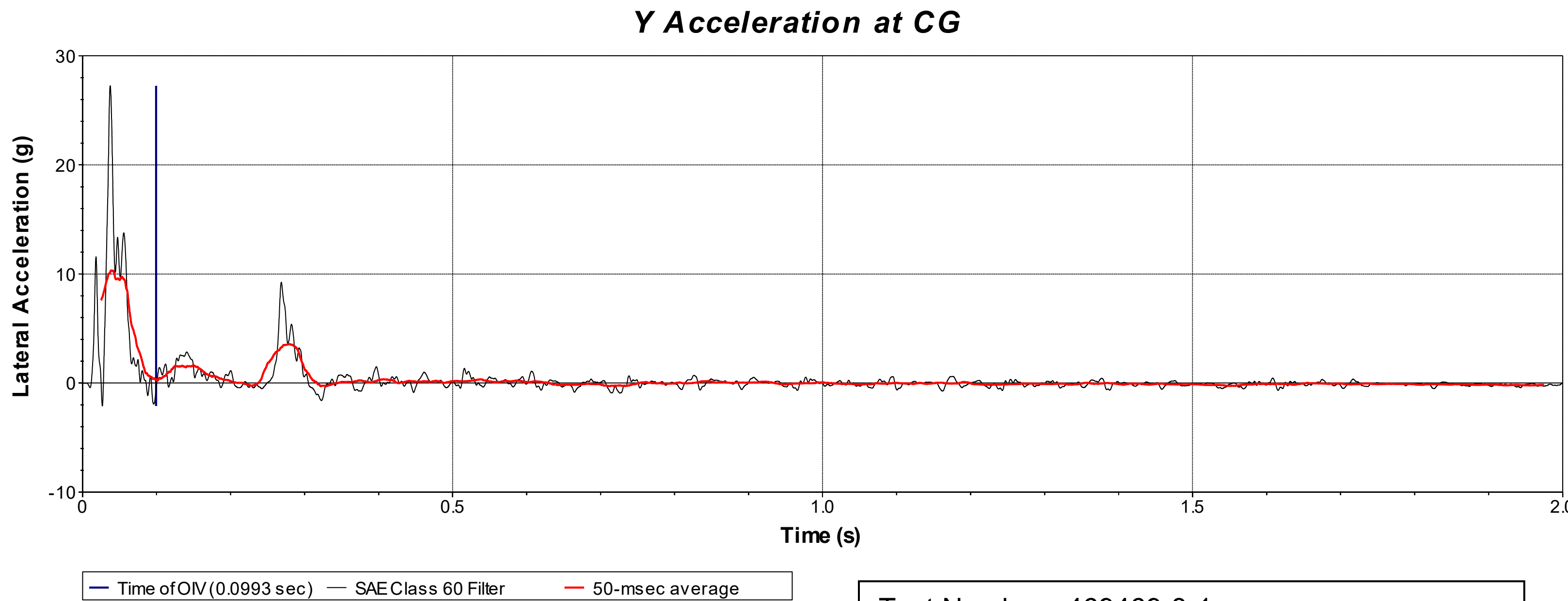
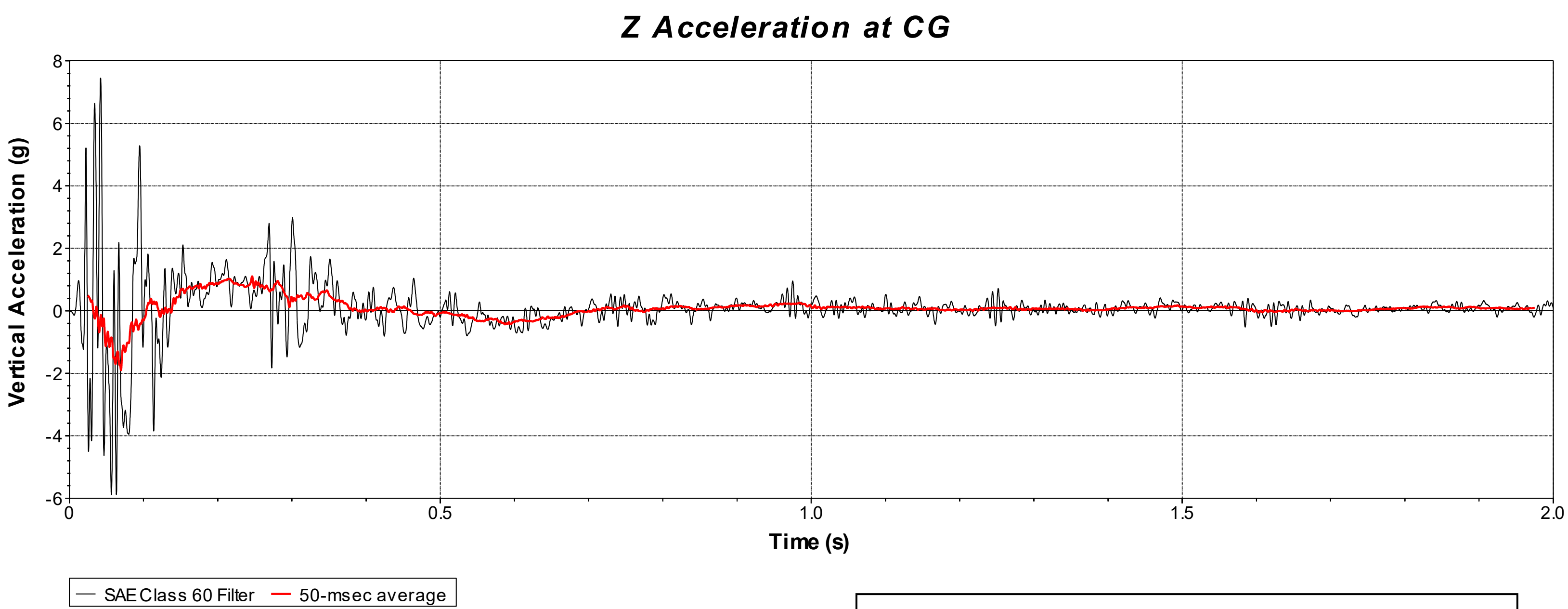


Figure C.10. Vehicle Longitudinal Accelerometer Trace for Test No. 469469-3-1 (Accelerometer Located at Center of Gravity).



Test Number: 469469-3-1
Test Standard: 2-10
Test Article: Low Profile Barrier
Test Vehicle: 1100C/ 2009 Kia Rio
Inertial Mass: 2440 lb
Gross Mass: 2605 lb
Impact Speed: 44.0 mi/h
Impact Angle: 25.1 degrees

Figure C.11. Vehicle Lateral Accelerometer Trace for Test No. 469469-3-1 (Accelerometer Located at Center of Gravity).

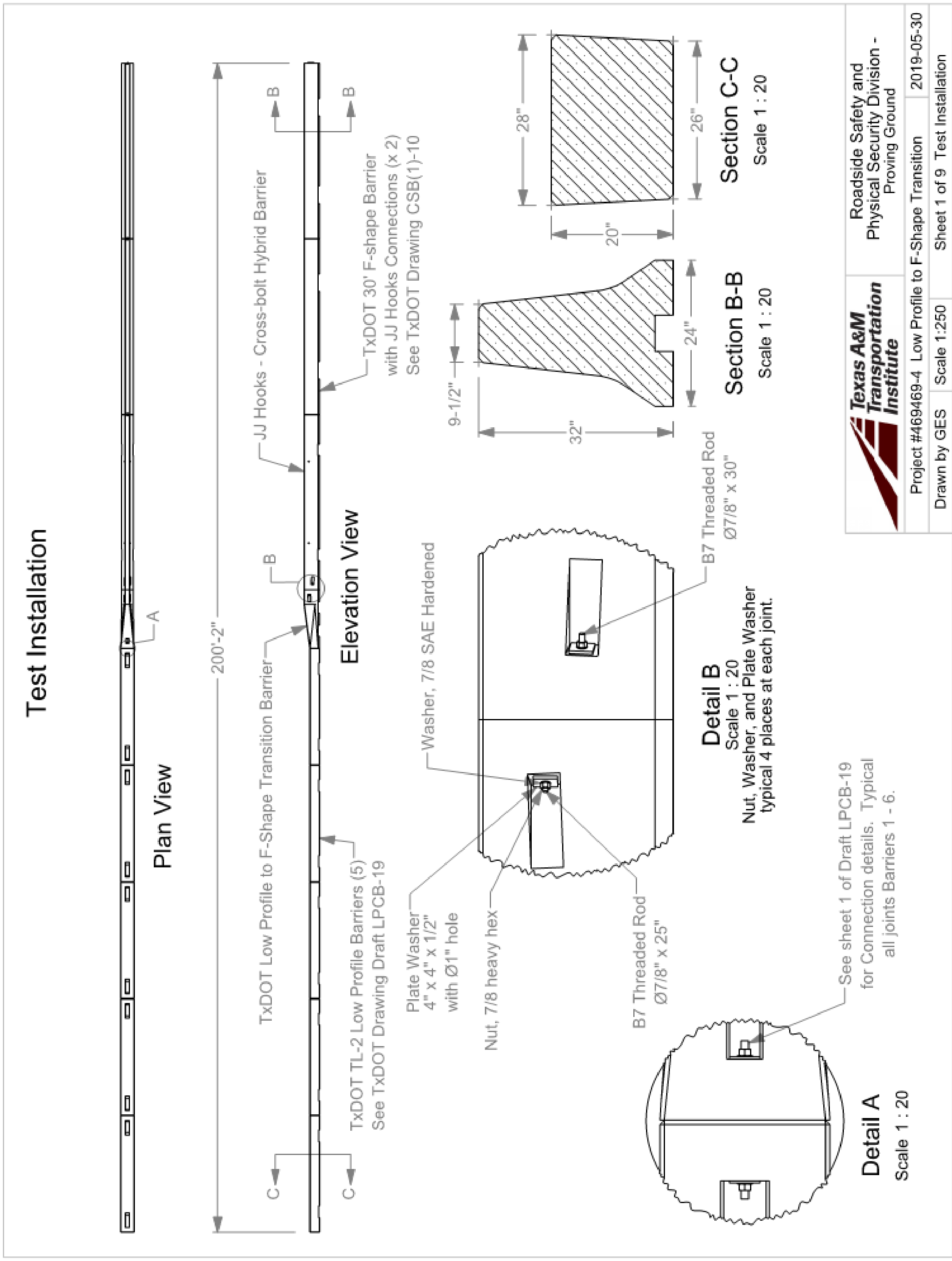


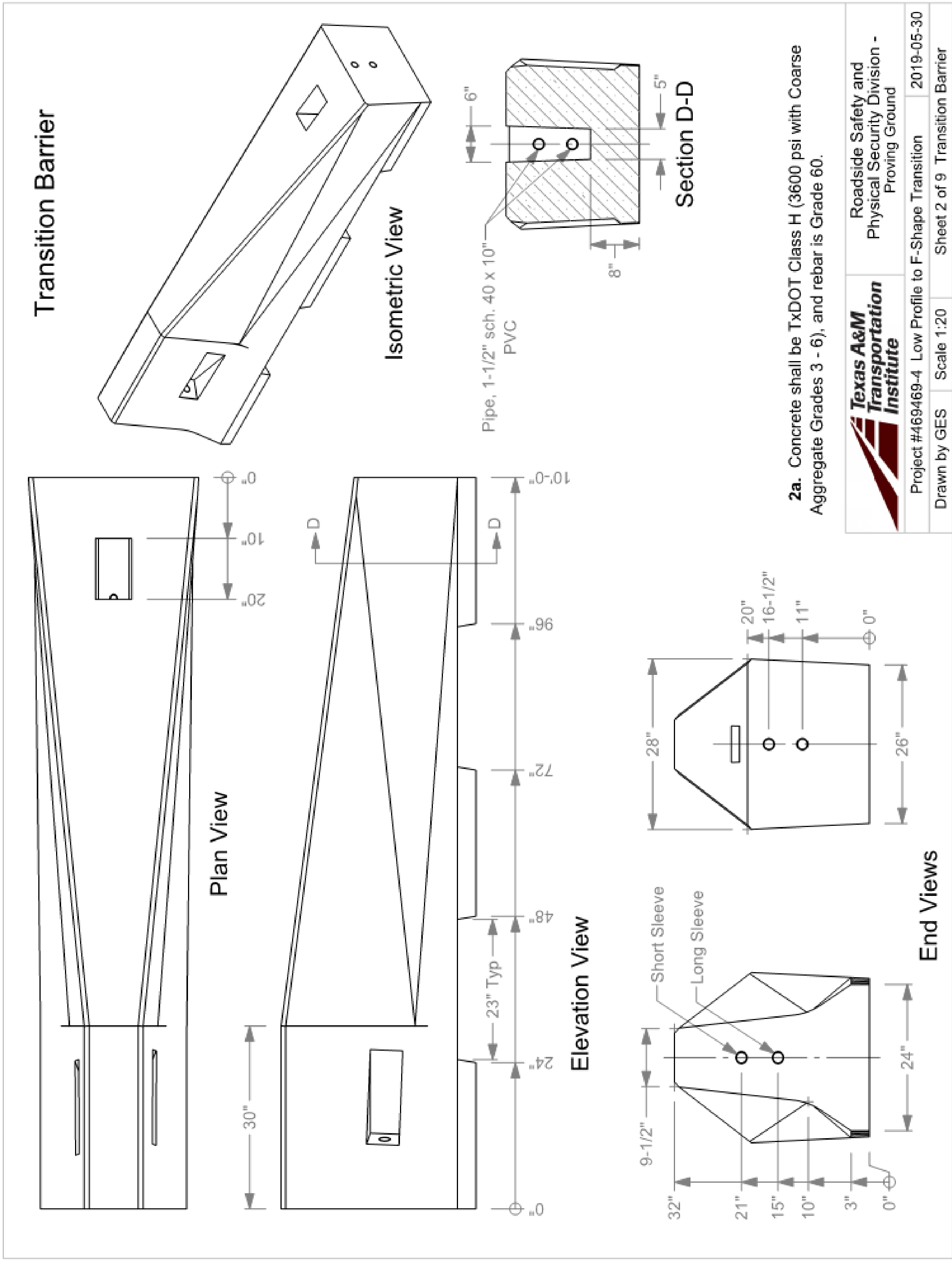
Test Number: 469469-3-1
Test Standard: 2-10
Test Article: Low Profile Barrier
Test Vehicle: 1100C/ 2009 Kia Rio
Inertial Mass: 2440 lb
Gross Mass: 2605 lb
Impact Speed: 44.0 mi/h
Impact Angle: 25.1 degrees

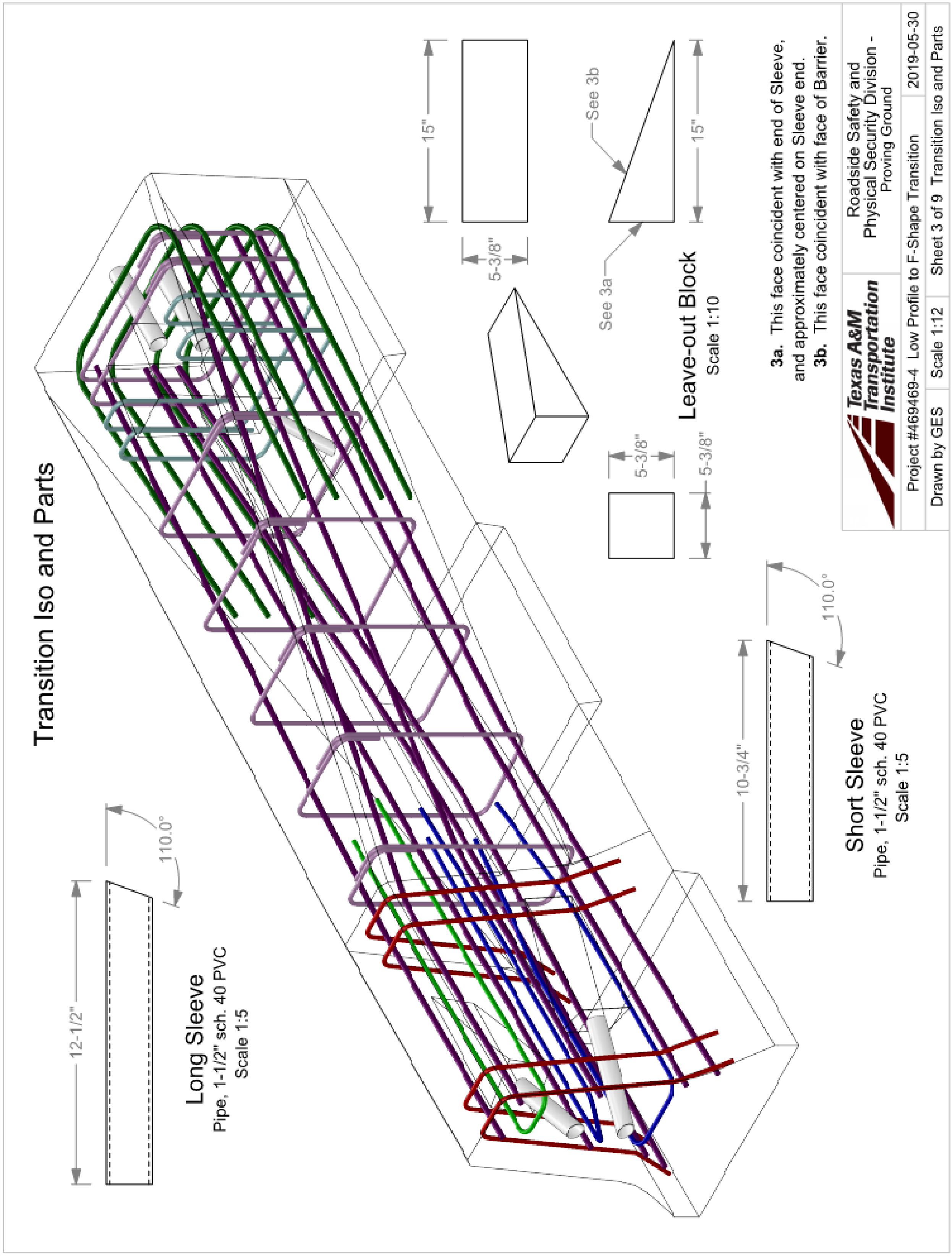
Figure C.12. Vehicle Vertical Accelerometer Trace for Test No. 469469-3-1 (Accelerometer Located at Center of Gravity).

APPENDIX D. TXDOT LOW-PROFILE-TO-F-SHAPE TRANSITION

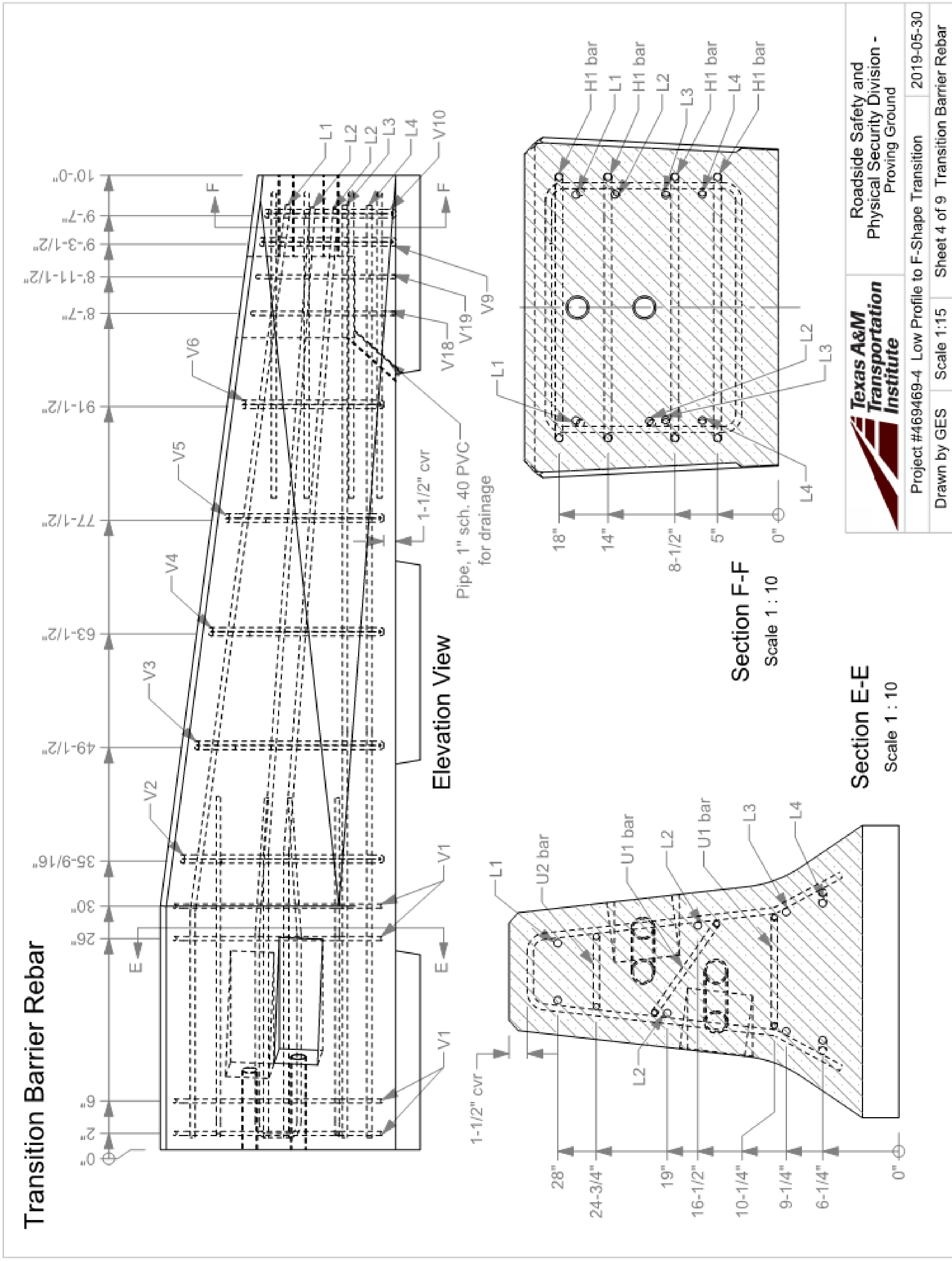
D.1. DETAILS OF LOW-PROFILE-TO-F-SHAPE TRANSITION




Transition Barrier
Plan View
Elevation View
Isometric View
Section D-D
End Views
Pipe, 1-1/2" sch. 40 x 10" PVC
Short Sleeve
Long Sleeve
23" Typ
0"
10"
20"
24"
48"
72"
96"
10'-0"
30"
6"
5"
8"
28"
26"
24"
9-1/2"
32"
21"
15"
10"
3"
16-1/2"
11"
D
2a. Concrete shall be TxDOT Class H (3600 psi with Coarse Aggregate Grades 3 - 6), and rebar is Grade 60.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #469469-4 Low Profile to F-Shape Transition
2019-05-30
Drawn by GES
Scale 1:20
Sheet 2 of 9 Transition Barrier

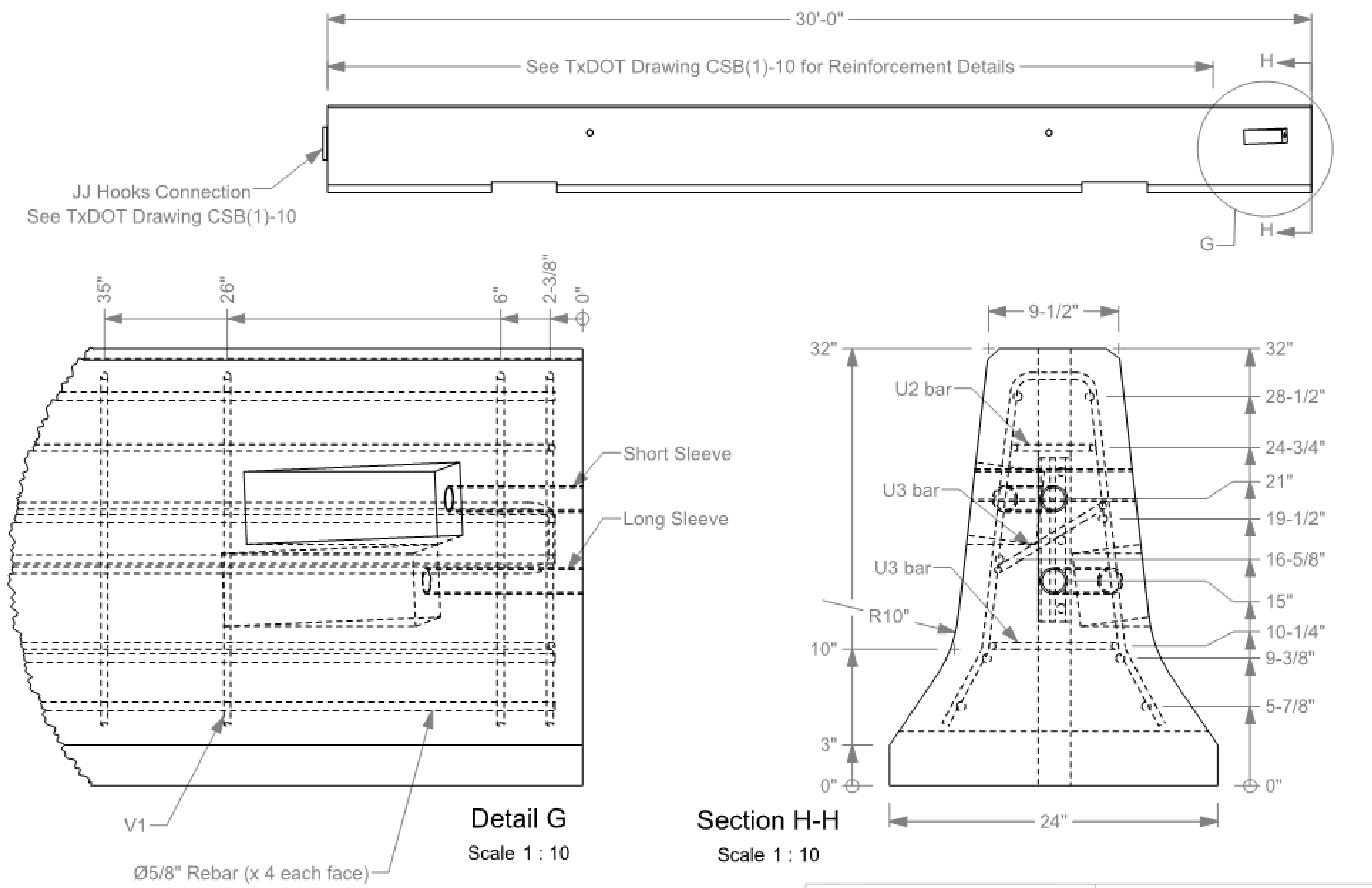


Transition Iso and Parts
Long Sleeve
Pipe, 1-1/2" sch. 40 PVC
Scale 1:5
12-1/2"
110.0°
Short Sleeve
Pipe, 1-1/2" sch. 40 PVC
Scale 1:5
10-3/4"
110.0°
Leave-out Block
Scale 1:10
15"
5-3/8"
5-3/8"
5-3/8"
15"
See 3a
See 3b
3a. This face coincident with end of Sleeve, and approximately centered on Sleeve end.
3b. This face coincident with face of Barrier.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #469469-4 Low Profile to F-Shape Transition
2019-05-30
Drawn by GES
Scale 1:12
Sheet 3 of 9 Transition Iso and Parts



Transition Barrier Rebar
Elevation View
Section F-F
Scale 1 : 10
Section E-E
Scale 1 : 10
Pipe, 1" sch. 40 PVC for drainage
1-1/2" cvr
Roadside Safety and Physical Security Division - Proving Ground
Texas A&M Transportation Institute
Project #469469-4
Low Profile to F-Shape Transition
2019-05-30
Drawn by GES
Scale 1:15
Sheet 4 of 9
Transition Barrier Rebar

Hybrid Barrier - Elevation

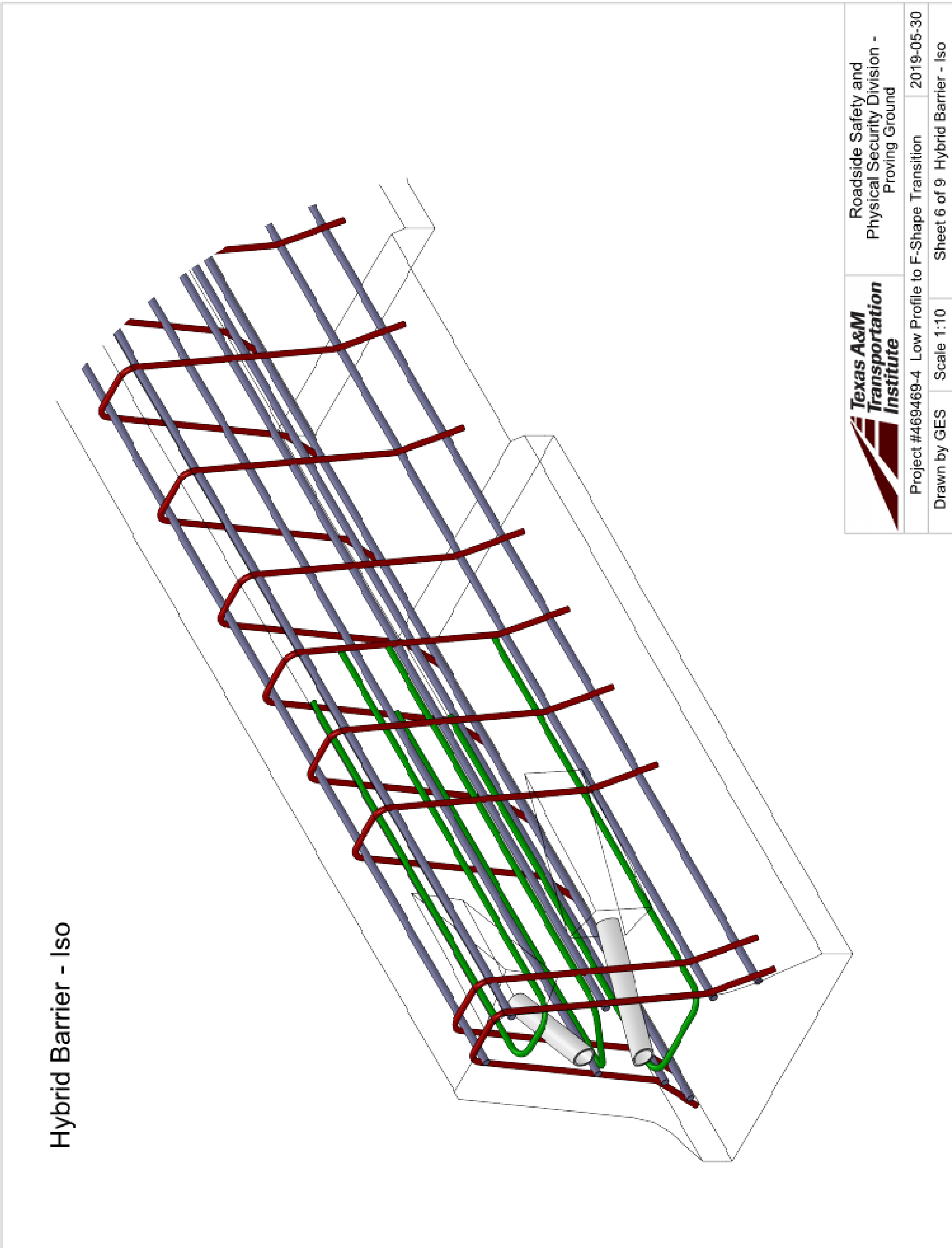


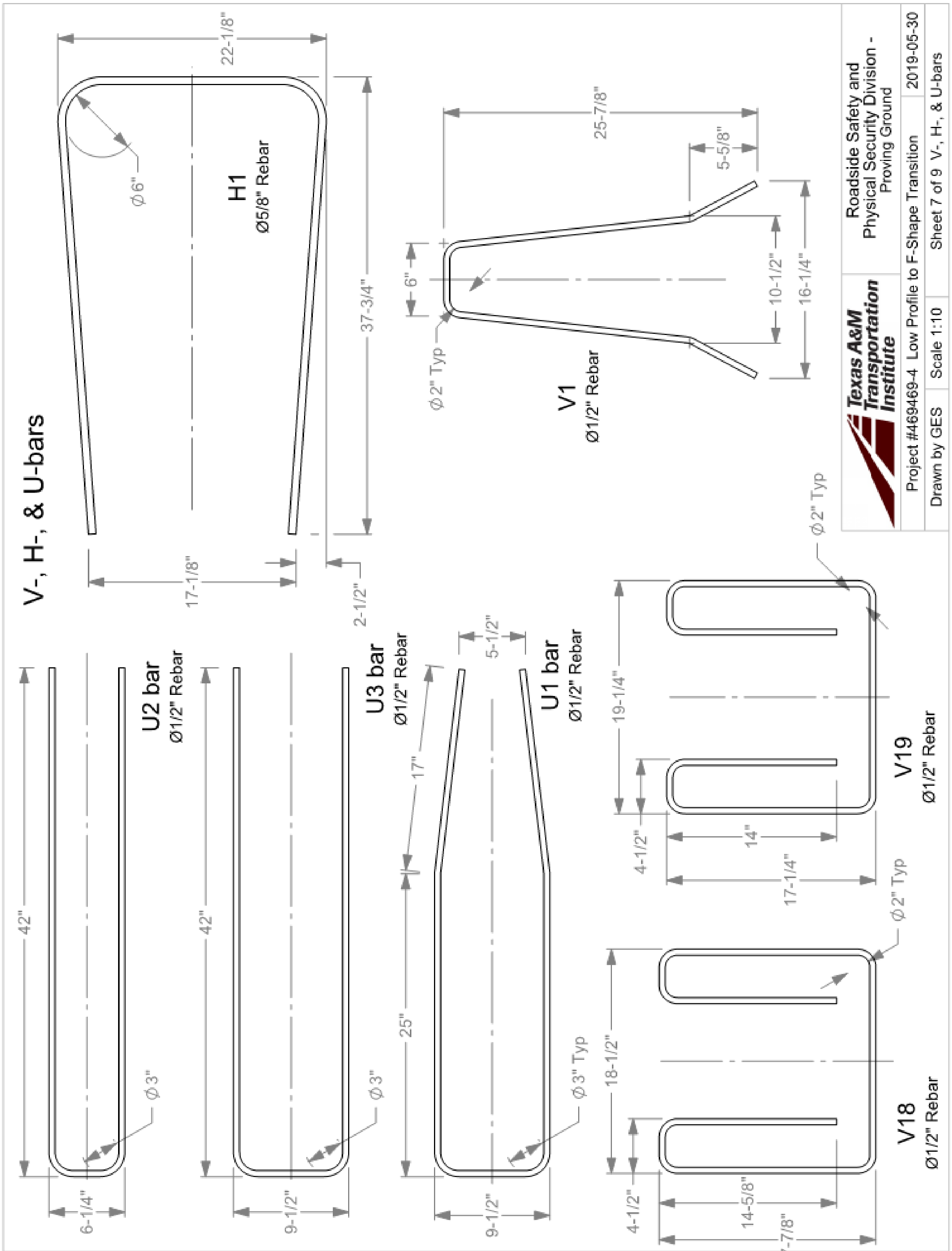
Detail G
Scale 1 : 10

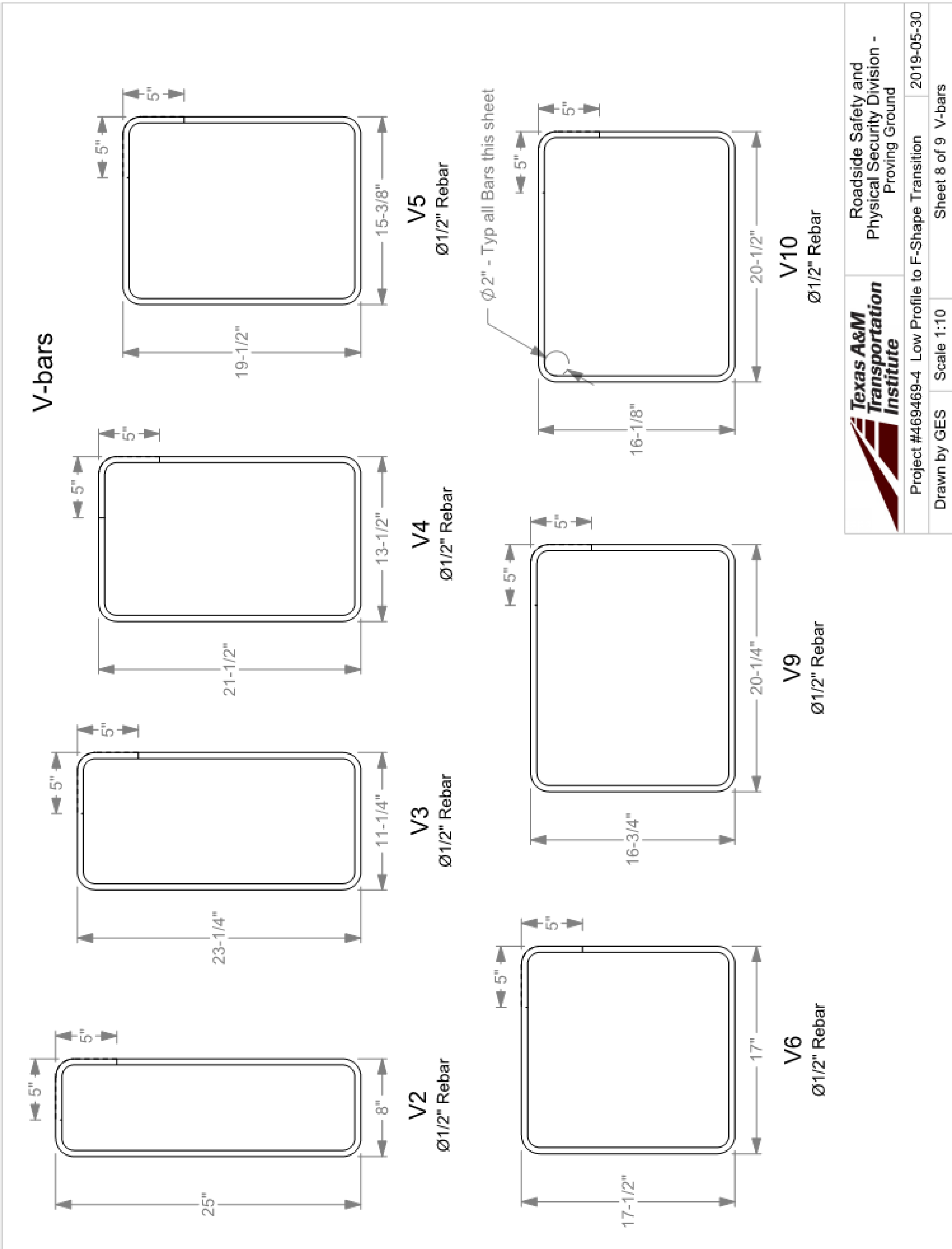
Section H-H
Scale 1 : 10

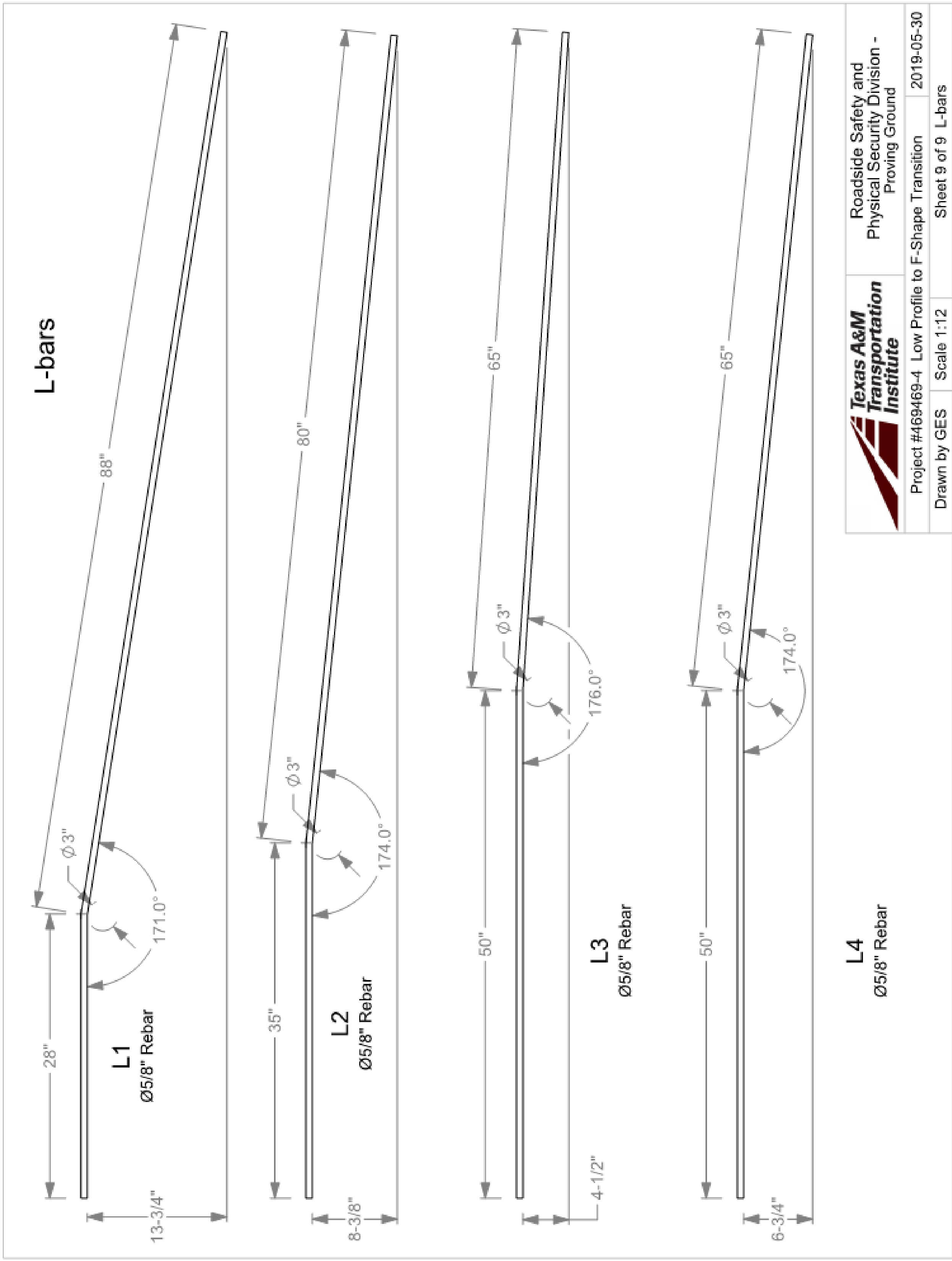
5a. Concrete shall be TxDOT Class H (3600 psi with Coarse Aggregate Grades 3 - 6), and rebar is Grade 60.

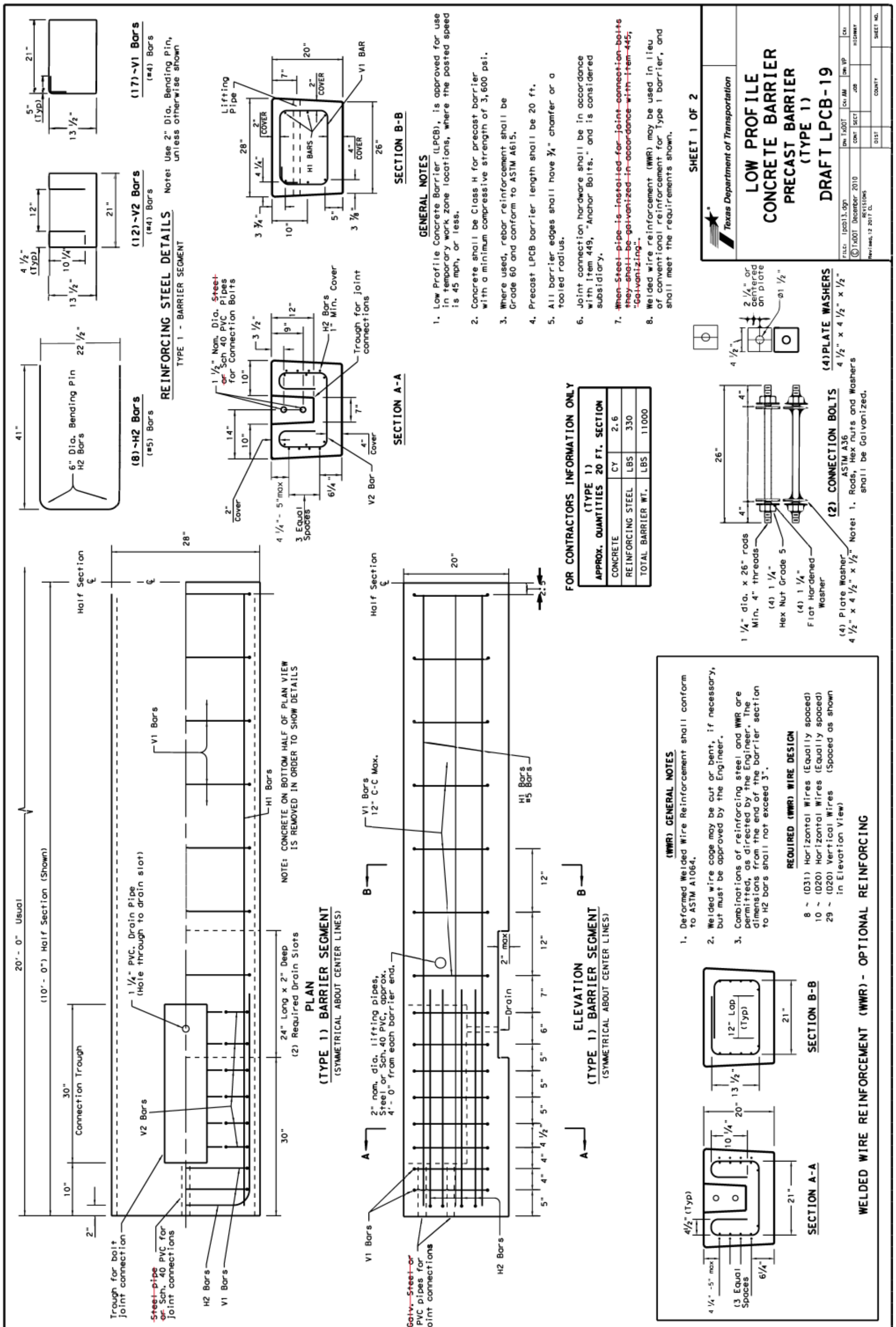
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #469469-4 Low Profile to F-Shape Transition		2019-05-30
Drawn by GES	Scale 1:50	Sheet 5 of 9 Hybrid Barrier - Elevation

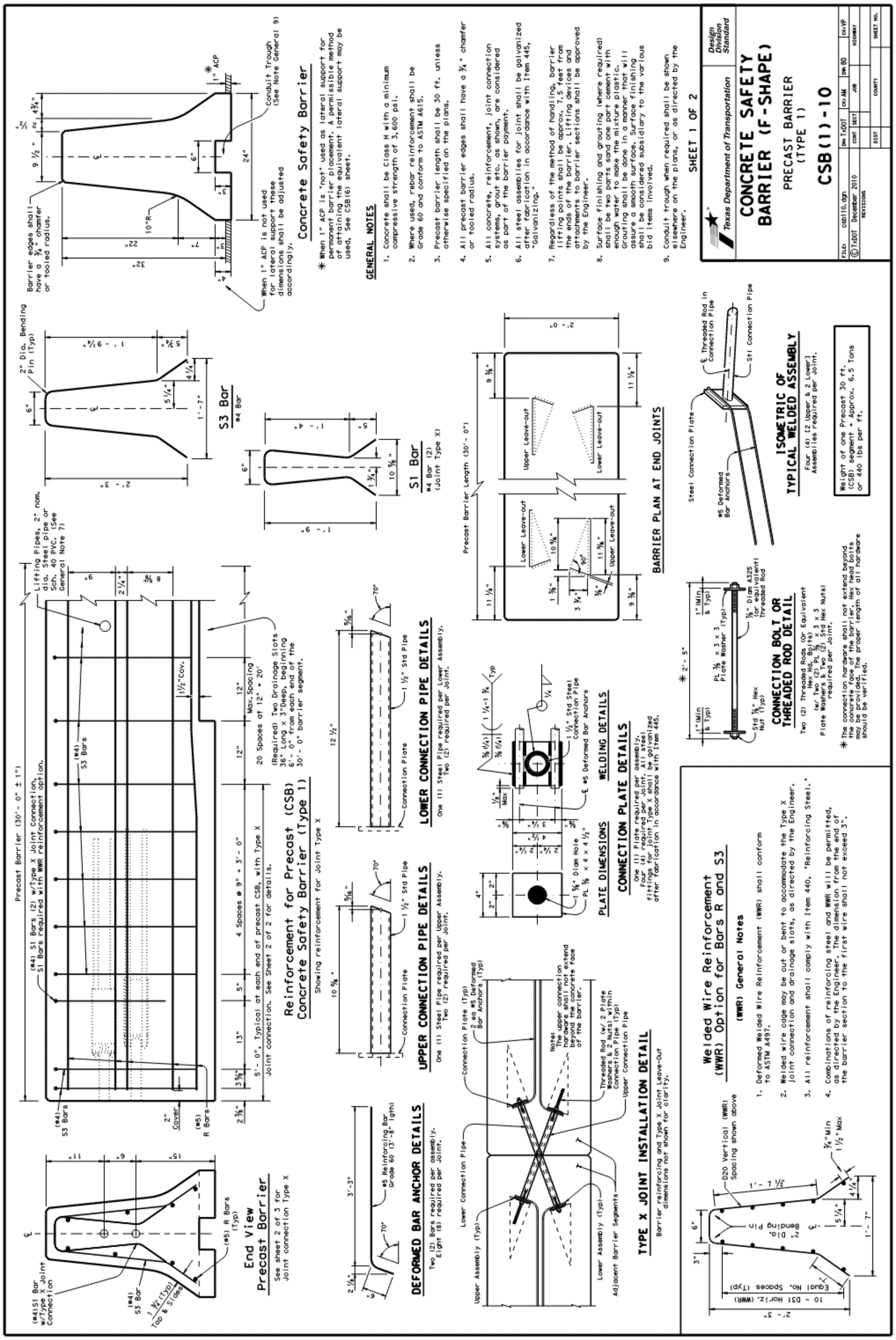

Hybrid Barrier - Iso
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #469469-4 Low Profile to F-Shape Transition
2019-05-30
Drawn by GES
Scale 1:10
Sheet 6 of 9 Hybrid Barrier - Iso

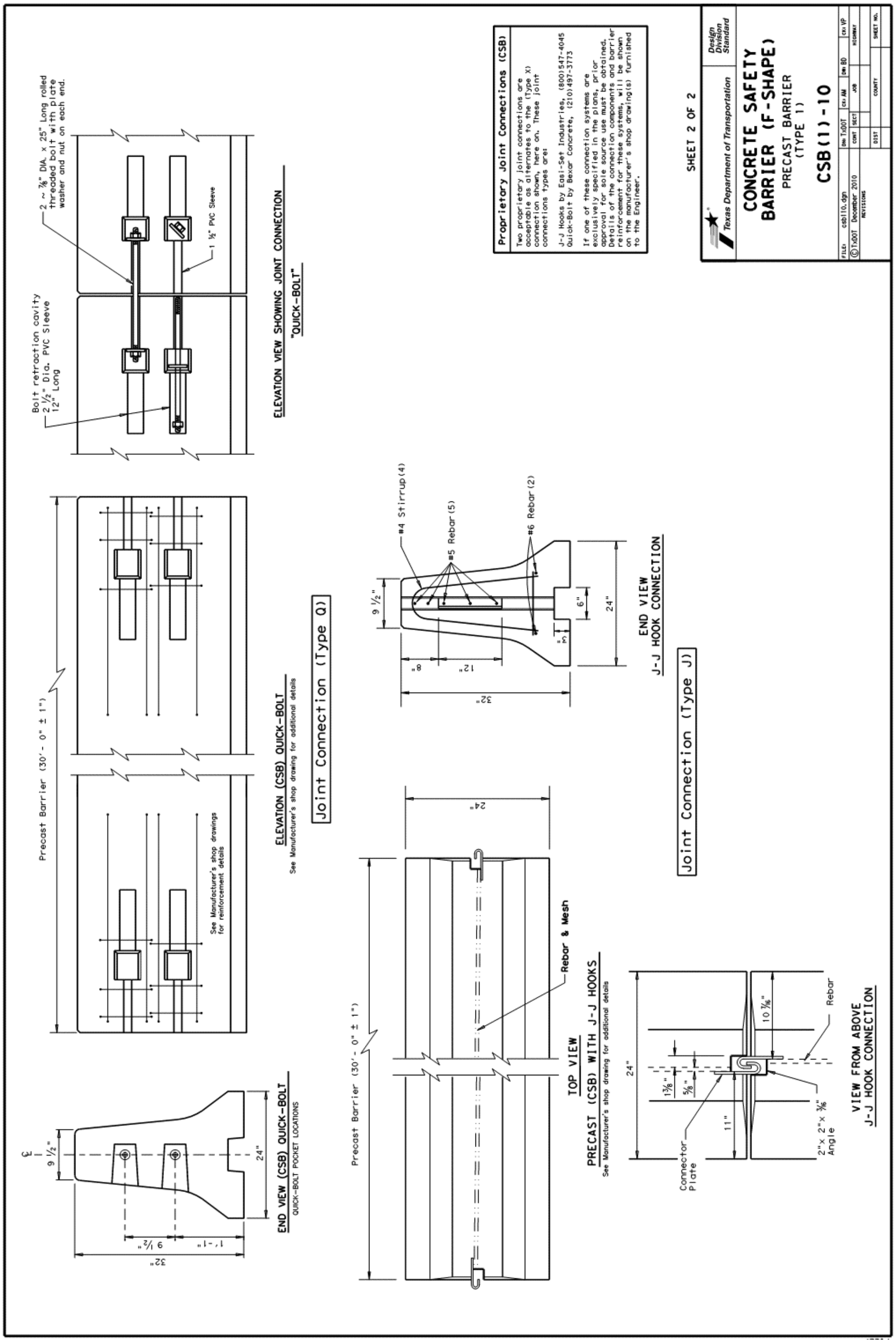

V-, H-, & U-bars
H1
Ø5/8" Rebar
Ø6"
22-1/8"
37-3/4"
17-1/8"
2-1/2"
V1
Ø1/2" Rebar
25-7/8"
5-5/8"
6"
10-1/2"
16-1/4"
Ø2" Typ
U2 bar
Ø1/2" Rebar
42"
Ø3"
6-1/4"
U3 bar
Ø1/2" Rebar
42"
Ø3"
9-1/2"
U1 bar
Ø1/2" Rebar
5-1/2"
17"
25"
Ø3" Typ
9-1/2"
V19
Ø1/2" Rebar
19-1/4"
4-1/2"
14"
17-1/4"
Ø2" Typ
V18
Ø1/2" Rebar
18-1/2"
4-1/2"
14-5/8"
17-7/8"
Ø2" Typ
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #469469-4
Low Profile to F-Shape Transition
2019-05-30
Drawn by GES
Scale 1:10
Sheet 7 of 9 V-, H-, & U-bars


V-bars
V2
Ø1/2" Rebar
V3
Ø1/2" Rebar
V4
Ø1/2" Rebar
V5
Ø1/2" Rebar
V6
Ø1/2" Rebar
V9
Ø1/2" Rebar
V10
Ø1/2" Rebar
Ø2" - Typ all Bars this sheet
5"
25"
8"
23-1/4"
11-1/4"
21-1/2"
13-1/2"
19-1/2"
15-3/8"
17-1/2"
17"
16-3/4"
20-1/4"
16-1/8"
20-1/2"
Roadside Safety and Physical Security Division - Proving Ground
Texas A&M Transportation Institute
Project #469469-4 Low Profile to F-Shape Transition
2019-05-30
Drawn by GES
Scale 1:10
Sheet 8 of 9 V-bars


L-bars
L1
Ø5/8" Rebar
L2
Ø5/8" Rebar
L3
Ø5/8" Rebar
L4
Ø5/8" Rebar
88"
28"
13-3/4"
171.0°
Ø3"
80"
35"
8-3/8"
174.0°
Ø3"
65"
50"
4-1/2"
176.0°
Ø3"
65"
50"
6-3/4"
174.0°
Ø3"
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #469469-4 Low Profile to F-Shape Transition
2019-05-30
Drawn by GES
Scale 1:12
Sheet 9 of 9 L-bars


Texas Department of Transportation
LOW PROFILE CONCRETE BARRIER PRECAST BARRIER (TYPE 1)
DRAFT LPCB-19
SHEET 1 OF 2
PLAN (TYPE 1) BARRIER SEGMENT
(SYMMETRICAL ABOUT CENTER LINES)
ELEVATION (TYPE 1) BARRIER SEGMENT
(SYMMETRICAL ABOUT CENTER LINES)
NOTE: CONCRETE ON BOTTOM HALF OF PLAN VIEW IS REMOVED IN ORDER TO SHOW DETAILS
20' - 0" Usual
(10' - 0") Half Section (Shown)
Connection Trough
1 1/4" PVC. Drain Pipe (Hole through to drain slot)
24" Long x 2" Deep (2) Required Drain Slots
2" nom. dia. lifting pipes, Steel or Sch.40 PVC, approx. 4'- 0" from each barrier end.
V1 Bars 12" C-C Max.
H1 Bars #5 Bars
Trough for bolt joint connection
Steel pipe or Sch. 40 PVC for joint connections
Galv. Steel or PVC pipes for joint connections
REINFORCING STEEL DETAILS
TYPE 1 - BARRIER SEGMENT
(8)~H2 Bars (#5) Bars
(12)~V2 Bars (#4) Bars
(17)~V1 Bars (#4) Bars
6" Dia. Bending Pin H2 Bars
Note: Use 2" Dia. Bending Pin, unless otherwise shown
SECTION A-A
SECTION B-B
1 1/2" Nom. Dia. Steel or Sch 40 PVC Pipes for Connection Bolts
Trough for joint connections
GENERAL NOTES
1. Low Profile Concrete Barrier (LPCB), is approved for use in temporary work zone locations, where the posted speed is 45 mph, or less.
2. Concrete shall be Class H for precast barrier with a minimum compressive strength of 3,600 psi.
3. Where used, rebar reinforcement shall be Grade 60 and conform to ASTM A615.
4. Precast LPCB barrier length shall be 20 ft.
5. All barrier edges shall have 3/4" chamfer or a tooled radius.
6. Joint connection hardware shall be in accordance with Item 449, "Anchor Bolts." and is considered subsidiary.
7. ~~When Steel pipe is installed for joint connection bolts they shall be galvanized in accordance with Item 445, "Galvanizing".~~
8. Welded wire reinforcement (WWR) may be used in lieu of conventional reinforcement for Type 1 barrier, and shall meet the requirements shown.
FOR CONTRACTORS INFORMATION ONLY
(TYPE 1) APPROX. QUANTITIES 20 FT. SECTION
CONCRETE CY 2.6
REINFORCING STEEL LBS 330
TOTAL BARRIER WT. LBS 11000
(2) CONNECTION BOLTS
ASTM A36
Note: 1. Rods, Hex nuts and Washers shall be Galvanized.
(4) PLATE WASHERS
4 1/2" x 4 1/2" x 1/2"
1 1/4" dia. x 26" rods Min. 4" threads
(4) 1 1/4" Hex Nut Grade 5
(4) 1 1/4" Flat Hardened Washer
(4) Plate Washer 4 1/2" x 4 1/2" x 1/2"
(WWR) GENERAL NOTES
1. Deformed Welded Wire Reinforcement shall conform to ASTM A1064.
2. Welded wire cage may be cut or bent, if necessary, but must be approved by the Engineer.
3. Combinations of reinforcing steel and WWR are permitted, as directed by the Engineer. The dimensions from the end of the barrier section to H2 bars shall not exceed 3".
REQUIRED (WWR) WIRE DESIGN
8 ~ (D31) Horizontal Wires (Equally spaced)
10 ~ (D20) Horizontal Wires (Equally spaced)
29 ~ (D20) Vertical Wires (Spaced as shown in Elevation View)
WELDED WIRE REINFORCEMENT (WWR) - OPTIONAL REINFORCING


End View
Precast Barrier
See sheet 2 of 3 for Joint connection Type X
Reinforcement for Precast (CSB)
Concrete Safety Barrier (Type 1)
Showing reinforcement for Joint Type X
Precast Barrier (30'- 0" ± 1")
(#4) S1 Bars (2) w/Type X Joint Connection, S1 Bars required with WWR reinforcement option.
Lifting Pipes, 2" nom. dia. Steel pipe or Sch. 40 PVC. (See General Note 7)
5'- 0", Typical at each end of precast CSB, with Type X Joint connection. See Sheet 2 of 2 for details.
20 Spaces at 12" = 20'
(Required) Two Drainage Slots 36" Long x 3"Deep, beginning 6'- 0" from each end of the 30'- 0" barrier segment.
S3 Bar
#4 Bar
S1 Bar
#4 Bar (2)
(Joint Type X)
Concrete Safety Barrier
Barrier edges shall have a ¾" chamfer or tooled radius.
When 1" ACP is not used for lateral support these dimensions shall be adjusted accordingly.
Conduit Trough (See Note General 9)
* When 1" ACP is "not" used as lateral support for permanent barrier placement. A permissible method of attaining the equivalent lateral support may be used, See CSB(6) sheet.
GENERAL NOTES
1. Concrete shall be Class H with a minimum compressive strength of 3,600 psi.
2. Where used, rebar reinforcement shall be Grade 60 and conform to ASTM A615.
3. Precast barrier length shall be 30 ft. unless otherwise specified on the plans.
4. All precast barrier edges shall have a ¾" chamfer or tooled radius.
5. All concrete, reinforcement, joint connection systems, grout etc. as shown, are considered as part of the barrier payment.
6. All steel assemblies for joint shall be galvanized after fabrication in accordance with Item 445, "Galvanizing."
7. Regardless of the method of handling, barrier lifting points shall be approx. 7.5 feet from the ends of the barrier. Lifting devices and attachments to barrier sections shall be approved by the Engineer.
8. Surface finishing and grouting (where required) shall be two parts sand one part cement with enough water to make the mixture plastic. Grouting shall be done in a manner that will assure a smooth surface. Surface finishing shall be considered subsidiary to the various bid items involved.
9. Conduit trough when required shall be shown elsewhere on the plans, or as directed by the Engineer.
DEFORMED BAR ANCHOR DETAILS
Two (2) Bars required per assembly. Eight (8) required per Joint.
UPPER CONNECTION PIPE DETAILS
One (1) Steel Pipe required per Upper Assembly. Two (2) required per Joint.
LOWER CONNECTION PIPE DETAILS
One (1) Steel Pipe required per Lower Assembly. Two (2) required per Joint.
TYPE X JOINT INSTALLATION DETAIL
Barrier reinforcing and Type X Joint Leave-Out dimensions not shown for clarity.
Note: The upper connection hardware shall not extend beyond the concrete face of the barrier.
PLATE DIMENSIONS
WELDING DETAILS
CONNECTION PLATE DETAILS
One (1) Plate required per assembly. Four (4) required per Joint. All steel fittings for joint Type X shall be galvanized after fabrication in accordance with Item 445.
BARRIER PLAN AT END JOINTS
Precast Barrier Length (30'- 0")
Welded Wire Reinforcement
(WWR) Option for Bars R and S3
(WWR) General Notes
1. Deformed Welded Wire Reinforcement (WWR) shall conform to ASTM A497.
2. Welded wire cage may be cut or bent to accommodate the Type X joint connection and drainage slots, as directed by the Engineer.
3. All reinforcement shall comply with Item 440, "Reinforcing Steel."
4. Combinations of reinforcing steel and WWR will be permitted, as directed by the Engineer. The dimension from the end of the barrier section to the first wire shall not exceed 3".
CONNECTION BOLT OR THREADED ROD DETAIL
Two (2) Threaded Rods (Or Equivalent Hex Hd. Bolts) (w/ Two (2) PL ⅜ x 3 x 3 Plate Washers & Two (2) Std Hex Nuts) required per Joint.
* The connection hardware shall not extend beyond the concrete face of the barrier. Hex head bolts may be provided. The proper length of all hardware should be verified.
ISOMETRIC OF TYPICAL WELDED ASSEMBLY
Four (4) (2 Upper & 2 Lower) Assemblies required per Joint.
Weight of one Precast 30 ft. (CSB) segment = Approx. 6.5 Tons or 440 lbs per ft.
SHEET 1 OF 2
Texas Department of Transportation
Design Division Standard
CONCRETE SAFETY BARRIER (F-SHAPE)
PRECAST BARRIER (TYPE 1)
CSB(1)-10
FILE: csb110.dgn
©TxDOT December 2010


END VIEW (CSB) QUICK-BOLT
QUICK-BOLT POCKET LOCATIONS
Precast Barrier (30'- 0" ± 1")
See Manufacturer's shop drawings for reinforcement details
ELEVATION (CSB) QUICK-BOLT
See Manufacturer's shop drawing for additional details
Bolt retraction cavity 2 1/2" Dia. PVC Sleeve 12" Long
2 ~ 7/8" DIA. x 25" Long rolled threaded bolt with plate washer and nut on each end.
1 1/2" PVC Sleeve
ELEVATION VIEW SHOWING JOINT CONNECTION
"QUICK-BOLT"
Joint Connection (Type Q)
Rebar & Mesh
TOP VIEW
PRECAST (CSB) WITH J-J HOOKS
See Manufacturer's shop drawing for additional details
#4 Stirrup(4)
#5 Rebar(5)
#6 Rebar(2)
END VIEW
J-J HOOK CONNECTION
Connector Plate
2"x 2"x 3/16" Angle
Rebar
VIEW FROM ABOVE
J-J HOOK CONNECTION
Joint Connection (Type J)
Proprietary Joint Connections (CSB)
Two proprietary joint connections are acceptable as alternates to the (Type X) connection shown, here on. These joint connections types are:
J-J Hooks by Easi-Set Industries, (800)547-4045
Quick-Bolt by Bexar Concrete, (210)497-3773
If one of these connection systems are exclusively specified in the plans, prior approval for sole source use must be obtained. Details of the connection components and barrier reinforcement for these systems, will be shown on the manufacturer's shop drawing(s) furnished to the Engineer.
SHEET 2 OF 2
Texas Department of Transportation
Design Division Standard
CONCRETE SAFETY BARRIER (F-SHAPE)
PRECAST BARRIER (TYPE 1)
CSB(1)-10
FILE: csb110.dgn
©TxDOT December 2010

D.2. 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	QF 7.3-01 Concrete Sampling	Doc. No. QF 7.3-01	Issue Date: 2018-06-18
Quality Form	Prepared by: Wanda L. Menges Approved by: Darrell L. Kuhn	Revision: 6	Page: 1 of 1

The information contained in this document is confidential to TTI Proving Ground.

Project No: 469469-4 **Casting Date:** 2015-06-28 **Mix Design (psi):** 3600

Name of Technician Taking Sample: Bill Griffith

Name of Technician Breaking Sample: Bill Griffith

Signature of Technician Taking Sample:

Signature of Technician Breaking Sample:

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	~~5450583~~	5450583	Transition 100%
	7119		

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
T1	2015-07-29	31 days	185000	6544	
			170000	6013	6213
			172000	6084	

CUSTOMER'S COPY

TICKET NO. 5490583

Martin Marietta

1503 LBJ Freeway
Suite 400
Dallas, Tx 75234

5490583

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
9:58	10:08	10:23	:	:	:	:

WATER ADDED ON JOB AT CUSTOMER'S REQUEST ________ GAL.
ALLOWABLE WATER (withheld from batch) 8.1 GAL.
TEST CYLINDER TAKEN ❑ YES ❑ NO BY ________
CYLINDER TAKEN ❑ BEFORE ❑ AFTER WATER

ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH. ANY WATER ADDED IN EXCESS OF SPECIFIED SLUMP IS AT CUSTOMER'S RISK.

CUSTOMER SIGNATURE
X

DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS AND CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED BY SIGNATURE ABOVE.

CUSTOMER NAME AND DELIVERY ADDRESS
TEXAS A & M UNIVERSI
TTI-Riverside Campus

PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT	GRID
617	7119	2044	3.0	469469-4	

DRIVER NAME	DATE
Kristen Taylor	6/28/19

CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY
783659	79546	4.00	4.00

LOAD QUANTITY	PRODUCT CODE	DESCRIPTION	UNIT PRICE	AMOUNT
4.00 CYDS	DBCC00	DOT, CLASS C, T1		
1.00 ea	12987	FREIGHT CHARGE		

SPECIAL DELIVERY INSTRUCTIONS
SOUTH 2818, RIGHT LEONARD RD, RIGHT ON HWY 47, LEFT
INTO RELLISTHEY WILL MEET YOU AT THE ROUNDA BOUT

SALES TAX

TOTAL

DANGER! MAY CAUSE ALKALI BURNS.
SEE WARNINGS ON REVERSE SIDE.

FOR OFFICE USE ONLY **FORM:**

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
7119	946453	user	5490583	77096	9:58	6/28/19

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
4.00 CYDS	DBCC00				D	78129

Material	Design Qty	Required	Batched	% Var	% Moisture	Actual Wat
1"CS	1920 lb	7680 lb	7720 lb	0.42%	0.10% M	1 gl
SAND-1	1292 lb	5400 lb	5440 lb	0.74%	4.30% M	28 gl
CMT-I/II	360 lb	1440 lb	1450 lb	0.69%		
FLYASH-C	240 lb	960 lb	950 lb	-1.04%		
H20	267 lb	720 lb	717 lb	-0.36%		86 gl
ZY-610	14 oz	58 oz	57 oz	-1.04%		

Actual Num Batches: 1
Load Total: 16281 lb Design 0.445 Water/Cement 0.445 T Design 128.0 gl Actual 114.9 gl To Add: 8.1 g
Slump: 3.00 in # Water in Truck: 5.0 gl Adjust Water: 0.0 gl / Load Trim Water: -2.0 gl/ CYD

469469-4

Concrete Core Test Report

Report Number: A1171057.0058
Service Date: 08/02/19
Report Date: 08/12/19
Task: PO #469469-11

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Client

Texas Transportation Institute
Attn: Gary Gerke
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project

Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information

Specified Strength:

Specified Length:
Mix ID:
Nominal Maximum Size Aggregate:

Sample Information

Placement Date:
Date Tested: 08/02/19 **Time:** 0000
Sampled By: Cullen Turney
Drill Directions: Vertical
Date Core Obtained: 08/02/19 **Time:** 0000
Date Ends Trimmed: 08/02/19 **Time:** 0000
Moisture Conditioning History: According to ASTM C-42

Laboratory Test Data

Core ID	Location	Cored Length (in)	Trim Length (in)	Capped Length (in)	Diam. (in)	Area (sq in)	Length / Diam. Ratio	Max Load (lbs)	Corr. Factor	Comp. Strength (psi)	Fracture Type	Density (pcf)	Tested By
1	PO #469469			8.76	3.92	12.07	2.04	98580	1.000	8170	3		DRH

Comments:

Services:
Terracon Rep.: Cullen Turney
Reported To:
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Gary Gerke (1) Terracon Consultants, Inc., Andrea Allen

Start/Stop: 0830-1030

Reviewed By:
Andrea Allen
Project Manager

Test Methods:

The tests were performed in general accordance with applicable ASTM, AASHTO, or DOT test methods. This report is exclusively for the use of the client indicated above and shall not be reproduced except in full without the written consent of our company. Test results transmitted herein are only applicable to the actual samples tested at the location(s) referenced and are not necessarily indicative of the properties of other apparently similar or identical materials.

D.3. *MASH* TEST 2-20 (CRASH TEST NO. 469469-4-1)

D.3.1. Vehicle Properties and Information

Table D.1. Vehicle Properties for Test No. 469469-4-1.

Vehicle Inventory Number: 1422

Date: 2019-07-29 | Test No.: 469469-04-1 | VIN No.: KNADE173186324788

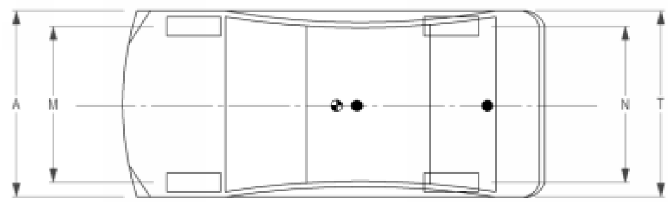
Year: 2008 | Make: Kia | Model: Rio

Tire Inflation Pressure: 32 PSI | Odometer: 177638 | Tire Size: 185/65R14

Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

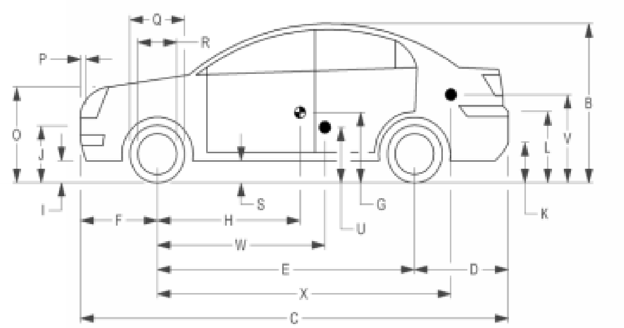
NOTES:



Engine Type: 4 CYL
Engine CID: 1.6 L

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

Optional Equipment:
None



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

Geometry: inches

A	66.38	F	33.00	K	12.25	P	4.12	U	14.75
B	51.50	G		L	25.25	Q	22.50	V	20.75
C	165.75	H	35.50	M	57.75	R	15.50	W	35.50
D	34.00	I	7.75	N	57.70	S	8.25	X	71.50
E	98.75	J	21.50	O	27.00	T	66.20		

Wheel Center Ht Front 11.00 | Wheel Center Ht Rear 11.00 | W-H 0.00

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Bottom of Hood Lip) = 24 ±4 inches
TOP OF RADIATOR SUPPORT = 28.25 inches; (M+N)/2 = 56 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1595	1549	1634
Back	1874	M_{rear}	866.00	871	951.00
Total	3638	M_{Total}	2461	0	2585

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

Mass Distribution:
lb | LF: 790 | RF: 759 | LR: 447 | RR: 424

Table D.2. Exterior Crush Measurements of Vehicle for Test No. 469469-4-1.

Vehicle Inventory Number: 1422

Date: 2019-07-29 Test No.: 469469-04-1 VIN No.: KNADE173186324788

Year: 2008 Make: Kia Model: Rio

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) (check one)		Bowing constant $\frac{X1+X2}{2}$ =	
< 4 inches			
≥ 4 inches			

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FT BUMPER	16	6	16	1	3.5	6	-	-	-	+24
2	SAME	16	7	34	0	.75	1.5	2	5	7	+68
	Measurements recorded										
	☑ inches or ☐ mm										

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

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

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

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

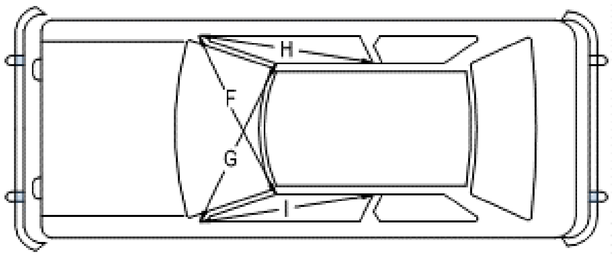
***Measure and document on the vehicle diagram the location of the maximum crush.

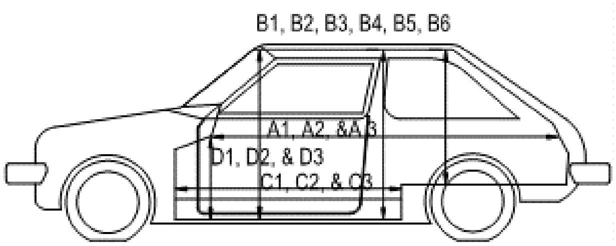
Note: Use as many lines/columns as necessary to describe each damage profile.

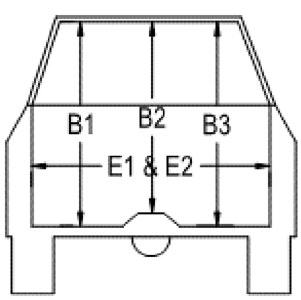
Table D.3. Occupant Compartment Measurements of Vehicle for Test No. 469469-4-1.

Vehicle Inventory Number: 1422

Date:	2019-07-29	Test No.:	469469-04-1	VIN No.:	KNADE173186324788
Year:	2008	Make:	Kia	Model:	Rio







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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

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

D.3.2. Sequential Photographs

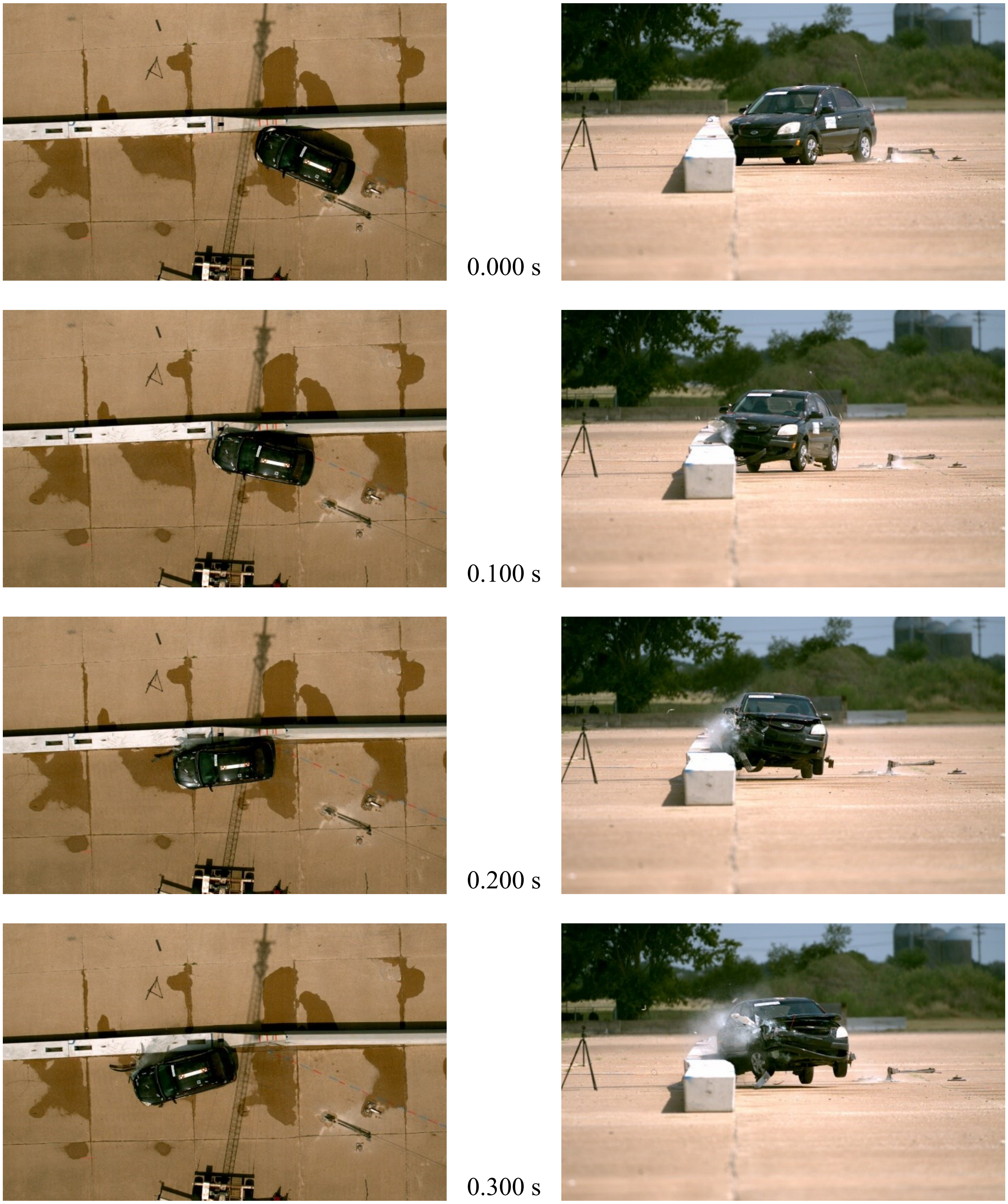


Figure D.1. Sequential Photographs for Test No. 469469-4-1 (Overhead and Gut Views).

0.400 s

0.500 s

0.600 s

0.700 s

Figure A.1. Sequential Photographs for Test No. 469469-4-1 (Overhead and Gut Views) (Continued).

0.000 s

0.100 s

0.200 s

0.300 s

0.400 s

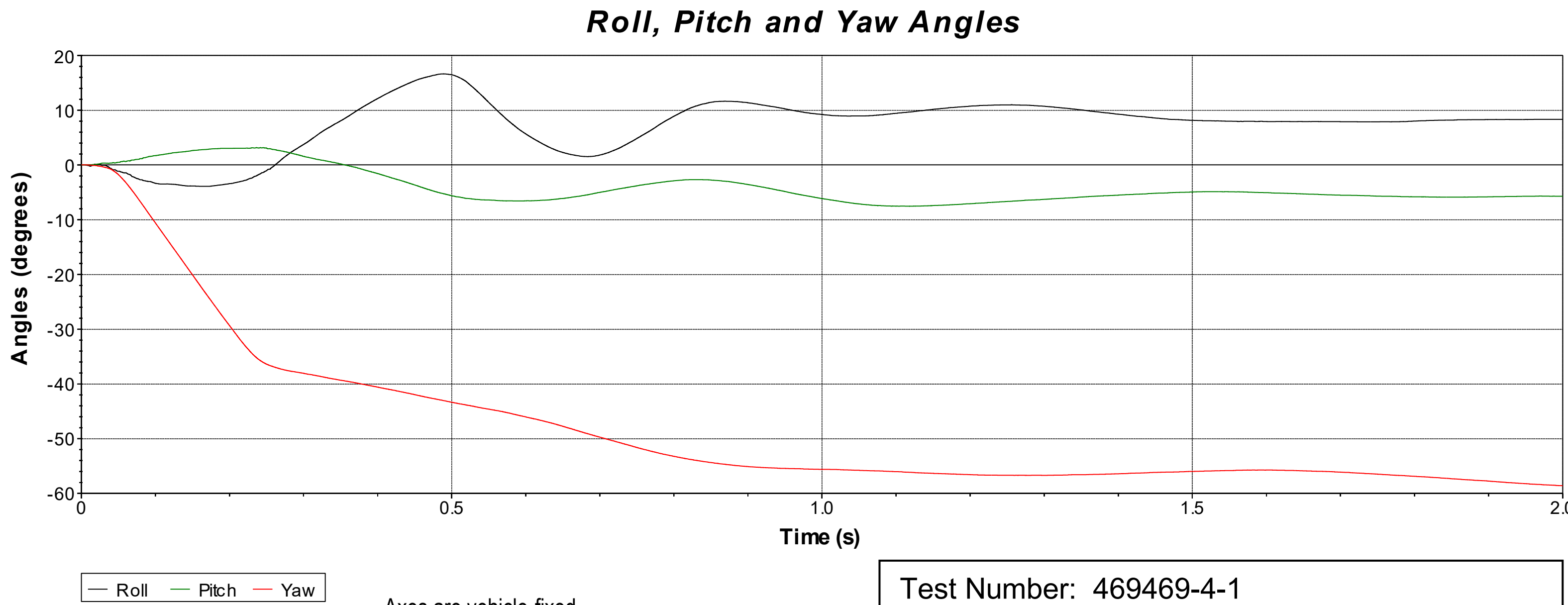
0.500 s

0.600 s

0.700 s

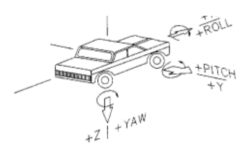
Figure D.2. Sequential Photographs for Test No. 469469-4-1 (Rear View).

D.3.3. Vehicle Angular Displacement



Axes are vehicle-fixed.
Sequence for determining orientation:

16. Yaw.
17. Pitch.
18. Roll.



Test Number: 469469-4-1
Test Standard: 2-20
Test Article: Low-Profile-to-F-Shape Transition
Test Vehicle: 1100C/ 2008 Kia Rio
Inertial Mass: 2420 lb
Gross Mass: 2585 lb
Impact Speed: 45.3 mi/h
Impact Angle: 24.6 degrees

Figure D.3. Vehicle Angular Displacements for Test No. 469469-4-1.

D.3.4. Vehicle Acceleration

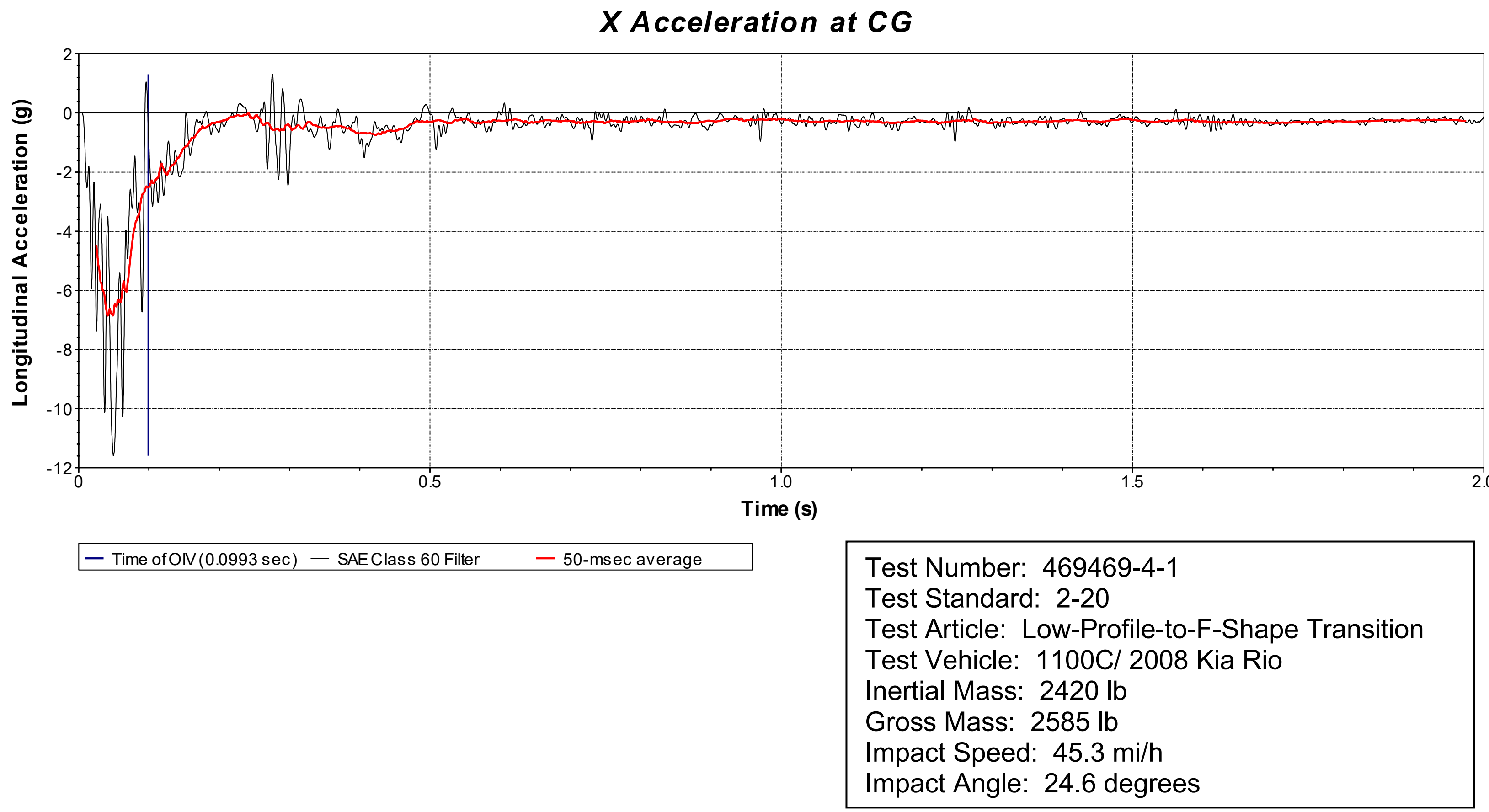


Figure D.4. Vehicle Longitudinal Accelerometer Trace for Test No. 469469-4-1 (Accelerometer Located at Center of Gravity).

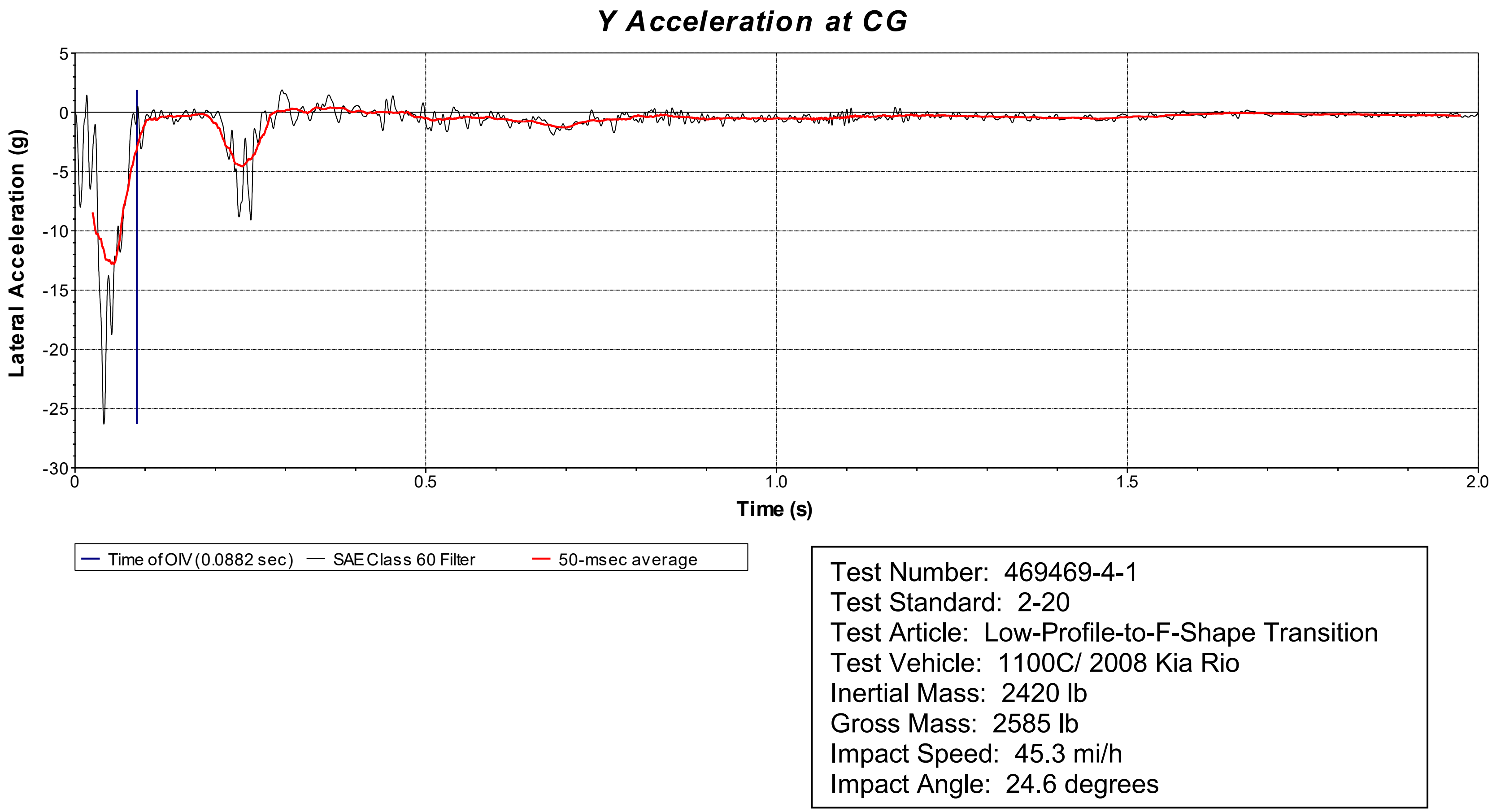
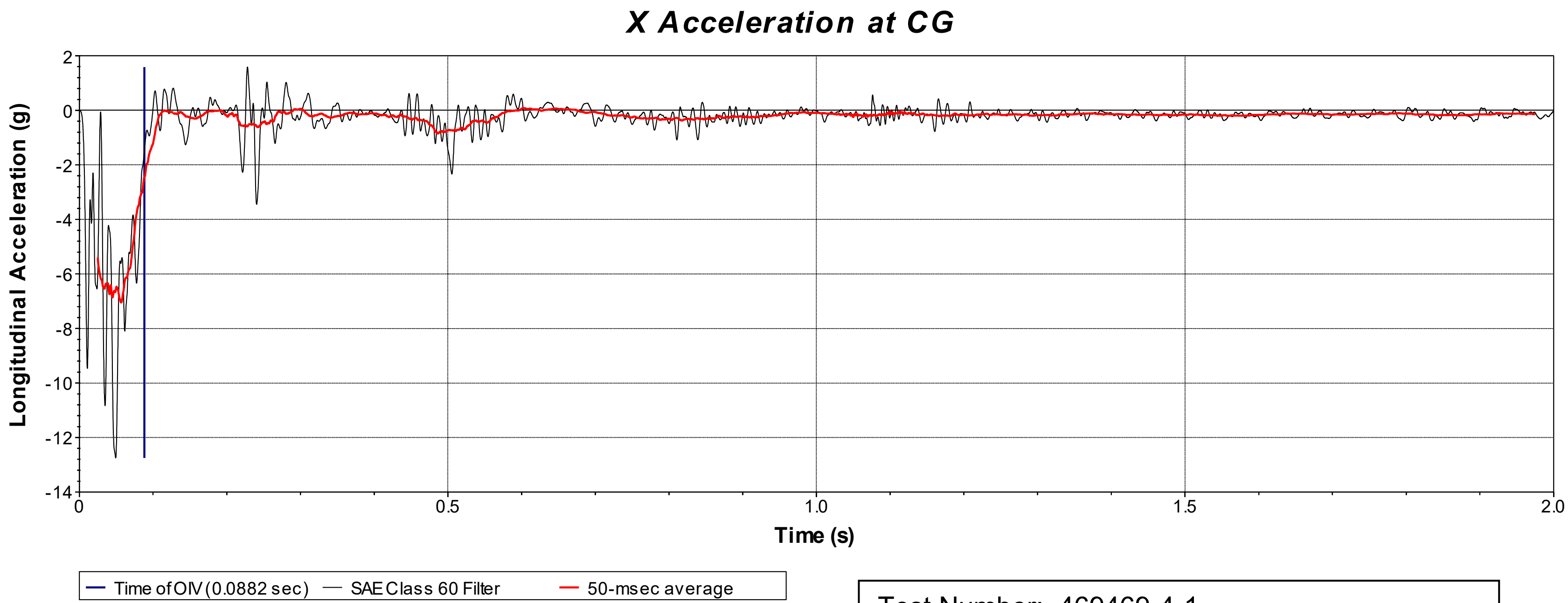


Figure D.5. Vehicle Lateral Accelerometer Trace for Test No. 469469-4-1 (Accelerometer Located at Center of Gravity).



Test Number: 469469-4-1
Test Standard: 2-20
Test Article: Low-Profile-to-F-Shape Transition
Test Vehicle: 1100C/ 2008 Kia Rio
Inertial Mass: 2420 lb
Gross Mass: 2585 lb
Impact Speed: 45.3 mi/h
Impact Angle: 24.6 degrees

Figure D.6. Vehicle Vertical Accelerometer Trace for Test No. 469469-4-1 (Accelerometer Located at Center of Gravity).

D.4. *MASH* TEST 2-21 (CRASH TEST NO. 469469-4-2)

D.4.1. Vehicle Properties and Information

Table D.4. Vehicle Properties for Test No. 469469-4-2.

Vehicle Inventory Number: 1361

Date:	2019-08-01	Test No.:	469469-04-2	VIN No.:	1C6RR6FT3FS613915
Year:	2015	Make:	DODGE	Model:	RAM1500

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

Tread Type: Highway — Odometer: 249398

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

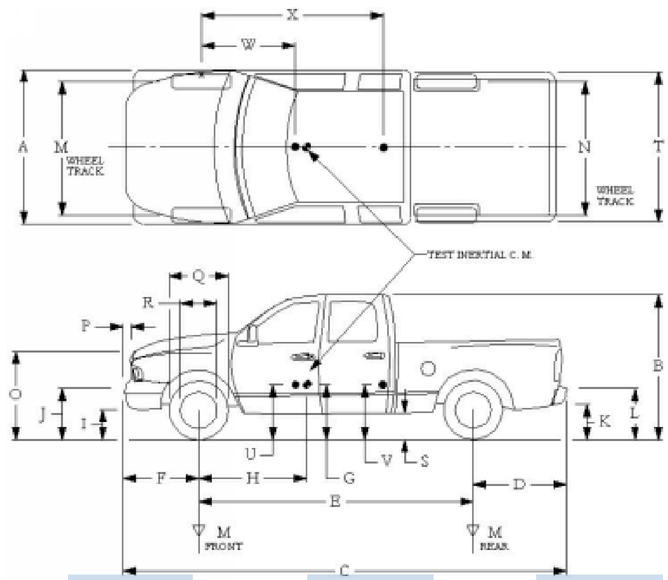
NOTES: None

Engine Type: V-8
Engine CID: 5.7 liter

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

Optional Equipment:
None

Dummy Data:
Type: N/A
Mass: 0 lb
Seat Position: N/A



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.88	L	30.00	Q	30.50	V	30.25
C	227.50	H	61.25	M	68.50	R	18.00	W	61.59
D	44.00	I	11.75	N	68.00	S	13.00	X	79.00
E	140.50	J	27.00	O	46.00	T	77.00		

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

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

GVWR Ratings:		Mass: lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2908	2825	
Back	3900	M_{rear}	2036	2205	
Total	6700	M_{Total}	4944	5030	0

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

Mass Distribution:
lb

LF:	1429	RF:	1396	LR:	1130	RR:	1075

Performed by: RK — Date: 2019-08-01

Table D.5. Measurements of Vehicle Vertical CG for Test No. 469469-4-2.

Vehicle Inventory Number: 1361

Date: 2019-08-01 Test No.: 469469-04-2 VIN: 1C6RR6FT3FS613915

Year: 2015 Make: DODGE Model: RAM1500

Body Style: Quad Cab Mileage: 249398

Engine: 5.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 100 (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70 R 17

Measured Vehicle Weights:		(lb)						
LF:	1429		RF:	1396		Front Axle:	2825	
LR:	1130		RR:	1075		Rear Axle:	2205	
Left:	2559		Right:	2471		Total:	5030	
						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:	61.59	inches	Rear of Front Axle		(63 ±4 inches allowed)			
Y:	-0.60	inches	Left -	Right +	of Vehicle Centerline			
Z:	28.88	inches	Above Ground		(minumum 28.0 inches allowed)			

Hood Height: 46.00 inches Front Bumper Height: 27.00 inches

43 ±4 inches allowed

Front Overhang: 40.00 inches Rear Bumper Height: 30.00 inches

39 ±3 inches allowed

Overall Length: 227.50 inches

237 ±13 inches allowed

Performed by: RK Date: 2019-08-01

Table D.6. Exterior Crush Measurements of Vehicle for Test No. 469469-4-2.

Vehicle Inventory Number: 1361

Date:	2019-08-01	Test No.:	469469-04-2	VIN No.:	1C6RR6FT3FS613915
Year:	2015	Make:	DODGE	Model:	RAM1500

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) (check one)		Bowing constant	$\frac{X1+X2}{2} =$
< 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	LF FRONT BUMPER	12	11	18	1	6	11	NA	NA	NA	+14
2	ABOVE GROUND	17	13	52	13	11	NA	NA	1	2	+36
	Measurements recorded										
	☑ inches or ☐ mm										

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

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

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

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

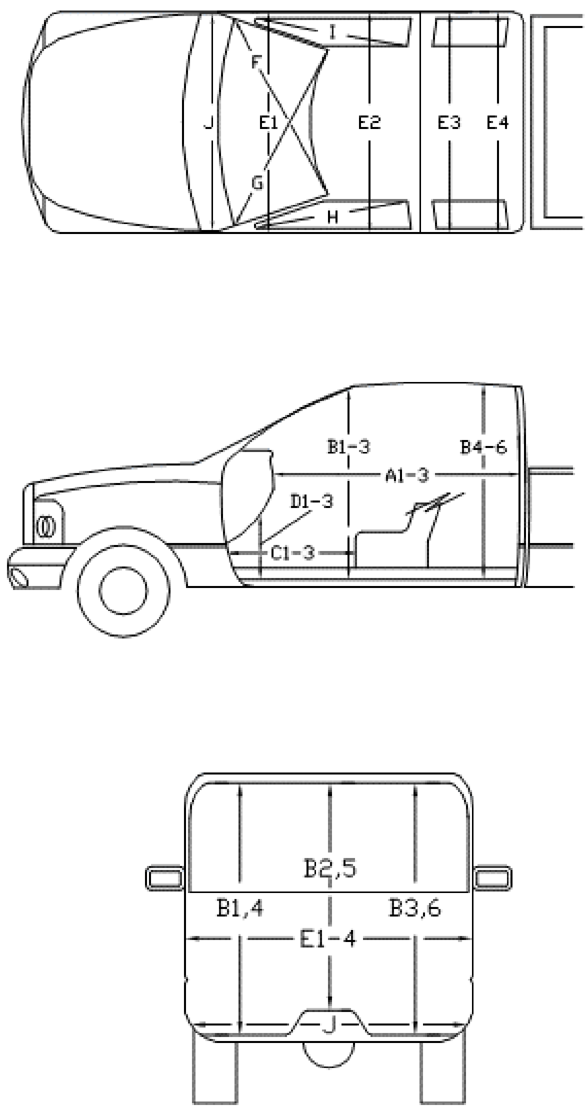
***Measure and document on the vehicle diagram the location of the maximum crush.

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

Performed by: RK Date: 2019-08-04

Table D.7. Occupant Compartment Measurements of Vehicle for Test No. 469469-4-2.

Vehicle Inventory Number:	1361				
Date:	2019-08-01	Test No.:	469469-04-2	VIN No.:	1C6RR6FT3FS613915
Year:	2015	Make:	DODGE	Model:	RAM1500



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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	58.50	0.00
E2	63.50	63.50	0.00
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	25.00	0.00

Performed by:	RK	Date:	2019-08-01

D.4.2. Sequential Photographs

0.000 s

0.100 s

0.200 s

0.300 s

Figure D.7. Sequential Photographs for Test No. 469469-4-2 (Overhead and Gut Views).

0.400 s

0.500 s

0.600 s

0.700 s

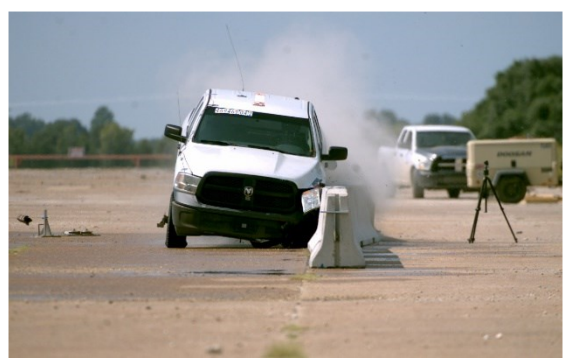


Figure A.1. Sequential Photographs for Test No. 469469-4-2 (Overhead and Gut Views) (Continued).


0.000 s

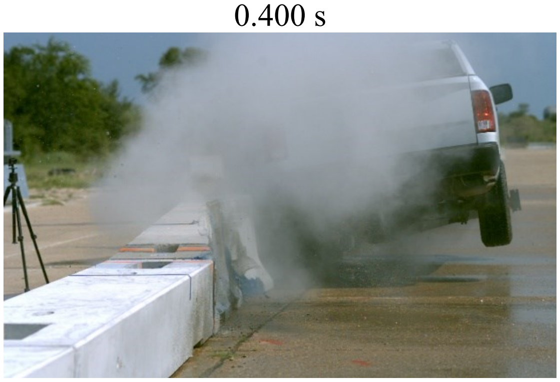

0.100 s


0.200 s


0.300 s


0.400 s


0.500 s


0.600 s

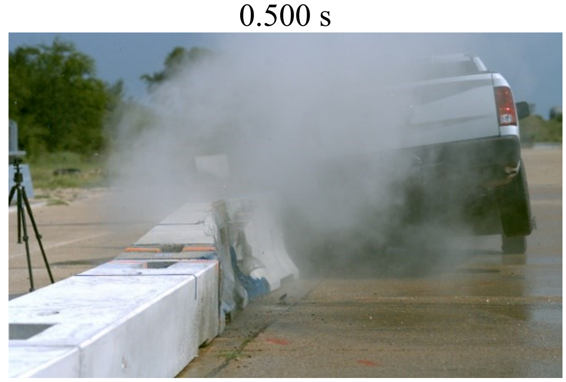

0.700 s

Figure D.8. Sequential Photographs for Test No. 469469-4-2 (Rear View).

D.4.3. Vehicle Angular Displacement

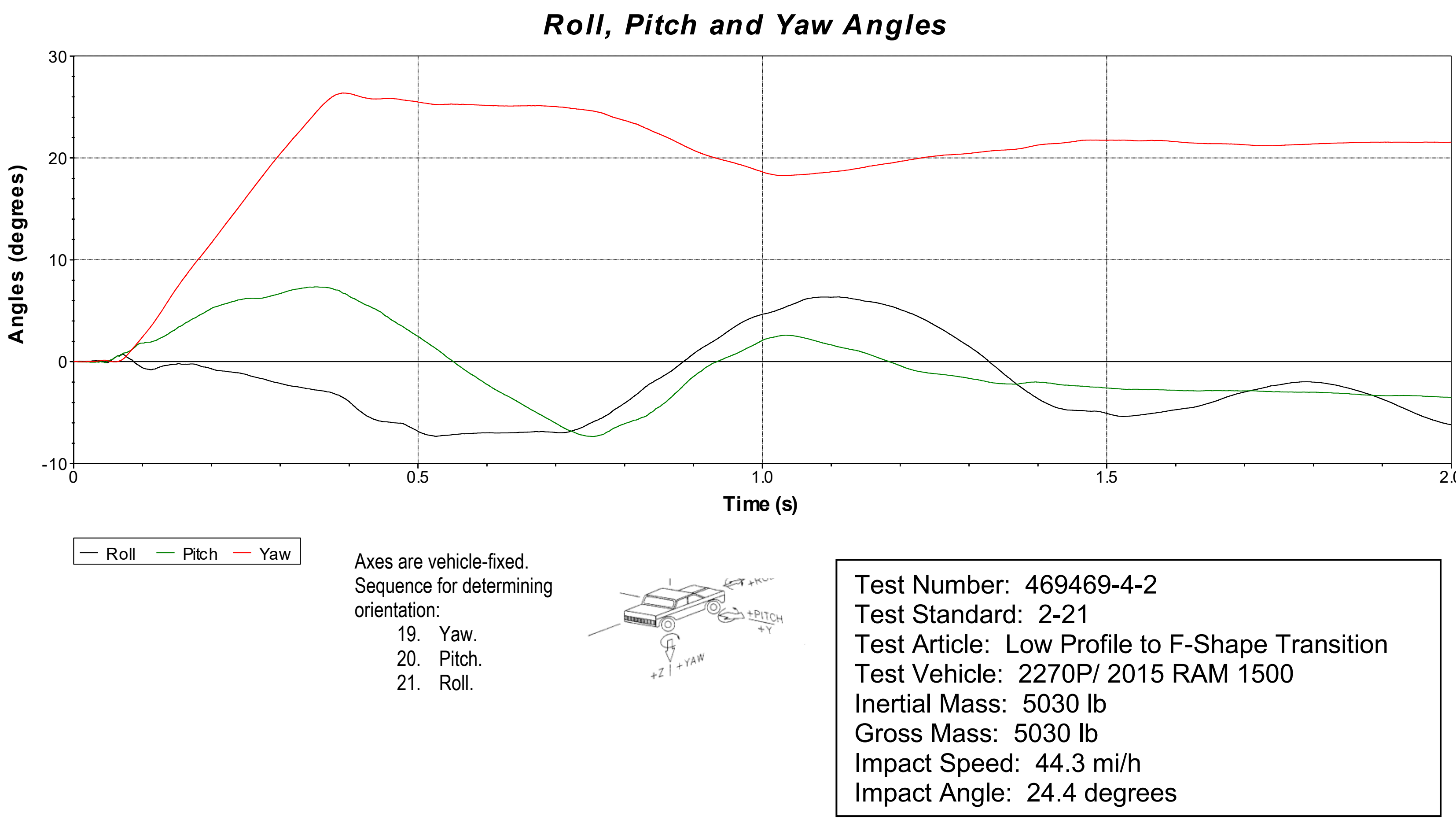


Figure D.9. Vehicle Angular Displacements for Test No. 469469-4-2.

D.4.4. Vehicle Acceleration

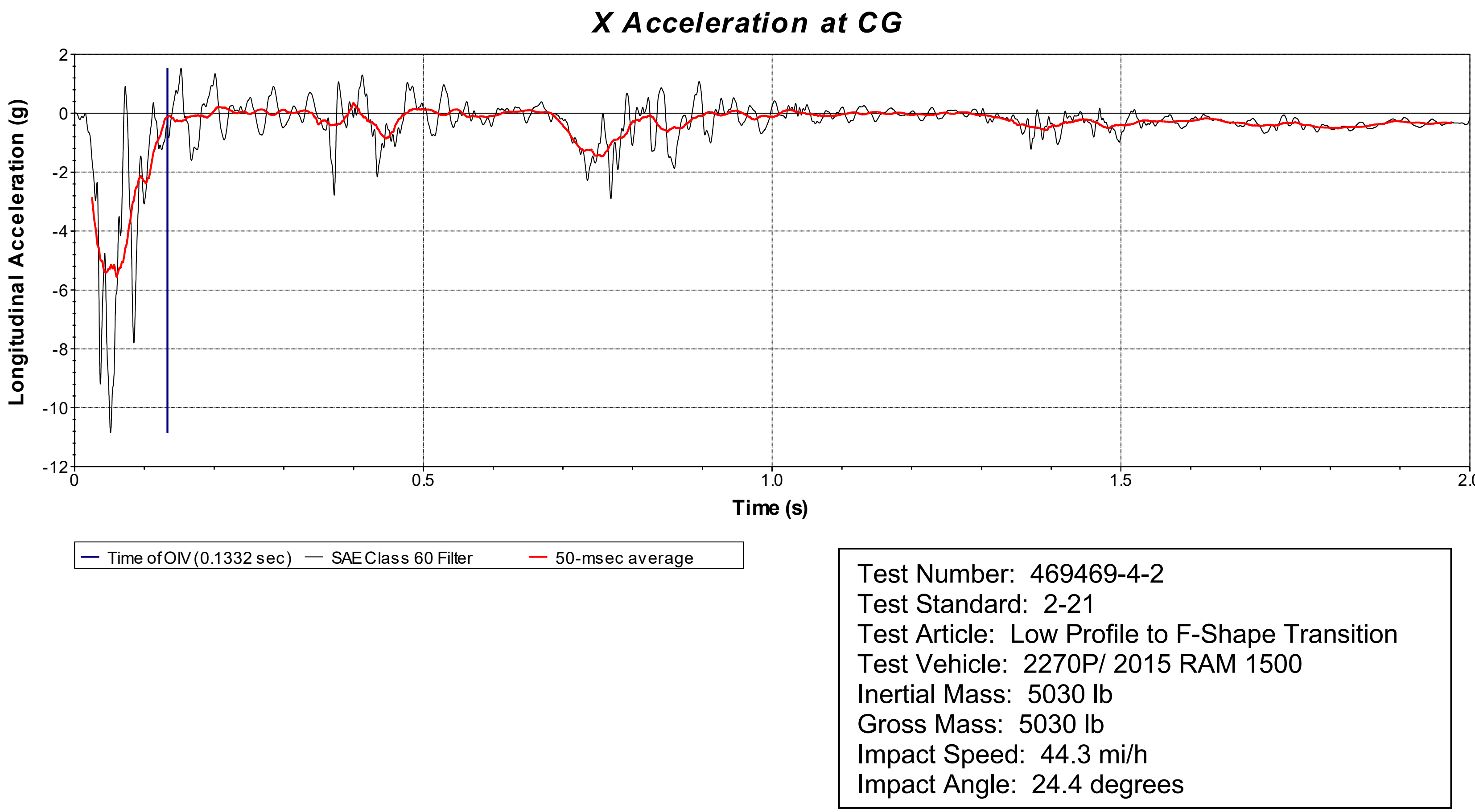
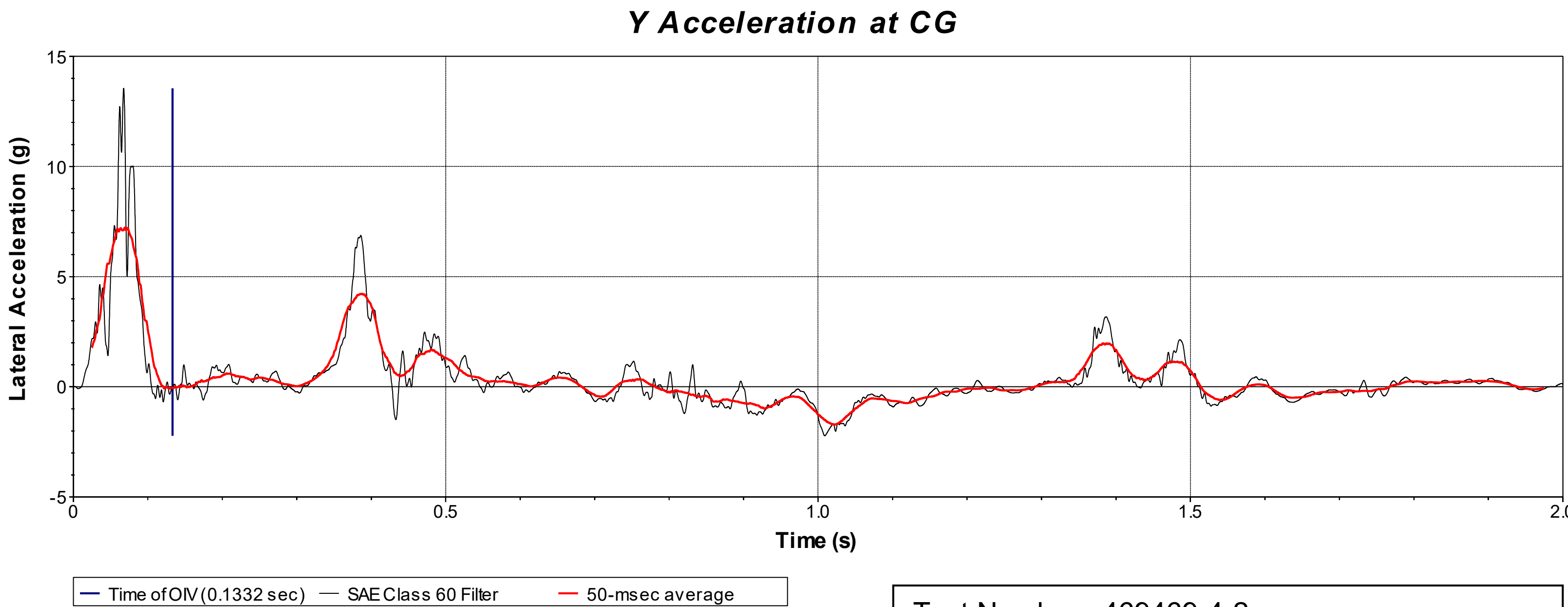
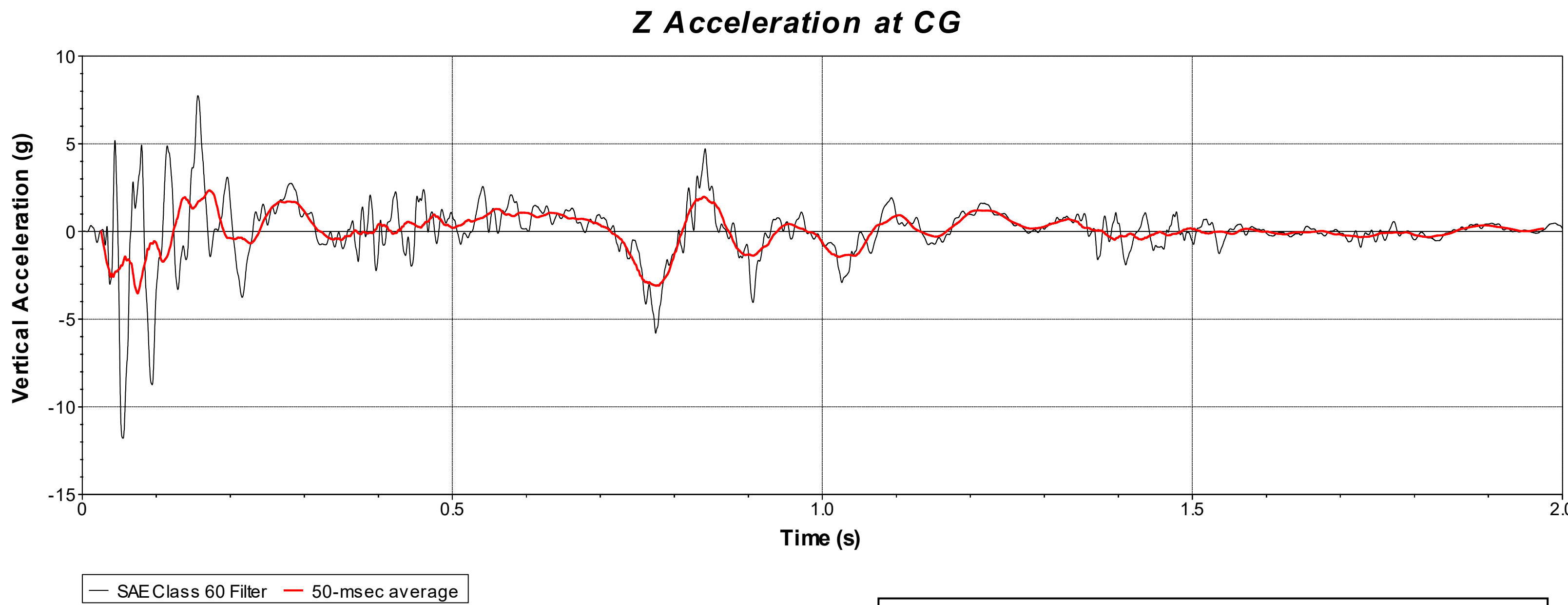


Figure D.10. Vehicle Longitudinal Accelerometer Trace for Test No. 469469-4-2 (Accelerometer Located at Center of Gravity).



Test Number: 469469-4-2
Test Standard: 2-21
Test Article: Low Profile to F-Shape Transition
Test Vehicle: 2270P/ 2015 RAM 1500
Inertial Mass: 5030 lb
Gross Mass: 5030 lb
Impact Speed: 44.3 mi/h
Impact Angle: 24.4 degrees

Figure D.11. Vehicle Lateral Accelerometer Trace for Test No. 469469-4-2 (Accelerometer Located at Center of Gravity).

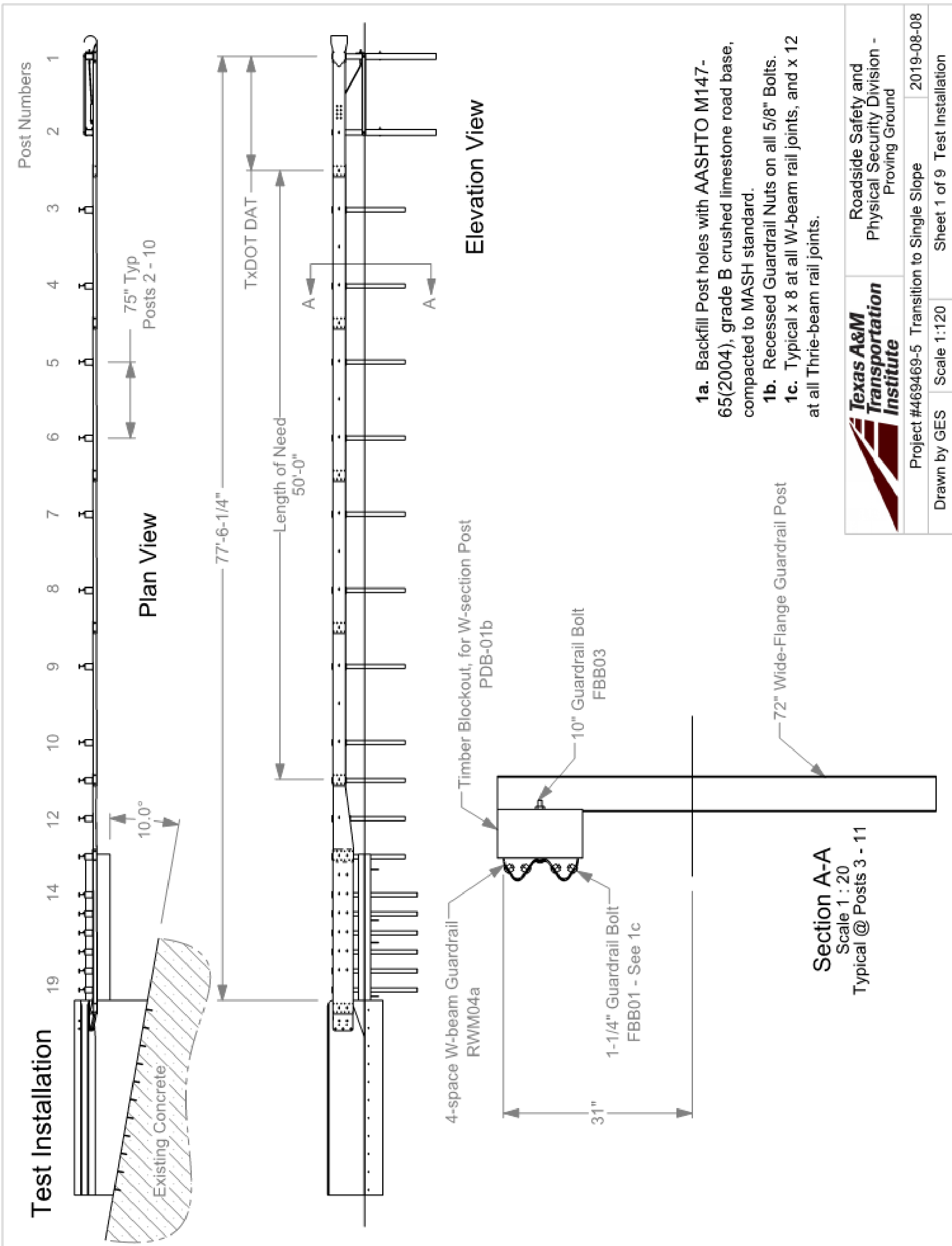


Test Number: 469469-4-2
Test Standard: 2-21
Test Article: Low Profile to F-Shape Transition
Test Vehicle: 2270P/ 2015 RAM 1500
Inertial Mass: 5030 lb
Gross Mass: 5030 lb
Impact Speed: 44.3 mi/h
Impact Angle: 24.4 degrees

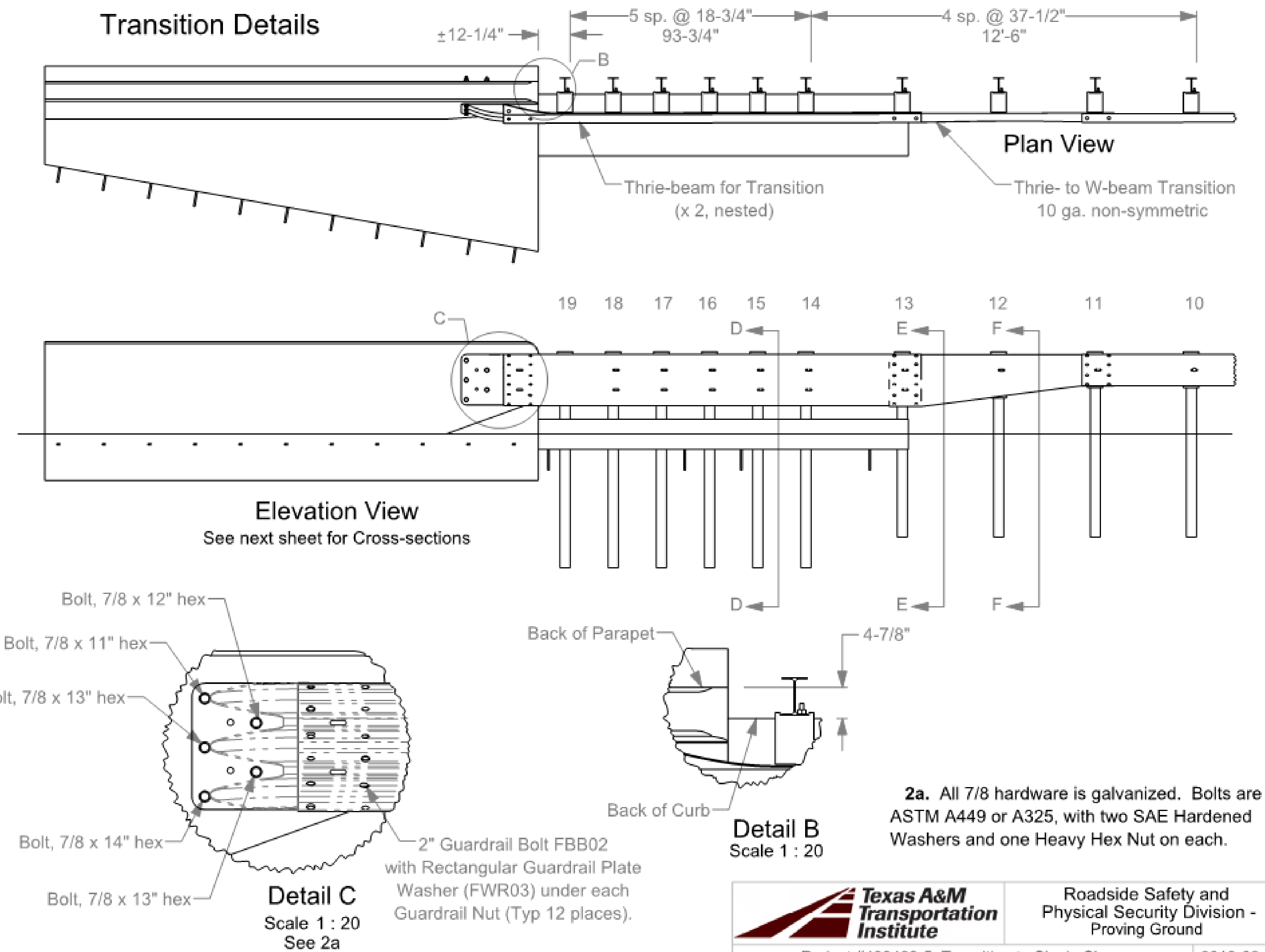
Figure D.12. Vehicle Vertical Accelerometer Trace for Test No. 469469-4-2 (Accelerometer Located at Center of Gravity).

APPENDIX E. TXDOT THRIE-BEAM TRANSITION WITHOUT END SHOE BLOCK

E.1. DETAILS OF THE THRIE-BEAM TRANSITION WITHOUT END SHOE BLOCK



Transition Details



2a. All 7/8 hardware is galvanized. Bolts are ASTM A449 or A325, with two SAE Hardened Washers and one Heavy Hex Nut on each.

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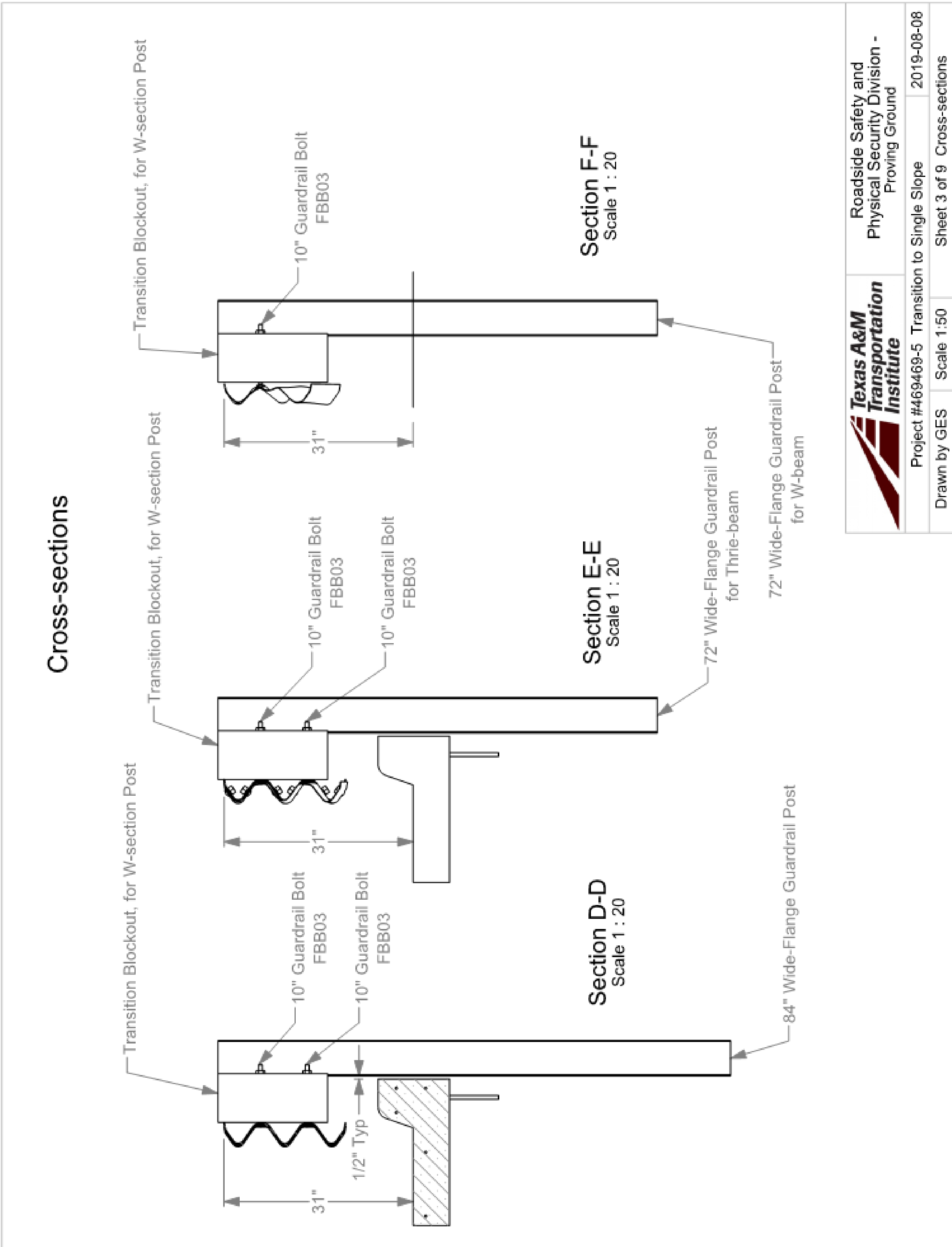
Project #469469-5 Transition to Single Slope		2019-08-08
Drawn by GES	Scale 1:50	Sheet 2 of 9 Transition Details


Cross-sections
Section D-D
Scale 1 : 20
Transition Blockout, for W-section Post
10" Guardrail Bolt
FBB03
10" Guardrail Bolt
FBB03
1/2" Typ
31"
84" Wide-Flange Guardrail Post
Section E-E
Scale 1 : 20
Transition Blockout, for W-section Post
10" Guardrail Bolt
FBB03
10" Guardrail Bolt
FBB03
31"
72" Wide-Flange Guardrail Post
for Thrie-beam
Section F-F
Scale 1 : 20
Transition Blockout, for W-section Post
10" Guardrail Bolt
FBB03
31"
72" Wide-Flange Guardrail Post
for W-beam
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Physical Security Division -
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Project #469469-5
Transition to Single Slope
2019-08-08
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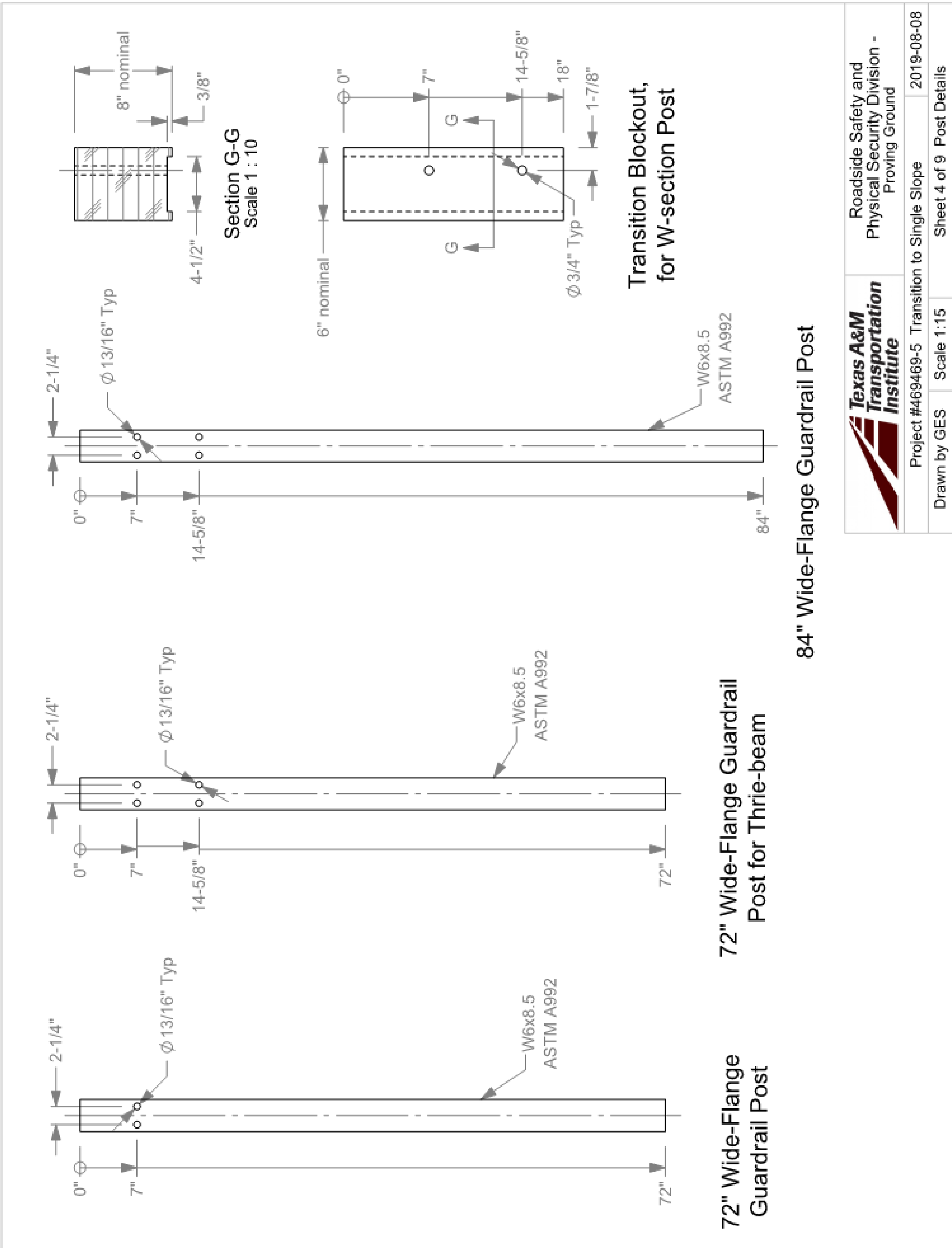
Scale 1:50
Sheet 3 of 9
Cross-sections



Section G-G
Scale 1 : 10
8" nominal
3/8"
4-1/2"
Transition Blockout,
for W-section Post
6" nominal
0"
7"
14-5/8"
18"
1-7/8"
G
G
Ø3/4" Typ
84" Wide-Flange Guardrail Post
2-1/4"
Ø13/16" Typ
W6x8.5
ASTM A992
0"
7"
14-5/8"
84"
72" Wide-Flange Guardrail
Post for Thrie-beam
2-1/4"
Ø13/16" Typ
W6x8.5
ASTM A992
0"
7"
14-5/8"
72"
72" Wide-Flange
Guardrail Post
2-1/4"
Ø13/16" Typ
W6x8.5
ASTM A992
0"
7"
72"
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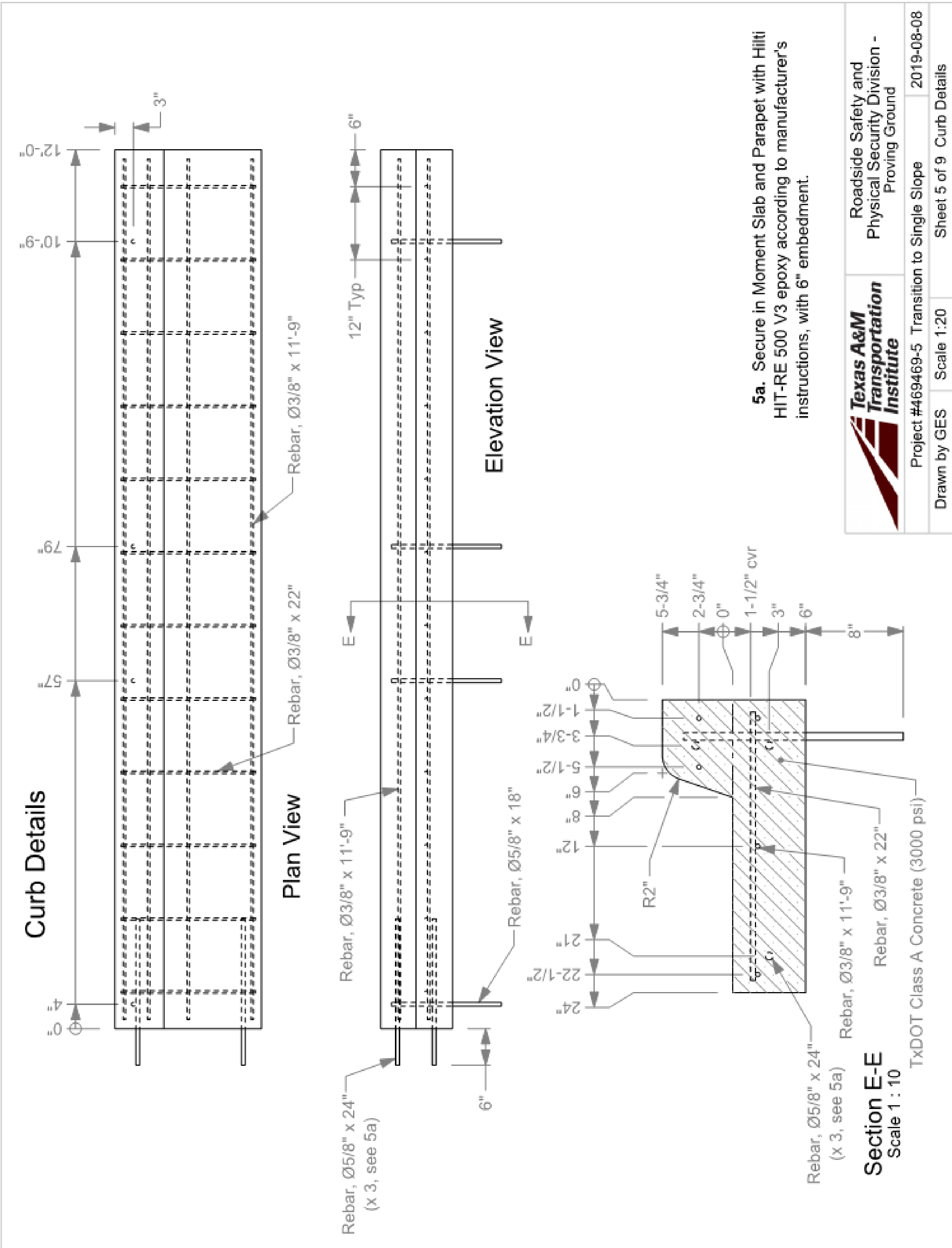
Physical Security Division -
Proving Ground
Project #469469-5 Transition to Single Slope
2019-08-08
Drawn by GES
Scale 1:15
Sheet 4 of 9 Post Details



Curb Details
Plan View
Elevation View
0"
4"
57"
79"
10'-9"
12'-0"
3"
Rebar, Ø3/8" x 22"
Rebar, Ø3/8" x 11'-9"
Rebar, Ø5/8" x 24"
(x 3, see 5a)
6"
12" Typ
E
E
Rebar, Ø5/8" x 18"
Section E-E
Scale 1 : 10
0"
1-1/2"
3-3/4"
5-1/2"
6"
8"
12"
21"
22-1/2"
24"
R2"
5-3/4"
2-3/4"
0"
1-1/2" cvr
3"
6"
8"
Rebar, Ø3/8" x 11'-9"
Rebar, Ø3/8" x 22"
TxDOT Class A Concrete (3000 psi)
5a. Secure in Moment Slab and Parapet with Hilti HIT-RE 500 V3 epoxy according to manufacturer's instructions, with 6" embedment.
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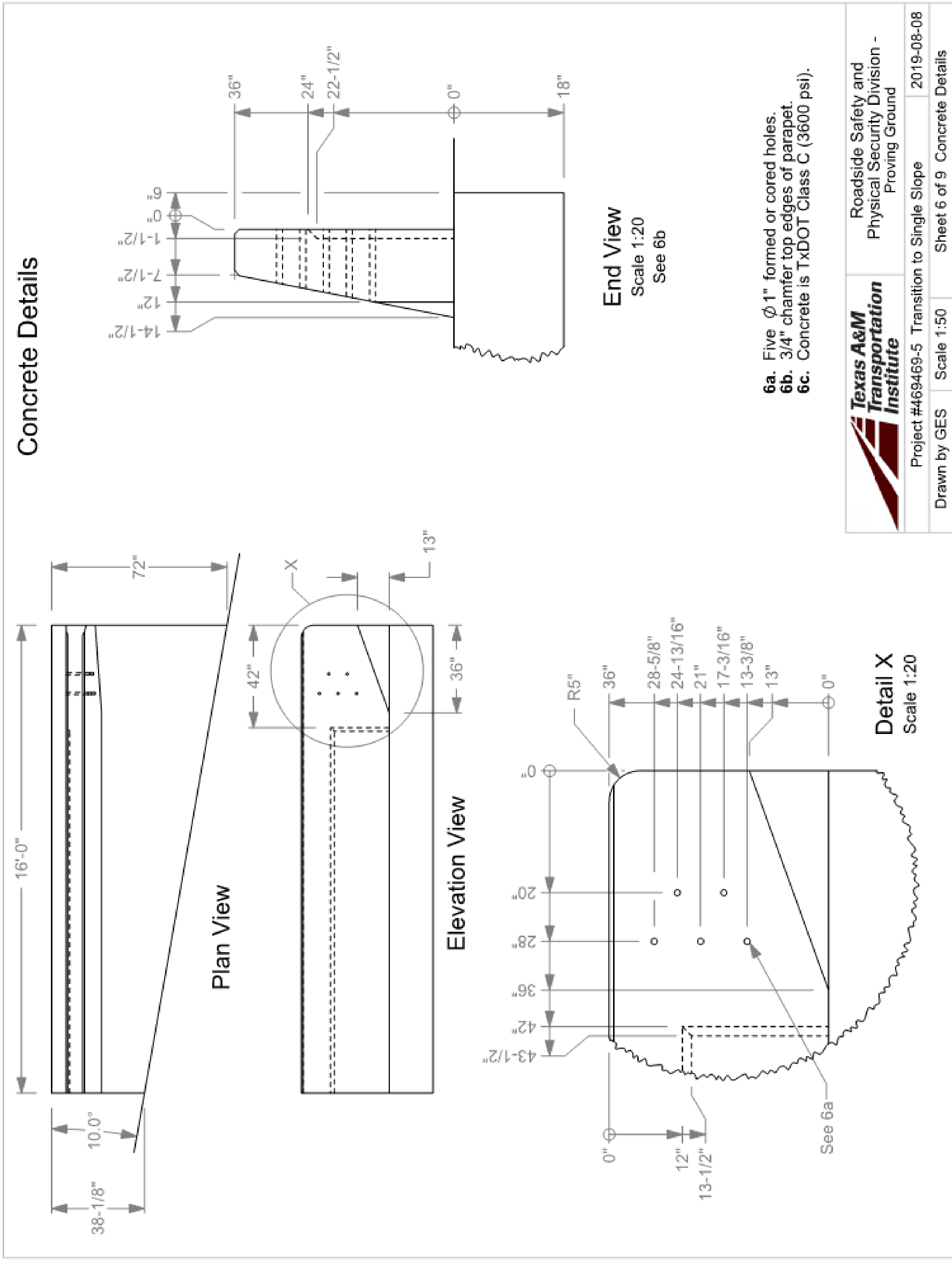
Project #469469-5 Transition to Single Slope
2019-08-08
Drawn by GES
Scale 1:20
Sheet 5 of 9 Curb Details



Concrete Details
Plan View
Elevation View
End View
Scale 1:20
See 6b
Detail X
Scale 1:20
See 6a
6a. Five ⌀1" formed or cored holes.
6b. 3/4" chamfer top edges of parapet.
6c. Concrete is TxDOT Class C (3600 psi).
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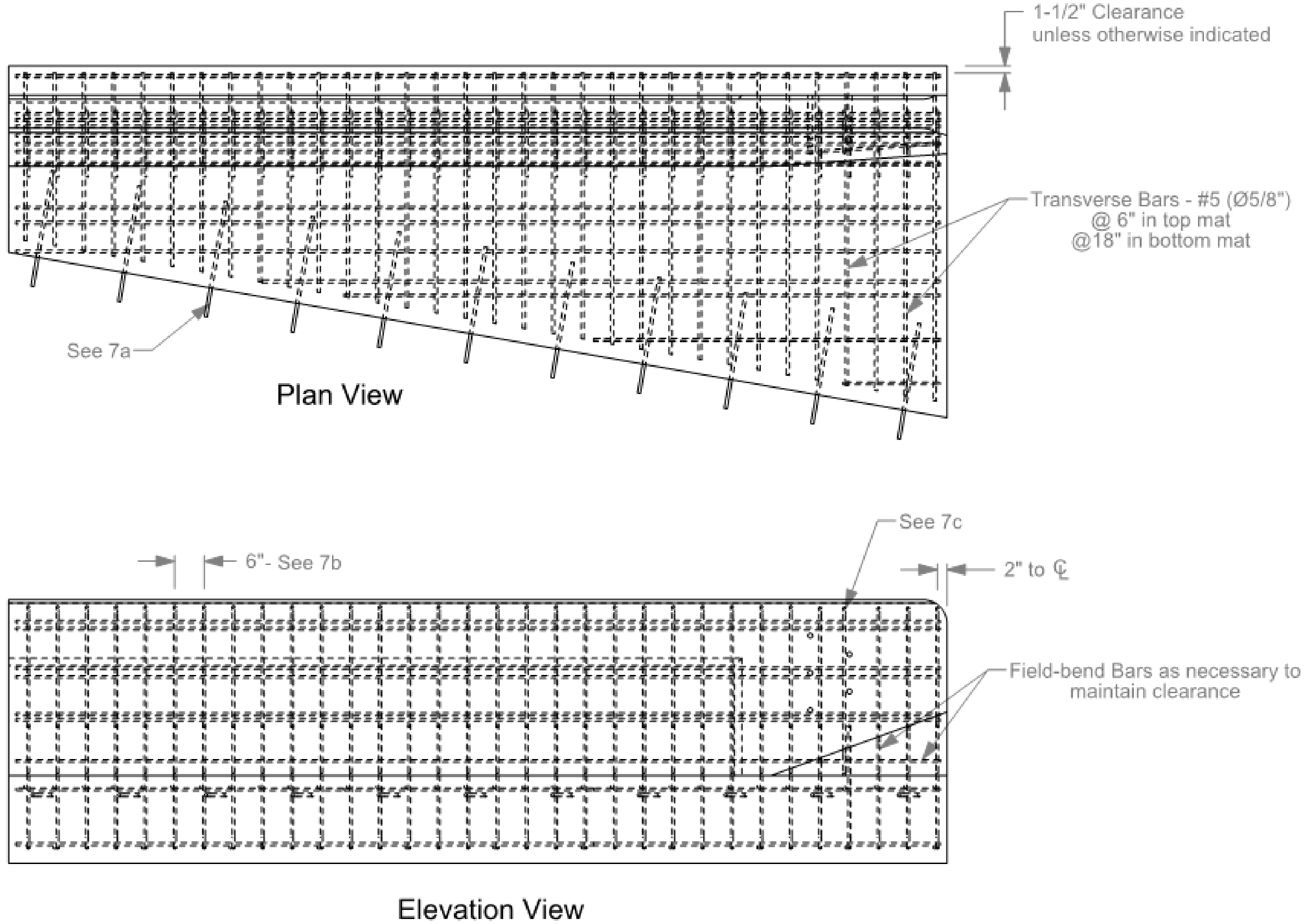
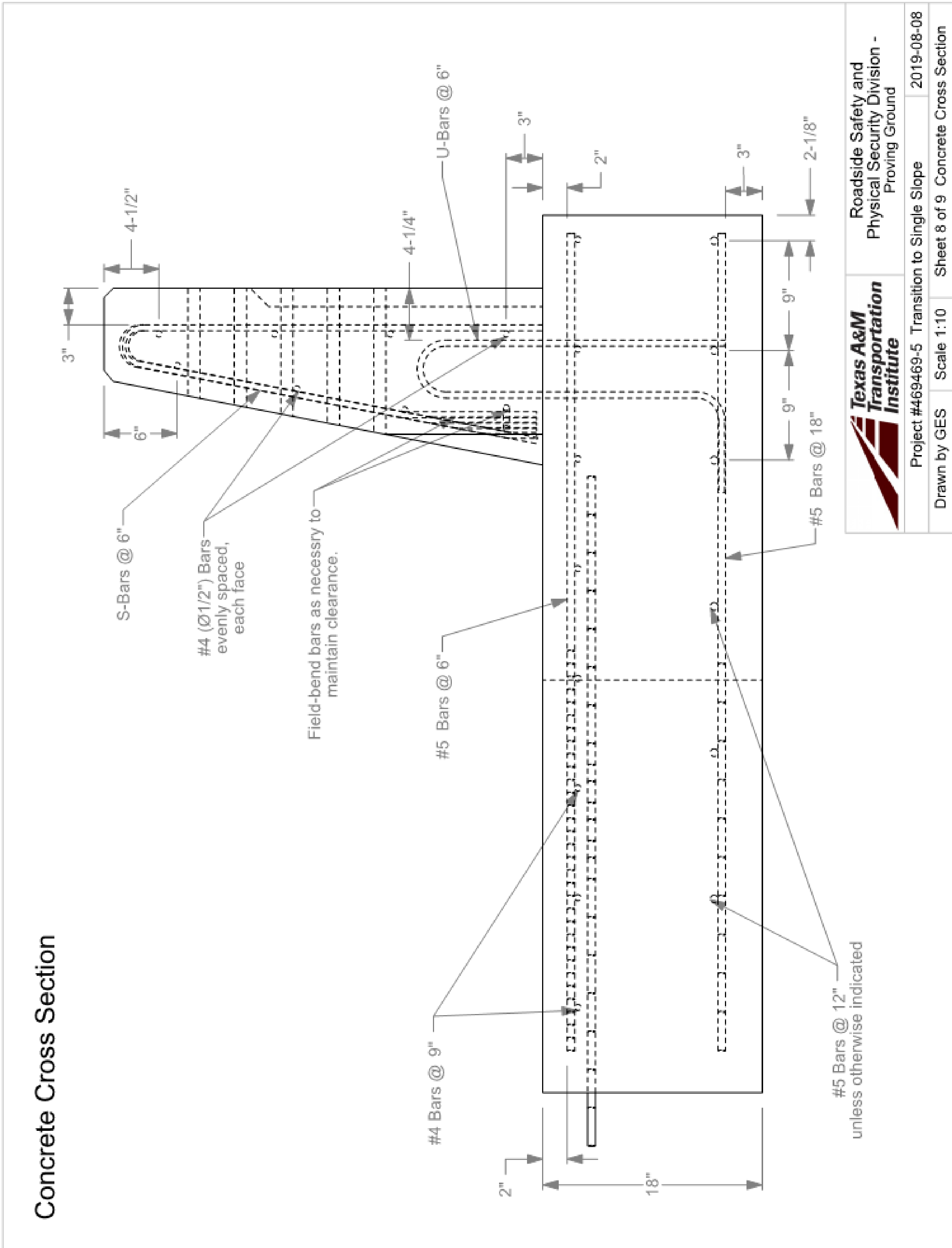
Project #469469-5
Transition to Single Slope
2019-08-08
Drawn by GES
Scale 1:50
Sheet 6 of 9 Concrete Details

Rebar Placement

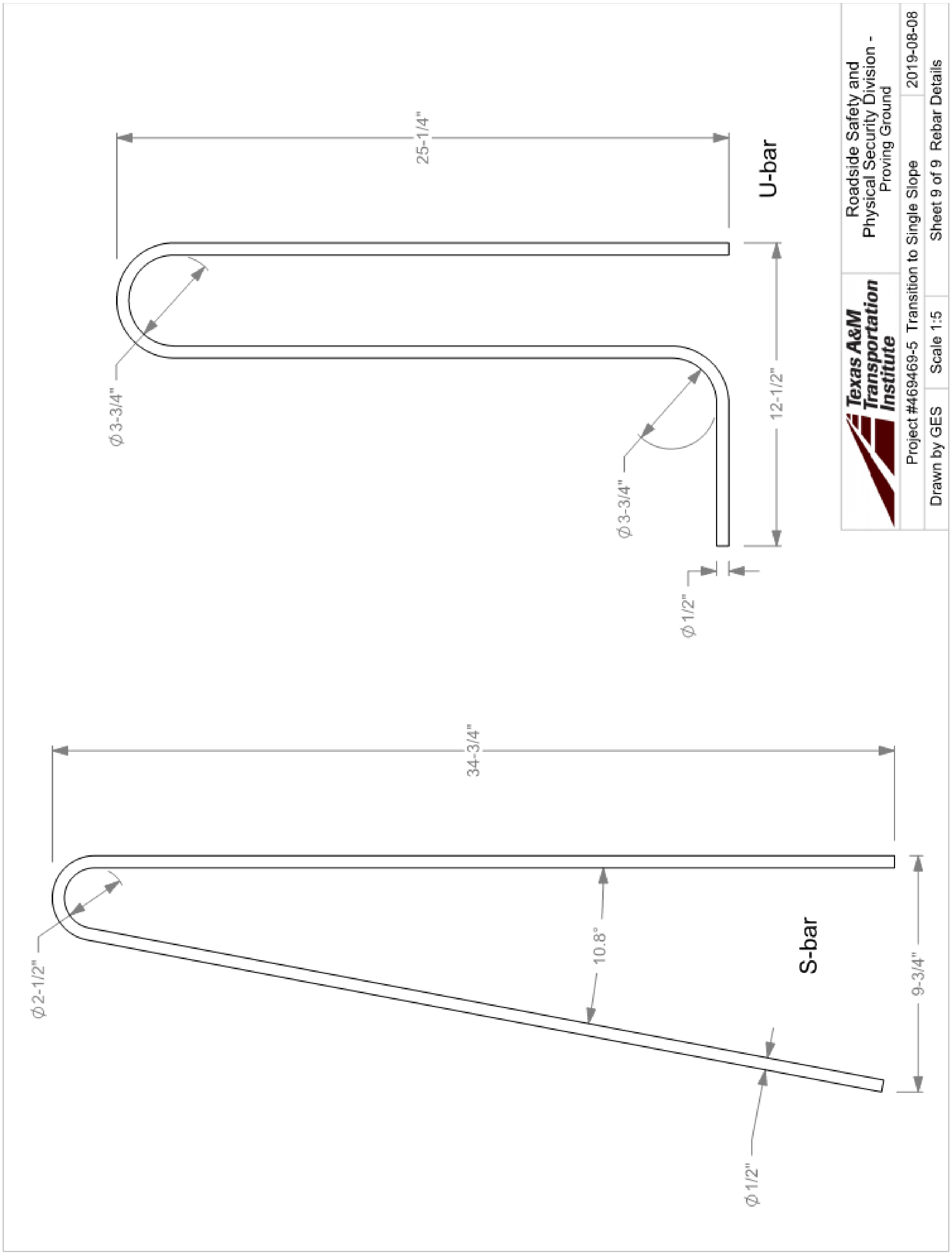


7a. 42" x 13" rebar, embedded in runway minimum 6" with Hilti RE500 epoxy according to manufacturer's instructions. 36" spacing.
7b. 6" spacing typical for U-bars, S-bars, and top transverse bars.
7c. Horizontal spacing on S-bars may be adjusted up to 2" to avoid bolt sleeves.

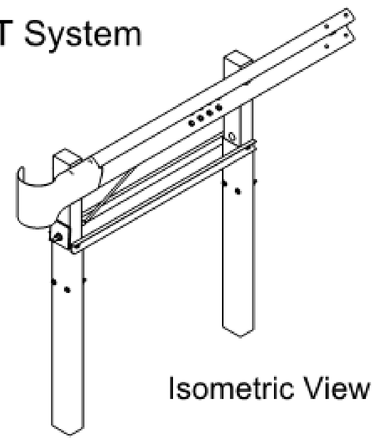
Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project #469469-5 Transition to Single Slope			2019-08-08
Drawn by GES	Scale 1:30	Sheet 7 of 9 Rebar Placement	



Concrete Cross Section
S-Bars @ 6"
#4 (Ø1/2") Bars evenly spaced, each face
Field-bend bars as necessry to maintain clearance.
U-Bars @ 6"
#5 Bars @ 6"
#5 Bars @ 18"
#4 Bars @ 9"
#5 Bars @ 12" unless otherwise indicated
3"
4-1/2"
6"
4-1/4"
3"
2"
3"
2-1/8"
9"
9"
2"
18"
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #469469-5 Transition to Single Slope
2019-08-08
Drawn by GES
Scale 1:10
Sheet 8 of 9 Concrete Cross Section

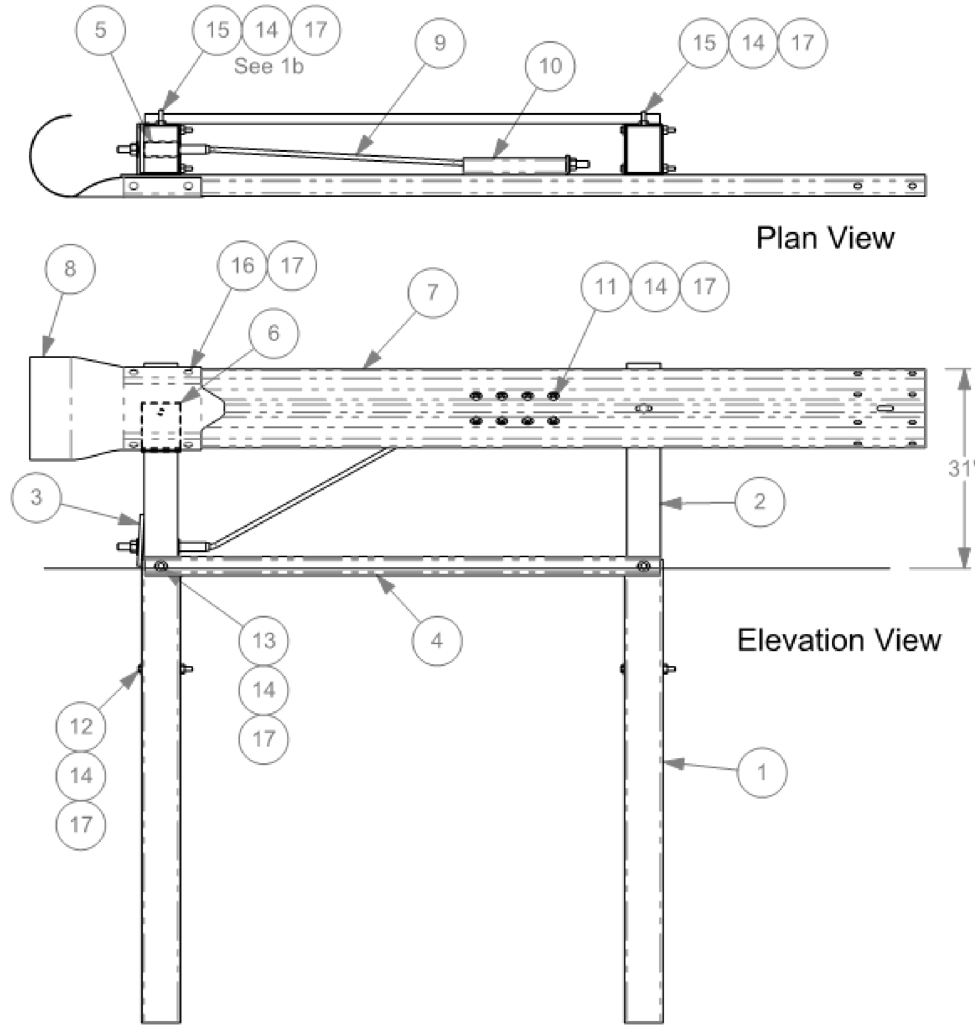

25-1/4"
U-bar
Ø 3-3/4"
12-1/2"
Ø 3-3/4"
Ø 1/2"
34-3/4"
S-bar
Ø 2-1/2"
10.8°
9-3/4"
Ø 1/2"
Roadside Safety and
Physical Security Division -
Proving Ground
Texas A&M Transportation Institute
Project #469469-5 Transition to Single Slope
2019-08-08
Drawn by GES
Scale 1:5
Sheet 9 of 9 Rebar Details

DAT System



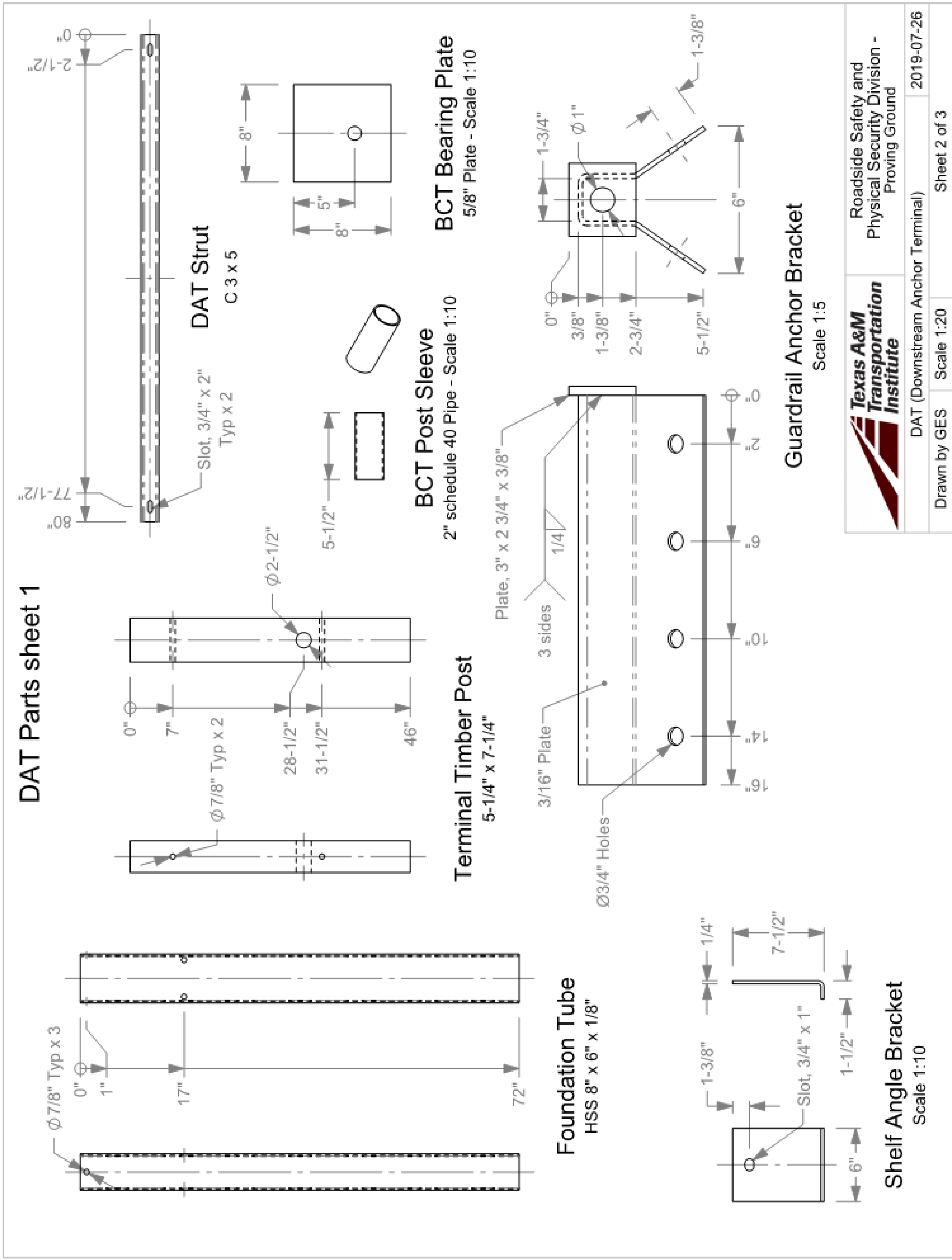
Isometric View

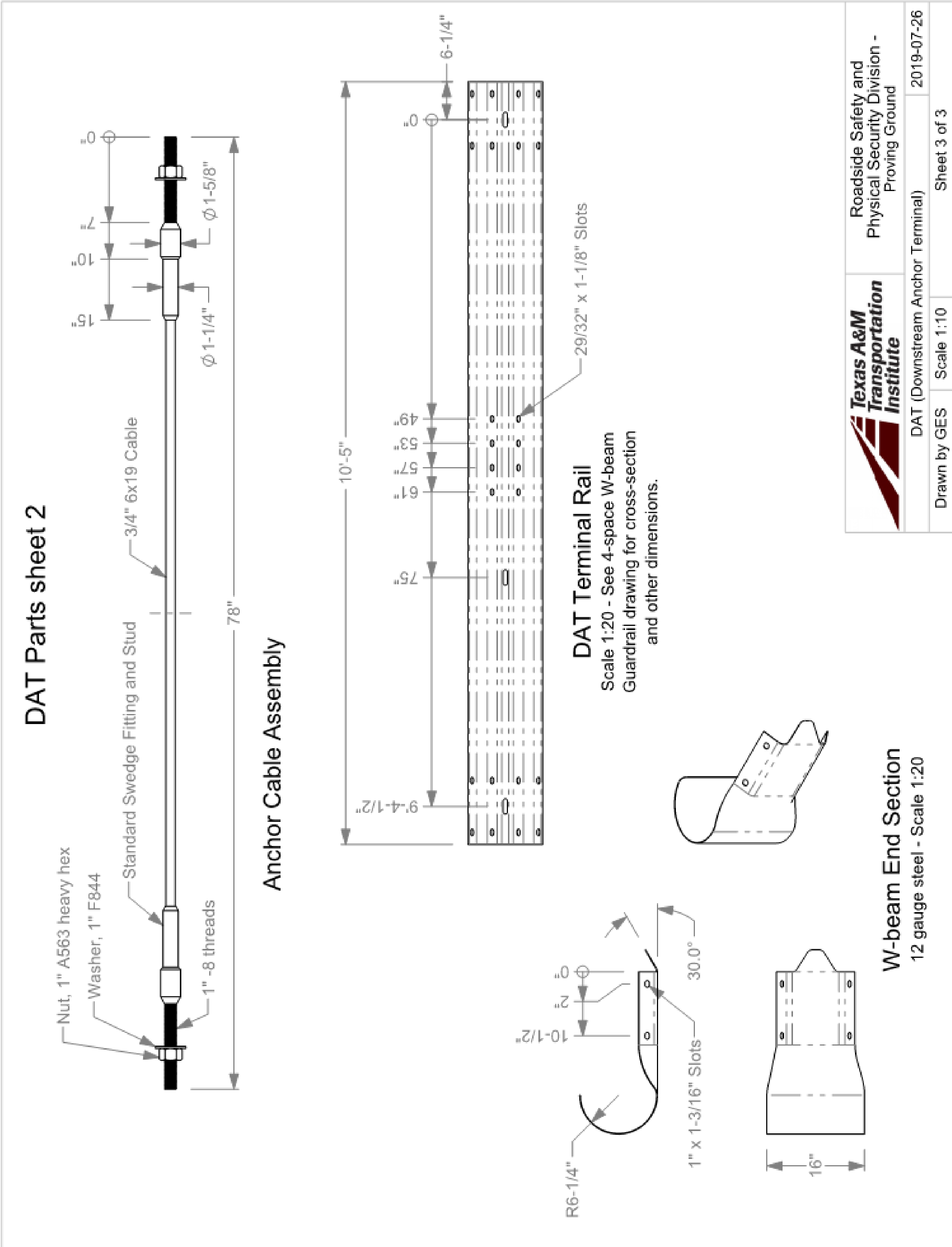
#	Part Name	Qty.
1	Foundation Tube	2
2	Terminal Timber Post	2
3	BCT Bearing Plate	1
4	DAT Strut	2
5	BCT Post Sleeve	1
6	Shelf Angle Bracket	1
7	DAT Terminal Rail	1
8	W-beam End Section	1
9	Anchor Cable Assembly	1
10	Guardrail Anchor Bracket	1
11	Bolt, 5/8 x 2" hex	8
12	Bolt, 5/8 x 8" hex	4
13	Bolt, 5/8 x 10" hex	2
14	Washer, 5/8 F844	16
15	10" Guardrail Bolt	2
16	1-1/4" Guardrail Bolt	4
17	Recessed Guardrail Nut	20



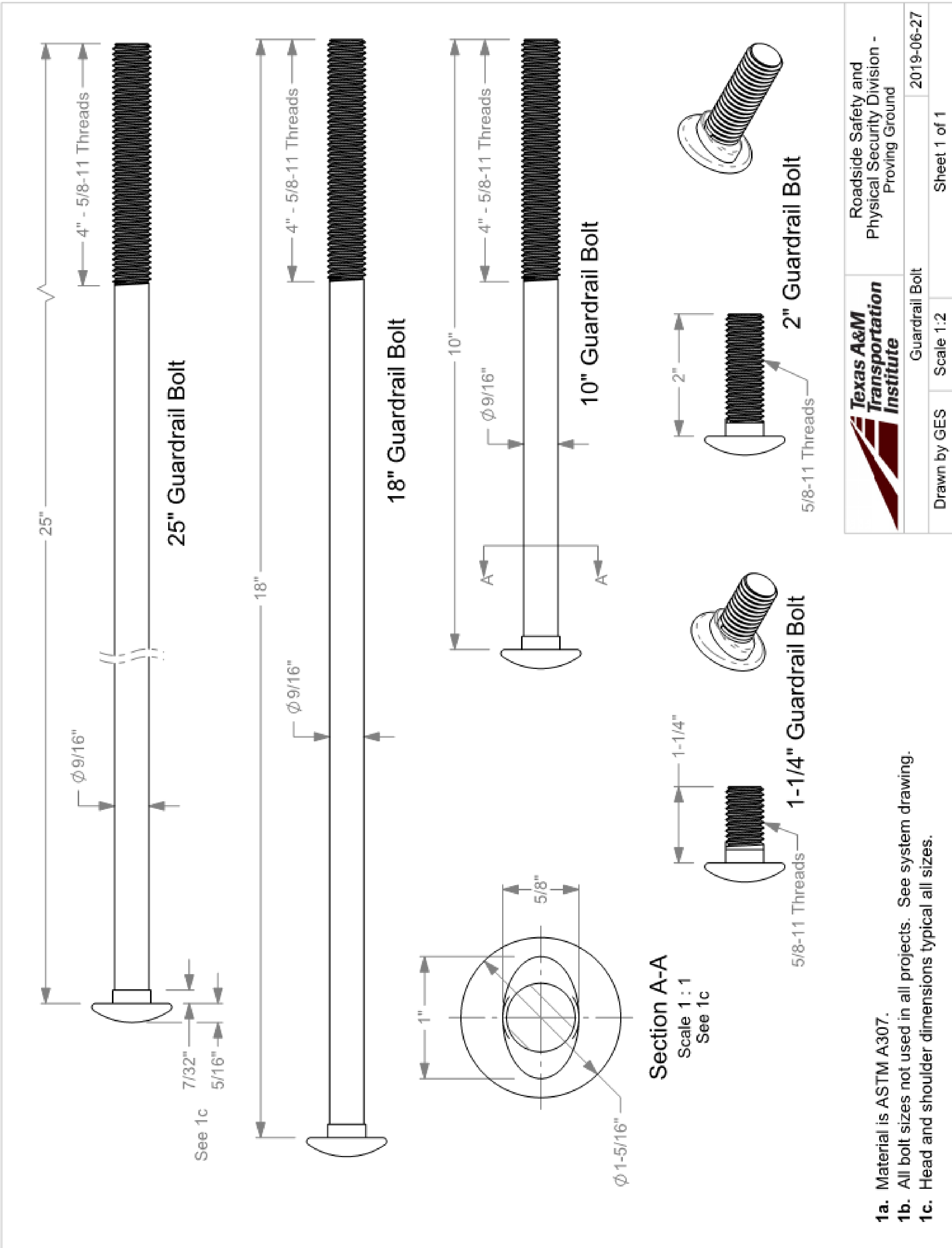
1a. All bolts are ASTM A307.
1b. Hardware secures Shelf Angle Bracket to Post. Rail is supported by Shelf Angle Bracket and does not attach directly to Post.

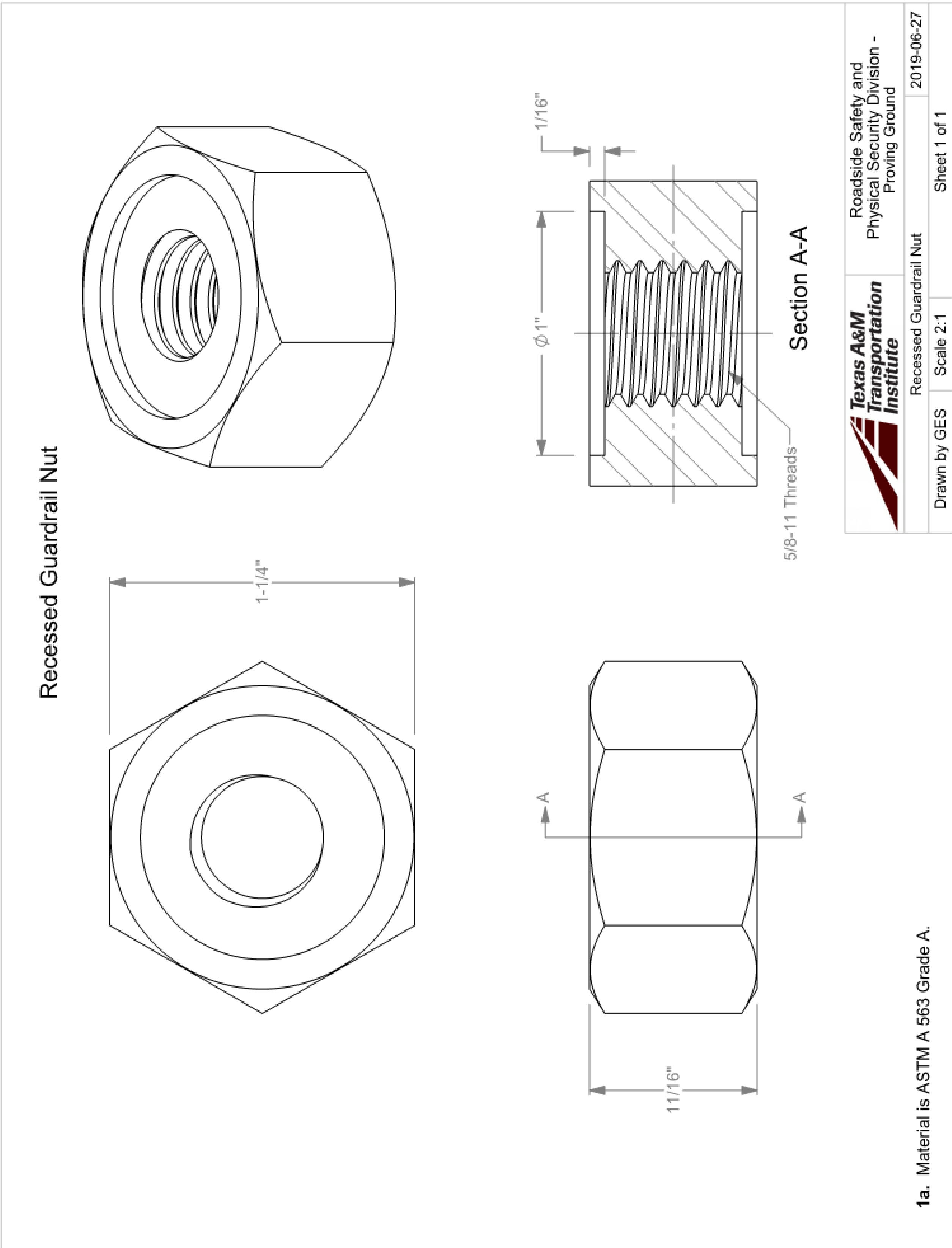
Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
DAT (Downstream Anchor Terminal)		2019-07-26
Drawn by GES	Scale 1:25	Sheet 1 of 3

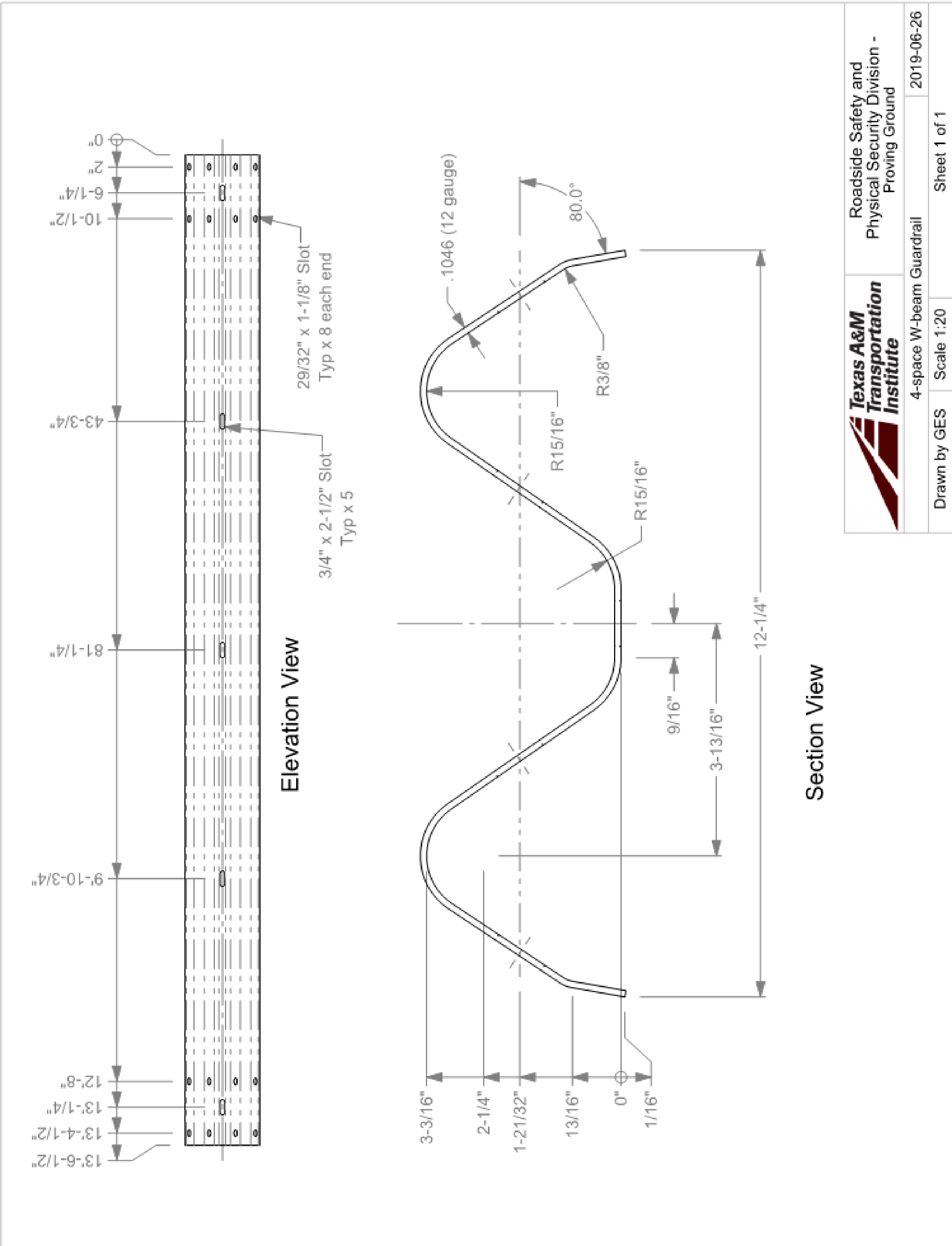

DAT Parts sheet 1
DAT Strut
C 3 x 5
Slot, 3/4" x 2"
Typ x 2
0"
2-1/2"
77-1/2"
80"
BCT Bearing Plate
5/8" Plate - Scale 1:10
8"
5"
BCT Post Sleeve
2" schedule 40 Pipe - Scale 1:10
5-1/2"
Guardrail Anchor Bracket
Scale 1:5
1-3/4"
Ø1"
1-3/8"
6"
3/8"
2-3/4"
5-1/2"
Plate, 3" x 2 3/4" x 3/8"
1/4
3 sides
3/16" Plate
Ø3/4" Holes
2"
6"
10"
14"
16"
Terminal Timber Post
5-1/4" x 7-1/4"
Ø2-1/2"
Ø7/8" Typ x 2
7"
28-1/2"
31-1/2"
46"
Foundation Tube
HSS 8" x 6" x 1/8"
Ø7/8" Typ x 3
1"
17"
72"
Shelf Angle Bracket
Scale 1:10
1/4"
7-1/2"
1-3/8"
Slot, 3/4" x 1"
1-1/2"
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
2019-07-26
DAT (Downstream Anchor Terminal)
Sheet 2 of 3
Drawn by GES
Scale 1:20

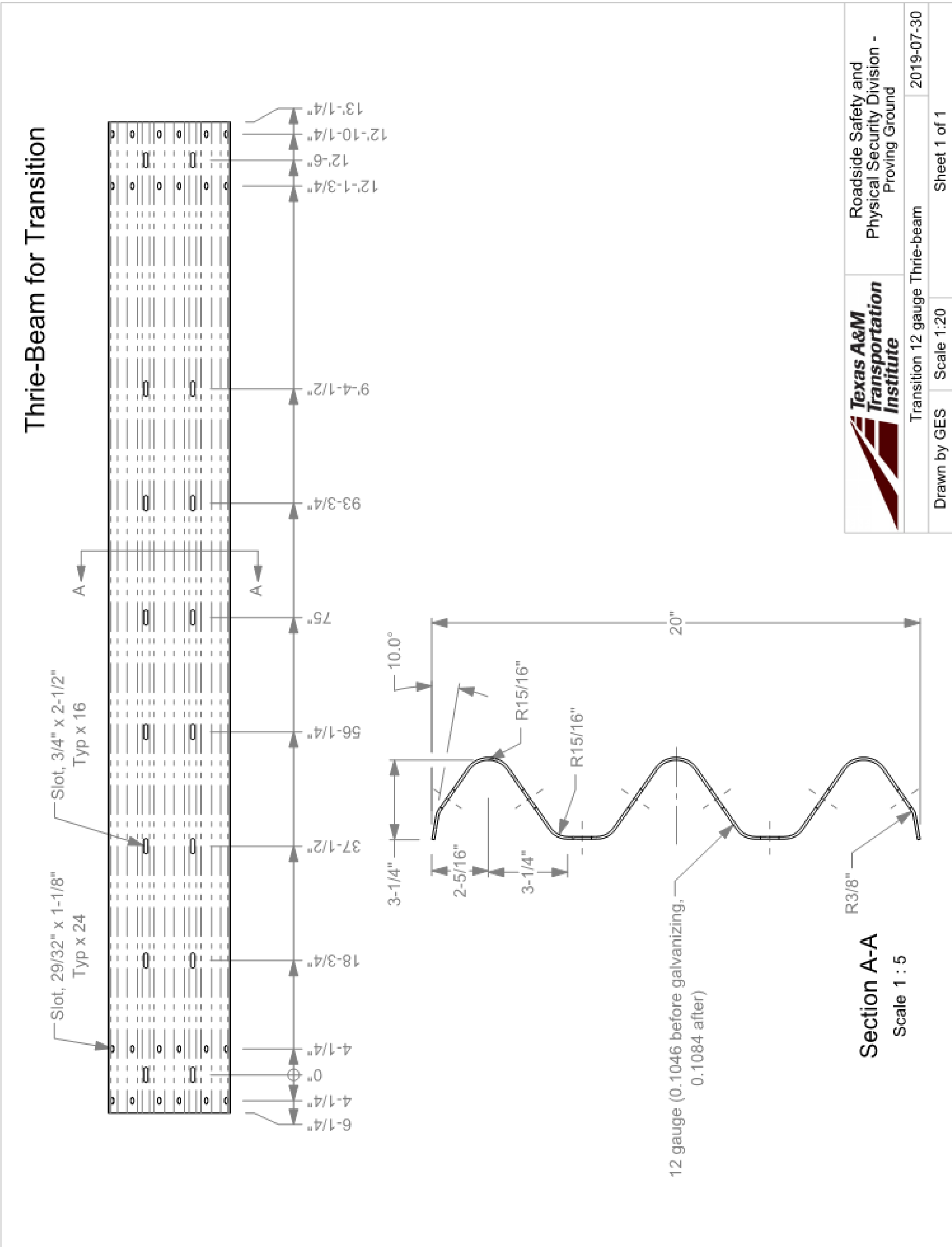


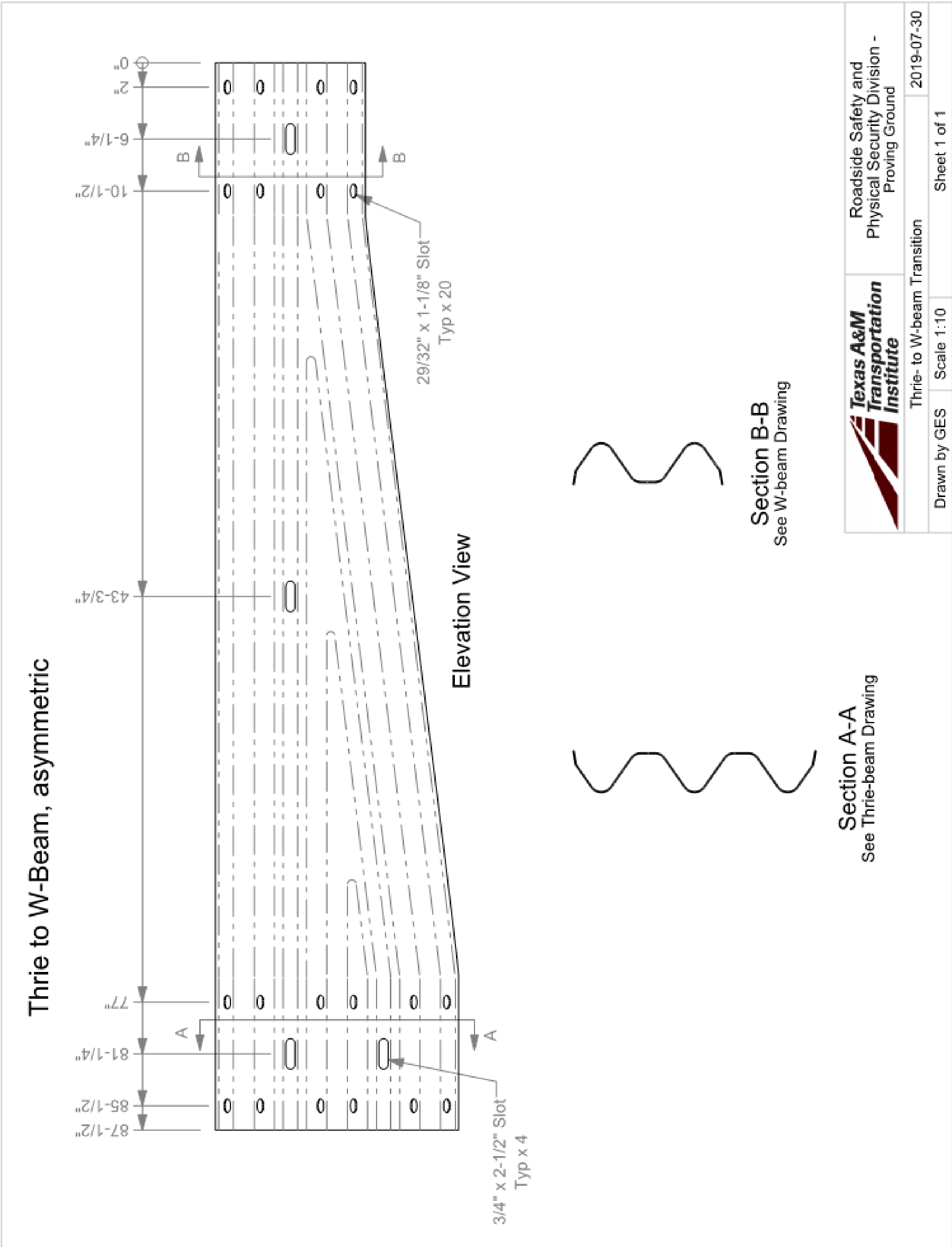
DAT Parts sheet 2
Anchor Cable Assembly
Nut, 1" A563 heavy hex
Washer, 1" F844
Standard Swedge Fitting and Stud
1" -8 threads
3/4" 6x19 Cable
Ø 1-5/8"
Ø 1-1/4"
0"
7"
10"
15"
78"
DAT Terminal Rail
Scale 1:20 - See 4-space W-beam
Guardrail drawing for cross-section
and other dimensions.
29/32" x 1-1/8" Slots
6-1/4"
10'-5"
49"
53"
57"
61"
75"
9'-4-1/2"
W-beam End Section
12 gauge steel - Scale 1:20
1" x 1-3/16" Slots
30.0°
2"
10-1/2"
R6-1/4"
16"
Texas A&M Transportation Institute
Roadside Safety and
Physical Security Division -
Proving Ground
DAT (Downstream Anchor Terminal)
2019-07-26
Drawn by GES
Scale 1:10
Sheet 3 of 3

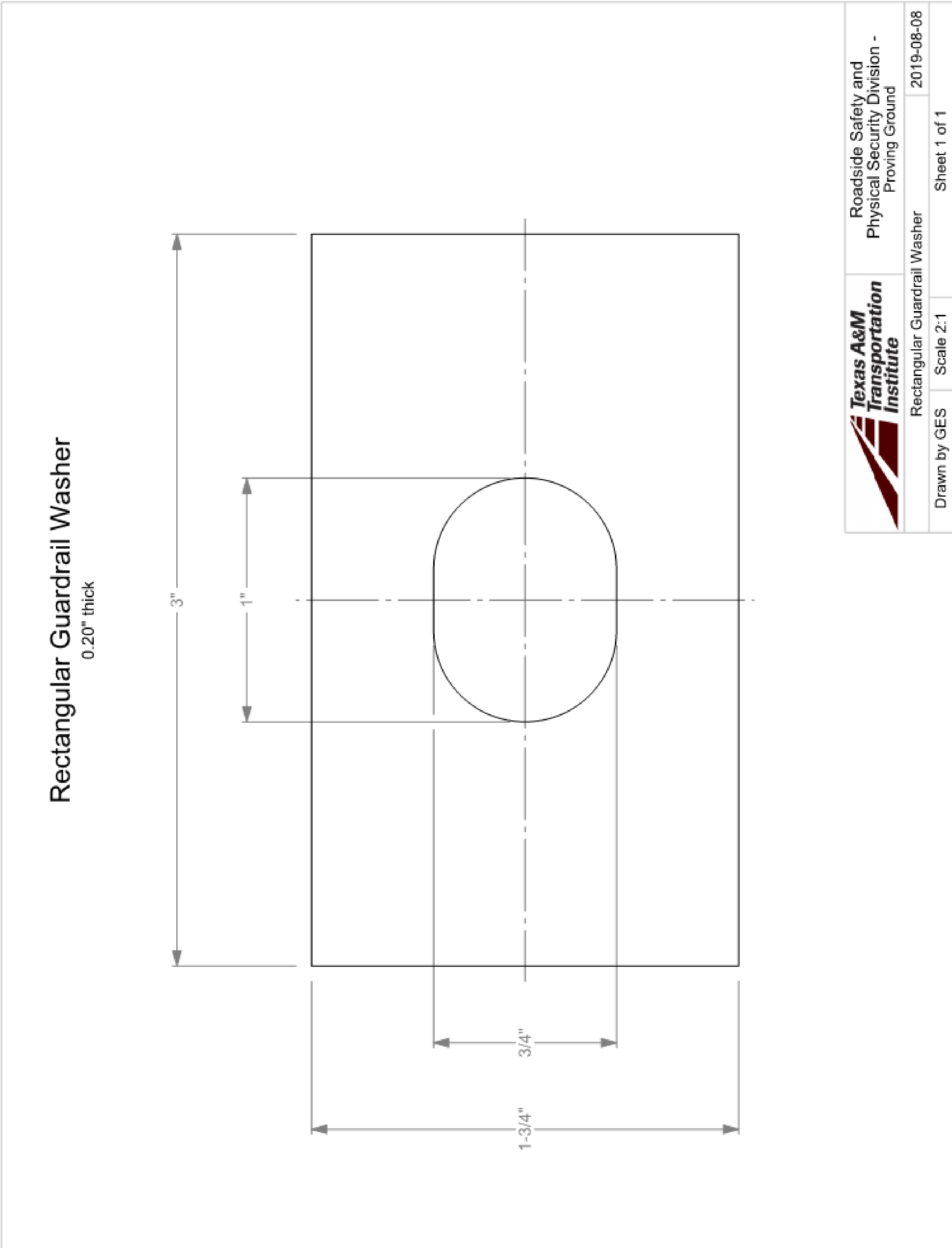

25" Guardrail Bolt
25"
4" - 5/8-11 Threads
Ø9/16"
7/32"
5/16"
See 1c
18" Guardrail Bolt
18"
4" - 5/8-11 Threads
Ø9/16"
10" Guardrail Bolt
10"
4" - 5/8-11 Threads
Ø9/16"
A
A
Section A-A
Scale 1 : 1
See 1c
5/8"
1"
Ø1-5/16"
2" Guardrail Bolt
2"
5/8-11 Threads
1-1/4" Guardrail Bolt
1-1/4"
5/8-11 Threads
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Guardrail Bolt
2019-06-27
Drawn by GES
Scale 1:2
Sheet 1 of 1
1a. Material is ASTM A307.
1b. All bolt sizes not used in all projects. See system drawing.
1c. Head and shoulder dimensions typical all sizes.


Recessed Guardrail Nut
1-1/4"
A
A
11/16"
1/16"
Ø1"
Section A-A
5/8-11 Threads
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Recessed Guardrail Nut
2019-06-27
Drawn by GES
Scale 2:1
Sheet 1 of 1
1a. Material is ASTM A 563 Grade A.


0"
2"
6-1/4"
10-1/2"
43-3/4"
81-1/4"
9'-10-3/4"
12'-8"
13'-1/4"
13'-4-1/2"
13'-6-1/2"
29/32" x 1-1/8" Slot
Typ x 8 each end
3/4" x 2-1/2" Slot
Typ x 5
Elevation View
.1046 (12 gauge)
80.0°
R3/8"
R15/16"
R15/16"
9/16"
3-13/16"
12-1/4"
Section View
3-3/16"
2-1/4"
1-21/32"
13/16"
0"
1/16"
Roadside Safety and
Physical Security Division -
Proving Ground
Texas A&M Transportation Institute
4-space W-beam Guardrail
2019-06-26
Drawn by GES
Scale 1:20
Sheet 1 of 1


Thrie-Beam for Transition
Slot, 29/32" x 1-1/8"
Typ x 24
Slot, 3/4" x 2-1/2"
Typ x 16
A
A
6-1/4"
4-1/4"
0"
4-1/4"
18-3/4"
37-1/2"
56-1/4"
75"
93-3/4"
9'-4-1/2"
12'-1-3/4"
12'-6"
12'-10-1/4"
13'-1/4"
10.0°
20"
R15/16"
R15/16"
3-1/4"
2-5/16"
3-1/4"
12 gauge (0.1046 before galvanizing,
0.1084 after)
R3/8"
Section A-A
Scale 1 : 5
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Transition 12 gauge Thrie-beam
2019-07-30
Drawn by GES
Scale 1:20
Sheet 1 of 1


Thrie to W-Beam, asymmetric
0"
2"
6-1/4"
10-1/2"
43-3/4"
77"
81-1/4"
85-1/2"
87-1/2"
B
B
A
A
29/32" x 1-1/8" Slot
Typ x 20
3/4" x 2-1/2" Slot
Typ x 4
Elevation View
Section B-B
See W-beam Drawing
Section A-A
See Thrie-beam Drawing
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
2019-07-30
Thrie- to W-beam Transition
Drawn by GES
Scale 1:10
Sheet 1 of 1


Rectangular Guardrail Washer
0.20" thick
3"
1"
3/4"
1-3/4"
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Rectangular Guardrail Washer
2019-08-08
Drawn by GES
Scale 2:1
Sheet 1 of 1

E.2. 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	QF 7.3-01 Concrete Sampling	Doc. No. QF 7.3-01	Issue Date: 2018-06-18
Quality Form	Prepared by: Wanda L. Menges Approved by: Darrell L. Kuhn	Revision: 6	Page: 1 of 1

The information contained in this document is confidential to TTI Proving Ground.

Project No: 469469-5 Casting Date: 2019-05-24 Mix Design (psi): 3500 psi

Name of Technician Taking Sample: Bill Griffith

Name of Technician Breaking Sample: Bill Griffith

Signature of Technician Taking Sample:

Signature of Technician Breaking Sample:

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	7130	5419755	100% of Slab

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
T1	2019-08-08	76 days	116000	4103	
			115000	4067	4091
			116000	4103	

TICKET NO.

CUSTOMER'S COPY

Martin Marietta

1503 LBJ Freeway
Suite 400
Dallas, Tx 75234

5419755

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
12:48	1:00	1:27	:	:	:	:

WATER ADDED ON JOB AT CUSTOMER'S REQUEST ________ GAL.
ALLOWABLE WATER (withheld from batch) 6.1 GAL.
TEST CYLINDER TAKEN ❑ YES ❑ NO BY ________
CYLINDER TAKEN ❑ BEFORE ❑ AFTER WATER

ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH. ANY WATER ADDED IN EXCESS OF SPECIFIED SLUMP IS AT CUSTOMER'S RISK.

CUSTOMER SIGNATURE
X

DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS AN CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED I SIGNATURE ABOVE.

CUSTOMER NAME AND DELIVERY ADDRESS
TEXAS A & M UNIVERSI
TTI-Riverside Campus

PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT	GRID
617	7130	2031	5.0	469469-3	

DRIVER NAME	DATE
Billy Lomuscio	5/24/19

CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY
783659	79546	3.00	3.00

LOAD QUANTITY	PRODUCT CODE		DESCRIPTION	UNIT PRICE	AMOUNT
3.00	CYDS	M9Z35617	COM, RG, Z, 3500, RE		
1.00	ea	12987	FREIGHT CHARGE		

465469-5

SPECIAL DELIVERY INSTRUCTIONS
2818-RT ON LEONARD RT ON HWY-47-LFT INTO RIVERSIDE
CAMPUS WILL MEET AT GATE

SALES TAX

TOTAL

DANGER! MAY CAUSE ALKALI BURNS.
SEE WARNINGS ON REVERSE SIDE.

FOR OFFICE USE ONLY **FORM:** 2662620

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
7130	943616	user	5419755	76224	12:48	5/24/19

Load Size	Mix Code	Returned	Qty	Mix Age	Seq	Load ID
3.00 CYDS	M9Z35617				D	77247

Material	Design Qty	Required	Batched	% Var	% Moisture	Actual Wat
1"RG	1316 lb	3964 lb	4040 lb	1.92%	0.40% M	2 gl
3/8"PG	504 lb	1515 lb	1560 lb	2.97%	0.20% M	gl
SAND-1	1447 lb	4475 lb	4480 lb	0.11%	3.00% M	16 gl
CMT-I/II	364 lb	1092 lb	1110 lb	1.65%		
FLYASH-C	121 lb	363 lb	350 lb	-3.58%		
H2O	250 lb	505 lb	504 lb	-0.21%		60 gl
ZY-610	15 oz	44 oz	43 oz	-1.56%		
ADVA190	9 oz	27 oz	28 oz	2.56%		

Actual Num Batches: 1
Load Total: 12048 lb Design 0.516 Water/Cement 0.514 T Design 89.1 gl Actual 78.8 gl To Add: 6.1 g
Slump: 5.00 in # Water in Truck: 5.0 gl Adjust Water: 0.0 gl / Load Trim Water: -2.0 gl/ CYD

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	QF 7.3-01 Concrete Sampling	Doc. No. QF 7.3-01	Issue Date: 2018-06-18
Quality Form	Prepared by: Wanda L. Menges Approved by: Darrell L. Kuhn	Revision: 6	Page: 1 of 1

The information contained in this document is confidential to TTI Proving Ground.

Project No: 469469-5 Casting Date: 2019-05-29 Mix Design (psi): ~~4000~~ 4500

Name of Technician Taking Sample: B. Griffith

Name of Technician Breaking Sample:

Signature of Technician Taking Sample:

Signature of Technician Breaking Sample:

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	5019	5425678	100% of Curb

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average
T1	2019-08-08	7 days	163000	5765	|
|	|	|	157000	5553	5601
|	|	|	155000	5487	|

CUSTOMER'S COPY

TICKET NO.

Martin Marietta

1503 LBJ Freeway
Suite 400
Dallas, Tx 75234

5425678

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
7:57	8 : 10	8 : 30	:	:	:	:

WATER ADDED ON JOB AT CUSTOMER'S REQUEST ________ GAL.
ALLOWABLE WATER (withheld from batch) ________ GAL.
TEST CYLINDER TAKEN ☐ YES ☐ NO BY ________
CYLINDER TAKEN ☐ BEFORE ☐ AFTER WATER

ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH. ANY WATER ADDED IN EXCESS OF SPECIFIED SLUMP IS AT CUSTOMER'S RISK.

CUSTOMER SIGNATURE
X

DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS AND CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED BY SIGNATURE ABOVE.

CUSTOMER NAME AND DELIVERY ADDRESS
TEXAS A & M UNIVERSI
TTI-Riverside Campus

PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT	GRID
617	9019	2034	4.0	469469	

DRIVER NAME	DATE
WATTS, RODNEY	5/29/19

CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY
783659	79546	3.00	3.00

LOAD QUANTITY	PRODUCT CODE		DESCRIPTION	UNIT PRICE	AMOUNT
3.00	CYDS	R9Z50636	COM,RG,Z,4500,RE		
1.00	ea	12987	FREIGHT CHARGE		

469469-5

SPECIAL DELIVERY INSTRUCTIONS
2818-RT ON LEONARD RT ON HWY-47-LFT INTO RELLIS CAMPUS GO AROUNDTHE ROUND ABOUT AND THEY WILL MEET AT GATE

SALES TAX

TOTAL

DANGER! MAY CAUSE ALKALI BURNS.
SEE WARNINGS ON REVERSE SIDE.

FOR OFFICE USE ONLY **FORM:** 2662731

Truck	Driver	User	Disp Ticket Num	Ticket ID	Time	Date
9019	726255	user	5425678	76335	7:57	5/29/19

Load Size	Mix Code	Returned Qty	Mix Age	Seq	Load ID
3.00 CYDS	R9Z50636			D	77358

Material	Design Qty	Required	Batched	% Var	% Moisture	Actual Wat
1"RG	1355 lb	4081 lb	4080 lb	-0.03%	0.40% M	2 gl
3/8"PG	510 lb	1533 lb	1520 lb	* -0.85%	0.20% M	gl
SAND-1	1298 lb	4014 lb	4040 lb	0.64%	3.00% M	15 gl
CMT-I/II	435 lb	1305 lb	1320 lb	1.15%		
FLYASH-C	145 lb	435 lb	430 lb	* -1.15%		
H20	258 lb	567 lb	564 lb	-0.46%		68 gl
ZY-610	17 oz	52 oz	52 oz	-0.38%		

Actual Num Batches: 1
Load Total: 11957 lb Design 0.445 Water/Cement 0.442 T Design 92.8 gl Actual 84.4 gl To Add: 5.3 gl
Slump: 4.00 in Water in Truck: 3.0 gl Adjust Water: 0.0 gl / Load Trim Water: -1.7 gl/ CYD

This Memorandum is an acknowledgement that a Bill of Lading has been issued and is not the original Bill of Lading, nor a copy or duplicate, covering the property named herein, and is intended solely for filing or record.

Carrier

RECEIVED, subject to the classifications and tariffs in effect on the date of receipt by the carrier of the property described in the Original Bill of Lading,
at Ft Worth (THP), TX 5-13 20, 19 from Trinity Highway Products,LLC

the property described below, in apparent good order, except as noted (contents and condition of contents of packages unknown) marked, consigned and destined as shown below, which said company (the word company 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 own railroad, water line, highway route or routes, or within the territory of its highway operations, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed, as to each carrier of all or any of 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 conditions not prohibited by law, whether printed or written, herein contained, including the conditions on back hereof, which are hereby agreed to by the shipper and accepted for himself and his assigns.

Shipper's No. 16-76113

S/O No. 1309727

Consigned to: SAMPLES, TESTING MATERIALS Cust. P.O. 469469-5 - TXDOT Load No.: 3-2

Destination: 3100 STATE HWY 47
BLDG 7090

Total Weight: 2,984.97

City: BRYAN State: TX Zip: 77807

Ship: 5/13/2019 1:13:52PM

Arrive: 5/13/19 5:00:00PM TRL#

Contact: GERY GERKE Phone: 936-825-4661

Delivering Carrier: BLAIR Vehicle or Car Initial: 561310 TRK# 1153 No. 1153C

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.

TRINITY HIGHWAY PRODUCTS, LLC
Per Trinity Highway Products,LLC
(Signature of Consignor)

If charges are to be prepaid, write or stamp here, "To be Prepaid."
TO BE PREPAID

Received $ ______ to apply in prepayment of the charges on the property described hereon.

Agent or Cashier

Per
(The signature here acknowledges only the amount prepaid.)
Charges advanced:

Collect On Delivery:
$ ______ **and remit to:** ______
Street ______ **City** ______ **State** ______

C.O.D. charge to be paid by Shipper ☐ Consignee ☐

No. Pkgs.	Piece Count	Description of Articles	*Wt.	Class or Rate	✓ Col.
		Upon delivery, all materials subject to Trinity Highway Products,LLC Storage Stain Policy No QMS-LG-002.			
		Project Info: TXDOT PROJECT #469469-5			
		LD Comments:			
	4	11G 12/12'6/3'1.5/S			
	11	533G 6'0 POST/8.5/DDR			
	2	724G 6'0 TUBE SL/.125X8X6			
	1	850G 12/BUFFER/ROLLED			
	1	980G T10/END SHOE/SLANT 1"HO			
	1	3000G CBL 3/4X6'6/DBL SWG/NOHWD			
	18	3300G WASHER,FLAT,5/8 R,TY B,G			
	12	3320G 3/16"X1.75"X3" WASHER			
	329	3340G 5/8" GR HEX NUT			
	280	3360G 5/8"X1.25" GR BOLT			
	24	3400G 5/8"X2" GR BOLT			
	125	3500G 5/8"X10" GR BOLT A307			
	10	3725G 7/8" WASHER F844 TYPE A/N			
	5	3742G 7/8" HVY HEX NUT A563 DH			
	9	4076B WD BLK RTD 6X8X14			
	2	4140B WD 4'0.25 POST 5.5X7.5			
	10	6065B WD BLK RTD 6X8X21.75			
	1	6565B PLYMR BLK 4X8X14 W/HANGER			
	8	6767B PLYMR BLK 4X8X18 TX			
	0	6900G 7/8"X15.5" HXBLT A449 5"T			
		*BackOrdered:5			
	2	12227G T12/12'6/3'1.5:6@1'6.75/S			
	6	14784G 7'0 POST/8.5#3HI TX			
	1	14785G 6'0 POST/8.5#3HI TX			
	2	19481G C3X5#X6'-8" RUBRAIL			
	1	20207G 12/9'4.5/8-HOLE ANCH/S			
	1	32218G T10/TRAN/TB:WB/ASYM/RT			

No. Pkgs.	Piece Count	Description of Articles	*Wt.	Class or Rate	✓ Col.
	1	36120A DAT-31-TX-HDW-CAN			

469465-5

SPECIAL INSTRUCTIONS:

SHIPPER LOAD - CONSIGNEE UNLOAD

16-76113

Total Weight # 2,084 3

*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 "carrier's or shipper's weight."
NOTE - Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property.
The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding ______ per ______

ORIGIN
SHIPPER OR AGENT — I hereby authorize this shipment and make the declaration of values (if any) and agree to the contract terms and conditions hereof.
SIGN HERE Brian Rodriguez DATE 5-13-19
AGENT OR DRIVER — This shipment received subject to exceptions as noted and according to the terms and conditions hereof.
(SIGN HERE) DATE

DESTINATION
CONSIGNEE OR AGENT — Received the above described property in good condition except as noted on the back hereof and agree to the foregoing contract terms and conditions.
SIGN HERE DATE / / TIME A.M. P.M.
DRIVER D. VEGA 5-13-19 NO

Permanent post-office address of shipper.

TRI 609-BF (R 10/93) (This Bill of Lading is to be signed by the shipper CONSIGNEE/CUSTOMER COPY

Certified Analysis

Trinity Highway Products LLC
2548 N.E. 28th St.
Ft Worth (THP), TX 76111 Phn:(817) 665-1499
Customer: SAMPLES, TESTING MATERIALS
2525 STEMMONS FRWY

DALLAS, TX 75207
Project: TXDOT PROJECT #469469-5

Order Number: 1309727 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 469469-5 - TXDOT
BOL Number: 76113 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 5/13/19

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
4	11G	12/12'6/3'1.5/S			2	F11819													
			M-180	A	2	1191763	60,900	82,100	26.0	0.210	0.750	0.008	0.002	0.030	0.090	0.004	0.040	0.002	4
			M-180	A	2	1191764	53,000	80,800	20.0	0.220	0.810	0.009	0.002	0.030	0.100	0.004	0.050	0.003	4
			M-180	A	2	1191766	53,800	78,100	30.0	0.210	0.770	0.009	0.002	0.030	0.090	0.000	0.040	0.002	4
			M-180	A	2	1292230	62,600	84,100	22.0	0.220	0.760	0.007	0.002	0.020	0.090	0.000	0.040	0.002	4
			M-180	B	2	235485	58,920	78,610	25.6	0.190	0.730	0.010	0.005	0.010	0.110	0.000	0.060	0.001	4
11	533G	6'0 POST/8.5/DDR	A-36			55060347	60,200	76,500	27.5	0.130	0.860	0.014	0.017	0.190	0.310	0.009	0.140	0.001	4
2	724G	6'0 TUBE SL/.125X8X6	A-500			A92132	55,160	74,134	27.0	0.200	0.470	0.010	0.003	0.040	0.080	0.000	0.050	0.001	4
1	850G	12/BUFFER/ROLLED	M-180	A	2	31847970	48,400	62,300	35.0	0.060	0.450	0.015	0.001	0.030	0.090	0.001	0.070	0.002	4
1	980G	T10/END SHOE/SLANT	M-180	B	2	231842	47,330	60,030	36.4	0.050	0.470	0.013	0.004	0.010	0.130	0.000	0.080	0.000	4
1	3000G	CBL 3/4X6'6/DBL	HW			132915													
18	3300G	WASHER,FLAT,5/8 R,TY	HW			P38498 R70030-02													
12	3320G	3/16"X1.75"X3" WASHER	HW			11747860													
329	3340G	5/8" GR HEX NUT	HW			19-42-014													
280	3360G	5/8"X1.25" GR BOLT	HW			20190107811													
24	3400G	5/8"X2" GR BOLT	HW			1578687													
125	3500G	5/8"X10" GR BOLT A307	HW			31732-B													

Certified Analysis

Trinity Highway Products LLC
2548 N.E. 28th St.
Ft Worth (THP), TX 76111 Phn:(817) 665-1499
Customer: SAMPLES, TESTING MATERIALS
2525 STEMMONS FRWY

DALLAS, TX 75207
Project: TXDOT PROJECT #469469-5

Order Number: 1309727 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 469469-5 - TXDOT
BOL Number: 76113 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 5/13/19

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
10	3725G	7/8" WASHER F844 TYPE	HW			P38089 R68188-01													
5	3742G	7/8" HVY HEX NUT A563	HW			P38088													
9	4076B	WD BLK RTD 6X8X14	HW			174													
2	4140B	WD 4'0.25 POST 5.5X7.5	HW			197													
10	6065B	WD BLK RTD 6X8X21.75	HW			197													
1	6565B	PLYMR BLK 4X8X14	HW			34364													
8	6767B	PLYMR BLK 4X8X18 TX	HW			34798													
2	12227G	T12/12'6/3'1.5:6@1'6.75/S			2	F11519													
			M-180	A	2	1190826	61,600	81,800	26.0	0.200	0.770	0.008	0.001	0.030	0.080	0.001	0.040	0.002	4
			M-180	A	2	1190827	54,200	75,500	29.0	0.200	0.760	0.008	0.001	0.030	0.080	0.003	0.040	0.002	4
			M-180	B	2	235485	58,920	78,610	25.6	0.190	0.730	0.010	0.005	0.010	0.110	0.000	0.060	0.001	4
			M-180	A	2	237551	62,790	81,520	24.6	0.200	0.730	0.016	0.004	0.020	0.140	0.000	0.070	0.001	4
6	14784G	7'0 POST/8.5#/3HI TX	A-36			55060347	60,200	76,500	27.5	0.130	0.860	0.014	0.017	0.190	0.310	0.009	0.140	0.001	4
1	14785G	6'0 POST/8.5#/3HI TX	A-36			55060347	60,200	76,500	27.5	0.130	0.860	0.014	0.017	0.190	0.310	0.009	0.140	0.001	4
2	19481G	C3X5#X6'-8" RUBRAIL	A-36			3086788	56,100	76,200	31.0	0.170	0.650	0.014	0.033	0.210	0.360	0.015	0.090	0.000	4
1	20207G	12/9'4.5/8-HOLE ANCH/S	RHC		2	L14818													4
			M-180	A	2	232196	61,710	79,460	28.7	0.180	0.720	0.012	0.005	0.020	0.120	0.000	0.070	0.002	4
			M-180	A	2	233123	63,570	82,430	22.7	0.190	0.720	0.013	0.004	0.020	0.110	0.000	0.070	0.000	4

Certified Analysis

Trinity Highway Products LLC
2548 N.E. 28th St.
Ft Worth (THP), TX 76111 Phn:(817) 665-1499
Customer: SAMPLES, TESTING MATERIALS
2525 STEMMONS FRWY

DALLAS, TX 75207
Project: TXDOT PROJECT #469469-5

Order Number: 1309727 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 469469-5 - TXDOT
BOL Number: 76113 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 5/13/19

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
			M-180	A	2	233124	62,720	82,150	24.5	0.190	0.720	0.011	0.003	0.010	0.130	0.001	0.060	0.000	4
			M-180	A	2	233125	63,900	83,490	21.4	0.200	0.730	0.018	0.004	0.020	0.110	0.000	0.090	0.001	4
			M-180	A	2	A90778	65,800	86,800	20.7	0.210	0.680	0.012	0.003	0.030	0.120	0.000	0.060	0.001	4
			M-180	A	2	A90779	55,100	78,200	20.6	0.190	0.660	0.010	0.002	0.020	0.120	0.000	0.070	0.001	4
			M-180	A	2	C88581	59,000	79,100	16.3	0.210	0.690	0.009	0.002	0.030	0.110	0.000	0.060	0.001	4
			M-180	A	2	C88582	63,500	82,200	23.6	0.200	0.710	0.011	0.001	0.040	0.090	0.000	0.060	0.001	4
1	32218G	T10/TRAN/TB:WB/ASYM/R	M-180	B	2	9401003	66,300	75,700	27.0	0.070	0.750	0.013	0.008	0.010	0.060	0.001	0.040	0.001	4
1	36120A	DAT-31-TX-HDW-CAN	A-36			4174233	48,700	68,700	34.0	0.200	0.400	0.011	0.010	0.010	0.040	0.001	0.050	0.001	4
	36120A		A-500			A809937	61,500	67,000	31.0	0.060	0.330	0.011	0.003	0.020	0.090	0.003	0.050	0.001	4
	36120A		HW			P38498 R70030-02													
	36120A		HW			19-42-014													
	36120A		HW			20190107811													
	36120A		HW			848773-8													
	36120A		HW			31732-B													
	36120A		HW			P38729 R71181-01													
	36120A		HW			P38562 R70589-01													
	36120A		HW			31654													

Certified Analysis

Trinity Highway Products LLC
2548 N.E. 28th St.
Ft Worth (THP), TX 76111 Phn:(817) 665-1499
Customer: SAMPLES, TESTING MATERIALS
2525 STEMMONS FRWY

DALLAS, TX 75207
Project: TXDOT PROJECT #469469-5

Order Number: 1309727 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 469469-5 - TXDOT
BOL Number: 76113 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 5/13/19

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
	36120A		HW			31433													
	36120A		A-36			1058859	56,400	76,100	25.0	0.140	0.710	0.012	0.019	0.190	0.370	0.015	0.180	0.003	4
	36120A		A-36			83187C	51,500	75,000	31.0	0.200	1.000	0.014	0.003	0.013	0.040	0.003	0.060	0.000	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy QMS-LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT, 23 CFR 635.410.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.

ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

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

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

NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
WASHERS COMPLY WITH ASTM F-436 SPECIFICATION AND/OR F-844 AND ARE GALVANIZED IN ACCORDANCE WITH ASTM F-2329, UNLESS OTHERWISE STATED.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 46000 LB

State of Texas, County of Tarrant. Sworn and subscribed before me this 13rd day of May, 2019 .

Notary Public:
Commission Expires:

JOMARY LUGINSLAND
Notary Public, State of Texas
Comm. Expires 05-28-2023
Notary ID 128624666

Jomary Luginsland

Certified By: Trinity Highway Products, LLC
Luis Ortiz
Quality Assurance

4 of 4

This Memorandum is an acknowledgement that a Bill of Lading has been issued and is not the original Bill of Lading, nor a copy or duplicate, covering the property named herein, and is intended solely for filing or record.

Carrier

Shipper's No. 16-76299

S/O No. 1309727

RECEIVED, subject to the classifications and tariffs in effect on the date of receipt by the carrier of the property described in the Original Bill of Lading,
at Ft Worth (THP), TX 5-28 20, 19 from Trinity Highway Products,LLC

the property described below, in apparent good order, except as noted (contents and condition of contents of packages unknown) marked, consigned and destined as shown below, which said company (the word company 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 own railroad, water line, highway route or routes, or within the territory of its highway operations, otherwise to deliver to another carrier on the route to said destination. It is mutually agreed, as to each carrier of all or any of 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 conditions not prohibited by law, whether printed or written, herein contained, including the conditions on back hereof, which are hereby agreed to by the shipper and accepted for himself and his assigns.

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.
TRINITY HIGHWAY PRODUCTS, LLC

Per Trinity Highway Products, LLC (Signature of Consignor)

If charges are to be prepaid, write or stamp here, "To be Prepaid."
TO BE PREPAID

Received $
to apply in prepayment of the charges on the property described hereon.

Agent or Cashier

Per
(The signature here acknowledges only the amount prepaid.)
Charges advanced:

Consigned to: SAMPLES, TESTING MATERIALS Cust. P.O. 469469-5 - TXDOT Load No.: 44-1
Destination: 3100 STATE HWY 47
BLDG 7090
Total Weight: 13.90

Ship: 5/28/2019
City: BRYAN State: TX Zip: 77807
Arrive: 5/28/19 5:00:00PM

Contact: GERY GERKE Phone: 936-825-4661
562310

Delivering Carrier: FED-EX Ground Vehicle or Car Initial: No.

Collect On Delivery:
$ **and remit to:**
Street **City** **State**

C.O.D. charge to be paid by **Shipper** ☐ **Consignee** ☐

No. Pkgs.	Piece Count	Description of Articles	*Wt.	Class or Rate	✓ Col.
		Upon delivery, all materials subject to Trinity Highway Products, LLC Storage Stain Policy No. OMS-LG-002.			
		Project Info: TXDOT PROJECT #469469-5			
		LD Comments:			
	5	6900G 7/8"X15.5" HXBLT A449 5"T			
		1-BOX			
		469469-5			

SPECIAL INSTRUCTIONS:
SHIPPER LOAD - CONSIGNEE UNLOAD

16-76299

Total Weight
13.90

3

*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 "carrier's or shipper's weight."
NOTE - Where the rate is dependent on value, shippers are required to state specifically in writing the agreed or declared value of the property.
The agreed or declared value of the property is hereby specifically stated by the shipper to be not exceeding per

ORIGIN
SHIPPER OR AGENT — I hereby authorize this shipment and make the declaration of values (if any) and agree to the contract terms and conditions hereof.
SIGN HERE DATE 5-28-19
AGENT OR DRIVER — This shipment received subject to exceptions as noted and according to the terms and conditions hereof.
(SIGN HERE) DATE

DESTINATION
CONSIGNEE OR AGENT — Received the above described property in good condition except as noted on the back hereof and agree to the foregoing contract terms and conditions.
SIGN HERE DATE / / TIME A.M. P.M.
DRIVER NO

Permanent post-office address of shipper.
TRI 609-RF (R 10/93) (This Bill of Lading is to be signed by the shipper

CONSIGNEE/CUSTOMER COPY

Certified Analysis

Trinity Highway Products LLC
2548 N.E. 28th St.
Ft Worth (THP), TX 76111 Phn:(817) 665-1499
Customer: SAMPLES, TESTING MATERIALS
2525 STEMMONS FRWY

DALLAS, TX 75207
Project: TXDOT PROJECT #469469-5

Order Number: 1309727 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: 469469-5 - TXDOT
BOL Number: 76299 Ship Date:
Document #: 1
Shipped To: TX
Use State: TX

As of: 5/28/19

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
5	6900G	7/8"X15.5" HXBLT A449 5"T	FAST			31966													4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy QMS-LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT, 23 CFR 635.410.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36 UNLESS OTHERWISE STATED.

ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT", 23 CFR 635.410.
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 (US DOMESTIC SHIPMENTS)
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM A-123 & ISO 1461 (INTERNATIONAL SHIPMENTS)

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

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

NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
WASHERS COMPLY WITH ASTM F-436 SPECIFICATION AND/OR F-844 AND ARE GALVANIZED IN ACCORDANCE WITH ASTM F-2329, UNLESS OTHERWISE STATED.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 46000 LB

State of Texas, County of Tarrant. Sworn and subscribed before me this 28th day of May, 2019 .

Notary Public:
Commission Expires: /

JOMARY LUGINSLAND
Notary Public, State of Texas
Comm. Expires 05-28-2023
Notary ID 128624666

Jomary Luginsland

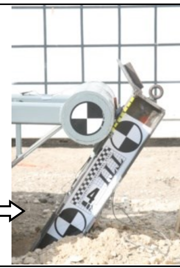
Certified By: Trinity Highway Products LLC
Quality Assurance

1 of 1

Table E.1. Summary of Strong Soil Test Results for Establishing Installation Procedure.

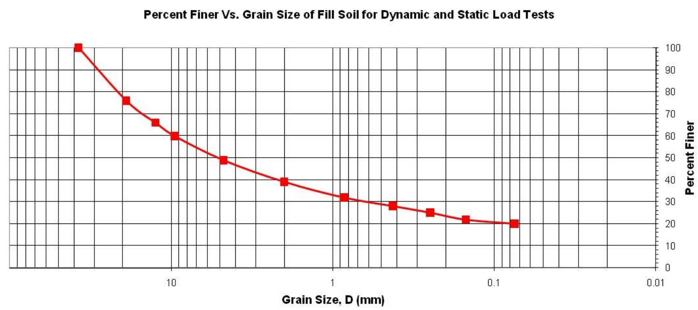
Dynamic Setup

Post-Test Photo of post

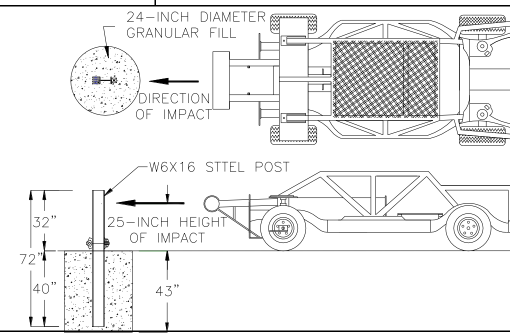


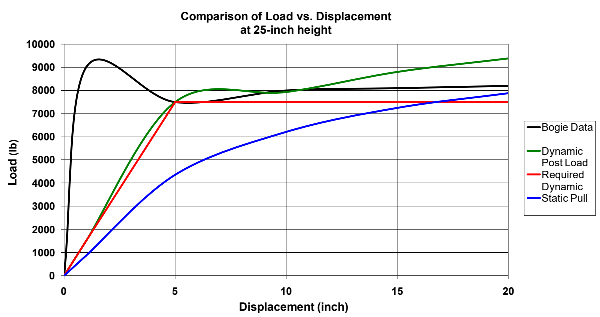
Post-Test Photo

Static Load Test

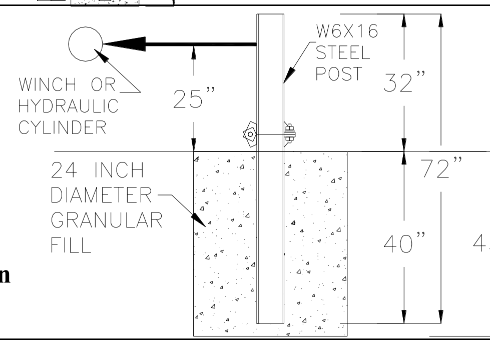


Dynamic Test Installation Details



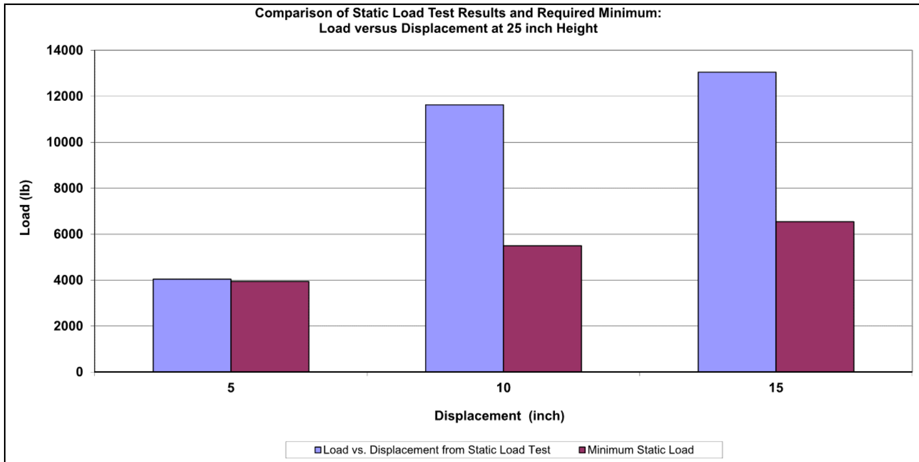


Static Load Test Installation Details

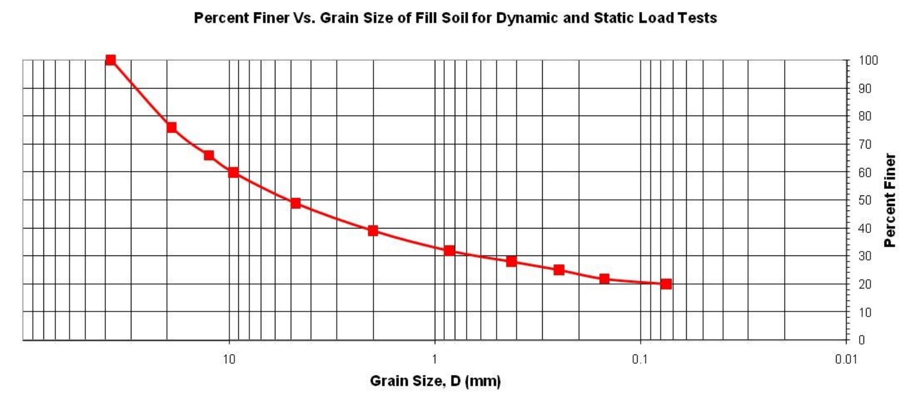


Date	2008-11-05
Test Facility and Site Location	TTI Proving Ground, 3100 SH 47, Bryan, TX 77807
In Situ Soil Description (ASTM D2487)	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis	AASHTO Grade B Soil-Aggregate (see sieve analysis above)
Description of Fill Placement Procedure	6-inch lifts tamped with a pneumatic compactor
Bogie Weight	5009 lb
Impact Velocity	20.5 mph

Table E.2. Test Day Static Soil Strength Documentation for Test No. 469468-10-1.



Static Load Setup



Post-Test Photo of Post

Date	2017-11-27
Test Facility and Site Location	TTI Proving Ground – 3100 SH 47, Bryan, Tx
In Situ Soil Description (ASTM D2487)	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis ..	AASHTO Grade B Soil-Aggregate (see sieve analysis)
Description of Fill Placement Procedure	6-inch lifts tamped with a pneumatic compactor

E.3. *MASH* TEST 3-21 (CRASH TEST NO. 469469-5)

E.3.1. Vehicle Properties and Information

Table E.3. Vehicle Properties for Test No. 469469-5.

Vehicle Inventory Number: 1427

Date: 2019-08-08 Test No.: 469469-5 VIN No.: 1C6RR6FT8DS655185

Year: 2013 Make: RAM Model: 1500

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

Tread Type: Highway Odometer: 172087

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

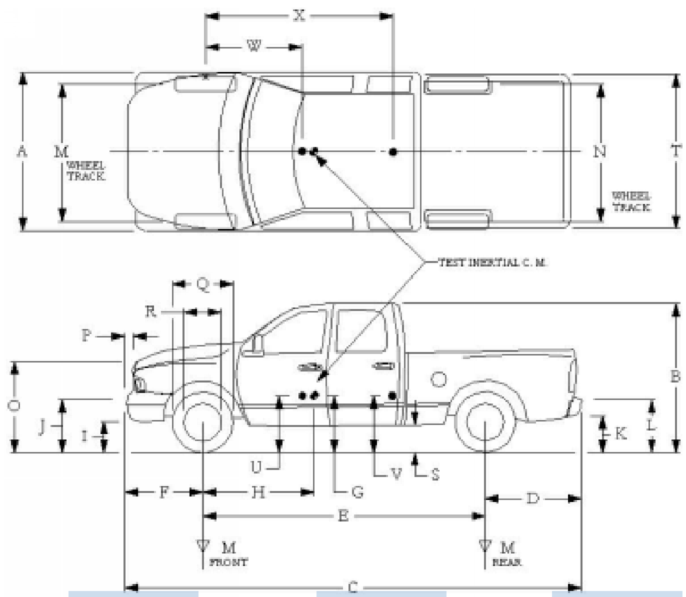
NOTES: None

Engine Type: V-8
Engine CID: 4.7 liter

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

Optional Equipment:
None

Dummy Data:
Type: NONE
Mass: 0 lb
Seat Position:



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	26.75
B	74.00	G	28.38	L	30.00	Q	30.50	V	30.25
C	227.50	H	60.46	M	68.50	R	18.00	W	60.40
D	44.00	I	11.75	N	68.00	S	13.00	X	79.00
E	140.50	J	27.00	O	46.00	T	77.00		

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

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

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2915	2870	
Back	3900	M_{rear}	2096	2168	
Total	6700	M_{Total}	5011	5038	0

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

Mass Distribution:
lb LF: 1437 RF: 1433 LR: 1117 RR: 1051

Performed by: SCD Date: 2019-08-08

Table E.4. Measurements of Vehicle Vertical CG for Test No. 469469-5.

Vehicle Inventory Number: 1427

Date:	2019-08-08	Test No.:	469469-5	VIN:	1C6RR6FT8DS655185
Year:	2013	Make:	RAM	Model:	1500
Body Style:	Quad Cab			Mileage:	172087
Engine:	4.7 liter V-8			Transmission:	Automatic
Fuel Level:	Empty	Ballast:	100		(440 lb max)
Tire Pressure: Front:	35 psi	Rear:	35 psi	Size:	265/70 R 17

Measured Vehicle Weights: (lb)

LF:	1437		RF:	1433		Front Axle:	2870
LR:	1117		RR:	1051		Rear Axle:	2168
Left:	2554		Right:	2484		Total:	5038
							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:	60.46	inches	Rear of Front Axle	(63 ±4 inches allowed)
Y:	-0.47	inches	Left - Right +	of Vehicle Centerline
Z:	28.38	inches	Above Ground	(minumum 28.0 inches allowed)

Hood Height:	46.00	inches	Front Bumper Height:	27.00	inches
	43 ±4 inches allowed				
Front Overhang:	40.00	inches	Rear Bumper Height:	30.00	inches
	39 ±3 inches allowed				
Overall Length:	227.50	inches			
	237 ±13 inches allowed				

Performed by: SCD Date: 2019-08-08

Table E.5. Exterior Crush Measurements of Vehicle for Test No. 469469-5.

Vehicle Inventory Number: 1427

Date: 2019-08-08 Test No.: 469469-5 VIN No.: 1C6RR6FT8DS655185

Year: 2013 Make: RAM Model: 1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable

End Damage	Side Damage
Undeformed end width ______	Bowing: B1 ______ X1 ______
Corner shift: A1 ______	B2 ______ X2 ______
A2 ______	
End shift at frame (CDC)	Bowing constant
(check one)	$\dfrac{X1 + X2}{2} =$ ______
< 4 inches ______	
≥ 4 inches ______	

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FT BUMPER	-	10	-	-	-	-	-	-	-	-
2	SAME	-	10	-	-	-	-	-	-	-	-
	Measurements recorded										
	☑ inches or ☐ mm										

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

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

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

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

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

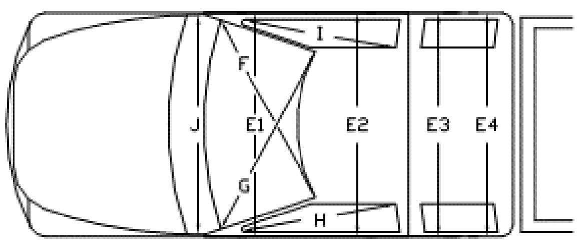
Note: Use as many lines/columns as necessary to describe each damage profile.

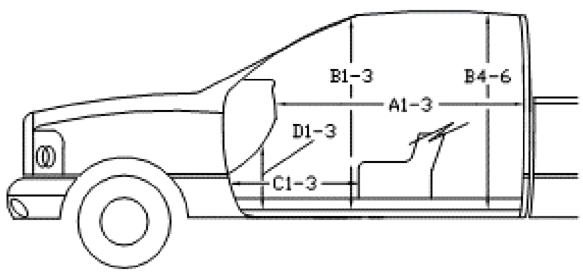
Performed by: SCD Date: 2019-08-08

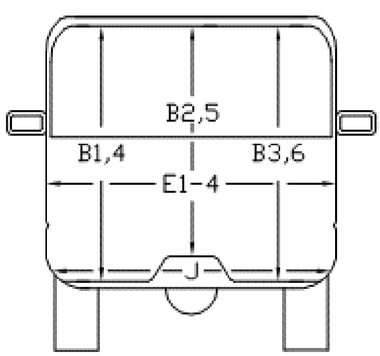
Table E.6. Occupant Compartment Measurements of Vehicle for Test No. 469469-5.

Vehicle Inventory Number: 1427

Date:	2019-08-08	Test No.:	469469-5	VIN No.:	1C6RR6FT8DS655185
Year:	2013	Make:	RAM	Model:	1500







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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	46.50	1.50
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	22.00	-4.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	12.50	1.00
E1	58.50	61.00	2.50
E2	63.50	65.50	2.00
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	21.50	-3.50

Performed by: SCD Date: 2019-08-08

E.3.2. Sequential Photographs

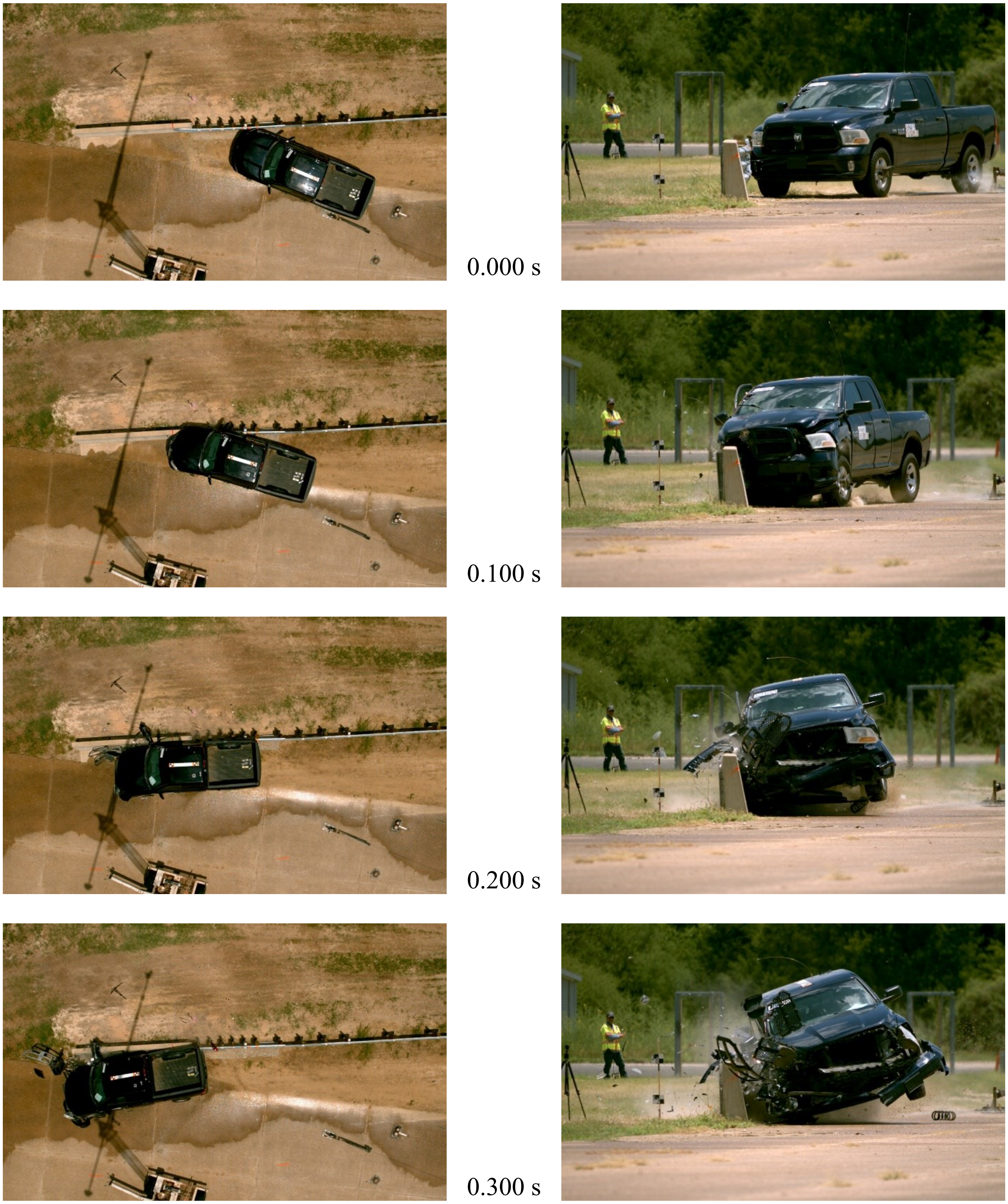


Figure E.1. Sequential Photographs for Test No. 469469-5 (Overhead and Gut Views).

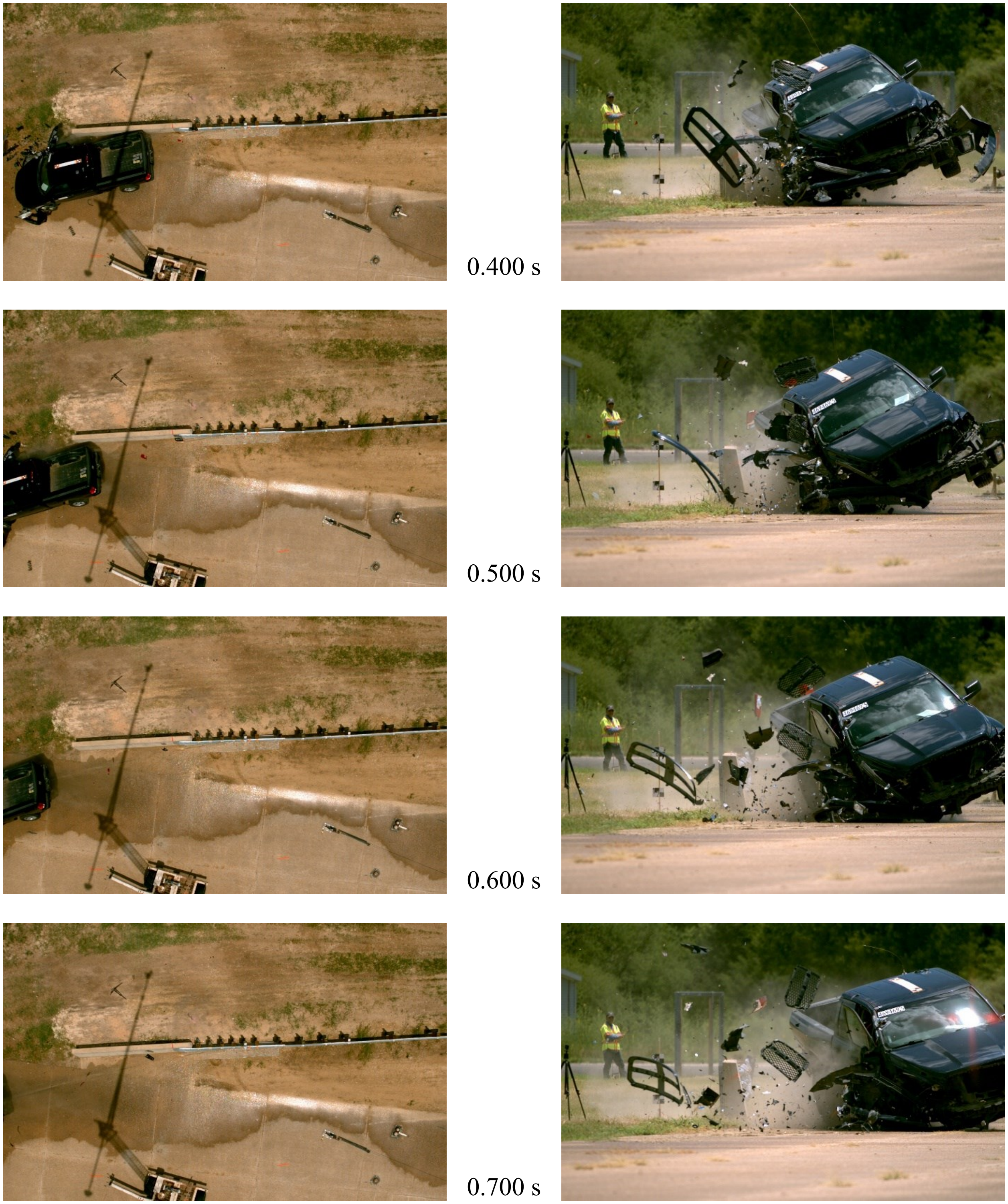


Figure A.1. Sequential Photographs for Test No. 469469-5 (Overhead and Gut Views) (Continued).


0.000 s


0.100 s


0.200 s


0.300 s


0.400 s

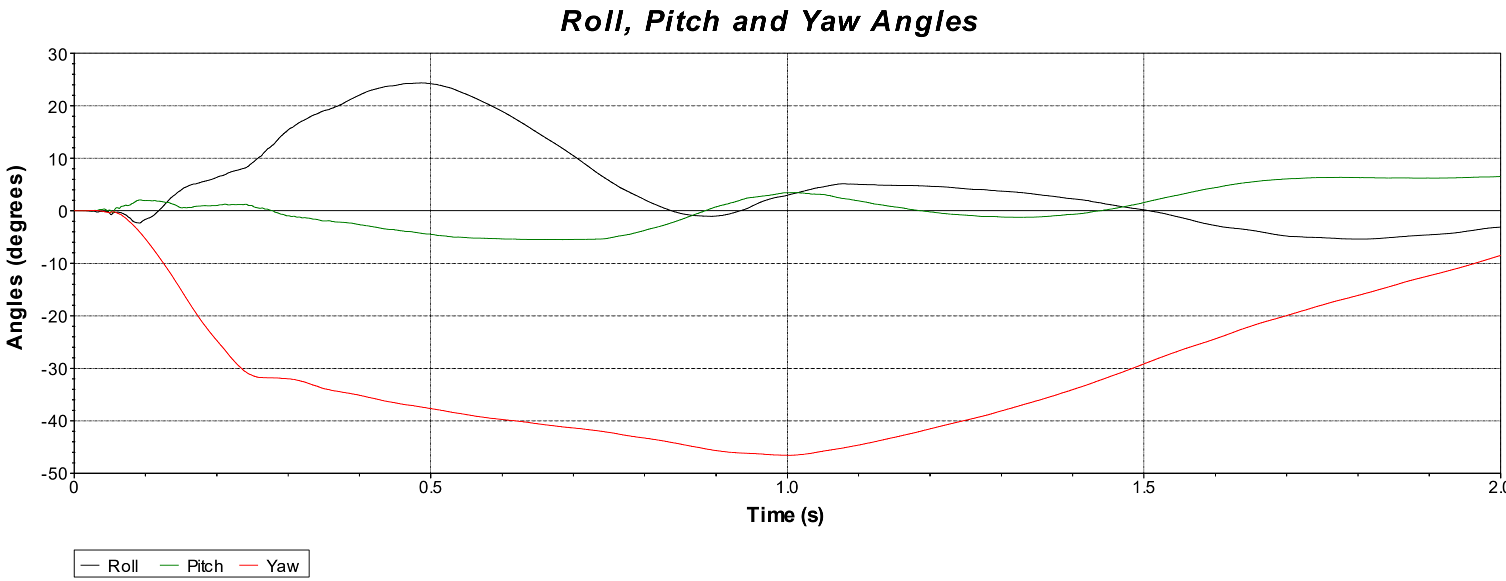

0.500 s


0.600 s


0.700 s

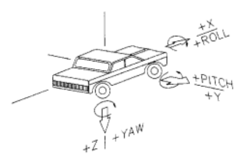
Figure E.2. Sequential Photographs for Test No. 469469-5 (Rear View).

E.3.3. Vehicle Angular Displacement



Axes are vehicle-fixed.
Sequence for determining orientation:

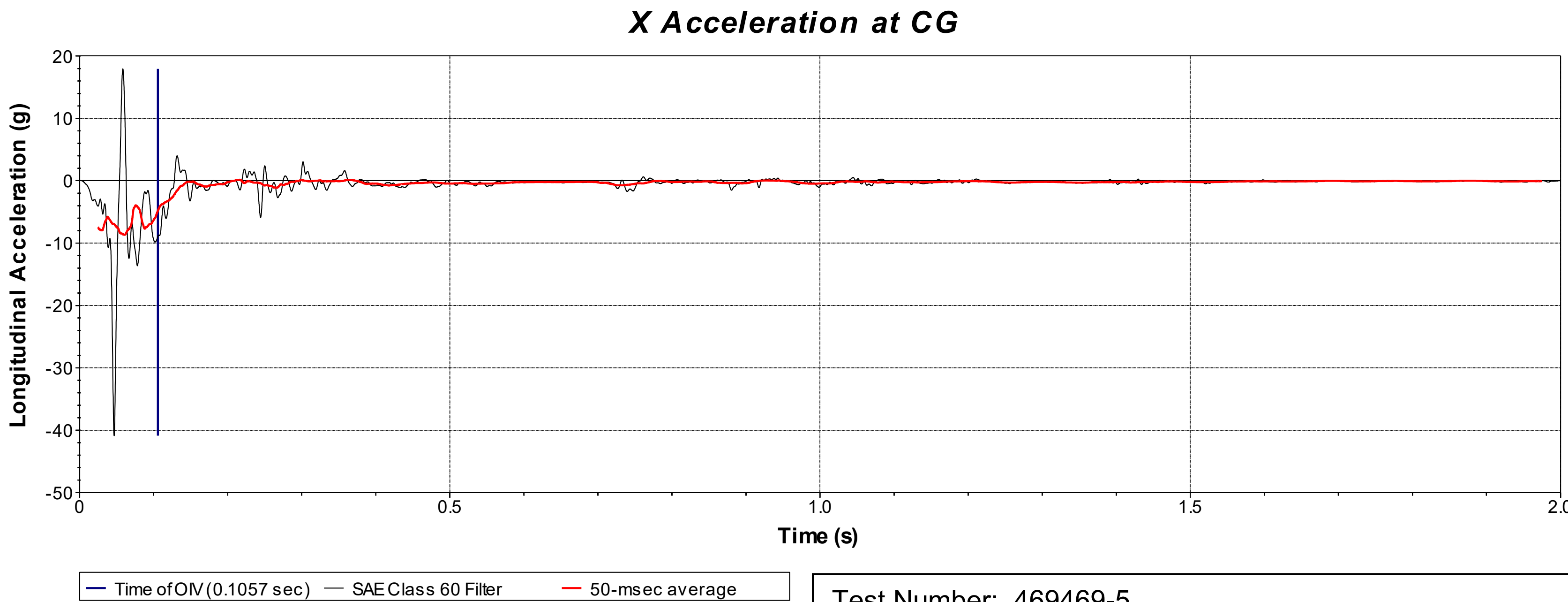
22. Yaw.
23. Pitch.
24. Roll.



Test Number: 469469-5
Test Standard: 3-21
Test Article: Thrie-Beam Transition without end shoe block
Test Vehicle: 2270P/ 2013 RAM 1500
Inertial Mass: 5038 lb
Gross Mass: 5038 lb
Impact Speed: 62.3 mi/h
Impact Angle: 25.1 degrees

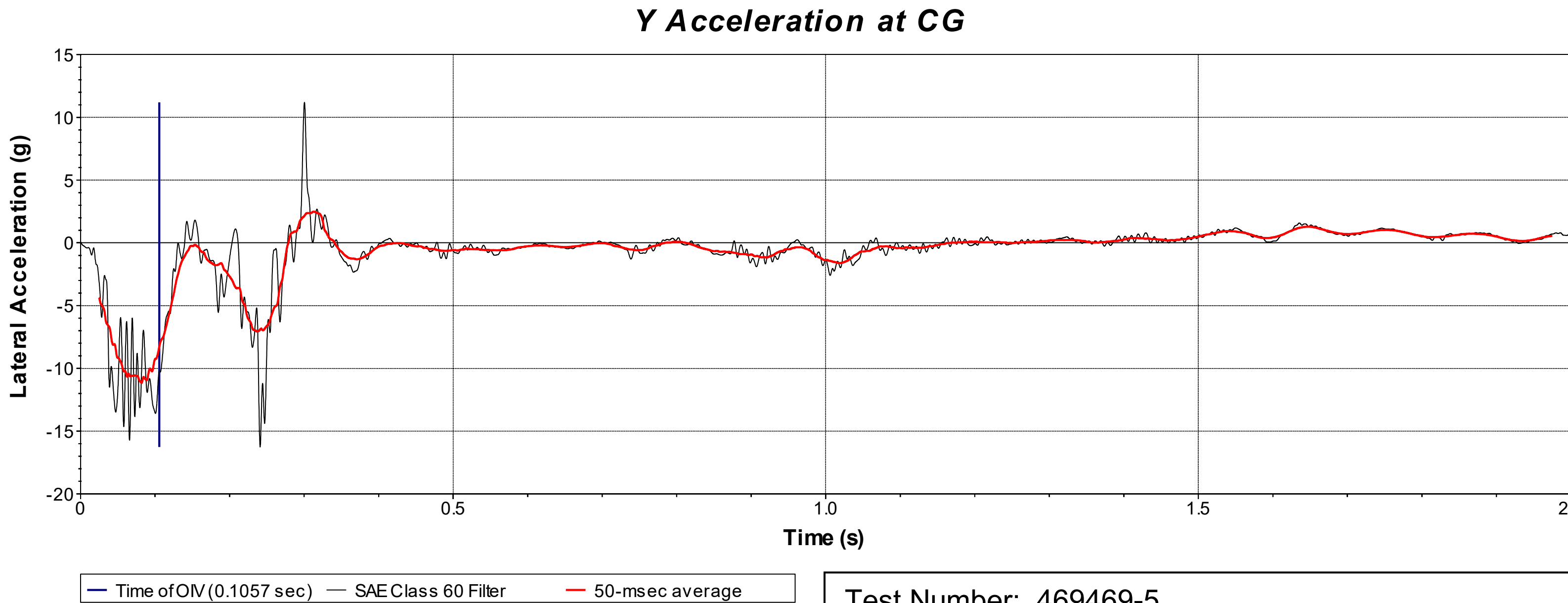
Figure E.3. Vehicle Angular Displacements for Test No. 469469-5.

E.3.4. Vehicle Acceleration



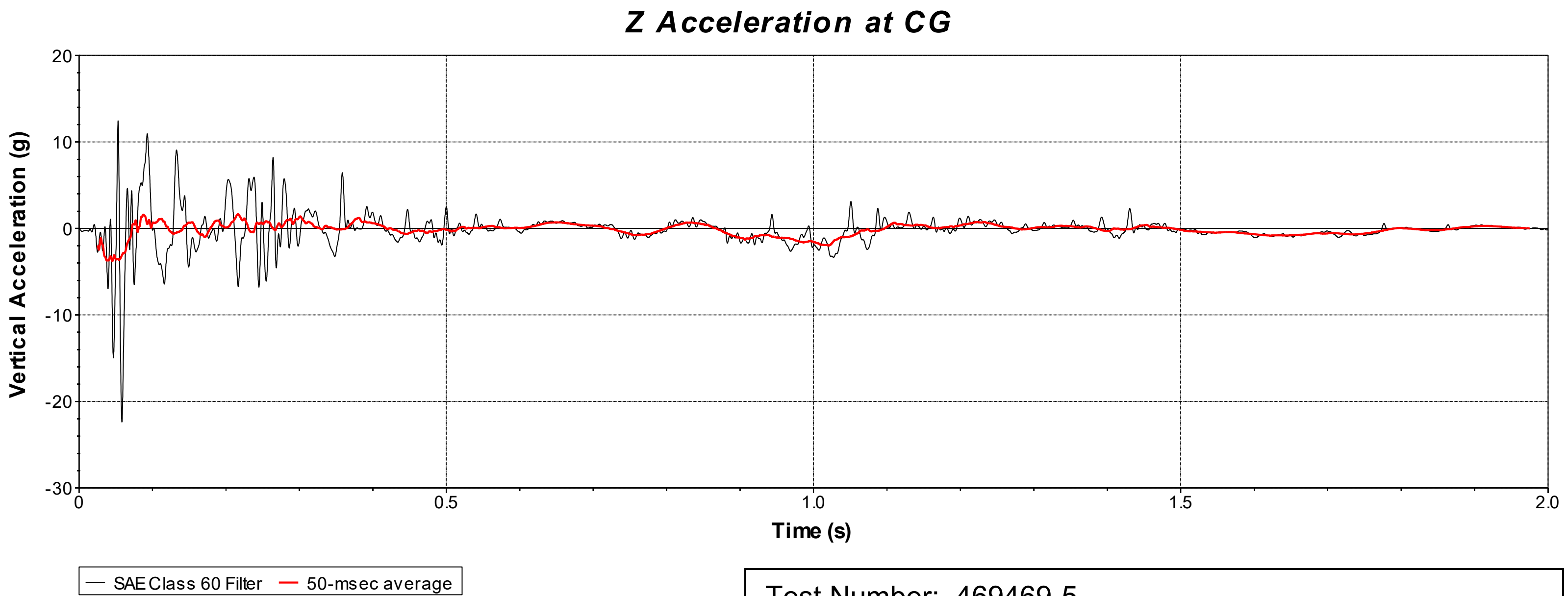
Test Number: 469469-5
Test Standard: 3-21
Test Article: Thrie-Beam Transition without end shoe block
Test Vehicle: 2270P/ 2013 RAM 1500
Inertial Mass: 5038 lb
Gross Mass: 5038 lb
Impact Speed: 62.3 mi/h
Impact Angle: 25.1 degrees

Figure E.4. Vehicle Longitudinal Accelerometer Trace for Test No. 469469-5 (Accelerometer Located at Center of Gravity).



Test Number: 469469-5
Test Standard: 3-21
Test Article: Thrie-Beam Transition without end shoe block
Test Vehicle: 2270P/ 2013 RAM 1500
Inertial Mass: 5038 lb
Gross Mass: 5038 lb
Impact Speed: 62.3 mi/h
Impact Angle: 25.1 degrees

Figure E.5. Vehicle Lateral Accelerometer Trace for Test No. 469469-5 (Accelerometer Located at Center of Gravity).

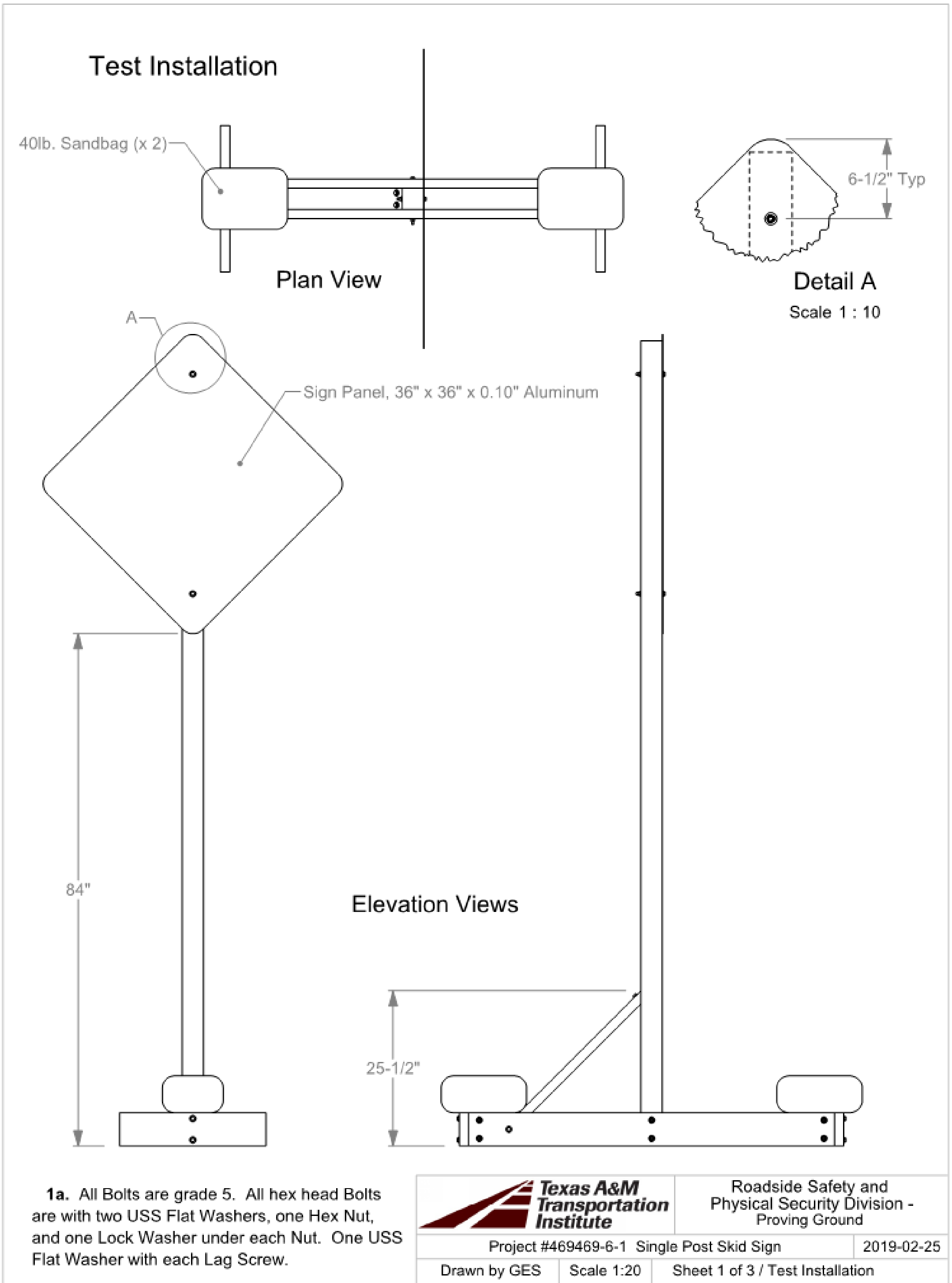


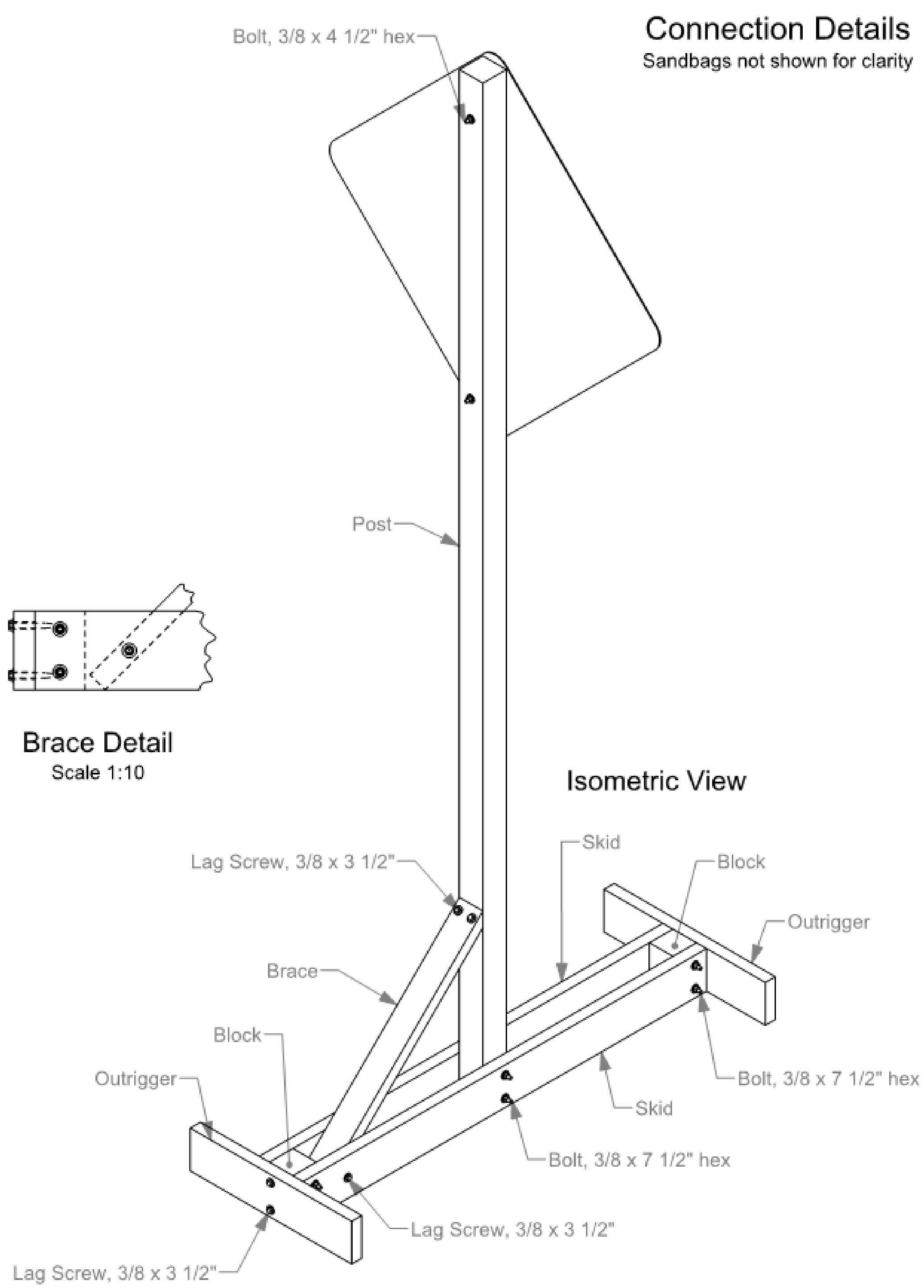
Test Number: 469469-5
Test Standard: 3-21
Test Article: Thrie-Beam Transition without end shoe block
Test Vehicle: 2270P/ 2013 RAM 1500
Inertial Mass: 5038 lb
Gross Mass: 5038 lb
Impact Speed: 62.3 mi/h
Impact Angle: 25.1 degrees

Figure E.6. Vehicle Vertical Accelerometer Trace for Test No. 469469-5 (Accelerometer Located at Center of Gravity).

APPENDIX F. TXDOT SINGLE WOOD POST SKID-MOUNTED SUPPORT SYSTEM

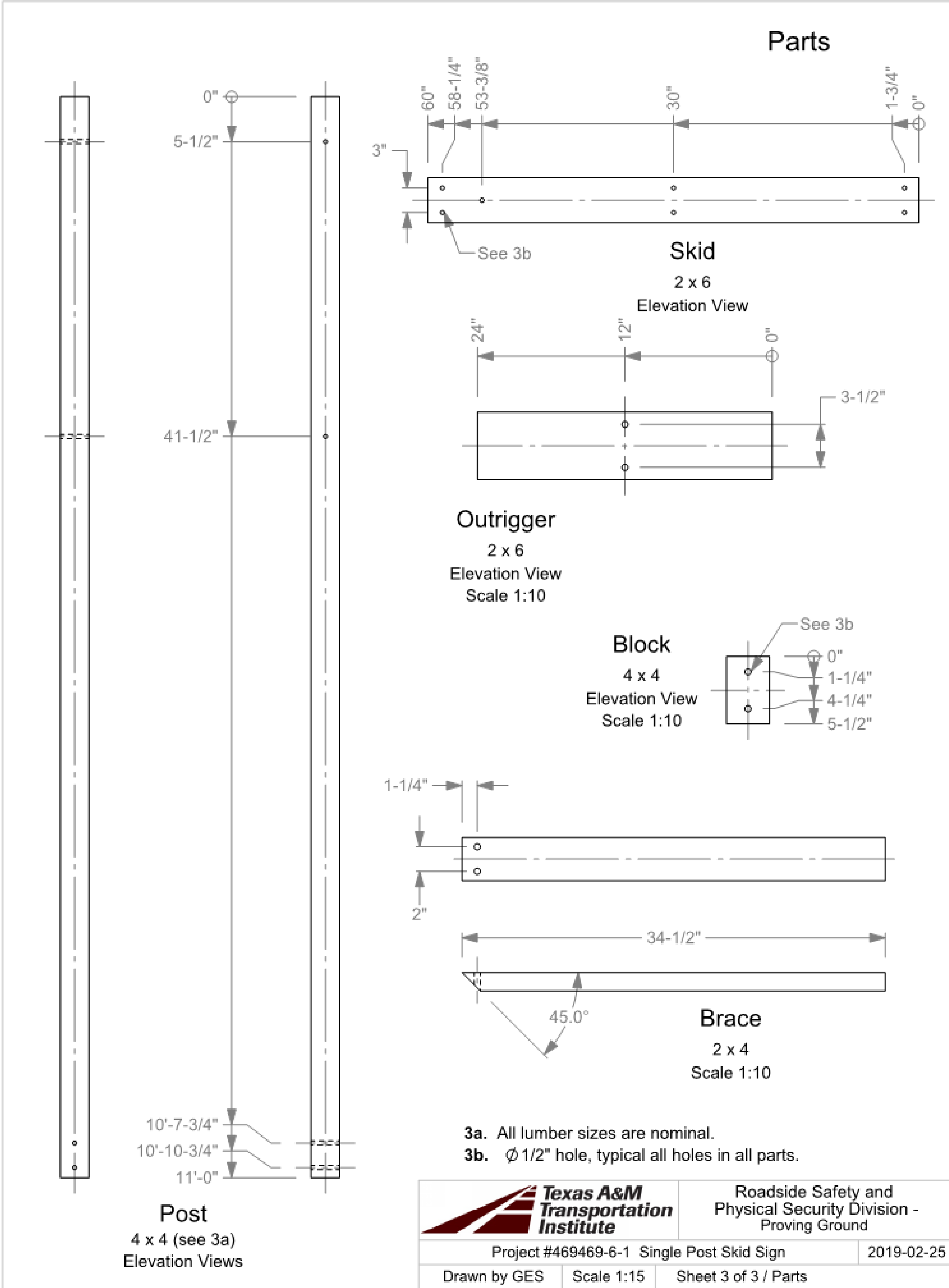
F.1. DETAILS OF THE SINGLE WOOD POST SKID-MOUNTED SUPPORT SYSTEM





2a. All Bolts are grade 5. All hex head Bolts are with two USS Flat Washers, one Hex Nut, and one Lock Washer under each Nut. One USS Flat Washer with each Lag Screw.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #469469-6-1 Single Post Skid Sign		2019-02-25
Drawn by GES	Scale 1:15	Sheet 2 of 3 / Connection Details


Parts
60"
58-1/4"
53-3/8"
30"
1-3/4"
0"
3"
See 3b
Skid
2 x 6
Elevation View
24"
12"
0"
3-1/2"
Outrigger
2 x 6
Elevation View
Scale 1:10
Block
4 x 4
Elevation View
Scale 1:10
See 3b
0"
1-1/4"
4-1/4"
5-1/2"
1-1/4"
2"
34-1/2"
45.0°
Brace
2 x 4
Scale 1:10
0"
5-1/2"
41-1/2"
10'-7-3/4"
10'-10-3/4"
11'-0"
Post
4 x 4 (see 3a)
Elevation Views
3a. All lumber sizes are nominal.
3b. ∅1/2" hole, typical all holes in all parts.
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #469469-6-1 Single Post Skid Sign
2019-02-25
Drawn by GES
Scale 1:15
Sheet 3 of 3 / Parts

F.2. *MASH* TEST 3-72 (CRASH TEST NO. 469469-06-02)

F.2.1. Vehicle Properties and Information

Table F.1. Vehicle Properties for Test No. 469469-06-02.

Vehicle Inventory Number: 1402

Date: 2019-04-16 Test No.: 469469-06-02 VIN No.: 1C6RR6FT7FS542816

Year: 2015 Make: RAM Model: 1500

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

Tread Type: Highway Odometer: 132352

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

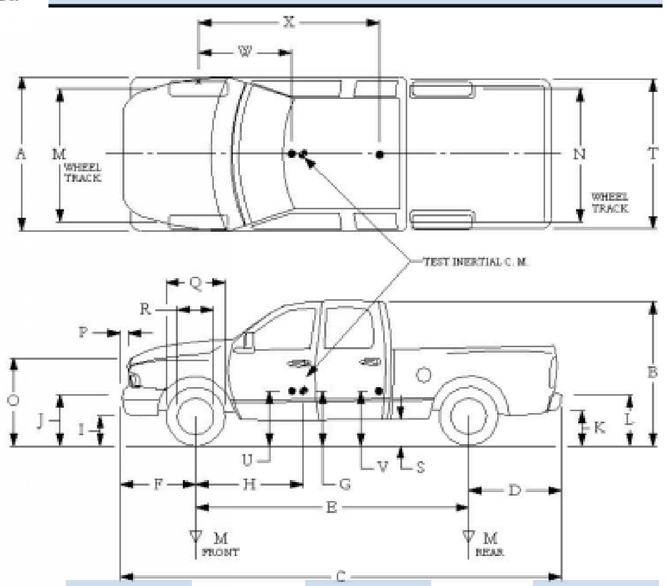
NOTES: None

Engine Type: V-8
Engine CID: 4.7 liter

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

Optional Equipment:
None

Dummy Data:
Type: NONE
Mass: 0 lb
Seat Position:



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	27.50
B	74.00	G	28.00	L	30.00	Q	30.50	V	31.25
C	227.50	H	62.10	M	68.50	R	18.00	W	62.10
D	44.00	I	11.75	N	68.00	S	13.00	X	76.50
E	140.50	J	27.00	O	46.00	T	77.00		

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

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

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2898	2803	
Back	3900	M_{rear}	2031	2223	
Total	6700	M_{Total}	4929	5026	0

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

Mass Distribution:
lb LF: 1392 RF: 1411 LR: 1148 RR: 1075

Performed by: SCD Date: 2019-04-16

Table F.2. Measurements of Vehicle Vertical CG for Test No. 469469-06-02.

Vehicle Inventory Number: 1402

Date: 2019-04-16 Test No.: 469469-06-02 VIN: 1C6RR6FT7FS542816

Year: 2015 Make: RAM Model: 1500

Body Style: Quad Cab Mileage: 132352

Engine: 4.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 140 (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70 R 17

Measured Vehicle Weights: (lb)					
LF:	1392	RF:	1411	Front Axle:	2803
LR:	1148	RR:	1075	Rear Axle:	2223
Left:	2540	Right:	2486	Total:	5026
					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:	62.14 inches	Rear of Front Axle	(63 ±4 inches allowed)		
Y:	-0.37 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: 27.00 inches

Front Overhang: 40.00 inches
39 ±3 inches allowed

Rear Bumper Height: 30.00 inches

Overall Length: 227.50 inches
237 ±13 inches allowed

Table F.3. Exterior Crush Measurements of Vehicle for Test No. 469469-06-02.

		Vehicle Inventory Number:	1402		
Date:	2019-04-16	Test No.:	469469-06-02	VIN No.:	1C6RR6FT7FS542816
Year:	2015	Make:	RAM	Model:	1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

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

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

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

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

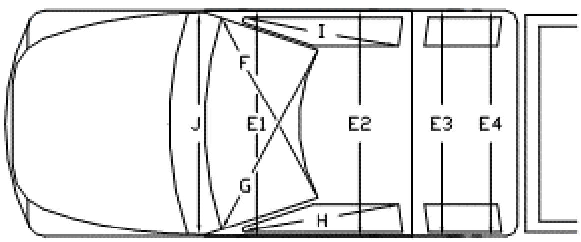
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

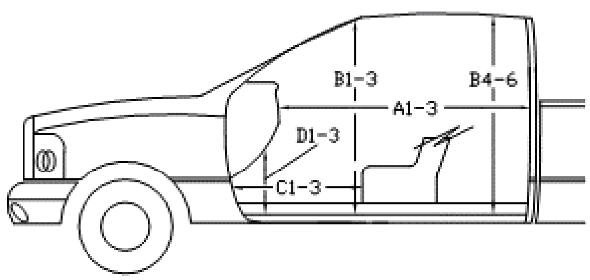
***Measure and document on the vehicle diagram the location of the maximum crush.

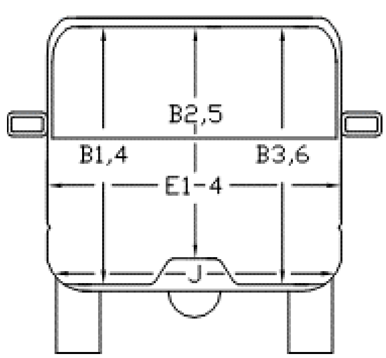
Note: Use as many lines/columns as necessary to describe each damage profile.

Table F.4. Occupant Compartment Measurements of Vehicle for Test No. 469469-06-02.

		Vehicle Inventory Number:	1402		
Date:	2019-04-16	Test No.:	469469-06-02	VIN No.:	1C6RR6FT7FS542816
Year:	2015	Make:	RAM	Model:	1500





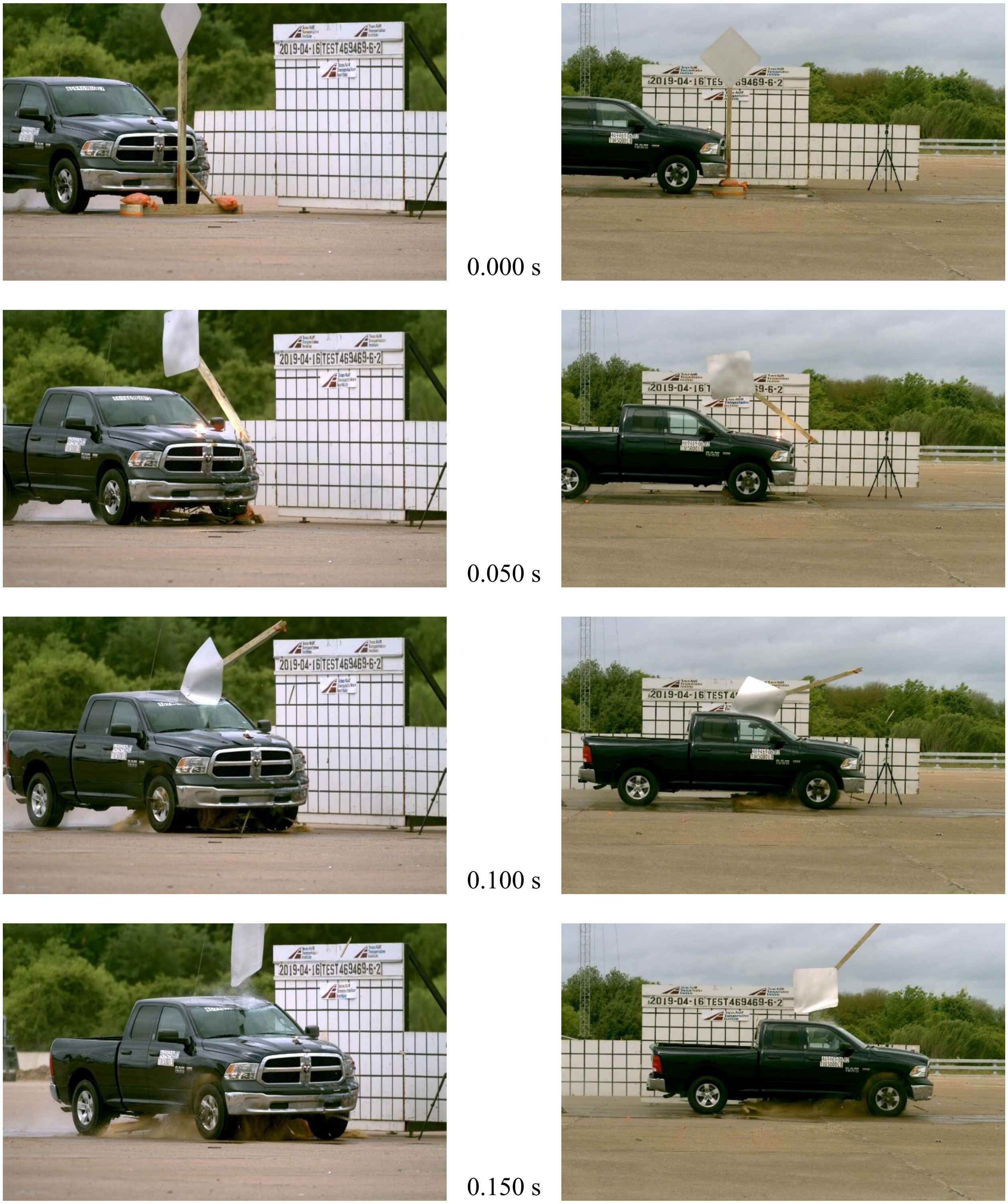


*Lateral area across the cab from driver's side kickpanel to passenger's side kickpanel.

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	34.50	-3.50
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	58.50	0.00
E2	63.50	63.50	0.00
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	25.00	0.00

F.2.2. Sequential Photographs



0.000 s

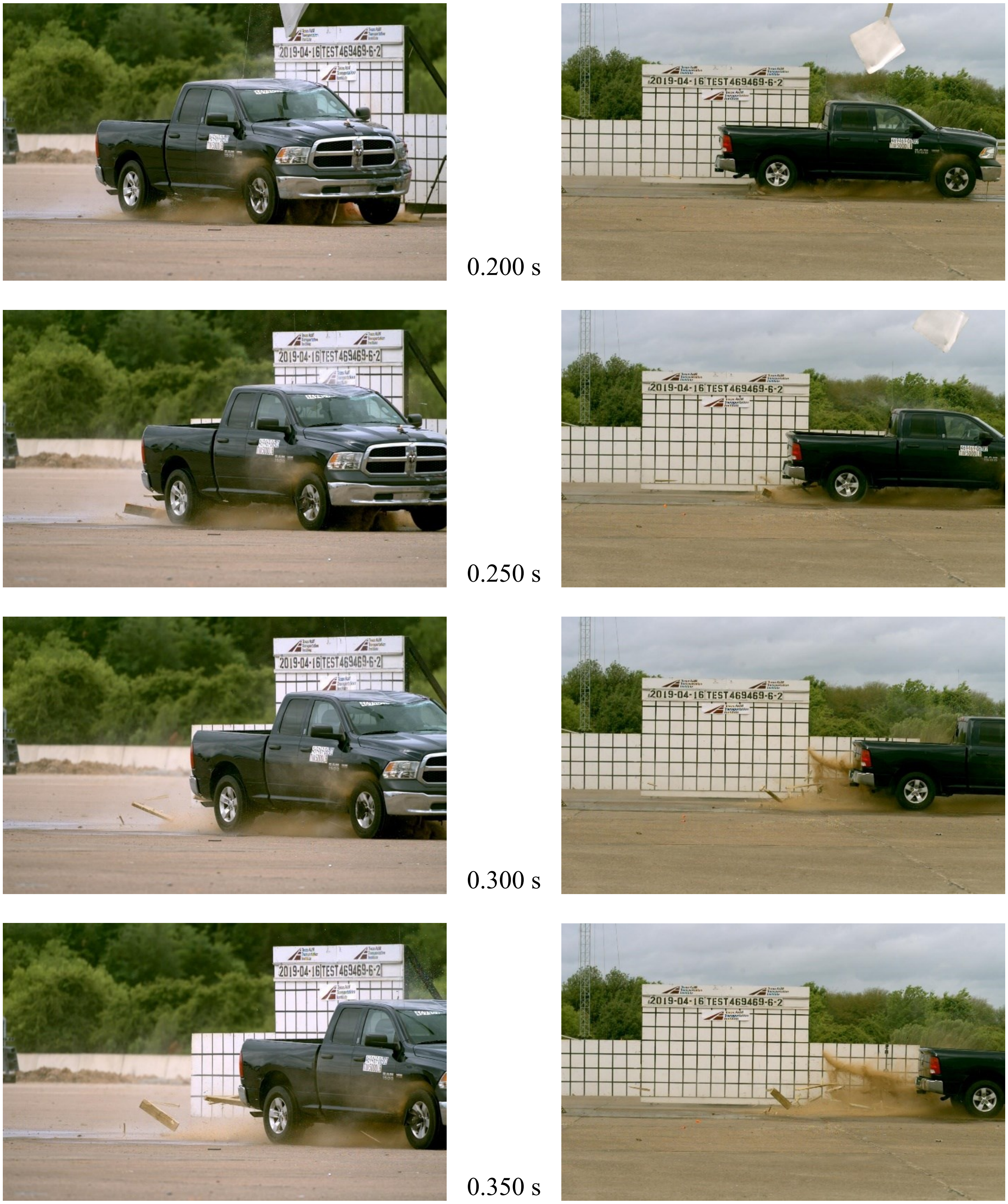
0.050 s

0.100 s

0.150 s

Figure F.1. Sequential Photographs for Test No. 469469-06-02

(Oblique and Right Angle views).



0.200 s

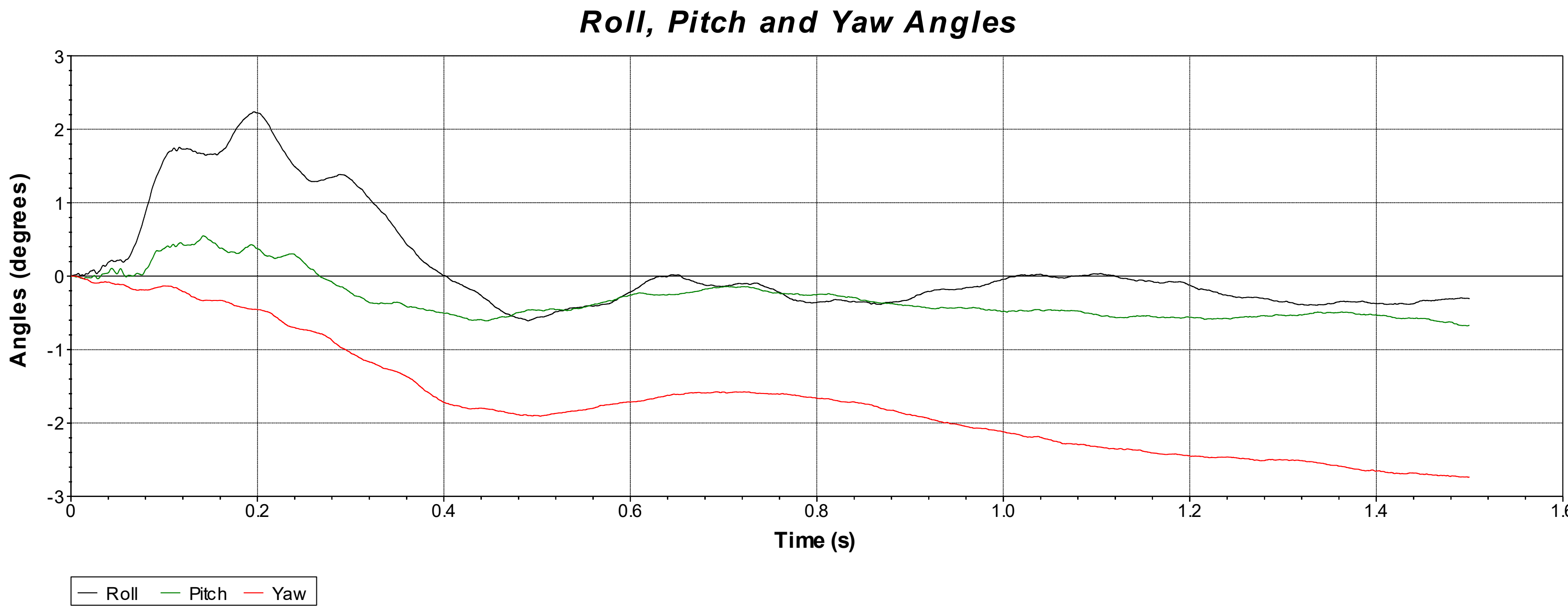
0.250 s

0.300 s

0.350 s

Figure A.1. Sequential Photographs for Test No. 469469-06-02 (Oblique and Right Angle views) (Continued).

F.2.3. Vehicle Angular Displacement



Test Number: 469469-06-02
Test Standard, Test Number: MASH 2016, 3-72
Test Article: Wood Skid Sign
Test Vehicle: 2015 RAM 1500
Inertial Mass: 5026 lb
Gross Mass: 5026 lb
Impact Speed: 62.2 mi/h
Impact Angle: 90 degrees

Axes are vehicle-fixed.
Sequence for determining orientation:

25. Yaw.
26. Pitch.
27. Roll.

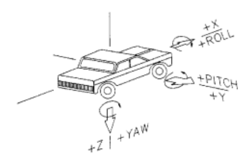
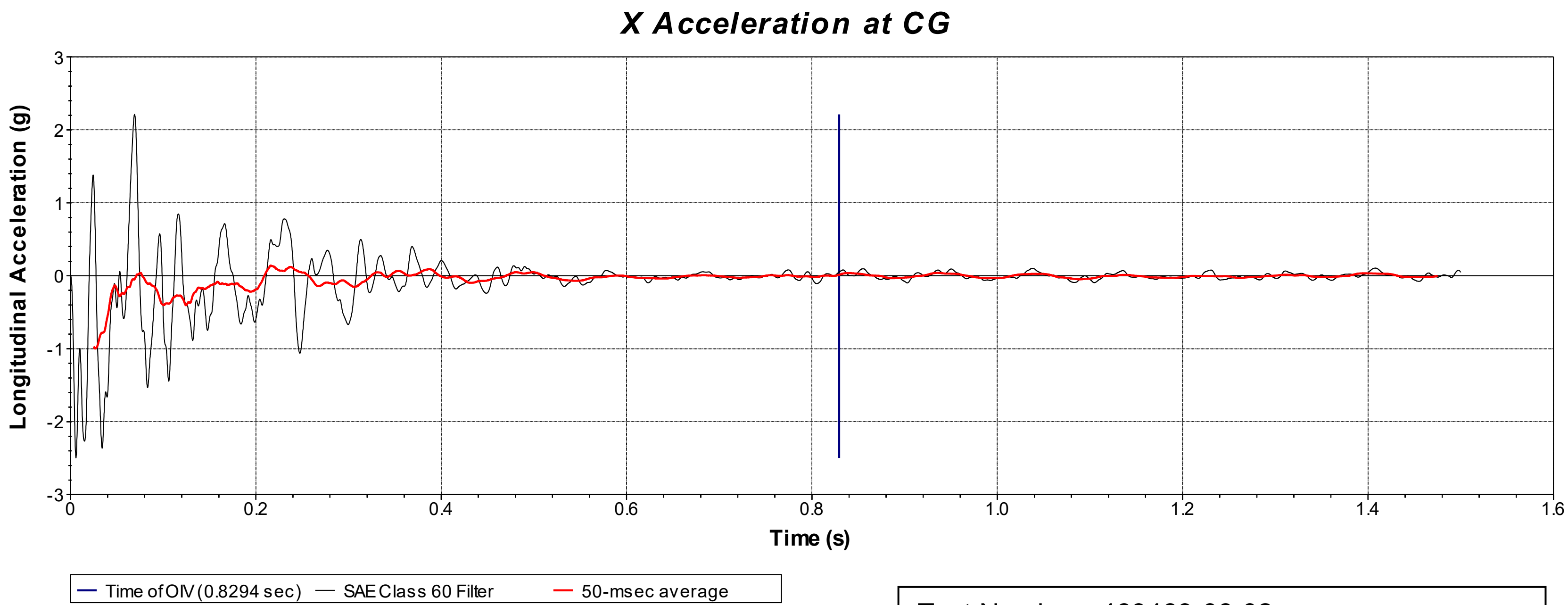


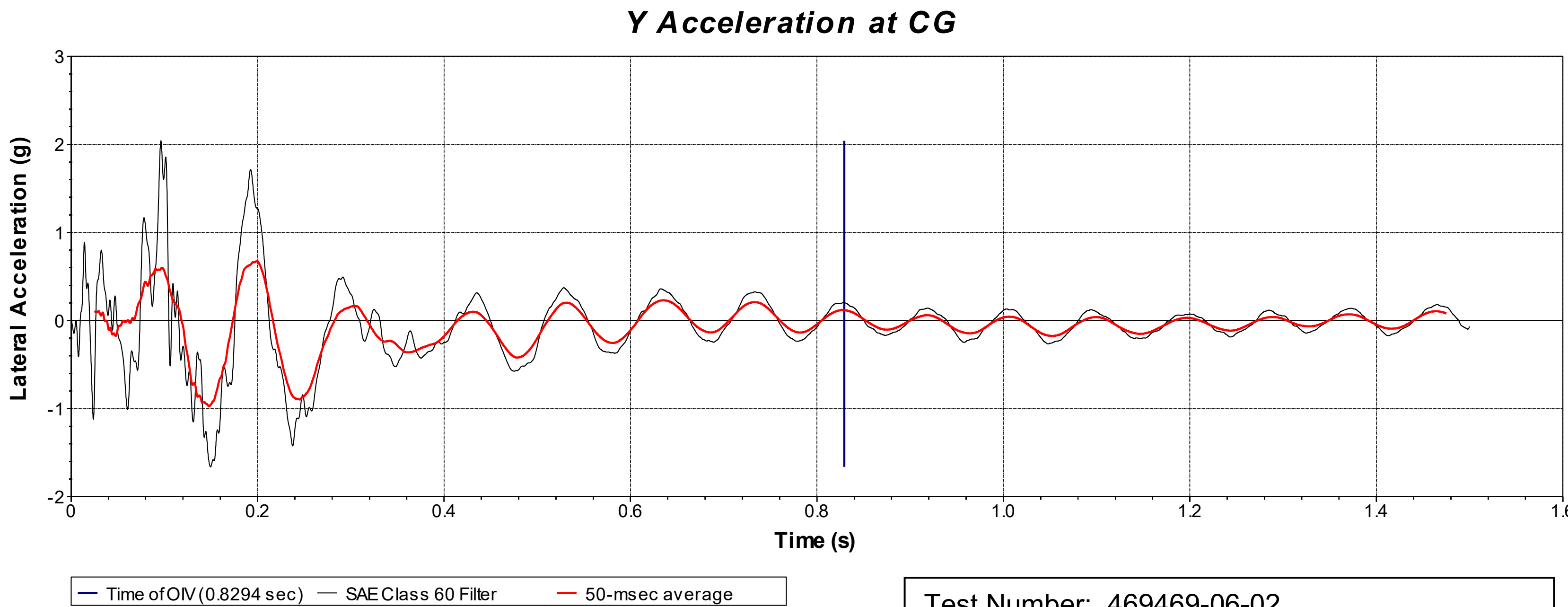
Figure F.3. Vehicle Angular Displacements for Test No. 469469-06-02.

F.2.4. Vehicle Acceleration



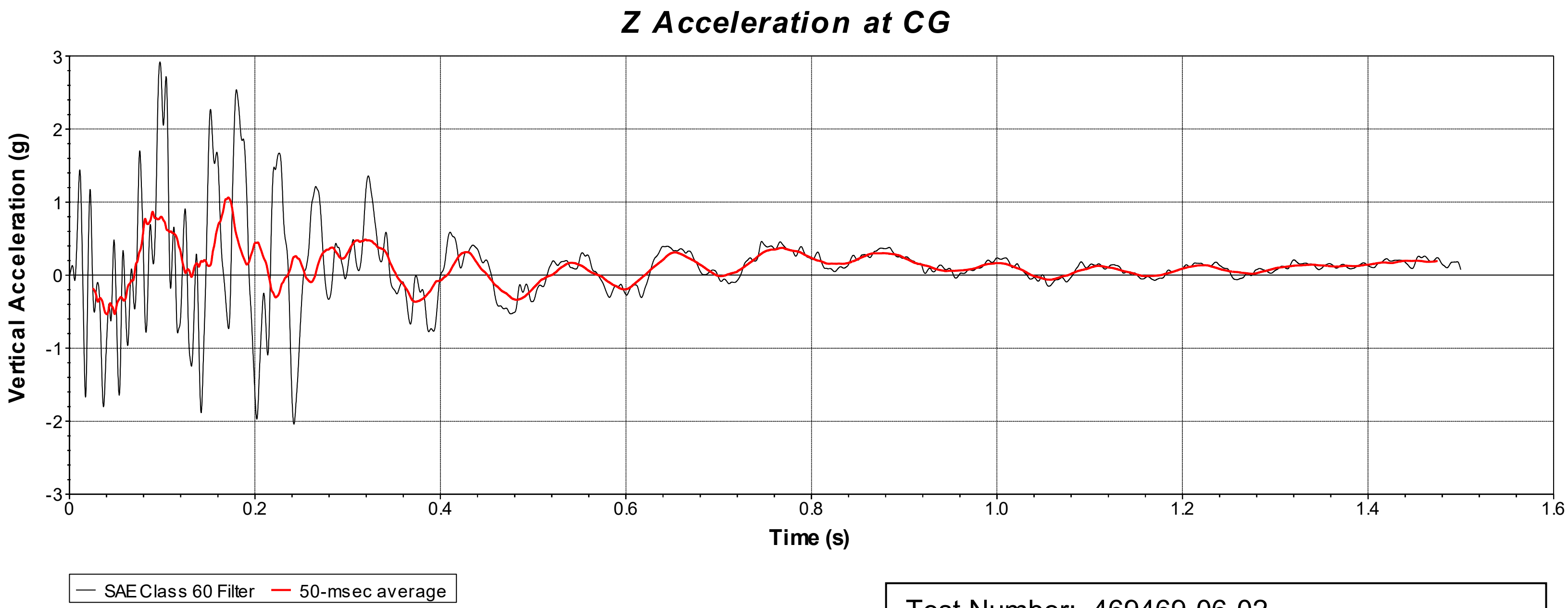
Test Number: 469469-06-02
Test Standard, Test Number: MASH 2016, 3-72
Test Article: Wood Skid Sign
Test Vehicle: 2015 RAM 1500
Inertial Mass: 5026 lb
Gross Mass: 5026 lb
Impact Speed: 62.2 mi/h
Impact Angle: 90 degrees

Figure F.4. Vehicle Longitudinal Accelerometer Trace for Test No. 469469-06-02 (Accelerometer Located at Center of Gravity).



Test Number: 469469-06-02
Test Standard, Test Number: MASH 2016, 3-72
Test Article: Wood Skid Sign
Test Vehicle: 2015 RAM 1500
Inertial Mass: 5026 lb
Gross Mass: 5026 lb
Impact Speed: 62.2 mi/h
Impact Angle: 90 degrees

Figure F.5. Vehicle Lateral Accelerometer Trace for Test No. 469469-06-02 (Accelerometer Located at Center of Gravity).

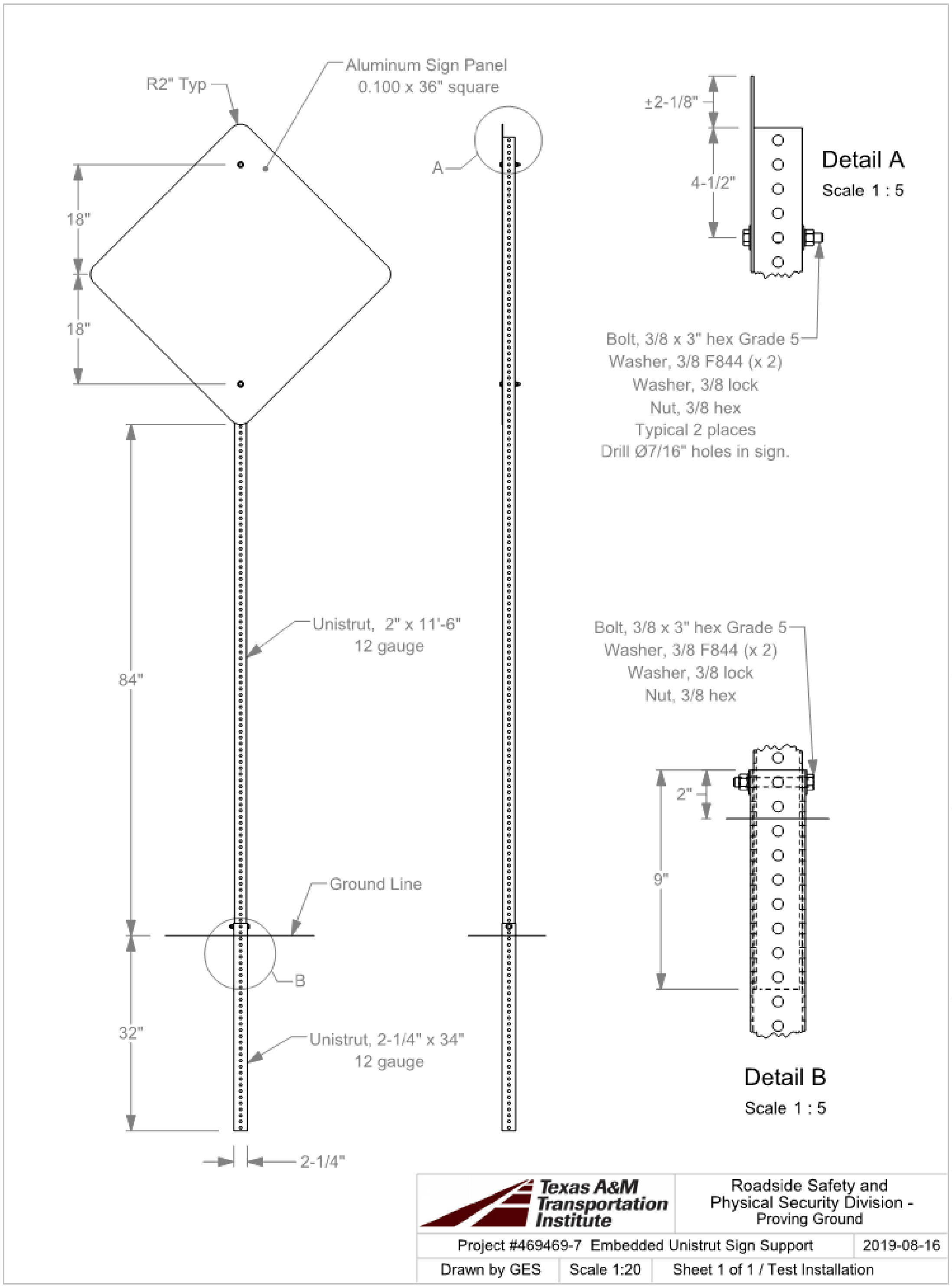


Test Number: 469469-06-02
Test Standard, Test Number: MASH 2016, 3-72
Test Article: Wood Skid Sign
Test Vehicle: 2015 RAM 1500
Inertial Mass: 5026 lb
Gross Mass: 5026 lb
Impact Speed: 62.2 mi/h
Impact Angle: 90 degrees

Figure F.6. Vehicle Vertical Accelerometer Trace for Test No. 469469-06-02 (Accelerometer Located at Center of Gravity).

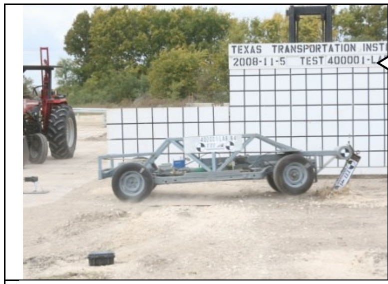
APPENDIX G. TXDOT PERFORATED SQUARE STEEL TUBE SIGN SUPPORT

G.1. DETAILS OF THE PERFORATED SQUARE STEEL TUBE SIGN SUPPORT 469469-07-02



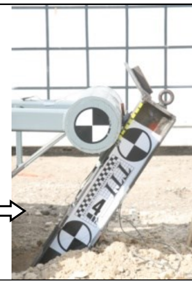
G.1.1. Supporting Certification Documents

Table G.1. Test Day Static Soil Strength Documentation for Test No. 469688-7-2.



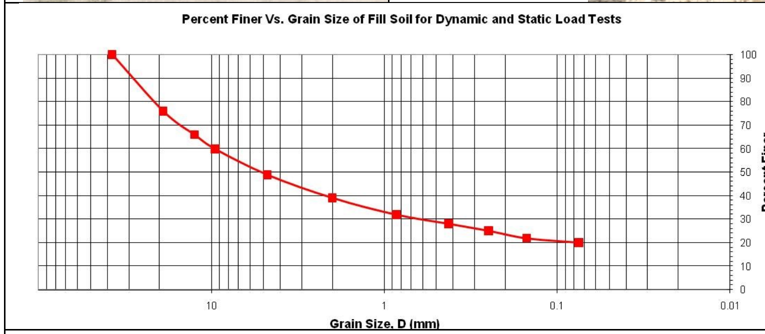
Dynamic Setup

Post-Test Photo of post

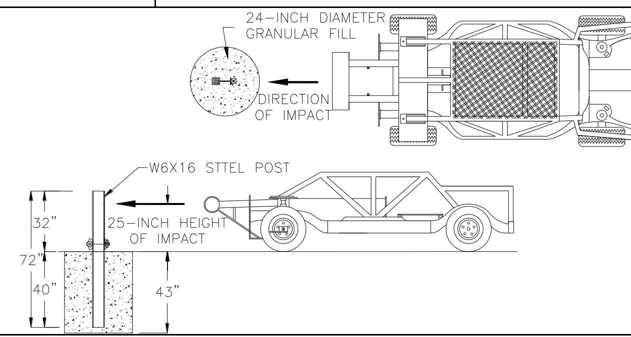


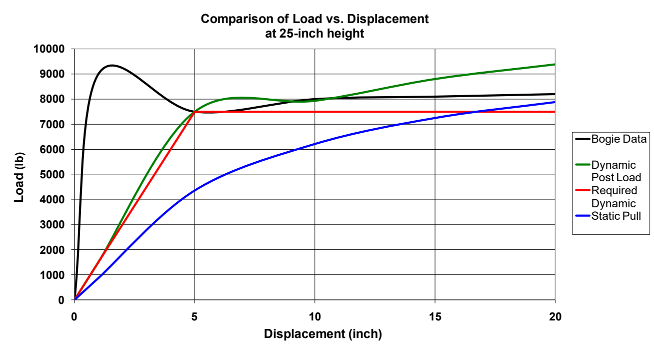
Post-Test Photo

Static Load Test

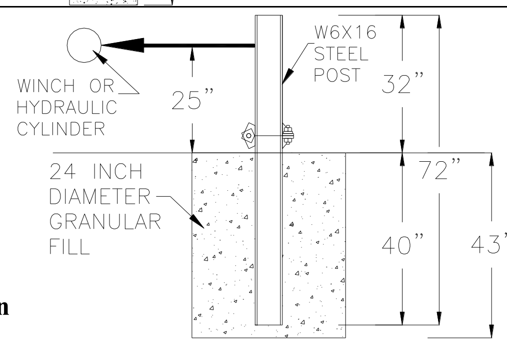


Dynamic Test Installation Details



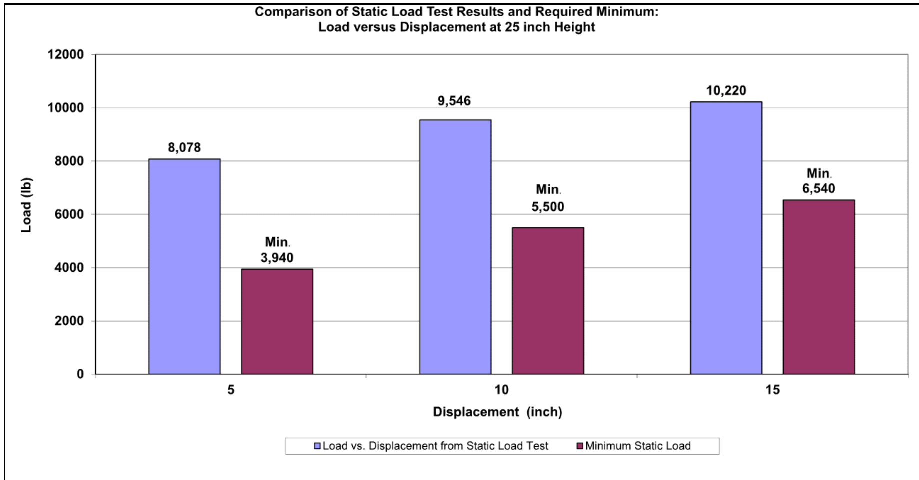


Static Load Test Installation Details

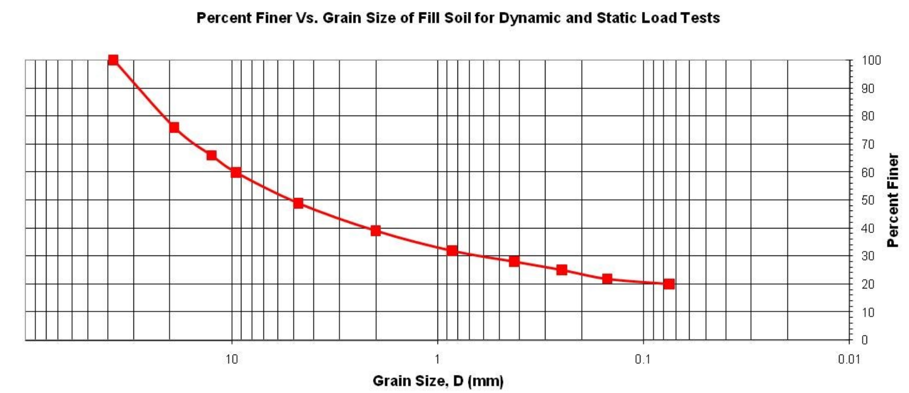


Date	2008-11-05
Test Facility and Site Location	TTI Proving Ground, 3100 SH 47, Bryan, TX 77807
In Situ Soil Description (ASTM D2487)	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis	AASHTO Grade B Soil-Aggregate (see sieve analysis above)
Description of Fill Placement Procedure	6-inch lifts tamped with a pneumatic compactor
Bogie Weight	5009 lb
Impact Velocity	20.5 mph

Table G.2. Test Day Static Soil Strength Documentation for Test No. 469469-7-2.



Static Load Setup



Post-Test Photo of Post

Date	2018-12-04
Test Facility and Site Location	TTI Proving Ground – 3100 SH 47, Bryan, Tx
In Situ Soil Description (ASTM D2487)	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis	AASHTO Grade B Soil-Aggregate (see sieve analysis)
Description of Fill Placement Procedure	6-inch lifts tamped with a pneumatic compactor

G.1.2. Vehicle Properties and Information

Table G.3. Vehicle Properties for Test No. 469469-07-02.

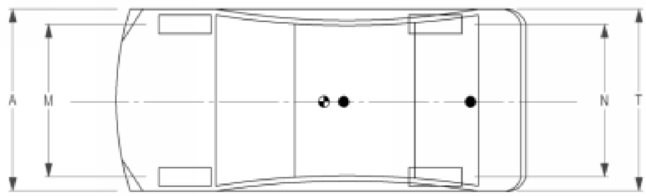
Vehicle Inventory Number: 1352

Date:	2019-08-23	Test No.:	469469-7-2	VIN No.:	KNADH4A31B6714470
Year:	2011	Make:	Kia	Model:	Rio
Tire Inflation Pressure:	32 PSI	Odometer:	138332	Tire Size:	185/65R14

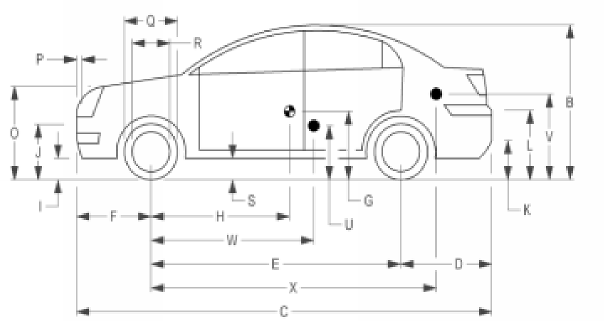
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES:



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



Dummy Data:
Type: 50th Percentile Male
Mass: 165 lb
Seat Position: OPPOSITE IMPACT

Geometry: inches

A	66.38	F	33.00	K	12.25	P	4.12	U	14.75
B	51.50	G		L	25.25	Q	22.50	V	20.75
C	165.75	H	35.16	M	57.75	R	15.50	W	35.10
D	34.00	I	7.75	N	57.70	S	8.25	X	71.50
E	98.75	J	21.50	O	27.00	T	66.20		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00 W-H 0.00

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Bottom of Hood Lip) = 24 ±4 inches
TOP OF RADIATOR SUPPORT = 28.25 inches; (M+N)/2 = 56 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1637	1573	1658
Back	1874	M_{rear}	907.00	870	950.00
Total	3638	M_{Total}	2544	2443	2608

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

Mass Distribution:
lb LF: 753 RF: 820 LR: 483 RR: 387

Performed by: SCD Date: 2019-08-23

Table G.4. Exterior Crush Measurements of Vehicle for Test No. 469469-07-02.

Vehicle Inventory Number: 1352

Date:	2019-08-23	Test No.:	469469-7-2	VIN No.:	KNADH4A31B6714470
Year:	2011	Make:	Kia	Model:	Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

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

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

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

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

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

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

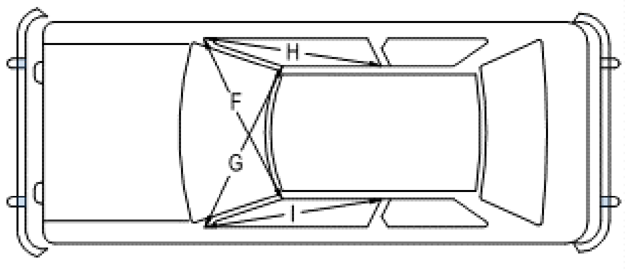
Note: Use as many lines/columns as necessary to describe each damage profile.

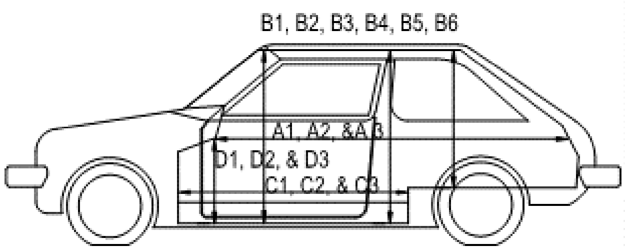
Performed by: ***SCD*** Date: 2019-08-23

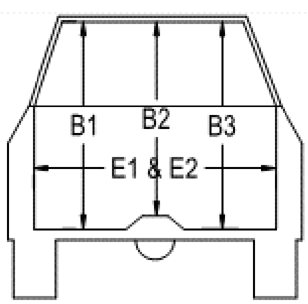
Table G.5. Occupant Compartment Measurements of Vehicle for Test No. 469469-07-02.

Vehicle Inventory Number: 1352

Date:	2019-08-23	Test No.:	469469-7-2	VIN No.:	KNADH4A31B6714470
Year:	2011	Make:	Kia	Model:	Rio







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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	67.50	67.50	0.00
A2	67.25	67.25	0.00
A3	67.75	67.75	0.00
B1	40.50	40.50	0.00
B2	39.00	31.50	-7.50
B3	40.50	29.00	-11.50
B4	36.25	36.25	0.00
B5	36.00	36.00	0.00
B6	36.25	36.25	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	9.50	9.50	0.00
D2	0.00	0.00	0.00
D3	9.50	9.50	0.00
E1	51.50	51.50	0.00
E2	51.00	51.00	0.00
F	51.00	51.00	0.00
G	51.00	51.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	51.00	51.00	0.00

Performed by: *SCD* Date: 2019-08-23

G.1.3. Sequential Photographs

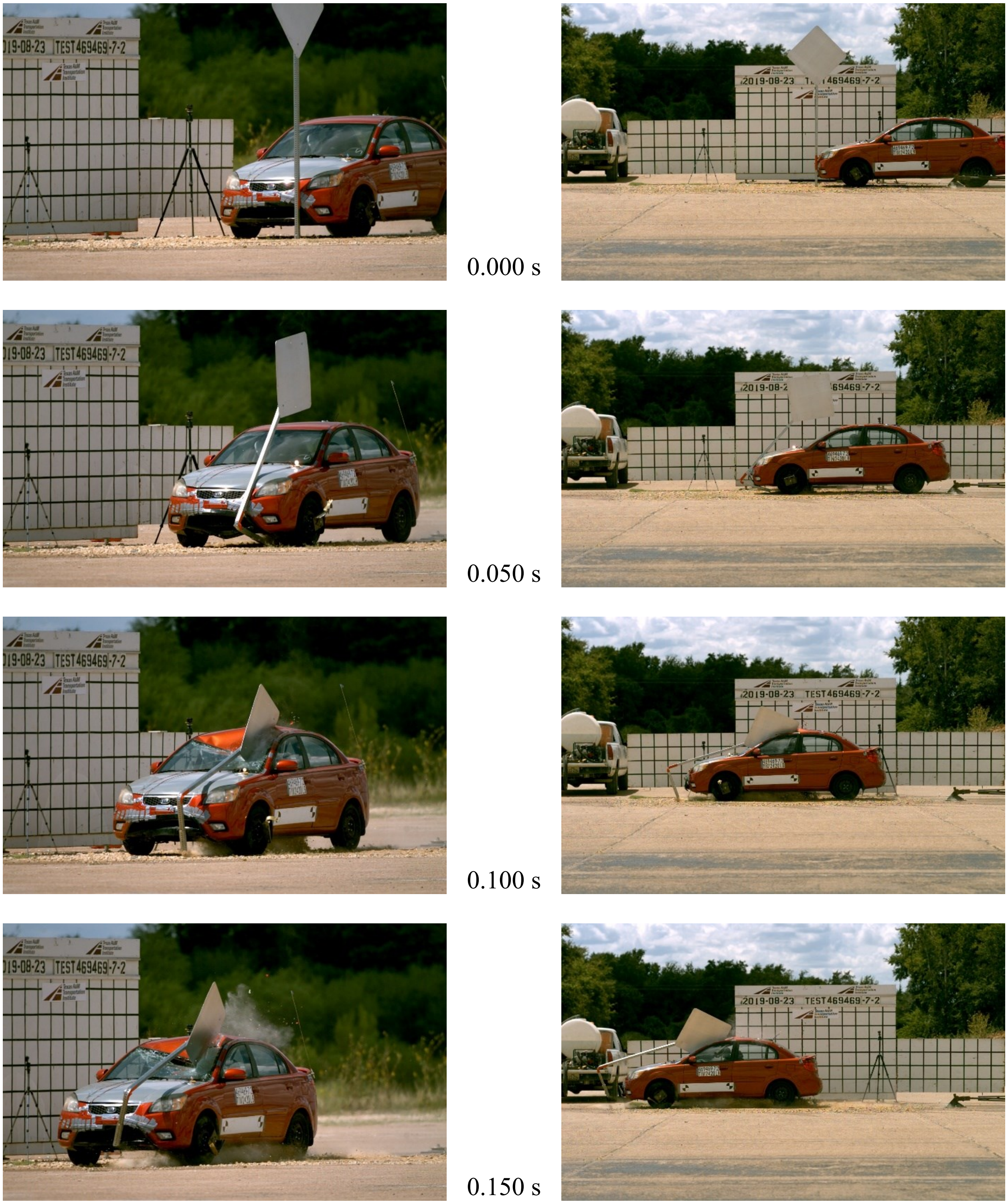


Figure G.1. Sequential Photographs for Test No. 469469-07-02

(Oblique and Right Angle views).

0.200 s

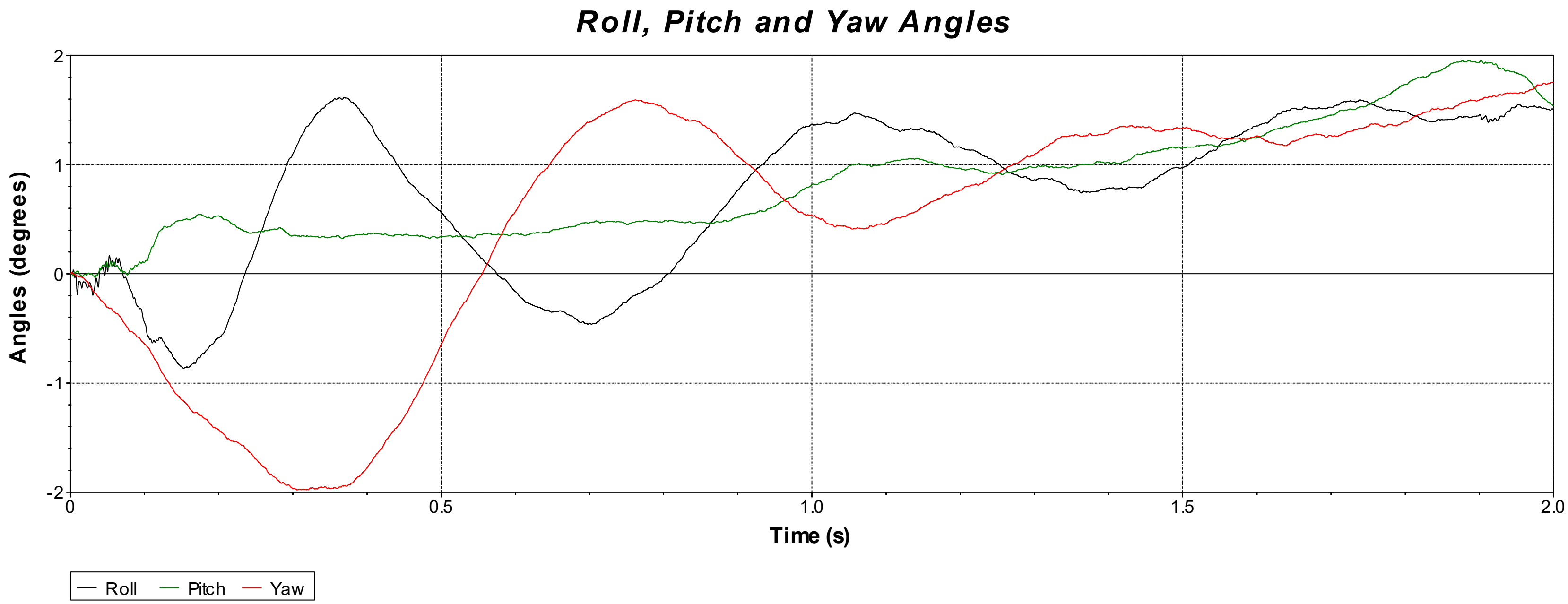
0.250 s

0.300 s

0.350 s

Figure A.1. Sequential Photographs for Test No. 469469-07-02 (Oblique and Right Angle views) (Continued).

G.1.4. Vehicle Angular Displacement



Test Number: 469469-07-02
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Embedded Unistrut® Sign Post
Test Vehicle: 2011 Kia Rio
Inertial Mass: 2443 lb
Gross Mass: 2608 lb
Impact Speed: 62.7 mi/h
Impact Angle: 0 degrees

Axes are vehicle-fixed.
Sequence for determining orientation:

28. Yaw.
29. Pitch.
30. Roll.

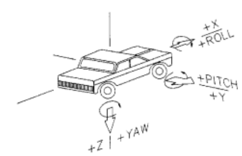
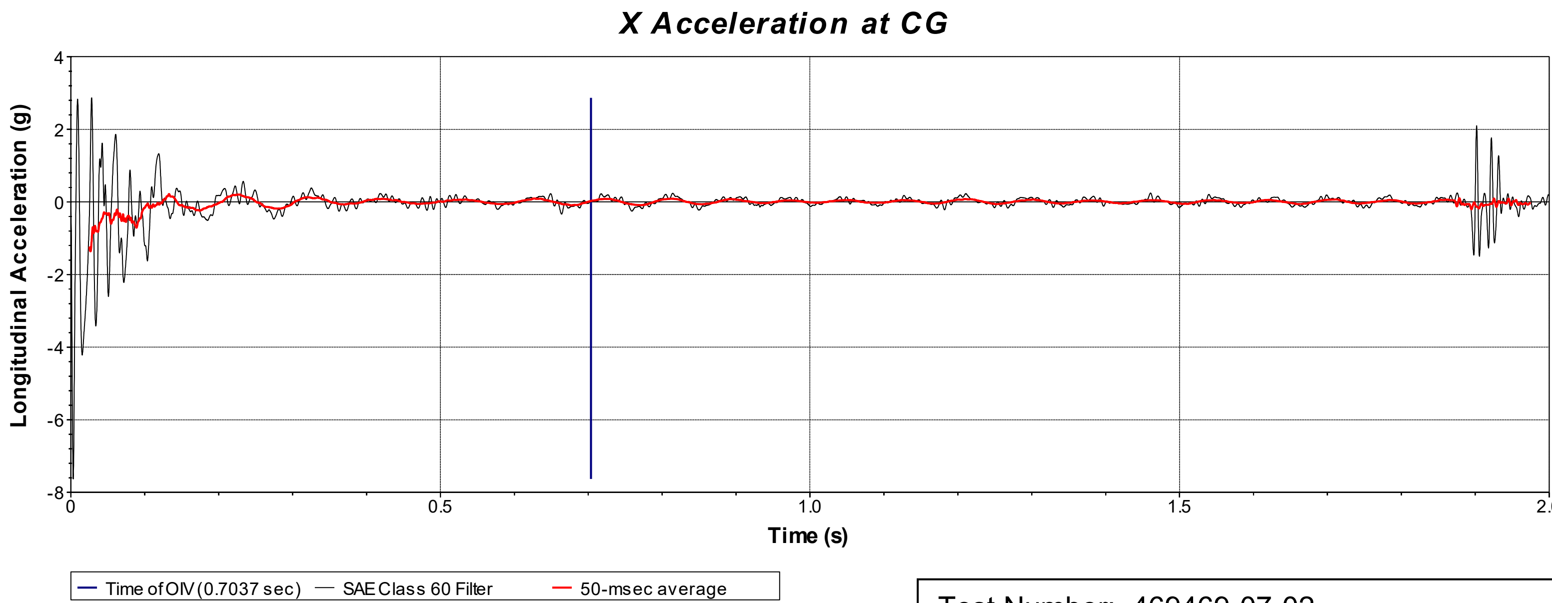


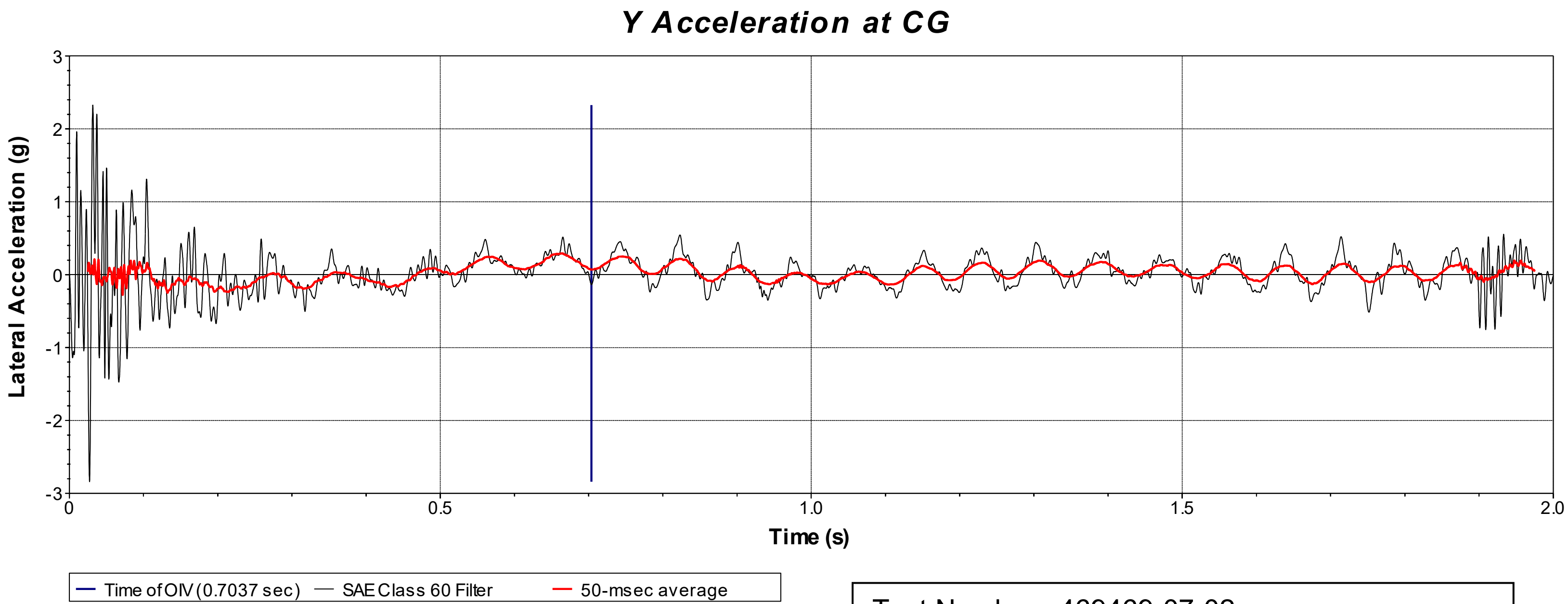
Figure G.3. Vehicle Angular Displacements for Test No. 469469-07-02.

G.1.5. Vehicle Acceleration



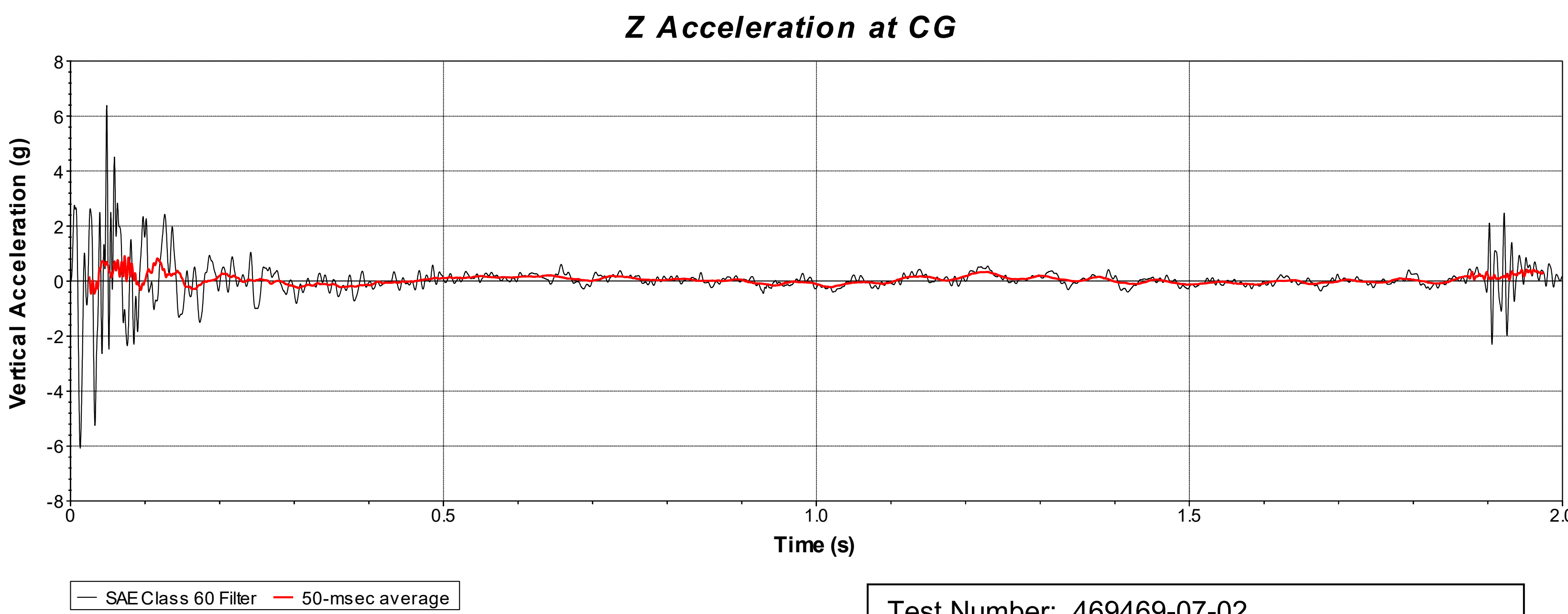
Test Number: 469469-07-02
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Embedded Unistrut® Sign Post
Test Vehicle: 2011 Kia Rio
Inertial Mass: 2443 lb
Gross Mass: 2608 lb
Impact Speed: 62.7 mi/h
Impact Angle: 0 degrees

Figure G.4. Vehicle Longitudinal Accelerometer Trace for Test No. 469469-07-02 (Accelerometer Located at Center of Gravity).



Test Number: 469469-07-02
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Embedded Unistrut® Sign Post
Test Vehicle: 2011 Kia Rio
Inertial Mass: 2443 lb
Gross Mass: 2608 lb
Impact Speed: 62.7 mi/h
Impact Angle: 0 degrees

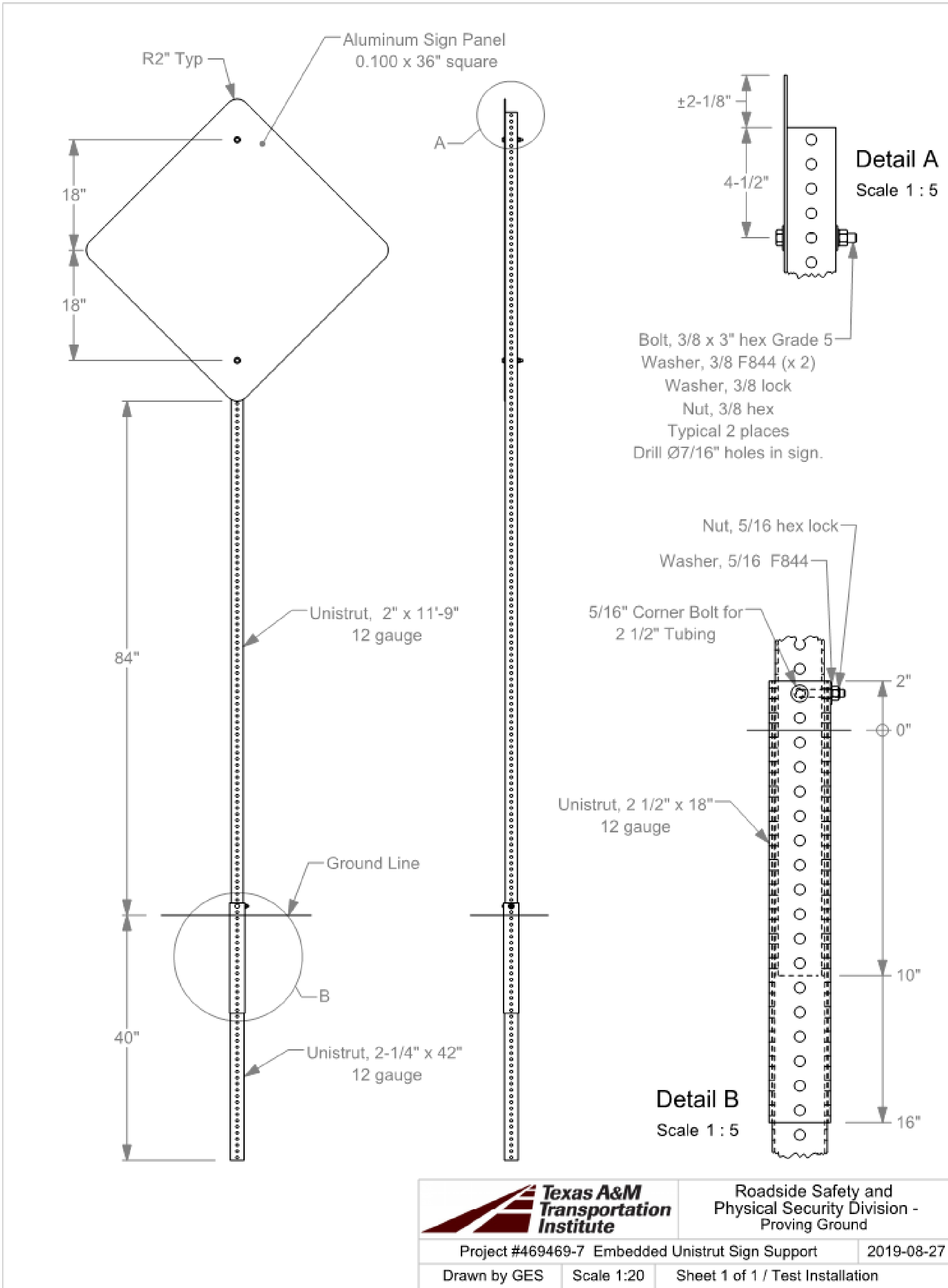
Figure G.5. Vehicle Lateral Accelerometer Trace for Test No. 469469-07-02 (Accelerometer Located at Center of Gravity).



Test Number: 469469-07-02
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Embedded Unistrut® Sign Post
Test Vehicle: 2011 Kia Rio
Inertial Mass: 2443 lb
Gross Mass: 2608 lb
Impact Speed: 62.7 mi/h
Impact Angle: 0 degrees

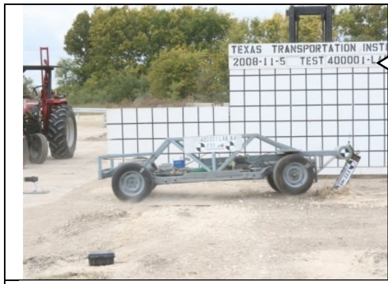
Figure G.6. Vehicle Vertical Accelerometer Trace for Test No. 469469-07-02 (Accelerometer Located at Center of Gravity).

G.2. DETAILS OF THE PERFORATED SQUARE STEEL TUBE SIGN SUPPORT 469469-07-05



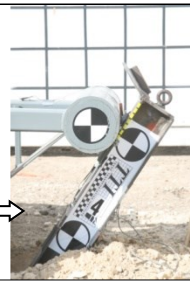
G.2.1. Supporting Certification Documents

Table G.6. Test Day Static Soil Strength Documentation for Test No. 469688-7-5.



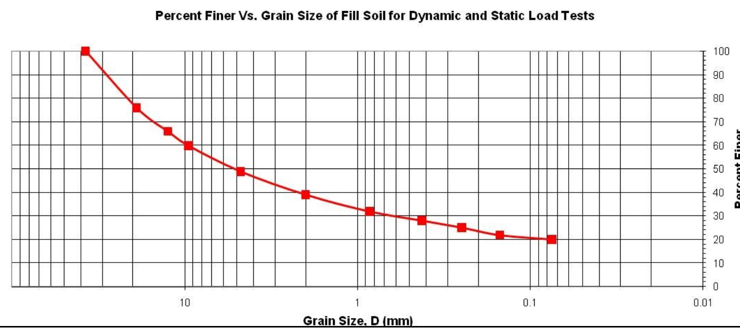
Dynamic Setup

Post-Test Photo of post

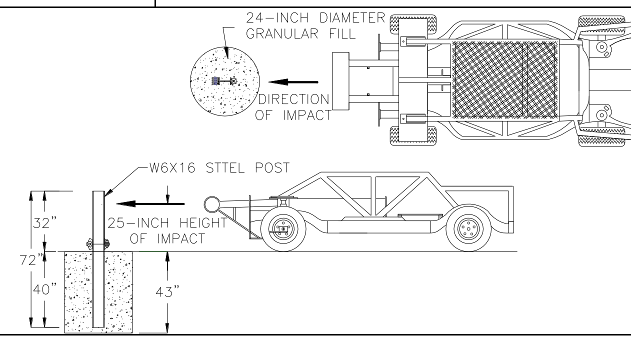


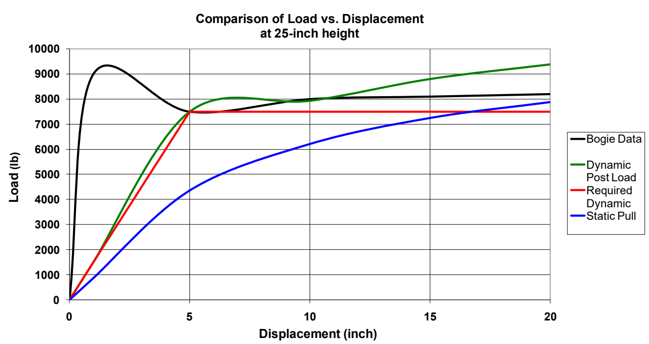
Post-Test Photo

Static Load Test

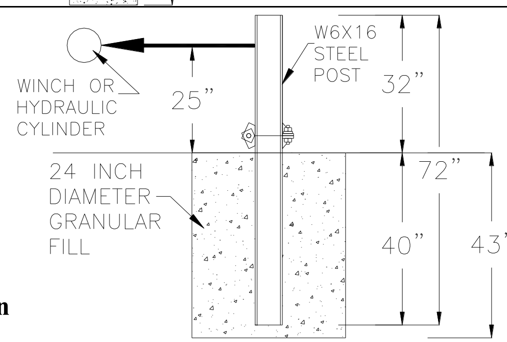


Dynamic Test Installation Details



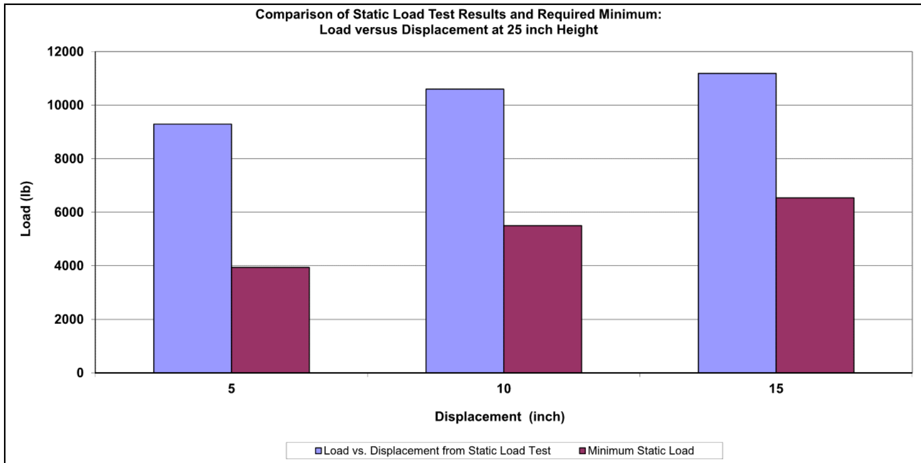


Static Load Test Installation Details

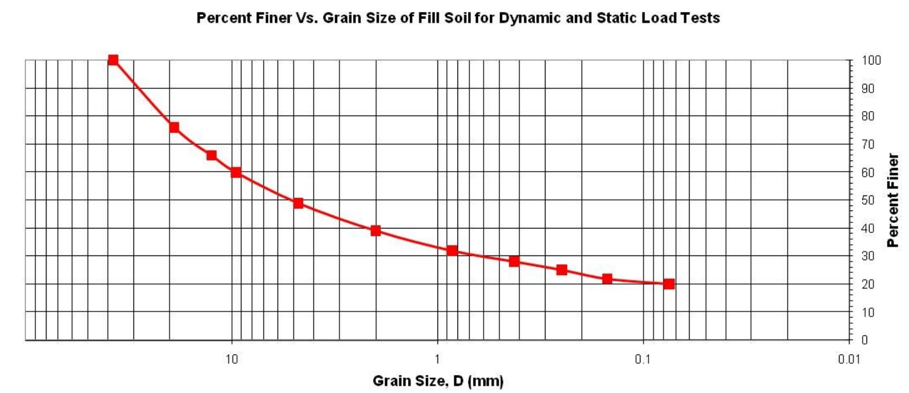


Date	2008-11-05
Test Facility and Site Location	TTI Proving Ground, 3100 SH 47, Bryan, TX 77807
In Situ Soil Description (ASTM D2487)	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis	AASHTO Grade B Soil-Aggregate (see sieve analysis above)
Description of Fill Placement Procedure	6-inch lifts tamped with a pneumatic compactor
Bogie Weight	5009 lb
Impact Velocity	20.5 mph

Table G.7. Test Day Static Soil Strength Documentation for Test No. 469688-7-5.



Static Load Setup



Post-Test Photo of Post

Date	2018-12-04
Test Facility and Site Location	TTI Proving Ground – 3100 SH 47, Bryan, Tx
In Situ Soil Description (ASTM D2487)	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis	AASHTO Grade B Soil-Aggregate (see sieve analysis)
Description of Fill Placement Procedure	6-inch lifts tamped with a pneumatic compactor

G.2.2. Vehicle Properties and Information

Table G.8. Vehicle Properties for Test No. 469469-07-05.

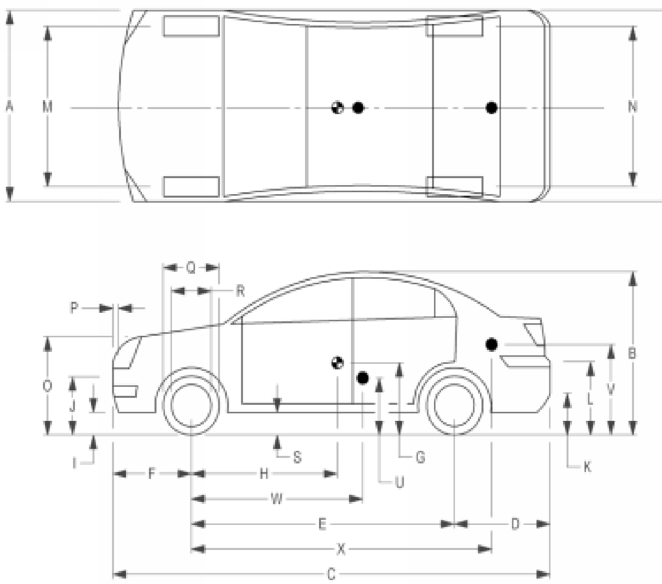
Vehicle Inventory Number: 1383

Date:	2019-08-29	Test No.:	469469-7-5	VIN No.:	KNADE123976267769
Year:	2007	Make:	Kia	Model:	Rio
Tire Inflation Pressure:	32 PSI	Odometer:		Tire Size:	185/65R14

Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES:



Engine Type: 4 CYL
Engine CID: 1.6 L

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

Optional Equipment:
None

Dummy Data:
Type: 50th Percentile Male
Mass: 165 lb
Seat Position: OPPOSITE IMPACT

Geometry: inches

A	66.38	F	33.00	K	12.25	P	4.12	U	14.75
B	51.50	G		L	25.25	Q	22.50	V	20.75
C	165.75	H	35.02	M	57.75	R	15.50	W	35.00
D	34.00	I	7.75	N	57.70	S	8.25	X	71.50
E	98.75	J	21.50	O	27.00	T	66.20		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00 W-H 0.00

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Bottom of Hood Lip) = 24 ±4 inches
TOP OF RADIATOR SUPPORT = 28.25 inches; (M+N)/2 = 56 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1598	1581	1666
Back	1874	M_{rear}	855.00	869	949.00
Total	3638	M_{Total}	2453	2450	2615

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

Mass Distribution:
lb LF: 800 RF: 781 LR: 427 RR: 442

Performed by: SCD Date: 2019-08-29

Table G.9. Exterior Crush Measurements of Vehicle for Test No. 469469-07-05.

Vehicle Inventory Number: 1383

Date: 2019-08-29 Test No.: 469469-7-5 VIN No.: KNADE123976267769

Year: 2007 Make: Kia Model: Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

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

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

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

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

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

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

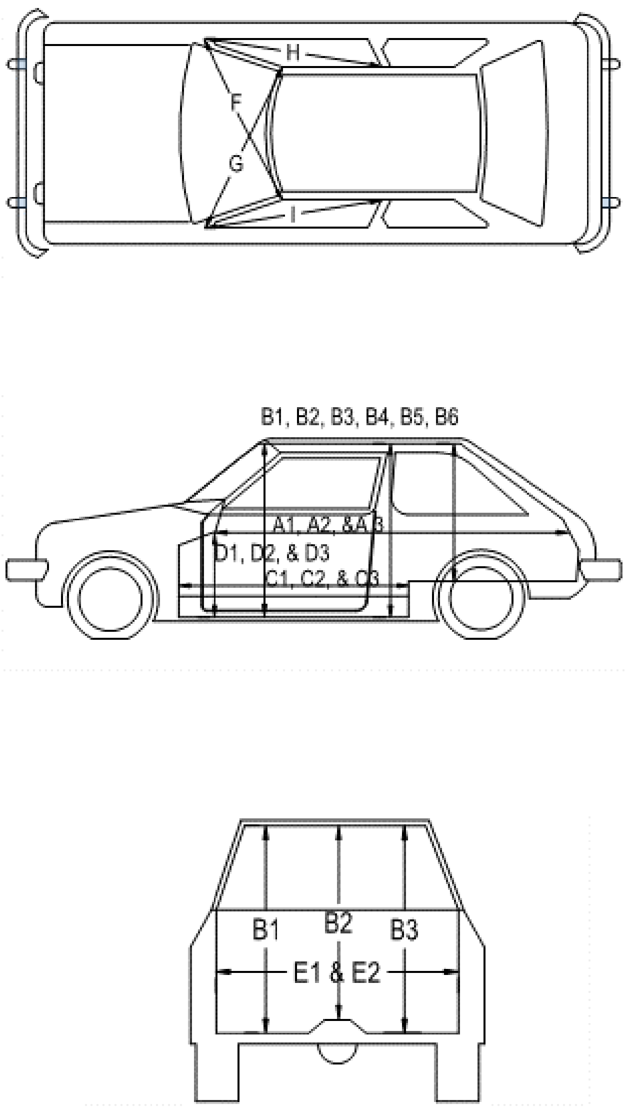
Note: Use as many lines/columns as necessary to describe each damage profile.

Performed by: *SCD* Date: 2019-08-29

Table G.10. Occupant Compartment Measurements of Vehicle for Test No. 469469-07-05.

Vehicle Inventory Number: 1383

Date:	2019-08-29	Test No.:	469469-7-5	VIN No.:	KNADE123976267769
Year:	2007	Make:	Kia	Model:	Rio



OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	67.50	67.50	0.00
A2	67.25	67.25	0.00
A3	67.75	67.75	0.00
B1	40.50	39.00	-1.50
B2	39.00	39.00	0.00
B3	40.50	40.50	0.00
B4	36.25	25.00	-11.25
B5	36.00	36.00	0.00
B6	36.25	36.25	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	9.50	9.50	0.00
D2	0.00	0.00	0.00
D3	9.50	9.50	0.00
E1	51.50	51.50	0.00
E2	51.00	51.00	0.00
F	51.00	51.00	0.00
G	51.00	51.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	51.00	51.00	0.00

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

Performed by: *SCD* Date: 2019-08-29

G.2.3. Sequential Photographs

0.000 s

0.050 s

0.100 s

0.150 s

Figure G.7. Sequential Photographs for Test No. 469469-07-05

(Oblique and Right Angle views).

0.200 s

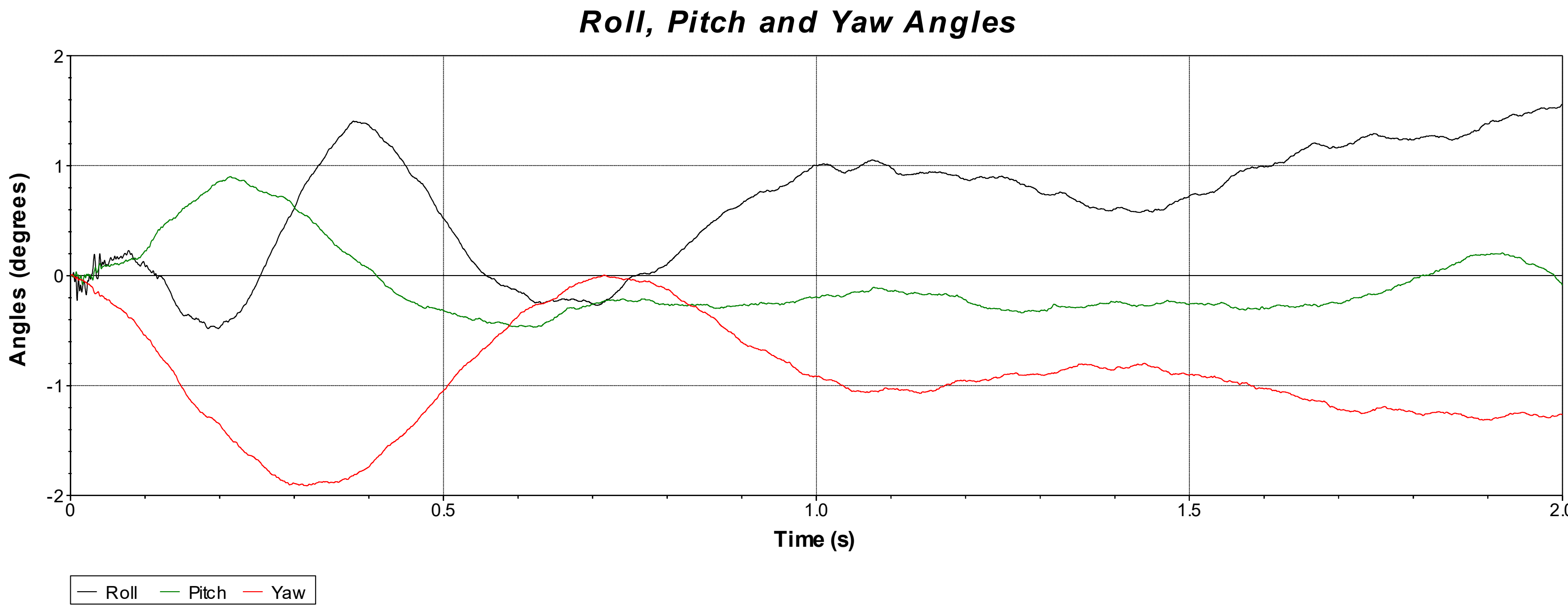
0.250 s

0.300 s

0.350 s

Figure G.7. Sequential Photographs for Test No. 469469-07-05 (Oblique and Right Angle views) (Continued).

G.2.4. Vehicle Angular Displacement



Test Number: 469469-07-05
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Embedded Unistrut® Sign Post
Test Vehicle: 2007 Kia Rio
Inertial Mass: 2450 lb
Gross Mass: 2615 lb
Impact Speed: 61.3 mi/h
Impact Angle: 0 degrees

Axes are vehicle-fixed.
Sequence for determining orientation:

31. Yaw.
32. Pitch.
33. Roll.

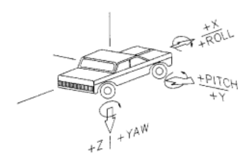
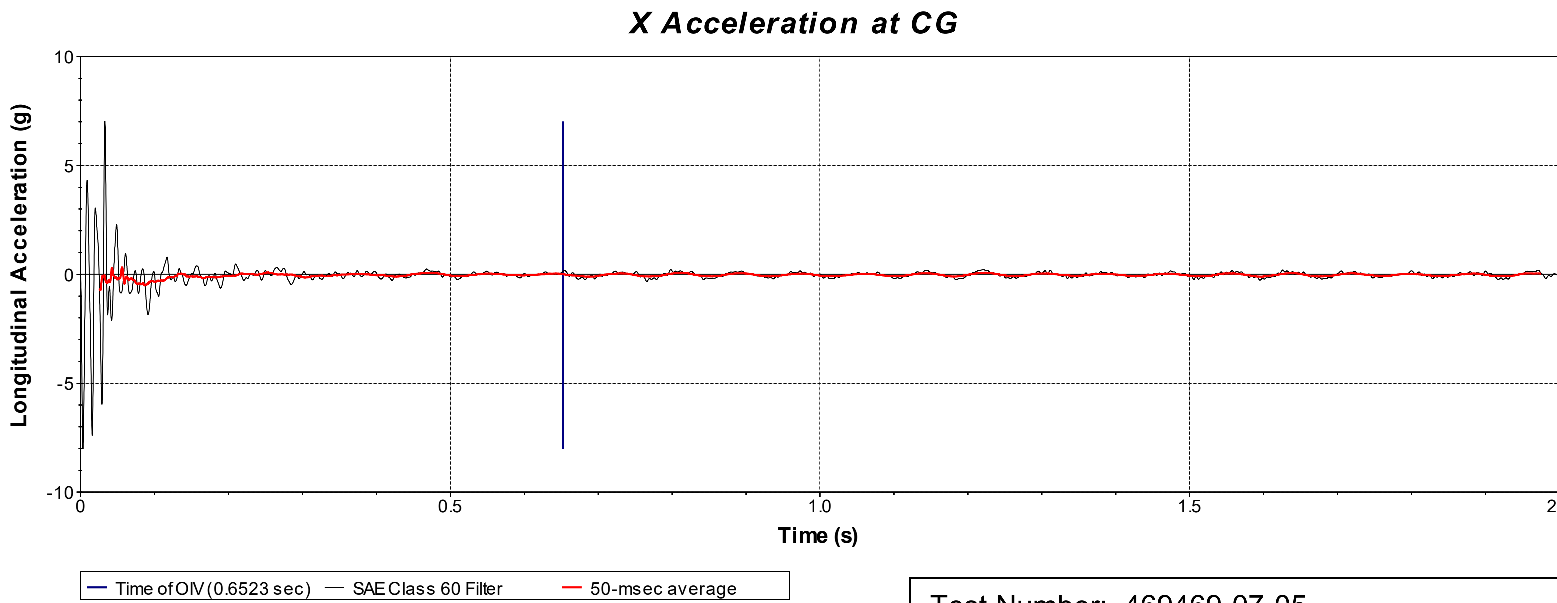


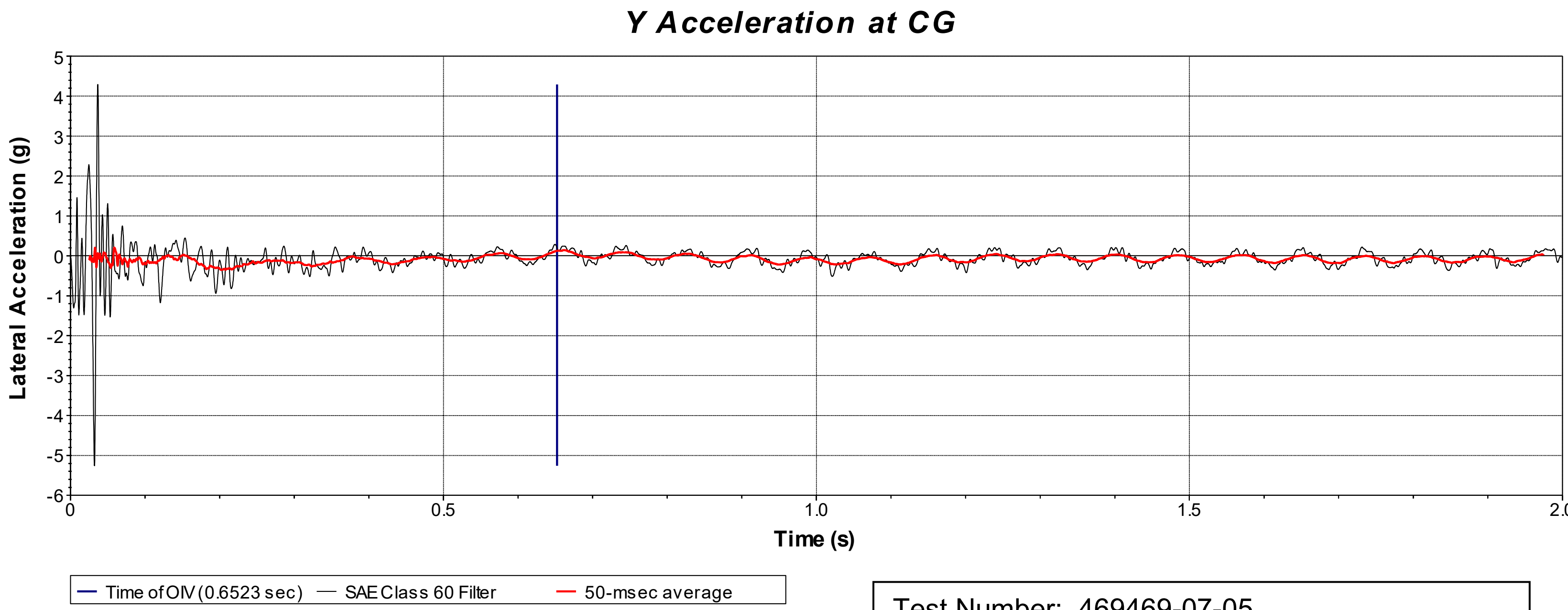
Figure G.8. Vehicle Angular Displacements for Test No. 469469-07-05.

G.2.5. Vehicle Acceleration



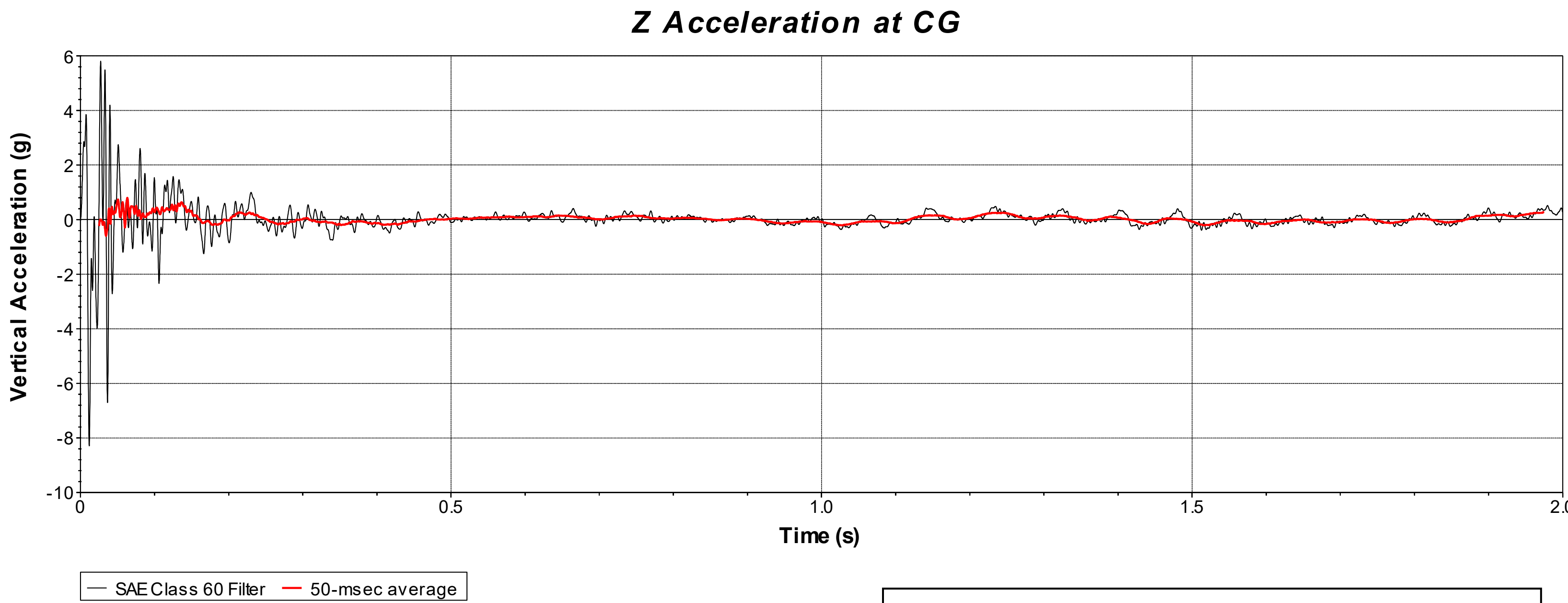
Test Number: 469469-07-05
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Embedded Unistrut® Sign Post
Test Vehicle: 2007 Kia Rio
Inertial Mass: 2450 lb
Gross Mass: 2615 lb
Impact Speed: 61.3 mi/h
Impact Angle: 0 degrees

Figure G.9. Vehicle Longitudinal Accelerometer Trace for Test No. 469469-07-05 (Accelerometer Located at Center of Gravity).



Test Number: 469469-07-05
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Embedded Unistrut® Sign Post
Test Vehicle: 2007 Kia Rio
Inertial Mass: 2450 lb
Gross Mass: 2615 lb
Impact Speed: 61.3 mi/h
Impact Angle: 0 degrees

Figure G.10. Vehicle Lateral Accelerometer Trace for Test No. 469469-07-05 (Accelerometer Located at Center of Gravity).

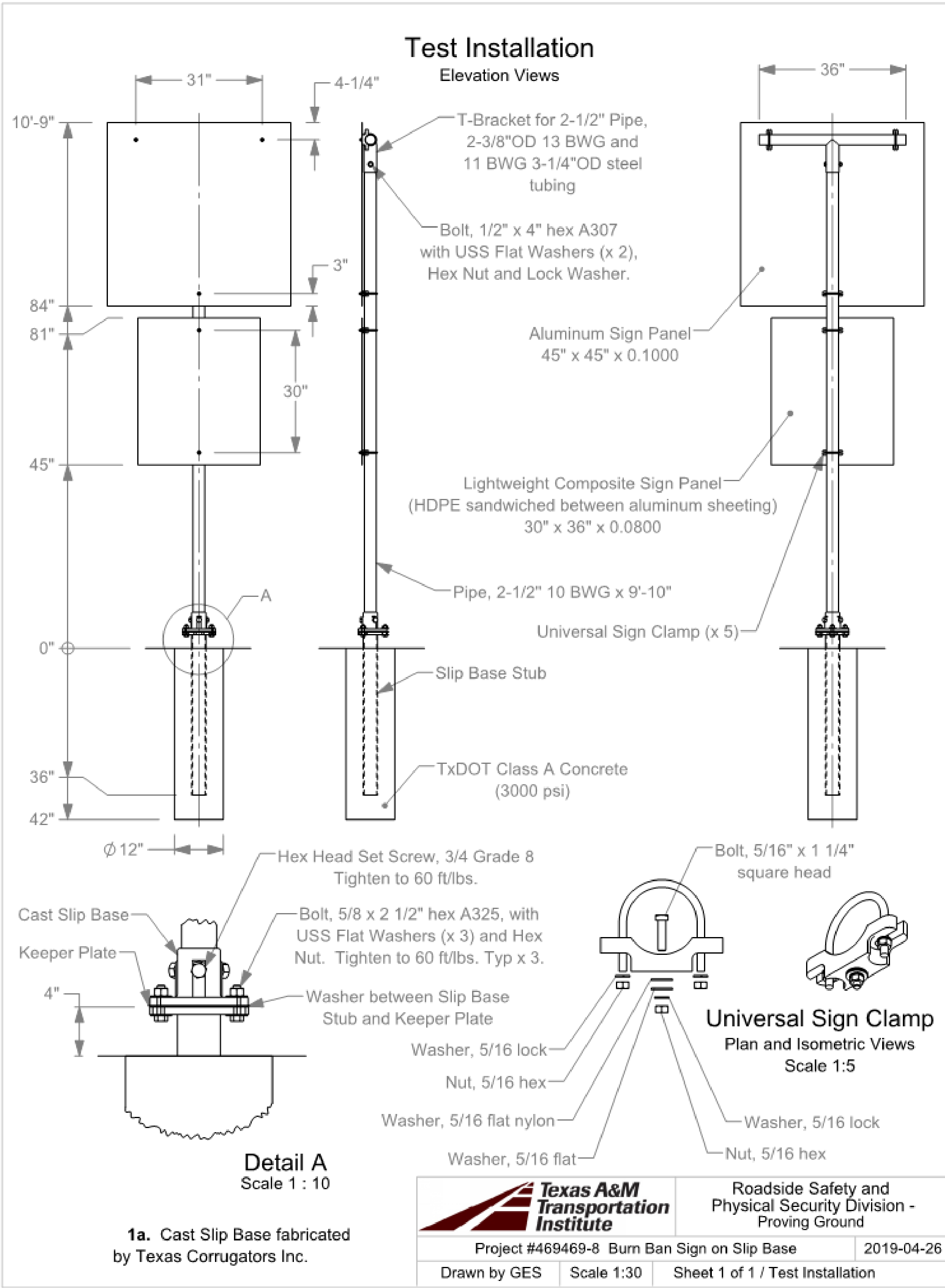


Test Number: 469469-07-05
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Embedded Unistrut® Sign Post
Test Vehicle: 2007 Kia Rio
Inertial Mass: 2450 lb
Gross Mass: 2615 lb
Impact Speed: 61.3 mi/h
Impact Angle: 0 degrees

Figure G.11. Vehicle Vertical Accelerometer Trace for Test No. 469469-07-05 (Accelerometer Located at Center of Gravity).

APPENDIX H. TXDOT BURN BAN SIGN ON SLIP BASE SUPPORT

H.1. DETAILS OF THE BURN BAN SIGN ON SLIP BASE SUPPORT



H.2. SUPPORTING CERTIFICATION DOCUMENTS

Trinity Highway Products , LLC
2548 N.E. 28th St.
Ft Worth, TX 76111

Customer: TEXAS CORRUGATORS INC
P.O.BOX 938

ROUNDROCK, TX 78680

Sales Order: 1162251
Customer PO: M-4084
BOL # 40110
Document # 1

Print Date: 1/13/12
Project: RESALE
Shipped To: TX
Use State: TX

Trinity Highway Products, LLC

Certificate Of Compliance For Trinity Industries, Inc. ** SMALL SIGNS SUPPORT **

NCHRP Report 350 Compliant

Pieces	Description
47	2.875RDBWG10@168 G210

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

TL-3 or TL-4 COMPLIANT when installed according to manufactures specifications

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT"
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM-123, UNLESS OTHERWISE STATED.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
WASHERS COMPLY WITH ASTM F-436 SPECIFICATION AND/OR F-844 AND ARE GALVANIZED IN ACCORDANCE WITH ASTM F-2329.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 49100 LB

State of Texas, County of Tarrant. Sworn and Subscribed before me this 13rd day of January, 2012

Trinity Highway Products, LLC
Certified By:
Quality Assurance

Notary Public:
Commission Expires

JOMARY LUGINSLAND
MY COMMISSION EXPIRES
May 24, 2015

1 of 1

Trinity Highway Products , LLC
2548 N.E. 28th St.
Ft Worth, TX 76111

Customer: TEXAS CORRUGATORS INC P.O.BOX 938 ROUNDROCK, TX 78680	Sales Order: 1161514 Customer PO: m-4066 BOL # 39889 Document # 1	Print Date: 12/29/11 Project: RESALE Shipped To: Use State: TX

Trinity Highway Products, LLC

Certificate Of Compliance For Trinity Industries, Inc. ** SMALL SIGNS SUPPORT **

NCHRP Report 350 Compliant

Pieces	Description
68	2.875RDBWG10@192 G210

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

TL-3 or TL-4 COMPLIANT when installed according to manufactures specifications

8-594596

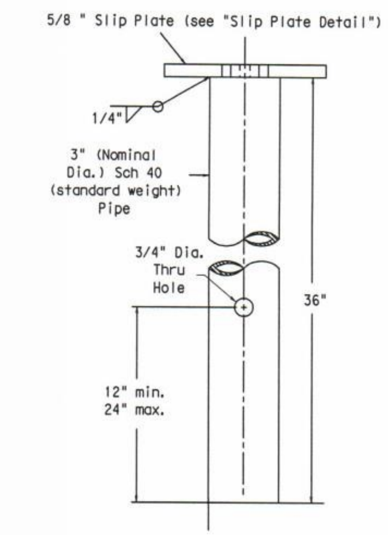
ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL COATINGS PROCESSES OF THE STEEL OR IRON ARE PERFORMED IN USA AND COMPLIES WITH THE "BUY AMERICA ACT"
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM-123, UNLESS OTHERWISE STATED.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
WASHERS COMPLY WITH ASTM F-436 SPECIFICATION AND/OR F-844 AND ARE GALVANIZED IN ACCORDANCE WITH ASTM F-2329.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 49100 LB

State of Texas, County of Tarrant. Sworn and Subscribed before me this 29th day of December, 2011

Trinity Highway Products, LLC
Certified By:
Quality Assurance

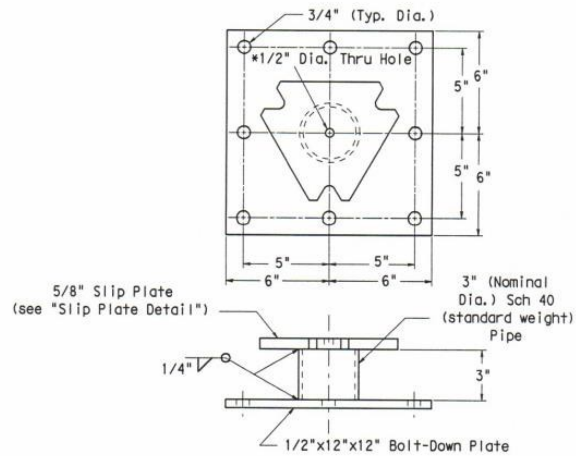
Notary Public:
Commission Expires:

JOMARY LUGINSLAND
MY COMMISSION EXPIRES
May 24, 2015



Pipe shall conform to ASTM A53 Gr B, A500 Gr B, or A501. Galvanize according to ASTM A123 after all fabrication is completed. Finished components shall be permanently marked to indicate manufacturer. Method, design and location of markings are subject to the approval of the TxDOT Traffic Standards Engineer.

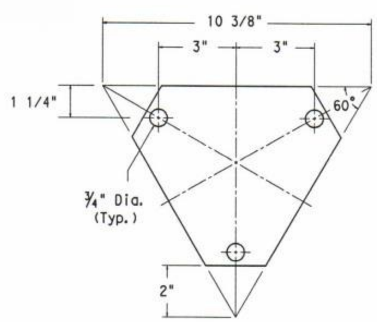
STUB



Pipe shall conform to ASTM A53 Gr B, A500 Gr B, or A501. Bolt-down plate shall conform to the same material requirements specified for the slip plate. Galvanize according to ASTM A123 after all fabrication is completed. Finished components shall be permanently marked to indicate manufacturer. Method, design and location of markings are subject to the approval of the TxDOT Traffic Standards Engineer.

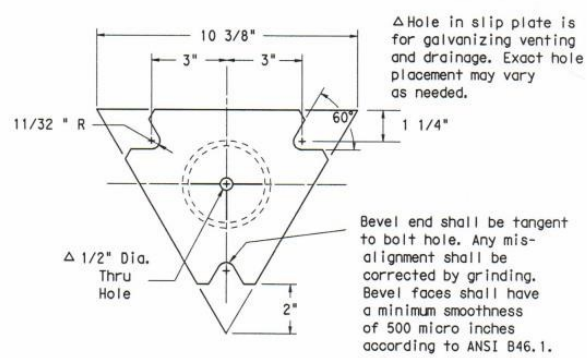
* Hole in slip plate and bolt-down plate is for galvanizing venting and drainage. Exact hole placement may vary as needed.

BOLT-DOWN ANCHOR



Bolt Keeper Plate shall be manufactured from 26 to 30 gauge galvanized sheet steel.

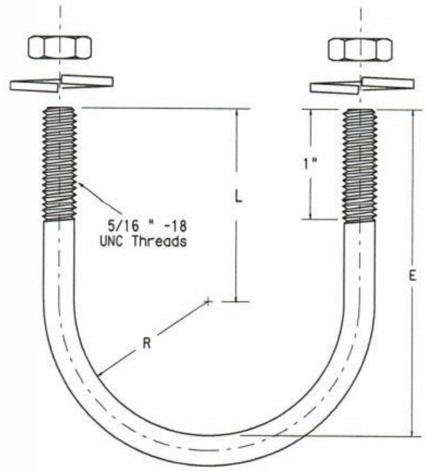
BOLT KEEPER PLATE



Slip plate shall conform to ASTM A36 or A572.

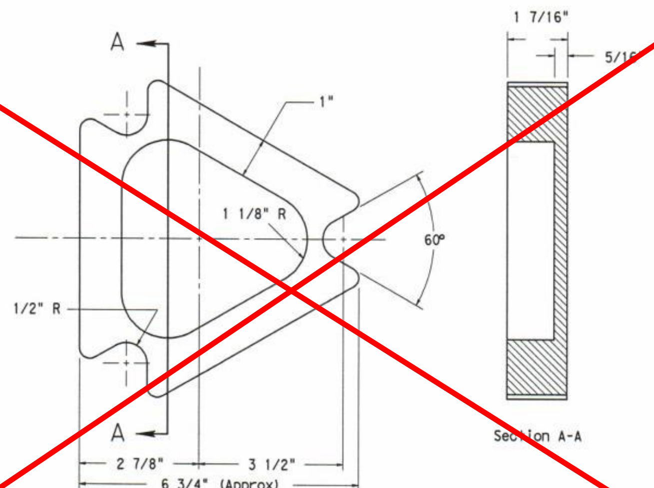
SLIP PLATE DETAIL

11.25.02



Standard Pipe Size	R	L	E
2"	1 7/32"	1 15/32"	2 11/16"
2 1/2"	1 15/32"	1 23/32"	3 3/16"
3"	1 25/32"	2 1/32"	3 13/16"

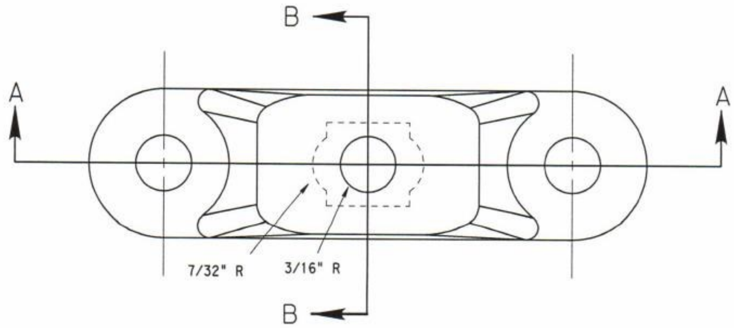
SIGN CLAMP U-BOLT

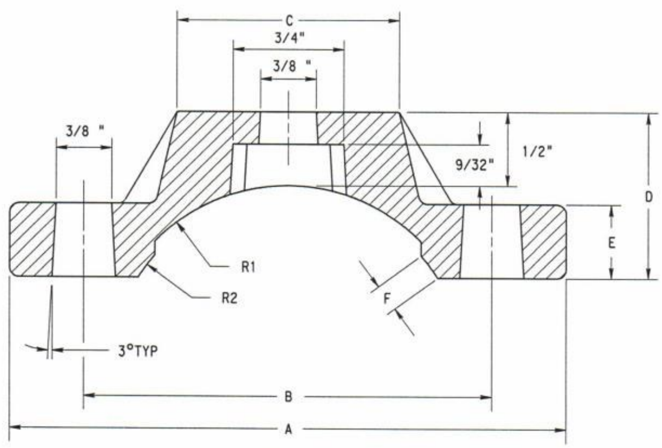


Lifting spacer shall be manufactured from 100% recycled ABS or polycarbonate plastic.
Sides may be slightly tapered to facilitate release of part from the mold.

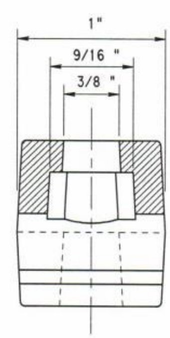
LIFTING SPACER

11.25.02





SECTION A - A



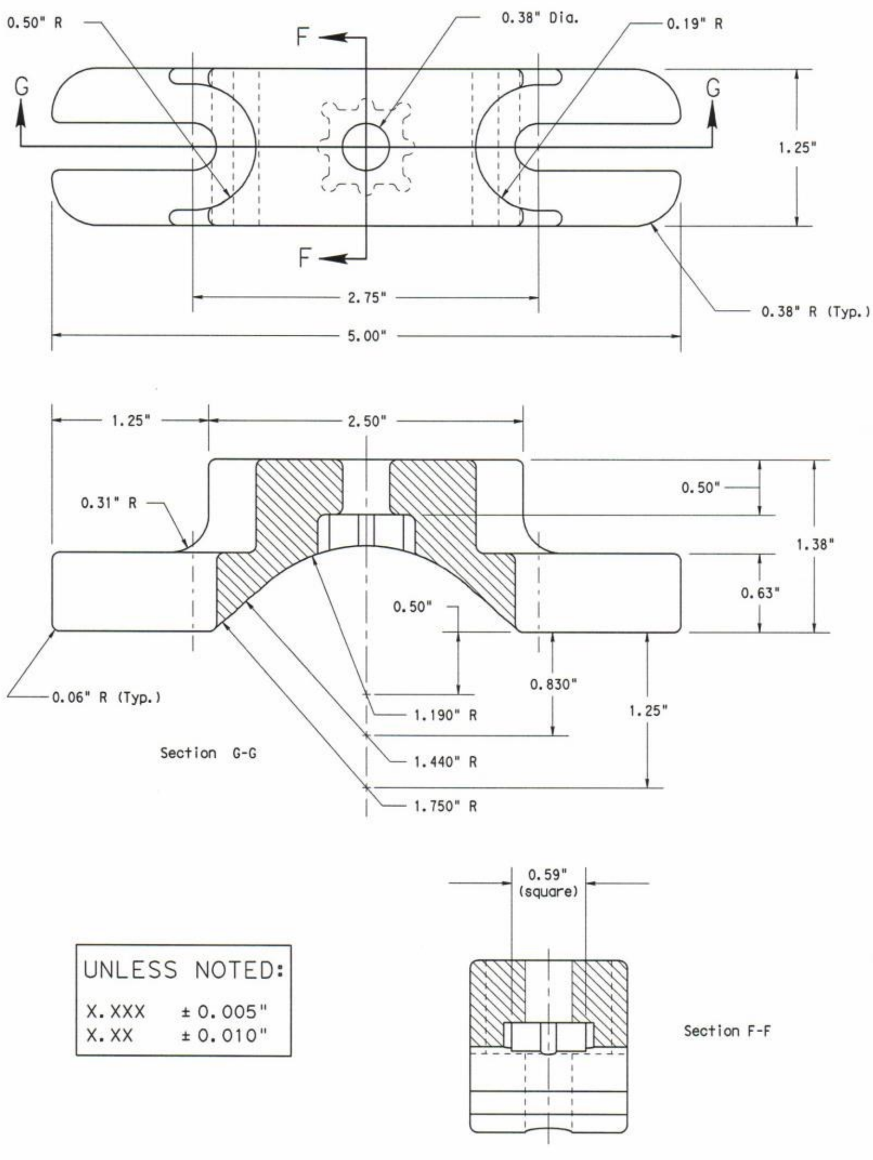
SECTION B - B

DIMENSIONS								
PIPE DIAMETER (NOMINAL)	A	B	C	D	E	F	R1	R2
2	3 3/4	2 3/4	1 1/2	1 1/8	1/2	3/16	1 1/4	1 3/16
2 1/2	4 1/4	3 1/4	2	1 1/4	1/2	1/4	1 1/2	1 7/16
3	4 7/8	3 7/8	2 1/2	1 3/8	5/8	1/4	1 13/16	1 3/4

Sign clamp casting shall meet ASTM B85 Alloy 360.0 or A360.0, ASTM B26 Alloy 356.0-F, or ASTM B108 Alloy 356.0-F or A444.0-T4.

SPECIFIC SIGN CLAMP

11.25.02

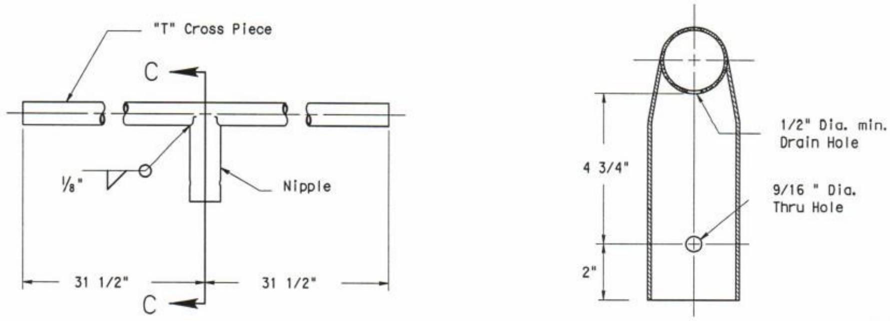


UNLESS NOTED:	
X.XXX	± 0.005"
X.XX	± 0.010"

Sign clamp casting shall meet ASTM B85 Alloy 360.0 or A360.0, ASTM B26 Alloy 356.0-F, or ASTM B108 Alloy 356.0-F or A444.0-T4.

UNIVERSAL SIGN CLAMP

11.25.02



Section C-C

"T" CROSS PIECE

13 BWG Tubing (2.375" outside diameter)
0.095" nominal wall thickness
Seamless or electric-resistance welded steel tubing
Steel shall be HSLAS Gr 55 per ASTM A1011 or ASTM A1008
Other steels may be used if they meet the following:
55,000 PSI minimum yield strength
70,000 PSI minimum tensile strength
18% minimum elongation in 2"
Wall thickness (uncoated) shall be within the range of 0.085" to 0.105"
Outside diameter (uncoated) shall be within the range of 2.355" to 2.395"

NIPPLE

11 BWG or greater Tubing (3.25" outside diameter)
Seamless or electric-resistance welded steel tubing
Steel shall be HSLAS Gr 55 per ASTM A1011 or ASTM A1008
Other steels may be used if they meet the following:
55,000 PSI minimum yield strength
70,000 PSI minimum tensile strength
20% minimum elongation in 2"
Outside diameter (uncoated) shall be within the range of 3.241" to 3.259"
Inside diameter (uncoated) shall be a minimum of 2.93"
Wall thickness shall be a minimum of 0.108"
Cut length shall be 8.000" ± 0.250". Notched and coped to provide snug fit with cross piece.
Drilled or punched as shown. Nipple shall provide snug fit with 2.875" post.
Nipple may be dimpled to provide snug fit.

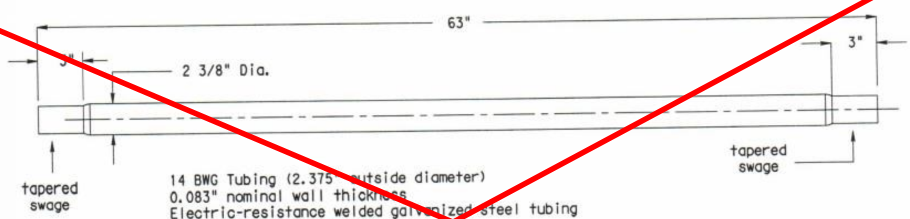
FABRICATED "T" BRACKET

Galvanize according to ASTM A123 after all fabrication is completed.

Finished components shall be permanently marked to indicate manufacturer. Method, design and location of markings are subject to the approval of the TxDOT Traffic Standards Engineer.

PREFABRICATED "T" BRACKET-TEXAS UNIVERSAL TRIANGULAR SLIPBASE SYSTEM

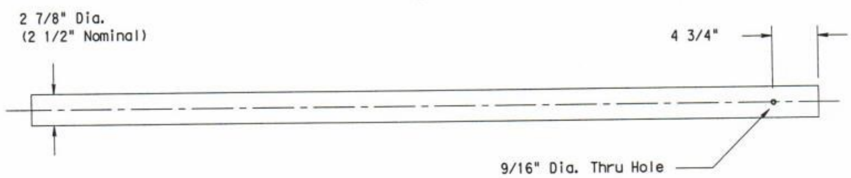
11.25.02



14 BWG Tubing (2.375" outside diameter)
0.083" nominal wall thickness
Electric-resistance welded galvanized steel tubing
Steel shall be SS Gr 40 per ASTM A653
Galvanization per ASTM A653 G210. Recoat tube outside diameter weld seam by
metallizing with zinc wire per ASTM B833.
Outside diameter (coated) shall be within the range of 2.369" to 2.381"
Tapered swage to provide snug fit in 2.375" 13 BWG to 10 BWG tubing.

Finished components shall be permanently marked to indicate manufacturer. Method, design and location of markings are subject to the approval of the TxDOT Traffic Standards Engineer.

EXTENDER



10 BWG Tubing (2.875" outside diameter)

0.134" nominal wall thickness
Seamless or electric-resistance welded steel tubing or pipe
Steel shall be HSLAS Gr 55 per ASTM A1011 or ASTM A1008
Other steels may be used if they meet the following:
- 55,000 PSI minimum yield strength
- 70,000 PSI minimum tensile strength
- 20% minimum elongation in 2"

Wall thickness (uncoated) shall be within the range of 0.122" to 0.138"
Outside diameter (uncoated) shall be within the range of 2.867" to 2.883"
Galvanization per ASTM A123 or ASTM A653 G210. For precoated steel tubing (ASTM A653), recoat tube outside diameter weld seam by metallizing with zinc wire per ASTM B833.

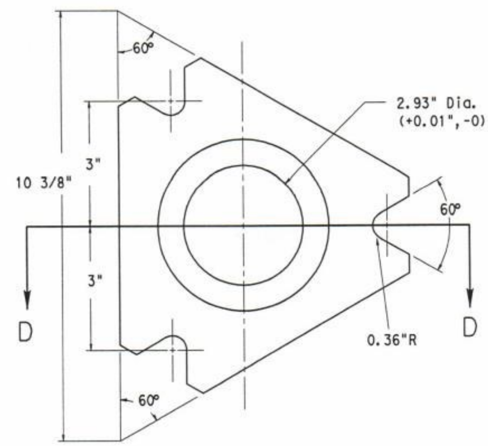
Schedule 80 Pipe (2.875" outside diameter)

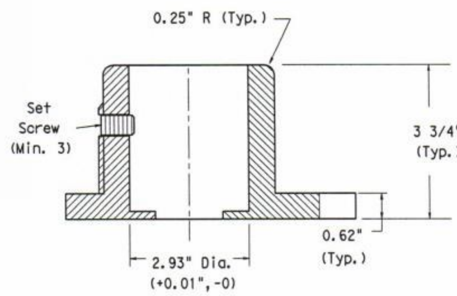
0.276" nominal wall thickness
Steel tubing per ASTM A500 Gr C
Other seamless or electric-resistance welded steel tubing or pipe with equivalent outside diameter and wall thickness may be used if they meet the following:
- 46,000 PSI minimum yield strength
- 62,000 PSI minimum tensile strength
- 21% minimum elongation in 2"

Wall thickness (uncoated) shall be within the range of 0.248" to 0.304"
Outside diameter (uncoated) shall be within the range of 2.855" to 2.895"
Galvanization per ASTM A123.

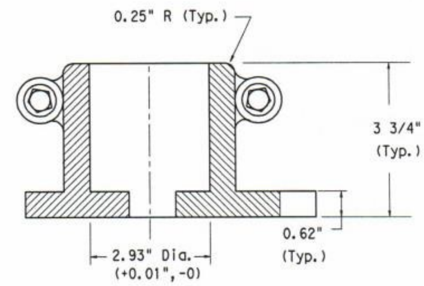
POST

11.25.02





Set Screw type Section D-D



Bolt Clamp type Section D-D

Steel Slipbase fabrication shall conform to ASTM A36 or A572, if fabrication consists of ductile iron casting it shall conform to ASTM A536 Grade 65-45-12 and be galvanized per ASTM a153 Class A.

Finished components shall be permanently marked to indicate manufacturer. Method, design and location of markings are subject to the approval of the TxDOT Traffic Standards Engineer.

A list of approved Triangular Slip bases can be found at
http://www.txdot.gov/business/producer_list.htm

SLIPBASE DETAIL

7.24.08

H.3. *MASH* TEST 3-61 (CRASH TEST NO. 469469-08-01)

H.3.1. Vehicle Properties and Information

Table H.1. Vehicle Properties for Test No. 469469-08-01.

Vehicle Inventory Number: 1398

Date: 2019-04-26 Test No.: 469469-08-1 VIN No.: KNADE123076186031

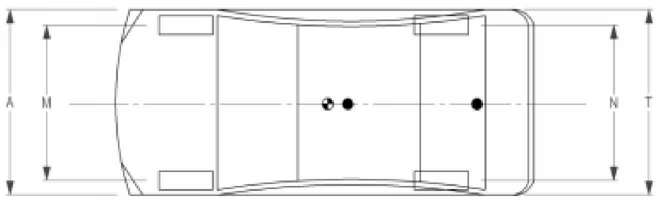
Year: 2007 Make: Kia Model: Rio

Tire Inflation Pressure: 32 PSI Odometer: 96458 Tire Size: 185/65R14

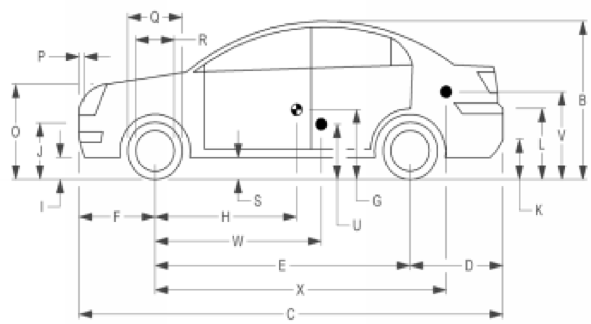
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES:



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



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

Geometry: inches

A	66.38	F	33.00	K	12.25	P	4.12	U	14.75
B	51.50	G		L	25.25	Q	22.50	V	20.50
C	165.75	H	36.06	M	57.75	R	15.50	W	36.00
D	34.00	I	7.75	N	57.70	S	8.25	X	72.50
E	98.75	J	21.50	O	27.00	T	66.20		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00 W-H 0.00

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Bottom of Hood Lip) = 24 ±4 inches
TOP OF RADIATOR SUPPORT = 28.25 inches; (M+N)/2 = 56 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1570	1535	1620
Back	1874	M_{rear}	897.00	883	963.00
Total	3638	M_{Total}	2467	2418	2583

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

Mass Distribution:
lb LF: 797 RF: 738 LR: 423 RR: 460

Table H.2. Exterior Crush Measurements of Vehicle for Test No. 469469-08-01.

Vehicle Inventory Number: 1398

Date:	2019-04-26	Test No.:	469469-08-1	VIN No.:	KNADE123076186031
Year:	2007	Make:	Kia	Model:	Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

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

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

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

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

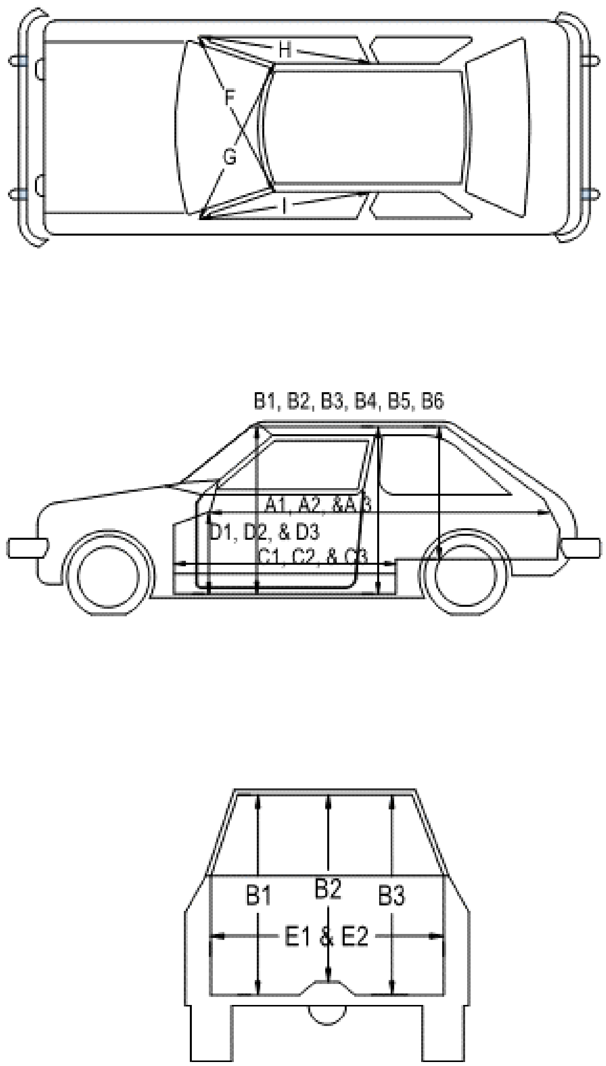
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

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

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

Table H.3. Occupant Compartment Measurements of Vehicle for Test No. 469469-08-01.

		Vehicle Inventory Number:	1398		
Date:	2019-04-26	Test No.:	469469-08-1	VIN No.:	KNADE123076186031
Year:	2007	Make:	Kia	Model:	Rio



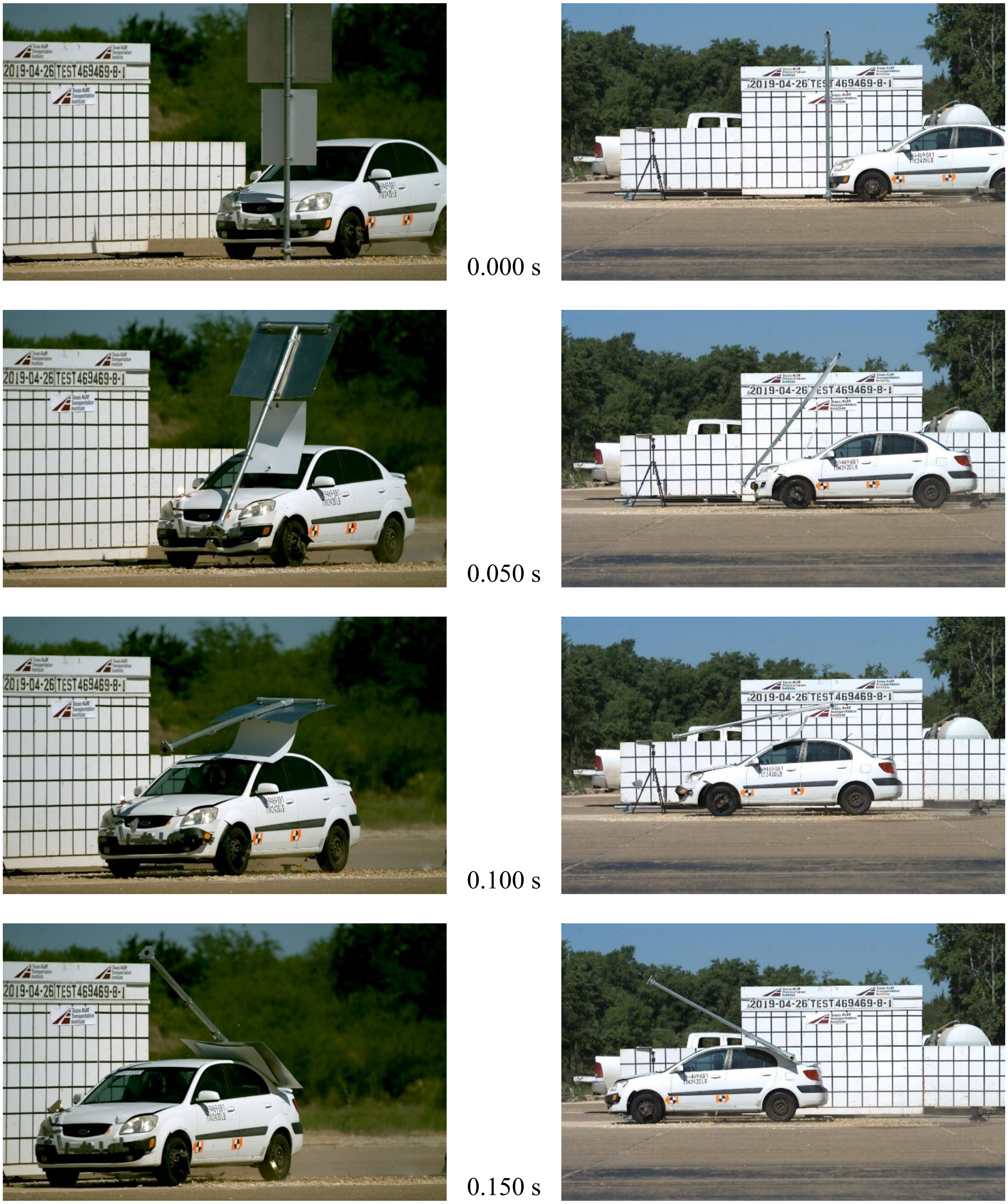
OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

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

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

Performed by: ***SCD*** Date: 2019-04-26

H.3.2. Sequential Photographs



0.000 s

0.050 s

0.100 s

0.150 s

Figure H.1. Sequential Photographs for Test No. 469469-08-01

(Oblique and Right Angle views).

0.200 s

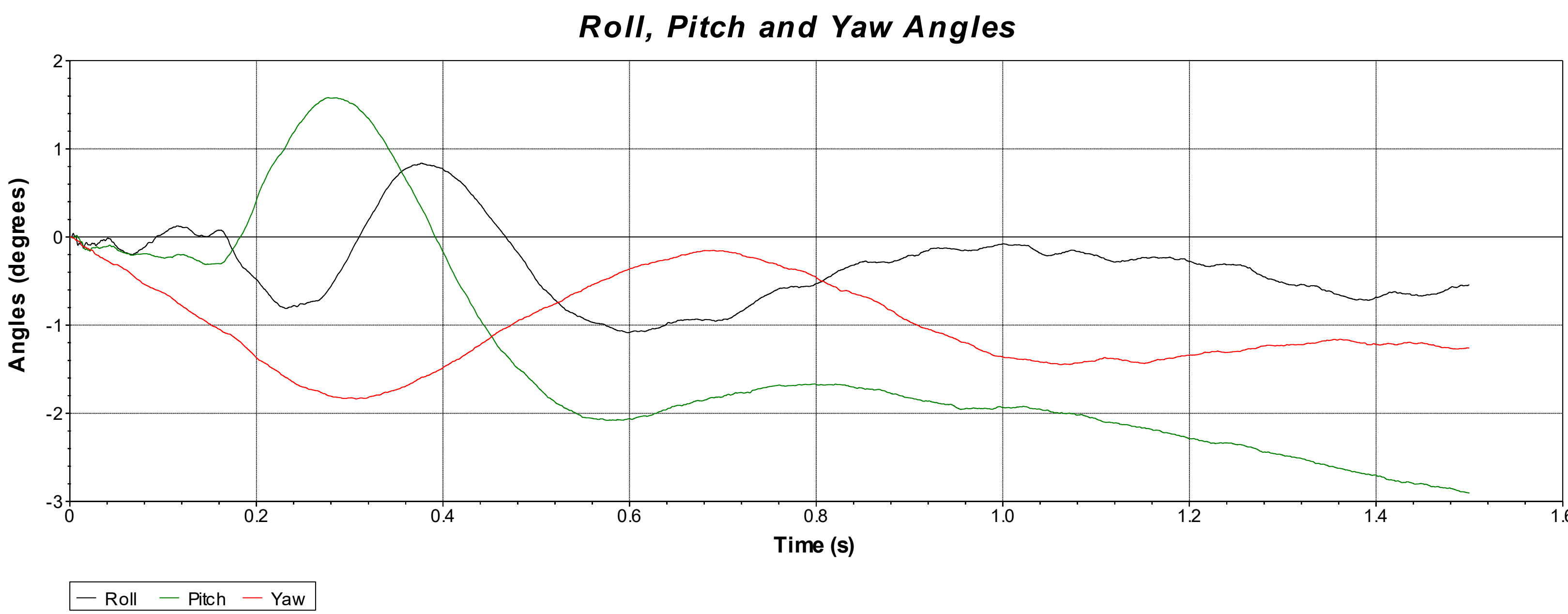
0.250 s

0.300 s

0.350 s

Figure A.1. Sequential Photographs for Test No. 469469-08-01 (Oblique and Right Angle views) (Continued).

H.3.3. Vehicle Angular Displacement



Test Number: 469469-08-01
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Burn Ban Sign with Slip Base
Test Vehicle: 2007 Kia Rio
Inertial Mass: 2418 lb
Gross Mass: 2583 lb
Impact Speed: 62.9 mi/h
Impact Angle: 0 degrees

Axes are vehicle-fixed.
Sequence for determining orientation:

34. Yaw.
35. Pitch.
36. Roll.

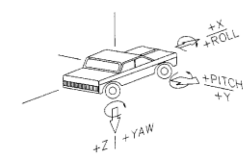


Figure H.2. Vehicle Angular Displacements for Test No. 469469-08-01.

H.3.4. Vehicle Acceleration

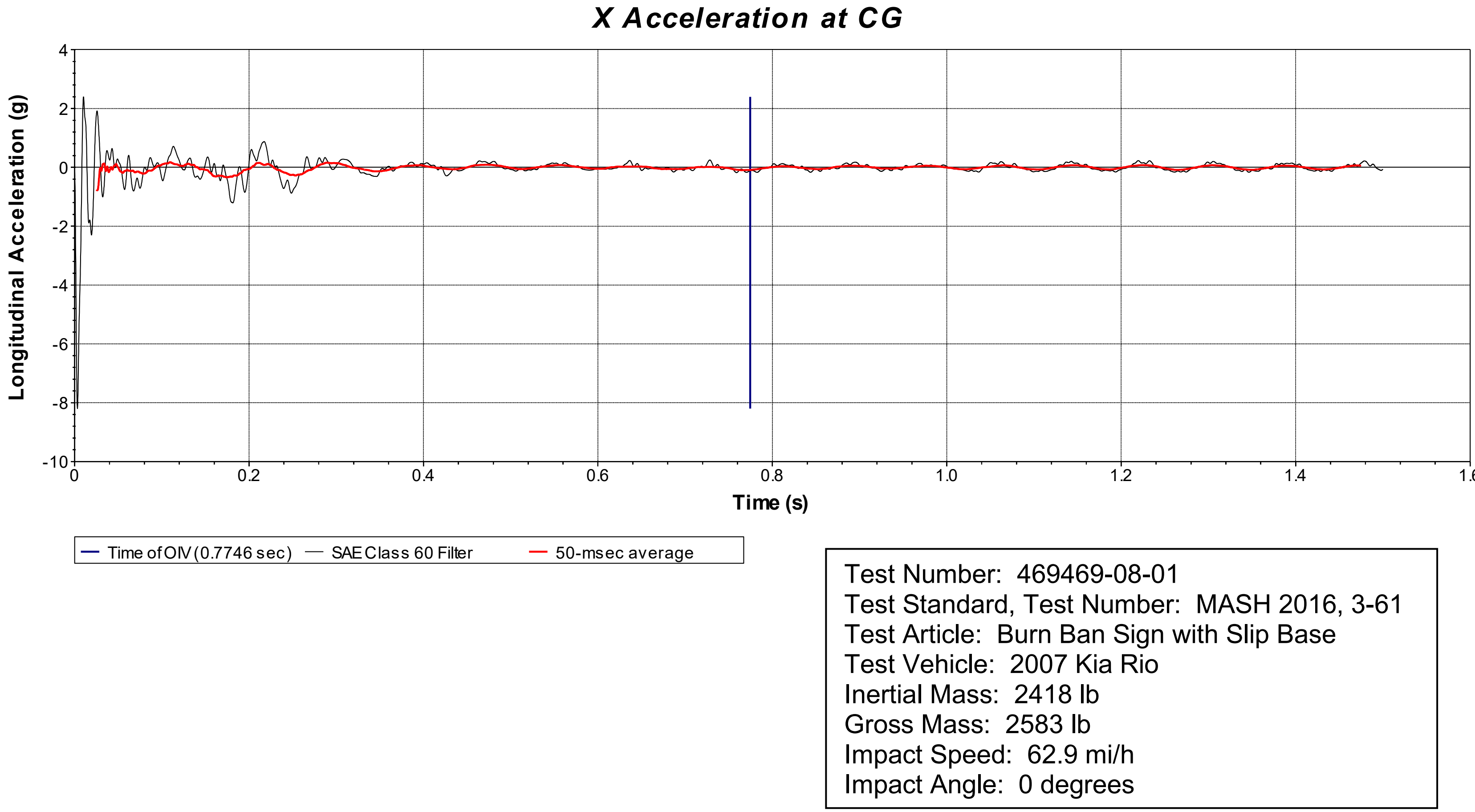
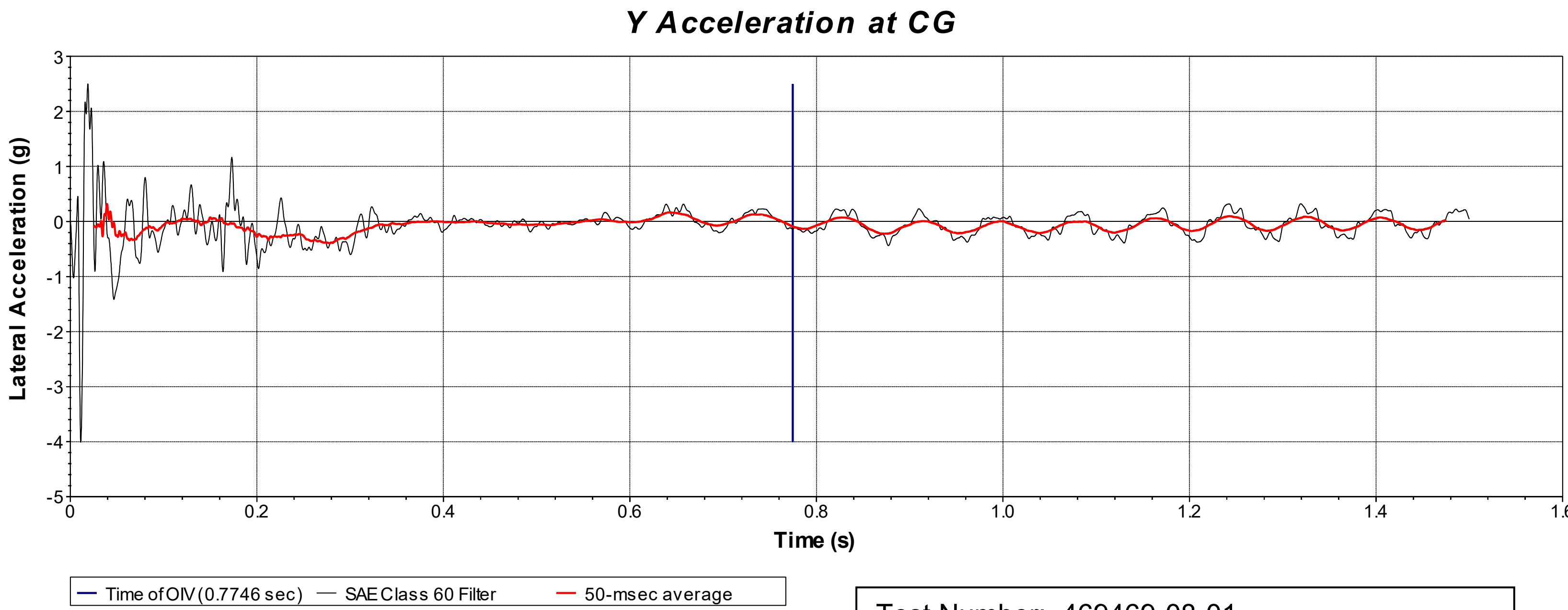


Figure H.3. Vehicle Longitudinal Accelerometer Trace for Test No. 469469-08-01 (Accelerometer Located at Center of Gravity).



Test Number: 469469-08-01
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Burn Ban Sign with Slip Base
Test Vehicle: 2007 Kia Rio
Inertial Mass: 2418 lb
Gross Mass: 2583 lb
Impact Speed: 62.9 mi/h
Impact Angle: 0 degrees

Figure H.4. Vehicle Lateral Accelerometer Trace for Test No. 469469-08-01 (Accelerometer Located at Center of Gravity).

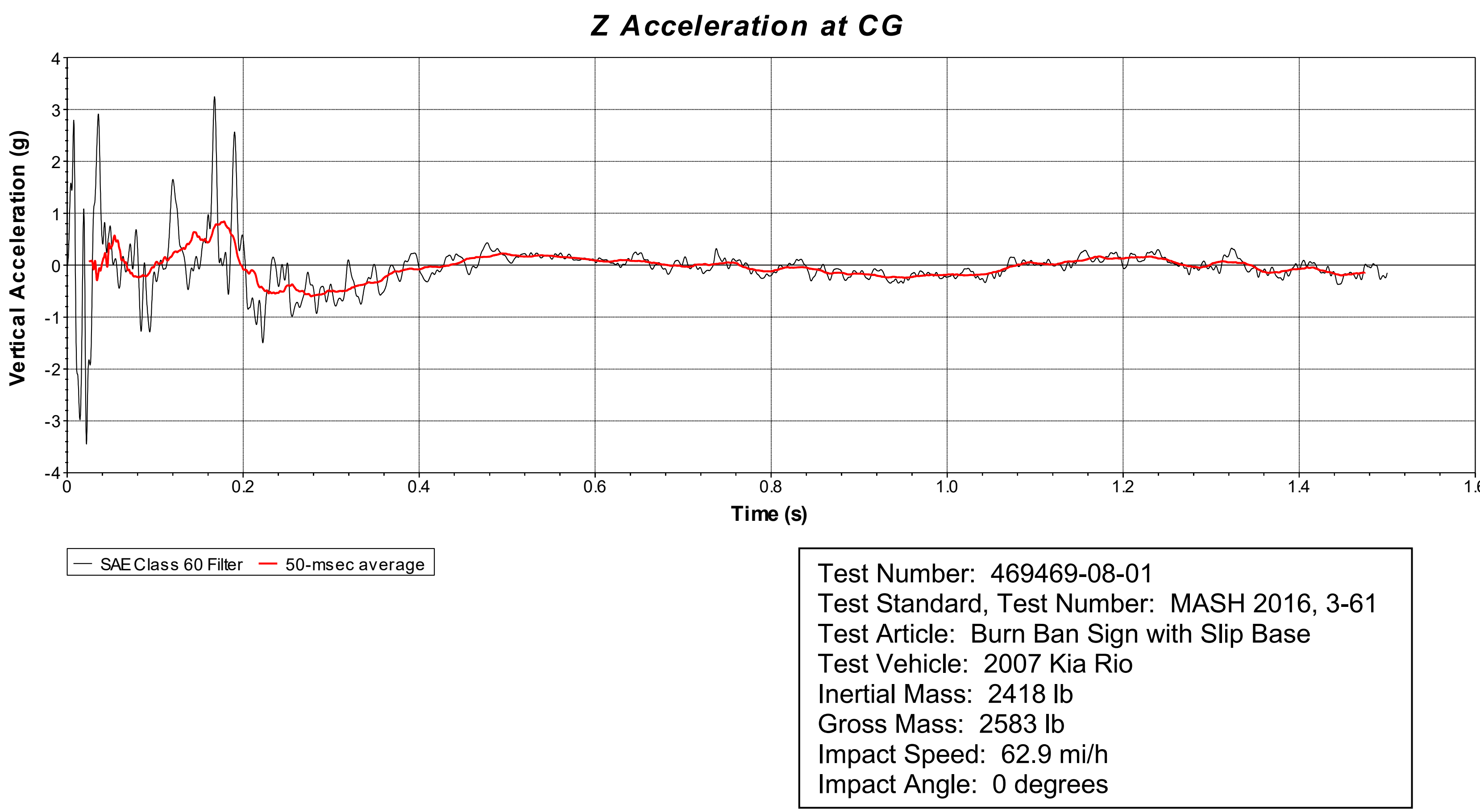
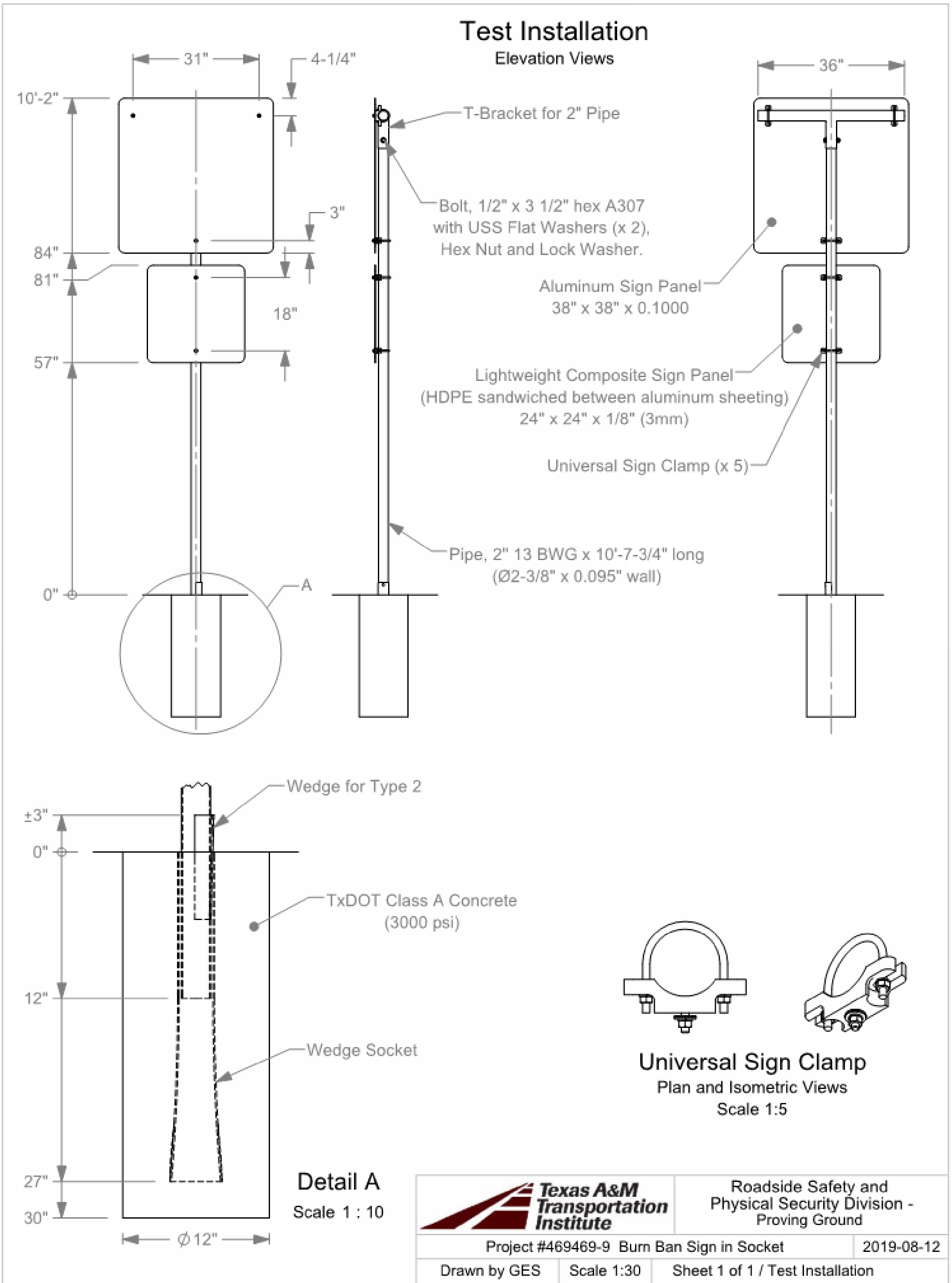


Figure H.5. Vehicle Vertical Accelerometer Trace for Test No. 469469-08-01 (Accelerometer Located at Center of Gravity).

APPENDIX I. TXDOT BURN BAN SIGN ON WEDGE AND SOCKET SUPPORT

I.1. DETAILS OF THE BURN BAN SIGN ON WEDGE AND SOCKET SUPPORT



I.2. *MASH* TEST 3-61 (CRASH TEST NO. 469469-09-01)

I.2.1. Vehicle Properties and Information

Table I.1. Vehicle Properties for Test No. 469469-09-01.

Vehicle Inventory Number: 1390

Date: 2019-08-14 Test No.: 469469-9-1 VIN No.: KNADE123086316648

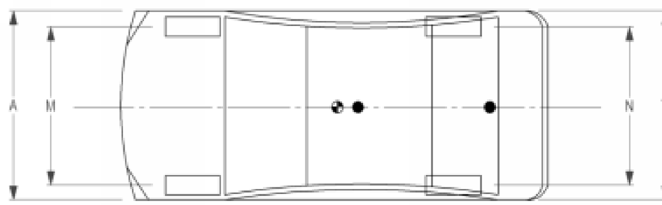
Year: 2008 Make: Kia Model: Rio

Tire Inflation Pressure: 32 PSI Odometer: 241986 Tire Size: 185/65R14

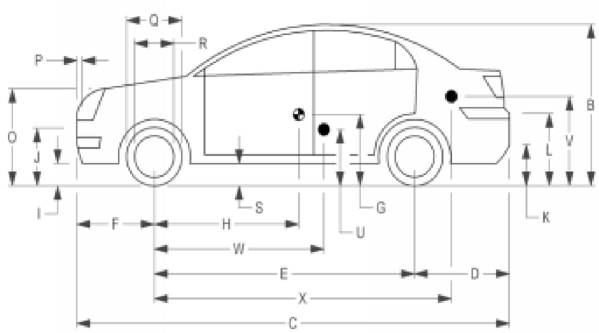
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES:



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



Dummy Data:
Type: 50th Percentile Male
Mass: 165 lb
Seat Position: OPPSITE IMPACT

Geometry: inches

A	66.38	F	33.00	K	12.25	P	4.12	U	14.75
B	51.50	G		L	25.25	Q	22.50	V	20.75
C	165.75	H	35.28	M	57.75	R	15.50	W	35.25
D	34.00	I	7.75	N	57.70	S	8.25	X	71.50
E	98.75	J	21.50	O	27.00	T	66.20		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00 W-H 0.00

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Bottom of Hood Lip) = 24 ±4 inches
TOP OF RADIATOR SUPPORT = 28.25 inches; (M+N)/2 = 56 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1598	1565	1650
Back	1874	M_{rear}	861.00	870	950.00
Total	3638	M_{Total}	2459	2435	2600

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

Mass Distribution:
lb LF: 768 RF: 797 LR: 450 RR: 420

Performed by: SCD Date: 2019-08-14

Table I.2. Exterior Crush Measurements of Vehicle for Test No. 469469-09-01.

Vehicle Inventory Number: 1390

Date:	2019-08-14	Test No.:	469469-9-1	VIN No.:	KNADE123086316648
Year:	2008	Make:	Kia	Model:	Rio

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) (check one)	Bowing constant
< 4 inches ______	$\frac{X1+X2}{2}$ = ______
≥ 4 inches ______	

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

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

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

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

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

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

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

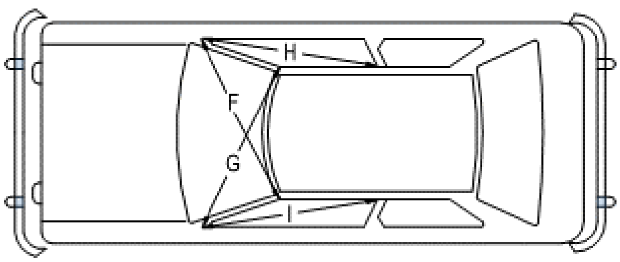
Note: Use as many lines/columns as necessary to describe each damage profile.

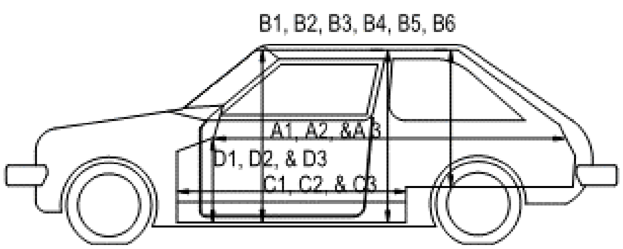
Performed by: *SCD* Date: 2019-08-14

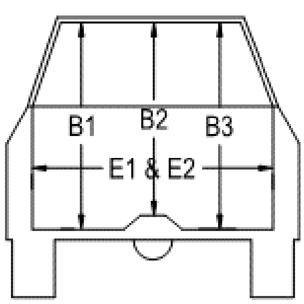
Table I.3. Occupant Compartment Measurements of Vehicle for Test No. 469469-09-01.

Vehicle Inventory Number: 1390

Date:	2019-08-14	Test No.:	469469-9-1	VIN No.:	KNADE123086316648
Year:	2008	Make:	Kia	Model:	Rio







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

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

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

Performed by: ***SCD*** Date: 2019-08-14

I.2.2. Sequential Photographs

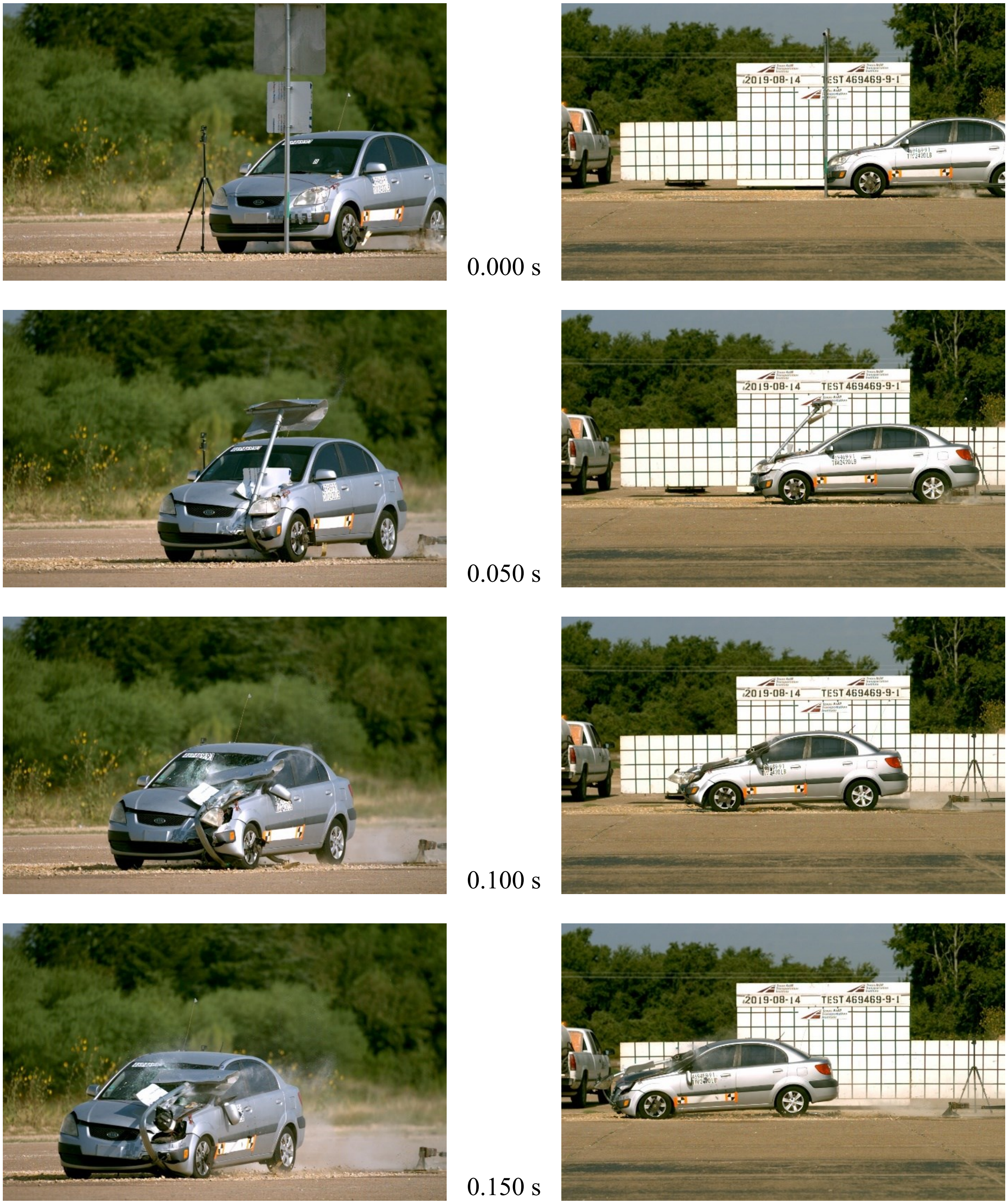


Figure I.1. Sequential Photographs for Test No. 469469-09-01

(Oblique and Right Angle views).

0.200 s

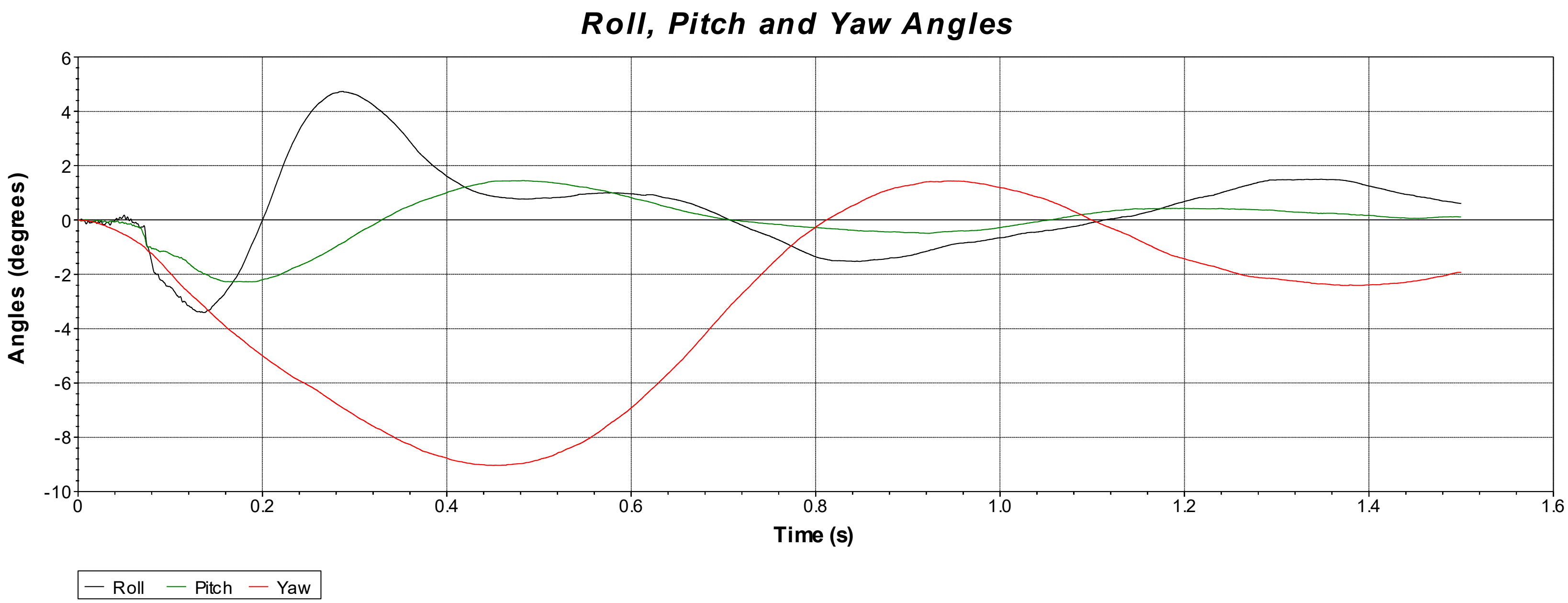
0.250 s

0.300 s

0.350 s

Figure A.1. Sequential Photographs for Test No. 469469-09-01 (Oblique and Right Angle views) (Continued).

I.2.3. Vehicle Angular Displacement



Test Number: 469469-09-01
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Burn Ban sign on wedge and socket support
Test Vehicle: 2008 Kia Rio
Inertial Mass: 2435 lb
Gross Mass: 2600 lb
Impact Speed: 63.7 mi/h
Impact Angle: 0 degrees

Axes are vehicle-fixed.
Sequence for determining orientation:

37. Yaw.
38. Pitch.
39. Roll.

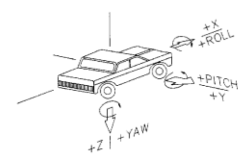
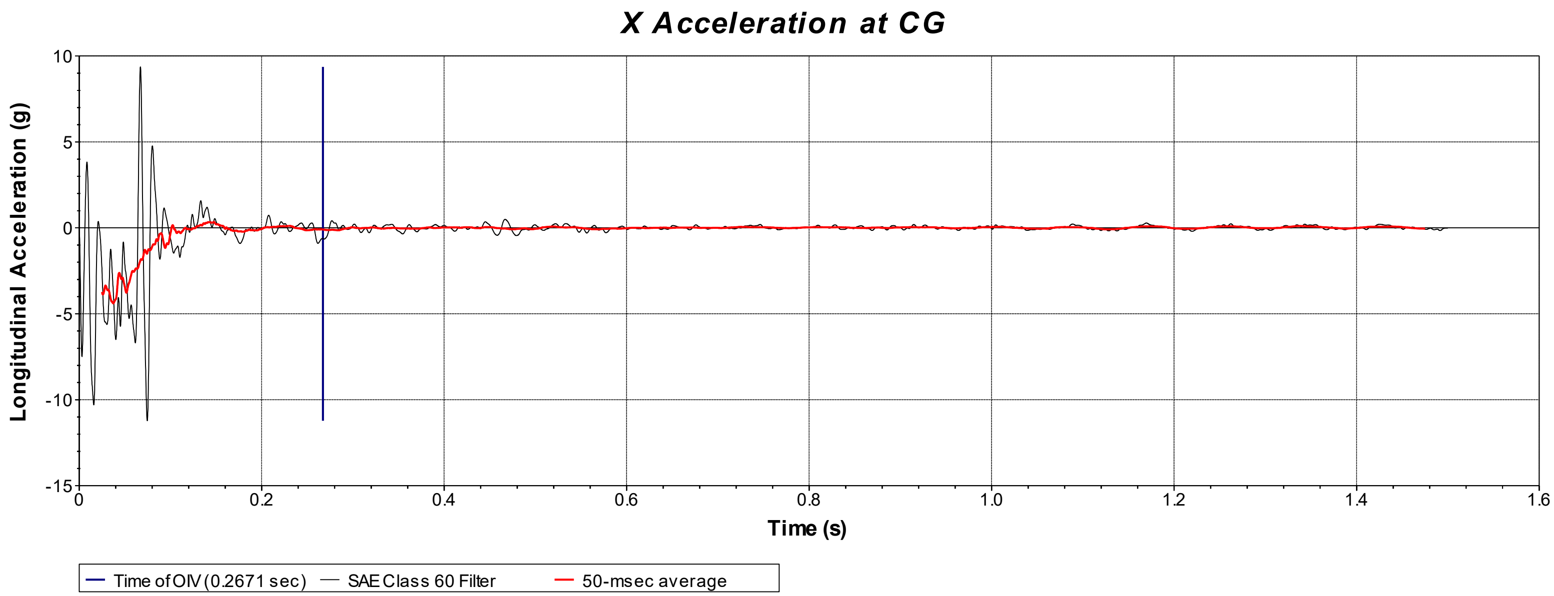


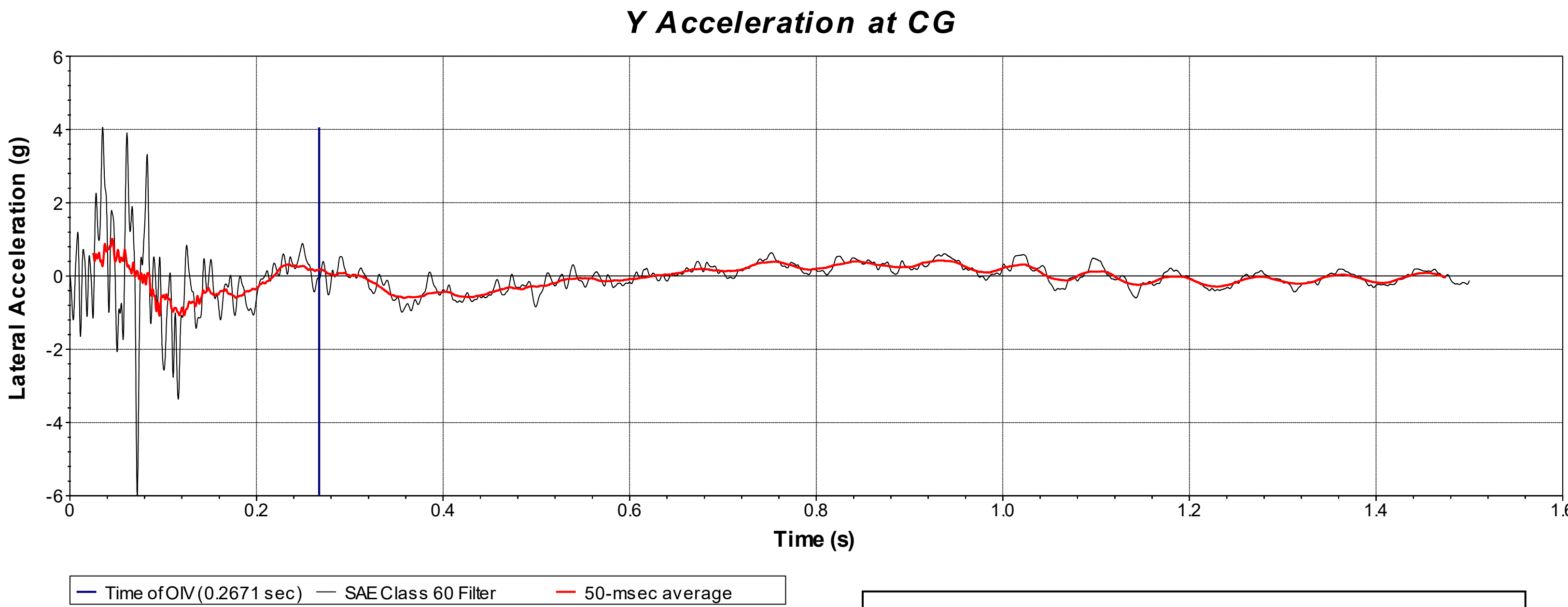
Figure I.2. Vehicle Angular Displacements for Test No. 469469-09-01.

I.2.4. Vehicle Acceleration



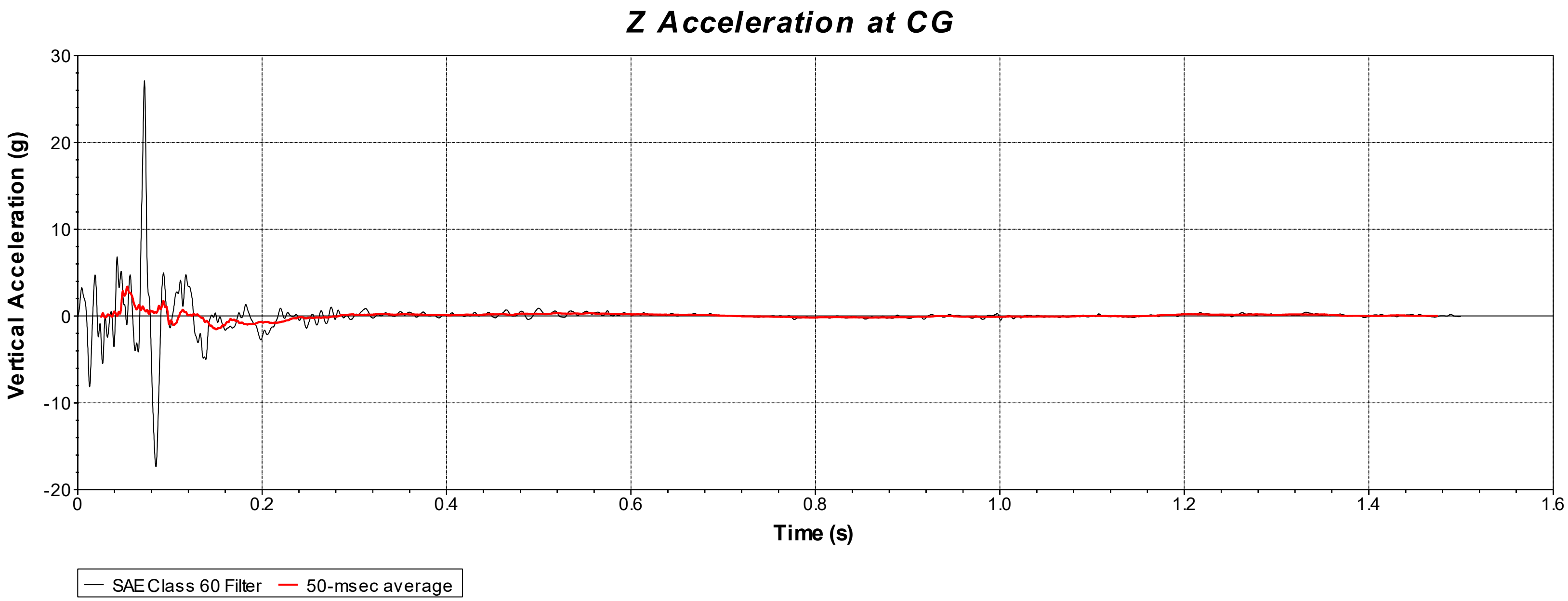
Test Number: 469469-09-01
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Burn Ban sign on wedge and socket support
Test Vehicle: 2008 Kia Rio
Inertial Mass: 2435 lb
Gross Mass: 2600 lb
Impact Speed: 63.7 mi/h
Impact Angle: 0 degrees

Figure I.3. Vehicle Longitudinal Accelerometer Trace for Test No. 469469-09-01 (Accelerometer Located at Center of Gravity).



Test Number: 469469-09-01
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Burn Ban sign on wedge and socket support
Test Vehicle: 2008 Kia Rio
Inertial Mass: 2435 lb
Gross Mass: 2600 lb
Impact Speed: 63.7 mi/h
Impact Angle: 0 degrees

Figure I.4. Vehicle Lateral Accelerometer Trace for Test No. 469469-09-01 (Accelerometer Located at Center of Gravity).



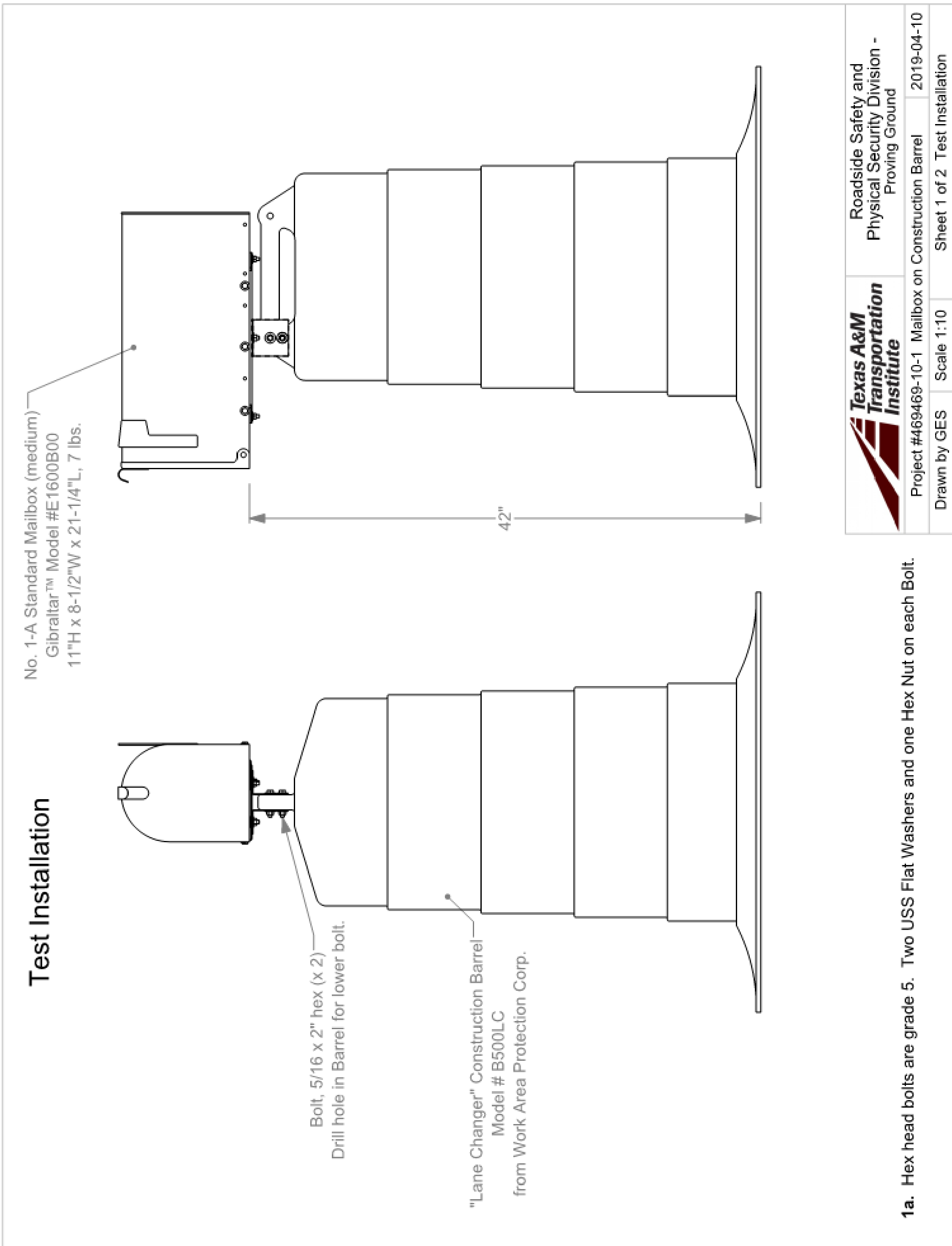
Test Number: 469469-09-01
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Burn Ban sign on wedge and socket support
Test Vehicle: 2008 Kia Rio
Inertial Mass: 2435 lb
Gross Mass: 2600 lb
Impact Speed: 63.7 mi/h
Impact Angle: 0 degrees

Figure I.5. Vehicle Vertical Accelerometer Trace for Test No. 469469-09-01 (Accelerometer Located at Center of Gravity).

APPENDIX J. TXDOT MAILBOXES

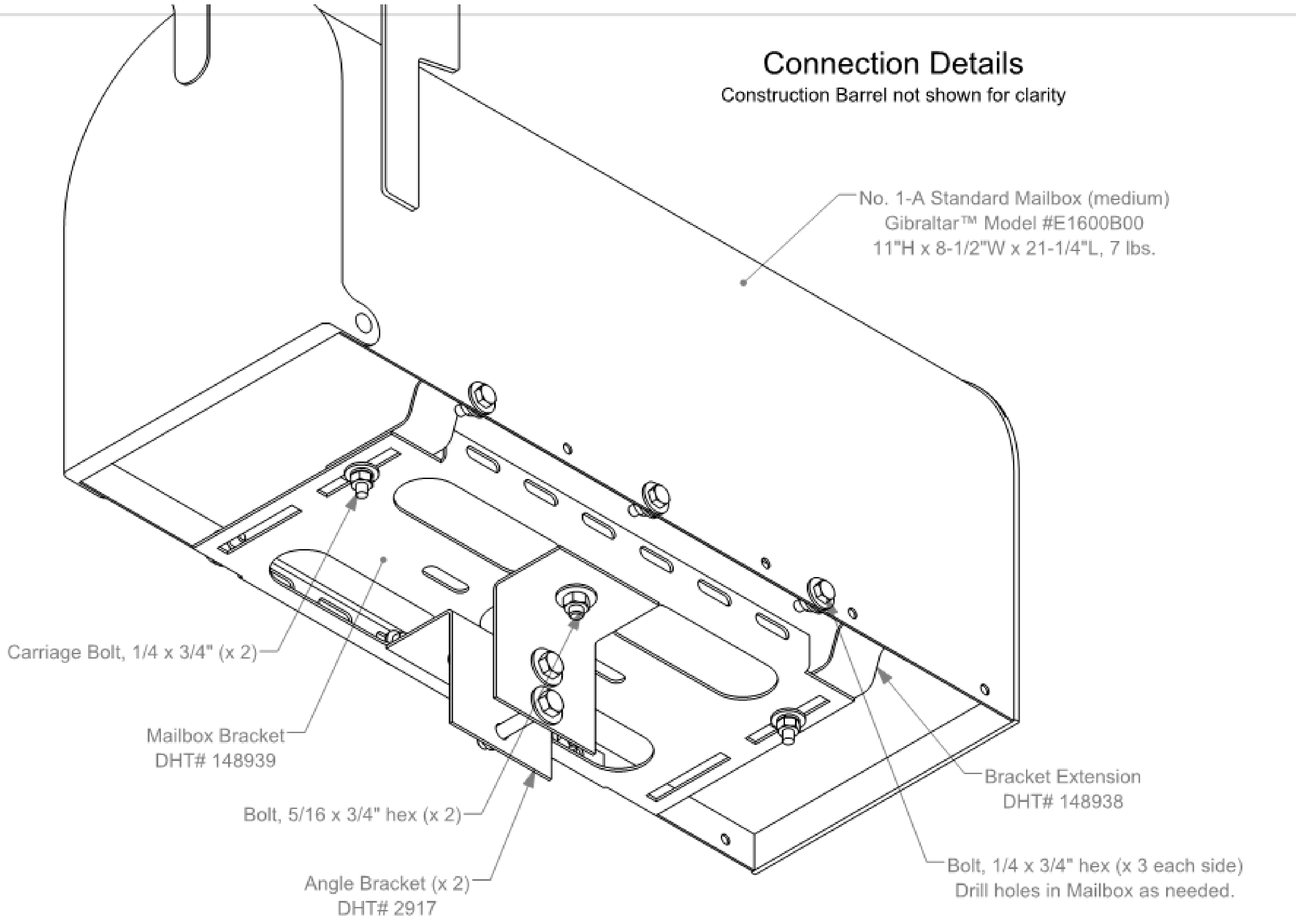
J.1. TXDOT SINGLE TEMPORARY MAILBOX ON PLASTIC DRUM

J.1.1. Details of the Single Temporary Mailbox on Plastic Drum



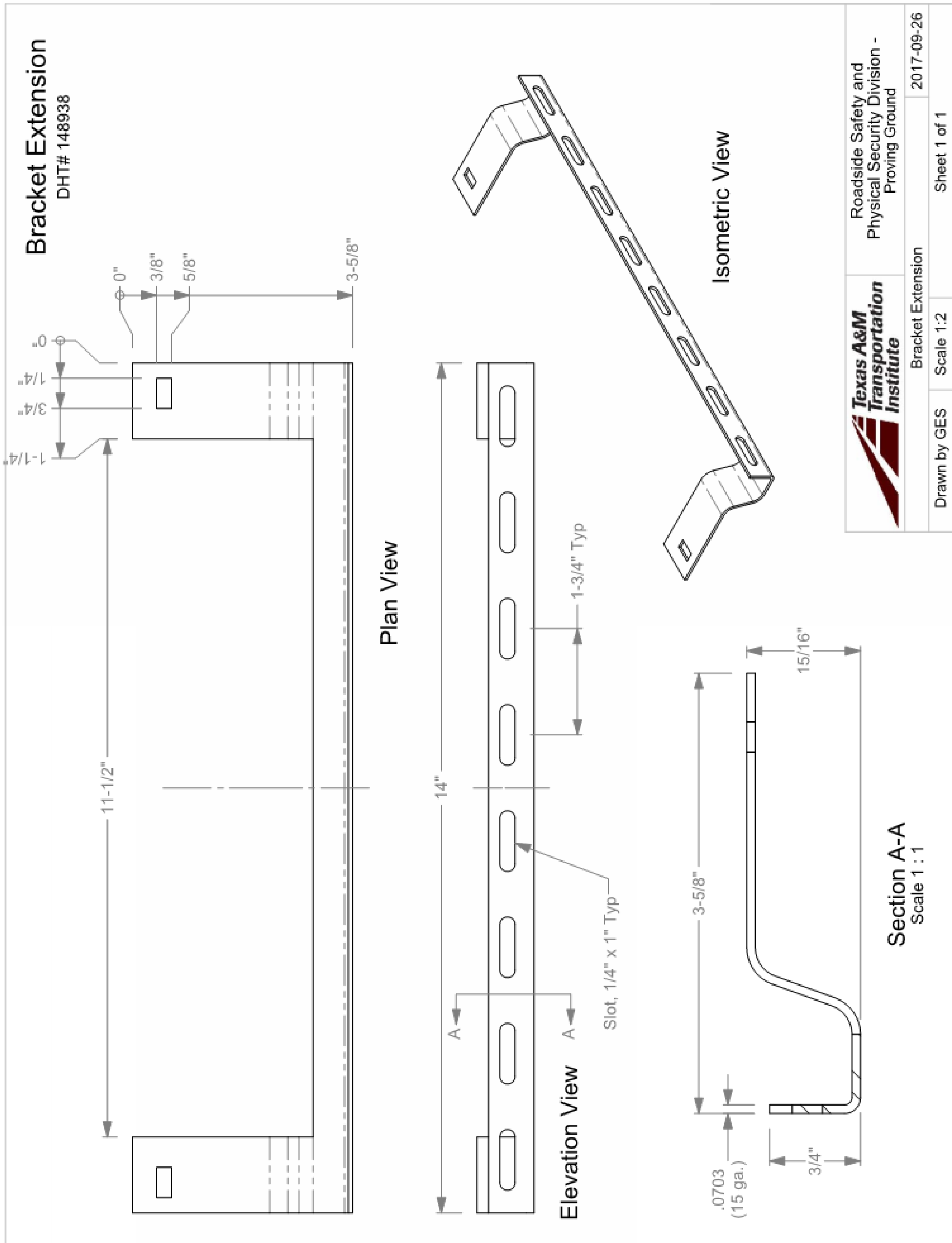
Connection Details

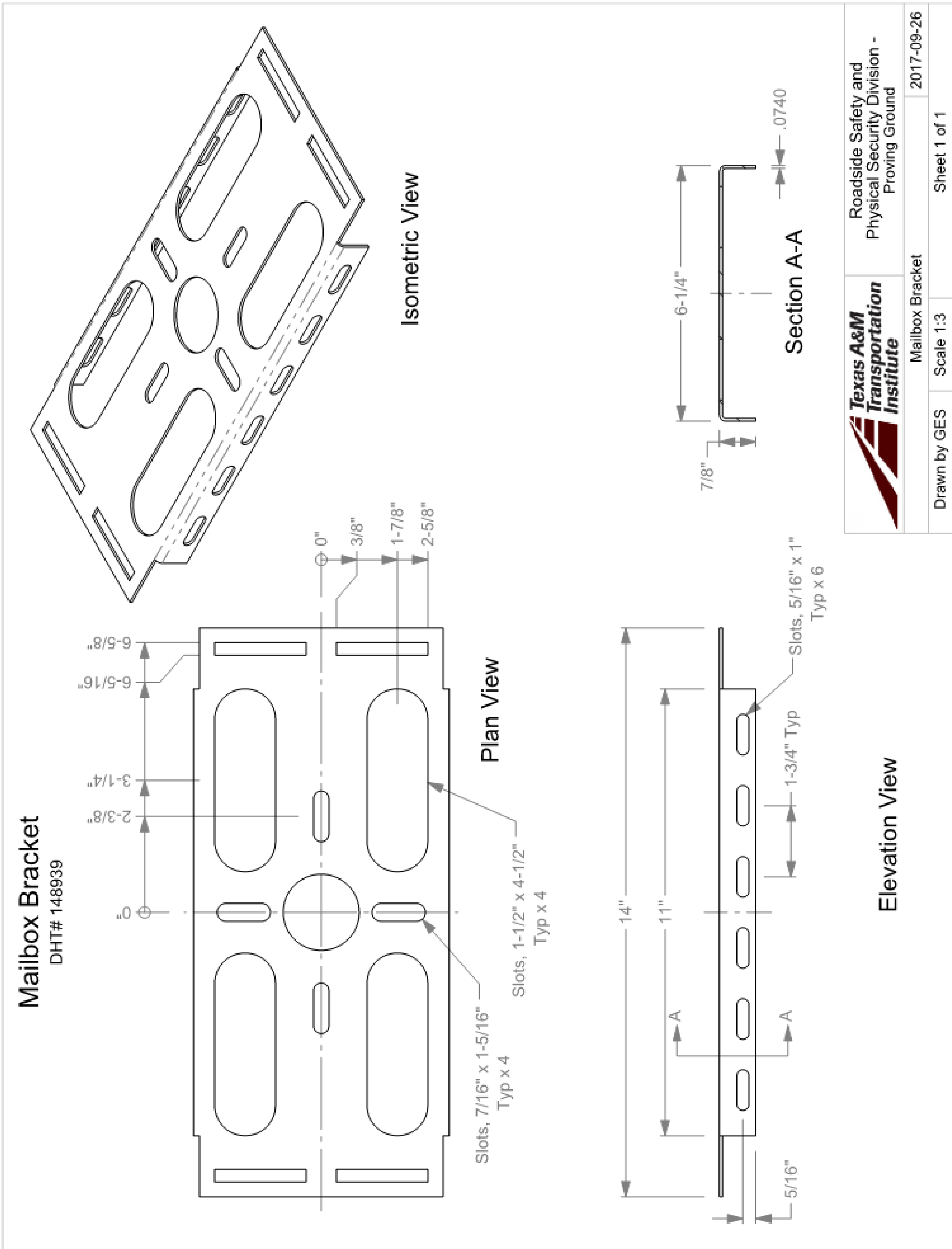
Construction Barrel not shown for clarity

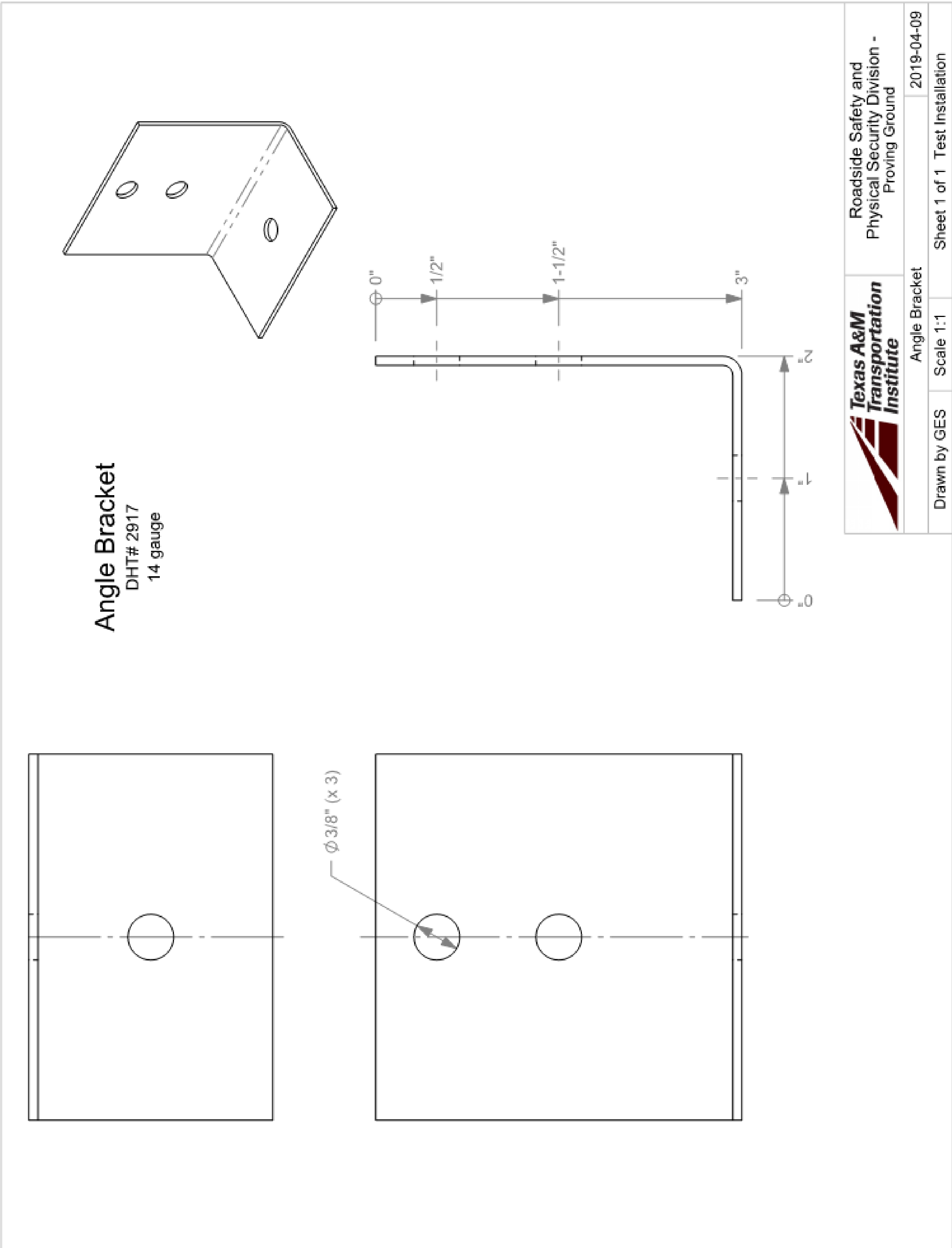


2a. Hex head bolts are grade 5. Two USS Flat Washers and one Hex Nut on each Bolt.

Texas A&M Transportation Institute	Roadside Safety and Physical Security Division - Proving Ground	
Project #469469-10-1 Mailbox on Construction Barrel		2019-04-10
Drawn by GES	Scale 1:3	Sheet 2 of 2 Connection Details


Bracket Extension
DHT# 148938
0"
3/8"
5/8"
3-5/8"
1/4"
3/4"
1-1/4"
11-1/2"
Plan View
14"
1-3/4" Typ
Slot, 1/4" x 1" Typ
A
A
Elevation View
Isometric View
15/16"
3-5/8"
.0703
(15 ga.)
3/4"
Section A-A
Scale 1 : 1
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Bracket Extension
2017-09-26
Drawn by GES
Scale 1:2
Sheet 1 of 1


Mailbox Bracket
DHT# 148939
Isometric View
Plan View
Elevation View
Section A-A
0"
2-3/8"
3-1/4"
6-5/16"
6-5/8"
3/8"
1-7/8"
2-5/8"
Slots, 7/16" x 1-5/16"
Typ x 4
Slots, 1-1/2" x 4-1/2"
Typ x 4
Slots, 5/16" x 1"
Typ x 6
14"
11"
1-3/4" Typ
5/16"
A
A
6-1/4"
.0740
7/8"
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Mailbox Bracket
2017-09-26
Drawn by GES
Scale 1:3
Sheet 1 of 1


Angle Bracket
DHT# 2917
14 gauge
0"
1/2"
1-1/2"
3"
0"
1"
2"
Ø 3/8" (x 3)
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
2019-04-09
Angle Bracket
Drawn by GES
Scale 1:1
Sheet 1 of 1
Test Installation

J.1.2. Vehicle Properties and Information

Table J.1. Vehicle Properties for Test No. 469469-10-1.

Vehicle Inventory Number: 1369

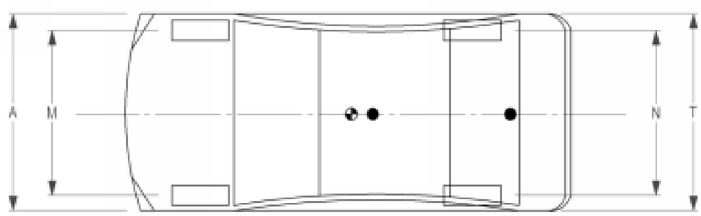
Date: 2019-04-11 Test No.: 469469-10-1 VIN No.: KNADH4A33B6954717

Year: Make: Kia Model: Rio

Tire Inflation Pressure: 32 PSI Odometer: 101770 Tire Size: 185/65R14

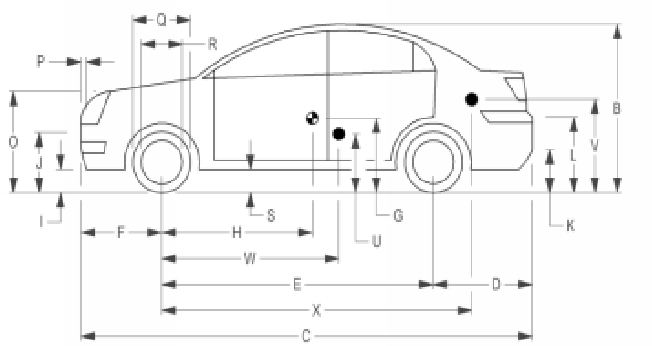
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.



NOTES:

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



Dummy Data:
Type: 50th Percentile Male
Mass: 165 lb
Seat Position: OPPSITE IMPACT

Geometry: inches

A	66.38	F	33.00	K	12.25	P	4.12	U	14.75
B	51.50	G		L	25.25	Q	22.50	V	20.50
C	165.75	H	36.01	M	57.75	R	15.50	W	36.00
D	34.00	I	7.75	N	57.70	S	8.25	X	102.00
E	98.75	J	21.50	O	27.00	T	66.20		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00 W-H 0.00

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Bottom of Hood Lip) = 24 ±4 inches
TOP OF RADIATOR SUPPORT = 28.26 inches; (M+N)/2 = 56 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1,570.00	1,550.00	1,635.00
Back	1874	M_{rear}	885.00	890.00	970.00
Total	3638	M_{Total}	2,455.00	2,440.00	2,605.00

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

Mass Distribution:
lb LF: 750 RF: 800 LR: 490 RR: 400

Performed by: SCD Date: 2019-04-11

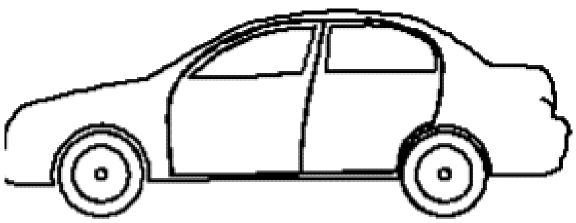
Table J.2. Exterior Crush Measurements of Vehicle for Test No. 469469-10-1.

Vehicle Inventory Number: 1369

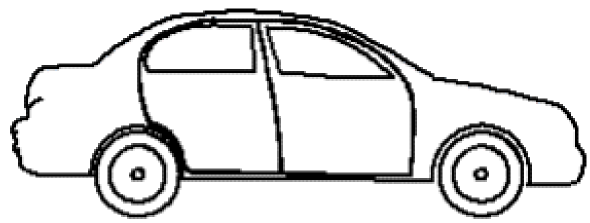
Date:	2019-04-11	Test No.:	469469-10-1	VIN No.:	KNADH4A33B6954717
Year:	2011	Make:	Kia	Model:	Rio
				Mileage:	101770

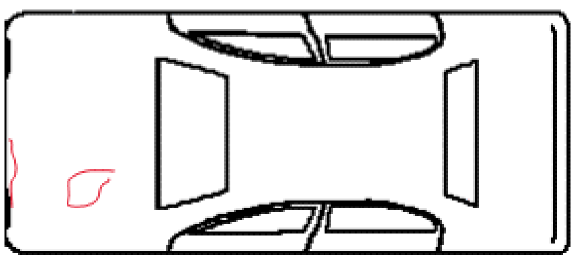
Please shade damage areas and note type of damage.

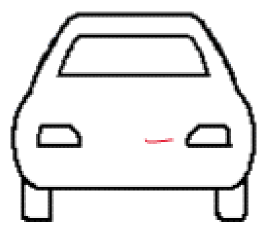
Driver's Side



Passenger Side







List vehicle damage:

SKUFF MARKS ON FT BUMPER LT OF CL

HOOD 8" X 20" DENT .75" DEEP LT SIDE OF CL

Table J.3. Exterior Crush Measurements of Vehicle for Test No. 469469-10-1.

Vehicle Inventory Number: 1369

Date:	2019-04-11	Test No.:	469469-10-1	VIN No.:	KNADH4A33B6954717
Year:	2011	Make:	Kia	Model:	Rio

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) (check one)		Bowing constant	
< 4 inches		$\frac{X1+X2}{2}$ =	
≥ 4 inches			

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

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

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

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

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

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

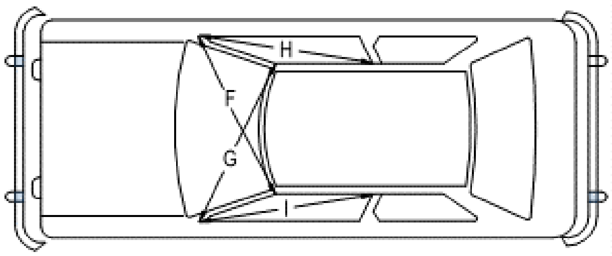
***Measure and document on the vehicle diagram the location of the maximum crush.

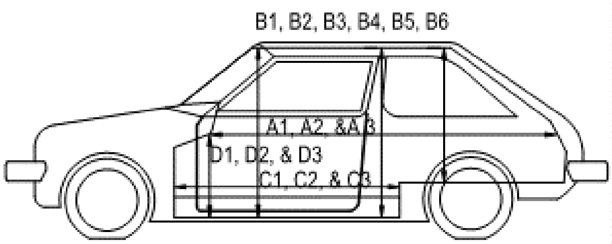
Note: Use as many lines/columns as necessary to describe each damage profile.

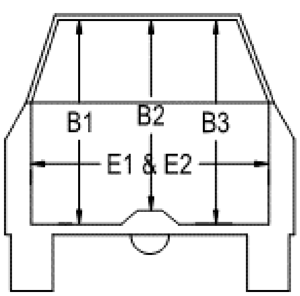
Table J.4. Occupant Compartment Measurements of Vehicle for Test No. 469469-10-1.

Vehicle Inventory Number: 1369

Date:	2019-04-11	Test No.:	469469-10-1	VIN No.:	KNADH4A33B6954717
Year:	2011	Make:	Kia	Model:	Rio







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

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

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

Performed by: ***SCD*** Date: 2019-04-11

J.1.3. Sequential Photographs

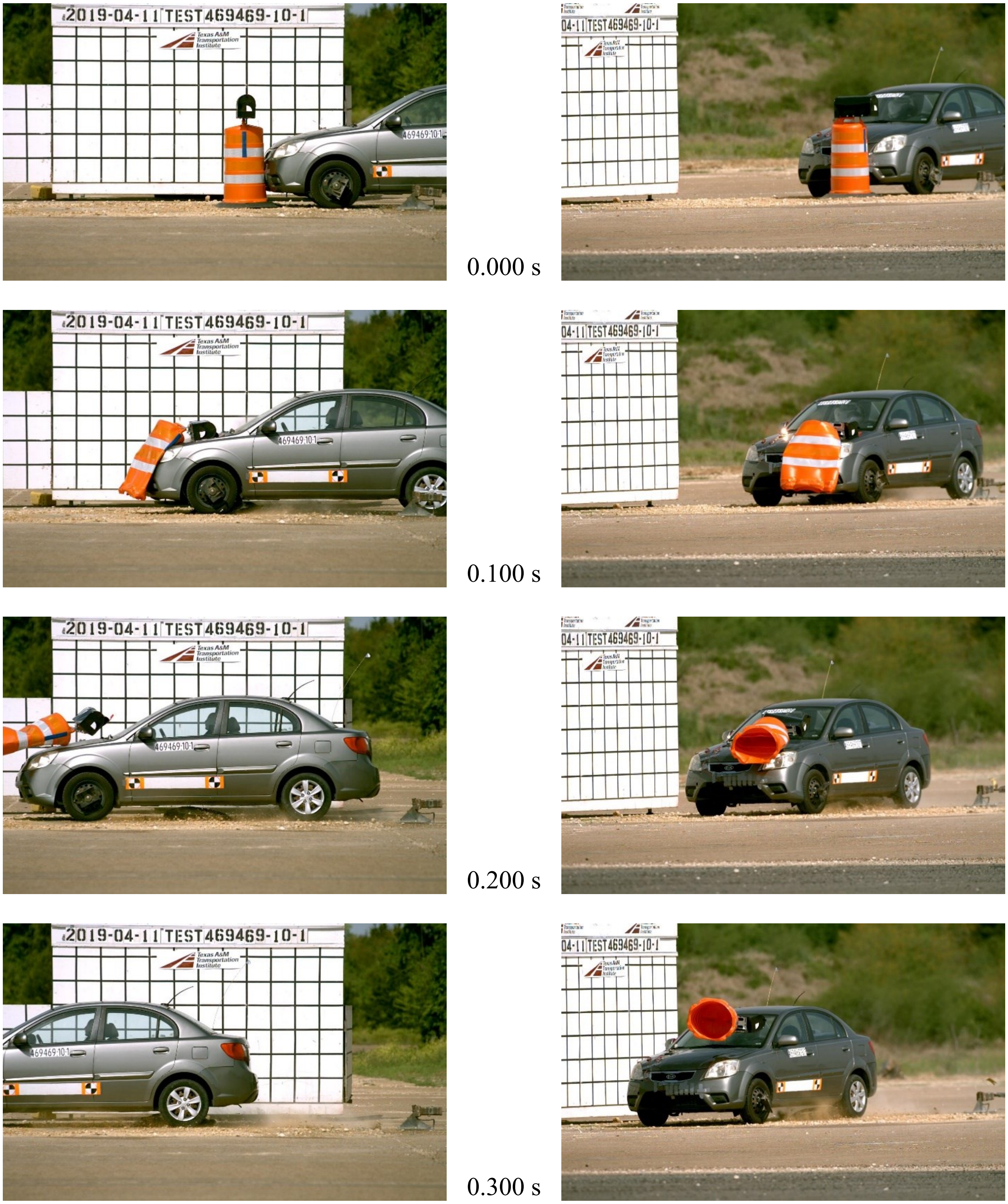


Figure J.1. Sequential Photographs for Test No. 469469-10-1 (Right Angle and Oblique Views).

0.500 s

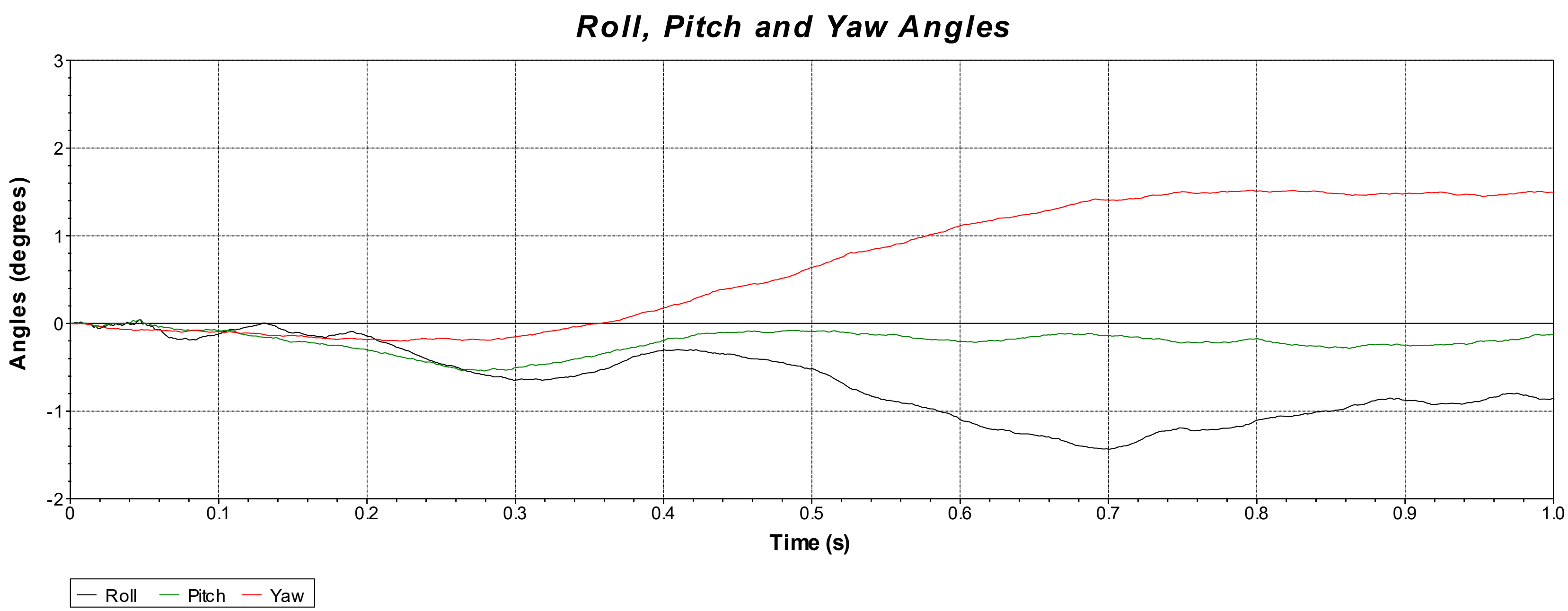
0.600 s

0.700 s

0.800 s

Figure A.1. Sequential Photographs for Test No. 469469-10-1 (Right Angle and Oblique Views) (Continued).

J.1.4. Vehicle Angular Displacement



Test Number: 469469-10-1
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Mailbox on Drum
Test Vehicle: 2011 Kia Rio (1100C)
Inertial Mass: 2440 lb
Gross Mass: 2605 lb
Impact Speed: 62.9 mi/h
Impact Angle: 0 degrees

Axes are vehicle-fixed.
Sequence for determining orientation:

40. Yaw.
41. Pitch.
42. Roll.

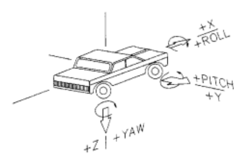


Figure J.2. Vehicle Angular Displacements for Test No. 469469-10-1.

J.1.5. Vehicle Acceleration

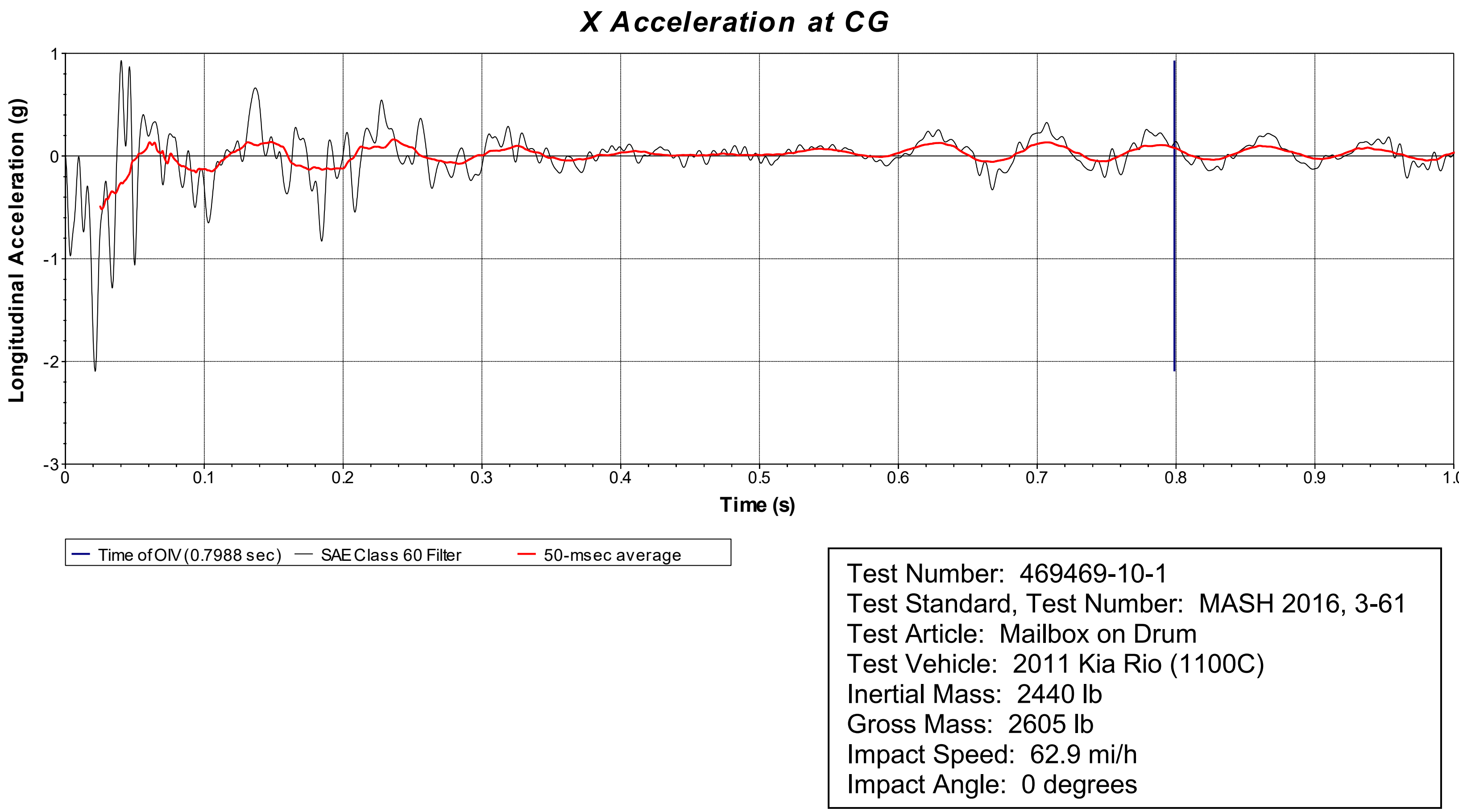
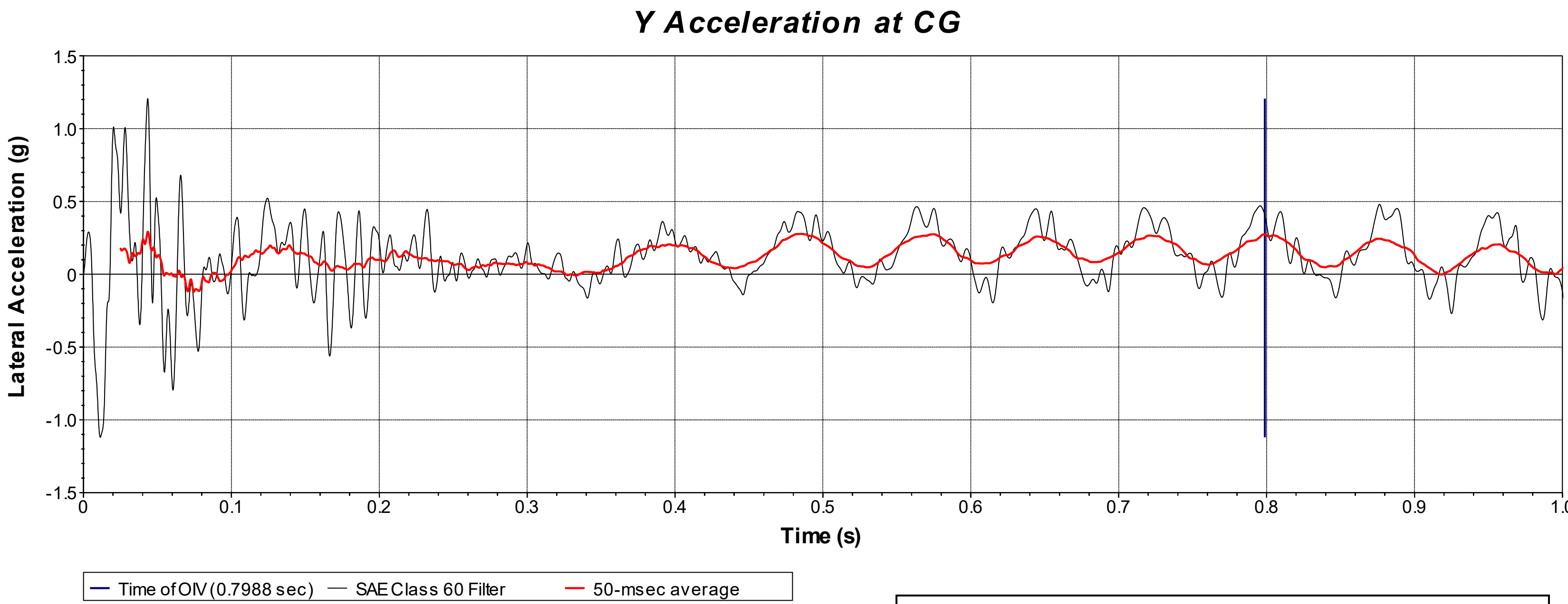
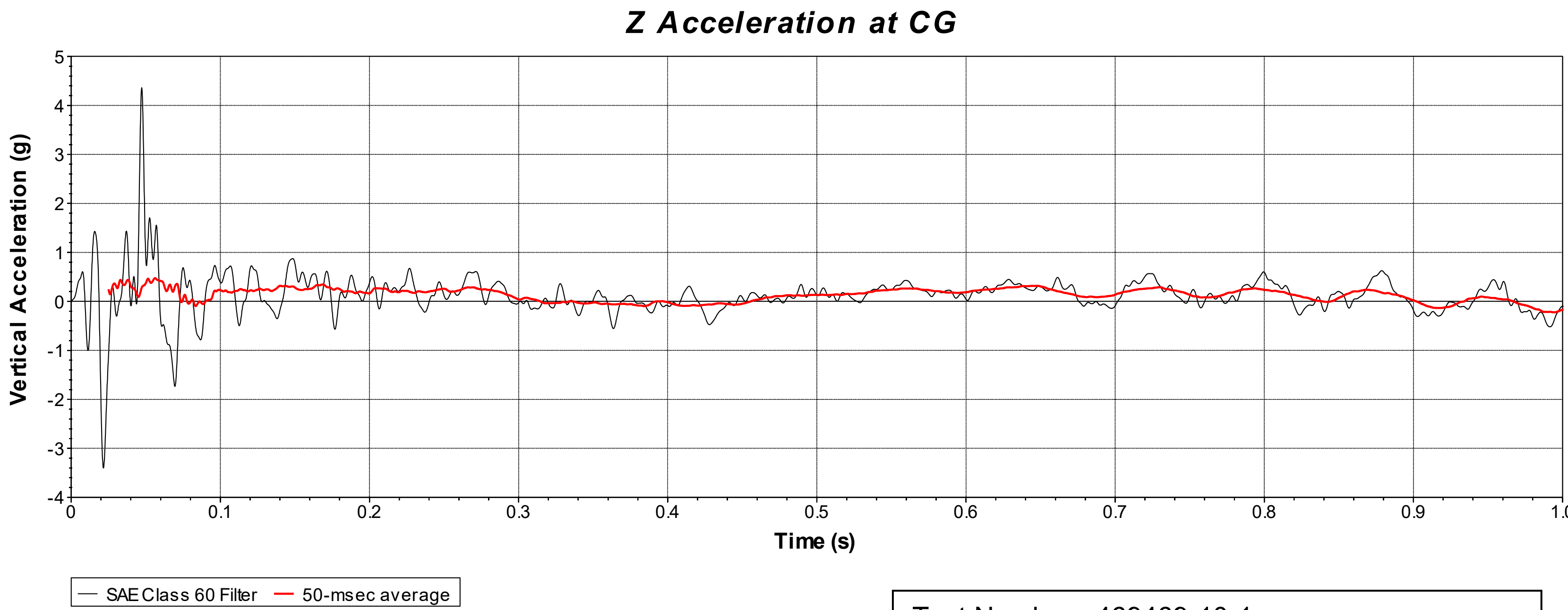


Figure J.3. Vehicle Longitudinal Accelerometer Trace for Test No. 469469-10-1 (Accelerometer Located at Center of Gravity).



Test Number: 469469-10-1
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Mailbox on Drum
Test Vehicle: 2011 Kia Rio (1100C)
Inertial Mass: 2440 lb
Gross Mass: 2605 lb
Impact Speed: 62.9 mi/h
Impact Angle: 0 degrees

Figure J.4. Vehicle Lateral Accelerometer Trace for Test No. 469469-10-1 (Accelerometer Located at Center of Gravity).

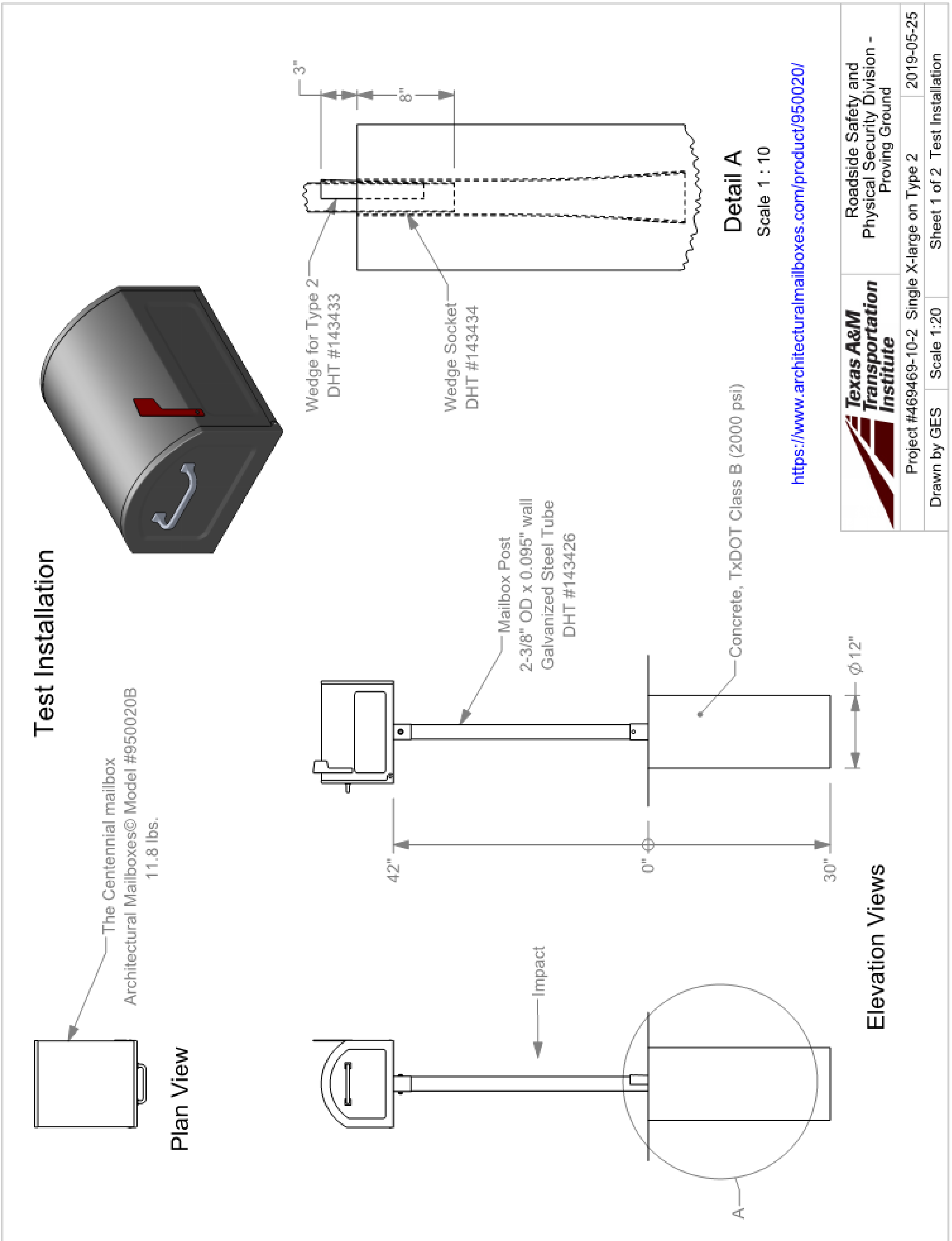


Test Number: 469469-10-1
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Mailbox on Drum
Test Vehicle: 2011 Kia Rio (1100C)
Inertial Mass: 2440 lb
Gross Mass: 2605 lb
Impact Speed: 62.9 mi/h
Impact Angle: 0 degrees

Figure J.5. Vehicle Vertical Accelerometer Trace for Test No. 469469-10-1 (Accelerometer Located at Center of Gravity).

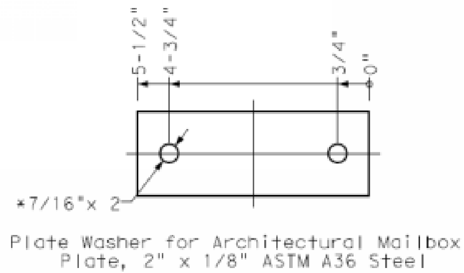
J.2. TXDOT CENTENNIAL MAILBOX ON TYPE 2 FOUNDATION

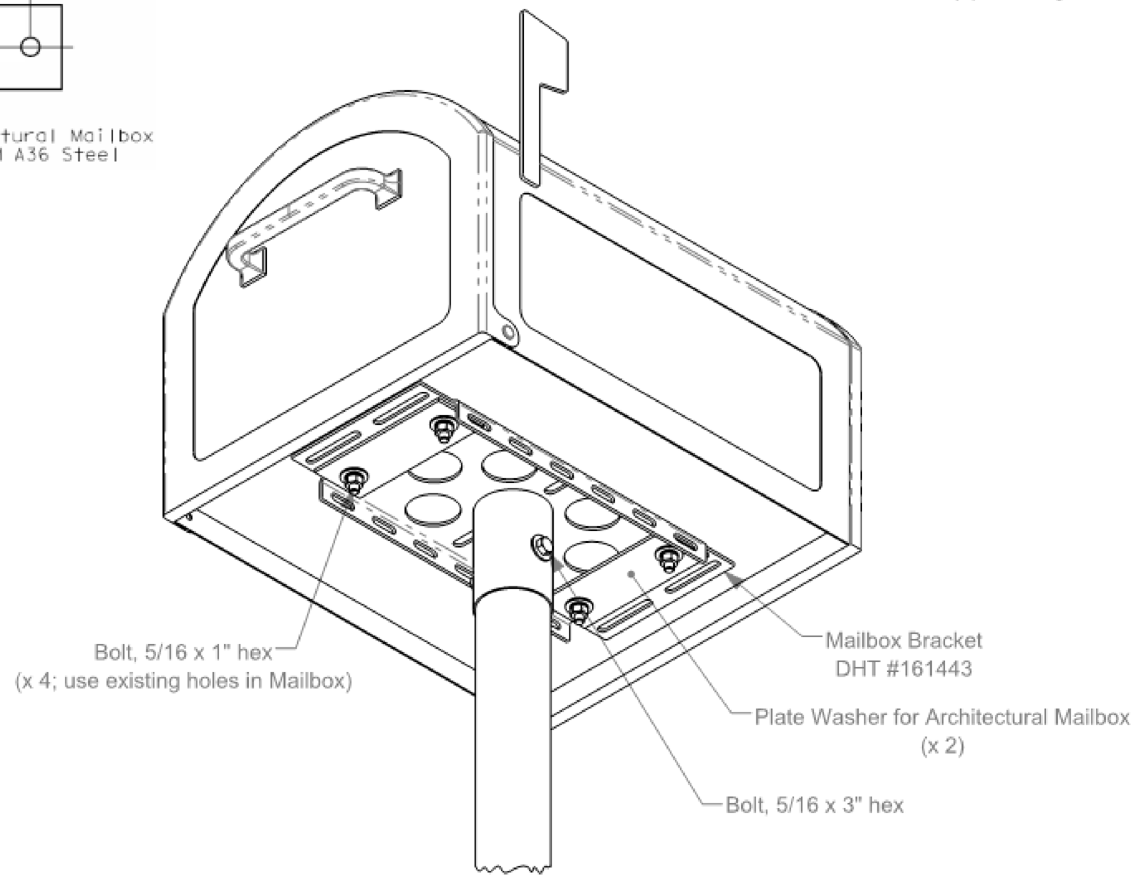
J.2.1. Details of the centennial Mailbox on Type 2 Foundation



Connection Details

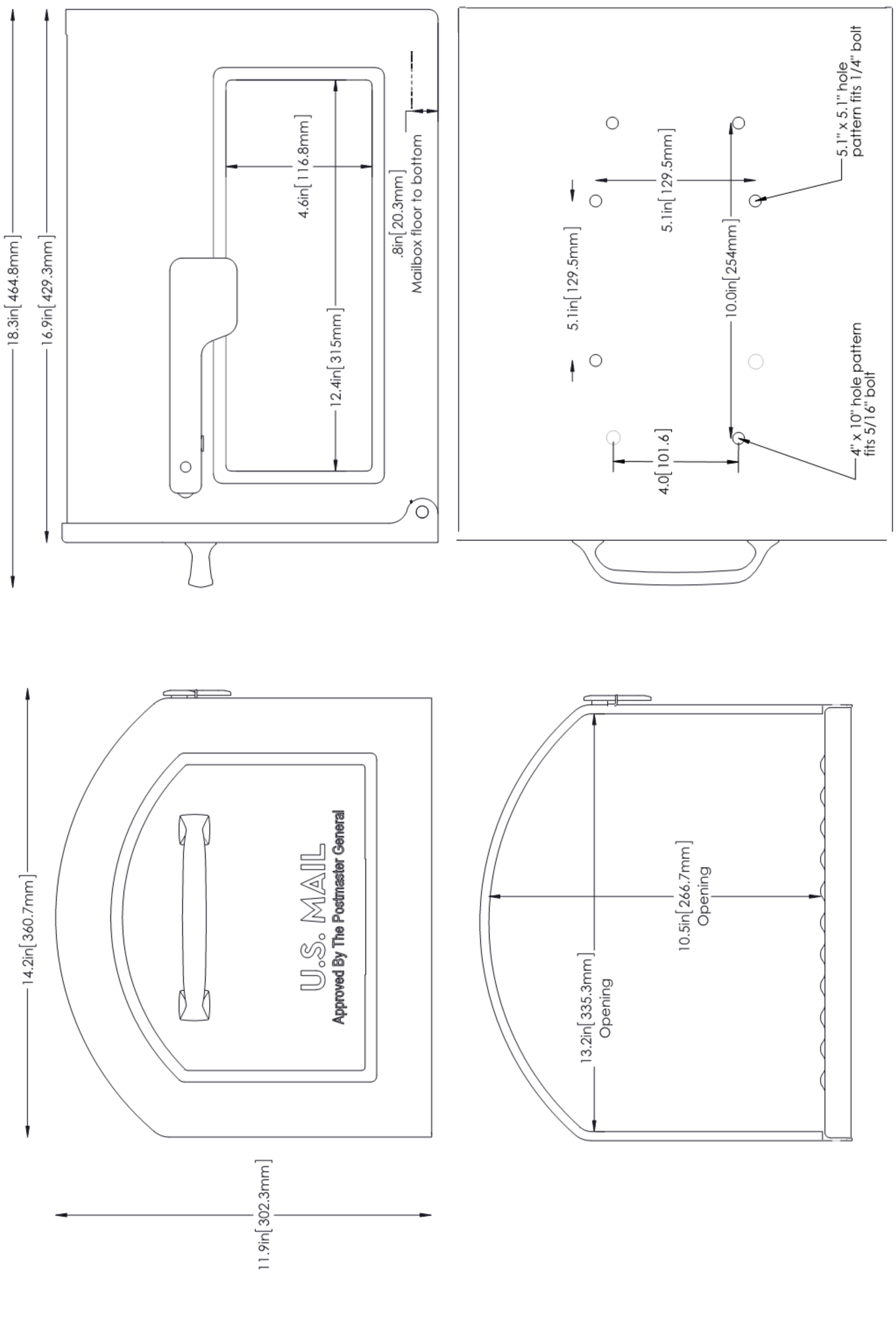
Plate Washer details from TxDOT
MB-15(1) Drawing, sheet 2

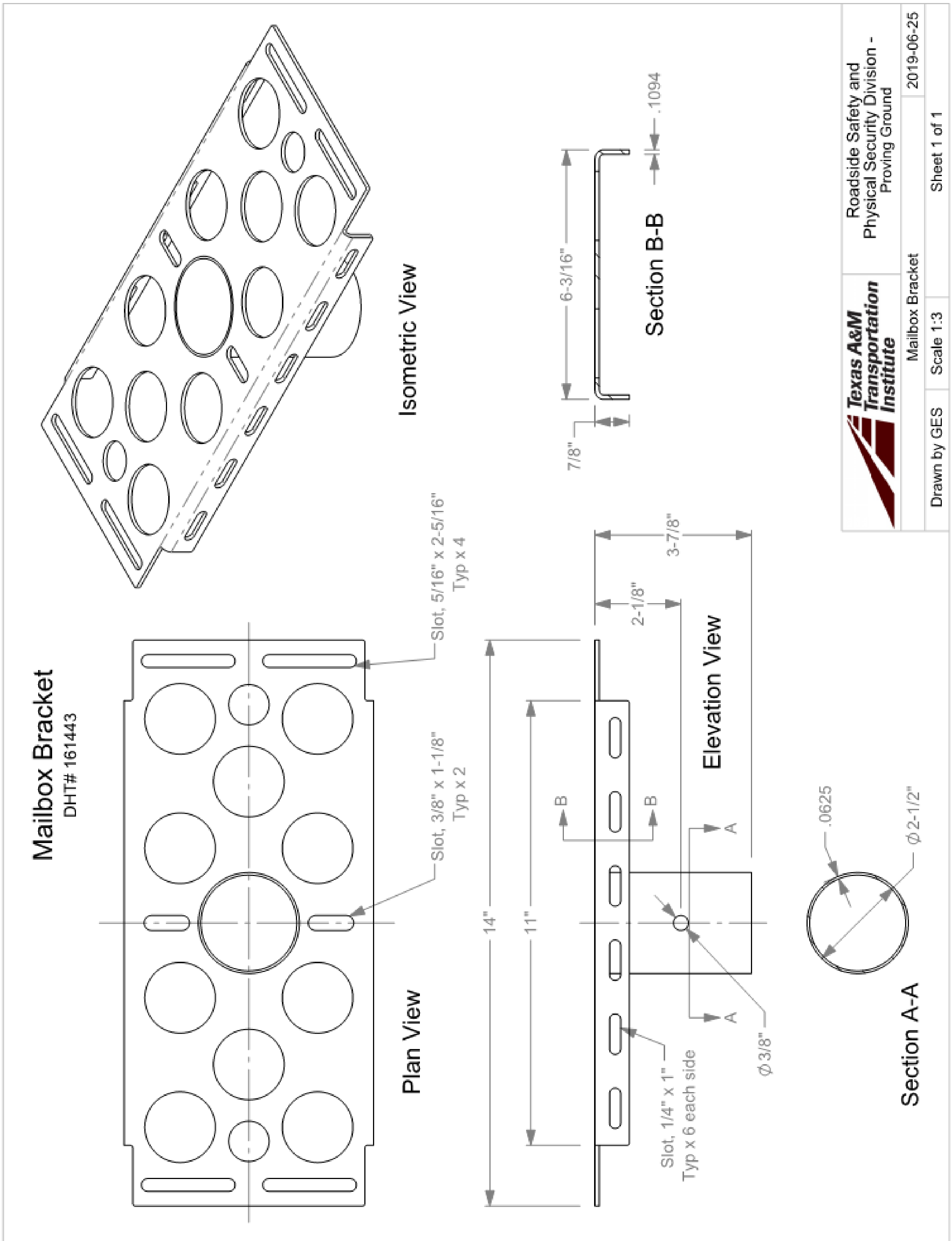




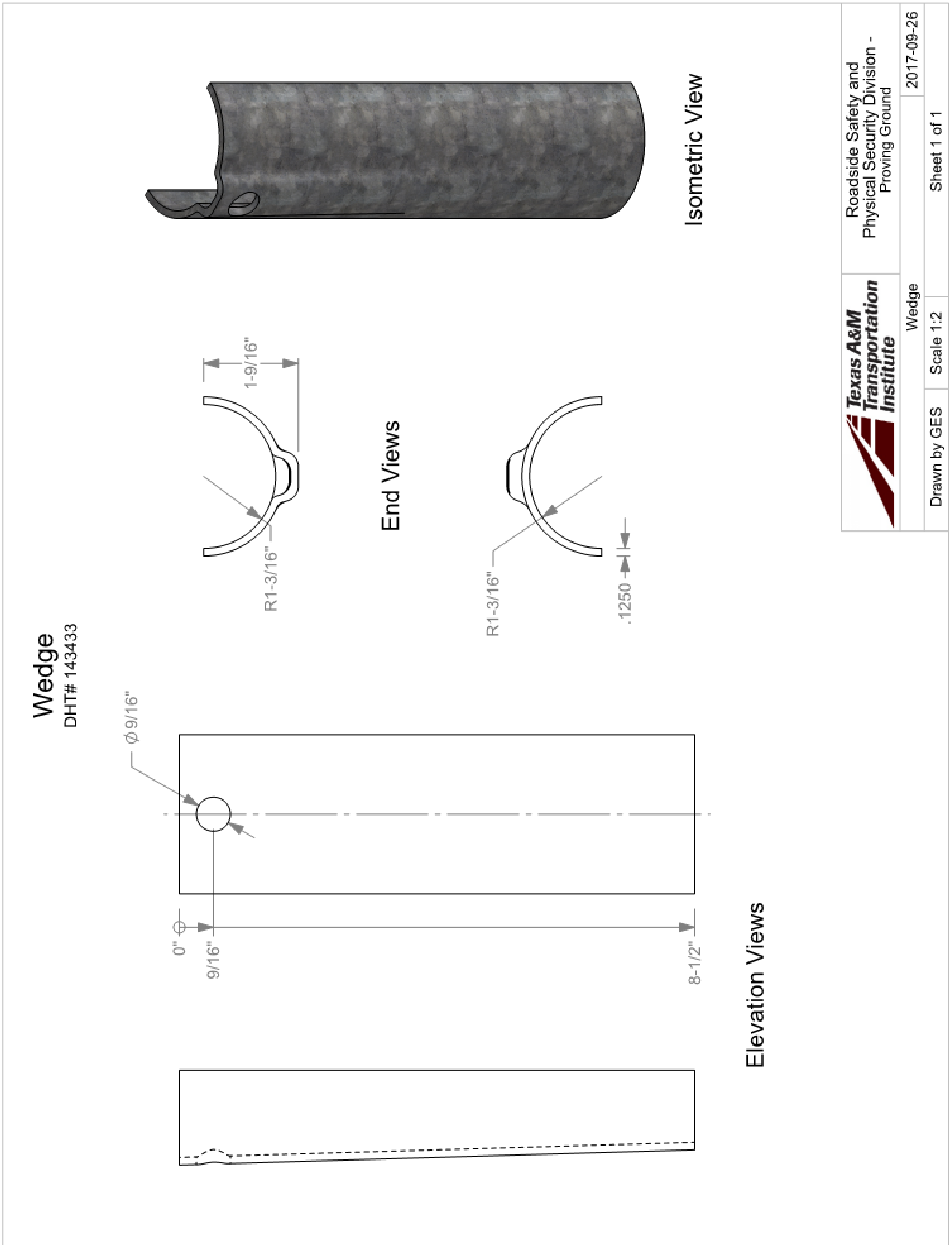
2a. All hex bolts are grade 5. Two USS flat washers, one lock washer, and hex nut on all hex bolts.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground	
Project #469469-10-2 Single X-large on Type 2			2019-05-25
Drawn by GES	Scale 1:5	Sheet 2 of 2 Connection Details	


18.3in[464.8mm]
16.9in[429.3mm]
4.6in[116.8mm]
12.4in[315mm]
.8in[20.3mm]
Mailbox floor to bottom
5.1in[129.5mm]
5.1in[129.5mm]
10.0in[254mm]
4.0[101.6]
5.1" x 5.1" hole
pattern fits 1/4" bolt
4" x 10" hole pattern
fits 5/16" bolt
14.2in[360.7mm]
11.9in[302.3mm]
U.S. MAIL
Approved By The Postmaster General
13.2in[335.3mm]
Opening
10.5in[266.7mm]
Opening



Mailbox Bracket
DHT# 161443
Plan View
Slot, 5/16" x 2-5/16"
Typ x 4
Slot, 3/8" x 1-1/8"
Typ x 2
14"
11"
Isometric View
Elevation View
2-1/8"
3-7/8"
B
A
Slot, 1/4" x 1"
Typ x 6 each side
Ø 3/8"
Section B-B
6-3/16"
7/8"
.1094
Section A-A
.0625
Ø 2-1/2"
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
2019-06-25
Mailbox Bracket
Sheet 1 of 1
Drawn by GES
Scale 1:3



Wedge
DHT# 143433
Ø9/16"
0"
9/16"
8-1/2"
Elevation Views
R1-3/16"
1-9/16"
End Views
R1-3/16"
.1250
Isometric View
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Wedge
2017-09-26
Drawn by GES
Scale 1:2
Sheet 1 of 1

J.2.2. Vehicle Properties and Information

Table J.5. Vehicle Properties for Test No. 469469-10-2.

Vehicle Inventory Number: 1369

Date: 2019-06-25 Test No.: 469469-10-2 VIN No.: KNADH4A33B6954717

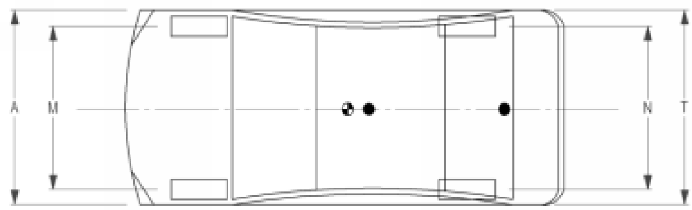
Year: 2011 Make: Kia Model: Rio

Tire Inflation Pressure: 32 PSI Odometer: 101770 Tire Size: 185/65R14

Describe any damage to the vehicle prior to test: None

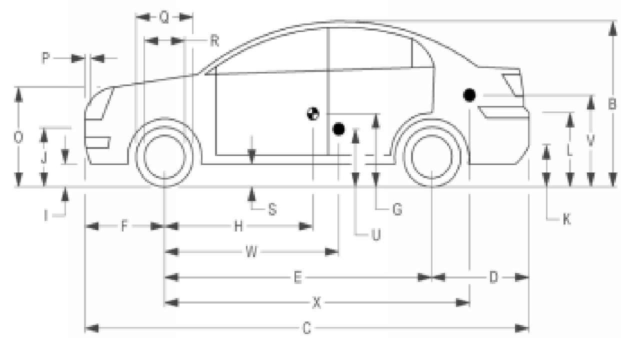
● Denotes accelerometer location.

NOTES:



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

Dummy Data:
Type: 50th Percentile Male
Mass: 165 lb
Seat Position: OPPSITE IMPACT



Geometry: inches

A	66.38	F	33.00	K	12.25	P	4.12	U	14.75
B	51.50	G		L	25.25	Q	22.50	V	20.50
C	165.75	H	36.01	M	57.75	R	15.50	W	36.00
D	34.00	I	7.75	N	57.70	S	8.25	X	71.50
E	98.75	J	21.50	O	27.00	T	66.20		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00 W-H 0.00

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Bottom of Hood Lip) = 24 ±4 inches
TOP OF RADIATOR SUPPORT = 28.25 inches; (M+N)/2 = 56 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1570	1550	1635
Back	1874	M_{rear}	885.00	890	970.00
Total	3638	M_{Total}	2455	2440	2605

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

Mass Distribution:
lb LF: 750 RF: 800 LR: 490 RR: 400

Performed by: SCD Date: 2019-06-25

Table J.6. Exterior Crush Measurements of Vehicle for Test No. 469469-10-2.

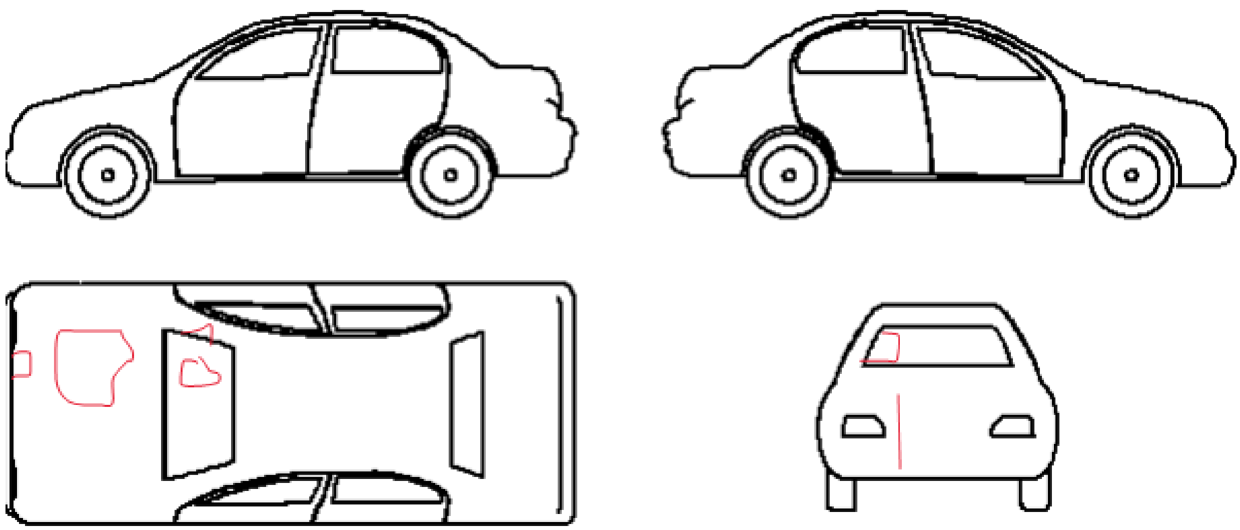
Vehicle Inventory Number: 1369

Date:	2019-06-25	Test No.:	469469-10-2	VIN No.:	KNADH4A33B6954717
Year:	2011	Make:	Kia	Model:	Rio
				Mileage:	101770

Please shade damage areas and note type of damage.

Driver's Side

Passenger Side



List vehicle damage:

FT BUMPER 3" DENT 14" TO RT OF CL

DENT IN RT SIDE OF HOOD 29"X31" 1.25"
DEEP WITH 2 .5"X2" CUTS

8"X8" BREAK IN WINDSHIELD

SMALL DENT IN RT A-POST

Performed by: *SCD* Date: 2019-06-25

Table J.7. Exterior Crush Measurements of Vehicle for Test No. 469469-10-2.

Vehicle Inventory Number: 1369

Date:	2019-06-25	Test No.:	469469-10-2	VIN No.:	KNADH4A33B6954717
Year:	2011	Make:	Kia	Model:	Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

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

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

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

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

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

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

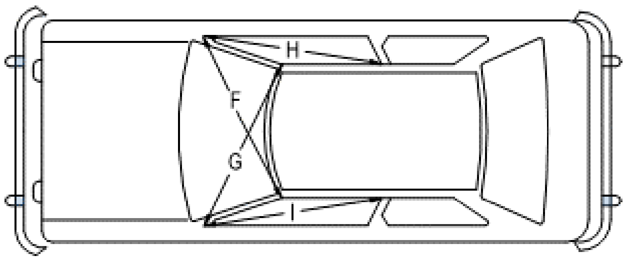
Note: Use as many lines/columns as necessary to describe each damage profile.

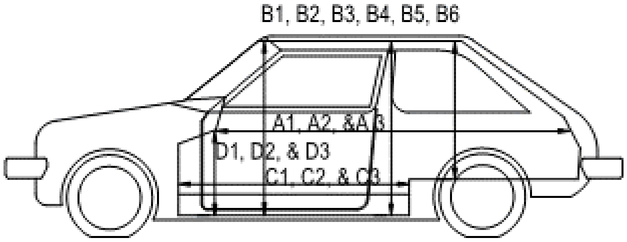
Performed by: SCD Date: 2019-06-26

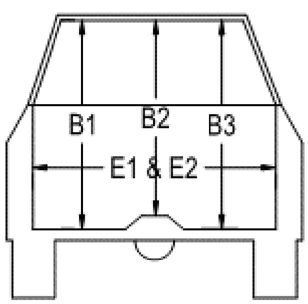
Table J.8. Occupant Compartment Measurements of Vehicle for Test No. 469469-10-2.

Vehicle Inventory Number: 1369

Date:	2019-06-25	Test No.:	469469-10-2	VIN No.:	KNADH4A33B6954717
Year:	2011	Make:	Kia	Model:	Rio







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

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

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

Performed by: ***SCD*** Date: 2019-06-26

J.2.3. Sequential Photographs

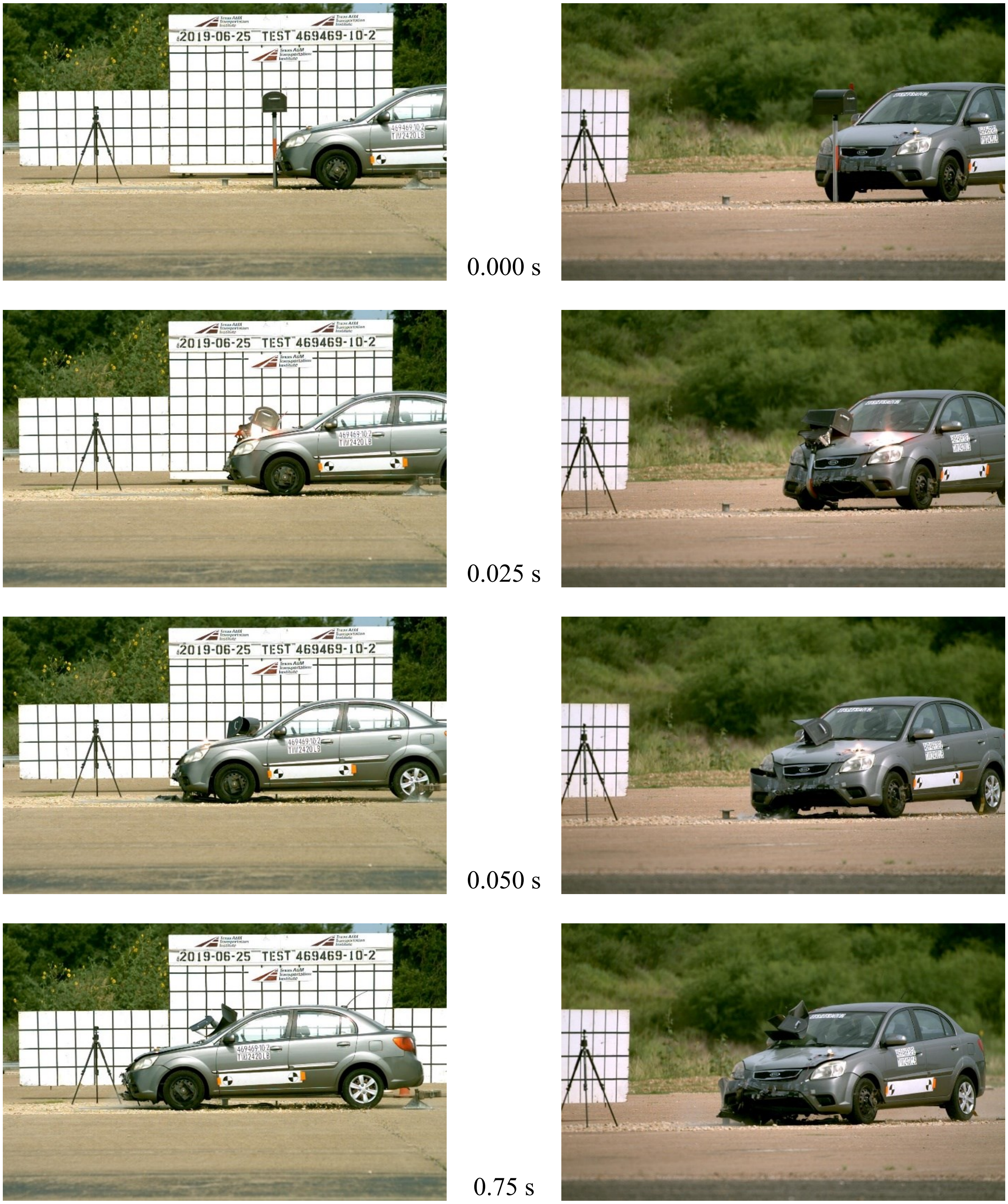
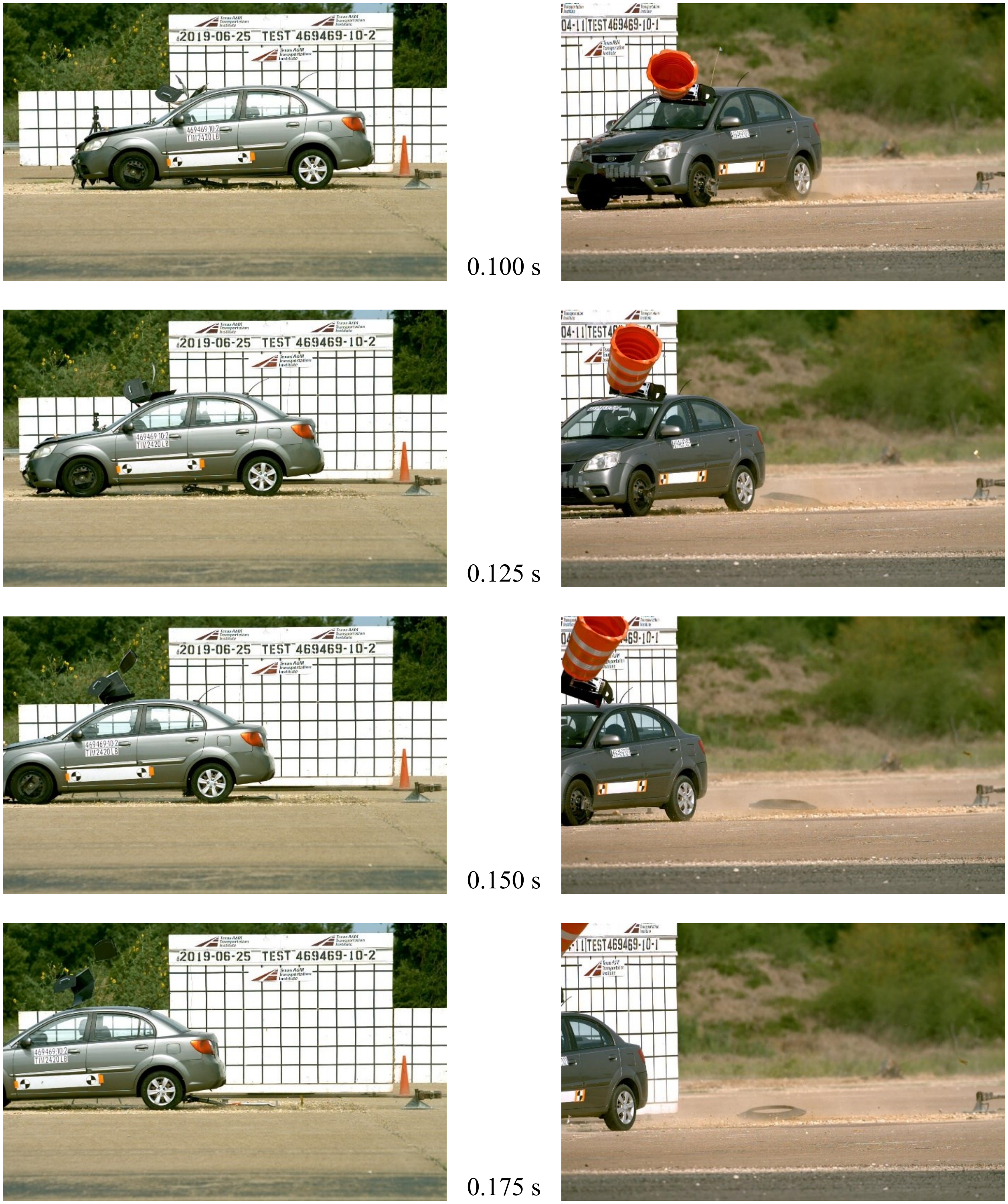


Figure J.6. Sequential Photographs for Test No. 469469-10-2 (Right Angle and Oblique Views).



0.100 s

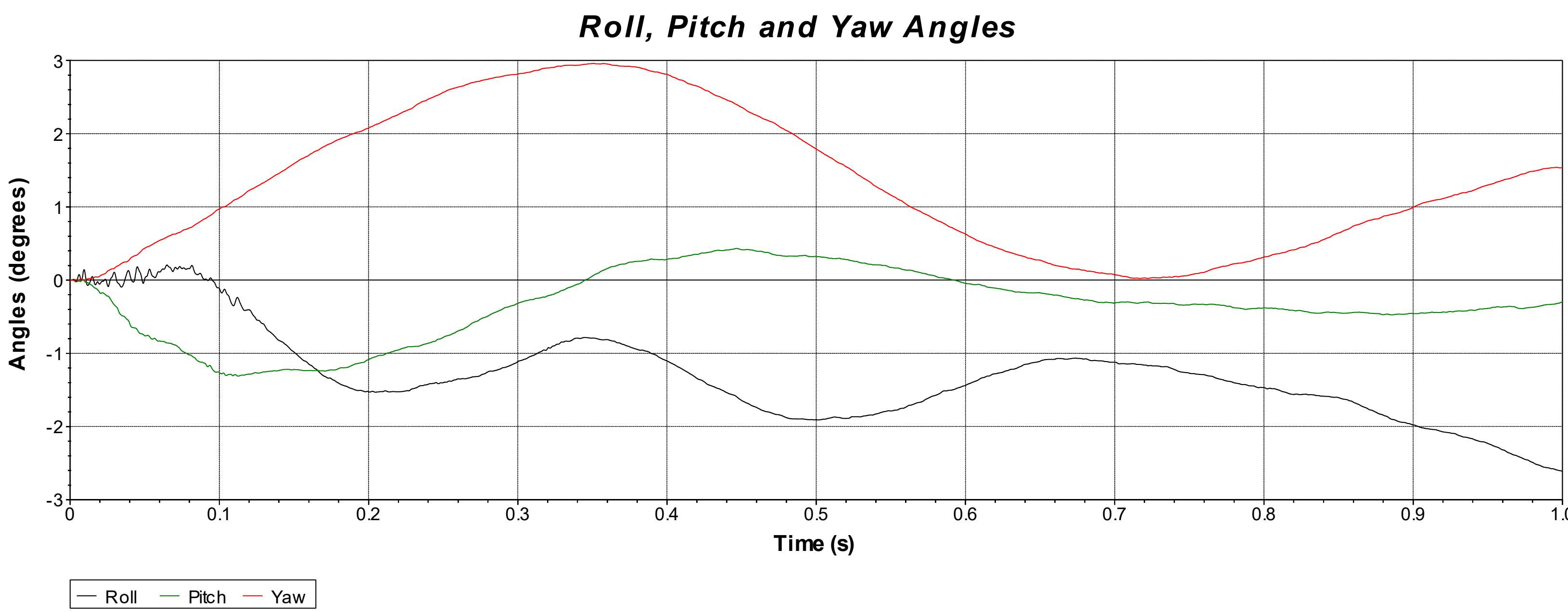
0.125 s

0.150 s

0.175 s

Figure J.6. Sequential Photographs for Test No. 469469-10-2 (Right Angle and Oblique Views) (Continued).

J.2.4. Vehicle Angular Displacement



Test Number: 469469-10-2 (Centennial)
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Centennial Model Mailbox on Type 2 Foundation
Test Vehicle: 2011 Kia Rio (1100C)
Inertial Mass: 2440 lb
Gross Mass: 2605 lb
Impact Speed: 63.0 mi/h
Impact Angle: 0 degrees

Axes are vehicle-fixed.
Sequence for determining orientation:

43. Yaw.
44. Pitch.
45. Roll.

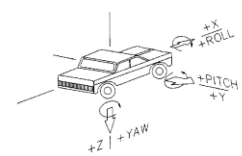
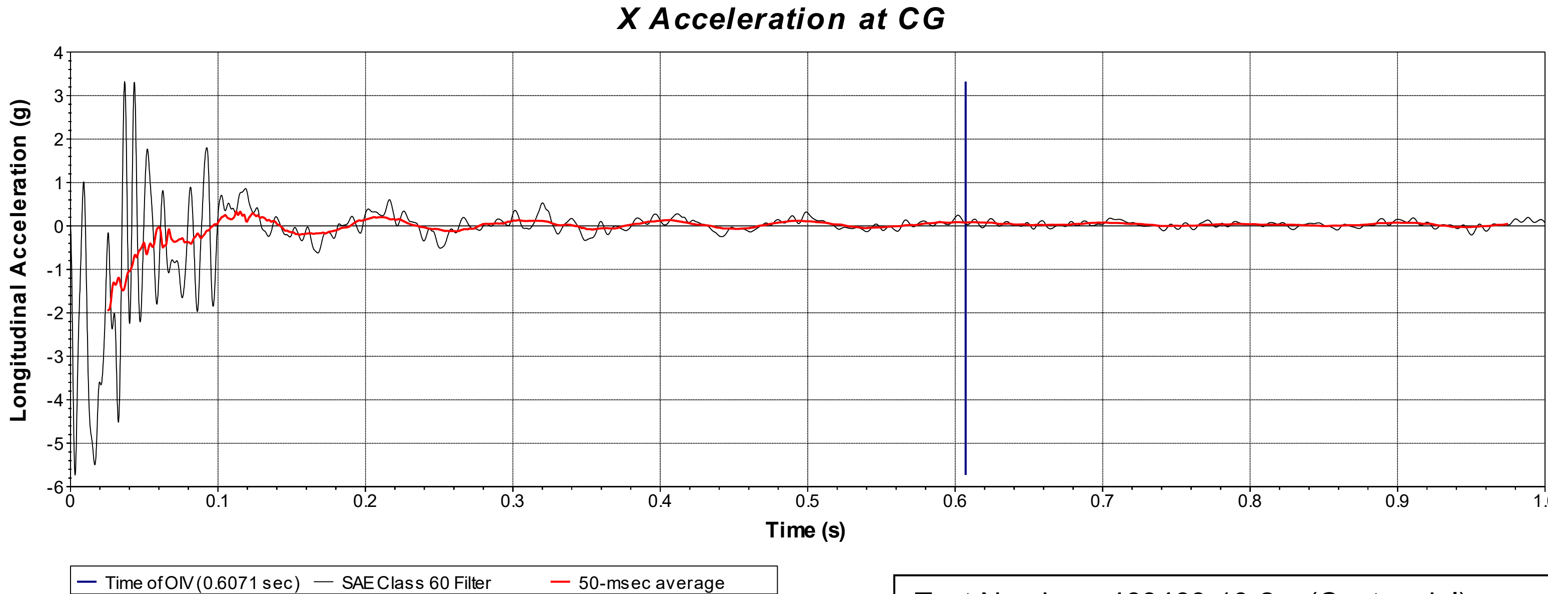


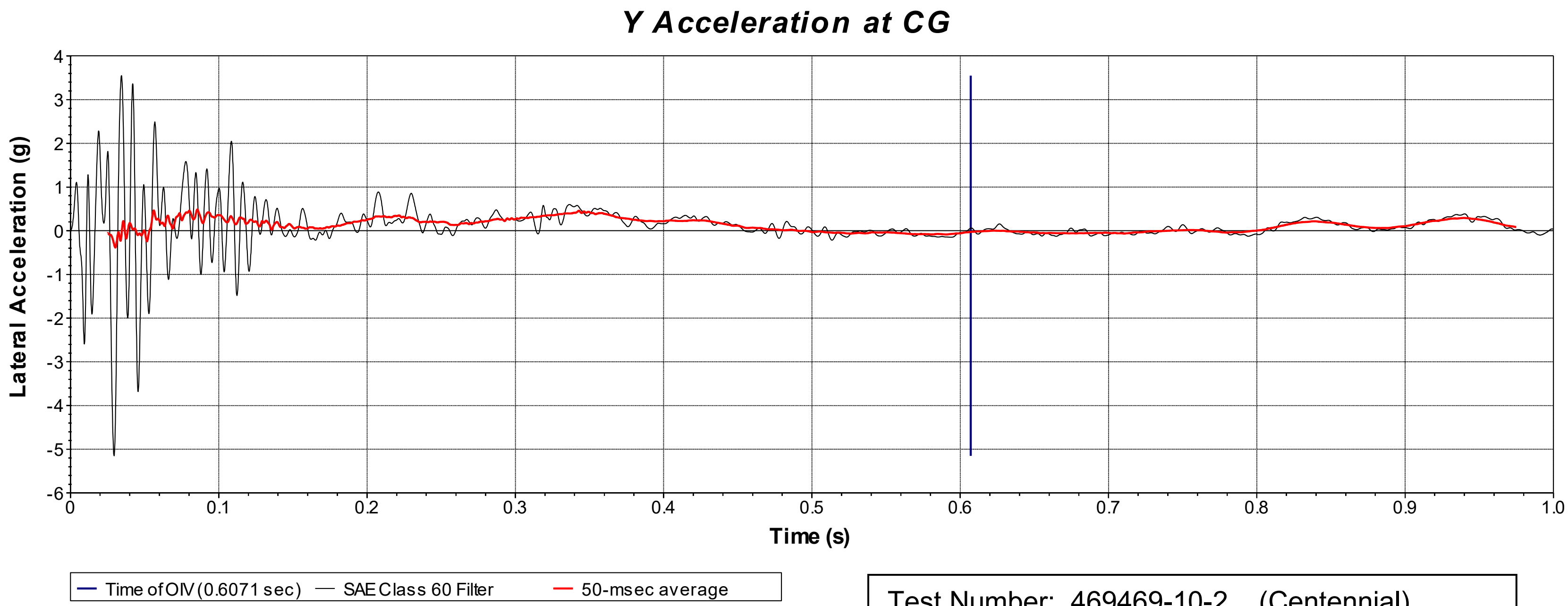
Figure J.7. Vehicle Angular Displacements for Test No. 469469-10-2.

J.2.5. Vehicle Acceleration



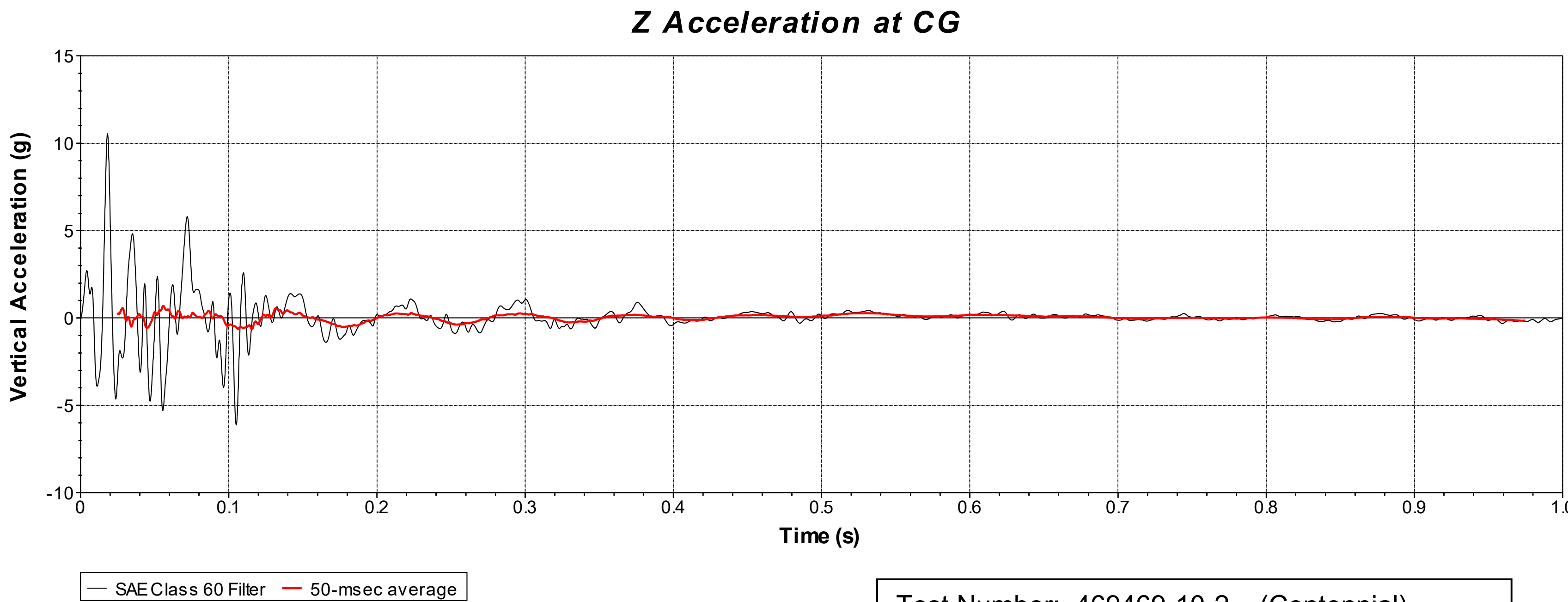
Test Number: 469469-10-2 (Centennial)
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Centennial Model Mailbox on Type 2 Foundation
Test Vehicle: 2011 Kia Rio (1100C)
Inertial Mass: 2440 lb
Gross Mass: 2605 lb
Impact Speed: 63 mi/h
Impact Angle: 0 degrees

Figure J.8. Vehicle Longitudinal Accelerometer Trace for Test No. 469469-10-2 (Accelerometer Located at Center of Gravity).



Test Number: 469469-10-2 (Centennial)
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Centennial Model Mailbox on Type 2 Foundation
Test Vehicle: 2011 Kia Rio (1100C)
Inertial Mass: 2440 lb
Gross Mass: 2605 lb
Impact Speed: 63 mi/h
Impact Angle: 0 degrees

Figure J.9. Vehicle Lateral Accelerometer Trace for Test No. 469469-10-2 (Accelerometer Located at Center of Gravity).

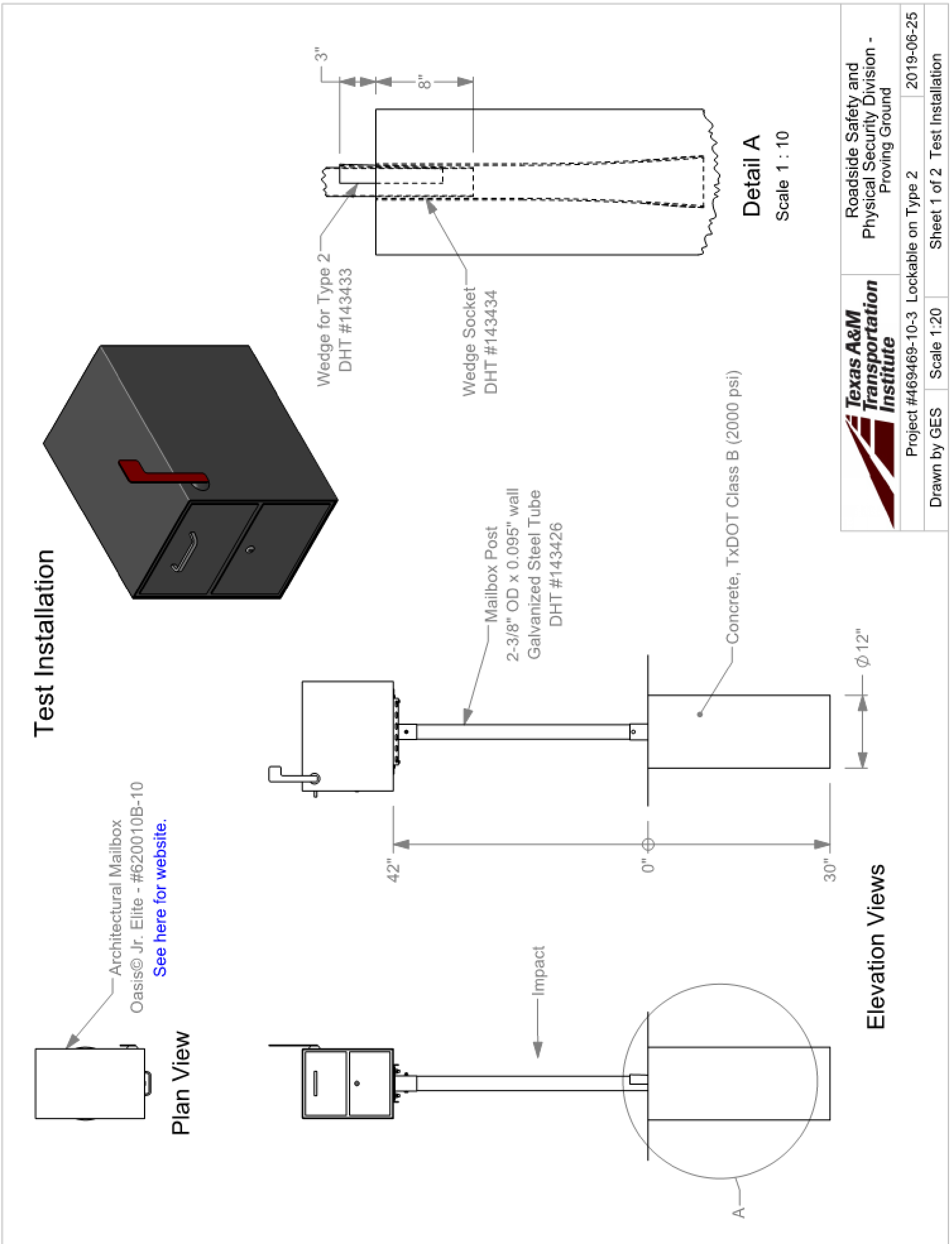


Test Number: 469469-10-2 (Centennial)
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Centennial Model Mailbox on Type 2 Foundation
Test Vehicle: 2011 Kia Rio (1100C)
Inertial Mass: 2440 lb
Gross Mass: 2605 lb
Impact Speed: 63 mi/h
Impact Angle: 0 degrees

Figure J.10. Vehicle Vertical Accelerometer Trace for Test No. 469469-10-2 (Accelerometer Located at Center of Gravity).

J.3. TXDOT LOCKABLE MAILBOX ON THIN-WALL GALVANIZED TUBE WITH TYPE 2 FOUNDATION

J.3.1. Details of the Lockable mailbox on thin-wall galvanized tube with Type 2 Foundation



Connection Details

Plate Washer details from TxDOT
MB-15(1) Drawing, sheet 2

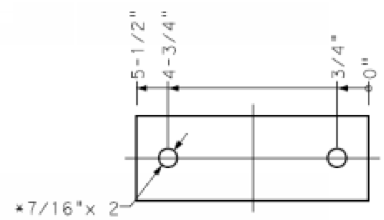
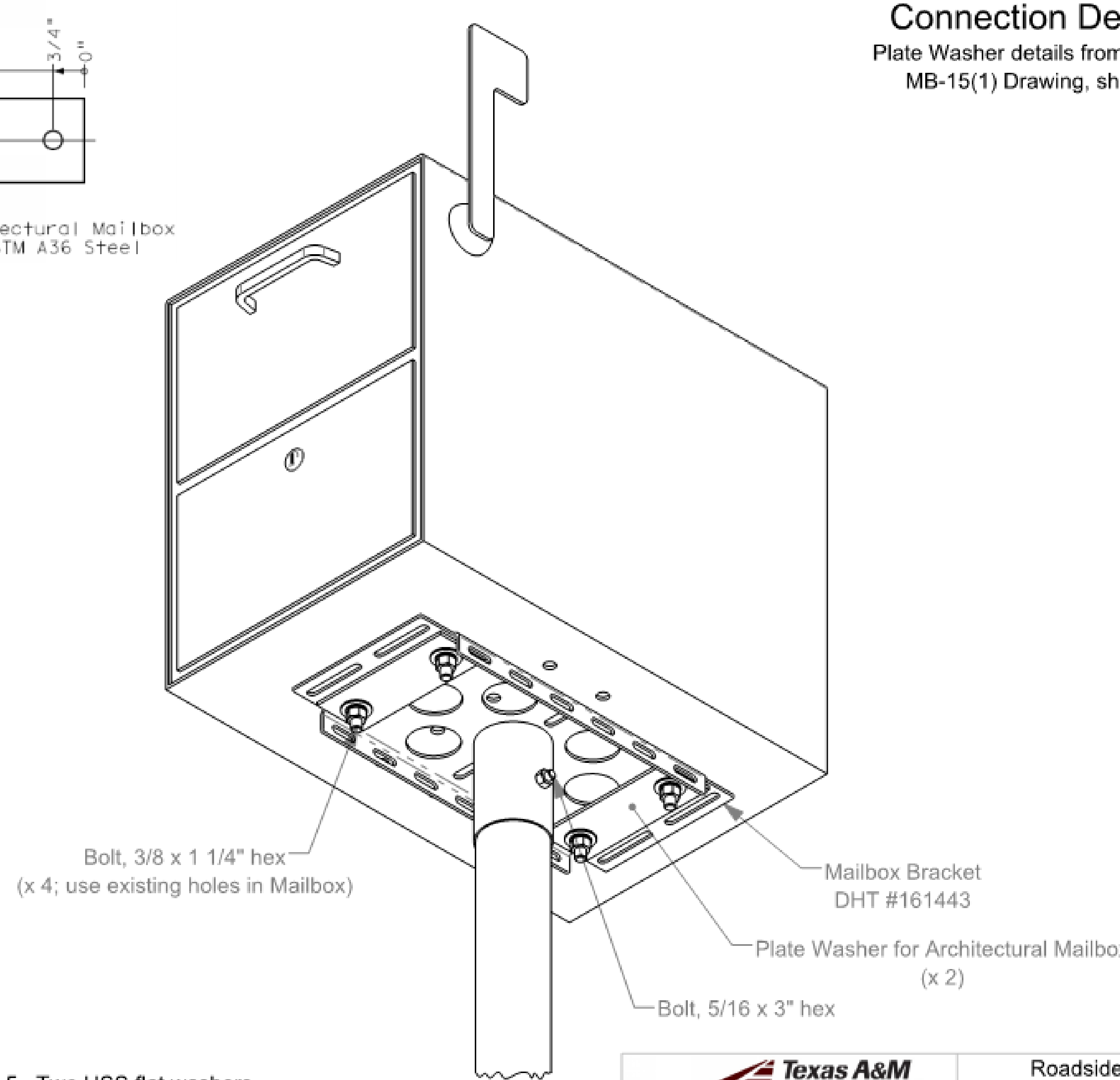
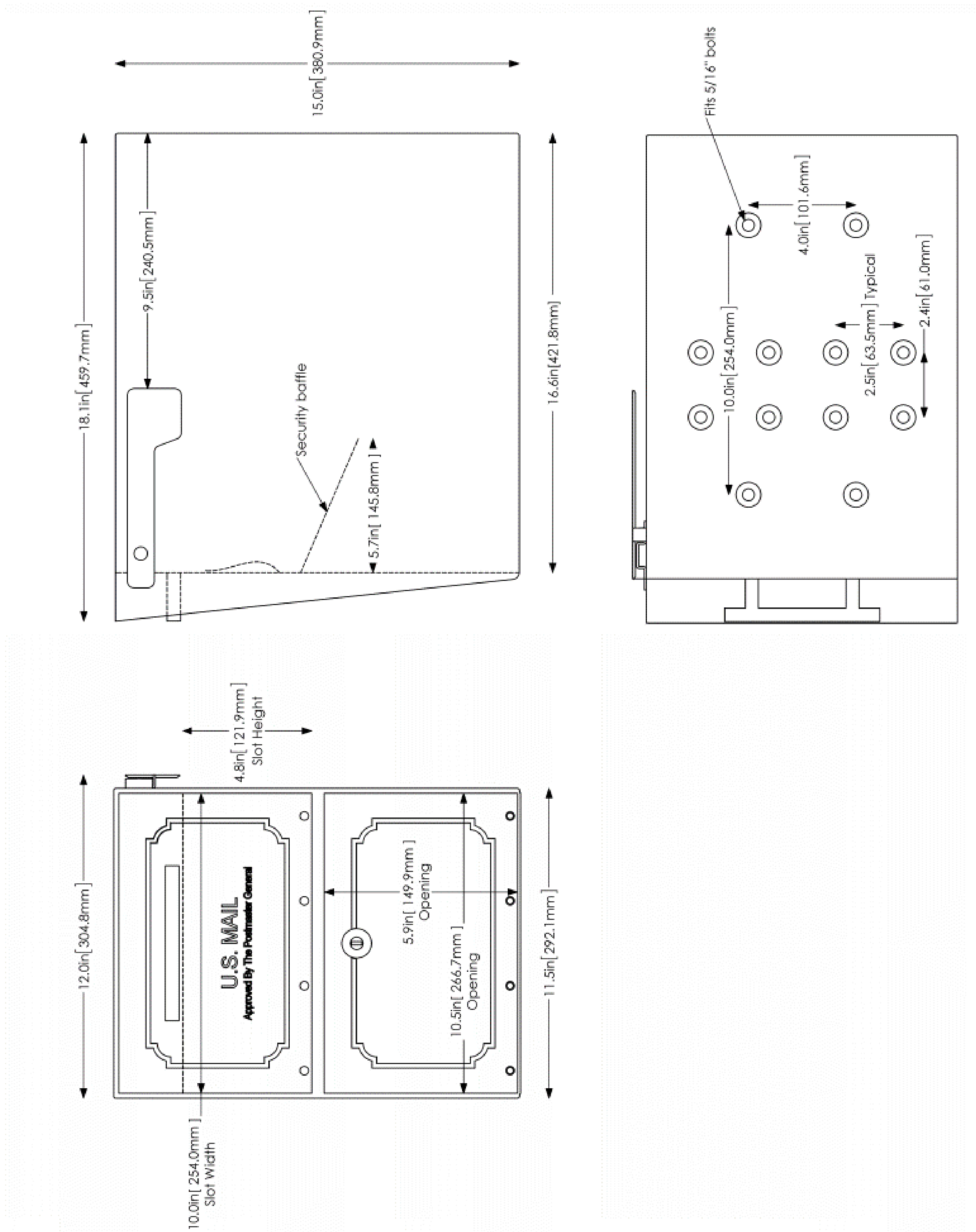


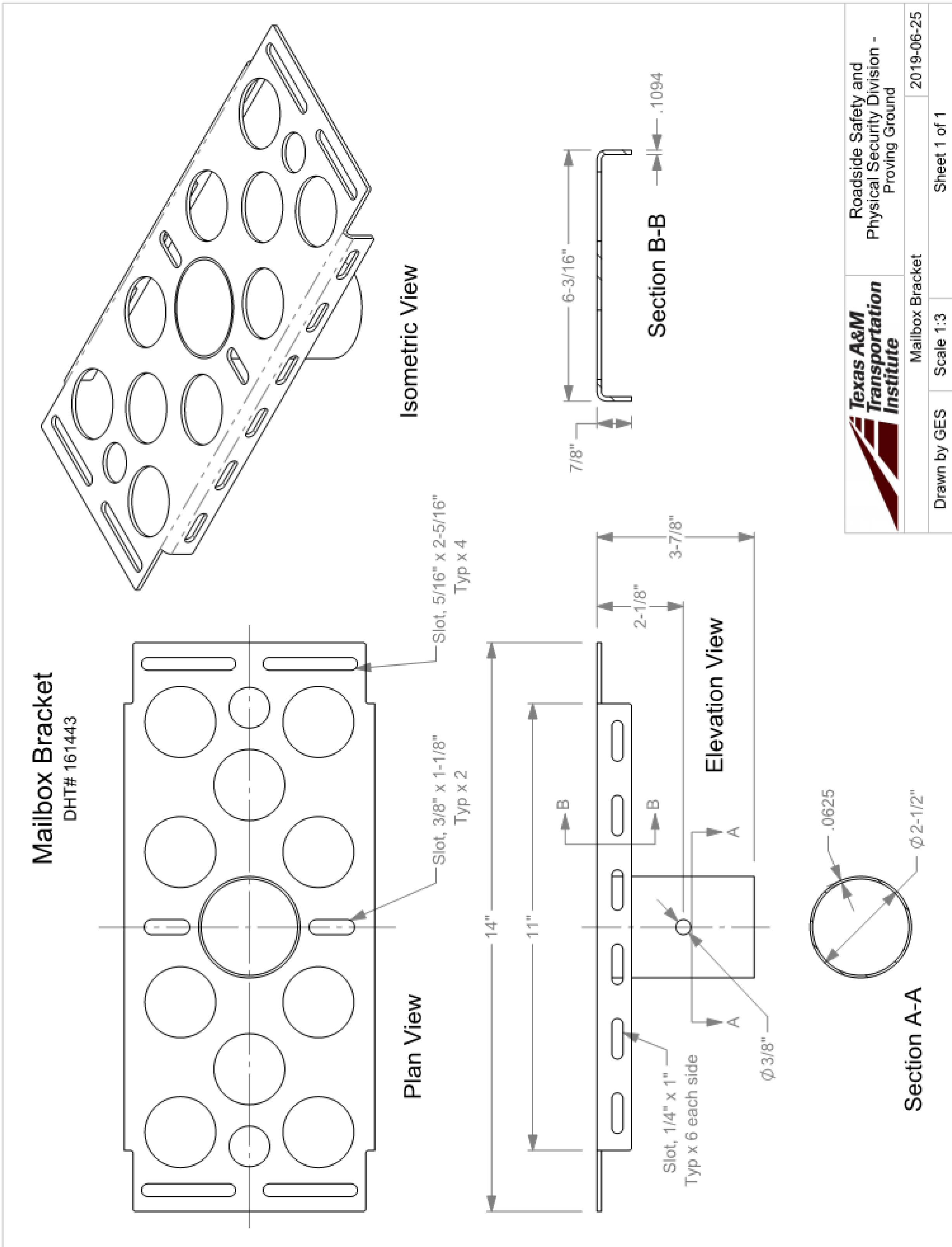
Plate Washer for Architectural Mailbox
Plate, 2" x 1/8" ASTM A36 Steel

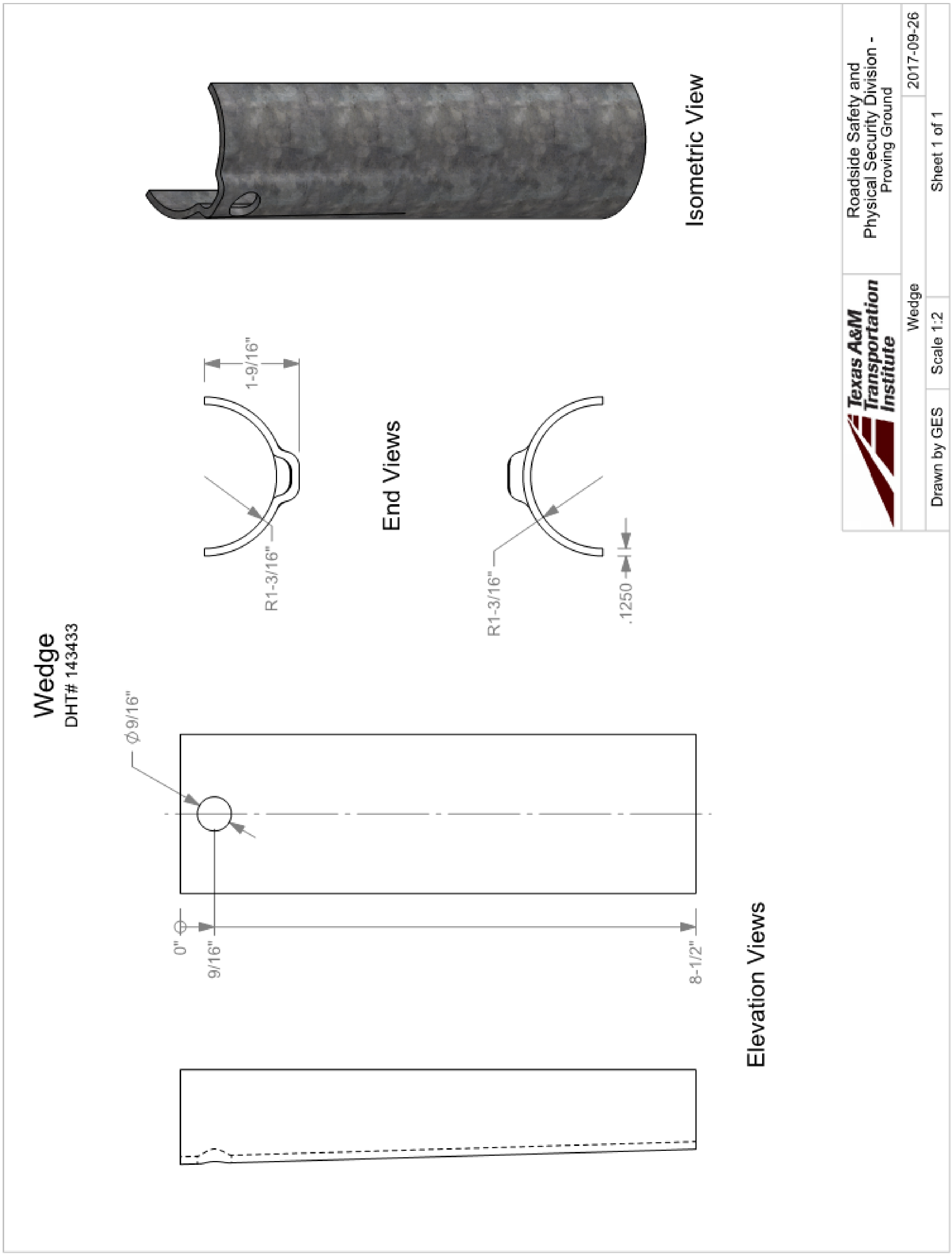


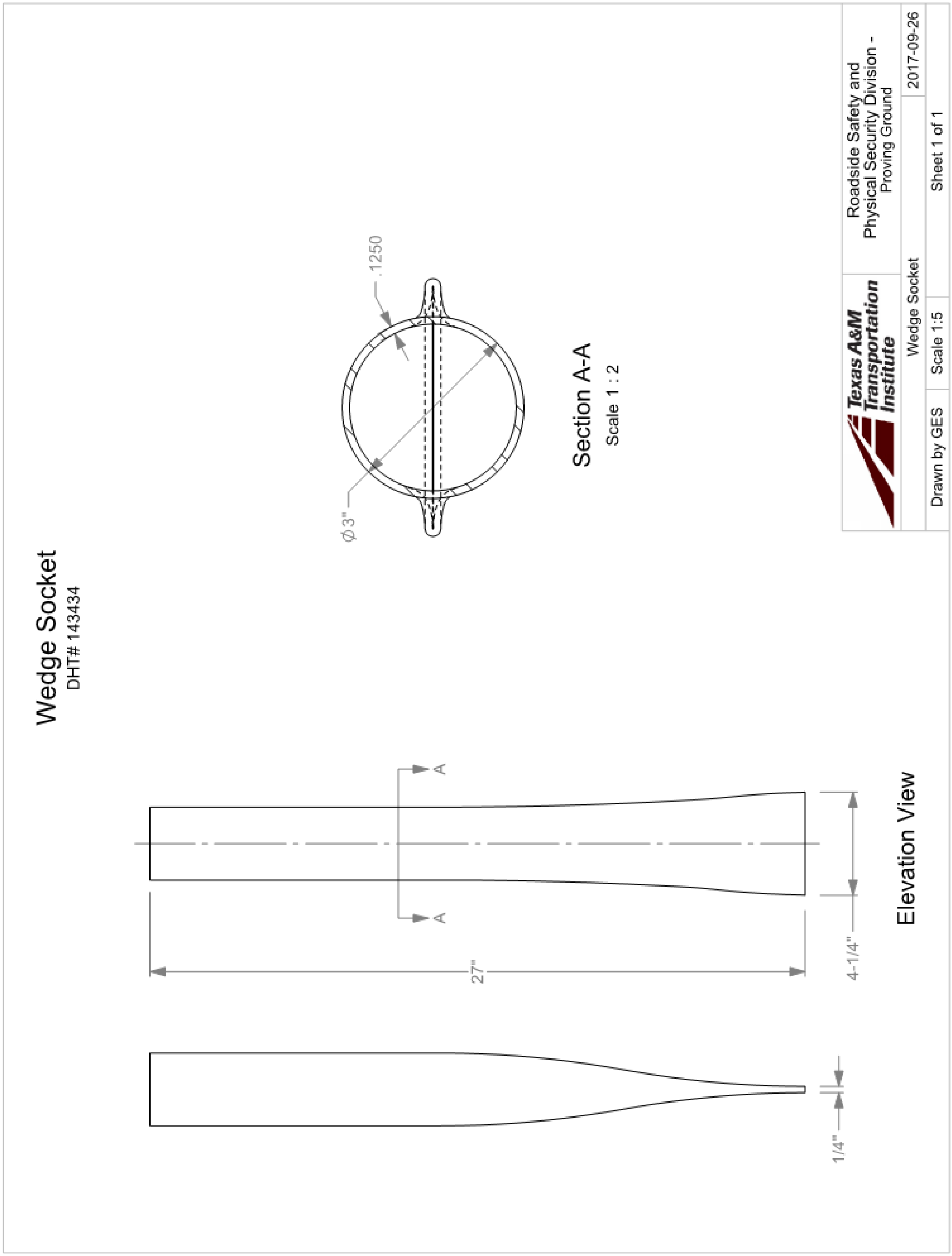
2a. All hex bolts are grade 5. Two USS flat washers, one lock washer, and hex nut on all hex bolts.

Texas A&M Transportation Institute		Roadside Safety and Physical Security Division - Proving Ground
Project #469469-10-3 Lockable on Type 2		2019-06-25
Drawn by GES	Scale 1:5	Sheet 2 of 2 Connection Details


15.0in[380.9mm]
18.1in[459.7mm]
9.5in[240.5mm]
16.6in[421.8mm]
Security baffle
5.7in[145.8mm]
Fits 5/16" bolts
4.0in[101.6mm]
10.0in[254.0mm]
2.5in[63.5mm] Typical
2.4in[61.0mm]
12.0in[304.8mm]
4.8in[121.9mm]
Slot Height
U.S. MAIL
Approved By The Postmaster General
5.9in[149.9mm]
Opening
10.5in[266.7mm]
Opening
11.5in[292.1mm]
10.0in[254.0mm]
Slot Width


Mailbox Bracket
DHT# 161443
Plan View
Slot, 5/16" x 2-5/16"
Typ x 4
Slot, 3/8" x 1-1/8"
Typ x 2
Isometric View
14"
11"
Elevation View
2-1/8"
3-7/8"
B
B
A
A
Slot, 1/4" x 1"
Typ x 6 each side
Ø 3/8"
Section A-A
.0625
Ø 2-1/2"
Section B-B
6-3/16"
7/8"
.1094
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Mailbox Bracket
2019-06-25
Drawn by GES
Scale 1:3
Sheet 1 of 1


Wedge
DHT# 143433
Ø9/16"
0"
9/16"
8-1/2"
Elevation Views
1-9/16"
R1-3/16"
End Views
R1-3/16"
.1250
Isometric View
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Wedge
2017-09-26
Drawn by GES
Scale 1:2
Sheet 1 of 1


Wedge Socket
DHT# 143434
.1250
Ø3"
Section A-A
Scale 1 : 2
A
A
27"
4-1/4"
1/4"
Elevation View
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Wedge Socket
2017-09-26
Drawn by GES
Scale 1:5
Sheet 1 of 1

J.3.2. Vehicle Properties and Information

Table J.9. Vehicle Properties for Test No. 469469-10-3.

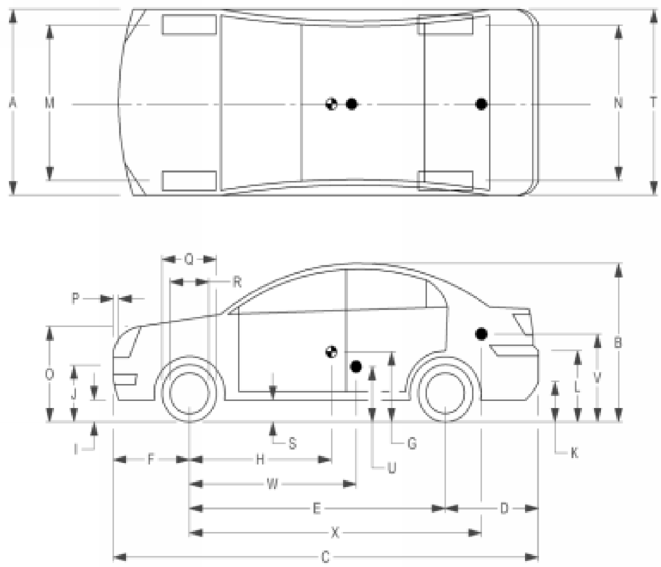
Vehicle Inventory Number: 1369

Date:	2019-06-25	Test No.:	469469-10-3	VIN No.:	KNADH4A33B6954717
Year:	2011	Make:	Kia	Model:	Rio
Tire Inflation Pressure:	32 PSI	Odometer:	101770	Tire Size:	185/65R14

Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES:



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

Dummy Data:
Type: 50th Percentile Male
Mass: 165 lb
Seat Position: OPPOSITE IMPACT

Geometry: inches

A	66.38	F	33.00	K	12.25	P	4.12	U	14.75
B	51.50	G		L	25.25	Q	22.50	V	20.50
C	165.75	H	36.01	M	57.75	R	15.50	W	36.00
D	34.00	I	7.75	N	57.70	S	8.25	X	71.50
E	98.75	J	21.50	O	27.00	T	66.20		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00 W-H 0.00

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Bottom of Hood Lip) = 24 ±4 inches
TOP OF RADIATOR SUPPORT = 28.25 inches; (M+N)/2 = 56 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1570	1550	1635
Back	1874	M_{rear}	885.00	890	970.00
Total	3638	M_{Total}	2455	2440	2605

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

Mass Distribution:
lb LF: 750 RF: 800 LR: 490 RR: 400

Performed by: SCD Date: 2019-06-25

Table J.10. Exterior Crush Measurements of Vehicle for Test No. 469469-10-3.

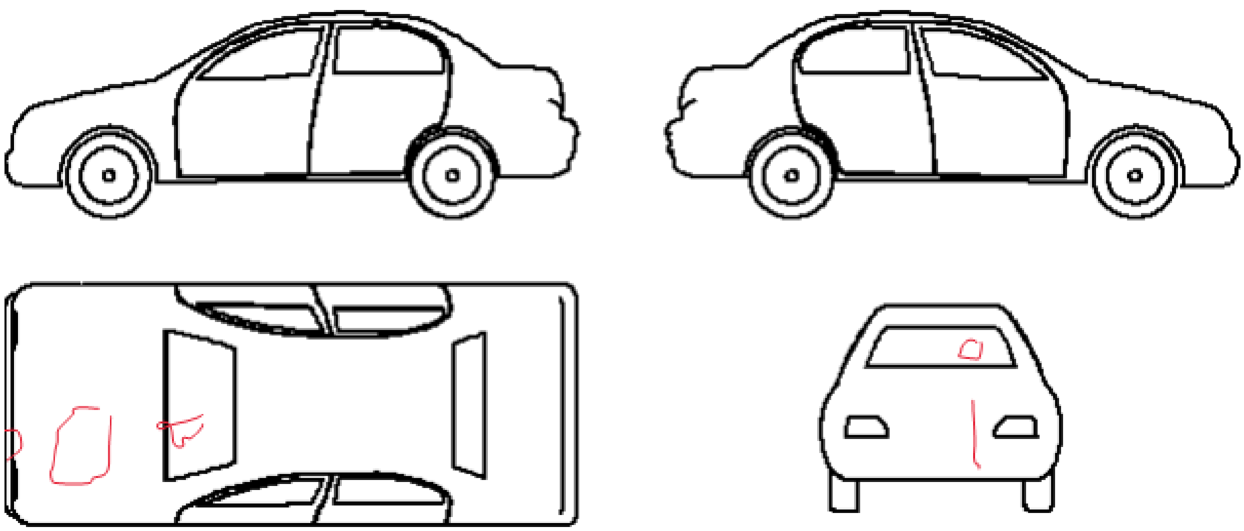
Vehicle Inventory Number: 1369

Date:	2019-06-25	Test No.:	469469-10-3	VIN No.:	KNADH4A33B6954717
Year:	2011	Make:	Kia	Model:	Rio
				Mileage:	101770

Please shade damage areas and note type of damage.

Driver's Side

Passenger Side



List vehicle damage:

3" DEEP DENT IN FT BUMPER 14" TO LT OF
CL

26" X 33" DENT IN LT SIDE OF HOOD 1.5"
DEEP WITH ONE .25" X .5 CUT

8" X 8" BREAK IN WINDSHIELD

Performed by: ***SCD*** Date: 2019-06-25

Table J.11. Exterior Crush Measurements of Vehicle for Test No. 469469-10-3.

Vehicle Inventory Number: 1369

Date:	2019-06-25	Test No.:	469469-10-3	VIN No.:	KNADH4A33B6954717
Year:	2011	Make:	Kia	Model:	Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable

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

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

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

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

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

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

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

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

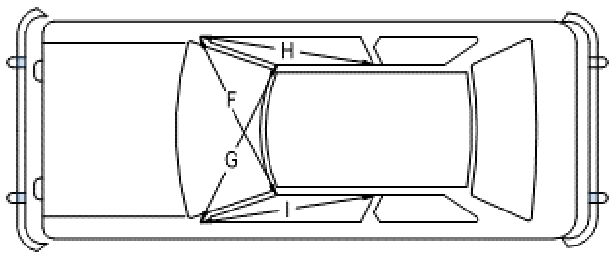
Note: Use as many lines/columns as necessary to describe each damage profile.

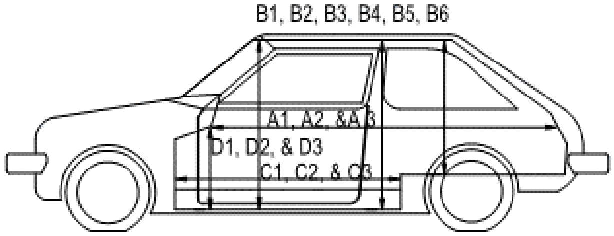
Performed by: **SCD** Date: 2019-06-26

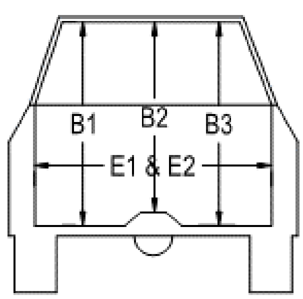
Table J.12. Occupant Compartment Measurements of Vehicle for Test No. 469469-10-3.

Vehicle Inventory Number: 1369

Date:	2019-06-25	Test No.:	469469-10-3	VIN No.:	KNADH4A33B6954717
Year:	2011	Make:	Kia	Model:	Rio







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

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

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

Performed by: ***SCD*** Date: 2019-06-26

J.3.3. Sequential Photographs

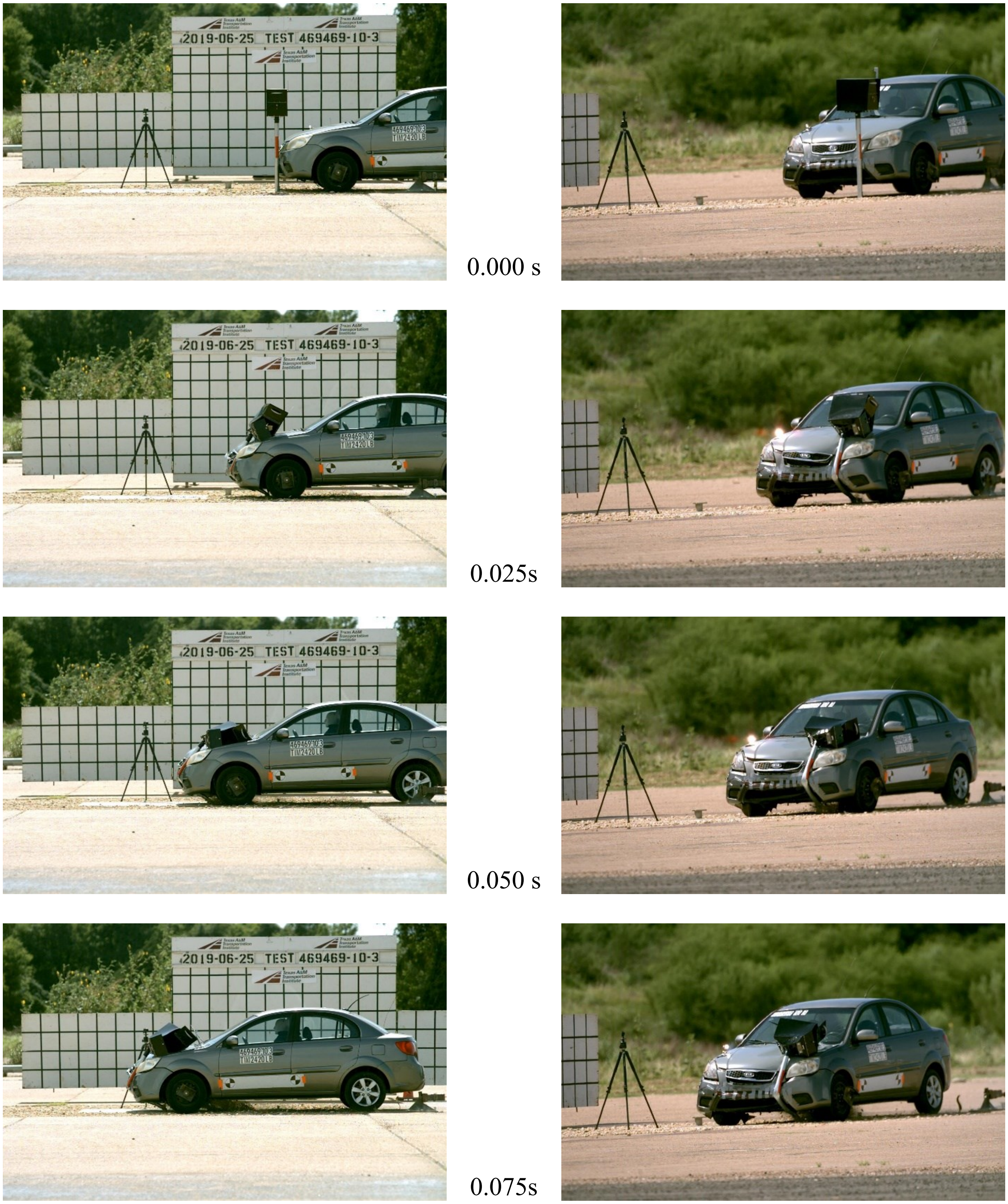


Figure J.11. Sequential Photographs for Test No. 469469-10-3 (Right Angle and Oblique Views).

0.100 s

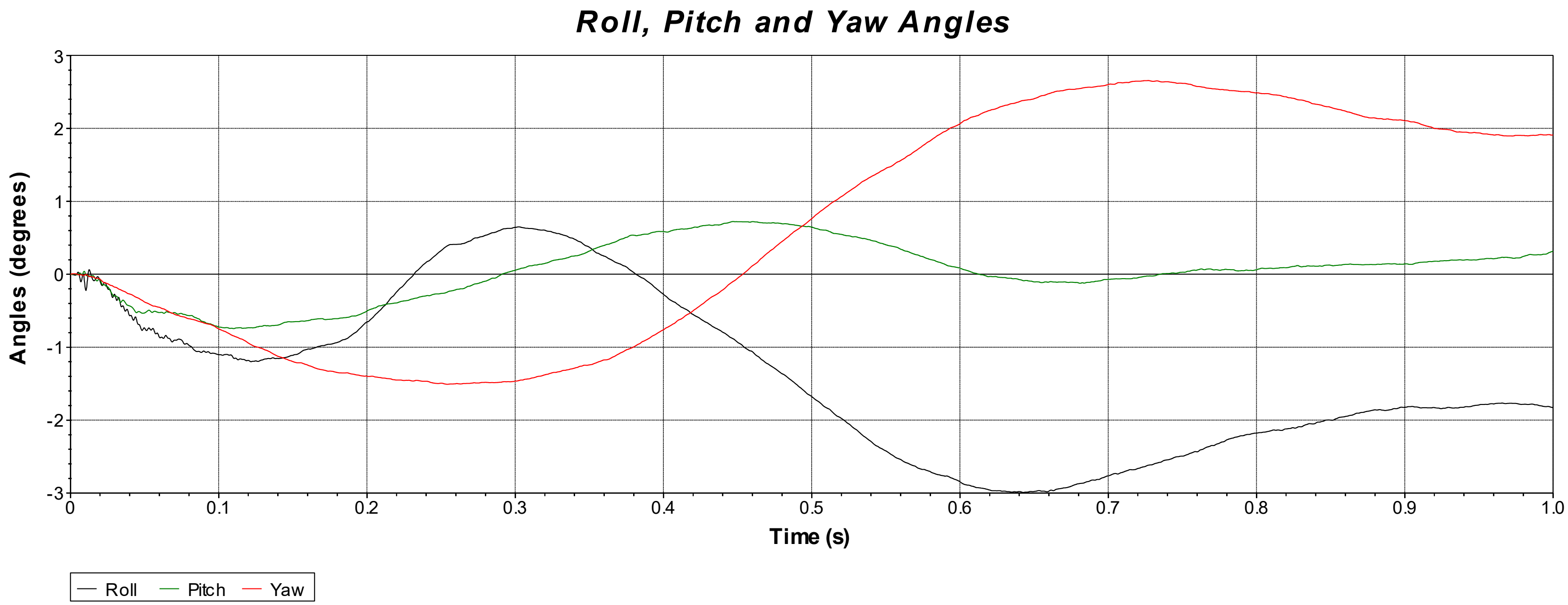
0.125 s

0.150 s

0.175 s

Figure A.1. Sequential Photographs for Test No. 469469-10-3 (Right Angle and Oblique Views) (Continued).

J.3.4. Vehicle Angular Displacement



Test Number: 469469-10-3 Lockable
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Lockable mailbox on Type 2 Foundation
Test Vehicle: 2011 Kia Rio (1100C)
Inertial Mass: 2440 lb
Gross Mass: 2605 lb
Impact Speed: 62.6 mi/h
Impact Angle: 0 degrees

Axes are vehicle-fixed.
Sequence for determining orientation:

46. Yaw.
47. Pitch.
48. Roll.

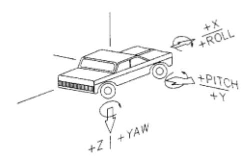


Figure J.12. Vehicle Angular Displacements for Test No. 469469-10-3.

J.3.5. Vehicle Acceleration

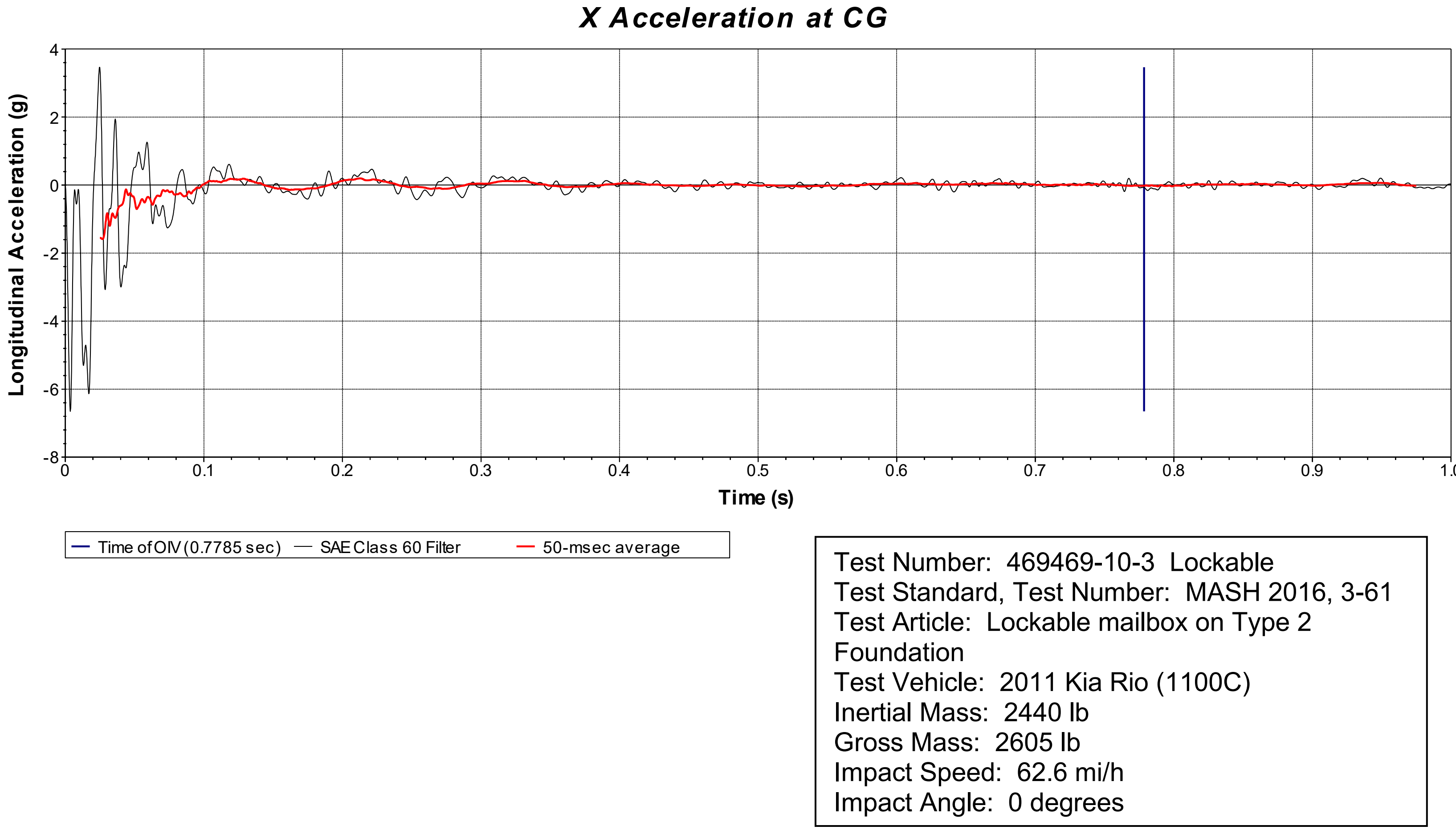
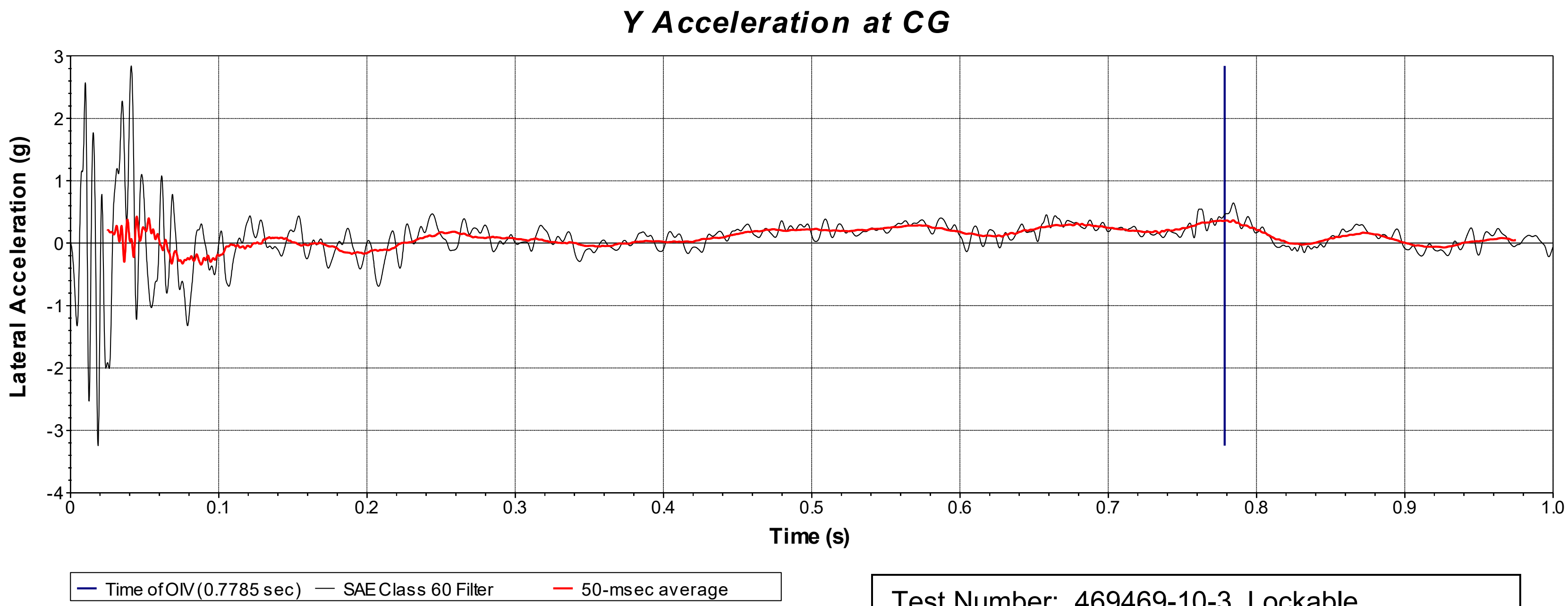
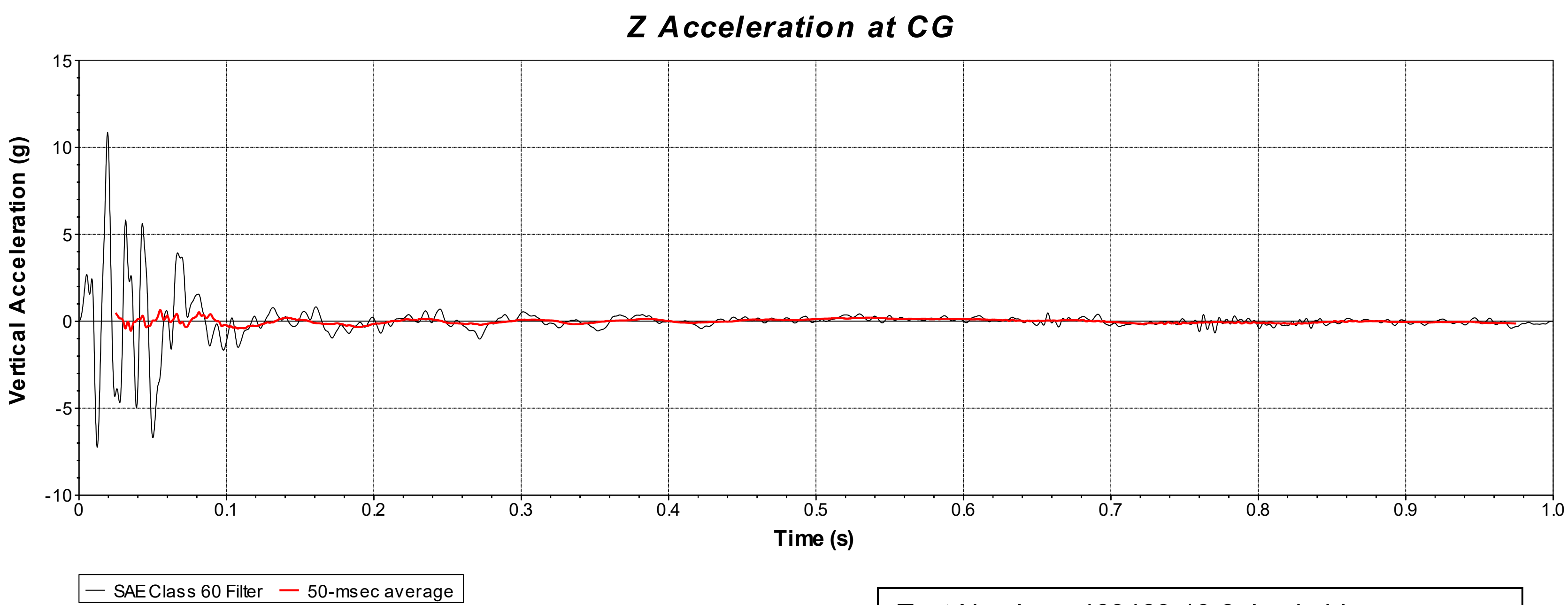


Figure J.13. Vehicle Longitudinal Accelerometer Trace for Test No. 469469-10-3 (Accelerometer Located at Center of Gravity).



Test Number: 469469-10-3 Lockable
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Lockable mailbox on Type 2 Foundation
Test Vehicle: 2011 Kia Rio (1100C)
Inertial Mass: 2440 lb
Gross Mass: 2605 lb
Impact Speed: 62.6 mi/h
Impact Angle: 0 degrees

Figure J.14. Vehicle Lateral Accelerometer Trace for Test No. 469469-10-3 (Accelerometer Located at Center of Gravity).

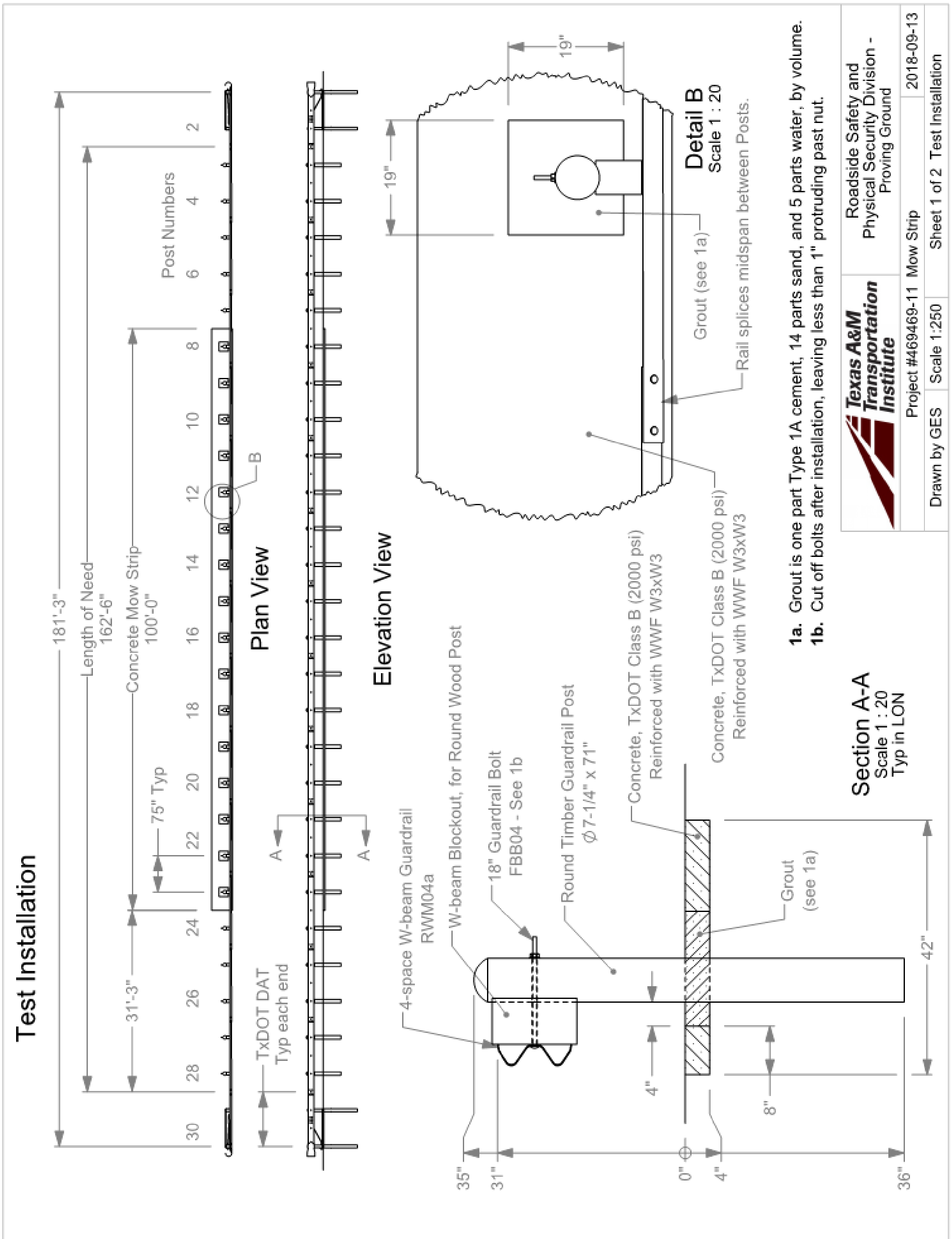


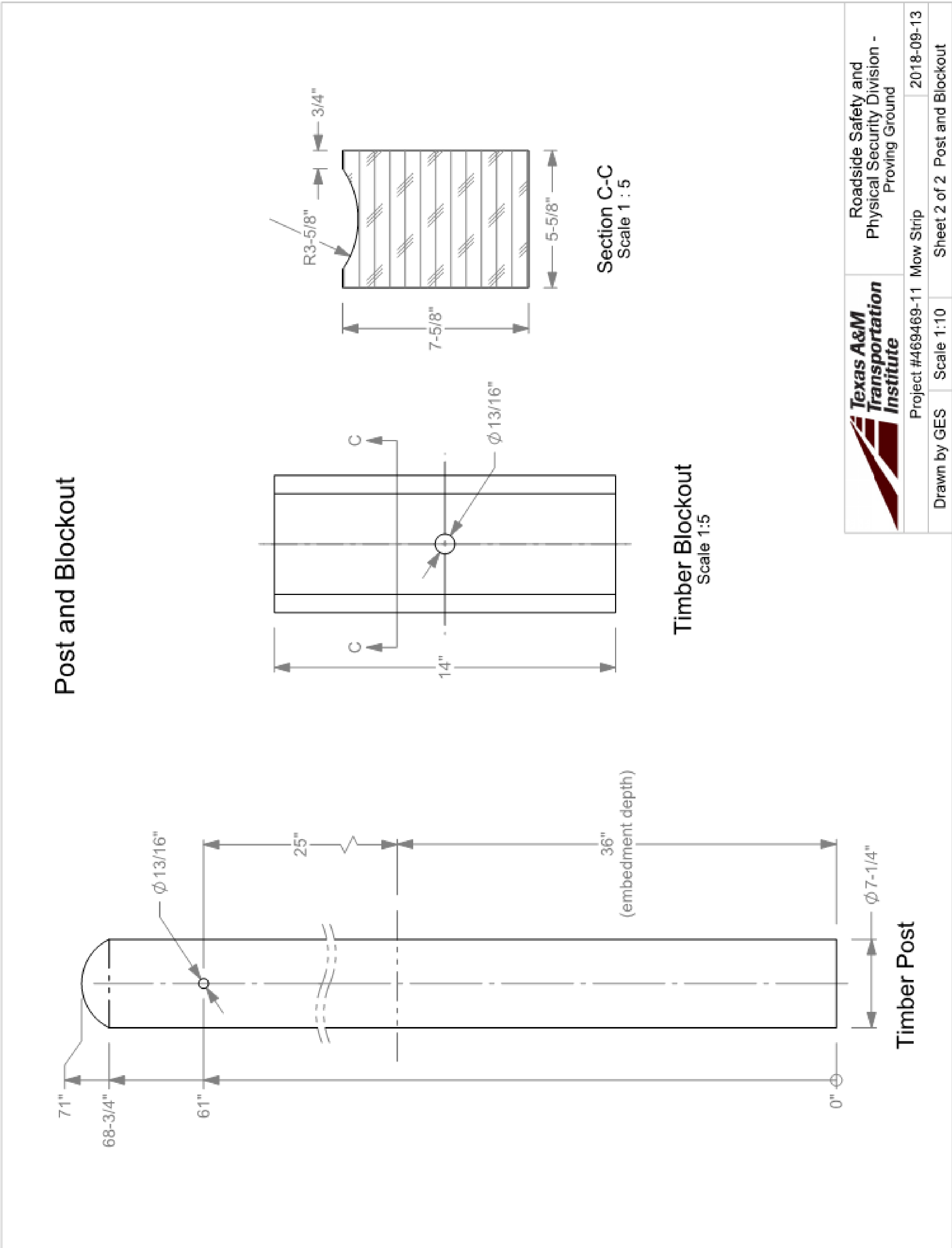
Test Number: 469469-10-3 Lockable
Test Standard, Test Number: MASH 2016, 3-61
Test Article: Lockable mailbox on Type 2 Foundation
Test Vehicle: 2011 Kia Rio (1100C)
Inertial Mass: 2440 lb
Gross Mass: 2605 lb
Impact Speed: 62.6 mi/h
Impact Angle: 0 degrees

Figure J.15. Vehicle Vertical Accelerometer Trace for Test No. 469469-10-3 (Accelerometer Located at Center of Gravity).

APPENDIX K. TXDOT ROUND WOOD POST GUARDRAIL IN CONCRETE MOW STRIP

K.1. DETAILS OF THE ROUND WOOD POST GUARDRAIL IN CONCRETE MOW STRIP




Post and Blockout
Timber Post
71"
68-3/4"
61"
0"
Ø13/16"
25"
36"
(embedment depth)
Ø7-1/4"
Timber Blockout
Scale 1:5
14"
Ø13/16"
C
C
Section C-C
Scale 1 : 5
R3-5/8"
3/4"
7-5/8"
5-5/8"
Texas A&M Transportation Institute
Roadside Safety and Physical Security Division - Proving Ground
Project #469469-11
Mow Strip
2018-09-13
Drawn by GES
Scale 1:10
Sheet 2 of 2 Post and Blockout

K.2. SUPPORTING CERTIFICATION DOCUMENTS

Certified Analysis

Trinity Highway Products , LLC
2548 N.E. 28th St.
Ft Worth (THP), TX 76111 Phn:(817) 665-1499

Customer: TEXAS A&M TRANS INSTITUTE
ROADSIDE SAFETY & PHYSICA
BUSINESS OFFICE
3135 TAMU
COLLEGE STATION, TX 77843-3135

Project: H2 TESTING OF NU-GUARD31

Order Number: 1271749 Prod Ln Grp: 3-Guardrail (Dom)
Customer PO: H2 TESTING
BOL Number: 64960 Ship Date: 1/6/2017
Document #: 1
Shipped To: TX
Use State: TX

As of: 2/13/17

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
25	11G	12/12'6/3'1.5/S			2	F10117													
			M-180	A	2	209337	61,740	79,690	26.0	0.190	0.750	0.012	0.004	0.010	0.140	0.000	0.050	0.002	4
			M-180	A	2	209340	59,890	78,740	27.8	0.190	0.710	0.012	0.004	0.010	0.130	0.000	0.060	0.001	4
4	724G	6'0 TUBE SL/.125X8X6	A-500			A82339	57,300	76,500	26.6	0.210	0.470	0.007	0.002	0.030	0.090	0.000	0.040	0.001	4
2	850G	12/BUFFER/ROLLED	M-180	A	2	21632240	47,800	59,000	32.0	0.060	0.370	0.008	0.005	0.030	0.110	0.002	0.050	0.002	4
2	3000G	CBL 3/4X6'6/DBL	HW			258592													
300	3340G	5/8" GR HEX NUT	HW			16-54-034													
200	3360G	5/8"X1.25" GR BOLT	HW			29419													
100	3500G	5/8"X10" GR BOLT A307	HW			28967-B													
89	3520G	5/8"X12" GR BOLT A307	HW			28318													
4	4140B	WD 4'0.25 POST 5.5X7.5	HW			TX-2630													
30	10628G	12/13'1.5/3'3.375/S				F10117													
			M-180	A		209337	61,740	79,690	26.0	0.190	0.750	0.012	0.004	0.010	0.140	0.000	0.050	0.002	4
			M-180	A		209340	59,890	78,740	27.8	0.190	0.710	0.012	0.004	0.010	0.130	0.000	0.060	0.001	4
4	19481G	C3X5#X6'-8" RUBRAIL	A-36			JW16106294	54,200	73,000	28.0	0.130	0.790	0.013	0.030	0.210	0.260	0.000	0.200	0.034	4
2	20207G	12/9'4.5/8-HOLE ANCH/S	RHC		2	L14416													4
			M-180	A	2	204672	60,180	78,330	26.1	0.190	0.730	0.011	0.003	0.020	0.100	0.000	0.050	0.000	4
			M-180	A	2	207479	62,640	83,470	27.4	0.190	0.720	0.013	0.006	0.020	0.140	0.000	0.070	0.000	4

GROUT COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0048
Service Date: 10/30/18
Report Date: 11/27/18 Revision 2 - Break correction
Task: PO #469469-11

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Client

Texas Transportation Institute
Attn: Gary Gerke
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project

Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Material Information

Specified Strength: 125 psi @

Mix ID: EFLOW15
Supplier: Martin Marietta
Batch Time: 1234 **Plant:** 617
Truck No.: 8102 **Ticket No.:** 5041911

Field Test Data

Test	Result	Specification
Slump (in):		Not Specified
Grout Temp. (F):	78	40 - 95
Ambient Temp. (F):	79	40 - 95

Sample Information

Sample Date: 10/30/18 **Sample Time:** 1320
Sampled By: Randolph E. Rohrbach
Weather Conditions: Cloudy, moderate wind
Accumulative Yards: 10/10 **Batch Size:** 5
Sample Size: 3" by 3"
Sample Location:
Placement Location: 439 439-11
Form Material: Cardboard Form **No. Units:** 3
Samples Plumb: Yes
Temperature Range:

Laboratory Test Data

Set No.	Specimen ID	Date Received	Date Tested	Age (days)	Area (sq in)	Maximum Load (lbs)	Compressive Strength (psi)	Tested By
1	A	10/31/18	11/08/18	9	10.73	339	30	BJA
1	B	10/31/18	11/08/18	9	10.73	565	50	BJA
1	C	10/31/18	11/08/18	9	10.73	396	40	BJA
						Average (9 days)	**40**	
1	D	10/31/18	11/19/18	20	10.82	1,020	90	AWD
1	E	10/31/18	11/19/18	20	11.08	1,130	100	AWD
1	F	10/31/18	11/19/18	20	11.09	1,190	110	AWD
						Average (20 days)	**100**	
1	I	10/31/18	11/27/18	28				
1	J	10/31/18	11/27/18	28				
1	K	10/31/18	11/27/18	28				
1	G	10/31/18		Hold				
1	H	10/31/18		Hold				
1	L	10/31/18		Hold				

Initial Cure: Onsite Cooler **Final Cure:** Cure Box
Comments:

GROUT COMPRESSIVE STRENGTH TEST REPORT

Report Number: A1171057.0048
Service Date: 10/30/18
Report Date: 11/27/18 Revision 2 - Break correction
Task: PO #469469-11

Terracon
6198 Imperial Loop
College Station, TX 77845-5765
979-846-3767 Reg No: F-3272

Client

Texas Transportation Institute
Attn: Gary Gerke
TTI Business Office
3135 TAMU
College Station, TX 77843-3135

Project

Riverside Campus
Riverside Campus
Bryan, TX

Project Number: A1171057

Samples Made By: Terracon
Services: Obtain sample of grout at the placement location and cast specimens for compressive strength determination.

Terracon Rep.: Randolph E. Rohrbach
Start/Stop: 1230-1500
Reported To:
Contractor:
Report Distribution:
(1) Texas Transportation Institute, Gary Gerke (1) Terracon Consultants, Inc., Andrea Gieser

Reviewed By:
Shane Sullivan
Project Manager

Test Methods: ASTM C109, ASTM C1019

The tests were performed in general accordance with applicable ASTM, AASHTO, or DOT test methods. This report is exclusively for the use of the client indicated above and shall not be reproduced except in full without the written consent of our company. Test results transmitted herein are only applicable to the actual samples tested at the location(s) referenced and are not necessarily indicative of the properties of other apparently similar or identical materials.

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	QF 7.3-01 Concrete Sampling	Doc. No. QF 7.3-01	Issue Date: 2018-06-18
Quality Form	Prepared by: Wanda L. Menges Approved by: Darrell L. Kuhn	Revision: 6	Page: 1 of 1

The information contained in this document is confidential to TTI Proving Ground.

Project No: 465469-11 **Casting Date:** 2018-10-30 **Mix Design (psi):** GROUT

Name of Technician Taking Sample ____________ Name of Technician Breaking Sample ____________

Signature of Technician Taking Sample ____________ Signature of Technician Breaking Sample ____________

Load No.	Truck No.	Ticket No.	Location (from concrete map)
T1	8102	5041511	FIRST 8 POST (STARTING NORTH)
T2	8102	5042319	Remaining POSTS

Load No.	Break Date	Cylinder Age	Total Load (lbs)	Break (psi)	Average

CUSTOMER'S COPY

TICKET NO.

5041911

Martin Marietta

1503 LBJ Freeway
Suite 400
Dallas, Tx 75234

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
12:34	12:45	13:05	13:10	:	13:30	13:48

WATER ADDED ON JOB AT CUSTOMER'S REQUEST 0 GAL.
ALLOWABLE WATER (withheld from batch) 13.1 GAL.
TEST CYLINDER TAKEN ❑ YES ❑ NO BY
CYLINDER TAKEN ❑ BEFORE ❑ AFTER WATER

ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH. ANY WATER ADDED IN EXCESS OF SPECIFIED SLUMP IS AT CUSTOMER'S RISK.

CUSTOMER SIGNATURE
X

DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS AND CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED BY SIGNATURE ABOVE.

CUSTOMER NAME AND DELIVERY ADDRESS
TEXAS A & M UNIVERSI
TTI-Riverside Campus

PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT	GRID
617	8102	2021	11.	439-11	

DRIVER NAME	DATE
LARRY JANTZEN	10/30/18

CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY
783659	51240	5.00	5.00

LOAD QUANTITY	PRODUCT CODE	DESCRIPTION	UNIT PRICE	AMOUNT
5.00 CYDS	EFLOW15	1.5SK FLOW FILL		
1.00 ea	12987	FREIGHT CHARGE		

8 POST

SPECIAL DELIVERY INSTRUCTIONS
2818-RT ON LEONARD RT ON HWY-47-LFT INTO RELLIS
CAMPUS WILL MEETAT GATE

SALES TAX

TOTAL

DANGER! MAY CAUSE ALKALI BURNS.
SEE WARNINGS ON REVERSE SIDE.

FOR OFFICE USE ONLY **FORM:** 2585294

```
Truck     Driver      User      Disp Ticket Num   Ticket ID   Time   Date
8102      #77135      user      5041911           70821       12:34  10/30/18
Load Size   Mix Code   Returned   Qty      Mix Age      Seq   Load ID
5.00 CYDS   EFLOW15                                     D     71801
Material    Design Qty   Required    Batched    % Var    % Moisture   Actual Wat
SAND-1      2658 lb      14901 lb    14860 lb   -0.44%   4.10% M      73 gl
CMT-I/II    142 lb       710 lb      700 lb     -1.41%
H2O         520 lb       1885 lb     1881 lb    -0.20%
Actual      Num Batches: 1                                            225 gl
Load Total: 17461 lb   Design 3.662  Water/Cement: 3.714 T   Design 311.6 gl   Actual 298.5 gl  To Add: 13.1 gl
Slump: 11.00 in   Water in Truck: 0.0 gl   Adjust Water: 0.0 gl / Load   Trim Water: -2.5 gl/ CYD
```

465469-11 TT

CUSTOMER'S COPY

TICKET NO.

5042319

Martin Marietta

1503 LBJ Freeway
Suite 400
Dallas, Tx 75234

LOAD TIME	TO JOB	ARRIVE JOB SITE	BEGIN POUR	FINISH POUR	LEAVE JOB SITE	ARRIVE PLANT
13:51	14:03	14:22	14:25	14:35	:	:

WATER ADDED ON JOB AT CUSTOMER'S REQUEST 1 GAL.
ALLOWABLE WATER (withheld from batch) 12.9 GAL.
TEST CYLINDER TAKEN ❑ YES ❑ NO BY
CYLINDER TAKEN ❑ BEFORE ❑ AFTER WATER

ADDITIONAL WATER ADDED TO THIS CONCRETE WILL REDUCE ITS STRENGTH. ANY WATER ADDED IN EXCESS OF SPECIFIED SLUMP IS AT CUSTOMER'S RISK.

CUSTOMER SIGNATURE
X

DELIVERY OF THESE MATERIALS IS SUBJECT TO THE TERMS AND CONDITIONS ON THE REVERSE SIDE HEREOF AS ACCEPTED BY SIGNATURE ABOVE.

CUSTOMER NAME AND DELIVERY ADDRESS
TEXAS A & M UNIVERSI
TTI-Riverside Campus

PLANT	TRUCK	ORDER NO.	SLUMP	P.O. #/JOB/LOT	GRID
817	8102	2021	11.	439-11	

DRIVER NAME	DATE
LARRY JANTZEN	10/30/18

CUSTOMER NUMBER	PROJECT	CUM. QTY	ORDERED QTY
783659	51240	10.00	10.00

LOAD QUANTITY	PRODUCT CODE	DESCRIPTION	UNIT PRICE	AMOUNT
5.00	CYDS	EFLOW15 1.5SK FLOW FILL		
1.00	ea	12907 FREIGHT CHARGE		

SPECIAL DELIVERY INSTRUCTIONS
2818-RT ON LEONARD RT ON HWY-47-LFT INTO RELLIS
CAMPUS WILL MEETAT GATE

SALES TAX

TOTAL

DANGER! MAY CAUSE ALKALI BURNS.
SEE WARNINGS ON REVERSE SIDE.

FOR OFFICE USE ONLY **FORM:** 2585302

```
Truck      Driver      User     Disp Ticket Num   Ticket ID   Time  Date
8102       777175      user     5042319           70829       13:51 10/30/18
Load Size  Mix Code    Returned    Qty            Mix Age     Seq   Load ID
5.00  CYDS EFLOW15                                            D     71809
Material   Design Qty   Required   Batched    % Var    % Moisture   Actual Wat
SAND-1     2858 lb      14901 lb   14920 lb   0.13%    4.10% M      73 gl
CNT-I/II   142 lb       710 lb     710 lb     0.00%
H2O        520 lb       1885 lb    1881 lb    -0.20%                225 gl
Actual     Num Batches: 1
Load Total:  17511 lb   Design 3.662 Water/Cement 3.662 T   Design 311.6 gl   Actual 298.7 gl   To Add: 12.9 gl
Slump: 11.00 in   # Water in Truck: 0.0 gl  Adjust Water: 0.0 gl / Load   Trim Water: -8.5 gl/ CYD
```

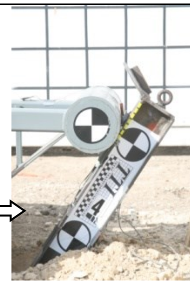
4654691

T2

Table K.1. Summary of Strong Soil Test Results for Establishing Installation Procedure.

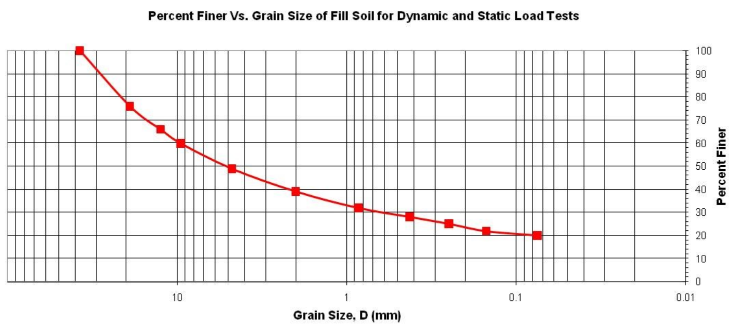
Dynamic Setup

Post-Test Photo of post

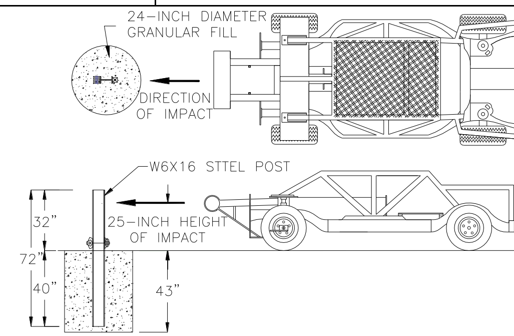


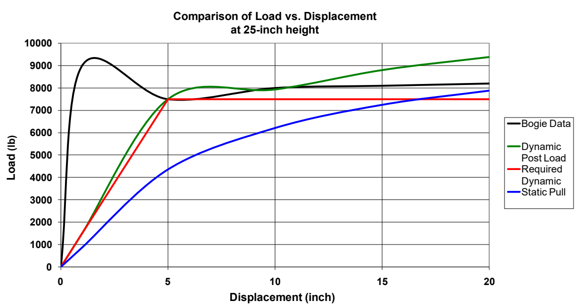
Post-Test Photo

Static Load Test

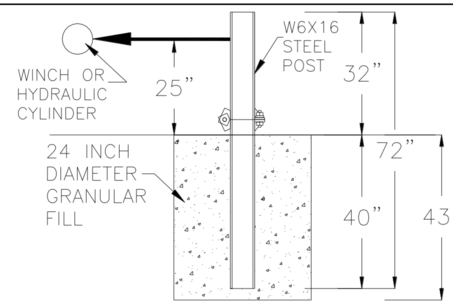


Dynamic Test Installation Details



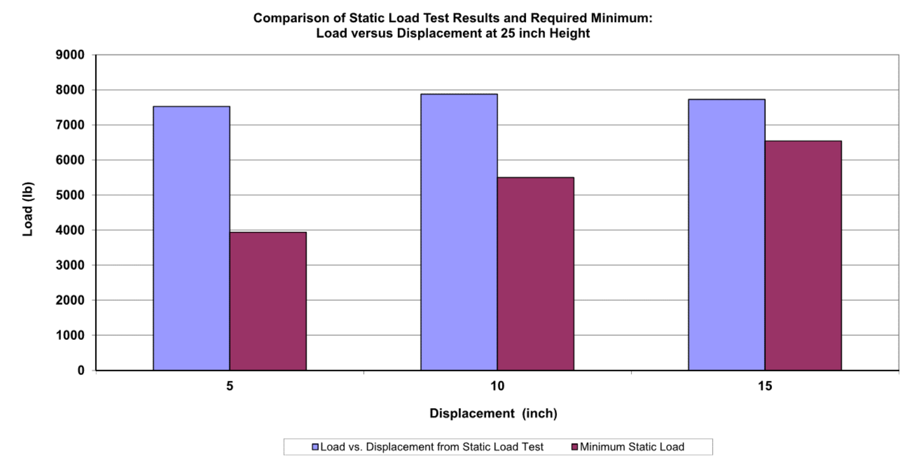


Static Load Test Installation Details

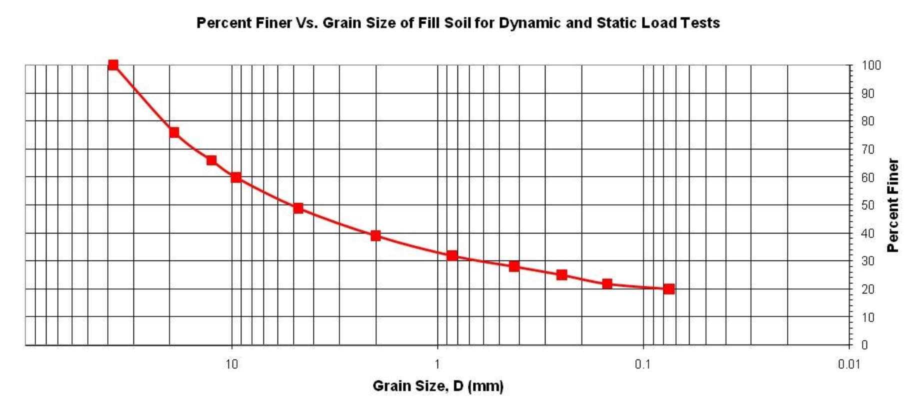


Date	2008-11-05
Test Facility and Site Location	TTI Proving Ground, 3100 SH 47, Bryan, TX 77807
In Situ Soil Description (ASTM D2487)	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis	AASHTO Grade B Soil-Aggregate (see sieve analysis above)
Description of Fill Placement Procedure	6-inch lifts tamped with a pneumatic compactor
Bogie Weight	5009 lb
Impact Velocity	20.5 mph

Table K.2. Test Day Static Soil Strength Documentation for Test No. 469688-5-1.



Static Load Setup



Post-Test Photo of Post

Date	2018-12-04
Test Facility and Site Location	TTI Proving Ground – 3100 SH 47, Bryan, Tx
In Situ Soil Description (ASTM D2487)	Sandy gravel with silty fines
Fill Material Description (ASTM D2487) and sieve analysis	AASHTO Grade B Soil-Aggregate (see sieve analysis)
Description of Fill Placement Procedure	6-inch lifts tamped with a pneumatic compactor

K.3. *MASH* TEST 3-11 (CRASH TEST NO. 469469-11)

K.3.1. Vehicle Properties and Information

Table K.3. Vehicle Properties for Test No. 469469-11.

Vehicle Inventory Number: 1347

Date: 2018-12-04 | Test No.: 469469-11-1 | VIN No.: 1C6RD6FT2CS280469

Year: 2012 | Make: RAM | Model: 1500

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

Tread Type: Highway | Odometer:

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

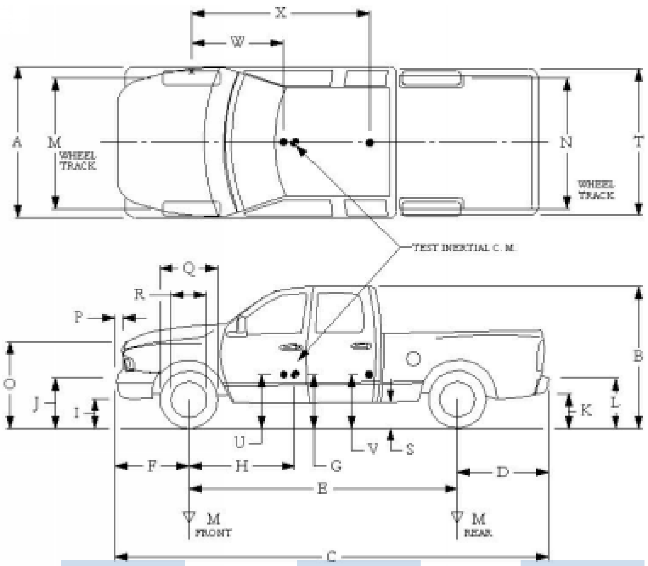
NOTES: None

Engine Type: V-8
Engine CID: 4.7 liter

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

Optional Equipment:
None

Dummy Data:
Type:
Mass: 0 lb
Seat Position:



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	27.50
B	74.00	G	28.00	L	30.00	Q	30.50	V	31.25
C	227.50	H	63.28	M	68.50	R	18.00	W	63.20
D	44.00	I	11.75	N	68.00	S	13.00	X	79.50
E	140.50	J	27.00	O	46.00	T	77.00		

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

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

GVWR Ratings:		Mass: lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2889	2759	
Back	3900	M_{rear}	2131	2261	
Total	6700	M_{Total}	5020	5020	0

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

Mass Distribution:
lb LF: 1398 RF: 1361 LR: 1122 RR: 1139

Performed by: SCD | Date: 2018-12-04

Table K.4. Measurements of Vehicle Vertical CG for Test No. 469469-11.

Vehicle Inventory Number: 1347

Date: 2018-12-04 Test No.: 469469-11-1 VIN: 1C6RD6FT2CS280469

Year: 2012 Make: RAM Model: 1500

Body Style: Quad Cab Mileage:

Engine: 4.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 171 (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70 R 17

Measured Vehicle Weights: (lb)						
LF:	1398	RF:	1361	Front Axle:	2759	
LR:	1122	RR:	1139	Rear Axle:	2261	
Left:	2520	Right:	2500	Total:	5020	
					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:	63.28	inches	Rear of Front Axle	(63 ±4 inches allowed)		
Y:	-0.14	inches	Left - Right +	of Vehicle Centerline		
Z:	28.00	inches	Above Ground	(minumum 28.0 inches allowed)		

Hood Height: 46.00 inches Front Bumper Height: 27.00 inches

43 ±4 inches allowed

Front Overhang: 40.00 inches Rear Bumper Height: 30.00 inches

39 ±3 inches allowed

Overall Length: 227.50 inches

237 ±13 inches allowed

Performed by: SCD Date: 2018-12-04

Table K.5. Exterior Crush Measurements of Vehicle for Test No. 469469-11.

Vehicle Inventory Number: 1347

Date: 2018-12-04 Test No.: 469469-11-1 VIN No.: 1C6RD6FT2CS280469

Year: 2012 Make: RAM Model: 1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	AT FT BUMPER		17								
2	SAME		11								
	Measurements recorded										
	☐ inches or ☐ mm										

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

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

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

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

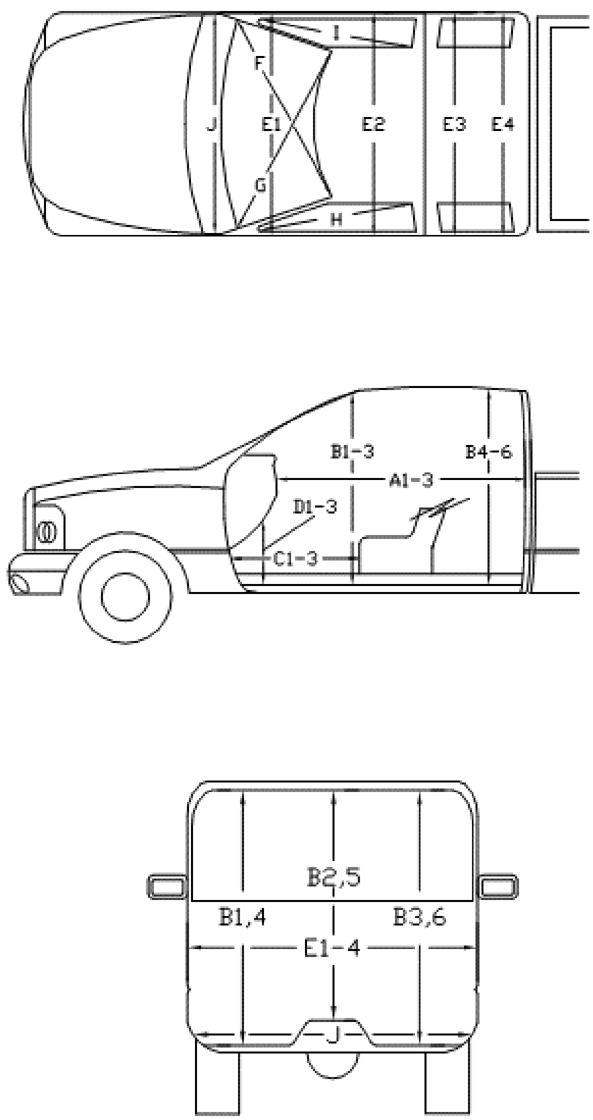
***Measure and document on the vehicle diagram the location of the maximum crush.

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

Table K.6. Occupant Compartment Measurements of Vehicle for Test No. 469469-11.

Vehicle Inventory Number: 1347

Date:	2018-12-04	Test No.:	469469-11-1	VIN No.:	1C6RD6FT2CS280469
Year:	2012	Make:	RAM	Model:	1500



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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	58.50	0.00
E2	63.50	63.50	0.00
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	25.00	0.00

Performed by: SCD Date: 2018-12-04

K.3.2. Sequential Photographs

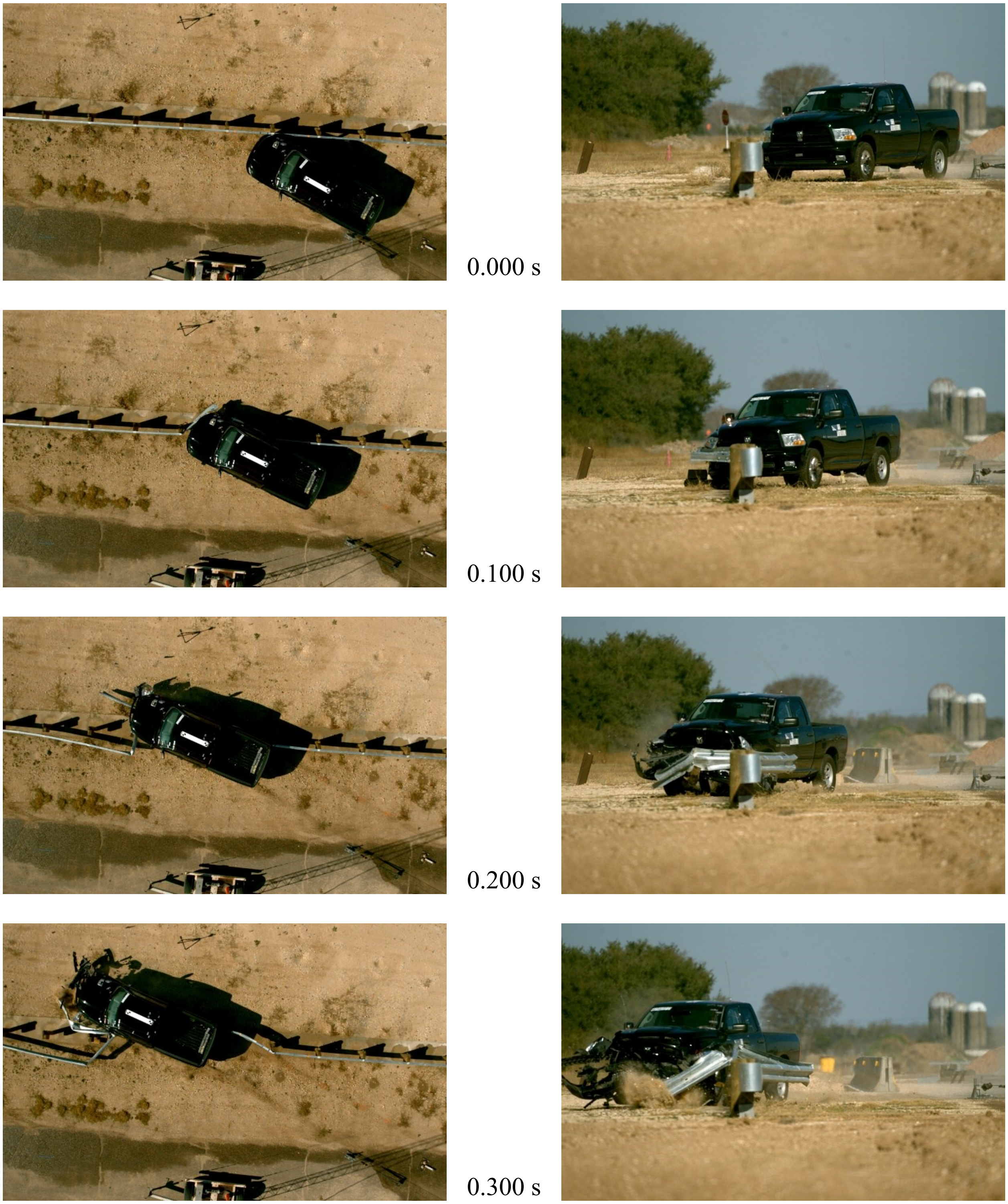


Figure K.1. Sequential Photographs for Test No. 469469-11 (Overhead and Gut Views).

0.500 s

0.600 s

0.700 s

0.800 s

Figure A.1. Sequential Photographs for Test No. 469469-11 (Overhead and Gut Views) (Continued).

0.000 s

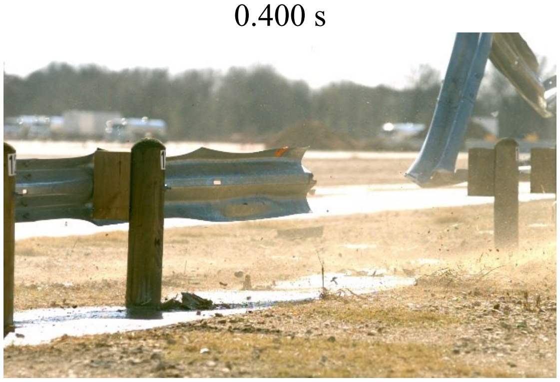
0.100 s

0.200 s

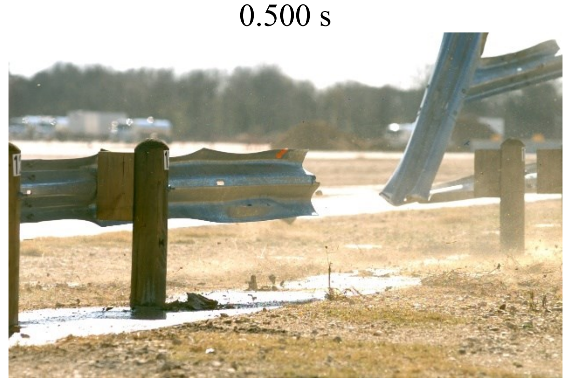
0.300 s

0.400 s

0.500 s



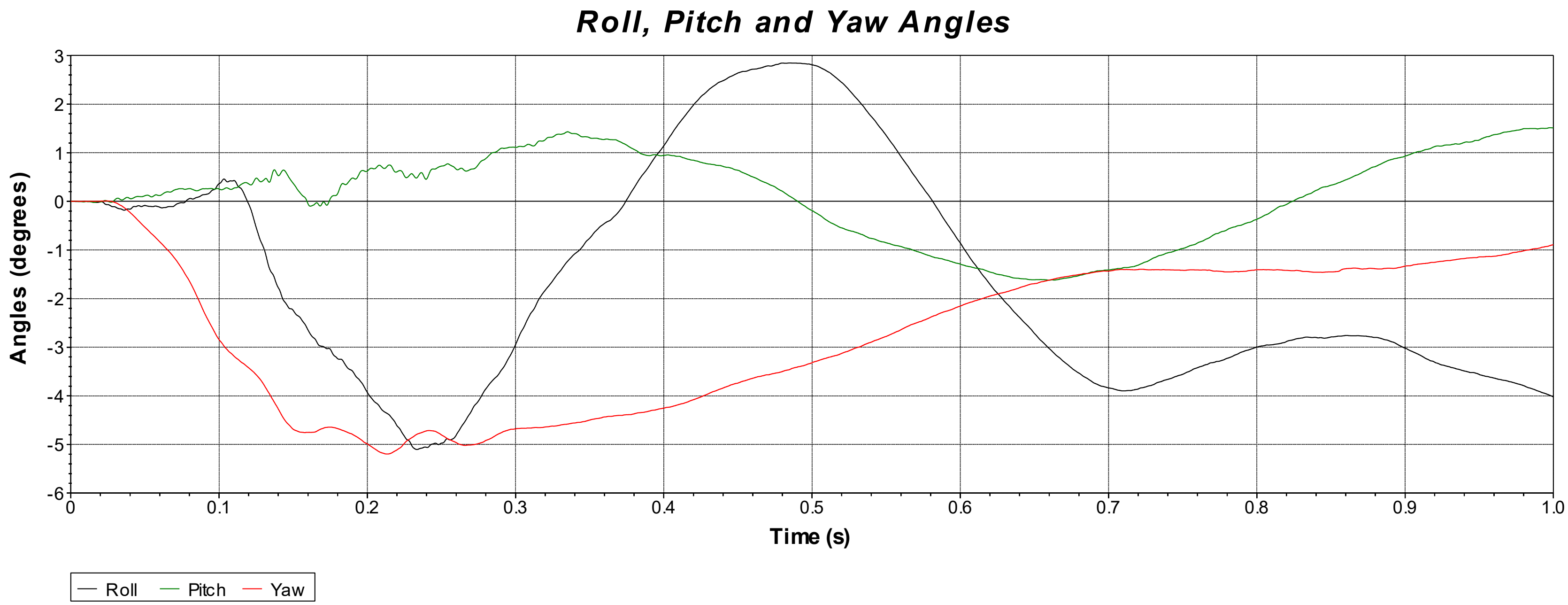
0.600 s



0.700 s

Figure K.2. Sequential Photographs for Test No. 469469-11 (Rear View).

K.3.3. Vehicle Angular Displacement



Test Number: 469469-11
Test Standard: MASH 2016, 3-11
Test Article: Round wood post guardrail in concrete mow strip
Test Vehicle: 2012 RAM 1500
Inertial Mass: 5020 lb
Gross Mass: 5020 lb
Impact Speed: 63.3 mi/h
Impact Angle: 25.3 degrees

Axes are vehicle-fixed.
Sequence for determining orientation:

49. Yaw.
50. Pitch.
51. Roll.

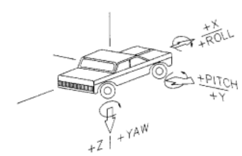


Figure K.3. Vehicle Angular Displacements for Test No. 469469-11.

K.3.4. Vehicle Acceleration

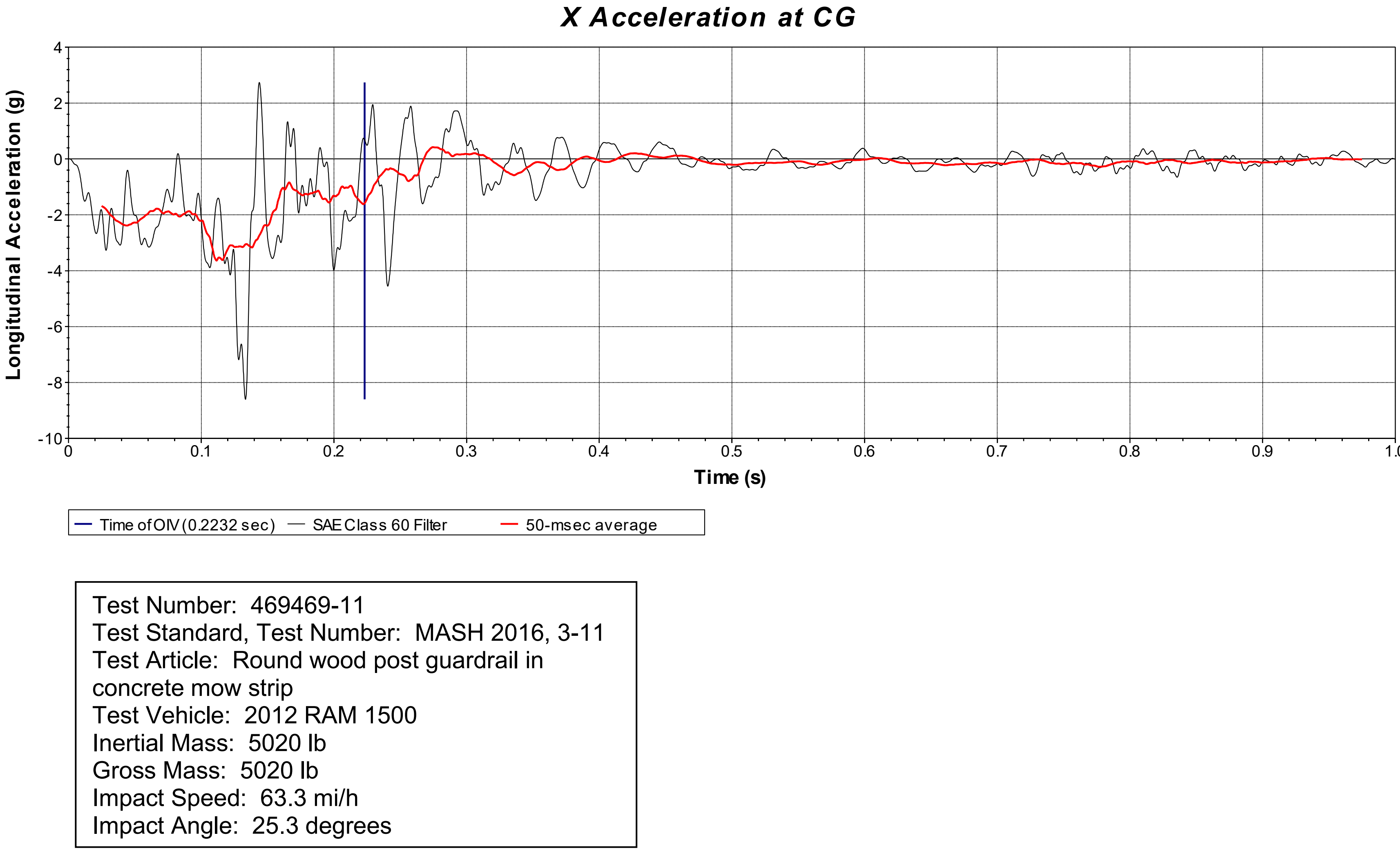
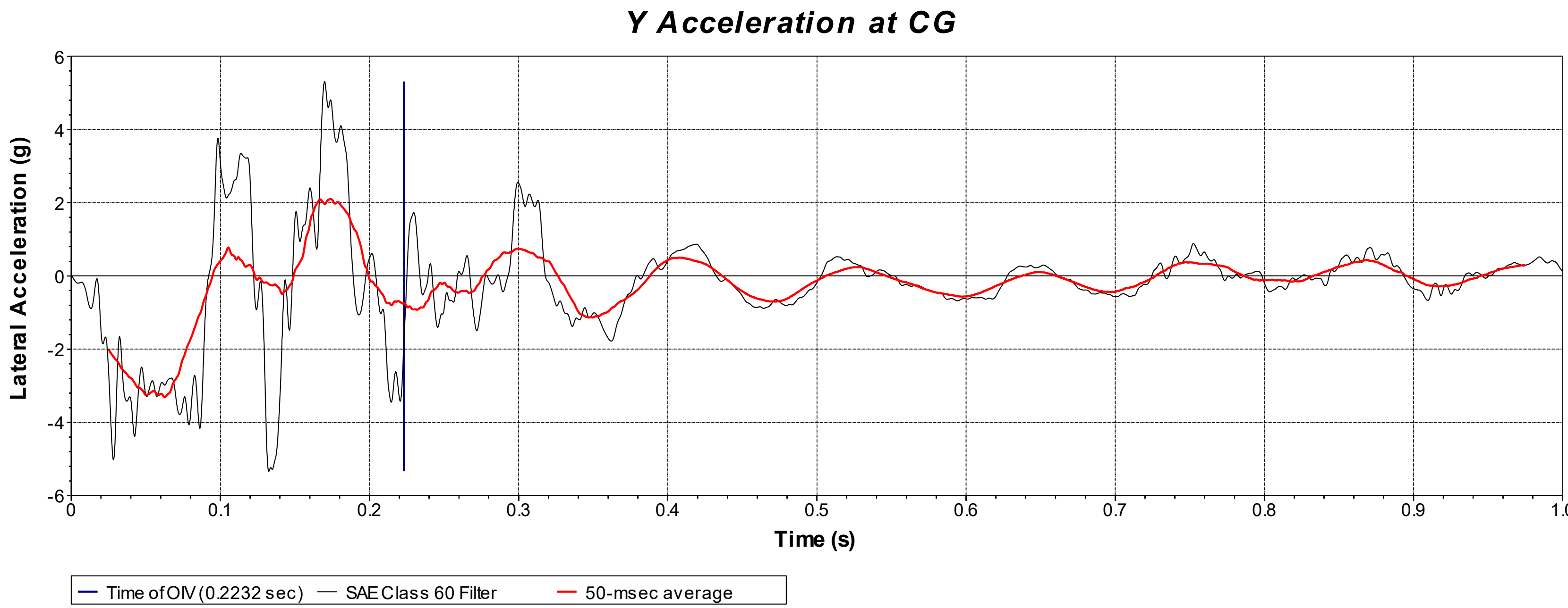
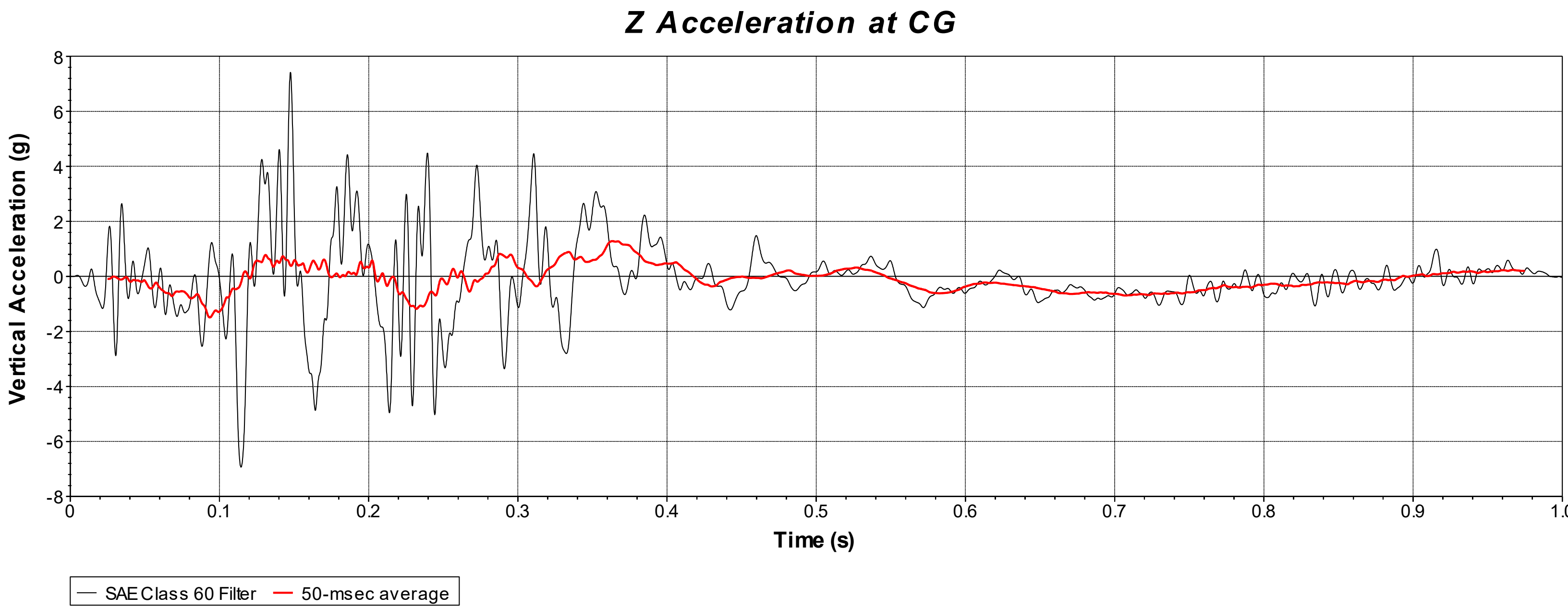


Figure K.4. Vehicle Longitudinal Accelerometer Trace for Test No. 469469-11 (Accelerometer Located at Center of Gravity).



Test Number: 469469-11
Test Standard, Test Number: MASH 2016, 3-11
Test Article: Round wood post guardrail in concrete mow strip
Test Vehicle: 2012 RAM 1500
Inertial Mass: 5020 lb
Gross Mass: 5020 lb
Impact Speed: 63.3 mi/h
Impact Angle: 25.3 degrees

Figure K.5. Vehicle Lateral Accelerometer Trace for Test No. 469469-11 (Accelerometer Located at Center of Gravity).

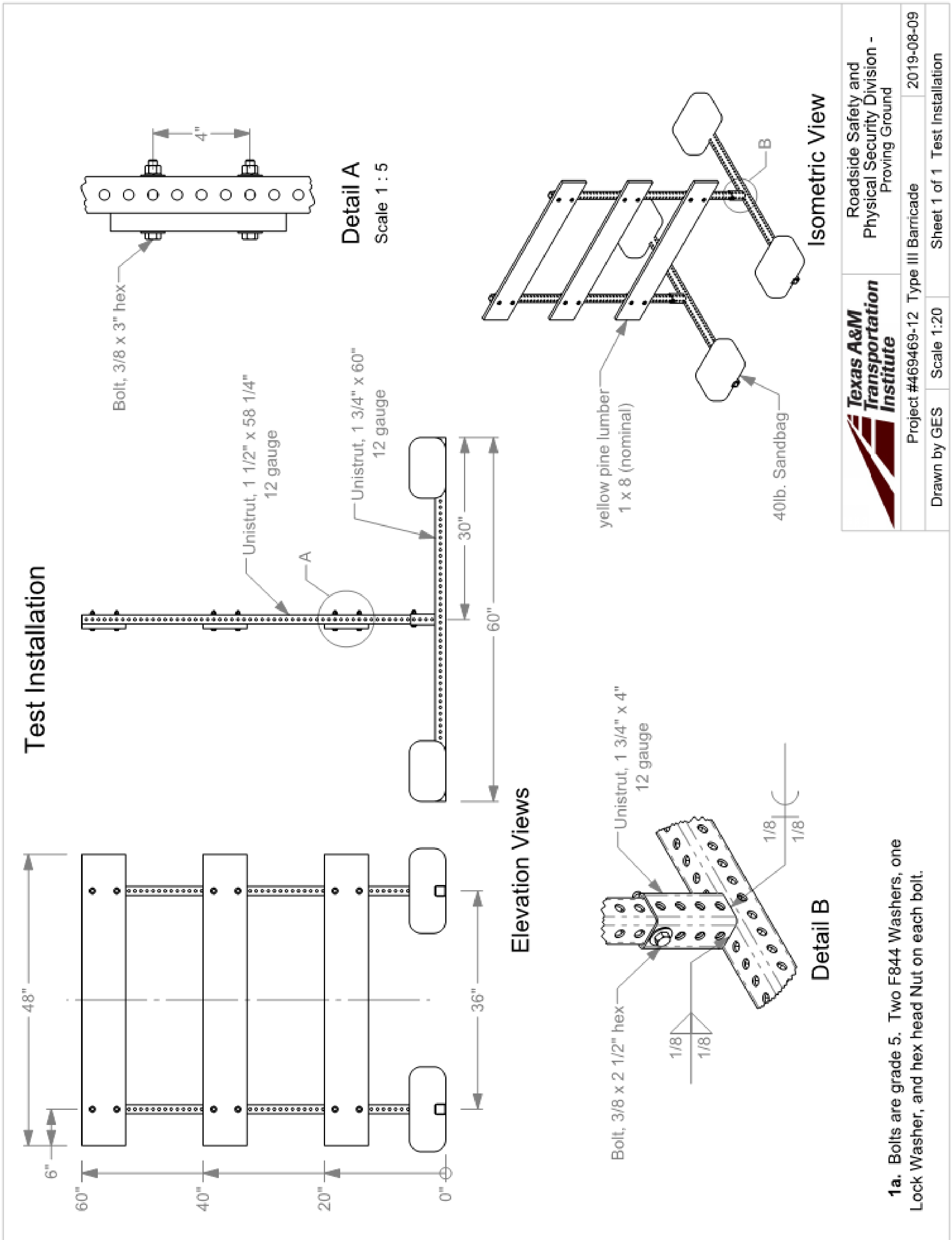


Test Number: 469469-11
Test Standard, Test Number: MASH 2016, 3-11
Test Article: Round wood post guardrail in concrete mow strip
Test Vehicle: 2012 RAM 1500
Inertial Mass: 5020 lb
Gross Mass: 5020 lb
Impact Speed: 63.3 mi/h
Impact Angle: 25.3 degrees

Figure K.6. Vehicle Vertical Accelerometer Trace for Test No. 469469-11 (Accelerometer Located at Center of Gravity).

APPENDIX L. TXDOT TYPE III BARRICADE

L.1. DETAILS OF THE TYPE III BARRICADE



L.2. *MASH* TEST 3-72 (CRASH TEST NO. 469469-12-01)

L.2.1. Vehicle Properties and Information

Table L.1. Vehicle Properties for Test No. 469469-12-01.

Vehicle Inventory Number: 1348

Date: 2019-08-27 Test No.: 469469-12-1 VIN No.: KNADE223996461999

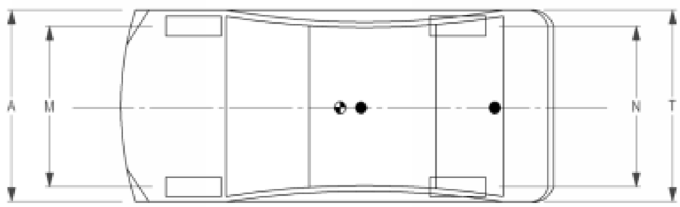
Year: 2009 Make: Kia Model: Rio

Tire Inflation Pressure: 32 PSI Odometer: 138064 Tire Size: 185/65R14

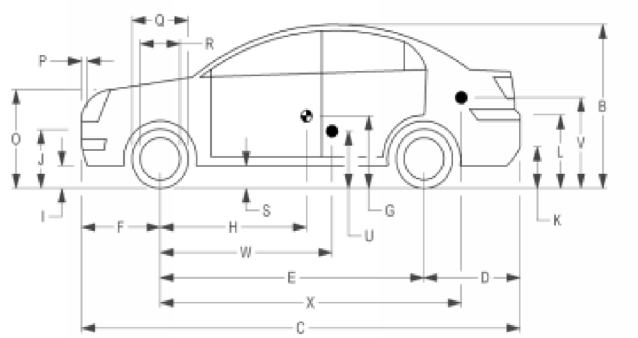
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES:



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



Dummy Data:
Type: 50th Percentile Male
Mass: 165 lb
Seat Position: OPPOSITE IMPACT

Geometry: inches

A	66.38	F	33.00	K	12.25	P	4.12	U	14.75
B	51.50	G		L	25.25	Q	22.50	V	20.75
C	165.75	H	35.31	M	57.75	R	15.50	W	35.30
D	34.00	I	7.75	N	57.70	S	8.25	X	71.50
E	98.75	J	21.50	O	27.00	T	66.20		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00 W-H 0.00

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Bottom of Hood Lip) = 24 ±4 inches
TOP OF RADIATOR SUPPORT = 28.25 inches; (M+N)/2 = 56 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1615	1552	1637
Back	1874	M_{rear}	912.00	864	944.00
Total	3638	M_{Total}	2527	2416	2581

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

Mass Distribution:
lb LF: 770 RF: 782 LR: 425 RR: 439

Performed by: SCD Date: 2019-08-27

Table L.2. Exterior Crush Measurements of Vehicle for Test No. 469469-12-01.

Vehicle Inventory Number: 1348

Date:	2019-08-27	Test No.:	469469-12-1	VIN No.:	KNADE223996461999
Year:	2009	Make:	Kia	Model:	Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable

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

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

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

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

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

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

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

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

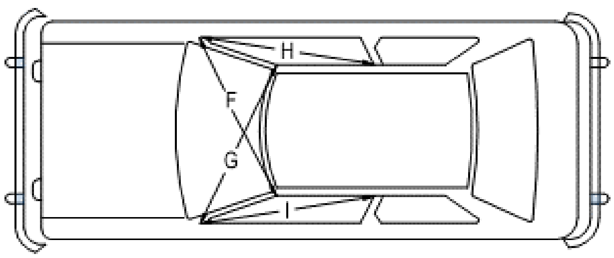
Note: Use as many lines/columns as necessary to describe each damage profile.

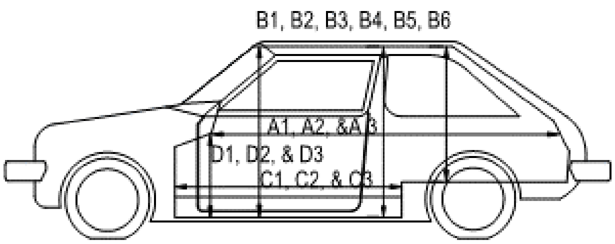
Performed by: **SCD** Date: 2019-08-27

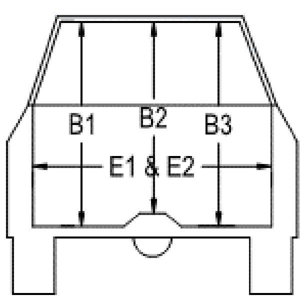
Table L.3. Occupant Compartment Measurements of Vehicle for Test No. 469469-12-01.

Vehicle Inventory Number: 1348

Date:	2019-08-27	Test No.:	469469-12-1	VIN No.:	KNADE223996461999
Year:	2009	Make:	Kia	Model:	Rio







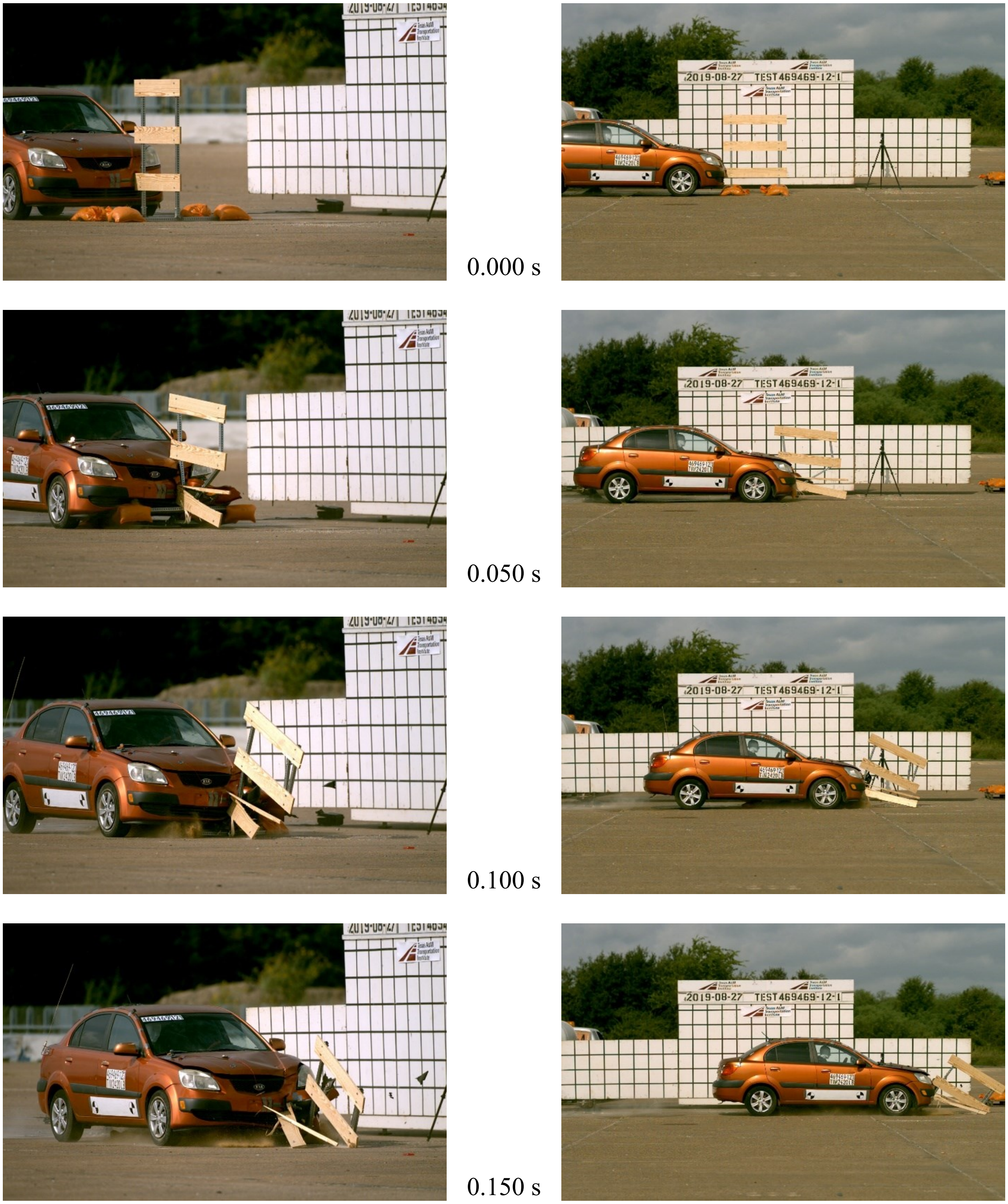
OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

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

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

Performed by: *SCD* Date: 2019-08-27

L.2.2. Sequential Photographs



0.000 s

0.050 s

0.100 s

0.150 s

Figure L.1. Sequential Photographs for Test No. 469469-12-01 (Oblique and Right Angle views).

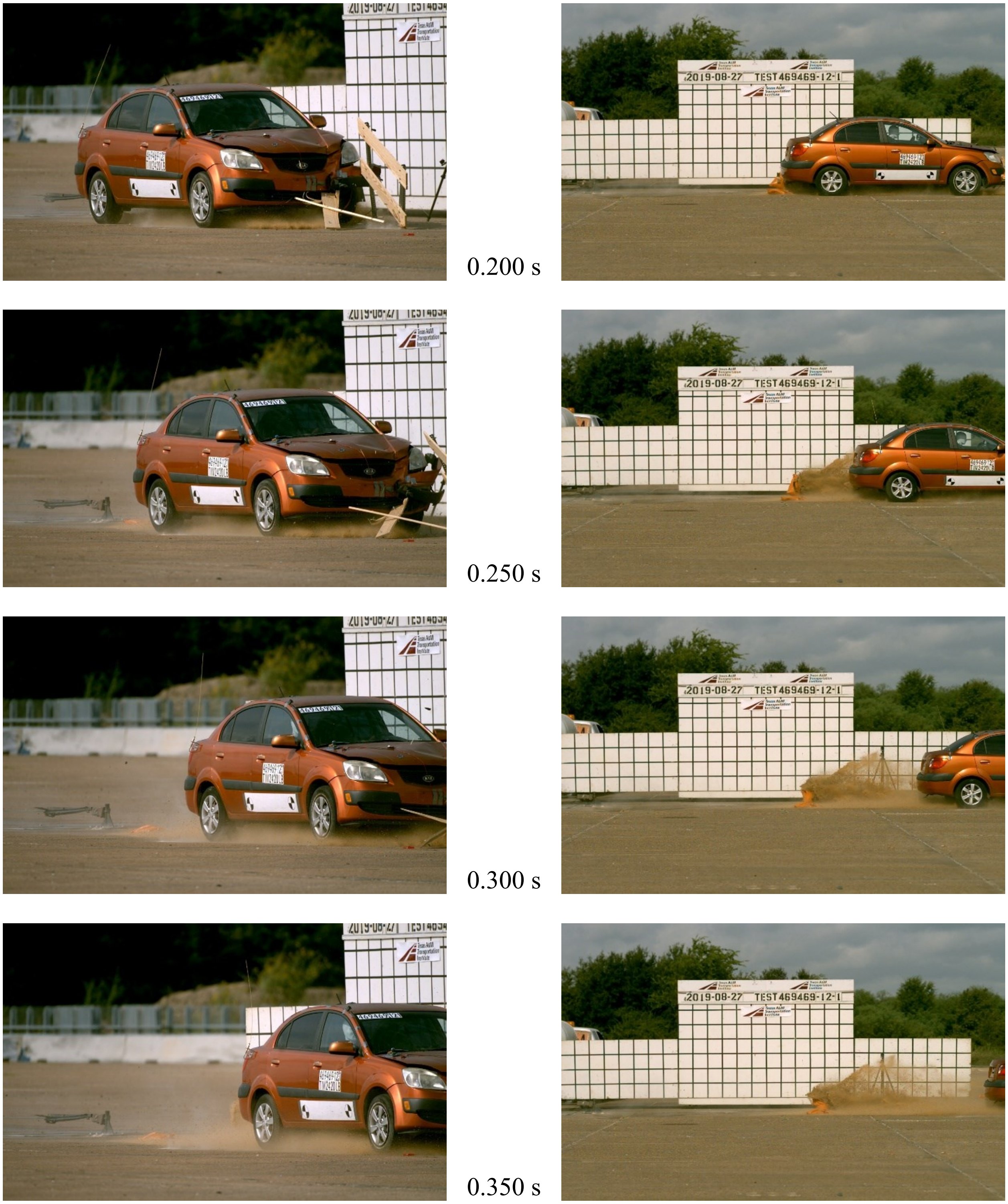


Figure L.1. Sequential Photographs for Test No. 469469-12-01 (Oblique and Right Angle views) (Continued).

L.3. *MASH* TEST 3-72 (CRASH TEST NO. 469469-12-02)

L.3.1. Vehicle Properties and Information

Table L.4. Vehicle Properties for Test No. 469469-12-02.

Vehicle Inventory Number: 1435

Date:	2019-08-20	Test No.:	469469-12-2	VIN No.:	1C6RR6FT2DS712366
Year:	2013	Make:	RAM	Model:	1500

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

Tread Type: Highway Odometer: 161447

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

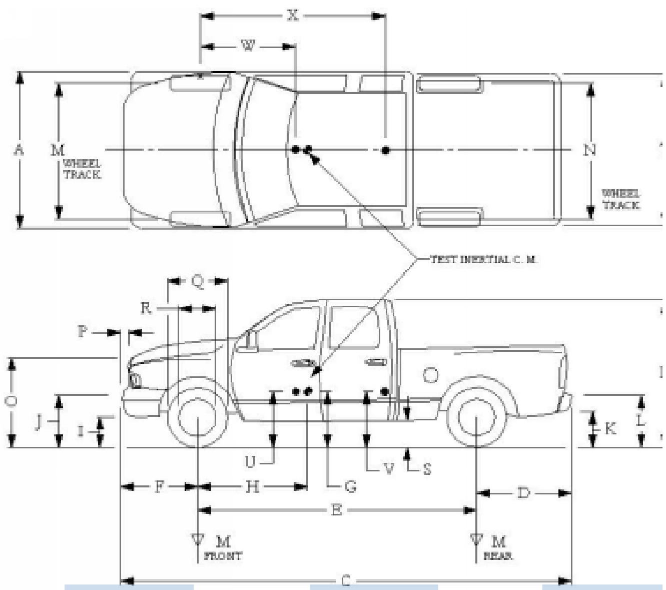
NOTES: None

Engine Type: V-8
Engine CID: 4.7 liter

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

Optional Equipment:
None

Dummy Data:
Type: NONE
Mass: 0 lb
Seat Position:



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	
B	74.00	G	28.40	L	30.00	Q	30.50	V	
C	227.50	H	61.83	M	68.50	R	18.00	W	
D	44.00	I	11.75	N	68.00	S	13.00	X	
E	140.50	J	27.00	O	46.00	T	77.00		

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

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

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2920	2824	
Back	3900	M_{rear}	2102	2220	
Total	6700	M_{Total}	5022	5044	0

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

Mass Distribution:
lb LF: 1443 RF: 1381 LR: 1078 RR: 1142

Performed by: SCD Date: 2019-08-27

Table L.5. Measurements of Vehicle Vertical CG for Test No. 469469-12-02.

Vehicle Inventory Number: 1435

Date: 2019-08-20 Test No.: 469469-12-2 VIN: 1C6RR6FT2DS712366

Year: 2013 Make: RAM Model: 1500

Body Style: Quad Cab Mileage: 161447

Engine: 4.7 liter V-8 Transmission: Automatic

Fuel Level: Empty Ballast: 120 (440 lb max)

Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70 R 17

Measured Vehicle Weights: (lb)								
LF:	1443		RF:	1381		Front Axle:	2824	
LR:	1078		RR:	1142		Rear Axle:	2220	
Left:	2521		Right:	2523		Total:	5044	
							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:	61.84	inches	Rear of Front Axle	(63 ±4 inches allowed)				
Y:	0.01	inches	Left -	Right +	of Vehicle Centerline			
Z:	28.40	inches	Above Ground	(minumum 28.0 inches allowed)				

Hood Height: 46.00 inches Front Bumper Height: 27.00 inches

43 ±4 inches allowed

Front Overhang: 40.00 inches Rear Bumper Height: 30.00 inches

39 ±3 inches allowed

Overall Length: 227.50 inches

237 ±13 inches allowed

Performed by: SCD Date: 2019-08-27

Table L.6. Exterior Crush Measurements of Vehicle for Test No. 469469-12-02.

Vehicle Inventory Number: 1435

Date: 2019-08-20 Test No.: 469469-12-2 VIN No.: 1C6RR6FT2DS712366

Year: 2013 Make: RAM Model: 1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

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

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

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

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

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

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

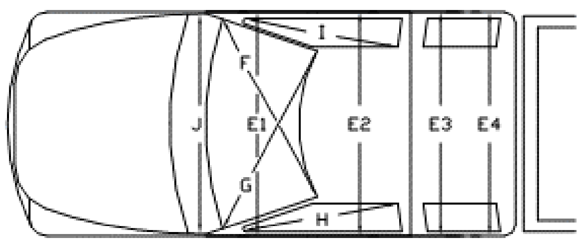
Note: Use as many lines/columns as necessary to describe each damage profile.

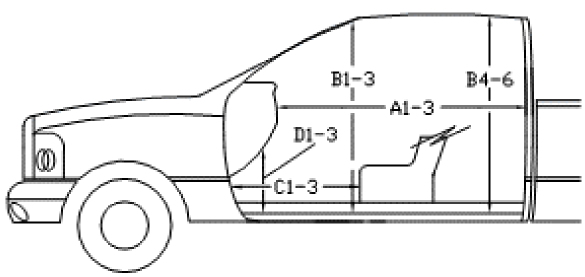
Performed by: SCD Date: 2019-08-27

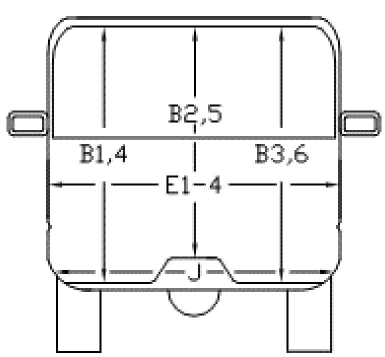
Table L.7. Occupant Compartment Measurements of Vehicle for Test No. 469469-12-02.

Vehicle Inventory Number: 1435

Date:	2019-08-20	Test No.:	469469-12-2	VIN No.:	1C6RR6FT2DS712366
Year:	2013	Make:	RAM	Model:	1500







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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	58.50	0.00
E2	63.50	63.50	0.00
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	25.00	0.00

Performed by: SCD   Date: 2019-08-27

L.3.2. Sequential Photographs

0.000 s

0.050 s

0.100 s

0.150 s

Figure L.2. Sequential Photographs for Test No. 469469-12-02

(Oblique and Right Angle views).


0.200 s



0.250 s



0.300 s



0.350 s


Figure L.2. Sequential Photographs for Test No. 469469-12-02 (Oblique and Right Angle views) (Continued).

L.4. *MASH* TEST 3-72 (CRASH TEST NO. 469469-12-03)

L.4.1. Vehicle Properties and Information

Table L.8. Vehicle Properties for Test No. 469469-12-03.

Vehicle Inventory Number: 1435

Date:	2019-08-29	Test No.:	469469-12-3	VIN No.:	1C6RR6FT2DS712366
Year:	2013	Make:	RAM	Model:	1500

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

Tread Type: Highway Odometer: 161447

Note any damage to the vehicle prior to test: None

● Denotes accelerometer location.

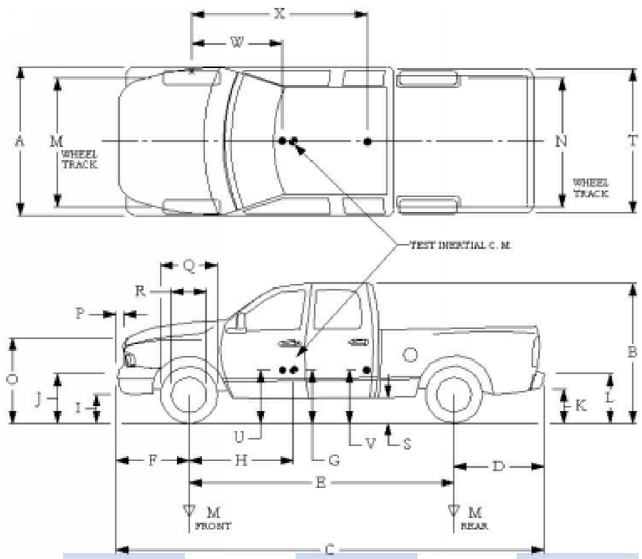
NOTES: None

Engine Type: V-8
Engine CID: 4.7 liter

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

Optional Equipment:
None

Dummy Data:
Type: NONE
Mass: 0 lb
Seat Position:



Geometry: inches

A	78.50	F	40.00	K	20.00	P	3.00	U	
B	74.00	G	28.40	L	30.00	Q	30.50	V	
C	227.50	H	61.83	M	68.50	R	18.00	W	
D	44.00	I	11.75	N	68.00	S	13.00	X	
E	140.50	J	27.00	O	46.00	T	77.00		

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

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

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	3700	M_{front}	2920	2824	
Back	3900	M_{rear}	2102	2220	
Total	6700	M_{Total}	5022	5044	0

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

Mass Distribution:
lb LF: 1443 RF: 1381 LR: 1078 RR: 1142

Performed by: SCD Date: 2019-08-29

Table L.9. Measurements of Vehicle Vertical CG for Test No. 469469-12-03.

Vehicle Inventory Number: 1435

Date:	2019-08-29	Test No.:	469469-12-3	VIN:	1C6RR6FT2DS712366
Year:	2013	Make:	RAM	Model:	1500
Body Style:	Quad Cab			Mileage:	161447
Engine:	4.7 liter V-8			Transmission:	Automatic
Fuel Level:	Empty	Ballast:	140 (440 lb max)		
Tire Pressure: Front:	35 psi	Rear:	35 psi	Size:	265/70 R 17

Measured Vehicle Weights: (lb)

LF:	1443	RF:	1381	Front Axle:	2824
LR:	1078	RR:	1142	Rear Axle:	2220
Left:	2521	Right:	2523	Total:	5044
					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:	61.84	inches	Rear of Front Axle	(63 ±4 inches allowed)
Y:	0.01	inches	Left - Right +	of Vehicle Centerline
Z:	28.40	inches	Above Ground	(minumum 28.0 inches allowed)

Hood Height:	46.00 inches		Front Bumper Height:	27.00 inches
	43 ±4 inches allowed			
Front Overhang:	40.00 inches		Rear Bumper Height:	30.00 inches
	39 ±3 inches allowed			
Overall Length:	227.50 inches			
	237 ±13 inches allowed			
Performed by:	SCD		Date:	2019-08-29

Table L.10. Exterior Crush Measurements of Vehicle for Test No. 469469-12-03.

Vehicle Inventory Number: 1435

Date:	2019-08-29	Test No.:	469469-12-3	VIN No.:	1C6RR6FT2DS712366
Year:	2013	Make:	RAM	Model:	1500

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable

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

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

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

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

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

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

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

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

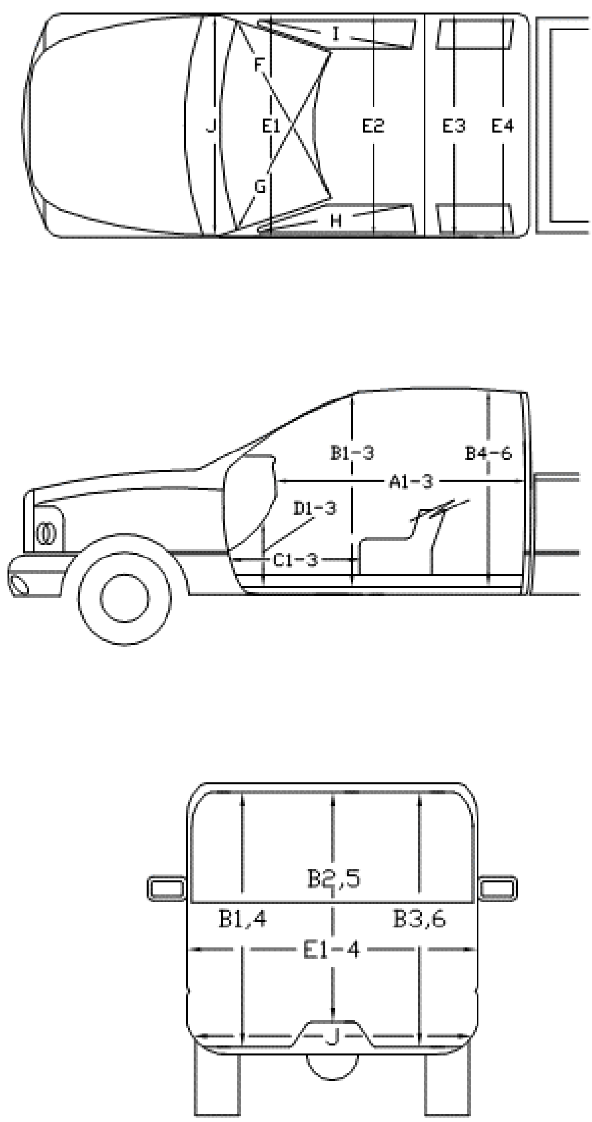
Note: Use as many lines/columns as necessary to describe each damage profile.

Performed by: SCD Date: 2019-08-29

Table L.11. Occupant Compartment Measurements of Vehicle for Test No. 469469-12-03.

Vehicle Inventory Number: 1435

Date:	2019-08-29	Test No.:	469469-12-3	VIN No.:	1C6RR6FT2DS712366
Year:	2013	Make:	RAM	Model:	1500



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

OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0.00
A2	63.00	63.00	0.00
A3	65.50	65.50	0.00
B1	45.00	45.00	0.00
B2	38.00	38.00	0.00
B3	45.00	45.00	0.00
B4	39.50	39.50	0.00
B5	43.00	43.00	0.00
B6	39.50	39.50	0.00
C1	26.00	26.00	0.00
C2	0.00	0.00	0.00
C3	26.00	26.00	0.00
D1	11.00	11.00	0.00
D2	0.00	0.00	0.00
D3	11.50	11.50	0.00
E1	58.50	58.50	0.00
E2	63.50	63.50	0.00
E3	63.50	63.50	0.00
E4	63.50	63.50	0.00
F	59.00	59.00	0.00
G	59.00	59.00	0.00
H	37.50	37.50	0.00
I	37.50	37.50	0.00
J*	25.00	25.00	0.00

Performed by: SCD Date: 2019-08-29

L.4.2. Sequential Photographs

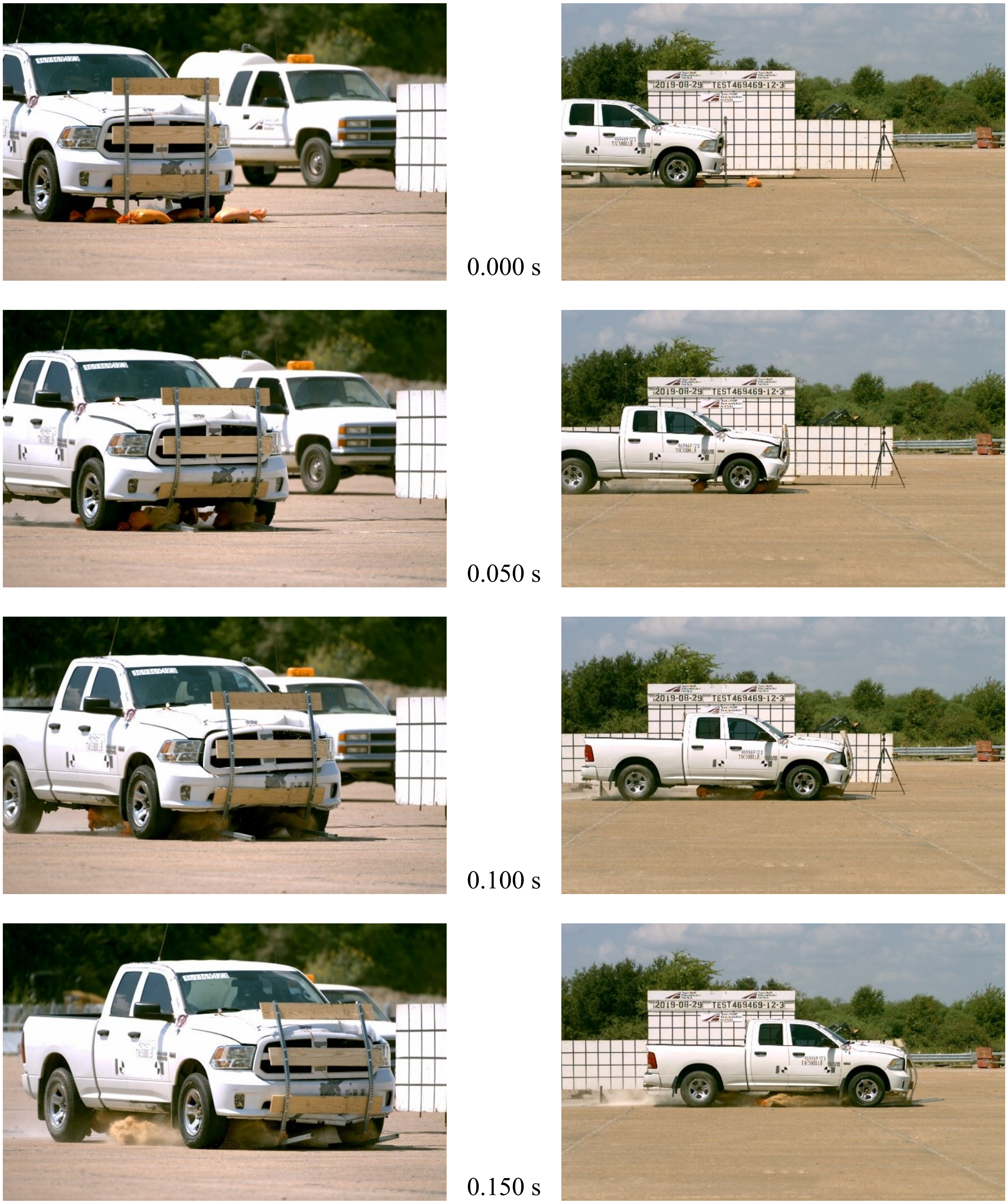


Figure L.3. Sequential Photographs for Test No. 469469-12-03

(Oblique and Right Angle views).


0.200 s



0.250 s



0.300 s



0.350 s


Figure L.3. Sequential Photographs for Test No. 469469-12-03 (Oblique and Right Angle views) (Continued).

L.5. *MASH* TEST 3-72 (CRASH TEST NO. 469469-12-04)

L.5.1. Vehicle Properties and Information

Table L.12. Vehicle Properties for Test No. 469469-12-04.

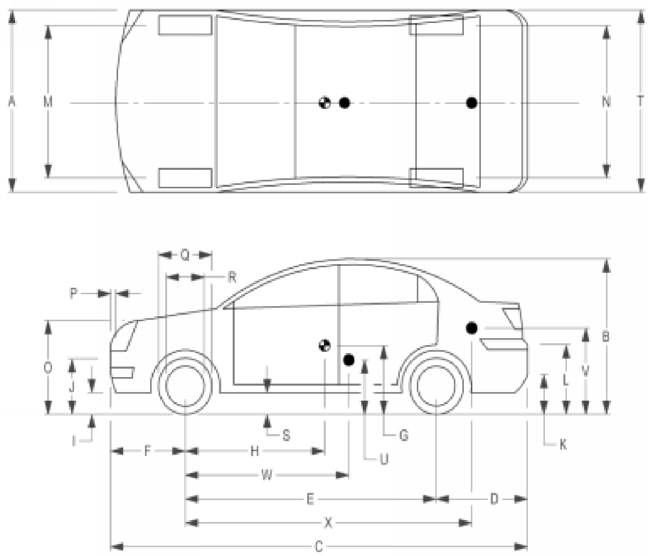
Vehicle Inventory Number: 1383

Date:	2019-08-27	Test No.:	469469-12-4	VIN No.:	KNADE123976267769
Year:	2007	Make:	Kia	Model:	Rio
Tire Inflation Pressure:	32 PSI	Odometer:	119140	Tire Size:	185/65R14

Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES:



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

Dummy Data:
Type: 50th Percentile Male
Mass: 165 lb
Seat Position: OPPOSITE IMPACT

Geometry: inches

A	66.38	F	33.00	K	12.25	P	4.12	U	
B	51.50	G		L	25.25	Q	22.50	V	
C	165.75	H	35.02	M	57.75	R	15.50	W	
D	34.00	I	7.75	N	57.70	S	8.25	X	
E	98.75	J	21.50	O	27.00	T	66.20		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00 W-H 0.00

RANGE LIMIT: A = 65 ±3 inches; C = 169 ±8 inches; E = 98 ±5 inches; F = 35 ±4 inches; H = 39 ±4 inches; O (Bottom of Hood Lip) = 24 ±4 inches
TOP OF RADIATOR SUPPORT = 28.25 inches; (M+N)/2 = 56 ±2 inches; W-H < 2 inches or use MASH Paragraph A4.3.2

GVWR Ratings:		**Mass:** lb	Curb	Test Inertial	Gross Static
Front	1718	M_{front}	1598	1581	1666
Back	1874	M_{rear}	855.00	869	949.00
Total	3638	M_{Total}	2453	2450	2615

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

Mass Distribution:
lb LF: 800 RF: 781 LR: 427 RR: 442

Performed by: SCD Date: 2019-08-27

Table L.13. Exterior Crush Measurements of Vehicle for Test No. 469469-12-04.

Vehicle Inventory Number: 1383

Date:	2019-08-27	Test No.:	469469-12-4	VIN No.:	KNADE123976267769
Year:	2007	Make:	Kia	Model:	Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

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

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

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

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

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

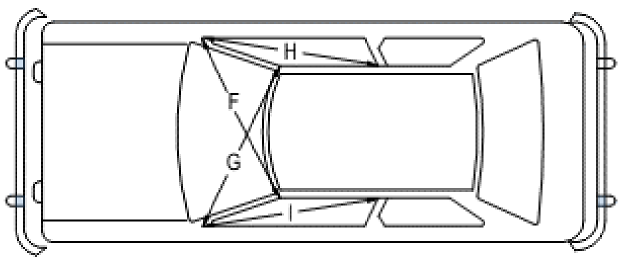
***Measure and document on the vehicle diagram the location of the maximum crush.

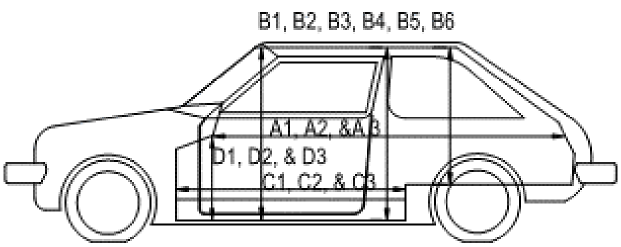
Note: Use as many lines/columns as necessary to describe each damage profile.

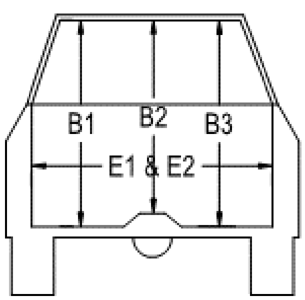
Performed by: **SCD** Date: 2019-08-27

Table L.14. Occupant Compartment Measurements of Vehicle for Test No. 469469-12-04.

Vehicle Inventory Number:	1383				
Date:	2019-08-27	Test No.:	469469-12-4	VIN No.:	KNADE123976267769
Year:	2007	Make:	Kia	Model:	Rio







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

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

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

Performed by: *SCD* Date: 2019-08-27

L.5.2. Sequential Photographs

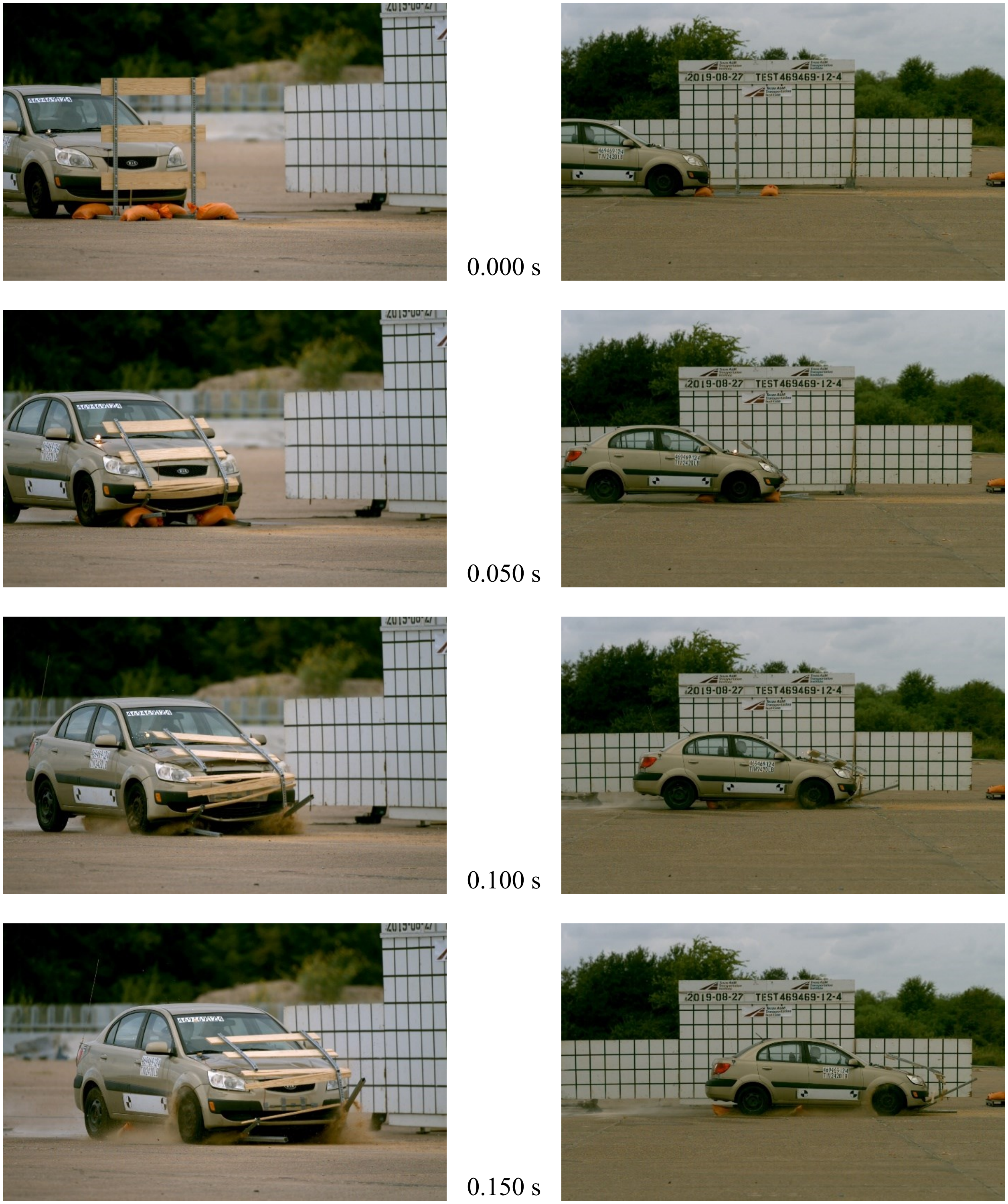


Figure L.4. Sequential Photographs for Test No. 469469-12-04 (Oblique and Right Angle views).

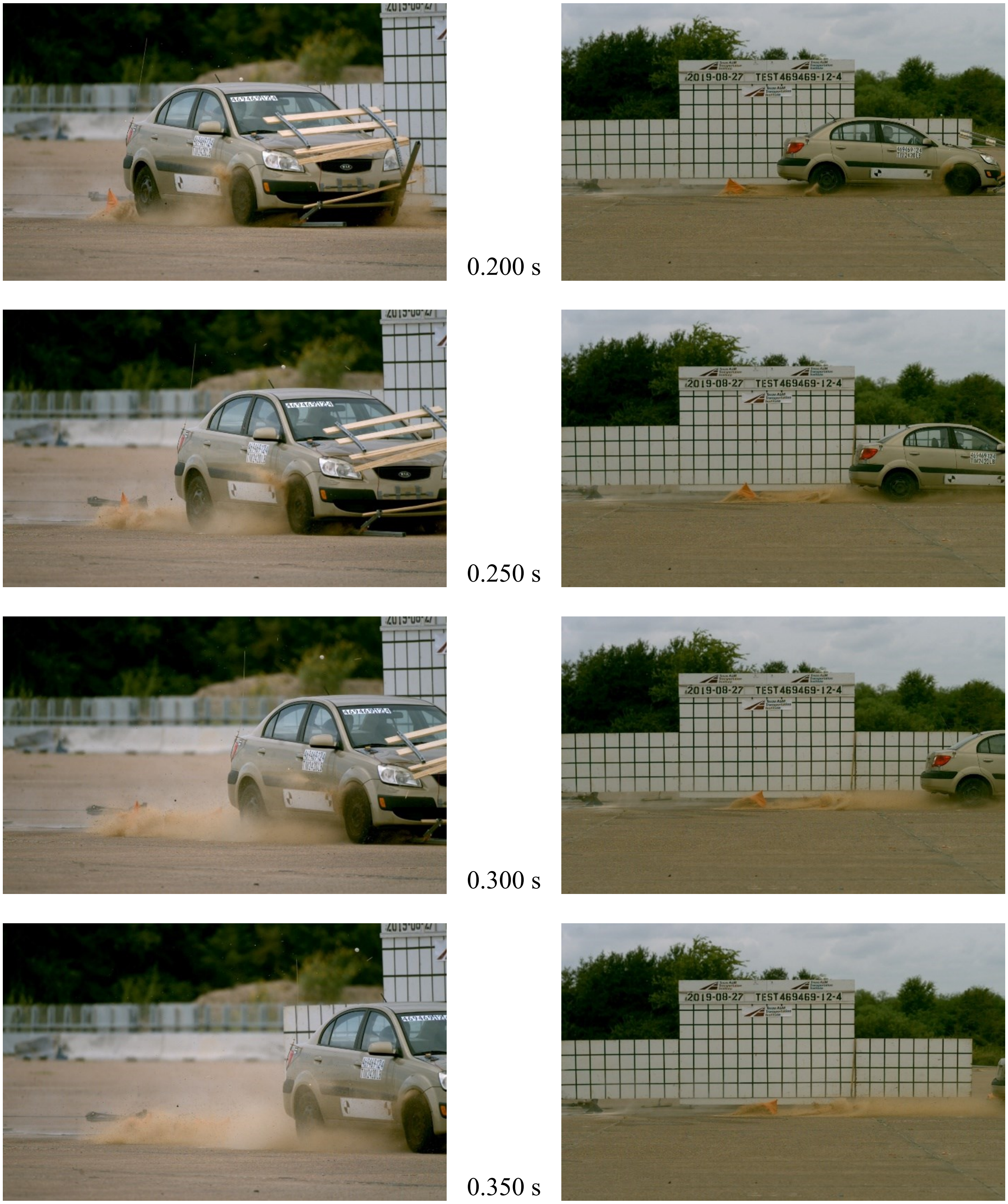


Figure L.4. Sequential Photographs for Test No. 469469-12-04 (Oblique and Right Angle views) (Continued).