

MASH EVALUATION OF TXDOT ROADSIDE SAFETY FEATURES – PHASE I





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Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE COLLEGE STATION, TEXAS

TEXAS DEPARTMENT OF TRANSPORTATION

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In 2009, the American Ass	sociation of State Highway and Tra	insportation Officials (AASHTO)
published the Manual for Assessing	ng Safety Hardware (MASH), which	h supersedes the previous crash test and
evaluation guidelines (1). A MAS	\tilde{H} implementation agreement was j	ointly developed and adopted by the
Federal Highway Administration	(FHWA) and AASHTO. It establis	hes implementation dates for different
categories of roadside safety feature	ires.	r r
Texas Department of Tran	sportation (TxDOT), Bridge, Desig	gn, Maintenance, and Traffic Operations
Divisions reviewed their standard	s for roadside safety devices and id	lentified those devices that require
testing and evaluation to assess M	ASH compliance. Under this project	ct, a total of 33 roadside safety systems
will be crash tested in accordance	with MASH criteria in three phases	s over a three-year period. In Phase I, the
following devices were crash teste	ed: 36-inch vertical parapet bridge	rail, 1-inch asphalt concrete pavement
lateral support for concrete media	n barrier, pinning pattern for precas	st concrete barrier on concrete, single
and dual embedded wood post sig	n support systems, pedestal poles v	with flashing beacons with and without
solar assembly, double mailbox sy	ystem on TxDOT Type 3 foundatio	n and winged channel support, double
mailbox system on TxDOT Type	2 foundation and thin walled galva	nized tube support, and multi-mailbox
system on TxDOT Type 1 founda	tion and thin walled galvanized tub	be support.
This report decuments the	area testing and evaluation of the	and aviana in accordance with MASH
criteria. The critical tests were ide	entified and performed to assess <i>MA</i>	<i>ASH</i> compliance.
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MASH EVALUATION OF TXDOT ROADSIDE SAFETY FEATURES – PHASE I

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

> > December 2017

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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 the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation. The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report. This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Roger P. Bligh, P.E. #78550.

TTI PROVING GROUND DISCLAIMER

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



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CHAPTER 1: INTRODUCTION

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

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

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

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

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

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

Device	Standard	Test Level	Recommended Tests	Comments
36-inch vertical parapet	N.A.	TL-4	4-12	Modify 32-inch T221 rail by increasing height adding additional reinforcement. Test at a joint in deck and rail.
1-inch ACP lateral support for concrete median barrier	SSCB(1F)-10	TL-4	4-12	TL-4 loading more critical than TL-3 for evaluation of barrier anchorage.
Pinning pattern for precast concrete barrier in concrete	CSB(7)-10	TL-3	3-11	JJ Hooks connection used for portable concrete barrier segments.
	DC/EV11		3-62 @ 0°	4×4-inch support more critical than 4×6-inch support.
Turboddod mood soot of on	bC(J)-14 (single)	TL-3	3-61, 3-62 @ 90°	<i>MASH</i> requires testing of signs at 90° if they are used at intersections.
Ellipeduced wood post sign	BC(5)-14	C IL	3-61, 3-62 (impact one post @ 0°)	
	(dual)	C-11	3-62 (impact two posts @ 0°)	Impacting two of two supports will evaluate secondary contact between sign assembly and vehicle.
-	RFBA-13 (without solar assembly)	TL-3	3-62	Concrete foundation option used.
Pedestal pole with flashing beacons	SPRFBA-13 (with solar assembly)	TL-3	3-62	Concrete foundation option used.
Mailbox Type 1 foundation (multi) 56-inch hanger	MB-15(1)	TL-3	3-61	
Mailbox Type 2 foundation (double)-thin walled galvanized tubing	MB-15(1)	TL-3	3-61	
Mailbox Type 3 foundation (double)-winged channel post	MB-15(1)	£-1L	3-61	

Table 1.1. Phase I Full-Scale Crash Testing.

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

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

CHAPTER 2: TXDOT 36-INCH VERTICAL WALL

2.1 BACKGROUND

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

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

2.2 TEST INSTALLATION

2.2.1 Overall Details

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

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

2.2.2 Parapet

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



TR No. 0-6946-1



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

2.2.3 Bridge Deck and Support Wall

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

2.2.4 Material Properties

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

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

2.3 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

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



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

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

2.4 TEST VEHICLE

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



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



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

2.5 WEATHER CONDITIONS

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

2.6 TEST DESCRIPTION

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

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

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

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

2.7 DAMAGE TO TEST INSTALLATION

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

2.8 DAMAGE TO TEST VEHICLE

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



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



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



Before Test

After Test

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

2.9 OCCUPANT RISK FACTORS

Data from the accelerometer, located at the vehicle center of gravity, were digitized for information purposes, and the results are shown in Table 2.2. Figure 2.9 summarizes these data and other pertinent information from the test. Figure A.2 in Appendix A.5 shows the

vehicle angular displacements, and Figures A.3 through A.8 in Appendix A.6 show vehicle accelerations versus time traces.

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

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

2.10 ASSESSMENT OF RESULTS

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

2.11 CONCLUSIONS

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

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



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

Tes	Agency: Texas A&M Transportation Institute	Test No.: 469467-1-1	est Date: 2017-08-15
	MASH Test 4-12 Evaluation Criteria	Test Results	Assessment
<u>Strr</u> A.	ctural Adequacy Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable	The 36-inch vertical concrete bridge rail contained and redirected the 10000S vehicle. The vehicle did not penetrate, underride, or override the installation. Maximum dynamic deflection during the test was 2.2 inches.	Pass
D.	upant Risk 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. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	No detached elements, fragments, or other debris from the test article were present to penetrate or show potential for penetrating the occupant compartment or present hazard to others in the area. No occupant compartment deformation or intrusion occurred.	Pass
С	It is preferable, although not essential, that the vehicle remain upright during and after collision.	The 10000S vehicle rolled onto its roof after exiting the barrier and traversing unpaved terrain.	NA

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

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

3.1 BACKGROUND

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

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

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

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

3.2 SYSTEM DETAILS

3.2.1 Test Article Design and Construction

The test installation was comprised of two sections of 42-inch tall SSCB: one 75-ft long and the other 44 ft-10¹/₄ inches long with a 1³/₄-inch wide expansion control joint between the sections. Thus, the overall length of the test installation was 120 ft-0 inches. The barrier was cast-in-place directly on top an existing concrete apron. There were no pins, anchors, rebar, or bolts securing the barrier to the apron.

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

The SSCB was 24 inches wide at the base and 8 inches wide at the top. The barrier had a slope of 10.8° on both the traffic side and the field side faces. The barrier was reinforced using steel welded wire mesh comprised of D9.4 (0.346-inch diameter) welded wire reinforcement (WWR) lateral stirrup bars spaced at 8-inch centers along the length of the barrier. The stirrup bars were bent to conform to the profile of the barrier and provide a minimum 1³/₄-inch concrete cover. Longitudinal reinforcement of the SSCB was comprised of seven D19.7 bars (0.501-inch diameter) equally spaced (approximately 6-inches) along the slope of each face and located inside the lateral stirrups.

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

3.2.2 Material Specifications

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

3.3 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

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

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

3.4 TEST VEHICLE

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




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



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



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

3.5 WEATHER CONDITIONS

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

3.6 TEST DESCRIPTION

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

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

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

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

3.7 DAMAGE TO TEST INSTALLATION

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

3.8 DAMAGE TO TEST VEHICLE

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

3.9 OCCUPANT RISK FACTORS

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



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



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



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



Before Test

After Test

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

Occupant Risk Factor	Value	Time
OIV		
Longitudinal	7.2 ft/s	at 0.2327 s on left side of
Lateral	13.4 ft/s	interior
Occupant Ridedown Accelerations		
Longitudinal	3.6 g	0.2327–0.2427 s
Lateral	6.4 g	0.2999–0.3099 s
THIV	17.1 km/h	at 0.2235 s on left side of
11111	4.7 m/s	interior
PHD	6.6 g	0.2999–0.3099 s
ASI	0.43	0.3403–0.3903 s
Maximum 50-ms Moving Average		
Longitudinal	−1.9 g	0.2067–0.2567 s
Lateral	3.7 g	0.1289–0.1789 s
Vertical	− 3.9 g	0.3151–0.3651 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	24.3	0.5338 s
Pitch	7.5	0.8803 s
Yaw	21.7	0.6395 s

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

3.10 ASSESSMENT OF RESULTS

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

3.11 CONCLUSIONS

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

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



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

	with 1-in	ch ACP Overlay.	
Tes	t Agency: Texas A&M Transportation Institute	Test No.: 469467-3-1	est Date: 2017-07-07
	MASH Test 4-12 Evaluation Criteria	Test Results	Assessment
Strı	ictural Adequacy		
А.	Test article should contain and redirect the vehicle or	The TxDOT 42-inch SSCB with 1-inch ACP	
	bring the vehicle to a controlled stop; the vehicle	lateral support contained and redirected the	
	should not penetrate, underride, or override the	10000S vehicle. The vehicle did not penetrate,	
	installation although controlled lateral deflection of	underride, or override the installation. Dynamic	Pass
	the test article is acceptable.	deflection was not measureable during the test	
		due to the vehicle obstructing the view. No	
		measureable permanent deformation was noted.	
Occ	supant Risk		
D.	Detached elements, fragments, or other debris from	No detached elements, fragments, or other debris	
	the test article should not penetrate or show potential	was present to penetrate or show potential for	
	for penetrating the occupant compartment, or present	penetrating the occupant compartment or to	
	an undue hazard to other traffic, pedestrians, or	present hazard to others in the area.	Dace
	personnel in a work zone.		1 (13)
	Deformations of, or intrusions into, the occupant	No occupant compartment deformation or	
	compartment should not exceed limits set forth in	intrusion occurred.	
	Section 5.3 and Appendix E of MASH.		
9.	It is preferable, although not essential, that the vehicle	The 10000S vehicle remained upright during and	Dace
	remain upright during and after collision.	after the collision event.	CCD 1

Table 3.3. Performance Evaluation Summary for MASH Test 4-12 on the TxDOT 42-inch Tall SSCB

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

4.1 BACKGROUND

Precast concrete barrier is used to provide positive protection in work zones. A buffer area must be maintained behind the precast concrete barrier to accommodate dynamic deflection of the barrier during a vehicle impact. If available space is restricted, the lateral barrier deflection is often reduced by pinning the barrier to the underlying concrete pavement or deck structure. TxDOT's standard detail for this practice includes the use of 1¹/₄-inch steel pins placed on the traffic side of the barrier. The pins are installed at an angle through the toe of the precast barrier and 6 inches into the concrete pavement.

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

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

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

4.2 SYSTEM DETAILS

4.2.1 Test Article Design and Construction

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

The barrier segments were manufactured by Tricon Precast Ltd. in Houston, Texas. Each barrier segment was 30 ft long (end-to-end) and 32-inches tall. The F-shape median barrier was 24-inches wide at the base and 9½-inches wide at the top with symmetrical $54\frac{1}{2}^{\circ}$ lower and $83\frac{1}{2}^{\circ}$ upper slopes on both faces. The ends were chamfered 1 inch at 45° as cast. Two drainage reliefs/forklift slots (each 35-inches long × $3\frac{1}{2}$ -inches high) were precast in the bottom of each barrier segment and were symmetrically centered 90 inches from each end. Two cast-in-place $2\frac{1}{2}$ -inch diameter PVC pipes located 77-inches from each end served as lifting holes. Each of the barrier segments was precast with reinforcing steel, wire mesh fabric, and 12-inch "J-J Hooks[®]" connections in each end. See TxDOT standard drawing CSB (1)-10 in Appendix C.1 for details.

The field side edge of the barriers was placed at the edge of a 6-inch thick, unreinforced concrete pavement. The soil behind the concrete pavement section was excavated to a depth of 8 inches to simulate a deck condition. Each barrier segment was secured to the concrete pavement using four drop anchor pins on the traffic side. The anchor pins were 1¹/₄-inch diameter \times 20-inches long with a 3-inch diameter \times ¹/₄-inch thick plate on the top and a ¹/₄-inch chamfer on the bottom. The pins were inserted through the barrier via cast-in-place 2-inch PVC pipe guides and extended 5¹/₂ inches into the deck through 1³/₈-inch diameter drilled holes. Other than the anchor pins, there were no additional bolts, plates, or adhesives securing the barriers to the concrete apron.

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

4.2.2 Material Specifications

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

4.3 TEST DESIGNATION AND ACTUAL IMPACT CONDITIONS

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

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



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



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

4.4 TEST VEHICLE

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



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



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

4.5 WEATHER CONDITIONS

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

4.6 TEST DESCRIPTION

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

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

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

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*. Brakes on the vehicle were applied 4.6 s after impact. The vehicle subsequently came to rest 286 ft downstream of the impact and 40 ft toward traffic lanes.

4.7 DAMAGE TO TEST INSTALLATION

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



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



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



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



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

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

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

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

4.8 DAMAGE TO TEST VEHICLE

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



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



Before Test

After Test

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

4.9 OCCUPANT RISK FACTORS

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

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

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



TR No. 0-6946-1

4.10 SUMMARY OF RESULTS

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

4.11 CONCLUSIONS

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

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

	P	avement.	
Test	t Agency: Texas A&M Transportation Institute	Test No.: 469467-5-1	est Date: 2017-07-26
	MASH Test 3-11 Evaluation Criteria	Test Results	Assessment
<u>Stru</u> A.	<u>ctural Adequacy</u> Test article should contain and redirect the vehicle or	The TxDOT 32-inch CSB(7)-10 pinned to	
	bring the vehicle to a controlled stop; the vehicle	concrete pavement contained and redirected the	
	should not penetrate, underride, or override the	2270P vehicle. Maximum dynamic deflection	Pass
	installation although controlled lateral deflection of the test article is acceptable	during the test was 24.6 inches.	
Occ	upant Risk		
D.	Detached elements, fragments, or other debris from	No detached elements, fragments, or other debris	
	the test article should not penetrate or show potential	from the test article were present to penetrate or	
	for penetrating the occupant compartment, or present	show potential for penetrating the occupant	
	an undue hazard to other traffic, pedestrians, or	compartment, or to present undue hazard to	Dace
	personnel in a work zone.	others in the area.	CCD 1
	Deformations of, or intrusions into, the occupant	No occupant compartment deformation or	
	compartment should not exceed limits set forth in	intrusion occurred.	
	Section 5.3 and Appendix E of MASH.		
F.	The vehicle should remain upright during and after	The 2270P vehicle remained upright during and	
	collision. The maximum roll and pitch angles are not	after the collision period. Maximum roll and	Pass
	to exceed 75 degrees.	pitch angles were both 17° .	
H.	Occupant impact velocities (OIV) should satisfy the	Longitudinal OIV was 12.5 ft/s, and lateral OIV	
	following limits: Preferred value of 30 ft/s, or	was 22.3 ft/s.	Pass
	maximum allowable value of 40 ft/s.		
Ι.	The occupant ridedown accelerations should satisfy	Maximum longitudinal occupant ridedown was	
	the following: Preferred value of 15.0 g, or maximum	4.3 g, and maximum lateral occupant ridedown	Pass
	allowable value of 20.49 g.	was 13.1 g.	

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

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

5.1 BACKGROUND

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

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

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

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

Researchers consulted with TxDOT on the applications and types of signs used in conjunction with the dual support configurations. It was determined that the maximum spacing of the two supports for the sign sizes typically utilized in temporary work zone applications is only 24 inches. With this close post spacing, it is highly probable that both supports will be impacted by an errant vehicle. Also, the review determined that the signs typically used on dual

support configurations are not deployed at or near intersections. Therefore, impacting the dual support system at 90° is not necessary.

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

5.2 SINGLE EMBEDDED WOOD POST SIGN SYSTEM

5.2.1 MASH Test 3-62 at 0°

5.2.2.1 System Details

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

The sign was attached to the post with two F3125/A325 Grade 5 steel $\frac{3}{8}$ -inch diameter, 4½-inch long hex bolts with flat washers, lock washers, and nuts through two $\frac{7}{16}$ -inch diameter holes drilled in the post a distance of 1½ inches from the top and bottom edges of the sign panel.

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

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

5.2.2.2 Test Designation and Actual Impact Conditions

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

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







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

5.2.2.3 Test Vehicle

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

5.2.2.4 Weather Conditions

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

5.2.2.5 Test Description

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



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



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

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

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

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

5.2.2.6 Damage to Test Installation

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

5.2.2.7 Damage to Test Vehicle

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

5.2.2.8 Occupant Risk Factors

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

5.2.2.9 Assessment of Results

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

5.2.2.10 Conclusions

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

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



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



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



Before Test

After Test

T .		T 4 •		T 7 I • I	e –			- -
HIGHTO	N '/	Inforior	AT LOCT	Vahicla	tor I a		/16U/16'/_6	_
TIZUIC.	J./.		UL LUSU	VUIIUUU	101 10	-OL 11U.	オリノオリノーリ	-1.

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

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



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

TR No. 0-6946-1

Te	st Agency: Texas A&M Transportation Institute	Test No.: 469467-6-1	Cest Date: 2017-08-22
	MASH Test 3-62 Evaluation Criteria	Test Results	Assessment
$\frac{\mathrm{St}}{B}$.	uctural Adequacy The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.	The TxDOT single embedded wood post sign system fractured as designed.	Pass
00	cupant Risk	Nono of the deteched fucements menotunited or	
D.	Detached elements, fragments, or other aebris from the test article should not penetrate or show potential	None of the detached fragments penetrated of showed potential for penetrating the occupant	
	for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or	compartment or to present hazard to others in the area.	Dase
	personnel in a work zone.		1 400
	Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in	No occupant compartment deformation or intrusion occurred.	
	Section 5.3 and Appendix E of MASH.		
F.	The vehicle should remain upright during and after	The 2270P vehicle remained upright during and	
	collision. The maximum roll and pitch angles are not	after the collision event. Maximum roll and pitch	Pass
	to exceed 75 degrees.	angles were 2.0° and 0.6° , respectively.	
H.	Occupant impact velocities (OIV) should satisfy the	No occupant contact occurred.	ł
	following limits: Preferred value of 10 ft/s, or maximum allowable value of 16 ft/s.		Pass
I.	The occupant ridedown accelerations should satisfy	No occupant contact occurred.	
	the following limits: Preferred value of 15.0 g, or		Pass
	maximum allowable value of 20.49 g.		
Ve	hicle Trajectory		
N.	Vehicle trajectory behind the test article is acceptable.	The 2270P vehicle came to rest 300 ft	Pass
		downstream of impact.	

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

5.2.3 *MASH* Test 3-62 at 90°

5.2.3.1 System Details

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

The sign was attached to the post with two F3125/A325 Grade 5 steel $\frac{3}{8}$ -inch diameter, 4½-inch long hex bolts with flat washers, lock washers, and nuts through two $\frac{7}{16}$ -inch diameter holes drilled in the post a distance of 3 inches from the top and bottom edges of the sign panel.

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

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

5.2.3.2 Test Designation and Actual Impact Conditions

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

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

5.2.3.3 Test Vehicle

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



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


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



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



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

5.2.3.4 Weather Conditions

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

5.2.3.5 Test Description

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

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

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

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

4.2.3.6 Damage to Test Installation

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



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

4.2.3.7 Damage to Test Vehicle

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



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



Before Test

After Test

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

5.2.3.8 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk and are shown in Table 5.5. Figure 5.16 summarizes these data and other pertinent information from the test. Figure D.10 in Appendix D.2 shows the vehicle

angular displacements, and Figures D.11 through D.16 in Appendix D.2 show vehicle acceleration versus time traces.

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

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

5.2.3.9 Assessment of Results

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

5.2.3.10 Conclusions

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

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



TR No. 0-6946-1

Tes	t Agency: Texas A&M Transportation Institute	Test No.: 469467-6-3	est Date: 2017-08-22
	MASH Test 3-62 Evaluation Criteria	Test Results	Assessment
$\frac{\text{Str}}{B}$.	uctural Adequacy The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.	The TxDOT single embedded wood post sign system fractured as designed.	Pass
0 C	supant Risk		
D.	Detached elements, fragments, or other debris from the test article should not penetrate or show potential	An 80-inch section of wood post and the sign panel penetrated through the windshield.	
	for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or		л Ц
	personnel in a work zone.		Fall
	Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in	Penetration of the windshield by wood post and sign panel.	
	Section 5.3 and Appendix E of MASH.	•	
F.	The vehicle should remain upright during and after	The 2270P vehicle remained upright during and	
	collision. The maximum roll and pitch angles are not	after the collision event. Maximum roll and pitch	Pass
	to exceed 75 degrees.	angles were 2.8° and 3.2°, respectively.	
H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s or	No occupant contact occurred.	Dace
	maximum allowable value of 16 ft/s.		
I.	The occupant ridedown accelerations should satisfy	No occupant contact occurred.	
	the following limits: Preferred value of 15.0 g, or		Pass
	maximum allowable value of 20.49 g.		
Ve	nicle Trajectory		
N.	Vehicle trajectory behind the test article is acceptable.	The 2270P vehicle came to rest 355 ft	Pass
		downstream of impact.	

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

5.3 DUAL EMBEDDED WOOD POST SYSTEM

5.3.1 System Details

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

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

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

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

5.3.2 MASH Test 3-62 at 0°

5.3.2.1 Test Designation and Actual Impact Conditions

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

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

5.3.2.2 Test Vehicle

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



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



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



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



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

5.3.2.3 Weather Conditions

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

5.3.2.4 Test Description

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

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

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

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

5.3.2.5 Damage to Test Installation

Figure 5.21 shows the damage to the TxDOT dual embedded wood sign system. Both posts fractured at ground level. The stubs appeared to have displaced 0.38 inch downstream of

the original location. A 32-inch long section of the right post was resting 42 ft downstream of impact. The remaining sections of both posts still attached to the sign panel were resting 115 ft downstream and 12 ft to the right of centerline.



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

5.3.2.6 Damage to Test Vehicle

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

the interior of the vehicle. Table D.9 in Appendix D.3 provides occupant compartment measurements.



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



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



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

5.3.2.7 Occupant Risk Factors

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

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

Table 5.8	. Occupant	Risk Factors	for Test No.	469467-6-4.
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5.3.8 Assessment of Results

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

5.3.2.9 Conclusions

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

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



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

		oysucili.	
Te	st Agency: Texas A&M Transportation Institute	Test No.: 469467-6-4 To	est Date: 2017-08-22
	MASH Test 3-62 Evaluation Criteria	Test Results	Assessment
$\frac{St_{1}}{B}$.	uctural Adequacy The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.	The TxDOT dual embedded wood post sign system fractured as designed.	Pass
ŏ	cupant Risk		
D.	Detached elements, fragments, or other debris from the test article should not penetrate or show potential	None of the detached fragments penetrated or showed potential for penetrating the occupant	
	for penetrating the occupant compartment, or present	compartment or to present hazard to others in the	
	an undue hazara to other traffic, pedestrians, or personnel in a work zone.	arca.	Pass
	Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in	Maximum occupant compartment deformation was 3.0 inches in the center roof area	
	Section 5.3 and Appendix E of MASH.		
F.	The vehicle should remain upright during and after	The 2270P vehicle remained upright during and	
	collision. The maximum roll and pitch angles are not	after the collision event. Maximum roll and pitch	Pass
	to exceed 75 degrees.	angles were 2.5° and 1.3° , respectively.	
H.	Occupant impact velocities (OIV) should satisfy the	No occupant contact occurred.	
	following limits: Preferred value of 10 ft/s, or		Pass
	maximum allowable value of 16 ft/s.		
I.	The occupant ridedown accelerations should satisfy	No occupant contact occurred.	
	the following limits: Preferred value of 15.0 g, or		Pass
	maximum allowable value of 20.49 g.		
Vé	hicle Trajectory		
N.	Vehicle trajectory behind the test article is acceptable.	The 2270P vehicle came to rest 370 ft	Pass
		downstream of impact.	

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

5.3.3 *MASH* Test 3-61 at 0°

5.3.3.1 Test Designation and Actual Impact Conditions

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

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

5.3.3.2 Test Vehicle

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



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



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

5.3.3.3 Weather Conditions

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

5.3.3.4 Test Description

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

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

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

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

5.3.3.5 Damage to Test Installation

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



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

5.3.3.6 Damage to Test Vehicle

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

the interior of the vehicle. Table D.11 in Appendix D.4 provides occupant compartment measurements.



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



Before Test

After Test

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

5.2.3.7 Occupant Risk Factors

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

Occupant Risk Factor	Value	Time
OIV		
Longitudinal	1.0 ft/s	at 0.0324 s on left side of interior
Lateral	2.0 ft/s	at 0.9324 s on left side of interior
Occupant Ridedown Accelerations		
Longitudinal	0.2 g	0.9352–0.9452 s
Lateral	0.3 g	0.9412–0.9512 s
THIV	2.4 km/h	at 0.9314 s on left side of interior
	0.7 m/s	
PHD	0.3 g	0.9414–0.9514 s
ASI	0.06	0.0015–0.0515 s
Maximum 50-ms Moving Average		
Longitudinal	-0.5 g	0.0012–0.0512 s
Lateral	-0.3 g	0.0083–0.0583 s
Vertical	0.5 g	0.0152–0.0652 s
Maximum Roll, Pitch, and Yaw Angles		
Roll	1.7 °	0.6511 s
Pitch	2.8 °	1.0000 s
Yaw	3.4 °	0.1131 s

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

5.2.8 Assessment of Results

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

5.3.2.9 Conclusions

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

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



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

Tes	t Agency: Texas A&M Transportation Institute	Test No.: 469467-6-2	Test Date: 2017-08-23
	MASH Test 3-61 Evaluation Criteria	Test Results	Assessment
$\frac{\text{Strt}}{B}$.	ictural Adequacy The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.	The TxDOT single embedded wood post sign system fractured as designed.	Pass
D. D.	<u>Supant Risk</u> 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	The sign panel and portions of the wood post contacted the windshield and punctured a hole adjacent to the roof line.	Fail
	Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	The windshield was shattered, depressed inward toward the occupant compartment 1.5 inches, and punctured near the roof line on the right side.	
F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.7° and 2.8° , respectively.	Pass
H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s, or maximum allowable value of 16 ft/s.	Longitudinal OIV was 1.0 ft/s, and lateral OIV was 2.0 ft/s.	Pass
I.	The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	Maximum longitudinal occupant ridedown acceleration was 0.2 g, and maximum lateral ridedown acceleration was 0.3 g.	Pass
<u>Veł</u> N.	<u>nicle Trajectory</u> Vehicle trajectory behind the test article is acceptable.	The 1100C vehicle came to rest 284 ft downstream of impact.	Pass

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

CHAPTER 6: TXDOT PEDESTAL POLE WITH BEACONS

6.1 BACKGROUND

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

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

6.2.1 Test Article and Installation Details

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

The test pole was an 18 ft long 4-inch Schedule 40 (4.5 inch outside diameter; 0.237 inch wall thickness) 6061-T6 aluminum pipe that was fitted with a pipe cap at the top. The sign panel measured 48-inches square and was manufactured of 0.125-inch thick aluminum sheet. Each of the two beacons (McCain) measured $13\frac{1}{2} \times 13\frac{1}{2} \times 6\frac{1}{2}$ inches deep and contained a 12-inch diameter lens and associated sun shield. The sign panel and beacons were attached to the pole with $4\frac{1}{2}$ -inch wide U-bolts and aluminum brackets

The 16-inch tall breakaway base (Component Products, Inc. model CPI-BAS-1-P) was manufactured of cast aluminum and measured 14-inches square at the base, tapering to 12 inches square at the top. A 5³/₄-inch diameter collar at the top of the base accommodated the base-to-pole connection. The bottom of the base was set approximately 1¹/₂-inches above the concrete apron to which it was mounted.

Four ³/₄-inch diameter 10 national coarse (UNC) thread, 9-inch long threaded anchor rods (ASTM A193 grade B7) connected the breakaway base to the concrete apron. These rods were embedded 5 inches in the apron on a 9-inch square pattern (12³/₄-inch bolt circle diameter) and secured using Hilti HIT-HY-200-R epoxy per Hilti's installation instructions. The base was attached using two sets of ³/₄-inch heavy hex nuts, lock washers, and USS flat washers per anchor rod.

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



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



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



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

6.2.2 Test Designation and Actual Impact Conditions

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

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

6.2.3 Test Vehicle

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



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



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

6.2.4 Weather Conditions

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

6.2.5 Test Description

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

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

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

6.2.6 Damage to Test Installation

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

6.2.7 Damage to Test Vehicle

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



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



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



Before Test

After Test



6.2.8 Occupant Risk Factors

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

6.2.9 Summary of Results

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

6.2.10 Conclusions

The TxDOT Pedestal Pole with Beacons without Solar Assembly yielded to the 2270P vehicle as designed by fracturing at the base. None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the

area. No occupant compartment deformation or intrusion occurred. The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 3° and 2° , respectively. Occupant risk factors were within the preferred limits of *MASH*. The 2270P vehicle came to rest 308 ft downstream of impact.

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

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

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



	201 a	r Assembly.	
Tes	t Agency: Texas A&M Transportation Institute	Test No.: 469467-7-1 To	est Date: 2017-08-17
	MASH Test 3-62 Evaluation Criteria	Test Results	Assessment
$\frac{Stri}{B}$.	<u>ictural Adequacy</u> The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.	The TxDOT Pedestal Pole with Beacons without Solar Assembly yielded to the 2270P vehicle as designed by fracturing at the base.	Pass
$\frac{Occ}{D}$.	<u>Supant Risk</u> Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.	None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area.	Pass
	Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	No occupant compartment deformation or intrusion occurred.	Pass
F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 3° and 2° , respectively.	Pass
H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s, or maximum allowable value of 16.4 ft/s.	Maximum longitudinal OIV was 2.6 ft/s, and no lateral contact was made.	Pass
I.	The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	Longitudinal occupant ridedown acceleration was 0.8 g, and lateral occupant ridedown acceleration was 0.6 g.	Pass
<u>Vel</u> N.	<u>nicle Trajectory</u> Vehicle trajectory behind the test article is acceptable.	The 2270P vehicle came to rest 308 ft downstream of impact.	Pass

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

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

6.3.1 Test Article and Installation Details

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

The test pole was an 18 ft long 4-inch Schedule 40 (4.500-inch outside diameter; 0.237-inch wall thickness) 6061-T6 aluminum pipe that was fitted with a pipe cap at the top. The sign panel measured 48-inches square and was manufactured of 0.125-inch thick aluminum sheet. Each of the two beacons (McCain) measured $13\frac{1}{2} \times 13\frac{1}{2} \times 6\frac{1}{2}$ inches deep and contained a 12-inch diameter lens and associated sun shield. The sign panel and beacons were attached to the pole with $4\frac{1}{2}$ -inch wide U-bolts and aluminum brackets.

The solar panel (Ameresco Solar model BSP-9012) was attached to the top of the pole and measured $48 \times 21 \times 1\frac{1}{2}$ inches thick. The battery box measured $15\frac{1}{2}$ -inches wide \times 17 inches deep \times 26 inches tall and contained two 12-volt GEL batteries. The battery cabinet was located behind and toward the top of the sign panel.

The 16-inch tall pedestal base (Component Products, Inc. model CPI-BAS-1-P) was manufactured of cast aluminum and measured 14-inches square at the base, tapering to 12 inches square at the top. A 5³/₄-inch diameter collar at the top of the base accommodated the base-to-pole connection. The bottom of the base was set approximately 1¹/₂-inches above the concrete apron to which it was mounted.

Four ³/₄-inch diameter 10 UNC thread, 9-inch long threaded anchor rods (ASTM A193 grade B7) connected the breakaway base to the concrete apron. These rods were embedded 5 inches in the apron on a 9-inch square pattern (12³/₄-inch bolt circle diameter) and secured using Hilti HIT-HY-200-R epoxy per Hilti's installation instructions. The base was attached using two sets of ³/₄-inch heavy hex nuts, lock washers, and USS flat washers per anchor rod.

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

6.3.2 Test Designation and Actual Impact Conditions

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


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



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



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

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

6.3.3 Test Vehicle

The 2012 Dodge RAM 1500 pickup truck, shown in Figure 6.11 and 6.12, used in the first test was reused for this crash test. The impact was aligned with the opposite ¹/₄-point along the front of the vehicle. The vehicle's test inertia weight was 5034 lb, and its gross static weight was 5034 lb. The height to the lower edge of the vehicle bumper was 11.0 inches, and height to the upper edge of the bumper was 26.5 inches. The height to the vehicle's center of gravity was 28.5 inches. Tables E.5 and E.6 in Appendix E.3 give additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.



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



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

6.3.4 Weather Conditions

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

6.3.5 Test Description

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

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

Table 6.4.	Events	during	Test	No.	469467-7-2.
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6.3.6 Damage to Test Installation

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

6.3.7 Damage to Test Vehicle

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



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



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



Before Test

After Test

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

6.2.8 Occupant Risk Factors

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

6.2.9 Summary of Results

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

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

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



TR No. 0-6946-1

	Α	ssembly.	
Tes	t Agency: Texas A&M Transportation Institute	Test No.: 469467-7-2 T	est Date: 2017-08-17
	MASH Test 3-62 Evaluation Criteria	Test Results	Assessment
$\frac{Strt}{B}$.	<u>actural Adequacy</u> The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.	The TxDOT Pedestal Pole with Beacons and Solar Assembly yielded to the 2270P vehicle as designed by fracturing at the base.	Pass
$\frac{Occ}{D}$.	<u>Supant Risk</u> Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.	None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area.	Pass
	Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	No occupant compartment deformation or intrusion occurred.	Pass
F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 2270P vehicle remained upright during and after the collision event. Maximum roll and pitch angles were both 2°.	Pass
H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s, or maximum allowable value of 16.4 ft/s.	Maximum longitudinal OIV was 2.6 ft/s, and maximum lateral OIV was 2.0 ft/s.	Pass
I.	The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	Longitudinal occupant ridedown acceleration was 0.9 g, and lateral occupant ridedown acceleration was 2.5 g.	Pass
<u>Veł</u> N.	<u>nicle Trajectory</u> Vehicle trajectory behind the test article is acceptable.	The 2270P vehicle came to rest 377 ft downstream of impact.	Pass

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

6.2.10 Conclusions

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

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

CHAPTER 7: TXDOT MAILBOX SYSTEMS

7.1 BACKGROUND

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



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

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

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

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

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

7.2.1 System Details

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

Two *Elite* No. 1-A standard arched-top mailboxes from Solar Group, Inc., a division of Gibraltar Industries Model #E1600B00 were attached to the top of the support post. Each *Elite* mailbox was delivered as a fabricated steel unit with approximate dimensions of 11 inches tall × $8\frac{3}{4}$ inches wide × $21\frac{1}{2}$ inches deep and weighed 7 lb. Attachment of each *Elite* mailbox to the post was accomplished using a mailbox bracket (DHT #148939), one extension bracket (DHT #148938), and associated SAE Grade 5 bolts, nuts, and washers. The mailboxes, located 10¹/₄-inches center to center, were secured to a bracket plate (DHT #3789) that was attached to the support post using a two-part angle bracket. Angle bracket Part "A" (DHT # 159489) was located on the outside of the rib of the wing channel post on the opposite side. The angle bracket parts were connected to the post using two $\frac{5}{16}$ -inch diameter × $2\frac{3}{4}$ -inch long SAE Grade 5 hex bolts, flat and lock washers, and nuts. The two mailboxes with brackets and hardware weighed 21.0 lb.

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

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

7.2.2 MASH Test 3-61

7.2.2.1 Test Designation and Actual Impact Conditions

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

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

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



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

7.2.2.2 Test Vehicle

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

7.2.2.3 Weather Conditions

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



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



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

7.2.2.4 Test Description

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

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

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

Table 7.1.	Events	during	Test	No.	469467	-8-4.
1 abic 7.11	LITT	uuring	ICSU	110.	107107	-0-4.

7.2.2.5 Damage to Test Installation

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



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

7.2.2.6 Damage to Test Vehicle

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

7.2.2.7 Occupant Risk Factors

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



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



Before Test

After Test

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

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



with Type 3 Foundation.

	Wingeu Channel Fr	st with type 3 roundation.	
Te	st Agency: Texas A&M Transportation Institute	Test No.: 469467-8-4	Test Date: 2017-08-03
	MASH Test 3-61 Evaluation Criteria	Test Results	Assessment
$\frac{St_1}{B}$.	<u>uctural Adequacy</u> The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.	The TxDOT double mailbox system on winged channel post with type 3 foundation fractured and released as designed.	Pass
<u>D</u> .	<u>cupant Risk</u> Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.	The mailboxes and support contacted the hood of the vehicle and then rotated up and over the vehicle without any secondary contact with the windshield. None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area.	Pass
	Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	No occupant compartment deformation or intrusion occurred.	
F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.2° and 2.0° , respectively.	Pass
H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s, or maximum allowable value of 16 ft/s.	No occupant contact occurred.	Pass
I.	The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	No occupant contact occurred.	Pass
<u>Ve</u> <u>N</u> .	<u>hicle Trajectory</u> Vehicle trajectory behind the test article is acceptable.	The 1100C vehicle came to rest 270 ft downstream of impact.	Pass

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

7.2.2.8 Assessment of Results

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

7.2.2.9 Conclusions

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

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

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

7.3.1 System Details

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

Two *Elite* No. 1-A standard arched-top mailboxes from Solar Group, Inc., a division of Gibraltar Industries Model #E1600B00 were attached to the top of the support post. Each *Elite* mailbox was delivered as a fabricated steel unit with approximate dimensions of 11 inches tall by 8³/₄ inches wide by 21¹/₂ inches deep and weighed 7 lb. Attachment of each *Elite* mailbox to the post was accomplished using a mailbox bracket (DHT #148939), one extension bracket (DHT #148938), and associated SAE Grade 5 bolts, nuts, and washers. The mailboxes, located 10-inches center to center, were secured plate and collar bracket (DHT #162323) that was attached to the support post using a ³/₈-inch diameter × 3¹/₂-inch long SAE Grade 5 hex bolt, flat and lock washers, and nut. The two boxes with brackets and hardware weighed 20 lb.

The two mailboxes were supported on a nominal 2-inch diameter x 16 gauge thick (2³/₈ inches outside diameter by 0.065 inch wall thickness) galvanized thin-wall steel tube (DHT #143426) formed from ASTM A513 Type 5 DOM steel tubing. The overall length of the support post was 57 inches and it weighed 7.5 lb.

The support post was inserted approximately 15 inches into a socket (DHT #143434) and secured with a wedge (DHT #143433) on the impact side. The socket was embedded 27 inches

deep, and installed flush with the top of a TxDOT Type 2 non-reinforced concrete footer that measured approximately 12 inches in diameter \times 30 inches deep. The total mass of the two mailboxes, connection hardware, and support post assembly was 27.5 lb.

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

7.3.2 MASH Test 3-61

7.3.2.1 Test Designation and Actual Impact Conditions

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

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

7.3.2.2 Test Vehicle

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

7.3.2.3 Weather Conditions

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

7.3.2.4 Test Description

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

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













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



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



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

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

Table 7.4.	Events	during	Test	No.	469467-8-3.
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7.3.2.5 Damage to Test Installation

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

7.3.2.6 Damage to Test Vehicle

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



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



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



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

7.3.2.7 Occupant Risk Factors

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

7.3.2.8 Assessment of Results

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

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

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



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Tes	t Agency: Texas A&M Transportation Institute	Test No.: 469467-8-3 To	est Date: 2017-08-03
	MASH Test 3-61 Evaluation Criteria	Test Results	Assessment
Stru B.	<u>actural Adequacy</u> The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.	The TxDOT double mailbox system on thin-walled galvanized tube with type 2 foundation yielded around the front of the vehicle and pulled out of the ground socket as designed.	Pass
<u>0c</u> D.	<u>Supant Risk</u> Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.	The mailboxes and support contacted the hood of the vehicle and then rotated up and over the vehicle without any secondary contact with the windshield. None of the detached fragments penetrated or showed potential for penetrating the occupant compartment or to present hazard to others in the area.	Pass
	Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.	No occupant compartment deformation or intrusion occurred.	
F.	The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.	The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.3° and 2.9° , respectively.	Pass
H.	Occupant impact velocities (OIV) should satisfy the following limits: Preferred value of 10 ft/s, or maximum allowable value of 16 ft/s.	No occupant contact occurred.	Pass
I.	The occupant ridedown accelerations should satisfy the following limits: Preferred value of 15.0 g, or maximum allowable value of 20.49 g.	No occupant contact occurred.	Pass
<u>Vel</u> N.	<u>nicle Trajectory</u> Vehicle trajectory behind the test article is acceptable.	The 1100C vehicle came to rest 283 ft downstream of impact.	Pass

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

7.3.2.9 Conclusions

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

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

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

7.4.1 System Details

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

Two *Stanley* No. 2 large arched-top mailboxes from Solar Group, Inc., a division of Gibraltar Industries, Model #ST200B00, were attached at the second and third (middle two) of the four mounting positions located $7\frac{1}{2}$ inches from the centerline of the support post. Each *Stanley* mailbox was delivered as a fabricated steel unit with approximate dimensions of 15 inches tall \times 11^{1/2} inches wide \times 24³/4</sup> inches deep and weighed 11 lb. Attachment of each *Stanley* mailbox to the horizontal segment of the thin-wall steel mounting post was accomplished using a mailbox bracket (DHT #148939), two extension brackets (DHT #148938), a pair of Part "A" angle brackets (DHT # 159489), and associated SAE Grade 5 bolts, nuts, and washers.

Two *Elite* No. 1-A standard arched-top mailboxes from Solar Group, Inc., a division of Gibraltar Industries Model #E1600B00, were attached at the first and fourth of the four mounting positions located 21 inches from the centerline of the support post. Each *Elite* mailbox was delivered as a fabricated steel unit with approximate dimensions of 11 inches tall \times 8³/₄ inches wide \times 21¹/₂ inches deep and weighed 7 lb. Attachment of each *Elite* mailbox to the horizontal segment of the thin-wall steel mounting post was accomplished using a mailbox bracket (DHT #148939), one extension bracket (DHT #148938), a pair of Part "A" angle brackets (DHT # 159489), and associated SAE Grade 5 bolts, nuts, and washers.
The four mailboxes were supported on a galvanized thin-wall steel tube support (DHT #149339) formed in the shape of a hanger from 2-inch nominal diameter \times 16 gauge thick (2 inches outside diameter \times 0.065 inch wall thickness) thin wall ASTM A513 Type 5 DOM steel tubing. The support post had outwardly sloping sides and a horizontal section on top to which the mailboxes were attached. The support post had an overall width of 56 inches and weighed 18 lb. The post's shorter leg was secured to the longer, supporting leg using two $\frac{3}{8}$ -inch diameter \times 4½-inch long SAE Grade 5 bolts, flat washers, and nuts.

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

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

7.4.2 MASH Test 3-61

7.4.2.1 Test Designation and Actual Impact Conditions

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

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

7.4.2.2 Test Vehicle

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

7.4.2.3 Weather Conditions

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



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



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



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

7.4.2.4 Test Description

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

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

Table 7.7. Events during	Test No.	469467-8-2.
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Brakes on the vehicle were applied at 1.4 s after impact. The vehicle subsequently came to rest 297 ft downstream of the impact.

7.4.2.5 Damage to Test Installation

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



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

7.4.2.6 Damage to Test Vehicle

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



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



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



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

7.4.2.7 Occupant Risk Factors

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

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

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

7.4.2.8 Assessment of Results

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

7.4.2.9 Conclusions

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

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

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2017-12-19

TR No. 0-6946-1

	JU-IIIUII ITAIIGU - I JPC IIIIII- WAIICU	Galvallecu Lude Will Lype I Foundation.	
Ē	est Agency: Texas A&M Transportation Institute	Test No.: 469467-8-2	est Date: 2017-08-31
	MASH Test 3-61 Evaluation Criteria	Test Results	Assessment
$\frac{S_1}{B}$	<u>ructural Adequacy</u> The test article should readily activate in a predictable	The TxDOT multiple mailbox system on 56-inch	
	manner by breaking away, fracturing, or yielding.	hanger-type thin-walled galvanized tube with type 1 foundation yielded to the vehicle by	Pass
		pulling out of the foundation socket as designed.	
0	ccupant Risk	الأمسم مقادلهم المحاصما مناممين ممسملسمام مس	
ח	. Detached elements, fragments, or other depris from the test article should not penetrate or show potential	showed potential for penetrating the occupant	
	for penetrating the occupant compartment, or present	compartment or to present hazard to others in the	
	an undue hazard to other traffic, pedestrians, or	area.	Dace
	personnel in a work zone.		0000 1
	Deformations of, or intrusions into, the occupant	Maximum occupant compartment deformation	
	compartment should not exceed limits set forth in	was 1.7 inches in the left windshield area.	
	Section 5.3 and Appendix E of MASH.		
F.	The vehicle should remain upright during and after	The 1100C vehicle remained upright during and	
	collision. The maximum roll and pitch angles are not	after the collision event. Maximum roll and pitch	Pass
	to exceed 75 degrees.	angles were 1.2° and 0.7°, respectively.	
Η	Occupant impact velocities (OIV) should satisfy the	No occupant contact occurred.	
	following limits: Preferred value of 10 ft/s, or		Pass
	maximum allowable value of 16 ft/s.		
Ι.	The occupant ridedown accelerations should satisfy	No occupant contact occurred.	
	the following limits: Preferred value of 15.0 g, or		Pass
	maximum allowable value of 20.49 g.		
\geq	ehicle Trajectory		
Z	Vehicle trajectory behind the test article is acceptable.	The 1100C vehicle came to rest 297 ft	Pace
		downstream of impact.	1 4 00

Table 7.9. Performance Evaluation Summary for MASH Test 3-62 at 0° on the TxDOT Multiple Mailbox System on56-inch Hanger-Type Thin-Walled Galvanized Tube with Type 1 Foundation.

CHAPTER 8: SUMMARY AND CONCLUSIONS

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

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

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

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

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

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

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

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

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

The TxDOT 32-inch CSB(7)-10 pinned to concrete pavement contained and redirected the 2270P vehicle. Maximum dynamic deflection during the test was 24.6 inches. No detached elements, fragments, or other debris from the test article were present to penetrate or show potential for penetrating the occupant compartment, or to present undue hazard to others in the area. No occupant compartment deformation or intrusion occurred. The 2270P vehicle remained

upright during and after the collision period. Maximum roll and pitch angles were 17° for both. Occupant risk values were within the preferred limits.

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

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

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

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

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

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

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

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

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

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

The support fractured in two locations (near ground level and at bumper height). The sign panel and fractured support posts rotated toward the vehicle and impacted the roof. Roof

deformation was within the limits set in *MASH*. The TxDOT dual embedded wood post sign system performed acceptably for *MASH* Test 3-62 at 0° .

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

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

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

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

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

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

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

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

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

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

8.6 MASH TESTING OF TXDOT MAILBOX SYSTEMS

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

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

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

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

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

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

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

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

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

CHAPTER 9: IMPLEMENTATION

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

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

9.1 TXDOT 36-INCH VERTICAL WALL

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

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

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

9.2 TXDOT 42-INCH TALL SSCB

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

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

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

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

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

When available space for barrier deflection is restricted, one practice to reduce the lateral barrier deflection is pinning the barrier to the underlying concrete pavement or deck structure. TxDOT standard practice includes the use of 1¹/₄-inch steel pins placed on the traffic side of the barrier. The pins are installed at an angle through the toe of the precast barrier and 6 inches into the concrete pavement.

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

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

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

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

9.4 TXDOT SINGLE AND DUAL EMBEDDED WOOD POST SIGN SYSTEMS

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

9.4.1 Single Sign Support System

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

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

9.4.2 Dual Sign Support System

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

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

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

9.5 TXDOT PEDESTAL POLE WITH BEACON

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

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

9.6 TXDOT MAILBOX SYSTEMS

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

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

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

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

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

A.1 DETAILS OF THE 36-INCH VERTICAL WALL



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A.2 SUPPORTING CERTIFICATION DOCUMENTS

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	341.					1927.												

Total Weight: 4,133 Lbs

Longest Length: 20-00

WEIGHT SUMMARY STRAIGHT LIGHT BENDING HEAVY BENDING TOTAL ITEMS PIECES ITEMS ITEMS SIZE LBS ITEMS PIECES LBS PIECES LBS PIECES LBS Rebar, Grade A706, Black 81 218 0 0 0 0 0 81 218 0 5 1 1 0 0 0 218 81 218 0 0 0 81 Rebar, Grade 60, Black 4 2 341 1,927 1 100 1,336 1 241 591 0 0 0 0 0 0 322 1,988 322 1,988 0 0 0 2 5 2 1,336 4 663 3,915 1 100 1 241 591 2 322 1,988 Total Weight: 4,133 Lbs

Longest Length: 20-00

v14.02.101 (T) (HOW)

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Wednesday, June 28, 2017 10:37 AM



TR No. 0-6946-17-1

A7

2017-12-19

CMC	steel mill eguin TX 74	DRIVE 8155-7510	For additional cop 830-372-87	oles call 71	TOWI	many heart
					Quality Assurance h	Manager
HEAT NO.:3065785		S CMC Rebar Houston-	West	CMC Sterling Steel	Del	livery#: 81899287
A706	0.04/6	L BRITTMOORE RD.	-	2001 Brittmoore Rd		IST PO#:
GRADE: ASTM A706-16 G	rade 420	D HOUSTON TX	<u>.</u>	Houston TX	CU	IST P/N:
(60) ROLL DATE: 09/14/2016 MELT DATE: 09/08/2016		US 77043-2208 T 713-690-0347 0	+ 0	US 77043-2208 7136900347 7136905758		VRY LBS / HEAT: 24030.000 LB VRY PCS / HEAT: 576 EA
Charact	eristic Val	пе	Characteristic	Value	Characterist	ttic Value
	C 0.2	8%	Bend Te	est 1 Passed		
	Mn 1.2	3%				
	P 0.0	15%				
	S 0.0	40%				
	Si 0.3	2%				
	Cu 0.3	%0				
	Cr 0.1	6%				
	Ni 0.1	%0				
	Mo 0.0	26%				
		34%				
	Sn 0.0	10%				
	AI 0.0	%00				
Carbon Eq	A706 0.5	1%				
Yield Strength	test 1 76.	8ksi				
Tensile Strength	test 1 104	1.1ksi			4	
Elongation	test 1 159	%				
Elongation Gage Lgth	test 1 8IN					
Bend Test Dia	meter 1.8	75IN			3.	

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

A.3 VEHICE PROPERTIES AND INFORMATION



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

Date:	2017-0	8-15	Test No.:	467469-1-1	VIN No.:	1HTMPAF	N73H564911
Year:	2003		Make:	International	Model:	4200	
		WEIGHTS (lb)		CURB	TES	ST INERTIAL	
		W _{fr}	ont axle	6060		7250	_
		Wre	ear axle	6550		15070	=
		W	TOTAL	12610	<u> </u>	22320	_
I	Ballast:		10282	(as-ne (lb) (See /	eded) MASH Section 4	.2.1.2 for recon	nmended ballasting)
Mass D (lb):	Distributi	on LF:	3650	RF: <u>3600</u>	LR:	7570	RR: 7500
Engine	Type:	UT		A		Locations (inches)
Engine	Size:	365		_	X ¹	У	Z ²
Trancm	viccion Tu	/DO:		Front:			
<u>_X</u>	Auto	or	Manual	Center:	139.00	0	49.00
	FWD _	x RWD	4WD	Rear:	239.00	0	49.00
Describ	be any da	image to the	e vehicle prior	to test: <u>None</u>			

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

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

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

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

Centered in middle of bed

62 inches to center of block to ground

Four 5/16 cables per block

¹ Referenced to the front axle

² Above ground

A.4 SEQUENTIAL PHOTOGRAPHS



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

















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

1.000 s






X Acceleration at CG

TR No. 0-6946-17-1

A-14

















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







Y Acceleration Rear of CG

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





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

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

T/1-ProjectFiles/4634 - TodxT - 734634 - To







B2. SUPPORTING CERTIFICATION DOCUMENTS

TR No. 0-6946-17-1





PROPOSAL

TRICON PRECAST CONCRETE TRAFFIC BARRIER

November 17, 2016

P.O. # 468957-5

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

5.

TPL # 1611026

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

ITEM	DESC	TPL PART	ITEM DESCRIPTION	QTY	UNIT	UNIT PRICE	EXTENSION
512	6005	2	Port CTB 30' - 32" F Shape JJ Connections	120	LF	\$57.80	\$6,936,00
			To be anchored to concrete paving		1		N
·····,	1		4 each f shape barrier for crash testing	1	1	····	
		K-/	w/ diagonal holes and pins on one side only:	1/ N	1/		
		17	1.25' x 20.5" anchor pins ASTM A36 w/ 2.25"	1 1	$^{\times}$	·	
		1	washer all galvanized. Certified papers for		>		na in the second s
			reinforcing, JJ Hooks Batch Tickets, and		<u> </u>		
			break test results on all barrier.				
							.,

INCLUSIONS / EXCLUSIONS

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Page 1 of 3

K-T Bolt Manufacturing Company, Inc.®

1150 Katy Fort-Bend Road Katy, Texas 77494 Ph: 281-391-2196 Fax: 281-391-2673 certs@k-tbolt.com

	Original Mill Test Report
Company:	Tricon Precast, LTD
Part Description:	100 pcs 1 1/4" x 20 1/2" Washer Head Drive Pin
Material Specification:	ASTM A36 - '12
Coating Specification:	Galvanized per ASTM F2329 / A153
Purchase Order Number:	8291
Lot Number:	46590-3
Comments:	None
Material Heat Number:	3064788

Chemical Analysis

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

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

Tensile and Hardness Test Results

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

Comments Test results reflect the original mill test report

K-T Bolt Manufacturing Co., Inc.

Quality Representative

All reports are the exclusive property of K-T Bolt Manufacturing Company, Inc.®. Any reproduction must be in their entirety and at the permission of same.

TS 7.						or.	1 A DC / ST7C	NOUT MAN
INDAU:	CUSTOMER SHIP TO REGAL METALS INTE	TUNATIONAL	CUSTOMER BILL TO REGAL METALS INTER	RNATIONAL	GRADE 60 (420)	R S	1AFB / SLLE sbar / #5 (16MM)	00000000000000000000000000000000000000
	I INC 207 SENTRY DR MANSFIELD,TX 76063 USA	3-3609	INC 207 SENTRY DR MANSFIELD, TX 76063- USA	-3609	LENGTH 40'00"		WEIGHT 24,282 LB	HEAT / BATCH 58027631/02
6065	SALES ORDER 4416559/000010		CUSTOMER MATE	RIAL N°	SPECIFICATIO ASTM A615/A615	N / DATE or REVI M-15 El	ISION	
SE ORDER NUMBER	BILL	OF LADING 0000215334	DATE 11/07/2016	~				
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mach	BHASKAR YA.	LAMANCHILI ECTOR			Donthe	Almos	JALITY ASSURANCE M	ж.

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GE GERDAU	CUSTOMER SHII REGAL METAL	? TO LS INTERNATIONAL	CUSTOMER BIL REGAL META	L TO LS INTERNATIONAL	GRADE 60 (420)		SHAPE Rebar /	/ SIZE #5 (16MM)	DOCUN 000000	ENT ID: 000
US-ML-MDLOTHIAN	INC 207 SENTRY D MANSFIELD, T USA	R X 76063-3609	INC 207 SENTRY D MANSFIELD, T USA)R X 76063-3609	LENGTH 40'00"		65 W	EIGHT 008 LB	HEAT/BATCH 58027888/02	
MIDLOTHIAN, TX 76065 USA	SALES ORDEF 4543455/00001	~ 0	CUSTOME	R MATERIAL N°	SPECIFI ASTM A6	CATION / DATE	or REVISION	*** z		
CUSTOMER FURCHASE ORDER NUMBER 350221		BILL OF LADING 1327-0000218247		ATB 2/07/2016	-					
CHEMICAL COMPOSITION S 0.42 0.72 0.011	S 0.039	% 0.21 0.22	N: 0.13	30 30	₩ 0.021	Sn 0.006	% 0.001	ND 0.000	ÅI 6.003	
CHEMICAL COMPOSITION CEq3% 0.58										
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MECHANICAL PROPERTIES Bei Biggs. 16.00	ndTest OK									
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The above figures are o specified requirements.	certified chemical an This material, inclu BHA QUA QUA	d physical test records as tding the billets, was mell skar YALAMANCHILI LITY DIRECTOR amanchil@gerden.com	contained in the p ed and manufactu	ternanent records of com red in the USA. CMTR o	pany. We certify th omplies with EN 1 Oov	at these data are c 0204 3.1. L/Jourth	orrect and in c TOM HAI QUALITY aail: Tommy.Ha	ompliance with ASSURANCE MGR. ASSURANCE MGR.	. 8	·. ·

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G F F C.	CUSTOMER SH	IP TO LS INTERNATIONAL	CUSTOMER BILL TO REGAL METALS INTERN	ATIONAL	GRADE 60 (420)	SHAPE / SIZE Rebar / #5 (16MM)	DOCUMENT ID: 000000000
US-ML-MIDLOTHIAN	INC 207 SENTRY J MANSFIELD, USA	DR TX 76063-3609	INC 207 SENTRY DR MANSFIELD,TX 76063-360 USA	6	19000" 40'00"	WEIGHT 24,032 LB	HEAT/BATCH 58027889/03
JUU WAKU KUAU MIDLOTHIAN, TX 76065 USA	SALES ORDE 4538466/0000	20	CUSTOMER MATERIA	LN°	SPECIFICATION / DATE or ASTM A615/A615M-15 E1	REVISION	
CUSTOMER PURCHASE ORDER NUMB YARD 53	BR,	BILL OF LADING 1327-0000218461	DATE 12/09/2016		2		
CHEMICAL COMPOSITION C Nn Nn S 0.42 0.76 0.012	\$ 0.026	81 0.27 0.21	510 16	දි <u>හ</u> 0.24 0.00	e Sp.	ပ္က လွှာ ၁.003 0.000	춼l 0.003
CHEMICAL COMPOSITION CERTXA706 0.58							
MECHANICAL PROPERTIES YS 65467	YS MPa 451	UTS PSI 100277	UTS MPa 691		G/L meh 8.000	G/L mm 200.0	
MECHANICAL PROPERTIES Blong 15.00	BendTest OK		, ,				
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Ma	cherry ou	ASKAR YALAMANCHILI ALITY DIRECTOR	•		Oom Llouit	TOM HARKINGTON QUALITY ASSURANCE MOR.	1.2
Phone: (409) 76	9-1014 Email: Bhaskar.Ya	lamanchili@gerdau.com			Phone: 972-779-1872 Ema	il: Tommy.Harrington@gerdau.com	

TR No. 0-6946-17-1

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GEPDALL	CUSTOMER SF	IF TO ALS INTERNATIONAL	CUSTOMER BI REGAL MET	LL TO ALS INTERNATIONAL	GRADE 60 (420)		SHAPE Rebar	// SIZE * #4 (13MM)	DOCUMENT ID: 000000000
US-ML-MDLOTHIAN	INC 207 SENTRY MANSFIELD USA	DR ,TX 76063-3609	INC 207 SENTRY MANSFIELD USA	DR ,TX 76063-3609	CO'00"			VEIGHT 2,024 LB	HEAT/BATCH 58028862/02
300 WAKD KUAU MIDLOTHLAN, TX 76065 USA	SALES ORDI 4938978/0000	3R 110	CUSTOM	BR MATERIAL N°	SPECIFI ASTM A	CATION / DATE (15/A615M-15 E1	or REVISIO	17	
CUSTOMER PURCHASE ORDER NUMBER RL3/28		BLL OF LADING 1327-0000230265		DATE 03/29/2017					
СНЕМІСАL СОМРОЗІНОМ С Мл 0.47 0.86 0.016	8 0.029	Si 0.23	5°0	یا 1 0.19	Mo 0.021	እካ 8.006	% 0.002	4% 0.000.0	Ål 0.004
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Phone: (409) 769-10	014 Email: Bhaskar.Y	alamanchili@gerdau.com			Phone	: 972-779-1872 Еп	aail: Tommy.H	arrington@gerdan.com	

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GERDAU	CUSTOMER SHP T REGAL METALS	0 INTERNATIONAL	CUSTOMER B REGAL MET	LL TO ALS INTERNATIONA	с 80 (С 1	420) 420)	SHA Reba	PE / SIZE r / #5 (16MM)	D0000	MENT ID: 00000
US-ML-MIDLOTHIAN	INC 207 SENTRY DR MANSFIELD, TX USA	76063-3609	INC 207 SENTRY MANSFIELD USA	DR .TX 76063-3609	LEP 40'0	IGTH 0"		WEIGHT 10,514 LB	HEAT / BAT 58027890/0	H
DUW WAKU KUAU MIDLOTHIAN, TX 76065 USA	SALES ORDER 4564328/000010	ž.	CUSTOM	ER MATERIAL N°	SPI AS7	SCIFICATION / DA M A615/A615M-15 E	TE or REVISI	NO		
CUSTOMER FURCHASE ORDER NUMBER 709567		BIL OF LADING 1327-0000218889		DATE 12/14/2016			*			
CHENICAL COMPOSITION C 0.42 0.80 0.017	\$S 0.035	Si Qu 0.21 0.32		6 0.29	Mo 0.034	Sn 0.007	0.002	0000.0 0000	ÅI 0.003	
CHEMICAL COMPOSITION CERT/A706 0.59										
MECHANICAL PROPERTIES PSI 65456 4	YS MPa 451	LST STU STU	t.	UTS MPa 689		G/L Hoth 1000	510	یلار 20.0	×	
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Fhone: (409) 769-101.	4 Email: Bhaskar.Yalam	anchili@gerdau.com				Phone: 972-779-1872	Email: Tomm	/.Harrington@gerdau.co	8	

JJE w/24" Rebar

Rebar Ref.#74084 A706 #5 Heat #2055671

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

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BitL OF AJORC- 1323-000070939 DATE 20007093 Activa (cores: AASITO RETRI: Activa (core: AASITO RETRI: 2000000000000000000000000000000000000	IBIL OF LUDRY- DATE DATE 1232.00004999 001 001 001 000 000 132.00004991 019 029 014 001 000 000 135 019 029 014 001 000 000 135 019 029 014 001 000 000 135 010 014 001 000 000 000 100 010 014 001 000 000 000 100 010 010 000 000 000 000 100 010 014 001 000 000 000 100 010 010 000 000 000 000 100 010 010 000 000 000 000 100 010 010 000 000 000 000 1000 010 010 000 000 000 000 1000 010 010 010 000 000 000 1000 010 010 010 010 000 000 1000 010 010 010		SALES ORDER 3780634/001220		. custic	MER MATE	RIAL N°	SPECIFICATION / ASTM AS29-14, AS72 ASTM A6-14 A36-14	DATE or REVI 2-15 ASME SA-36	SION		
No. No. No. No. No. No. State State State State State State	No. No. No. No. No. No.	1	B CI	fLL OF LADING ~ 23-000074939		DATE -		ASTM A709-15, AAS CSA G40-20-13/040.2	HTO M270-12	1	•	
Abit TSQN MA Abit TSQN MA Abit TSQ	Minimum Minimum Minimum Minimum Minimum		\$\$ 0.018 .	い。 200 219	3.9	ž*00	の の 1 0 1 0 0	Mo 227 0.016	£*00	Z%00	. Pb . Pb 0.0030	
000 13000 517 750,5 5700 371 000 37700 37700 37700 377 000 57700 37700 377 000 57700 37700 377 000 57700 377 377 000 57700 377 377 000 57700 377 377 000 57700 377 377 000 57700 377 377 000 57700 377 377 000 57700 377 377 000 57700 377 377 000 57700 377 377 000 57700 377 377 000 57700 377 377 000 57700 377 377 000 5700 370 377 000 5700 5700 377 000 5700 5700 377 000 5700 5700 378 000 5700 5700 570 000 5700 5700 570 000 5700 570 570 000 <	6.1 1500 150 150 150 150 0.00 100 100 100 100 0.01 100 100 100 100 0.01 100 100 100 100 0.01 100 100 100 100 0.01 100 100 100 100 0.01 100 100 100 100	1]
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field chamical and physical test records as contained in the permanent records of company. We certify that these data are connect and in compliance with is materical, including the billets, was melled and manufactured in the USA. CMTR complies with EN (1020, 3.1.) RIASEAR YALMANCHELL RUALITY DRRECOR	fied chemical and physical test records as contained in the permanent records of company. We certify that these data are correct and in compliance with fix material, including the billets, was melled and manufactured in the USA. CMTR complies with EN 10204 3.1. HARSTOR YALANAVERTILI	22 55										
fied chemical and physical test records as contained in the permanent records of company. We certify that these data are context and in compliance with is material, including the Billets, was melled and manufactured in the USA. CMTR complies with EN 10204 3.1. BILASEAR YALMANATERLI	field chernical and physical test records as contained in the permanent records of company. We certify that these data are convect and in compliance with is inaterial, including the billets, was melled and manufactured in the USA. CMTR complies with EN (0204 3.1. BitASKAR YALASAANTHILL VAXANANTHILL CAUTE COMPLIES (0204 3.1. OLALITY DIRECTOR CAUTER OF CAUTER COMPLIES (0204 3.1.) CAUTER COMPLIANCE SAFE							•••				
Ted chemical and physical test records as contained in the permanent records of company. We certify that these data are contest and in compliance with a material, including the Billets, was melted and manufactured in the USA. CMTR complies with EN 10204 3.1. ILLAREAR YALMANTHILLAREAREAL TO REPORT	Ted chemical and physical test records as contained in the permanent recerds of company. We certify that these data are connect and in compliance with a material, including the billets, was melhed and manufactured in the USA. CMTR complies with EN (0204 3.1. UAX WANC BILASKAR YALASANTERLA CONTRACT AND BILASKAR YALASANTERLA CONTRACT AND CONT					x				s.		à
		Line A	ad chemical and phys material, including ti sulasKAR Y.	sicul test records as , te billets, was melte AL-MANTHILJ RICTOR	contained in th ed and manufar	e permanent <i>r</i> e anwed in the U	ecords of company. W JSA. CMTR complies	Vo certify that these data swith EN 10204 3.1.	ו מורכ לסודעכן מוזען בארי אאאיז קעראנו	in compliance with wave rry veserkaare sear		

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Cast Date: 1 6-15-17			Tested By:	K.Ma		· · ··	
Break Date:	. 6-16-17		Days:				
Time:	5:5.6 Am.		<u>ļ.</u>	<u> </u>		•	
		I .	1	[]	Cone	Amb.	
II	, lood		PSI	Avg.	Temp	Temp	Flov
	LUdu		<u>, or</u>	<u></u>			
	IVISE		1 21.0			•	~
•	53;490	. 7	.4,240	·		1.5	
	53,940	<u>.</u> <u>.</u>	4,290				
· ·	SW/Columns/Caps			· · · · · · · · · · · · · · · · · · ·			•
•:	62,100	1	4,940			· · ·	
	61,510	2	4,900	·			
•	· · Ċoping	· ·			<u> </u>		·
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•.	73,310	2	5,840		۰.	•	
	MSE-Exposed	13	· · · -				
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F-Shape	CIR	<u> </u>	1 00 6				
	86,970	<u>` / .</u>	6,920				
	86,680	2	6,900				
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Job:	BARRII	ER1 Date:	Jun 15	, 2017 Star	t:11:29 Dis	sch:	11:36	Ref#:	7092
Operator:	JULIO	Durat	:ion/Wai	t: 8:05/0:05	Batch#:153	8633	٢	lixer#:	1
Mix:	H-7013	B5GCPT Mix N	lame: TR	UCK		•			
Required:	999999	9,00 Bate	ched: 55	350.85					
Amount:	3.50 0	CY							
PreWet: 70%		1.9		•					
		•	•						
Material	Bin	Moist/ABS%	Design	Target	Actual		%Err	*Note	Jogs
3/4	2	1.38/0.00	1620	5691:5806	5752	Lb	0.1	-P	2
Liberty	3	4.86/0.00	1483	5388:5497	5410	$\mathbf{L}\mathbf{p}$	-0.6		5
HOLCIM	1		455	1577:1624	1584	$\mathbf{L}\mathbf{b}$	-0.6		5
POZZO	4		245	849:870	854	Lb	-0.5		2
ADVA575	2		7.75	184.18:195.57	192.00	Oz	1.1		
RECOVER	1		3.00	71,30:75.70	74.00	Oz	0.7		
VMAR-3	. 5		3.00	63.50:83.50	75.00	Oz	2.0	<u>`</u>	
Prewet				36.5:37.1	36.9	Ga	0.5		
Water			÷	15.5:15.7	16.1	Ga	3.2		
Dry Mixing			0:30		0:30	S			
Wet Mixing		1	1:45		1:51	S			
Total Mixin	ıg		3:13		·3:13	S			
Total Moist	ure:		26.3	92.0	92.4	Ga	0.4		
Water/Cemen	it:		0.313	0.316					

	· ·		INCOMP Recent Limited		247		
		CONC	RETE SUM	MARY			. '
ast Date:	16-16-17		Tested By:	Dr.			
Break Date:	6-17-17		Days:			<u></u>	
Time:	6:00 Am.	·	<u>ļ.</u>	<u> </u>	· · · ·	•	
•	· · ·				Cone	Amb.	
Mix #	Load	Cyl#	PSI	Avg.	Temp	<u>Temp</u>	Flor
	MSE	T	67070	5740		12	
i		5	73790	59570.	1.56	.70	
<u>. </u>		· .		0,0,,0,		25	•
	SW/Columns/Cans	· · · · ·				۰ .	
· · · · · · · · · · · · · · · · · · ·	· ·	··/	7110.90	SIGD	5-	-72	•
		1.2	71340	5690	726	-20	
	· · Ċoning						9
·	i i i i i i i i i i i i i i i i i i i	1	67080.	5340	- P	1-70	
		· 2	75260	5990	10.	57.0	o omitike
	MSE-Exposed						_
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			•			2	
	SW-Exposed						•
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,	MSE-Color				,		
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·. ·.	Coping-Color						
					·		•
		•			•		
	CTB ·			· .	•		•
F.Chana.		• ].	66920	5330	7.0	247	
Sterres		2	67160	\$3.50	10.	210	
·,	Bridge	<u> </u>					
<u></u>	· · ·		• •		•	•	
<u>·</u>							• •
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*********	******	*****	*****	*****	****	******	*****	******	***	***	*****	******	****
Job:	BARRIE	ER1	Date:	Jun 1	16,	2017	Start	:11:24	Dis	sch:	11:34	Ref#:	7139
Operator:	TRICOL	N	Durat	ion/Wa	ait	: 10:42/	1:55	Batch	:15	5368	0	Mixer	: 2
Mix:	H-7013	35GCPT	Mix N	lame: 7	TRUC	CK							
Required:	999999	9,00	Bato	hed: 5	5539	95.85							
Amount:	3.50 0	CY											•
PreWet; 70%	5.												
							•						
Material	Bin	Moist,	/ABS%	Desigr	n	Targ	et	Actu	al		%Err	*Note	Jogs
3/4	2	1.38/0	0.00	1620		5691:5	806	57	84	$\mathbf{L}\mathbf{p}$	0.6	-P	3
Liberty	3	3.92/0	00.0	1483		5340:5	448	53	66	Lb	-0.5	-P	5
HOLCIM	1			455		1577;1	624	15	98	$\mathbf{L}\mathbf{b}$	0.3		3
POZZO	4			245		849:8	70	8	62	$\mathbf{L}\mathbf{b}$	0.5		1
ADVA575	2			7.75	1	L84,18:1	95.57	192.	00	Oz	1.1		
RECOVER	1			3.00		71.30:7	5.70	74.	00	Oz	0.7		
VMAR-3	5			3.00		63.50:8	3.50	74.	00	Oz	0.7		
Prewet						40.6:4	1.2	4 C	.9	Ga	0.2	·	
Water					•	17.3:1	7.6	18	.1	Ga	4.0		
Dry Mixing				0:30				0:	30	S			
Wet Mixing				1:45				3:	44	s			
Total Mixin	ıg .		•	5:13				5:	13	S			•
Total Moist	ure:			26.3		92.	0	92	.7	Ga	0.7		
Water/Cemen	nt:			0.313		0.31	4						

# **B.3 VEHICLE PROPERTIES AND INFORMATION**



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

Date:	2017-07-07	Test No.:	469467-3-1		VIN No.:	1HTMMAAL05H105654	
Year:	2005	Make:	International		Model: <u>4300</u>		
WEIGHTS ( Ib ) Wfront axle Wrear axle WTOTAL		CUR	CURB 6930 6640 13570		<b>ST INERTIAI</b> 8060 14210 22210	-  	
E	Ballast:	8700	( lb )	(See M	ASH Section 4	4.2.1.2 for rec	commended ballasting)
Mass D (lb ):	Distribution LF	: 4140	RF:	3920	LR:	7300	<b>RR:</b> 6910
Engine	Type: DT			Ace	celerometer	r Locations	( inches )
Engine	Size: 466		_		<b>x</b> ¹	У	Z ²
Transm	ission Type:			Front:			
x	Auto or	Manual		Center:	132.4	0	47.25
	FWD <u>x</u> RWD	4WD		Rear:	232.40	0	47.25

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

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

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

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

Centered in middle of bed

62 inches to center of block to ground

Four ⁵/₁₆-inch cables per block

¹ Referenced to the front axle

² Above ground

# **B.4 SEQUENTIAL PHOTOGRAPHS**













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

0.150 s

0.300 s















Out of View

1.050 s

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

Out of View

0.900 s



0.000 s



0.150 s



0.300 s



0.450 s

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



0.600 s



0.750 s



0.900 s



1.050 s



# **B.5 VEHICLE ANGULAR DISPLACEMENT**



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

# **B.6 VEHICLE ACCELERATIONS**






















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

TR No. 0-6946-17-1



TR No. 0-6946-17-1

# C.2 SUPPORTING CERTIFICATION DOCUMENTS



# C.3 VEHICLE PROPERTIES AND INFORMATION

Date	: 2017	-07-26		Test No.:	467469-	5-1	VIN No.:	1C6RDC6GF	P2C519	3320
Year	: 2012			Make:	Dodge		Model:	RAM 1500		
Tire	Size:	265/70	R17			Tire	Inflation Pre	essure: 40 psi		
Trea	d Type:	Highwa	ıy				Odo	meter: 20757	9	
Note	any dam	age to th	e veł	nicle prior to t	est: N	one				
• De	enotes aco	celerome	eter lo	ocation.			◀X ◀W►			
NOT	ES: <u>No</u>	ne					717		1	
Engi Engi	ne Type: ne CID:	V-8 4.7 I	iter g	as		EEL ACK			1	WHEEL
Tran 	smission Auto FWD	Type: or <u>x</u> R	WD	_ Manual 4WD		R I	1	TEST INE	RTIAL C.M.	•
Optional Equipment:										
Dummy Data: Type: <u>No dummy</u> Mass: <u>NA</u> Seat Position: <u>NA</u>				J	- F - F			-D-		
Geo	metry:	inches				-	PRONT	– C –––––		•
Α	78.50		F _	40.00	K	19.75	_ P _	3.00	U _	27.50
B	74.00		G _	28.25	. L _	29.50	_ Q _	30.50	V _	29.75
с <u>-</u>	225.50		Н_	61.99	M	68.50	_ R _	18.00	W _	62.00
D _	47.00		I _	11.75	N	68.00	_ S _	13.25	Х_	78.25
Ε	140.50 Wheel Center Height Fro	er nt	J _	27.00 14.75 Cle	O Wheel W arance (Froi	45.50 ell nt)	_ T _ 6.00	77.00 Bottom Frame Height - Front	_	17.00
	Wheel Center Height Rea	er ar		14.75 Cle	Wheel W arance (Rea	ell ar)	9.25	Bottom Frame Height - Rear		25.50
GVW	/R Rating	IS:		Mass: lb	С	urb	Test	Inertial	Gros	s Static
Fron	t	3700		Mfront		2851		2813		
Back		3900		M _{rear}		2030		2221		
Tota	I	6700		MTotal		4881		5034		
Mas	s Distribu	ition:	I F·	1404	RE.	(Allowable	Range for TIM and	GSM = 5000 lb ±110 lb)	R. ,	1120
ii.	,		<u> </u>		· · · · -					

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

Date: 2017-0	<u>7-26</u> Te	est No.: _4	469467-5-1	<u> </u>	VIN: 1C6	RDC	C6GP2C519	3320		
Year: 2012		Make: [	Dodge		Model:	RA	VI 1500			
Body Style: _	Quad Cab				Mileage:	207	579			
Engine: <u>4.7 I</u>	iter V-8 ga	S		Trans	mission:	Aut	omatic			
Fuel Level: _E	Empty	Ball	ast:	232 lk	D			(440	lb max)	
Tire Pressure:	Front:	35 ps	i Rea	r: 35	psi Si	ze:	265/70R1	7		
Measured Ve	hicle Wei	ahte (	h)							
		gints. (i	5)							
LF:	1404		RF:	1409		F	ront Axle:	2813		
LR:	1101		RR:	1120		F	Rear Axle:	2221		
l eft [.]	2505		Right [.]	2529			Total	5034		
	2000		- Tright.				5000 ±1	10 lb allow ed		
\\/b	ool Basa:	140 5	inchee	Trock: E:	69 5	inak	De Di	69	inchoo	
	148 +12 inch	es allow ed	Inches	Hack. F.	Track = (F+R	$\frac{1101}{2}$	67 +1.5 inche	s allow ed	Inches	
Center of Gra	<b>ivity</b> , SAE	J874 Sus	pension N	<i>l</i> ethod						
X:	61.99	inches	Rear of F	ront Axle	(63 ±4 inche	s allo	w ed)			
Y:	0.16	inches	Left -	Right +	of Vehicle	e Ce	nterline			
Z:	28.25	inches	Above Gr	ound	(minumum 28	3.0 ind	ches allow ed)			
Hood Heig	ht:	45.50	inches	Front I	Bumper He	eight	: 	27.00 ir	nches	
	43 ±4 ir	nches allowed								
Front Overhar	Front Overhang: 40.00 inches Rear Bumper Height: 29.50 inches									
	39 ±3 inches allowed									
Overall Leng	th:	225.50	inches							
	237 ±13	3 inches allow	ed							

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

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

Date:	2017-07-26	Test No.:	467469-5-1	VIN No.:	1C6RDC6GP2C5193320
Year:	2012	Make:	Dodge	Model:	RAM 1500

# VEHICLE CRUSH MEASUREMENT SHEET¹

Complete Wh	en 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)	X1+X2 _
< 4 inches	
$\geq$ 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.

		Direct I	Damage								
Specific Impact Number	Plane* of C-Measurements	Width** (CDC)	Max*** Crush	Field L**	$C_1$	C ₂	C ₃	$C_4$	C ₅	C ₆	±D
1	Front plane at bumper ht	16	14	36	1	3	4.5	8	12	14	+8
2	Side plane at bumper ht	16	15	53	0	2			14	15	+75
	Measurements recorded										
	in inches										

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

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

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

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

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

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

Date:	2017-07-26	Test No.:	467469-5-1	VIN No.:	1C6RDC6GP2C5193320
Year:	2012	Make:	Dodge	Model:	RAM 1500









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

### OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0
A2	63.00	63.00	0
A3	65.50	65.50	0
B1	44.00	44.00	0
B2	37.75	37.75	0
B3	44.00	44.00	0
B4	39.50	39.50	0
B5	43.25	43.25	0
B6	39.50	39.50	0
C1	27.00	27.00	0
C2			
C3	26.50	26.50	0
D1	11.50	11.50	0
D2			
D3	11.50	11.50	0
E1	62.00	62.00	0
E2	62.50	62.50	0
E3	62.50	62.50	0
E4	62.50	62.50	0
F	59.00	59.00	0
G	59.00	59.00	0
Н	38.00	38.00	0
I	38.00	38.00	0
J*	22.50	22.50	0

### C.4 SEQUENTIAL PHOTOGRAPHS



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



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



0.000 s



0.100 s



0.200 s



0.300 s

Figure C.2. Sequential Photographs for Test No. 469467-5-1 (Rear View).



0.400 s



0.500 s



0.600 s











### C.6 VEHICLE ACCELERATIONS

TR No. 0-6946-17-1

2017-12-19





















# APPENDIX D. MASH TESTING ON EMBEDDED WOOD SIGN SUPPORTS

#### D.1 MASH TEST 3-62 ON SINGLE EMBEDDED WOOD SIGN SUPPORT AT 0°

Date:	2017-08-2	2	Test No.:	469467-6-1	<u> </u>	VIN No.:	1D7RB16P4B	S6927	07	
Year:	2011		Make:	Dodge		Model:	RAM 1500			
Tire Siz	:e: <u>265</u> /	/70R17			Tire Infla	ation Pres	sure: <u>35 psi</u>			
Tread T	ype: High	nway			Odometer: 151312					
Note ar	ny damage to	o the ve	hicle prior to t	est: Non	e					
	tos accolor	motor	acation			X	•			
				1		T		)	- +	
NOTES	: <u>INONE</u>				$( \top )$				T I	
Engine Engine	Type: V CID: 4	/-8 .7 liter		A M WHEEL						
Transm _ <u>x</u>	iission Type: Auto or FWD x	RWD	_ Manual 4WD	·		<u></u>		fial c. m.		
Optiona Non	al Equipment e	t:		P-					B B	
Dummy Data:Type:No dummyMass:NASeat Position:NA			ny	J-J-I-						
Geome	try: inche	s			FRON	T'	C	EAR		
Α	78.50	F_	40.00	Κ	20.75	Ρ	3.00	U	27.50	
В	75.00	G	28.00	L	29.50	Q	30.50	V	30.50	
C	227.50	Η.	62.63	Μ	68.50	R	18.00	W	62.63	
D	47.00	 	11.00	N	68.00	s	13.25	Х _	78.63	
E Wh	140.50 eel Center	J_	26.50	O Wheel Well	46.00	Т	77.00 Bottom Frame			
He	eight Front		14.75 Cle	arance (Front)		6.00	Height - Front		17.00	
vvn H	eight Rear		14.75 Cle	earance (Rear)		9.25	Height - Rear		25.50	
GVWR	Ratings:		Mass: Ib	Curt	<u>)</u>	<u>Test Ir</u>	ertial	Gross	Static	
Front	370	00	Mfront		2827		2785			
Back	390	00	M _{rear}		1922		2240			
Total	670	00	M _{Total}	2	4749		5025			
Mass D	) istribution:				(Allowable Rang	ge for TIM and G	SM = 5000 lb ±110 lb)			
lb		LF:	1390	RF:	1395	LR:	<u>1115</u> RF	R: <u>1</u>	125	

Date: 2017-0	<u>)8-22</u> T	est No.:	469467-6-	-1	VIN: <u>1</u>	07RB16	P4BS69	2707	
Year: 2011		Make:	Dodge		Model:	RAM	1500		
Body Style:	Quad-Cab	1			Mileage:	15131	12		
Engine: 4.7	liter V-8			Tran	smission:	Auton	natic		
Fuel Level:	Empty	Bal	last:	207	lb			(44	0 lb max)
Tire Pressure:	Front:	<u>35</u> ps	si Re	ar: <u>35</u>	_psi S	Size: _2	265/70R	17	
Measured Ve	hicle Wei	ghts: (I	b)						
LF:	1390		RF:	1395		Fror	nt Axle:	2785	
LR:	1115		RR:	1125		Rea	r Axle:	2240	
Left:	2505		Right:	2520			Total:	5025	
							5000 ±110	) lb allow ed	
Wh	eel Base:	140.50	inches	Track: F:	68.50	inches	R:	68.00	inches
	148 ±12 inch	es allow ed			Track = (F+R	)/2 = 67 ±	1.5 inches	allow ed	
Center of Gra	<b>avity</b> , SAE	J874 Sus	pension N	<i>l</i> ethod					
X:	62.63	inches	Rear of F	ront Axle	(63 ±4 inches	s allow ed	)		
Y:	0.10	inches	Left -	Right +	of Vehicle	Cente	rline		
Z:	28.00	inches	Above Gr	ound	(minumum 28	.0 inches	allow ed)		
Hood Heid	aht:	46.00	inches	Front	Bumper H	leiaht:		26.50	inches
	43 ±4	inches allowed				- g			
Front Overha	ing:	40.00	inches	Rear	Bumper H	leight:		29.50	inches
	39 ±3	inches allowed	t						
Overall Leng	gth:	227.50	inches						
	237 ±1	3 inches allow	ved						
Test Conduc	tor(s):								

#### Table D.2. Measurements of Vehicle Vertical CG for Test No. 469467-6-1.











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

#### OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After	Differ.
		(inches)	
A1	65.00	65.00	0
A2	62.50	62.50	0
A3	65.25	65.25	0
B1	44.75	44.75	0
B2	38.00	38.00	0
B3	44.75	44.75	0
B4	39.50	39.50	0
B5	43.00	43.00	0
B6	39.50	39.50	0
C1	26.50	26.50	0
C2			
C3	26.50	26.50	0
D1	11.25	11.25	0
D2			
D3	11.25	11.25	0
E1	58.50	58.50	0
E2	63.50	63.50	0
E3	63.50	63.50	0
E4	63.50	63.50	0
F	59.00	59.00	0
G	59.00	59.00	0
Н	37.50	37.50	0
I	37.50	37.50	0
J*	23.50	23.50	0















Figure D.1. Sequential Photographs for Test No. 469467-6-1 (Perpendicular and Oblique Views).



0.060 s

















Figure D.1. Sequential Photographs for Test No. 469467-6-1 (Perpendicular and Oblique Views) (Continued).

D-5







THE HOLD

Axes are vehicle-fixed. Sequence for determining orientation:

Yaw. Pitch. Roll.

<del>.</del> . . .





2017-12-19









TR No. 0-6946-17-1



X Acceleration Rear of CG

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











#### D.2 MASH TEST 3-62 ON SINGLE EMBEDDED SIGN SUPPORT AT 90°

		I abic		c i i opei					
Date:	2017-08	3-22	Test No.:	469467-6	6-3	VIN No.:	1D7RB16P4	3S692	707
Year:	2011		Make:	Dodge		_ Model:	RAM 1500		
Tire Siz	ze: <u>2</u>	65/70R17			Tire	Inflation Pres	ssure: <u>35 psi</u>		
Tread T	Гуре: <u>Н</u>	ighway				Odor	neter: 151312	2	
Note an	ny damage	e to the ve	hicle prior to	test: <u>Sr</u>	mall dent at	right quarter	point of bumpe	er and	hood
<ul> <li>Dence</li> </ul>	otes accel	erometer	location.			◀X ◀W►			
NOTES 	S: <u>Previo</u> 467-6-1	ously used	d in Test No.			717			
Engine Engine	Type: CID:	V-8 4.7 liter		A M	EEL				WHEEL WHEEL
Transm 	nission Typ Auto FWD <u>x</u>	oe: or RWD	Manual 4WD		R	1	TEST INER	TIAL C. M.	
Optiona Non	al Equipmo e	ent:							
Dummy Data:         Type:       No dummy         Mass:       NA         Seat Position:       NA								-D-	
Geome	etry: inc	hes				FRONT	- C	REAR	_
А	78.50	F	40.00	К	20.75	Р	3.00	U	27.50
В	75.00	G	28.00		29.50	Q	30.50	V	30.50
С	227.50	– н	62.63	M	68.50		18.00	w	62.63
D	47.00	I	11.00	N	68.00	s	13.25	Х	78.63
E	140.50	J	26.50	0	46.00	Т	77.00		
Wh	eel Center		14 75 CIA	Wheel We	ell htt	6.00	Bottom Frame		17 00
Wh H	leel Center		14.75 Cie	Wheel We earance (Rea	ell Ir)	9.25	Bottom Frame Height - Rear		25.50
							-		
GVWR	Ratings:		Mass: Ib	<u>C</u> (	<u>urb</u>	Test li	<u>nertial</u>	<u>Gros</u>	<u>s Static</u>
Front	3	3700	M _{front}		2827		2785		
Back	3	3900	M _{rear}		1922		2240		
Total		6700	MTotal		4749	Range for TIM and (	5025		
Mass D	Distributio	on:			Allowable	nange for This and t	JOIN - JUUU ID ±1 10 ID)		
lb		LF	1390	RF:	1395	LR: _	<u>1115</u> RI	R:	1125

#### Table D.4. Vehicle Properties for Test No. 469467-6-3.

Date: 2017-0	Date: 2017-08-22 Test No.: 469467-6-3 VIN: 1D7RB16P4BS692707											
Year: 2011		Make:	Dodge		Model:	RAM 1500						
Body Style:	Quad-Cab				Mileage:	151312						
Engine: 4.7	liter V-8			Tran	smission:	Automatic						
Fuel Level:	Empty	Bal	last:	207	lb		(44	0 lb max)				
Tire Pressure:	Front:	<u>35</u> ps	si Re	ar: <u>35</u>	psi S	Size: <u>265/70</u> F	R17					
Measured Ve	hicle Wei	ghts: (I	b)									
LF:	1390		RF:	1395		Front Axle:	2785					
LR:	1115		RR:	1125		Rear Axle:	2240					
Left:	2505		Right:	2520		Total:	5025 0 lb allow ed					
\ <b>\</b> /b		140 50	inches	Trook: E:	69.50	inches Dt	69.00	inches				
VVI	148 ±12 inch	es allow ed	Inches	Паск. г.	00.50 Track = (F+R	1000000000000000000000000000000000000	s allow ed	inches				
Contor of Cr			noncion N	Acthod								
Center of Gra	avily, SAL	J074 Sus		hethoù								
X:	62.63	inches	Rear of F	ront Axle	(63 ±4 inches	s allow ed)						
Y:	0.10	inches	Left -	Right +	of Vehicle	Centerline						
Z:	28.00	inches	Above Gr	ound	(minumum 28	.0 inches allow ed)						
Hood Heig	ght:	46.00	_ inches	Front	Bumper H	leight:	26.50	inches				
	43 ±4	inches allowed	נ									
Front Overha	ng:	40.00	_ inches	Rear	Bumper H	leight:	29.50	inches				
	39 ±3	inches allowed	Ł									
Overall Leng	gth:	227.50	inches									
	237 ±1	3 inches allow	ved									
Test Conduc	tor(s):											

#### Table D.5. Measurements of Vehicle Vertical CG for Test No. 469467-6-3.











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

#### OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After	Differ.
		(inches)	
A1	65.00	65.00	0
A2	62.50	62.50	0
A3	65.25	65.25	0
B1	44.75	44.75	0
B2	38.00	38.00	0
B3	44.75	44.75	0
B4	39.50	39.50	0
B5	43.00	43.00	0
B6	39.50	39.50	0
C1	26.50	26.50	0
C2			
C3	26.50	26.50	0
D1	11.25	11.25	0
D2			
D3	11.25	11.25	0
E1	58.50	58.50	0
E2	63.50	63.50	0
E3	63.50	63.50	0
E4	63.50	63.50	0
F	59.00	59.00	0
G	59.00	59.00	0
Н	37.50	37.50	0
I	37.50	37.50	0
J*	23.50	23.50	0



Figure D.9. Sequential Photographs for Test No. 469467-6-3 (Perpendicular and Oblique Views).














0.175 s

Figure D.9. Sequential Photographs for Test No. 469467-6-3 (Perpendicular and Oblique Views) (Continued).

0.150 s











50-msec average

SAE Class 60 Filter

Time of OIV (0 sec)















X Acceleration Rear of CG













#### MASH TEST 3-62 ON DUAL EMBEDDED SIGN SUPPORT AT 0° **D.3**

	1	able I	J.7. Venici	e i i opei			40/-0-4.		
Date:	2017-08-22		Test No.:	469467-	6-4	VIN No.:	1D7RB16P4E	3S6927	07
Year:	2011		_ Make:	Dodge		_ Model:	RAM 1500		
Tire Siz	ze: <u>265/7</u>	70R17			Tire	Inflation Pres	ssure: <u>35 psi</u>		
Tread T	Type: <u>High</u>	way				Odor	neter: <u>151312</u>	2	
Note ar	ny damage to	the ve	hicle prior to t	test: <u>S</u>	mall dents a	t right and le	ft qtr pt of bum	per and	hood
Denotes accelerometer location.									
NOTES 	S: <u>Previous</u> 467-6-1 and 4	y used 169467	l in Test No. 7-6-3			717			
Engine Engine	Type: <u>V-</u> CID: <u>4</u> .	8 7 liter			HEEL ACK				- N T
Transm 	iission Type: Auto or FWD <u>x</u>	RWD	_ Manual 4WD	<u>.</u>	R Q		-TEST INER'	FIAL C. M.	
Optional Equipment:								5	
Dummy Data:Type:No dummyMass:NASeat Position:NA			↓ J-↓ -						
Geome	etry: inches	5				FRONT	۹ [ ۱	EAR	
А	78.50	F	40.00	К	20.75	Р	3.00	U	27.50
В	75.00	G	28.00	L	29.50	Q	30.50	V	30.50
С	227.50	Н	62.63	М	68.50	R	18.00	W	62.63
D	47.00	Ι	11.00	N	68.00	S	13.25	Χ	78.63
E	140.50	J	26.50	0	46.00	_ т_	77.00		
Wh He	eel Center		14.75 Cle	Wheel W arance (Fro	/ell nt)	6.00	Bottom Frame Height - Front		17.00
Wh	eel Center		4475 0	Wheel W	/ell	0.05	Bottom Frame		05 50
Н	eight Rear		<u>14.75</u> Cle	earance (Re	ar)	9.20	Height - Rear		25.50
GVWR	Ratings:		Mass: Ib	C	urb	Test Ir	nertial	Gros	s Static
Front	3700	)	M _{front}		2827		2785		
Back	3900	)	Mrear		1922		2240		
Total	670	)	M _{Total}		4749		5025		
Mass D	Distribution				(Allowable	Range for TIM and C	GSM = 5000 lb ±110 lb)		
lb		LF:	1390	RF:	1395	LR:	<u>1115</u> RF	२:1	125

Date:         2017-08-22         Test No.:         469467-6-4         VIN:         1D7RB16P4BS692707									
Year: 2011		Make:	Dodge		Model:	RAN	A 1500		
Body Style:	Quad-Cab	1			Mileage:	151:	312		
Engine: 4.7	liter V-8			Tran	smission:	Auto	omatic		
Fuel Level: Empty Ballast: 207 lb (440 lb )								0 lb max)	
Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70R17									
Measured Ve	hicle Wei	ghts: (I	b)						
LF:	1390		RF:	1395		Fro	ont Axle:	2785	
LR:	1115		RR:	1125		Re	ear Axle:	2240	
Left:	2505		Right:	2520			Total: 5000 ±110	5025 Ib allow ed	
Wh	eel Base:	140.50	inches	Track: F:	68.50	inches	s R:	68.00	inches
	148 ±12 inch	es allow ed			Track = (F+R	)/2 = 67	±1.5 inches	allow ed	
Center of Gra	<b>avity</b> , SAE	J874 Sus	pension N	<i>l</i> ethod					
X:	62.63	inches	Rear of F	ront Axle	(63 ±4 inches	s allow e	ed)		
Y:	0.10	inches	Left -	Right +	of Vehicle	Cent	erline		
7:	28.00	inches	Above Gr	ound	(minumum 28	0 inche	es allow ed)		
	20100								
Hood Hei	ght:	46.00	_ inches	Front	Bumper H	leight	:	26.50	inches
Front Overba	na.	40.00	inches	Rear		loiaht		29 50	inches
	39 ±3	inches allowed	3	iteai	Damper I	icigi it.		20.00	1101103
Overall Leng	gth:	227.50	inches						
	237 ±1	3 inches allow	ved						
Test Conduc	tor(s):								

#### Table D.8. Measurements of Vehicle Vertical CG for Test No. 469467-6-4.











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

#### OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After (inches)	Differ.
A1	65.00	65.00	0
A2	62.50	62.50	0
A3	65.25	65.25	0
B1	44.75	43.75	-1.00
B2	38.00	35.00	-3.00
B3	44.75	43.75	-1.00
B4	39.50	38.50	-1.00
B5	43.00	40.00	-3.00
B6	39.50	38.50	-1.00
C1	26.50	26.50	0
C2			
C3	26.50	26.50	0
D1	11.25	11.25	0
D2			
D3	11.25	11.25	0
E1	58.50	58.50	0
E2	63.50	63.50	0
E3	63.50	63.50	0
E4	63.50	63.50	0
F	59.00	59.00	0
G	59.00	59.00	0
н	37.50	37.50	0
I	37.50	37.50	0
J*	23.50	23.50	0





0.000 s

0.025 s













Figure D.17. Sequential Photographs for Test No. 469467-6-4 Perpendicular and Oblique Views).



0.050 s









0.125 s







Figure D.17. Sequential Photographs for Test No. 469467-6-4 Perpendicular and Oblique Views) (Continued).



0.1 0.0 0.8 0.7 Roll, Pitch, and Yaw Angles 0.0 Time (s) 0.5 Test Number: 469467-6-4 Test Standard Test Number: MASH Test 3-62 at 0 Degree Test Article: TxDOT Dual Embedded Wood Sign System Test Vehicle: 2011 Dodge RAM 1500 Inertial Mass: 5025 lb Gross Mass: 5025 lb Impact Speed: 62.7 mi/h Impact Angle: 0 degrees 0.4 0.3 Yaw 0.2 Mwww. Pitch 0.1 Roll ⁺0 42 4 ò ÷ (səərgəb) zəlgnA



The Hold

Axes are vehicle-fixed. Sequence for determining orientation:

Yaw. Pitch. Roll.

<del>.</del> . . .

X Acceleration at CG













X Acceleration Rear of CG







Y Acceleration Rear of CG

Figure D.23. Vehicle Lateral Accelerometer Trace for Test No. 469467-6-4 (Accelerometer Located Rear of Center of Gravity).





#### D.4 MASH TEST 3-61 ON DUAL EMBEDDED SIGN SUPPORT AT 0°

Table D.10. Ven	incre i roper des for i	CSI 110. 40	J <b>74</b> 07-0-28	•	
Date: 2017-08-23 Test No.:	469467-6-2	VIN No.:	KNADH4	A30B6872	976
Year: 2011 Make:	Kia	Model:	Rio		
Tire Inflation Pressure: 32 psi	Odometer:107379	)	Tire Size:	18565R1	4
Describe any damage to the vehicle p	rior to test: <u>None</u>				
Denotes accelerometer location.					<b>A</b>
NOTES: None	A M		<b></b>		N T
Engine Type: <u>4 cylinder</u>					<u> </u>
Engine CID: <u>1.6 liter</u>					
x Auto or Manual	<b>⊸</b> -Q⊣				4
x FWD RWD 4W		4	`	7	
Optional Equipment:			0		B
INDIE		$\mathbb{R}$			, Ţ ¦
					* * * *
Type: 50 th percentile male	I F►	—H∎			K
Mass: 165 lb		WE			
Seat Position: Driver			-X		
Geometry: inches			С ———		
A <u>66.38</u> F <u>33.00</u>	K 10.50	Ρ	4.12	U	15.00
B <u>58.00</u> G <u></u>	L 24.50	Q	22.50	V	19.50
С 165.75 Н 35.89	M 57.75	R	15.50	W	35.89
D 34.00 I 7.75	N 57.70	S	9.00	X _	105.60
E <u>98.75</u> J <u>21.00</u>	O <u>28.00</u>	т	33.20		
Wheel Center Ht Front 11.00	_ Wheel Center H	Rear	11.00	W-H	0
GVWR Ratings: Mass: Ib	) Curb	Test I	nertial	Gros	s Static
Front 1718 M _{front}	<u>1570</u>		1546		1631
Back 1874 Mrear	890		883		963
Total <u>3638</u> M _{Total}	2460		2429		2594
Mass Distribution	Allowable TIM = 24	20 lb ±55 lb   Allow	able GSM = 2585 I	b ± 55 lb	
lb LF:761	RF: <u>785</u>	LR: _	472	RR: _	411

# Table D.10. Vehicle Properties for Test No. 469467-6-2.

Date:	2017-08-23	Test No.:	469467-6-2	\	VIN No.: K	NADH4A30B68	372976
Year:	2011	Make:	Kia	1	Model: R	lio	
	H-			O( DEF		COMPARTI	MENT EMENT
	F				Before	After (inches)	Differ.
	Ğ			A1	67.50	67.50	0
				A2	67.50	67.50	0
$\checkmark$				A3	67.75	67.75	0
				B1	40.50	40.50	0
				B2	36.75	36.75	0
	B1, B2,	B3, B4, B5, B6		B3	40.50	40.50	0
	A1, A2, &A B D1, D2, & D3 C1, C2, & C3			B4	36.25	36.25	0
$\bigcap$		2, &A B		B5	35.75	35.75	0
$\square$		& C3		B6	36.25	36.25	0
				C1	26.00	26.00	0
				C2			
				C3	26.00	26.00	0
				D1	9.50	9.50	0
				D2			
				D3	9.75	9.75	0
	B1	B2 B3		E1	51.50	51.50	0
	( <b>⊢</b> E1	& E2 + -   )		E2	51.00	51.00	0
				F	51.00	51.00	0
				G	51.00	51.00	0
				Н	38.00	38.00	0
				I	38.00	38.00	0
				J*	51.00	51.00	0

# Table D.11. Occupant Compartment Measurements for Test No. 469467-6-2.

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



Figure D.25. Sequential Photographs for Test No. 469467-6-2 (Perpendicular and Oblique Views).



Figure D.25. Sequential Photographs for Test No. 469467-6-2 (Perpendicular and Oblique Views) (Continued).









Figure D.27. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-6-2 (Accelerometer Located at Center of Gravity).

















TR No. 0-6946-17-1

D-46





# APPENDIX E. MASH TESTING OF THE PEDESTAL POLE BEACON

#### E.1 MATERIAL CERTIFICATION DOCUMENTS

Texas Highway Products, LTDPACKING TICKET1309 Clark St., Round Rock, TX 7868117 - SO-002792Phone: (512) 255-7633Fax: (512) 255-7634www.trafficsignals.comDATE: 07-07-2017

BILL N-Line Traffic Maintenance

TO: 2620 Clarks Lane Bryan, TX 77898 SHIPN-Line Traffic MaintenanceTO:Texas Transportation Institute3100 SH 47 BLDG 7090ATTN: Gary Gerke 936-825-4661Byran, TX 77807

Attn:

Phone:

Shipping Instructions: None

CUSTOMER PO #	JOB DESCRIPTION	SHIPPING METHOD	SHIPPING TERMS	
999830	N-LINE (SOLAR FLASHER ASSEMBLIES)		FOB Destination	

ITEM	PRODUCT NAME	DESCRIPTION	e na klipiti Districti <b>LOT</b> Bong Dent	QTY ORDERED	QTY SHIPPED	DATE SHIPPED	QTY BACK- ORDERED
1	M66156	12" Beacon Yellow Poly Signal	THP Main	4	4	07/14/17	O
2	M19275	12" Poly Yel Tunnel Visor	THP Main	4	4	07/14/17	0
3	DI-433-3230-905XL	12vDC 12 Watt Yellow Full Ball Led	THP Main	4	4	07/14/17	0
4	SE-0567-P29	Side-of-Pole Assy, 1-Way Tri-Stud For 8" Or 12" Signal & 4-1/2" Od Pole, Alum (Yellow)	THP Main	4	4	07/14/17	0
5	SE-3054-P01	Signal Closure Kit-(Yellow)	THP Main	4	4	07/14/17	0
6	2-Battery-Cabinet	2 Battery Cabinet24 Hour Or School Zone	THP Main	2	2	07/14/17	0
7	SM-1012-2SK-BRS	Lock With 2 Short Keys, Police Type Brass	THP Main	2	2	07/14/17	0.
8	SP-5293-PNC	Cabinet Mounting Bracket Assy(Set of 2) (Unpainted)	THP Main	2	2	07/14/17	0
9	MK-E-27SLDG	Deka Solar 8g27 Battery - Includes Hardware.	THP Main	4	4	07/14/17	. 0 .
10	Cabinet-Backpanel1CP	Solar Cabinet Backpanel Cardinal 1cp - 1st Design	THP Main	2	2	07/14/17	0
11	DPC2000-24hr-DUAL	24hr Controller - Calibrated For Double 12" Yellow LEDs, Deka 8g27 Batteries (NON DIMMING)	THP Main	2	2	07/14/17	0
12	CPI-AP-18-40	18' ALUMINUM POLE SCH 40 SPUN AND TOE	THP Main	2	2	07/14/17	0
13	CPI-APC-1	4" Aluminum Pole Cap	THP Main	2	2	07/14/17	<i>.</i>
14	CPI-BAS-1-PDP	SQUARE ALUMINUM BASE W/ NATURAL FINISH W/ PLASTIC DOOR, 1/2-13 NC female threaded hole near the bottom of the base for grounding	THP Main	2	2	07/14/17	0



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15	CPI-GRDLUG50-COP	1/2" Copper Ground Lug	THP Main	2	2	07/14/17	0
16	CPI-RBC-1	POLE AND BASE RE-ENFORCING COLLAR	THP Main	2	2	07/14/17	0
17	SH-0206-4-PNC	Sign Clamp, U-Bolt, 4" (4-1/2" Od) Pipe, Set of 2, Alum	THP Main	2	2	07/14/17	0
18	Sunbelt-Hardware-RD	Includes: (1) 3/8"X4 1/2"X6 Ubolt, (2) 3/8-16x3hhb, (4) 3/8 16 Nylon Lock Nut, (6) 3/8 F/W, (2) 3/8 L/W	THP Main	2	2	07/14/17	0
19	Solar-Harness	12-2C Tray Cable, 600v 90c	THP Main	2	2	07/14/17	0
20	PowerUP-HPMH50-90	Side of Pole solar panel mount	THP Main	2	2	07/14/17	0
21	PowerUP-BSP90-12	90 Watt Solar Panel	THP Main	2	2	07/14/17	0
22	Chance-Stretlight-Found	C11242ng4vp - 8" Diameter X 60" Shaft, 1" Thick X 15.75" Square Base.	THP Main	2	2	07/14/17	0

MARK PACKAGES AS: PO 999830

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# E.2 *MASH* TEST 3-62 ON PEDESTAL BASE WITH BEACON WITHOUT SOLAR PANEL

		I able	E.I. venici	e Prope	erties for 1	est No. 46	9467-7-1.		
Date:	2017-08-1	17	Test No.:	469467	<b>'</b> -7-1	VIN No.:	1C6RD6FT5	CS289	859
Year:	2012		Make:	Dodge		Model:	RAM 1500		
Tire Siz	e: <u>265</u>	/70R17			Tire	Inflation Pre	ssure: <u>35 psi</u>		
Tread T	ype: <u>Hig</u>	hway				Odo	meter: 21727	4	
Note an	ny damage t	o the ve	hicle prior to	test: I	None				
• Deno	otes acceler	ometer	location.			◄X ◀₩►			
NOTES	: None			-		717		. <del></del>	
Engine Engine	Type: <u>v</u> CID: <u>t</u>	/-8 5.7 liter		-     -     -	WHEEL FRACK				N T WHEEL TRACK
Transm 	ission Type Auto or FWD <u>x</u>	: _ RWD	Manual 4WD		R H			RTIAL C. M.	, <u> </u>
Optiona Non	al Equipmen e	ıt:		-				2	
Dummy Type: Mass:	v Data: <u>1</u>	<u>No dumr</u> NA	my	- ↓ J-↓				)) - D-	
Seat F	Position: 1	NA		-		-	E		
Geome	try: inche	es			4	M FRONT	-с	M rear	-
Α	78.50	F	40.00	K	20.75	_ P _	3.00	U	27.50
В	75.00	G	28.50	_ L	29.50	Q	30.50	V	30.75
С	227.50	Н	61.90	Μ	68.50	R	18.00	W	61.90
D	47.00	I	11.00	N	68.00	S	13.25	X	77.40
E	140.50	J	26.50	0	46.00	_ т_	77.00	_	
Wh He	eel Center eight Front		14.75 Cle	Wheel Nearance (Fr	Nell ont)	6.00	Bottom Frame Height - Front		17.00
Who Ho	eel Center eight Rear		14.75 Cl	ا Wheel arance (R	Vell ear)	9.25	Bottom Frame Height - Rear		25.50
GVWR	Ratings:		Mass: Ib		Curb	Test	nertial	Gros	s Static
Front	37	00	Mfront	-	2871		2816		
Back	39	00	M _{rear}		2086		2218		
Total	67	00	M _{Total}		4957		5037		
Mass D	)istribution				(Allowable	Range for TIM and	GSM = 5000 lb ±110 lb)		
lb		LF:	1411	RF:	1405	LR:	<u>1105</u> R	R:	1113

Date: 2017-0	Date: 2017-08-17 Test No.: 469467-7-1 VIN: 1C6RD6FT5CS289859									
Year: 2012		Make: [	Dodge		Model:	RAM	1500			
Body Style: _	Quad Cab				Mileage:	2172	274			
Engine: 5.7 I	Engine: 5.7 liter V-8 Transmission: Automatic									
Fuel Level: Empty Ballast: 190 lb (440 lb max							lb max)			
Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70R17										
Measured Ve	- hicle Wei	ahte (l	h)		·					
measured ve		gino. (i	5)							
LF:	1411		RF:	1405		Fr	ront Axle:	2816		
LR:	1105		RR:	1113		R	ear Axle:	2218		
	0540		<b>D</b> : 14	0540			<b>Ŧ</b> / 1	5004		
Lett:	2516		Right:	2518			1 Otal:	0 lb allowed		
							5000 ±11	o ib allow ed		
Wh	eel Base:	140.50	inches	Track: F:	68.50	inche	es R:	68.00	inches	
	148 ±12 inch	es allow ed			Track = (F+R	R)/2 = 6	67 ±1.5 inches	s allow ed		
Center of Gra	<b>ivity</b> , SAE	J874 Sus	spension N	<b>/l</b> ethod						
X:	61.90	inches	Rear of F	ront Axle	(63 ±4 inche	s allow	red)			
Y:	0.01	inches	Left -	Right +	of Vehicle	e Cer	nterline			
Z:	28.50	inches	Above Gr	ound	(minumum 28	3.0 incł	nes allow ed)			
Hood Heig	ht:	46.00	inches	Front E	Bumper He	eight:		<u>26.50</u> ir	nches	
	43 ±4 ii	nches allowed								
Front Overha	ng:	40.00	inches	Rear E	Bumper He	eight:		29.50 ir	nches	
	39 ±3 ii	nches allowed								
Overall Leng	th:	227.50	inches							
	237 ±1	3 inches allow	ed							

#### Table E.2. Measurements of Vehicle Vertical CG for Test No. 469467-7-1.
### Table E.3. Exterior Crush Measurements of Vehicle for Test No. 469467-7-1.

Date:	2017-08-17	Test No.:	469467-7-1	VIN No.:	1C6RD6FT5CS289859
Year:	2012	Make:	Dodge	Model:	RAM 1500

# VEHICLE CRUSH MEASUREMENT SHEET¹

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)	X1+X2							
< 4 inches								
$\geq$ 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.

		Direct I	Direct Damage								
Specific Impact Number	Plane* of C-Measurements	Width** (CDC)	Max*** Crush	Field L**	$C_1$	$C_2$	C ₃	$C_4$	C5	C ₆	±D
1	Front plane at bumper ht	14	6.5	38	0	0	4	6.5	4	4	+19
	Measurements recorded										
	in inches										

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

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

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

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

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

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

Date:	2017-08-17	Test No.:	469467-7-1	VIN No.:	1C6RD6FT5CS289859
Year:	2012	Make:	Dodge	Model:	RAM 1500









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

# OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After	Differ.
	(ii	nches or mm)	)
A1	65.25	65.25	0
A2	63.25	63.25	0
A3	65.50	65.50	0
B1	44.50	44.50	0
B2	38.00	38.00	0
B3	44.50	44.50	0
B4	39.50	39.50	0
B5	43.00	43.00	0
B6	39.50	39.50	0
C1	26.00	26.00	0
C2			-
C3	26.00	26.00	0
D1	11.50	11.50	0
D2			-
D3	11.50	11.50	0
E1	58.75	58.75	0
E2	63.50	63.50	0
E3	63.50	63.50	0
E4	63.50	63.50	0
F	59.00	59.00	0
G	59.00	59.00	0
Н	37.50	37.50	0
I	37.50	37.50	0
J*	23.25	23.25	0





0.000 s











Figure E.1. Sequential Photographs for Test No. 469467-7-1 (Perpendicular and Oblique Views).

0.140 s







0.280 s













Figure E.1. Sequential Photographs for Test No. 469467-7-1 (Perpendicular and Oblique Views) (Continued).



0.420 s



Roll, Pitch, and Yaw Angles



HOLIA+ 福白

Sequence for determining orientation:

Yaw. Pitch. Roll.

<del>..</del> vi w





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





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# X Acceleration Rear of CG



Figure E.6. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-7-1 (Accelerometer Located Rear of Center of Gravity).











Figure E.8. Vehicle Vertical Accelerometer Trace for Test No. 469467-7-1 (Accelerometer Located Rear of Center of Gravity).

# E.3 *MASH* TEST 3-62 ON THE PEDESTAL POLE WITH BEACONS AND SOLAR ASSEMBLY

	Ta	ble h	2.5. Vehicle	e Propei	rties for Te	est No. 469	467-7-2.			
Date: 201	7-08-17		Test No.:	469467-	7-2	VIN No.:	1C6RD6FT5	5CS2898	859	
Year: 201	2		Make:	Dodge		Model:	RAM 1500			
Tire Size:	265/70	R17			Tire I	nflation Pres	ssure: <u>35 ps</u>	i		
Tread Type:	Highwa	ay				Odor	neter: 21727	74		
Note any dar	Note any damage to the vehicle prior to test: 6.5 inch dent at right qtr pt of bumper, grill, hood									
<ul> <li>Denotes a</li> </ul>	ccelerom	eter le	ocation.		-	•X •₩	-			
NOTES: P 469467-7	reviously ·1	used	in Test No.			7117		<u>)                                    </u>		
Engine Type: Engine CID:	v-8 5.7	liter			HEEL				WHEEL TRACK	
Transmissior <u>x</u> Auto FWD	Type: or <u>x</u> R	WD	_ Manual 4WD			1	TEST INI	ERTIAL C. M.	4	
Optional Equ None	ipment:			- 0 -				2		
Dummy Data Type: Mass: Seat Positic	: <u>No (</u> NA m: NA	dumn	ny	<u>↓</u> 」-[				-D-		
Geometry:	inches				<b>4</b>	M front	- C	7 M rear	-	
A 78.5	0	F	40.00	К	20.75	P	3.00	U	27.50	
B <u>75.0</u>	0	G	28.50	_ L _	29.50	Q	30.50	V _	30.75	
C 227.5	0	н	61.90	M	68.50	R	18.00	W _	61.90	
D 47.0	0	Ι	11.00	N	68.00	S	13.25	Χ_	77.40	
E 140.5	0	J	26.50	0	46.00	T	77.00	_		
Wheel Cer Height Fr	nter ont		14.75 Cle	Wheel W arance (Fro	/ell nt)	6.00	Bottom Frame Height - Front	; t	17.00	
Wheel Cer Height R	nter ear		14.75 Cle	Wheel W earance (Re	/ell ar)	9.25	Bottom Frame Height - Rea	; r	25.50	
GVWR Ratin	as:		Mass: Ib	C	urb	Test Ir	nertial	Gros	s Static	
Front	3700		M _{front}		2871		2816			
Back	3900	-	M _{rear}		2086		2218			
Total	6700	-	M _{Total}		4957		5037			
Mass Distrik	ution	-			(Allowable	Range for TIM and C	GSM = 5000 lb ±110 lb)	)		
lb		LF:	1411	RF:	1405	LR:	1105 F	R:	1113	

Date: 2017-08-17 Test No.: 469467-7-2 VIN: 1C6RD6FT5CS289859										
Year: 2012 Make: Dodge Model: RAM 1500										
Body Style: Quad Cab Mileage: 217274										
Engine: <u>5.7 liter V-8</u> Transmission: <u>Automatic</u>										
Fuel Level:       Empty       Ballast:       190 lb       (440 lb max)									lb max)	
Tire Pressure: Front: 35 psi Rear: 35 psi Size: 265/70R17										
Measured Ve	hicle Wei	ahts: (	b)							
		<b>J</b> (								
LF:	1411		RF:	1405		F	ront Axle:	2816		
LR:	1105		RR:	1113		F	Rear Axle:	2218		
Left:	2516		Right:	2518			Total:	5034		
							5000 ±11	0 lb allow ed		
Wh	eel Base:	140 50	inches	Track: F:	68.50	inch	nes R'	68.00	inches	
	148 ±12 inch	es allow ed		114014.11	Track = (F+R	2)/2 =	67 ±1.5 inche	s allow ed		
Center of Gra	<b>ivity</b> , SAE	J874 Sus	pension N	<i>l</i> ethod						
X·	61.90	inches	Rear of F	ront Avle	(63 ±4 incho		w od)			
X.	01.50	Inches				5 8110	weu)			
Y:	0.01	inches	Left -	Right +	of Vehicle	Ce	nterline			
Z:	28.50	inches	Above Gr	ound	(minumum 28	3.0 inc	thes allow ed)			
	20100				(mindinalize					
Hood Heig	ht:	46.00	inches	Front E	Bumper He	eight	:	26.50 ir	nches	
	43 ±4 iı	nches allowed								
Front Overha	na:	40.00	inches	Rear I	Bumper He	eiaht	:	29.50 ir	nches	
	39 ±3 inches allowed									
Overall Leng	th:	227.50	inches							
-	237 ±13	3 inches allow	ed							

## Table E.6. Measurements of Vehicle Vertical CG for Test No. 469467-7-2.

### Table E.7. Exterior Crush Measurements of Vehicle for Test No. 469467-7-2.

Date:	2017-08-17	Test No.:	469467-7-2	VIN No.:	1C6RD6FT5CS289859
Year:	2012	Make:	Dodge	Model:	RAM 1500

# VEHICLE CRUSH MEASUREMENT SHEET¹

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)	X1+X2							
< 4 inches								
$\geq$ 4 inches								

### Note: Measure C₁ to C₆ from Driver to Passenger Side in Front or Rear impacts – Rear to Front in Side Impacts.

		Direct I	Direct Damage								
Specific Impact Number	Plane* of C-Measurements	Width** (CDC)	Max*** Crush	Field L**	$C_1$	$C_2$	C ₃	C ₄	C ₅	C ₆	±D
1	Front plane at bumper ht	14	6.5	38	4	4	6.5	4	0	0	-19
	Measurements recorded										
	in inches										

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

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

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

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

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

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

Date:	2017-08-17	Test No.:	469467-7-2	VIN No.:	1C6RD6FT5CS289859
Year:	2012	Make:	Dodge	Model:	RAM 1500









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

# OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before	After	Differ.						
	(inches or mm)								
A1	65.25	65.25	0						
A2	63.25	63.25	0						
A3	65.50	65.50	0						
B1	44.50	44.50	0						
B2	38.00	38.00	0						
B3	44.50	44.50	0						
B4	39.50	39.50	0						
B5	43.00	43.00	0						
B6	39.50	39.50	0						
C1	26.00	26.00	0						
C2			-						
C3	26.00	26.00	0						
D1	11.50	11.50	0						
D2			-						
D3	11.50	11.50	0						
E1	58.75	58.75	0						
E2	63.50	63.50	0						
E3	63.50	63.50	0						
E4	63.50	63.50	0						
F	59.00	59.00	0						
G	59.00	59.00	0						
Н	37.50	37.50	0						
I	37.50	37.50	0						
J*	23.25	23.25	0						





0.000 s













Figure E.9. Sequential Photographs for Test No. 469467-7-2 (Perpendicular and Oblique Views).



0.140 s





0.280 s











Figure E.9. Sequential Photographs for Test No. 469467-7-2 (Perpendicular and Oblique Views) (Continued).

0.490 s

0.420 s





Figure E.10. Vehicle Angular Displacements for Test No. 469467-7-1.













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2017-12-19



TR No. 0-6946-17-1

2017-12-19











# APPENDIX F. MASH TESTING OF TXDOT MAILBOX SYSTEMS

# F.1 *MASH* TEST 3-61 AT 0 DEGREES ON DOUBLE MAILBOX SYSTEM ON WINGED CHANNEL POST WITH TYPE 3 FOUNDATION

	Iut		e i ropertie		1101 10.							
Date:	2017-08-03	Test No.:	469467-8-4		/IN No.:	KNADH4A30B6857166						
Year:	2011	Make:	Kia	N	Nodel:	Rio						
Tire Inf	flation Pressure:	32 psi	Odometer:	111224		Tire Size:	185/65R	14				
Describe any damage to the vehicle prior to test: <u>None</u>												
• Den	otes accelerome	ter location.	<b>A</b>			F		A				
NOTES: None			- A M			••-		N T				
Engine	Type: 4 cyl	inder	- , ,	+								
Engine	CID: <u>1.6 li</u>	ter	-									
Transm <u>x</u> Optiona <u>Nor</u>	nission Type: Auto or FWD <u></u> R\ al Equipment: ne	Manual WD 4WD				•						
Dumm Type: Mass Seat I	y Data: : <u>50th</u> : <u>165</u> Position: Fron	percentile male lb t Passenger			H_S E			K K				
Geome	etry: inches		F									
Α 6	6.385 F	33.00	K <u>10</u>	).50	Ρ	4.12	U _	15.25				
Β	<u>58.00</u> G	; <u> </u>	L 24	.50	Q	22.50	V	20.50				
C _ 1	l <u>65.75</u> H	35.22	M <u>57</u>	7.75	R	15.50	W _	35.00				
D	34.00	7.75	N <u>5</u> 7	7.75	s	9.00	Х _	107.00				
E	<u>98.75</u> J	21.00	O <u>28</u>	3.00	т	66.25	_					
Whe	eel Center Ht Fro	ont <u>11.00</u>	Wheel (	Center Ht Re	ear	11.00	W-H	0				
GVWR Ratings: Mass: Ib Curb Test Inertial Gross Stati								ss Static				
Front	1718	Mfront	1570			1569	1654					
Back	1874	M _{rear}	899			870	950					
Total	3592	M _{Total}	2469			2439 2604						
		_	Allov	wable TIM = 2420 lb	±55 lb   Allowa	able GSM = 2585 lb	± 55 lb					
Mass I Ib	Distribution:	LF: <u>771</u>	RF:	798	LR:	446	RR:	424				

F-1



### Table F.2. Occupant Compartment Measurements for Test No. 469467-6-1.



Figure F.1. Sequential Photographs for Test No. 469467-8-4 (Perpendicular and Oblique Views).



Figure F.1. Sequential Photographs for Test No. 469467-8-4 (Perpendicular and Oblique Views) (Continued).





Axes are vehicle-fixed. Sequence for determining orientation:

Yaw. Pitch. Roll.

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Figure F.4. Vehicle Lateral Accelerometer Trace for Test No. 469467-8-4 (Accelerometer Located at Center of Gravity).

1.0 Test Number: 469467-8-4 Test Standard Test Number: MASH Test 3-61 at 0 Degree Test Standard Test Number: MASH Test 3-61 at 0 Degree Test Article: TxDOT Double Mailbox System on Winged Channel Post with Type 3 Foundation Test Vehicle: 2011 Kia Rio Inertial Mass: 2439 lb Gross Mass: 2439 lb Gross Mass: 2604 lb Impact Speed: 63.3 mi/h Impact Angle: 0 degrees 0.0 0.8 0.7 Z Acceleration at CG 0.0 5 Time (s) 0.5 0.4 50-msec average 0.3 0.2 SAE Class 60 Filter 0.1 4-40 à 9 ĉ ή 4 ή Vertical Acceleration (g)



TR No. 0-6946-17-1












## F.2 *MASH* TEST 3-61 AT 0 DEGREES OF DOUBLE MAILBOX SYSTEM ON THIN-WALLED GALVANIZED TUBE WITH TYPE 2 FOUNDATION

			-								
Date:	2017-08-03	Test No.:	469467-8-3	VIN No.:	KNADH4	A30B6857	166				
Year:	2011	Make:	Kia	Model:	Rio						
Tire Infl	ation Pressure: 32	2 psi	Odometer: 11	1224	Tire Size:	185/65R	14				
Describe any damage to the vehicle prior to test: <u>Small dents at left qtr pt bumper and hood with hood</u>											
depression of 1.25 on left side											
<ul> <li>Denotes accelerometer location.</li> </ul>					· · · · ·						
NOTES	: Previously used	in Test No.	A M		••	-	N T				
409407-0-4											
Engino	Turpo: 4 outlindor						¥   •				
Engine	CID: 1.6 liter										
Transm	ission Type:			<ul> <li>Q →</li> </ul>							
<u> </u>	Auto or FWD RWD	_ Manual 	P	R			Ī				
Optional Equipment:											
None	9										
Dummy	Data:			H	G		К				
Type: Mass	<u>50" perce</u> 165 lb	entile male		- W							
Seat P	Position: Front Pas	senger		E	-X						
Goomo	try: inches		-		C						
A 6	6.385 F	33.00	K 10.50	Р	4.12	U	15.25				
в (	58.00 G		L 24.50	Q	22.50	v	20.50				
C 10	65.75 H	35.22	M 57.75		15.50	W	35.00				
D :	34.00 I	7.75	N 57.75	S	9.00	X	107.00				
E _ 9	98.75 J	21.00	O <u>28.00</u>	Т	66.25						
Whe	el Center Ht Front	11.00	Wheel Cent	er Ht Rear	11.00	W-H	0				
	Datingo	Maggarilla	Curb	Teet I	nortial	Cros	o Statio				
Eront	1718	Miront	<u>Cuib</u> 1570	16511	1569	<u>G105</u>	1654				
Back	1874	Mrear	899		870		950				
Total	3592	MTotal	2469		2439		2604				
Allowable TIM = 2420 lb ±55 lb   Allowable GSM = 2585 lb ± 55 lb											
Mass D Ib	istribution: LF:	771	RF: <u>798</u>	LR:	446	RR:	424				

## Table F.3. Vehicle Properties for Test No. 469467-8-3.



## Table F.4. Occupant Compartment Measurements for Test No. 469467-8-3.



Figure F.9. Sequential Photographs for Test No. 469467-8-3 (Perpendicular and Oblique Views).



Figure F.9. Sequential Photographs for Test No. 469467-8-3 (Perpendicular and Oblique Views) (Continued).





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Axes are vehicle-fixed. Sequence for determining orientation:

Yaw. Pitch. Roll.

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F.3 MASH TEST 3-61 AT 0 DEGREES OF MULTIPLE MAILBOXES ON 56-INCH HANGER-TYPE THIN-WALLED GALVANIZED TUBE WITH TYPE 1 FOUNDATION

Table F.5.Vehicle Properties for Test No. 469467-8-2.												
Date: 2017-08-03	Test No.:	469467-8-2	VIN No.:	KNADH4	A30B6857	166						
Year: 2011	Make:	Kia	Model:	Rio								
Tire Inflation Pressure:	32 psi	_ Odometer: _111224		Tire Size:	185/65R	14						
Describe any damage to the vehicle prior to test: <u>Two very small dents at the right and left qtr points.</u> Hood was replaced												
Denotes accelerometer location.												
NOTES: Previously use 469467-8-4 and 8-3	ed in Test No.	- A M		<b>e-•</b>		N T						
Engine Type: 4 cyline	der					<u> </u>						
Engine CID: <u>1.6 lite</u> Transmission Type: <u>x</u> Auto or <u>x</u> FWD RWI Optional Equipment: <u>None</u>	r Manual D 4WD		R	•								
Dummy Data:Type:50th peMass:165 lbSeat Position:Front F	rcentile male		н <mark>— s</mark> — w — е			<u>к</u>						
Geometry: inches				0	-							
A <u>66.385</u> F	33.00	K <u>10.50</u>	P	4.12	U _	15.25						
B <u>58.00</u> G		L <u>24.50</u>	Q	22.50	V	20.50						
C <u>165.75</u> H	35.22	N 57.75	к	0.00		35.00						
D <u>34.00</u> I	21.00	0 28.00	з <u> </u>	<u>9.00</u>	^ _	107.00						
Wheel Center Ht From	t <u>11.00</u>	Wheel Center Ht	Rear	11.00	W-H	0						
GVWR Ratings:	Mass: Ib	Curb	<u>Test I</u>	nertial	Gros	s Static						
Front 1718	Mfront	1570		1569		1654						
Back <u>1874</u>	Mrear	899		870		950						
Total <u>3592</u>	M _{Total}	2469		2439		2604						
Mass Distribution:	F: <u>771</u>	Allowable TIM = 24:	LR:	able GSM = 2585 lb	* 55 lb RR:	424						



## Table F.6. Occupant Compartment Measurements for Test No. 469467-8-3.



Figure F.9. Sequential Photographs for Test No. 469467-8-2 (Perpendicular and Oblique Views).



Figure F.9. Sequential Photographs for Test No. 469467-8-2 (Perpendicular and Oblique Views) (Continued).





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Axes are vehicle-fixed. Sequence for determining orientation:

Yaw. Pitch. Roll.

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Figure F.22. Vehicle Longitudinal Accelerometer Trace for Test No. 469467-8-2 (Accelerometer Located Rear of Center of Gravity).







