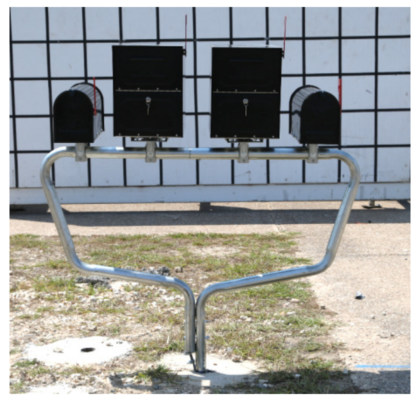
TTI: 9-1002-15

Texas A&M Transportation Institute

CRASH TESTING AND EVALUATION OF MULTIPLE MAILBOX SUPPORTS FOR USE WITH LOCKING ARCHITECTURAL MAILBOXES



ACCREDITED
ISO 17025 Laboratory
Testing Certificate # 2821.01

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

Test Report 9-1002-15-7

Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the
Federal Highway Administration and the
Texas Department of Transportation
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16. Abstract

Some homeowners and businesses are becoming increasingly concerned about mail-identity theft. Consequently, there is a growing demand for the use of locking mailboxes for theft deterrence and vandal resistance. There are a number of mailbox products on the market that offer enhanced security for mail and small parcels. They typically feature an upper hopper for incoming mail, and a lower lockable compartment for mail retrieval. These lockable mailboxes are significantly larger and can be 4 to 5 times heavier than standard lightweight mailboxes, which are approximately 5 inches wide, 6 inches tall, and 19 inches long, and weigh less than 5 lb. Therefore, TxDOT requested evaluation of their crashworthiness before permitting their use on the state highway system. Under TxDOT Project 9-1002-12, crash tests were performed following *Manual for Assessing Safety Hardware* (*MASH*) guidelines and procedures to assess the impact performance of lockable, secure mailboxes in both single and multiple-mount configurations. Testing of the larger (15 inches tall, 11.5 inches wide, and 18 inches deep), heavier (approximately 23 lb) locking mailboxes on multiple-mount support posts resulted in failure due to vehicle windshield deformation and intrusion.

Under this project, crashworthiness of proposed designs for multiple-mailbox supports used with a combination of lockable and standard mailboxes was evaluated. This evaluation was performed to determine if TxDOT can permit their use on the state highway system. The crash tests were performed following the latest *MASH* guidelines and evaluation criteria.

Two proposed designs were evaluated through full-scale crash testing:

1) 11-gauge (0.125-inch) steel tube multiple-mount support with 4-inch embedment.
2) 16-gauge (0.0625-inch) steel tube multiple-mount support with inclusion of ¼-inch-diameter wire rope and with 6-inch embedment.

Both systems satisfied all required *MASH* evaluation criteria at low and high impact speeds using an 1100C passenger car. Implementation of these designs can be accomplished through appropriate revision of the TxDOT Mailbox Mounting and Spacing standard (MB-11(1)) by the Maintenance Division.

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Texas Department of Transportation
and the
Federal Highway Administration

February 2017

TEXAS A&M TRANSPORTATION INSTITUTE
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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, and its contents are not intended for construction, bidding, or permit purposes. In addition, the above listed agencies assume no liability for its contents or use thereof. 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. The engineer in charge of the project was Roger P. Bligh, P.E. (Texas, #78550).

TTI PROVING GROUND DISCLAIMER

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

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

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CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

This project was set up to provide the Texas Department of Transportation (TxDOT) with a mechanism to quickly and effectively evaluate high-priority issues related to roadside safety devices. Roadside safety devices shield motorists from roadside hazards such as non-traversable terrain and fixed objects. Some obstacles that cannot be moved out of the clear zone (e.g., mailboxes, sign supports) are designed to break away. To maintain the desired level of safety for the motoring public, these safety devices must be designed to accommodate a variety of site conditions and placement locations, and a changing vehicle fleet. Periodically, there is a need to assess the compliance of existing safety devices with current vehicle testing criteria. Under this project, roadside safety issues are identified and prioritized for investigation. Each roadside safety issue is addressed with a separate work plan, and the results are summarized in an individual test report.

1.2 RESEARCH PROBLEM STATEMENT

Some homeowners and businesses are becoming increasingly concerned about mail-identity theft. Consequently, there is a growing demand for the use of locking mailboxes for theft deterrence and vandal resistance. There are a number of mailbox products on the market that offer enhanced security for mail and small parcels. They typically feature an upper hopper for incoming mail, and a lower lockable compartment for mail retrieval.

The dual compartment security feature makes the lockable mailboxes larger and heavier than standard mailboxes. As an example, the Oasis Jr.® locking architectural mailbox is 15 inches tall × 11.5 inches wide × 18 inches deep and weighs 22.4 lb. By contrast, a common sized rural mailbox (T1) is approximately 6 inches tall × 5 inches wide × 18.5 inches long and weighs less than 5 lb. Lockable mailboxes are significantly larger and can be 4 to 5 times heavier than standard mailboxes. Under a previously funded TxDOT research project, crash tests were conducted to assess the impact performance of lockable, secure mailboxes in both single and multiple-mount configurations (*1*). Previous testing of the larger, heavier locking mailboxes on multiple-mount support posts resulted in failure due to vehicle windshield deformation and occupant compartment intrusion.

Therefore, TxDOT requested assistance with the development of a nonproprietary multiple-mailbox support suitable for use with secure lockable mailboxes and standard mailboxes. The device is intended to meet the evaluation criteria recommended in the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH*) (*2*).

1.3 RESEARCH OBJECTIVES

The objective of this research task was to develop a nonproprietary multiple-mailbox support system for use with both standard mailboxes and lockable, secure mailboxes. The mailbox support is intended to meet *MASH* Test Level 3 evaluation criteria.

Reported herein are details of the multiple-mailbox supports evaluated for use with lockable and standard mailboxes, descriptions of the tests performed, assessment of test results, and implementation recommendations.

CHAPTER 2: LITERATURE REVIEW AND ALTERNATIVES

2.1 PREVIOUS RESEARCH AND TESTING

In 1980, Ross et al. conducted a research study to evaluate the impact behavior of different mailbox support designs (*3*). One of those full-scale crash tests was conducted to evaluate the crashworthiness of a multiple-mailbox support for use with standard mailboxes. Testing was performed and evaluated according to the recommendations reported in Transportation Circular (TRC) No. 191, dated February 1978 (*4*). The mailbox support type tested in Test No.1 was a 2-inch outer diameter (OD) formed steel tube with 0.070-inch wall thickness. The support was driven into a V-wing socket for a total embedment of 1.5 ft, and four standard mailboxes were attached to the support. Figure 2.1 shows details of the tested mailbox installation.

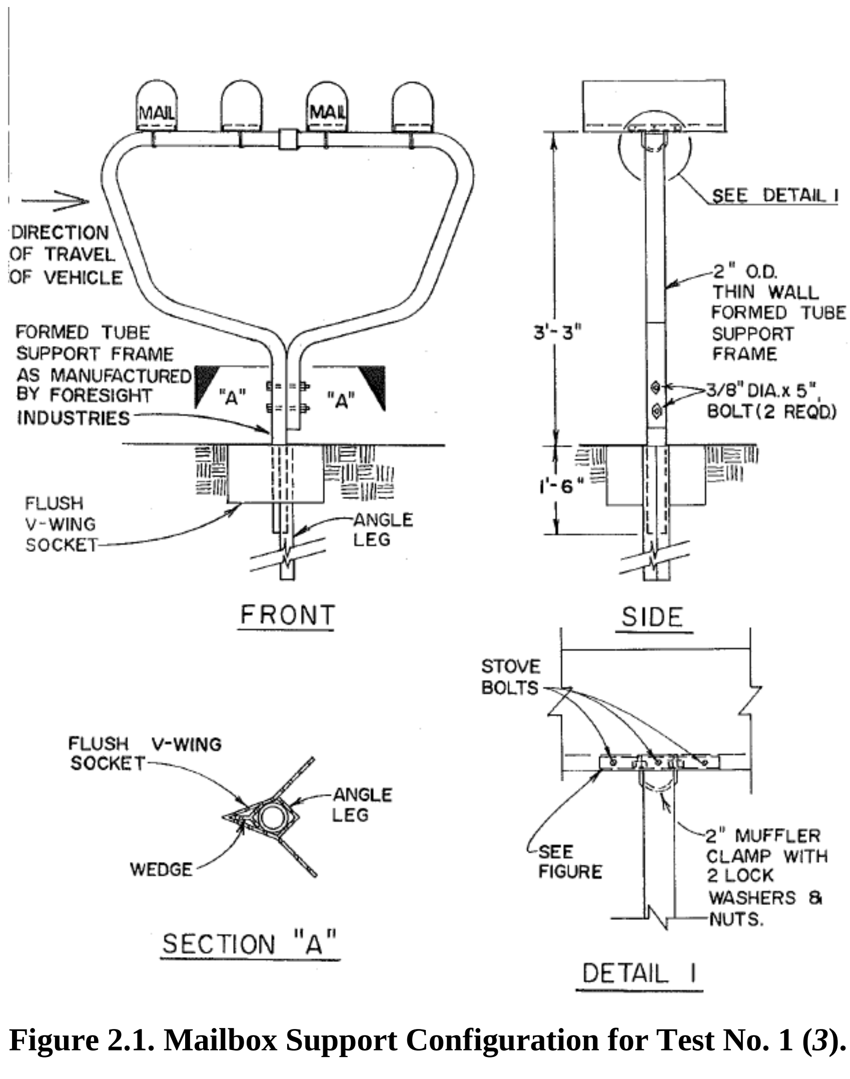
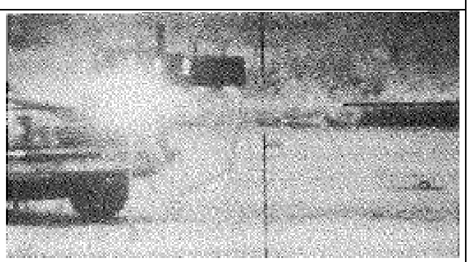
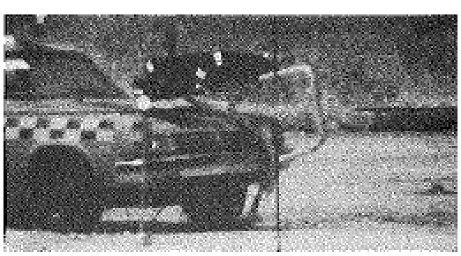


Figure 2.1. Mailbox Support Configuration for Test No. 1 (*3*).

The test was conducted at 60 mi/h with a 1974 Chevrolet Vega weighing 2320 lb (Figure 2.2). The impact point on the vehicle was 15 inches to the left of the center of the bumper. The change in momentum of the vehicle during impact with the design was well below the preferable limit of 750 lb-s recommended in TRC No. 191 (Table 2.1). The system was proven acceptable for up to four mailboxes. There was no penetration of the passenger compartment by the test article and the windshield remained unbroken after the impact event. Vehicle and test article deformation after test are reported in Figure 2.3(a) and (b), respectively. The vehicle sustained only minor damage and was still operable at the end of the test.

Time (s)	Test Frames
0.000	
0.014	
0.037	
0.053	

Time (s)	Test Frames
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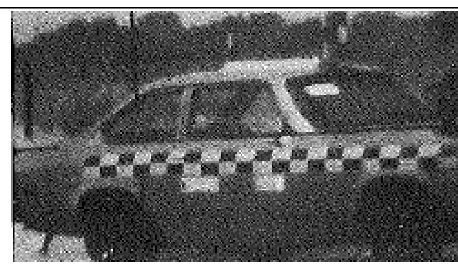
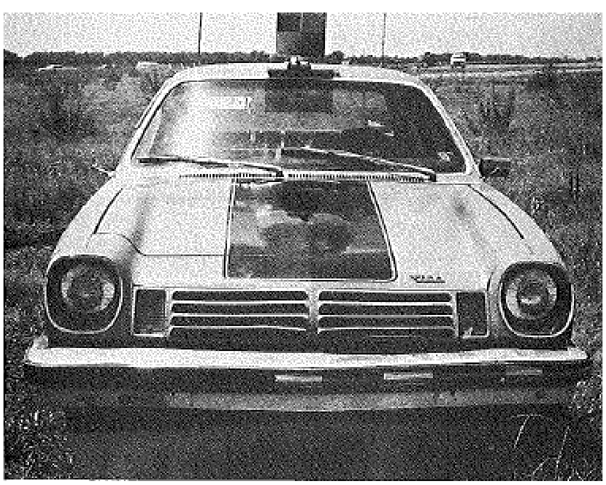
0.129	
0.212	
0.292	

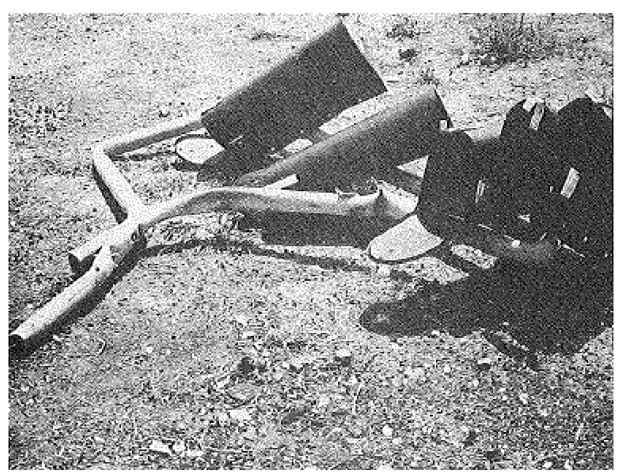
Figure 2.2. Sequential Photographs for Test No. 1 (*3*).

Table 2.1. Summary of Mailbox Crash Test Results for Test No. 1 (*3*).

TEST NO.	1
MAILBOX SUPPORT DATA	
Figure Showing Support Configuration	2
Support Hardware	2.0" O.D. Formed Steel Tube .070 in. Wall Thickness
Embedment Depth (ft)	1.5
Embedment Method	Driven V-Wing Socket
# of Mailboxes	4
ACCELEROMETER DATA	
Change in Momemtum (lb-sec)	93.7
Duration of Event (sec)	.031
Peak Deceleration (g's)	14.78
Maximum 50 msec Average Deceleration (g's)	7.53
VEHICLE DAMAGE CLASSIFICATION	
TAD	FL-0
SAE	12-FLMN1
Was Passenger Compartment Penetrated?	No
Was Windshield Broken?	No



(a)



(b)

Figure 2.3. (a) Vehicle and (b) Test Article after Test No. 1 (*3*).

In 2006, Sheikh et al. conducted a research testing project to evaluate the crashworthiness of the Shur-Tite® multiple-mailbox mount design according to *NCHRP Report 350* requirements (*5*, *6*). The test article had four mailboxes mounted on top (Figure 2.4). Two of these mailboxes were small, measuring approximately 9 inches × 7 inches × 19 inches and weighing 7 lb. The remaining two mailboxes were large, measuring approximately 15 inches × 11.5 inches × 23.5 inches and weighing 13 lb 10 oz. The mailbox frame was placed into a 3-inch diameter × 17-inch long plastic tube socket (DHT 160891) that was embedded in a 12-inch diameter × 30-inch deep concrete footing. The mailbox support frame was secured in place using a plastic wedge (DHT 160892) inserted between the vertical support frame tube and the plastic socket in the concrete footing.

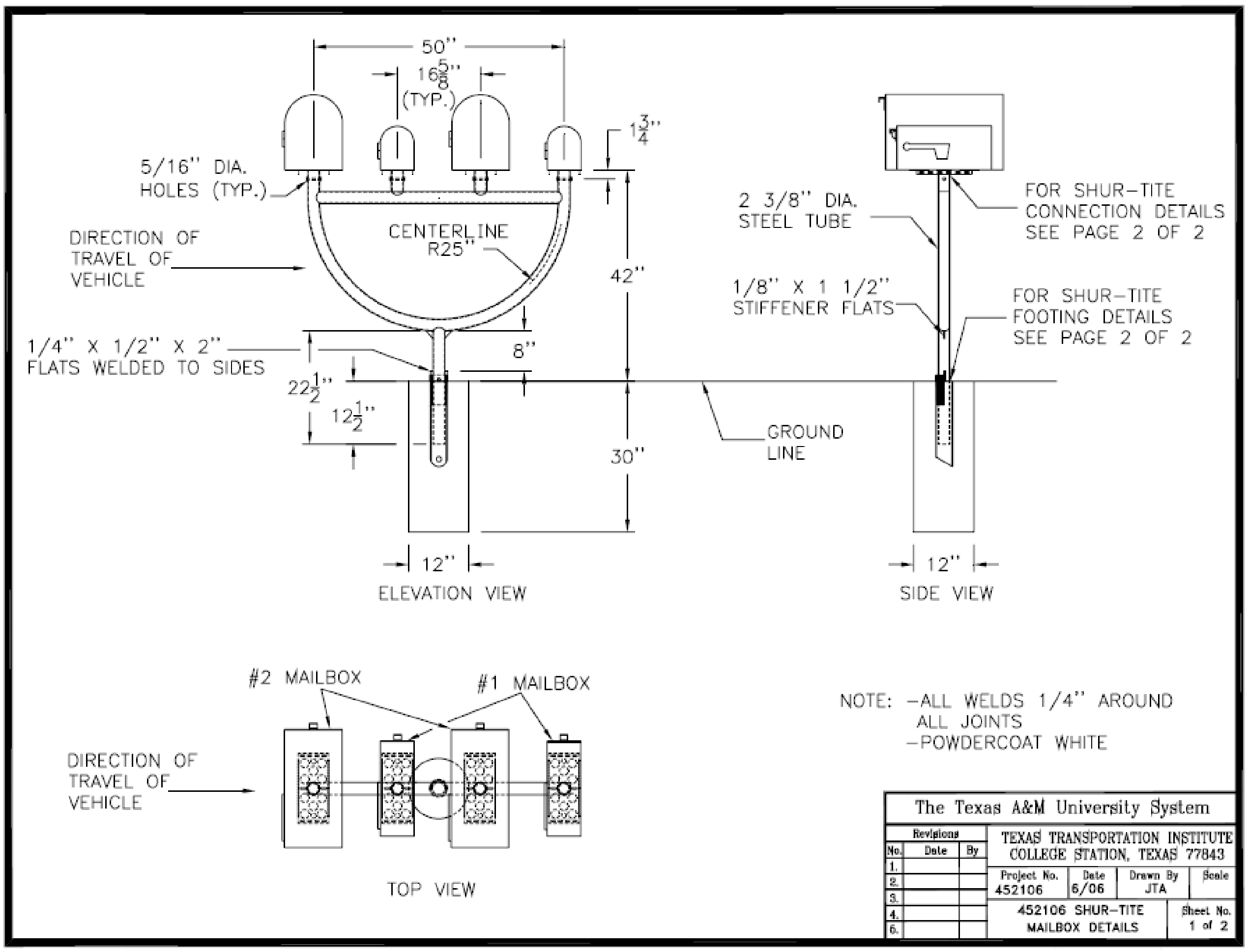
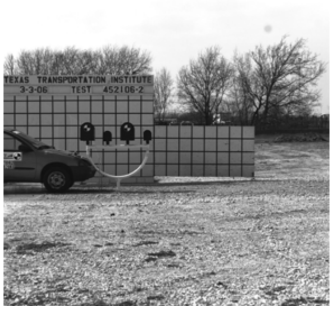


Figure 2.4. Details of the Shur-Tite® Multiple-Mailbox Mount Installation (*5*).The Shur-Tite® multiple-mailbox support yielded to the vehicle by pulling out of the ground socket. The support did not penetrate or show potential for penetrating the occupant compartment, or present undue hazard to others in the area. The Shur-Tite® multiple-mailbox mount with mailboxes rode up into and shattered the windshield, but did not block the driver's vision. The windshield was deformed inward 3.2 inches without any holes or penetration. The vehicle remained upright during and after the collision event. Occupant risk factors were within preferred limits of *NCHRP Report 350*. The vehicle traveled straight forward and did not intrude into adjacent

traffic lanes. The vehicle came to rest behind the installation. Frames from the high-speed full-scale crash test are presented in Figure 2.5.

Time (s)	Test Frames
0.000	
0.037	
0.075	
0.112	

Time (s)	Test Frames
0.150	
0.200	
0.250	
0.300	

Figure 2.5. Sequential Photographs for Test No. 452106-2 (*5*).

The vehicle sustained minimal damage to the hood and bumper as shown in Figure 2.6(a). The front bumper had a slight indention at the point of contact with the support, and the hood had an indentation on the impact side that measured 33.5 inches long × 5.9 inches wide. The windshield was shattered over an area approximately 31.5 inches in diameter and was deformed 3.2 inches inward toward the occupant compartment. Some of the mailboxes were deformed, but all remained attached to the support. The vertical section of the support was deformed 11.8 inches from the end, and the arc of the support was severely deformed (Figure 2.6[b]).

(a)

(b)

Figure 2.6. (a) Vehicle and (b) Test Article after Test No. 452106-2 (*5*).Based on these crash test results, the researchers concluded that the Shur-Tite® multiple-mailbox mount successfully passed all requirements of the *NCHRP Report 350* safety evaluation criteria.

Some homeowners and businesses have become increasingly concerned about mail-identity theft. Consequently, there is a growing demand for the use of locking mailboxes for theft deterrence and vandal resistance. Due to the higher mass and greater height of the lockable, secure mailboxes, there is a possibility that the crash safety performance of the mailbox support with these mailboxes may deteriorate. Under TxDOT project 9-1002-12-9, researchers performed crash tests following *MASH* guidelines and procedures to assess the impact performance of lockable, secure mailboxes on both single- and multiple-mount configurations (*1*). A single locking mailbox was successfully crash tested on a thin-wall steel tube support post installed in a releasable wedge-and-socket foundation. Testing of the larger, heavier locking mailboxes on multiple-mount support posts was unsuccessful due to windshield deformation and penetration.

One of the multiple-mailbox support designs tested was a SHUR-TITE® Products multiple-mailbox post (DHT 164116) installed in a concrete footing using a plastic socket (DHT 160891) and wedge (DHT 160892). Figure 2.7 shows the support was made by a semi-circular tube with a 25-inch centerline radius and horizontal cross member fabricated from 2⅜-inch OD × 0.065-inch thick galvanized steel tube with a white powder coat. Two locking architectural mailboxes were installed on the support. Each mailbox was 15 inches tall × 11½ inches wide × 18 inches deep, and weighed 22.6 lb. One mailbox was placed at the critical location at the upstream exterior mount position adjacent to the impacting vehicle, and the second was positioned at an interior location. The weight of the fabricated multiple-mailbox support was 23.6 lb. A 22½-inch long thin-wall steel tube was vertically welded at the bottom of the semi-circular steel tube. The vertical steel tube was installed with a SHUR-TITE® Products plastic wedge anchor system. The socket (DHT 160891) was 3½ inches OD × $^{7}/_{16}$ inch wall thickness × 17 inches long. The socket was embedded in a non-reinforced concrete footing that was approximately 12 inches in diameter × 30 inches deep. The support post was inserted approximately 13 inches into the socket and secured in place with a plastic locking wedge (DHT 160892) that was driven between the socket and front face of the support post. The total weight of the two mailboxes and post assembly was 72.4 lb.

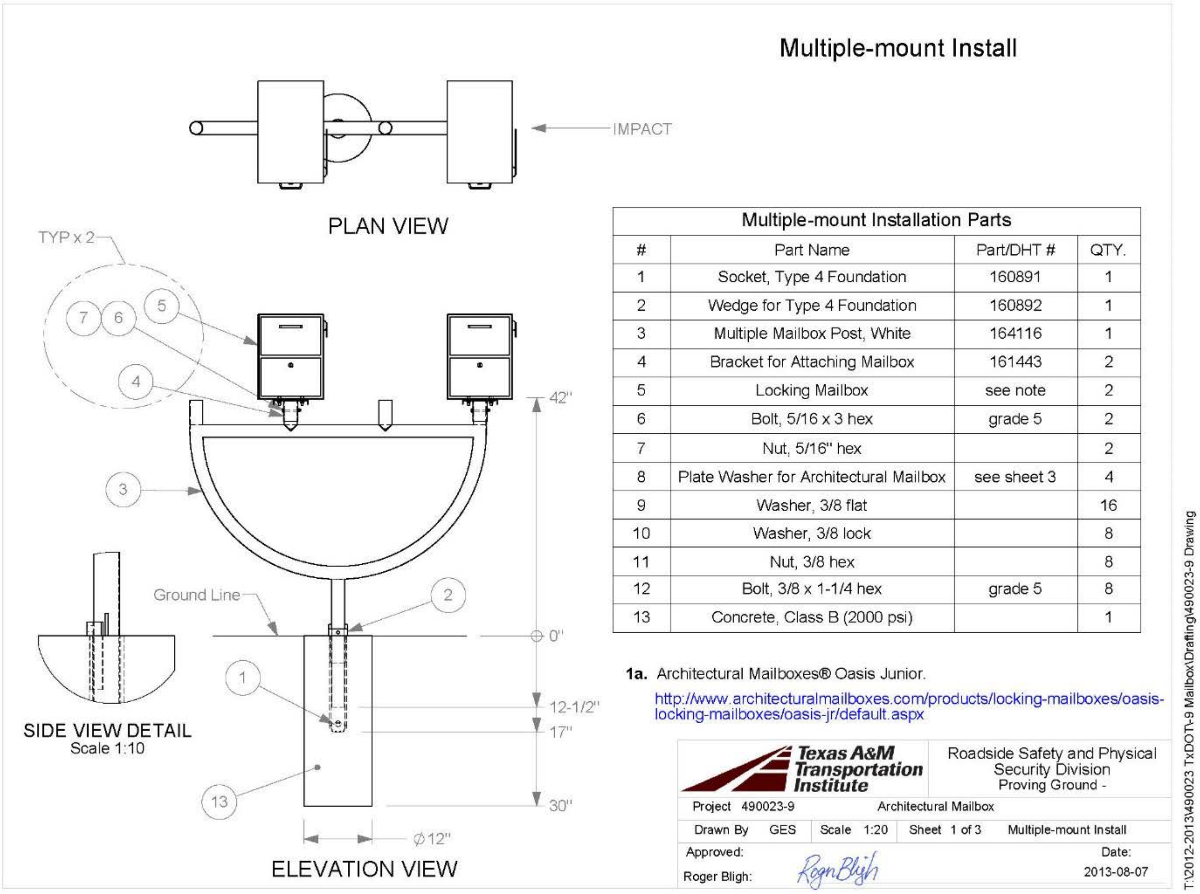


Figure 2.7. Details of the Dual Locking Architectural Mailbox on Shur-Tite® Multiple-Mailbox Mount Post (*1*).This configuration was tested with a passenger car at both low speed (Test No. 490023-9-3) and high speed (Test No. 490023-9-4). In the low-speed test, the vehicle lifted the support out of the foundation socket as designed and pushed it forward of the vehicle (Figure 2.8). The mailboxes remained attached to the support, and there was no contact with the vehicle windshield. Vehicle damage was minor and occupant risk parameters were below preferred values. The SHUR-TITE® multiple-mount support post with dual locking architectural mailboxes met all applicable *MASH* criteria for Test 3-60.

In the high-speed test, the mailbox support released from the foundation socket. However, the support post collapsed in the region in contact with the vehicle, and the released mailbox system rotated into the vehicle windshield (Figure 2.9). The windshield had 4.5 inches of deformation, which exceeds the *MASH* threshold. Consequently, the SHUR-TITE® multiple-mount support post with dual locking architectural mailboxes did not satisfy *MASH* criteria for Test 3-61.

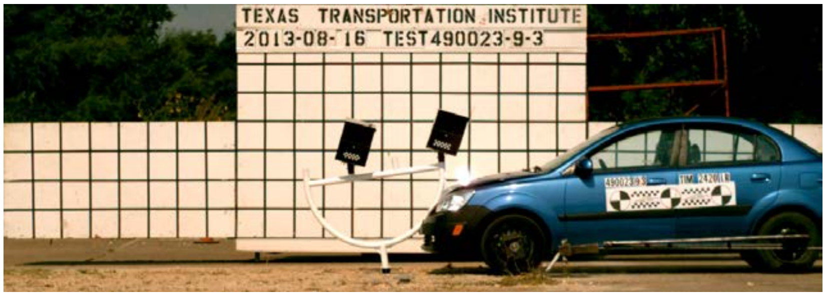
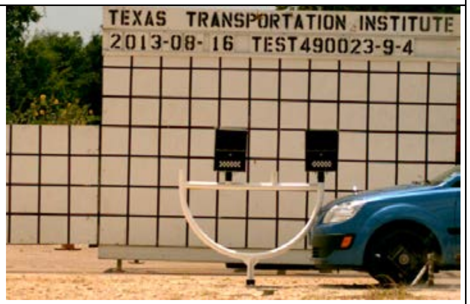
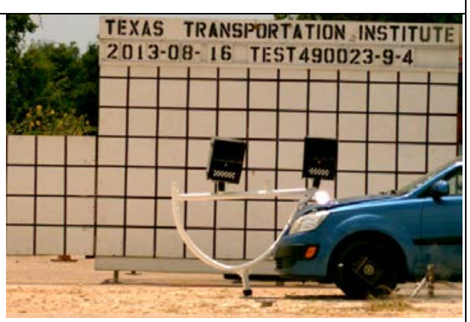
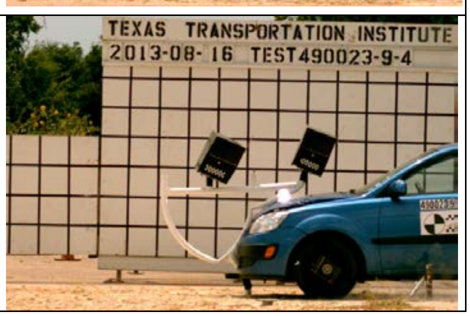
Time (s)	Test Frames
0.000	
0.026	
0.069	
0.101	
0.123	

Figure 2.8. Sequential Photographs for Test No. 490023-9-3 (*1*).

Time (s)	Test Frames
0.000	
0.006	
0.010	
0.011	
0.024	

Time (s)	Test Frames
0.033	
0.044	
0.054	
0.083	

Figure 2.9. Sequential Photographs for Test No. 490023-9-4 (*1*).

The researchers performed additional testing to determine if impact performance would be improved if the locking architectural mailboxes were placed on the interior of the multiple-mailbox mounting post. Standard mailboxes were placed on the exterior of the multiple-mailbox support post for a total of four mailboxes (Figure 2.10). It was theorized that the small outer mailbox might restrict the rotation of the heavier, taller lockable mailboxes, and thereby help limit windshield engagement. This mailbox combination was evaluated on both the SHUR-TITE® multiple-mount support and the formed thin-wall steel tube multiple-mount support at high-speed with the passenger car (Test Nos. 490023-9-5 and 490023-9-6, respectively).

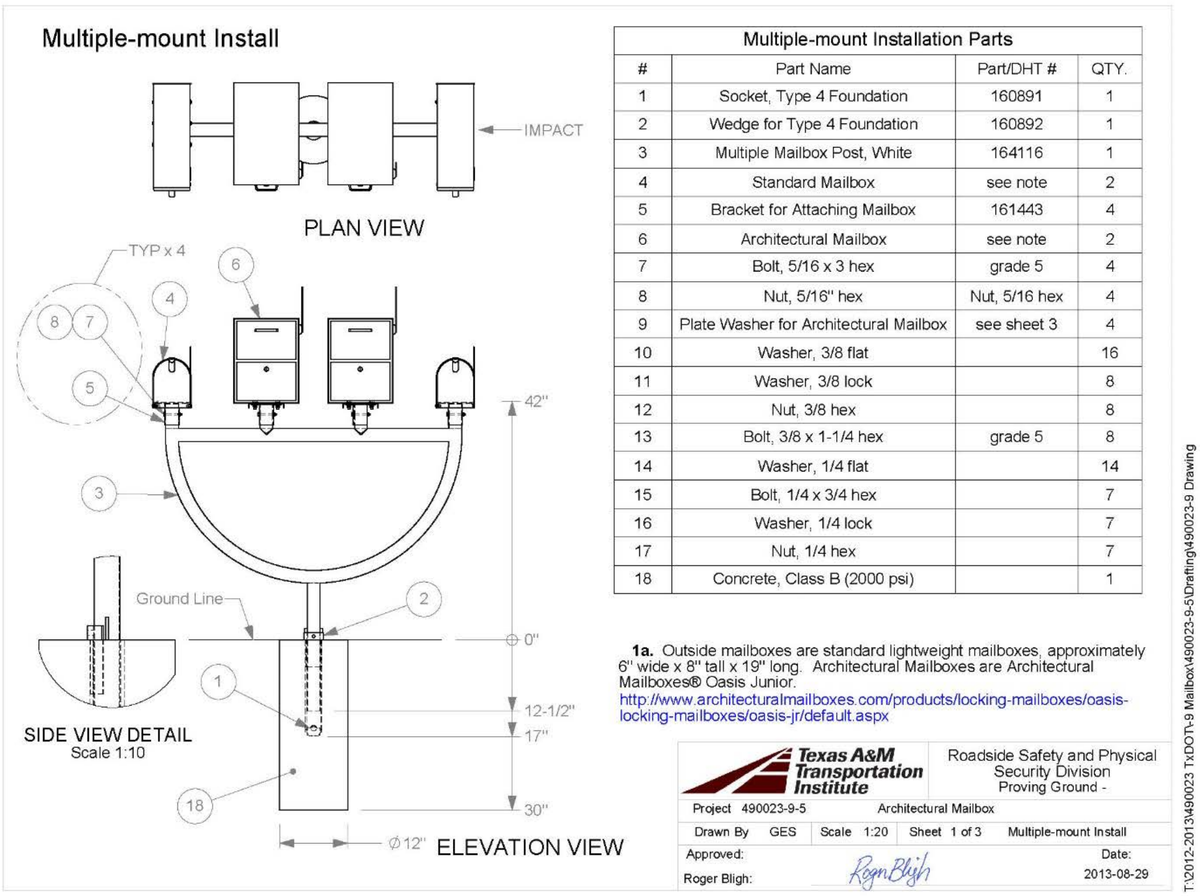


Figure 2.10. Details of the Locking Architectural Mailboxes and Standard Mailboxes on Shur-Tite® Multiple-Mailbox Mount Post (*1*).

In the high-speed test of the combination mailbox configuration on the SHUR-TITE® multiple-mount support post, the support did not release from the foundation socket. The support fractured into multiple pieces, leaving the foundation stub partially embedded in the foundation socket (Figure 2.11). The fractured support and mailboxes impacted and created a large hole in the vehicle windshield (Figure 2.12). Consequently, the SHUR-TITE® multiple-mount support post with a combination of standard and locking architectural mailboxes did not satisfy *MASH* criteria for Test 3-61.

Time (s)	Test Frames
0.000	
0.005	
0.012	
0.014	

Time (s)	Test Frames
0.036	
0.041	
0.050	
0.085	

Figure 2.11. Sequential Photographs for Test No. 490023-9-5 (*1*).

(a) (b)

Figure 2.12. (a) Vehicle and (b) Test Article after Test No. 490023-9-5 (*1*).

The second multiple-mailbox support design tested was a formed thin-wall steel tube multiple-mount support (Figure 2.13).The mailbox configuration used in this test was the same as used in Test No. 490023-9-5. The thin-wall steel tube mailbox support post (DHT 149339) was formed from 2-inch OD × 0.065-inch thick galvanized welded mechanical tubing. The support post had outward sloping sides and a horizontal section on top to which the mailboxes were attached. The support had an overall width of 56 inches and weighed 18 lb. The longer end of the support was inserted approximately 9 inches into a V-wing socket (DHT 160446) that was embedded flush with the top of a non-reinforced concrete footing that was approximately 12 inches in diameter × 30 inches deep. The support was secured in the socket using a triangular-shaped wedge. The total weight of the four mailboxes, connection hardware, and post assembly was 88.0 lb.

In the high-speed test of the combination mailbox configuration on the formed thin-wall steel tube multiple-mount support post, the support released from the foundation socket as designed but fractured in the impacted region (Figure 2.14). The ruptured support and attached mailboxes contacted and shattered the windshield of the vehicle. Maximum deformation of the windshield was 3.5 inches, which exceeds the *MASH* threshold (Figure 2.15). Also, there were several small tears at the base of the windshield behind the dashboard. Consequently, the formed thin-wall steel tube multiple-mount support post with a combination of standard and locking architectural mailboxes did not satisfy *MASH* criteria for Test 3-61.

Results of the crash testing suggested further research was required to develop a multiple-mailbox support that can be used with the larger, heavier lockable mailboxes. Possible modifications included increasing the strength of the support post to facilitate release of the support from the foundation, and to prevent localized collapse and/or rupture of the support during impact.

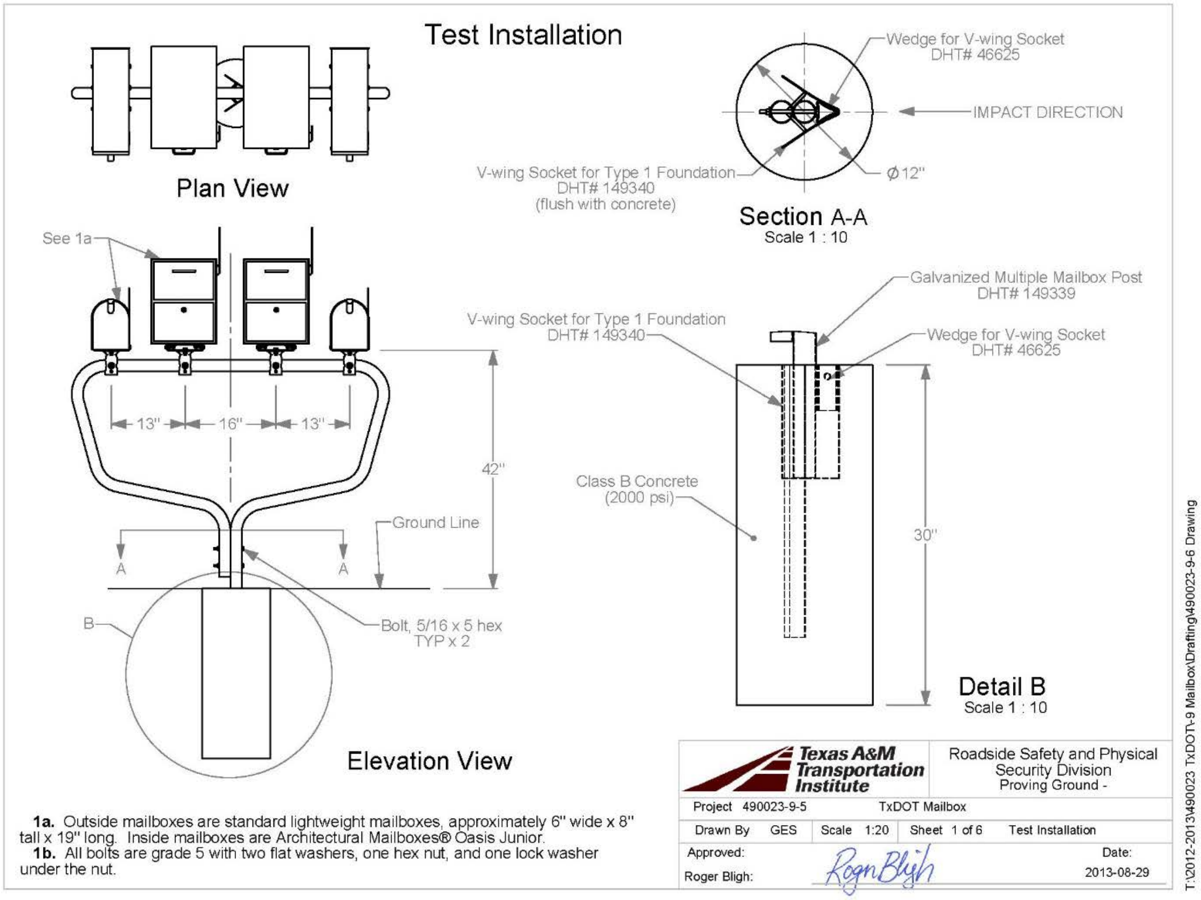


Figure 2.13. Details of the Locking Architectural Mailboxes and Standard Mailboxes on Shur-Tite® Multiple Mailbox Mount Post (*1*).

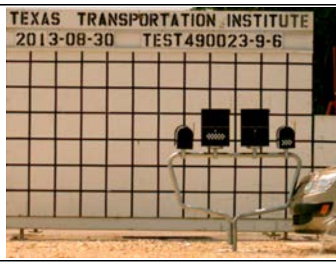
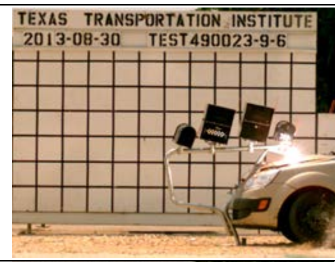
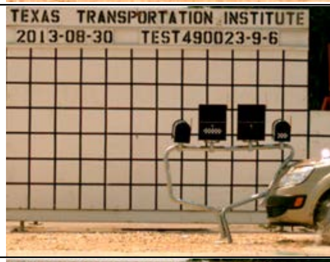
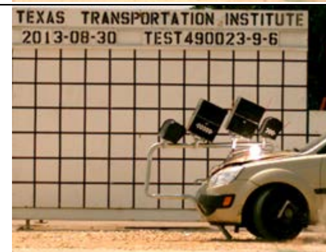
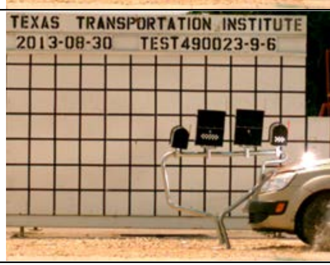
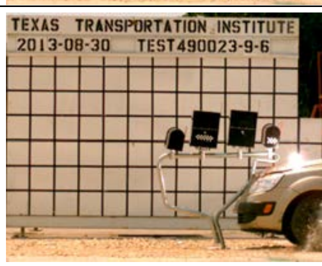
Time (s)	Test Frames	Time (s)	Test Frames
0.000		0.024	
0.008		0.035	
0.014		0.057	
0.016		0.088	

Figure 2.14. Sequential Photographs for Test No. 490023-9-6 (*1*).

(a)

(b)

Figure 2.15. (a) Vehicle and (b) Test Article after Test No. 490023-9-6 (*1*).

2.2 DESIGN ALTERNATIVES

The researchers in this project developed design alternatives with the potential to meet impact performance requirements and provide some desirable functional characteristics. A total of four concepts were developed for consideration under this project. These included both retrofit and new design alternatives. A brief summary of each of these concepts is presented in the following sections.

2.2.1 Proposed Retrofit Options

The systems evaluated in the previous crash tests failed as a result of contact between the support system and the vehicle windshield. The collapse and rupture of the support post was a significant factor in this behavior. The retrofit options retain the existing support post in the design; however, additional structural elements are added to the support post to improve its impact performance. If demonstrated to be crashworthy, the additional structural elements would only need to be added when the larger, heavier lockable mailboxes are used. Otherwise, the existing mailbox support inventory would be unaltered. The objective was to develop retrofit concepts that would be relatively inexpensive and easy to apply.

2.2.1.1 Retrofit Design 1: Wire Rope Option

In the previous tests, the support post ruptured and separated. This resulted in the impacting vehicle submarining under the mailboxes rather than pushing the mailboxes forward. Consequently, the mailboxes interacted with the windshield. In this option, a ¼-inch diameter wire rope is added inside the existing thin-wall steel tube support post. The cable is intended to keep the support post from separating during impact and, thus, preventing the vehicle from submarining under the mailboxes. Figure 2.16 provides details of the wire rope retrofit option.

2.2.1.2 Retrofit Design 2: Brace Option

In this retrofit design, external diagonal braces are added to the existing support post. The braces are clamped onto the support post using plates and U-bolts. The braces are intended to strengthen the support post and enable it to act as a frame that helps distribute the impact forces to other parts of the support post, specifically the horizontal member. The distribution of impact forces to the horizontal member helps transfer momentum to the support and mailboxes and prevent local collapse and rupture of the support post. Figure 2.17 provides details of the braced retrofit option.

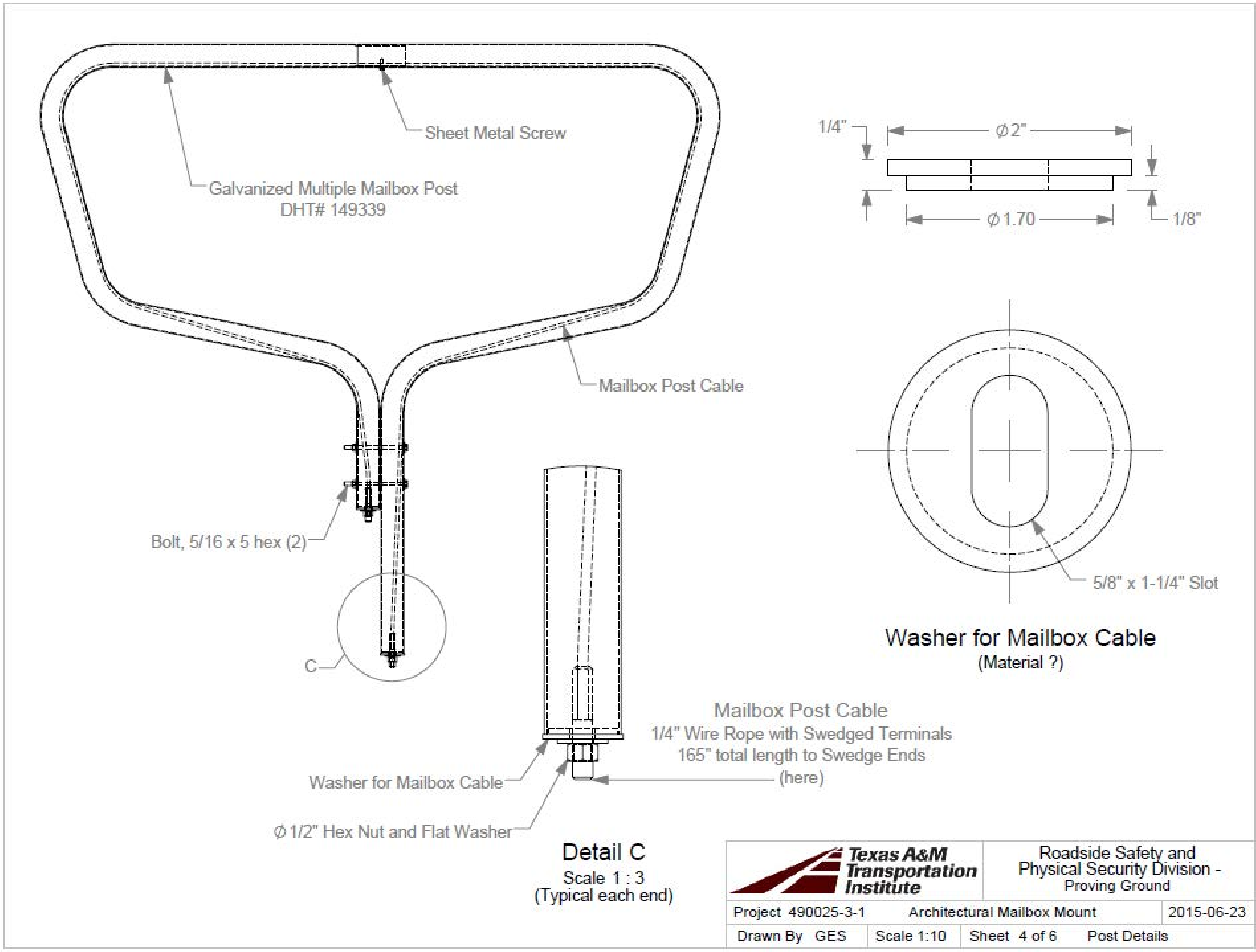


Figure 2.16. Retrofit Design 1: Wire Rope Option.

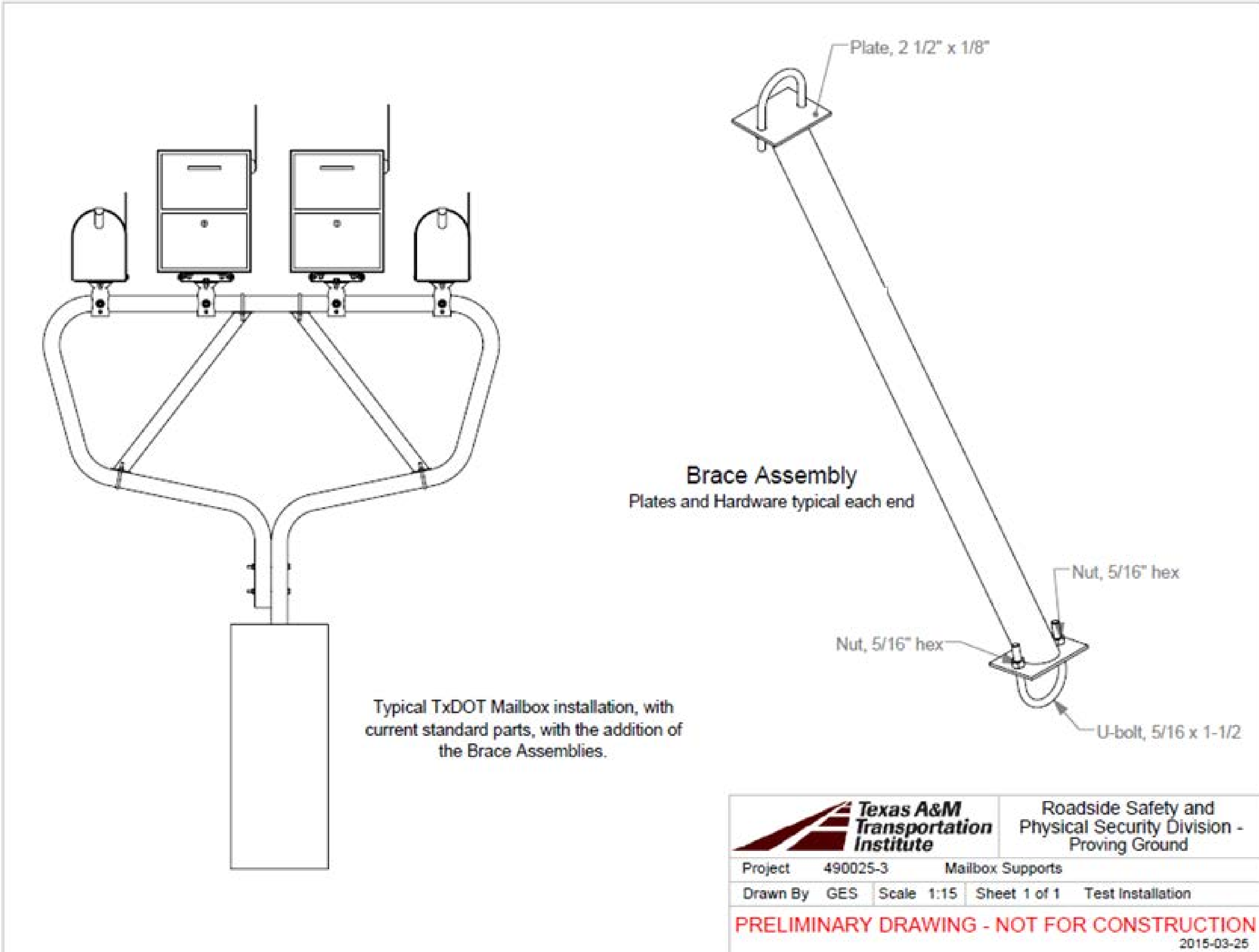


Figure 2.17. Retrofit Design 2: Brace Option.

2.2.2 Proposed New Design Options

The new design options are not as constrained as the retrofit options, which require the use and adaptation of existing hardware components. Researchers can develop a new support post rather than be restricted to modifying or adding to the existing support post. If successful, adoption of a new design would mean that a different inventory of parts might be required for installations that include secure mailboxes compared to those that only use standard mailboxes. The need for different inventory and proper design selection can be avoided if the same system is adopted for all multiple-mailbox configurations. The objective was to develop new design options that would have satisfactory impact performance and be cost-effective to fabricate and install.

2.2.2.1 New Design 1: Increased Steel Tube Thickness

In this design, the thickness of the thin-wall steel tube support post is increased to 11 gauge. The increased thickness should strengthen the support and make it more resistant to buckling and fracturing upon vehicle impact. Figure 2.18 provides details of the increased support thickness option.

2.2.2.2 New Design 2: Reverse Support Geometry. In this option, a new support post design with different geometry is proposed. More specifically, the bottom horizontal member is longer than the upper horizontal member creating a “reverse angle” on the sides of the support compared to the current design. The support post assembly is assembled for two symmetrical sections connected together at the top and bottom. The reverse angle can potentially help push the mailboxes down and in front of the vehicle rather than up and over the hood. Also, at time of contact of the support with the vehicle bumper, the mailboxes have a greater offset from the windshield, which can provide more distance to transfer forward momentum to the support system prior to contact with the windshield. In addition to the change in geometry, the support post thickness has been changed to 11 gauge (2.0-inch OD with wall thickness of 0.125 inch) similar to New Design 1. This modification should increase the strength of the support and help prevent localized buckling and fracture of the support under vehicle impact. Because the reverse geometry might make it more difficult for the support to release from its socket, the embedment has been reduced to 6 inches (from a minimum of 7 inches to a maximum of 9 inches currently used). Figure 2.19 provides details of the reverse support geometry option.

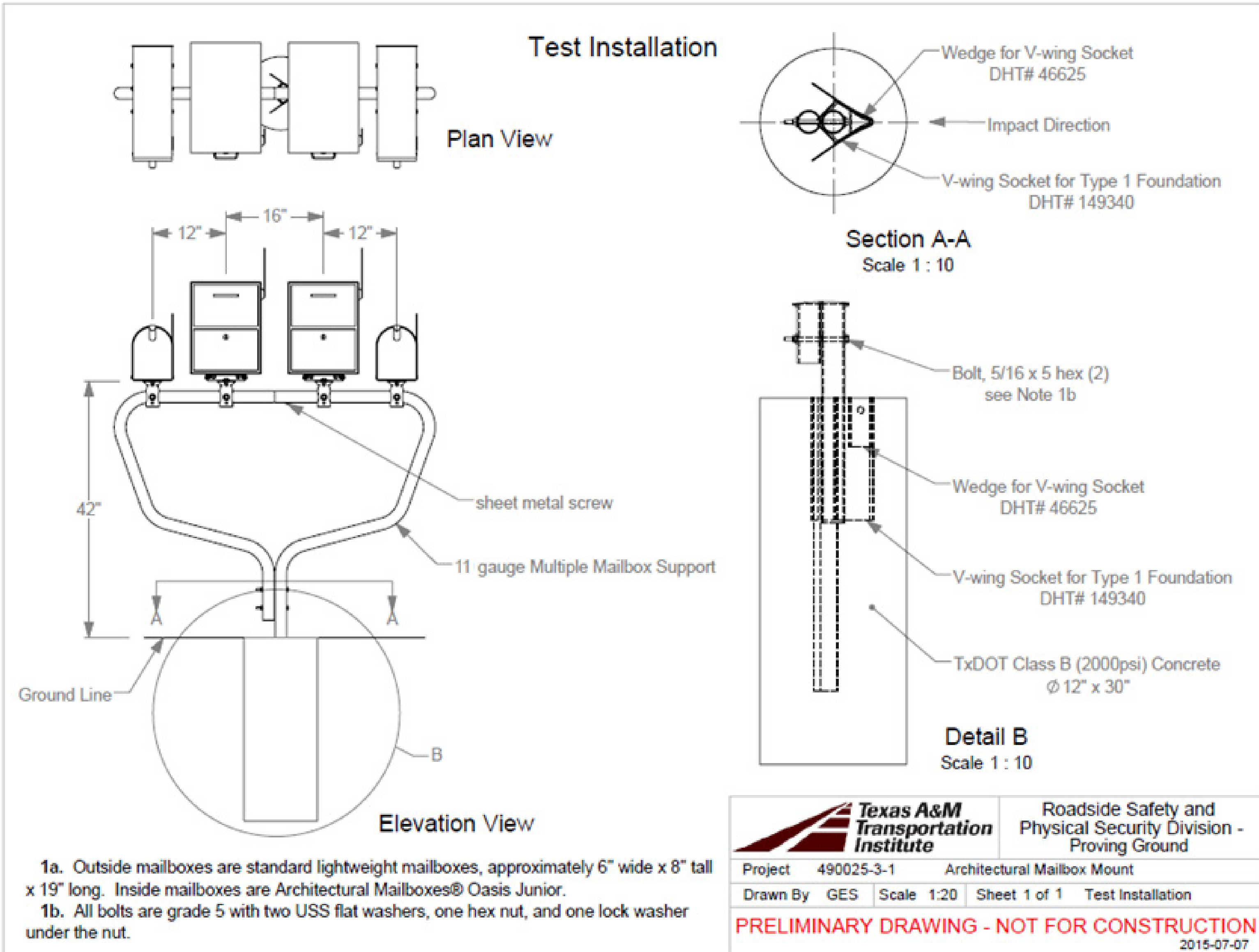


Figure 2.18. New Design 1: Increased Steel Tube Thickness.

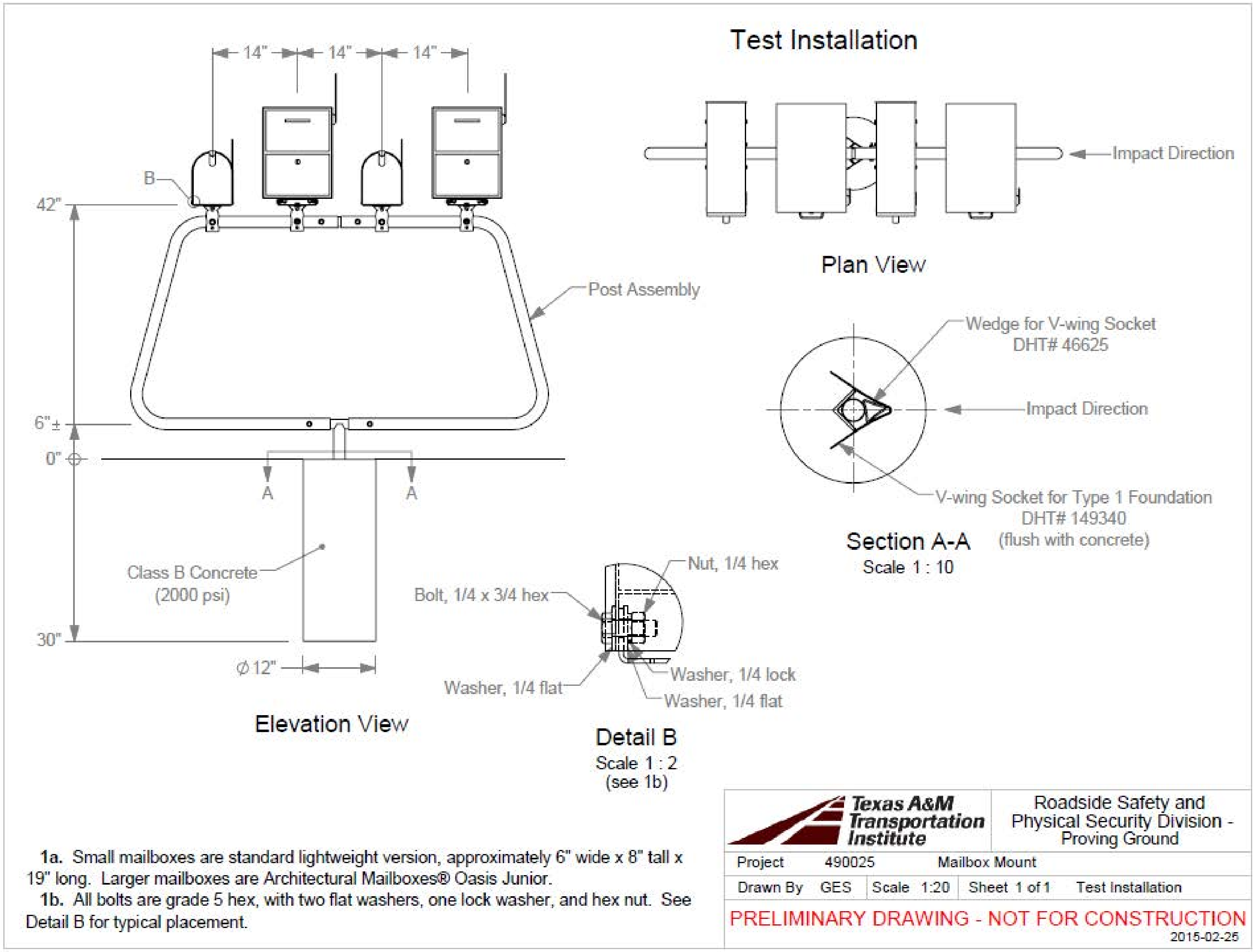


Figure 2.19. New Design 2: Reverse Geometry.

2.3 PRIORITIZATION

The design alternatives developed for a nonproprietary multiple-mailbox support system for use with lockable, secure mailboxes were critically reviewed by the TxDOT personnel. They ranked the options, giving consideration to factors such as expected impact performance, cost, constructability, installation, and maintenance. The ranking analysis resulted in the selection of one new design option and one retrofit option as follows:

1. New Design 1: Increased Steel Tube Thickness Option.
2. Retrofit Design 1: Wire Rope Option.

They further decided to reduce the embedment depth from current TxDOT standards (7-inch min; 9-inch max) to help facilitate release of the support system from the socket. Easier release of the support from the socket could reduce deformation of the support during impact and reduce the probability of support fracture. The new embedment depth was selected such that the stability and rigidity of the support under service loading is maintained.

CHAPTER 3: TEST REQUIREMENTS AND EVALUATION CRITERIA

3.1 CRASH TEST MATRIX

According to the *Manual for Assessing Safety Hardware*, three tests are recommended for evaluation of breakaway support structures to test level three (TL-3). Details of these tests are summarized below.

***MASH* Test 3-60**: A 2420-lb passenger car (denoted 1100C) impacting the support structure at a nominal speed of 19 mi/h. The purpose of this test is to evaluate the breakaway, fracture, or yielding mechanism of the support, as well as occupant risk.

***MASH* Test 3-61**: An 1100C vehicle impacting the support structure at a nominal speed of 62 mi/h. The test is intended to evaluate the behavior of the support structure, vehicle trajectory, and occupant risk during a high-speed impact.

***MASH* Test 3-62**: A 5000-lb pickup truck (denoted 2270P) impacting the support structure at a nominal speed of 62 mi/h. The test is intended to evaluate the behavior of the support structure, vehicle trajectory, and occupant risk during a high-speed impact with a light truck vehicle.

The impact performance of the multiple-mailbox support for use with lockable, secure mailboxes was evaluated using *MASH* Tests 3-60 and 3-61 with the small passenger car. The small passenger car is considered the critical design vehicle based on the mailbox mounting height that is dictated by the United States Postal Service. As shown in Figure 3.1, 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 pickup truck significantly decreases the probability of windshield impact and occupant compartment intrusion.

Figure 3.1. Vehicle/Installation Geometrics for 2270P Pickup Truck.

The crash test and data analysis procedures were in accordance with guidelines presented in *MASH*. Chapter 4 presents brief descriptions of these procedures.

3.2 EVALUATION CRITERIA

The crash tests were evaluated in accordance with applicable criteria presented in *MASH*. The performance of breakaway support structures is judged primarily on the basis of structural adequacy and occupant risk. Structural adequacy is judged on the ability of the support to readily activate in a predicable manner by breaking away, fracturing, or yielding. Occupant risk is evaluated based on factors such as occupant compartment deformation, intrusion of structural components into the vehicle windshield, vehicle stability, and occupant impact velocity. The appropriate safety evaluation criteria from Table 5-1 of *MASH* were used to evaluate the crash tests reported herein. These criteria are listed in further detail under the assessment of the crash tests.

CHAPTER 4: TEST CONDITIONS

4.1 TEST FACILITY

The full-scale crash tests reported herein were performed at the Texas A&M Transportation Institute (TTI) Proving Ground, an International Standards Organization (ISO) 17025-accredited laboratory with American Association for Laboratory Accreditation Mechanical Testing certificate 2821.01. The full-scale crash test was performed according to TTI Proving Ground quality procedures, and according to the *MASH* guidelines and standards.

The TTI Proving Ground is a 2000-acre complex of research and training facilities located 10 miles northwest of the main campus of Texas A&M University. The site, formerly a United States Army Air Corps base, has large expanses of concrete runways and parking aprons that are well suited for experimental research and testing in the areas of vehicle performance and handling, vehicle-roadway interaction, durability and efficacy of highway pavements, and safety evaluation of roadside safety hardware. The site selected for construction and testing of the multiple-mailbox supports was an out-of-service apron. The apron consists of an unreinforced jointed-concrete pavement in 12.5-ft × 15-ft blocks nominally 6 inches deep. The aprons were built in 1942, and the joints have some displacement, but are otherwise flat and level.

4.2 EVALUATION CRITERIA

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

4.3 DATA ACQUISITION SYSTEMS

4.3.1 Vehicle Instrumentation and Data Processing

Each test vehicle was instrumented with a self-contained, on-board data acquisition system. The signal conditioning and acquisition system is a 16-channel, Tiny Data Acquisition System (TDAS) Pro that Diversified Technical Systems, Inc. produced. The accelerometers, which measure the x, y, and z axes of vehicle acceleration, are strain gauge type with linear millivolt output proportional to acceleration. Angular rate sensors, measuring vehicle roll, pitch, and yaw rates, are ultra-small, solid-state units designed for crash test service. The TDAS Pro hardware and software conform to the latest SAE J211, Instrumentation for Impact Test. Each of the 16 channels is capable of providing precision amplification, scaling, and filtering based on transducer specifications and calibrations. During the test, data are recorded from each channel at a rate of 10,000 values per second with a resolution of one part in 65,536. Once data are recorded, internal batteries back these up inside the unit should the primary battery cable be severed. Initial contact of the pressure switch on the vehicle bumper provides a time zero mark and initiates the recording process. After each test, the data are downloaded from the TDAS Pro unit into a laptop computer at the test site. The Test Risk Assessment Program (TRAP) software then processes the raw data to produce detailed reports of the test results.

Each of the TDAS Pro units is returned to the factory annually for complete recalibration. Accelerometers and rate transducers are also calibrated annually with traceability to the National Institute for Standards and Technology (NIST). All accelerometers are calibrated annually according to SAE J211 *4.6.1* by means of an ENDEVCO® 2901, precision primary vibration standard. This device and its support instruments are returned to the factory annually for a NIST traceable calibration. The subsystems of each data channel are also evaluated annually, using instruments with current NIST traceability, and the results are factored into the accuracy of the total data channel, per Society of Automotive Engineers (SAE) J211. Calibrations and evaluations are also made any time data are suspect. Acceleration data are measured with an expanded uncertainty of ±1.7 percent at a confidence factor of 95 percent (k=2).

TRAP uses the data from the TDAS Pro to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 10-millisecond (ms) average ridedown acceleration. TRAP calculates change in vehicle velocity at the end of a given impulse period and computes maximum average accelerations over 50-ms intervals in each of the three directions. For reporting purposes, the data from the vehicle-mounted accelerometers are filtered with a 60-Hz digital filter, and acceleration versus time curves for the longitudinal, lateral, and vertical directions are plotted using TRAP.

TRAP uses the data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.0001-s intervals, then plots yaw, pitch, and roll versus time. These displacements are in reference to the vehicle–fixed coordinate system with the initial position and orientation of the vehicle–fixed coordinate systems being initial impact. Rate of rotation data is measured with an expanded uncertainty of ±0.7 percent at a confidence factor of 95 percent (k=2).

4.3.2 Anthropomorphic Dummy Instrumentation

An Alderson Research Laboratories Hybrid II, 50th percentile male anthropomorphic dummy, restrained with lap and shoulder belts, was placed in the driver's position of the 1100C test vehicles. The dummy was uninstrumented.

4.3.3 Photographic Instrumentation and Data Processing

Photographic coverage of each test included two high-speed cameras: one placed perpendicular to the vehicle path/installation, and a second placed to have a field of view in front of the installation at a 45-degree angle. A flashbulb activated by a pressure-sensitive tape switch was positioned on the impacting vehicle to indicate the instant of contact with the installation and was visible from each camera. The video from these high-speed cameras was analyzed to observe phenomena occurring during the collision and to obtain time–event, displacement, and angular data. A mini-digital video camera and still cameras recorded and documented conditions of the test vehicle and installation before and after the test.

CHAPTER 5: LOCKING ARCHITECTURAL AND STANDARD MAILBOXES ON MULTIPLE-MOUNT SUPPORT – DESIGN 1: 11-GAUGE STEEL TUBE WITH 4-INCH EMBEDMENT DEPTH

5.1 TEST ARTICLE DESIGN AND CONSTRUCTION

The test installation consisted of two Oasis Jr.® locking architectural mailboxes manufactured by Architectural Mailboxes, LLC, attached to the interior of the multiple-mount support with the centerline of each box located 8 inches from the centerline of the support post. Two PostMaster® Classic standard mailboxes from Solar Group, Inc., a division of Gibraltar Industries, were attached on either side of the locking mailboxes with the centerline of each box located 21 inches from the centerline of the support post. All of the mailboxes were empty.

The attachment of the locking architectural mailboxes to the horizontal segment of the thin-wall steel mounting post was accomplished using two mailbox brackets (see TxDOT Drawing DHT 148939 in Appendix A), two Part "A" angle bracket connectors (see TxDOT Drawing DHT 159489 in Appendix A), and two plate washers per mailbox. One mailbox bracket was attached flush with the bottom of the locking mailbox (flanges pointed outward) using four ⅜-inch diameter × 1¼-inch long SAE J429 Grade 5 bolts using existing holes in the mailbox and bracket. A 2-inch wide × 5½-inch long × ⅛-inch thick ASTM A36 plate washer was positioned over the bracket at each end to help strengthen the connection and prevent pullout of the bolts during impact. A ⅜-inch flat washer, a lock washer, and a nut were used for each bolt.

The two angle bracket connectors were attached to the second mailbox bracket using a ⅜-inch diameter × 1-inch long SAE J429 Grade 5 bolt through existing slots in the mailbox bracket. The flanges of the second mailbox bracket faced away from the angle bracket connectors. The two mailbox brackets were then nested together and connected using four ¼-inch diameter × ¾-inch long SAE J429 Grade 5 bolts on each side using hand holes through the bottom of the bracket. A hole was drilled through the horizontal section of the thin-wall steel tube support post at the desired mailbox position. The angle connection brackets were clamped to the thin-wall steel tube support using a ⅜-inch diameter × 4-inch long SAE J429 Grade 5 bolt through the support post and connection brackets.

The standard mailboxes were attached to the horizontal segment of the 11-gauge steel mounting post using a mailbox bracket (see TxDOT Drawing DHT 148939 in Appendix A) and two Part "A" angle bracket connectors (see TxDOT Drawing DHT 159489 in Appendix A) per mailbox. The two angle bracket connectors were attached to the mailbox bracket using a ⅜-inch diameter × 1-inch long SAE J429 Grade 5 bolt through existing slots in the mailbox bracket. The flanges of the mailbox bracket faced away from the angle bracket connectors. The mailbox bracket was nested inside the flanges at the bottom of the mailbox and connected to the mailbox with three ¼-inch diameter × ¾-inch long SAE J429 Grade 5 bolts on each side. A hole was drilled through the horizontal section of the thin-wall steel tube support post at the desired mailbox position. The angle connection brackets were clamped to the thin-wall steel tube support using a ⅜-inch diameter × 4-inch long SAE J429 Grade 5 bolt through the support post and connection brackets.

The 11-gauge steel tube multiple-mailbox support post was formed from 2-inch OD × 0.125-inch thick welded mechanical tubing. The support post had outwardly sloping sides and a horizontal section on top to which the mailboxes were attached. The support had an overall width of 53¼ inches and weighed 30.2 lb.

The longer end of the support was inserted approximately 4 inches into a V-wing socket (see TxDOT Drawing DHT 160446 in Appendix A), which was embedded flush with the top of a non-reinforced concrete footing that was approximately 12 inches in diameter × 30 inches deep. The reduced embedment depth of 4 inches was chosen to facilitate the support system's release from the socket. The 4 inch embedment depth was proven to maintain support system stability and rigidity under service loading based on field experiments with the test installation. The concrete for the footing was specified as Class B with a minimum 28-day unconfined compressive strength of 2000 psi. A triangular wedge (see TxDOT Drawing DHT 46625 in Appendix A) was driven into the V-wing socket on the impact side of the support post to secure it inside the foundation.

The total weight of the four mailboxes, connection hardware, and post assembly was 99.8 lb. Figure 5.1 shows details of the test installation. Details of the connections for both the architectural locking and standard mailbox assemblies are depicted in Figure 5.2. Figure 5.3 provides details of the mailbox support geometry. Figure 5.4 presents photographs of the completed test installation.

5.2 *MASH* TEST 3-61 (CRASH TEST NO. 490025-3-2)

5.2.1 Test Designation and Actual Impact Conditions

MASH Test 3-61 involves an 1100C passenger car weighing 2420 lb ±55 lb and impacting the support structure at an impact speed of 62 mi/h ±2.5 mi/h and a critical impact angle of 0 degrees ±1.5 degrees. The target impact point was 10 inches to the right of the vehicle centerline with the center of the mailbox support post with the mailboxes oriented perpendicular to the path of the vehicle. The 2009 Kia Rio used in the test weighed 2434 lb. The actual impact speed and angle were 64.1 mi/h and 0 degrees, respectively. The actual impact point was 10 inches to the right of the vehicle centerline.

5.2.2 Test Vehicle

Figures 5.5 and 5.6 show the 2009 Kia Rio used for the crash test. Test inertia weight of the vehicle was 2434 lb, and its gross static weight was 2599 lb. The height to the lower edge of the vehicle bumper was 9.5 inches, and the height to the upper edge of the bumper was 21.5 inches. Table B.1 in Appendix B.1 gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

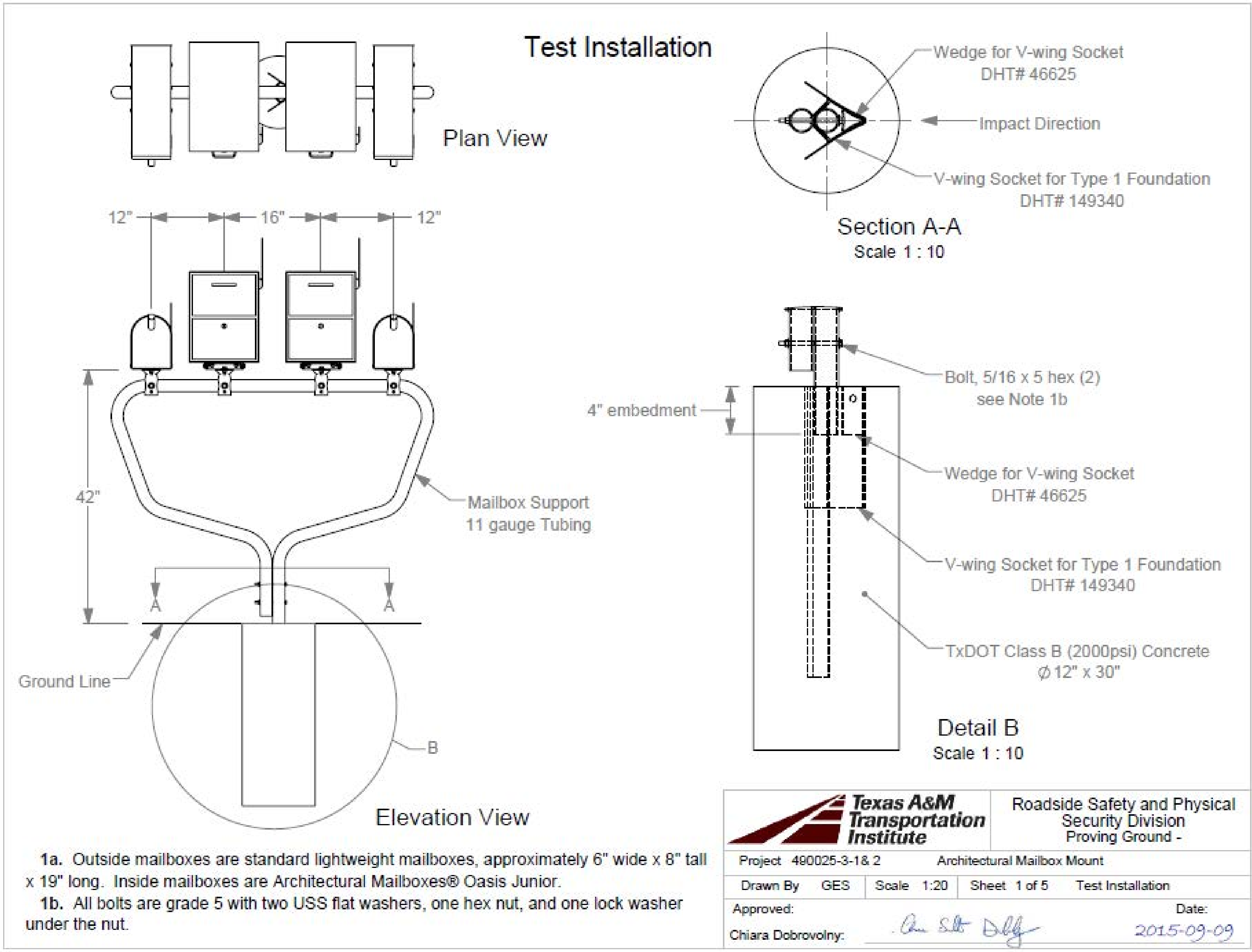


Figure 5.1. Details of the Locking Architectural and Standard Mailboxes 11-Gauge Support Installation.

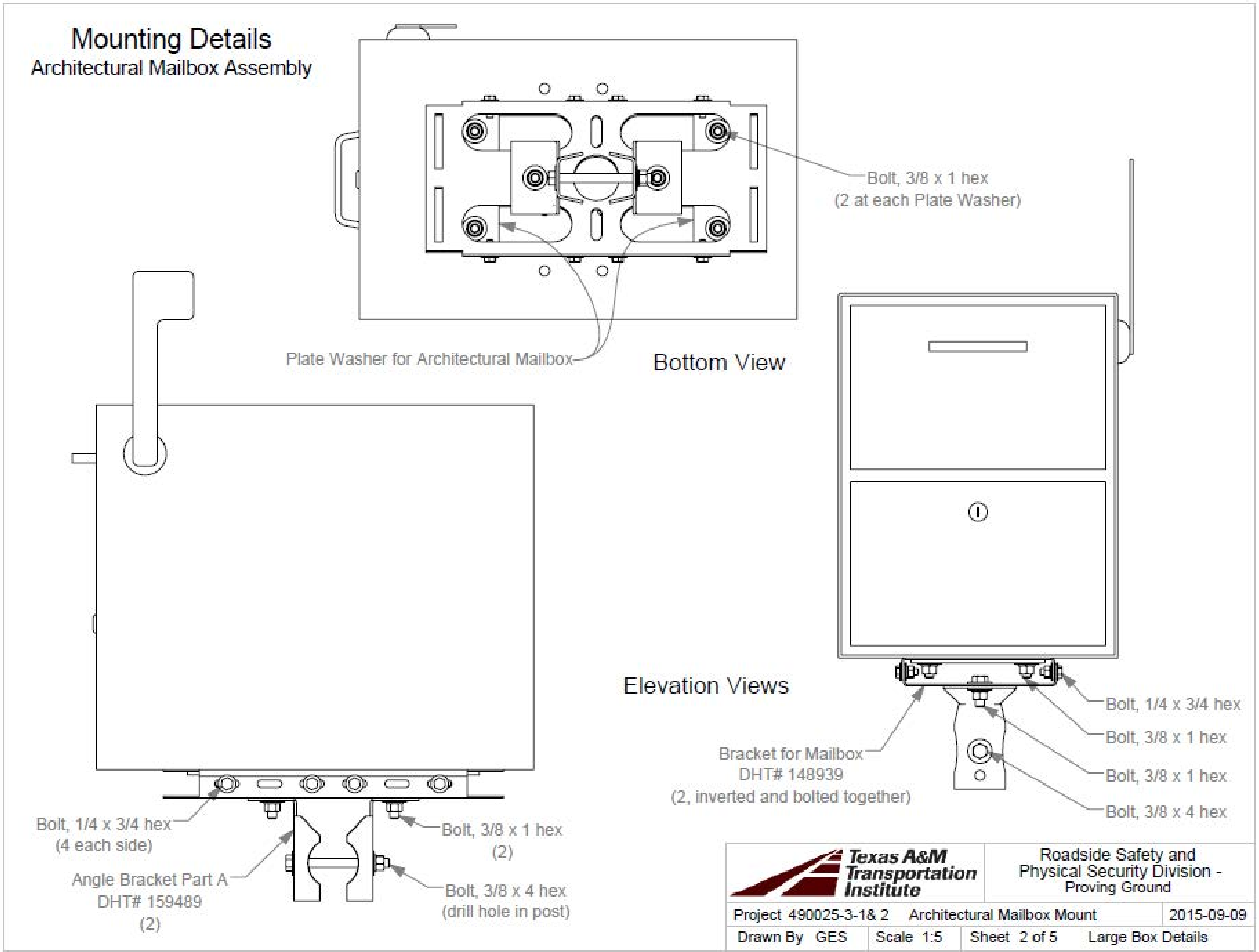


Figure 5.2. Connection Details for Locking Architectural and Standard Mailboxes Assemblies.

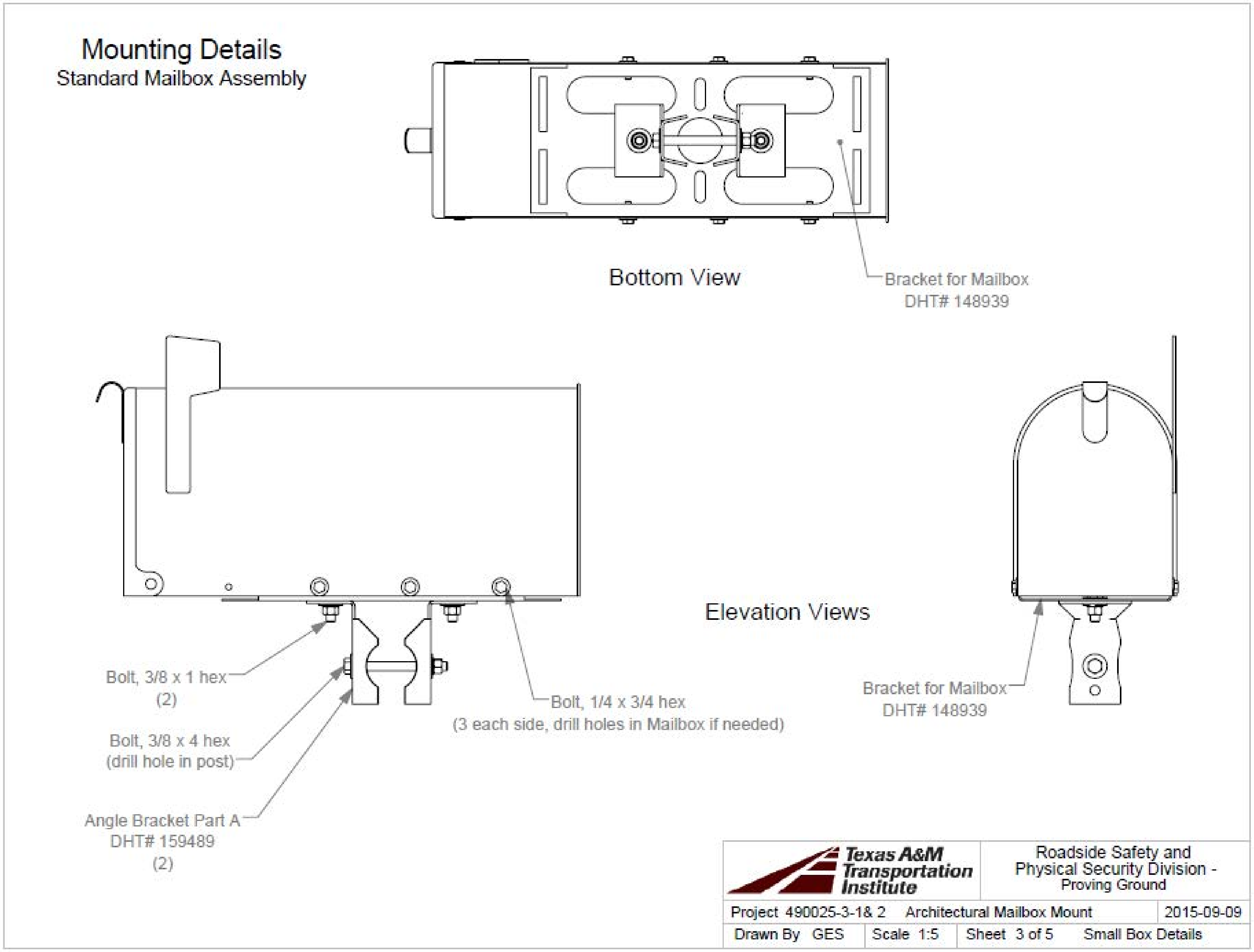


Figure 5.2. Connection Details for Locking Architectural and Standard Mailboxes Assemblies (Continued).

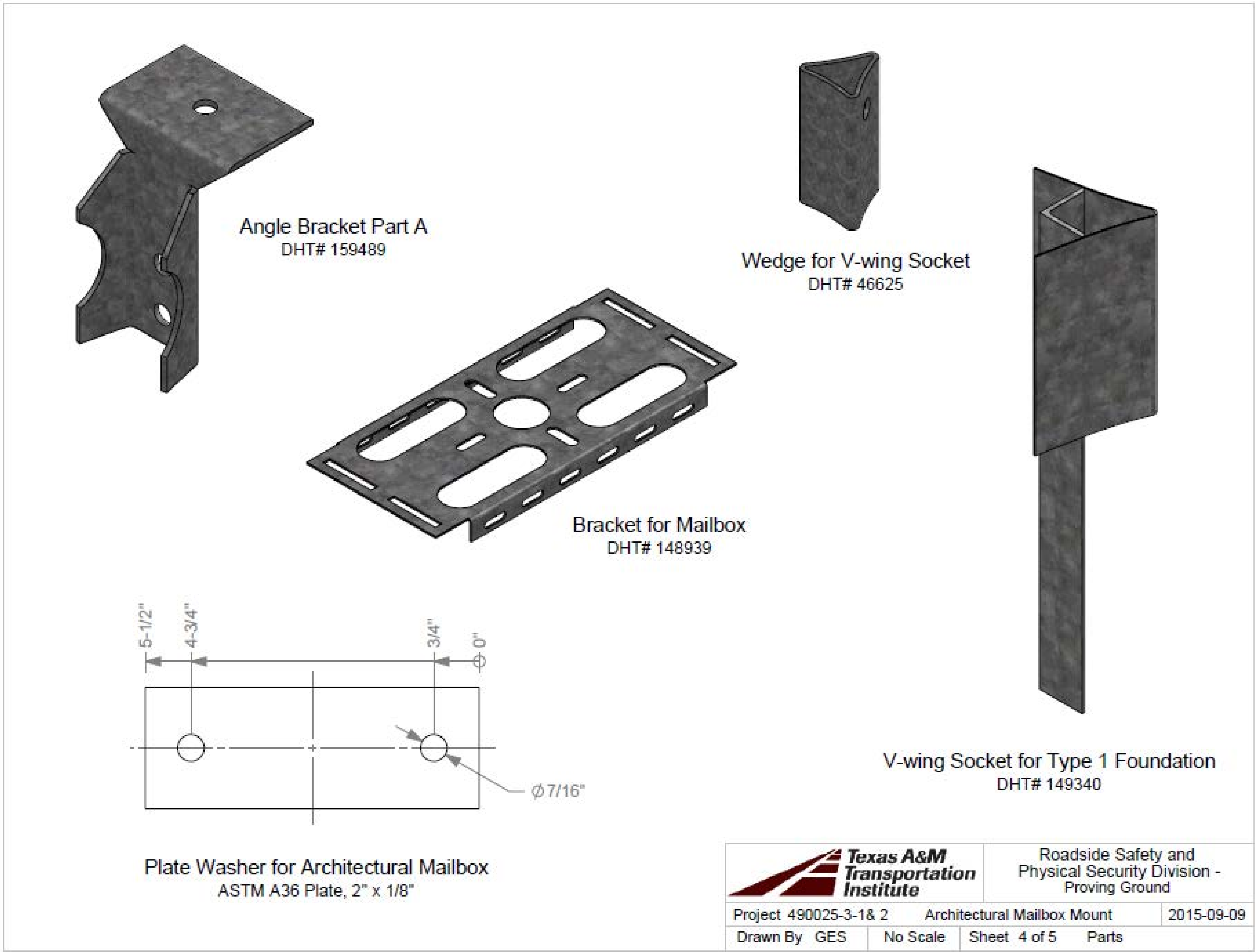


Figure 5.2. Connection Details for Locking Architectural and Standard Mailboxes Assemblies (Continued).

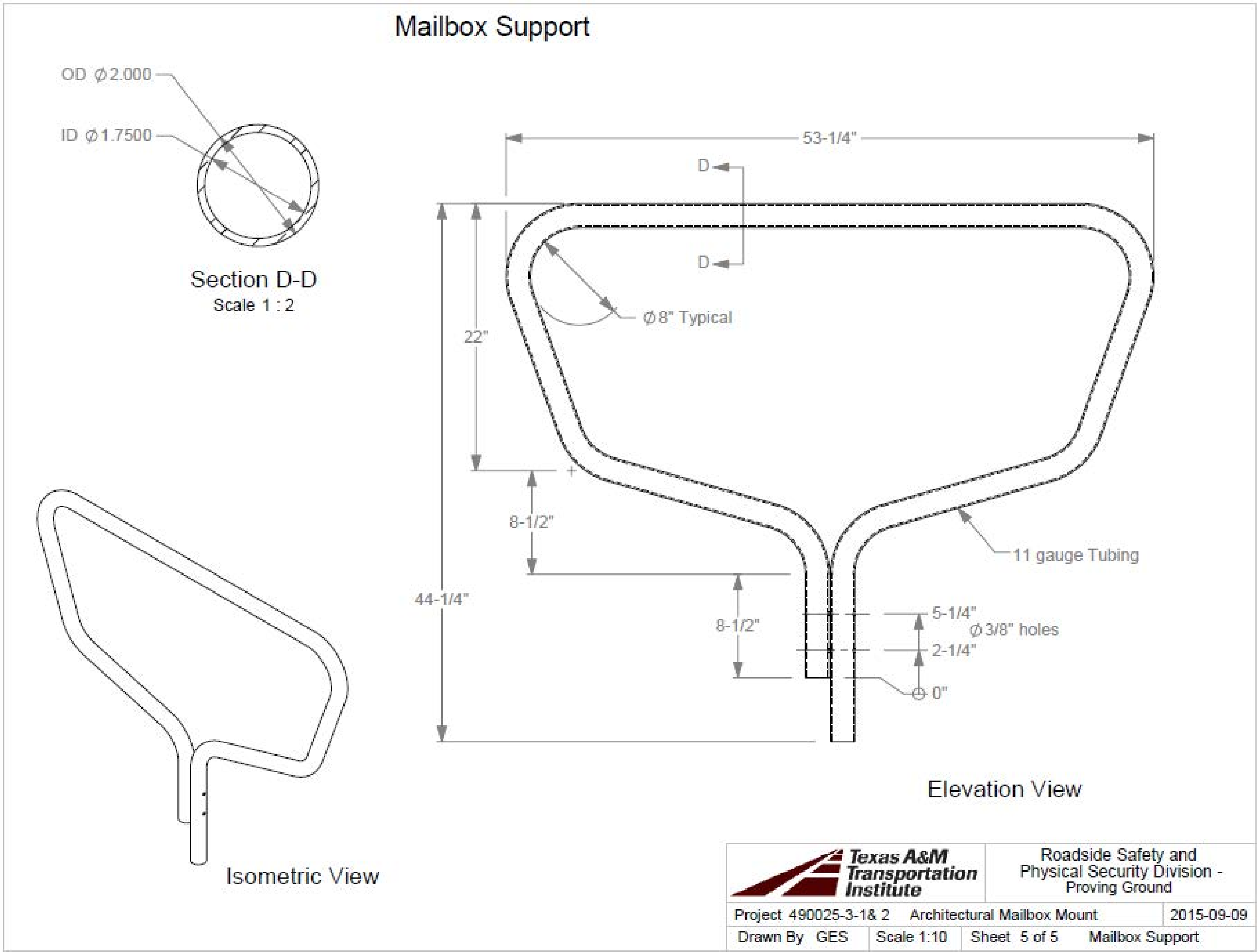


Figure 5.3. Details of 11-Gauge Steel Tube Multiple Mailbox Support Geometry.

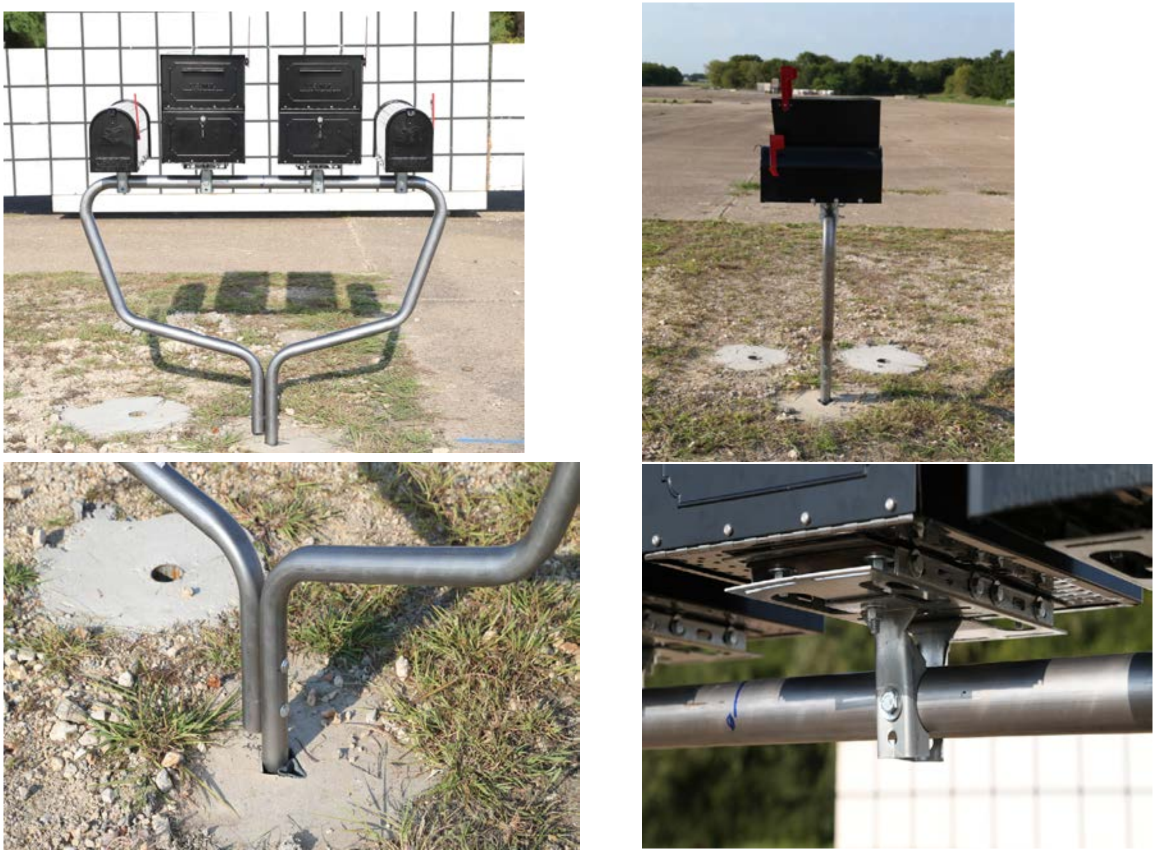


Figure 5.4. Locking Architectural and Standard Mailboxes on 11-Gauge Steel Tube Multiple Mailbox Support before Testing.

Figure 5.5. Vehicle/Installation Geometrics for Test No. 490025-3-2.

Figure 5.6. Vehicle before Test No. 490025-3-2.

5.2.3 Weather Conditions

The test was performed on the morning of August 25, 2015. Weather conditions at the time of testing were as follows: (a) wind speed: 5 mi/h; (b) wind direction: 289 degrees with respect to the vehicle (vehicle was traveling in a southerly direction); (c) temperature: 93°F; (d) relative humidity: 57 percent.

5.2.4 Test Description

The 2009 Kia Rio, traveling at an impact speed of 64.1 mi/h, impacted the multiple-mount post with two locking architectural mailboxes and two standard mailboxes at 0 degrees, with the centerline of the support aligned at 10 inches to the right of the vehicle centerline. At approximately 0.025 s after impact, the support post lifted and was fully out of the socket. At 0.082 s, the mailboxes and support post began to rotate away and separate from the vehicle. At 0.209 s, the support and mailbox system were 77 inches above ground (19 inches above the vehicle roof), while the vehicle was traveling at a speed of 62.5 mi/h. Brakes on the vehicle were applied 1.7 s after impact, and the vehicle came to rest 306 ft downstream of impact. Figure B.1 in Appendix B.2 shows sequential photographs of the test period.

5.2.5 Damage to Test Installation

Figures 5.7 and 5.8 show the damage to the multiple-mailbox support installation. The support post lifted out of the socket as designed. The support post and the mailboxes were deformed, as were the brackets attaching the mailboxes to the support post. The mailboxes remained attached to the support post and the assembly came to rest behind the vehicle 184 ft downstream and 4 ft left of impact, with the support base pointing left relative to the vehicle path.

5.2.6 Damage to Test Vehicle

Figure 5.9 shows damage to the exterior of the vehicle, and Figure 5.10 shows the interior of the vehicle after the test. The hood, bumper, and grill were deformed. The maximum hood deformation was 8 inches. There was no contact of any components of the mailbox system with the windshield. Tables B.2 and B.3 in Appendix B.1 provide exterior crush and occupant compartment measurements, respectively.

Figure 5.7. Vehicle/Installation Positions after Test No. 490025-3-2.

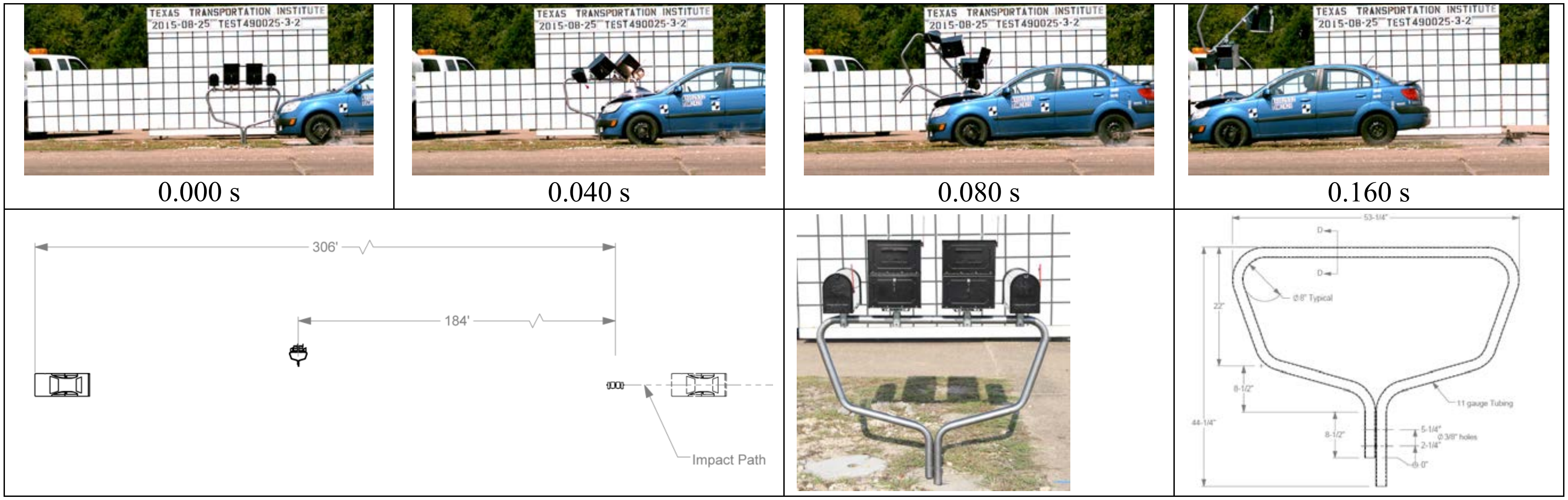
Figure 5.8. Installation after Test No. 490025-3-2.

Figure 5.9. Vehicle after Test No. 490025-3-2.

Figure 5.10. Interior of Vehicle after Test No. 490025-3-2.

5.2.7 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk. In the longitudinal direction, the occupant impact velocity (OIV) was 3.94 ft/s at 0.566 s, the highest 0.010-s occupant ridedown acceleration was 0.2 *g* from 0.575 to 0.585 s, and the maximum 0.050-s average acceleration was −2.5 *g* between 0.0017 and 0.0517 s. In the lateral direction, the OIV was 0.66 ft/s at 0.566 s, the highest 0.010-s occupant ridedown acceleration was 0.3 *g* from 0.6066 to 0.6166 s, and the maximum 0.050-s average was 0.3 *g* between 0.0424 and 0.0924 s. Theoretical Head Impact Velocity (THIV) was 4.4 km/h or 1.2 m/s at 0.566 s; Post-Impact Head Decelerations (PHD) was 0.3 *g* between 0.5763 and 0.5863 s; and Acceleration Severity Index (ASI) was 0.23 between 0.0215 and 0.0715 s. Figure 5.11 summarizes these data and other pertinent information from the test. Figure B.2 in Appendix B.3 shows the vehicle angular displacements, and Figures B.3 through B.8 in Appendix B.4 show accelerations versus time traces.



General Information	
Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	MASH Test 3-61
TTI Test No.	490025-3-2
Test Date	2015-08-25
Test Article	
Type	11-gauge Steel Multiple Mailbox Support
Name	Locking Architectural and Standard Mailboxes on 11-gauge Steel Tube Multiple Mailbox Support
Installation Height	42 inches (grade to bottom of boxes)
Material or Key Elements	Two locking mailboxes and two standard mailboxes on formed 11-gauge tube support; V-loc wedge and socket in concrete footing
Soil Type and Condition	Concrete footing in crushed limestone, dry
Test Vehicle	
Type/Designation	1100C
Make and Model	2009 Kia Rio
Curb	2479 lb
Test Inertial	2434 lb
Dummy	165 lb
Gross Static	2599 lb

Impact Conditions	
Speed	64.1 mi/h
Angle	0 degrees
Location/Orientation	Perpendicular
Exit Conditions	
Speed	62.5 mi/h
Angle	0 degrees
Occupant Risk Values	
Occupant Impact Velocity	
Longitudinal	3.94 ft/s
Lateral	0.66 ft/s
Ridedown Accelerations	
Longitudinal	0.2 g
Lateral	0.3 g
THIV	4.4 km/h (1.2 m/s)
PHD	0.3 g
ASI	0.23
Max. 0.050-s Average	
Longitudinal	−2.5 g
Lateral	0.3 g
Vertical	1.1 g

Post-Impact Trajectory	
Stopping Distance	306 ft downstream
Vehicle Stability	
Maximum Yaw Angle	5.3 degrees
Maximum Pitch Angle	2.2 degrees
Maximum Roll Angle	2.7 degrees
Vehicle Snagging	NA
Vehicle Pocketing	NA
Debris Pattern	
Longitudinal	184 ft
Lateral	4 ft
Vehicle Damage	
VDS	12FR2
CDC	12FREN2
Max. Exterior Deformation	8 inches
OCDI	FS0000000
Max. Occupant Compartment Deformation	None

Figure 5.11. Summary of Results for *MASH* Test 3-61 on the Locking Architectural and Standard Mailboxes on 11-Gauge Steel Tube Multiple Mailbox Support.

5.2.8 Assessment of Test Results

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

5.2.8.1 Structural Adequacy

B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.

Results: The multiple-mount post with attached locking architectural and standard mailboxes activated by yielding to the vehicle and lifting out of the foundation socket. (PASS)

5.2.8.2 Occupant Risk

D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.
Deformation of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH. (roof ≤4.0 inches; windshield = ≤3.0 inches; side windows = no shattering by test article structural member; wheel/foot well/toe pan ≤9.0 inches; forward of A-pillar ≤12.0 inches; front side door area above seat ≤9.0 inches; front side door below seat ≤12.0 inches; floor pan/transmission tunnel area ≤12.0 inches).

Results: The locking architectural and the standard mailboxes remained together and attached to the support post. The mailbox installation did not penetrate or show potential for penetrating the occupant compartment, nor presenting a hazard to others in the area. (PASS)
Results: No occupant compartment deformation occurred. (PASS)

F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.

Results: The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 2.7 degrees and 2.2 degrees, respectively. (PASS)

H. Occupant impact velocities should satisfy the following:
Longitudinal and Lateral Occupant Impact Velocity

Preferred	*Maximum*
10 ft/s	*16.4 ft/s*

Results: Longitudinal OIV was 3.94 ft/s, and lateral OIV was 0.66 ft/s. (PASS)

I. Occupant ridedown accelerations should satisfy the following:
Longitudinal and Lateral Occupant Ridedown Accelerations

Preferred	*Maximum*
15.0 g	*20.49 g*

Results: Longitudinal ridedown acceleration was 0.2 g, and lateral ridedown acceleration was 0.3 g. (PASS)

5.2.8.3 Vehicle Trajectory

N. Vehicle trajectory behind the test article is acceptable.

Result: The 1100C vehicle came to rest downstream and in line with the original position of the mailbox installation. (PASS)

5.3. *MASH* TEST 3-60 (CRASH TEST NO. 490025-3-1)

5.3.1 Test Designation and Actual Impact Conditions

MASH Test 3-60 involves an 1100C passenger car weighing 2420 lb ±55 lb impacting the support structure at an impact speed of 19 mi/h ±2.5 mi/h and a critical impact angle of 0 degrees ±1.5 degrees. The target impact point was 10 inches to the right of the vehicle centerline with the center of the mailbox support post, with the mailboxes oriented perpendicular to the path of the vehicle. The 2009 Kia Rio used in the test weighed 2427 lb, and the actual impact speed and angle were 19.4 mi/h and 0 degrees. The actual impact point was 10 inches to the right of the vehicle centerline.

5.3.2 Test Vehicle

Figures 5.12 and 5.13 show the 2009 Kia Rio used for the crash test. Test inertia weight of the vehicle was 2427 lb, and its gross static weight was 2598 lb. The height to the lower edge of the vehicle bumper was 9.5 inches, and the height to the upper edge of the bumper was 21.5 inches. Table C.1 in Appendix C.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.

5.3.3 Weather Conditions

The test was performed on the afternoon of August 25, 2015. Weather conditions at the time of testing were as follows: (a) wind speed: 12 mi/h; (b) wind direction: 188 degrees with respect to the vehicle (vehicle was traveling in a southerly direction); (c) temperature: 87°F; (d) relative humidity: 62 percent.

Figure 5.12. Vehicle/Installation Geometrics for Test No. 490025-3-1.

Figure 5.13. Vehicle before Test No. 490025-3-1.

5.3.4 Test Description

The 2009 Kia Rio, traveling at an impact speed of 19.4 mi/h, impacted the multiple-mount post with two locking architectural and two standard mailboxes at 0 degrees with the centerline of the support aligned at 10 inches right from the centerline of the vehicle. At approximately 0.068 s after impact, the support post began to pull out of the socket, and at 0.090 s, it was completely out of the socket and being pushed forward by the vehicle. At 0.100 s, the mailbox support lost contact with the hood and continued to travel downstream from the impact location with the vehicle traveling at a speed of 17.0 mi/h. The mailbox support contacted the ground surface at 0.192 s. Brakes on the vehicle were applied 3.3 s after impact, and the vehicle came to rest 90 ft downstream of impact with the mailbox support behind the vehicle. Figure C.1 in Appendix C.2 shows sequential photographs of the test period.

5.3.5 Damage to Test Installation

Figures 5.14 and 5.15 show the damage to the locking architectural multiple-mailbox installation. The support post lifted out of the socket as designed. The support post was kinked and flattened at its lower 4 inches on the vertical stub, but was otherwise undamaged. The mailboxes remained attached to the support post and the assembly came to rest behind the vehicle 50 ft downstream of impact and 11 ft to the right, with the base of the support pointing downstream-left at approximately 45 degrees.

Figure 5.14. Vehicle/Installation Positions after Test No. 490025-3-1.

Figure 5.15. Installation after Test No. 490025-3-1.

5.3.6 Vehicle Damage

Figure 5.16 shows damage to the exterior of the vehicle, and Figure 5.17 shows the interior of the vehicle after the test. The hood and bumper were deformed. The maximum hood deformation was 3.25 inches. There was no contact of any components of the mailbox system with the windshield. Tables C.2 and C.3 in Appendix C.1 provide exterior crush and occupant compartment measurements, respectively.

5.3.7 Occupant Risk Factors

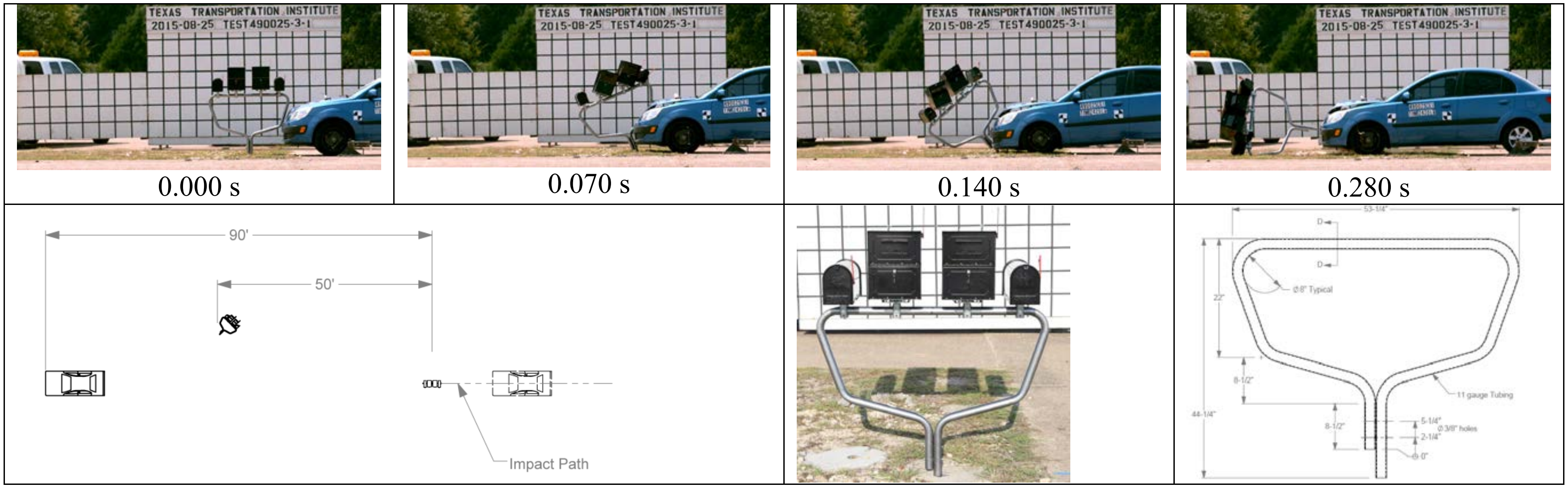
Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk. In the longitudinal direction, the OIV was 3.94 ft/s at 0.5981 s, the highest 0.010-s occupant ridedown acceleration was 0.1 g from 0.6448 to 0.6548 s, and the maximum 0.050-s average acceleration was -1.5 g between 0.0340 and 0.0840 s. In the lateral direction, the OIV was 1.64 ft/s at 0.5981 s, the highest 0.010-s occupant ridedown acceleration was 0.2 g from 0.8874 to 0.8974 s, and the maximum 0.050-s average was 0.4 g between 0.0883 and 0.1383 s. THIV was 4.7 km/h or 1.3 m/s at 0.6011 s; PHD was 0.2 g between 0.8872 and 0.8972 s; and ASI was 0.15 between 0.0618 and 0.1118 s. Figure 5.18 summarizes these data and other pertinent information from the test. Figure C.2 in Appendix C.3 shows the vehicle angular displacements, and Figures C.3 through C.8 in Appendix C.4 show accelerations versus time traces.


Figure 5.16. Vehicle after Test No. 490025-3-1.

Before Test

After Test

Figure 5.17. Interior of Vehicle for Test No. 490025-3-1.



General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	MASH Test 3-60
TTI Test No.	490025-3-1
Test Date	2015-08-25

Test Article

Type	11-gauge Steel Multiple Mailbox Support
Name	Locking Architectural and Standard Mailboxes on 11-gauge Steel Tube Multiple Mailbox Support
Installation Height	42 inches (grade to bottom of boxes)
Material or Key Elements	Two locking mailboxes and two standard mailboxes on formed 11-gauge tube support; V-loc wedge and socket in concrete footing
Soil Type and Condition	Concrete footing in crushed limestone, dry

Test Vehicle

Type/Designation	1100C
Make and Model	2009 Kia Rio
Curb	2388 lb
Test Inertial	2427 lb
Dummy	165 lb
Gross Static	2598 lb

Impact Conditions

Speed	19.4 mi/h
Angle	0 degrees
Location/Orientation	Perpendicular

Exit Conditions

Speed	17.0 mi/h
Angle	0 degrees

Occupant Risk Values

Occupant Impact Velocity	
Longitudinal	3.94 ft/s
Lateral	1.64 ft/s
Ridedown Accelerations	
Longitudinal	0.1 G
Lateral	0.2 G
THIV	4.7 km/h (1.3 m/s)
PHD	0.2 G
ASI	0.15
Max. 0.050-s Average	
Longitudinal	−1.5 G
Lateral	0.4 G
Vertical	−0.9 G

Post-Impact Trajectory

Stopping Distance	90 ft downstream

Vehicle Stability

Maximum Yaw Angle	4 degrees
Maximum Pitch Angle	2.5 degrees
Maximum Roll Angle	1.9 degrees
Vehicle Snagging	NA
Vehicle Pocketing	NA

Debris Pattern

Longitudinal	50 ft
Lateral	11 ft

Vehicle Damage

VDS	12FR1
CDC	12FREN1
Max. Exterior Deformation	3.25 inches
OCDI	FS0000000
Max. Occupant Compartment Deformation	None

Figure 5.18. Summary of Results for *MASH* Test 3-60 on the Locking Architectural and Standard Mailboxes on 11-Gauge Steel Tube Multiple Mailbox Support.

5.3.8 Assessment of Test Results

An assessment of the test based on the applicable *MASH* safety evaluation criteria for Test 3-60 is provided below.

5.3.8.1 Structural Adequacy

B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.

<u>Results</u>: The multiple-mount post with attached the locking architectural and standard mailboxes activated by yielding to the vehicle and lifting out of the foundation socket. (PASS)

5.3.8.2 Occupant Risk

D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.
Deformation of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH. (roof ≤4.0 inches; windshield = ≤3.0 inches; side windows = no shattering by test article structural member; wheel/foot well/toe pan ≤9.0 inches; forward of A-pillar ≤12.0 inches; front side door area above seat ≤9.0 inches; front side door below seat ≤12.0 inches; floor pan/transmission tunnel area ≤12.0 inches).

<u>Results</u>: The locking architectural and the standard mailboxes remained attached to the support post. The mailbox installation did not penetrate or show potential for penetrating the occupant compartment, nor present hazard to others in the area. (PASS)
<u>Results</u>: No occupant compartment deformation occurred. (PASS)

F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.

<u>Results</u>: The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.9 degrees and 2.5 degrees, respectively. (PASS)

H. Occupant impact velocities should satisfy the following:
Longitudinal and Lateral Occupant Impact Velocity

<u>Preferred</u>	*<u>Maximum</u>*
10 ft/s	*16.4 ft/s*

Results: Longitudinal OIV was 3.94 ft/s, and lateral OIV was 1.64 ft/s. (PASS)

I. Occupant ridedown accelerations should satisfy the following:

Longitudinal and Lateral Occupant Ridedown Accelerations

Preferred	*Maximum*
15.0 g	*20.49 g*

Results: Longitudinal ridedown acceleration was 0.1 g, and lateral ridedown acceleration was 0.2 g. (PASS)

5.3.8.3 Vehicle Trajectory

N. Vehicle trajectory behind the test article is acceptable.

Result: The 1100C vehicle came to rest downstream and in line with the original position of the mailbox installation. (PASS)

CHAPTER 6: LOCKING ARCHITECTURAL AND STANDARD MAILBOXES ON MULTIPLE-MOUNT SUPPORT – DESIGN 2: 16-GAUGE STEEL TUBE WITH INTERNAL ¼-INCH DIAMETER WIRE ROPE AND 6-INCH EMBEDMENT DEPTH

6.1 TEST ARTICLE DESIGN AND CONSTRUCTION

The test installation consisted of two Oasis Jr.® locking architectural mailboxes manufactured by Architectural Mailboxes, LLC, attached to the interior of the multiple-mount support with the centerline of each box located 8 inches from the centerline of the support post. Two PostMaster® Classic standard mailboxes from Solar Group, Inc., a division of Gibraltar Industries, were attached on either side of the locking mailboxes with the centerline of each box located 21 inches from the centerline of the support post. All of the mailboxes were empty.

The attachment of the locking architectural mailboxes to the horizontal segment of the thin-wall steel mounting post was accomplished using two mailbox brackets (see TxDOT Drawing DHT 148939 in Appendix A), two Part "A" angle bracket connectors (see TxDOT Drawing DHT 159489 in Appendix A), and two plate washers per mailbox. One mailbox bracket was attached flush with the bottom of the locking mailbox (flanges pointed outward) using four ⅜-inch diameter × 1¼-inch long SAE Grade 5 bolts using existing holes in the mailbox and bracket. A 2-inch wide × 5½-inch long × ⅛-inch thick ASTM A36 steel plate washer was positioned over the bracket at each end to help strengthen the connection and prevent pullout during impact. A ⅜-inch flat washer, lock washer, and nut were used for each bolt.

The two angle bracket connectors were attached to the second mailbox bracket using a ⅜-inch diameter × 1-inch long SAE Grade 5 bolt through existing slots in the mailbox bracket. The flanges of the second mailbox bracket faced away from the angle bracket connectors. The two mailbox brackets were then nested together with flanges overlapping and connected to one another using four ¼-inch diameter × ¾-inch long SAE Grade 5 bolts on each side using hand holes through the bottom of the bracket. A hole was drilled through the horizontal section of the thin-wall steel tube support post at the desired mailbox position. The angle connection brackets were clamped to the thin-wall steel tube support using a ⅜-inch diameter × 4-inch long SAE Grade 5 bolt through the support post and connection brackets.

The standard mailboxes were attached to the horizontal segment of the 16-gauge steel mounting post using a mailbox bracket (see TxDOT Drawing DHT 148939 in Appendix A) and two Part "A" angle bracket connectors (see TxDOT Drawing DHT 159489 in Appendix A) per mailbox. The two angle bracket connectors were attached to the mailbox bracket using a ⅜-inch diameter × 1-inch long SAE Grade 5 bolt through existing slots in the mailbox bracket. The flanges of the mailbox bracket faced away from the angle bracket connectors. The mailbox bracket was nested inside the flanges at the bottom of the mailbox and connected together with three ¼-inch diameter × ¾-inch long SAE Grade 5 bolts on each side. A hole was drilled through the horizontal section of the thin-wall steel tube support post at the desired mailbox position. The angle connection brackets were clamped to the thin-wall steel tube support using a ⅜-inch diameter × 4-inch long SAE Grade 5 bolt through the support post and connection brackets.

The 16-gauge steel tube multiple-mailbox support post was formed from 2-inch OD × 0.0625-inch thick galvanized welded mechanical tubing. The support post had outwardly sloping sides and a horizontal section on top to which the mailboxes were attached. The support had an overall width of 55½ inches and weighed 19.4 lb. The shorter end of the bent support post was bolted to the longer end using two $^{5}/_{16}$-inch diameter × 5-inch long SAE Grade 5 bolts.

A ¼-inch diameter wire rope was inserted through the support post and secured at both ends of the support using a plate washer and ¼-inch wire rope clamps. The ends of the wire rope passed through a hole in the plate washer and a clamp was used at each end to secure the position of the cable. At the shorter support end, the wire rope was doubled and the tag end was stuck inside the tubing. At the longer support end, the wire rope was not doubled. A short piece was added to allow the wire rope clip to function properly. The wire rope was added to keep the support together as a connected system in the event of support rupture during impact, thus preventing parts of the support system from behaving independently and constituting a hazard to the vehicle and its occupants.

The longer end of the support was inserted approximately 6 inches into a V-wing socket (see TxDOT Drawing DHT 160446 in Appendix A) that was embedded flush with the top of a non-reinforced concrete footing that was approximately 12 inches in diameter × 30 inches deep. A reduced embedment depth of 6 inches was chosen to facilitate release of the support system from the socket. Tests 490025-3-1 and 490025-3-2 were conducted with the 2-inch diameter support embedded only 4 inches in the socket. When the 2-inch OD 16-gauge tube was embedded 4 inches, it did not maintain structural stability and rigidity. When the embedment depth was increased to 6 inches, the 16-gauge support post was stable and rigid within the socket under service loading. The discrepancy in required embedment depth for the two systems was determined to be the result of variations in the dimensions of the supplied triangular wedges. Full-scale crash tests 490025-3-3 and 490025-3-4 were conducted with the test article embedded 6 inches in the socket. Additional analyses were performed to develop implementation recommendations regarding allowable wedge dimension tolerances. The concrete for the footing was specified as Class B with a minimum 28-day unconfined compressive strength of 2000 psi. A triangular wedge (see TxDOT Drawing DHT 46625 in Appendix A) was driven into the V-wing socket on the impact side of the support post to secure it inside the foundation.

The total weight of the four mailboxes, connection hardware, and post assembly was 89 lb. Figure 6.1 shows details of the test installation. Details of the connections for both the locking architectural and standard mailbox assemblies are depicted in Figure 6.2. Figure 6.3 provides details of the mailbox support geometry. Figure 6.4 presents photographs of the completed test installation.

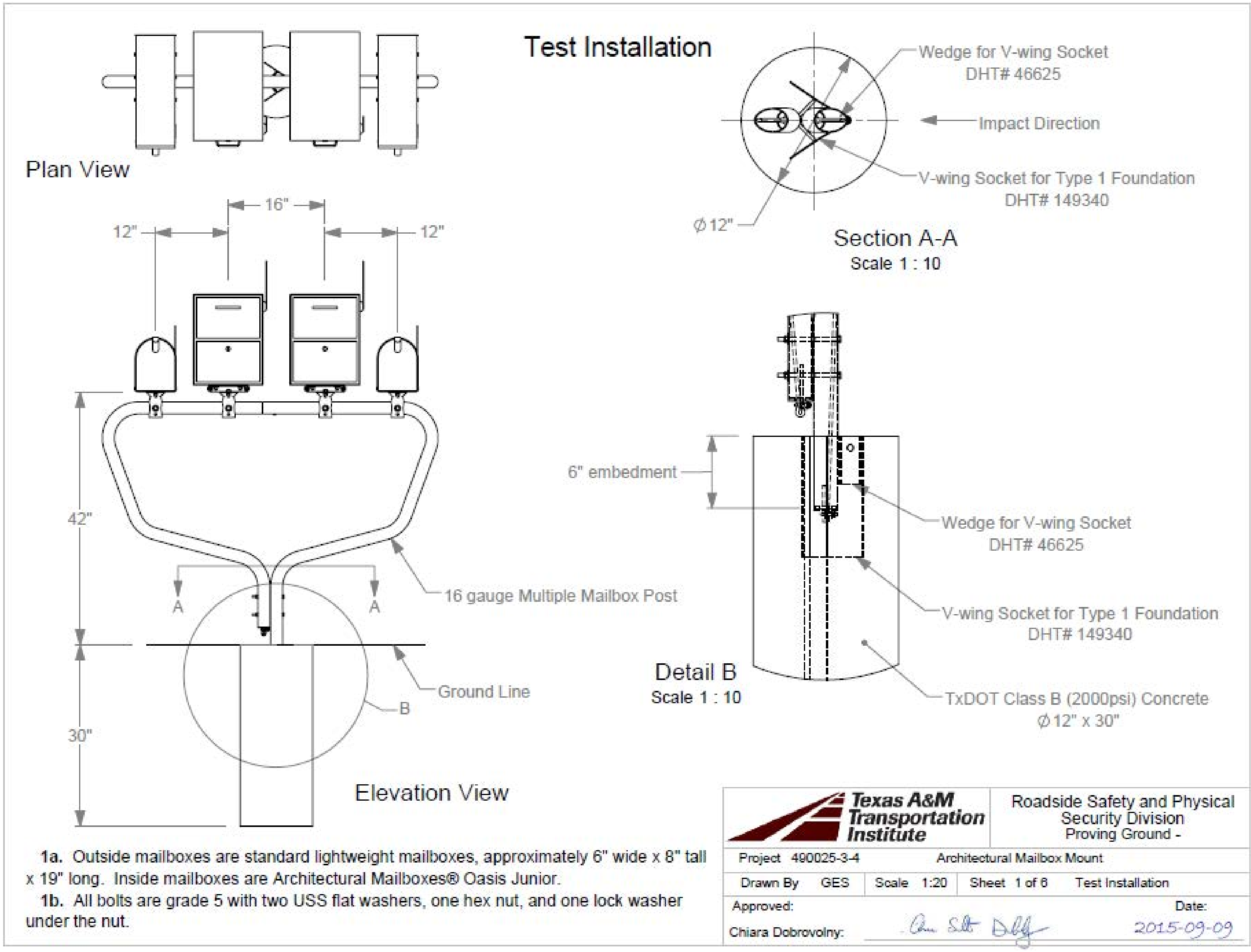


Figure 6.1. Details of the Locking Architectural and Standard Mailboxes 16-Gauge Support Installation.

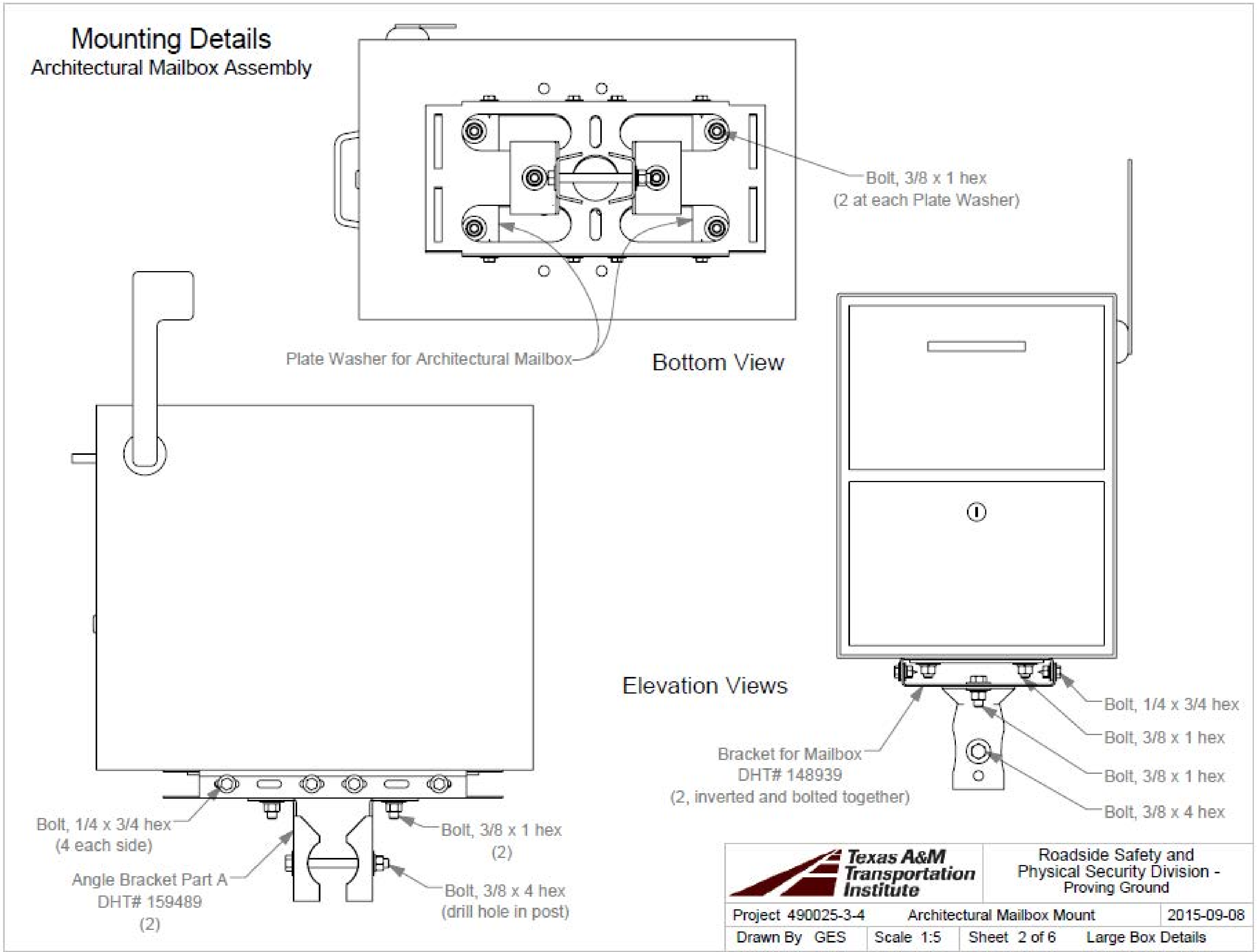


Figure 6.2. Connection Details for Locking Architectural and Standard Mailboxes Assemblies.

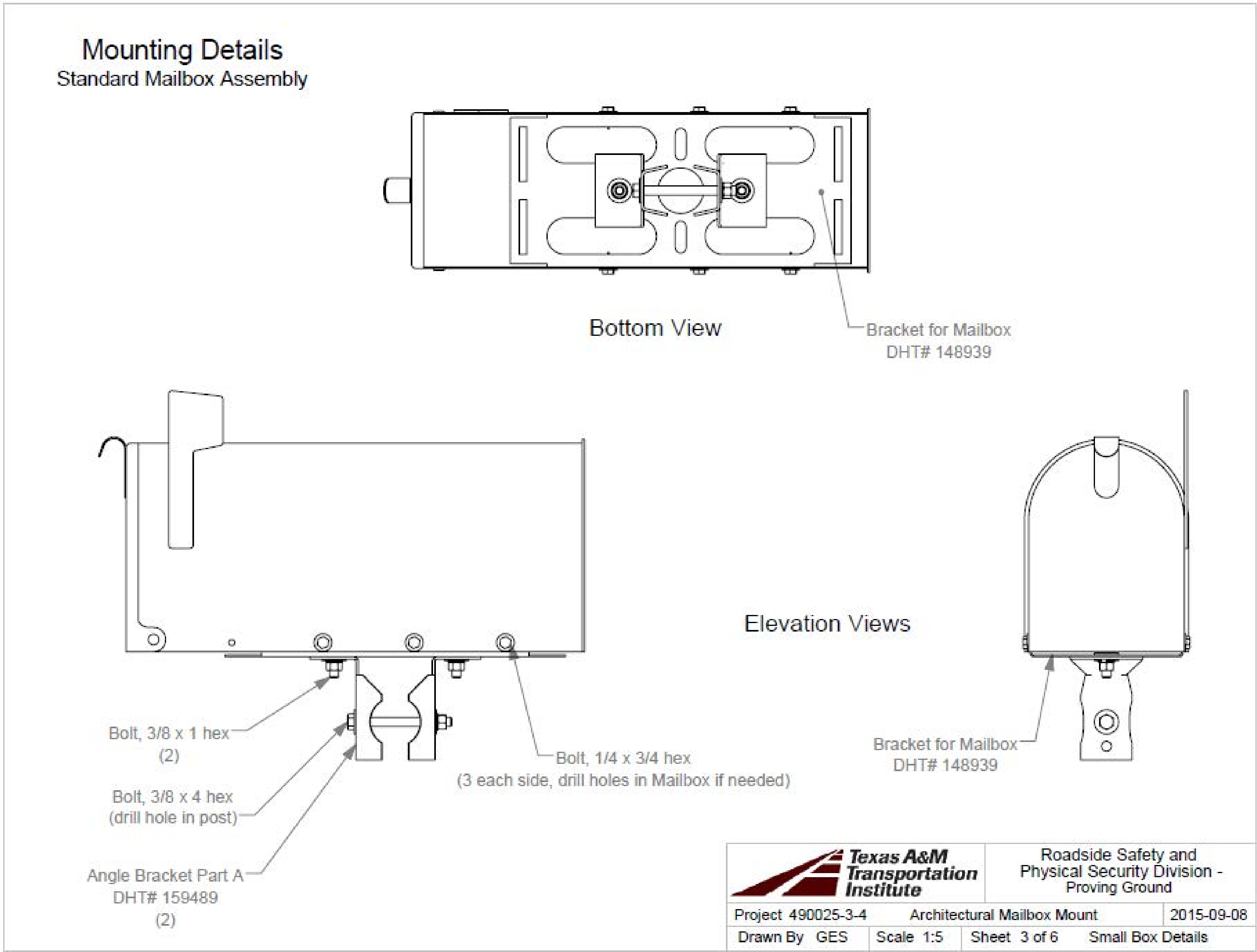


Figure 6.2. Connection Details for Locking Architectural and Standard Mailboxes Assemblies (Continued).

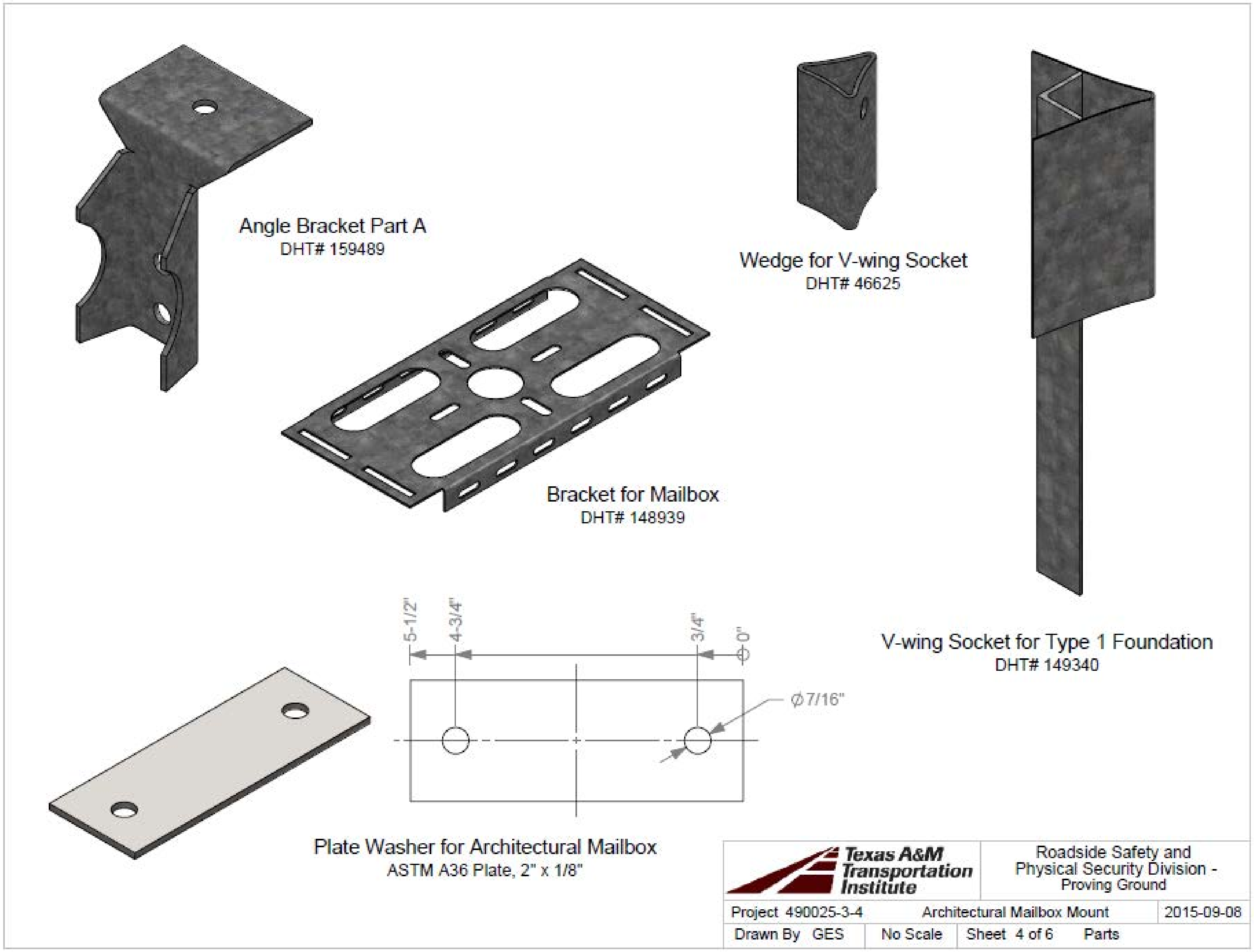


Figure 6.2. Connection Details for Locking Architectural and Standard Mailboxes Assemblies (Continued).

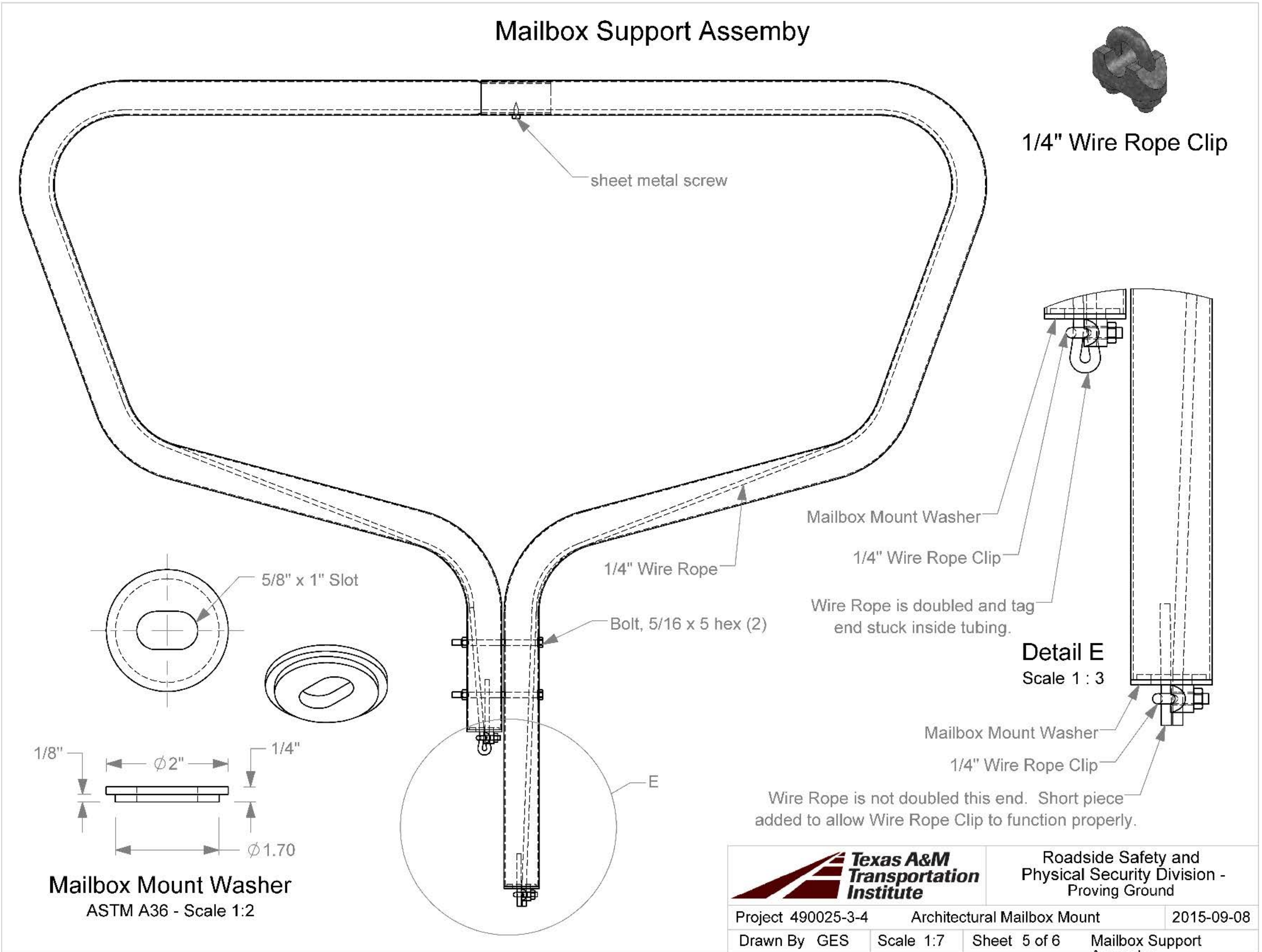


Figure 6.3. Details of 16-Gauge Steel Tube Multiple Mailbox Support Geometry.

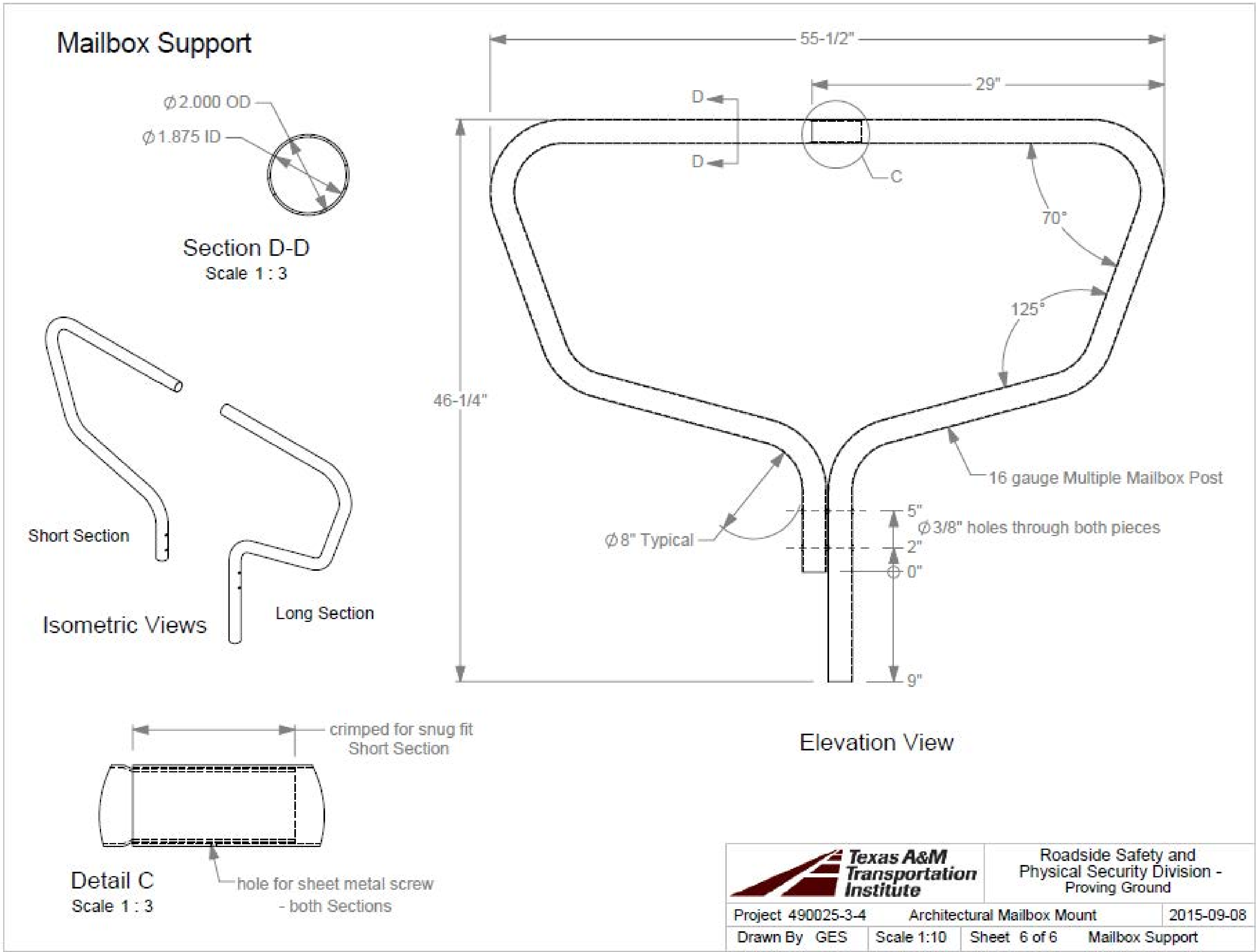


Figure 6.3. Details of 16-Gauge Steel Tube Multiple Mailbox Support Geometry (Continued).

Figure 6.4. Locking Architectural and Standard Mailboxes on 16-Gauge Steel Tube Multiple-Mailbox Support before Testing.

6.2 *MASH* TEST 3-61 (CRASH TEST NO. 490025-3-4)

6.2.1 Test Designation and Actual Impact Conditions

MASH Test 3-61 involves an 1100C passenger car weighing 2420 lb ±55 lb impacting the support structure at an impact speed of 62 mi/h ±2.5 mi/h and a critical impact angle of 0 degrees ±1.5 degrees. The target impact point was 10 inches to the right of the vehicle centerline with the centerline of the mailbox support post, with the mailboxes oriented perpendicular to the path of the vehicle. The 2010 Kia Rio used in the test weighed 2438 lb, and the actual impact speed and angle were 63.1 mi/h and 0 degrees, respectively. The actual impact point was 10 inches to the right of the vehicle centerline.

6.2.2 Test Vehicle

Figures 6.5 and 6.6 show the 2010 Kia Rio used for the crash test. Test inertia weight of the vehicle was 2438 lb, and its gross static weight was 2603 lb. The height to the lower edge of the vehicle bumper was 9.5 inches, and the height to the upper edge of the bumper was 21.5 inches. Table D.1 in Appendix D.1 gives additional dimensions and information on the vehicle. The vehicle was directed into the installation using a cable reverse tow and guidance system, and was released to be freewheeling and unrestrained just prior to impact.

Figure 6.5. Vehicle/Installation Geometrics for Test No. 490025-3-4.

Figure 6.6. Vehicle before Test No. 490025-3-4.

6.2.3 Weather Conditions

The test was performed on the morning of August 26, 2015. Weather conditions at the time of testing were as follows: (a) wind speed: 4 mi/h; (b) wind direction: 83 degrees with respect to the vehicle (vehicle was traveling in a southerly direction); (c) temperature: 86°F; (d) relative humidity: 60 percent.

6.2.4 Test Description

The 2010 Kia Rio, traveling at an impact speed of 63.1 mi/h, impacted the 16-gauge multiple-mount post with two locking architectural mailboxes and two standard mailboxes at 0 degrees, with the centerline of the support aligned at 10 inches to the right of the vehicle centerline. At approximately 0.021 s after impact, the support post started pulling out of the socket, together with the wedge. At 0.031 s after impact, the support post was fully out of the socket. At 0.058 s, the leading small mailbox impacted the windshield. At 0.067 s, the leading large mailbox impacted the windshield. At 0.233 s the support and mailbox system was 76 inches above ground (21 inches above the vehicle roof) while the vehicle was traveling at a speed of 61.5 mi/h. Brakes on the vehicle were applied at 1.1 s after impact, and the vehicle came to rest 270 ft downstream of impact. Figure D.1 in Appendix D.2 shows sequential photographs of the test period.

6.2.5 Damage to Test Installation

Figures 6.7 and 6.8 show damage to the mailbox support installation. The support post was lifted out of the socket and was pushed forward by the vehicle in the direction of travel. The support post was deformed and buckled in the area of contact with the vehicle bumper. However, the support did not fracture. The mailboxes and their brackets attaching them to the support post were deformed. The mailboxes remained attached to the support post and the assembly came to rest behind the vehicle 270 ft downstream of impact, with the support base pointing downstream left. The door of the locking architectural mailboxes detached from the mailbox, and came to rest behind the vehicle 158 ft downstream of impact; it did not, however, show potential for penetrating the occupant compartment, or present an undue hazard to other traffic. The single wire rope clip connection used at the longer support end to secure the wire rope slipped off the rope.

Figure 6.7. Vehicle/Installation Positions after Test No. 490025-3-4.

Figure 6.8. Installation after Test No. 490025-3-4.

6.2.6 Vehicle Damage

Figure 6.9 shows damage to the exterior of the vehicle, and Figure 6.10 shows the interior of the vehicle after the test. The hood, bumper, and grill were deformed. The maximum hood deformation was 3 inches. The windshield was shattered and deformed due to contact with the mailboxes and support. Maximum windshield deformation was 3 inches. Tables D.2 and D.3 in Appendix D.1 provide exterior crush and occupant compartment measurements.

6.2.7 Occupant Risk Factors

Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk. In the longitudinal direction, the OIV was 3.28 ft/s at 0.714 s, the highest 0.010-s occupant ridedown acceleration was 0.2 g from 0.9501 to 0.9601 s, and the maximum 0.050-s average acceleration was −1.2 g between 0.0014 and 0.0514 s. In the lateral direction, the OIV was 0.66 ft/s at 0.714 s, the highest 0.010-s occupant ridedown acceleration was 0.2 g from 0.8352 to 0.8452 s, and the maximum 0.050-s average was 0.3 g between 0.1211 and 0.1711 s. THIV was 3.6 km/h or 1.0 m/s at 0.7135 s; PHD was 0.3 g between 0.8379 and 0.8479 s; and ASI was 0.12 between 0.0625 and 0.1125 s. Figure 6.11 summarizes these data and other pertinent information from the test. Figure D.2 in Appendix D.3 shows the vehicle angular displacements, and Figures D.3 through D.8 in Appendix D.4 show accelerations versus time traces.

Figure 6.9. Vehicle after Test No. 490025-3-4.


Before


After

Figure 6.10. Interior of Vehicle before and after Test No. 490025-3-4.

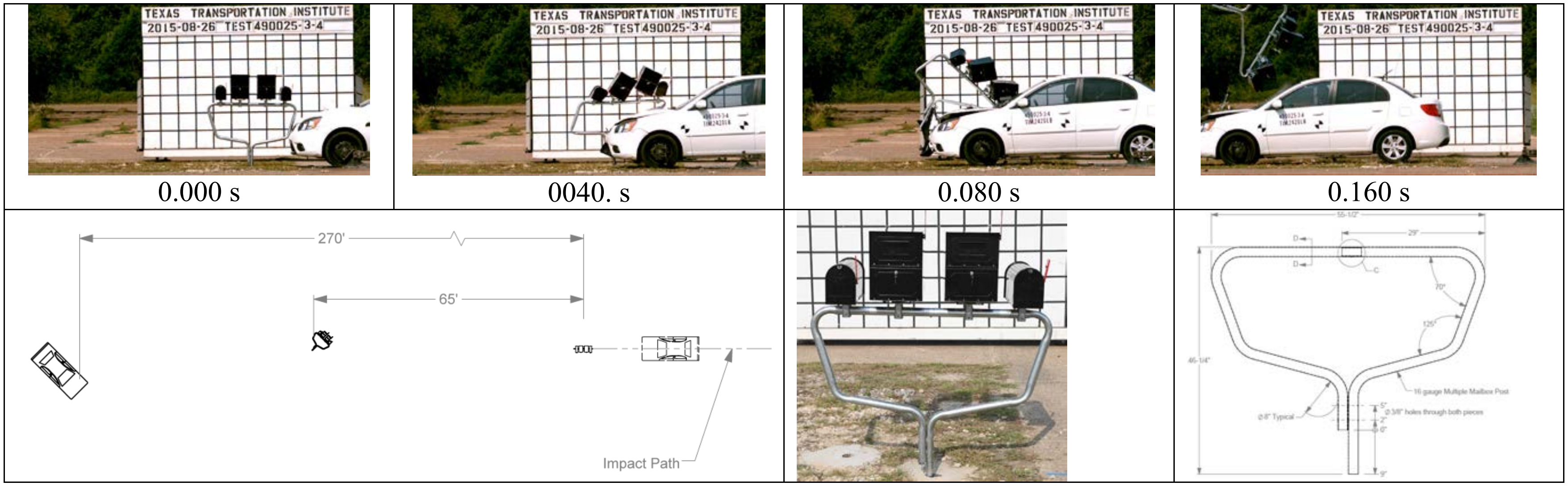
6.2.8 Assessment of Test Results

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

6.2.8.1 Structural Adequacy

B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.

Results: The multiple-mount post with attached locking architectural and standard mailboxes activated by yielding to the vehicle and lifting out of the foundation socket. (PASS)



General Information
- Test Agency........................ Texas A&M Transportation Institute (TTI)
- Test Standard Test No........ MASH Test 3-61
- TTI Test No. 490025-3-4
- Test Date........................... 2015-08-26

Test Article
- Type .... 16-gauge Steel Multiple Mailbox Support
- Name................................. Locking Architectural and Standard Mailboxes on 16-gauge Steel Tube Multiple Mailbox Support
- Installation Height .... 42 inches (grade to bottom of boxes)
- Material or Key Elements.... Two locking mailboxes and two standard mailboxes on formed 16-gauge tube support, with reduced embedment and inclusion of ¼" wire rope; one clip; V-loc wedge and socket in concrete footing

Soil Type and Condition...... Concrete footing in crushed limestone, dry

Test Vehicle
- Type/Designation................ 1100C
- Make and Model .... 2010 Kia Rio
- Curb .... 2496 lb
- Test Inertial........................ 2438 lb
- Dummy.............................. 165 lb
- Gross Static........................ 2603 lb

Impact Conditions
- Speed .... 63.1 mi/h
- Angle .... 0 degrees
- Location/Orientation........... Perpendicular

Exit Conditions
- Speed .... 61.5 mi/h
- Angle .... 0 degrees

Occupant Risk Values
- Occupant Impact Velocity
  - Longitudinal .... 3.28 ft/s
  - Lateral .... 0.66 ft/s
- Ridedown Accelerations
  - Longitudinal .... 0.2 g
  - Lateral .... 0.2 g
- THIV .... 3.6 km/h (1.0 m/s)
- PHD.................................. 0.3 g
- ASI.................................... 0.12

Max. 0.050-s Average
- Longitudinal .... -1.2 g
- Lateral .... 0.3 g
- Vertical .... 1.1 g

Post-Impact Trajectory
- Stopping Distance.................... 270 ft downstream

Vehicle Stability
- Maximum Yaw Angle .... 1.7 degrees
- Maximum Pitch Angle .... 1.6 degrees
- Maximum Roll Angle................. 1.5 degrees
- Vehicle Snagging..................... NA
- Vehicle Pocketing .... NA

Debris Pattern
- Longitudinal .... 270 ft
- Lateral .... 0 ft

Vehicle Damage
- VDS.. 12FR2
- CDC.. 12FRAN2
- Max. Exterior Deformation .... 3 inches
- OCDI FS0000000
- Max. Occupant Compartment Deformation....................... 3 inches - windshield

Figure 6.11. Summary of Results for *MASH* Test 3-61 on the Locking Architectural and Standard Mailboxes on 16-Gauge Steel Tube Multiple Mailbox Support.

6.2.8.2 Occupant Risk

D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.
Deformation of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH. (roof ≤4.0 inches; windshield = ≤3.0 inches; side windows = no shattering by test article structural member; wheel/foot well/toe pan ≤9.0 inches; forward of A-pillar ≤12.0 inches; front side door area above seat ≤9.0 inches; front side door below seat ≤12.0 inches; floor pan/transmission tunnel area ≤12.0 inches).

Results: The locking architectural and the standard mailboxes remained attached to the support post. The door of the locking architectural mailboxes detached from the mailbox, but did not show potential for penetrating the occupant compartment, or present hazard to other traffic. The mailbox installation did not penetrate or show potential for penetrating the occupant compartment, nor present hazard to others in the area. (PASS)

Results: Windshield deformation was 3 inches. (PASS)

F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.

Results: The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.5 degrees and 1.6 degrees, respectively. (PASS)

I. Occupant impact velocities should satisfy the following:
Longitudinal and Lateral Occupant Impact Velocity

Preferred	*Maximum*
10 ft/s	*16.4 ft/s*

Results: Longitudinal OIV was 3.28 ft/s, and lateral OIV was 0.66 ft/s. (PASS)

I. Occupant ridedown accelerations should satisfy the following:
Longitudinal and Lateral Occupant Ridedown Accelerations

Preferred	*Maximum*
15.0 g	*20.49 g*

Results: Longitudinal ridedown acceleration was 0.2 g, and lateral ridedown acceleration was 0.2 g. (PASS)

6.2.8.3 *Vehicle Trajectory*

N. Vehicle trajectory behind the test article is acceptable.

Result: The 1100C vehicle came to rest downstream and in line with the original position of the mailbox installation. (PASS)

6.3 *MASH* TEST 3-60 (CRASH TEST NO. 490025-3-3)

The test article for Test No. 490025-3-3 was identical to the one used in Test No. 490025-3-4 with the exception that two wire rope clamps were used to secure the ¼-inch diameter wire rope at each end of the multiple-mailbox support instead of one (see Figure 6.12). This modification was applied after the ¼-inch diameter wire rope slipped off the single clamp during Test No. 490025-3-4. The research team used two clamps, instead of one, to increase the clamping force on the wire rope and prevent or further delay any slippage of the wire rope during impact. This would help reduce deformation of the support post and ensure that the support stayed together as a connected system in the event of support rupture during impact.

6.3.1 Test Designation and Actual Impact Conditions

MASH Test 3-60 involves an 1100C passenger car weighing 2420 lb ±55 lb impacting the support structure at an impact speed of 19 mi/h ±2.5 mi/h and a critical impact angle of 0 degrees ±1.5 degrees. The target impact point was 10 inches to the right of the vehicle centerline with the centerline of the mailbox support post, with the mailboxes oriented perpendicular to the path of the vehicle. The 2009 Kia Rio used in the test weighed 2427 lb, and the actual impact speed and angle were 19.3 mi/h and 0 degrees, respectively. The actual impact point was 10 inches to the right of the vehicle centerline.

6.3.2 Test Vehicle

Figures 6.13 and 6.14 show the 2009 Kia Rio used for the crash test. Test inertia weight of the vehicle was 2427 lb, and its gross static weight was 2598 lb. The height to the lower edge of the vehicle bumper was 9.5 inches, and the height to the upper edge of the bumper was 21.5 inches. Table E.1 in Appendix E.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.

6.3.3 Weather Conditions

The test was performed on the afternoon of August 26, 2015. Weather conditions at the time of testing were as follows: (a) wind speed: 2 mi/h; (b) wind direction: 179 degrees with respect to the vehicle (vehicle was traveling in a southerly direction); (c) temperature: 93°F; (d) relative humidity: 44 percent.

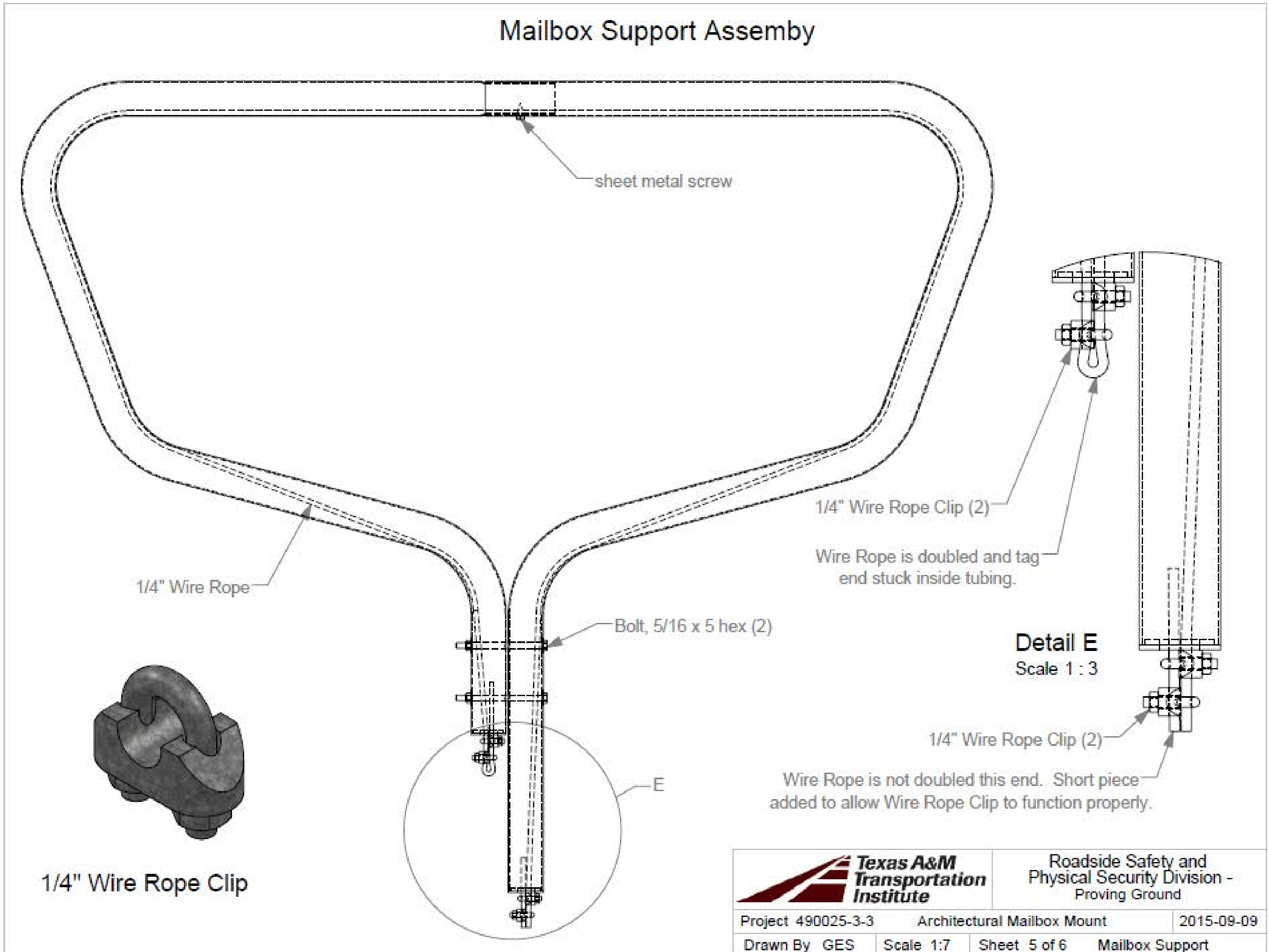


Figure 6.12. Details of the Locking Architectural and Standard Mailboxes 16-Gauge Support Installation Used for Test No. 490025-3-3.

Figure 6.13. Vehicle/Installation Geometrics for Test No. 490025-3-3.

Figure 6.14. Vehicle before Test No. 490025-3-3.

6.3.4 Test Description

The 2009 Kia Rio, traveling at an impact speed of 19.3 mi/h, impacted the 16-gauge multiple-mount post with two locking architectural and two standard mailboxes at 0 degrees, with the centerline of the support aligned at 10 inches right from the centerline of the vehicle. At approximately 0.077 s after impact, the support post began pulling out of the socket, and at 0.113 s was completely out of the socket. At 0.113 s, the support post separated from the hood and at 0.138 s it separated from upper bumper of the vehicle while the vehicle continued traveling forward at a speed of 17.4 mi/h. Brakes on the vehicle were applied 3.5 s after impact, and the vehicle came to rest 90 ft downstream of impact with the mailbox support behind the vehicle. Figure E.1 in Appendix E.2 shows sequential photographs of the test period.

6.3.5 Damage to Test Installation

Figures 6.15 and 6.16 show the damage to the mailbox support installation. The support post was lifted out of the socket and pushed forward by the vehicle in the direction of travel. The support tube was kinked and flattened in the lower 6 inches of the vertical stub, but was otherwise undamaged. The mailboxes remained attached to the support post and the assembly came to rest behind the vehicle 60 ft downstream of impact with the base of the support pointing upstream-left.

Figure 6.15. Vehicle/Installation Positions after Test No. 490025-3-3.

Figure 6.16. Installation after Test No. 490025-3-3.

6.3.6 Vehicle Damage

Figure 6.17 shows the damage to the exterior of the vehicle, and Figure 6.18 shows the interior of the vehicle after the test. The hood, bumper, and grill were deformed. The maximum hood deformation was 3.5 inches. There was no contact of any components of the mailbox system with the windshield. Tables E.2 and E.3 in Appendix E.1 provide exterior crush and occupant compartment measurements, respectively.

Figure 6.17. Vehicle after Test No. 490025-3-3.

Before Test

After Test

Figure 6.18. Interior of Vehicle for Test No. 490025-3-3.

6.3.7 Occupant Risk Factors

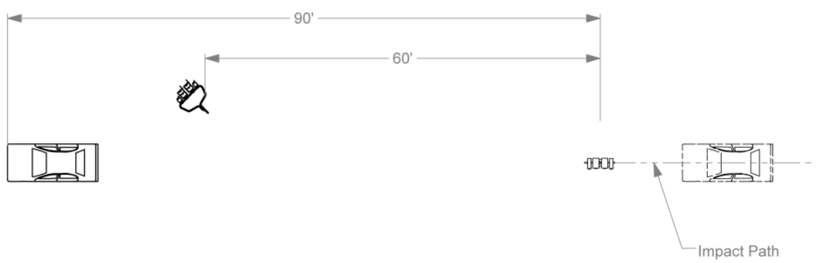
Data from the accelerometer, located at the vehicle center of gravity, were digitized for evaluation of occupant risk. In the longitudinal direction, the OIV was 3.28 ft/s at 0.7244 s, the highest 0.010-s occupant ridedown acceleration was 0.3 *g* from 0.8133 to 0.8233 s, and the maximum 0.050-s average acceleration was −1.1 *g* between 0.0528 and 0.1028 s. In the lateral direction, the OIV was 1.31 ft/s at 0.7244 s, the highest 0.010-s occupant ridedown acceleration was 0.2 *g* from 0.8157 to 0.8257 s, and the maximum 0.050-s average was 0.3 *g* between 0.0938 and 0.1438 s. THIV was 3.8 km/h or 1.1 m/s at 0.7262 s; PHD was 0.3 *g* between 0.8141 and 0.8241 s; and ASI was 0.11 between 0.0754 and 0.1254 s. Figure 6.19 summarizes these data and other pertinent information from the test. Figure E.2 in Appendix E.3 shows the vehicle angular displacements, and Figures E.3 through E.8 in Appendix E.4 show accelerations versus time traces.

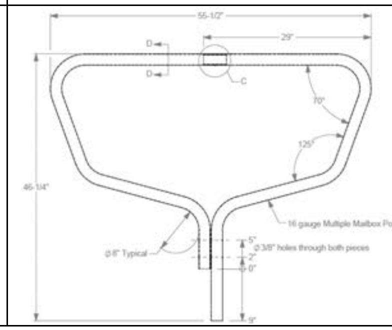
0.000 s

0.070 s

0.140 s

0.280 s





General Information

Test Agency	Texas A&M Transportation Institute (TTI)
Test Standard Test No.	MASH Test 3-60
TTI Test No.	490025-3-3
Test Date	2015-08-26

Test Article

Type	16-gauge Steel Multiple Mailbox Support
Name	Locking Architectural and Standard Mailboxes on 16-gauge Steel Tube Multiple Mailbox Support
Installation Height	42 inches (grade to bottom of boxes)
Material or Key Elements	Two locking mailboxes and two standard mailboxes on formed 16-gauge tube support, with reduced embedment and inclusion of ¼” wire rope; two clips; V-loc wedge and socket in concrete footing

Soil Type and Condition ...... Concrete footing in crushed limestone, dry

Test Vehicle

Type/Designation	1100C
Make and Model	2009 Kia Rio
Curb	2388 lb
Test Inertial	2427 lb
Dummy	165 lb
Gross Static	2598 lb

Impact Conditions

Speed	19.3 mi/h
Angle	0 degrees
Location/Orientation	Perpendicular

Exit Conditions

Speed	17.4 mi/h
Angle	0 degrees

Occupant Risk Values

Occupant Impact Velocity	
Longitudinal	3.28 ft/s
Lateral	1.31 ft/s
Ridedown Accelerations	
Longitudinal	0.3 g
Lateral	0.2 g
THIV	3.8 km/h (1.1 m/s)
PHD	0.3 g
ASI	0.11
Max. 0.050-s Average	
Longitudinal	−1.1 g
Lateral	0.3 g
Vertical	−0.6 g

Post-Impact Trajectory

Stopping Distance	90 ft downstream

Vehicle Stability

Maximum Yaw Angle	1.5 degrees
Maximum Pitch Angle	1.2 degrees
Maximum Roll Angle	0.6 degrees
Vehicle Snagging	NA
Vehicle Pocketing	NA

Debris Pattern

Longitudinal	60 ft
Lateral	12 ft

Vehicle Damage

VDS	12FR1
CDC	12FREN1
Max. Exterior Deformation	3.5 inches
OCDI	FS0000000
Max. Occupant Compartment Deformation	None

Figure 6.19. Summary of Results for *MASH* Test 3-60 on the Locking Architectural and Standard Mailboxes on 16-Gauge Steel Tube Multiple-Mailbox Support.

6.3.8 Assessment of Test Results

An assessment of the test based on the applicable *MASH* safety evaluation criteria for *MASH* Test 3-60 is provided below.

6.3.8.1 Structural Adequacy

B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.

Results: The multiple-mount post with attached locking architectural and standard mailboxes activated by yielding to the vehicle and lifting out of the foundation socket. (PASS)

6.3.8.2 Occupant Risk

D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.
Deformation of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH. (roof ≤4.0 inches; windshield = ≤3.0 inches; side windows = no shattering by test article structural member; wheel/foot well/toe pan ≤9.0 inches; forward of A-pillar ≤12.0 inches; front side door area above seat ≤9.0 inches; front side door below seat ≤12.0 inches; floor pan/transmission tunnel area ≤12.0 inches).

Results: The locking architectural and the standard mailboxes remained attached to the support post. The mailbox installation did not penetrate or show potential for penetrating the occupant compartment, nor present hazard to others in the area. (PASS)
Results: No occupant compartment deformation occurred. (PASS)

F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.

Results: The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 0.6 degrees and 1.2 degrees, respectively. (PASS)

H. Occupant impact velocities should satisfy the following:
Longitudinal and Lateral Occupant Impact Velocity

Preferred	*Maximum*
10 ft/s	*16.4 ft/s*

Results: Longitudinal OIV was 3.94 ft/s, and lateral OIV was 1.64 ft/s. (PASS)

I. Occupant ridedown accelerations should satisfy the following:

Longitudinal and Lateral Occupant Ridedown Accelerations

Preferred	*Maximum*
15.0 g	*20.49 g*

Results: Longitudinal ridedown acceleration was 0.1 g, and lateral ridedown acceleration was 0.2 g. (PASS)

6.3.8.3 Vehicle Trajectory

N. Vehicle trajectory behind the test article is acceptable.

Result: The 1100C vehicle came to rest downstream and in line with the original position of the mailbox installation. (PASS)

CHAPTER 7: SUMMARY AND CONCLUSIONS

Concern about mail-identity theft has increased the demand for locking mailboxes. The dual compartment security feature incorporated into these lockable mailboxes makes them considerably larger and heavier than standard mailboxes. Therefore, before TxDOT can permit use of these mailboxes on the state highway system, their crashworthiness had to be evaluated.

Under this project, crash tests were performed following *MASH* guidelines and procedures to assess the impact performance of lockable and standard mailboxes on nonproprietary multiple-mount configurations. A summary of the findings is presented below.

7.1 MULTIPLE-MOUNT SUPPORT OF 11-GAUGE STEEL TUBE WITH 4-INCH EMBEDMENT

7.1.1 Multiple-Mount Support of 11-Gauge Steel Tube with 4-inch Embedment – Test No. 490025-3-2

In the high-speed test of the combination mailbox configuration on the 11-gauge steel tube multiple-mount support with 4-inch embedment, the support successfully released from the foundation socket. The locking architectural and the standard mailboxes remained attached to the support post. The support post deformed but did not rupture. The mailbox installation did not penetrate, contact, or show potential for penetrating the occupant compartment, nor present a hazard to others in the area. No occupant compartment deformation occurred. As summarized in Table 7.1, the 11-gauge steel tube multiple-mount support with 4-inch embedment with a combination of standard and locking architectural mailboxes satisfied *MASH* evaluation criteria for Test 3-61.

7.1.2 Multiple-Mount Support of 11-Gauge Steel Tube with 4-inch Embedment – Test No. 490025-3-1

In the low-speed test of the combination mailbox configuration on the 11-gauge steel tube multiple-mount support with 4-inch embedment, the support successfully released from the foundation socket. The locking architectural and the standard mailboxes remained attached to the support post. The support post was kinked and flattened at its lower 4 inches, but otherwise was undamaged. The mailbox installation did not penetrate, contact, or show potential for penetrating the occupant compartment, nor present hazard to others in the area. No occupant compartment deformation occurred. As summarized in Table 7.2, the 11-gauge steel tube multiple-mount support with 4-inch embedment with a combination of standard and locking architectural mailboxes satisfied *MASH* evaluation criteria for Test 3-60.

Table 7.1. Performance Evaluation Summary for *MASH* Test 3-61 on the Combination Locking Architectural Mailboxes and Standard Mailboxes on the 11-Gauge Steel Tube Multiple-Mount Support with 4-inch Embedment.

Test Agency: Texas A&M Transportation Institute | Test No.: 490025-3-2 | Test Date: 2015-08-25

MASH Test 3-61 Evaluation Criteria	Test Results	Assessment
<u>*Structural Adequacy*</u> *B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*	The multiple-mount support yielded to the 1100C vehicle and pulled out of the foundation socket.	Pass
<u>*Occupant Risk*</u> *D. Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	The locking architectural and the standard mailboxes remained attached to the support post. The mailbox installation did not penetrate or show potential for penetrating the occupant compartment, nor 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 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 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 2.7 degrees and 2.2 degrees, respectively.	Pass
H. Longitudinal and lateral occupant impact velocities should fall below the preferred value of 10 ft/s, or at least below the maximum allowable value of 16.4 ft/s.	Longitudinal occupant impact velocity was 3.94 ft/s, and lateral occupant impact velocity was 0.66 ft/s.	Pass
I. Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 g, or at least below the maximum allowable value of 20.49 g.	Longitudinal ridedown acceleration was 0.2 *g*, and lateral ridedown acceleration was 0.3 *g*.	Pass
<u>*Vehicle Trajectory*</u> *N. Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest downstream and in line with the original position of the mailbox installation.	Pass

Table 7.2. Performance Evaluation Summary for *MASH* Test 3-60 on the Combination Locking Architectural Mailboxes and Standard Mailboxes on the 11-Gauge Steel Tube Multiple-Mount Support with 4-inch Embedment.

Test Agency: Texas A&M Transportation Institute | Test No.: 490025-3-1 | Test Date: 2015-08-25

***MASH* Test 3-60 Evaluation Criteria**	**Test Results**	**Assessment**
<u>Structural Adequacy</u> B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*	The multiple-mount support with attached locking architectural and standard mailboxes activated by yielding to the vehicle and lifting out of the foundation socket.	Pass
<u>Occupant Risk</u> D. *Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	The locking architectural and the standard mailboxes remained attached to the support post. The mailbox installation did not penetrate or show potential for penetrating the occupant compartment, nor 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 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 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.9 degrees and 2.5 degrees, respectively.	Pass
H. *Longitudinal and lateral occupant impact velocities should fall below the preferred value of 10 ft/s, or at least below the maximum allowable value of 16.4 ft/s.*	Longitudinal occupant impact velocity was 3.94 ft/s, and lateral occupant impact velocity was 1.64 ft/s.	Pass
I. *Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 g, or at least below the maximum allowable value of 20.49 g.*	Longitudinal ridedown acceleration was 0.1 *g*, and lateral ridedown acceleration was 0.2 *g*.	Pass
<u>Vehicle Trajectory</u> N. *Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest downstream and in line with the original position of the mailbox installation.	Pass

7.2 MULTIPLE-MOUNT SUPPORT OF 16-GAUGE STEEL TUBE WITH ¼-INCH DIAMETER WIRE ROPE AND 6-INCH EMBEDMENT

7.2.1 Multiple-Mount Support of 16-Gauge Steel Tube with ¼-inch Diameter Wire Rope and 6-inch Embedment – Test No. 490025-3-4

In the high-speed test of the combination mailbox configuration on the 16-gauge steel tube multiple-mount support with ¼-inch diameter wire rope (single clip at longer end) and 6-inch embedment, the support successfully released from the foundation socket. The locking architectural and the standard mailboxes remained attached to the support post. The door of the locking architectural mailboxes detached from the mailbox, but did not show potential for penetrating the occupant compartment, or present hazard to other traffic. The support post deformed, but did not fracture. A windshield deformation of 3 inches was recorded due to contact with the mailboxes assembly. As summarized in Table 7.3, the 16-gauge steel tube multiple-mount support with ¼-inch diameter wire rope and 6-inch embedment with a combination of standard and locking architectural mailboxes satisfied *MASH* evaluation criteria for Test 3-61.

7.2.2 Multiple-Mount Support of 16-Gauge Steel Tube with ¼-inch Diameter Wire Rope and 6-inch Embedment – Test No. 490025-3-3

In the low-speed test of the combination mailbox configuration on the 16-gauge steel tube multiple-mount support with ¼-inch diameter wire rope (double clip at longer end) and 6-inch embedment, the support successfully released from the foundation socket. The locking architectural and the standard mailboxes remained attached to the support post. The support tube was kinked and flattened at its lower 6 inches, but was otherwise undamaged. The mailbox installation did not penetrate, contact, or show potential for penetrating the occupant compartment, nor present hazard to others in the area. No occupant compartment deformation occurred. As summarized in Table 7.4, the 16-gauge steel tube multiple-mount support with ¼-inch diameter wire rope and 6-inch embedment with a combination of standard and locking architectural mailboxes satisfied *MASH* evaluation criteria for Test 3-60.

Table 7.3. Performance Evaluation Summary for *MASH* Test 3-61 on the Combination Locking Architectural Mailboxes and Standard Mailboxes on the 16-Gauge Steel Tube Multiple-Mount Support with ¼-inch Wire Rope and 6-inch Embedment.

Test Agency: Texas A&M Transportation Institute | Test No.: 490025-3-4 | Test Date: 2015-08-26

***MASH* Test 3-61 Evaluation Criteria**	**Test Results**	**Assessment**
<u>Structural Adequacy</u> B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*	The multiple-mount support yielded to the 1100C vehicle and pulled out of the foundation socket.	Pass
<u>Occupant Risk</u> D. *Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	The mailboxes remained attached to the support post. The door of the locking architectural mailboxes detached from the mailbox, but did not show potential for penetrating the occupant compartment, or present hazard to other traffic. The mailbox installation did not penetrate or show potential for penetrating the occupant compartment, nor 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.	Windshield deformation of 3 inches was recorded.	Pass
F. *The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.*	The 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 1.5 degrees and 1.6 degrees, respectively.	Pass
H. *Longitudinal and lateral occupant impact velocities should fall below the preferred value of 10 ft/s, or at least below the maximum allowable value of 16.4 ft/s.*	Longitudinal OIV was 3.28 ft/s, and lateral OIV was 0.66 ft/s.	Pass
I. *Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 g, or at least below the maximum allowable value of 20.49 g.*	Longitudinal ridedown acceleration was 0.2 *g* and lateral ridedown acceleration was 0.2 *g*.	Pass
<u>Vehicle Trajectory</u> N. *Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest downstream and in line with the original position of the mailbox installation.	Pass

Table 7.4. Performance Evaluation Summary for *MASH* Test 3-60 on the Combination Locking Architectural Mailboxes and Standard Mailboxes on the 16-Gauge Steel Tube Multiple-Mount Support with ¼-inch Wire Rope and 6-inch Embedment.

Test Agency: Texas A&M Transportation Institute | Test No.: 490025-3-3 | Test Date: 2015-08-26

***MASH* Test 3-60 Evaluation Criteria**	**Test Results**	**Assessment**
Structural Adequacy		
B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*	The multiple-mount post with attached locking architectural and standard mailboxes activated by yielding to the vehicle and lifting out of the foundation socket.	Pass
Occupant Risk		
D. *Detached elements, fragments, or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.*	The locking architectural and the standard mailboxes remained attached to the support post. The mailbox installation did not penetrate or show potential for penetrating the occupant compartment, nor present hazard to others in the area.	Pass
Deformation 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 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 1100C vehicle remained upright during and after the collision event. Maximum roll and pitch angles were 0.6 degrees and 1.2 degrees, respectively.	Pass
H. *Longitudinal and lateral occupant impact velocities should fall below the preferred value of 10 ft/s, or at least below the maximum allowable value of 16.4 ft/s.*	Longitudinal OIV was 3.28 ft/s, and lateral OIV was 1.31 ft/s.	Pass
I. *Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15.0 g, or at least below the maximum allowable value of 20.49 g.*	Longitudinal ridedown acceleration was 0.3 *g*, and lateral ridedown acceleration was 0.2 *g*.	Pass
Vehicle Trajectory		
N. *Vehicle trajectory behind the test article is acceptable.*	The 1100C vehicle came to rest downstream and in line with the original position of the mailbox installation.	Pass

CHAPTER 8: IMPLEMENTATION STATEMENT*

8.1 GENERAL MULTIPLE-MOUNT MAILBOX SUPPORT CONSIDERATIONS

Mail-identity theft is a rising concern among homeowners. Consequently, there is an increased demand for locking mailboxes. These mailboxes contain a mail-receiving hopper above a lockable compartment that is used for mail retrieval. In this project, the crashworthiness of proposed designs for multiple-mailbox support for use with a combination of lockable and standard mailboxes was evaluated to determine if TxDOT can permit their use on the state highway system. The crash tests were performed following the latest *MASH* guidelines and procedures.

The small passenger car was considered the critical design vehicle based on the mailbox mounting height. Testing with a pickup truck was deemed unnecessary due to the relative height of the pickup truck bumper and hood with respect to the mailbox support system mounting height. 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 pickup truck significantly decrease the probability of windshield impact and occupant compartment intrusion.

There are a variety of lockable mailboxes on the market. The lockable mailboxes selected for testing were Oasis Jr.® locking architectural mailboxes manufactured by Architectural Mailboxes, LLC. This type of mailbox is 15 inches tall × 11½ inches wide × 18 inches deep, and weighs approximately 22.4 lb without connection hardware attached. Other lockable mailboxes are considered acceptable alternatives provided the size and weight of the tested design are not exceeded. The use of mailboxes larger or heavier than the model tested will require further evaluation.

The number of lockable architectural mailboxes used on a multiple-mailbox support post should be limited to two units, as tested. These two lockable architectural mailboxes should be placed at the interior locations, as tested.

Due to the heavier lockable mailbox, the galvanized steel tube supports may experience some long-term movement when installed in the soil embedded Type 2 foundation. To avoid this long-term movement and associated maintenance, it is recommended that the steel anchor socket (DHT 143434) be embedded in a 12-inch diameter × 24-inch deep unreinforced concrete footer similar to the Type 4 foundation. In fact, this modification can be applied to all mailbox configurations installed in a Type 2 foundation, regardless of size or weight.

The connection of the mailbox to the support post is of critical importance. The lockable mailbox should be attached to the multiple-mailbox support using the improved connection developed and tested under this project. A mailbox bracket (DHT 161443) was attached to the bottom of the locking mailbox using four ⅜-inch diameter × 1¼-inch long SAE Grade 5 bolts using existing holes in the mailbox and bracket. A 2-inch wide × 5½-inch long × ⅛-inch thick plate washer fabricated from ASTM A36 steel (or equivalent) was positioned over each end of the bracket to help secure each set of two bolts at the front and back of the mailbox. A ⅜-inch flat washer, lock washer, and nut were used for each bolt. The collar on the mailbox bracket was secured to the support post using a $^{5}/_{16}$-inch diameter × 3-inch long SAE Grade 5 bolt.

8.2 MULTIPLE-MOUNT MAILBOX SUPPORT OF 11-GAUGE STEEL TUBE WITH 4-INCH EMBEDMENT

Oasis Jr.® lockable mailboxes were evaluated when mounted on an 11-gauge steel tube multiple-mount support with 4-inch embedment in combination with standard mailboxes. The system satisfied all required *MASH* evaluation criteria both at low and high impact speeds when impacted by a passenger car.

This configuration is considered suitable for implementation and use on the state highway system. Implementation can be accomplished through appropriate revision of the TxDOT Mailbox Mounting and Spacing standard (MB-11(1)) by the Maintenance Division.

A tolerance of ±0.5 inches is recommended for embedment depth. This was the result of an investigation carried out on the relationship between support wall thickness and acceptable post embedment required to achieve support stability for service loads (see Appendix F).

8.3 MULTIPLE-MOUNT MAILBOX SUPPORT OF 16-GAUGE STEEL TUBE WITH ¼-INCH DIAMETER WIRE ROPE AND 6-INCH EMBEDMENT

Oasis Jr.® lockable mailboxes were evaluated when mounted on a 16-gauge steel tube multiple-mount support that included a ¼-inch diameter wire rope and 6-inch embedment in combination with standard mailboxes. The system satisfied all required *MASH* evaluation criteria both at low and high impact speeds when impacted by a passenger car.

This configuration is considered suitable for implementation and use on the state highway system. Implementation can be accomplished through appropriate revision of the TxDOT Mailbox Mounting and Spacing standard (MB-11(1)) by the Maintenance Division.

A tolerance of ±0.5 inches is recommended for embedment depth. This was the result of an investigation carried out on the relationship between support wall thickness and acceptable post embedment (from the stability perspective) (see Appendix F). Moreover, the researchers suggest the option of using two ¼-inch diameter wire rope clips at one end of the cable and a swage at the other end (see Figure 8.1). The option to have a swaged end cable would allow a tighter cable connection.

8.4 COMPARISON BETWEEN USE OF 11-GAUGE AND 16-GAUGE SUPPORT SYSTEMS

Table 8.1 presents a comprehensive comparison of the performance, material costs, unit installation cost, inventory, and applications of the proposed multiple-mailbox support system designs for use with lockable mailboxes.

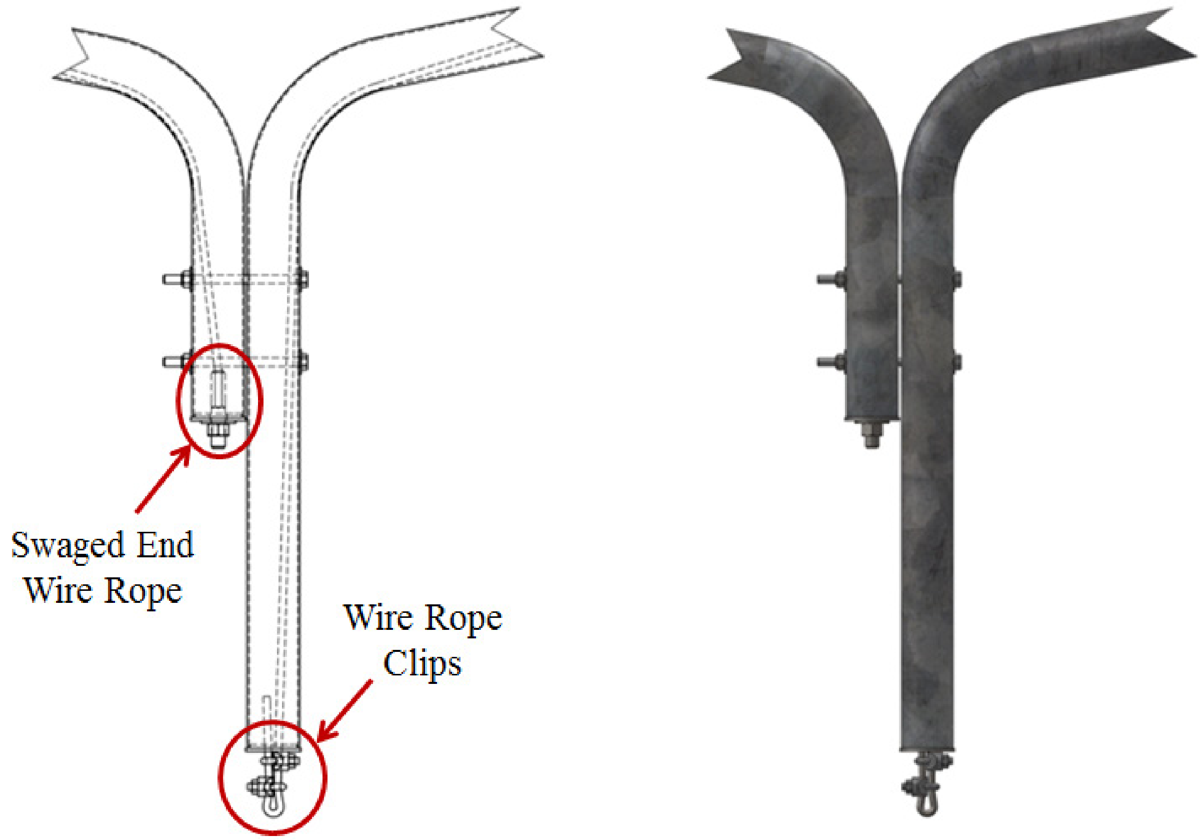


Figure 8.1. Multiple Mailbox Support of 16-Gauge Steel Tube with Inclusion of Swaged End Wire Rope and 6-inch Embedment.

Table 8.1. Comparison between 11-Gauge and 16-Gauge Support Systems.

	11-Gauge (0.125-inch) Steel Tube, 4-inch Embedment	**16-Gauge (0.0625-inch) Steel Tube, ¼-inch Wire Rope, 6-inch Embedment**		
Performance	• Readily activated by yielding to vehicle and lifting out of foundation socket • Limited support deformation and no buckling • No occupant compartment deformation • Better stable function (better for heavier mailboxes)	• Readily activated by yielding to vehicle and lifting out of foundation socket • Substantial deformation & buckling • Occupant compartment deformation to windshield • Stable function, still not as much as with the 11-gauge support		
Embedment Required	• 4 inches (±0.5 inches)	• 6 inches (±0.5 inches)		
Material Cost	• 11-gauge steel tube – $48.60	• 16-gauge steel tube – $32.40 • ¼-inch wire rope – 35 c/ft = $5.25 • ¼-inch wire rope clip (4 clips) – $2.56 • washers – $4.00	OR	• 16-gauge steel tube – $32.40 • ¼-inch wire rope w/ swaged end – $52 • ¼-inch wire rope clip (2 clips) – $1.28 • washers – $4.00
Cost per Installation	$48.60 Plus: • Labor to install support into wedge and socket	$44.21 Plus: • Bolt tubes together at top • Labor to install cable and clamp it into support – difficulty feeding cable through post • Labor to install support into wedge and socket	OR	$89.68 Plus: • Bolt tubes together at top • Labor to install cable and clamp it into support – difficulty feeding cable through post • Labor to install support into wedge and socket
Inventory	• 11-gauge supports • Different inventory item if existing 16-gauge support still used for standard mailboxes	• 16-gauge supports (current inventory item) • Wire ropes or wire rope with swaged ends • Wire rope clips, washers, and extra bolt for top telescopic connection		
Application	The 11-gauge support would be used as lockable mailboxes support, but it can also be adopted for use with standard mailboxes.	The 16-gauge support would be used as lockable mailboxes support only with included wire rope and modified embedment to 6 inches. In this case, however, it would require cutting of the support end to allow for only 6 inches embedment and required mailbox installation height. The same 16-gauge support will still be used for supporting only standards mailboxes, and no wire rope and modified embedment would be required.		

From a performance perspective, both systems readily activated by yielding to the vehicle and lifting out of the foundation socket. The 11-gauge support had limited deformation and no local buckling or rupture was observed during either the high-speed or low-speed tests. The 16-gauge support with wire rope had significant deformation and buckling as a consequence of the vehicle impact during the high speed test. There was no occupant compartment deformation in either test with the 11-gauge support. In the high-speed test with the 16-gauge support with wire rope, the mailboxes contacted the windshield resulting in 3 inches of windshield deformation.

Based on current material costs, it is estimated that the cost per unit installation for the 11-gauge support design is $48.60. The estimated material cost associated with the 16-gauge support with wire rope is $44.21 and $89.68 with and without the swaged cable end, respectively. These costs do not include labor required to install and secure the wire rope inside the 16-gauge support.

If the 11-gauge support is adopted for use with the locking architectural mailboxes, it is recommended that it be adopted for use with multiple standard mailbox configurations, as well. This would eliminate the need to maintain dual inventory and would simplify both design selection of the appropriate support type and field inspection after installation.

To use the current 16-gauge support design with locking architectural mailboxes, the wire rope retrofit will need to be used. Due to the difference in required embedment when the 16-gauge support is used for lockable mailboxes, it will require cutting of the support end to allow for only 6 inches of embedment and the required mailbox installation height. Alternatively, the embedment depth for the 16-gauge support with standard mailboxes could also be modified. This would permit standardization of a different length support to avoid field cutting when locking architectural mailboxes are used. Note that although the same 16-gauge support post can be utilized, additional inventory items necessary to accommodate locking architectural mailboxes include wire rope (or wire rope with swaged end), wire rope clamps, and plate washers (that are used at the ends of the support post to secure the wire rope in place.

REFERENCES

1. R.P. Bligh, W.L. Menges, and D.L. Kuhn. *Crash Test and Evaluation of Locking Architectural Mailboxes*. Report No. FHWA/TX-14/9-1002-12-9, Texas A&M Transportation Institute, College Station, Texas, 2013.

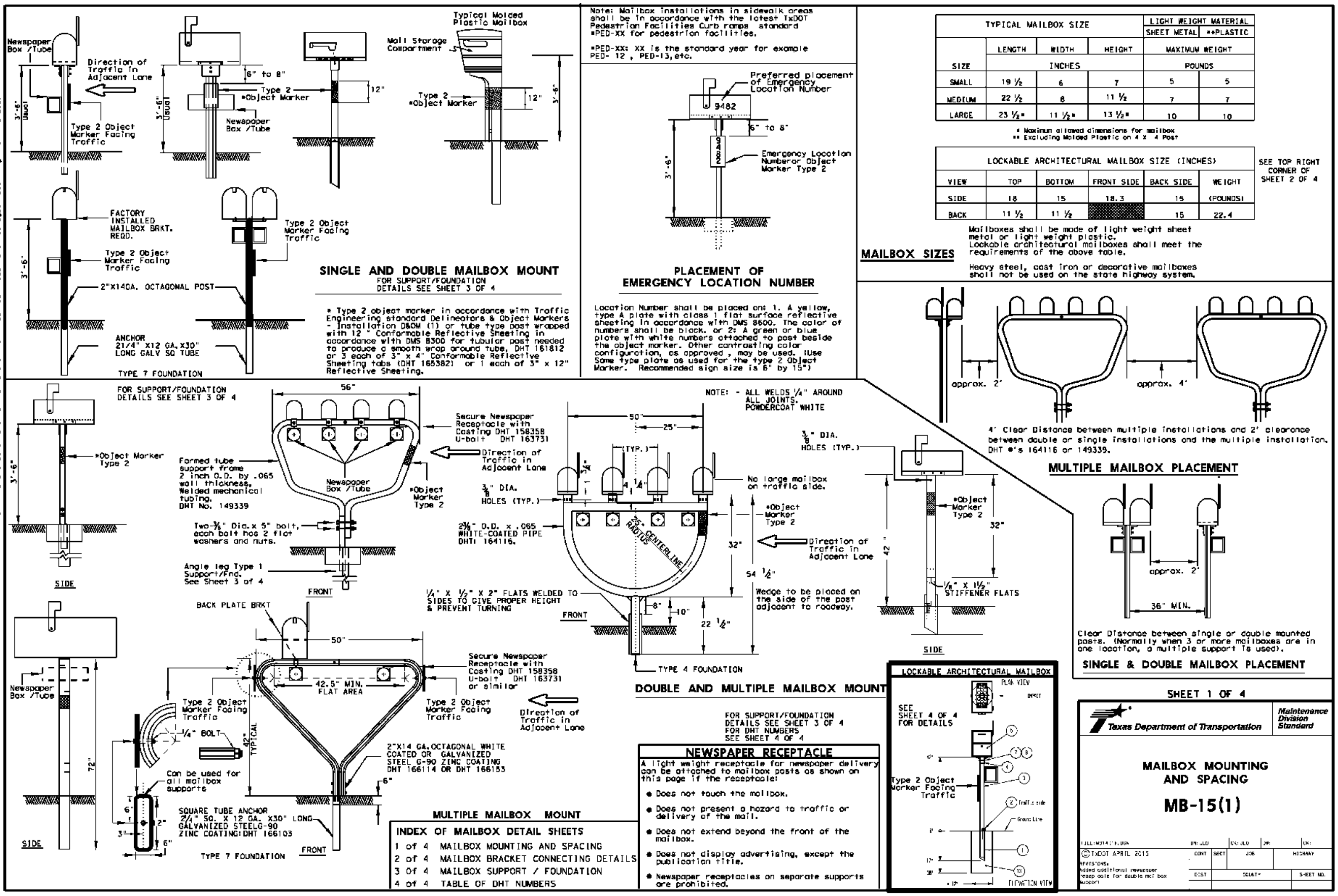
2. AASHTO. *Manual for Assessing Safety Hardware*. American Association of State Highway and Transportation Officials, Washington, D.C., 2009.

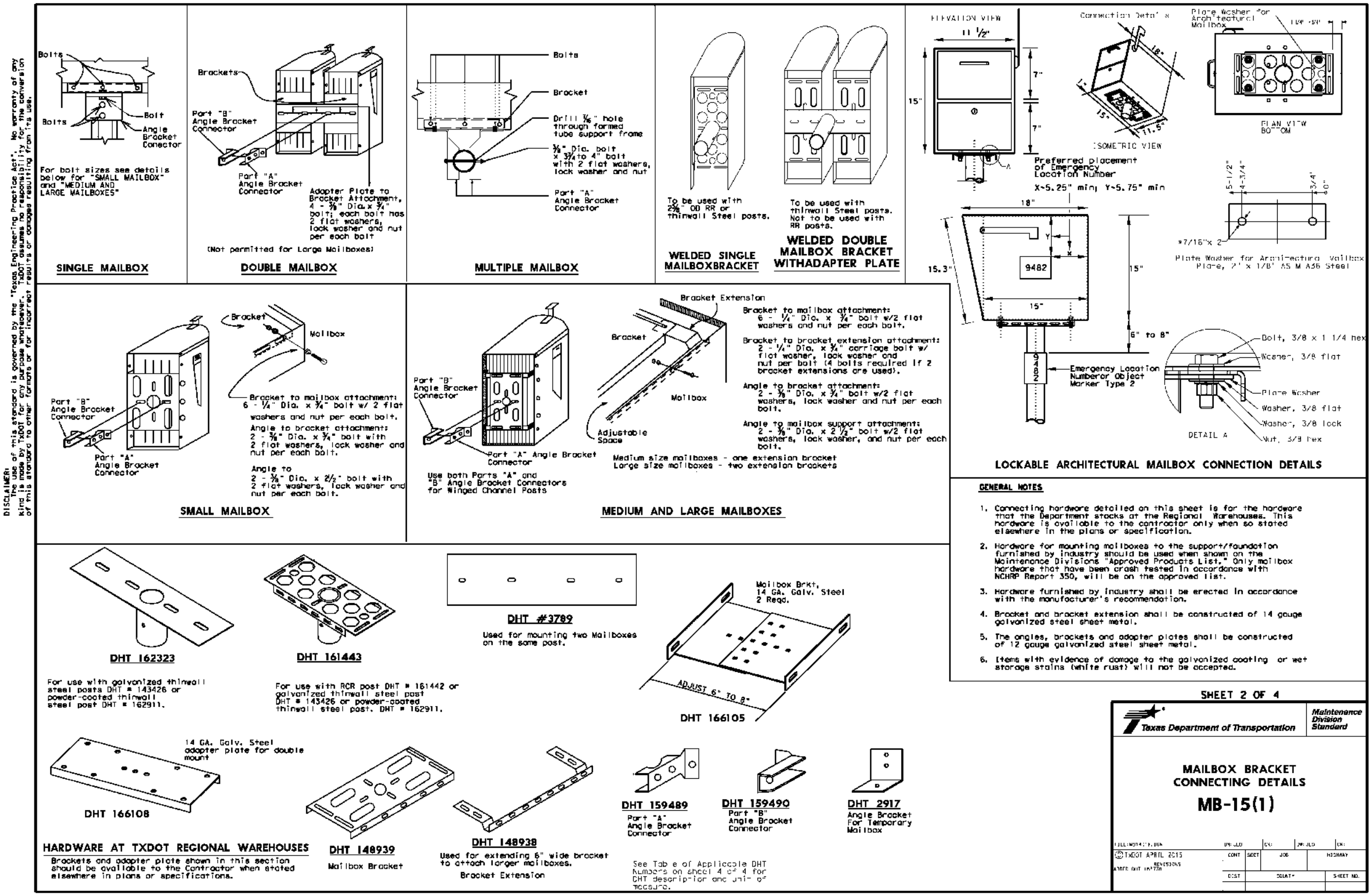
3. H.E. Ross, J.W. Miller, and D.L. Sicking. *Test and Evaluation of Rural Mailbox Supports*. Report No. 0969-1 on SDHPT Contract No. TTI (1980)4, Texas Transportation Institute, College Station, Texas, 1980.

4. Transportation Research Board. *Recommended Procedures for Vehicle Crash Testing of Highway Appurtenances*. TRC 191, National Academy of Sciences, Washington, D.C., February 1978.

5. N.M. Sheikh, R.P. Bligh, W.L. Menges, and R.R. Haug. *Crash Testing and Evaluation of the Shur-Tite® Multiple Mailbox Mounts*. Report No. FHWA/TX-06/0-5210-2, Texas Transportation Institute, College Station, Texas, 2006.

6. H.E. Ross, Jr., D.L. Sicking, R.A. Zimmer, and J.D. Michie. *Recommended Procedures for the Safety Performance Evaluation of Highway Features*. National Cooperative Highway Research Program Report 350, Transportation Research Board, National Research Council, Washington, D.C., 1993.


SINGLE AND DOUBLE MAILBOX MOUNT
FOR SUPPORT/FOUNDATION DETAILS SEE SHEET 3 OF 4
* Type 2 object marker in accordance with Traffic Engineering standard Delineators & Object Markers - Installation D&OM (1) or tube type post wrapped with 12" Conformable Reflective Sheeting in accordance with DMS 8300 for tubular post needed to produce a smooth wrap around tube, DHT 161812 or 3 each of 3" x 4" Conformable Reflective Sheeting tabs (DHT 165382) or 1 each of 3" x 12" Reflective Sheeting.
Note: Mailbox installations in sidewalk areas shall be in accordance with the latest TxDOT Pedestrian Facilities Curb ramps standard *PED-XX for pedestrian facilities.
*PED-XX: XX is the standard year for example PED- 12 , PED-13,etc.
PLACEMENT OF EMERGENCY LOCATION NUMBER
Location Number shall be placed on: 1. A yellow, type A plate with class 1 flat surface reflective sheeting in accordance with DMS 8600. The color of numbers shall be black. or 2: A green or blue plate with white numbers attached to post beside the object marker. Other contrasting color configuration, as approved , may be used. (Use Same type plate as used for the type 2 Object Marker. Recommended sign size is 6" by 15")
TYPICAL MAILBOX SIZE
LIGHT WEIGHT MATERIAL
SHEET METAL **PLASTIC
SIZE LENGTH WIDTH HEIGHT MAXIMUM WEIGHT
INCHES POUNDS
SMALL 19 1/2 6 7 5 5
MEDIUM 22 1/2 8 11 1/2 7 7
LARGE 23 1/2* 11 1/2* 13 1/2* 10 10
* Maximum allowed dimensions for mailbox
** Excluding Molded Plastic on 4 X 4 Post
LOCKABLE ARCHITECTURAL MAILBOX SIZE (INCHES)
VIEW TOP BOTTOM FRONT SIDE BACK SIDE WEIGHT
SIDE 18 15 18.3 15 (POUNDS)
BACK 11 1/2 11 1/2 15 22.4
SEE TOP RIGHT CORNER OF SHEET 2 OF 4
MAILBOX SIZES
Mailboxes shall be made of light weight sheet metal or light weight plastic. Lockable architectural mailboxes shall meet the requirements of the above table.
Heavy steel, cast iron or decorative mailboxes shall not be used on the state highway system.
4' Clear Distance between multiple installations and 2' clearance between double or single installations and the multiple installation. DHT #'s 164116 or 149339.
MULTIPLE MAILBOX PLACEMENT
Clear Distance between single or double mounted posts. (Normally when 3 or more mailboxes are in one location, a multiple support is used).
SINGLE & DOUBLE MAILBOX PLACEMENT
DOUBLE AND MULTIPLE MAILBOX MOUNT
MULTIPLE MAILBOX MOUNT
INDEX OF MAILBOX DETAIL SHEETS
1 of 4 MAILBOX MOUNTING AND SPACING
2 of 4 MAILBOX BRACKET CONNECTING DETAILS
3 of 4 MAILBOX SUPPORT / FOUNDATION
4 of 4 TABLE OF DHT NUMBERS
NEWSPAPER RECEPTACLE
A light weight receptacle for newspaper delivery can be attached to mailbox posts as shown on this page if the receptacle:
● Does not touch the mailbox.
● Does not present a hazard to traffic or delivery of the mail.
● Does not extend beyond the front of the mailbox.
● Does not display advertising, except the publication title.
● Newspaper receptacles on separate supports are prohibited.
LOCKABLE ARCHITECTURAL MAILBOX
SHEET 1 OF 4
Texas Department of Transportation
Maintenance Division Standard
MAILBOX MOUNTING AND SPACING
MB-15(1)


DISCLAIMER: The use of this standard is governed by the "Texas Engineering Practice Act". No warranty of any kind is made by TxDOT for any purpose whatsoever. TxDOT assumes no responsibility for the conversion of this standard to other formats or for incorrect results or damages resulting from its use.
Bolts
Bolt
Angle Bracket Conector
For bolt sizes see details below for "SMALL MAILBOX" and "MEDIUM AND LARGE MAILBOXES"
SINGLE MAILBOX
Brackets
Part "B" Angle Bracket Connector
Part "A" Angle Bracket Connector
Adapter Plate to Bracket Attachment, 4 - 3/8" Dia. x 3/4" bolt; each bolt has 2 flat washers, lock washer and nut per each bolt
(Not permitted for Large Mailboxes)
DOUBLE MAILBOX
Bolts
Bracket
Drill 7/16" hole through formed tube support frame
3/8" Dia. bolt x 3 1/4 to 4" bolt with 2 flat washers, lock washer and nut
Part "A" Angle Bracket Connector
MULTIPLE MAILBOX
To be used with 2 3/8" OD RR or thinwall Steel posts.
WELDED SINGLE MAILBOXBRACKET
To be used with thinwall Steel posts. Not to be used with RR posts.
WELDED DOUBLE MAILBOX BRACKET WITHADAPTER PLATE
ELEVATION VIEW
11 1/2"
15"
7"
7"
Preferred placement of Emergency Location Number
X=5.25" min; Y=5.75" min
ISOMETRIC VIEW
Connection Detail A
Plate Washer for Architectural Mailbox
PLAN VIEW BOTTOM
18"
15.3"
9482
15"
15"
6" to 8"
Emergency Location Number or Object Marker Type 2
Plate Washer for Architectural Mailbox Plate, 2" x 1/8" AS M A36 Steel
Bolt, 3/8 x 1 1/4 hex
Washer, 3/8 flat
Plate Washer
Washer, 3/8 flat
Washer, 3/8 lock
Nut, 3/8 hex
DETAIL A
LOCKABLE ARCHITECTURAL MAILBOX CONNECTION DETAILS
Bracket
Mailbox
Part "B" Angle Bracket Connector
Part "A" Angle Bracket Connector
Bracket to mailbox attachment: 6 - 1/4" Dia. x 3/4" bolt w/ 2 flat washers and nut per each bolt.
Angle to bracket attachment: 2 - 3/8" Dia. x 3/4" bolt with 2 flat washers, lock washer and nut per each bolt.
Angle to mailbox attachment: 2 - 3/8" Dia. x 2 1/2" bolt with 2 flat washers, lock washer and nut per each bolt.
SMALL MAILBOX
Bracket Extension
Bracket
Mailbox
Adjustable Space
Part "B" Angle Bracket Connector
Part "A" Angle Bracket Connector
Use both Parts "A" and "B" Angle Bracket Connectors for Winged Channel Posts
Bracket to mailbox attachment: 6 - 1/4" Dia. x 3/4" bolt w/2 flat washers and nut per each bolt.
Bracket to bracket extension attachment: 2 - 1/4" Dia. x 3/4" carriage bolt w/ flat washer, lock washer and nut per bolt (4 bolts required if 2 bracket extensions are used).
Angle to bracket attachment: 2 - 3/8" Dia. x 3/4" bolt w/2 flat washers, lock washer and nut per each bolt.
Angle to mailbox support attachment: 2 - 3/8" Dia. x 2 1/2" bolt w/2 flat washers, lock washer, and nut per each bolt.
Medium size mailboxes - one extension bracket
Large size mailboxes - two extension brackets
MEDIUM AND LARGE MAILBOXES
GENERAL NOTES
1. Connecting hardware detailed on this sheet is for the hardware that the Department stocks at the Regional Warehouses. This hardware is available to the contractor only when so stated elsewhere in the plans or specification.
2. Hardware for mounting mailboxes to the support/foundation furnished by industry should be used when shown on the Maintenance Divisions "Approved Products List." Only mailbox hardware that have been crash tested in accordance with NCHRP Report 350, will be on the approved list.
3. Hardware furnished by industry shall be erected in accordance with the manufacturer's recommendation.
4. Bracket and bracket extension shall be constructed of 14 gauge galvanized steel sheet metal.
5. The angles, brackets and adapter plates shall be constructed of 12 gauge galvanized steel sheet metal.
6. Items with evidence of damage to the galvanized coating or wet storage stains (white rust) will not be accepted.
DHT 162323
For use with galvanized thinwall steel posts DHT # 143426 or powder-coated thinwall steel post DHT # 162911.
DHT 161443
For use with RCR post DHT # 161442 or galvanized thinwall steel post DHT # 143426 or powder-coated thinwall steel post. DHT # 162911.
DHT #3789
Used for mounting two Mailboxes on the same post.
Mailbox Brkt, 14 GA. Galv. Steel 2 Reqd.
ADJUST 6" TO 8"
DHT 166105
14 GA. Galv. Steel adapter plate for double mount
DHT 166108
HARDWARE AT TXDOT REGIONAL WAREHOUSES
Brackets and adapter plate shown in this section should be available to the Contractor when stated elsewhere in plans or specifications.
DHT 148939
Mailbox Bracket
DHT 148938
Used for extending 6" wide bracket to attach larger mailboxes.
Bracket Extension
DHT 159489
Part "A" Angle Bracket Connector
DHT 159490
Part "B" Angle Bracket Connector
DHT 2917
Angle Bracket For Temporary Mailbox
See Table of Applicable DHT Numbers on sheet 4 of 4 for DHT description and unit of measure.
SHEET 2 OF 4
Texas Department of Transportation
Maintenance Division Standard
MAILBOX BRACKET CONNECTING DETAILS
MB-15(1)
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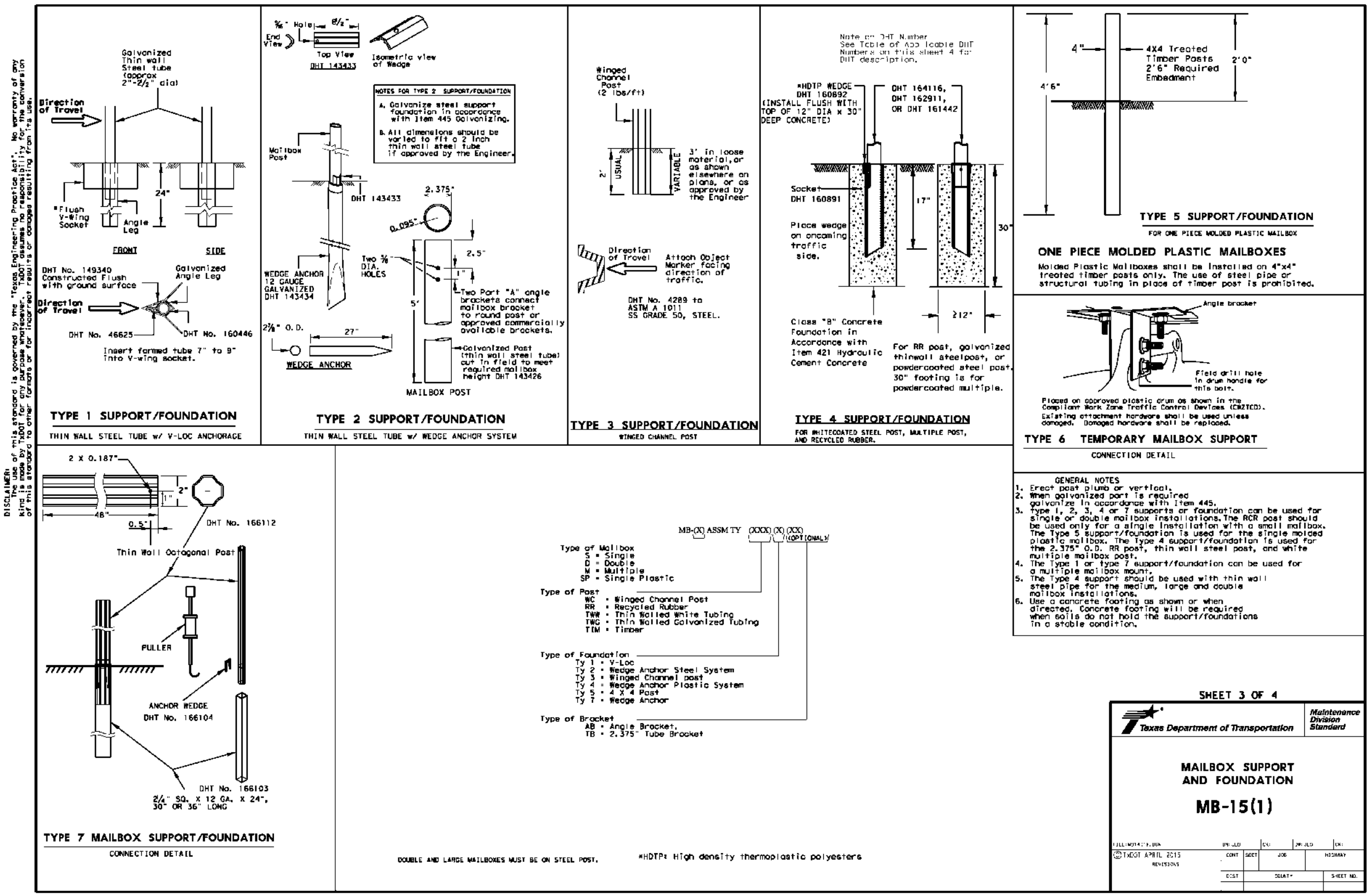
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TYPE 1 SUPPORT/FOUNDATION
THIN WALL STEEL TUBE w/ V-LOC ANCHORAGE
TYPE 2 SUPPORT/FOUNDATION
THIN WALL STEEL TUBE w/ WEDGE ANCHOR SYSTEM
NOTES FOR TYPE 2 SUPPORT/FOUNDATION
A. Galvanize steel support foundation in accordance with Item 445 Galvanizing.
B. All dimensions should be varied to fit a 2 inch thin wall steel tube if approved by the Engineer.
TYPE 3 SUPPORT/FOUNDATION
WINGED CHANNEL POST
TYPE 4 SUPPORT/FOUNDATION
FOR WHITECOATED STEEL POST, MULTIPLE POST, AND RECYCLED RUBBER.
TYPE 5 SUPPORT/FOUNDATION
FOR ONE PIECE MOLDED PLASTIC MAILBOX
ONE PIECE MOLDED PLASTIC MAILBOXES
Molded Plastic Mailboxes shall be installed on 4"x4" treated timber posts only. The use of steel pipe or structural tubing in place of timber post is prohibited.
TYPE 6 TEMPORARY MAILBOX SUPPORT
CONNECTION DETAIL
TYPE 7 MAILBOX SUPPORT/FOUNDATION
CONNECTION DETAIL
GENERAL NOTES
1. Erect post plumb or vertical.
2. When galvanized part is required galvanize in accordance with Item 445.
3. Type 1, 2, 3, 4 or 7 supports or foundation can be used for single or double mailbox installations. The RCR post should be used only for a single installation with a small mailbox. The Type 5 support/foundation is used for the single molded plastic mailbox. The Type 4 support/foundation is used for the 2.375" O.D. RR post, thin wall steel post, and white multiple mailbox post.
4. The Type 1 or type 7 support/foundation can be used for a multiple mailbox mount.
5. The Type 4 support should be used with thin wall steel pipe for the medium, large and double mailbox installations.
6. Use a concrete footing as shown or when directed. Concrete footing will be required when soils do not hold the support/foundations in a stable condition.
MB-(X) ASSM TY (XXX) (X) (XX) (OPTIONAL)
Type of Mailbox
S = Single
D = Double
M = Multiple
SP = Single Plastic
Type of Post
WC = Winged Channel Post
RR = Recycled Rubber
TWW = Thin Walled White Tubing
TWG = Thin Walled Galvanized Tubing
TIM = Timber
Type of Foundation
Ty 1 = V-Loc
Ty 2 = Wedge Anchor Steel System
Ty 3 = Winged Channel post
Ty 4 = Wedge Anchor Plastic System
Ty 5 = 4 X 4 Post
Ty 7 = Wedge Anchor
Type of Bracket
AB = Angle Bracket.
TB = 2.375" Tube Bracket
DOUBLE AND LARGE MAILBOXES MUST BE ON STEEL POST.
*HDTP: High density thermoplastic polyesters
SHEET 3 OF 4
Texas Department of Transportation
Maintenance Division Standard
MAILBOX SUPPORT AND FOUNDATION
MB-15(1)
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LOCKABLE ARCHITECTURAL MAILBOX

SINGLE-MOUNT INSTALLATION PARTS			
#	PART NAME	PART/DHT #	QTY
1	SOCKET, TYPE 4 FOUNDATION	160891	1
2	WEDGE FOR TYPE 4 FOUNDATION	160892	1
3	THIN-WALL WHITE STEEL TUBE 2.375 OD	162911	1
4	BRACKET FOR ATTACHING MAILBOX	161443	1
5	ARCHITECTURAL MAILBOX	SEE NOTE	1
6	NUT, 5/16" HEX	NUT, 5/16" HEX	1
7	BOLT, 5/16 X 3 HEX	GRADE 5	1
8	PLATE WASHER FOR ARCHITECTURAL MAILBOX	SEE SEE SHEET 2	2
9	WASHER, 3/8 FLAT		8
10	WASHER, 3/8 LOCK		4
11	NUT, 3/8 HEX		4
12	BOLT, 3/8 X 1-1/4 HEX	GRADE 5	4
13	CONCRETE, CLASS B (2000 PSI)		1

LOCKABLE ARCHITECTURAL MAILBOX DETAILS

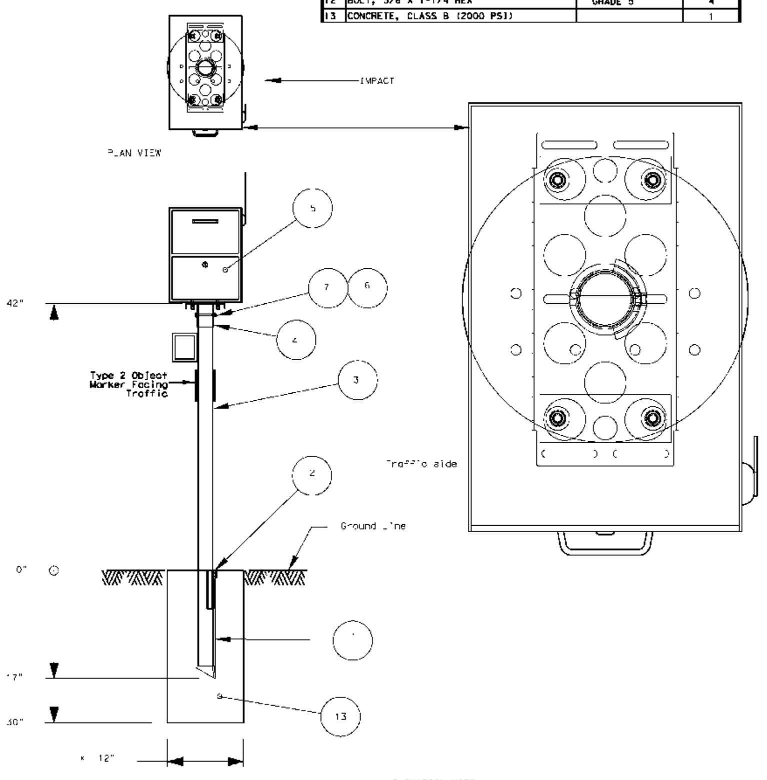


TABLE OF APPLICABLE DHT NUMBERS	
DHT NUMBER	DESCRIPTION
FOUNDATIONS	
46625	WEDGE FOR V-WING SOCKET FOR TYPE 1 FOUNDATION
149340	V-WING SOCKET FOR TYPE 1 FOUNDATION
143433	WEDGE FOR TYPE 2 FOUNDATION
143434	ANCHOR FOR TYPE 2 FOUNDATION
166103	ANCHOR FOR TYPE 7 FOUNDATION
160891	SOCKET FOR TYPE 4 FOUNDATION
160892	WEDGE FOR TYPE 4 FOUNDATION
166104	WEDGE FOR TYPE 7 FOUNDATION
POSTS	
4289	WINGED CHANNEL MAILBOX POST
149339	MULTIPLE MAILBOX POST (GALVANIZED TUBING)
164116	MULTIPLE MAILBOX POST (WHITE COATED)
166114	MULTIPLE MAILBOX POST (WHITE COATED OCTAGONAL)
166153	MULTIPLE MAILBOX POST (GALVANIZED OCTAGONAL)
161442	RECYCLED RUBBER POST, FOR SMALL MAILBOX ONLY
143426	THIN-WALL GALVANIZED STEEL TUBE 2.375" OUTER DIAMETER
162911	THINWALL WHITE STEEL TUBE 2.375" OUTER DIAMETER
166152	SINGLE OR DOUBLE THIN-WALL MAILBOX POST GALVANIZED 2" OCTAGONAL
166112	SINGLE OR DOUBLE THIN-WALL MAILBOX POST WHITECOATED 2" OCTAGONAL
REFLECTIVE SHEETING	
161812	REFLECTIVE SHEETING FOR EMERGENCY LOCATION NUMBER PANEL
CONNECTING HARDWARE	
2917	ANGLE BRACKET USED FOR TEMPORARY MAILBOX SUPPORT
166105	BRACKET FOR SINGLE MOUNTING OF MAILBOXES (MOUNTING KIT)
3789	PLATE FOR DOUBLE MOUNTING OF MAILBOXES
166108	BRACKET FOR DOUBLE MOUNTING OF MAILBOXES (MOUNTING KIT)
166111	BRACKET FOR MULTIPLE MOUNTING OF MAILBOXES (MOUNTING KIT)
148939	BRACKET FOR ATTACHING SMALL OR MEDIUM SIZE MAIL BOX
148938	EXTENDER TO BRACKET FOR ATTACHING LARGE MAILBOX
159489	ANGLE BRACKET PART A
159490	ANGLE BRACKET PART B
162323	BRACKET FOR DOUBLE MOUNTING OF MAILBOXES ON THINWALL STEEL POST, GALVANIZED OR POWDERCOATED.
161443	BRACKET FOR ATTACHING MAILBOX TO RECYCLED RUBBER POST AND TO MULTIPLE WHITE MAILBOX POST
158358	CASTING (NEWSPAPER RECEPTACLE BRACKET)
163731	U-BOLT (NEWSPAPER RECEPTACLE BRACKET)
160698	BOLT;HEX HEAD, GALV;3/8"DIA X 3/4"L HD, W/2-FLAT WASHERS
163750	BOLT;HEX HEAD, GALV;3/8" X 1-1/2, 16 NC, W/WASHERS
160701	BOLT;HEX HEAD, GALV;3/8"DIA X 2-1/2"L, HD, W/2-FLAT WASHERS
163730	BOLT;HEX HEAD, GALV;3/8" X 3-1/2", NC, W/NUT, 2 FLAT WASHERS
160699	BOLT;HEX HEAD, GALV;3/8"DIA X 3-3/4"L HD, W/2-FLAT WASHERS
160700	BOLT;HEX HEAD, GALV;3/8"DIA X 4"L HD, W/2-FLAT WASHERS

SHEET 4 OF 4

Texas Department of Transportation

Maintenance Division Standard

DHT NUMBERS TABLE

MB-15(1)

REVISIONS

APPENDIX B: *MASH* TEST 3-61 (CRASH TEST NO. 490025-3-2)

B.1 VEHICLE PROPERTIES AND INFORMATION

Table B.1. Vehicle Properties for Test No. 490025-3-2.

Date: 2015-08-25 Test No.: 490025-3-2 VIN No.: KNADE223X96456858

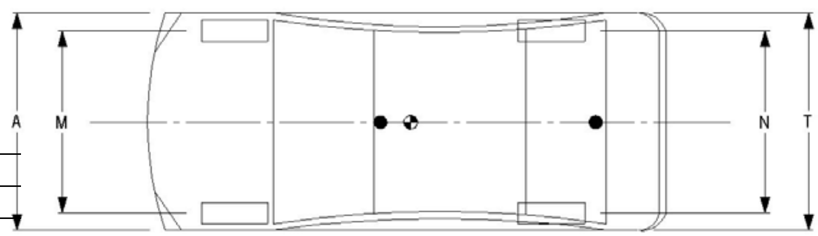
Year: 2009 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 101262 Tire Size: 185/65R14

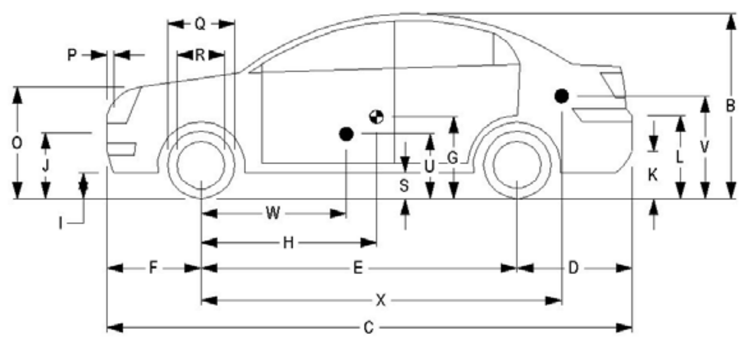
Describe any damage to the vehicle prior to test: None

- ● Denotes accelerometer location.

NOTES: None



Engine Type: 4 cylinder
Engine CID: 1.6 liter
Transmission Type:
x Auto or ____ Manual
____ FWD x RWD ____ 4WD
Optional Equipment:
None



Dummy Data:
Type: 50th percentile male
Mass: 165 lb
Seat Position: Driver

Geometry: inches

A	66.38	F	33.00	K	12.75	P	4.12	U	14.50
B	58.25	G	—	L	25.00	Q	22.19	V	21.50
C	165.75	H	35.46	M	57.75	R	15.38	W	44.00
D	34.00	I	9.5	N	57.12	S	9.00	X	109.00
E	98.75	J	21.5	O	31.50	T	66.12		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00

GVWR Ratings:		**Mass**: lb	Curb	Test Inertial	Gross Static
Front	1918	M_{front}	1585	1560	1651
Back	1874	M_{rear}	894	874	948
Total	3638	M_{Total}	2479	2434	2599

Mass Distribution:
lb LF: 812 RF: 748 LR: 420 RR: 454

Table B.2. Exterior Crush Measurements of Vehicle for Test No. 490025-3-2.

Date:	2015-08-25	Test No.:	490025-3-2	VIN No.:	KNADE223X96456858
Year:	2009	Make:	Kia	Model:	Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	Front plane above bumper	9	8	—	—	—	—	—	—	—	—
	Measurements recorded										
	in inches										

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

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

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

Record the value for each C-measurement and maximum crush.

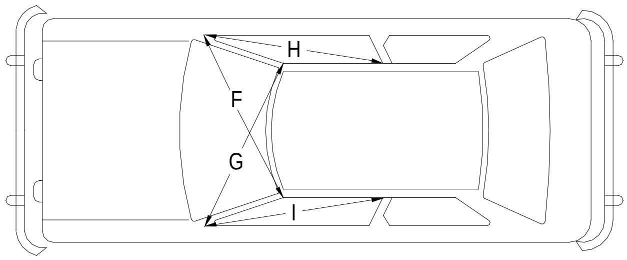
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

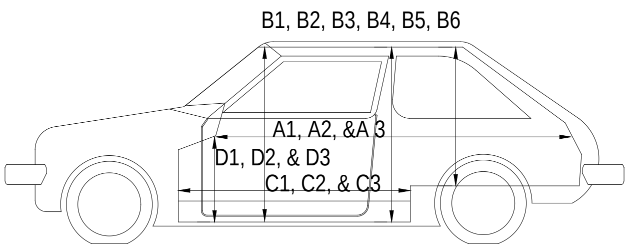
***Measure and document on the vehicle diagram the location of the maximum crush.

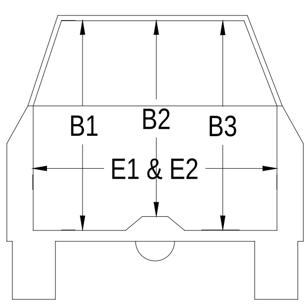
Note: Use as many lines/columns as necessary to describe each damage profile.

Table B.3. Occupant Compartment Measurements of Vehicle for Test No. 490025-3-2.

Date:	2015-08-25	Test No.:	490025-3-2	VIN No.:	KNADE223X96456858
Year:	2009	Make:	Kia	Model:	Rio







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	After (inches)
A1	67.50	67.50
A2	67.00	67.00
A3	67.75	37.75
B1	40.25	40.25
B2	36.00	36.00
B3	40.25	40.25
B4	36.25	36.25
B5	35.75	35.75
B6	36.25	36.25
C1	25.50	25.50
C2	—	—
C3	24.50	24.50
D1	9.50	9.50
D2	—	—
D3	9.50	9.50
E1	51.50	51.50
E2	51.00	51.00
F	51.00	51.00
G	51.00	51.00
H	37.50	37.50
I	37.50	37.50
J*	50.75	50.75

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

B.2 SEQUENTIAL PHOTOGRAPHS

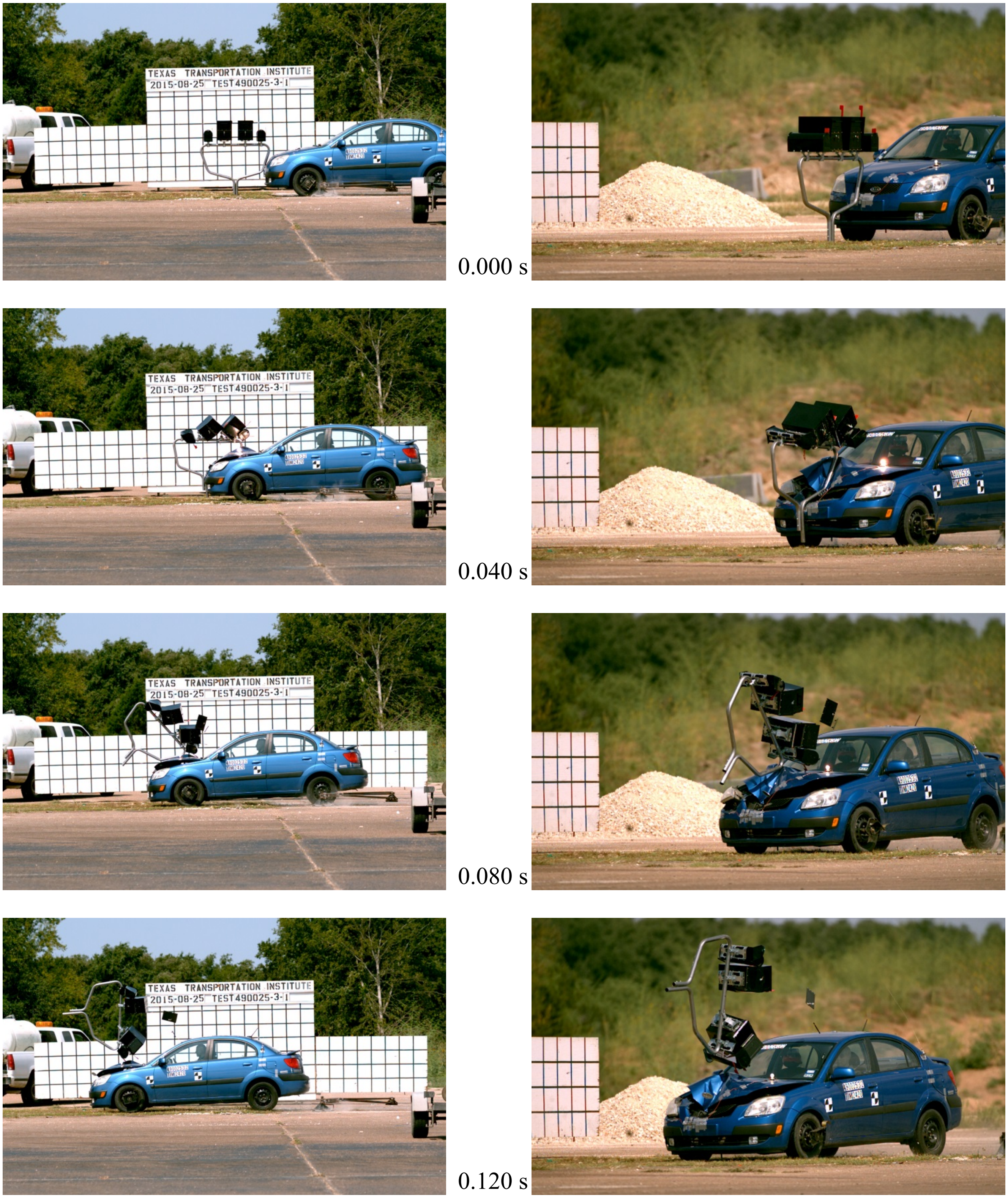


Figure B.1. Sequential Photographs for Test No. 490025-3-2 (Perpendicular and Oblique Views).

0.160 s

0.200 s

0.240 s

0.280 s

Figure B.1. Sequential Photographs for Test No. 490025-3-2 (Perpendicular and Oblique Views) (Continued).

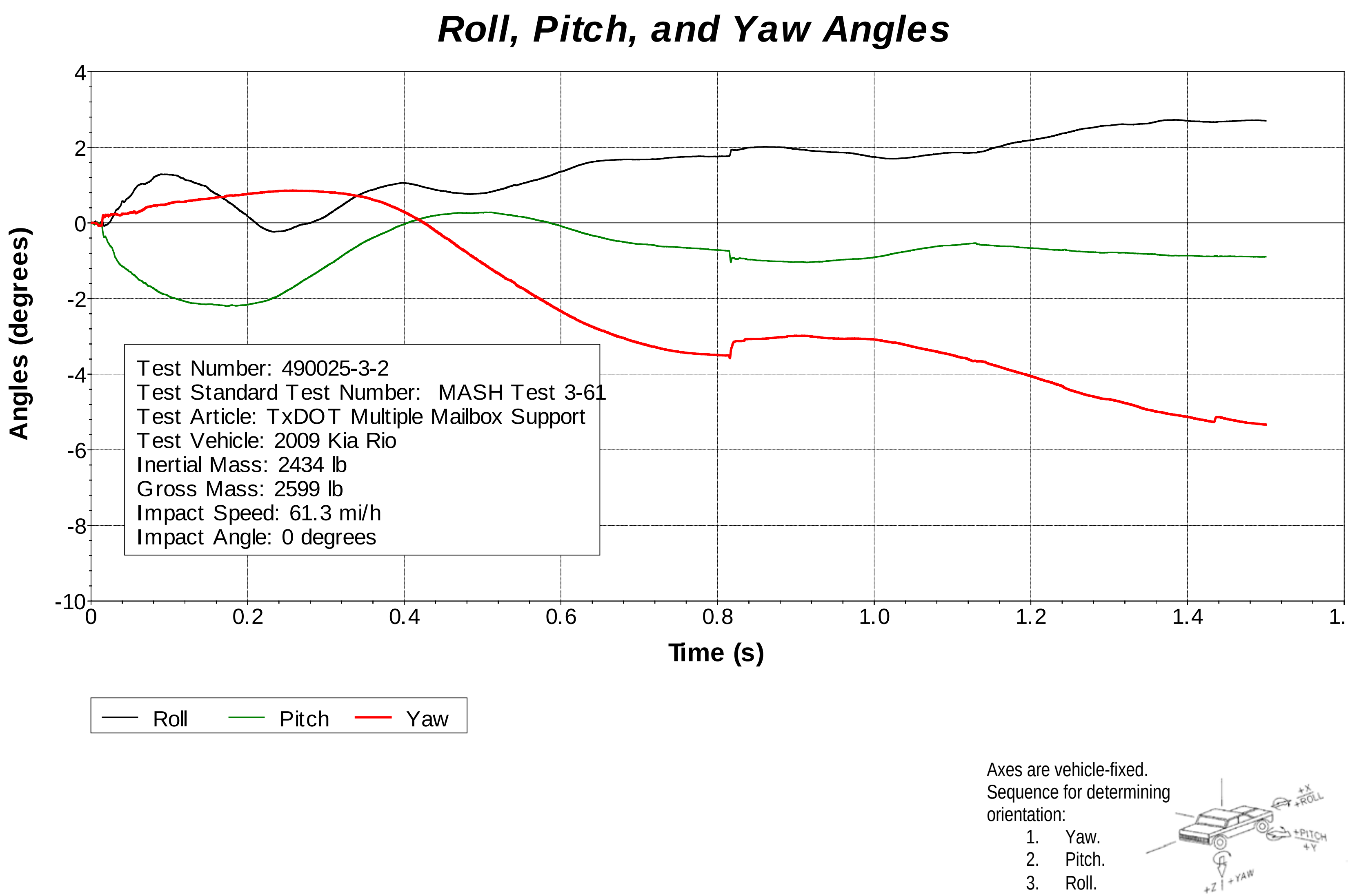


Figure B.2. Vehicle Angular Displacements for Test No. 490025-3-2.

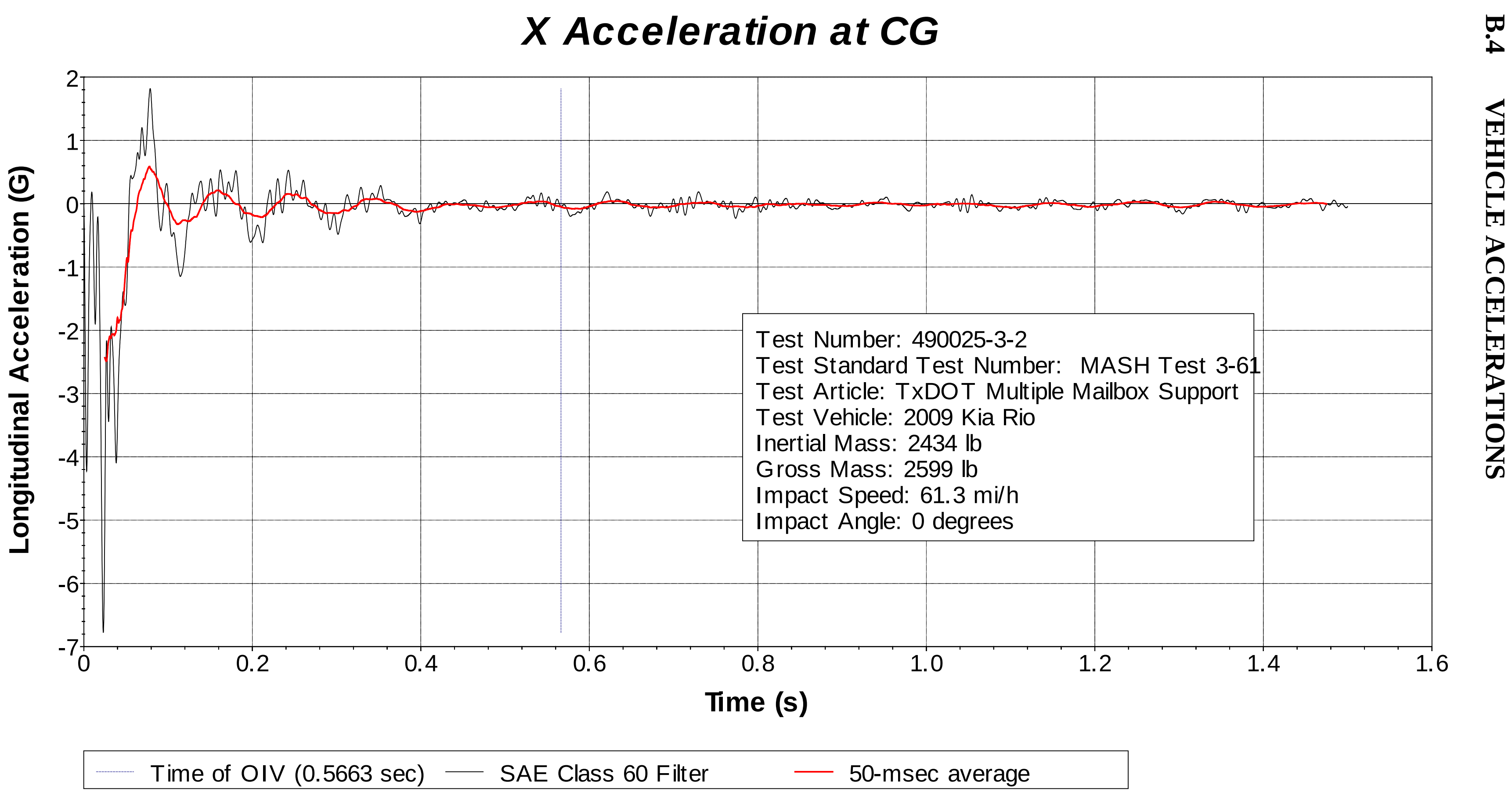


Figure B.3. Vehicle Longitudinal Accelerometer Trace for Test No. 490025-3-2 (Accelerometer Located at Center of Gravity).

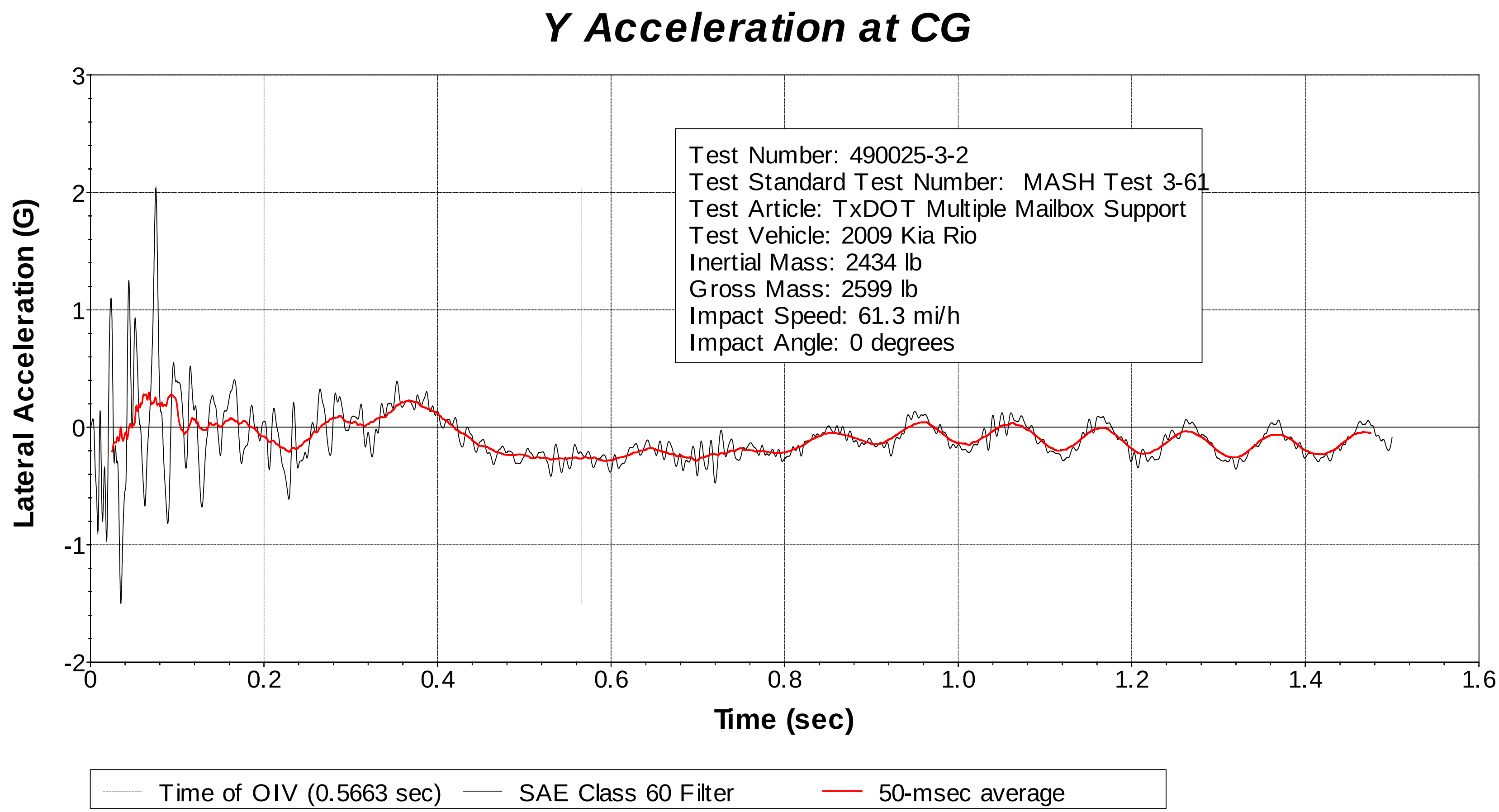


Figure B.4. Vehicle Lateral Accelerometer Trace for Test No. 490025-3-2 (Accelerometer Located at Center of Gravity).

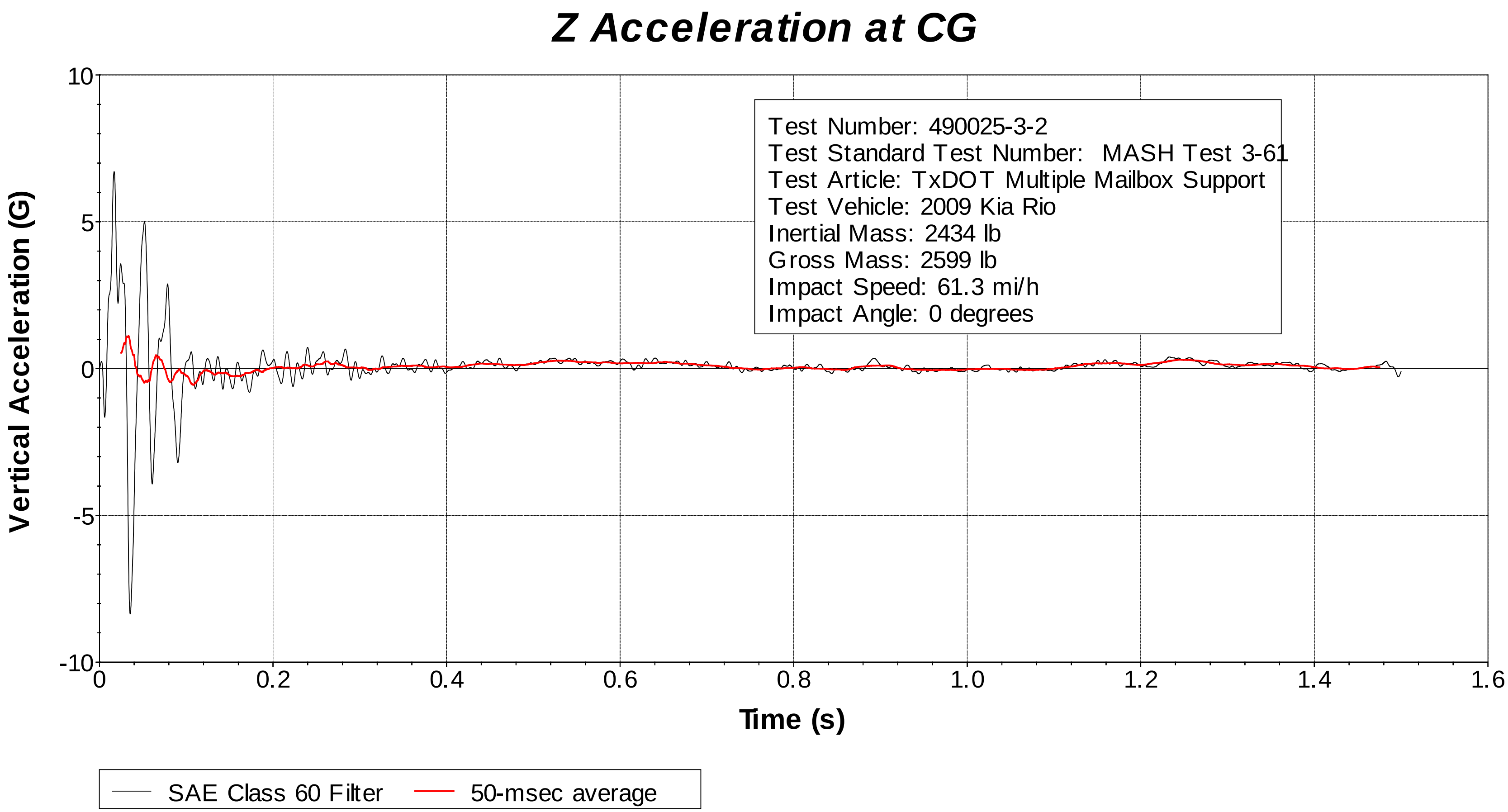


Figure B.5. Vehicle Vertical Accelerometer Trace for Test No. 490025-3-2 (Accelerometer Located at Center of Gravity).

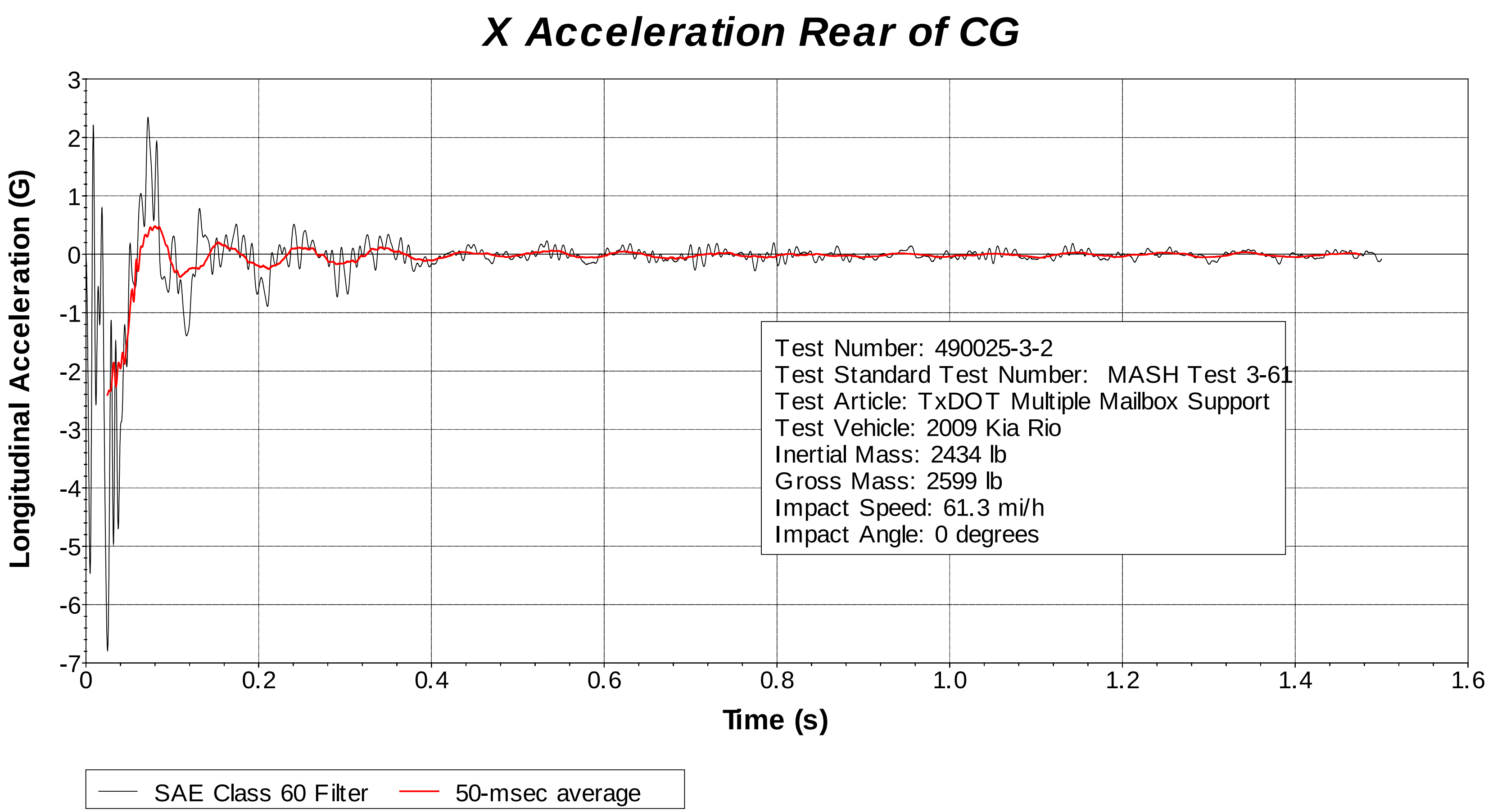


Figure B.6. Vehicle Longitudinal Accelerometer Trace for Test No. 490025-3-2 (Accelerometer Located Rear of Center of Gravity).

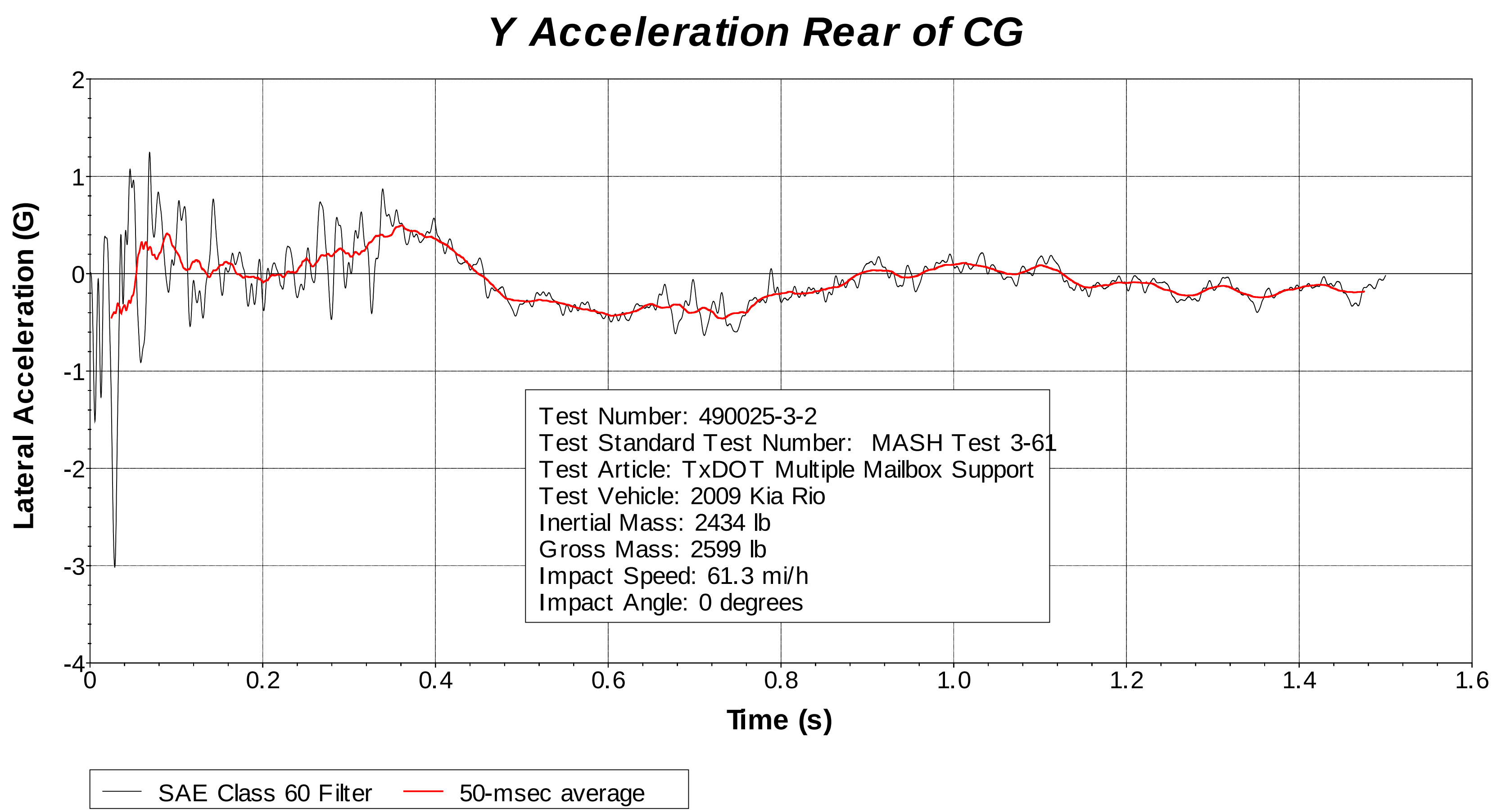


Figure B.7. Vehicle Lateral Accelerometer Trace for Test No. 490025-3-2 (Accelerometer Located Rear of Center of Gravity).

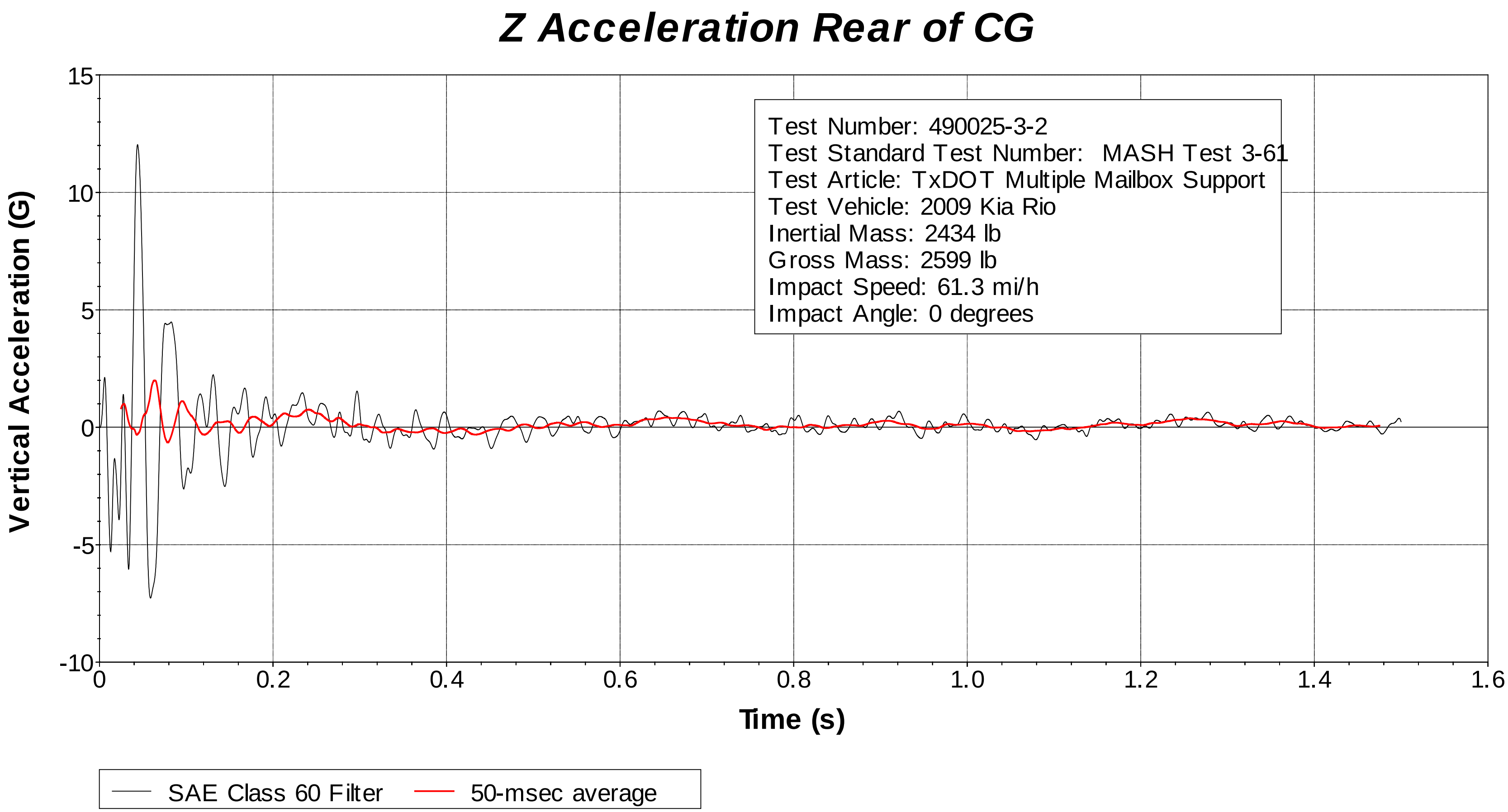


Figure B.8. Vehicle Vertical Accelerometer Trace for Test No. 490025-3-2 (Accelerometer Located Rear of Center of Gravity).

APPENDIX C: *MASH* TEST 3-60 (CRASH TEST NO. 490025-3-1)

C.1 VEHICLE PROPERTIES AND INFORMATION

Table C.1. Vehicle Properties for Test No. 490025-3-1.

Date: 2015-08-25 Test No.: 490025-3-1 VIN No.: KNADE273796451987

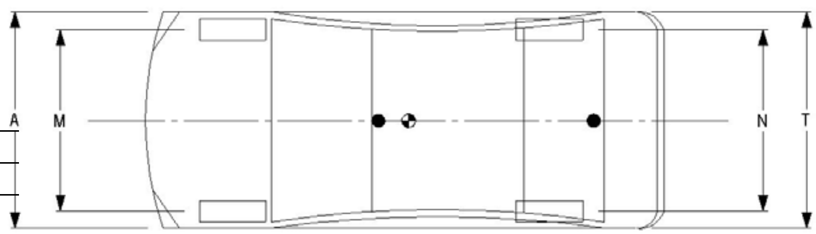
Year: 2009 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 78218 Tire Size: 185/65R14

Describe any damage to the vehicle prior to test: None

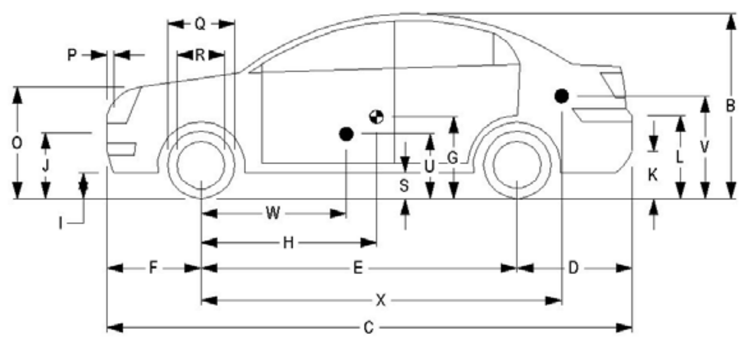
● Denotes accelerometer location.

NOTES: None



Engine Type: 4 cylinder
Engine CID: 1.4 liter
Transmission Type:
___ Auto or x Manual
x FWD ___ RWD ___ 4WD
Optional Equipment:
None

Dummy Data:
Type: 50th percentile male
Mass: 165 lb
Seat Position: Driver



Geometry: inches

A	66.38	F	33.00	K	12.75	P	4.12	U	14.50
B	58.25	G	—	L	25.00	Q	22.19	V	21.50
C	165.75	H	36.37	M	57.75	R	15.38	W	44.00
D	34.00	I	9.50	N	57.12	S	9.00	X	109.00
E	98.75	J	21.50	O	31.50	T	66.12		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00

GVWR Ratings:		Mass: lb	Curb	Test Inertial	Gross Static
Front	1918	M_{front}	1530	1534	1624
Back	1874	M_{rear}	858	893	874
Total	3638	M_{Total}	2388	2427	2598

Mass Distribution:
lb LF: 782 RF: 752 LR: 435 RR: 458

Table C.2. Exterior Crush Measurements of Vehicle for Test No. 490025-3-1.

Date: 2015-08-25 Test No.: 490025-3-1 VIN No.: KNADE273796451987

Year: 2009 Make: Kia Model: Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
1	Front plane above bumper	9.25	3.25	—	—	—	—	—	—	—	—
	Measurements recorded										
	in inches										

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

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

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

Record the value for each C-measurement and maximum crush.

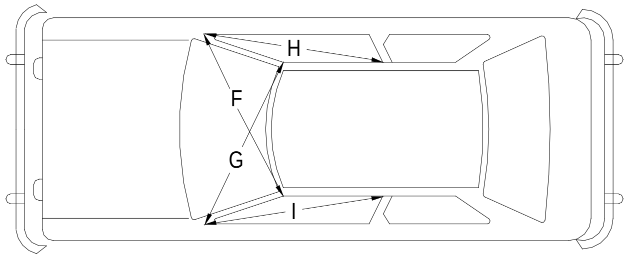
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

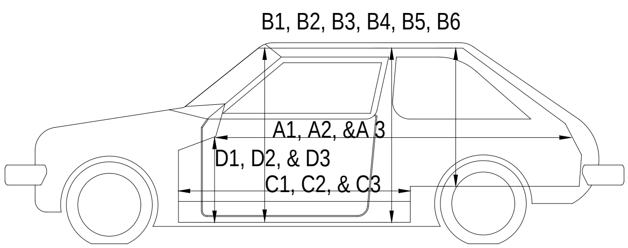
***Measure and document on the vehicle diagram the location of the maximum crush.

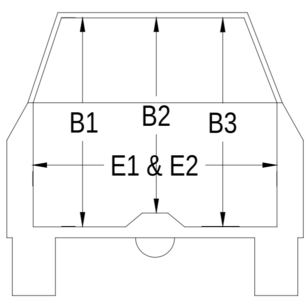
Note: Use as many lines/columns as necessary to describe each damage profile.

Table C.3. Occupant Compartment Measurements of Vehicle for Test No. 490025-3-1.

Date:	2015-08-25	Test No.:	490025-3-1	VIN No.:	KNADE273796451987
Year:	2009	Make:	Kia	Model:	Rio







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	After (inches)
A1	67.50	67.50
A2	67.00	67.00
A3	67.75	37.75
B1	40.25	40.25
B2	36.00	36.00
B3	40.25	40.25
B4	36.25	36.25
B5	35.75	35.75
B6	36.25	36.25
C1	25.50	25.50
C2	—	—
C3	24.50	24.50
D1	9.50	9.50
D2	—	—
D3	9.50	9.50
E1	51.50	51.50
E2	51.00	51.00
F	51.00	51.00
G	51.00	51.00
H	37.50	37.50
I	37.50	37.50
J*	50.75	50.75

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

C.2 SEQUENTIAL PHOTOGRAPHS

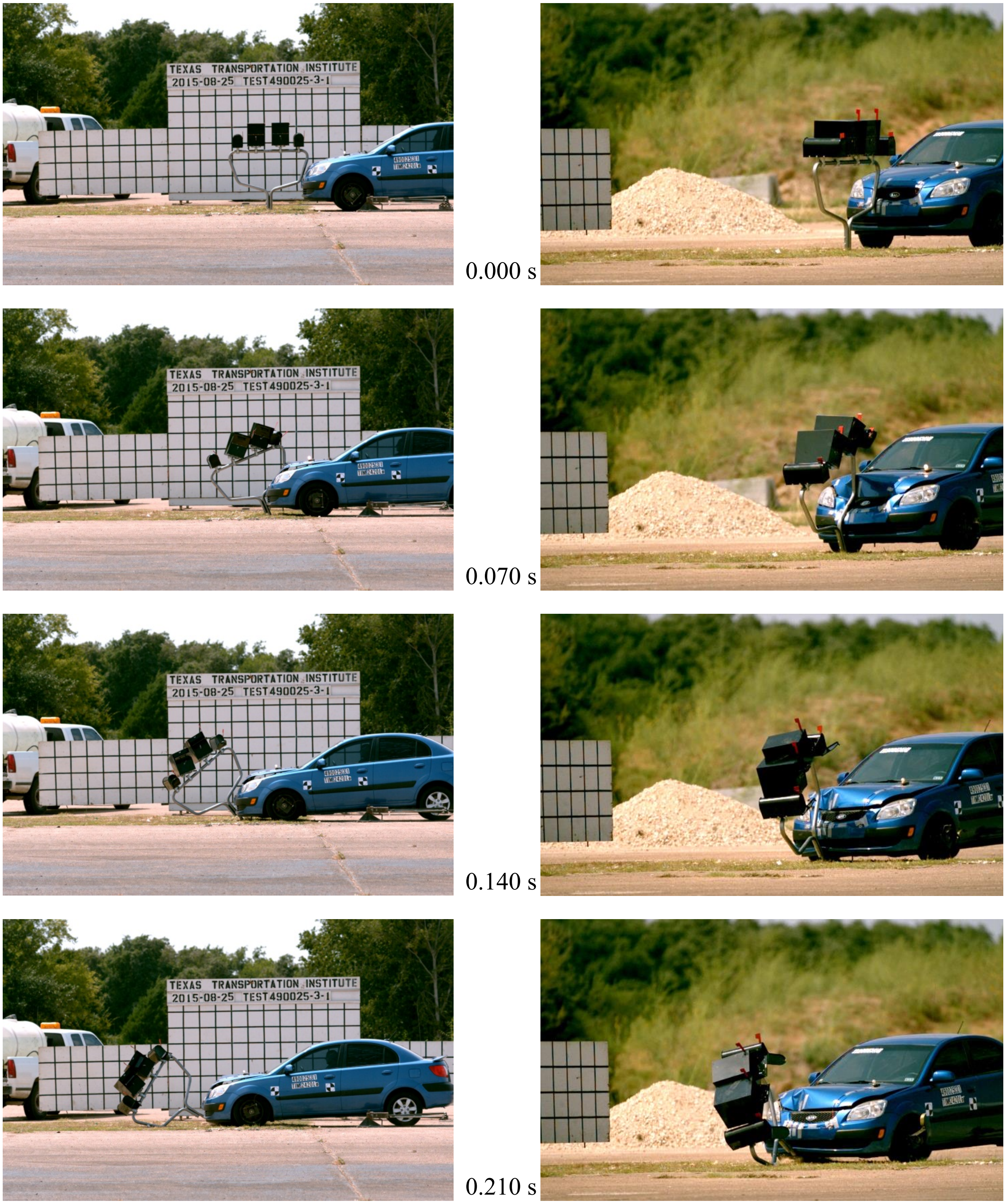
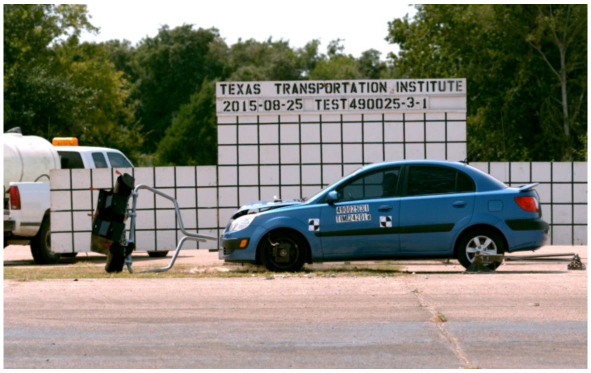
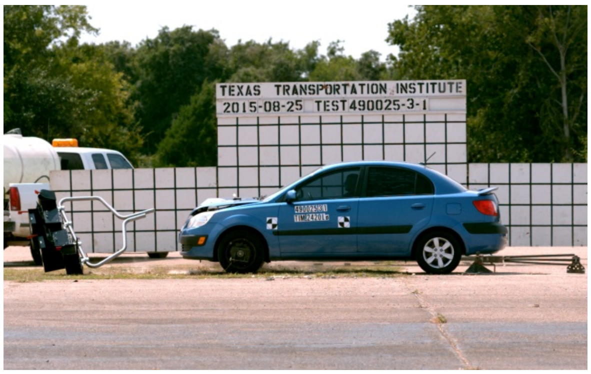


Figure C.1. Sequential Photographs for Test No. 490025-3-1 (Perpendicular and Oblique Views).



0.280 s

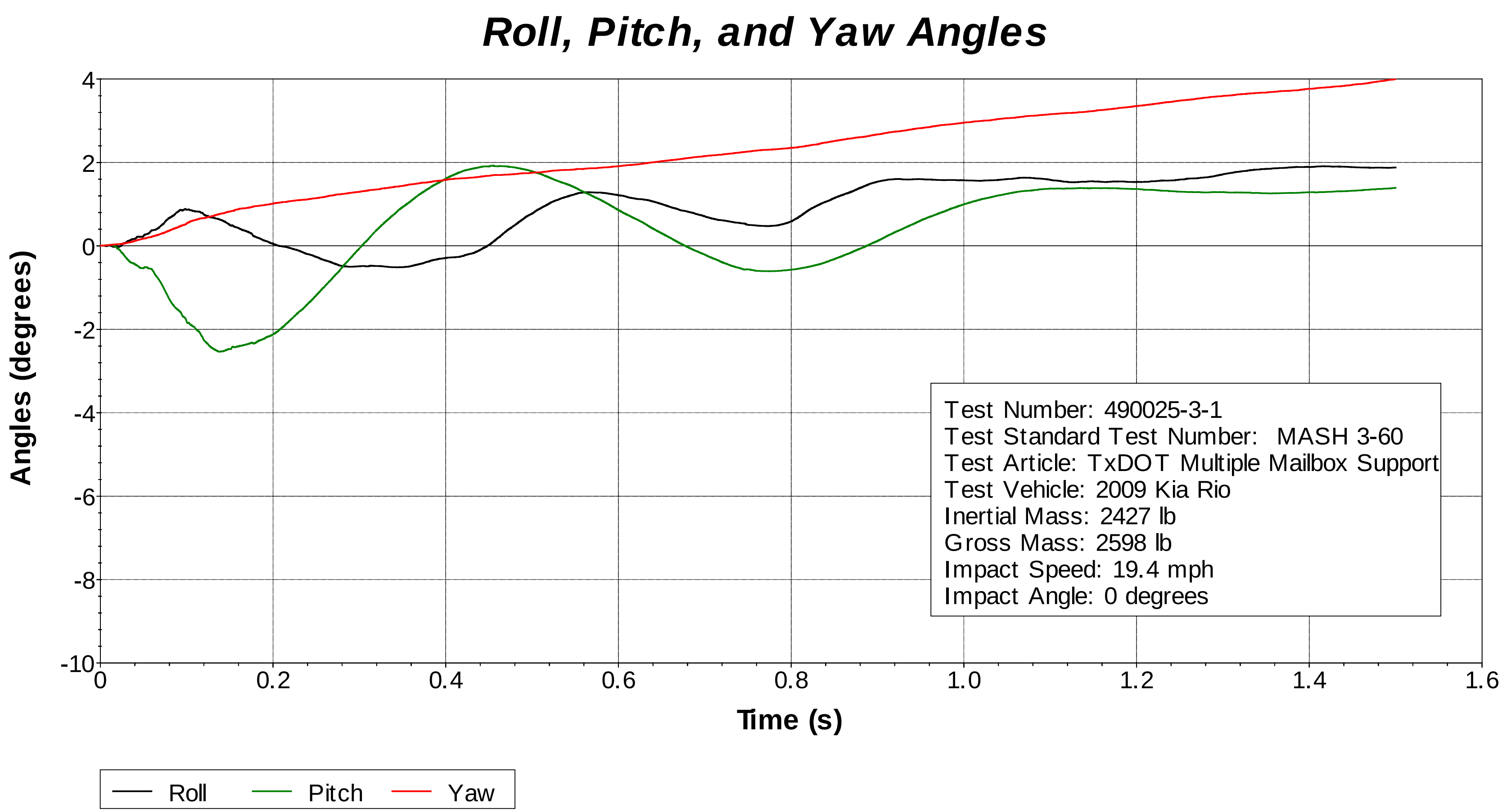


0.350 s

0.420 s

0.490 s

Figure C.1. Sequential Photographs for Test No. 490025-3-1 (Perpendicular and Oblique Views) (Continued).



Axes are vehicle-fixed.
Sequence for determining orientation:

1. Yaw.
2. Pitch.
3. Roll.

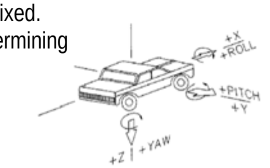


Figure C.2. Vehicle Angular Displacements for Test No. 490025-3-1.

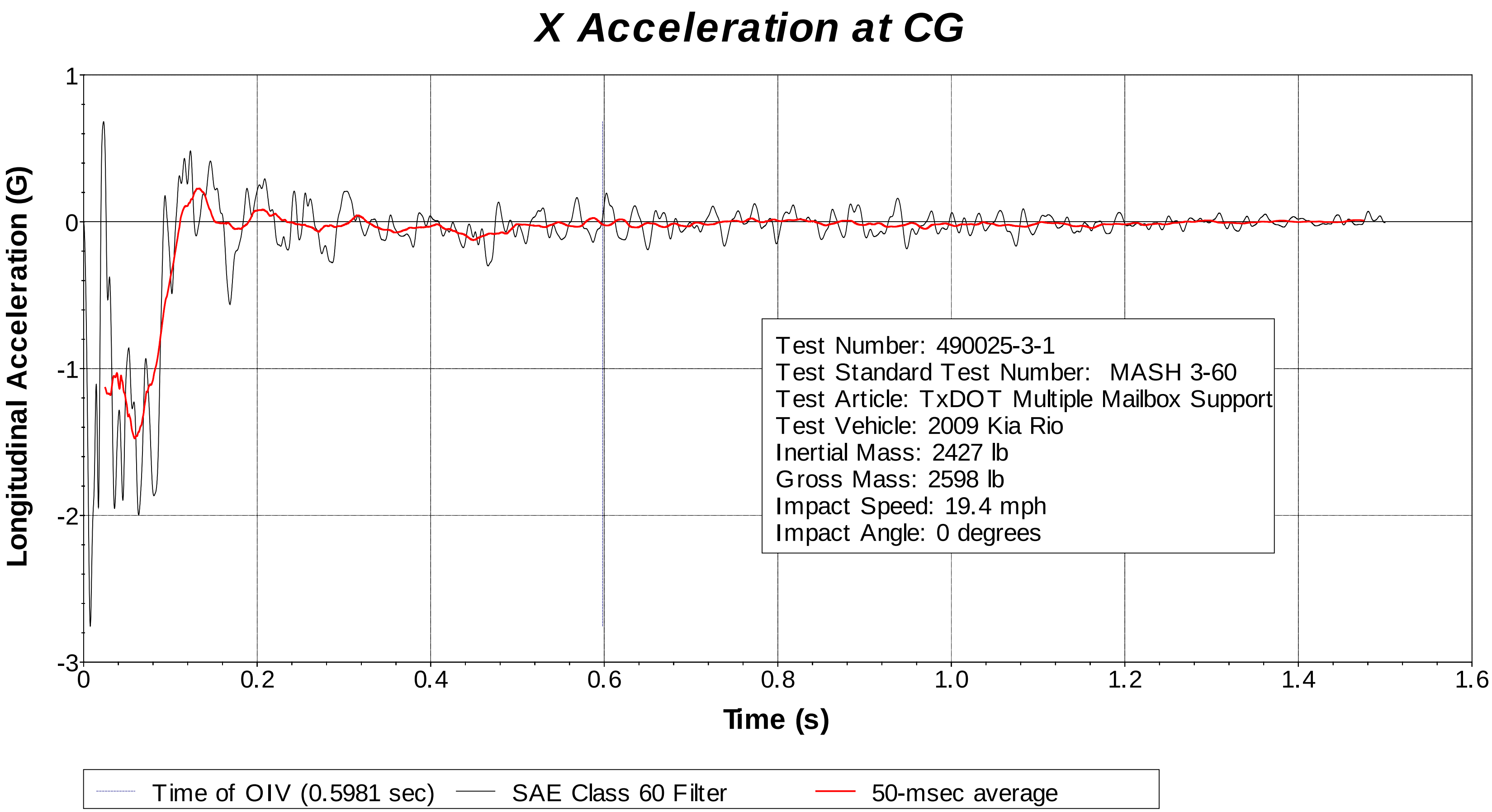


Figure C.3. Vehicle Longitudinal Accelerometer Trace for Test No. 490025-3-1 (Accelerometer Located at Center of Gravity).

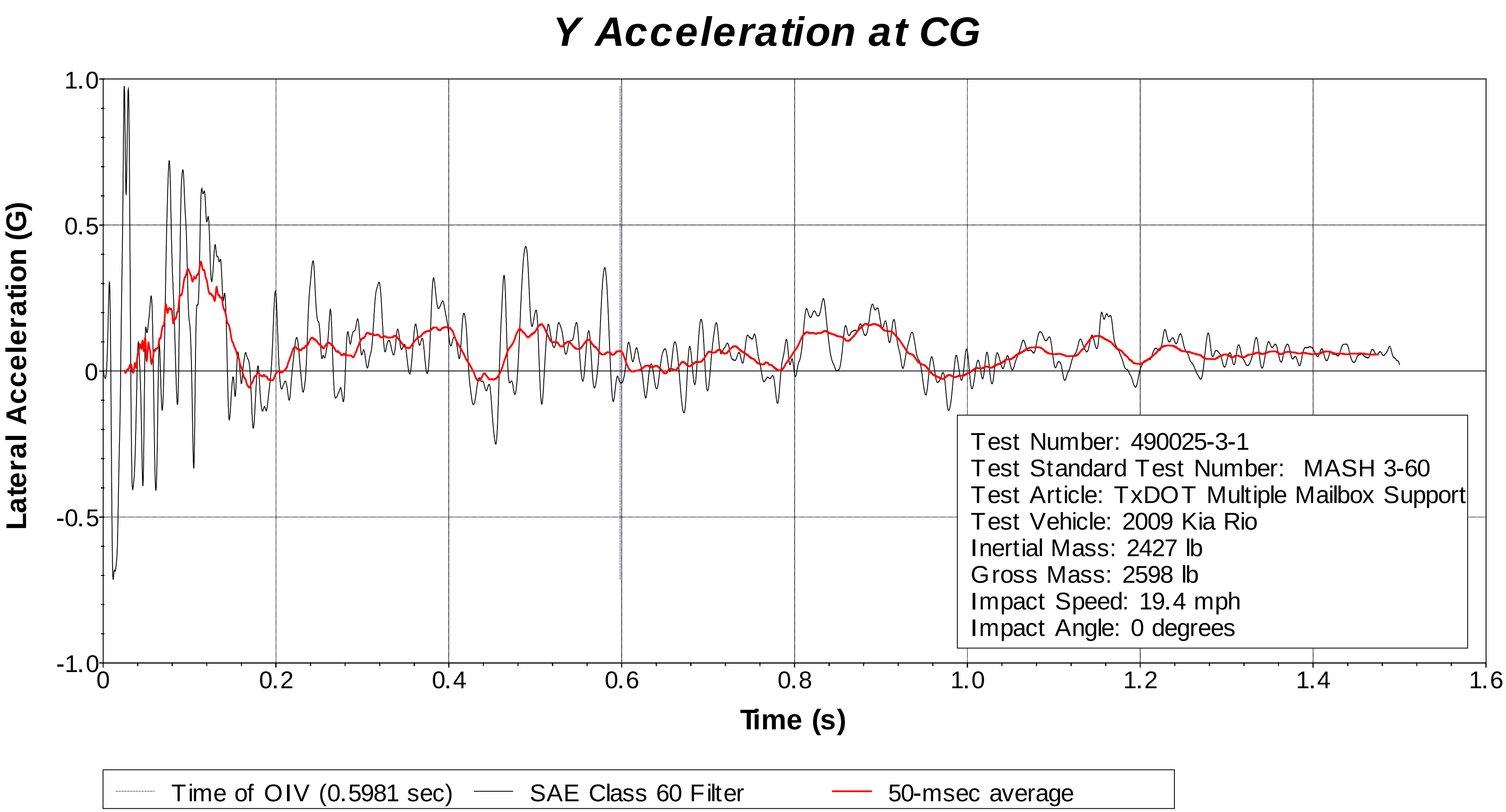


Figure C.4. Vehicle Lateral Accelerometer Trace for Test No. 490025-3-1 (Accelerometer Located at Center of Gravity).

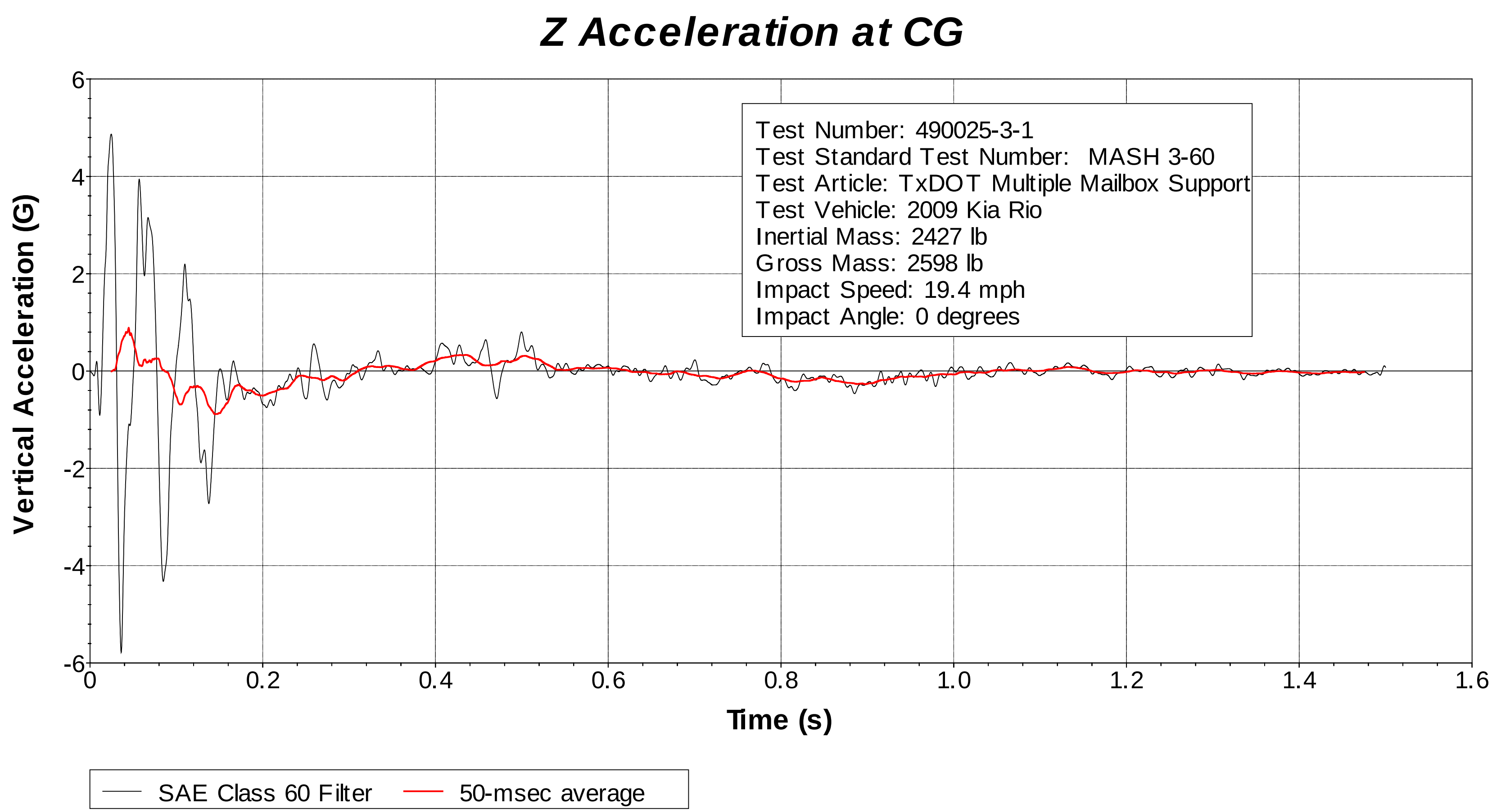


Figure C.5. Vehicle Vertical Accelerometer Trace for Test No. 490025-3-1 (Accelerometer Located at Center of Gravity).

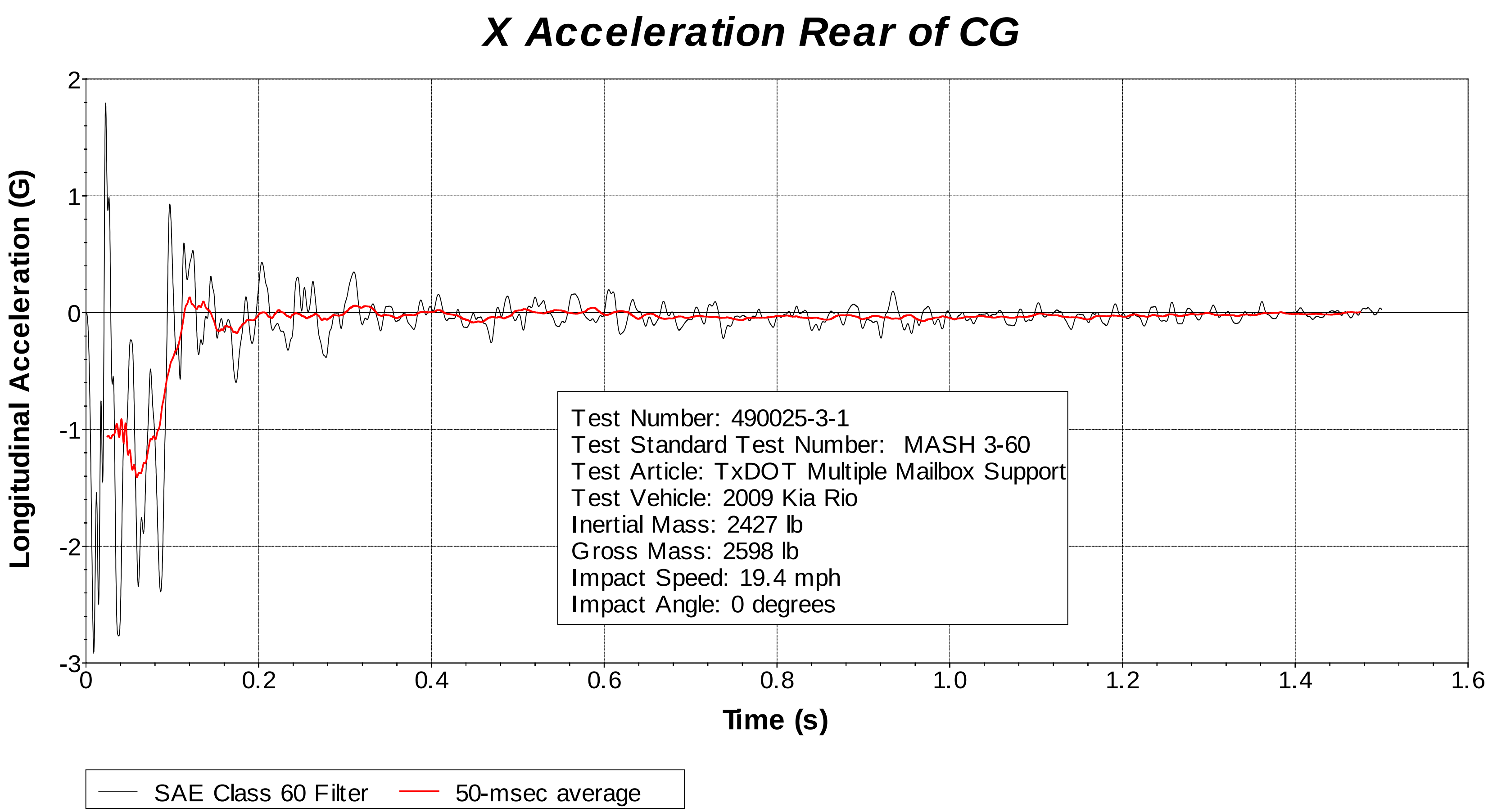


Figure C.6. Vehicle Longitudinal Accelerometer Trace for Test No. 490025-3-1 (Accelerometer Located Rear of Center of Gravity).

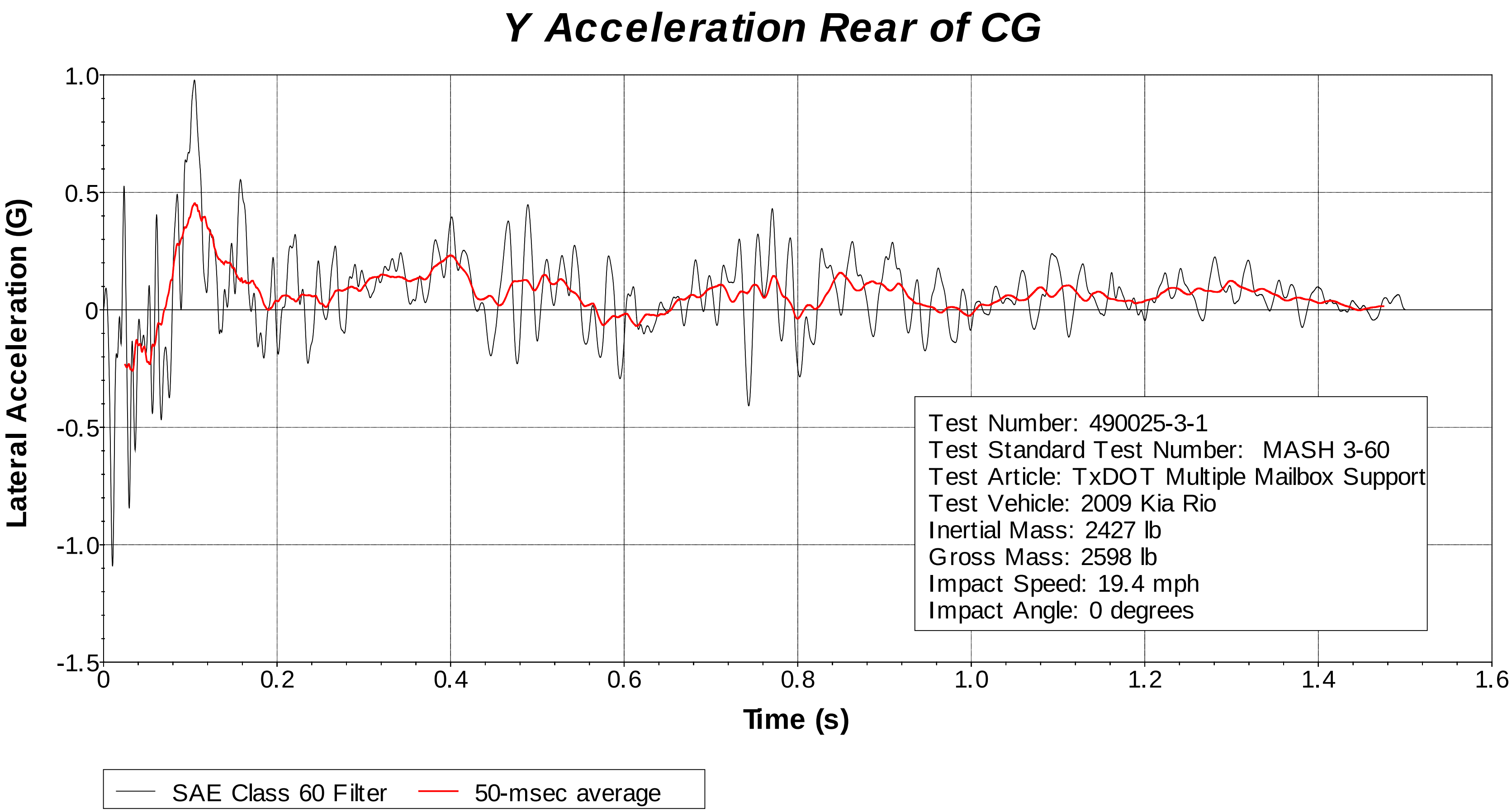


Figure C.7. Vehicle Lateral Accelerometer Trace for Test No. 490025-3-1 (Accelerometer Located Rear of Center of Gravity).

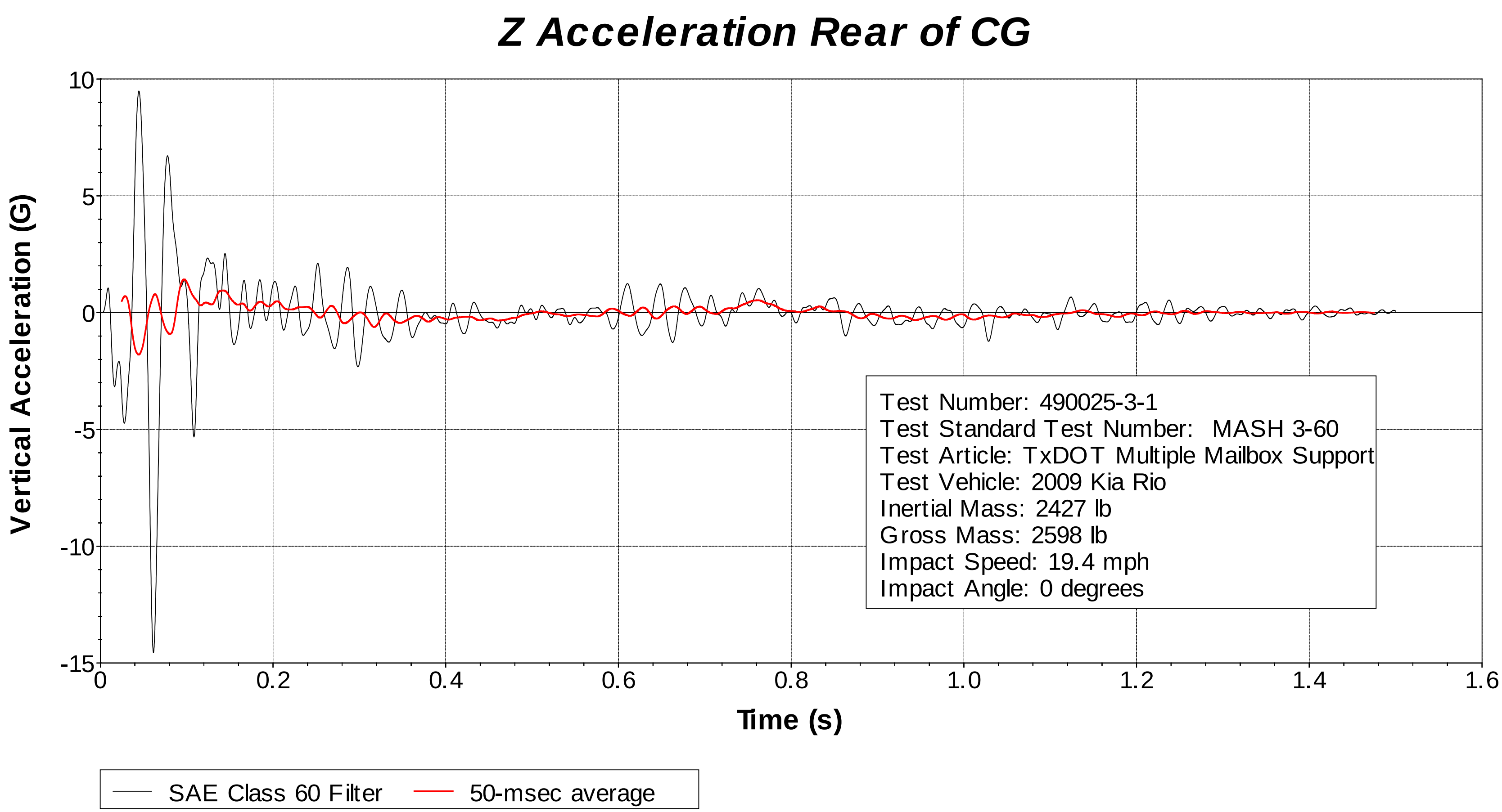


Figure C.8. Vehicle Vertical Accelerometer Trace for Test No. 490025-3-1 (Accelerometer Located Rear of Center of Gravity).

APPENDIX D: *MASH* TEST 3-61 (CRASH TEST NO. 490025-3-4)

D.1 VEHICLE PROPERTIES AND INFORMATION

Table D.1. Vehicle Properties for Test No. 490025-3-4.

Date: 2015-08-26 Test No.: 490025-3-4 VIN No.: KNADN4A38A6673513

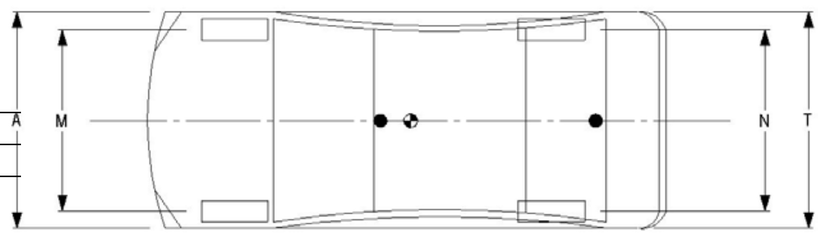
Year: 2010 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 96902 Tire Size: 185/65R14

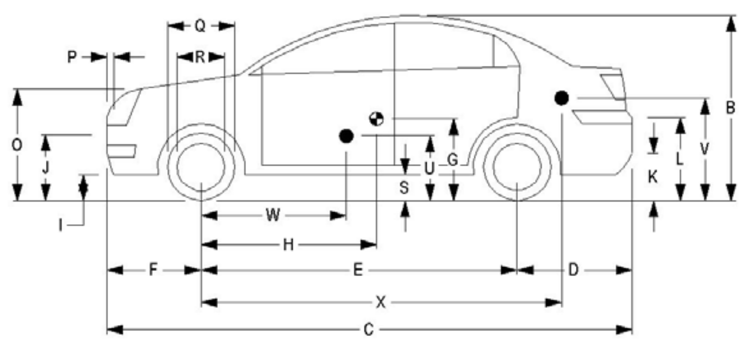
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES: None



Engine Type: 4 cylinder
Engine CID: 1.6 liter
Transmission Type:
X Auto or ___ Manual
X FWD ___ RWD ___ 4WD
Optional Equipment:
None



Dummy Data:
Type: 50th percentile male
Mass: 165 lb
Seat Position: Driver

Geometry: inches

A	66.38	F	33.00	K	12.75	P	4.12	U	14.50
B	58.25	G	—	L	25.00	Q	22.19	V	21.50
C	165.75	H	35.89	M	57.25	R	15.38	W	44.00
D	34.00	I	9.50	N	57.12	S	9.00	X	109.00
E	98.75	J	21.50	O	31.50	T	66.12		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00

GVWR Ratings:		**Mass**: lb	Curb	Test Inertial	Gross Static
Front	1918	M_{front}	1590	1552	1642
Back	1874	M_{rear}	906	886	961
Total	3638	M_{Total}	2496	2496	2603

Mass Distribution:
lb LF: 787 RF: 765 LR: 440 RR: 446

Table D.2. Exterior Crush Measurements of Vehicle for Test No. 490025-3-4.

Date:	2015-08-26	Test No.:	490025-3-4	VIN No.:	KNADN4A38A6673513
Year:	2010	Make:	Kia	Model:	Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
1	Front plane above bumper	10.0	3.0	—	—	—	—	—	—	—	—
	Measurements recorded										
	in inches										

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

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

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

Record the value for each C-measurement and maximum crush.

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

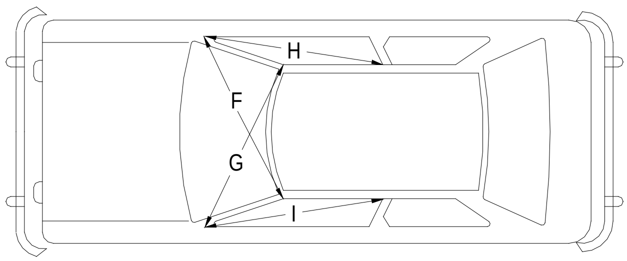
***Measure and document on the vehicle diagram the location of the maximum crush.

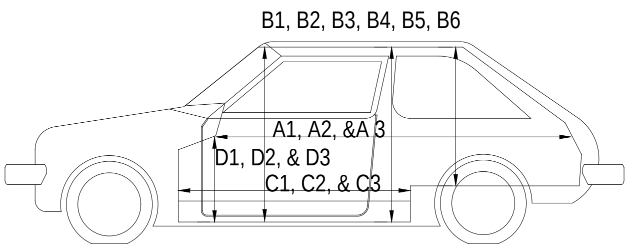
Note: Use as many lines/columns as necessary to describe each damage profile.

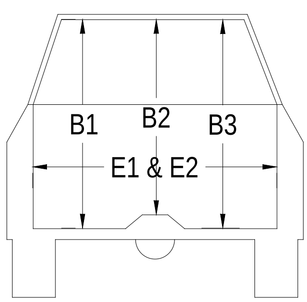
Table D.3. Occupant Compartment Measurements of Vehicle for Test No. 490025-3-4.

Date: 2015-08-26 Test No.: 490025-3-4 VIN No.: KNADN4A38A6673513

Year: 2010 Make: Kia Model: Rio







OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	**After** (inches)
A1	67.50	67.50
A2	67.00	67.00
A3	67.75	37.75
B1	40.25	40.25
B2	36.00	36.00
B3	40.25	40.25
B4	36.25	36.25
B5	35.75	35.75
B6	36.25	36.25
C1	25.50	25.50
C2	—	—
C3	24.50	24.50
D1	9.50	9.50
D2	—	—
D3	9.50	9.50
E1	51.50	51.50
E2	51.00	51.00
F	51.00	51.00
G	51.00	51.00
H	37.50	37.50
I	37.50	37.50
J*	50.75	50.75

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

D.2 SEQUENTIAL PHOTOGRAPHS

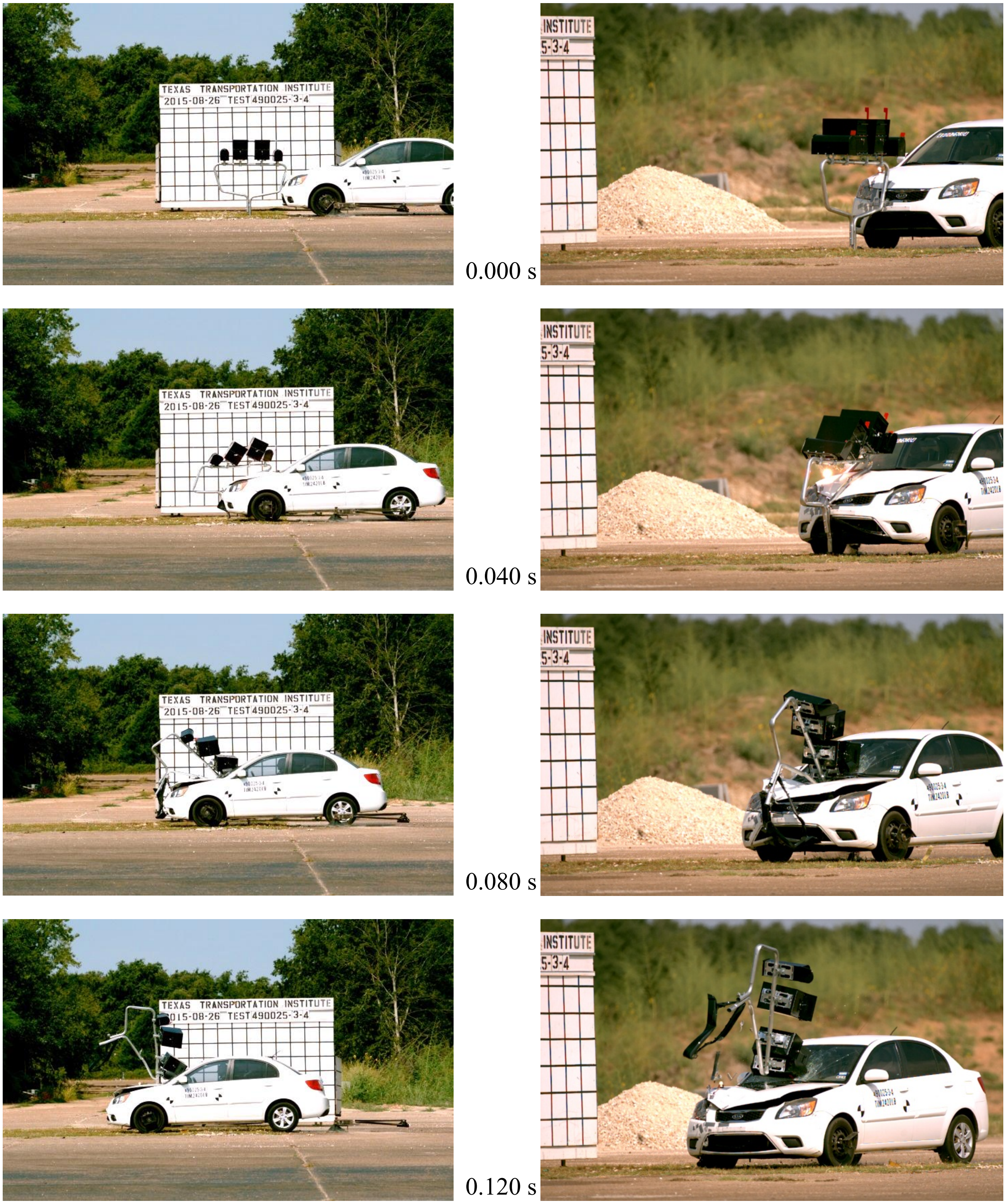


Figure D.1. Sequential Photographs for Test No. 490025-3-4 (Perpendicular and Oblique Views).

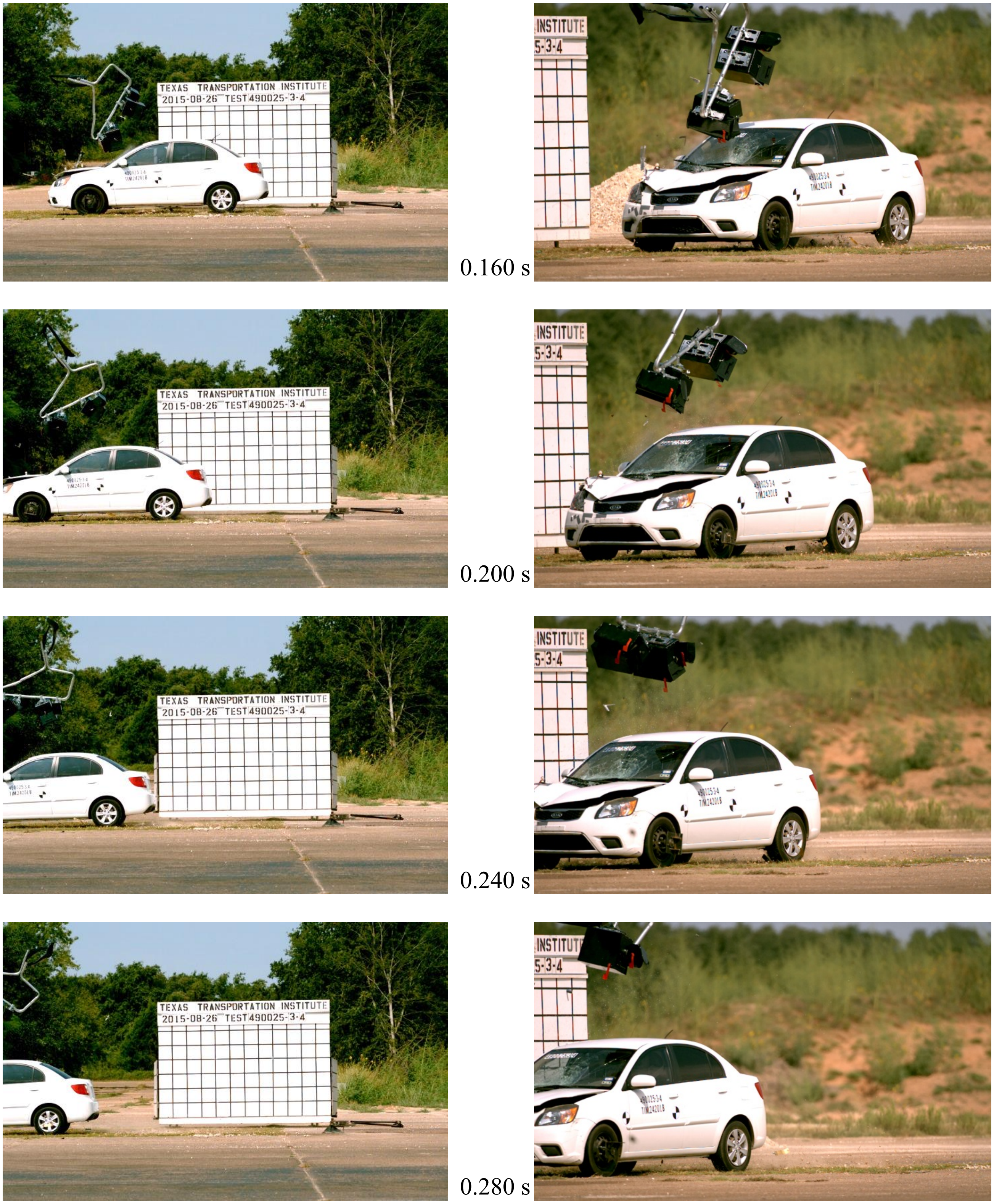
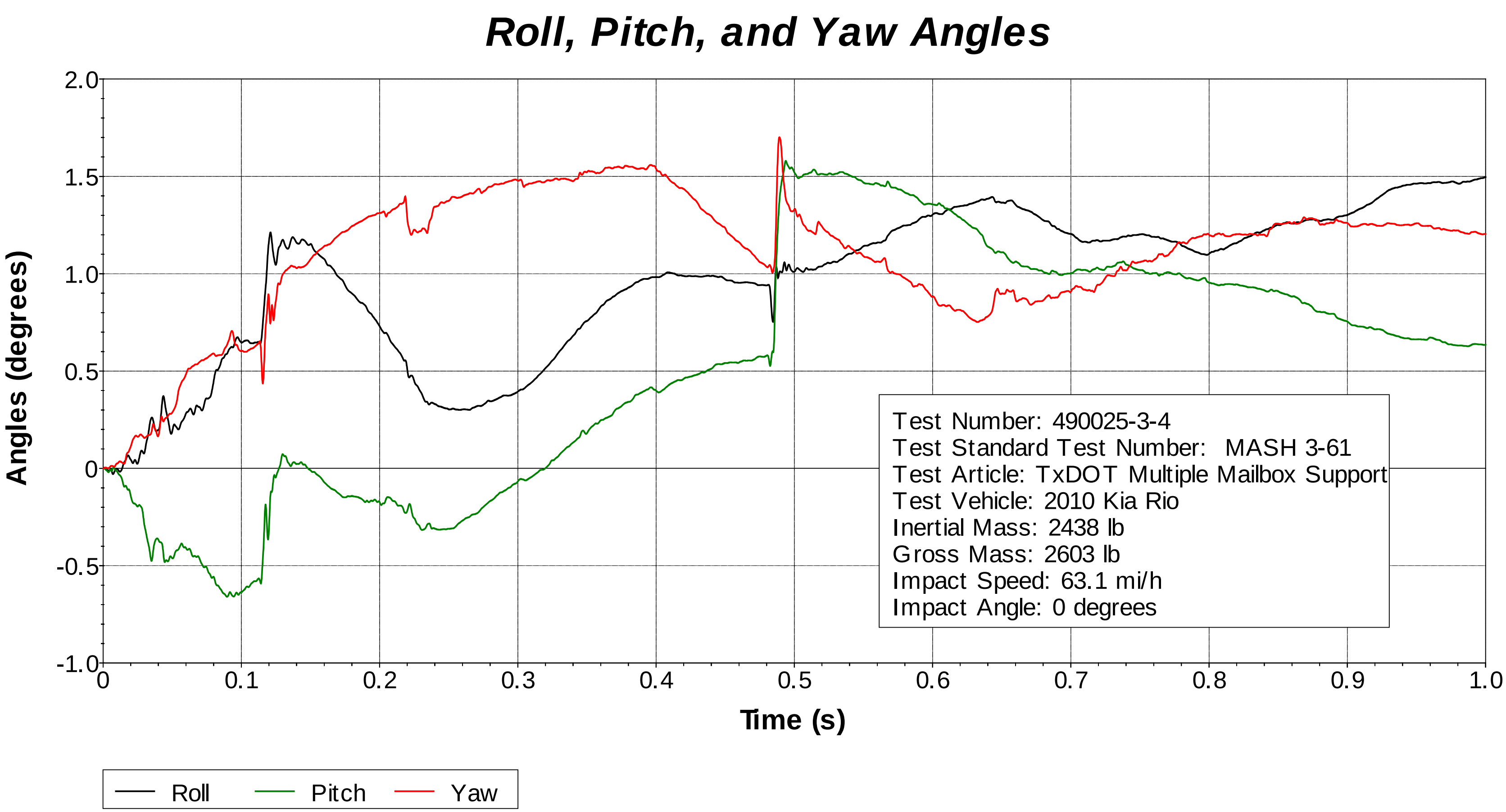


Figure D.1. Sequential Photographs for Test No. 490025-3-4 (Perpendicular and Oblique Views) (Continued).



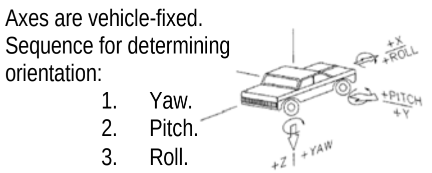


Figure D.2. Vehicle Angular Displacements for Test No. 490025-3-4.

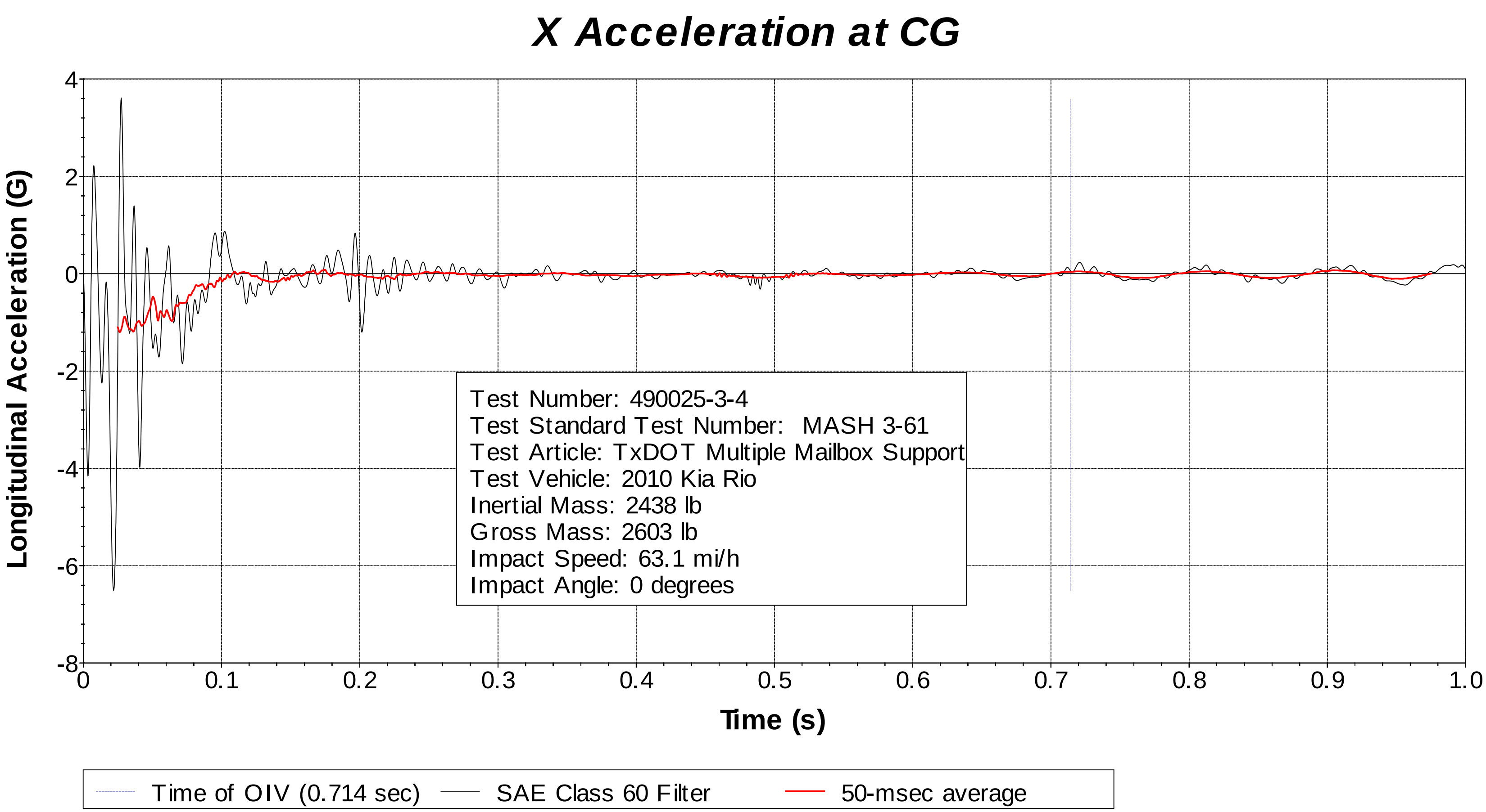


Figure D.3. Vehicle Longitudinal Accelerometer Trace for Test No. 490025-3-4 (Accelerometer Located at Center of Gravity).

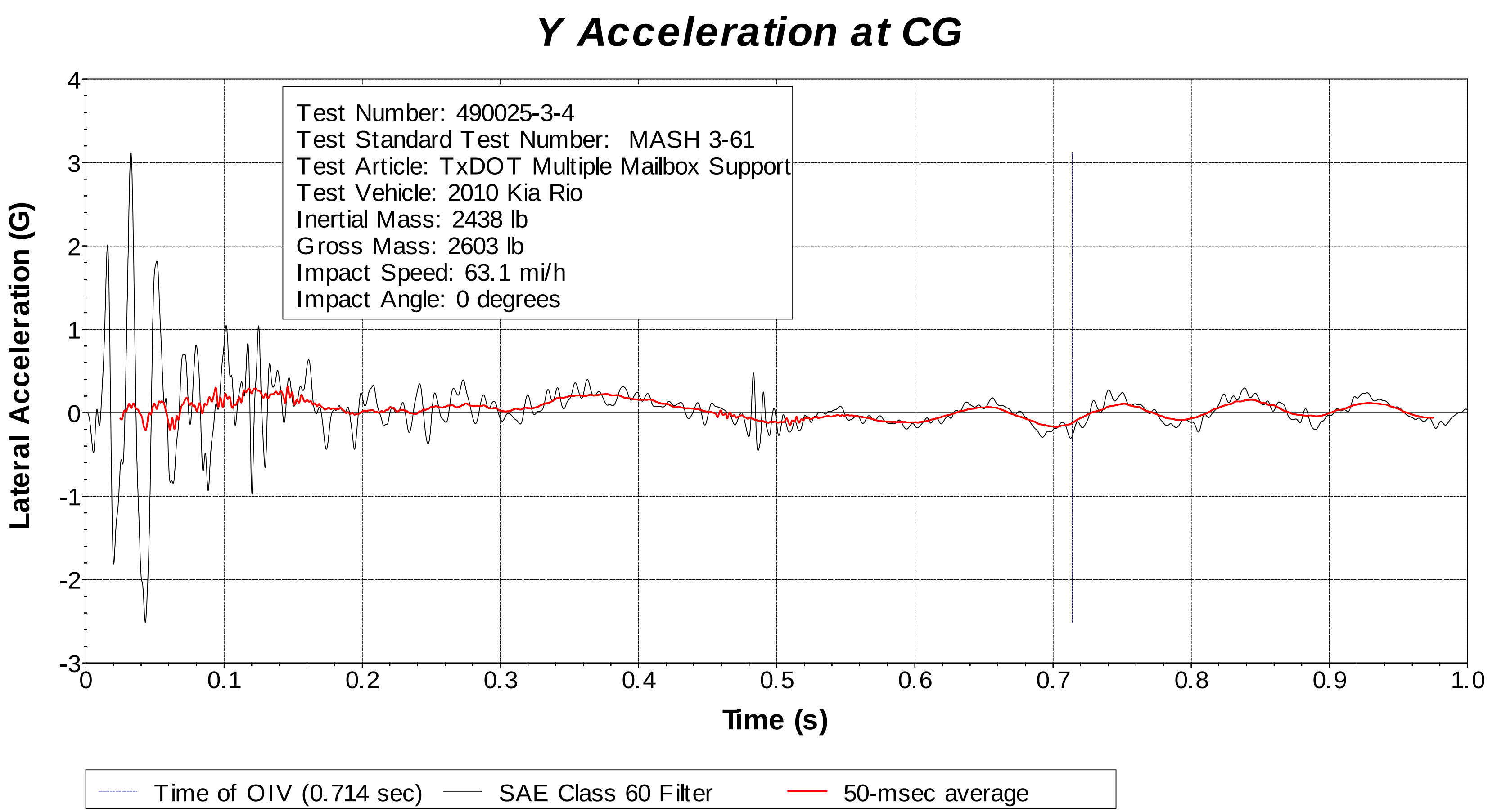


Figure D.4. Vehicle Lateral Accelerometer Trace for Test No. 490025-3-4 (Accelerometer Located at Center of Gravity).

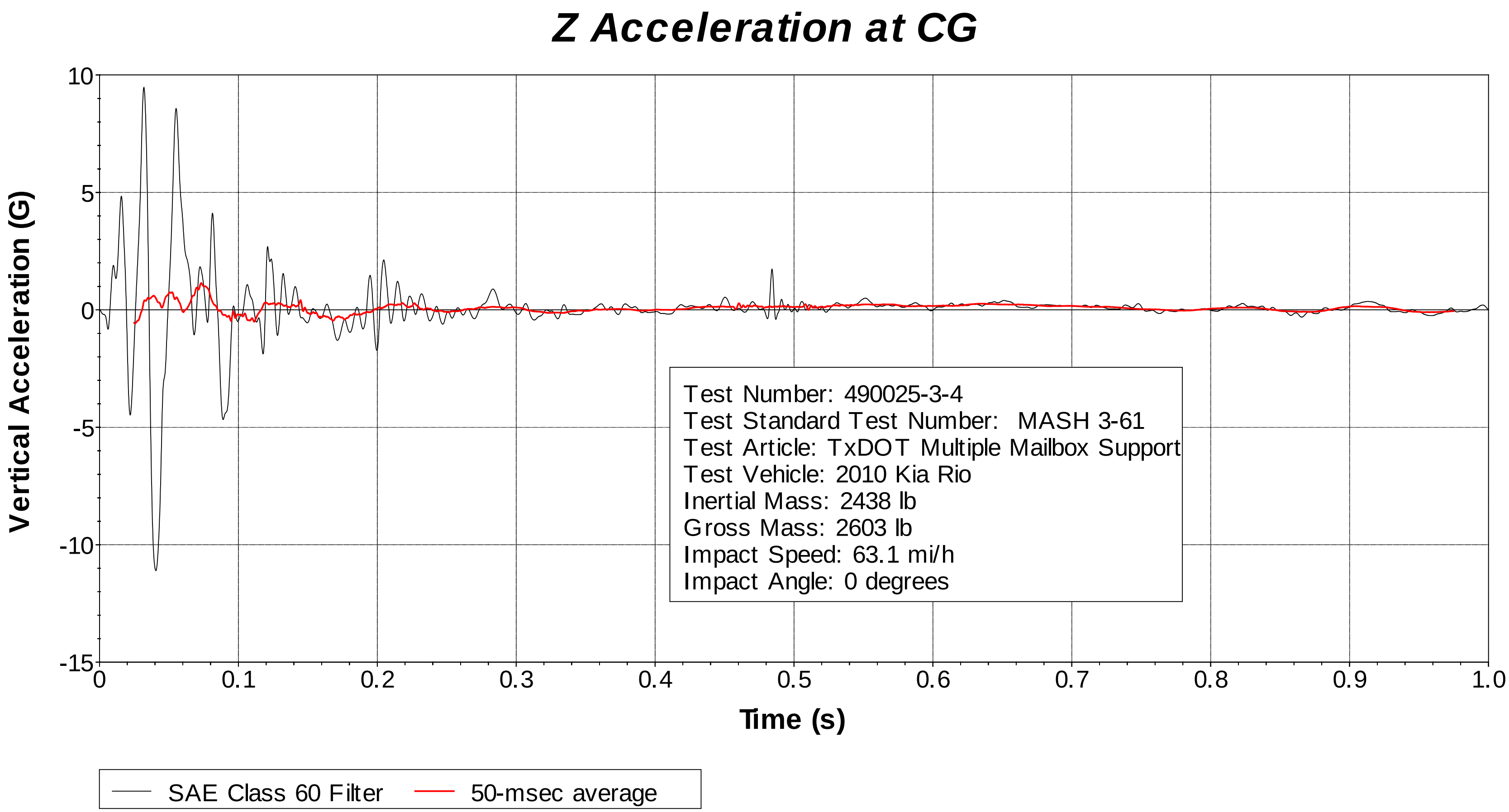


Figure D.5. Vehicle Vertical Accelerometer Trace for Test No. 490025-3-4 (Accelerometer Located at Center of Gravity).

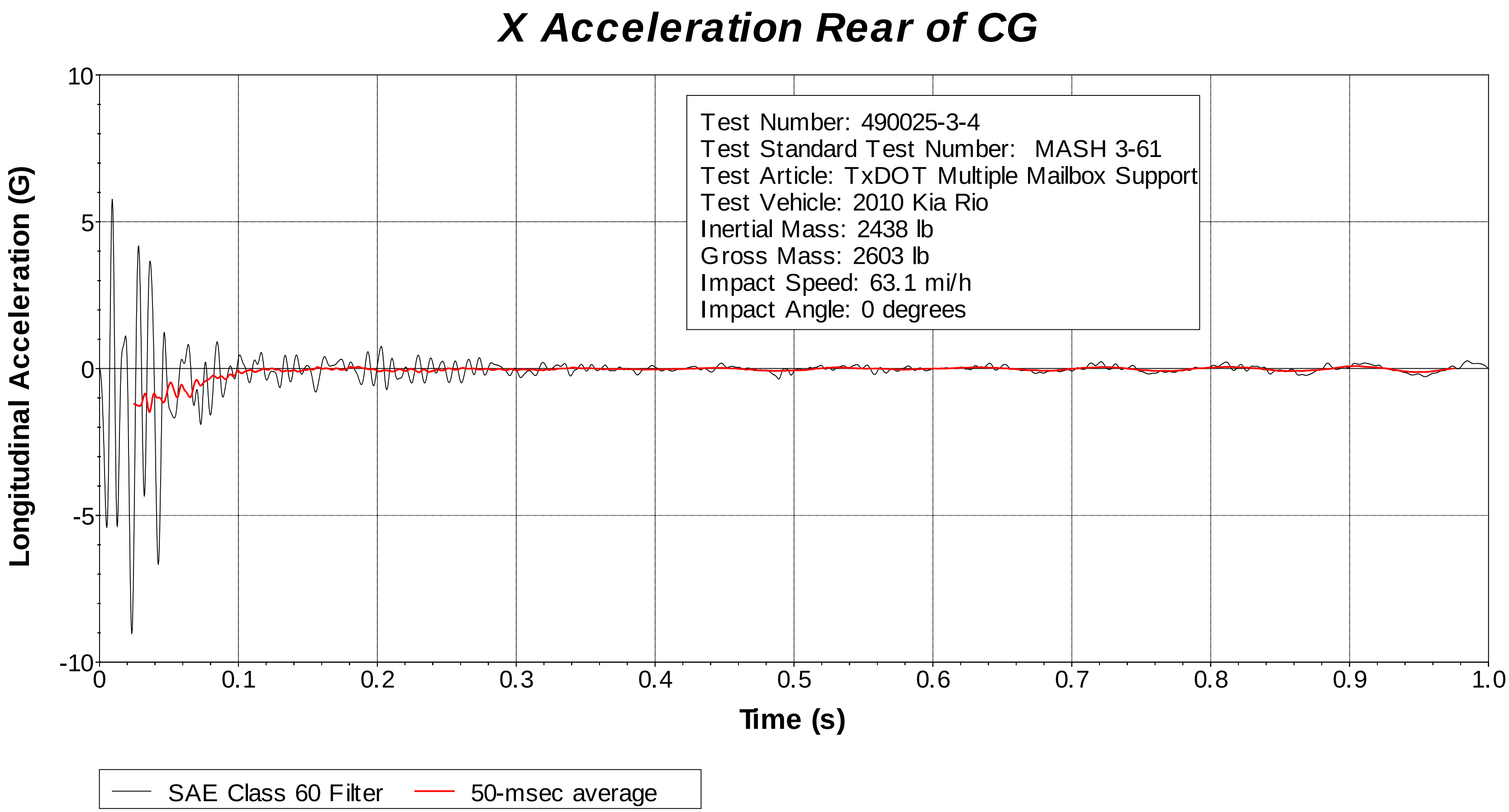


Figure D.6. Vehicle Longitudinal Accelerometer Trace for Test No. 490025-3-4 (Accelerometer Located Rear of Center of Gravity).

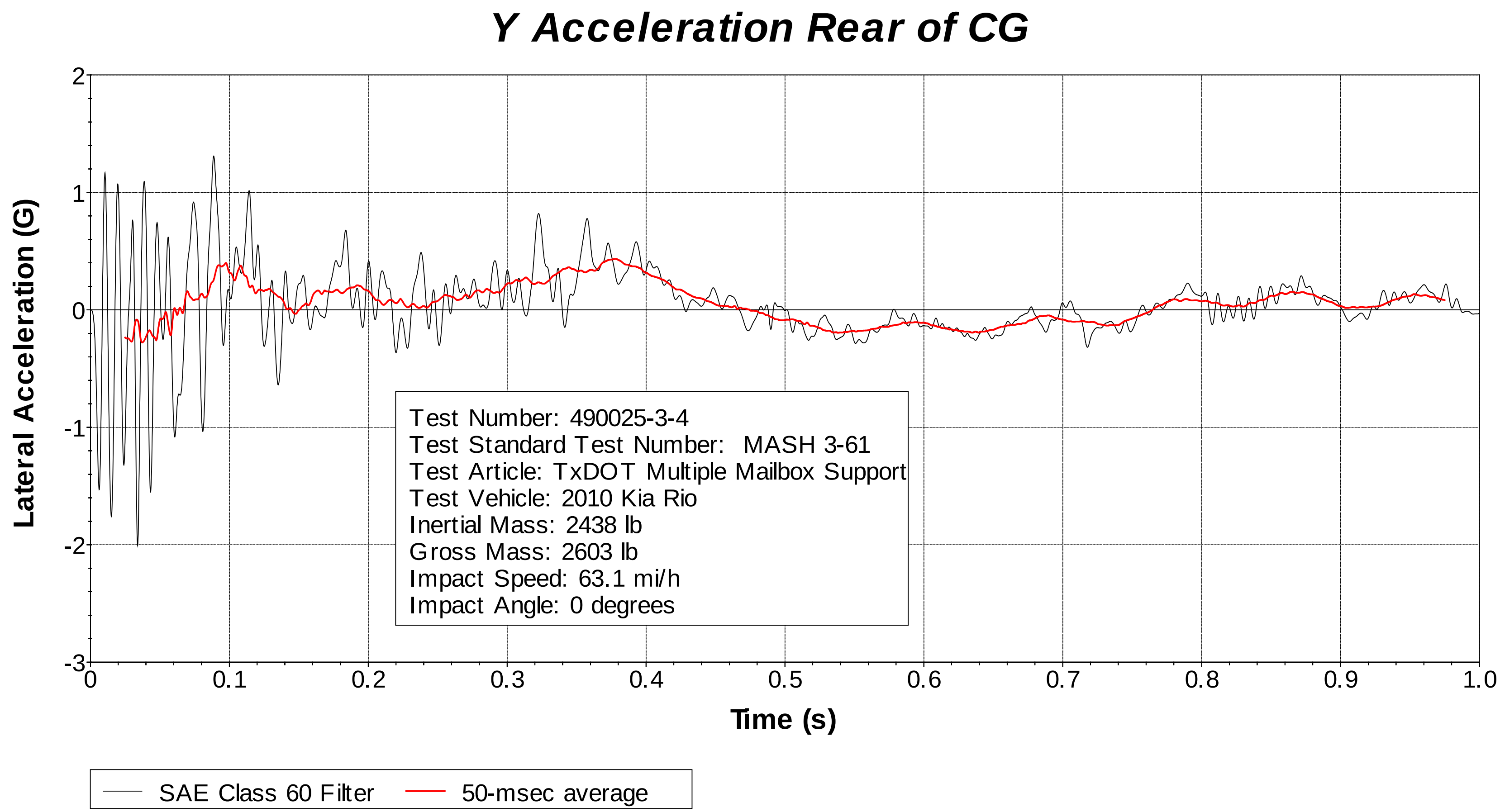


Figure D.7. Vehicle Lateral Accelerometer Trace for Test No. 490025-3-4 (Accelerometer Located Rear of Center of Gravity).

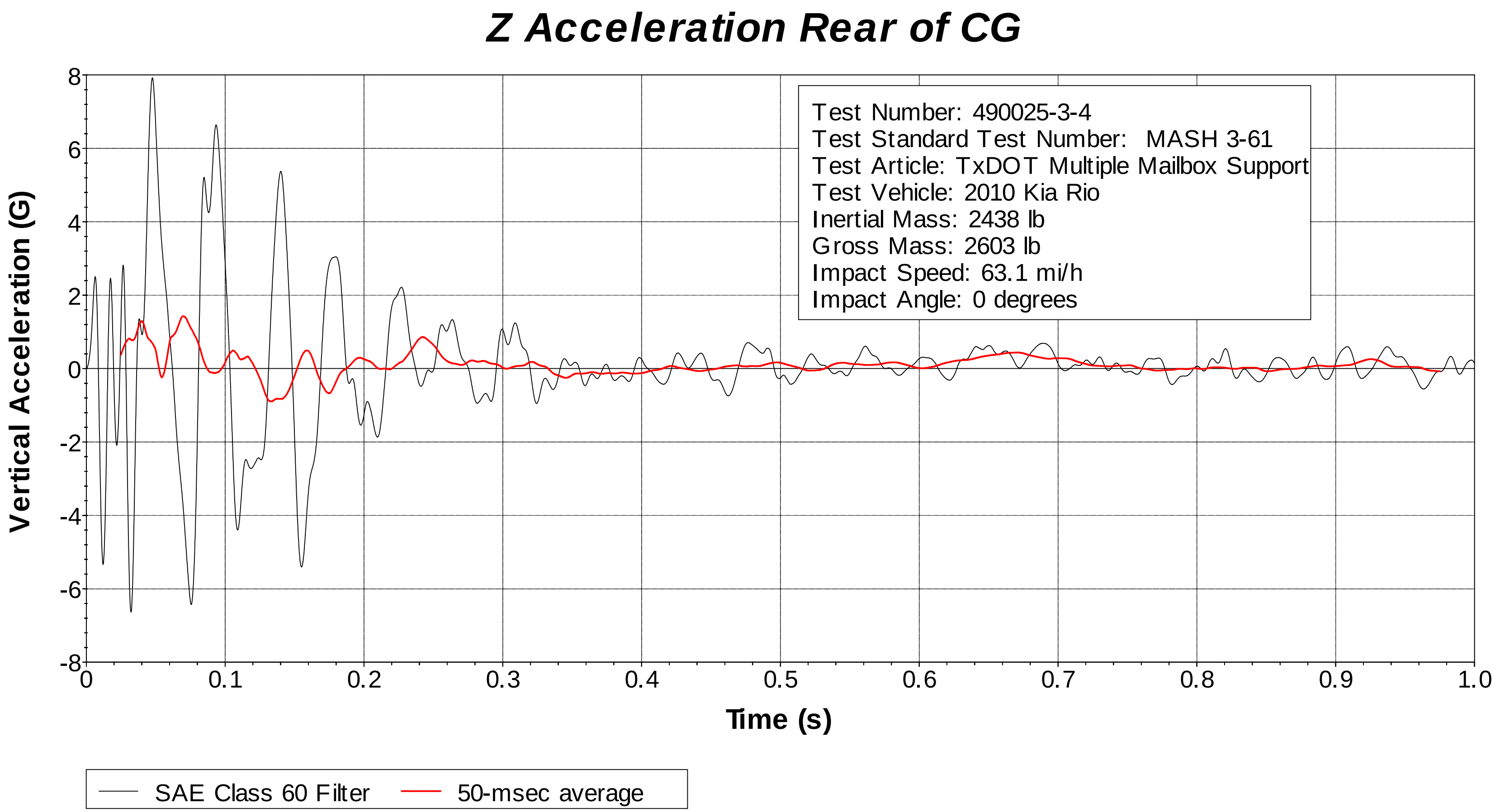


Figure D.8. Vehicle Vertical Accelerometer Trace for Test No. 490025-3-4 (Accelerometer Located Rear of Center of Gravity).

APPENDIX E: *MASH* TEST 3-60 (CRASH TEST NO. 490025-3-3)

E.1 VEHICLE PROPERTIES AND INFORMATION

Table E.1. Vehicle Properties for Test No. 490025-3-3.

Date: 2015-08-26 Test No.: 490025-3-3 VIN No.: KNADE273796451987

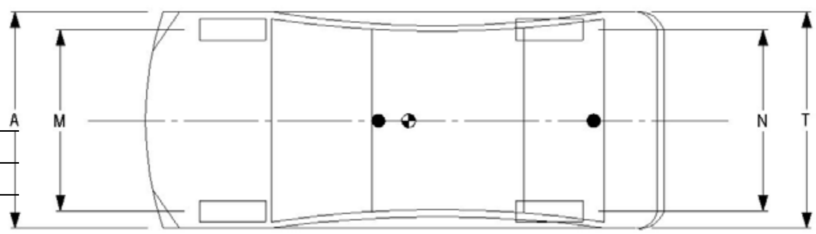
Year: 2009 Make: Kia Model: Rio

Tire Inflation Pressure: 32 psi Odometer: 78218 Tire Size: 185/65R14

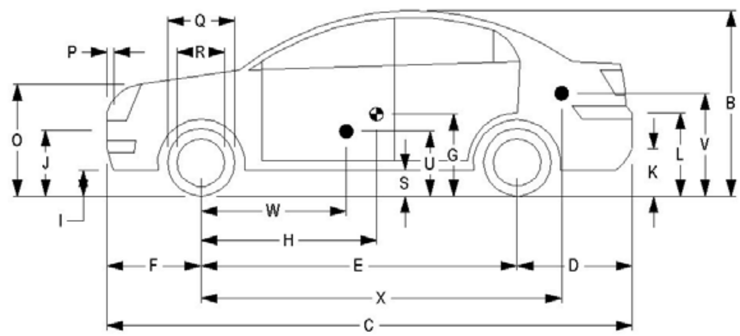
Describe any damage to the vehicle prior to test: None

● Denotes accelerometer location.

NOTES: None



Engine Type: 4 cylinder
Engine CID: 1.6 liter
Transmission Type:
____ Auto or x Manual
x FWD ____ RWD ____ 4WD
Optional Equipment:
None



Dummy Data:
Type: 50^{th} percentile male
Mass: 165 lb
Seat Position: Driver

Geometry: inches

A	66.38	F	33.00	K	12.75	P	4.12	U	14.50
B	58.25	G	—	L	25.00	Q	22.19	V	21.50
C	165.75	H	36.37	M	57.75	R	15.38	W	44.00
D	34.00	I	9.50	N	57.12	S	9.00	X	109.00
E	98.75	J	21.50	O	31.50	T	66.12		

Wheel Center Ht Front 11.00 Wheel Center Ht Rear 11.00

GVWR Ratings:		**Mass**: lb	Curb	Test Inertial	Gross Static
Front	1918	M_{front}	1530	1534	1624
Back	1874	M_{rear}	858	893	974
Total	3638	M_{Total}	2388	2427	2598

Mass Distribution:
lb LF: 782 RF: 752 LR: 435 RR: 458

Table E.2. Exterior Crush Measurements of Vehicle for Test No. 490025-3-3.

Date: 2015-08-26 Test No.: 490025-3-3 VIN No.: KNADE273796451987

Year: 2009 Make: Kia Model: Rio

VEHICLE CRUSH MEASUREMENT SHEET[1]

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

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

Specific Impact Number	Plane* of C-Measurements	Direct Damage		Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
		Width** (CDC)	Max*** Crush								
1	Front plane above bumper	12	3.5	—	—	—	—	—	—	—	—
	Measurements recorded										
	in inches										

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

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

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

Record the value for each C-measurement and maximum crush.

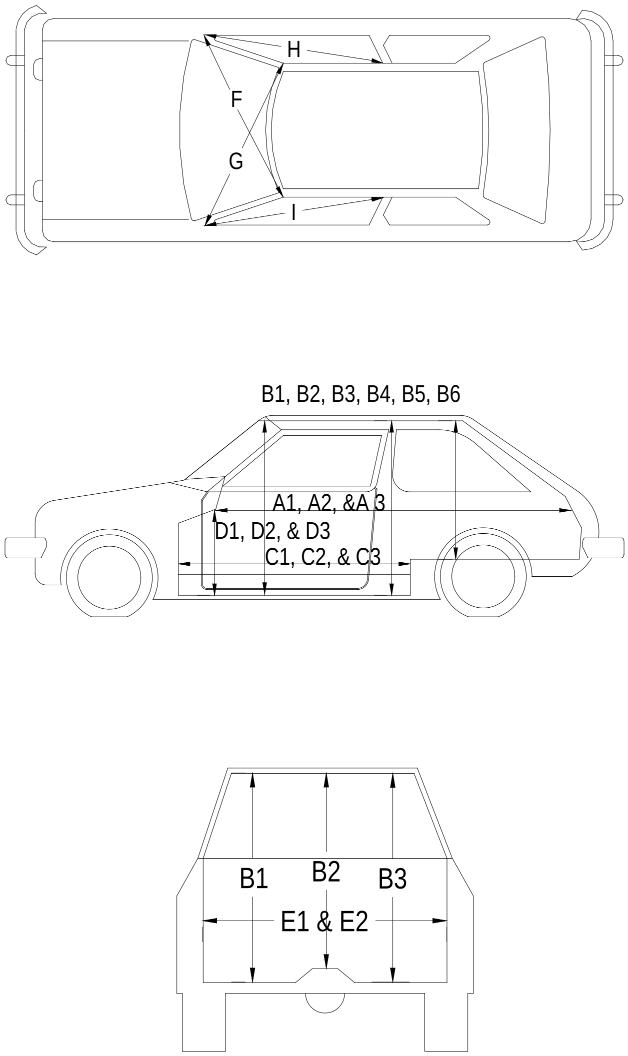
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

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

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

Table E.3. Occupant Compartment Measurements of Vehicle for Test No. 490025-3-3.

Date:	2015-08-26	Test No.:	490025-3-3	VIN No.:	KNADE273796451987
Year:	2009	Make:	Kia	Model:	Rio

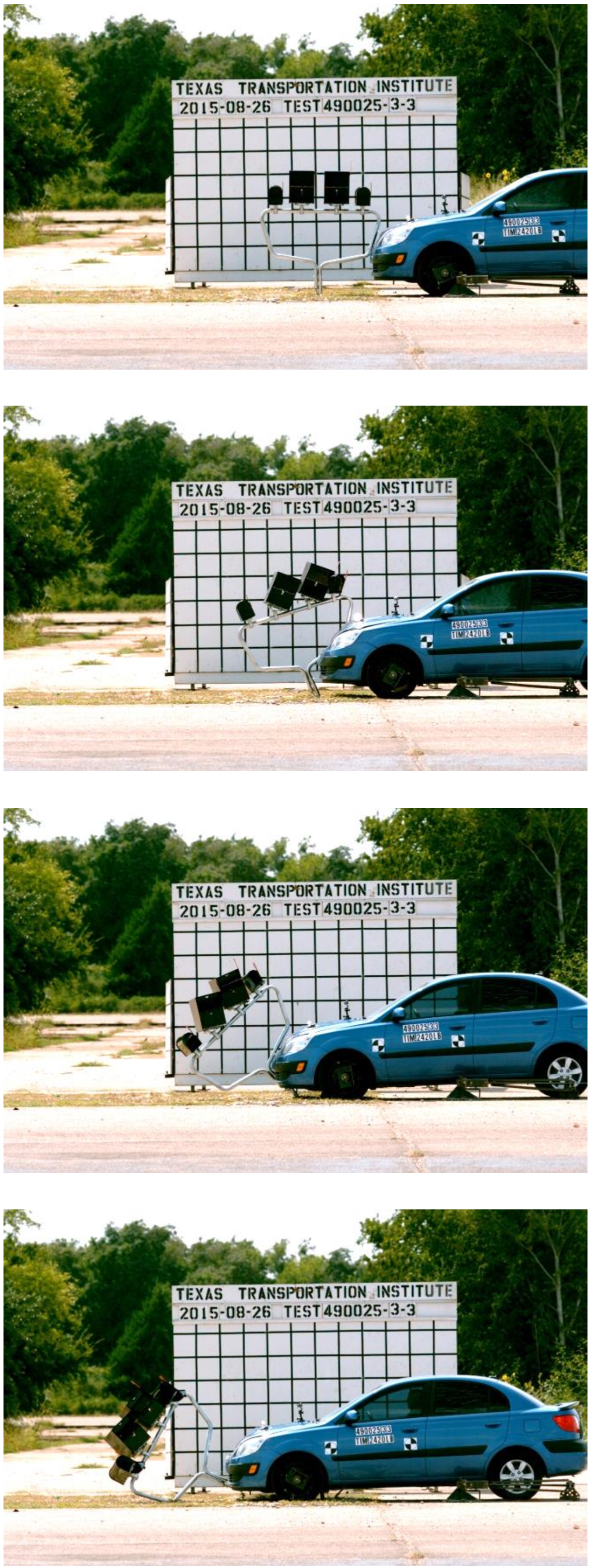


OCCUPANT COMPARTMENT DEFORMATION MEASUREMENT

	Before (inches)	**After** (inches)
A1	67.50	67.50
A2	67.00	67.00
A3	67.75	37.75
B1	40.25	40.25
B2	36.00	36.00
B3	40.25	40.25
B4	36.25	36.25
B5	35.75	35.75
B6	36.25	36.25
C1	25.50	25.50
C2	—	—
C3	24.50	24.50
D1	9.50	9.50
D2	—	—
D3	9.50	9.50
E1	51.50	51.50
E2	51.00	51.00
F	51.00	51.00
G	51.00	51.00
H	37.50	37.50
I	37.50	37.50
J*	50.75	50.75

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

E.2 SEQUENTIAL PHOTOGRAPHS



0.000 s

0.070 s

0.140 s

0.210 s

Figure E.1. Sequential Photographs for Test No. 490025-3-3 (Perpendicular and Oblique Views).

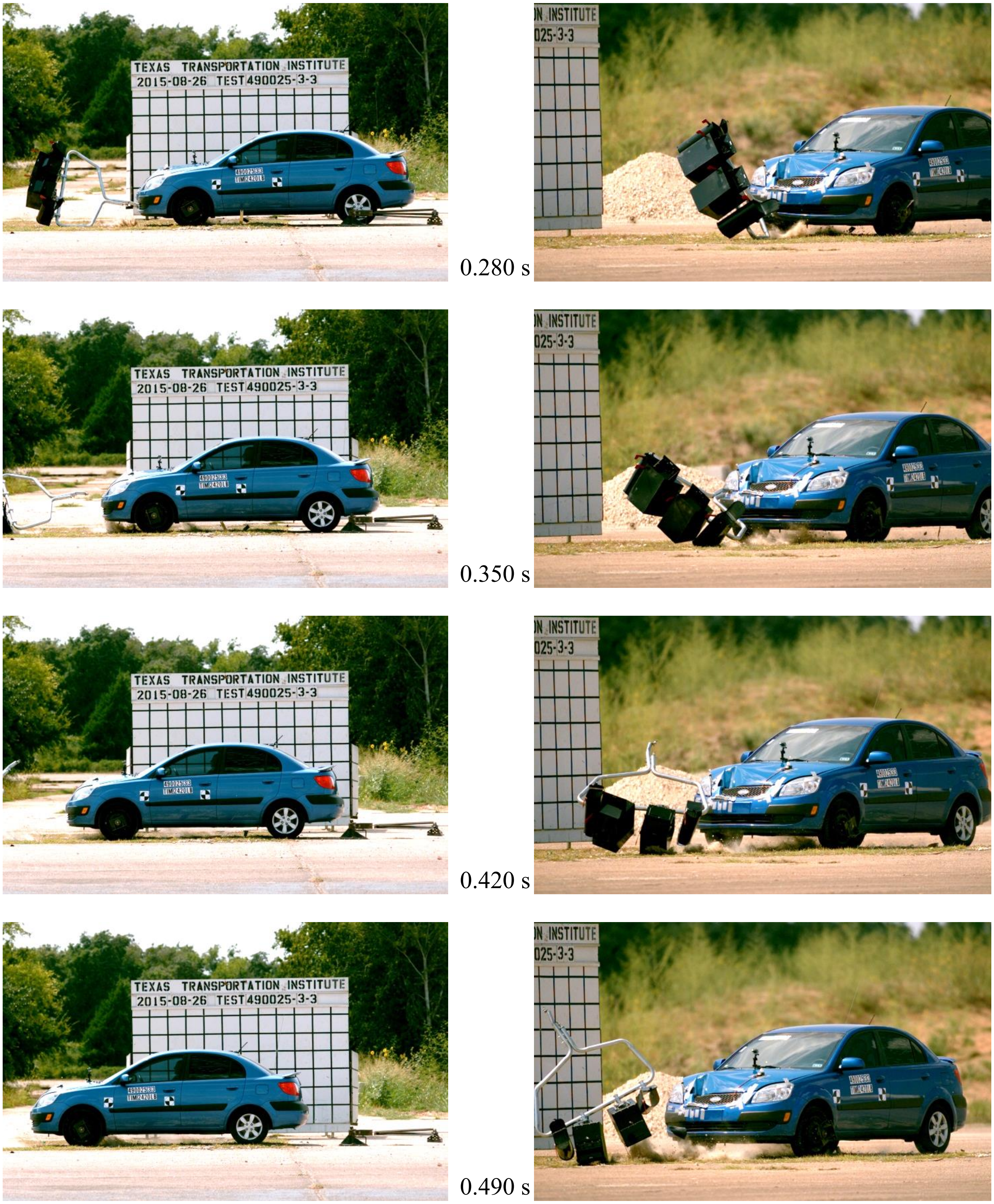
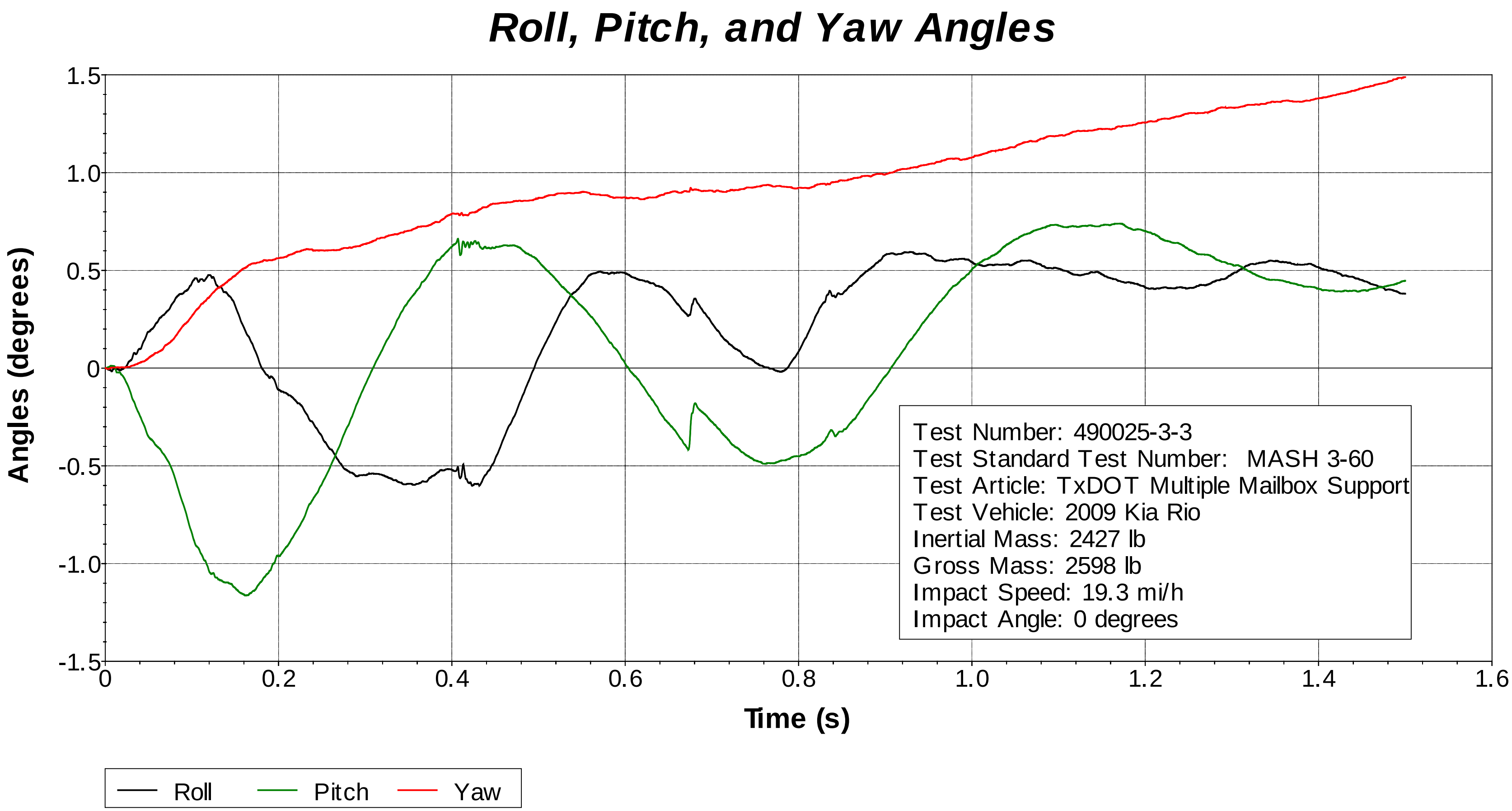


Figure E.1. Sequential Photographs for Test No. 490025-3-3 (Perpendicular and Oblique Views) (Continued).



Axes are vehicle-fixed.
Sequence for determining orientation:

1. Yaw.
2. Pitch.
3. Roll.

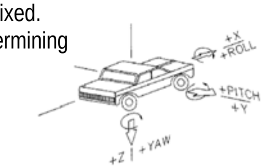


Figure E.2. Vehicle Angular Displacements for Test No. 490025-3-3.

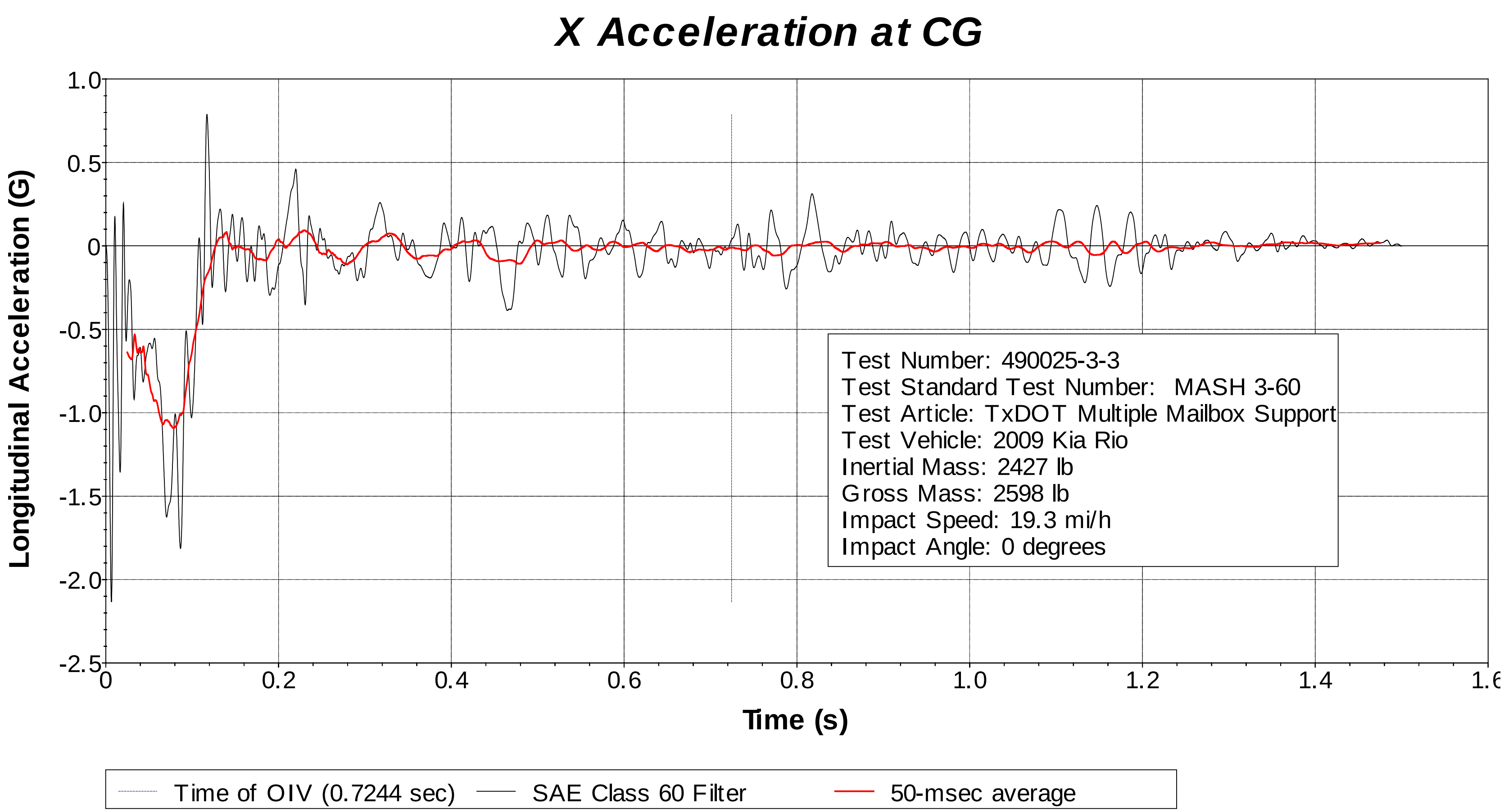


Figure E.3. Vehicle Longitudinal Accelerometer Trace for Test No. 490025-3-3 (Accelerometer Located at Center of Gravity).

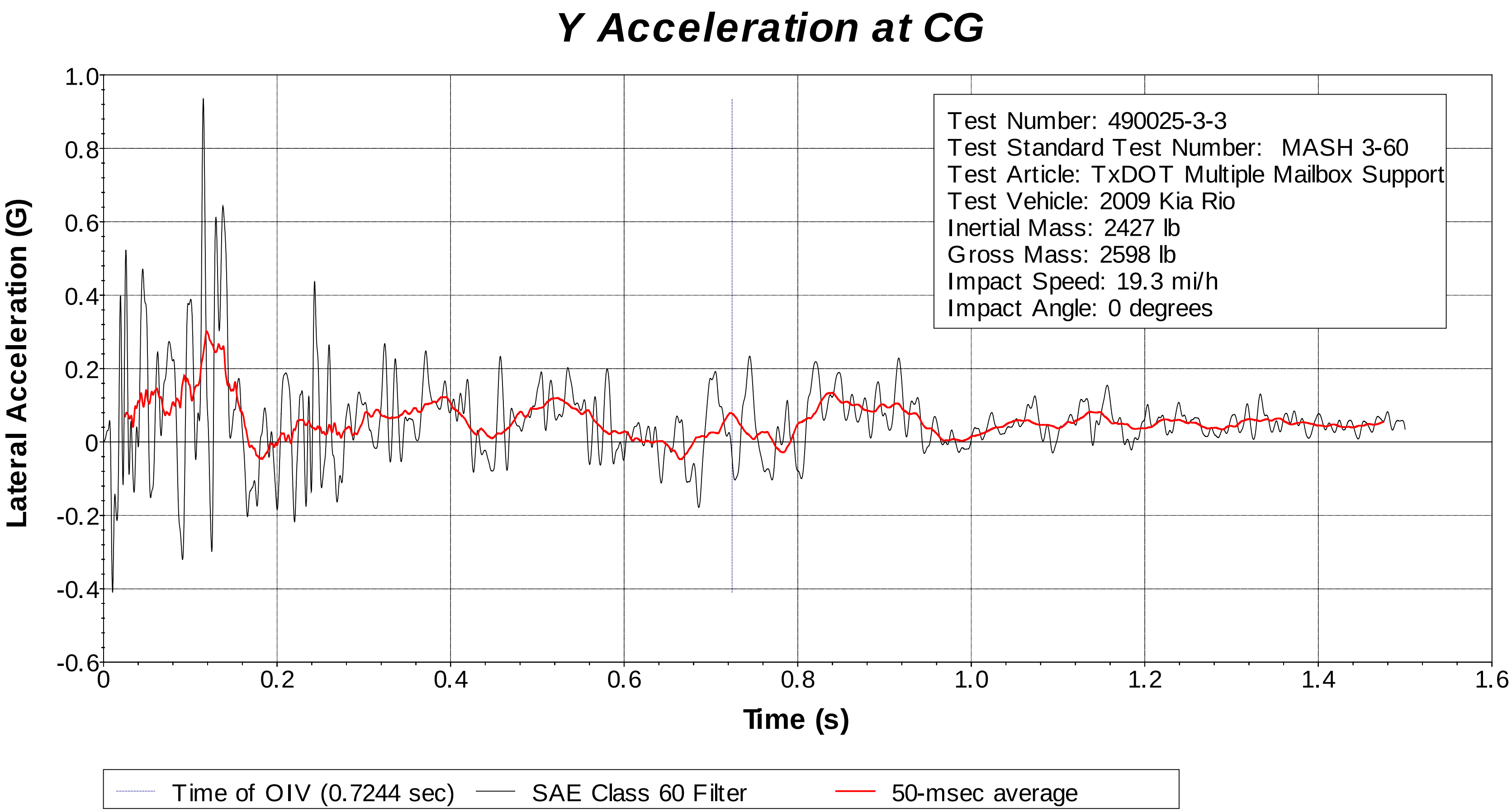


Figure E.4. Vehicle Lateral Accelerometer Trace for Test No. 490025-3-3 (Accelerometer Located at Center of Gravity).

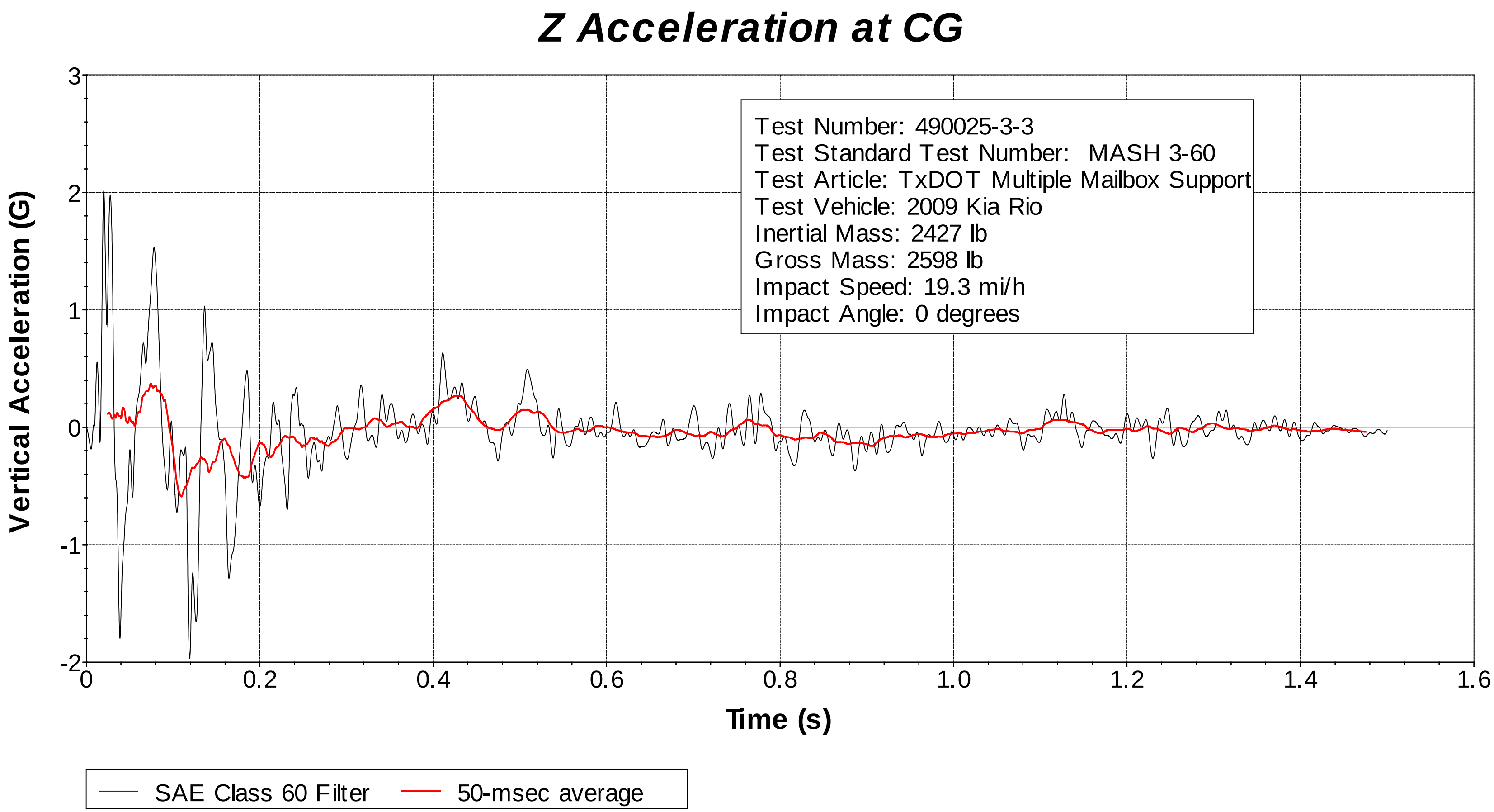


Figure E.5. Vehicle Vertical Accelerometer Trace for Test No. 490025-3-3 (Accelerometer Located at Center of Gravity).

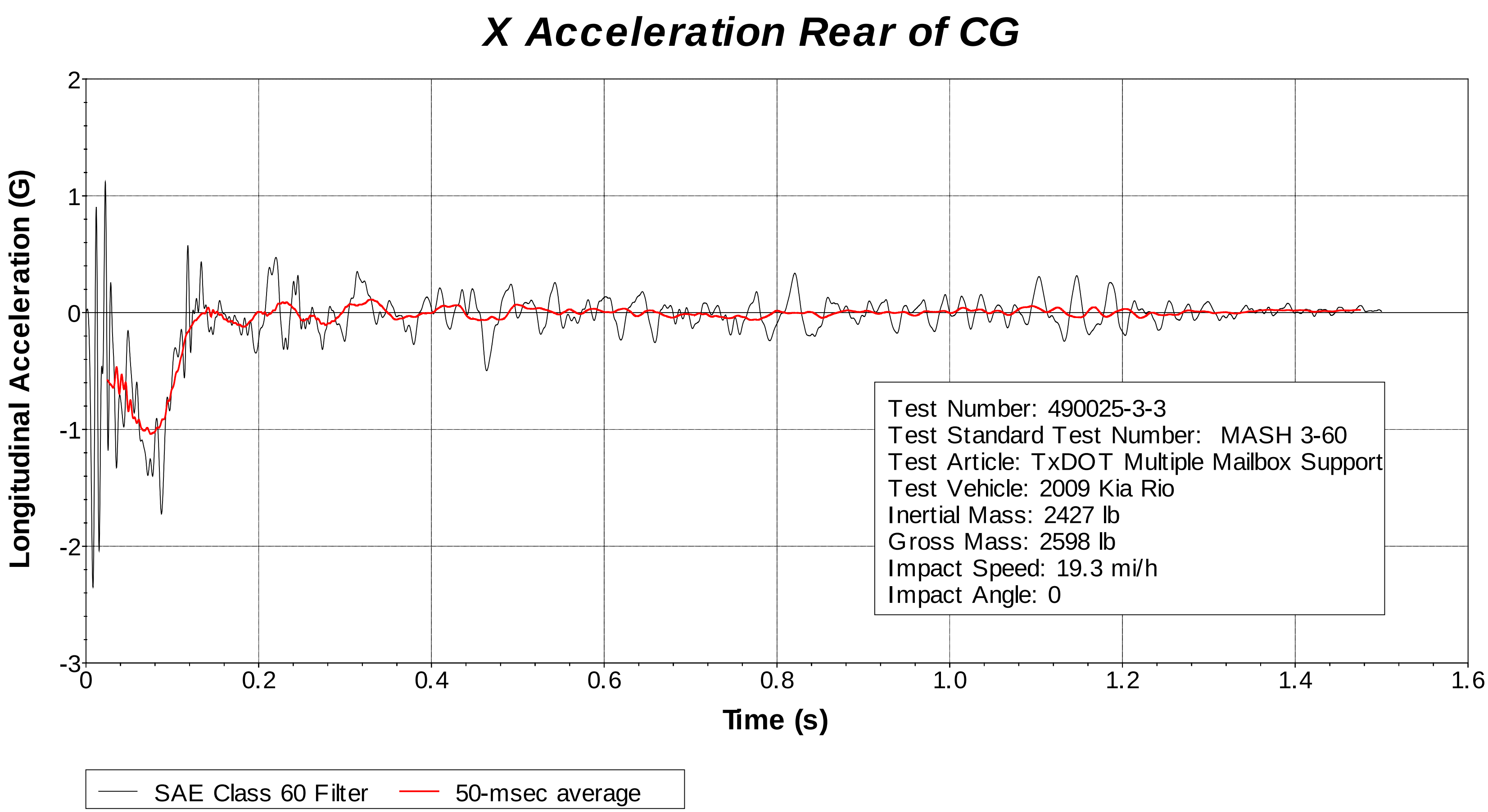


Figure E.6. Vehicle Longitudinal Accelerometer Trace for Test No. 490025-3-3 (Accelerometer Located Rear of Center of Gravity).

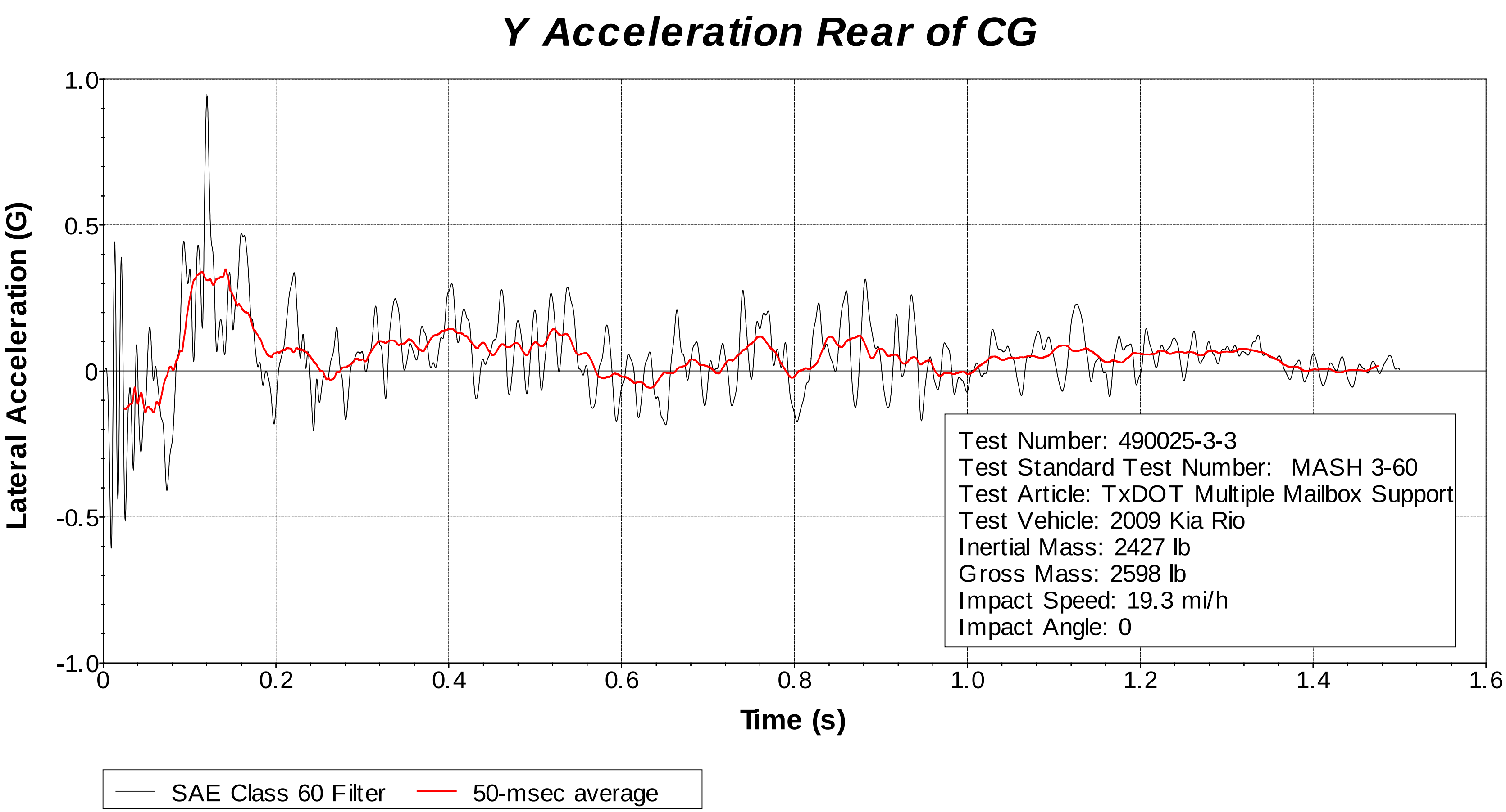


Figure E.7. Vehicle Lateral Accelerometer Trace for Test No. 490025-3-3 (Accelerometer Located Rear of Center of Gravity).

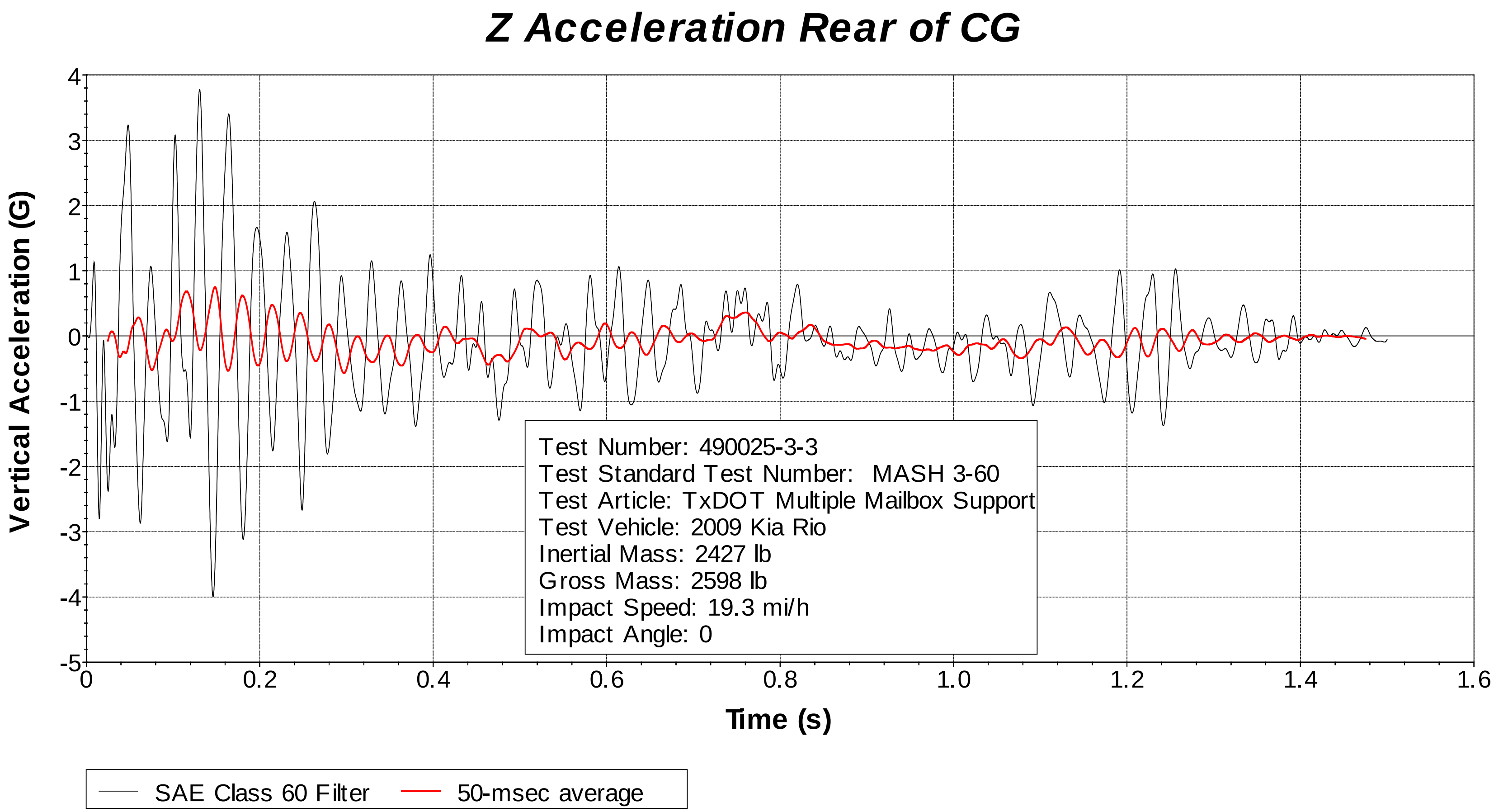


Figure E.8. Vehicle Vertical Accelerometer Trace for Test No. 490025-3-3 (Accelerometer Located Rear of Center of Gravity).

APPENDIX F: SUPPORT EMBEDMENT DEPTH TOLERANCE STUDY

A small study was conducted to determine tolerances for embedment depths for the 2.0-inch OD 11- and 16-gauge multiple-mailbox support posts.

The 11-gauge and 16-gauge posts were embedded at various depths in the standard V-wing socket and support stability was evaluated in each case. The same socket system was used in all cases. The researchers used a number of wedges provided by the manufacturer that are the same as those used in the field. Each wedge was measured to determine its width. Embedment support was determined using the wedge that had the smallest width and, therefore, a higher potential for support instability under load.

Table F.1 shows the results of this embedment tolerance study. The 2.0-inch OD 11-gauge tube had good stability at both 4- and 3.5-inch embedment depths. The 2.0-inch OD 16-gauge tube had good stability at both 6- and 5.5-inch embedment depths. Since the same wedge and socket system was used in all tested cases, the researchers concluded that an appropriate embedment tolerance recommendation would be ±0.5 inches:

- 2.0-inch OD 11-gauge: Embedment depth of 4 inches ±0.5 inches.
- 2.0-inch OD 16-gauge: Embedment depth of 6 inches ±0.5 inches

Table F.1. Multiple-Mailbox Supports Embedment Depth Tolerance Study Results.

Support Type	Embedment Depth (inches)	Stability
11-Gauge (0.125-inch)	4	✓
	3.5	✓
16-Gauge (0.0625-inch)	4	✗
	6	✓
	5.5	✓