1. REPORT NO. FHWA/CA25-3170	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE DEVELOPMENT AND CRASH TESTING OF A CONCRETE POST-AND-BEAM BRIDGE RAILING, CALIFORNIA TYPE 86H, MASH TL-4		5. REPORT DATE October 2024 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Victor O. Lopez, Robert Meline, David Whitesel, Christopher Caldwell		8. PERFORMING ORGANIZATION REPORT NO. **FHWA/CA25-3170**
9. PERFORMING ORGANIZATION NAME AND ADDRESS Roadside Safety Research Group California Department of Transportation 5900 Folsom Blvd., Sacramento, CA. 95819		10. WORK UNIT NO. 11. CONTRACT OR GRANT NO. **FHWA/CA25-3170**
12. SPONSORING AGENCY NAME AND ADDRESS California Department of Transportation 5900 Folsom Blvd., Sacramento, CA. 95819		13. TYPE OF REPORT & PERIOD COVERED FINAL 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This project was performed in cooperation with the US Department of Transportation, Federal Highway Administration, under the research project titled “DEVLEOPMENT AND CRASH TESTING OF A TYPE 86H CONCRETE POST-AND-BEAM BRIDGE RAILING IN COMPLIANCE WITH MASH 2016, TEST LEVEL 4, FOR USE IN CALIFORNIA”. This work was performed at the request of Structure Policy and Innovation, Caltrans Division of Engineering Services.

16. ABSTRACT

Three full-scale crash tests of the California Concrete Barrier Type 86H were conducted to meet the Implementation Agreement for the Manual for Assessing Safety Hardware (MASH) 2016. The California Department of Transportation (Caltrans) needed a MASH 2016 compliant concrete post and beam bridge rail to replace existing NCHRP Report 350 (Report 350) rails. The Type 86H is intended to replace existing concrete baluster bridge railings on rehab and bridge-replacement projects for bridges on the California State and National Historic Registers. The Type 86H is also intended to be constructed on new bridge projects requiring a historic-looking and aesthetically pleasing “see through” concrete barrier rail.

The Type 86H is a 1067 mm (42 in.) tall vehicular barrier and a 1219 mm (48 in.) tall combination vehicular and bicycle bridge rail. The rail element is a 254 mm (10 in.) high by 381 mm (15 in.) deep, reinforced concrete beam. The steel reinforced concrete post spacing is 3 m (10 ft) extending up from a sloping 18-inch-high concrete curb. The sloped top of the curb is intended to improve visibility through the rail and help shed water and other debris from the barrier. The tested Type 86H rail was 30.5 m (100 ft) long and constructed and tested at the Caltrans Dynamic Test Facility in West Sacramento, CA. The first 23.2 m (76 ft) of the rail was mounted to a simulated bridge deck overhang which connected to a concrete anchor block with last 7.3 m (24 ft) of the downstream rail mounted to a reaction slab.

The full suite of MASH 2016 Test Level 4 (TL-4) crash tests was conducted; Test 4-10 (1100C), 4-11 (2270P) and 4-12 (10000S) (test designations 110MASH4C21-01, 110MASH4P21-02, 110MASH4S21-03 respectively). All three tests met the MASH 2016 evaluation criteria for Test Level 4 (TL-4) longitudinal barriers. The results of all three tests were within the limits of the MASH 2016 guidelines.

17. KEY WORDS Barriers, Crash Test, Bridge rail, Vehicle Impact Test, Steel, Concrete Post-and-beam, historic, see-through, aesthetic, MASH, Crashworthy	18. DISTRIBUTION STATEMENT No Restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161

19. SECURITY CLASSIF. (OF THIS REPORT) Unclassified	20. SECURITY CLASSIF. (OF THIS PAGE) Unclassified	21. NO. OF PAGES **235**	22. PRICE

California Department of Transportation
Report No. FHWA/CA25-3170
October 2024

DEVELOPMENT AND CRASH TESTING OF A CONCRETE POST-AND-BEAM BRIDGE RAILING, CALIFORNIA TYPE 86H, MASH TL-4

STATE OF CALIFORNIA

DEPARTMENT OF TRANSPORTATION
DIVISION OF RESEARCH, INNOVATION AND SYSTEM INFORMATION
OFFICE OF SAFETY INNOVATION AND COOPERATIVE RESEARCH
ROADSIDE SAFETY RESEARCH GROUP

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Report Prepared by .... Victor O. Lopez, P.E.

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ACCREDITED
Testing Cert # 3046.01

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UNCERTAINTY OF MEASUREMENT STATEMENT

The Caltrans Roadside Safety Research Group (RSRG) has determined the uncertainty of measurements in the testing of roadside safety hardware as well as in standard full-scale crash testing of roadside safety features. The results contained in this report are only for the tested article(s) and not any other articles based on the same design. Information regarding the uncertainty of measurements for critical parameters is available upon request by the California Department of Transportation Roadside Safety Research Group.

ACKNOWLEDGEMENTS

This work was accomplished in cooperation with the United States Department of Transportation, Federal Highway Administration.

Special appreciation is due to the following staff members of the Materials Engineering and Testing Services, Structures Construction, and the Division of Research, Innovation, and System Information for their enthusiastic and competent help on this project:

Thanks to the Road Safety Research Group (RSRG) staff, Eemom Amini, Ed Ung, Phil Fong, Justin Elis, Eric Jacobson, Karim Mirza, Arvern Lofton, and Larry Baumeister for test preparation, data reduction, vehicle preparation, video processing, and assistance during tests. Thanks to Dave Bengal, Independent Camera Operator. Thanks to Martin Zanotti, Charles Gill, James Olivo, and Michael Pieruccini for their support in the machine shop. Thanks to Larry McCrum for his support in the concrete lab. Thanks to Scott Lorenzo in the Photography Unit for his support with still photos. Also, thanks to John Lammers, Hogni Setberg, Delia Munoz, Mayra Velasquez, Luis Guzman for test article constructability and construction support.

The bridge rail design and load evaluation were performed by Greg Kaderabek, Tillat Satter, Kimberly Mori, Tony Yoon, Don Lee, Ashraf Ahmed, and Jim Gutierrez, Caltrans Division of Engineering Services, Structures and Engineering Services. Special thanks to DES Supervising Bridge Engineer Joel Magana.

Thanks to:

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1. Introduction

1.1. Problem

In 2016, the California Department of Transportation (Caltrans) established a timeline for the implementation of the Manual for Assessing Safety Hardware (MASH) (AASHTO, 2016). MASH is a testing standard for evaluating the safety of roadside hardware, and replaces the previous testing guidelines, the National Cooperative Highway Research Program, Report 350. The Caltrans timeline was consistent with the 2015 American Association of State Highway Transportation Officials (AASHTO) and Federal Highway Administration (FHWA) Joint Implementation Agreement. The agreement specifies that new installations of roadside safety hardware comply with MASH 2016 for Federal Aid Eligibility. Caltrans adopted a plan that all bridge rail projects advertised on or after October 31, 2019, that include permanent and full bridge rail replacements, meet MASH criteria.

1.2. Objective

The objective of this research project is to construct a test section of a historic-looking and aesthetically pleasing concrete post and beam bridge rail, the California Concrete Barrier Type 86H (Type 86H), and then conduct the required crash tests under the MASH 2016 Test Level 4 (TL-4) criteria for longitudinal barriers.

1.3. Background

There are many bridges in California built with the aesthetically pleasing concrete baluster rail that are on the National Historic Register. One well known example is the Bixby Creek Bridge. Built in 1932, the Bixby Creek Bridge is located along the California Coast near Big Sur in Monterey County. The Bixby Creek Bridge is an open-spandrel arch bridge along the California coast that locals call “the gateway to Big Sur”. A picture of the Bixby Creek Bridge is shown in Figure 1-1.

Figure 1-1 Bixby Creek Spandrel Arch Bridge

Unfortunately, existing historic baluster rails do not meet the current crashworthiness requirements of the MASH 2016 standards. With the intent to build new bridges with aesthetically pleasing historic-looking barrier rails and, when necessary, to replace existing non-MASH compliant baluster rails in the California Highway system, the Division of Engineering Services has completed the design of the Concrete Barrier Type 86H shown in Figure 1-2 and Figure 1-3. The Type 86H rail is a historic-looking and aesthetically pleasing "see through" concrete barrier rail.

Figure 1-2 Concrete Barrier Type 86H (Non-Traffic Face)

Figure 1-3 Type 86H Side View

The Concrete Barrier Type 86H, shown in Figure 1-4, is the first barrier intended to meet MASH standards designed by the State of California that resembles the old, historic baluster rail. It is very similar in shape to the California Concrete Barrier Type 85 shown in Figure 1-5. The Type 85 Barrier is a post and beam concrete barrier that has recently been tested and approved for MASH compliance. Both the Type 85 and the Type 86H have a sloping curb to facilitate removal of snow in colder climate environments and slightly increased view through the baluster opening. The Type 86H is 152 mm (6 in.) taller than the Type 85 and it has a 254 mm (10 in.) deep beam versus the 305 mm (12 in.) deep beam on the Type 85. The curb on the Type 86H is 152 mm (6 in.) taller than the curb on the Type 85. For the Type 86H, the space in between the main structural posts and below the top rail has been designed to have arched windows which provides a similar appearance to the traditional historical baluster rail. The cross sections shown in Figure 1-4 and Figure 1-5 are taken at the structural posts of both rails.

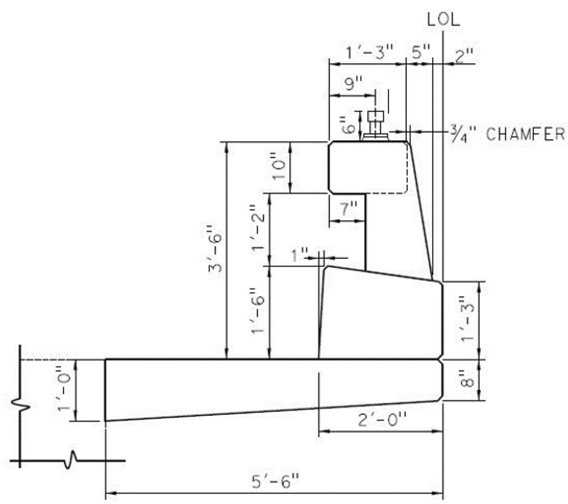

Figure 1-4 Type 86H Concrete Post and Beam Barrier Rail (MASH TL-4)

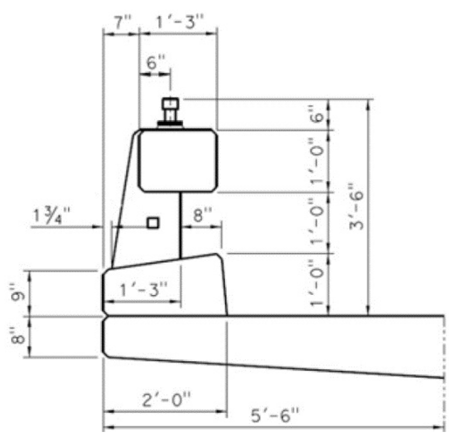

Figure 1-5 Type 85 Concrete Post and Beam Barrier Rail (MASH TL-4)

1.4. Literature Search

Prior to project initiation, a literature and product search were conducted related to MASH TL-4 concrete post and beam bridge rails. The results of the search concluded that MASH testing had not been conducted on a bridge rail similar in design to the Type 86H that would eliminate the need for crash testing. Over the course of this research project, additional concrete post and beam bridge rails have been tested for MASH compliance. It should be noted that for tests conducted and sponsored by others, complete test documentation including test reports and videos, can be difficult to obtain. Complete documentation is required as part of the Caltrans, Highway Safety Features New Products Committee hardware review and approval process. The following concrete baluster bridge rails are of interest and Caltrans has requested full testing documentation:

Texas C411

The Texas C411 Concrete Baluster Bridge Rail, shown in Figure 1-6, was tested by Texas A&M Transportation Institute (TTI) for the Texas Department of Transportation (TXDOT). The small car and pickup (1100C and 2270P) TL-2 tests were conducted in May of 2018. The test documentation report, Test Report 0-6946-R2 published in March 2019, indicated the bridge rail met the MASH 2016 TL-2 criteria.

Figure 1-6 Texas C411 Concrete Baluster Bridge Rail (MASH TL-2)

Texas C412

The Texas C412 Concrete Baluster Bridge Rail shown in Figure 1-7 was tested by TTI for TXDOT. The tractor trailer (36000V), which is a Test Level 5 test, was conducted in June of 2018. The test documentation report, Test Report 0-6946-R2 dated March 2019, indicated the bridge rail met MASH 2016 TL-5 criteria. The report notes that test designations 5-10 and 5-11 were unnecessary due to testing conducted on a similar bridge rail, the New Jersey Department of Transportation (NJDOT) Balustrade Pulaski Skyway Bridge Parapet.

According to the Federal Highway Administration (FHWA) Federal Aid Eligibility Letter B-285 (B-285) tests on the Pulaski Skyway Bridge Parapet were performed by TTI, through the Rutgers Infrastructure Monitoring and Evaluation (RIME) Group Laboratory, for the New Jersey Department of Transportation. B-285 includes basic information and test summary sheets. The summary sheets in B-285 are excerpts from TTI Report No. 607451-1-3, which does not appear to have been published to this day. However, test excerpts are included in a RIME report “Route 139 Rehabilitation: Pulaski Skyway Contract 2” dated June 2017. The final report and crash test videos for tests 4-10 and 4-11 from NJDOT and RIME were received in January of 2021. FHWA Letter B-285 mentions that the bridge rail design itself is non-proprietary and that it was developed as part of funding in 2013 from NJDOT Research Bureau to RIME. B-285 includes the required MASH Test Level 4 (TL-4) tests, all conducted in December of 2016, the small car, pickup, and van body (1100C, 2270P and 10000S respectively). All the tests met the respective MASH TL-4 requirements.

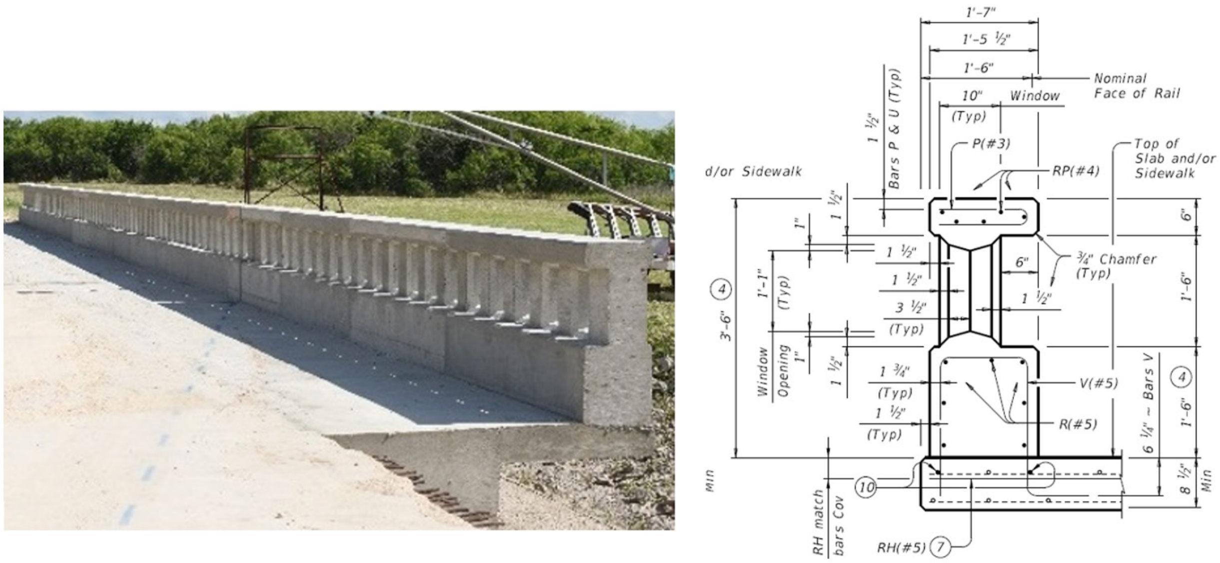

Figure 1-7 Texas C412 Concrete Baluster Bridge Rail (MASH TL-5)

1.5. Scope

The MASH 2016 TL-4 test matrix for longitudinal barriers requires three full-scale dynamic crash tests: a small car (1100C) impacting the barrier at 100 kph (62 mph) and at a 25° angle, a pickup truck (2270P) impacting at 100 kph (62 mph) and 25°, and a single-unit truck (SUT or 10000S) impacting at 90 kph (56 mph) and a 15° angle. Prior to testing, a Minor B contract was executed for construction of the Concrete Barrier Type 86H at the Caltrans Dynamic Test Facility. The Type 86H bridge rail was constructed by an experienced bridge contractor following the Caltrans construction standards. The construction activities were overseen by Caltrans personnel.

2. Test Article Details

2.1. Barrier Design

The Type 86H bridge rail was designed to be a MASH compliant, historic-looking and aesthetically pleasing concrete baluster rail. The 1067 mm (42 in.) tall vehicular barrier height was selected to exceed the minimum height of 914 mm (36 in.) recommended for the MASH TL-4 tests. When compared to the Type 85 (see Figure 1-5) the overall shape of the Type 86H (see Figure 2-1) provides improved visibility by increasing the vertical gap below the beam by 51 mm (2 in.) and, similar to the Type 85, by sloping the top of the curb downward toward the backside of the barrier. The sloped curb reduces the visual obstruction of the back of the curb and helps water and other debris to flow off, away from the roadway. The curb face height was raised to 457 mm (18 in.) to improve the redirection of the test vehicles and to reduce the opportunity for the front wheel to enter the gap below the beam. In addition, the concrete rail post was offset from the beam 178 mm (7 in.) to reduce the opportunity for wheel snagging. To enhance the versatility of where the barrier can be used, a bicycle rail was added to the top of the beam.

The bicycle rail was offset from the face of the barrier to reduce the possibility of vehicle snag. It is worth noting that LS-Dyna finite element models were created in-house to check the interaction (wheel snag) between the small car and pickup with the Type 86H concrete barrier during impact. Although a comparison of the actual crash tests and the simulations was not performed for this project, they were critical in determining the optimum cross section required to insure the crashworthiness of this rail and they reinforced the importance of setting back the structural post away from the face of rail beam.

The design and load evaluation were completed by Structure Policy and Innovation in the Caltrans Division of Engineering Services. For this evaluation the design of the Type 86H focused on the structural integrity of the barriers subject to MASH TL-4 loading in compliance with 2012, Sixth Edition, AASHTO LRFD Bridge Design Specification with California Amendments. The three barrier components (Rail, Post, & Curb) and the deck overhang were separately evaluated against flexural, shear, and torsional demands under different limit states. In addition to structural calculations, a finite element analysis study was conducted by Caltrans Division of Engineering Services using the software CSibridge to determine the demands on each component. Strengths and demands of the rail, post, and curb were then assessed under Extreme II Limit State, and the overhang under Extreme II and Strength I Limit State.

The Type 86H bridge rail barrier design consists of a steel reinforced concrete railing/beam and posts mounted on a concrete curb that is 1067 mm (42 in.) tall to the top of the traffic railing and 1219 mm (48 in.) tall to the top of the bicycle rail. The Type 86H posts are spaced 3.1 m (10 ft) apart. See the cross-section below for the general configuration. The detail sheets, which were used to construct the test article, are shown in Appendix B (Figure 11-1 through Figure 11-8). The material design strengths are as follows: Concrete (C) of 24.8 MPa (3.6 ksi) and reinforcing steel (T) of 413.7 MPa (60 ksi), where C = Compressive Strength and T = Tensile Strength.

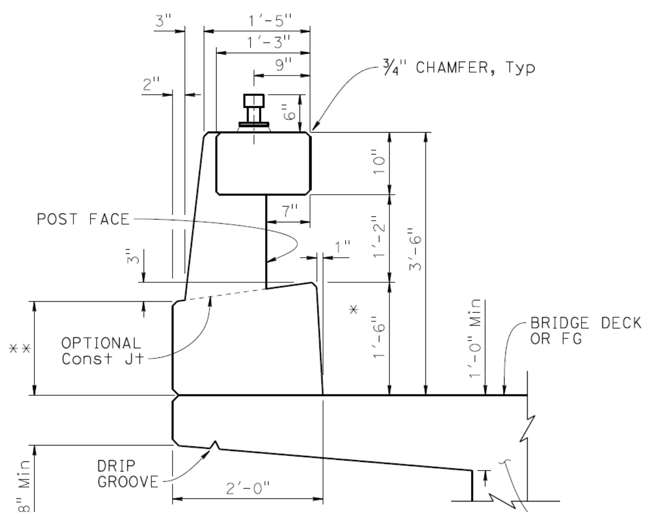

Figure 2-1 Type 86H Cross-Section

2.2. Construction

A construction contract was executed and awarded on August 13, 2020 to build the Concrete Barrier Type 86H at the Caltrans Dynamic Test Facility (test site) in the same location where the California Steel ST-75 bridge rail was constructed in 2018. A cross section of the existing ST-75 depicting the overhang removal for construction of the new Type 86H is shown in Figure 2-2. The total length of the new test article was 30.5 m (100 ft). The first 23.2 m (76 ft) was constructed to simulate a concrete bridge deck and overhang supporting the barrier rail. A 25 mm (1 in.) gap was included between Posts 4 and 5 to simulate an expansion joint, both on the deck and the bridge rail. The remaining 7.3 m (24 ft) of the barrier rail consisted of an existing concrete reaction slab supporting a drilled and bonded segment of Type 86H rail. This latter portion of rail provided a sufficient length of barrier to successfully conduct the test. Refer to the plan in Figure 2-4 and the cross section of the rail construction for this region in Figure 2-5 for more information. For simplicity of construction and to reduce construction costs, the existing 23.1 m (76 ft) long concrete anchor block used for the previous crash testing of both the ST-70 Side Mounted bridge rail and the ST-75 bridge rail was utilized. The existing anchor block consisting of steel reinforced Portland Cement Concrete (PCC) measuring 1.4 m (4.5 ft) deep by 3.0 m (10 ft) in width was originally built in late 2014. As mentioned above, the existing rigidly connected overhang portion of the Type 75 bridge test article was removed without damaging the transverse #5 overhang bars. The existing preserved #5 bars were re-used in the construction of the overhang. The hatched region shown in Figure 2-2 shows the limits of removal. Figure 2-3 shows a part of the cross section with the new overhang. It is worth noting that a very small percentage of additional reinforcement was added in the region near the centerline of three structural posts to meet the required placement of bundled bars as shown in the plans. For more detail on these bundled bars, refer to Figure 11-3 and Figure 11-4 in Appendix B.

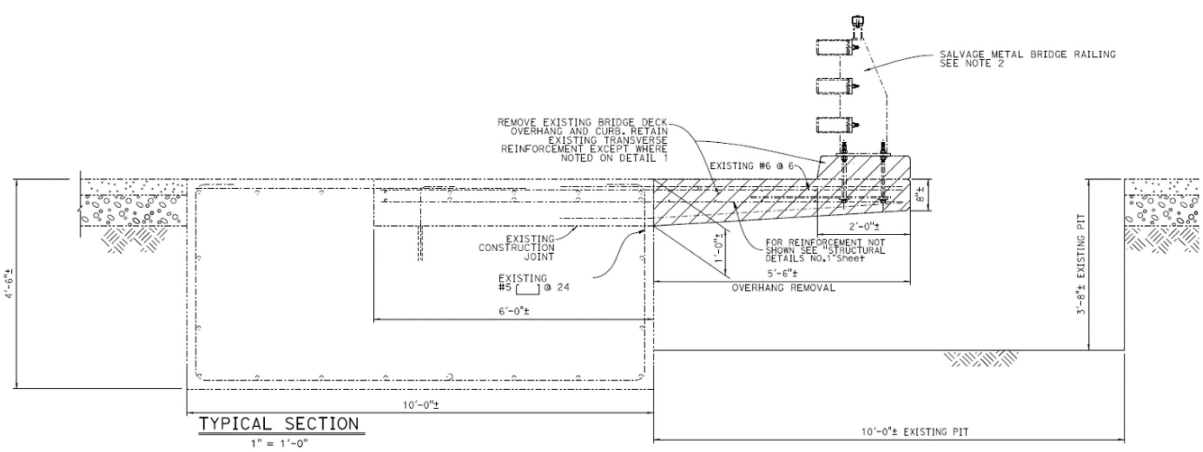

Figure 2-2 Cross Section of Existing Concrete Block and Overhang Removal

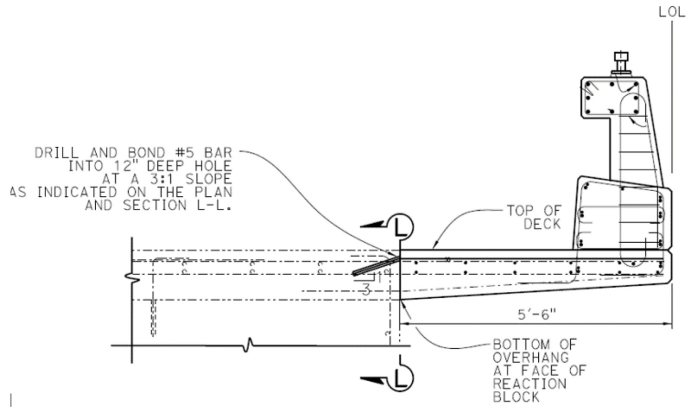

Figure 2-3 Partial Cross Section of New Overhang with the Type 86H Barrier Rail

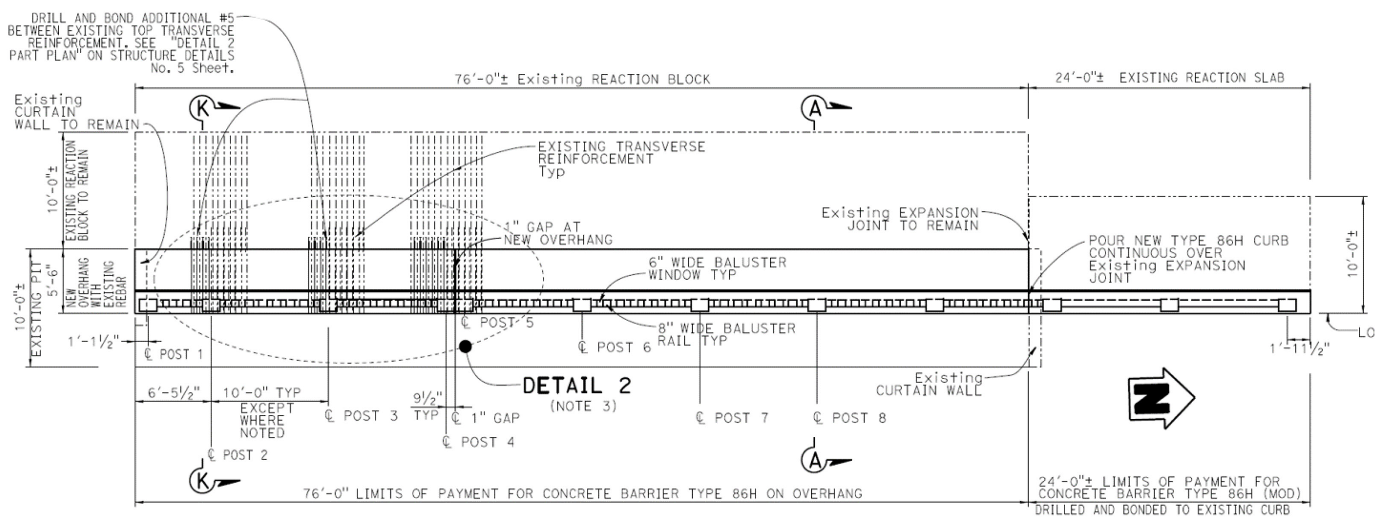

Figure 2-4 Plan View of Type 86H Test Article

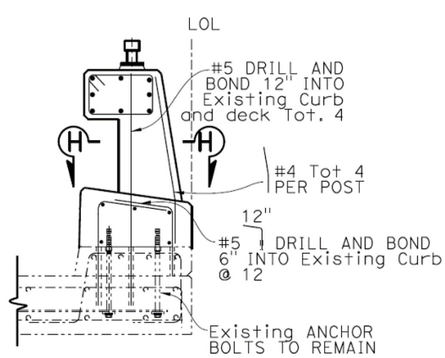

Figure 2-5 Partial Cross Section of Drilled and Bonded Type 86H (MOD) on Existing Reaction Slab

During construction of the Type 86H overhang, strain gages were installed on reinforcement at locations of interest in the deck, post and beam so that loading during impact could be measured. For a report on this supplemental strain gauge work performed at the request of the Division of Engineering Services, please refer to the report titled “Dynamic Stress and Deflection Measurements of The Concrete Post-and-Beam Bridge Railing, CALIFORNIA TYPE 86H FHWA/CA25-3170 Supplement A”.

Construction of the Type 86H was completed in four stages. The first stage consisted of removal of the steel components of the ST-75 bridge rail and the demolition of the existing curb, end block and overhang. After removal of the steel rail and posts, the contractor saw-cut 25 mm (1 in.) into to the concrete deck where the overhang attached to the anchor block (see dashed orange line in Figure 2-6). The concrete was removed using an excavator with a hammer attachment and by using hand-held jackhammers. Extreme care was exercised to ensure minimal damage to the existing transverse reinforcement during the removal of the concrete. These sequential steps are depicted by Figure 2-6 thru Figure 2-9.

Figure 2-6 Unbolting of the ST-75 Steel Bridge Rail and Painting of Overhang Saw-Cut Line

Figure 2-7 Initial saw-cut line for overhang removal

Figure 2-8 Removal of ST-75 Test Article Overhang with Excavator Hammer Attachment

Figure 2-9 Removal of ST-75 Test Article Overhang at Saw Cut Line with Jackhammers

The second stage involved construction of the new overhang. Prior to placing the concrete, this stage required the installation of wood forms for the overhang, installation of new longitudinal overhang steel reinforcement, and curb and structural post steel reinforcement. As mentioned at the beginning of this section of the report, additional transverse reinforcement was epoxied into the existing concrete anchor block in-line with the structural posts, as required by the plans. This stage also involved the correct positioning and installation of the reinforcement for the concrete curb and posts and the installation of the first set of strain gauges (at the overhang and post reinforcement). See Figure 2-10 thru Figure 2-26.

Figure 2-10 Installation of the Supports for the Formwork for the Overhang Construction

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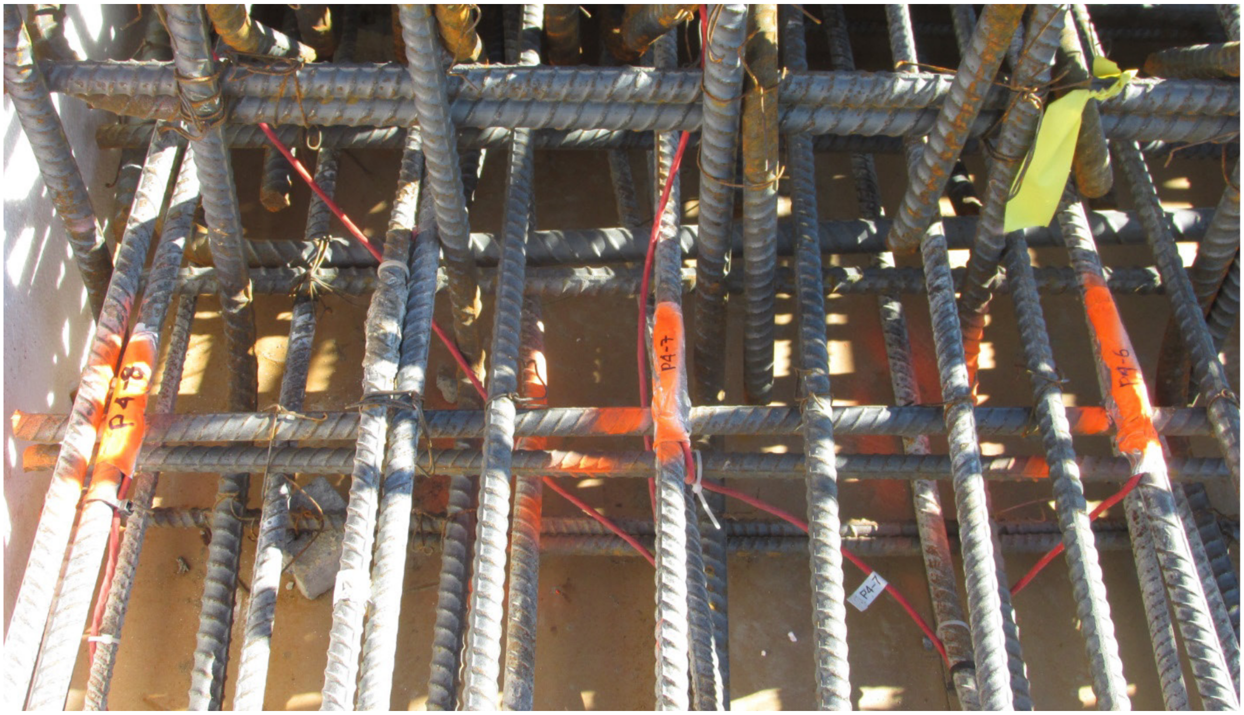

Figure 2-22 Installation of Uniaxial Strain Gauges and Cable at Post 4 Prior to Deck Pour

Figure 2-23 Installation of Uniaxial Strain Gauges and Cable at Post 3 Prior to Deck Pour

Figure 2-24 Bridge Rail Overhang Concrete Pour

Figure 2-25 Concrete Samples Taken During the Curb Pour by Caltrans Staff

Figure 2-26 Concrete Finish and Placement of Curing Compound

The third stage involved the forming of the concrete curb and the positioning and partial embedment of the baluster post reinforcement within the curb. This stage also required the placement of the remaining longitudinal curb reinforcement along with the second set of “hair pin” rebar in the upper portion of the curb. The contractor requested that the upper set of “hair pins” at each post location be omitted because the area was too congested with reinforcement (Figure 2-27). After consulting with the designer, the request was granted to improve the constructability of the Type 86H. It is worth noting that that it was quite challenging for the contractor to set the location and secure the vertical baluster post reinforcement prior to pouring the concrete curb. A plywood template made it possible and more practical to inspect the placement of the baluster reinforcement (see Figure 2-28 and Figure 2-33). Once all the required reinforcement was installed, the curb forms were installed and secured, then the curb concrete was poured. See Figure 2-27 thru Figure 2-36 for additional pictures of the third stage of construction.

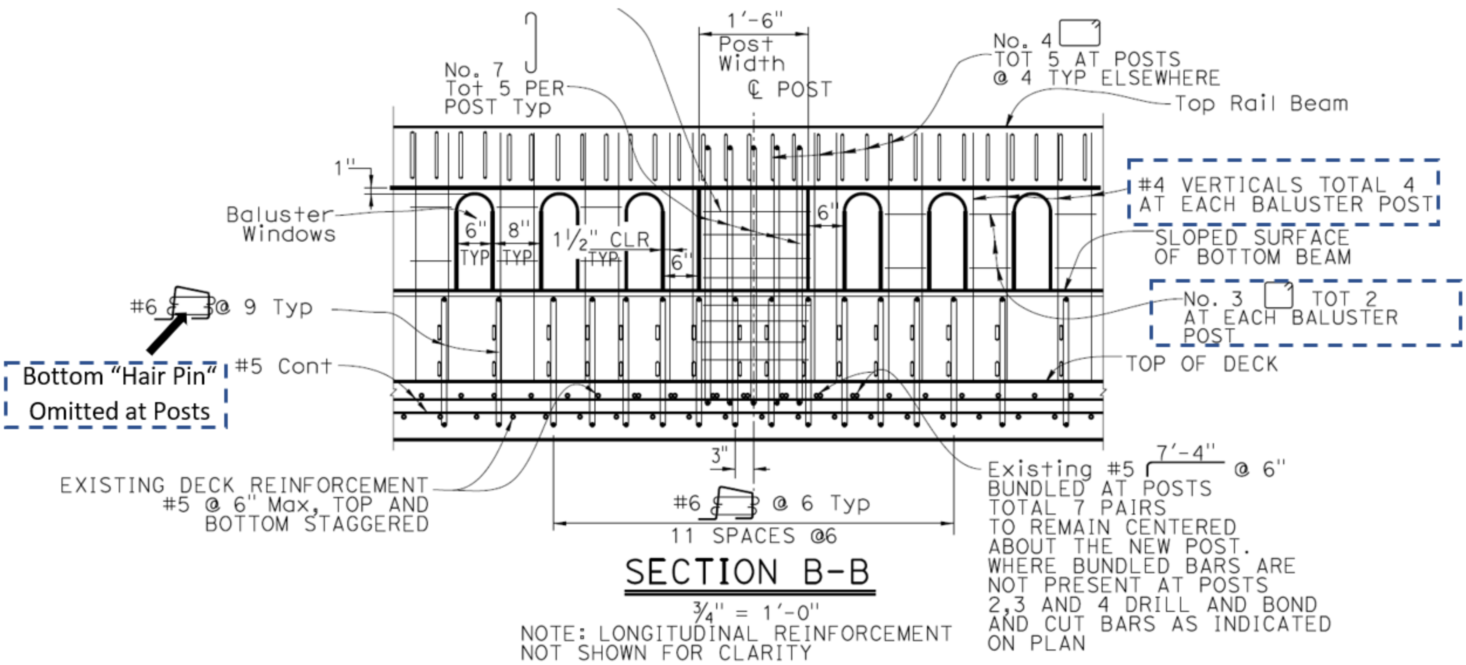

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Figure 2-34 Concrete Samples Taken During the Curb Pour by Caltrans Staff

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Figure 2-36 Removal of Concrete Curb Forms

The fourth and final stage involved the forming and pouring of the structural posts, baluster posts and structural beam. This required the placement of the remaining reinforcement for the structural posts and structural beam and placement of the second and final set of strain gages. The forms for the space between the beam and the curb were also placed (see Figure 2-40). To form the baluster windows the contractor secured arch-shaped Styrofoam blocks (see Figure 2-38 and Figure 2-39) vertically between the front and the back forms below the rail beam. During the process of forming the structural posts, an extra 32 mm (1.25 in.) was added to the non-traffic side increasing its dimension to 432 mm (17 in.) instead of 400 mm (15.75 in.). The purpose of the increased dimension was to accommodate the installation of the main vertical #7 bars, (see Figure 2-37). This change was approved by the structural designer. Also with the approval of the structural designer, the end of four of the six #7 rail bars at Structural Posts 4 and 5, had to be trimmed to allow installation (see Figure 2-42 and Figure 2-43). The top #7 bars were placed with a 180-degree hook without a problem. The lower bars had to be installed as 90-degree bends (see Figure 2-43 and Construction Details in Figure 11-5 of Appendix B). The last concrete pour involving the posts and beams, along with the removal of the forms and installation of the bicycle rails, was completed as shown in Figure 2-44 thru Figure 2-51. The final step performed to complete the construction of the Type 86H rail was to install and secure the bicycle rail. This was accomplished by drilling and bonding the plan-specified 19 mm (.75 in.) diameter threaded rods using Simpson SET-3G epoxy. To avoid conflict of installation of the threaded rods in the heavily reinforced post regions and after approval from DES and Earthquake Engineering, the embedment of the threaded rods was reduced from 203 mm (8 in.) to 152 mm (6 in.). A picture of the completed Type 86H concrete barrier rail can be found in Figure 2-51.

Figure 2-37 Forming of the Back Side and Side of the Structural Post (Post Form increased to 17 in.)

Figure 2-38 Positioning of the Arched Styrofoam Baluster Windows Prior to Installation of Front Form

Figure 2-39 Forming of the Baluster Post (placement of the front form)

Figure 2-40 Forming of the Underside of the Beam

Figure 2-41 Preparation for Splicing of No. 7 Longitudinal Reinforcement

Figure 2-42 Installation Conflict at Space between Post 4 and 5

Figure 2-43 Resolved Conflict and Completion of Installation of Beam Reinforcement at Post 4

Figure 2-44 Installation of Uniaxial Strain Gauges and Cable Prior to Post and Beam Pour

Figure 2-45 Formwork and Rebar in Place for Bridge Rail Post and Beam Concrete Pour

Figure 2-46 Bridge Rail Post and Beam Concrete Pour

Figure 2-47 Concrete Sampling and Slump Test During the Post and Beam Pour by Caltrans Staff

Figure 2-48 Removal of Forms View from the Back

Figure 2-49 Drilling and Bonding of the Threaded Rods for Tubular Bicycle Railing

Figure 2-50 Installation of Tubular Bicycle Railing and Mortar Pad at Supports

Figure 2-51 Completed Bridge Rail Type 86H

In summary, the Type 86H bridge rail was constructed in four stages. The first stage involved the demolition. The remaining stages involved three concrete pours: the deck overhang, the curb, and the posts and beam (poured at the same time). At each stage, rebar extending from one section to the next needed to be installed and aligned properly. Concrete curing compound was used to limit moisture loss. During this work, time was allocated in the contract for Caltrans staff to install the strain gages and wiring. Care was taken to protect strain gages and their wiring during construction, including running wiring through conduit in the curb. It is worth noting that the rebar subcontractor had difficulty bending the curb rebar into a shape that would fit as specified in the plans, requiring a few attempts. This was possibly due to the congestion of rebar in the deck and curb and the angled shape of the rebar used for the sloping curb. The post and beam were formed and poured successfully after some adjustments were made at the expansion joint region. Finally, the bicycle rail was installed and aligned. The bicycle rail was placed 229 mm (9 in.) from the face of the beam as specified in the contract plans.

Each concrete pour was sampled and cast into standard 152 mm x 305 mm (6 in. x 12 in.) cylinders for testing. The 28-day concrete strengths were above 35.8 MPa (5200 psi), 38.6 MPa (5600 psi) and 45.5MPa (6600 psi) for the overhang, curb and post and beam, respectively. The reinforcement was A615 Grade 60 / A706-60 (dual grade) rebar with a minimum yield strength of 448 MPa (65 ksi). The concrete and steel strength measurements were provided by other labs and are outside of our Scope of Accreditation. The bicycle rail was A500-13 Grade B (C) steel. Construction details can be found in the Appendix B, Figure 11-1 through Figure 11-8. Concrete strength test results and material certifications can be found in the Appendix C: Material Properties and Certifications, Section 12.

3. Test Requirements and Evaluation Criteria

3.1. Crash Test Matrix

MASH Test Level 4 for longitudinal barriers consists of three crash tests as follows:

1. A 1,100 kg (2,420 lb) small car at 100 kph (62 mph) and a 25° impact angle (MASH 2016 Test No. 4-10).
2. A 2,270 kg (5,000 lb) pickup truck at 100 kph (62 mph) and a 25° impact angle (MASH 2016 Test No. 4-11).
3. A 10,000 kg (22,000 lb) single-unit truck at 90 kph (56 mph) and a 15° impact angle (MASH 2016 Test No. 4-12).

The objective of this project is to verify that the Type 86H Bridge Rail meets the evaluation criteria of MASH Test 4-10, 4-11, and 4-12.

3.2. Evaluation Criteria

The evaluation criteria for longitudinal barriers are those set forth in MASH 2016 Table 2-2. For Test 4-10 and 4-11 they are A, D, F, H, and I. For Test 4-12 they are: A, D, and G. Evaluation Criteria are explained later in the Assessment Summary for each test.

4. Test Conditions

4.1. Test Facilities

Crash testing was conducted at the Caltrans Dynamic Test Facility in West Sacramento, California. The test area is a large, flat, asphalt concrete surface. At the time of testing, there were no obstructions nearby.

4.2. Test Vehicles

4.2.1. Test 4-10

The vehicle for Test 4-10 was a 2015 Nissan Versa Sedan in good condition. The MASH 2016 1100C test vehicle for the Type 86H Bridge Rail was assigned test identification number 110MASH4C21-01. The vehicle was free of major body damage and not missing any structural parts. The vehicle was not modified in any way and had all the standard equipment. The test inertial mass of 1107 kg (2441 lb) was within the recommended mass limits of MASH 2016. Test vehicle measurement sheets are shown in Table 10-7 through Table 10-10. To achieve the desired impact speed, the vehicle was towed with a 2:1 mechanical advantage. A speed control device was installed in the tow vehicle, which limited the acceleration of the vehicle once the target impact speed was reached. The steering was accomplished by means of a guidance rail anchored to the ground and a guide arm attached to the vehicle wheel hub (see Figure 10-8). Remote braking was possible at any time during the test via radio control. The vehicle was released from the guidance rail approximately 7.6 m (25 ft) before contacting the test article and was completely unconstrained before impact. Photos of the test vehicle prior to the impact are shown in Figure 4-1 through Figure 4-6. See Appendix A, Figure 10-1 and Figure 10-2 for more information on vehicle equipment and instrumentation.

Figure 4-1 MASH 4-10 Test Vehicle Front Right

Figure 4-2 MASH 4-10 Test Vehicle Passenger Side

Figure 4-3 MASH 4-10 Test Vehicle Front

Figure 4-4 MASH 4-10 Test Vehicle Driver Side

Figure 4-5 MASH 4-10 Test Vehicle Rear

Figure 4-6 MASH 4-10 Test Vehicle at Impact Point

4.2.2. Test 4-11

The test vehicle for Test 4-11 was a 2018 Dodge RAM 1500 Quad Cab pickup. The MASH 2016 2270P test for the Type 86H Bridge Rail was assigned test identification number 110MASH4P21-02. The vehicle was free of major body damage and not missing any structural parts. The vehicle was not modified in any way and had all the standard equipment. The test inertial mass of 2235 kg (4928 lb) was within the recommended mass limits of MASH 2016. The height of the vehicle Center of Gravity was 738 mm (29 in.) and was above the minimum recommended in MASH of 710 mm (28 in.). Test vehicle measurement sheets are shown in Table 10-14 through Table 10-21. To achieve the desired impact speed, the vehicle was self-powered. A speed control device was installed in the vehicle to limit the acceleration of the vehicle once the target impact speed was reached. The steering was accomplished by means of a guidance rail anchored to the ground and a guide arm attached to the vehicle wheel hub. The electric power steering system was de-energized prior to testing to reduce steering harmonics and improve lateral impact point accuracy. Remote braking was possible at any time during the test via radio control. The vehicle was released from the guidance rail and power to the engine was cut approximately 6.1 m (20 ft) before contacting the test article and was completely unconstrained before impact. Photos of the test vehicle are shown in Figure 4-7 through Figure 4-11. See Figure 10-3 and Figure 10-4 for more information on vehicle equipment and instrumentation.

Figure 4-7 MASH 4-11 Test Vehicle Front Right

Figure 4-8 MASH 4-11 Test Vehicle Passenger Side

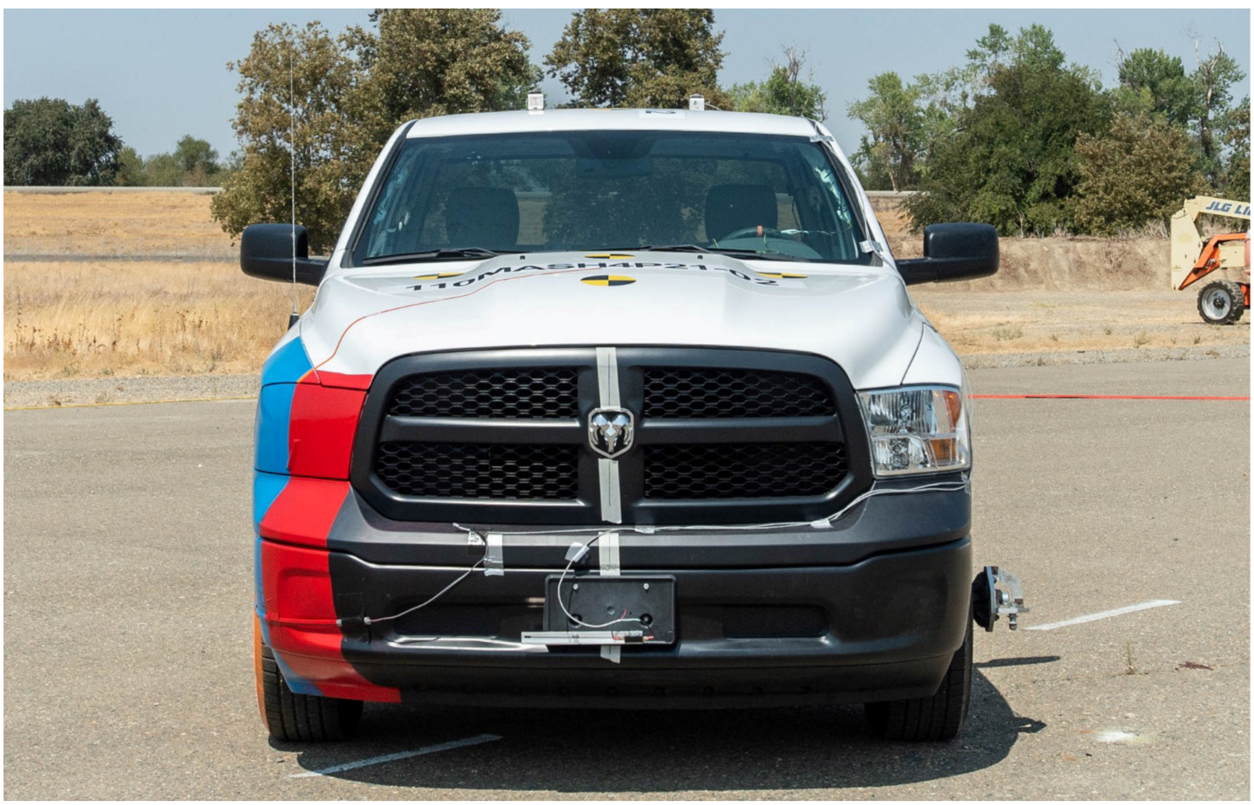

Figure 4-9 MASH 4-11 Test Vehicle Front

Figure 4-10 MASH 4-11 Test Vehicle Driver Side

Figure 4-11 MASH 4-11 Test Vehicle Rear

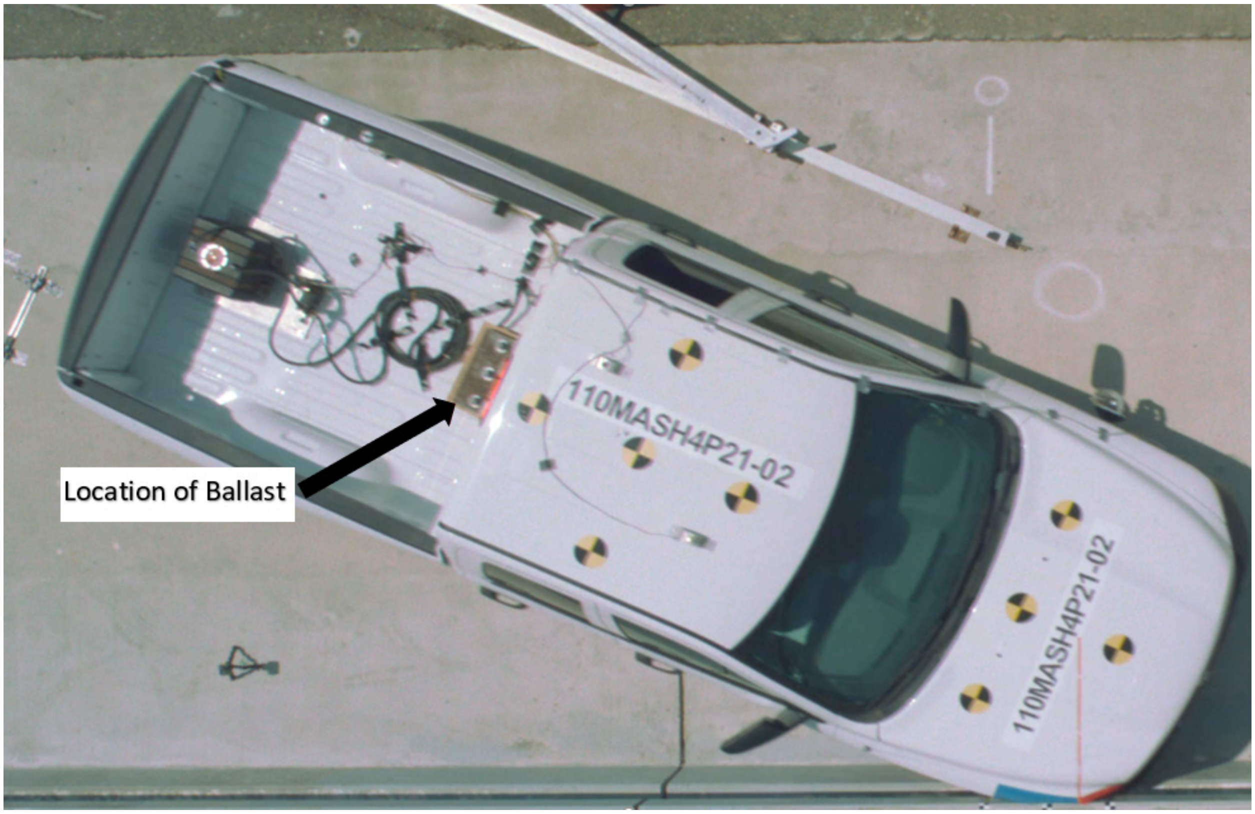

Figure 4-12 MASH 4-11 Test Vehicle Ballast

Figure 4-13 MASH 4-11 Test Vehicle at Impact Point

4.2.3. Test 4-12

The test vehicle for Test 4-12 was a 2009 Freightliner M2 106 18-foot Box Truck. The test vehicle complied with all MASH 2016 requirements for 10000S vehicles. The MASH 2016 10000S test for the Type 86H bridge rail was assigned test identification number 110MASH4S21-03. The vehicle was in good condition and not missing any standard equipment. The cargo box was strengthened according to Ford's *2005 Body Builder Layout Book* to reduce the chance of it separating from the frame thus reducing loading on the barrier during the test, see Figure 4-23 and Figure 4-24. The curb weight of the vehicle was 5831 kg (12855 lb). With instrumentation, other equipment, and ballast installed, the test inertial mass was 10144 kg (22364 lb), which was within the recommended mass limits of MASH 2016. See Figure 4-20 and Figure 4-21 for ballast in the cargo box. The ballast consisted of three 1.5 m by 1.5 m by 51 mm (5 ft by 5 ft by 2 in.) steel plates, 5 smaller steel plates measuring approximately 1.5 m by 300 mm x 51 mm (5 ft x 12 in. x 2 in.) and one thinner steel plate measuring 1.5 m x 600 mm x 25 mm (5 ft x 24 in. x 1 in.) bolted on top of wood beams fastened to the cargo bed. Each of the large plates weighed approximately 907 kg (2000 lb). The smaller plates weighed approximately 177.8 kg (392 lb) each. They were mounted and secured uniformly across the length and width of the cargo bed using 8 threaded rods 25 mm (1 in.) in diameter through the bed to c-channel brackets under the bed. The wood posts were connected to each other with steel plates using wood screws and secured to the cargo bed with wood screws and angle brackets. The center of mass of the ballast was 1625 mm (63.9 in.) from the ground, which was within MASH recommended limits of 1600 mm +/- 50 mm (63 in. +/- 2 in.). Test vehicle measurement sheets are shown in Appendix A, Table 10-27 through Table 10-30. To achieve the desired impact speed, it was necessary to push the test vehicle with a Ford F-350 Dually in addition to its own self-power to get up to the target impact speed. The Ford F-350 Dually backed off the test vehicle about 213 m (700 ft) prior to impact. A speed control device was installed in the push vehicle, which limited the acceleration of the push vehicle once the target impact speed was reached. The speed governor of the test vehicle was reprogrammed to limit speed the maximum speed to 90.1 kph (56 mph). The steering was accomplished by means of a guidance rail anchored to the ground and a guide arm attached to the vehicle wheel hub. Remote braking was possible at any time during the test via radio control. The vehicle was released from the guidance rail and power to the engine was cut approximately 7.62 m (25 ft) before contacting the test article and was completely unconstrained before impact. Photos of the test vehicle are shown in Figure 4-14 through Figure 4-24. See Figure 4-22 and Appendix A for more information on vehicle equipment and instrumentation.

Figure 4-14 MASH 4-12 Test Vehicle Front Right

Figure 4-15 MASH 4-12 Test Vehicle Passenger Side

Figure 4-16 MASH 4-12 Test Vehicle Front

Figure 4-17 MASH 4-12 Test Vehicle Driver Side

Figure 4-18 MASH 4-12 Test Vehicle Rear

Figure 4-19 MASH 4-12 Test Vehicle at Impact Point

Figure 4-20 MASH 4-12 Test Vehicle Ballast in Cargo Box

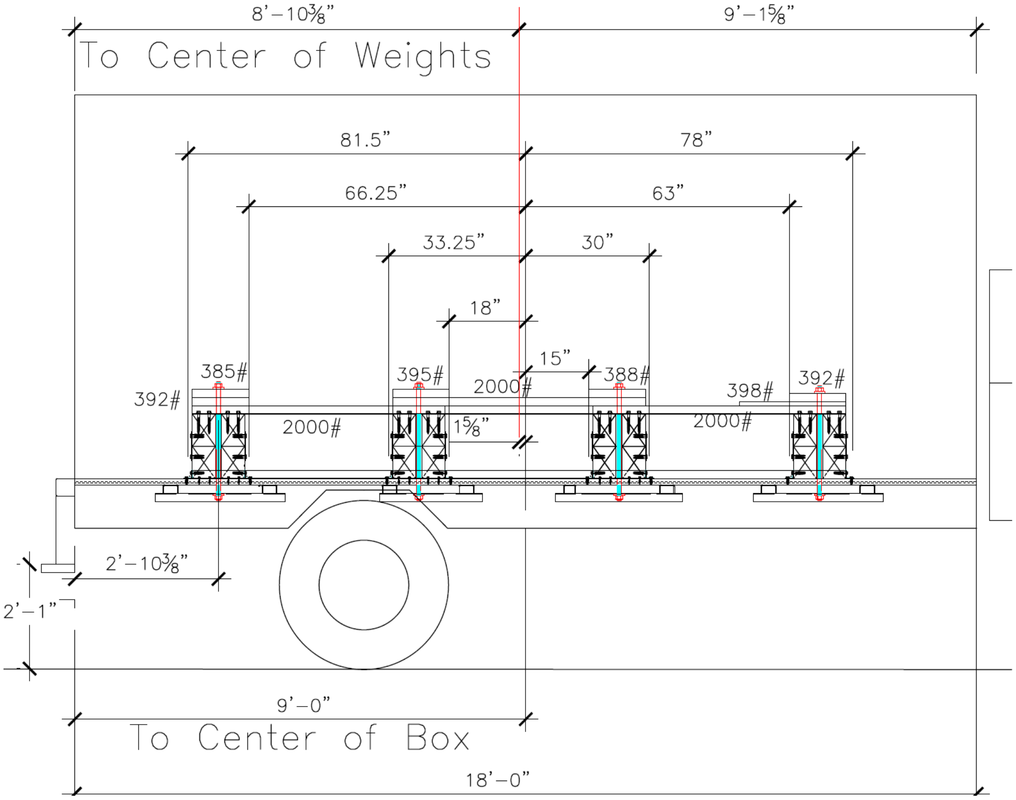

Figure 4-21 MASH 4-12 Side View Diagram of Test Vehicle Ballast in Cargo Box

Figure 4-22 MASH 4-12 Test Vehicle Instrumentation Equipment in Cargo Box

Figure 4-23 MASH 4-12 Test Vehicle Front Shear Plate and Ballast Mounting Plate

Figure 4-24 MASH 4-12 Test Vehicle Rear Shear Plate and Ballast Mounting Plate

4.3. Test Documentation

The tests were documented using still cameras, video cameras, high-definition high-speed digital video cameras, and DTS SLICE data acquisition systems to record accelerations and rotational rate changes. The impact phase of each crash test was recorded with five high-definition, high-speed digital video cameras, a normal-speed DVC format video camera, digital SLR cameras and action cameras mounted inside and outside the test vehicle set to record video. The test vehicle and barrier were photographed before and after impact with the DVC format camera and a digital SLR camera.

In accordance with the MASH 2016 guidelines for Tests 4-10 and 4-11, two sets of orthogonal accelerometers and angular rate sensors were mounted in test vehicles to measure lateral, longitudinal, and vertical accelerations, along with the roll, pitch, and yaw rates. The data was analyzed in Test Risk Assessment Program version 2.3.11 (TRAP) to determine the occupant impact velocities, ridedown accelerations, maximum vehicle rotation, and other occupant risk quantities. For test 4-12, two sets of accelerometers and angular rate sensors were in the cab and another two sets were located at the vehicle's center of gravity in the cargo box area. Unfortunately, one of the sets in the cargo box malfunctioned due to a wire splice disconnecting during impact and did not record data. TRAP was also used to analyze Test 4-12 to determine the occupant impact velocities, ridedown accelerations, and maximum vehicle rotation at the locations where the instruments were mounted. Even though MASH does not set a limit for OIV, ORA, or angular data, they were reported in this report for comparison purposes. See Appendix A, Figure 10-5 through Figure 10-7 for more information on vehicle instrumentation and test documentation.

5. Test 110MASH4C21-01 (4-10)

5.1. Impact Description and Results

The Critical Impact Point selected was 1.1 m (3.6 ft) upstream from the upstream edge of post 4, as recommended in Table 2-7 of MASH 2016 (AASHTO, 2016). The front edge of the post was selected instead of the middle of the post (as shown in MASH 2016 Figure 2-1) to increase the chance of wheel snag on the post. The impact angle of 25° was set with a Total Station when laying out the guide rail. The intended impact speed was 100 kph (62 mph). As seen in Figure 5-1, checkered tape was added upstream and downstream of the target CIP to aid in determining that the impact point was within MASH 2016 (Figure 2-1 Note 2) tolerance of ±30 cm (~12 in.).

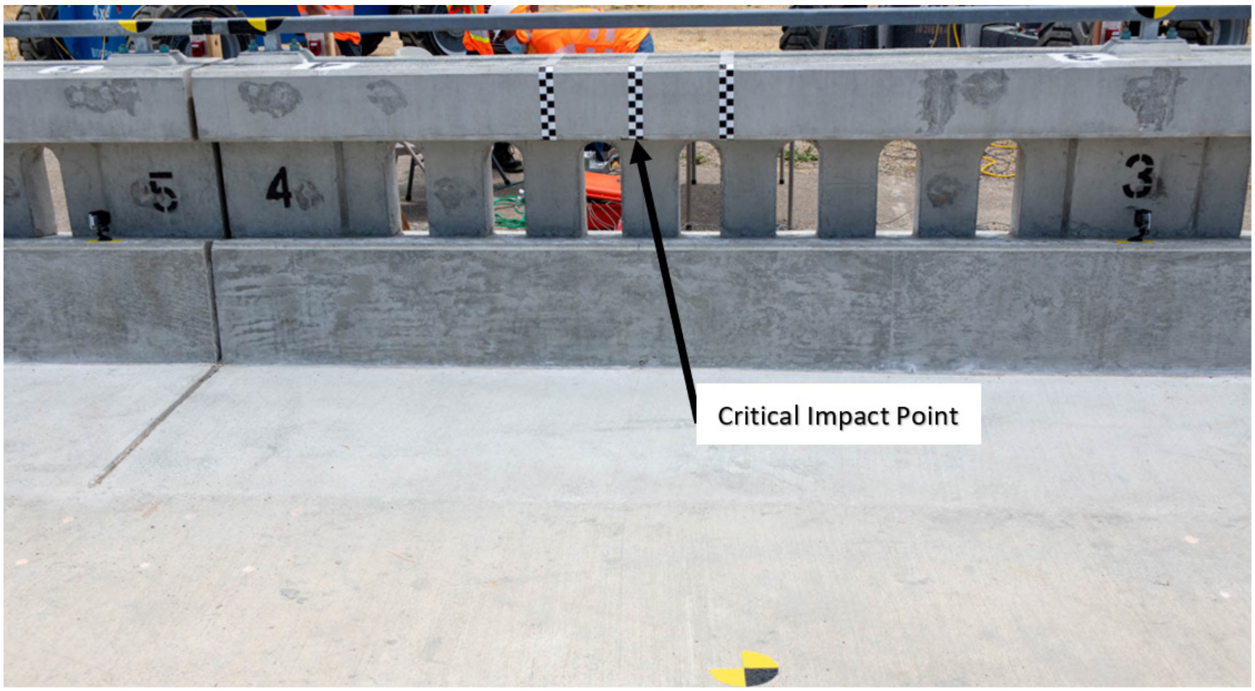

Figure 5-1 Test Article Impact Area Pre-Test 4-10

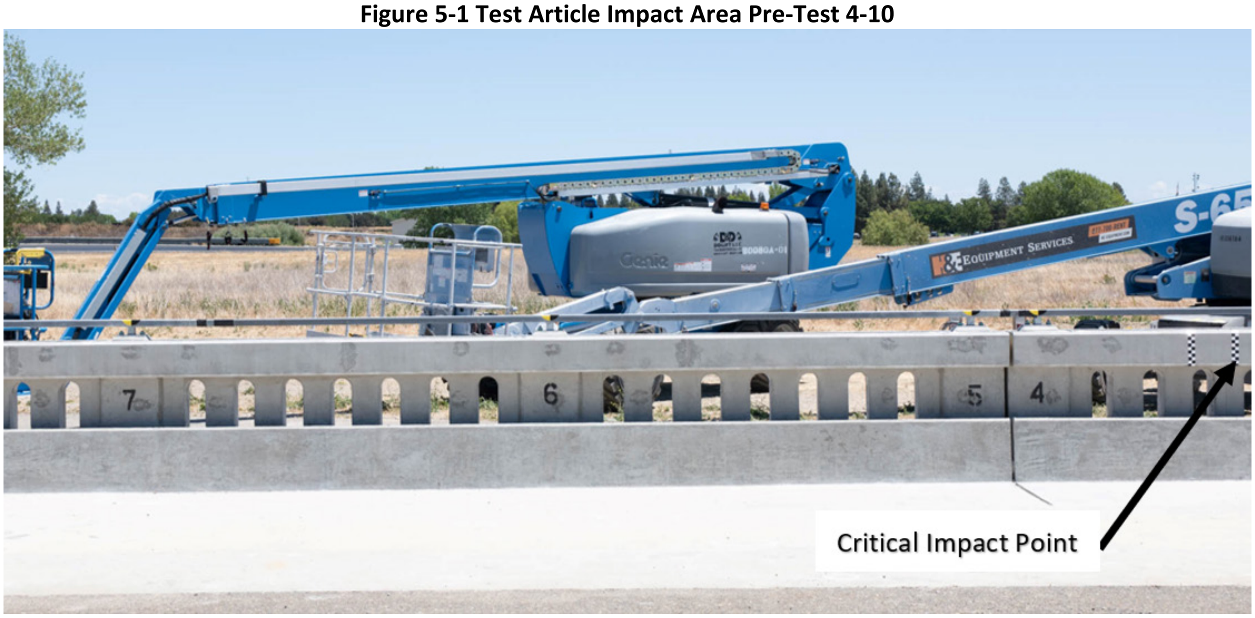

Figure 5-2 Test Article Downstream of Impact Area Pre-Test 4-10

5.2. Test Description

The crash was performed in the afternoon of May 26, 2021. According to the Sacramento Executive Airport Weather Station, weather conditions were reported as clear skies and an ambient temperature of 82 deg F, with wind speeds of approximately 9 mph from the northwest (NW). The vehicle was traveling approximately north-northeast (NNE).

The 1100C vehicle impacted the barrier at 99.6 kph (61.9 mph) and 25.2°. The vehicle impact point on the Type 86H bridge rail was approximately 1.1 m (3.6 ft) upstream of the upstream face of post 4, which was about 15 mm (0.6 in.) upstream of the Critical Impact Point (CIP). The vehicle was contained and smoothly redirected at an exit speed and angle of 77.5 kph (48.1 mph) and 8.2°, respectively. After exiting the bridge rail, the remote brakes were applied, and the car came to a stop about 63.6 m (208.7 ft) downstream of and 33 m (108.2 ft) on the traffic side of the barrier. Still photos of the vehicle during the test are shown in Figure 5-3 through Figure 5-6. A detailed description of the sequential events is shown in the table below.

Table 5-1 Test 110MASH4C21-01 Test Sequence of Events

Time (s)	EVENT
0.000	Initial contact of the vehicle front bumper with the barrier curb
0.006	Initial flash of impact bulb
0.008	Initial contact of front tire with barrier curb
0.016	Vehicle hood begins to contact the bottom corner of the barrier beam
0.026	Vehicle passenger side headlight impacts barrier at the front face of the baluster post upstream of post 4.
0.036	Top of front passenger window begins to deform outward.
~0.046	Bottom right corner of windshield begins to crack. Bumper and grill begin to separate from vehicle. Vehicle begins to redirect (yaw left)
~0.058	Passenger side window begins to shatter prior to surrogate occupant’s head crossing the side window’s vertical plane.
0.078	Left rear tire lift off the ground (approximate) and surrogate head protrudes through vertical window plane.
0.126	Surrogate occupant’s head is at greatest protrusion and does not impact the top beam.
0.166	Vehicle is roughly parallel to rail face
0.186	Rear right tire contacts barrier curb at expansion joint and rear taillight begins to be impacted before shattering.
0.322	Approximate time vehicle loses contact with barrier (obscured by dust and debris)
0.380	Left rear tire returns to ground (approximate)
1.074	Brakes are applied (obtained from SLICE Unit Event Channel Data)

Figure 5-3 Test 4-10 Downstream Camera Impact View

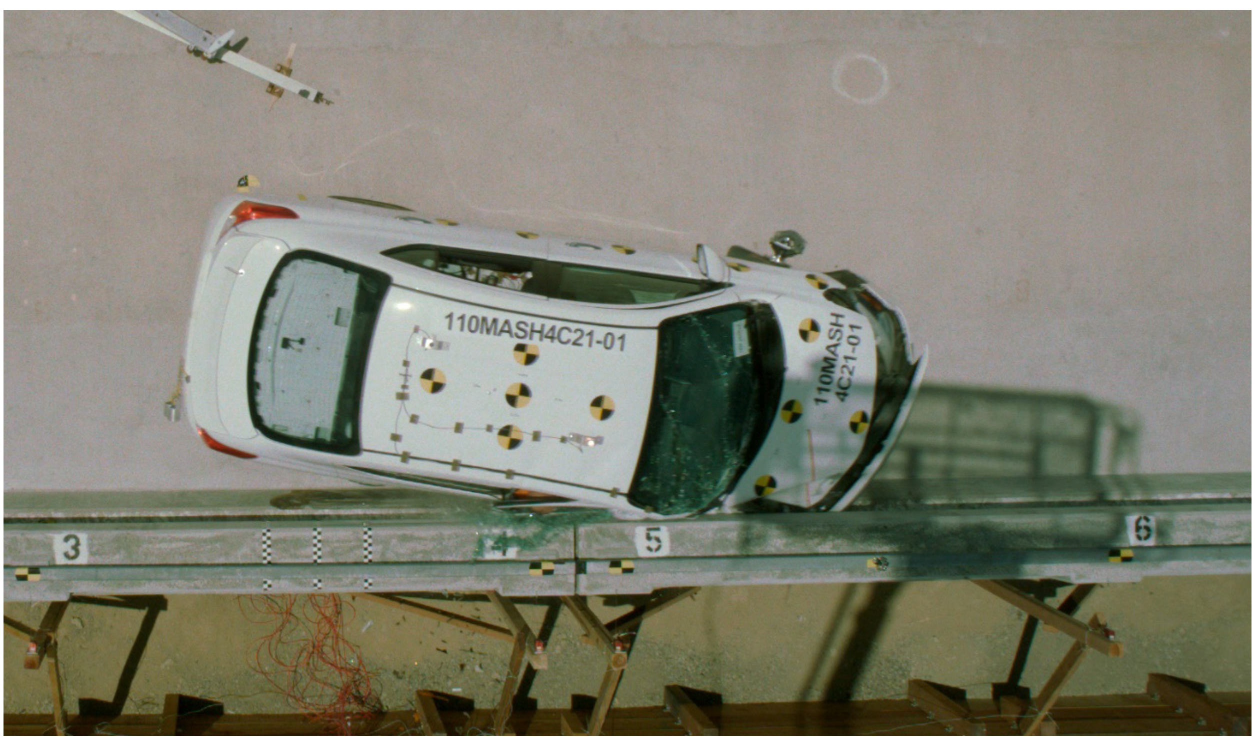

Figure 5-4 Test 4-10 Overhead Camera Impact View

Figure 5-5 Test 4-10 Pan Camera Impact View

Figure 5-6 Test 4-10 Upstream Camera Impact View

5.3. Barrier Damage

There was no significant damage to the barrier. There were minor surface scrapes on the top edge of the curb face approximately 2.0 m (6.6 ft) in length. The traffic side face of the concrete curb had marks from the painted tires and superficial marks from the bumper and side of the test vehicle. The vertical face of the concrete beam had horizontal marks from the side-view mirror rubbing up against it. Barrier damage is shown in Figure 5-7 through Figure 5-9. The orange contact marks are from the front right tire. The green contact marks are from the rear right tire. Dynamic deflection of the bridge rail was very small and unmeasurable from the overhead video. There was no permanent deflection of the Type 86H. Strain gage and string potentiometer data were collected during the test and are available upon request but are not within the Lab's Scope of Accreditation.

Figure 5-7 Test 4-10 Vehicle Marks and Minor Scrapes on Type 86H at Critical Impact Point

Figure 5-8 Test 4-10 Overview of Barrier Post-Test

Figure 5-9 Test 4-10 Tire Marks Post-Test (view from downstream)

5.4. Vehicle Damage

The 1100C front right corner and the passenger's side of the vehicle sustained damage during the impact. For the passenger side of the vehicle, mainly the right front and rear quarter panels were damaged, with a large indentation caused by the beam of the bridge rail. The front passenger wheel was pushed back and tilted away from the vehicle, remaining attached to the strut and steering arm. The front bumper cover, grill, and both headlights were completely detached from the vehicle. The windshield was spider-cracked across its surface, and it buckled more than 76 mm (3 in.) outward on the passenger side, lower section. This occurrence, in itself, is not considered a failure considering that the deformation was outward and away from the occupant compartment. The passenger side window shattered due to the deformation and buckling of the A-Pillar and passenger door which occurred when the vehicle struck the barrier. All the other windows remained undamaged. The front passenger wheel was damaged and tire was deflated, all remaining tires remained inflated. The airbags did not deploy because the vehicle was towed and there was no power to the airbag system. The maximum amount of passenger compartment deformation measured by known points was 168 mm (6.6 in.), which occurred on the passenger-side in the toe pan/wheel well area of the floorboard. All interior deformation measurements were below the maximum MASH 2016 limits and are shown in Appendix A: Table 10-11 through Table 10-13. As previously mentioned, the windshield deformation exceeded the MASH limit of 76 mm (3 in.) however it is not considered a failure since it bowed away from the occupant compartment. See Figure 5-10 to Figure 5-23 for pictures of the vehicle damage described above. See Appendix D for undercarriage photos showing no damage.

Figure 5-10 Test 4-10 Test Vehicle Damage (front/hood and windshield)

Figure 5-11 Test Vehicle Damage (front right)

Figure 5-12 Test 4-10 Test Vehicle Damage (right)

Figure 5-13 Test 4-10 Test Vehicle Damage (front right)

Figure 5-14 Test 4-10 Test Vehicle Damage (front left)

Figure 5-15 Test 4-10 Test Vehicle Damage (right rear)

Figure 5-16 Test 4-10 Test Vehicle Damage (right rear)

Figure 5-17 Test 4-10 Test Vehicle Damage Windshield / Exterior

Figure 5-18 Test 4-10 Test Vehicle Damage Windshield / Exterior Deformation Away from Occupant

Figure 5-19 Test 4-10 Test Vehicle Damage Windshield / Interior View

Figure 5-20 Test 4-10 Floorboard Deformation

Figure 5-21 Test 4-10 Floorboard Deformation

Figure 5-22 Test 4-10 Floorboard Deformation

Figure 5-23 Test 4-10 Floorboard Deformation

Table 5-2 Test 110MASH4C21-01 Test Data Summary Sheet


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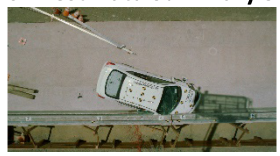
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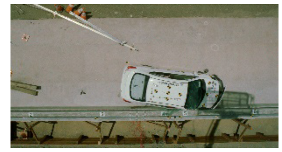
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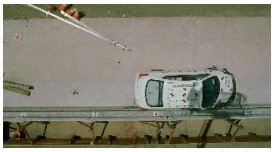
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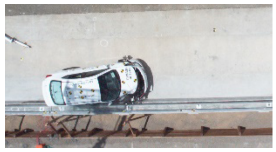
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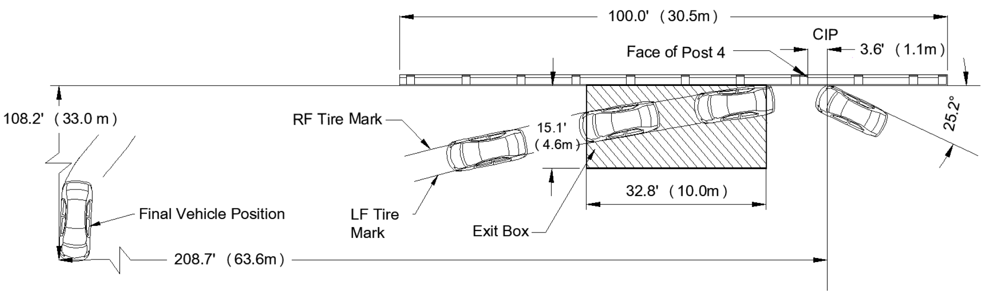

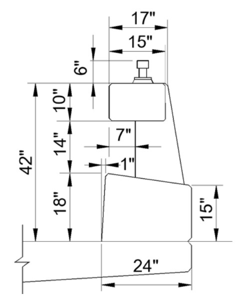

Test Agency California, Department of Transportation
Test Number 110MASH4C21-01
Test Designation MASH 2016 Test 4-10
Date 5/26/2021
Test Article CA Type 86H Bridge Rail
Total Length 100 ft (30.5 m)
Key Elements – Barrier

- Description CA Type 86H Bridge Rail
- Base Width 24 in. (610 mm)
- Height 42 in. (1067 mm)

Test Vehicle

- Type/Designation 1100C
- Make and Model 2015 Nissan Versa
- Curb 2445 lb (1109 kg)
- Test Inertial 2441 lb (1107 kg)
- Gross Static 2617 lb (1187 kg)

Impact Conditions

- Speed 61.9 mph (99.6 kph)
- Angle 25.2°
- Location/Orientation 3.6 ft (1.1 m) upstream of upstream face of post
- Impact Severity 56.6 kip-ft (76.8 kJ)

Exit Conditions

- Speed 48.1 mph (77.5 kph)
- Angle 8.2 °

Exit Box Criterion Pass
Post-impact Trajectory

- Vehicle Stability Satisfactory
- Stopping Distance (from point of impact) Approx. 209 ft downstream and 108 ft laterally in front

*Measured from String Potentiometers and is not within the Lab's scope of accreditation.

Test Article Damage Minor scrapes
Test Article Deflections

- Permanent Set 0.0 in. (0 mm) *
- Dynamic 0.1 in. (2 mm) *
- Working Width 24.0 in. (610 mm)

Vehicle Damage Moderate to Heavy

- VDS[ref] 1-RFQ-5, 1-RD-3 2-RP-3, 4-RBQ-3
- CDC[ref] 01FZHW8, 03FDHS5
- Maximum Deformation Approx. 6.6 in.(168 mm) at Wheel/foot well and toe pan areas.
- Vehicle Snagging None
- Vehicle Pocketing None

Transducer Data

Evaluation Criteria	Transducer SLICE-656	Transducer SLICE-659	MASH Limit
OIV Longitudinal Ft/s (m/s)	22.3 (6.8)	22.6 (6.9)	±40 (12.2)
OIV Lateral Ft/s (m/s)	30.8 (9.4)	32.8 (10.0)	±40 (12.2)
ORA Longitudinal. g's	-6.0	-6.0	±20.49
ORA Lateral. g's	-12.1	-11.8	±20.49
Max. Roll Angle Deg.	8.5	9.5	±75
Max. Pitch Angle Deg.	-6.1	-5.2	±75
Max. Yaw Angle Deg.	-47.4	-48.6	N/A
THIV – ft/s (m/s)	38.1 (11.6)	39.4 (12.0)	N/A
PHD – g's	13.4	13.1	N/A
ASI	2.71	2.83	N/A

5.5. Discussion of Test Results

5.5.1. General Evaluation Methods

MASH 2016 recommends that crash test performance be assessed according to three evaluation factors: (1) structural adequacy, (2) occupant risk, and (3) post-impact vehicular response.

The structural adequacy and occupant risk associated with the Type 86H Bridge Rail were evaluated using evaluation criteria found in Tables 2.2A (Recommended Test Matrices for Longitudinal Barriers), 5.1A (Safety Evaluation Guidelines for Structural Adequacy), and 5.1B (Safety Evaluation Guidelines for Occupant Risk) of MASH 2016. The post-impact vehicular response was evaluated using Section 5.2.3 of MASH 2016.

5.5.2. Structural Adequacy

The structural adequacy of the Type 86H Bridge Rail was acceptable during Test 4-10.

Refer to Table 5-3 for the assessment summary of the safety evaluation criteria for the Type 86H Bridge Rail.

5.5.3. Occupant Risk

The occupant risk was acceptable. As mentioned previously, all interior deformation measurements were below the maximum MASH 2016 limits. All interior deformation measurements are shown in Appendix A: Table 10-11 through Table 10-13.

There was no penetration of the occupant compartment by the Type 86H or potential for it. The occupant compartment was not compromised. The dummy’s head protruded slightly beyond the plane of the passenger side window, but it did not show potential for striking any portion of the barrier. Occupant impact velocities and ridedown accelerations were below MASH 2016 limits. The roll, and pitch of the vehicle were within acceptable limits, the yaw value does not have a MASH 2016 criterion limit.

Refer to Table 5-3 for the 1100C test assessment summary of the safety evaluation criteria for the Type 86H Bridge Rail.

5.5.4. Vehicle Trajectory

The vehicle trajectory was acceptable. The exit trajectory was within the exit box.

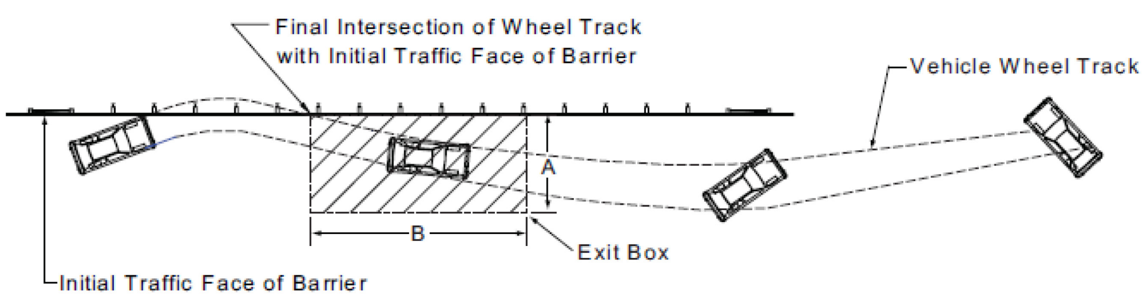

Figure 5-24 Exit Box for Longitudinal Barriers (AASHTO, 2016)

Refer to Table 5-2 and Table 5-3 for the 1100C vehicle trajectory diagram and assessment summary of the safety evaluation criteria for the Type 86H Bridge Rail.

Table 5-3 110MASH4C21-01 Assessment Summary for Test 4-10

<table>
<tr><th>Evaluation Criteria</th><th>Test Results</th><th>Assessment</th></tr>
<tr><td>Structural Adequacy
A. Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation, although controlled lateral deflection of the test article is acceptable.</td><td>The vehicle was contained and redirected smoothly.</td><td>PASS</td></tr>
<tr><td>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 personnel in a work zone.

Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E.</td><td>The barrier did not detach any elements, fragments, and/or other debris.
Deformations of, or intrusions into, the occupant compartment were within MASH 2016 limits.</td><td>PASS</td></tr>
<tr><td>Occupant Risk
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td><td>The vehicle remained upright during and after the collision.</td><td>PASS</td></tr>
<tr><td>Occupant Risk
H. Occupant Impact Velocities (OIV) (see Appendix A, Section A5.2.2 for calculation procedure) should satisfy the following limits:
<table><tr><th colspan="3">Occupant Impact Velocity Limits, ft/s (m/s)</th></tr><tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr><tr><td>Longitudinal and Lateral</td><td>30 ft/s

(9.1 m/s)</td><td>40 ft/s

(12.2 m/s)</td></tr></table></td><td><u>DAS Long. ft/sec (m/s)</u>
SLICE 656: 22.3 (6.8)
SLICE 659: 22.6 (6.9)

<u>DAS Lat. ft/sec (m/s)</u>
SLICE 656: 30.8 (9.4)
SLICE 659: 32.8 (10.0)</td><td>PASS</td></tr>
<tr><td>Occupant Risk
I. The occupant ridedown acceleration (see Appendix A, Section A5.3 for calculation procedure) should satisfy the following limits:
<table><tr><th colspan="3">Occupant Ridedown Acceleration Limits (G)</th></tr><tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr><tr><td>Longitudinal and Lateral</td><td>15.0 G</td><td>20.49 G</td></tr></table></td><td><u>DAS Long. G Lat. G</u>

SLICE 656: -6.0 -12.1
SLICE 659: -6.0 -11.8</td><td>PASS</td></tr>
<tr><td>Vehicle Trajectory
It is preferable that the vehicle be smoothly redirected, and this is typically indicated when the vehicle leaves the barrier within the "exit box". The concept of the exit box is defined by the initial traffic face of the barrier and a line parallel to the initial traffic face of the barrier, at a distance A plus the width of the vehicle plus 16 percent of the length of the vehicle, starting at the final intersection (break) of the wheel track with the initial traffic face of the barrier for a distance of B. All wheel tracks of the vehicle should not cross the parallel line within the distance B.</td><td>A = 15.1 ft (4.57 m)

B = 32.8 ft (10 m)</td><td>PASS</td></tr>
</table>

6. Test 110MASH4P21-02 (4-11)

6.1. Impact Description and Results

The Critical Impact Point selected was 1.3 meters (4.3 ft) from the centerline of post 6, as recommended in Table 2-7 of MASH 2016 (AASHTO, 2016). The impact angle of 25° was set with a Total Station when laying out the guide rail. The intended impact speed was 100 kph (62 mph).

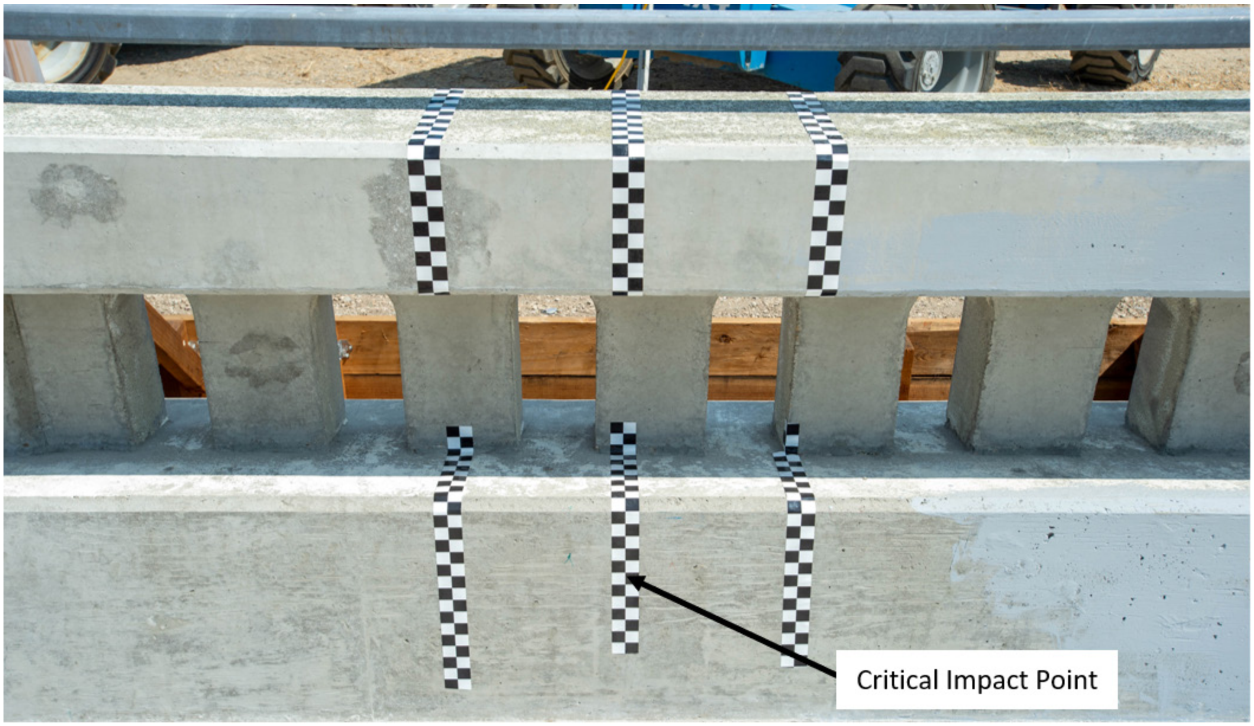

Figure 6-1 Test Article Impact Area Pre-Test 4-11

Figure 6-2 Test Article Downstream of Impact Area Pre-Test 4-11

6.2. Test Description

The crash was performed the afternoon of August 25, 2021. According to the Sacramento Executive Airport Weather Station, weather conditions were as follows: clear, temperature approximately 81 deg F, and wind of approximately 7 mph from the south (S). The vehicle was traveling approximately north-northeast (NNE).

The 2270P vehicle impacted the barrier at 99.7 kph (62 mph) and angle of 25.3°. The vehicle impact point on the Type 86H bridge rail was approximately 1.3 meters (4.3 ft) upstream from the centerline of post 6, which was 0.01 m (0.5 in.) upstream of the Critical Impact Point. The vehicle was contained and smoothly redirected with an exit speed and angle of 80.4 kph (50 mph) and 6.7°, respectively. After the vehicle exited the bridge rail, the remote brakes were applied, and the vehicle came to a stop about 79.6 m (261 ft) downstream and 2.38 m (7.82 ft) on the field side of the barrier. Still photos of the vehicle during the test are shown in Figure 6-3 through Figure 6-6. A detailed description of the sequential events is shown in the table below.

Table 6-1 Test 110MASH4P21-02 Test Sequence of Events

Time (s)	EVENT
0.000	Initial contact of the vehicle front bumper with the curb section of the barrier
0.002	Initial flash of impact bulb
0.004	Right front tire contacts barrier curb and right headlight begins to contact the barrier rail beam
0.020	Right front tire loses contact with ground and begins to climb up on the curb
0.036	Front edge of passenger door comes into contact with barrier beam
0.042	Top of front passenger door window begins to deform outward
0.046	Right front corner of hood begins to deform after contacting bicycle rail at Post 6 and vehicle begins to redirect (yaw left) and passenger airbags begins to deploy
0.058	Windshield begins form a diagonal crack on the passenger side.
0.082	Left front tire lift off the ground (approximate)
0.132	Left rear tire lift off the ground (approximate)
0.182	Vehicle is roughly parallel to rail face
0.188	Rear tail light first comes into contact with the concrete barrier beam
0.212	Rear right tire contacts barrier curb (approximate)
0.382	Vehicle loses contact with the test article (approximate)
0.548	Left front tire returns to the ground (approximate)
0.662	Left rear tire returns to the ground (approximate)
1.157	Brakes are applied (obtained from SLICE Unit Event Channel Data)

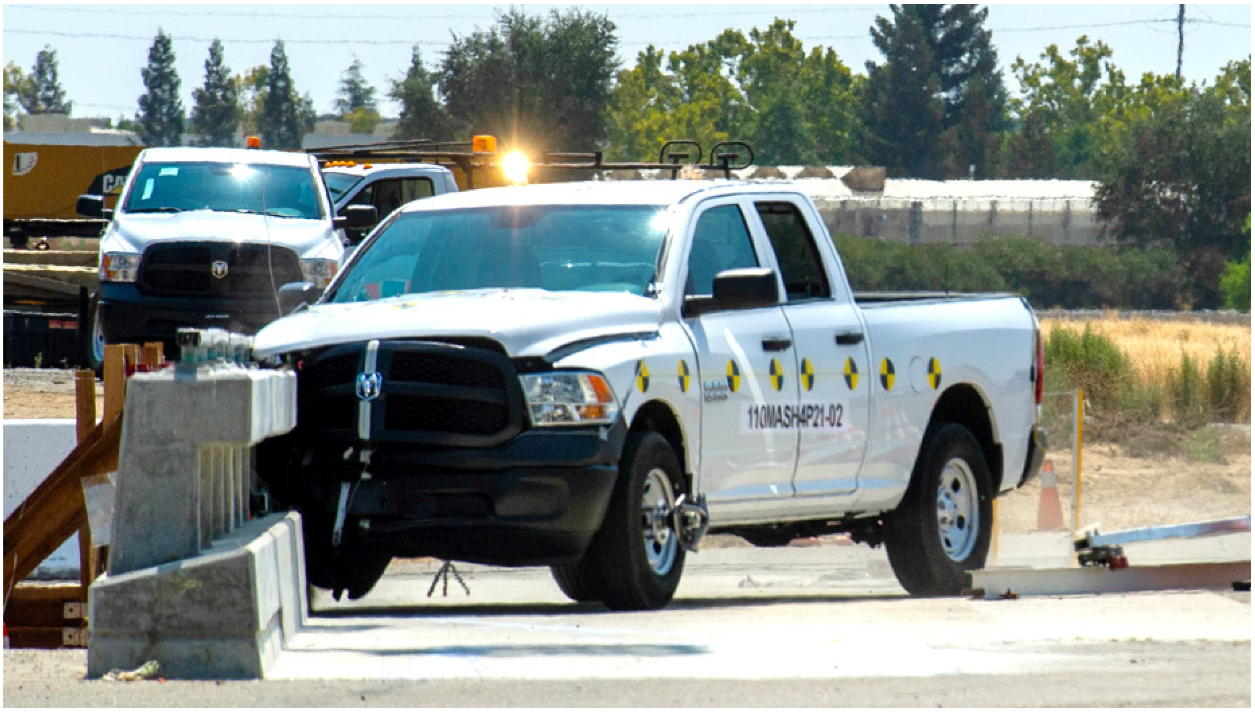

Figure 6-3 Test 4-11 Downstream Camera Impact View

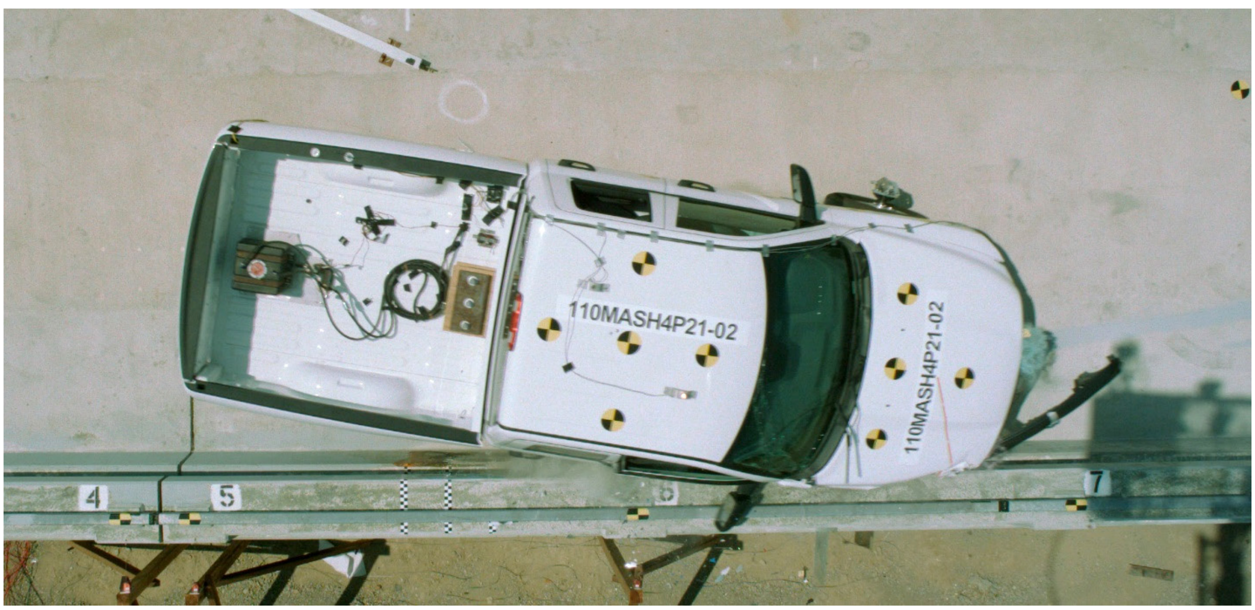

Figure 6-4 Test 4-11 Overhead Camera Impact View

Figure 6-5 Test 4-11 Pan Camera Impact View

Figure 6-6 Test 4-11 Upstream Camera Impact View

6.3. Barrier Damage

There was no significant damage to the barrier. There were moderate surface concrete spalls on the top edge of the curb face approximately 1.52 m (5 ft) in length. These spalls were likely caused by the passenger front wheel rim. There was no spalling on the beam. The face of the beam and curb had marks from the painted tires and superficial marks from the bumper and side of the test vehicle. Barrier damage is shown in Figure 6-7 through Figure 6-9. The red and blue contact marks on the beam are from the region around the passenger side headlight. The orange mark is from the front passenger side tire and the green contact marks are from the rear right tire. Dynamic deflection of the bridge rail was estimated at 7 mm (0.26 in.) using string potentiometers. The simulated bridge deck rocked downward slightly during the initial impact of the vehicle and with the tail slap. There was no permanent deflection. The bicycle rail was slightly contacted by the front corner of the hood at Post 6, but there was little snagging and the rail appeared undamaged. Strain gage and string potentiometer data were collected during the test and are available upon request but are not within the Lab's Scope of Accreditation.

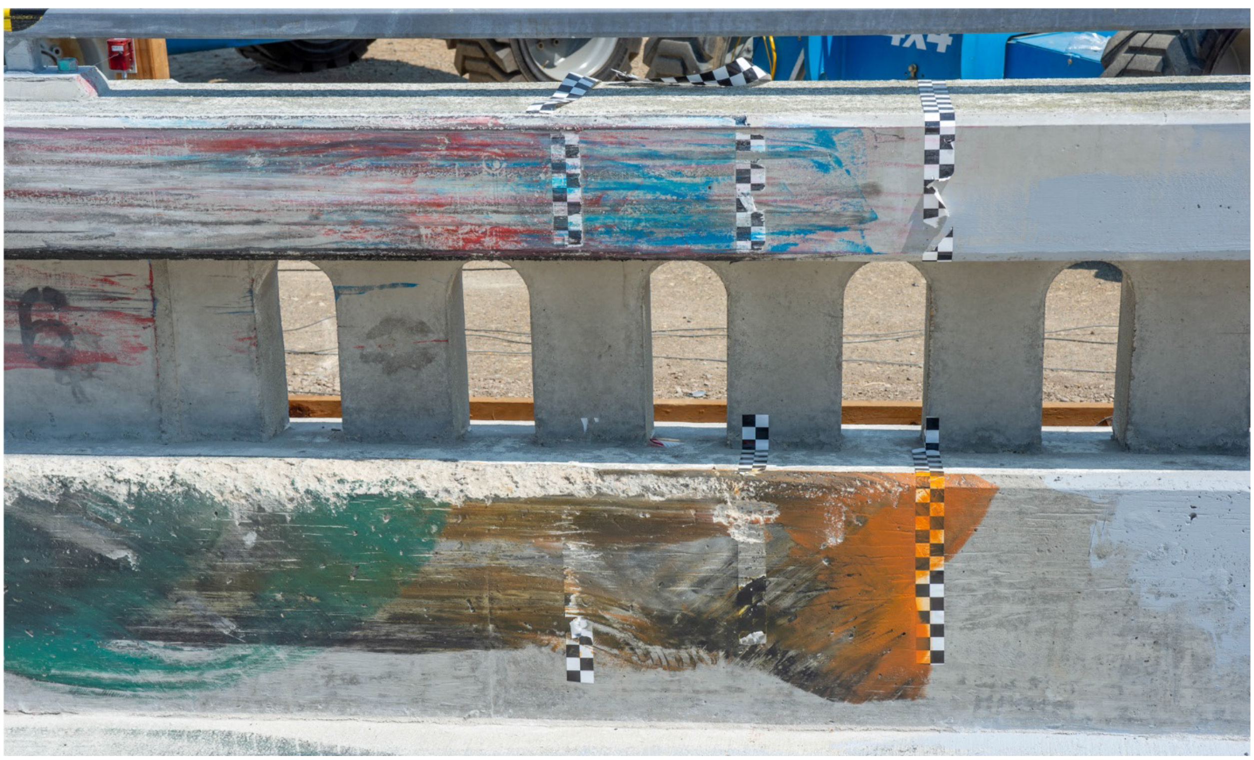

Figure 6-7 Test 4-11 Vehicle Marks with Minor Concrete Spalling on Type 86H at Critical Impact Point

Figure 6-8 Test 4-11 Vehicle Marks with Minor Concrete Spalling on Type 86H near Post 6

Figure 6-9 Test 4-11 Type 86H Overview of Barrier Post-Test with Tire Marks (view looking downstream)

6.4. Vehicle Damage

The 2270P front right corner and right side of the test vehicle sustained most of the damage from the impact. The mid-height portion of the front passenger tire and wheel impacted the top corner of the concrete curb, causing two of the lug nuts to be sheared off and a tilting of the tire into the space between the top beam and the curb. The front bumper was partially damaged, mainly the front right portion during initial impact with the barrier. The right headlight was completely shattered and detached from the vehicle as a result of the impact with the 254 mm (10 in.)-tall vertical face of the barrier beam. Most of the length of the passenger side of the vehicle including the right front fender, right doors, and the right side of the bed contacted the barrier beam. The front right corner of the hood had a small tear caused by contact with the bicycle rail at Post 6. The tearing was minor and did not affect the deformation results or the overall trajectory of the vehicle. The doors on the test vehicle all remained closed and latched during impact except for the window frame of the front passenger door which deformed outward, creating a gap between the window portion of the door and the body of the vehicle. The windshield was spider-cracked across its surface on the passenger side without any inward or outward deformation. The other window glass areas of the vehicle remained undamaged. The front grill and left headlight were also detached during the impact. The maximum amount of passenger compartment deformation measured by known points was 125 mm (4.9 in.), which occurred at the floorboard and wheel well of the passenger side. All interior deformations were below the maximum MASH 2016 limits and are shown in Appendix A: Table 10-22 through Table 10-26. See Figure 6-10 to Figure 6-20 for pictures of the vehicle damage described above. See Appendix D for undercarriage photos showing no damage.

Figure 6-10 Test 4-11 Test Vehicle Damage (front, hood and windshield)

Figure 6-11 Test 4-11 Test Vehicle Damage (front right)

Figure 6-12 Test 4-11 Test Vehicle Damage (right)

Figure 6-13 Test 4-11 Test Vehicle Damage (front right)

Figure 6-14 Test 4-11 Test Vehicle Hood Minor Tearing Damage (front right)

Figure 6-15 Test 4-11 Test Vehicle Damage (right rear)

Figure 6-16 Test 4-11 Test Vehicle Damage (left front)

Figure 6-17 Test 4-11 Test Vehicle Damage Windshield/Exterior

Figure 6-18 Test 4-11 Test Vehicle Damage front right with hood opened

Figure 6-19 Test 4-11 Test Vehicle Damage Windshield / Interior View

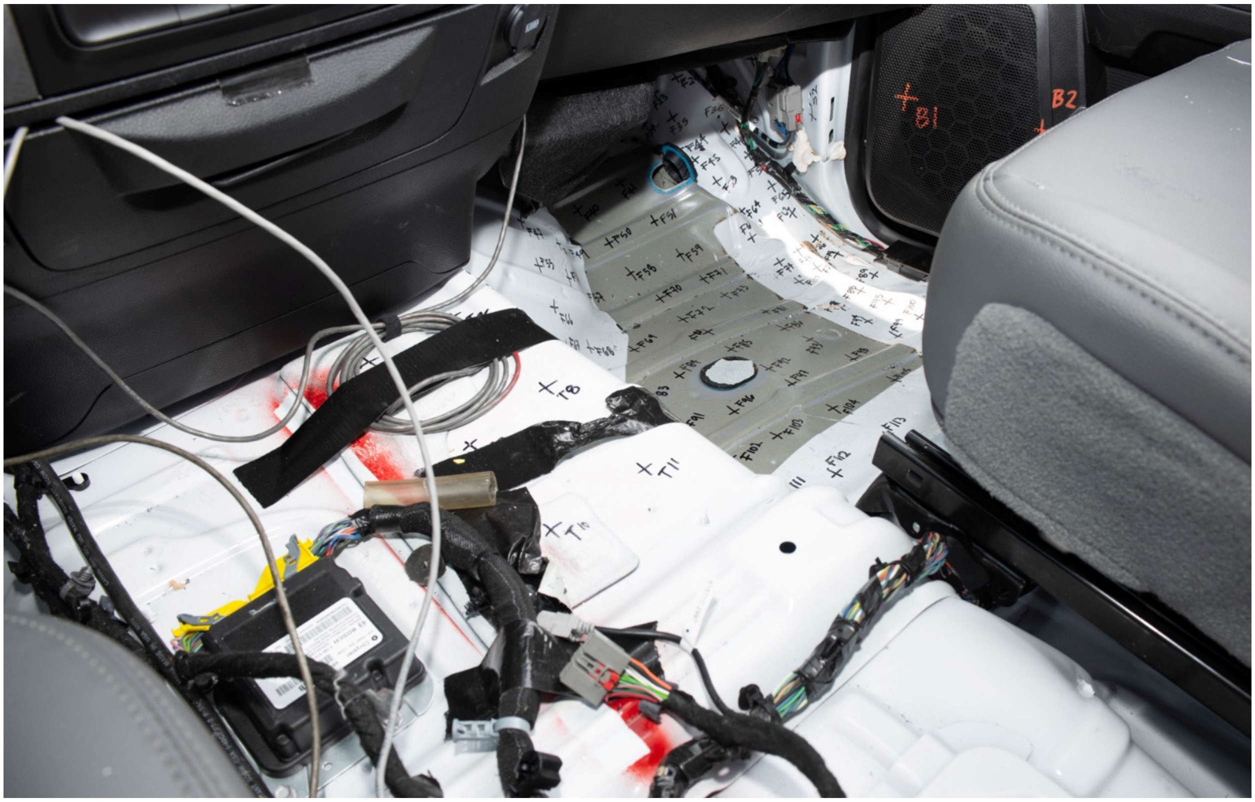

Figure 6-20 Test 4-11 Test Vehicle Floorboard Deformation

Table 6-2 Test 110MASH4P21-02 Test Data Summary Sheet


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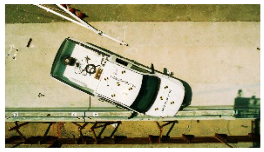
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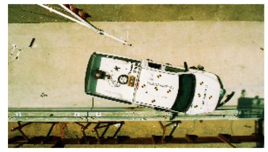
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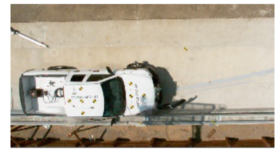
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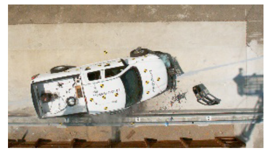
0.240 sec. [Frame 323]]


0.300 sec. [Frame 353]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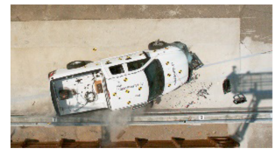
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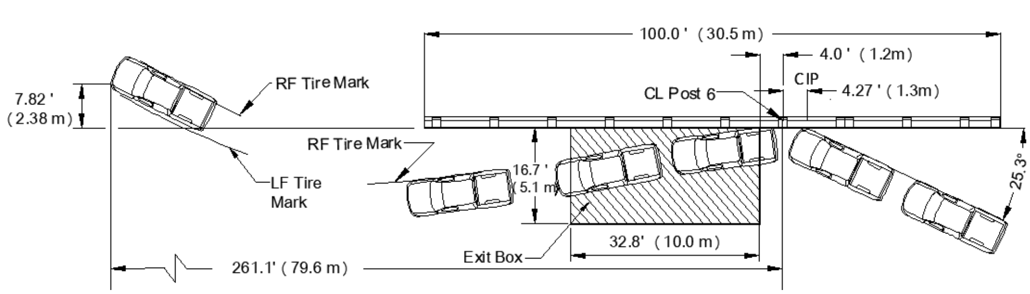
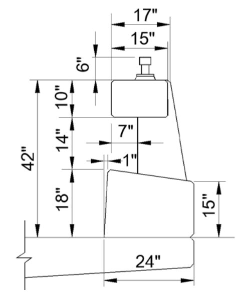




Test Agency .... California, Department of Transportation
Test Number 110MASH4P21-02
Test Designation .... MASH 2016 Test 4-11
Date 8/25/2021
Test Article .... CA Type 86H Bridge Rail
Total Length .... 100 ft (30.5 m)
Key Elements – Barrier

- Description .... CA Type 86H Bridge Rail
- Base Width .... 24 in. (610 mm)
- Height .... 42 in. (1067 mm)

Test Vehicle

- Designation/Make/Model .... 2270P/ 2018 Dodge RAM 1500 Quad Cab
- Curb .... 4792 lb (2174 kg)
- Test Inertial .... 4928 lb (2235 kg)
- Gross Static .... 4928 lb (2235 kg)

Impact Conditions

- Speed .... 62 mph (99.7 kph)
- Angle .... 25.3°
- Location/Orientation .... 4.27 ft (1.3 m) upstream of middle of post
- Impact Severity .... 115.5 kip-ft (157 kJ)

Exit Conditions

- Speed .... 50 mph (80.4 kph)
- Angle .... 6.7 °

Exit Box Criterion .... Pass

Post-impact Trajectory

- Vehicle Stability .... Satisfactory
- Stopping Distance (from point of impact) Approx. 261 ft downstream and 7.82 ft laterally behind

Test Article Damage .... Minor scrapes and concrete spalling at the top of the curb

*Measured from String Potentiometers and is not within the Lab's scope of accreditation.

Test Article Deflections

- Permanent Set .... ~0.0 in. (~0 mm) *
- Dynamic .... ~0.26 in. (~7 mm) *
- Working Width .... 24.0 in. (610 mm)

Vehicle Damage .... Moderate

- VDS[3] 01-RFQ-6, 03-RBQ-4,
- CDC[4] 01FRHK6, 03RDHK7,
- Maximum Deformation at Floorboard/wheel well .... Approx. 4.9 in. (125 mm)
- Vehicle Snagging .... None
- Vehicle Pocketing .... None

Transducer Data

Evaluation Criteria	Transducer SLICE-659	Transducer SLICE-656	MASH Limit
OIV Longitudinal Ft/s (m/s)	23.3 (7.1)	23.3 (7.1)	±40 (12.2)
OIV Lateral Ft/s (m/s)	29.5 (9.0)	29.5 (9.0)	±40 (12.2)
ORA Longitudinal. g's	-4.6	-4.6	±20.49
ORA Lateral. g's	-8.6	-8.3	±20.49
Max. Roll Angle Deg.	15.6	15.1	±75
Max. Pitch Angle Deg.	-4.4	-5.1	±75
Max. Yaw Angle Deg.	-40.7	-40.3	N/A
THIV – ft/s (m/s)	37.1 (11.3)	37.4 (11.4)	N/A
PHD – g's	9.2	8.7	N/A
ASI	2.20	2.22	N/A

6.5. Discussion of Test Results

6.5.1.General Evaluation Methods

MASH 2016 recommends that crash test performance be assessed according to three evaluation factors: (1) structural adequacy, (2) occupant risk, and (3) post-impact vehicular response.

The structural adequacy and occupant risk associated with the Type 86H Bridge Rail were evaluated using evaluation criteria found in Tables 2.2A (Recommended Test Matrices for Longitudinal Barriers), 5.1A (Safety Evaluation Guidelines for Structural Adequacy), and 5.1B (Safety Evaluation Guidelines for Occupant Risk) of MASH 2016. The post-impact vehicular response was evaluated using Section 5.2.3 of MASH 2016.

6.5.2.Structural Adequacy

The structural adequacy of the Type 86H Bridge Rail was acceptable during Test 4-11.

Refer to Table 6-3 for the assessment summary of the safety evaluation criteria for the Type 86H Bridge Rail.

6.5.3.Occupant Risk

The occupant risk was acceptable. As mentioned previously, all interior deformation measurements were below the maximum MASH 2016 limits. Interior deformation measurements are shown in Appendix A: Table 10-11 through Table 10-13.

There was no penetration of the occupant compartment by the Type 86H or potential for it. The occupant compartment was not compromised. Occupant impact velocities and ridedown accelerations were below MASH 2016 limits. The roll and pitch of the vehicle were within acceptable limits, the yaw value does not have a MASH 2016 criterion limit.

Refer to Table 6-3 for the 2270P assessment summary of the safety evaluation criteria for the Type 86H Bridge Rail.

6.5.4.Vehicle Trajectory

The vehicle trajectory was acceptable. The exit trajectory was within the exit box. The roll, pitch, and yaw of the vehicle were below the maximum limits.

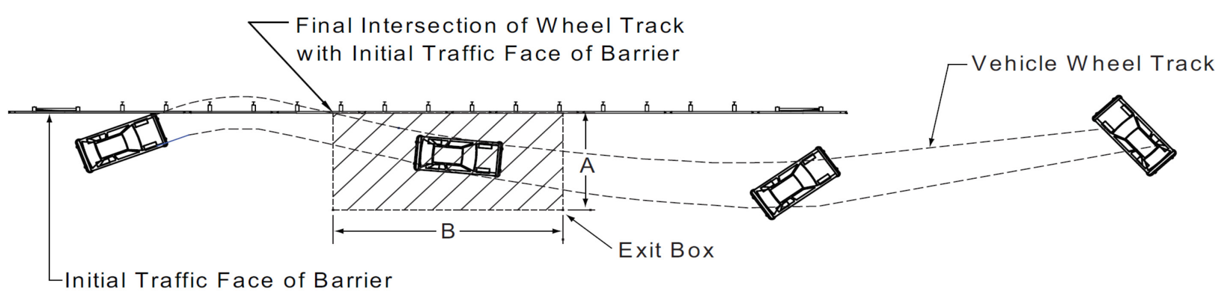


Figure 6-21 Exit Box for Longitudinal Barriers (AASHTO, 2016)

Refer to Table 6-2 and Table 6-3Table 6-3 for the 2270P vehicle trajectory diagram and assessment summary of the safety evaluation criteria for the Type 86H bridge rail.

Table 6-3 110MASH4P21-02 Assessment Summary for Test 4-11

<table>
<tr><th>Evaluation Criteria</th><th>Test Results</th><th>Assessment</th></tr>
<tr><td>Structural Adequacy
A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td><td>The vehicle was contained and redirected smoothly.</td><td>PASS</td></tr>
<tr><td>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 personnel in a work zone.

Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E.</td><td>The barrier did not detach any elements, fragments, and/or other debris</td><td>PASS</td></tr>
<tr><td>Occupant Risk
F. The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td><td>The vehicle remained upright during and after the collision.</td><td>PASS</td></tr>
<tr><td>Occupant Risk
H. Occupant Impact Velocities (OIV) (see Appendix A, Section A5.3 for calculation procedure) should satisfy the following limits:
<table><tr><th colspan="3">Occupant Impact Velocity Limits, ft/s (m/s)</th></tr><tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr><tr><td>Longitudinal and Lateral</td><td>30 ft/s

(9.1 m/s)</td><td>40 ft/s

(12.2 m/s)</td></tr></table></td><td><u>DAS Long. ft/sec (m/s)</u>
SLICE 656: 23.3 (7.1)
SLICE 659: 23.3 (7.1)

<u>DAS Lat. ft/sec (m/s)</u>
SLICE 656: 29.5 (9.0)
SLICE 659: 29.5 (9.0)</td><td>PASS</td></tr>
<tr><td>Occupant Risk
I. The occupant ridedown acceleration (see Appendix A, Section A5.3 for calculation procedure) should satisfy the following limits:
<table><tr><th colspan="3">Occupant Ridedown Acceleration Limits (G)</th></tr><tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr><tr><td>Longitudinal and Lateral</td><td>15.0 G</td><td>20.49 G</td></tr></table></td><td><u>DAS Long. G Lat. G</u>

SLICE 656: -4.6 -8.3
SLICE 659: -4.6 -8.6</td><td>PASS</td></tr>
<tr><td>Vehicle Trajectory
It is preferable that the vehicle be smoothly redirected, and this is typically indicated when the vehicle leaves the barrier within the "exit box". The concept of the exit box is defined by the initial traffic face of the barrier and a line parallel to the initial traffic face of the barrier, at a distance A plus the width of the vehicle plus 16 percent of the length of the vehicle, starting at the final intersection (break) of the wheel track with the initial traffic face of the barrier for a distance of B. All wheel tracks of the vehicle should not cross the parallel line within the distance B.</td><td>A = 16.7 ft (5.1 m)
B = 32.8 ft (10 m)</td><td>PASS</td></tr>
</table>

7. Test 110MASH4S21-03 (4-12)

7.1. Impact Description and Results

The Critical Impact Point selected was 1.5 meters (4.9 ft) from the centerline of post 4, as recommended in Table 2-7 of MASH 2016 (AASHTO, 2016). The impact angle of 15° was set with a Total Station when laying out the guide rail. The intended impact speed was 90 kph (56 mph).

Figure 7-1 Test Article Impact Area Pre-Test 4-12

Figure 7-2 Test Article Downstream of Impact Area Pre-Test 4-12

7.2. Test Description

The crash was performed in the afternoon of December 8, 2021. According to the Sacramento Executive Airport Weather Station, weather conditions were as follows: misty, temperature approximately 52 deg F, and wind of approximately 5 mph from the south-south-east (SSE). The vehicle was traveling approximately north-northeast (NNE).

The 10000S vehicle impacted the barrier at a speed of 88.1 kph (54.7 mph) and angle of 15.0°. The vehicle impacted the Type 86H at approximately 1.36 meters (4.46 ft) upstream from the centerline of post 4, which was approximately 140 mm (5.5 in.) downstream of the Critical Impact Point. The vehicle was contained and smoothly redirected at an exit speed and angle of 76 kph (47 mph) and 6.6°, respectively. During the impact, the cargo box leaned over the bridge rail for a Working Width of about 1200 mm (48 in.) at a height of approximately 3.4 m (11 ft). The working width measurement is not within the Scope of Accreditation. After the vehicle exited the bridge rail, the remote brakes were applied, and the vehicle rolled onto the driver's side and came to a stop. The final resting position of the vehicle was approximately 80.0 m (263 ft) downstream of the impact point and 11.1 m (36.4 ft) toward the non-traffic side of the barrier. Still photos of the vehicle during the test are shown in Figure 7-3 through Figure 7-6. A detailed description of the sequential events is shown in the table below.

Table 7-1 Test 110MASH4S21-03 Test Sequence of Events

Time (s)	EVENT
0.000	Initial contact of the front right panel with the barrier beam and tire with the curb
0.002	initial flash of impact bulb
0.016	Right front tire begins to lift just after it contacts the curb
0.024	Front axle begins to shift to the left as it rotates while climbing the curb
0.052	Front right wheel well slightly rubs up against bicycle rail
0.106	Left front tire begins to lift with reference to the ground surface
0.112	Cargo Box appears to begin to redirect (yaw left) and front right corner of cargo box overrides and contacts the top of the barrier beam
0.230	Left rear tires begin to lift with reference to the ground surface
0.270	Rear right tire contacts barrier curb
0.398	Front right tire returns to the ground surface (approximate)
0.428	Vehicle is roughly parallel to rail face
0.700	Front left tire returns to the ground surface
0.790	Maximum leaning of the cargo box over the barrier rail occurs before it rotates back
0.828	Vehicle loses contact with the test article (approximate)
1.046	Rear left tire returns to the ground surface (approximate covered by debris)
2.237	Brakes are applied (obtained from SLICE Unit Event Channel Data)

Figure 7-3 Test 4-12 Downstream Camera Impact View

Figure 7-4 Test 4-12 Overhead Camera Impact View

Figure 7-5 Test 4-12 Pan Camera Impact View

Figure 7-6 Test 4-12 Upstream Camera Impact View

7.3. Barrier Damage

There was minor to moderate damage to the barrier face. The concrete curb was scuffed with moderate concrete spalling from the impact point to just downstream of post 6. The traffic side of the beam was scuffed with minor concrete spalling from a point just upstream of the critical impact to the expansion joint between posts 4 and 5. The spalling primarily occurred on the top corner of the curb and top corner of the beam with some minor spalling on the bottom corner of the beam. The deeper spalling of the curb was caused by the front right wheel lugs and rim during the initial impact, measured approximately 38 mm by 0.4 m (1.5 in. by 1.3 ft) maximum depth by length of spall. Additional marks and gouges may have been caused by the steel passenger steps, rear wheel and rear bumper frame. The spalling that occurred on top of the beam appears to have been caused by the bottom of the cargo box as it scraped across the surface of the beam. There were no spalls on the vertical edges of post 5 indicating that there was no snag at the post downstream of the expansion joint. No rebar was exposed and there was no evidence of concrete structural cracking. The beam-mounted bicycle railing was undamaged except for the grout pad mentioned below. Overall, the bicycle rail performed well. The bicycle rail was slightly contacted by the top of the wheel well of the test vehicle near post 6 leaving minor white and black paint marks. A small portion of the grout underneath the bicycle rail post base plates at post 6 was spalled. The minor spalling was most likely due to the impact of the lower side and rear corner of the cargo box. See Figure 7-7 through Figure 7-12 for photos of barrier damage. The orange contact marks are from the front right tire. The green contact marks are from the rear right tire. String potentiometer and strain gage data were collected at 10,000 sample/sec during the test. Strain gage data do not fall under the Scope of Accreditation but are available upon request. The dynamic and permanent deflection data were collected from string potentiometers and measured a maximum of 18 mm (0.7 in.) and less than 3 mm (0.1 in.), respectively. The edge of deck vertical motion was also measured with string potentiometers and they were very similar to the lateral bridge rail deflections. Measurements made with String Potentiometers are not within the Lab's Scope of Accreditation.

Figure 7-7 Test 4-12 Vehicle Marks and Concrete Spalling on Type 86H at Critical Impact Point

Figure 7-8 Test 4-12 Vehicle Marks and Concrete Spalling on Type 86H at expansion joint

Figure 7-9 Test 4-12 Vehicle Marks and Concrete Spalling on Type 86H Looking Downstream

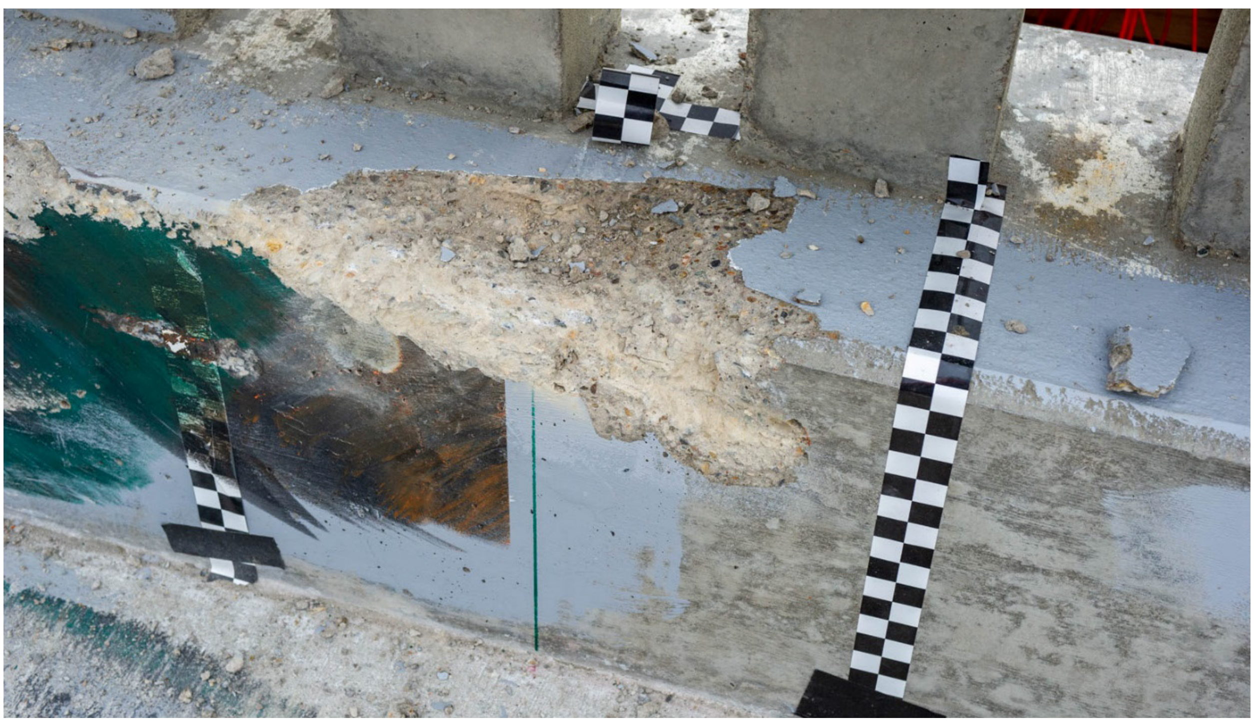


Figure 7-10 Test 4-12 Moderate Concrete Curb Spalling on Type 86H

Figure 7-11 Test 4-12 Beam and Bicycle Rail Mortar Pad Spalling at the expansion joint on Type 86H

Figure 7-12 Test 4-12 Minor Bicycle Rail Mortar Pad Spalling at Post 6 Type 86H

7.4. Vehicle Damage

The 10000S front right corner and passenger side of the vehicle sustained most of the damage from the initial impact with the concrete post and beam system. During the impact the vehicle remained upright as it traveled downstream within the length of the bridge rail, exiting the bridge rail within the exit box criteria. Upon impact with the concrete curb and beam, the right front tire was pushed up and into the engine area, causing the U-bolt connections of the axle to fail, ultimately resulting in a complete detachment of the front axle from the truck. The front right corner of the cab initially rolled towards the barrier along with the box. However, while exiting the rail, the cab and box rolled away from the rail with enough momentum to cause the 10000S to roll onto the driver's side and slide to a stop. The detached axle continued to roll coming to a stop approximately 12 m (39 ft) downstream from the front of the van body. The van body truck came to a stop on its side, downstream from the end of the barrier rail, approximately 80.0 m (262.6 ft) downstream of the critical impact point and 11.1 m (36.4 ft) behind the traffic-face of the rail. The fact that the vehicle rolled onto its side is not a failure in the MASH 2016 criteria for this test. The passenger side of the front bumper was deformed, the passenger side headlight was damaged, and the right front fender was detached. The rear suspension remained attached as did the rear wheels and tires. All tires remained inflated. The steps on the passenger side were partially deformed and the top step was partially detached and rotated due to contact with the concrete rail. The driver's side door, A-pillar, fender, and cab roof were deformed from the impact with the ground after the vehicle left the Type 86H. All the window glass was undamaged during interaction with the test article. The cracking of the windshield occurred after the cab impacted the ground. Nearly all the damage to the cargo box also occurred when the vehicle rolled onto its side. The shear plates and bolts that were installed on the frame remained intact (see Figure 7-21 thru Figure 7-24). The bed shifted a minor amount. The threaded rods used to secure the ballast were undamaged and kept the motion of the ballast to a minimum. The maximum amount of passenger compartment deformation measured by known points was 100 mm (4 in.), which occurred at the roof. This deformation was most likely due to the impact of the driver side of test vehicle with the ground after rolling on its side after the vehicle separated from the rail. The roof deformation over the passenger side was away from the occupant compartment and therefore is acceptable. The largest deformation resulting from the interaction between the test vehicle and the barrier rail occurred at the A and B Pillars. The maximum deformation in this area was 73 mm (2.9 in.). This value is below the MASH 2016 limit of 127 mm (5 in.). The overall exterior vehicle damage is described as Moderate to Heavy. All interior deformation measurements are shown in Appendix A: Table 10-31 through Table 10-35. See Figure 7-13 to Figure 7-26 for pictures of the vehicle damage described above.

Figure 7-13 Test 4-12 Vehicle Damage (front, hood and windshield)

Figure 7-14 Test 4-11 Test Vehicle Damage (front right)

Figure 7-15 MASH 4-12 Test Vehicle Front Undercarriage and Damaged Suspension After Impact

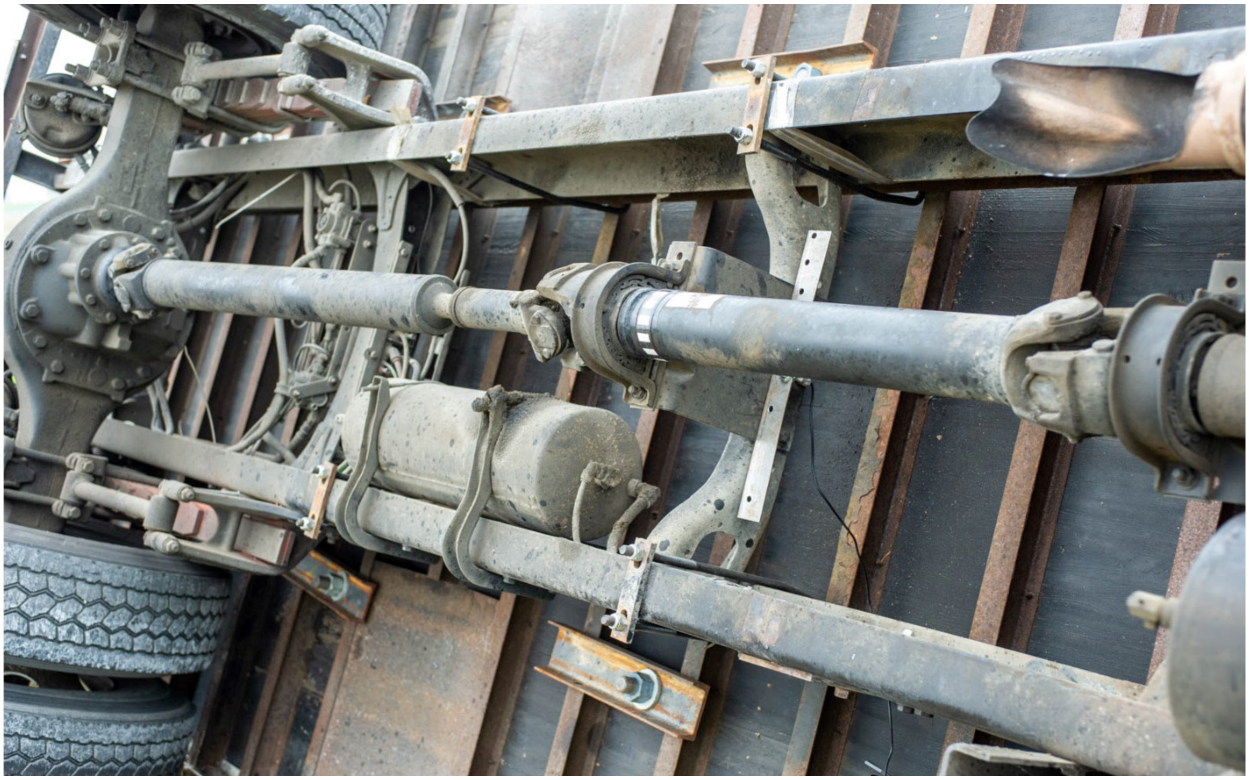


Figure 7-16 MASH 4-12 Test Vehicle Undamaged Undercarriage After Impact (rear)

Figure 7-17 Test 4-12 Test Vehicle After Impact (Rear)

Figure 7-18 Test 4-12 Test Vehicle Ballast After Impact

Figure 7-19 Test 4-12 Test Vehicle After Impact (Overall View)

Figure 7-20 Test 4-12 Test Vehicle After Impact (front right)

Figure 7-21 Test 4-12 Front Left Shear Plate After Impact

Figure 7-22 Test 4-12 Front Right Shear Plate After Impact

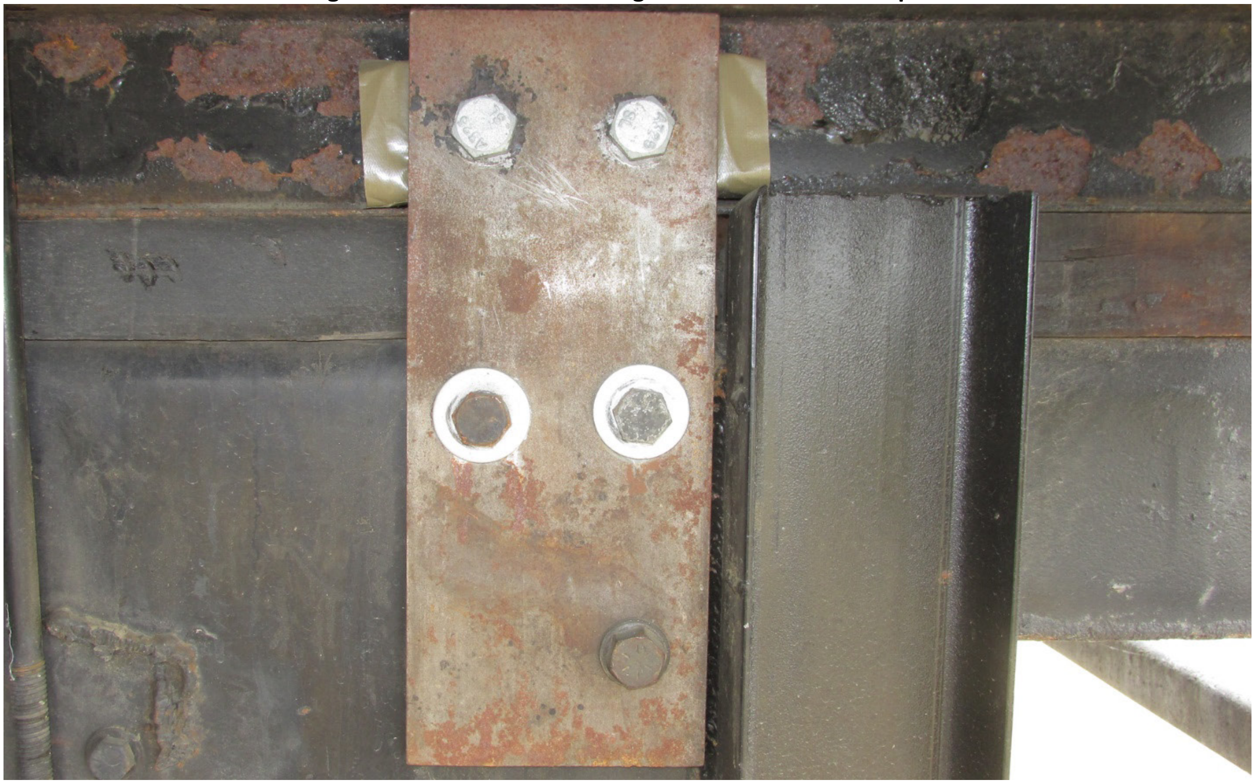


Figure 7-23 Test 4-12 Rear Left Shear Plate After Impact

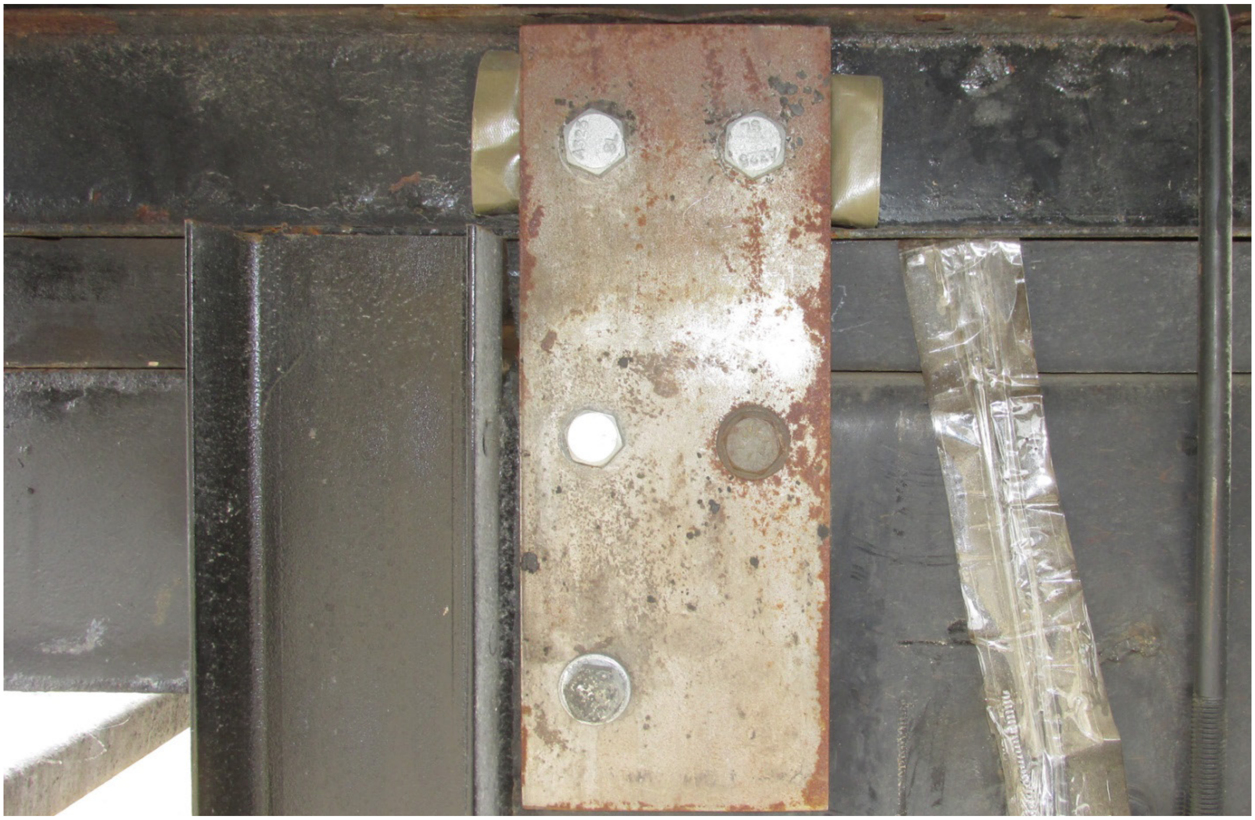


Figure 7-24 Test 4-12 Rear Right Shear Plate After Impact

Figure 7-25 Test 4-12 Detached Front Axle (final position)

Figure 7-26 Test 4-12 Test Vehicle Passenger-Side Floorboard Deformation

Table 7-2 Test 110MASH4S21-03 Test Data Summary Sheet


0.000 sec. [Frame 285]


0.160 sec. [Frame 365]


0.320 sec. [Frame 445]

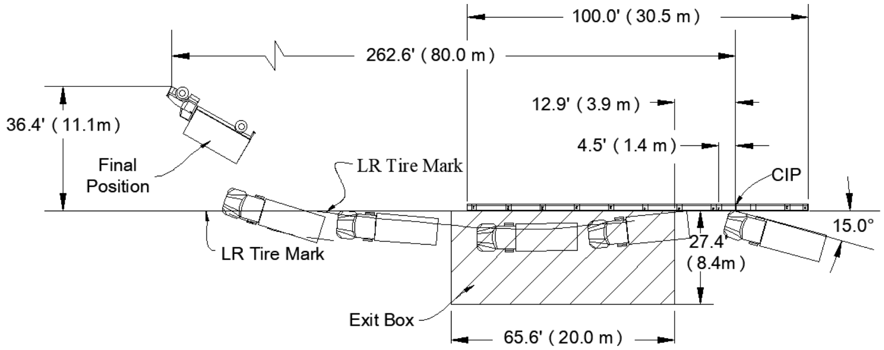

0.480 sec. [Frame 525]

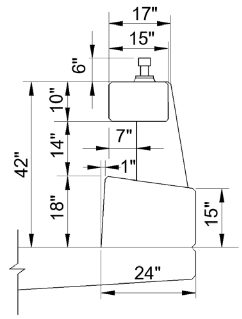

0.640 sec. [Frame 605]


0.800 sec. [Frame 685]


0.960 sec. [Frame 765]


1.120 sec. [Frame 845]





Test Agency.................California, Department of Transportation
Test Number.................110MASH4S21-03
Test Designation.................MASH 2016 Test 4-12
Date.................12/8/2021
Test Article.................CA Type 86H Bridge Rail
Total Length.................100 ft (30.5 m)
Key Elements – Barrier

- Description.................CA Type 86H Bridge Rail
- Base Width.................24 in. (610 mm)
- Height.................42 in. (1067 mm)

Test Vehicle

- Type/Designation...10000S
- Make and Model...2009 Freightliner M2 106 18-foot Box Truck
- Curb.................12855 lb (5831 kg)
- Test Inertial.................22364 lb (10144 kg)
- Gross Static.................22364 lb (10144 kg)

Impact Conditions

- Speed.................54.7 mph (88.1 kph)
- Angle.................15.0°
- Location/Orientation.................4.5 ft (1.4 m) upstream of middle of post 4
- Impact Severity.................150 kip-ft (203 kJ)

Exit Conditions

- Speed.................47 mph (76 kph)
- Angle.................6.6 °

Exit Box Criterion.................Pass

Post-impact Trajectory

- Vehicle Stability.................Not applicable
- Stopping Distance (from point of impact) Approx. 263 ft downstream and 36 ft laterally behind

Test Article Damage.................Minor scrapes and moderate concrete spalling at the top of the rail and curb.

Test Article Deflections

- Permanent Set*.................~0.1 in. (~3 mm)
- Dynamic*.................~0.7 in. (~18 mm)
- Working Width*.................~48 in. (~1.2 m) at a height of approximately 11 ft off the ground.

Vehicle Damage Moderate

- VDS[ref].................01-RFQ-2, 03-RD-2,03-RBQ-2 03-RP-2, R&T-2
- CDC[ref].................01RFEK6, 03RDEK9, 09LDGW3
- Maximum Deformation.................Approx. 4.0 in. (100 mm) at Roof (likely due to driver side impact with ground).
- Vehicle Snagging.................None
- Vehicle Pocketing.................None

Transducer Data

Evaluation Criteria	Transducer SLICE-656 (inside cab)	Transducer SLICE-659 (inside cab)	Transducer SLICE-758 (in cargo box)	MASH Limit
OIV Long. Ft/s (m/s)	4.9 (1.5)	4.9 (1.5)	7.2 (2.2)	N/A
OIV Lateral Ft/s (m/s)	13.5 (4.1)	13.8 (4.2)	11.8 (3.6)	N/A
ORA Long. g's	-5.9	-5.8	-4.6	N/A
ORA Lateral g's	-7.4	-7.2	-7.2	N/A
Max. Roll Angle Deg.	20.1	19.3	24.3	N/A
Max. Pitch Angle Deg.	-3.7	-4.3	-4.8	N/A
Max. Yaw Angle Deg.	-19.0	-18.1	-18.2	N/A

*Measured from String Potentiometers and is not within the Lab's scope of accreditation.

7.5. Discussion of Test Results

7.5.1.General Evaluation Methods

MASH 2016 recommends that crash test performance be assessed according to three evaluation factors: (1) structural adequacy, (2) occupant risk, and (3) post-impact vehicular response.

The structural adequacy and occupant risk associated with the Type 86H concrete bridge rail were evaluated using evaluation criteria found in Tables 2.2A (Recommended Test Matrices for longitudinal barriers), 5.1A (Safety Evaluation Guidelines for Structural Adequacy), and 5.1B (Safety Evaluation Guidelines for Occupant Risk) of MASH 2016. The post-impact vehicular response was evaluated using Section 5.2.3 of MASH 2016.

7.5.2.Structural Adequacy

The structural adequacy of the Type 86H concrete bridge rail was acceptable in Test 4-12.

Refer to Table 7-3 for the assessment summary of the safety evaluation criteria for Test 4-12 of the Type 86H concrete bridge rail.

7.5.3.Occupant Risk

The occupant risk was acceptable. As previously mentioned, the maximum amount of passenger compartment deformation measured by known points was 100 mm (4 in.), which occurred at the roof. This deformation was due to the impact of the test vehicle with the ground after the vehicle separated from the rail. The roof deformation over the passenger side was away from the occupant compartment and therefore is acceptable. The largest deformation resulting from the interaction between the test vehicle and the barrier rail occurred at the A and B Pillars. The maximum deformation in this area was 73 mm (2.9 in.). All interior deformations were below the maximum MASH 2016 limits, except as noted in Section 7.4 above. All interior deformation measurements are shown in Appendix A: Table 10-31 through Figure 10-35. There was no penetration of the occupant compartment by the Type 86H or potential for it. The occupant compartment was not compromised. The vehicle rolled onto its side after it lost contact with the bridge rail, and although this outcome is not the preferred result for this test, the vehicle remaining upright is not a requirement of MASH 2016 Test 4-12.

Refer to Table 7-3 for the assessment summary of the safety evaluation criteria for Test 4-12 of the Type 86H Concrete Bridge Rail.

7.5.4.Vehicle Trajectory

The vehicle trajectory was acceptable. The exit trajectory was within the exit box.

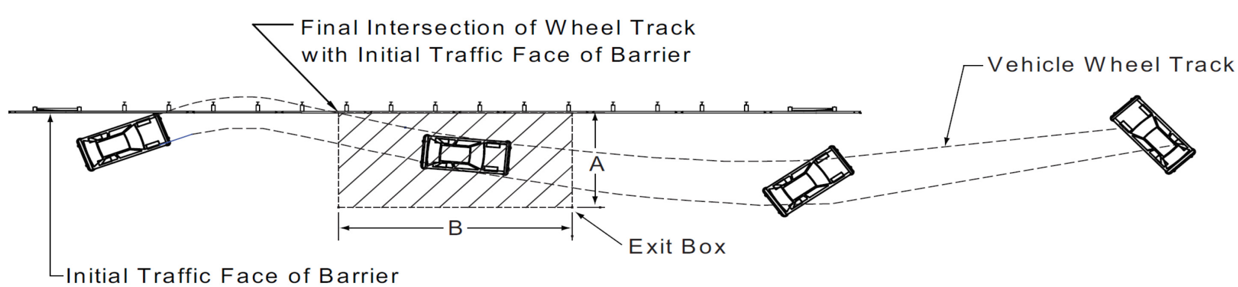


Figure 7-27 Exit Box for Longitudinal Barriers (AASHTO, 2016)

Refer to Table 7-2 and Table 7-3 for the 10000S vehicle trajectory diagram and assessment summary of the safety evaluation criteria for Test 4-12 of the 86H Concrete Bridge Rail.

Table 7-3 110MASH4S19-02 Assessment Summary for Test 4-12

Evaluation Criteria	Test Results	Assessment
Structural Adequacy A. Test article should contain and redirect the vehicle; the vehicle should not penetrate, underride, or override the installation, although controlled lateral deflection of the test article is acceptable.	The vehicle was contained and redirected smoothly.	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 personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E.	The barrier did not detach any elements, fragments, and/or other debris	PASS
Occupant Risk G. It is preferable, although not essential, that the vehicle remain upright during and after the collision.	The vehicle rolled onto the driver's side and skidded until it came to rest.	PASS
Vehicle Trajectory It is preferable that the vehicle be smoothly redirected, and this is typically indicated when the vehicle leaves the barrier within the "exit box". The concept of the exit box is defined by the initial traffic face of the barrier and a line parallel to the initial traffic face of the barrier, at a distance A plus the width of the vehicle plus 16 percent of the length of the vehicle, starting at the final intersection (break) of the wheel track with the initial traffic face of the barrier for a distance of B. All wheel tracks of the vehicle should not cross the parallel line within the distance B.	A = 27.4 ft (8.4 m) B = 65.6 ft (20 m)	PASS

8. Conclusions and Recommendations

Based on the physical crash testing involved in this project, the following conclusions can be drawn:

1. The Type 86H concrete Bridge Rail can successfully contain and redirect an 1100-kg (2420 lb) small car impacting at 100 kph (62 mph) and 25°.
2. The Type 86H concrete Bridge Rail can successfully contain and redirect a 2270-kg (5000 lb) pickup car impacting at 100 kph (62 mph) and 25°.
3. The Type 86H concrete Bridge Rail can successfully contain and redirect a 10000-kg (22000 lb) single-unit truck impacting at 90 kph (56 mph) and 15°.

As tested, The Type 86H bridge rail meets the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware 2016* (MASH 2016) criteria for Test 4-10, Test 4-11, and Test 4-12 for longitudinal barriers. Based on the successful completion of these tests the Type 86H concrete bridge rail meets the MASH 2016 safety criteria for a Test Level 4 (TL-4) longitudinal barrier.

The Type 86H concrete bridge rail demonstrated it has significant remaining capacity to contain and redirect the 10000S test vehicle, which was the last of the three tests to be conducted on the Type 86H.

Implementation will be carried out by Caltrans' Division of Structure Policy and Innovation. They will be responsible for the preparation of Standard Plans (if required) and specifications for the California Concrete Bridge Rail Type 86H, with technical support from the Division of Research, Innovation and System Information.

9. References

1. Manual for Assessing Safety Hardware, Second Edition 2016 (MASH 2016). American Association of State Highway and Transportation Officials. Washington, DC. 2016.
2. Robert Meline. Vehicle Crash Tests of the Type 80 Bridge Rail. California Department of Transportation. Sacramento. March 1999.
3. Bridge Rails and Barriers: A Reference Guide for Transportation Projects in the Coastal Zone. California Department of Transportation. Sacramento. circa 2012 (ADA update 2019)
4. Test Report 0-6946-R2: Mash Evaluation of TXDOT Roadside Safety Features-PHASE II. Texas A&M Transportation Institute. March 2019.
5. MASH Implementation for California Bridge Railings, July 2019. Office of Design and Technical Services, Caltrans. July 2019.
6. Federal Aid Eligibility Letter HSST-1/B-285 to RIME Laboratory, Rutgers, The State University of New Jersey. Federal Highway Administration. July 7, 2017.
7. Vehicle Damage Scale for Traffic Crash Investigators. Texas Department of Public Safety. Austin. 2006.
8. Collision Deformation Classification SAE Recommended Practice J224 MAR80. Society of Automotive Engineers. New York, NY. 1980

10. Appendix A: Vehicle Equipment and Test Data

10.1. Test Vehicle Equipment

10.1.1. 4-10 Test 110MASH4C21-01

The vehicle used for this test was a 2015 Nissan Versa Sedan. Since the vehicle was towed and not self-powered, the fuel in the gas tank was pumped out and gaseous CO_2 added to purge the gas vapors and eliminate oxygen. A pair of Lithium-Ion Battery Packs were mounted in the vehicle to power two DTS SLICE MICRO systems. The DTS SLICE MICRO systems were each installed with a set of triaxial accelerometers, angular rate sensors and a bridge layer. A 12-volt deep-cycle gel cell battery powered the Electronic Control Box.

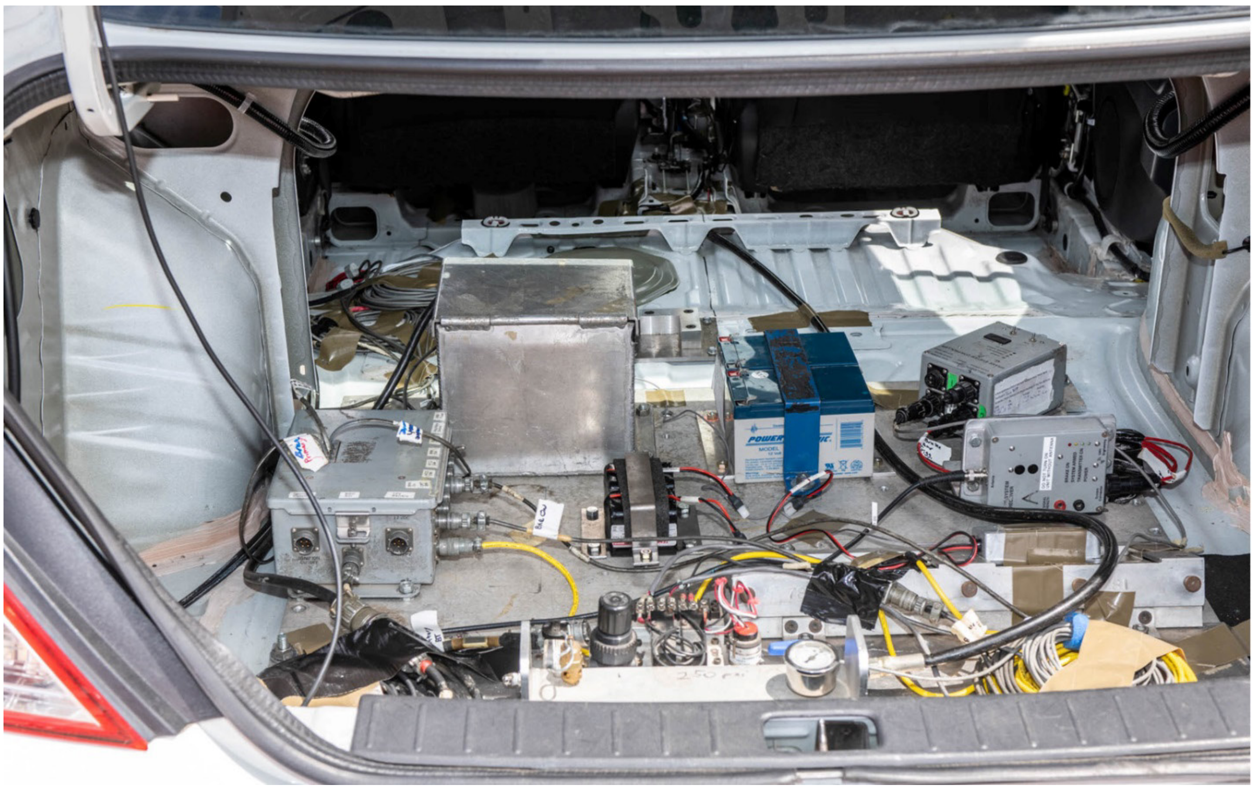


Figure 10-1 Main Instrumentation Test 4-10

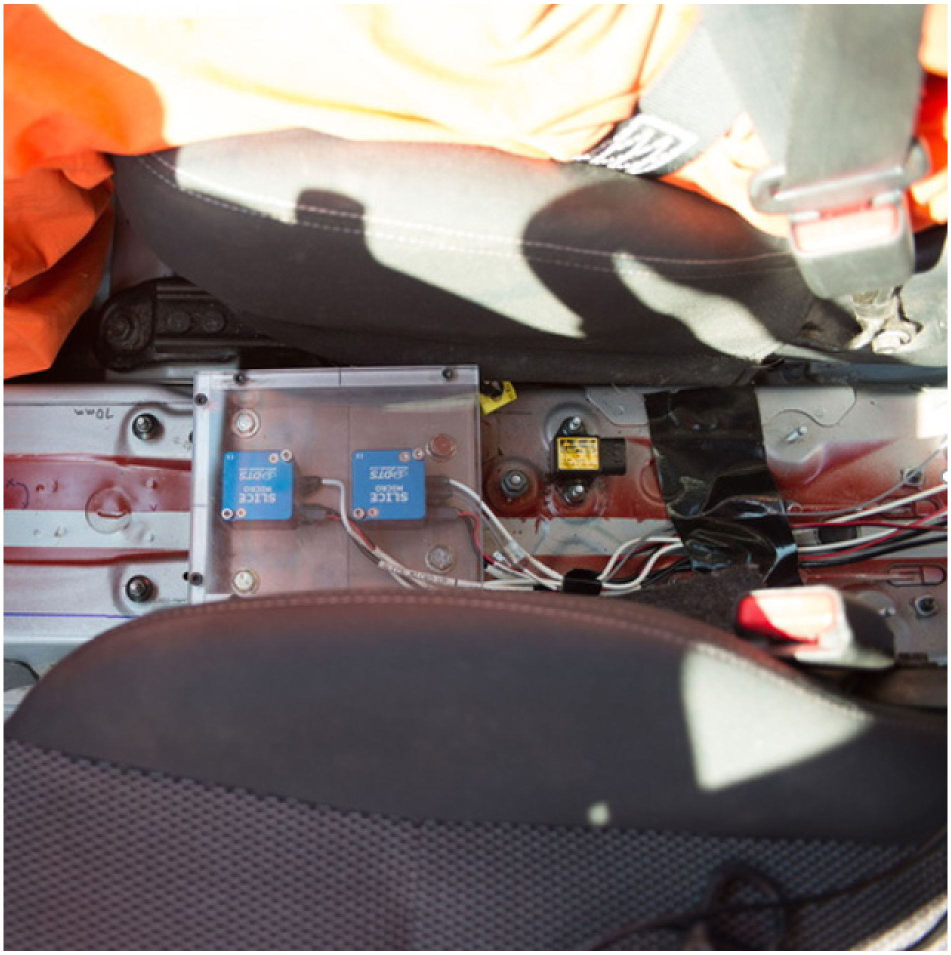


Figure 10-2 DTS SLICE Micro Mount Position in the Vehicle Test 4-10

A 4800 kPa (700 psi) CO_2 system, actuated by a solenoid valve, controlled remote braking after the impact and emergency braking, if necessary. Part of this system was a pneumatic ram which was attached to the brake pedal. The operating pressure for the ram was adjusted through a pressure regulator during a series of trial runs prior to the actual test. Adjustments were made to ensure the shortest stopping distance without locking up the wheels. When activated, the brakes could be applied in less than 100 milliseconds.

A speed control device was connected in-line with the engine ignition coil power circuits on the tow vehicle. It was used to regulate the speed based on the signal from the tow vehicle transmission speed sensor. This device was calibrated prior to the test by conducting a series of trial runs through a speed trap comprised of two tape switches (set at a specific distance apart) and a digital timer.

10.1.2. 4-11 Test 110MASH4P21-02

The vehicle used for this test was a 2018 Dodge RAM 1500 Quad Cab. A pair of Lithium-Ion Battery Packs were mounted in the vehicle to power two DTS SLICE MICRO systems. The DTS SLICE MICRO systems were each installed with a set of triaxial accelerometers, angular rate sensors and a bridge layer. A 12-volt deep-cycle gel cell battery powered the Electronic Control Box.

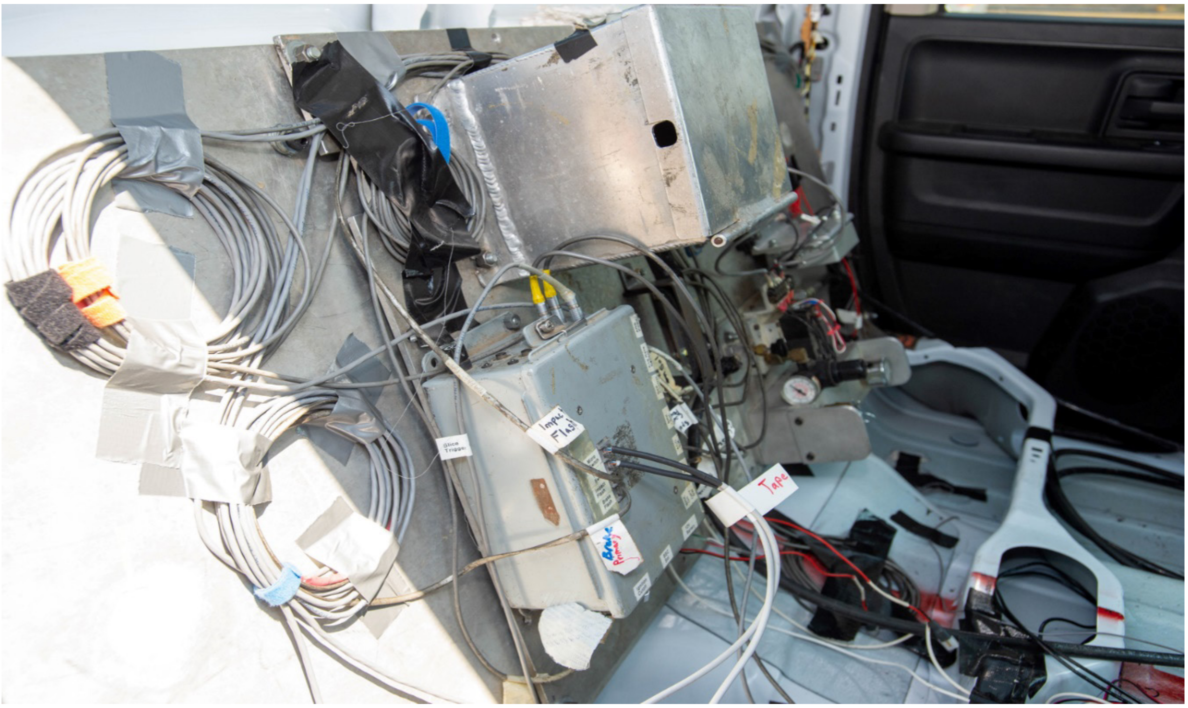


Figure 10-3 Test 4-11 Vehicle Instrumentation

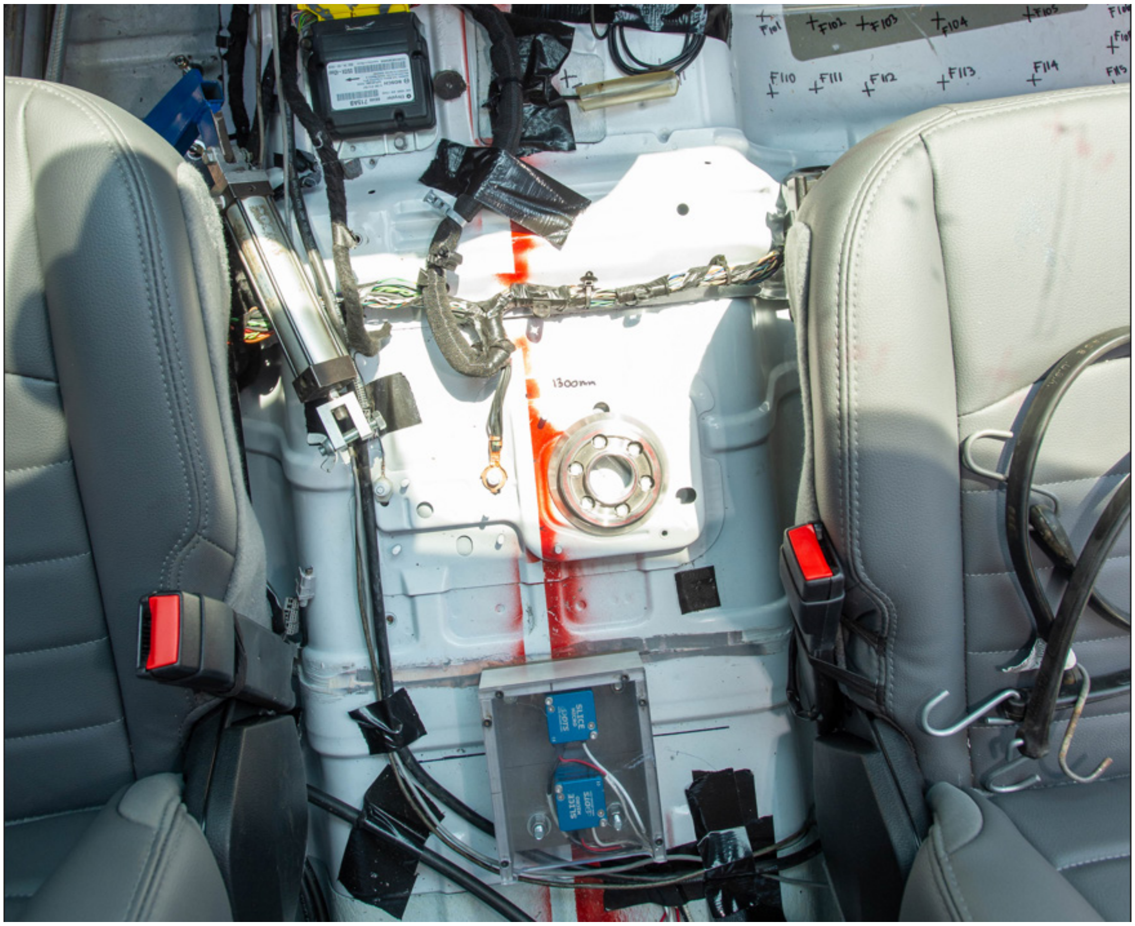


Figure 10-4 Test 4-11 DTS SLICE Micro Mount Position in the Vehicle

A 4800 kPa (700 psi) CO_2 system, actuated by a solenoid valve, controlled remote braking after the impact and emergency braking if necessary. Part of this system was a pneumatic ram which was attached to the brake pedal. The operating pressure for the ram was adjusted through a pressure regulator during a series of trial runs prior to the actual test. Adjustments were made to ensure the shortest stopping distance without locking up the wheels. When activated, the brakes could be applied in less than 100 milliseconds.

A speed control device was connected in-line with the with the engine ignition coil power circuits on the self-powered test vehicle. It was used to regulate the speed based on drive shaft rotation detected by an optical sensor. This device was calibrated prior to the test by conducting a series of trial runs through a speed trap comprised of two tape switches (set at a specific distance apart) and a digital timer.

10.1.3. 4-12 Test 110MASH4S21-03

The vehicle used for this test was a 2009 Freightliner M2 106 18-foot Box Truck. Two DTS SLICE MICRO systems were installed in the cargo box area. Also, two DTS SLICE MICRO systems were installed in the cab of the vehicle. Each DTS SLICE MICRO system had a set of triaxial accelerometers, angular rate sensors and bridge layer and were powered by a lithium-ion battery pack. A 12-volt deep-cycle gel cell battery powered the Electronic Control Box.

Figure 10-5 Test 4-12 DTS SLICE Micro Mount Position in the Cab

Figure 10-6 Test 4-12 DTS SLICE Micro Mount Position in Cargo Box

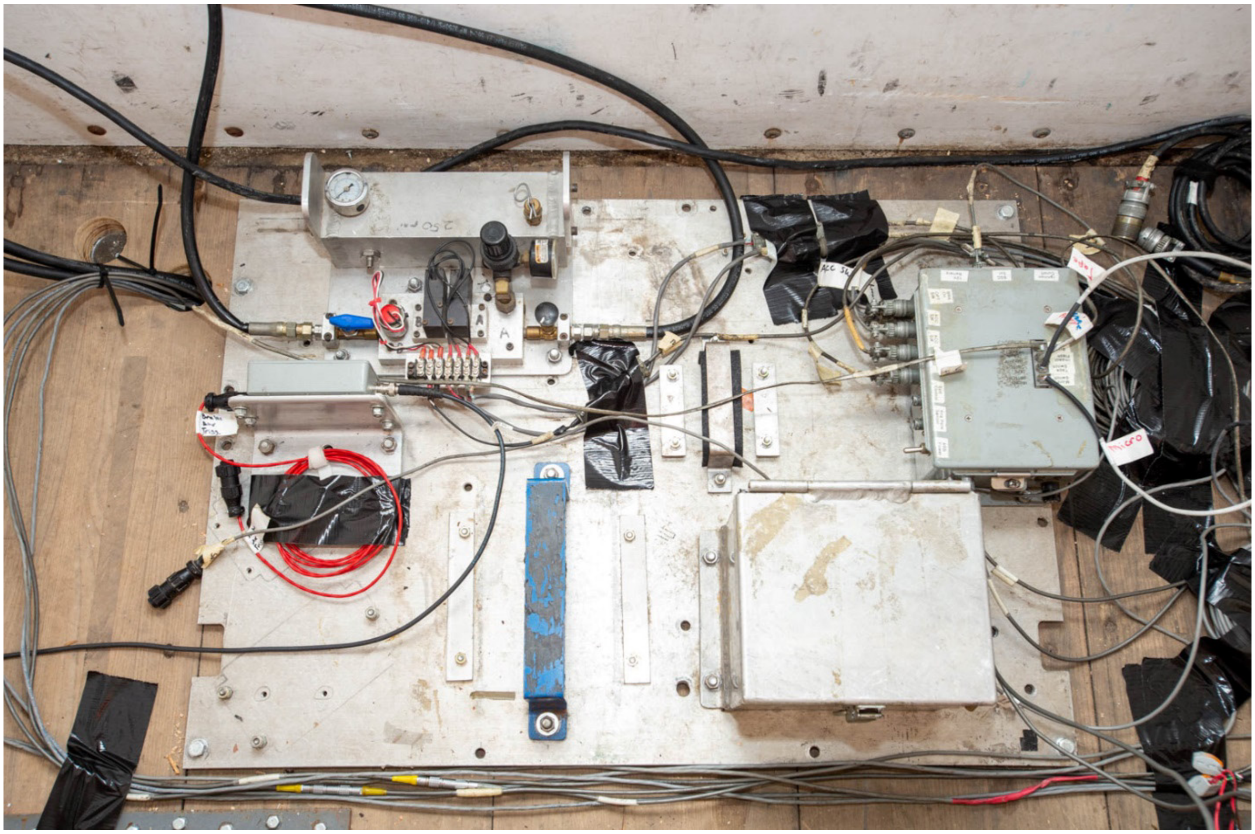


Figure 10-7 Test 4-12 Vehicle Instrumentation Mounted in Cargo Box

A 4800 kPa (700 psi) CO_2 system, actuated by a solenoid valve, controlled remote braking after the impact and emergency braking if necessary. Part of this system was a pneumatic ram which was attached to the brake pedal. The operating pressure for the ram was adjusted through a pressure regulator during a series of trial runs prior to the actual test. Adjustments were made to ensure the shortest stopping distance without locking up the wheels. When activated, the brakes could be applied in less than 100 milliseconds.

The test vehicle speed was controlled by an onboard speed limiter that is standard for this self-powered test vehicle. The vehicle's limiter was programed by a local service provider prior to the test. To ensure that the limiter was set properly, a series of test runs were conducted using a GHM Engineering HFW80 Fifth Wheel Sensor.

The test vehicle was also pushed by another vehicle so that the impact speed could be reached in the limited distance of roughly 640 m (2100 ft) available at the testing facility. A set push distance was established. Once the push vehicle had traveled this distance, it slowed down and allowed the test vehicle to continue accelerating until it reached the target speed.

10.2. Test Vehicle Guidance System

A rail guidance system directed the test vehicles into the barrier. The guidance rail, anchored at approximately 3.8 m (12.5 ft) intervals along its length, was used to guide a mechanical arm, which was attached to the hub of the front left wheel of the test vehicle. A plate and lever were used to trigger the release pin on the guidance arm, thereby releasing the vehicle from the guidance system before impact.

Figure 10-8 Typical Guidance System Layout

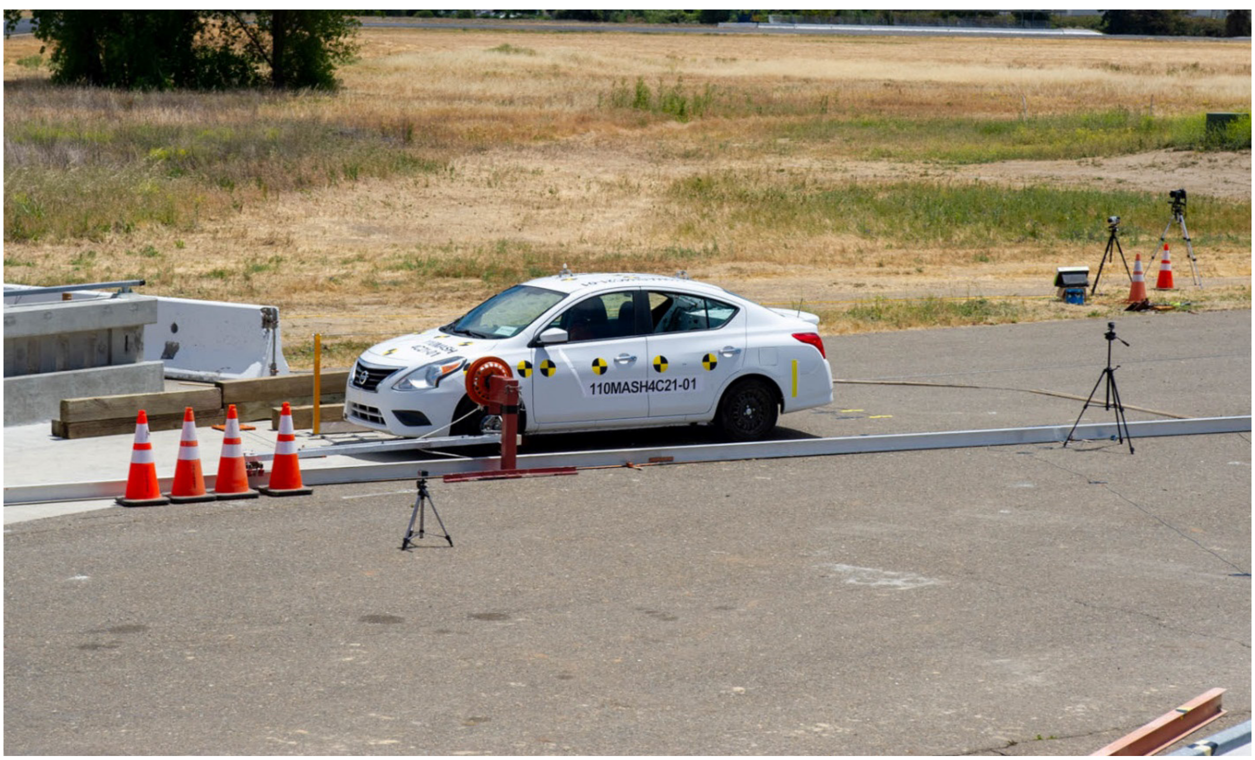


Figure 10-9 Guide Arm Releasing from Test Vehicle

Figure 10-10 Guide Arm Released from Vehicle

10.3. Friction Brake

For all three tests conducted on the Type 86H an in-house designed and modified Guide Arm Brake was utilized. Before Test 110MASH4C21-01 was performed, continuous testing was done of a modified version of the friction brake system consisting of a metal assembly (Figure 10-11 and Figure 10-12) that allows for the rope attached to the guide arm brake to dissipate the kinetic energy of the moving guide arm by means of friction between the assembly's friction assembly and the surface of the rope sliding through it.

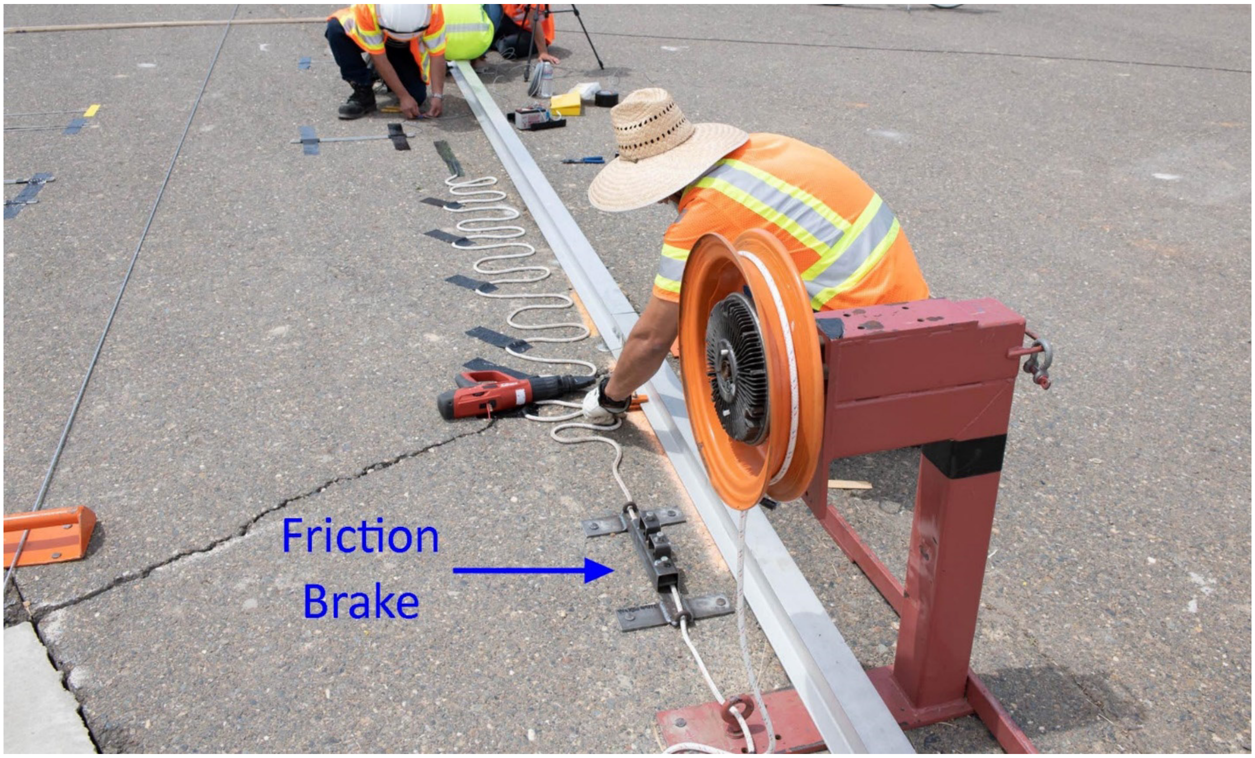


Figure 10-11 Guide Arm Brake System with Friction Brake

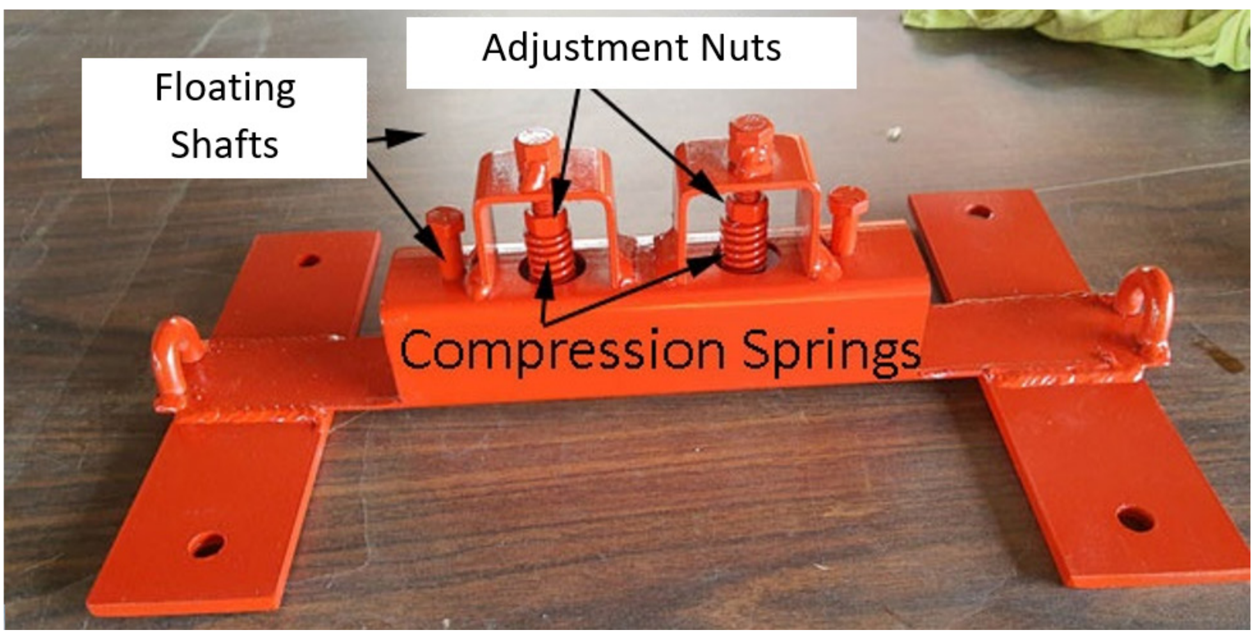


Figure 10-12 Friction Brake Close Up View

Figure 10-13 Guide Arm Brake System with Friction Brake (Prior To Pick up Test)

Figure 10-14 Released Guide Arm with Engaged Friction Brake (Pickup Test Prior to Impact)

10.4. Photo - Instrumentation

Several high-speed video cameras recorded the impact during the test. The high-speed video frame rates were set to 500 frames per second. The types of cameras and their locations are shown in Table 10-1 thru Table 10-3. The origin of the coordinates is at the intended point of impact.

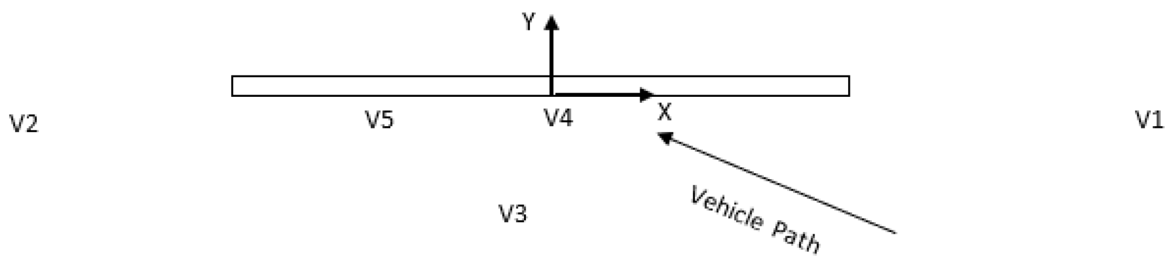


Figure 10-15 High-Speed Video Camera Locations (Not to Scale)

Table 10-1 110MASH4C21-01 Camera Types and Location Coordinates

Camera Location	Camera Make/Model	Camera Serial No.	Lens	Lens Serial No.	Coordinates, ft (m) *		
					x	y	z
V1 Upstream	Vision Research Miro LC111	22361	35 mm	173792	84.7 (25.8)	0.2 (0.1)	3.7 (1.1)
V2 Downstream	Vision Research Miro R321S	25386	100-200 mm	402495	-309.1 (-94.2)	-2.4 (-0.7)	4.6 (1.4)
V3 Across	Vision Research Miro M110	13235	20 mm	182398	-7.1 (-2.2)	-56.4 (-17.2)	4.8 (1.5)
V4 Upstream Tower	Vision Research VEO440	24663	20 mm	447169	1.4 (0.4)	-6.8 (-2.1)	37.1 (11.3)
V5 Downstream Tower	Vision Research Miro R321S	25385	14 mm	217706	-29.2 (-8.9)	-10.4 (-3.2)	47.5 (14.5)

Table 10-2 110MASH4P21-02 Camera Types and Location Coordinates

Camera Location	Camera Make/Model	Camera Serial No.	Lens	Lens Serial No.	Coordinates, ft (m) *		
					x	y	z
V1 Upstream	Vision Research Miro LC111	22361	35 mm	173792	91.7 (28.0)	-0.9 (-0.3)	4.3 (1.3)
V2 Downstream	Vision Research Miro R321S	25386	100-200 mm	402495	-296.0 (-90.2)	-2.3 (-0.7)	5.0 (1.5)
V3 Across	Vision Research Miro M110	13235	20 mm	182398	2.1 (0.6)	-59.0 (-18.0)	5.0 (1.5)
V4 Upstream Tower	Vision Research VEO440	24663	20 mm	447169	-0.2 (-0.1)	-4.8 (-1.5)	32.4 (9.9)
V5 Downstream Tower	Vision Research Miro R321S	25385	14 mm	217706	-20.6 (-6.3)	-8.9 (-2.7)	39.2 (12.0)

Table 10-3 110MASH4S21-03 Camera Types and Location Coordinates

Camera Location	Camera Make/Model	Camera Serial No.	Lens	Lens Serial No.	Coordinates, ft (m) *		
					x	y	z
V1 Upstream	Vision Research Miro LC111	22361	35 mm	173792	92.2 (28.0)	-0.3 (-0.1)	4.8 (1.5)
V2 Downstream	Vision Research Miro R321S	25386	100-200 mm	402495	-308.1 (-93.9)	-1.7 (-0.5)	4.8 (1.5)
V3 Across	Vision Research Miro M110	13235	20 mm	182398	1.2 (0.4)	-64.8 (-19.8)	6.1 (1.9)
V4 Upstream Tower	Vision Research Miro 110	24663	20 mm	447169	-1.67 (-0.5)	-5.7 (-1.7)	39.9 (12.2)
V5 Downstream Tower	Vision Research Miro 110	25385	14 mm	217706	-24.5 (-7.5)	-9.6 (-2.9)	49.7 (15.2)

*Camera coordinates were determined using the total station surveying equipment.

The following are the pretest procedures that were required to enable video data reduction to be performed using the Research's video analysis software (Phantom Camera Control):

1. Butterfly targets were attached to the top and sides of the test vehicle. The targets were located on the vehicle at intervals of 500 mm (19.7 in.) and 1000 mm (39.4 in.). The targets established scale factors.
2. A flashbulb was mounted on the test vehicle and was electronically triggered by a tape switch on the front bumper to establish initial vehicle-to-barrier contact. A separate flashbulb is normally installed to capture the time of the application of the vehicle brakes. Due to irregularities in the function of the brake flashbulb system, the brake flashbulb was not used in any of the tests. The time of the braking was determined using the event channel signal recorded by the DTS SLICE Micro data acquisition units.
3. High-speed digital video cameras were all time-coded using a portable computer and were triggered as the test vehicle passed over a tape switch located in the vehicle path upstream of the impact point.

10.5. Electronic Instrumentation and Data

Transducer data were recorded at 10,000 samples/second on two separate Diversified Technical Systems, Inc. (DTS) SLICE Micro data acquisition systems that were mounted in the test vehicle. The DTS SLICE units each contain a set of accelerometers, angular rate sensors and a bridge layer and were mounted at the center of gravity. TRAP was used to process the data. Accelerometer and angular rate sensor specifications are shown in Table 10-4 thru Table 10-6.

Table 10-4 4-10 Test 110MASH4C21-01 Accelerometer and Angular Rate Sensor Specifications

Type	Manufacturer	Model	Serial #	Location	Range
Triaxial Accelerometer	Diversified Technical Systems	SLICE MICRO 500 g	AC00200	CG	±500 g
Triaxial Angular Rate Sensors	Diversified Technical Systems	SLICE MICRO 1500 degree/sec	AR00165	CG	±1500 deg/s
Triaxial Accelerometer	Diversified Technical Systems	SLICE MICRO 500 g	AC00223	CG	±500 g
Triaxial Angular Rate Sensors	Diversified Technical Systems	SLICE MICRO 1500 degree/sec	AR00166	CG	±1500 deg/s

Table 10-5 4-11 Test 110MASH4P21-02 Accelerometer and Angular Rate Sensor Specifications

Type	Manufacturer	Model	Serial #	Location	Range
Triaxial Angular Rate Sensors	Diversified Technical Systems	SLICE MICRO 1500 degree/sec	AR00165	CG	±1500 deg/s
Triaxial Accelerometer	Diversified Technical Systems	SLICE MICRO 500 g	AC00200	CG	±500 g
Triaxial Angular Rate Sensors	Diversified Technical Systems	SLICE MICRO 1500 degree/sec	AR00165	CG	±1500 deg/s
Triaxial Accelerometer	Diversified Technical Systems	SLICE MICRO 500 g	AC00223	CG	±500 g

Table 10-6 4-12 Test 110MASH4S21-03 Accelerometer and Angular Rate Sensor Specifications

Type	Manufacturer	Model	Serial #	Location	Range
Triaxial Angular Rate Sensors	Diversified Technical Systems	SLICE MICRO 1500 degree/sec	AR00181	CG in Cargo Box	±1500 deg/s
Triaxial Angular Rate Sensors	Diversified Technical Systems	SLICE MICRO 1500 degree/sec	AR00180	CG in Cargo Box	±1500 deg/s
Triaxial Accelerometer	Diversified Technical Systems	SLICE MICRO 500 g	AC00235	CG in Cargo Box	±500 g
Triaxial Accelerometer	Diversified Technical Systems	SLICE MICRO 500 g	AC00234	CG in Cargo Box	±500 g
Triaxial Accelerometer	Diversified Technical Systems	SLICE MICRO 500 g	AC00200	Along CL of Vehicle in the cab	±500 g
Triaxial Angular Rate Sensors	Diversified Technical Systems	SLICE MICRO 1500 degree/sec	AR00165	Along CL of Vehicle in the cab	±1500 deg/s
Triaxial Accelerometer	Diversified Technical Systems	SLICE MICRO 500 g	AC00223	Along CL of Vehicle in the cab	±500 g
Triaxial Angular Rate Sensors	Diversified Technical Systems	SLICE MICRO 1500 degree/sec	AR00166	Along CL of Vehicle in the cab	±1500 deg/s

A rigid stand with three retro-reflective 90° polarizing tape strips spaced 1000 mm (39.4 in.) apart was placed on the ground near the test article and alongside the path of the test vehicle. The strips were measured immediately before the test to account for any thermal expansion. The test vehicle had an onboard optical sensor that produced sequential impulses or “event blips” as the vehicle passed the reflective tape strips. The event blips were recorded concurrently with the DTS SLICE sensor signals on the SLICE’s bridge layer, serving as "event markers”. The impact velocity of the vehicle could be determined from these sensor impulses, the data record time, and the known distance between the tape strips. A pressure sensitive tape switch on the front bumper of the vehicle closed at the instant of impact and triggered two events: 1) “event marker” was added to the recorded data, and 2) a flashbulb mounted on the top of the vehicle was activated. One set of pressure activated tape switches, connected to a speed trap, were placed 4 m apart just upstream of the test article to check the impact speed of the test vehicle. It is worth noting that the speed trap measurement is not a reported measurement value, however it is used to validate the reported impact speed. The layout for all the pressure sensitive tape switches and reflective tape is shown in Figure 10-16.

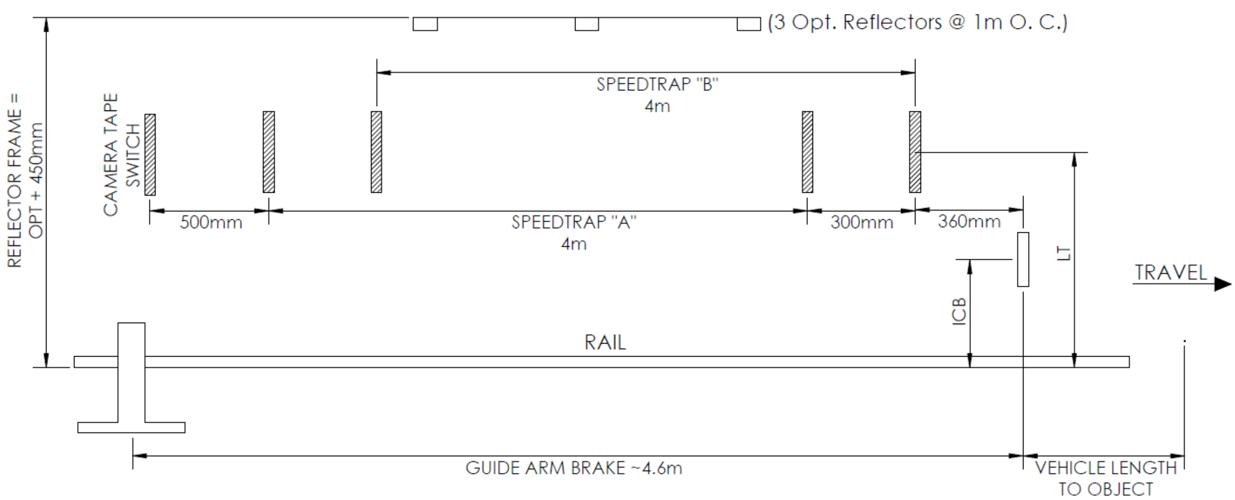


Figure 10-16 Speed Trap Tape Layout

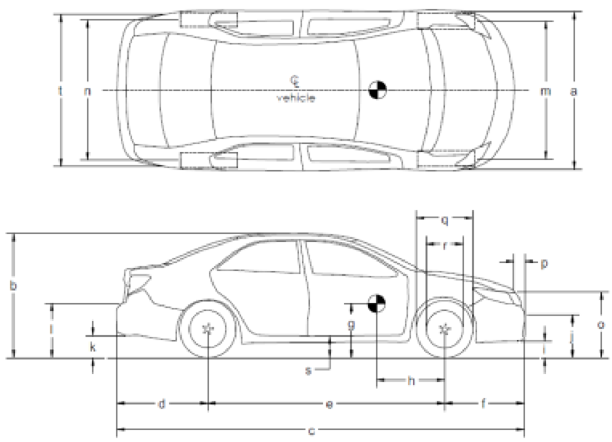
10.6. Vehicle Measurements

10.6.1. Test 110MASH4C21-01

Table 10-7 Test 4-10 Exterior Vehicle Measurements

Date: 4/29/2021 Test Number: 110MASH4C21-01 Model: Nissan
Make: Versa Sedan VIN: 3N1CN7AP9FL820434
Tire Size: P185/65R15 86H Year: 2015 Odometer: 97176
Tire Inflation Pressure: 33 psi Tape Measure Used: 5m-CP01 CLE:*** DRISI 1902
Measure by: Chris C, Dave S Staff: Scale Set Used: 2500

(All Measurements Refer to Impacting Side)



Vehicle Geometry - mm (inches)

a	1691	(66.57)	b	1490	(58.66)
c	4466	(175.83)	d	1024	(40.31)
e	2599	(102.32)	f	840	(33.07)
g	N/A	N/A	h	1049	(41.3)
i*	184	(7.24)	j*	423	(16.65)
k	300	(11.81)	l	647	(25.47)
m	1480	(58.27)	n	1477	(58.15)
o**	777	(30.59)	p	202	(7.95)
q	623	(24.53)	r	413	(16.26)
s	285	(11.22)	t	1691	(66.57)

Wheel Center Height: 291 (11.46)
Engine Type: gas, 4-cycle, 4-cylinder
Engine Size: 97.5 in^3
Transmission Type:
Automatic or Manual: Automatic
FWD or RWD or 4WD: FWD

~~* i & j taken from the functional bumper (may be inside bumper cover)~~ <-- Remove this line. Measurements have changed per ILC 2018. CC 4/29/2021

** o taken from top of radiator support bracket, centerline of vehicle

*** CLE is the inventory number and should be located on the door jamb of the vehicle.

Mass Distribution

			Scale				Scale
Left Front:	351.2	(774.25)	red	Right Front:	289.85	(639)	green
Left Rear:	223.95	(493.72)	yellow	Right Rear:	242.4	(534.39)	blue

Weights

kg (lbs)	Curb		Test Inertial		Gross Static	
W_{front}	661.40	(1458.11)	641.05	(1413.25)	683.1	(1505.95)
W_{rear}	447.55	(986.66)	466.35	(1028.11)	503.8	(1110.67)
W_{total}	1108.95	(2444.78)	1107.4	(2441.36)	1186.9	(2616.62)

GVWR Ratings

Front:	793.8	(1750)
Back:	774.7	(1708)
Total:	1554.0	(3426)

Dummy Data
Type: Hybrid III 50th Percentile Male
Mass: 79.5 kg (175 lbs)
Seat Position: passenger

Note any damage prior to test: See Attachment 5.4.2 Curb Weight for test 110MASH4C21-01

Data Transferred to Electronic Copy By: Christopher Caldwell Date: 5/13/2021

Transfer Checked by: Dave Sawko Date: 5/27/2021

Table 10-8 Test 4-10 CG Calculation: Curb Weight

Policies and Procedures Manual	Revised:8/17/2017
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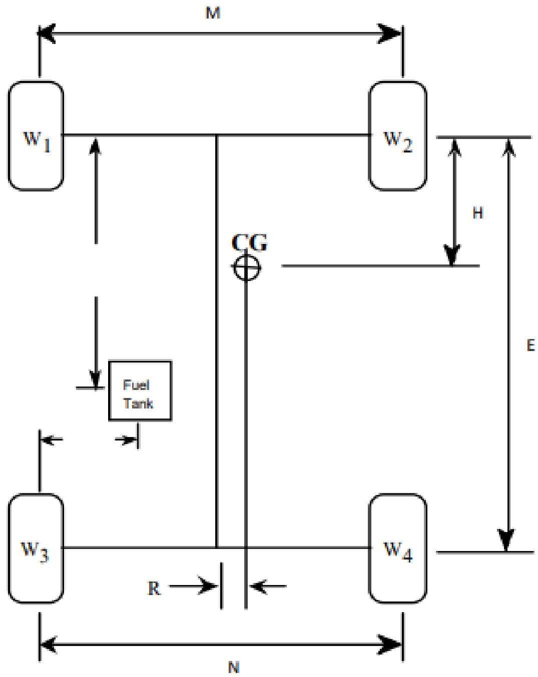
Attachment 5.4.2 --- CG Data Calculation Worksheet

CG Calculation Worksheet #1: **Curb Weight**

Make:	Nissan	Test Number:	110MASH4C21-01
Model:	Versa Sedan	Date:	4/28/2021
Year:	2015	Temperature:	72°F
VIN:	3N1CN7AP9FL820434	Scale Set Used:	2500
Fuel in Tank:	3/16		
Fuel Removed:	none		
Measured By:	Chris C		
	Dave S		
Support Staff	Steve W		



W1 = Left Front (LF) = 348.85 kg
Scale Used: red

W2 = Right Front (RF) = 312.55 kg
Scale Used: green

W3 = Left Rear (LR) = 218.45 kg
Scale Used: yellow

W4 = Right Rear (RR) = 229.1 kg
Scale Used: blue

Total Weight:
Wtotal (measured) = 1109.1 kg

Wtotal (calculated) = 1108.95 kg

Distance between front wheels:
M = 1480 mm

Distance between rear wheels:
N = 1477 mm

Distance from front to rear wheels:
E = 2599 mm

Distance from front wheels back to CG:
H = 1049 mm

Distance from vehicle centerline to CG:
R = -17 mm

$$W_{Total} = W_1 + W_2 + W_3 + W_4$$

$$H = \frac{(W_3 + W_4)E}{W_{Total}}$$

$$R = \frac{(W_2 - W_1)M + (W_4 - W_3)N}{2W_{Total}}$$

Data Transferred to Electronic Copy By:	Chris Caldwell	Date:	4/29/2021
Transfer Checked by:	Dave Sawko	Date:	5/27/2021

If R is negative the CG is left of center, if R is positive the CG is right of center

Curb Weight Conditions: (vehicle condition, items removed, items added, environmental conditions, etc.)
Minor scratch on driver door. Mino Scratch on upper rear driver side rear passenger door and pillar area. Curb rash front bottom bumper passenger side. Damage to top corner of passenger door. Tire sensor will not go off.

Test 110MASH4C21-01 CG Data Calculation Worksheet.xlsx Curb WorkSheet

Table 10-9 Test 4-10 CG Calculation: Test Inertial Weight

Policies and Procedures Manual	Revised: 8/17/2017
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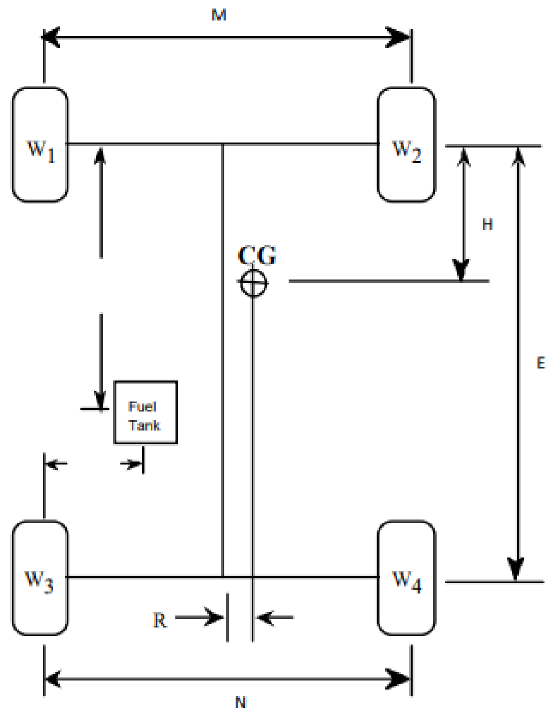
Attachment 5.4.2 --- CG Data Calculation Worksheet

CG Calculation Worksheet #2: **Test Inertial Weight**

Make:	Nissan	Test Number:	110MASH4C21-01
Model:	Versa Sedan	Date:	5/12/2021
Year:	2015	Temperature:	74°F
VIN:	3N1CN7AP9FL820434	Scale Set Used:	2500
Fuel in Tank:	1/2 tank		
Fuel Removed:	none		
Measured By:	Chris C		
	Dave S		
Support Staff	Vue Her		



W1 = Left Front (LF) = 351.2 kg
Scale Used: red

W2 = Right Front (RF) = 289.85 kg
Scale Used: green

W3 = Left Rear (LR) = 223.95 kg
Scale Used: yellow

W4 = Right Rear (RR) = 242.4 kg
Scale Used: blue

Total Weight:
Wtotal (measured) = 1107.4 kg

Wtotal (calculated) = 1107.4 kg

Distance between front wheels:
M = 1480 mm

Distance between rear wheels:
N = 1477 mm

Distance from front to rear wheels:
E = 2599 mm

Distance from front wheels back to CG:
H = 1094 mm

Distance from vehicle centerline to CG:
R = -29 mm

$$W_{Total} = W_1 + W_2 + W_3 + W_4$$

$$H = \frac{(W_3 + W_4)E}{W_{Total}}$$

$$R = \frac{(W_2 - W_1)M + (W_4 - W_3)N}{2W_{Total}}$$

Data Transferred to Electronic Copy By: Christopher Caldwell	Date:	5/13/2021
Transfer Checked by: Dave Sawko	Date:	5/27/2021

If R is negative the CG is left of center, if R is positive the CG is right of center

Test Inertial Weight Conditions: (vehicle condition, items removed, items added, environmental conditions, etc.)
See curb weight worksheet for damages. Interior removed to make room for instrumentation. Instrumentation installed.
Car battery removed and databrick batteries added to move CG for Slice units.

Table 10-10 Test 4-10 CG Calculation: Gross Static Weight

Policies and Procedures Manual	Revised: 8/17/2017
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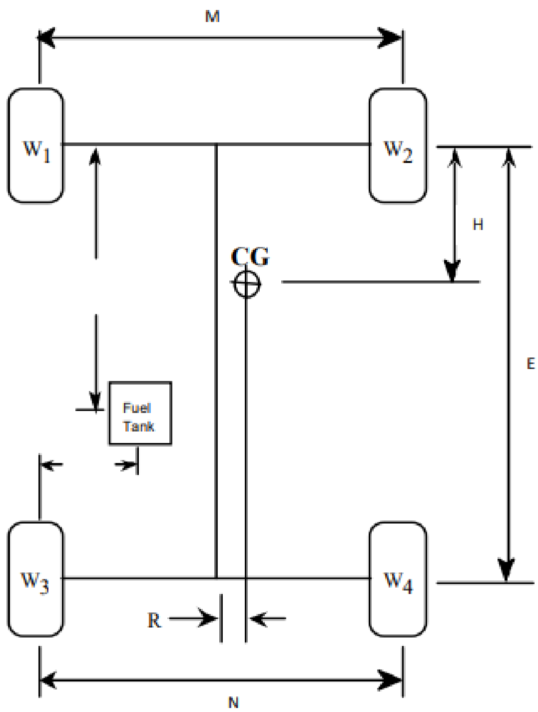
Attachment 5.4.2 --- CG Data Calculation Worksheet

CG Calculation Worksheet #3: **Gross Static Weight**

Make:	Nissan	Test Number:	110MASH4C21-01
Model:	Versa Sedan	Date:	5/12/2021
Year:	2015	Temperature:	74°F
VIN:	3N1CN7AP9FL820434	Scale Set Used:	2500
Fuel in Tank:	1/2 tank		
Fuel Removed:	none		
Measured By:	Chris C		
	Dave S		
Support Staff	Vue Her		



W1 = Left Front (LF) = 362.25 kg
Scale Used: red

W2 = Right Front (RF) = 320.85 kg
Scale Used: green

W3 = Left Rear (LR) = 233.85 kg
Scale Used: yellow

W4 = Right Rear (RR) = 269.95 kg
Scale Used: blue

Total Weight:
Wtotal (measured) = 1187.15 kg

Wtotal (calculated) = 1186.9 kg

Distance between front wheels:
M = 1480 mm

Distance between rear wheels:
N = 1477 mm

Distance from front to rear wheels:
E = 2599 mm

Distance from front wheels back to CG:
H = 1103 mm

Distance from vehicle centerline to CG:
R = -3 mm

$$W_{Total} = W_1 + W_2 + W_3 + W_4$$

$$H = \frac{(W_3 + W_4)E}{W_{Total}}$$

$$R = \frac{(W_2 - W_1)M + (W_4 - W_3)N}{2W_{Total}}$$

Data Transferred to Electronic Copy By:	Christopher Caldwell	Date:	5/13/2021
Transfer Checked by:	Dave Sawko	Date:	5/27/2021

If R is negative the CG is left of center, if R is positive the CG is right of center

Gross Static Weight Conditions: (vehicle condition, items removed, items added, environmental conditions, etc.)
Dummy Added

Table 10-11 Test 4-10 Pre, Post Interior and Deformation Measurement Page 1

Policies and Procedures Manual — Revised: 9/16/2019
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Attachment 5.5 --- Interior Vehicle Measurement Report

Vehicle Type	1100C	Test Number	110MASH4C21-01
Make	Versa Sedan	Model	Nissan
Year	2015	Color	White
VIN #	3N1CN7AP9FL820434		

Transmission Tunnel and Floor Pan Area Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
F1	1708 (67.2)	101 (4)	49 (1.9)	1730 (68.1)	81 (3.2)	63 (2.5)	22 (0.9)	-20 (-0.8)	13 (0.5)	33 (1.3)
F2	1610 (63.4)	103 (4.1)	68 (2.7)	1631 (64.2)	88 (3.5)	74 (2.9)	21 (0.8)	-15 (-0.6)	7 (0.3)	27 (1.1)
F3	1485 (58.5)	101 (4)	75 (3)	1505 (59.2)	87 (3.4)	85 (3.3)	19 (0.8)	-14 (-0.5)	10 (0.4)	26 (1)
F4	1392 (54.8)	98 (3.9)	79 (3.1)	1413 (55.6)	87 (3.4)	87 (3.4)	20 (0.8)	-12 (-0.5)	8 (0.3)	25 (1)

Foot/Wheel Well and Toe Pan Area Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
T1	2020 (79.5)	217 (8.5)	68 (2.7)	2008 (79)	197 (7.8)	12 (0.5)	-12 (-0.5)	-20 (-0.8)	-57 (-2.2)	61 (2.4)
T2	2024 (79.7)	328 (12.9)	71 (2.8)	1967 (77.4)	268 (10.5)	14 (0.6)	-57 (-2.3)	-60 (-2.4)	-57 (-2.2)	100 (4)
T3	2023 (79.7)	426 (16.8)	73 (2.9)	1985 (78.2)	360 (14.2)	28 (1.1)	-38 (-1.5)	-66 (-2.6)	-45 (-1.8)	88 (3.5)
T4	2026 (79.8)	533 (21)	72 (2.8)	1981 (78)	460 (18.1)	18 (0.7)	-44 (-1.7)	-73 (-2.9)	-54 (-2.1)	101 (4)
T5	1965 (77.4)	630 (24.8)	54 (2.1)	1877 (73.9)	503 (19.8)	-13 (-0.5)	-88 (-3.5)	-127 (-5)	-67 (-2.6)	168 (6.6)
T6	1960 (77.2)	211 (8.3)	139 (5.5)	1949 (76.7)	221 (8.7)	82 (3.2)	-11 (-0.4)	10 (0.4)	-57 (-2.2)	59 (2.3)
T7	1967 (77.4)	328 (12.9)	139 (5.5)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
T8	1956 (77)	431 (17)	127 (5)	1927 (75.9)	369 (14.5)	87 (3.4)	-29 (-1.2)	-62 (-2.4)	-40 (-1.6)	79 (3.1)
T9	1968 (77.5)	530 (20.9)	141 (5.5)	1937 (76.3)	466 (18.4)	92 (3.6)	-31 (-1.2)	-63 (-2.5)	-49 (-1.9)	85 (3.4)
T10	1959 (77.1)	619 (24.4)	147 (5.8)	1883 (74.1)	520 (20.5)	83 (3.3)	-75 (-3)	-100 (-3.9)	-65 (-2.5)	141 (5.5)
T11	1855 (73)	211 (8.3)	188 (7.4)	1855 (73.1)	248 (9.8)	137 (5.4)	0 (0)	37 (1.4)	-51 (-2)	63 (2.5)
T12	1859 (73.2)	323 (12.7)	202 (8)	1824 (71.8)	299 (11.8)	125 (4.9)	-35 (-1.4)	-24 (-0.9)	-78 (-3.1)	89 (3.5)
T13	1865 (73.4)	428 (16.8)	171 (6.7)	1840 (72.4)	373 (14.7)	134 (5.3)	-25 (-1)	-55 (-2.2)	-37 (-1.5)	71 (2.8)
T14	1862 (73.3)	537 (21.1)	193 (7.6)	1845 (72.6)	483 (19)	158 (6.2)	-17 (-0.7)	-54 (-2.1)	-36 (-1.4)	67 (2.6)
T15	1867 (73.5)	630 (24.8)	203 (8)	1833 (72.2)	550 (21.6)	135 (5.3)	-34 (-1.3)	-80 (-3.2)	-68 (-2.7)	111 (4.4)
T16	1764 (69.4)	218 (8.6)	204 (8)	1770 (69.7)	254 (10)	169 (6.6)	6 (0.3)	36 (1.4)	-35 (-1.4)	51 (2)
T17	1765 (69.5)	324 (12.7)	217 (8.5)	1737 (68.4)	295 (11.6)	155 (6.1)	-29 (-1.1)	-29 (-1.1)	-62 (-2.4)	74 (2.9)
T18	1754 (69.1)	426 (16.8)	180 (7.1)	1730 (68.1)	379 (14.9)	147 (5.8)	-24 (-0.9)	-47 (-1.9)	-33 (-1.3)	62 (2.5)
T19	1766 (69.5)	538 (21.2)	220 (8.7)	1750 (68.9)	491 (19.3)	186 (7.3)	-16 (-0.6)	-48 (-1.9)	-34 (-1.3)	61 (2.4)
T20	1754 (69)	630 (24.8)	223 (8.8)	1741 (68.5)	578 (22.8)	180 (7.1)	-13 (-0.5)	-52 (-2.1)	-43 (-1.7)	69 (2.7)
T21	1679 (66.1)	213 (8.4)	205 (8.1)	1685 (66.3)	245 (9.6)	179 (7)	6 (0.2)	32 (1.3)	-26 (-1)	42 (1.6)
T22	1681 (66.2)	326 (12.8)	220 (8.7)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
T23	1689 (66.5)	425 (16.7)	188 (7.4)	1666 (65.6)	381 (15)	157 (6.2)	-23 (-0.9)	-44 (-1.7)	-31 (-1.2)	59 (2.3)
T24	1694 (66.7)	541 (21.3)	222 (8.7)	1682 (66.2)	495 (19.5)	201 (7.9)	-12 (-0.5)	-46 (-1.8)	-21 (-0.8)	52 (2)
T25	1702 (67)	631 (24.8)	230 (9)	1689 (66.5)	582 (22.9)	188 (7.4)	-13 (-0.5)	-49 (-1.9)	-42 (-1.7)	66 (2.6)
T26	1586 (62.4)	212 (8.3)	209 (8.2)	1591 (62.7)	237 (9.3)	191 (7.5)	5 (0.2)	25 (1)	-18 (-0.7)	32 (1.2)
T27	1586 (62.4)	323 (12.7)	220 (8.7)	1577 (62.1)	324 (12.8)	234 (9.2)	-9 (-0.4)	1 (0)	14 (0.6)	17 (0.7)
T28	1594 (62.7)	423 (16.6)	193 (7.6)	1569 (61.8)	388 (15.3)	173 (6.8)	-24 (-1)	-35 (-1.4)	-20 (-0.8)	47 (1.9)
T29	1603 (63.1)	543 (21.4)	225 (8.9)	1588 (62.5)	505 (19.9)	208 (8.2)	-14 (-0.6)	-38 (-1.5)	-17 (-0.7)	44 (1.7)
T30	1609 (63.4)	635 (25)	239 (9.4)	1596 (62.9)	593 (23.4)	219 (8.6)	-13 (-0.5)	-41 (-1.6)	-20 (-0.8)	47 (1.9)
T31	1477 (58.1)	216 (8.5)	227 (8.9)	1482 (58.3)	230 (9)	211 (8.3)	5 (0.2)	14 (0.5)	-16 (-0.6)	21 (0.8)
T32	1480 (58.3)	328 (12.9)	228 (9)	1474 (58)	334 (13.2)	224 (8.8)	-6 (-0.2)	6 (0.3)	-4 (-0.1)	10 (0.4)
T33	1485 (58.5)	419 (16.5)	205 (8.1)	1463 (57.6)	392 (15.4)	190 (7.5)	-22 (-0.9)	-27 (-1.1)	-16 (-0.6)	38 (1.5)
T34	1506 (59.3)	541 (21.3)	229 (9)	1492 (58.8)	512 (20.2)	213 (8.4)	-14 (-0.6)	-29 (-1.2)	-16 (-0.6)	36 (1.4)
T35	1511 (59.5)	633 (24.9)	238 (9.4)	1503 (59.2)	600 (23.6)	236 (9.3)	-7 (-0.3)	-34 (-1.3)	-2 (-0.1)	34 (1.4)

Side Front Panel Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
S1	1919 (75.6)	689 (27.1)	-32 (-1.3)	1828 (72)	587 (23.1)	-92 (-3.6)	-92 (-3.6)	-102 (-4)	-60 (-2.4)	150 (5.9)
S2	1891 (74.5)	689 (27.1)	28 (1.1)	1828 (72)	606 (23.9)	-32 (-1.2)	-63 (-2.5)	-82 (-3.2)	-60 (-2.3)	120 (4.7)
S3	1844 (72.6)	686 (27)	86 (3.4)	1800 (70.9)	583 (23)	30 (1.2)	-44 (-1.7)	-103 (-4)	-56 (-2.2)	125 (4.9)
S4	1803 (71)	684 (26.9)	166 (6.5)	1774 (69.8)	594 (23.4)	116 (4.6)	-29 (-1.1)	-90 (-3.5)	-50 (-2)	107 (4.2)

Table 10-12 Test 4-10 Pre, Post Interior and Deformation Measurement Page 2

Attachment 5.5 --- Interior Vehicle Measurement Report

Vehicle Type	1100C	Test Number	110MASH4C21-01
Make	Versa Sedan	Model	Nissan
Year	2015	Color	White
VIN #	3N1CN7AP9FL820434		

Roof Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
R1	1371 (54)	109 (4.3)	-936 (-36.9)	1363 (53.7)	112 (4.4)	-960 (-37.8)	-8 (-0.3)	3 (0.1)	-24 (-1)	26 (1)
R2	1365 (53.7)	207 (8.2)	-932 (-36.7)	1360 (53.5)	211 (8.3)	-960 (-37.8)	-5 (-0.2)	4 (0.1)	-27 (-1.1)	28 (1.1)
R3	1356 (53.4)	347 (13.7)	-926 (-36.4)	1351 (53.2)	350 (13.8)	-959 (-37.8)	-6 (-0.2)	3 (0.1)	-33 (-1.3)	34 (1.3)
R4	1343 (52.9)	495 (19.5)	-914 (-36)	1340 (52.8)	499 (19.6)	-953 (-37.5)	-3 (-0.1)	3 (0.1)	-39 (-1.5)	39 (1.5)
R5	1240 (48.8)	106 (4.2)	-987 (-38.9)	1232 (48.5)	106 (4.2)	-1008 (-39.7)	-9 (-0.3)	0 (0)	-21 (-0.8)	23 (0.9)
R6	1238 (48.7)	203 (8)	-996 (-39.2)	1230 (48.4)	203 (8)	-1019 (-40.1)	-8 (-0.3)	0 (0)	-24 (-0.9)	25 (1)
R7	1229 (48.4)	335 (13.2)	-991 (-39)	1222 (48.1)	335 (13.2)	-1010 (-39.8)	-7 (-0.3)	0 (0)	-19 (-0.7)	20 (0.8)
R8	1219 (48)	467 (18.4)	-982 (-38.6)	1211 (47.7)	468 (18.4)	-1012 (-39.8)	-8 (-0.3)	0 (0)	-30 (-1.2)	31 (1.2)
R9	1134 (44.6)	103 (4.1)	-1000 (-39.4)	1124 (44.3)	103 (4.1)	-1020 (-40.1)	-10 (-0.4)	0 (0)	-19 (-0.8)	22 (0.8)
R10	1133 (44.6)	194 (7.7)	-1008 (-39.7)	1124 (44.2)	194 (7.6)	-1029 (-40.5)	-9 (-0.3)	0 (0)	-21 (-0.8)	22 (0.9)
R11	1125 (44.3)	328 (12.9)	-1005 (-39.6)	1115 (43.9)	328 (12.9)	-1022 (-40.2)	-10 (-0.4)	0 (0)	-17 (-0.7)	20 (0.8)
R12	1113 (43.8)	454 (17.9)	-997 (-39.3)	1107 (43.6)	455 (17.9)	-1014 (-39.9)	-6 (-0.2)	1 (0)	-17 (-0.7)	18 (0.7)
R13	1037 (40.8)	107 (4.2)	-1017 (-40)	1028 (40.5)	106 (4.2)	-1035 (-40.7)	-10 (-0.4)	-1 (0)	-17 (-0.7)	20 (0.8)
R14	1032 (40.6)	183 (7.2)	-1016 (-40)	1022 (40.3)	184 (7.2)	-1034 (-40.7)	-9 (-0.4)	1 (0)	-19 (-0.7)	21 (0.8)
R15	1033 (40.7)	324 (12.8)	-1013 (-39.9)	1023 (40.3)	325 (12.8)	-1033 (-40.7)	-10 (-0.4)	1 (0)	-20 (-0.8)	23 (0.9)
R16	1025 (40.3)	448 (17.6)	-1004 (-39.5)	1015 (39.9)	448 (17.6)	-1025 (-40.4)	-10 (-0.4)	0 (0)	-21 (-0.8)	24 (0.9)

Windshield Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
W1	1525 (60)	123 (4.8)	-899 (-35.4)	1520 (59.8)	126 (4.9)	-919 (-36.2)	-5 (-0.2)	3 (0.1)	-20 (-0.8)	21 (0.8)
W2	1519 (59.8)	296 (11.6)	-894 (-35.2)	1518 (59.8)	300 (11.8)	-927 (-36.5)	-1 (0)	4 (0.2)	-32 (-1.3)	33 (1.3)
W3	1496 (58.9)	470 (18.5)	-891 (-35.1)	1494 (58.8)	475 (18.7)	-935 (-36.8)	-2 (-0.1)	6 (0.2)	-45 (-1.8)	45 (1.8)
W4	1621 (63.8)	119 (4.7)	-854 (-33.6)	1624 (64)	119 (4.7)	-864 (-34)	3 (0.1)	0 (0)	-10 (-0.4)	10 (0.4)
W5	1617 (63.6)	309 (12.2)	-849 (-33.4)	1614 (63.5)	314 (12.4)	-877 (-34.5)	-2 (-0.1)	5 (0.2)	-28 (-1.1)	29 (1.1)
W6	1596 (62.8)	500 (19.7)	-845 (-33.3)	1599 (63)	506 (19.9)	-890 (-35)	3 (0.1)	6 (0.2)	-45 (-1.8)	45 (1.8)
W7	1760 (69.3)	114 (4.5)	-787 (-31)	1759 (69.3)	113 (4.4)	-801 (-31.5)	-1 (0)	-1 (0)	-14 (-0.6)	14 (0.6)
W8	1764 (69.5)	310 (12.2)	-776 (-30.5)	1762 (69.4)	312 (12.3)	-795 (-31.3)	-2 (-0.1)	2 (0.1)	-20 (-0.8)	20 (0.8)
W9	1736 (68.3)	519 (20.5)	-773 (-30.4)	1735 (68.3)	526 (20.7)	-810 (-31.9)	-1 (0)	7 (0.3)	-37 (-1.4)	37 (1.5)
W10	1921 (75.6)	116 (4.6)	-705 (-27.8)	1925 (75.8)	114 (4.5)	-719 (-28.3)	4 (0.2)	-2 (-0.1)	-14 (-0.6)	15 (0.6)
W11	1909 (75.2)	299 (11.8)	-701 (-27.6)	1919 (75.5)	298 (11.7)	-717 (-28.2)	9 (0.4)	-1 (-0.1)	-16 (-0.6)	18 (0.7)
W12	1885 (74.2)	533 (21)	-687 (-27.1)	1900 (74.8)	536 (21.1)	-737 (-29)	15 (0.6)	2 (0.1)	-50 (-1.9)	52 (2)

Dashboard Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
D1	1614 (63.5)	215 (8.5)	-505 (-19.9)	1605 (63.2)	166 (6.5)	-554 (-21.8)	-9 (-0.4)	-49 (-1.9)	-49 (-1.9)	70 (2.8)
D2	1611 (63.4)	325 (12.8)	-510 (-20.1)	1598 (62.9)	274 (10.8)	-565 (-22.2)	-13 (-0.5)	-51 (-2)	-55 (-2.1)	76 (3)
D3	1618 (63.7)	440 (17.3)	-509 (-20)	1600 (63)	390 (15.3)	-568 (-22.3)	-18 (-0.7)	-51 (-2)	-59 (-2.3)	80 (3.1)
D4	1633 (64.3)	547 (21.6)	-505 (-19.9)	1611 (63.4)	498 (19.6)	-566 (-22.3)	-21 (-0.8)	-49 (-1.9)	-61 (-2.4)	82 (3.2)

A and B Pillar Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
P1	708 (27.9)	587 (23.1)	-844 (-33.2)	696 (27.4)	581 (22.9)	-852 (-33.5)	-12 (-0.5)	-6 (-0.2)	-8 (-0.3)	16 (0.6)
P2	750 (29.5)	632 (24.9)	-737 (-29)	745 (29.3)	627 (24.7)	-748 (-29.5)	-5 (-0.2)	-5 (-0.2)	-11 (-0.4)	13 (0.5)
P3	779 (30.7)	680 (26.8)	-583 (-23)	772 (30.4)	677 (26.7)	-592 (-23.3)	-7 (-0.3)	-2 (-0.1)	-9 (-0.4)	12 (0.5)
P4	809 (31.8)	693 (27.3)	-417 (-16.4)	805 (31.7)	691 (27.2)	-426 (-16.8)	-4 (-0.2)	-2 (-0.1)	-9 (-0.3)	10 (0.4)
P5	860 (33.9)	694 (27.3)	-272 (-10.7)	857 (33.7)	692 (27.3)	-281 (-11)	-3 (-0.1)	-2 (-0.1)	-9 (-0.4)	10 (0.4)
P6	943 (37.1)	711 (28)	-36 (-1.4)	940 (37)	709 (27.9)	-45 (-1.8)	-3 (-0.1)	-2 (-0.1)	-10 (-0.4)	11 (0.4)
P7	1785 (70.3)	671 (26.4)	-668 (-26.3)	1776 (69.9)	635 (25)	-726 (-28.6)	-8 (-0.3)	-36 (-1.4)	-58 (-2.3)	69 (2.7)
P8	1587 (62.5)	643 (25.3)	-767 (-30.2)	1593 (62.7)	654 (25.7)	-827 (-32.5)	7 (0.3)	11 (0.5)	-59 (-2.3)	61 (2.4)
P9	1464 (57.6)	614 (24.2)	-833 (-32.8)	1466 (57.7)	619 (24.4)	-885 (-34.8)	2 (0.1)	6 (0.2)	-51 (-2)	52 (2)

Table 10-13 Test 4-10 Pre, Post Interior and Deformation Measurement Page 2

Attachment 5.5 --- Interior Vehicle Measurement Report

Vehicle Type	1100C	Test Number	110MASH4C21-01
Make	Versa Sedan	Model	Nissan
Year	2015	Color	White
VIN #	3N1CN7AP9FL820434		

Above Seat Front Side Door Area Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
A1	1592 (62.7)	703 (27.7)	-488 (-19.2)	1547 (60.9)	659 (26)	-519 (-20.4)	-45 (-1.8)	-44 (-1.7)	-31 (-1.2)	70 (2.8)
A2	1469 (57.8)	709 (27.9)	-494 (-19.5)	1422 (56)	685 (27)	-531 (-20.9)	-47 (-1.8)	-24 (-1)	-37 (-1.5)	64 (2.5)
A3	1274 (50.2)	709 (27.9)	-496 (-19.5)	1230 (48.4)	716 (28.2)	-537 (-21.1)	-44 (-1.7)	7 (0.3)	-41 (-1.6)	61 (2.4)
A4	1095 (43.1)	702 (27.6)	-494 (-19.5)	1055 (41.5)	735 (28.9)	-533 (-21)	-41 (-1.6)	33 (1.3)	-39 (-1.5)	65 (2.6)
A5	930 (36.6)	693 (27.3)	-497 (-19.6)	888 (35)	743 (29.2)	-538 (-21.2)	-42 (-1.7)	50 (2)	-41 (-1.6)	77 (3)

Below Seat Front Side Door Area Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
B1	1625 (66.3)	681 (27.8)	2 (0.1)	1567 (63.9)	640 (26.1)	-33 (-1.4)	-58 (-2.4)	-41 (-1.7)	-36 (-1.5)	80 (3.2)
B2	1486 (60.6)	681 (27.8)	7 (0.3)	1439 (58.7)	691 (28.2)	-28 (-1.1)	-46 (-1.9)	10 (0.4)	-35 (-1.4)	59 (2.4)
B3	1326 (54.1)	681 (27.8)	18 (0.7)	1282 (52.3)	710 (29)	-24 (-1)	-44 (-1.8)	29 (1.2)	-42 (-1.7)	68 (2.8)
B4	1153 (47.1)	682 (27.8)	28 (1.1)	1115 (45.5)	744 (30.4)	-12 (-0.5)	-38 (-1.6)	62 (2.5)	-40 (-1.6)	83 (3.4)

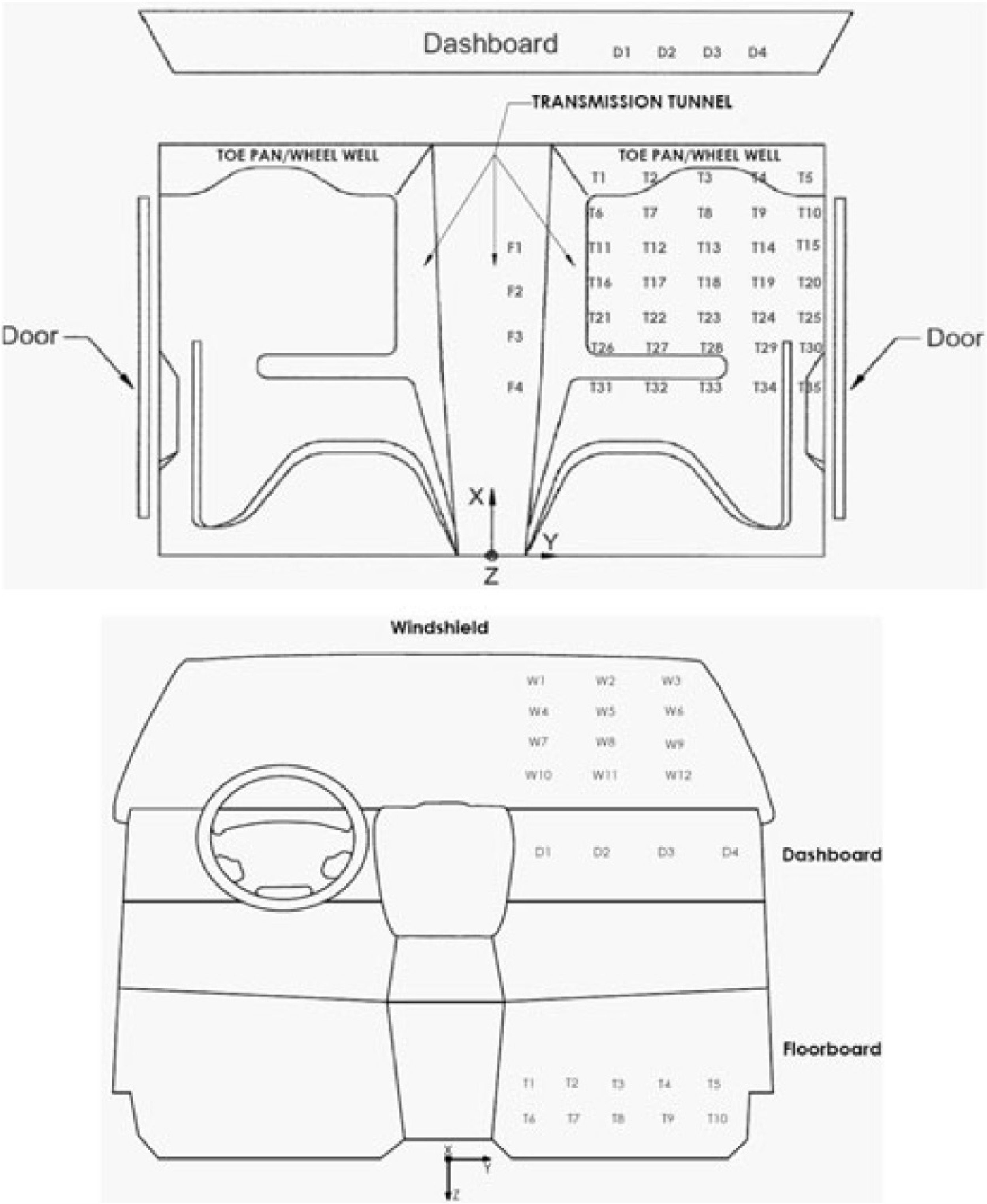


Figure 10-17 Schematic of Measured Interior Points for Floorboard, Dashboard, Windshield, Toe Pan, Wheel Well and Transmission Tunnel

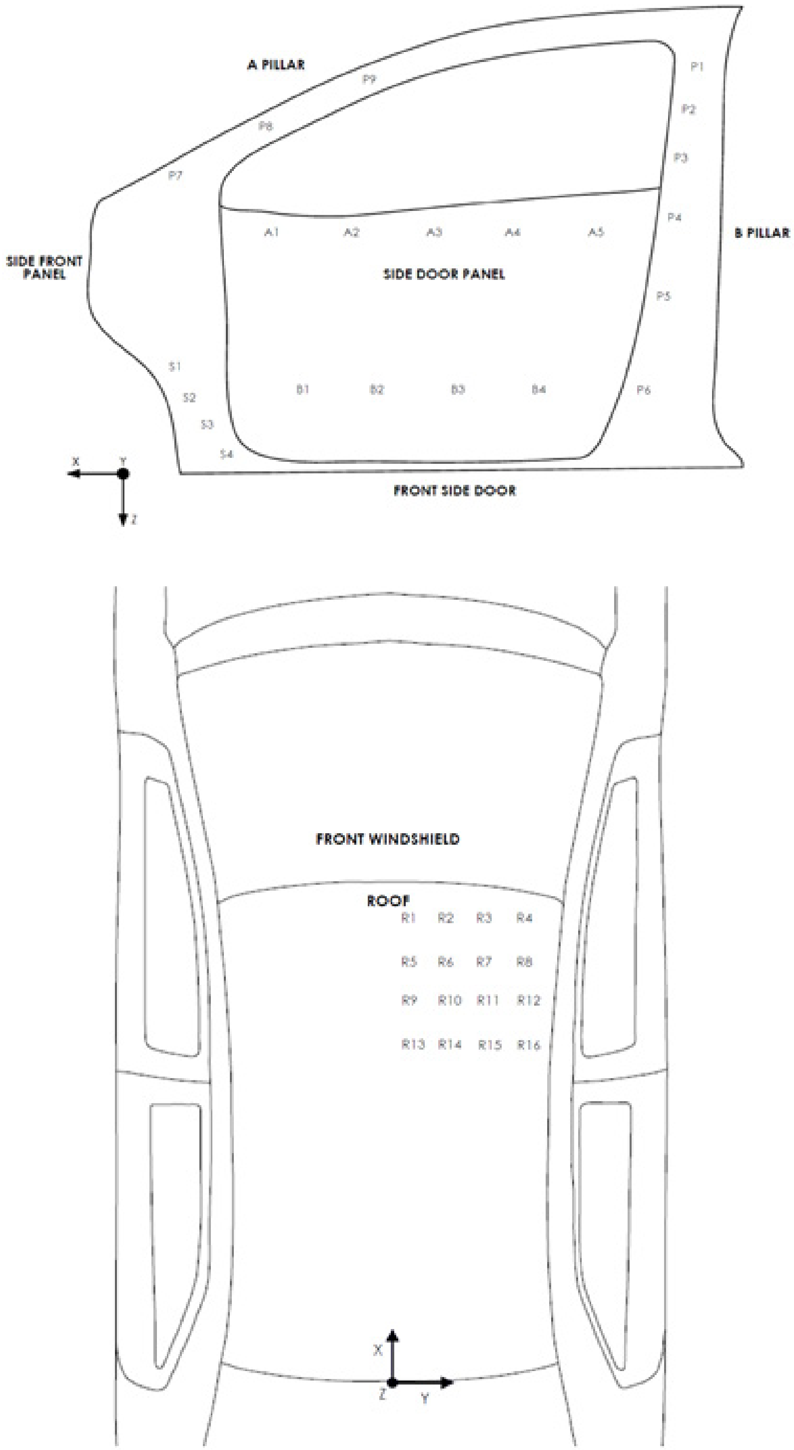


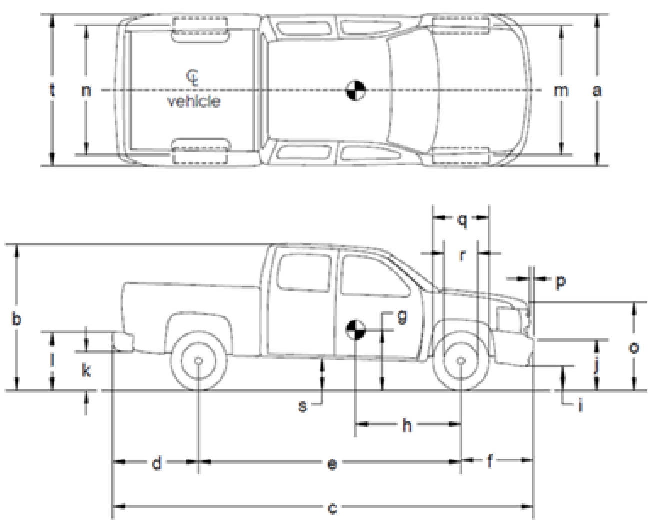
Figure 10-18 Schematic of Measured Points for the A Pillar, B Pillar, Side Front Door Panel, Side Door Panel, Front Side Door and Roof

10.6.2. Test 110MASH4P21-02

Table 10-14 Test 4-11 Exterior Vehicle Measurements

Date:	7/8/2021	Test Number:	110MASH4P21-02	Model:	Dodge
Make:	Ram 1500	VIN:	1C6RR6FG3JS290753		
Tire Size:	P265/70R17	Year:	2018	Odometer:	281.8
Tire Inflation Pressure:	40	Tape Measure Used:	5m-CP01 & 5m-CP03	CLE:**	DRISI 1803
Measured by:	Chris C & David S	Staff:	David W	Scale Set Used:	2500

*(All Measurements Refer to Impacting Side)



Vehicle Geometry - mm (inches)

a	1968	(77.48)	b	1926	(75.83)
c*	5823	(229.25)	d	1227	(48.31)
e	3572	(140.63)	f	1022	(40.24)
g	737	(29)	h	1623	(63.9)
i	330	(12.99)	j	687	(27.05)
k	525	(20.67)	l	780	(30.71)
m	1730	(68.11)	n	1710	(67.32)
o	1184	(46.61)	p	100	(3.94)
q	795	(31.3)	r	467	(18.39)
s	355	(13.98)	t	1969	(77.52)

Wheel Center Height Front:	384	(15.12)
Wheel Center Height Rear:	384	(15.12)
Wheel Well Clearance (F)	117	(4.61)
Wheel Well Clearance (R)	180	(7.09)
Frame Height (F):	249	(9.8)
Frame Height (R):	521	(20.51)
Engine Type:	gasoline	
Engine Size:	3.6L	

Transmission Type:

Automatic or Manual: Automatic

FWD or RWD or 4WD: RWD

Mass Distribution - kg (lbs)

** CLE is the inventory number and should be located on the door jamb of the vehicle.

* Note: measured with 100ft-QD01 19' 1-2/8" (5823mm)

Left Front:	603.55	(1330.58)	Scale:	red	Right Front:	616.25	(1358.58)	Scale:	green
Left Rear:	526.4	(1160.49)	Scale:	yellow	Right Rear:	489.25	(1078.59)	Scale:	blue

Weights

kg (lbs)	Curb		Test Inertial		Gross Static	
W_{front}	1219.65	(2688.82)	1219.8	(2689.15)	1219.8	(2689.15)
W_{rear}	954	(2103.17)	1015.65	(2239.09)	1015.65	(2239.09)
W_{total}	2173.65	(4792)	2235.45	(4928.24)	2235.45	(4928.24)

GAWR and GVWR Ratings - kg (lbs)

Front:	1679	(3701.5)
Back:	1770	(3902.12)
Total:	3085	(6801.15)

Dummy Data

Type:	N/A
Mass:	N/A
Seat Position:	N/A

Note any damage prior to test: New, no damage.

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Transfer Checked by:	Victor O. Lopez	Date:	3/9/2022

Table 10-15 Test 4-11 CG Calculation: Curb Weight

Attachment 5.4.2 --- CG Data Calculation Worksheet

CG Calculation Worksheet #1: **Curb Weight**

Make:	Dodge	Test Number:	110MASH4P21-02
Model:	Ram 1500	Date:	7/7/2021
Year:	2018	Temperature:	77 °F
VIN:	1C6RR6FG3JS290753	Scale Set Used:	2500
Fuel in Tank:	1/4 tank		
Fuel Removed:	none		
Measured By:	Chris C		
	David W		
Support Staff	David S		

W1 = Left Front (LF) = 599.85 kg
Scale Used: red

W2 = Right Front (RF) = 619.8 kg
Scale Used: green

W3 = Left Rear (LR) = 500.5 kg
Scale Used: yellow

W4 = Right Rear (RR) = 453.5 kg
Scale Used: blue

Total Weight:
Wtotal (measured) = 2173.85 kg

Wtotal (calculated) = 2173.65 kg

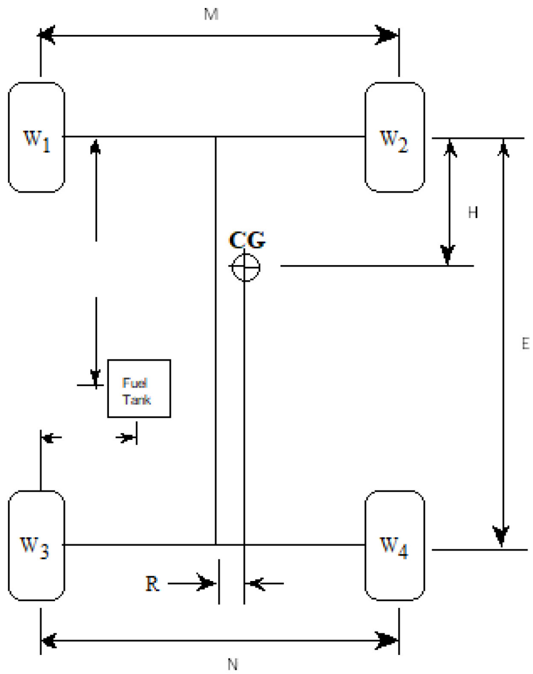
Distance between front wheels:
M = 1730 mm

Distance between rear wheels:
N = 1710 mm

Distance from front to rear wheels:
E = 3572 mm

Distance from front wheels back to CG:
H = 1568 mm

Distance from vehicle centerline to CG:
R = -11 mm



$$W_{Total} = W_1 + W_2 + W_3 + W_4$$

$$H = \frac{(W_3 + W_4)E}{W_{Total}}$$

$$R = \frac{(W_2 - W_1)M + (W_4 - W_3)N}{2W_{Total}}$$

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Christopher Caldwell		Date:	7/8/2021
Transfer Checked by:			
Victor Lopez		Date:	6/16/2022

If R is negative the CG is left of center, if R is positive the CG is right of center

Curb Weight Conditions: (vehicle condition, items removed, items added, environmental conditions, etc.)
New Vehicle

Table 10-16 Test 4-11 CG Calculation: Test Inertial Weight

CG Calculation Worksheet #2: **Test Inertial Weight**

Make:	Dodge	Test Number:	110MASH4P21-02
Model:	Ram 1500	Date:	8/3/2021
Year:	2018	Temperature:	76°F
VIN:	1C6RR6FG3JS290753	Scale Set Used:	2500
Fuel in Tank:	none		
Fuel Removed:	8 gal.		
Measured By:	Chris C		
	Steve W		
Support Staff			

W1 = Left Front (LF) = 603.55 kg
Scale Used: red

W2 = Right Front (RF) = 616.25 kg
Scale Used: green

W3 = Left Rear (LR) = 526.4 kg
Scale Used: yellow

W4 = Right Rear (RR) = 489.25 kg
Scale Used: blue

Total Weight:
Wtotal (measured) = 2235.75 kg

Wtotal (calculated) = 2235.45 kg

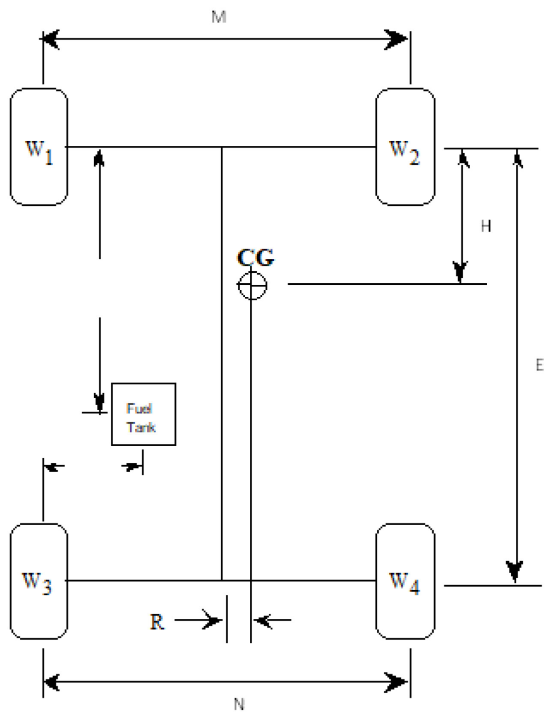
Distance between front wheels:
M = 1730 mm

Distance between rear wheels:
N = 1710 mm

Distance from front to rear wheels:
E = 3572 mm

Distance from front wheels back to CG:
H = 1623 mm

Distance from vehicle centerline to CG:
R = -9 mm



$$W_{Total} = W_1 + W_2 + W_3 + W_4$$

$$H = \frac{(W_3 + W_4)E}{W_{Total}}$$

$$R = \frac{(W_2 - W_1)M + (W_4 - W_3)N}{2W_{Total}}$$

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Transfer Checked by:	Victor Lopez	Date:	6/16/2022

If R is negative the CG is left of center, if R is positive the CG is right of center

Test Inertial Weight Conditions: (vehicle condition, items removed, items added, environmental conditions, etc.)
Equipment installed. Spare tire was not removed. 8 gal. fuel removed from tank and 2.5 gal added to fuel cell.
Ballest: 2 steel plates each weighing 16.5 kg (36.5 lbs)

Table 10-17 Test 4-11 CG Calculation: Gross Static Weight

CG Calculation Worksheet #3: **Gross Static Weight**

Make:	Dodge	Test Number:	110MASH4P21-02
Model:	Ram 1500	Date:	
Year:	2018	Temperature:	
VIN:	1C6RR6FG3JS290753	Scale Set Used:	
Fuel in Tank:			
Fuel Removed:			
Measured By:			
Support Staff			

Same as Test Inertial Weight

W1 = Left Front (LF) = ______ kg
Scale Used: ______

W2 = Right Front (RF) = ______ kg
Scale Used: ______

W3 = Left Rear (LR) = ______ kg
Scale Used: ______

W4 = Right Rear (RR) = ______ kg
Scale Used: ______

Total Weight:
Wtotal (measured) = ______ kg
Wtotal (calculated) = ______ kg

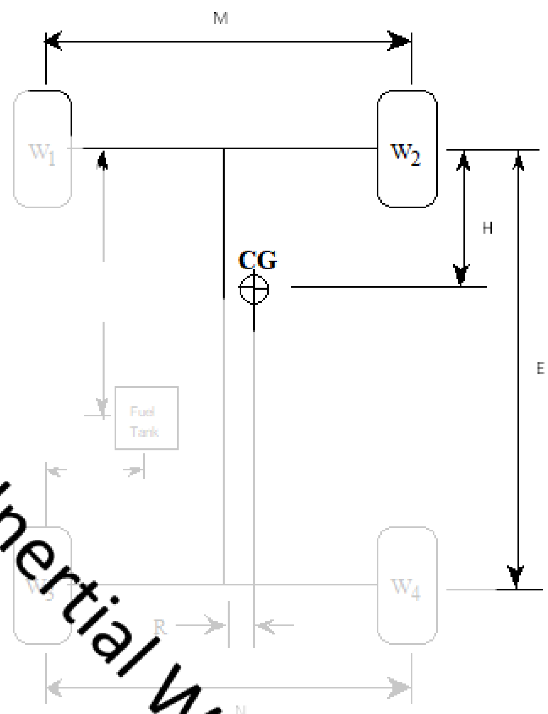
Distance between front wheels:
M = 1730 mm

Distance between rear wheels:
N = 1710 mm

Distance from front to rear wheels:
E = 3572 mm

Distance from front wheels back to CG:
H = #DIV/0! mm

Distance from vehicle centerline to CG:
R = #DIV/0! mm



$$W_{Total} = W_1 + W_2 + W_3 + W_4$$

$$H = \frac{(W_3 + W_4)E}{W_{Total}}$$

$$R = \frac{(W_2 - W_1)M + (W_4 - W_3)N}{2W_{Total}}$$

Data Transferred to Electronic Copy By:	Date:
Transfer Checked by:	Date:

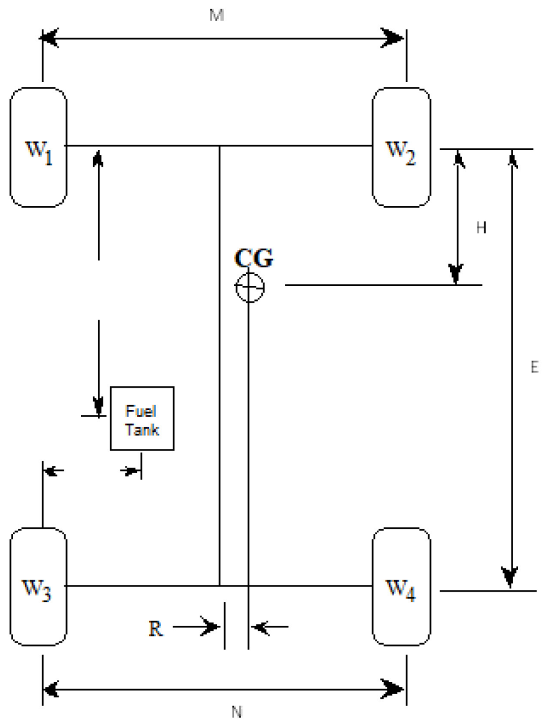
If R is negative the CG is left of center, if R is positive the CG is right of center

Gross Static Weight Conditions: (vehicle condition, items removed, items added, environmental conditions, etc.)

Table 10-18 Test 4-11 CG Calculation: Vertical CG Weight

CG Calculation Worksheet #4: **Vertical CG Weight**

Make:	Dodge	Test Number:	110MASH4P21-02
Model:	Ram 1500	Date:	7/28/2021
Year:	2018	Temperature:	76°F
VIN:	1C6RR6FG3JS290753	Scale Set Used:	2500
Fuel in Tank:	none		
Fuel Removed:	none		
Measured By:	Chris C		
	David W		
Support Staff	Steve W		



W1 = Left Front (LF) = 614 kg
Scale Used: red

W2 = Right Front (RF) = 619 kg
Scale Used: green

W3 = Left Rear (LR) = 528.55 kg
Scale Used: yellow

W4 = Right Rear (RR) = 500.8 kg
Scale Used: blue

Total Weight:
Wtotal (measured) = 2262.45 kg

Wtotal (calculated) = 2262.35 kg

Distance between front wheels:
M = 1730 mm

Distance between rear wheels:
N = 1710 mm

Distance from front to rear wheels:
E = 3572 mm

Distance from front wheels back to CG:
H = 1625 mm

Distance from vehicle centerline to CG:
R = -9 mm

$$W_{Total} = W_1 + W_2 + W_3 + W_4$$

$$H = \frac{(W_3 + W_4)E}{W_{Total}}$$

$$R = \frac{(W_2 - W_1)M + (W_4 - W_3)N}{2W_{Total}}$$

Data Transferred to Electronic Copy By:			
Christopher Caldwell		Date:	7/28/2021
Transfer Checked by:			
Victor Lopez		Date:	6/16/2022

If R is negative the CG is left of center, if R is positive the CG is right of center

Gross Static Weight Conditions: (vehicle condition, items removed, items added, environmental conditions, etc.)
Modified for vertical CG measurement.

Table 10-19 Test 4-11 Vertical CG Calculation: Worksheet

Vehicle Information

Year:	2018	Model:	Ram 1500
Make:	Dodge	VIN:	1C6RRFG3JS290753
Curb or Inertial Measurement:	Inertial	Test #:	110MASH4P21-02
Tape Measure Used:	5m-CP03	Scale Set Used:	2500

Vehicle and Equipment Measurements

Vehicle Mass and Measurements (From CG Worksheet):

Hub to Hub Wheel Base:	3572	mm	Vehicle Width (Ave of Center of Tires)	1720	mm
Cgy Offset (-Driver side, +Pass. Side):	-9	mm	Total Vehicle Mass:	2262.35	kg
Dvr. Front Tire Mass:	614	kg	Dvr. Rear Tire Mass:	528.55	kg
Scale Color:	red		Scale Color:	yellow	
Pass. Front Tire Mass:	619	kg	Pass. Rear Tire Mass:	500.8	kg
Scale Color:	green		Scale Color:	blue	

Vehicle Height From the Top of the Rim Inner Lip to the Bottom of the Wheel Well:

Driver Front:	300	mm	Driver Rear:	349	mm
Passenger Front:	307	mm	Passenger Rear:	360	mm

Height From Ground to Center of Support:

Driver Front:	450	mm	Driver Rear:	455	mm
Passenger Front:	485	mm	Passenger Rear:	455	mm

Shock Mass:

Driver Front:	2.15	kg	Passenger Front:	2.2	kg
Scale Color:	blue		Scale Color:	blue	

Height From Ground to Center of Wheel Hub:

Driver Front:	384	mm	Driver Rear:	384	mm
Passenger Front:	384	mm	Passenger Rear:	384	mm

Table 10-20 Test 4-11 Vertical CG Calculation: Worksheet (continued)

RSRG Vertical Center of Gravity Worksheet (Cont.)

Vertical Center of Gravity Measurement

Number of Used Chain Links:

Vehicle Level:					
Front:	51	links	Rear:	59	links
Vehicle Front Up:			Angle:	16	degrees
Front:	45	links	Rear:	70	links
Vehicle Rear Up:			Angle:	19	degrees
Front:	60	links	Rear:	49	links
Driver Side CGz:			**Passenger Side CGz:**		
Maximum:	748	mm	Maximum:	746	mm
Middle:	743	mm	Middle:	742	mm
Minimum:	738	mm	Minimum:	739	mm
Width:	2	mm	Width:	1	mm

Conducted by:	Christopher Caldwell	Date:	7/28/2021
Transferred to electronic copy by:	Christopher Caldwell	Date:	7/28/2021
Checked by:	Victor Lopez	Date:	6/16/2022

Table 10-21 Test 4-11 Vertical CG Calculation: Measurement and Report

Vehicle Center of Gravity Measurements

Project Title: MASH 2016 Compliance of Roadside Safety Features (Develop MASH bridge railing that satisfies State and Federal historic preservation requirements [Type 86H Bridge Rail])

Vehicle Test Number:	110MASH4P2021-02	Model:	Ram 1500
Make:	Dodge	Year:	2018
VIN:	1C6RR6FG3JS290753		

Vehicle Weights (Test Inertail):

Left Front Tire:	603.6 kg	Right Front Tire:	616.3 kg	Front Axle:	1219.8 kg
Left Rear Tire:	526.4 kg	Right Rear tire:	489.3 kg	Rear Axle:	1015.7 kg
Ballast and Location:	33 kg steel plates in the truck bed against the passenger cab along the center line.			Total:	2235.5 kg

Vehicle Wheel Base Measurements:

Vehicle length from center of front tires to center of back tires:	3572.0	mm
Vehicle width from center of left front tire to center of right front tire:	1730.0	mm
Vehicle width from center of left rear tire to center of right rear tire:	1710.0	mm

Center of Gravity:

X:	1623.0	mm	Center of front tire to CG.
Y:	-9.0	mm	The CG will be left if negative and right if positive of vehicle's center line.
Z:	738.0	mm	CG location above ground level

Table 10-22 Test 4-11 Pre, Post Interior and Deformation Measurement Page 1

Vehicle Type	2200P	Test Number	110MASH4P21-02
Make	Dodge	Model	Ram 1500
Year	2018	Color	White
VIN #	1C6RR6FG3JS290753		

Transmission Tunnel and Floor Pan Area Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
T1	1652 (65)	104 (4.1)	-16 (-0.6)	1647 (64.9)	105 (4.1)	-18 (-0.7)	-4 (-0.2)	1 (0)	-2 (-0.1)	5 (0.2)
T2	1657 (65.2)	187 (7.4)	-14 (-0.5)	1652 (65)	187 (7.4)	-20 (-0.8)	-5 (-0.2)	0 (0)	-7 (-0.3)	8 (0.3)
T3	1688 (66.4)	268 (10.5)	12 (0.5)	1681 (66.2)	249 (9.8)	12 (0.5)	-6 (-0.3)	-19 (-0.7)	1 (0)	20 (0.8)
T4	1602 (63.1)	105 (4.1)	-8 (-0.3)	1596 (62.8)	102 (4)	-12 (-0.5)	-6 (-0.2)	-2 (-0.1)	-4 (-0.1)	7 (0.3)
T5	1615 (63.6)	188 (7.4)	-8 (-0.3)	1610 (63.4)	189 (7.5)	-17 (-0.7)	-5 (-0.2)	1 (0)	-9 (-0.4)	11 (0.4)
T6	1621 (63.8)	261 (10.3)	36 (1.4)	1616 (63.6)	251 (9.9)	30 (1.2)	-5 (-0.2)	-11 (-0.4)	-6 (-0.2)	13 (0.5)
T7	1528 (60.2)	111 (4.4)	6 (0.2)	1524 (60)	113 (4.4)	3 (0.1)	-5 (-0.2)	2 (0.1)	-3 (-0.1)	6 (0.2)
T8	1538 (60.5)	188 (7.4)	4 (0.2)	1532 (60.3)	190 (7.5)	-3 (-0.1)	-5 (-0.2)	2 (0.1)	-8 (-0.3)	9 (0.4)
T9	1538 (60.5)	263 (10.3)	46 (1.8)	1532 (60.3)	261 (10.3)	36 (1.4)	-5 (-0.2)	-2 (-0.1)	-11 (-0.4)	12 (0.5)
T10	1422 (56)	103 (4.1)	13 (0.5)	1418 (55.8)	102 (4)	6 (0.3)	-4 (-0.2)	-2 (-0.1)	-6 (-0.3)	8 (0.3)
T11	1427 (56.2)	189 (7.4)	20 (0.8)	1421 (56)	192 (7.6)	12 (0.5)	-6 (-0.2)	3 (0.1)	-9 (-0.4)	11 (0.4)
T12	1428 (56.2)	265 (10.4)	57 (2.2)	1420 (55.9)	267 (10.5)	40 (1.6)	-8 (-0.3)	2 (0.1)	-16 (-0.6)	18 (0.7)

Foot/Wheel Well and Toe Pan Area Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
F1	2052 (80.8)	498 (19.6)	-52 (-2.1)	2048 (80.6)	489 (19.3)	-39 (-1.5)	-5 (-0.2)	-8 (-0.3)	13 (0.5)	17 (0.7)
F2	2084 (82.1)	560 (22)	-44 (-1.7)	2084 (82)	542 (21.4)	-20 (-0.8)	-1 (0)	-18 (-0.7)	24 (0.9)	30 (1.2)
F3	2085 (82.1)	617 (24.3)	-43 (-1.7)	2079 (81.9)	600 (23.6)	-21 (-0.8)	-6 (-0.2)	-17 (-0.7)	23 (0.9)	29 (1.2)
F4	2077 (81.8)	699 (27.5)	-68 (-2.7)	2058 (81)	677 (26.7)	-46 (-1.8)	-18 (-0.7)	-21 (-0.8)	22 (0.8)	35 (1.4)
F5	2065 (81.3)	735 (28.9)	-84 (-3.3)	2032 (80)	688 (27.1)	-74 (-2.9)	-33 (-1.3)	-46 (-1.8)	10 (0.4)	58 (2.3)
F6	2043 (80.4)	782 (30.8)	-95 (-3.7)	1989 (78.3)	696 (27.4)	-100 (-3.9)	-54 (-2.1)	-87 (-3.4)	-4 (-0.2)	102 (4)
F7	2042 (80.4)	820 (32.3)	-117 (-4.6)	1971 (77.6)	719 (28.3)	-134 (-5.3)	-71 (-2.8)	-101 (-4)	-17 (-0.7)	125 (4.9)
F8	2043 (80.4)	498 (19.6)	-11 (-0.4)	2036 (80.1)	483 (19)	4 (0.2)	-7 (-0.3)	-15 (-0.6)	16 (0.6)	23 (0.9)
F9	2066 (81.3)	532 (20.9)	-4 (-0.2)	2062 (81.2)	513 (20.2)	17 (0.7)	-4 (-0.2)	-19 (-0.8)	21 (0.8)	29 (1.1)
F10	2074 (81.6)	566 (22.3)	-4 (-0.2)	2069 (81.4)	546 (21.5)	19 (0.7)	-5 (-0.2)	-20 (-0.8)	23 (0.9)	31 (1.2)
F11	2076 (81.7)	625 (24.6)	-4 (-0.2)	2067 (81.4)	606 (23.9)	19 (0.8)	-9 (-0.4)	-19 (-0.8)	23 (0.9)	31 (1.2)
F12	2069 (81.5)	653 (25.7)	-16 (-0.6)	2057 (81)	632 (24.9)	7 (0.3)	-12 (-0.5)	-21 (-0.8)	23 (0.9)	33 (1.3)
F13	2041 (80.3)	708 (27.9)	-26 (-1)	2019 (79.5)	680 (26.8)	-7 (-0.3)	-22 (-0.9)	-28 (-1.1)	19 (0.8)	40 (1.6)
F14	2029 (79.9)	743 (29.2)	-47 (-1.9)	1995 (78.5)	680 (26.8)	-39 (-1.6)	-34 (-1.3)	-63 (-2.5)	8 (0.3)	72 (2.8)
F15	2022 (79.6)	783 (30.8)	-61 (-2.4)	1966 (77.4)	696 (27.4)	-67 (-2.6)	-56 (-2.2)	-87 (-3.4)	-6 (-0.2)	104 (4.1)
F16	2017 (79.4)	827 (32.6)	-72 (-2.8)	1953 (76.9)	725 (28.5)	-86 (-3.4)	-64 (-2.5)	-102 (-4)	-14 (-0.5)	121 (4.8)
F17	2019 (79.5)	496 (19.5)	14 (0.6)	2011 (79.2)	476 (18.7)	30 (1.2)	-8 (-0.3)	-19 (-0.8)	15 (0.6)	26 (1)
F18	2033 (80.1)	538 (21.2)	27 (1.1)	2028 (79.8)	515 (20.3)	49 (1.9)	-6 (-0.2)	-23 (-0.9)	22 (0.9)	32 (1.3)
F19	2034 (80.1)	567 (22.3)	27 (1.1)	2028 (79.8)	544 (21.4)	50 (2)	-7 (-0.3)	-23 (-0.9)	22 (0.9)	33 (1.3)
F20	2037 (80.2)	621 (24.4)	26 (1)	2028 (79.8)	598 (23.6)	50 (2)	-9 (-0.4)	-22 (-0.9)	24 (0.9)	34 (1.3)
F21	2035 (80.1)	668 (26.3)	20 (0.8)	2022 (79.6)	644 (25.4)	43 (1.7)	-13 (-0.5)	-24 (-0.9)	23 (0.9)	36 (1.4)
F22	2012 (79.2)	715 (28.2)	12 (0.5)	1988 (78.3)	678 (26.7)	26 (1)	-24 (-0.9)	-38 (-1.5)	14 (0.6)	47 (1.8)
F23	1997 (78.6)	753 (29.6)	8 (0.3)	1951 (76.8)	680 (26.8)	9 (0.3)	-46 (-1.8)	-72 (-2.9)	1 (0.1)	86 (3.4)
F24	1990 (78.3)	786 (31)	-2 (-0.1)	1929 (76)	700 (27.5)	-12 (-0.5)	-61 (-2.4)	-87 (-3.4)	-10 (-0.4)	106 (4.2)
F25	1984 (78.1)	829 (32.7)	-2 (-0.1)	1921 (75.6)	734 (28.9)	-18 (-0.7)	-63 (-2.5)	-95 (-3.7)	-17 (-0.7)	116 (4.6)
F26	2015 (79.3)	748 (29.5)	-24 (-0.9)	1974 (77.7)	681 (26.8)	-21 (-0.8)	-40 (-1.6)	-67 (-2.6)	3 (0.1)	78 (3.1)
F27	2002 (78.8)	789 (31.1)	-29 (-1.2)	1941 (76.4)	700 (27.6)	-41 (-1.6)	-61 (-2.4)	-89 (-3.5)	-11 (-0.4)	108 (4.3)
F28	1999 (78.7)	827 (32.6)	-36 (-1.4)	1937 (76.3)	728 (28.7)	-51 (-2)	-62 (-2.4)	-100 (-3.9)	-15 (-0.6)	118 (4.7)
F29	1987 (78.2)	497 (19.6)	37 (1.5)	1979 (77.9)	475 (18.7)	53 (2.1)	-7 (-0.3)	-22 (-0.9)	16 (0.6)	29 (1.1)
F30	1993 (78.5)	540 (21.2)	52 (2)	1987 (78.2)	516 (20.3)	72 (2.9)	-6 (-0.2)	-24 (-0.9)	21 (0.8)	32 (1.3)
F31	1997 (78.6)	568 (22.3)	49 (1.9)	1990 (78.3)	543 (21.4)	70 (2.7)	-8 (-0.3)	-24 (-1)	20 (0.8)	33 (1.3)
F32	2003 (78.9)	619 (24.4)	47 (1.8)	1991 (78.4)	596 (23.5)	62 (2.4)	-12 (-0.5)	-24 (-0.9)	15 (0.6)	30 (1.2)
F33	2005 (79)	675 (26.6)	47 (1.8)	1994 (78.5)	650 (25.6)	68 (2.7)	-12 (-0.5)	-25 (-1)	21 (0.8)	35 (1.4)
F34	1996 (78.6)	720 (28.4)	39 (1.5)	1966 (77.4)	675 (26.6)	51 (2)	-29 (-1.2)	-45 (-1.8)	12 (0.5)	55 (2.2)
F35	1978 (77.9)	764 (30.1)	39 (1.5)	1924 (75.7)	685 (27)	32 (1.3)	-54 (-2.1)	-80 (-3.1)	-7 (-0.3)	97 (3.8)
F36	1969 (77.5)	831 (32.7)	36 (1.4)	1902 (74.9)	745 (29.3)	17 (0.7)	-67 (-2.6)	-86 (-3.4)	-19 (-0.7)	111 (4.4)
F37	1872 (73.7)	390 (15.4)	-14 (-0.5)	1862 (73.3)	382 (15.1)	-6 (-0.3)	-10 (-0.4)	-8 (-0.3)	8 (0.3)	15 (0.6)

Table 10-23 Test 4-11 Pre, Post Interior and Deformation Measurement Page 2

Vehicle Type	2200P	Test Number	110MASH4P21-02
Make	Dodge	Model	Ram 1500
Year	2018	Color	White
VIN #	1C6RR6FG3JS290753		

Foot/Wheel Well and Toe Pan Area Measurements (Cont.) - Dimensions in mm (inches

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
F38	1894 (74.6)	458 (18)	31 (1.2)	1883 (74.1)	445 (17.5)	45 (1.8)	-10 (-0.4)	-13 (-0.5)	14 (0.6)	22 (0.9)
F39	1931 (76)	499 (19.6)	74 (2.9)	1924 (75.8)	474 (18.7)	94 (3.7)	-6 (-0.3)	-25 (-1)	20 (0.8)	33 (1.3)
F40	1935 (76.2)	554 (21.8)	87 (3.4)	1927 (75.9)	528 (20.8)	106 (4.2)	-8 (-0.3)	-25 (-1)	19 (0.8)	33 (1.3)
F41	1940 (76.4)	622 (24.5)	85 (3.3)	1923 (75.7)	593 (23.4)	91 (3.6)	-17 (-0.7)	-28 (-1.1)	6 (0.2)	34 (1.3)
F42	1964 (77.3)	723 (28.5)	66 (2.6)	1938 (76.3)	668 (26.3)	80 (3.1)	-26 (-1)	-55 (-2.2)	13 (0.5)	62 (2.5)
F43	1938 (76.3)	731 (28.8)	88 (3.5)	1912 (75.3)	673 (26.5)	108 (4.3)	-26 (-1)	-58 (-2.3)	20 (0.8)	67 (2.6)
F44	1958 (77.1)	756 (29.8)	70 (2.8)	1912 (75.3)	685 (27)	72 (2.9)	-46 (-1.8)	-71 (-2.8)	2 (0.1)	85 (3.4)
F45	1942 (76.4)	766 (30.2)	87 (3.4)	1903 (74.9)	703 (27.7)	90 (3.6)	-39 (-1.5)	-63 (-2.5)	3 (0.1)	74 (2.9)
F46	1948 (76.7)	835 (32.9)	82 (3.2)	1908 (75.1)	762 (30)	65 (2.5)	-40 (-1.6)	-73 (-2.9)	-17 (-0.7)	85 (3.3)
F47	1824 (71.8)	383 (15.1)	17 (0.7)	1817 (71.5)	372 (14.6)	24 (0.9)	-7 (-0.3)	-11 (-0.4)	7 (0.3)	14 (0.6)
F48	1835 (72.2)	441 (17.4)	60 (2.4)	1829 (72)	425 (16.7)	75 (2.9)	-6 (-0.2)	-16 (-0.6)	14 (0.6)	23 (0.9)
F49	1870 (73.6)	486 (19.1)	93 (3.6)	1866 (73.5)	463 (18.2)	112 (4.4)	-4 (-0.2)	-23 (-0.9)	20 (0.8)	30 (1.2)
F50	1883 (74.1)	558 (22)	111 (4.4)	1874 (73.8)	532 (20.9)	133 (5.2)	-8 (-0.3)	-26 (-1)	21 (0.8)	35 (1.4)
F51	1883 (74.1)	629 (24.8)	112 (4.4)	1872 (73.7)	603 (23.7)	129 (5.1)	-12 (-0.5)	-26 (-1)	17 (0.7)	33 (1.3)
F52	1909 (75.2)	732 (28.8)	106 (4.2)	1887 (74.3)	685 (27)	124 (4.9)	-22 (-0.9)	-47 (-1.8)	18 (0.7)	55 (2.2)
F53	1909 (75.1)	775 (30.5)	107 (4.2)	1881 (74)	720 (28.3)	119 (4.7)	-28 (-1.1)	-55 (-2.2)	11 (0.4)	63 (2.5)
F54	1907 (75.1)	837 (33)	107 (4.2)	1875 (73.8)	773 (30.4)	96 (3.8)	-32 (-1.3)	-64 (-2.5)	-11 (-0.4)	72 (2.9)
F55	1782 (70.2)	376 (14.8)	48 (1.9)	1776 (69.9)	360 (14.2)	56 (2.2)	-6 (-0.3)	-16 (-0.6)	8 (0.3)	19 (0.7)
F56	1798 (70.8)	428 (16.8)	83 (3.3)	1792 (70.6)	407 (16)	96 (3.8)	-6 (-0.2)	-20 (-0.8)	13 (0.5)	25 (1)
F57	1815 (71.5)	469 (18.5)	133 (5.2)	1809 (71.2)	445 (17.5)	149 (5.9)	-6 (-0.3)	-25 (-1)	16 (0.6)	30 (1.2)
F58	1847 (72.7)	560 (22)	140 (5.5)	1839 (72.4)	533 (21)	160 (6.3)	-9 (-0.3)	-27 (-1.1)	21 (0.8)	35 (1.4)
F59	1842 (72.5)	635 (25)	143 (5.6)	1833 (72.2)	609 (24)	164 (6.4)	-9 (-0.4)	-26 (-1)	20 (0.8)	34 (1.3)
F60	1818 (71.6)	732 (28.8)	153 (6)	1800 (70.9)	702 (27.6)	163 (6.4)	-18 (-0.7)	-30 (-1.2)	10 (0.4)	36 (1.4)
F61	1829 (72)	780 (30.7)	153 (6)	1813 (71.4)	744 (29.3)	175 (6.9)	-16 (-0.6)	-36 (-1.4)	22 (0.9)	45 (1.8)
F62	1825 (71.8)	833 (32.8)	158 (6.2)	1813 (71.4)	793 (31.2)	166 (6.5)	-12 (-0.5)	-40 (-1.6)	8 (0.3)	42 (1.7)
F63	1862 (73.3)	739 (29.1)	127 (5)	1838 (72.4)	705 (27.7)	136 (5.4)	-24 (-0.9)	-34 (-1.3)	10 (0.4)	43 (1.7)
F64	1867 (73.5)	778 (30.6)	132 (5.2)	1845 (72.6)	730 (28.7)	152 (6)	-22 (-0.9)	-48 (-1.9)	20 (0.8)	56 (2.2)
F65	1863 (73.4)	834 (32.8)	137 (5.4)	1843 (72.6)	785 (30.9)	135 (5.3)	-21 (-0.8)	-49 (-1.9)	-2 (-0.1)	53 (2.1)
F66	1750 (68.9)	372 (14.6)	79 (3.1)	1742 (68.6)	350 (13.8)	87 (3.4)	-8 (-0.3)	-22 (-0.9)	7 (0.3)	24 (0.9)
F67	1724 (67.9)	367 (14.5)	115 (4.5)	1716 (67.6)	344 (13.5)	120 (4.7)	-8 (-0.3)	-24 (-0.9)	6 (0.2)	26 (1)
F68	1747 (68.8)	412 (16.2)	140 (5.5)	1738 (68.4)	387 (15.2)	151 (5.9)	-10 (-0.4)	-25 (-1)	10 (0.4)	29 (1.1)
F69	1743 (68.6)	468 (18.4)	165 (6.5)	1732 (68.2)	442 (17.4)	177 (7)	-12 (-0.5)	-25 (-1)	12 (0.5)	30 (1.2)
F70	1800 (70.8)	561 (22.1)	157 (6.2)	1791 (70.5)	536 (21.1)	177 (7)	-8 (-0.3)	-26 (-1)	20 (0.8)	34 (1.3)
F71	1801 (70.9)	635 (25)	157 (6.2)	1793 (70.6)	609 (24)	182 (7.2)	-8 (-0.3)	-26 (-1)	25 (1)	37 (1.4)
F72	1759 (69.2)	559 (22)	167 (6.6)	1749 (68.9)	533 (21)	187 (7.3)	-10 (-0.4)	-26 (-1)	19 (0.8)	34 (1.3)
F73	1768 (69.6)	639 (25.1)	167 (6.6)	1760 (69.3)	613 (24.1)	193 (7.6)	-8 (-0.3)	-25 (-1)	26 (1)	37 (1.5)
F74	1778 (70)	750 (29.5)	171 (6.7)	1771 (69.7)	724 (28.5)	196 (7.7)	-7 (-0.3)	-26 (-1)	25 (1)	37 (1.4)
F75	1779 (70)	784 (30.9)	171 (6.7)	1770 (69.7)	757 (29.8)	191 (7.5)	-9 (-0.4)	-27 (-1.1)	20 (0.8)	35 (1.4)
F76	1783 (70.2)	834 (32.8)	178 (7)	1779 (70)	803 (31.6)	196 (7.7)	-4 (-0.2)	-31 (-1.2)	18 (0.7)	36 (1.4)
F77	1740 (68.5)	750 (29.5)	173 (6.8)	1737 (68.4)	723 (28.5)	210 (8.3)	-3 (-0.1)	-27 (-1.1)	38 (1.5)	46 (1.8)
F78	1745 (68.7)	788 (31)	173 (6.8)	1739 (68.5)	760 (29.9)	206 (8.1)	-5 (-0.2)	-27 (-1.1)	34 (1.3)	44 (1.7)
F79	1748 (68.8)	833 (32.8)	187 (7.4)	1745 (68.7)	807 (31.8)	206 (8.1)	-3 (-0.1)	-27 (-1.1)	18 (0.7)	33 (1.3)
F80	1710 (67.3)	549 (21.6)	162 (6.4)	1700 (66.9)	526 (20.7)	178 (7)	-10 (-0.4)	-23 (-0.9)	16 (0.6)	30 (1.2)
F81	1709 (67.3)	647 (25.5)	163 (6.4)	1701 (67)	623 (24.5)	195 (7.7)	-8 (-0.3)	-25 (-1)	32 (1.3)	41 (1.6)
F82	1672 (65.8)	348 (13.7)	155 (6.1)	1659 (65.3)	323 (12.7)	158 (6.2)	-13 (-0.5)	-24 (-0.9)	3 (0.1)	27 (1.1)
F83	1662 (65.4)	405 (15.9)	171 (6.8)	1652 (65.1)	382 (15.1)	173 (6.8)	-10 (-0.4)	-22 (-0.9)	2 (0.1)	25 (1)
F84	1664 (65.5)	463 (18.2)	172 (6.8)	1656 (65.2)	440 (17.3)	173 (6.8)	-9 (-0.3)	-22 (-0.9)	2 (0.1)	24 (0.9)
F85	1669 (65.7)	548 (21.6)	172 (6.8)	1662 (65.4)	525 (20.7)	184 (7.2)	-7 (-0.3)	-23 (-0.9)	11 (0.4)	27 (1.1)
F86	1671 (65.8)	642 (25.3)	173 (6.8)	1666 (65.6)	617 (24.3)	200 (7.9)	-5 (-0.2)	-25 (-1)	27 (1.1)	37 (1.5)
F87	1670 (65.7)	748 (29.5)	175 (6.9)	1667 (65.6)	722 (28.4)	218 (8.6)	-3 (-0.1)	-26 (-1)	43 (1.7)	51 (2)
F88	1675 (65.9)	789 (31.1)	172 (6.8)	1668 (65.7)	761 (30)	212 (8.3)	-6 (-0.3)	-28 (-1.1)	39 (1.6)	49 (1.9)
F89	1685 (66.4)	832 (32.7)	190 (7.5)	1681 (66.2)	805 (31.7)	213 (8.4)	-4 (-0.2)	-27 (-1.1)	23 (0.9)	35 (1.4)
F90	1604 (63.1)	343 (13.5)	171 (6.7)	1593 (62.7)	320 (12.6)	167 (6.6)	-10 (-0.4)	-23 (-0.9)	-4 (-0.1)	25 (1)
F91	1610 (63.4)	403 (15.9)	173 (6.8)	1602 (63.1)	381 (15)	173 (6.8)	-9 (-0.3)	-22 (-0.9)	0 (0)	23 (0.9)

Table 10-24 Test 4-11 Pre, Post Interior and Deformation Measurement Page 3

Vehicle Type	2200P	Test Number	110MASH4P21-02
Make	Dodge	Model	Ram 1500
Year	2018	Color	White
VIN #	1C6RR6FG3JS290753		

Foot/Wheel Well and Toe Pan Area Measurements (Cont.) - Dimensions in mm (inches

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
F92	1613 (63.5)	547 (21.5)	174 (6.9)	1606 (63.2)	525 (20.7)	182 (7.2)	-6 (-0.3)	-22 (-0.9)	8 (0.3)	24 (1)
F93	1637 (64.4)	647 (25.5)	174 (6.9)	1631 (64.2)	622 (24.5)	202 (8)	-6 (-0.2)	-25 (-1)	28 (1.1)	38 (1.5)
F94	1629 (64.1)	749 (29.5)	176 (6.9)	1625 (64)	723 (28.5)	220 (8.6)	-4 (-0.1)	-26 (-1)	44 (1.7)	51 (2)
F95	1631 (64.2)	791 (31.1)	176 (6.9)	1626 (64)	762 (30)	211 (8.3)	-4 (-0.2)	-28 (-1.1)	35 (1.4)	45 (1.8)
F96	1582 (62.3)	459 (18.1)	174 (6.8)	1572 (61.9)	438 (17.2)	175 (6.9)	-9 (-0.4)	-21 (-0.8)	1 (0.1)	23 (0.9)
F97	1578 (62.1)	544 (21.4)	175 (6.9)	1571 (61.8)	523 (20.6)	183 (7.2)	-7 (-0.3)	-21 (-0.8)	9 (0.3)	24 (0.9)
F98	1578 (62.1)	652 (25.7)	176 (6.9)	1572 (61.9)	628 (24.7)	204 (8)	-6 (-0.2)	-24 (-1)	28 (1.1)	37 (1.5)
F99	1585 (62.4)	749 (29.5)	177 (7)	1580 (62.2)	723 (28.5)	221 (8.7)	-5 (-0.2)	-26 (-1)	45 (1.8)	52 (2)
F100	1587 (62.5)	796 (31.3)	177 (7)	1584 (62.4)	769 (30.3)	216 (8.5)	-3 (-0.1)	-26 (-1)	39 (1.5)	47 (1.9)
F101	1536 (60.5)	340 (13.4)	173 (6.8)	1525 (60)	320 (12.6)	166 (6.6)	-11 (-0.4)	-20 (-0.8)	-6 (-0.3)	24 (0.9)
F102	1527 (60.1)	396 (15.6)	175 (6.9)	1516 (59.7)	376 (14.8)	168 (6.6)	-10 (-0.4)	-20 (-0.8)	-7 (-0.3)	24 (0.9)
F103	1520 (59.8)	454 (17.9)	176 (6.9)	1511 (59.5)	435 (17.1)	170 (6.7)	-9 (-0.3)	-19 (-0.7)	-6 (-0.2)	22 (0.9)
F104	1520 (59.8)	542 (21.3)	176 (6.9)	1513 (59.6)	522 (20.5)	184 (7.2)	-7 (-0.3)	-20 (-0.8)	8 (0.3)	23 (0.9)
F105	1519 (59.8)	651 (25.6)	177 (7)	1514 (59.6)	628 (24.7)	203 (8)	-5 (-0.2)	-22 (-0.9)	26 (1)	35 (1.4)
F106	1534 (60.4)	749 (29.5)	178 (7)	1530 (60.2)	726 (28.6)	216 (8.5)	-4 (-0.1)	-22 (-0.9)	38 (1.5)	44 (1.7)
F107	1528 (60.2)	797 (31.4)	178 (7)	1525 (60.1)	774 (30.5)	212 (8.4)	-3 (-0.1)	-23 (-0.9)	34 (1.4)	42 (1.6)
F108	1477 (58.1)	747 (29.4)	179 (7)	1474 (58)	726 (28.6)	209 (8.2)	-3 (-0.1)	-22 (-0.8)	30 (1.2)	37 (1.5)
F109	1474 (58)	798 (31.4)	179 (7)	1471 (57.9)	775 (30.5)	213 (8.4)	-4 (-0.1)	-22 (-0.9)	34 (1.4)	41 (1.6)
F110	1449 (57)	341 (13.4)	176 (6.9)	1437 (56.6)	323 (12.7)	166 (6.5)	-11 (-0.4)	-19 (-0.7)	-9 (-0.4)	24 (0.9)
F111	1451 (57.1)	392 (15.4)	177 (7)	1440 (56.7)	373 (14.7)	171 (6.7)	-10 (-0.4)	-19 (-0.8)	-6 (-0.3)	23 (0.9)
F112	1445 (56.9)	451 (17.7)	177 (7)	1436 (56.5)	433 (17)	171 (6.7)	-9 (-0.4)	-18 (-0.7)	-6 (-0.2)	21 (0.8)
F113	1449 (57)	539 (21.2)	178 (7)	1442 (56.8)	521 (20.5)	180 (7.1)	-7 (-0.3)	-18 (-0.7)	2 (0.1)	19 (0.8)
F114	1444 (56.8)	646 (25.4)	178 (7)	1440 (56.7)	627 (24.7)	188 (7.4)	-3 (-0.1)	-19 (-0.8)	10 (0.4)	22 (0.9)
F115	1428 (56.2)	742 (29.2)	174 (6.9)	1428 (56.2)	724 (28.5)	188 (7.4)	0 (0)	-18 (-0.7)	13 (0.5)	23 (0.9)
F116	1427 (56.2)	797 (31.4)	175 (6.9)	1425 (56.1)	777 (30.6)	203 (8)	-2 (-0.1)	-20 (-0.8)	29 (1.1)	35 (1.4)
F117	1391 (54.8)	738 (29)	161 (6.3)	1390 (54.7)	721 (28.4)	176 (6.9)	-1 (0)	-16 (-0.6)	15 (0.6)	22 (0.9)
F118	1388 (54.7)	792 (31.2)	155 (6.1)	1388 (54.7)	777 (30.6)	180 (7.1)	0 (0)	-15 (-0.6)	25 (1)	29 (1.1)

Side Front Panel Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
S1	1911 (75.2)	863 (34)	-25 (-1)	1878 (74)	780 (30.7)	-25 (-1)	-33 (-1.3)	-83 (-3.3)	0 (0)	89 (3.5)
S2	1811 (71.3)	865 (34.1)	20 (0.8)	1786 (70.3)	792 (31.2)	26 (1)	-24 (-1)	-73 (-2.9)	6 (0.2)	78 (3.1)
S3	1812 (71.3)	866 (34.1)	-82 (-3.2)	1781 (70.1)	781 (30.7)	-80 (-3.2)	-30 (-1.2)	-85 (-3.4)	1 (0.1)	90 (3.6)

Roof Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
R1	1443 (56.8)	233 (9.2)	-1048 (-41.3)	1445 (56.9)	250 (9.9)	-1049 (-41.3)	3 (0.1)	17 (0.7)	0 (0)	17 (0.7)
R2	1428 (56.2)	364 (14.3)	-1043 (-41.1)	1429 (56.3)	383 (15.1)	-1043 (-41.1)	2 (0.1)	18 (0.7)	-1 (0)	18 (0.7)
R3	1402 (55.2)	492 (19.4)	-1037 (-40.8)	1400 (55.1)	507 (20)	-1040 (-41)	-3 (-0.1)	16 (0.6)	-3 (-0.1)	16 (0.6)
R4	1347 (53)	663 (26.1)	-1025 (-40.4)	1345 (52.9)	676 (26.6)	-1030 (-40.5)	-3 (-0.1)	13 (0.5)	-4 (-0.2)	14 (0.5)
R5	1286 (50.6)	215 (8.5)	-1113 (-43.8)	1280 (50.4)	229 (9)	-1115 (-43.9)	-6 (-0.3)	14 (0.6)	-2 (-0.1)	16 (0.6)
R6	1269 (50)	330 (13)	-1111 (-43.7)	1263 (49.7)	344 (13.5)	-1112 (-43.8)	-6 (-0.3)	13 (0.5)	-2 (-0.1)	15 (0.6)
R7	1250 (49.2)	437 (17.2)	-1107 (-43.6)	1245 (49)	449 (17.7)	-1108 (-43.6)	-5 (-0.2)	13 (0.5)	-1 (-0.1)	14 (0.5)
R8	1206 (47.5)	609 (24)	-1097 (-43.2)	1199 (47.2)	620 (24.4)	-1099 (-43.3)	-7 (-0.3)	11 (0.4)	-2 (-0.1)	13 (0.5)
R9	1167 (45.9)	201 (7.9)	-1131 (-44.5)	1166 (45.9)	217 (8.5)	-1131 (-44.5)	-1 (0)	16 (0.6)	0 (0)	16 (0.6)
R10	1145 (45.1)	300 (11.8)	-1130 (-44.5)	1140 (44.9)	315 (12.4)	-1129 (-44.5)	-5 (-0.2)	16 (0.6)	0 (0)	17 (0.7)
R11	1118 (44)	406 (16)	-1125 (-44.3)	1113 (43.8)	420 (16.5)	-1124 (-44.3)	-5 (-0.2)	14 (0.5)	1 (0)	15 (0.6)
R12	1087 (42.8)	574 (22.6)	-1114 (-43.9)	1080 (42.5)	585 (23)	-1114 (-43.8)	-7 (-0.3)	11 (0.5)	0 (0)	13 (0.5)
R13	999 (39.3)	179 (7)	-1142 (-45)	995 (39.2)	195 (7.7)	-1141 (-44.9)	-4 (-0.2)	16 (0.6)	1 (0)	17 (0.7)
R14	973 (38.3)	296 (11.7)	-1139 (-44.9)	967 (38.1)	309 (12.2)	-1137 (-44.8)	-6 (-0.2)	13 (0.5)	2 (0.1)	15 (0.6)
R15	954 (37.6)	397 (15.6)	-1135 (-44.7)	948 (37.3)	410 (16.1)	-1133 (-44.6)	-6 (-0.2)	13 (0.5)	2 (0.1)	14 (0.6)
R16	933 (36.7)	541 (21.3)	-1126 (-44.3)	927 (36.5)	552 (21.7)	-1125 (-44.3)	-6 (-0.2)	11 (0.4)	2 (0.1)	13 (0.5)

Table 10-25 Test 4-11 Pre, Post Interior and Deformation Measurement Page 4

Vehicle Type	2200P	Test Number	110MASH4P21-02
Make	Dodge	Model	Ram 1500
Year	2018	Color	White
VIN #	1C6RR6FG3JS290753		

Roof Measurements (Cont.) - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
R17	841 (33.1)	168 (6.6)	-1146 (-45.1)	836 (32.9)	182 (7.2)	-1140 (-44.9)	-5 (-0.2)	15 (0.6)	6 (0.2)	16 (0.6)
R18	826 (32.5)	304 (12)	-1141 (-44.9)	822 (32.3)	317 (12.5)	-1138 (-44.8)	-4 (-0.2)	13 (0.5)	3 (0.1)	14 (0.6)
R19	813 (32)	400 (15.7)	-1138 (-44.8)	808 (31.8)	411 (16.2)	-1135 (-44.7)	-5 (-0.2)	12 (0.5)	2 (0.1)	13 (0.5)
R20	829 (32.6)	551 (21.7)	-1128 (-44.4)	823 (32.4)	560 (22)	-1125 (-44.3)	-6 (-0.2)	9 (0.4)	3 (0.1)	11 (0.4)

Windshield Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
W1	1517 (59.7)	306 (12.1)	-1018 (-40.1)	1518 (59.8)	321 (12.7)	-1020 (-40.2)	1 (0.1)	15 (0.6)	-2 (-0.1)	15 (0.6)
W2	1502 (59.1)	419 (16.5)	-1012 (-39.9)	1504 (59.2)	434 (17.1)	-1018 (-40.1)	2 (0.1)	15 (0.6)	-6 (-0.2)	16 (0.6)
W3	1476 (58.1)	550 (21.6)	-1005 (-39.5)	1476 (58.1)	565 (22.2)	-1012 (-39.8)	0 (0)	15 (0.6)	-8 (-0.3)	17 (0.7)
W4	1422 (56)	659 (26)	-1008 (-39.7)	1421 (55.9)	673 (26.5)	-1015 (-40)	-1 (0)	14 (0.6)	-7 (-0.3)	16 (0.6)
W5	1648 (64.9)	328 (12.9)	-944 (-37.2)	1651 (65)	342 (13.5)	-949 (-37.3)	3 (0.1)	14 (0.5)	-4 (-0.2)	14 (0.6)
W6	1632 (64.3)	441 (17.4)	-941 (-37)	1641 (64.6)	454 (17.9)	-943 (-37.1)	8 (0.3)	13 (0.5)	-2 (-0.1)	15 (0.6)
W7	1593 (62.7)	575 (22.7)	-940 (-37)	1597 (62.9)	591 (23.3)	-953 (-37.5)	4 (0.1)	15 (0.6)	-13 (-0.5)	20 (0.8)
W8	1550 (61)	698 (27.5)	-935 (-36.8)	1550 (61)	712 (28)	-944 (-37.2)	0 (0)	14 (0.6)	-9 (-0.4)	17 (0.7)
W9	1750 (68.9)	337 (13.3)	-886 (-34.9)	1757 (69.2)	348 (13.7)	-887 (-34.9)	7 (0.3)	11 (0.4)	0 (0)	13 (0.5)
W10	1733 (68.2)	464 (18.3)	-879 (-34.6)	1742 (68.6)	472 (18.6)	-878 (-34.6)	9 (0.3)	8 (0.3)	2 (0.1)	12 (0.5)
W11	1686 (66.4)	593 (23.4)	-884 (-34.8)	1692 (66.6)	605 (23.8)	-893 (-35.1)	6 (0.2)	12 (0.5)	-8 (-0.3)	16 (0.6)
W12	1646 (64.8)	726 (28.6)	-873 (-34.4)	1647 (64.8)	736 (29)	-882 (-34.7)	1 (0)	11 (0.4)	-8 (-0.3)	13 (0.5)
W13	1850 (72.8)	354 (13.9)	-823 (-32.4)	1859 (73.2)	364 (14.3)	-822 (-32.4)	8 (0.3)	10 (0.4)	1 (0.1)	13 (0.5)
W14	1828 (72)	484 (19)	-818 (-32.2)	1839 (72.4)	493 (19.4)	-817 (-32.2)	11 (0.4)	9 (0.4)	1 (0)	14 (0.6)
W15	1795 (70.7)	616 (24.3)	-814 (-32)	1808 (71.2)	627 (24.7)	-813 (-32)	13 (0.5)	11 (0.4)	1 (0)	17 (0.7)
W16	1744 (68.7)	746 (29.4)	-807 (-31.8)	1746 (68.8)	755 (29.7)	-811 (-31.9)	3 (0.1)	9 (0.3)	-5 (-0.2)	10 (0.4)
W17	1954 (76.9)	357 (14.1)	-759 (-29.9)	1960 (77.2)	366 (14.4)	-757 (-29.8)	7 (0.3)	9 (0.3)	2 (0.1)	11 (0.4)
W18	1916 (75.4)	498 (19.6)	-761 (-29.9)	1925 (75.8)	506 (19.9)	-759 (-29.9)	9 (0.3)	9 (0.3)	1 (0.1)	12 (0.5)
W19	1885 (74.2)	640 (25.2)	-750 (-29.5)	1895 (74.6)	650 (25.6)	-750 (-29.5)	11 (0.4)	10 (0.4)	0 (0)	15 (0.6)
W20	1838 (72.4)	764 (30.1)	-738 (-29.1)	1841 (72.5)	773 (30.4)	-740 (-29.1)	3 (0.1)	9 (0.3)	-2 (-0.1)	9 (0.4)

Dashboard Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
D1	1635 (64.4)	300 (11.8)	-636 (-25)	1639 (64.5)	303 (11.9)	-640 (-25.2)	4 (0.2)	3 (0.1)	-4 (-0.2)	6 (0.2)
D2	1641 (64.6)	412 (16.2)	-632 (-24.9)	1644 (64.7)	415 (16.3)	-634 (-25)	3 (0.1)	2 (0.1)	-1 (-0.1)	4 (0.2)
D3	1647 (64.9)	519 (20.4)	-628 (-24.7)	1650 (64.9)	522 (20.5)	-628 (-24.7)	2 (0.1)	3 (0.1)	0 (0)	3 (0.1)
D4	1658 (65.3)	661 (26)	-620 (-24.4)	1659 (65.3)	663 (26.1)	-618 (-24.3)	1 (0)	2 (0.1)	2 (0.1)	3 (0.1)
D5	1547 (60.9)	319 (12.6)	-360 (-14.2)	1546 (60.9)	312 (12.3)	-367 (-14.5)	-1 (0)	-7 (-0.3)	-7 (-0.3)	10 (0.4)
D6	1552 (61.1)	455 (17.9)	-363 (-14.3)	1549 (61)	447 (17.6)	-370 (-14.6)	-3 (-0.1)	-8 (-0.3)	-7 (-0.3)	11 (0.4)
D7	1557 (61.3)	560 (22.1)	-370 (-14.6)	1549 (61)	552 (21.7)	-377 (-14.8)	-8 (-0.3)	-8 (-0.3)	-7 (-0.3)	13 (0.5)
D8	1565 (61.6)	670 (26.4)	-371 (-14.6)	1548 (61)	663 (26.1)	-379 (-14.9)	-17 (-0.7)	-7 (-0.3)	-7 (-0.3)	20 (0.8)
D9	1572 (61.9)	749 (29.5)	-373 (-14.7)	1548 (61)	742 (29.2)	-379 (-14.9)	-23 (-0.9)	-7 (-0.3)	-6 (-0.2)	25 (1)
D10	1582 (62.3)	861 (33.9)	-378 (-14.9)	1571 (61.8)	852 (33.5)	-384 (-15.1)	-11 (-0.4)	-10 (-0.4)	-6 (-0.2)	16 (0.6)
D11	1650 (65)	859 (33.8)	-608 (-23.9)	1646 (64.8)	855 (33.6)	-611 (-24.1)	-4 (-0.1)	-4 (-0.2)	-3 (-0.1)	6 (0.3)

Table 10-26 Test 4-11 Pre, Post Interior and Deformation Measurement Page 5

Vehicle Type	2200P	Test Number	110MASH4P21-02
Make	Dodge	Model	Ram 1500
Year	2018	Color	White
VIN #	1C6RR6FG3JS290753		

A and B Pillar Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
P1	734 (28.9)	734 (28.9)	-1001 (-39.4)	729 (28.7)	743 (29.3)	-993 (-39.1)	-5 (-0.2)	9 (0.4)	9 (0.3)	13 (0.5)
P2	742 (29.2)	797 (31.4)	-823 (-32.4)	742 (29.2)	803 (31.6)	-818 (-32.2)	0 (0)	6 (0.2)	5 (0.2)	8 (0.3)
P3	764 (30.1)	837 (33)	-684 (-26.9)	765 (30.1)	843 (33.2)	-679 (-26.7)	1 (0)	6 (0.2)	6 (0.2)	8 (0.3)
P4	798 (31.4)	859 (33.8)	-499 (-19.6)	795 (31.3)	861 (33.9)	-492 (-19.4)	-3 (-0.1)	2 (0.1)	7 (0.3)	8 (0.3)
P5	815 (32.1)	863 (34)	-352 (-13.9)	814 (32)	864 (34)	-346 (-13.6)	-2 (-0.1)	1 (0)	6 (0.2)	6 (0.3)
P6	827 (32.6)	864 (34)	-197 (-7.8)	827 (32.6)	863 (34)	-191 (-7.5)	0 (0)	-1 (0)	6 (0.2)	6 (0.2)
P7	857 (33.7)	864 (34)	-27 (-1.1)	855 (33.7)	861 (33.9)	-20 (-0.8)	-1 (-0.1)	-3 (-0.1)	7 (0.3)	8 (0.3)
P8	867 (34.1)	864 (34)	76 (3)	866 (34.1)	860 (33.9)	84 (3.3)	-1 (-0.1)	-4 (-0.1)	7 (0.3)	8 (0.3)
P9	1718 (67.6)	825 (32.5)	-718 (-28.3)	1717 (67.6)	817 (32.2)	-718 (-28.3)	-1 (-0.1)	-8 (-0.3)	0 (0)	8 (0.3)
P10	1597 (62.9)	780 (30.7)	-778 (-30.6)	1599 (62.9)	777 (30.6)	-784 (-30.9)	1 (0)	-3 (-0.1)	-6 (-0.2)	7 (0.3)
P11	1417 (55.8)	738 (29)	-894 (-35.2)	1420 (55.9)	743 (29.2)	-902 (-35.5)	3 (0.1)	5 (0.2)	-7 (-0.3)	9 (0.4)

Above Seat Front Side Door Area Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
A1	1558 (61.4)	877 (34.5)	-557 (-21.9)	1534 (60.4)	863 (34)	-551 (-21.7)	-24 (-0.9)	-15 (-0.6)	6 (0.2)	29 (1.1)
A2	1414 (55.7)	878 (34.6)	-557 (-21.9)	1389 (54.7)	870 (34.2)	-553 (-21.8)	-25 (-1)	-9 (-0.3)	4 (0.2)	27 (1)
A3	1269 (49.9)	880 (34.6)	-555 (-21.9)	1243 (48.9)	880 (34.6)	-553 (-21.8)	-25 (-1)	1 (0)	3 (0.1)	25 (1)
A4	1131 (44.5)	881 (34.7)	-557 (-21.9)	1108 (43.6)	889 (35)	-552 (-21.7)	-24 (-0.9)	8 (0.3)	5 (0.2)	25 (1)
A5	1003 (39.5)	883 (34.8)	-556 (-21.9)	978 (38.5)	898 (35.4)	-551 (-21.7)	-25 (-1)	15 (0.6)	6 (0.2)	29 (1.2)
A6	885 (34.8)	884 (34.8)	-554 (-21.8)	860 (33.9)	904 (35.6)	-548 (-21.6)	-25 (-1)	20 (0.8)	6 (0.2)	32 (1.3)
A7	1560 (61.4)	853 (33.6)	-359 (-14.1)	1531 (60.3)	819 (32.2)	-354 (-13.9)	-29 (-1.1)	-34 (-1.3)	5 (0.2)	45 (1.8)
A8	1417 (55.8)	823 (32.4)	-353 (-13.9)	1387 (54.6)	796 (31.4)	-349 (-13.7)	-30 (-1.2)	-27 (-1.1)	5 (0.2)	41 (1.6)
A9	1266 (49.9)	821 (32.3)	-348 (-13.7)	1237 (48.7)	803 (31.6)	-344 (-13.5)	-30 (-1.2)	-18 (-0.7)	4 (0.2)	35 (1.4)
A10	1121 (44.1)	821 (32.3)	-347 (-13.7)	1091 (43)	814 (32)	-347 (-13.7)	-30 (-1.2)	-8 (-0.3)	-1 (0)	31 (1.2)
A11	1002 (39.4)	825 (32.5)	-345 (-13.6)	973 (38.3)	826 (32.5)	-344 (-13.6)	-28 (-1.1)	1 (0)	0 (0)	28 (1.1)
A12	912 (35.9)	842 (33.1)	-343 (-13.5)	886 (34.9)	852 (33.5)	-340 (-13.4)	-26 (-1)	10 (0.4)	3 (0.1)	28 (1.1)

Below Seat Front Side Door Area Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
B1	1682 (68.6)	847 (34.6)	-41 (-1.7)	1647 (67.2)	788 (32.2)	-35 (-1.4)	-35 (-1.4)	-60 (-2.4)	6 (0.2)	69 (2.8)
B2	1526 (62.3)	849 (34.7)	-38 (-1.6)	1495 (61)	820 (33.5)	-31 (-1.3)	-32 (-1.3)	-29 (-1.2)	8 (0.3)	43 (1.8)
B3	1404 (57.3)	910 (37.2)	-28 (-1.1)	1376 (56.2)	888 (36.2)	-26 (-1)	-28 (-1.1)	-22 (-0.9)	2 (0.1)	36 (1.5)
B4	1287 (52.5)	911 (37.2)	-30 (-1.2)	1259 (51.4)	893 (36.5)	-26 (-1.1)	-27 (-1.1)	-17 (-0.7)	4 (0.2)	33 (1.3)
B5	1133 (46.2)	912 (37.2)	-24 (-1)	1106 (45.1)	900 (36.7)	-21 (-0.9)	-27 (-1.1)	-11 (-0.5)	3 (0.1)	30 (1.2)
B6	997 (40.7)	915 (37.4)	-23 (-0.9)	971 (39.6)	911 (37.2)	-23 (-0.9)	-26 (-1.1)	-4 (-0.2)	0 (0)	26 (1.1)
B7	927 (37.8)	872 (35.6)	-43 (-1.8)	908 (37.1)	868 (35.4)	-36 (-1.5)	-19 (-0.8)	-4 (-0.2)	7 (0.3)	20 (0.8)

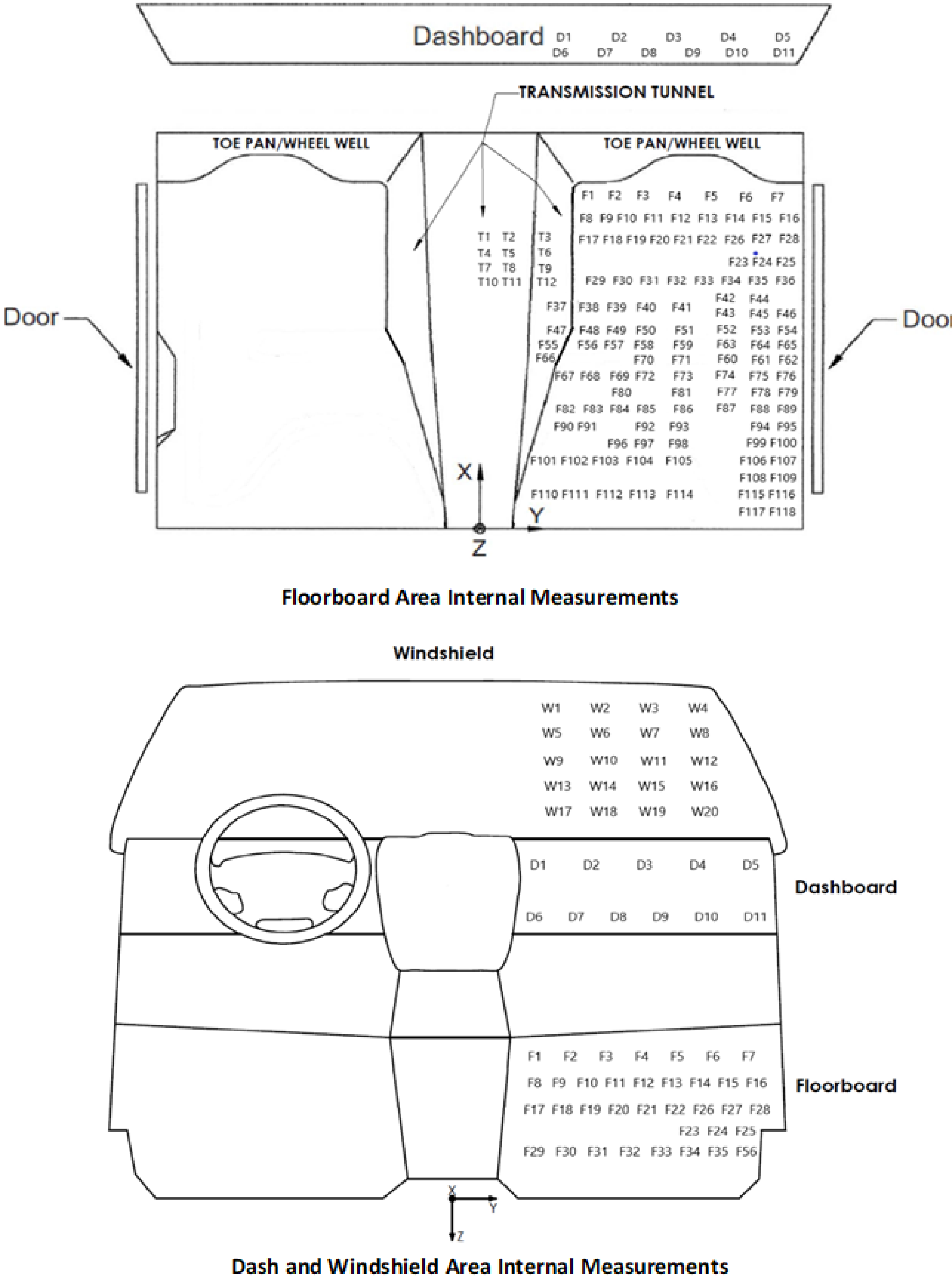
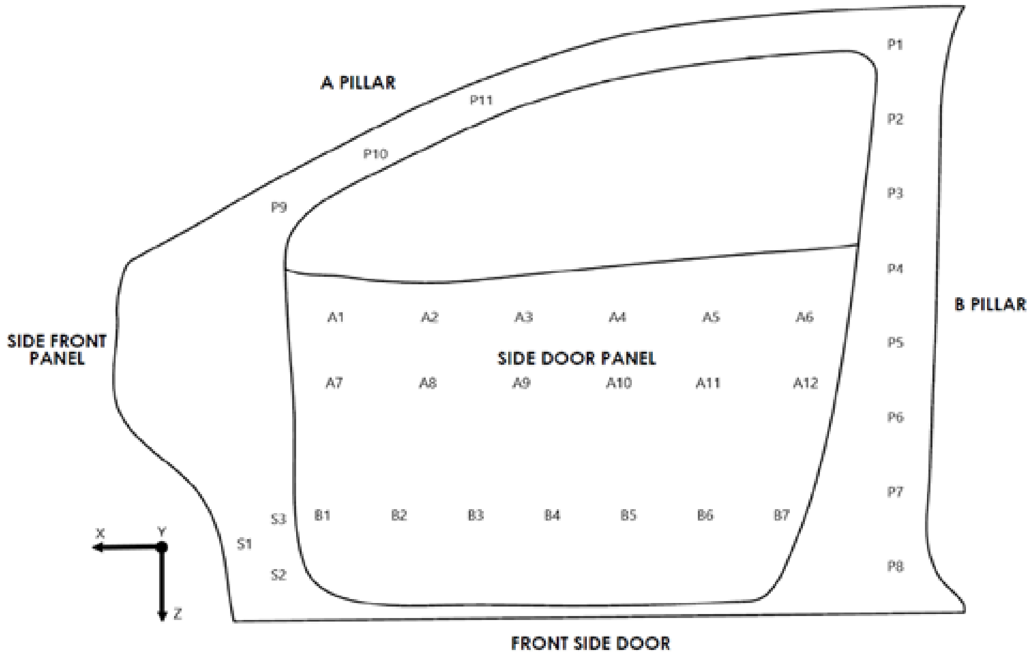
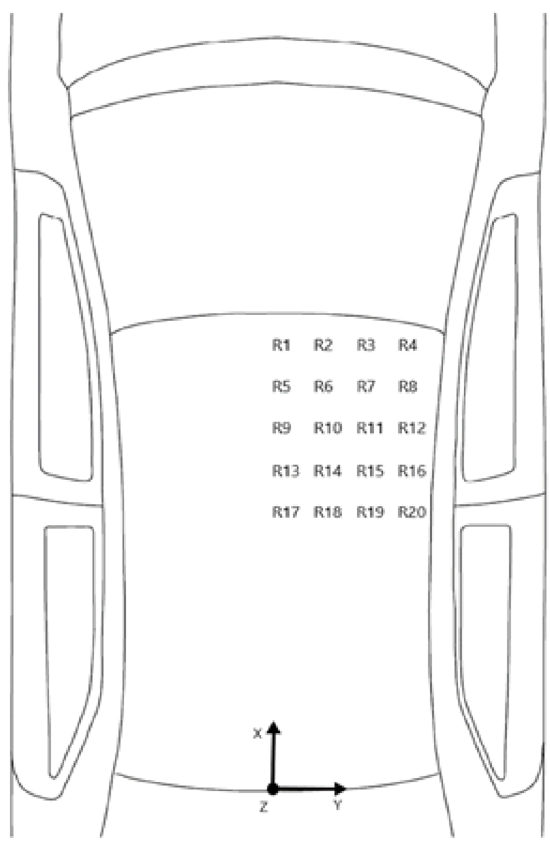


Figure 10-19 Schematic of Measured Interior Points for Floorboard, Dashboard, Windshield, Toe Pan, Wheel Well and Transmission Tunnel



Front Door Area Internal Measurements



Roof Area Internal Measurements

Figure 10-20 Schematic of Measured Points for the A Pillar, B Pillar, Side Front Door Panel, Side Door Panel, Front Side Door and Roof

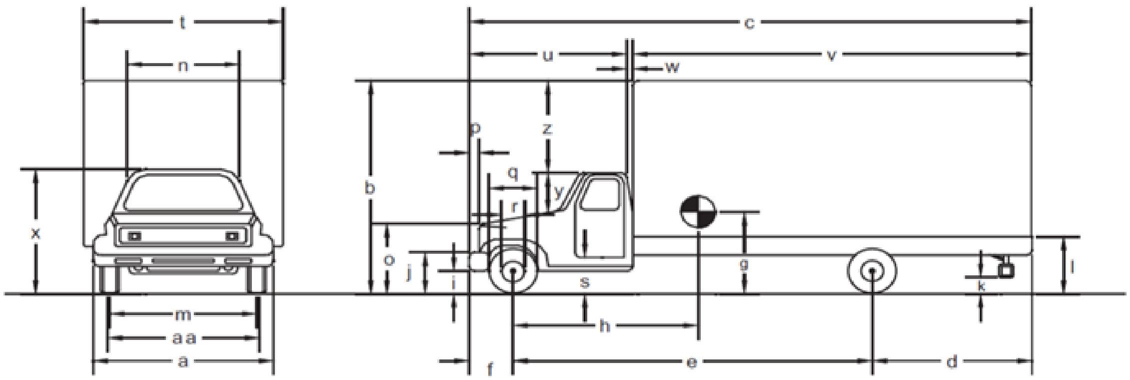
10.6.3. Test 110MASH4S21-03

Table 10-27 Test 4-12 Exterior Vehicle Measurements

Policies and Procedures Manual	Revised:1/23/2019
Roadside Safety Research Group	Page 1

Attachment 5.4.7 --- 10000S Single Unit Truck Parameters

Date:	10/12/2021	Test Number:	110MASH4S21-03	Model:	Business Class M2
Tire Size Front:	295/75R22.5G	Odometer:	334738.8 miles	Make:	Freightliner
Tire Size Rear:	295/75R22.5G	VIN:	1FVACWDT09HAH4233	Year:	2009
Tire Inflation Pressure:	100 psi	Tape Measure Used:	5m-CP03	CLE:*	DRISI2101
Measured by:	Chris C	Staff:	Victor L	Scale Set Used:	10000



Vehicle Geometry - mm (inches) Tape Measure Used: 5m-CP03 & 100ft-+QD01

	mm	(in)		mm	(in)		mm	(in)
a)	2328	(91.65)	j)	780	(30.71)	s)	867	(34.13)
b)	3630	(142.91)	k)	656	(25.83)	t)	2435	(95.87)
c)	8680	(341.73)	l)	1286	(50.63)	u)	2774	(109.21)
d)	2030	(79.92)	m)	2100	(82.68)	v)	5829	(229.49)
e)	5534	(217.87)	n)	2140	(84.25)	w)	65	(2.56)
f)	1116	(43.94)	o)	1365	(53.74)	x)	2515	(99.02)
g)	n/a	n/a	p)	90	(3.54)	y)	855	(33.66)
h)	3544	(139.53)	q)	1000	(39.37)	z)	1040	(40.94)
i)	420	(16.54)	r)	600	(23.62)	aa)	2180	(85.83)

Weights - kg (lbs)

	Curb		Test Inertial		Gross Static	
$W_{front\ axel}$	2935	(6470.5)	3647	(8040.1)	3647	(8040.1)
$W_{rear\ axel}$	2896	(6384.5)	6497	(14323.2)	6497	(14323.2)
W_{TOTAL}	5831	(12854.9)	10144	(22363.3)	10144	(22363.3)

Wheel Center Height Front:	492	(19.37)
Wheel Center Height Rear:	500	(19.69)
Wheel Well Clearance (FR):	205	(8.07)
Wheel Well Clearance (RR):	228	(8.98)

Ballast: 4335.4 (9557.8) Scale: 10000 lbs Scales

Engine Type: Diesel ISB 240

Engine Size: 408/6.7L

Ballast - vertical CG from ground mm (inches): 1625 (64)

Transmission Type:
Automatic
RWD

Mass Distribution

Left Front	1862	(4104.9)	Scale:	red	Right Front	1785	(3935.2)	Scale:	green
Left Rear	3232	(7125.2)	Scale:	yellow	Right Rear	3265	(7198)	Scale:	blue

Note any damage prior to test: None

Data Transferred to Electronic Copy By:	Christopher Caldwell	Date:	12/13/2021
Transfer Checked by:	Victor O. Lopez	Date:	1/13/2022

* CLE is the inventory number and should be located on the door jamb of the vehicle.

Table 10-28 Test 4-12 CG Calculation: Curb Weight

CG Calculation Worksheet #1: **Curb Weight**

Make:	Freightliner	Test Number:	110MASH4S21-03
Model:	Business Class M2	Date:	10/12/2021
Year:	2009	Temperature:	60°F
VIN:	1FVACWDT09HAH4233	Scale Set Used:	10000
Fuel in Tank:	~3/8		
Fuel Removed:	none		
Measured By:	Chris C Victor L		
	David S		
Support Staff	Steve W		
	Vue H		

W1 = Left Front (LF) = 1503 kg
Scale Used: red

W2 = Right Front (RF) = 1432 kg
Scale Used: green

W3 = Left Rear (LR) = 1383 kg
Scale Used: yellow

W4 = Right Rear (RR) = 1513 kg
Scale Used: blue

Total Weight:
Wtotal (measured) = 5830 kg

Wtotal (calculated) = 5831 kg

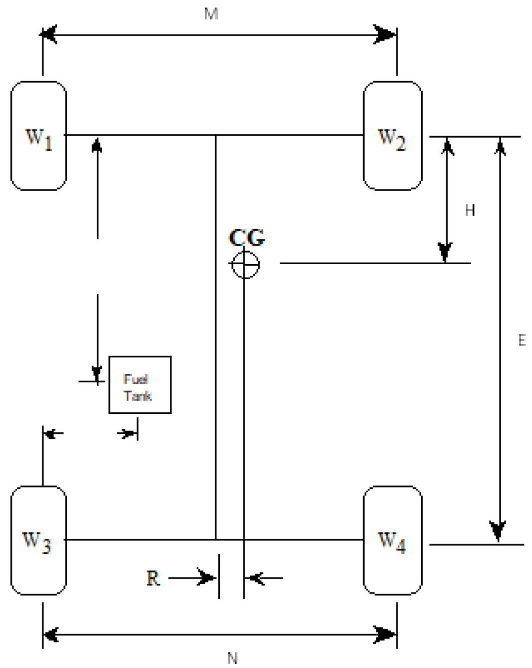
Distance between front wheels:
M = 2100 mm

Distance between rear wheels:
N = 2180 mm

Distance from front to rear wheels:
E = 5534 mm

Distance from front wheels back to CG:
H = 2748 mm

Distance from vehicle centerline to CG:
R = 12 mm



$$W_{Total} = W_1 + W_2 + W_3 + W_4$$

$$H = \frac{(W_3 + W_4)E}{W_{Total}}$$

$$R = \frac{(W_2 - W_1)M + (W_4 - W_3)N}{2W_{Total}}$$

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Christopher Caldwell		Date:	10/12/2021
Transfer Checked by:			
Victor O. Lopez		Date:	1/14/2022

If R is negative the CG is left of center, if R is positive the CG is right of center

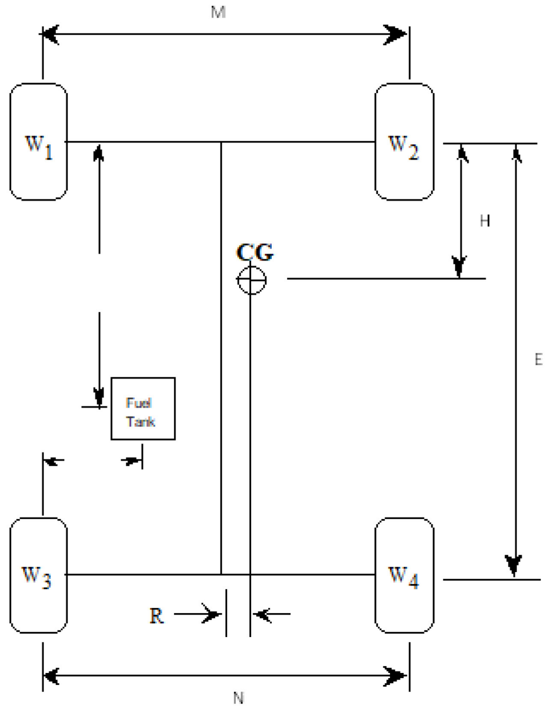
Curb Weight Conditions: (vehicle condition, items removed, items added, environmental conditions, etc.)
No damage, Nothing removed.

110MASH4S21-03 --- CG Data Calculation Worksheet.xlsx Curb WorkSheet

Table 10-29 Test 4-12 CG Calculation: Test Inertial Weight

CG Calculation Worksheet #2: **Test Inertial Weight**

Make:	Freightliner	Test Number:	110MASH4S21-03
Model:	Business Class M2	Date:	11/30/2022
Year:	2009	Temperature:	61 °F
VIN:	1FVACWDT09HAH4233	Scale Set Used:	10000 Scales
Fuel in Tank:	1/2 of 1 tank		
Fuel Removed:	n/a		
Measured By:	Chris C		
	Victor L		
Support Staff	David S		
	Vue H		



W1 = Left Front (LF) = 1862 kg
Scale Used: red

W2 = Right Front (RF) = 1785 kg
Scale Used: green

W3 = Left Rear (LR) = 3232 kg
Scale Used: yellow

W4 = Right Rear (RR) = 3265 kg
Scale Used: blue

Total Weight:
Wtotal (measured) = 10145 kg

Wtotal (calculated) = 10144 kg

Distance between front wheels:
M = 2100 mm

Distance between rear wheels:
N = 2180 mm

Distance from front to rear wheels:
E = 5534 mm

Distance from front wheels back to CG:
H = 3544 mm

Distance from vehicle centerline to CG:
R = -4 mm

$$W_{Total} = W_1 + W_2 + W_3 + W_4$$

$$H = \frac{(W_3 + W_4)E}{W_{Total}}$$

$$R = \frac{(W_2 - W_1)M + (W_4 - W_3)N}{2W_{Total}}$$

Data Transferred to Electronic Copy By:			
Christopher Caldwell		Date:	11/30/2021
Transfer Checked by:			
Victor O. Lopez		Date:	1/14/2022

If R is negative the CG is left of center, if R is positive the CG is right of center

Test Inertial Weight Conditions: (vehicle condition, items removed, items added, environmental conditions, etc.)
Ballast and equipment installed. Passenger side fuel tank emptied.

110MASH4S21-03 --- CG Data Calculation Worksheet.xlsx Test Inertial WorkSheet

Table 10-30 Test 4-12 CG Calculation: Gross Static Weight

CG Calculation Worksheet #3: **Gross Static Weight**

Make:	Freightliner	Test Number:	110MASH4S21-03
Model:	Business Class M2	Date:	
Year:	2009	Temperature:	
VIN:	1FVACWDT09HAH4233	Scale Set Used:	
Fuel in Tank:			
Fuel Removed:			
Measured By:			
Support Staff			

W1 = Left Front (LF) = ______ kg
Scale Used:

W2 = Right Front (RF) = ______ kg
Scale Used:

W3 = Left Rear (LR) =
Scale Used:

W4 = Right Rear (RR) =
Scale Used:

Total Weight:
Wtotal (me

Wto ______ kg

Distance
M = ______ mm

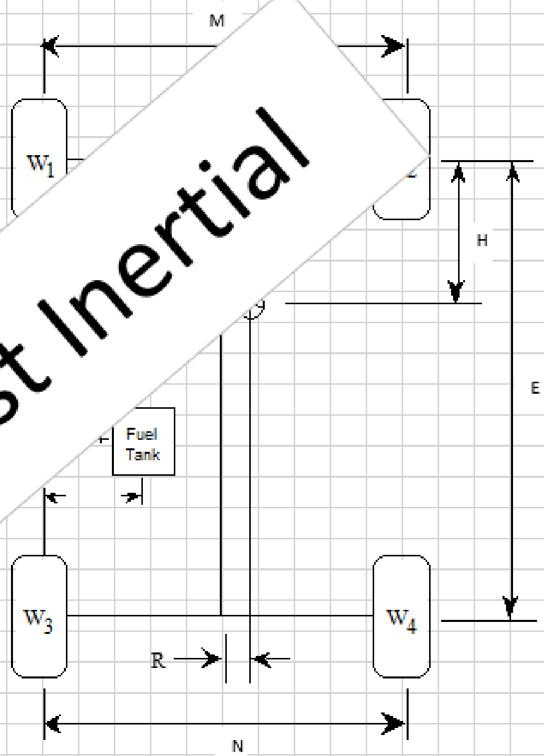
Distance between heels:
N = ______ mm

Distance from front to rear wheels:
E = ______ mm

Distance from front wheels back to CG:
H = #DIV/0! mm

Distance from vehicle centerline to CG:
R = #DIV/0! mm

Same as Test Inertial



$$W_{Total} = W_1 + W_2 + W_3 + W_4$$

$$H = \frac{(W_3 + W_4)E}{W_{Total}}$$

$$R = \frac{(W_2 - W_1)M + (W_4 - W_3)N}{2W_{Total}}$$

Data Transferred to Electronic Copy By: ______ Date:

Transfer Checked by: ______ Date:

If R is negative the CG is left of center, if R is positive the CG is right of center

Gross Static Weight Conditions: (vehicle condition, items removed, items added, environmental conditions, etc.)

110MASH4S21-03 --- CG Data Calculation Worksheet.xlsx Gross Static WorkSheet

Table 10-31 Test 4-12 Pre, Post Interior and Deformation Measurement Page 1

Attachment 5.5 --- Interior Vehicle Measurement Report

Vehicle Type	10000S	Test Number	110MASH4S21-03
Make	Freightliner	Model	Business Class M2
Year	2009	Color	White
VIN #	1FVACWDT09HAH4233		

Transmission Tunnel and Floor Pan Area Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
T1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Foot/Wheel Well and Toe Pan Area Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
F1	973 (38.3)	668 (26.3)	84 (3.3)	971 (38.2)	663 (26.1)	72 (2.8)	-2 (-0.1)	-5 (-0.2)	-12 (-0.5)	13 (0.5)
F2	973 (38.3)	742 (29.2)	117 (4.6)	972 (38.3)	739 (29.1)	105 (4.1)	-1 (0)	-3 (-0.1)	-12 (-0.5)	12 (0.5)
F3	977 (38.5)	813 (32)	123 (4.8)	976 (38.4)	809 (31.9)	112 (4.4)	-1 (0)	-4 (-0.2)	-11 (-0.4)	12 (0.5)
F4	979 (38.6)	883 (34.8)	119 (4.7)	980 (38.6)	879 (34.6)	108 (4.3)	1 (0)	-4 (-0.2)	-11 (-0.4)	11 (0.4)
F5	978 (38.5)	957 (37.7)	121 (4.7)	968 (38.1)	942 (37.1)	83 (3.3)	-10 (-0.4)	-15 (-0.6)	-37 (-1.5)	41 (1.6)
F6	979 (38.5)	1044 (41.1)	107 (4.2)	966 (38)	1030 (40.5)	58 (2.3)	-13 (-0.5)	-15 (-0.6)	-49 (-1.9)	53 (2.1)
F7	985 (38.8)	1119 (44)	70 (2.7)	977 (38.5)	1105 (43.5)	31 (1.2)	-8 (-0.3)	-13 (-0.5)	-39 (-1.5)	41 (1.6)
F8	984 (38.7)	1166 (45.9)	61 (2.4)	982 (38.7)	1152 (45.3)	36 (1.4)	-2 (-0.1)	-14 (-0.5)	-24 (-1)	28 (1.1)
F9	888 (35)	666 (26.2)	93 (3.6)	886 (34.9)	662 (26.1)	82 (3.2)	-1 (-0.1)	-3 (-0.1)	-11 (-0.4)	11 (0.4)
F10	886 (34.9)	746 (29.4)	126 (5)	886 (34.9)	741 (29.2)	116 (4.5)	0 (0)	-5 (-0.2)	-10 (-0.4)	11 (0.5)
F11	883 (34.8)	816 (32.1)	132 (5.2)	884 (34.8)	811 (31.9)	122 (4.8)	0 (0)	-5 (-0.2)	-10 (-0.4)	11 (0.4)
F12	882 (34.7)	885 (34.8)	129 (5.1)	882 (34.7)	880 (34.7)	120 (4.7)	1 (0)	-5 (-0.2)	-9 (-0.3)	10 (0.4)
F13	886 (34.9)	955 (37.6)	129 (5.1)	885 (34.8)	947 (37.3)	121 (4.8)	-1 (-0.1)	-8 (-0.3)	-8 (-0.3)	11 (0.4)
F14	885 (34.9)	1049 (41.3)	135 (5.3)	869 (34.2)	1025 (40.4)	73 (2.9)	-16 (-0.6)	-24 (-0.9)	-61 (-2.4)	68 (2.7)
F15	890 (35)	1116 (43.9)	147 (5.8)	873 (34.4)	1087 (42.8)	91 (3.6)	-17 (-0.7)	-29 (-1.1)	-56 (-2.2)	65 (2.6)
F16	887 (34.9)	1161 (45.7)	132 (5.2)	879 (34.6)	1134 (44.7)	98 (3.9)	-8 (-0.3)	-27 (-1.1)	-34 (-1.3)	44 (1.7)
F17	941 (37.1)	1113 (43.8)	108 (4.2)	929 (36.6)	1092 (43)	55 (2.2)	-13 (-0.5)	-21 (-0.8)	-53 (-2.1)	58 (2.3)
F18	937 (36.9)	1161 (45.7)	93 (3.7)	931 (36.7)	1142 (45)	67 (2.6)	-5 (-0.2)	-19 (-0.8)	-26 (-1)	33 (1.3)
F19	804 (31.7)	602 (23.7)	81 (3.2)	804 (31.6)	598 (23.5)	72 (2.8)	0 (0)	-4 (-0.2)	-8 (-0.3)	9 (0.4)
F20	806 (31.7)	670 (26.4)	104 (4.1)	805 (31.7)	667 (26.2)	95 (3.7)	-1 (0)	-3 (-0.1)	-9 (-0.4)	10 (0.4)
F21	806 (31.7)	745 (29.3)	133 (5.2)	807 (31.8)	741 (29.2)	123 (4.8)	1 (0)	-4 (-0.2)	-10 (-0.4)	11 (0.4)
F22	812 (32)	812 (32)	139 (5.5)	813 (32)	807 (31.8)	129 (5.1)	1 (0)	-5 (-0.2)	-10 (-0.4)	11 (0.4)
F23	816 (32.1)	889 (35)	135 (5.3)	817 (32.2)	884 (34.8)	126 (5)	0 (0)	-4 (-0.2)	-8 (-0.3)	9 (0.4)
F24	814 (32)	956 (37.7)	136 (5.4)	816 (32.1)	951 (37.4)	139 (5.5)	2 (0.1)	-6 (-0.2)	2 (0.1)	7 (0.3)
F25	811 (31.9)	1047 (41.2)	144 (5.7)	796 (31.3)	1022 (40.2)	93 (3.7)	-15 (-0.6)	-25 (-1)	-51 (-2)	58 (2.3)
F26	812 (32)	1081 (42.6)	149 (5.9)	794 (31.2)	1058 (41.6)	89 (3.5)	-18 (-0.7)	-23 (-0.9)	-60 (-2.4)	67 (2.6)
F27	827 (32.6)	1120 (44.1)	171 (6.7)	815 (32.1)	1090 (42.9)	120 (4.7)	-12 (-0.5)	-30 (-1.2)	-52 (-2)	61 (2.4)
F28	816 (32.1)	1155 (45.5)	165 (6.5)	810 (31.9)	1127 (44.4)	125 (4.9)	-6 (-0.2)	-28 (-1.1)	-40 (-1.6)	49 (1.9)
F29	823 (32.4)	1205 (47.4)	60 (2.4)	834 (32.8)	1199 (47.2)	45 (1.8)	11 (0.4)	-6 (-0.2)	-16 (-0.6)	20 (0.8)
F30	783 (30.8)	1202 (47.3)	101 (4)	789 (31.1)	1190 (46.9)	83 (3.3)	6 (0.2)	-12 (-0.5)	-19 (-0.7)	23 (0.9)
F31	748 (29.4)	602 (23.7)	90 (3.6)	749 (29.5)	596 (23.5)	81 (3.2)	2 (0.1)	-6 (-0.2)	-9 (-0.4)	11 (0.4)
F32	747 (29.4)	663 (26.1)	110 (4.3)	749 (29.5)	662 (26.1)	102 (4)	2 (0.1)	-1 (-0.1)	-8 (-0.3)	9 (0.3)
F33	749 (29.5)	747 (29.4)	141 (5.6)	752 (29.6)	742 (29.2)	129 (5.1)	2 (0.1)	-4 (-0.2)	-12 (-0.5)	13 (0.5)
F34	747 (29.4)	815 (32.1)	147 (5.8)	749 (29.5)	811 (31.9)	136 (5.4)	2 (0.1)	-4 (-0.1)	-11 (-0.4)	12 (0.5)
F35	745 (29.3)	892 (35.1)	143 (5.6)	748 (29.4)	888 (35)	133 (5.2)	3 (0.1)	-3 (-0.1)	-10 (-0.4)	11 (0.4)
F36	743 (29.2)	959 (37.7)	146 (5.7)	744 (29.3)	957 (37.7)	148 (5.8)	1 (0)	-2 (-0.1)	2 (0.1)	3 (0.1)
F37	743 (29.2)	1042 (41)	153 (6)	734 (28.9)	1019 (40.1)	120 (4.7)	-8 (-0.3)	-23 (-0.9)	-33 (-1.3)	41 (1.6)
F38	741 (29.2)	1082 (42.6)	159 (6.3)	729 (28.7)	1058 (41.7)	104 (4.1)	-12 (-0.5)	-24 (-0.9)	-56 (-2.2)	62 (2.4)
F39	753 (29.6)	1124 (44.2)	190 (7.5)	741 (29.2)	1094 (43.1)	143 (5.6)	-12 (-0.5)	-29 (-1.2)	-47 (-1.9)	57 (2.2)
F40	752 (29.6)	1160 (45.7)	176 (6.9)	743 (29.3)	1131 (44.5)	137 (5.4)	-8 (-0.3)	-29 (-1.1)	-39 (-1.5)	49 (1.9)
F41	739 (29.1)	1210 (47.6)	144 (5.7)	742 (29.2)	1188 (46.8)	124 (4.9)	3 (0.1)	-22 (-0.9)	-20 (-0.8)	30 (1.2)
F42	688 (27.1)	600 (23.6)	95 (3.8)	691 (27.2)	595 (23.4)	88 (3.5)	2 (0.1)	-5 (-0.2)	-7 (-0.3)	9 (0.4)
F43	697 (27.4)	662 (26.1)	116 (4.6)	701 (27.6)	662 (26.1)	110 (4.3)	4 (0.2)	0 (0)	-6 (-0.2)	7 (0.3)
F44	693 (27.3)	747 (29.4)	146 (5.8)	694 (27.3)	745 (29.3)	137 (5.4)	1 (0)	-3 (-0.1)	-9 (-0.4)	10 (0.4)
F45	688 (27.1)	817 (32.2)	152 (6)	688 (27.1)	814 (32)	144 (5.7)	0 (0)	-3 (-0.1)	-8 (-0.3)	9 (0.3)
F46	682 (26.9)	892 (35.1)	148 (5.8)	685 (27)	887 (34.9)	141 (5.5)	2 (0.1)	-4 (-0.2)	-8 (-0.3)	9 (0.4)
F47	680 (26.8)	959 (37.8)	153 (6)	682 (26.9)	955 (37.6)	150 (5.9)	2 (0.1)	-4 (-0.2)	-2 (-0.1)	5 (0.2)
F48	676 (26.6)	1039 (40.9)	160 (6.3)	674 (26.5)	1027 (40.4)	151 (6)	-2 (-0.1)	-12 (-0.5)	-9 (-0.4)	15 (0.6)

Table 10-32 Test 4-12 Post Interior and Deformation Measurement Page 2

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Attachment 5.5 --- Interior Vehicle Measurement Report

Vehicle Type	10000S	Test Number	110MASH4S21-03
Make	Freightliner	Model	Business Class M2
Year	2009	Color	White
VIN #	1FVACWDT09HAH4233		

Foot/Wheel Well and Toe Pan Area Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
F49	675 (26.6)	1090 (42.9)	171 (6.7)	659 (26)	1065 (41.9)	122 (4.8)	-15 (-0.6)	-25 (-1)	-49 (-1.9)	57 (2.2)
F50	695 (27.4)	1126 (44.3)	203 (8)	686 (27)	1097 (43.2)	159 (6.2)	-10 (-0.4)	-29 (-1.2)	-44 (-1.7)	54 (2.1)
F51	693 (27.3)	1165 (45.9)	199 (7.9)	685 (27)	1136 (44.7)	158 (6.2)	-8 (-0.3)	-29 (-1.2)	-41 (-1.6)	51 (2)
F52	688 (27.1)	1217 (47.9)	195 (7.7)	688 (27.1)	1186 (46.7)	173 (6.8)	0 (0)	-31 (-1.2)	-22 (-0.9)	38 (1.5)
F53	616 (24.3)	601 (23.7)	102 (4)	617 (24.3)	595 (23.4)	99 (3.9)	0 (0)	-6 (-0.2)	-2 (-0.1)	7 (0.3)
F54	621 (24.5)	663 (26.1)	123 (4.8)	621 (24.4)	663 (26.1)	121 (4.8)	-1 (0)	0 (0)	-1 (-0.1)	2 (0.1)
F55	618 (24.3)	749 (29.5)	153 (6)	619 (24.4)	747 (29.4)	145 (5.7)	1 (0)	-3 (-0.1)	-8 (-0.3)	8 (0.3)
F56	610 (24)	817 (32.2)	159 (6.3)	611 (24.1)	814 (32)	152 (6)	1 (0)	-3 (-0.1)	-8 (-0.3)	8 (0.3)
F57	610 (24)	891 (35.1)	155 (6.1)	614 (24.2)	889 (35)	147 (5.8)	4 (0.1)	-2 (-0.1)	-8 (-0.3)	9 (0.4)
F58	606 (23.9)	958 (37.7)	160 (6.3)	611 (24)	956 (37.6)	153 (6)	5 (0.2)	-2 (-0.1)	-8 (-0.3)	9 (0.4)
F59	608 (23.9)	1041 (41)	169 (6.6)	610 (24)	1036 (40.8)	172 (6.8)	1 (0.1)	-5 (-0.2)	3 (0.1)	6 (0.2)
F60	614 (24.2)	1119 (44)	184 (7.3)	602 (23.7)	1102 (43.4)	143 (5.6)	-13 (-0.5)	-16 (-0.6)	-42 (-1.6)	46 (1.8)
F61	618 (24.3)	1166 (45.9)	215 (8.5)	610 (24)	1139 (44.8)	185 (7.3)	-8 (-0.3)	-27 (-1.1)	-31 (-1.2)	41 (1.6)
F62	616 (24.2)	1213 (47.8)	218 (8.6)	616 (24.2)	1184 (46.6)	196 (7.7)	0 (0)	-29 (-1.2)	-22 (-0.9)	37 (1.5)
F63	507 (20)	603 (23.7)	111 (4.4)	508 (20)	597 (23.5)	113 (4.5)	1 (0)	-7 (-0.3)	2 (0.1)	7 (0.3)
F64	510 (20.1)	667 (26.3)	135 (5.3)	511 (20.1)	663 (26.1)	133 (5.2)	0 (0)	-4 (-0.1)	-2 (-0.1)	4 (0.2)
F65	512 (20.2)	753 (29.6)	163 (6.4)	514 (20.2)	750 (29.5)	156 (6.1)	2 (0.1)	-3 (-0.1)	-7 (-0.3)	7 (0.3)
F66	506 (19.9)	815 (32.1)	169 (6.6)	506 (19.9)	811 (31.9)	162 (6.4)	0 (0)	-4 (-0.1)	-6 (-0.3)	7 (0.3)
F67	504 (19.8)	895 (35.2)	165 (6.5)	507 (19.9)	891 (35.1)	155 (6.1)	3 (0.1)	-3 (-0.1)	-10 (-0.4)	11 (0.4)
F68	503 (19.8)	965 (38)	173 (6.8)	505 (19.9)	963 (37.9)	158 (6.2)	2 (0.1)	-2 (-0.1)	-15 (-0.6)	15 (0.6)
F69	506 (19.9)	1043 (41.1)	182 (7.1)	506 (19.9)	1042 (41)	169 (6.7)	1 (0)	-1 (0)	-13 (-0.5)	13 (0.5)
F70	506 (19.9)	1122 (44.2)	191 (7.5)	506 (19.9)	1116 (43.9)	179 (7.1)	1 (0)	-5 (-0.2)	-11 (-0.4)	12 (0.5)
F71	409 (16.1)	594 (23.4)	128 (5)	410 (16.1)	590 (23.2)	127 (5)	0 (0)	-4 (-0.2)	-1 (0)	4 (0.2)
F72	410 (16.1)	673 (26.5)	149 (5.9)	411 (16.2)	667 (26.3)	148 (5.8)	1 (0)	-6 (-0.2)	-1 (0)	6 (0.2)
F73	416 (16.4)	754 (29.7)	171 (6.7)	416 (16.4)	752 (29.6)	166 (6.5)	0 (0)	-2 (-0.1)	-5 (-0.2)	6 (0.2)
F74	414 (16.3)	811 (31.9)	173 (6.8)	416 (16.4)	809 (31.9)	168 (6.6)	2 (0.1)	-2 (-0.1)	-5 (-0.2)	6 (0.2)
F75	417 (16.4)	898 (35.4)	174 (6.8)	419 (16.5)	896 (35.3)	164 (6.5)	2 (0.1)	-3 (-0.1)	-10 (-0.4)	10 (0.4)
F76	420 (16.5)	968 (38.1)	182 (7.1)	420 (16.5)	966 (38)	166 (6.5)	1 (0)	-2 (-0.1)	-15 (-0.6)	16 (0.6)
F77	416 (16.4)	1042 (41)	190 (7.5)	418 (16.4)	1040 (40.9)	170 (6.7)	2 (0.1)	-2 (-0.1)	-20 (-0.8)	20 (0.8)
F78	410 (16.2)	1125 (44.3)	199 (7.8)	412 (16.2)	1121 (44.1)	193 (7.6)	2 (0.1)	-4 (-0.2)	-6 (-0.2)	7 (0.3)
F79	334 (13.2)	749 (29.5)	176 (6.9)	336 (13.2)	748 (29.4)	171 (6.7)	1 (0.1)	-1 (0)	-5 (-0.2)	6 (0.2)
F80	306 (12.1)	820 (32.3)	171 (6.7)	307 (12.1)	818 (32.2)	165 (6.5)	1 (0)	-2 (-0.1)	-6 (-0.2)	6 (0.2)
F81	311 (12.2)	906 (35.7)	174 (6.8)	313 (12.3)	903 (35.6)	168 (6.6)	2 (0.1)	-3 (-0.1)	-6 (-0.2)	7 (0.3)
F82	334 (13.1)	967 (38.1)	182 (7.2)	336 (13.2)	966 (38)	175 (6.9)	2 (0.1)	-1 (-0.1)	-7 (-0.3)	7 (0.3)
F83	308 (12.1)	1043 (41)	176 (6.9)	311 (12.2)	1042 (41)	169 (6.7)	3 (0.1)	0 (0)	-6 (-0.3)	7 (0.3)
F84	307 (12.1)	1120 (44.1)	184 (7.3)	310 (12.2)	1119 (44)	177 (6.9)	3 (0.1)	-1 (0)	-8 (-0.3)	8 (0.3)
F85	309 (12.2)	1210 (47.6)	208 (8.2)	312 (12.3)	1207 (47.5)	200 (7.9)	3 (0.1)	-3 (-0.1)	-8 (-0.3)	9 (0.4)

Side Front Panel Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
S1	893 (35.2)	1194 (47)	-114 (-4.5)	895 (35.2)	1196 (47.1)	-125 (-4.9)	2 (0.1)	1 (0.1)	-12 (-0.5)	12 (0.5)
S2	958 (37.7)	1190 (46.9)	-15 (-0.6)	959 (37.7)	1196 (47.1)	-30 (-1.2)	1 (0)	5 (0.2)	-14 (-0.6)	15 (0.6)
S3	898 (35.4)	1196 (47.1)	-32 (-1.3)	901 (35.5)	1205 (47.4)	-48 (-1.9)	3 (0.1)	8 (0.3)	-15 (-0.6)	18 (0.7)
S4	889 (35)	1186 (46.7)	5 (0.2)	888 (35)	1190 (46.9)	-15 (-0.6)	0 (0)	4 (0.2)	-20 (-0.8)	20 (0.8)

Table 10-33 Test 4-12 Post Interior and Deformation Measurement Page 3

Attachment 5.5 --- Interior Vehicle Measurement Report

Vehicle Type	10000S	Test Number	110MASH4S21-03
Make	Freightliner	Model	Business Class M2
Year	2009	Color	White
VIN #	1FVACWDT09HAH4233		

Roof Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
R1	738 (29.1)	539 (21.2)	-1186 (-46.7)	664 (26.1)	554 (21.8)	-1177 (-46.3)	-74 (-2.9)	15 (0.6)	9 (0.4)	76 (3)
R2	736 (29)	666 (26.2)	-1186 (-46.7)	671 (26.4)	684 (26.9)	-1182 (-46.6)	-65 (-2.6)	18 (0.7)	4 (0.1)	68 (2.7)
R3	726 (28.6)	762 (30)	-1186 (-46.7)	672 (26.4)	776 (30.5)	-1186 (-46.7)	-54 (-2.1)	14 (0.6)	0 (0)	56 (2.2)
R4	704 (27.7)	851 (33.5)	-1185 (-46.6)	656 (25.8)	868 (34.2)	-1187 (-46.7)	-48 (-1.9)	17 (0.7)	-2 (-0.1)	51 (2)
R5	696 (27.4)	929 (36.6)	-1184 (-46.6)	655 (25.8)	946 (37.3)	-1189 (-46.8)	-41 (-1.6)	17 (0.7)	-5 (-0.2)	45 (1.8)
R6	711 (28)	1015 (39.9)	-1183 (-46.6)	683 (26.9)	1029 (40.5)	-1193 (-47)	-28 (-1.1)	15 (0.6)	-10 (-0.4)	33 (1.3)
R7	596 (23.5)	540 (21.2)	-1186 (-46.7)	526 (20.7)	566 (22.3)	-1171 (-46.1)	-70 (-2.8)	26 (1)	15 (0.6)	77 (3)
R8	642 (25.3)	667 (26.3)	-1182 (-46.5)	582 (22.9)	690 (27.2)	-1175 (-46.2)	-60 (-2.4)	23 (0.9)	7 (0.3)	65 (2.5)
R9	645 (25.4)	750 (29.5)	-1183 (-46.6)	592 (23.3)	773 (30.4)	-1179 (-46.4)	-53 (-2.1)	23 (0.9)	4 (0.1)	58 (2.3)
R10	632 (24.9)	837 (33)	-1181 (-46.5)	588 (23.2)	862 (33.9)	-1181 (-46.5)	-44 (-1.7)	25 (1)	0 (0)	51 (2)
R11	623 (24.5)	912 (35.9)	-1180 (-46.4)	584 (23)	936 (36.8)	-1182 (-46.5)	-40 (-1.6)	23 (0.9)	-2 (-0.1)	46 (1.8)
R12	616 (24.3)	1021 (40.2)	-1205 (-47.5)	586 (23.1)	1044 (41.1)	-1213 (-47.8)	-30 (-1.2)	22 (0.9)	-8 (-0.3)	38 (1.5)
R13	510 (20.1)	667 (26.3)	-1321 (-52)	448 (17.6)	697 (27.4)	-1329 (-52.3)	-62 (-2.5)	30 (1.2)	-8 (-0.3)	69 (2.7)
R14	475 (18.7)	761 (30)	-1279 (-50.4)	422 (16.6)	796 (31.4)	-1273 (-50.1)	-53 (-2.1)	35 (1.4)	7 (0.3)	64 (2.5)
R15	490 (19.3)	868 (34.2)	-1308 (-51.5)	445 (17.5)	899 (35.4)	-1314 (-51.7)	-45 (-1.8)	31 (1.2)	-6 (-0.2)	55 (2.2)
R16	492 (19.4)	937 (36.9)	-1310 (-51.6)	455 (17.9)	969 (38.1)	-1315 (-51.8)	-37 (-1.4)	32 (1.2)	-5 (-0.2)	49 (1.9)
R17	474 (18.6)	1049 (41.3)	-1298 (-51.1)	446 (17.6)	1081 (42.6)	-1303 (-51.3)	-27 (-1.1)	32 (1.3)	-5 (-0.2)	43 (1.7)
R18	399 (15.7)	530 (20.9)	-1316 (-51.8)	329 (13)	570 (22.4)	-1331 (-52.4)	-70 (-2.8)	40 (1.6)	-15 (-0.6)	82 (3.2)
R19	400 (15.8)	664 (26.1)	-1315 (-51.8)	338 (13.3)	704 (27.7)	-1325 (-52.2)	-62 (-2.5)	40 (1.6)	-10 (-0.4)	75 (3)
R20	380 (14.9)	751 (29.6)	-1283 (-50.5)	326 (12.8)	793 (31.2)	-1275 (-50.2)	-54 (-2.1)	42 (1.6)	8 (0.3)	69 (2.7)
R21	386 (15.2)	852 (33.5)	-1311 (-51.6)	340 (13.4)	894 (35.2)	-1316 (-51.8)	-46 (-1.8)	42 (1.7)	-5 (-0.2)	62 (2.5)
R22	387 (15.3)	924 (36.4)	-1313 (-51.7)	349 (13.7)	964 (38)	-1318 (-51.9)	-39 (-1.5)	40 (1.6)	-5 (-0.2)	56 (2.2)
R23	378 (14.9)	1026 (40.4)	-1302 (-51.3)	348 (13.7)	1069 (42.1)	-1307 (-51.4)	-31 (-1.2)	43 (1.7)	-4 (-0.2)	53 (2.1)
R24	317 (12.5)	759 (29.9)	-1285 (-50.6)	262 (10.3)	808 (31.8)	-1276 (-50.2)	-55 (-2.2)	50 (2)	9 (0.4)	74 (2.9)
R25	307 (12.1)	856 (33.7)	-1312 (-51.6)	262 (10.3)	903 (35.5)	-1315 (-51.8)	-45 (-1.8)	47 (1.9)	-3 (-0.1)	65 (2.6)
R26	299 (11.8)	908 (35.7)	-1316 (-51.8)	258 (10.2)	955 (37.6)	-1319 (-51.9)	-41 (-1.6)	47 (1.9)	-3 (-0.1)	63 (2.5)
R27	277 (10.9)	1029 (40.5)	-1305 (-51.4)	245 (9.6)	1080 (42.5)	-1308 (-51.5)	-32 (-1.3)	52 (2)	-4 (-0.1)	61 (2.4)
R28	164 (6.5)	772 (30.4)	-1288 (-50.7)	106 (4.2)	834 (32.8)	-1275 (-50.2)	-58 (-2.3)	62 (2.4)	13 (0.5)	86 (3.4)
R29	158 (6.2)	857 (33.7)	-1313 (-51.7)	109 (4.3)	916 (36.1)	-1310 (-51.6)	-48 (-1.9)	60 (2.4)	4 (0.2)	77 (3)
R30	156 (6.1)	917 (36.1)	-1317 (-51.9)	111 (4.4)	977 (38.5)	-1315 (-51.8)	-45 (-1.8)	61 (2.4)	2 (0.1)	76 (3)
R31	132 (5.2)	1031 (40.6)	-1307 (-51.4)	101 (4)	1095 (43.1)	-1306 (-51.4)	-31 (-1.2)	64 (2.5)	0 (0)	71 (2.8)
R32	63 (2.5)	764 (30.1)	-1290 (-50.8)	4 (0.2)	834 (32.8)	-1276 (-50.2)	-59 (-2.3)	70 (2.8)	14 (0.6)	92 (3.6)
R33	55 (2.1)	858 (33.8)	-1315 (-51.8)	5 (0.2)	928 (36.5)	-1307 (-51.5)	-49 (-1.9)	70 (2.8)	7 (0.3)	86 (3.4)
R34	50 (2)	929 (36.6)	-1318 (-51.9)	8 (0.3)	1000 (39.4)	-1313 (-51.7)	-41 (-1.6)	71 (2.8)	5 (0.2)	82 (3.2)
R35	49 (1.9)	1032 (40.6)	-1308 (-51.5)	16 (0.6)	1102 (43.4)	-1306 (-51.4)	-34 (-1.3)	70 (2.8)	2 (0.1)	78 (3.1)
R36	-47 (-1.8)	761 (30)	-1291 (-50.8)	-105 (-4.1)	841 (33.1)	-1275 (-50.2)	-58 (-2.3)	80 (3.2)	16 (0.6)	100 (4)
R37	-48 (-1.9)	848 (33.4)	-1317 (-51.8)	-94 (-3.7)	929 (36.6)	-1308 (-51.5)	-46 (-1.8)	81 (3.2)	9 (0.4)	94 (3.7)
R38	-44 (-1.7)	925 (36.4)	-1320 (-52)	-84 (-3.3)	1004 (39.5)	-1314 (-51.7)	-39 (-1.6)	78 (3.1)	6 (0.2)	88 (3.5)
R39	-44 (-1.7)	1031 (40.6)	-1309 (-51.5)	-75 (-3)	1109 (43.7)	-1307 (-51.5)	-31 (-1.2)	78 (3.1)	2 (0.1)	84 (3.3)

Windshield Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
W1	932 (36.7)	709 (27.9)	-1061 (-41.8)	884 (34.8)	710 (28)	-1067 (-42)	-49 (-1.9)	1 (0)	-6 (-0.2)	49 (1.9)
W2	920 (36.2)	816 (32.1)	-1056 (-41.6)	881 (34.7)	817 (32.2)	-1064 (-41.9)	-39 (-1.5)	2 (0.1)	-8 (-0.3)	40 (1.6)
W3	905 (35.6)	915 (36)	-1049 (-41.3)	875 (34.4)	918 (36.1)	-1058 (-41.7)	-30 (-1.2)	3 (0.1)	-9 (-0.4)	32 (1.3)
W4	889 (35)	994 (39.1)	-1045 (-41.2)	862 (33.9)	997 (39.3)	-1056 (-41.6)	-27 (-1)	3 (0.1)	-10 (-0.4)	29 (1.1)
W5	867 (34.1)	1078 (42.4)	-1040 (-41)	845 (33.3)	1083 (42.6)	-1050 (-41.3)	-22 (-0.9)	5 (0.2)	-10 (-0.4)	25 (1)
W6	987 (38.9)	714 (28.1)	-948 (-37.3)	949 (37.4)	715 (28.2)	-959 (-37.8)	-39 (-1.5)	1 (0)	-11 (-0.4)	40 (1.6)
W7	972 (38.3)	836 (32.9)	-944 (-37.1)	942 (37.1)	835 (32.9)	-955 (-37.6)	-31 (-1.2)	0 (0)	-11 (-0.4)	33 (1.3)
W8	955 (37.6)	933 (36.8)	-940 (-37)	929 (36.6)	934 (36.8)	-952 (-37.5)	-26 (-1)	1 (0)	-12 (-0.5)	29 (1.2)
W9	936 (36.8)	1016 (40)	-939 (-37)	914 (36)	1017 (40.1)	-950 (-37.4)	-22 (-0.9)	2 (0.1)	-12 (-0.5)	25 (1)
W10	913 (35.9)	1097 (43.2)	-935 (-36.8)	895 (35.2)	1101 (43.3)	-946 (-37.2)	-18 (-0.7)	4 (0.2)	-11 (-0.4)	22 (0.8)

Table 10-34 Test 4-12 Post Interior and Deformation Measurement Page 4

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Attachment 5.5 --- Interior Vehicle Measurement Report

Vehicle Type	10000S	Test Number	110MASH4S21-03
Make	Freightliner	Model	Business Class M2
Year	2009	Color	White
VIN #	1FVACWDT09HAH4233		

Windshield Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
W11	888 (34.9)	1191 (46.9)	-911 (-35.9)	872 (34.3)	1197 (47.1)	-926 (-36.5)	-16 (-0.6)	5 (0.2)	-15 (-0.6)	22 (0.9)
W12	1034 (40.7)	716 (28.2)	-854 (-33.6)	1000 (39.4)	714 (28.1)	-870 (-34.3)	-34 (-1.3)	-2 (-0.1)	-16 (-0.6)	38 (1.5)
W13	1018 (40.1)	840 (33.1)	-849 (-33.4)	989 (38.9)	838 (33)	-866 (-34.1)	-29 (-1.2)	-2 (-0.1)	-17 (-0.7)	34 (1.3)
W14	999 (39.3)	946 (37.2)	-847 (-33.3)	974 (38.3)	945 (37.2)	-863 (-34)	-25 (-1)	-1 (0)	-16 (-0.6)	29 (1.2)
W15	987 (38.8)	1028 (40.5)	-829 (-32.6)	965 (38)	1029 (40.5)	-846 (-33.3)	-21 (-0.8)	1 (0)	-17 (-0.7)	27 (1.1)
W16	955 (37.6)	1155 (45.5)	-806 (-31.7)	939 (37)	1157 (45.6)	-823 (-32.4)	-16 (-0.6)	2 (0.1)	-17 (-0.7)	23 (0.9)
W17	1086 (42.8)	721 (28.4)	-747 (-29.4)	1060 (41.7)	717 (28.2)	-760 (-29.9)	-26 (-1)	-4 (-0.1)	-14 (-0.5)	30 (1.2)
W18	1068 (42.1)	845 (33.3)	-744 (-29.3)	1045 (41.1)	844 (33.2)	-760 (-29.9)	-23 (-0.9)	-1 (0)	-16 (-0.6)	28 (1.1)
W19	1052 (41.4)	959 (37.7)	-730 (-28.7)	1033 (40.7)	958 (37.7)	-744 (-29.3)	-19 (-0.7)	-1 (0)	-15 (-0.6)	24 (0.9)
W20	1034 (40.7)	1052 (41.4)	-716 (-28.2)	1019 (40.1)	1050 (41.3)	-731 (-28.8)	-16 (-0.6)	-2 (-0.1)	-15 (-0.6)	22 (0.9)
W21	988 (38.9)	1213 (47.8)	-674 (-26.5)	977 (38.5)	1215 (47.8)	-687 (-27.1)	-11 (-0.4)	2 (0.1)	-13 (-0.5)	17 (0.7)
W22	1133 (44.6)	732 (28.8)	-649 (-25.6)	1110 (43.7)	727 (28.6)	-666 (-26.2)	-23 (-0.9)	-4 (-0.2)	-17 (-0.7)	29 (1.1)
W23	1113 (43.8)	857 (33.8)	-648 (-25.5)	1094 (43.1)	854 (33.6)	-663 (-26.1)	-19 (-0.7)	-3 (-0.1)	-15 (-0.6)	24 (1)
W24	1089 (42.9)	980 (38.6)	-642 (-25.3)	1074 (42.3)	977 (38.5)	-656 (-25.8)	-15 (-0.6)	-4 (-0.1)	-14 (-0.6)	21 (0.8)
W25	1071 (42.2)	1076 (42.4)	-622 (-24.5)	1058 (41.7)	1073 (42.3)	-637 (-25.1)	-13 (-0.5)	-2 (-0.1)	-15 (-0.6)	20 (0.8)
W26	1017 (40)	1220 (48)	-601 (-23.7)	1006 (39.6)	1223 (48.1)	-615 (-24.2)	-11 (-0.4)	2 (0.1)	-13 (-0.5)	17 (0.7)
W27	1173 (46.2)	736 (29)	-564 (-22.2)	1153 (45.4)	730 (28.8)	-582 (-22.9)	-19 (-0.8)	-5 (-0.2)	-18 (-0.7)	27 (1.1)
W28	1151 (45.3)	870 (34.3)	-562 (-22.1)	1135 (44.7)	865 (34.1)	-580 (-22.8)	-17 (-0.7)	-5 (-0.2)	-18 (-0.7)	25 (1)
W29	1124 (44.2)	1001 (39.4)	-557 (-21.9)	1110 (43.7)	996 (39.2)	-575 (-22.6)	-14 (-0.6)	-4 (-0.2)	-19 (-0.7)	24 (0.9)
W30	1085 (42.7)	1121 (44.1)	-555 (-21.8)	1076 (42.4)	1117 (44)	-569 (-22.4)	-9 (-0.4)	-4 (-0.2)	-14 (-0.5)	17 (0.7)
W31	1035 (40.7)	1239 (48.8)	-532 (-21)	1028 (40.5)	1237 (48.7)	-546 (-21.5)	-7 (-0.3)	-1 (-0.1)	-14 (-0.5)	16 (0.6)

Dashboard Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
D1										
D2										
D3										
D4										
D5										
D6										
D7										
D8										
D9										
D10										
D11										
D12										
D13										
D14										
D15										
D16										
D17										
D18										
D19										

Points lost during impact.

Table 10-35 Test 4-12 Post Interior and Deformation Measurement Page 5

Attachment 5.5 --- Interior Vehicle Measurement Report

Vehicle Type	10000S	Test Number	110MASH4S21-03
Make	Freightliner	Model	Business Class M2
Year	2009	Color	White
VIN #	1FVACWDT09HAH4233		

A and B Pillar Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
P1	651 (25.6)	1140 (44.9)	-1136 (-44.7)	631 (24.8)	1159 (45.6)	-1147 (-45.2)	-21 (-0.8)	19 (0.7)	-11 (-0.4)	30 (1.2)
P2	673 (26.5)	1151 (45.3)	-1088 (-42.8)	656 (25.8)	1165 (45.8)	-1099 (-43.3)	-17 (-0.7)	14 (0.6)	-10 (-0.4)	24 (0.9)
P3	707 (27.8)	1174 (46.2)	-1023 (-40.3)	692 (27.2)	1188 (46.8)	-1034 (-40.7)	-15 (-0.6)	14 (0.6)	-11 (-0.5)	24 (0.9)
P4	736 (29)	1180 (46.5)	-955 (-37.6)	724 (28.5)	1191 (46.9)	-967 (-38.1)	-11 (-0.4)	11 (0.4)	-12 (-0.5)	19 (0.8)
P5	759 (29.9)	1186 (46.7)	-901 (-35.5)	746 (29.4)	1196 (47.1)	-912 (-35.9)	-13 (-0.5)	10 (0.4)	-12 (-0.5)	20 (0.8)
P6	785 (30.9)	1199 (47.2)	-829 (-32.6)	773 (30.5)	1207 (47.5)	-840 (-33.1)	-12 (-0.5)	8 (0.3)	-11 (-0.4)	18 (0.7)
P7	814 (32.1)	1204 (47.4)	-744 (-29.3)	806 (31.7)	1206 (47.5)	-759 (-29.9)	-8 (-0.3)	2 (0.1)	-16 (-0.6)	18 (0.7)
P8	840 (33.1)	1202 (47.3)	-679 (-26.7)	834 (32.8)	1202 (47.3)	-695 (-27.4)	-6 (-0.3)	0 (0)	-16 (-0.6)	17 (0.7)
P9	861 (33.9)	1204 (47.4)	-570 (-22.5)	852 (33.6)	1205 (47.4)	-584 (-23)	-8 (-0.3)	1 (0.1)	-14 (-0.5)	16 (0.6)
P10	-114 (-4.5)	1185 (46.7)	-1084 (-42.7)	-129 (-5.1)	1257 (49.5)	-1082 (-42.6)	-15 (-0.6)	71 (2.8)	2 (0.1)	73 (2.9)
P11	-112 (-4.4)	1196 (47.1)	-1010 (-39.8)	-132 (-5.2)	1265 (49.8)	-1003 (-39.5)	-19 (-0.8)	68 (2.7)	7 (0.3)	71 (2.8)
P12	-114 (-4.5)	1208 (47.6)	-937 (-36.9)	-131 (-5.2)	1268 (49.9)	-935 (-36.8)	-18 (-0.7)	60 (2.4)	2 (0.1)	62 (2.5)
P13	-114 (-4.5)	1216 (47.9)	-858 (-33.8)	-129 (-5.1)	1270 (50)	-855 (-33.7)	-15 (-0.6)	54 (2.1)	3 (0.1)	56 (2.2)
P14	-118 (-4.6)	1222 (48.1)	-796 (-31.3)	-132 (-5.2)	1272 (50.1)	-790 (-31.1)	-14 (-0.6)	50 (2)	6 (0.2)	52 (2.1)
P15	-120 (-4.7)	1228 (48.3)	-725 (-28.6)	-134 (-5.3)	1273 (50.1)	-722 (-28.4)	-14 (-0.5)	45 (1.8)	3 (0.1)	47 (1.9)
P16	-131 (-5.2)	1234 (48.6)	-642 (-25.3)	-143 (-5.6)	1273 (50.1)	-637 (-25.1)	-13 (-0.5)	39 (1.5)	4 (0.2)	41 (1.6)
P17	-140 (-5.5)	1239 (48.8)	-553 (-21.8)	-153 (-6)	1271 (50.1)	-545 (-21.5)	-14 (-0.5)	33 (1.3)	8 (0.3)	36 (1.4)
P18	-141 (-5.6)	1241 (48.9)	-480 (-18.9)	-155 (-6.1)	1269 (50)	-475 (-18.7)	-14 (-0.5)	28 (1.1)	6 (0.2)	32 (1.3)
P19	-142 (-5.6)	1242 (48.9)	-386 (-15.2)	-151 (-5.9)	1265 (49.8)	-379 (-14.9)	-9 (-0.4)	22 (0.9)	7 (0.3)	25 (1)
P20	-141 (-5.5)	1243 (48.9)	-277 (-10.9)	-147 (-5.8)	1258 (49.5)	-274 (-10.8)	-6 (-0.2)	15 (0.6)	3 (0.1)	17 (0.7)
P21	-144 (-5.7)	1236 (48.6)	-137 (-5.4)	-147 (-5.8)	1245 (49)	-136 (-5.3)	-2 (-0.1)	9 (0.4)	2 (0.1)	10 (0.4)

Above Seat Front Side Door Area Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
A1	751 (29.5)	1206 (47.5)	-445 (-17.5)	743 (29.3)	1214 (47.8)	-459 (-18.1)	-7 (-0.3)	8 (0.3)	-15 (-0.6)	18 (0.7)
A2	683 (26.9)	1201 (47.3)	-446 (-17.6)	675 (26.6)	1211 (47.7)	-458 (-18)	-8 (-0.3)	10 (0.4)	-12 (-0.5)	17 (0.7)
A3	603 (23.7)	1203 (47.4)	-454 (-17.9)	595 (23.4)	1215 (47.9)	-463 (-18.2)	-8 (-0.3)	13 (0.5)	-9 (-0.4)	18 (0.7)
A4	491 (19.3)	1195 (47.1)	-466 (-18.4)	483 (19)	1212 (47.7)	-477 (-18.8)	-8 (-0.3)	17 (0.7)	-10 (-0.4)	21 (0.8)
A5	366 (14.4)	1183 (46.6)	-481 (-19)	359 (14.1)	1205 (47.5)	-490 (-19.3)	-7 (-0.3)	22 (0.9)	-8 (-0.3)	25 (1)
A6	241 (9.5)	1193 (47)	-499 (-19.7)	233 (9.2)	1220 (48)	-504 (-19.9)	-8 (-0.3)	27 (1.1)	-5 (-0.2)	29 (1.1)
A7	132 (5.2)	1207 (47.5)	-518 (-20.4)	124 (4.9)	1239 (48.8)	-520 (-20.5)	-8 (-0.3)	32 (1.3)	-2 (-0.1)	33 (1.3)
A8	40 (1.6)	1213 (47.8)	-537 (-21.1)	32 (1.3)	1249 (49.2)	-538 (-21.2)	-8 (-0.3)	36 (1.4)	-1 (-0.1)	37 (1.4)

Below Seat Front Side Door Area Measurements - Dimensions in mm (inches)

Point	Pre-Impact			Post-Impact			Difference			Magnitude
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ	
B1	736 (30.1)	1235 (50.4)	-13 (-0.5)	737 (30.1)	1226 (50)	-25 (-1)	1 (0)	-10 (-0.4)	-12 (-0.5)	15 (0.6)
B2	653 (26.6)	1239 (50.6)	-10 (-0.4)	652 (26.6)	1232 (50.3)	-22 (-0.9)	0 (0)	-7 (-0.3)	-13 (-0.5)	15 (0.6)
B3	572 (23.3)	1263 (51.5)	10 (0.4)	574 (23.4)	1256 (51.3)	0 (0)	2 (0.1)	-6 (-0.3)	-10 (-0.4)	12 (0.5)
B4	473 (19.3)	1270 (51.9)	26 (1.1)	475 (19.4)	1266 (51.7)	19 (0.8)	3 (0.1)	-4 (-0.2)	-8 (-0.3)	9 (0.4)
B5	351 (14.3)	1239 (50.6)	21 (0.8)	350 (14.3)	1238 (50.5)	14 (0.6)	-1 (-0.1)	0 (0)	-7 (-0.3)	7 (0.3)
B6	236 (9.6)	1236 (50.5)	35 (1.4)	237 (9.7)	1240 (50.6)	25 (1)	1 (0)	4 (0.1)	-10 (-0.4)	11 (0.4)
B7	635 (25.9)	1235 (50.4)	122 (5)	635 (25.9)	1221 (49.8)	112 (4.6)	0 (0)	-15 (-0.6)	-10 (-0.4)	18 (0.7)
B8	544 (22.2)	1237 (50.5)	134 (5.5)	546 (22.3)	1225 (50)	123 (5)	2 (0.1)	-12 (-0.5)	-10 (-0.4)	16 (0.6)
B9	416 (17)	1237 (50.5)	152 (6.2)	418 (17.1)	1229 (50.2)	142 (5.8)	2 (0.1)	-8 (-0.3)	-10 (-0.4)	12 (0.5)

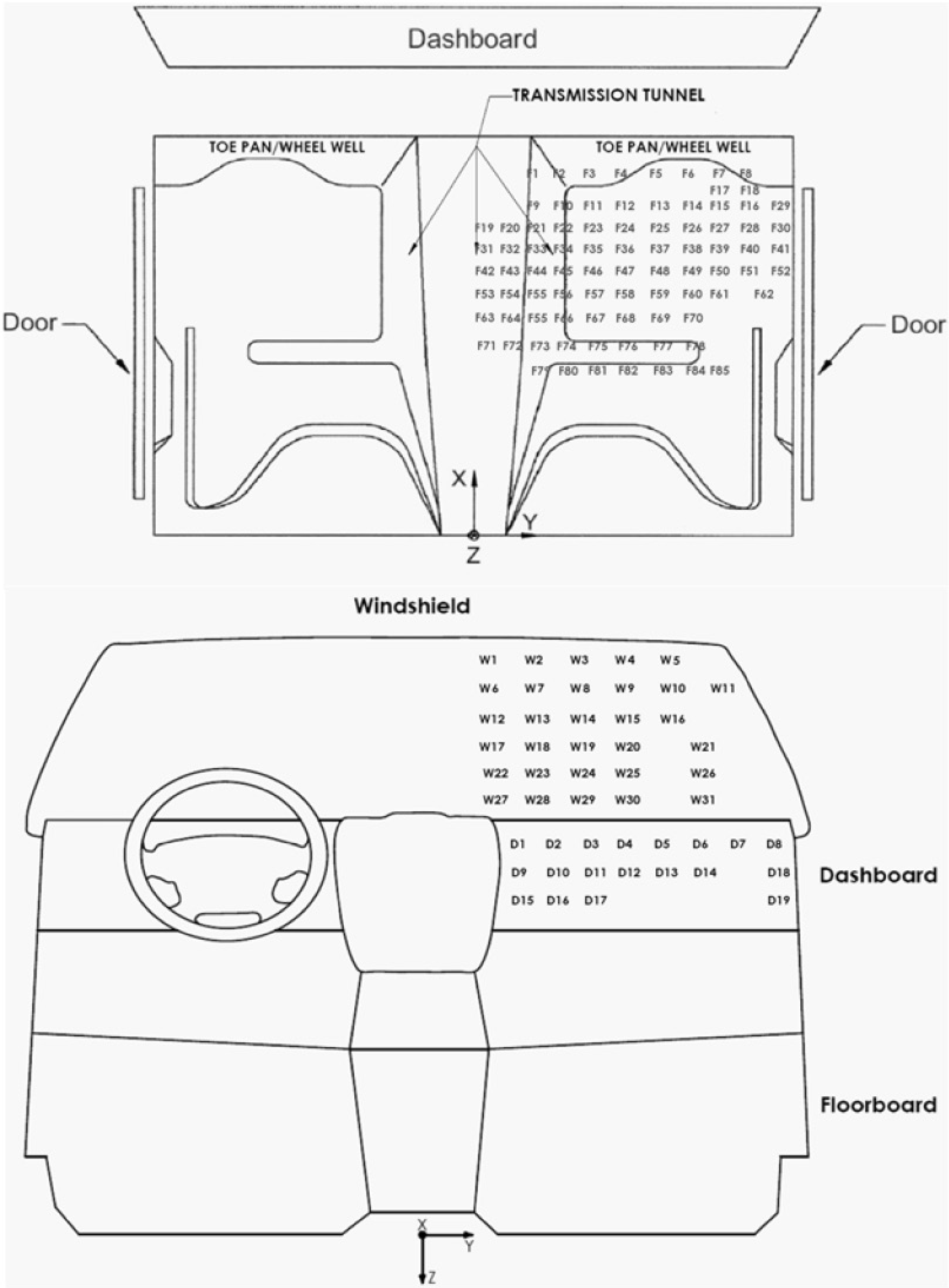


Figure 10-21 Schematic of Measured Interior Points for Floorboard, Dashboard, Windshield, Toe Pan, Wheel Well and Transmission Tunnel

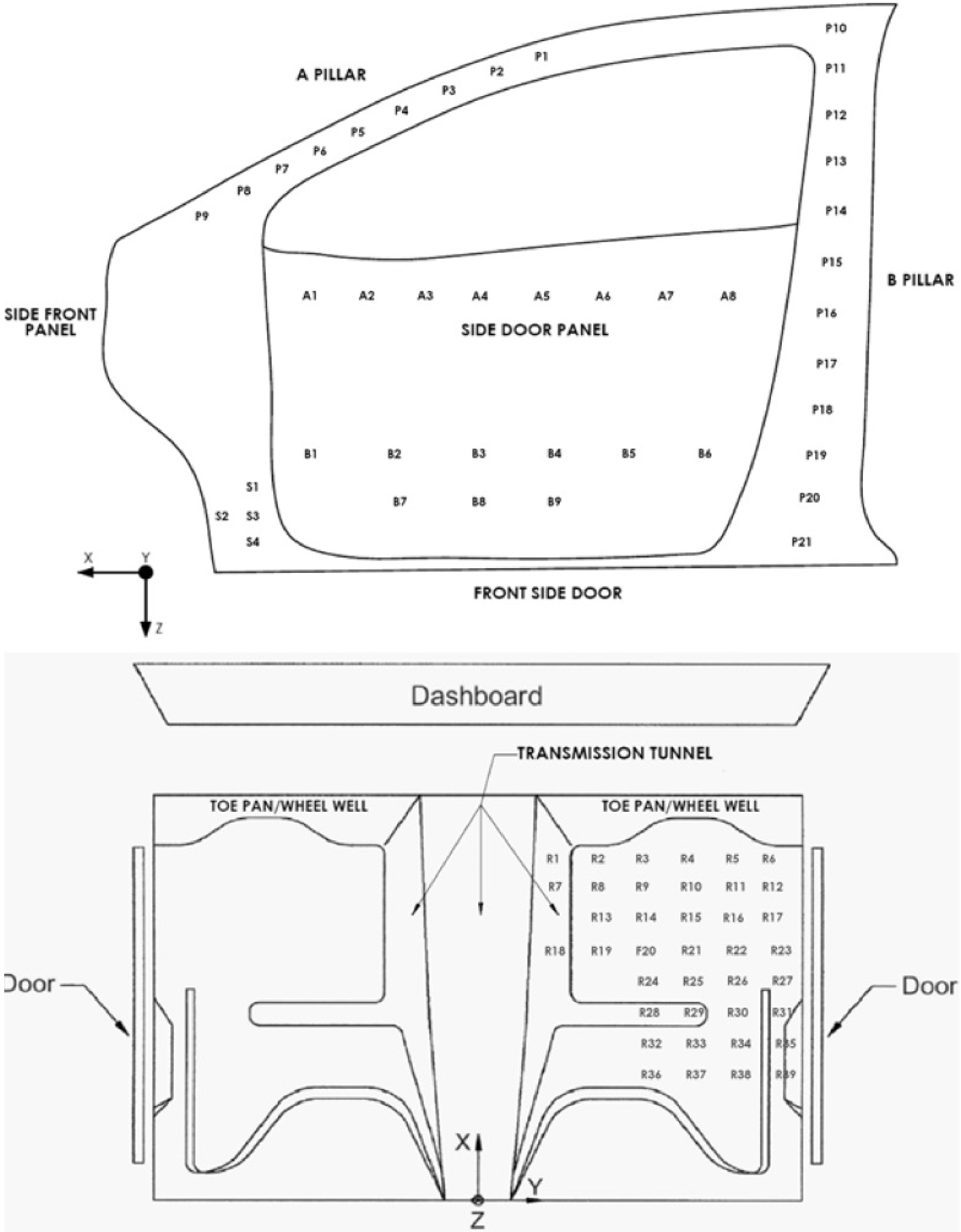


Figure 10-22 Schematic of Measured Points for the A Pillar, B Pillar, Side Front Door Panel, Side Door Panel, Front Side Door and Roof

10.7. Data Plots

The TRAP data plots, and summary sheets are shown in Figure 10-23 through Figure 10-71. The plots included are the accelerations, angular rate sensor rates, angular rate sensor degrees, Acceleration Severity Index (ASI), and TRAP test summary sheets. All data were analyzed using TRAP.

10.7.1. Data Plots - Test 110MASH4C21-01 (Test 4-10)

The data from both SLICE systems were analyzed using TRAP. The TRAP results sheets and data plots are shown below.

DTS SLICE BASE 659 Plots

Test Summary Report (Using SAE Class 180 Filter on Acceleration Data and Angular Velocity/Displacement Data)

General Information
Test Agency: California Department of Transportation
Test Number: 110MASH4C21-01
Test Date: 05/26/2021
Test Article: DTS BA00659 Type 86H MASH Test 4-10

Test Vehicle
Description: 2015 Nissan Versa Sedan
Test Inertial Mass: 1107 kg
Gross Static Mass: 1107 kg

Impact Conditions
Speed: 99.6 km/h
Angle: 25.2 degrees

Occupant Risk Factors
Impact Velocity (m/s) at 0.0870 seconds on right side of interior
x-direction 6.9
y-direction 10.0

THIV (km/hr): 43.4 at 0.0855 seconds on right side of interior
THIV (m/s): 12.0

Ridedown Accelerations (g's)
x-direction -6.0 (0.1931 - 0.2031 seconds)
y-direction -11.8 (0.1922 - 0.2022 seconds)

PHD (g's): 13.1 (0.1924 - 0.2024 seconds)

ASI: 2.83 (0.0606 - 0.1106 seconds)

Max. 50msec Moving Avg. Accelerations (g's)
x-direction -13.1 (0.0301 - 0.0801 seconds)
y-direction -20.3 (0.0297 - 0.0797 seconds)
z-direction 4.8 (0.0132 - 0.0632 seconds)

Max Roll, Pitch, and Yaw Angles (degrees)
Roll 9.5 (0.2631 seconds)
Pitch -5.2 (0.9134 seconds)
Yaw -48.6 (1.0097 seconds)

Figure 10-23 Test 4-10 TRAP Summary Sheet (DTS SLICE Micro TRAP BA00659)

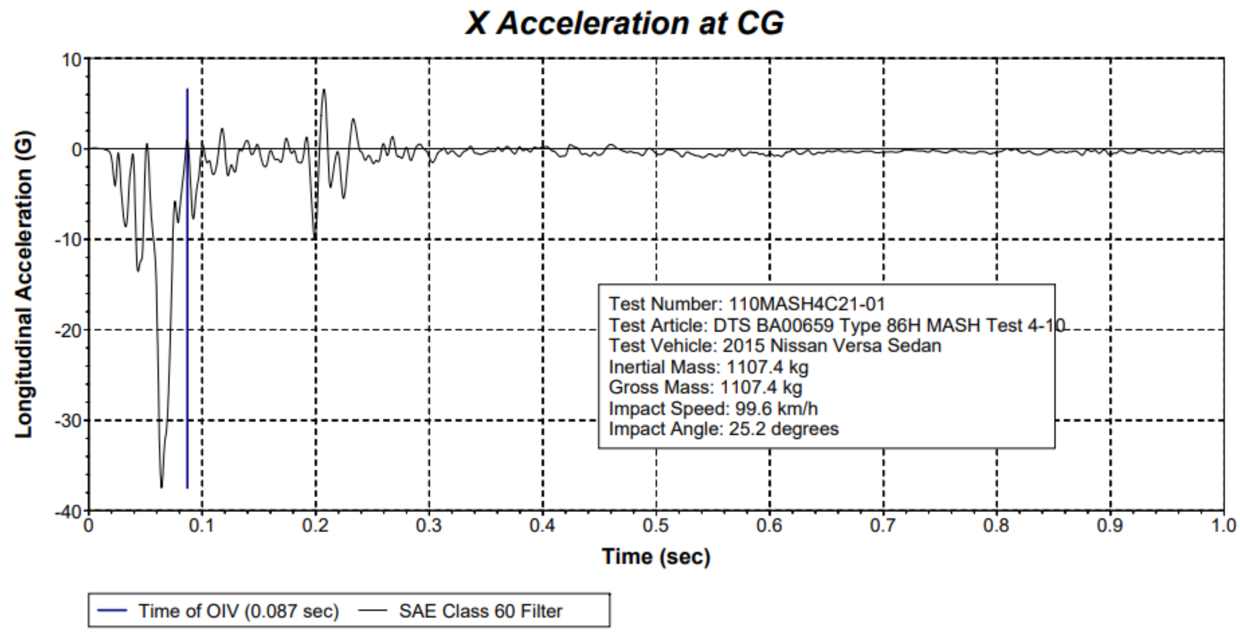


Figure 10-24 Test 4-10 Longitudinal Acceleration (DTS SLICE Micro TRAP BA00659)

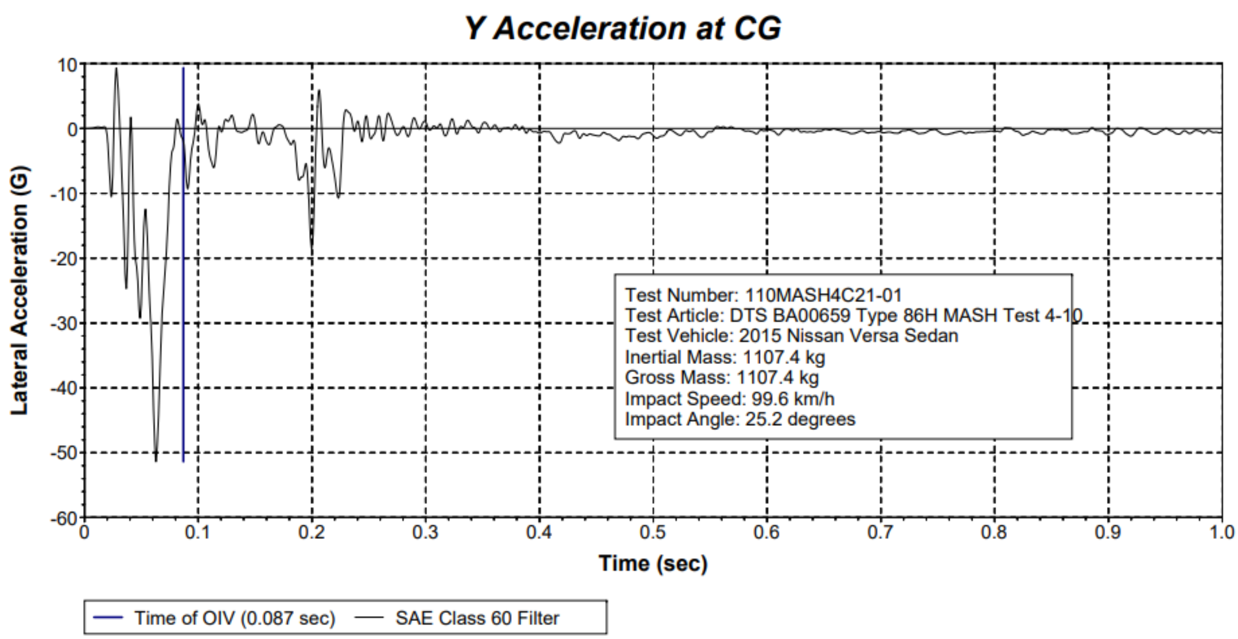


Figure 10-25 Test 4-10 Lateral Acceleration (DTS SLICE Micro TRAP BA00659)

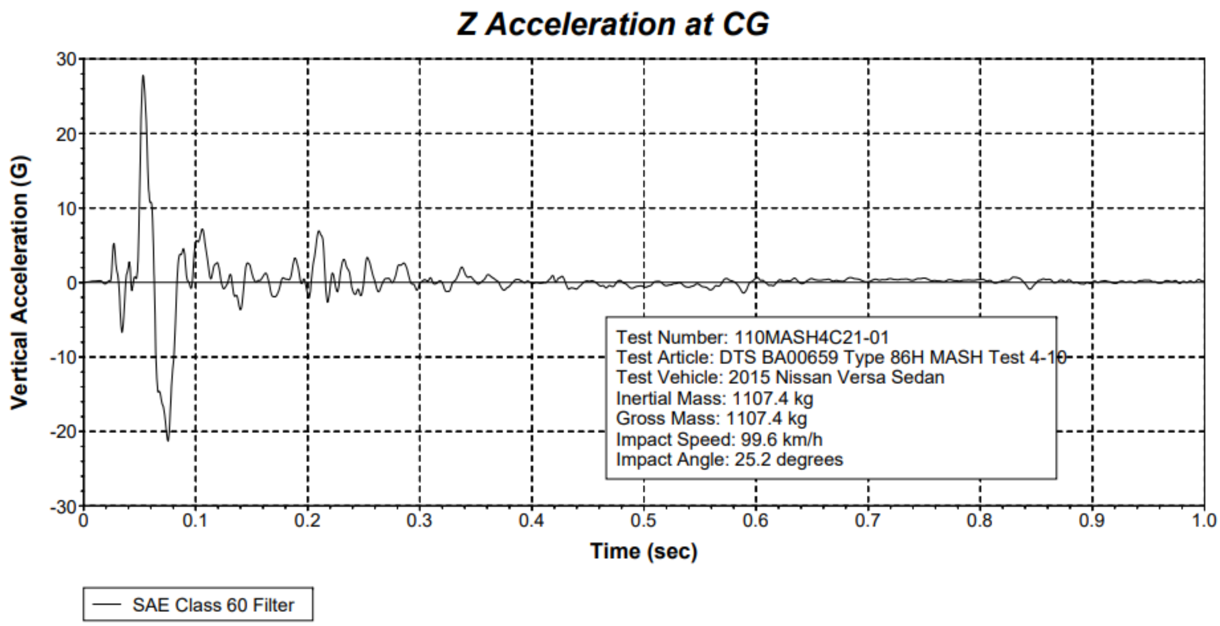


Figure 10-26 Test 4-10 Vertical Acceleration (DTS SLICE Micro TRAP BA00659)

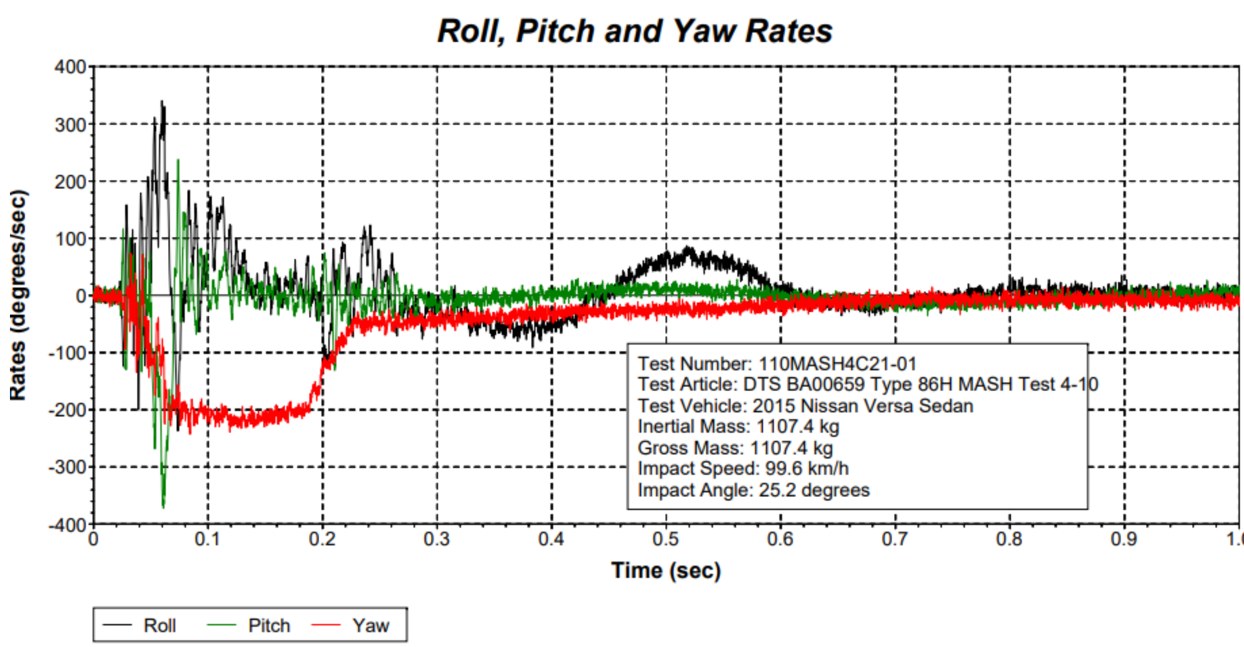


Figure 10-27 Test 4-10 Roll, Pitch, and Yaw Rates (DTS SLICE Micro TRAP BA00659)

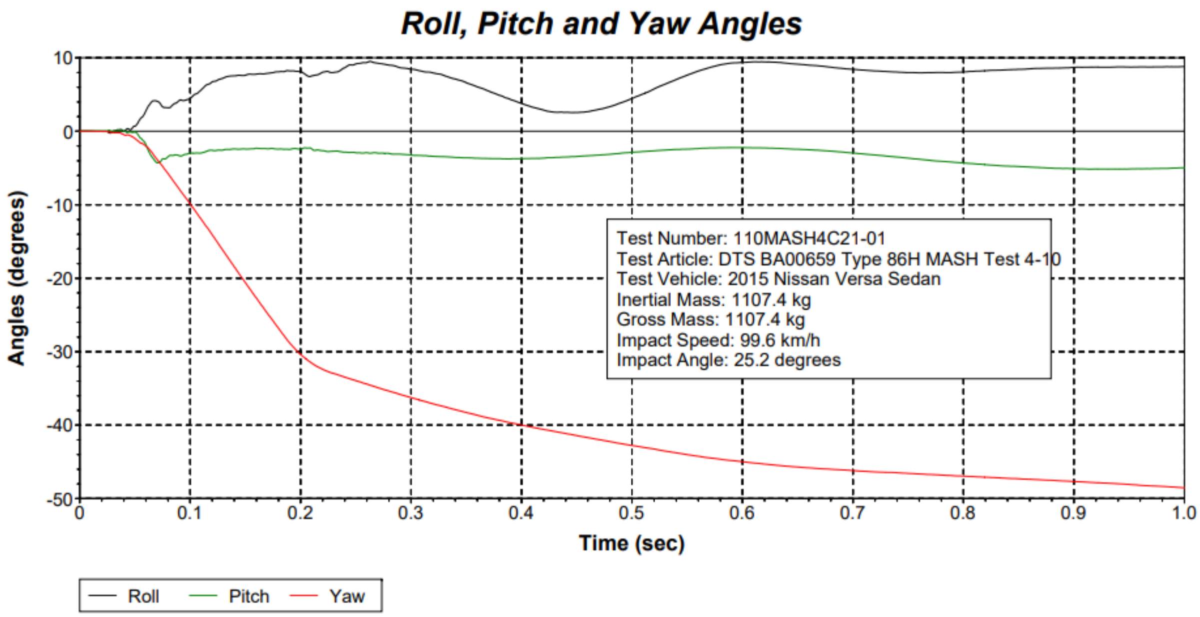


Figure 10-28 Test 4-10 Roll, Pitch, and Yaw Angles (DTS SLICE Micro TRAP BA00659)

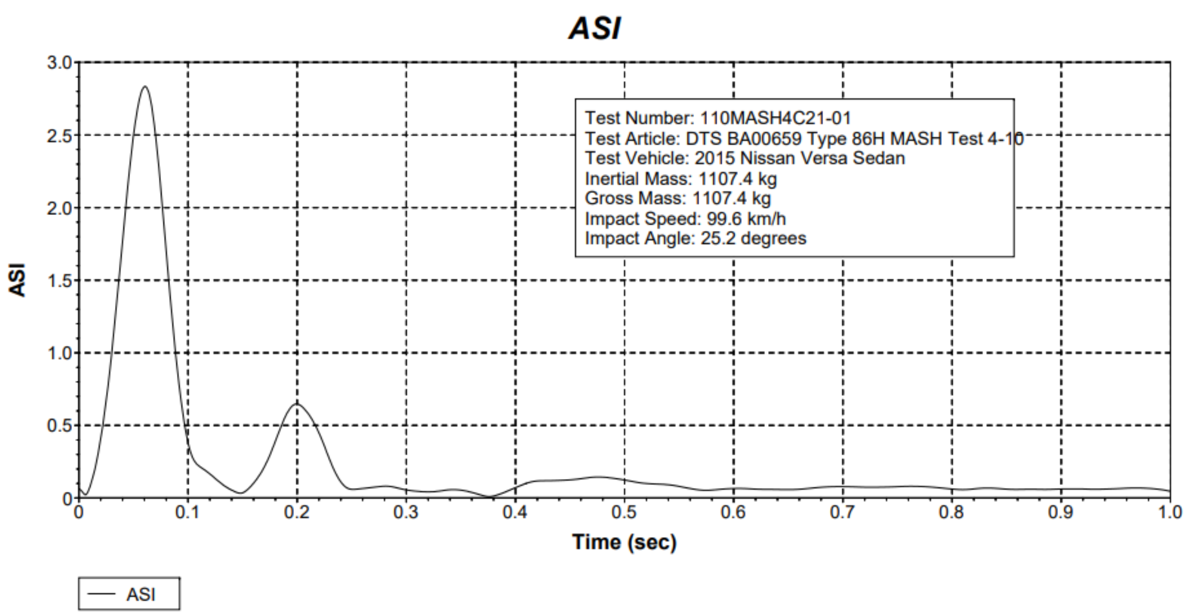


Figure 10-29 Test 4-10 Acceleration Severity Index (DTS SLICE Micro TRAP BA00659)

DTS SLICE BASE 656 Plots

Test Summary Report (Using SAE Class 180 Filter on Acceleration Data and Angular Velocity/Displacement Data)

General Information
Test Agency: California Department of Transportation
Test Number: 110MASH4C21-01
Test Date: 05/26/2021
Test Article: DTS BA00656 Type 86H MASH Test 4-10

Test Vehicle
Description: 2015 Nissan Versa Sedan
Test Inertial Mass: 1107 kg
Gross Static Mass: 1107 kg

Impact Conditions
Speed: 99.6 km/h
Angle: 25.2 degrees

Occupant Risk Factors
Impact Velocity (m/s) at 0.0889 seconds on right side of interior
x-direction 6.8
y-direction 9.4

THIV (km/hr): 41.7 at 0.0872 seconds on right side of interior
THIV (m/s): 11.6

Ridedown Accelerations (g's)
x-direction -6.0 (0.1932 - 0.2032 seconds)
y-direction -12.1 (0.1921 - 0.2021 seconds)

PHD (g's): 13.4 (0.1924 - 0.2024 seconds)

ASI: 2.71 (0.0609 - 0.1109 seconds)

Max. 50msec Moving Avg. Accelerations (g's)
x-direction -13.1 (0.0300 - 0.0800 seconds)
y-direction -19.2 (0.0298 - 0.0798 seconds)
z-direction 3.5 (0.0135 - 0.0635 seconds)

Max Roll, Pitch, and Yaw Angles (degrees)
Roll 8.5 (0.2630 seconds)
Pitch -6.1 (0.9462 seconds)
Yaw -47.4 (1.0104 seconds)

Figure 10-30 Test 4-10 TRAP Summary Sheet (DTS SLICE Micro TRAP BA00656)

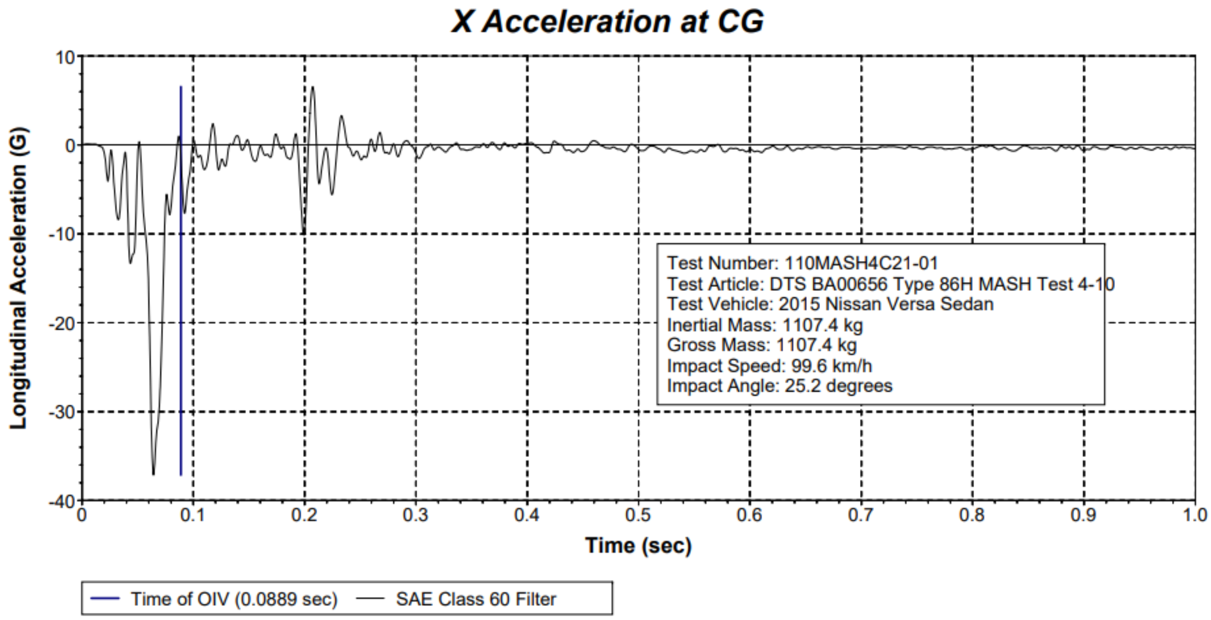


Figure 10-31 Test 4-10 Longitudinal Acceleration (DTS SLICE Micro TRAP BA00656)

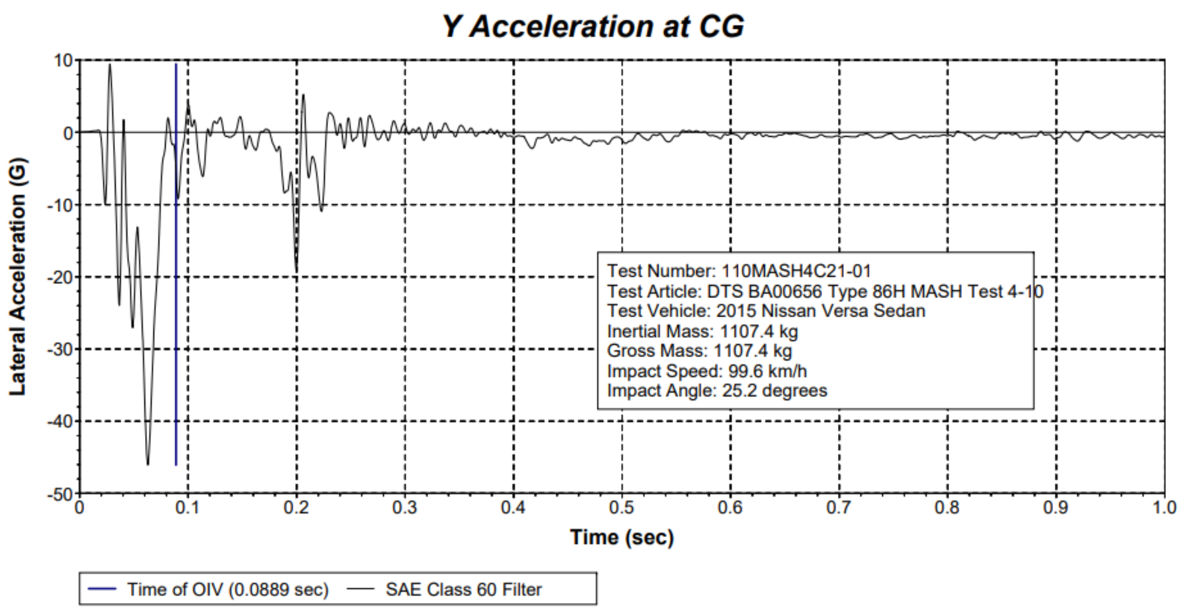


Figure 10-32 Test 4-10 Lateral Acceleration (DTS SLICE Micro TRAP BA00656)

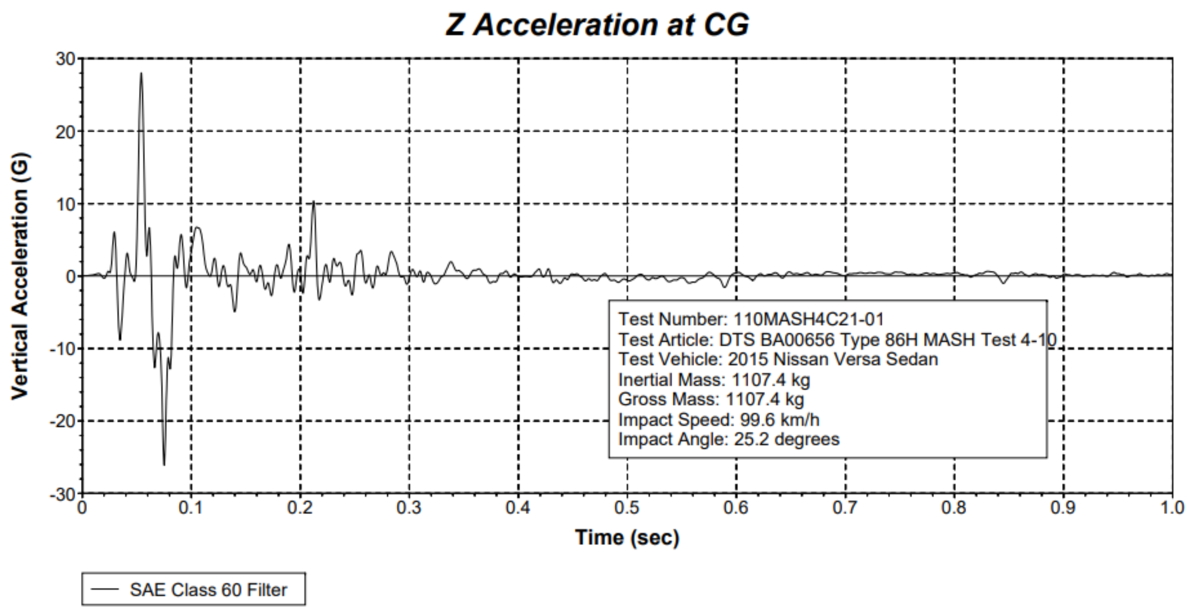


Figure 10-33 Test 4-10 Vertical Acceleration (DTS SLICE Micro TRAP BA00656)

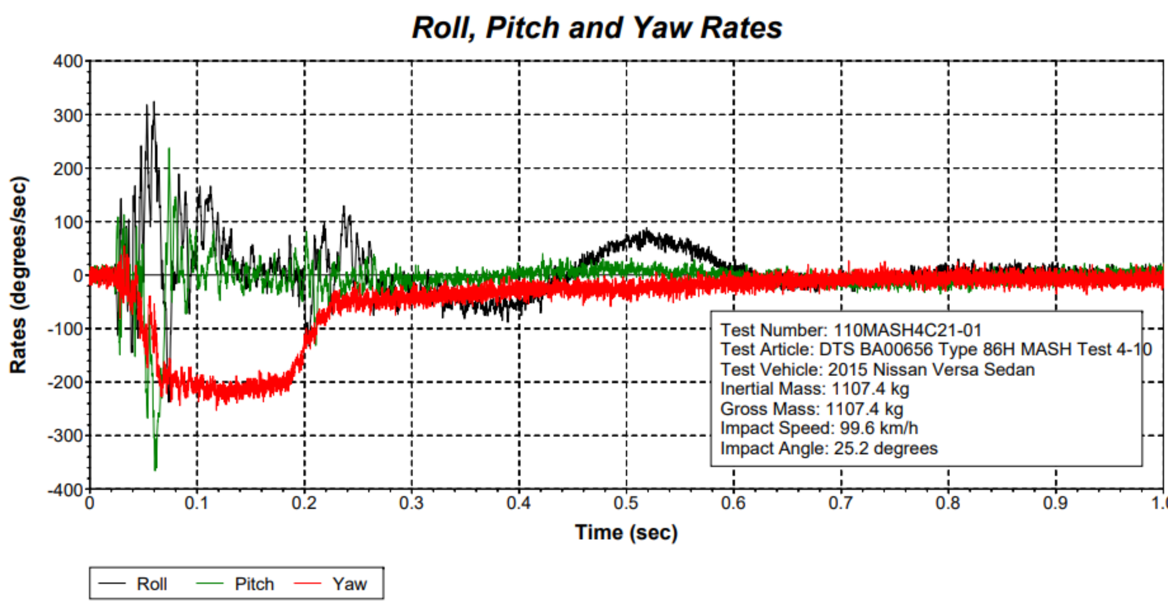


Figure 10-34 Test 4-10 Roll, Pitch, and Yaw Rates (DTS SLICE Micro TRAP BA00656)

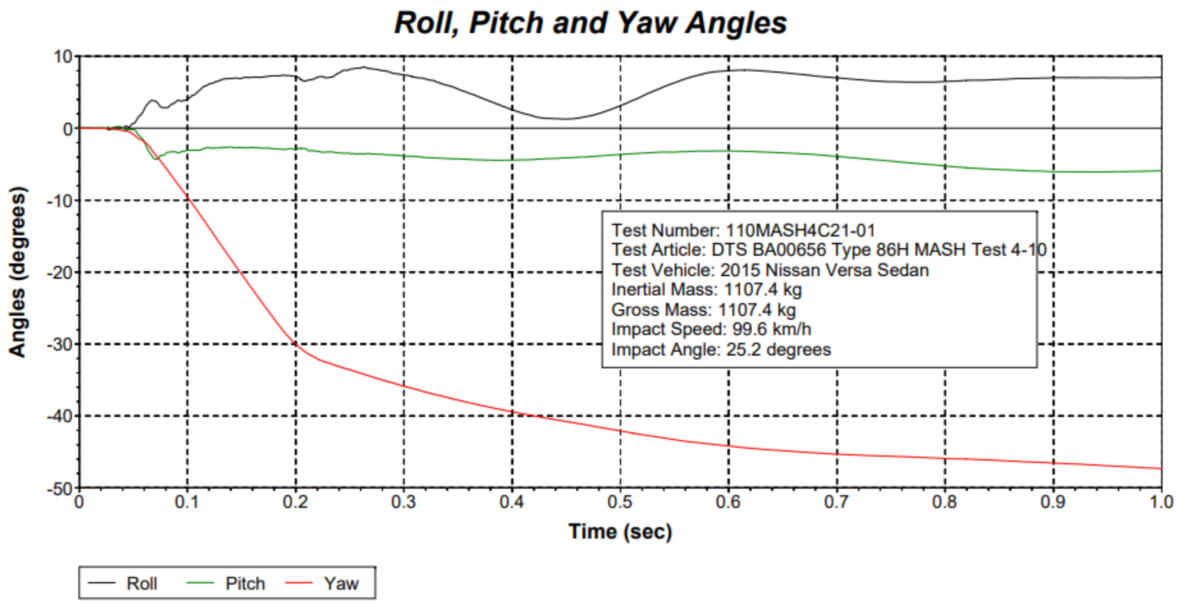


Figure 10-35 Test 4-10 Roll, Pitch, and Yaw Angles (DTS SLICE Micro TRAP BA00656)

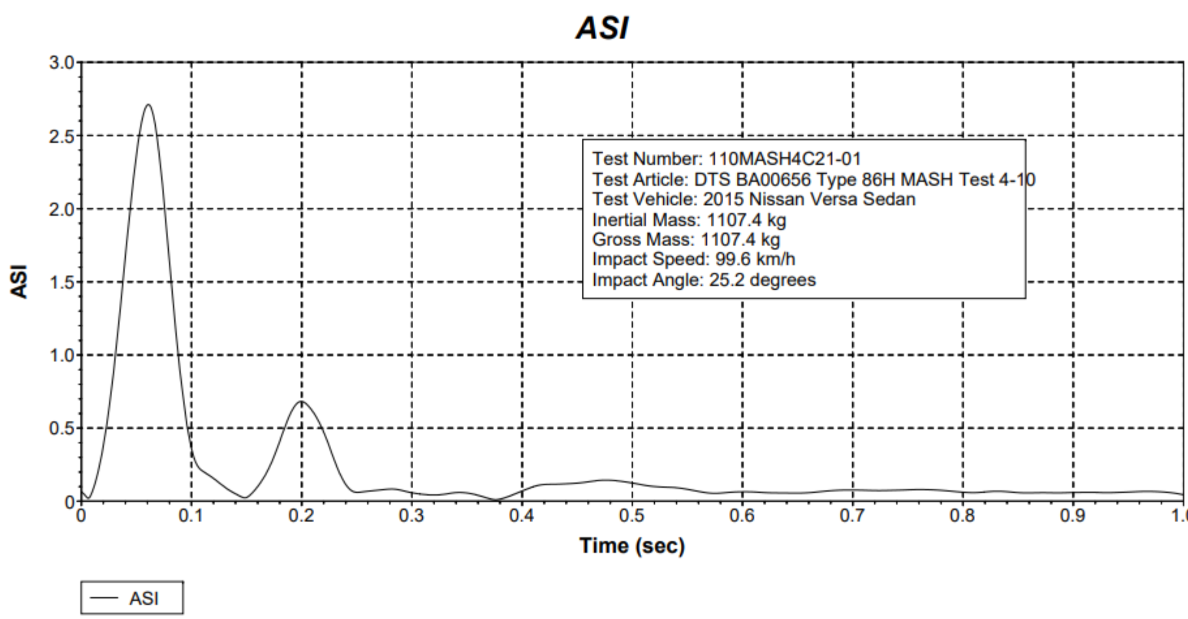


Figure 10-36 Test 4-10 Acceleration Severity Index (DTS SLICE Micro TRAP BA00656)

10.7.2 Data Plots - Test 110MASH4P21-02 (Test 4-11)

The data from both SLICE systems were analyzed using TRAP. The TRAP results sheets and data plots are shown below.

DTS SLICE BASE 659 Plots

Test Summary Report (Using SAE Class 180 Filter on Acceleration Data and Angular Velocity/Displacement Data)

General Information
Test Agency: California Department of Transportation
Test Number: 110MASH4P21-02
Test Date: 08/25/2021
Test Article: DTS BA00659 Type 86H MASH Test 4-11

Test Vehicle
Description: 2018 Dodge Ram 1500
Test Inertial Mass: 2235 kg
Gross Static Mass: 2235 kg

Impact Conditions
Speed: 99.7 km/h
Angle: 25.3 degrees

Occupant Risk Factors
Impact Velocity (m/s) at 0.0982 seconds on right side of interior
x-direction 7.1
y-direction 9.0

THIV (km/hr): 40.9 at 0.0959 seconds on right side of interior
THIV (m/s): 11.3

Ridedown Accelerations (g's)
x-direction -4.6 (0.2324 - 0.2424 seconds)
y-direction -8.6 (0.2360 - 0.2460 seconds)

PHD (g's): 9.2 (0.2328 - 0.2428 seconds)

ASI: 2.20 (0.0666 - 0.1166 seconds)

Max. 50msec Moving Avg. Accelerations (g's)
x-direction -12.0 (0.0469 - 0.0969 seconds)
y-direction -16.1 (0.0441 - 0.0941 seconds)
z-direction -2.7 (0.0493 - 0.0993 seconds)

Max Roll, Pitch, and Yaw Angles (degrees)
Roll 15.6 (0.3977 seconds)
Pitch -4.4 (0.6353 seconds)
Yaw -40.7 (0.8211 seconds)

Figure 10-37 Test 4-11 TRAP Summary Sheet (DTS SLICE Micro TRAP BA00659)

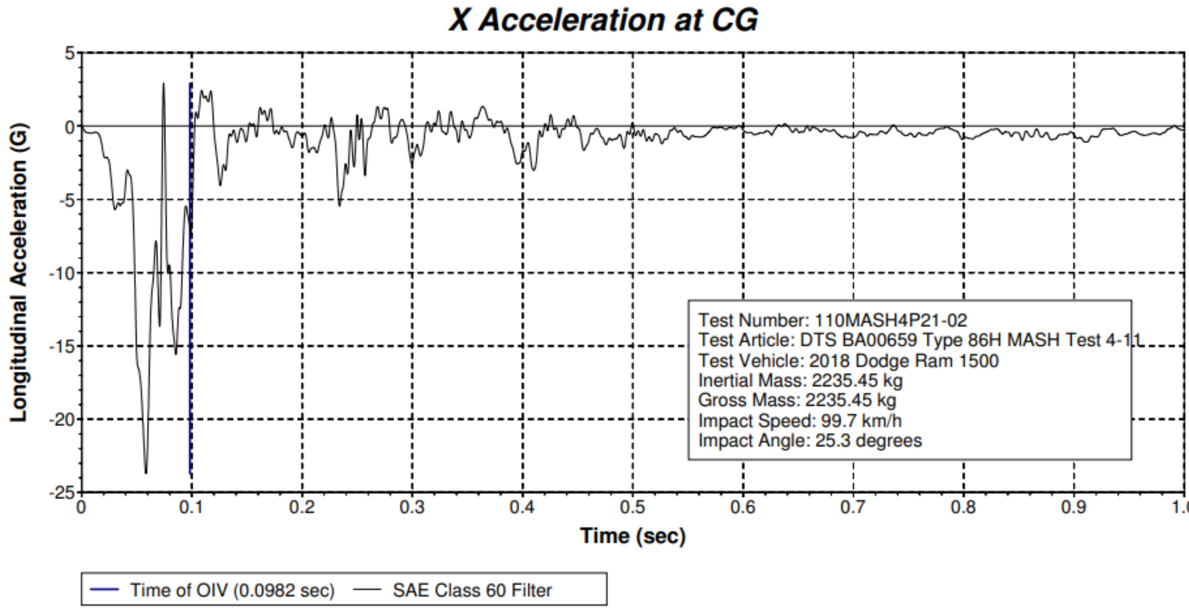


Figure 10-38 Test 4-11 Longitudinal Acceleration (DTS SLICE Micro TRAP BA00659)

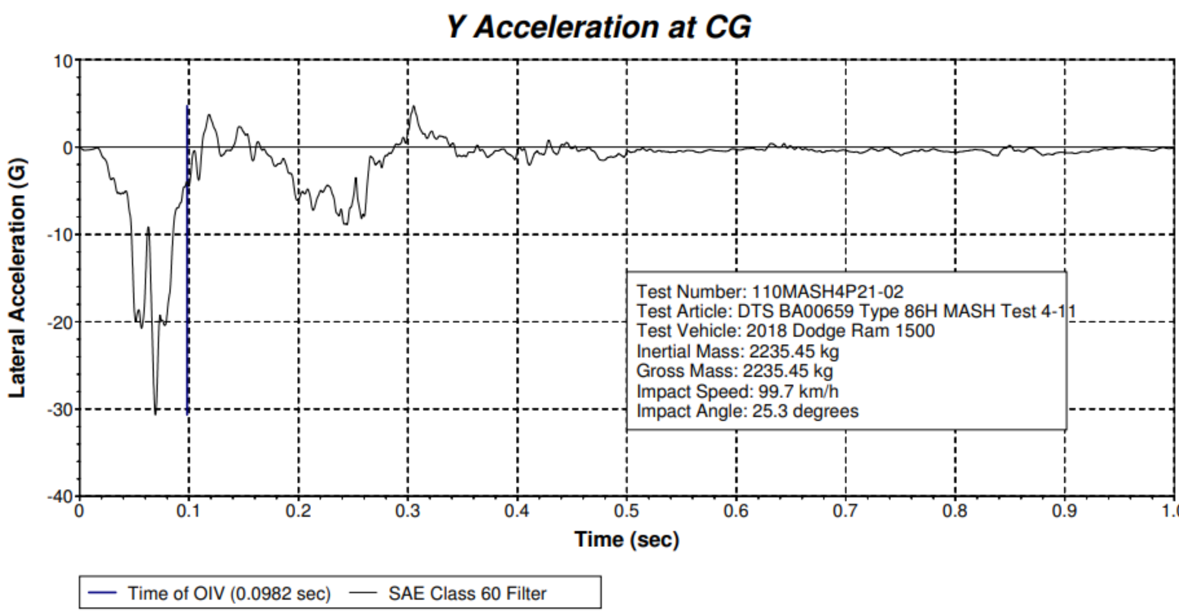


Figure 10-39 Test 4-11 Lateral Acceleration (DTS SLICE Micro TRAP BA00659)

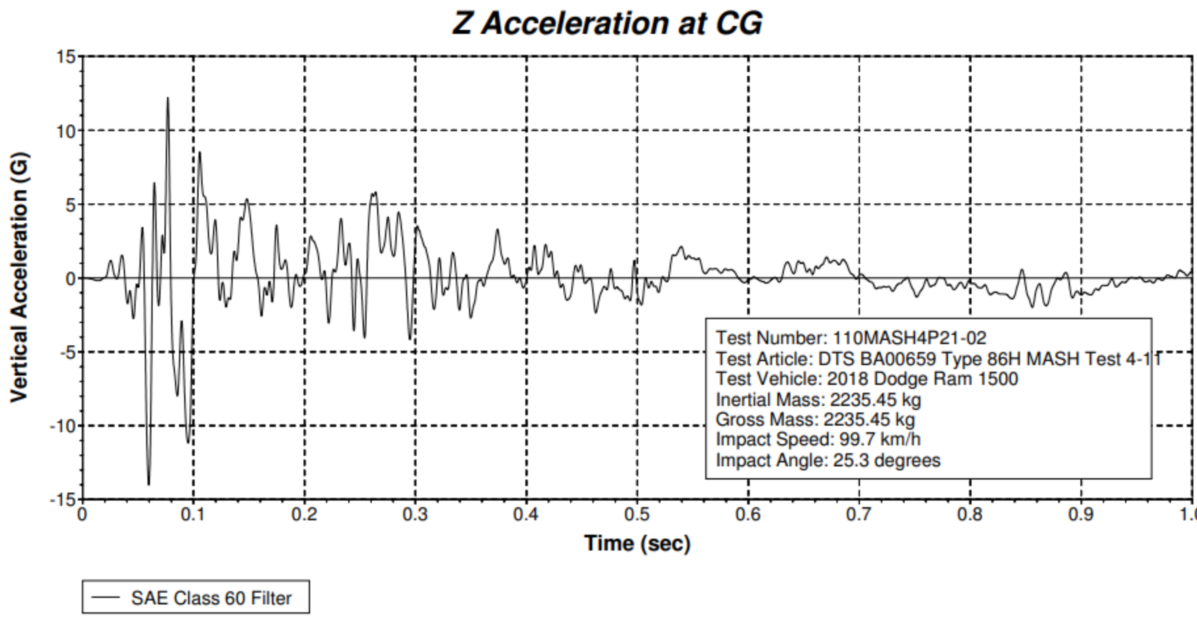


Figure 10-40 Test 4-11 Vertical Acceleration (DTS SLICE Micro TRAP BA00659)

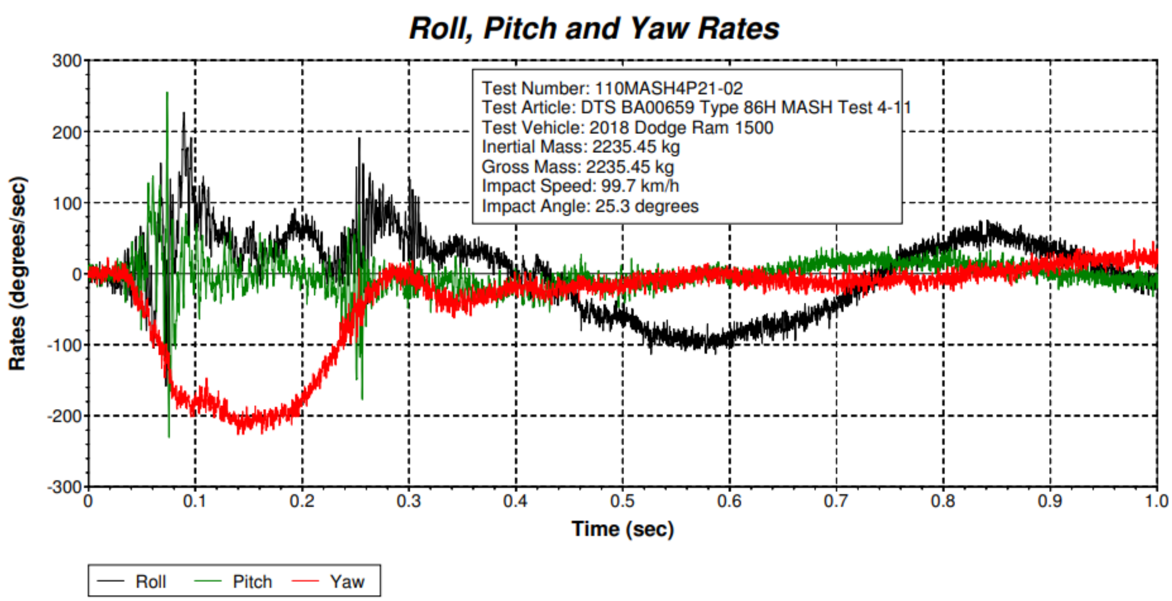


Figure 10-41 Test 4-11 Roll, Pitch, and Yaw Rates (DTS SLICE Micro TRAP BA00659)

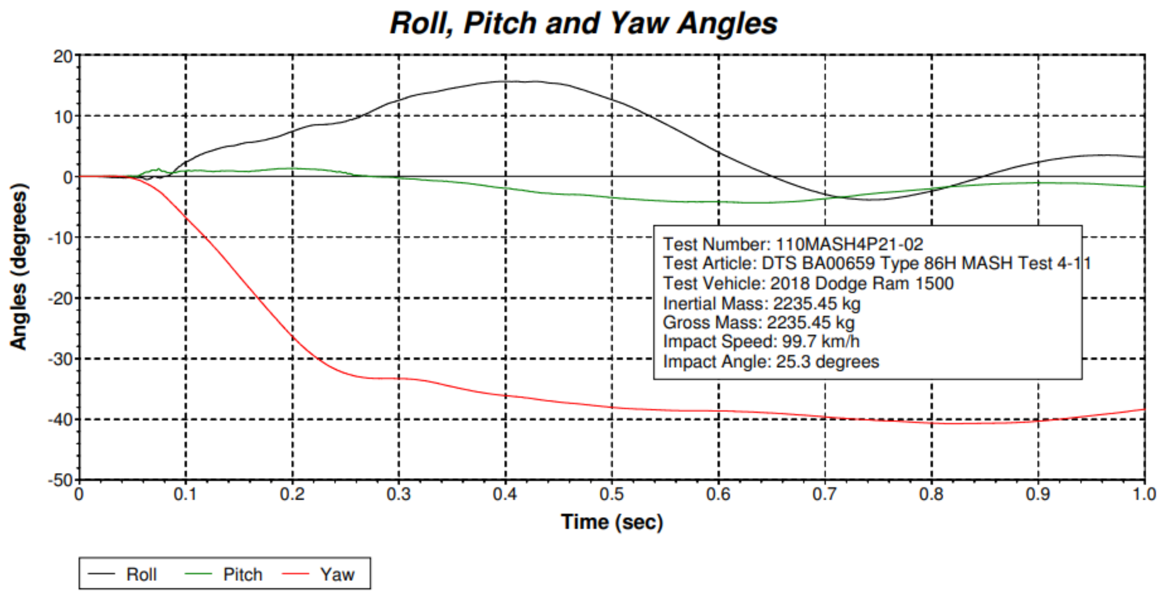


Figure 10-42 Test 4-11 Roll, Pitch, and Yaw Angles (DTS SLICE Micro TRAP BA00659)

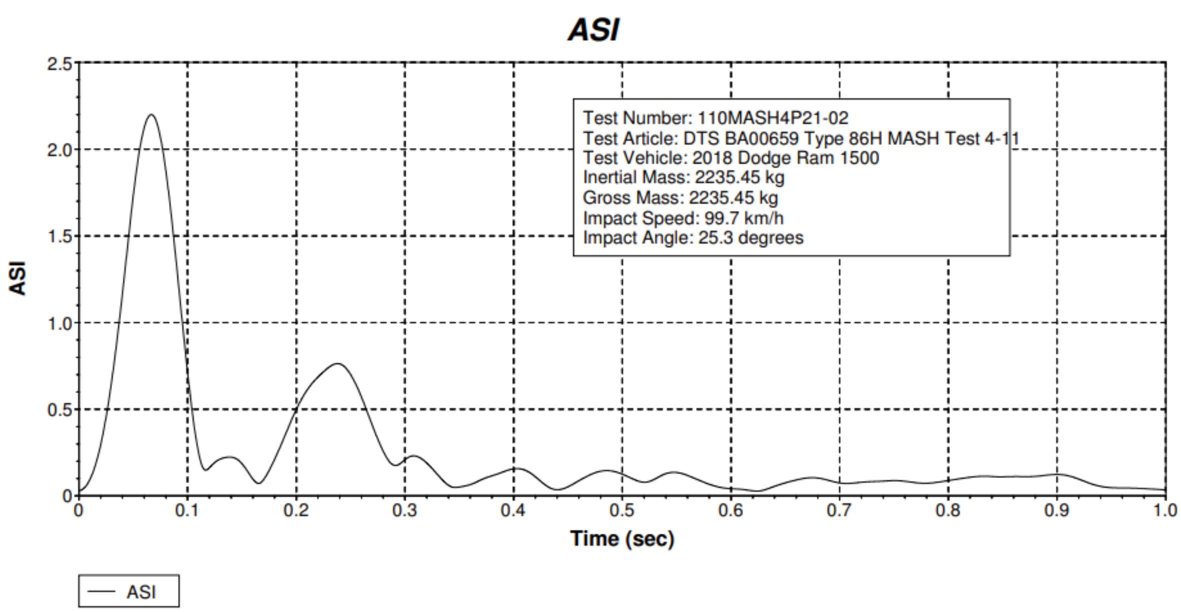


Figure 10-43 Test 4-11 Acceleration Severity Index (DTS SLICE Micro TRAP BA00659)

DTS SLICE BASE 656 Plots

Test Summary Report (Using SAE Class 180 Filter on Acceleration Data and Angular Velocity/Displacement Data)

General Information
Test Agency: California Department of Transportation
Test Number: 110MASH4P21-02
Test Date: 08/25/2021
Test Article: DTS BA00656 Type 86H MASH Test 4-11

Test Vehicle
Description: 2018 Dodge Ram 1500
Test Inertial Mass: 2235 kg
Gross Static Mass: 2235 kg

Impact Conditions
Speed: 99.7 km/h
Angle: 25.3 degrees

Occupant Risk Factors
Impact Velocity (m/s) at 0.0981 seconds on right side of interior
x-direction 7.1
y-direction 9.0

THIV (km/hr): 41.0 at 0.0959 seconds on right side of interior
THIV (m/s): 11.4

Ridedown Accelerations (g's)
x-direction -4.6 (0.2324 - 0.2424 seconds)
y-direction -8.3 (0.2361 - 0.2461 seconds)

PHD (g's): 8.7 (0.2327 - 0.2427 seconds)

ASI: 2.22 (0.0667 - 0.1167 seconds)

Max. 50msec Moving Avg. Accelerations (g's)
x-direction -12.0 (0.0469 - 0.0969 seconds)
y-direction -16.2 (0.0442 - 0.0942 seconds)
z-direction -3.4 (0.0493 - 0.0993 seconds)

Max Roll, Pitch, and Yaw Angles (degrees)
Roll 15.1 (0.3969 seconds)
Pitch -5.1 (0.6442 seconds)
Yaw -40.3 (0.8236 seconds)

Figure 10-44 Test 4-11 TRAP Summary Sheet (DTS SLICE Micro TRAP BA00656)

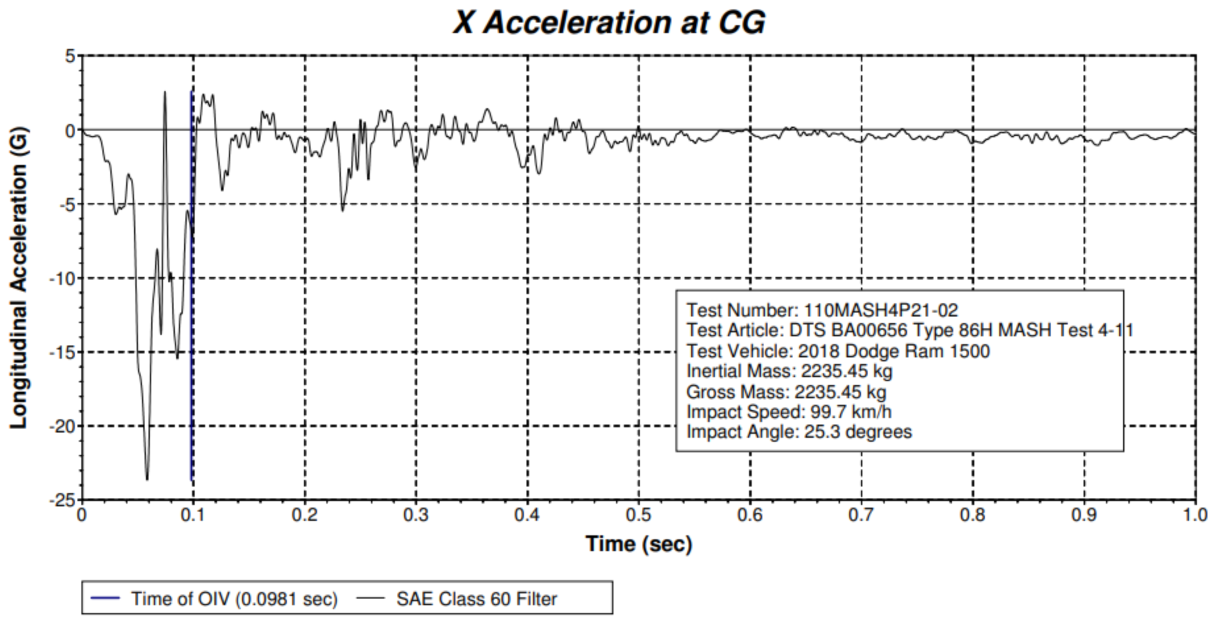


Figure 10-45 Test 4-11 Longitudinal Acceleration (DTS SLICE Micro TRAP BA00656)

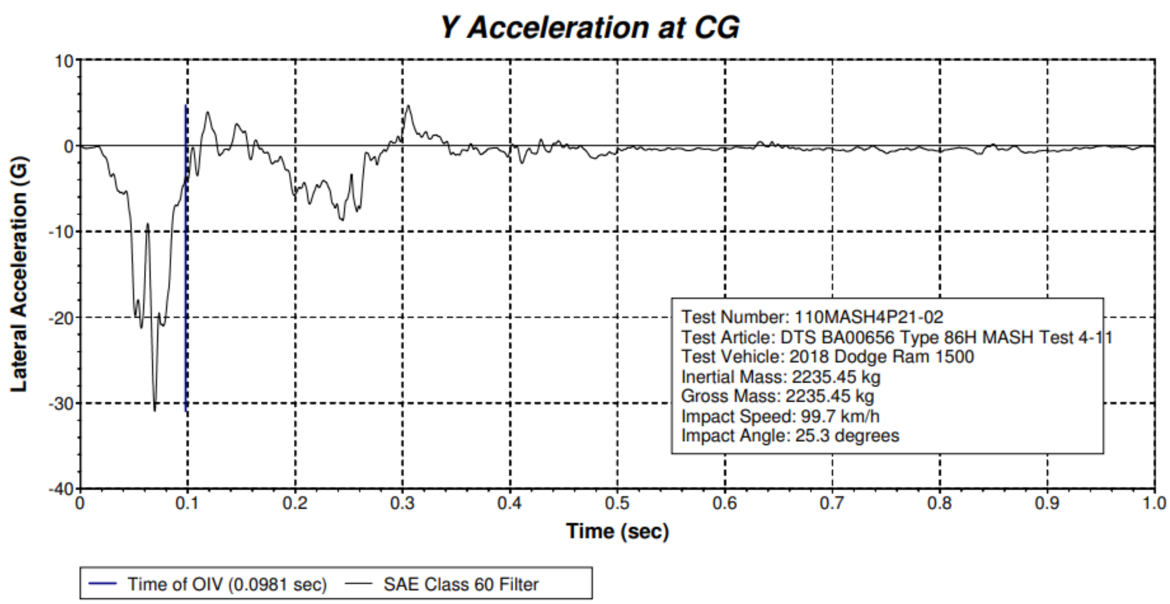


Figure 10-46 Test 4-11 Lateral Acceleration (DTS SLICE Micro TRAP BA00656)

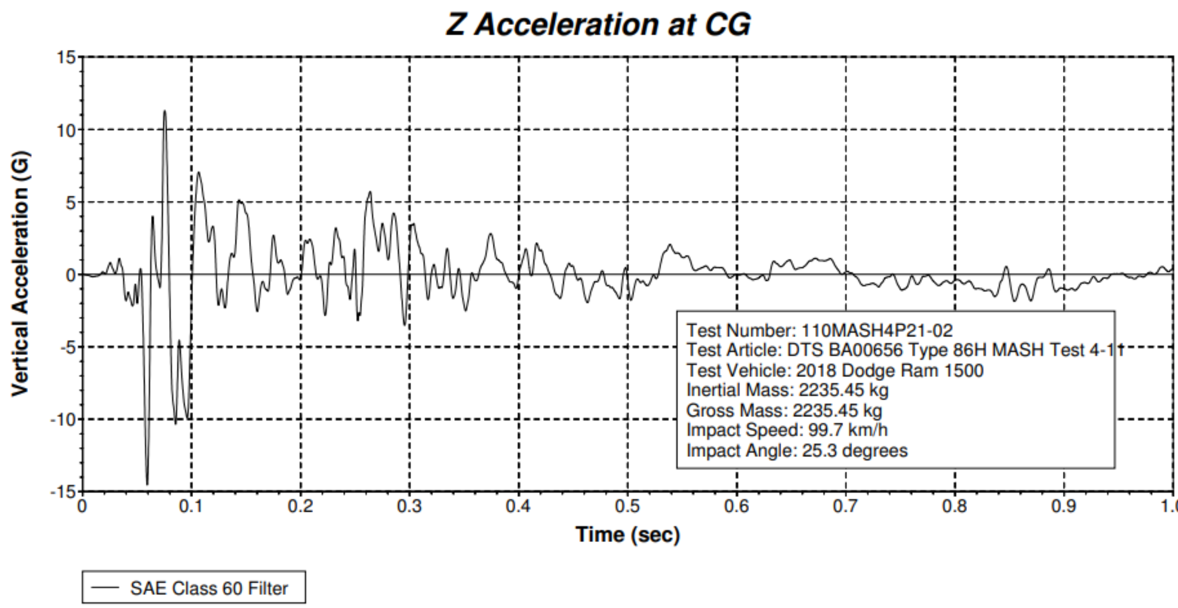


Figure 10-47 Test 4-11 Vertical Acceleration (DTS SLICE Micro TRAP BA00656)

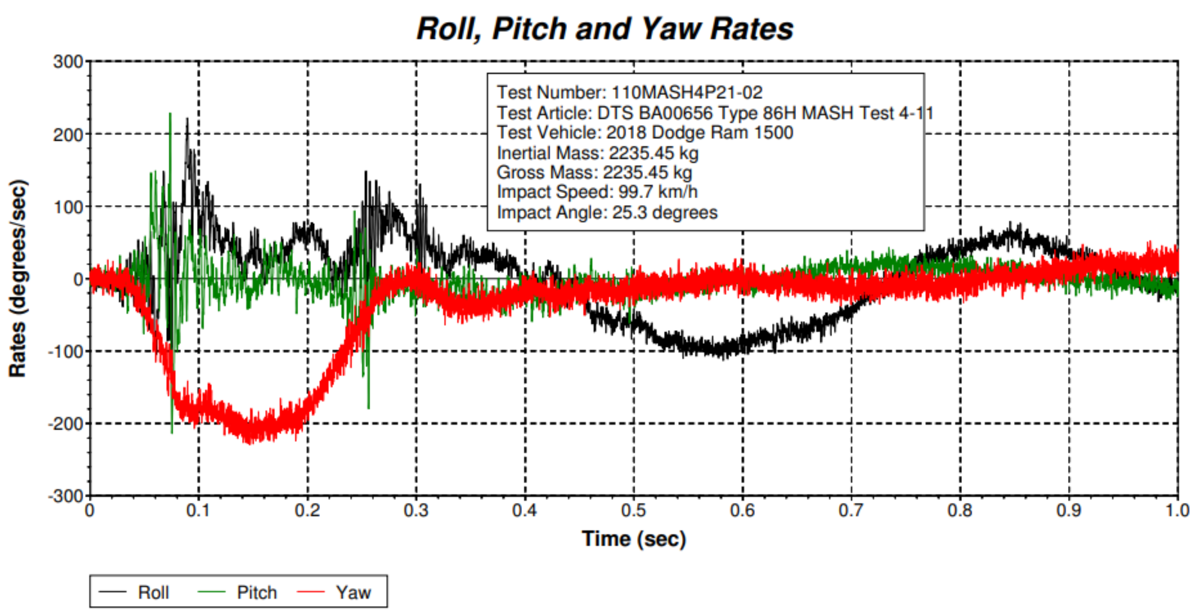


Figure 10-48 Test 4-11 Roll, Pitch, and Yaw Rates (DTS SLICE Micro TRAP BA00656)

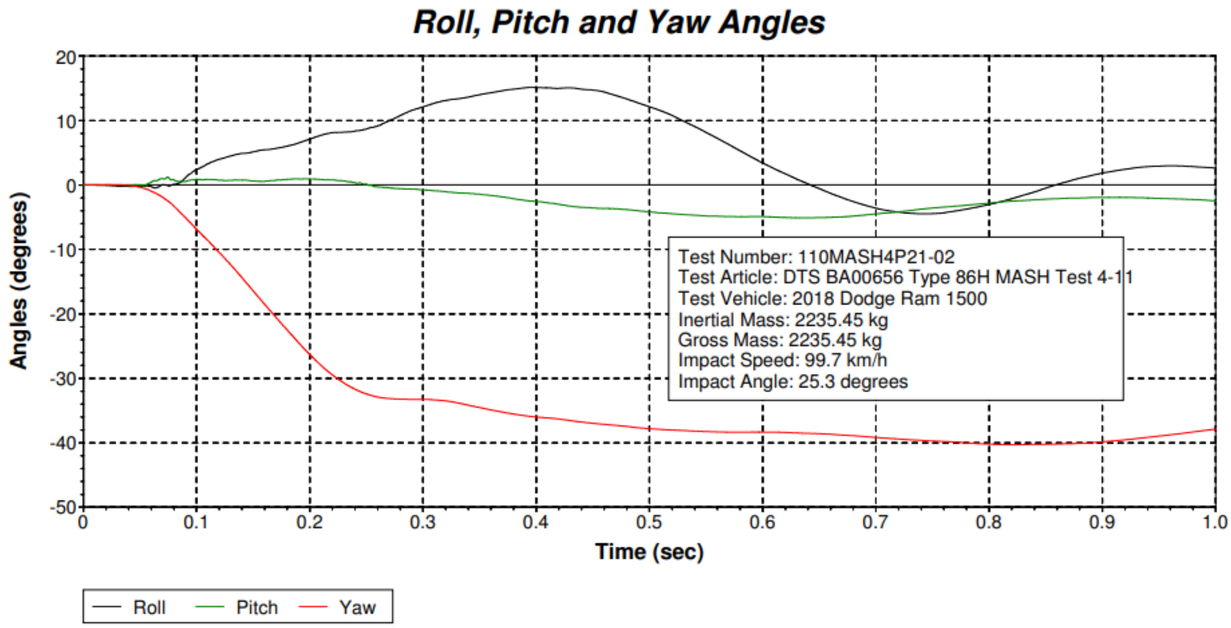


Figure 10-49 Test 4-11 Roll, Pitch, and Yaw Angles (DTS SLICE Micro TRAP BA00656)

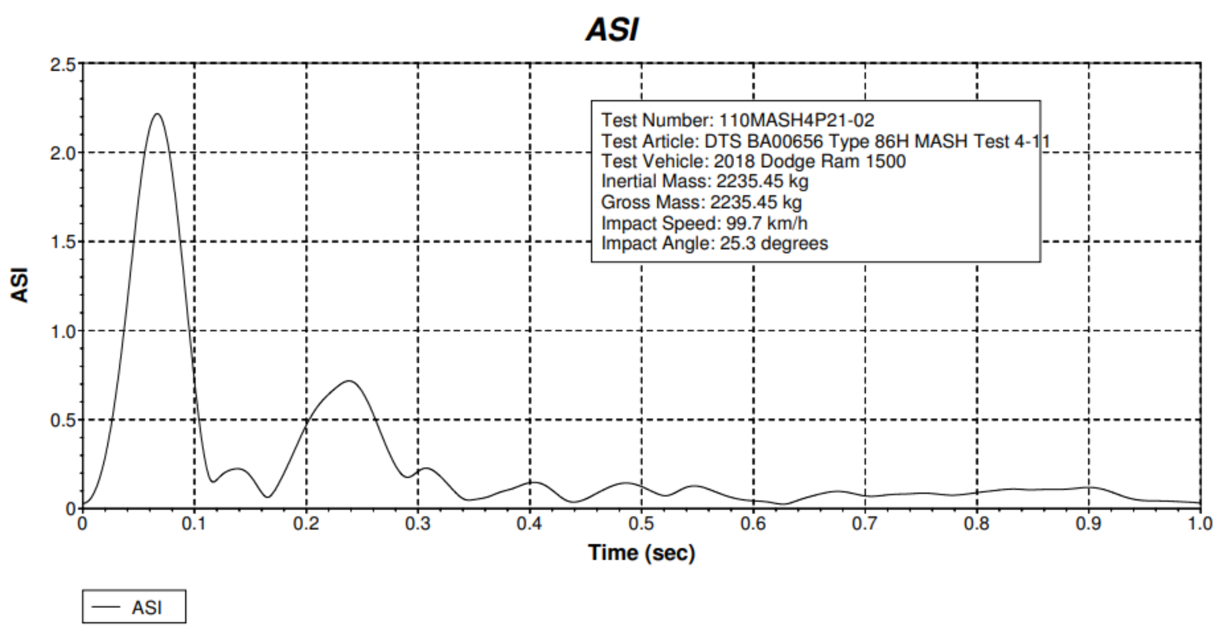


Figure 10-50 Test 4-11 Acceleration Severity Index (DTS SLICE Micro TRAP BA00656)

10.7.3 Data Plots - Test 110MASH4S21-03 (Test 4-12)

Two sets of accelerometers and angular rate sensors were installed in the cab and one in the cargo box area. The data plots for these sets of instrumentation are shown below.

DTS SLICE BASE 656 Plots (Inside Cab)

Test Summary Report (Using SAE Class 180 Filter on Acceleration Data and Angular Velocity/Displacement Data)

General Information
Test Agency: California Department of Transportation
Test Number: 110MASH4S21-03
Test Date: 12/8/2021
Test Article: DTS BA00656 Type 86H MASH Test 4-12 Cab

Test Vehicle
Description: 2009 Freightliner Busniess Class M2
Test Inertial Mass: 10144 kg
Gross Static Mass: 10144 kg

Impact Conditions
Speed: 88.1 km/h
Angle: 15.0 degrees

Occupant Risk Factors
Impact Velocity (m/s) at 0.1292 seconds on right side of interior
x-direction 1.5
y-direction 4.1

THIV (km/hr): 15.6 at 0.1282 seconds on right side of interior
THIV (m/s): 4.3

Ridedown Accelerations (g's)
x-direction -5.9 (0.7520 - 0.7620 seconds)
y-direction -7.4 (0.3064 - 0.3164 seconds)

PHD (g's): 7.5 (0.3127 - 0.3227 seconds)

ASI: 0.82 (0.0580 - 0.1080 seconds)

Max. 50msec Moving Avg. Accelerations (g's)
x-direction -4.2 (0.0306 - 0.0806 seconds)
y-direction -6.5 (0.0322 - 0.0822 seconds)
z-direction -4.0 (0.0586 - 0.1086 seconds)

Max Roll, Pitch, and Yaw Angles (degrees)
Roll 20.1 (0.5857 seconds)
Pitch -3.7 (0.7631 seconds)
Yaw -19.0 (0.9668 seconds)

Figure 10-51 Test 4-12 TRAP Summary Sheet (DTS SLICE Micro TRAP BA00656)

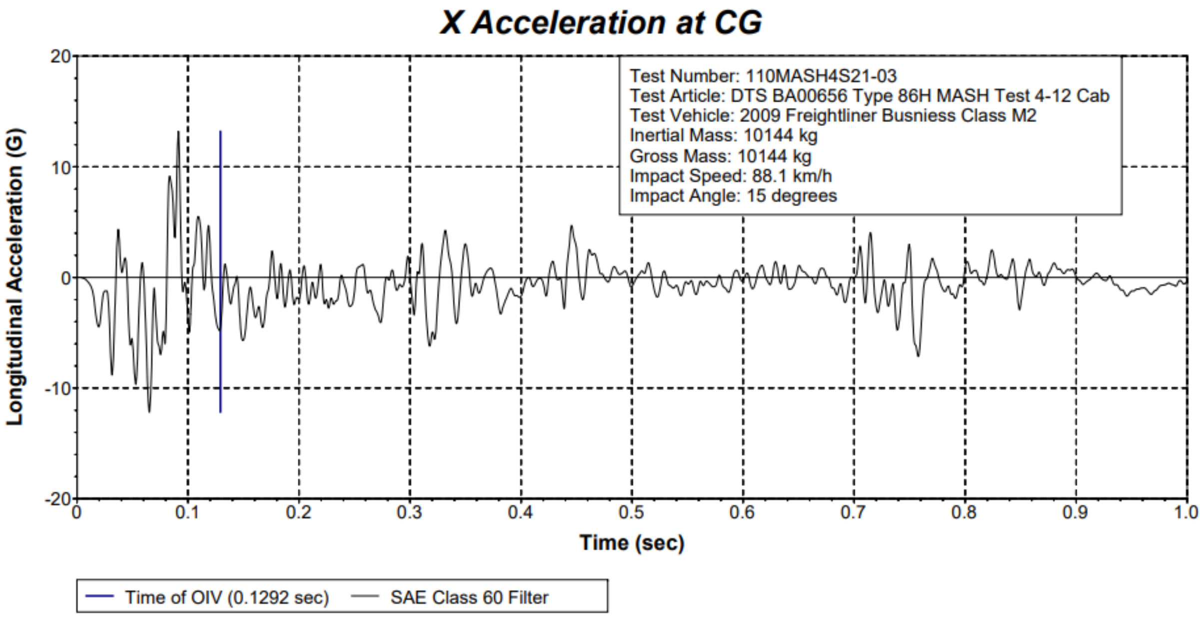


Figure 10-52 4-12 Longitudinal Acceleration (DTS SLICE Micro TRAP BA00656)

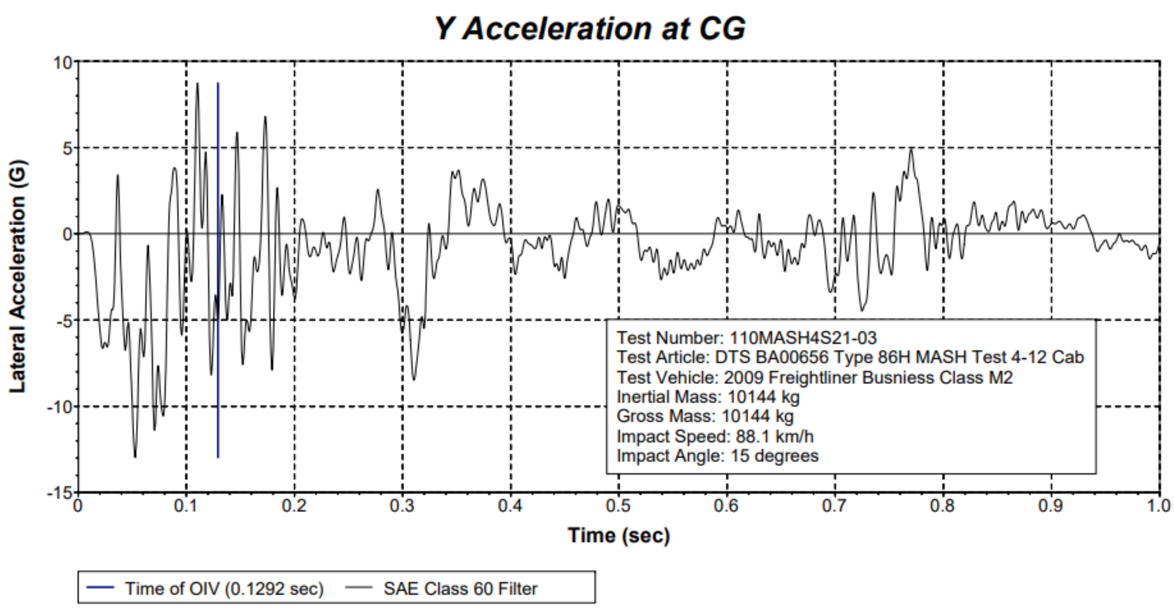


Figure 10-53 Test 4-12 Lateral Acceleration (DTS SLICE Micro TRAP BA00656)

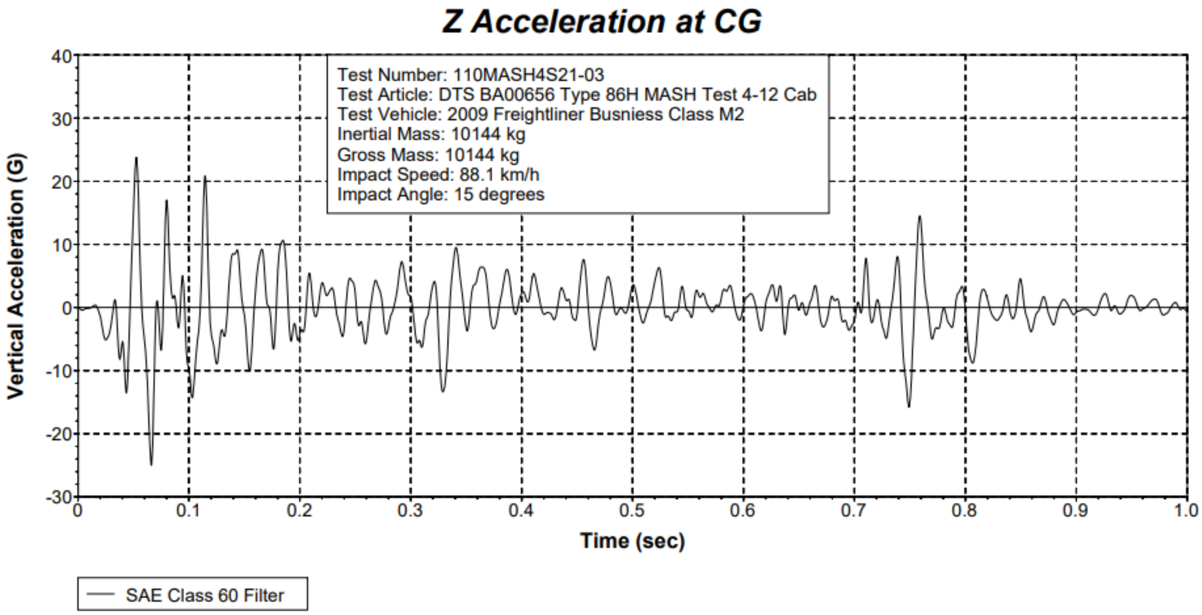


Figure 10-54 Test 4-12 Vertical Acceleration (DTS SLICE Micro TRAP BA00656)

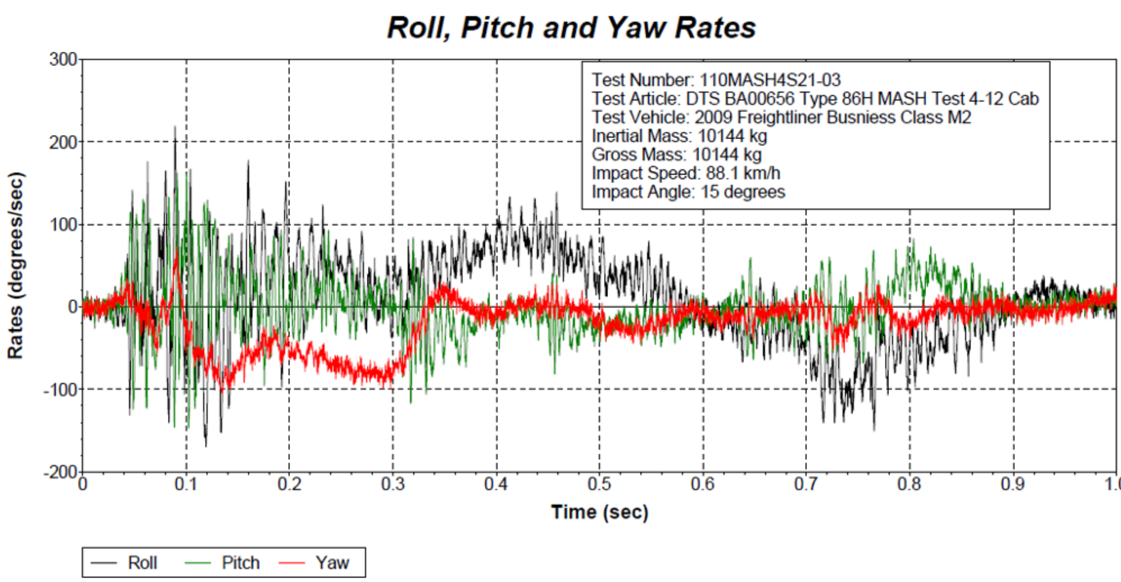


Figure 10-55 Test 4-12 Roll, Pitch, and Yaw Rates (DTS SLICE Micro TRAP BA00656)

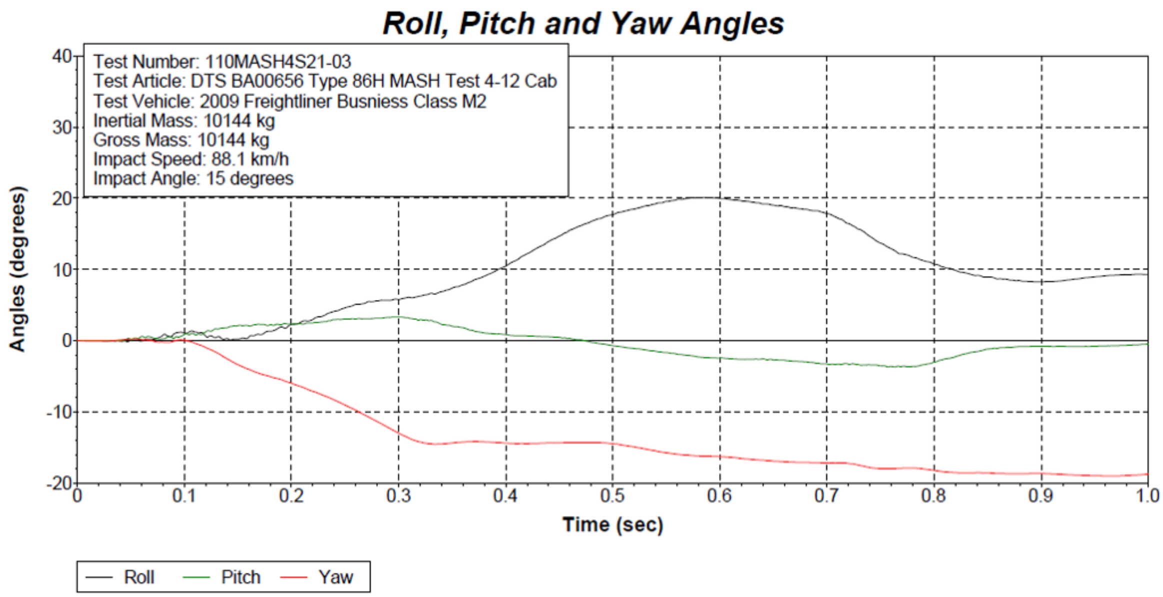


Figure 10-56 Test 4-12 Roll, Pitch, and Yaw Angles (DTS SLICE Micro TRAP BA00656)

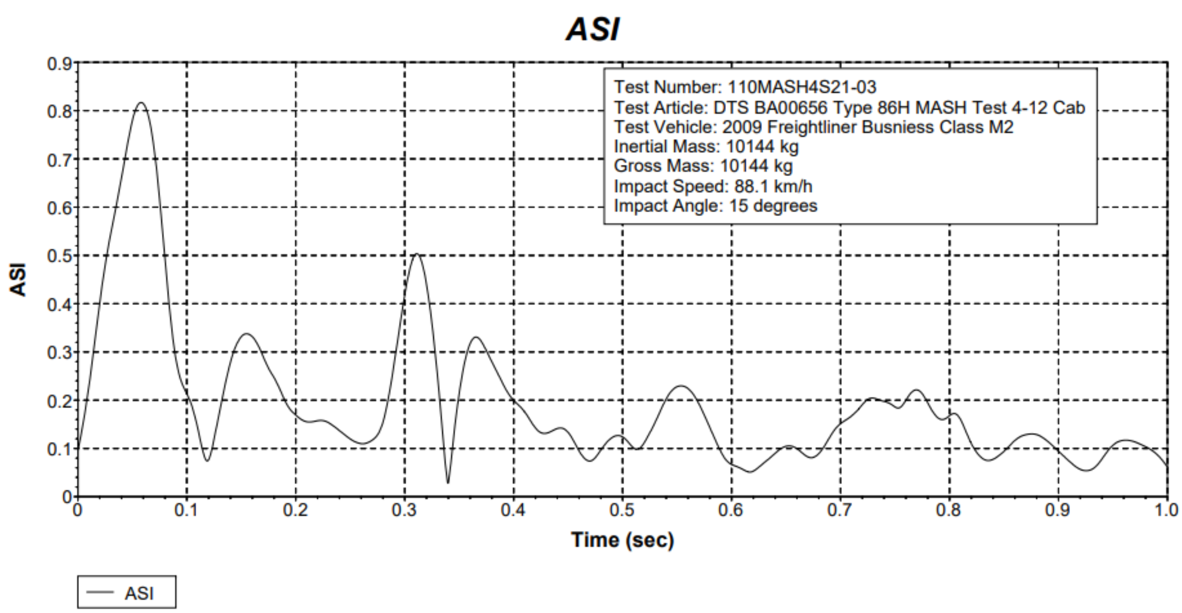


Figure 10-57 Test 4-12 Acceleration Severity Index (DTS SLICE Micro TRAP BA00656)

DTS SLICE BASE 659 Plots (Inside Cab)

Test Summary Report (Using SAE Class 180 Filter on Acceleration Data and Angular Velocity/Displacement Data)

General Information
Test Agency: California Department of Transportation
Test Number: 110MASH4S21-03
Test Date: 12/8/2021
Test Article: DTS BA00659 Type 86H MASH Test 4-12 Cab

Test Vehicle
Description: 2009 Freightliner Busniess Class M2
Test Inertial Mass: 10144 kg
Gross Static Mass: 10144 kg

Impact Conditions
Speed: 88.1 km/h
Angle: 15.0 degrees

Occupant Risk Factors
Impact Velocity (m/s) at 0.1292 seconds on right side of interior
x-direction 1.5
y-direction 4.2

THIV (km/hr): 16.0 at 0.1283 seconds on right side of interior
THIV (m/s): 4.4

Ridedown Accelerations (g's)
x-direction -5.8 (0.7520 - 0.7620 seconds)
y-direction -7.2 (0.3062 - 0.3162 seconds)

PHD (g's): 7.2 (0.3062 - 0.3162 seconds)

ASI: 0.81 (0.0581 - 0.1081 seconds)

Max. 50msec Moving Avg. Accelerations (g's)
x-direction -4.3 (0.0307 - 0.0807 seconds)
y-direction -6.3 (0.0375 - 0.0875 seconds)
z-direction -4.5 (0.0603 - 0.1103 seconds)

Max Roll, Pitch, and Yaw Angles (degrees)
Roll 19.3 (0.5731 seconds)
Pitch -4.3 (0.7567 seconds)
Yaw -18.1 (0.9499 seconds)

Figure 10-58 Test 4-12 TRAP Summary Sheet (DTS SLICE Micro TRAP BA00659)

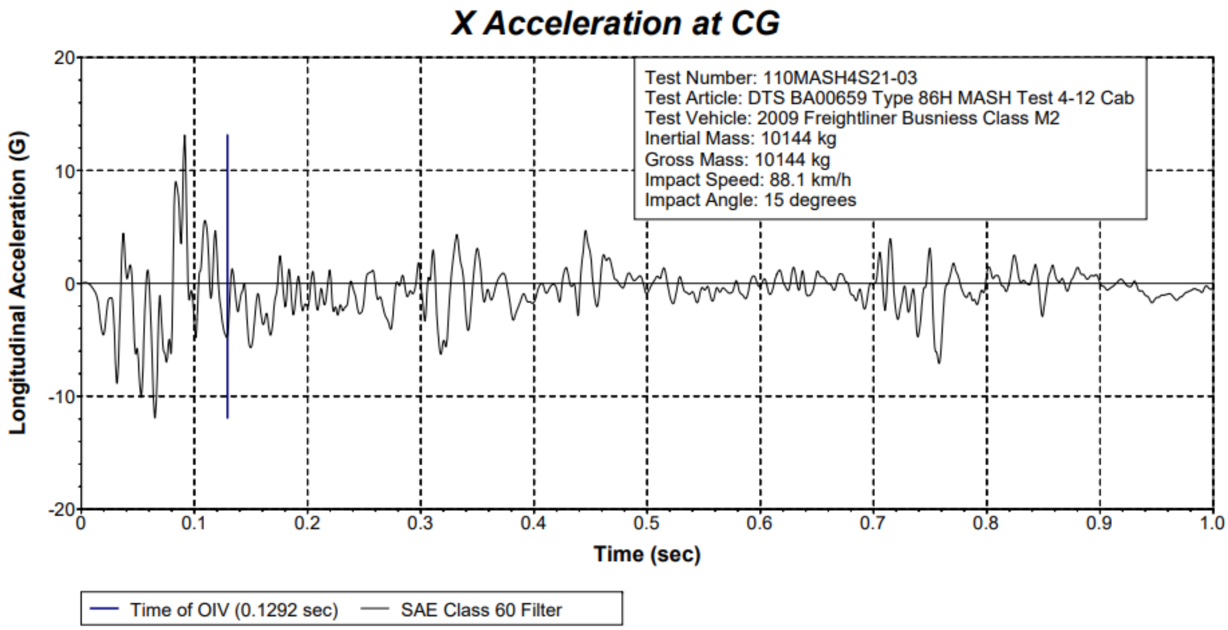


Figure 10-59 Test 4-12 Longitudinal Acceleration (DTS SLICE Micro TRAP BA00659)

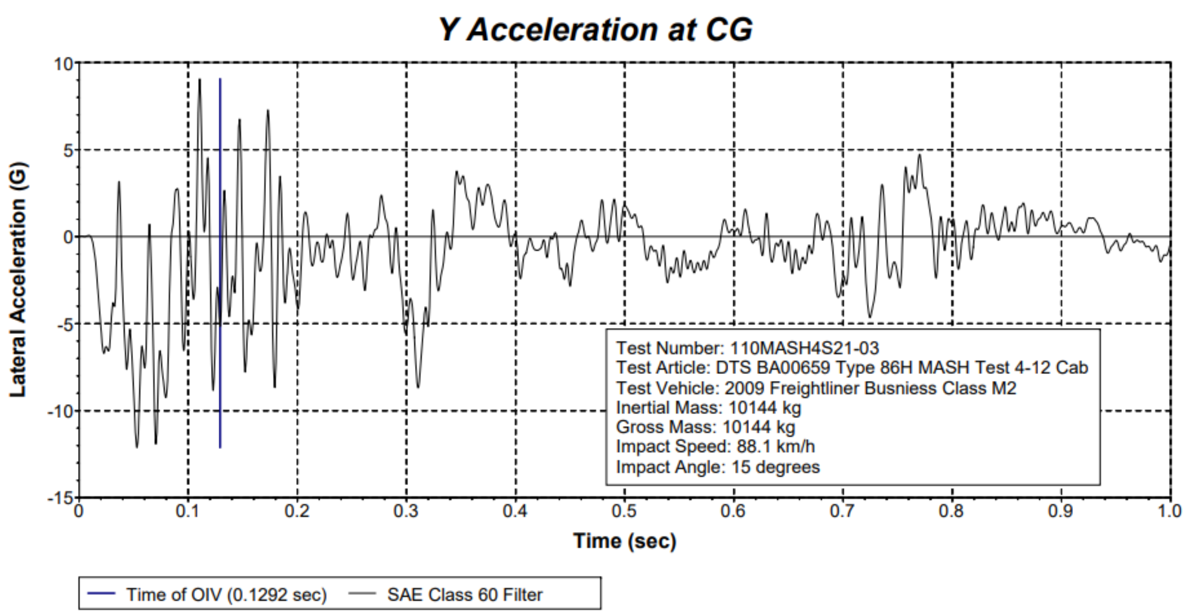


Figure 10-60 Test 4-12 Lateral Acceleration (DTS SLICE Micro TRAP BA00659)

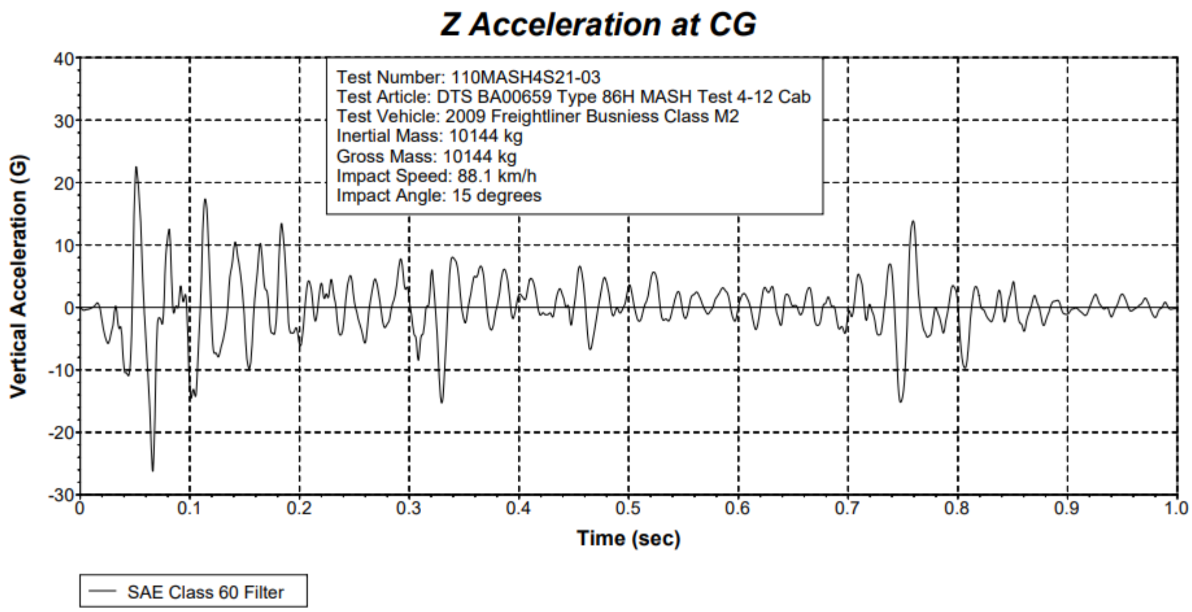


Figure 10-61 Test 4-12 Vertical Acceleration (DTS SLICE Micro TRAP BA00659)

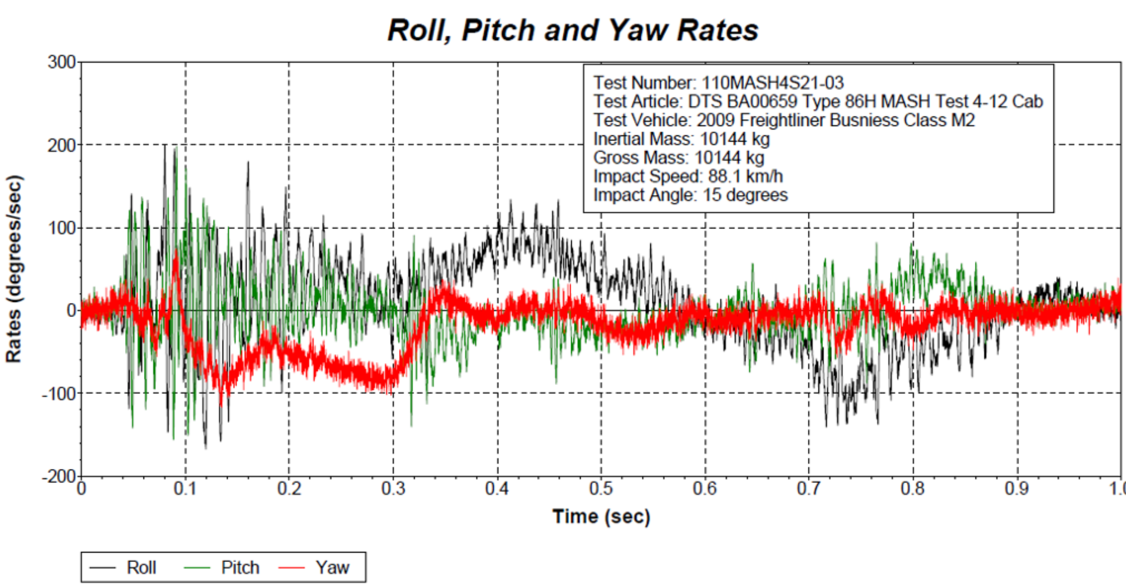


Figure 10-62 Test 4-12 Roll, Pitch, and Yaw Rates (DTS SLICE Micro TRAP BA00659)

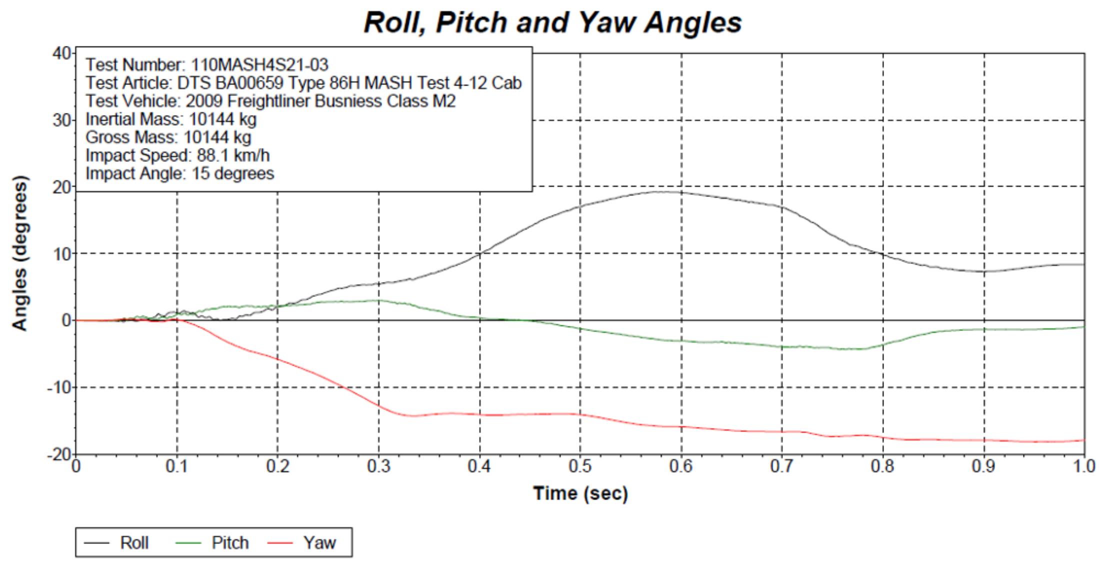


Figure 10-63 Test 4-12 Roll, Pitch, and Yaw Angles (DTS SLICE Micro TRAP BA00659)

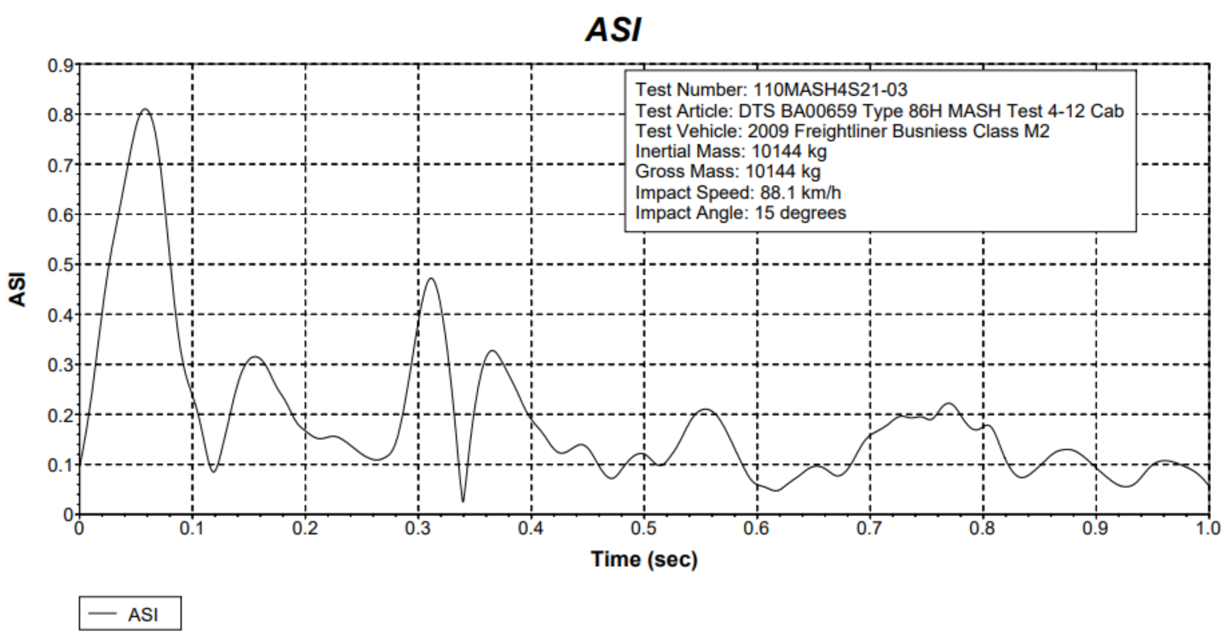


Figure 10-64 Test 4-12 Acceleration Severity Index (DTS SLICE Micro TRAP BA00659)

DTS SLICE BASE 758 Plots (Inside Cargo Box)

Test Summary Report (Using SAE Class 180 Filter on Acceleration Data and Angular Velocity/Displacement Data)

General Information
- Test Agency: California Department of Transportation
- Test Number: 110MASH4S21-03
- Test Date: 12/8/2021
- Test Article: DTS BA00758 Type 86H MASH Test 4-12 Cargo

Test Vehicle
- Description: 2009 Freightliner Busniess Class M2
- Test Inertial Mass: 10144 kg
- Gross Static Mass: 10144 kg

Impact Conditions
- Speed: 88.1 km/h
- Angle: 15.0 degrees

Occupant Risk Factors

Impact Velocity (m/s) at 0.2101 seconds on right side of interior

x-direction	2.2	
y-direction	3.6	
THIV (km/hr):	15.4	at 0.2036 seconds on right side of interior
THIV (m/s):	4.3	

Ridedown Accelerations (g's)

x-direction	-4.6	(0.2642 - 0.2742 seconds)
y-direction	-7.2	(0.2908 - 0.3008 seconds)
PHD (g's):	7.3	(0.2908 - 0.3008 seconds)
ASI:	0.61	(0.3021 - 0.3521 seconds)

Max. 50msec Moving Avg. Accelerations (g's)

x-direction	-2.0	(0.0670 - 0.1170 seconds)
y-direction	-5.1	(0.2771 - 0.3271 seconds)
z-direction	2.1	(0.3515 - 0.4015 seconds)

Max Roll, Pitch, and Yaw Angles (degrees)

Roll	24.3	(0.7501 seconds)
Pitch	-4.8	(0.8079 seconds)
Yaw	-18.2	(0.8327 seconds)

Figure 10-65 Test 4-12 TRAP Summary Sheet (DTS SLICE Micro TRAP BA00758)

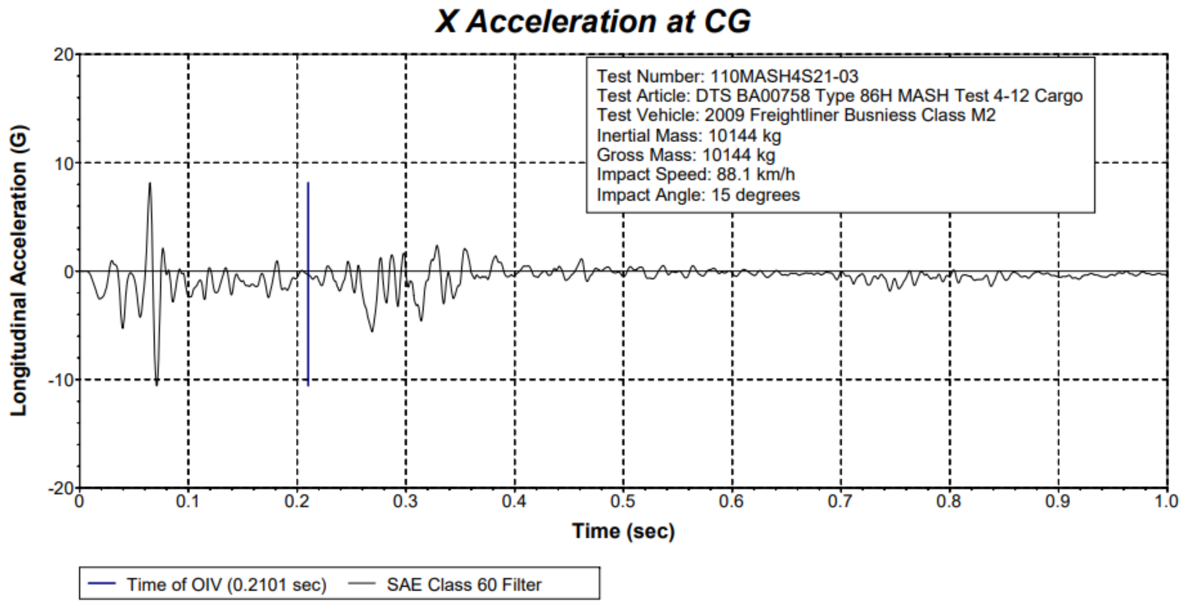


Figure 10-66 Test 4-12 Longitudinal Acceleration (DTS SLICE Micro TRAP BA00758)

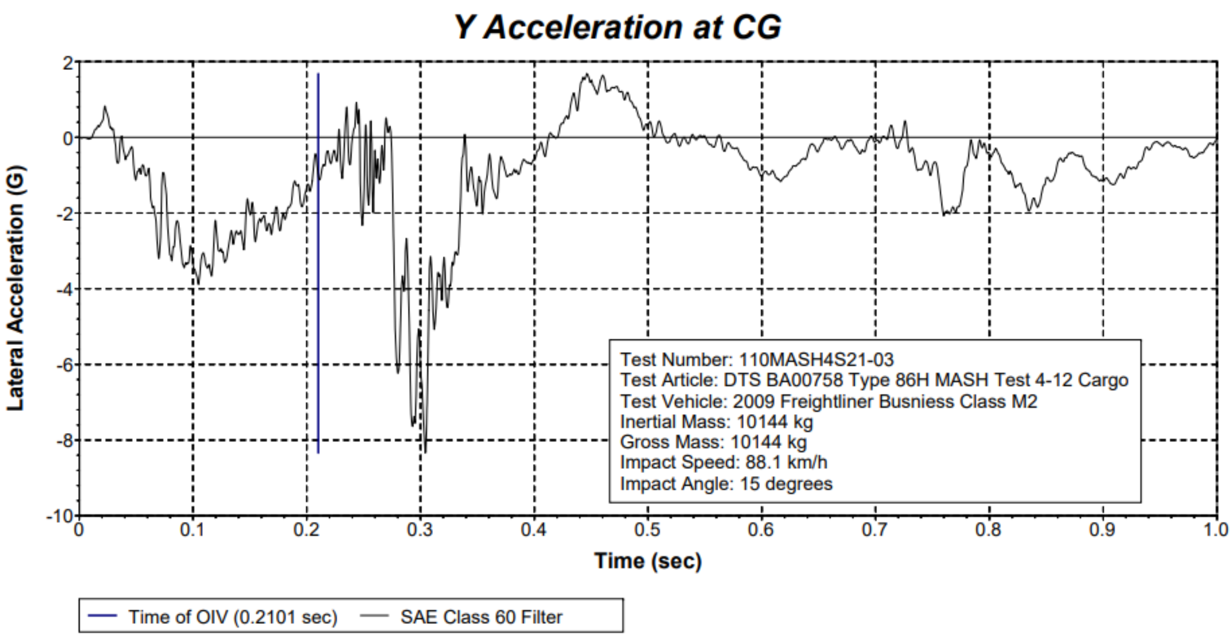


Figure 10-67 Test 4-12 Lateral Acceleration (DTS SLICE Micro TRAP BA00758)

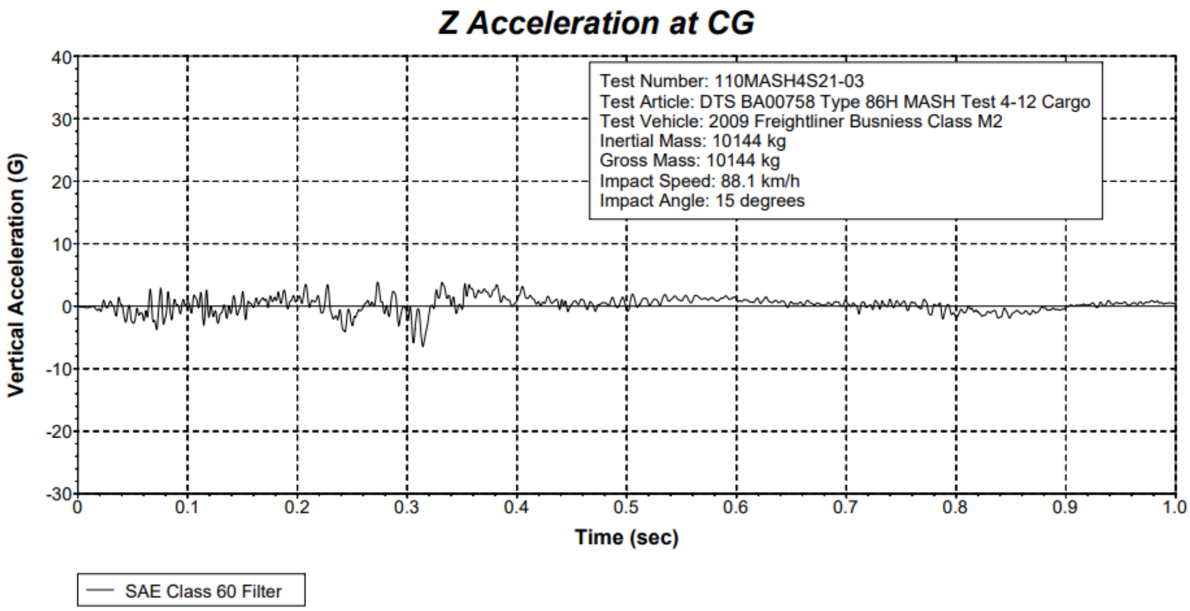


Figure 10-68 Test 4-12 Vertical Acceleration (DTS SLICE Micro TRAP BA00758)

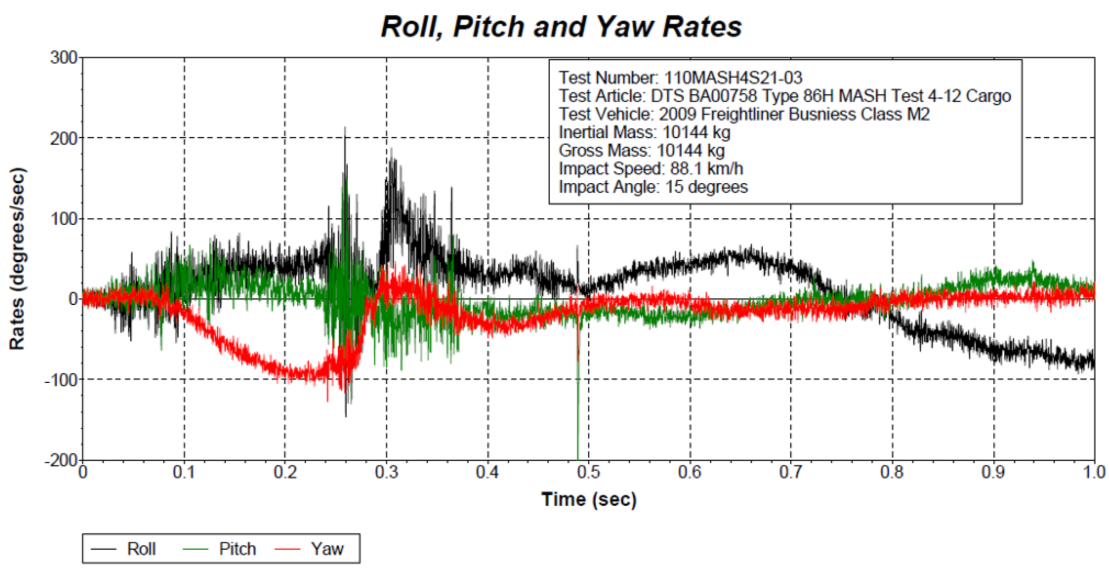


Figure 10-69 Test 4-12 Roll, Pitch, and Yaw Rates (DTS SLICE Micro TRAP BA00758)

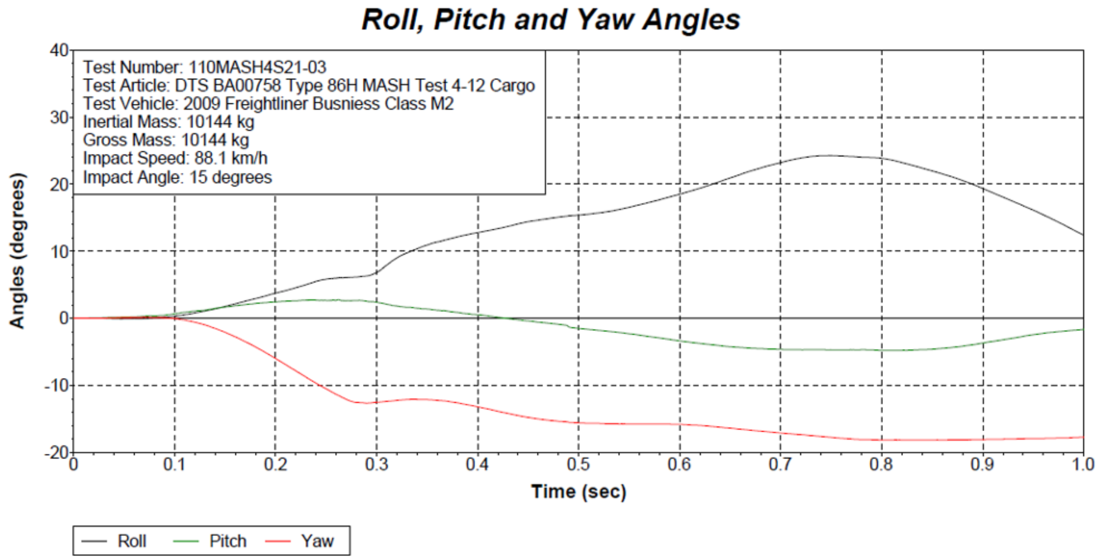


Figure 10-70 Test 4-12 Roll, Pitch, and Yaw Angles (DTS SLICE Micro TRAP BA00758)

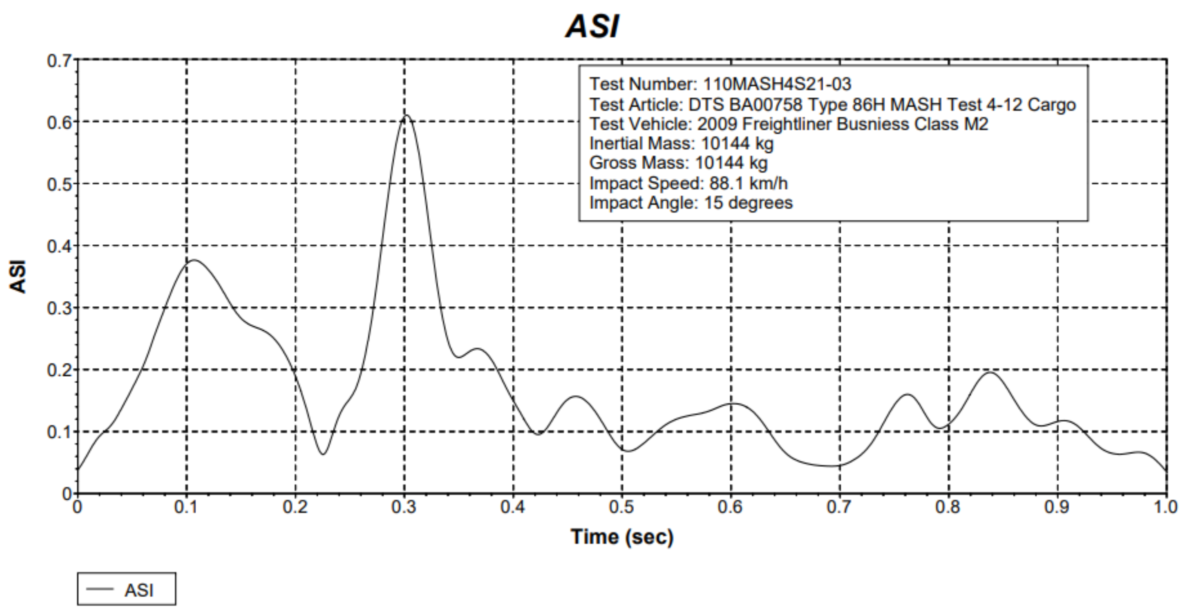


Figure 10-71 Test 4-12 Acceleration Severity Index (DTS SLICE Micro TRAP BA00758)

11. Appendix B: Detail Drawings

The following details in Figure 11-1 through Figure 11-8 were used for the construction of the Type 86H bridge rail test article. The redlined portion are as-built changes made in the field.

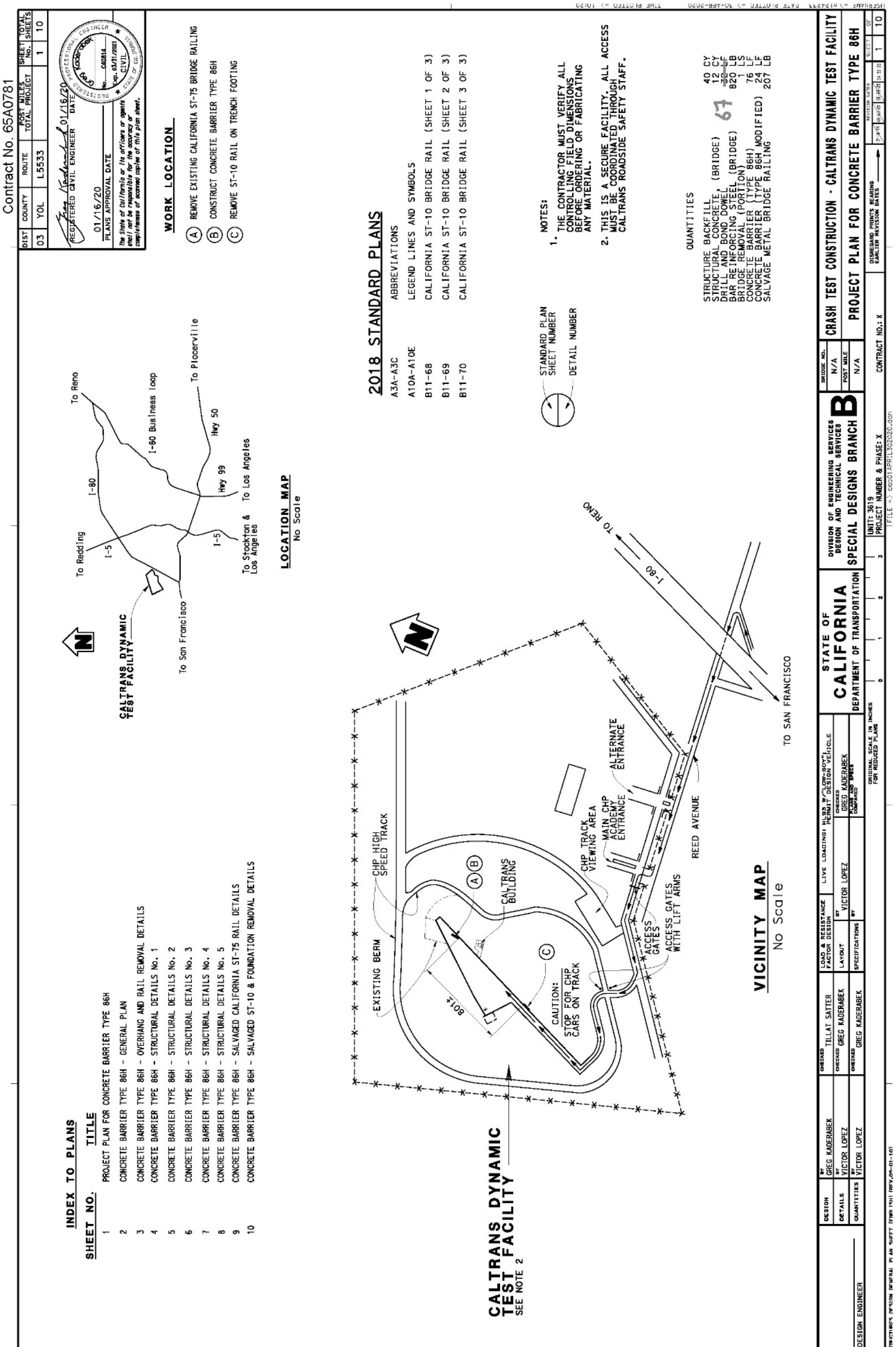


Figure 11-1 Type 86H Test Article Project Plan for Concrete Barrier Type 86H

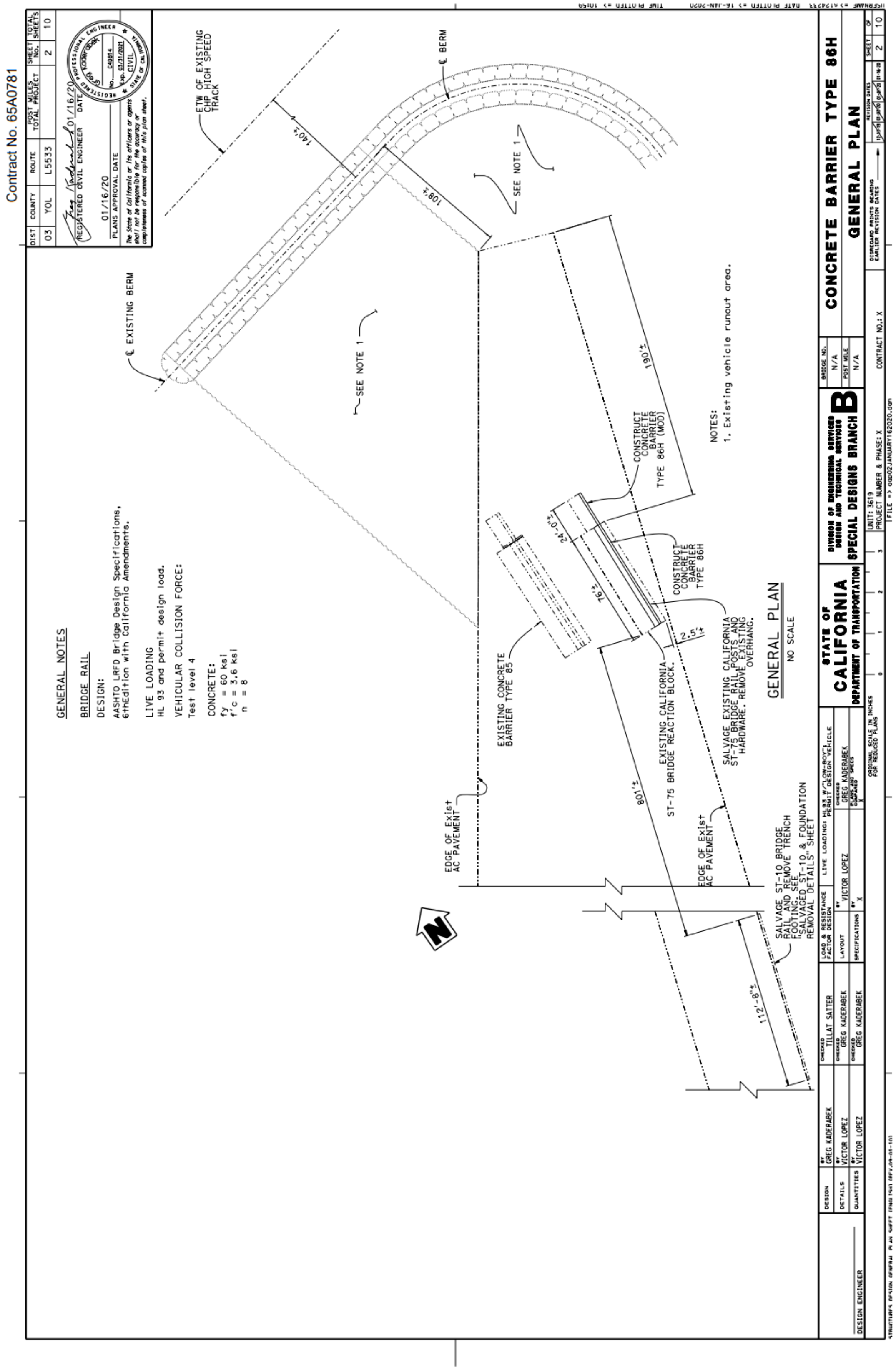


Figure 11-2 Type 86H Test Article General Plan

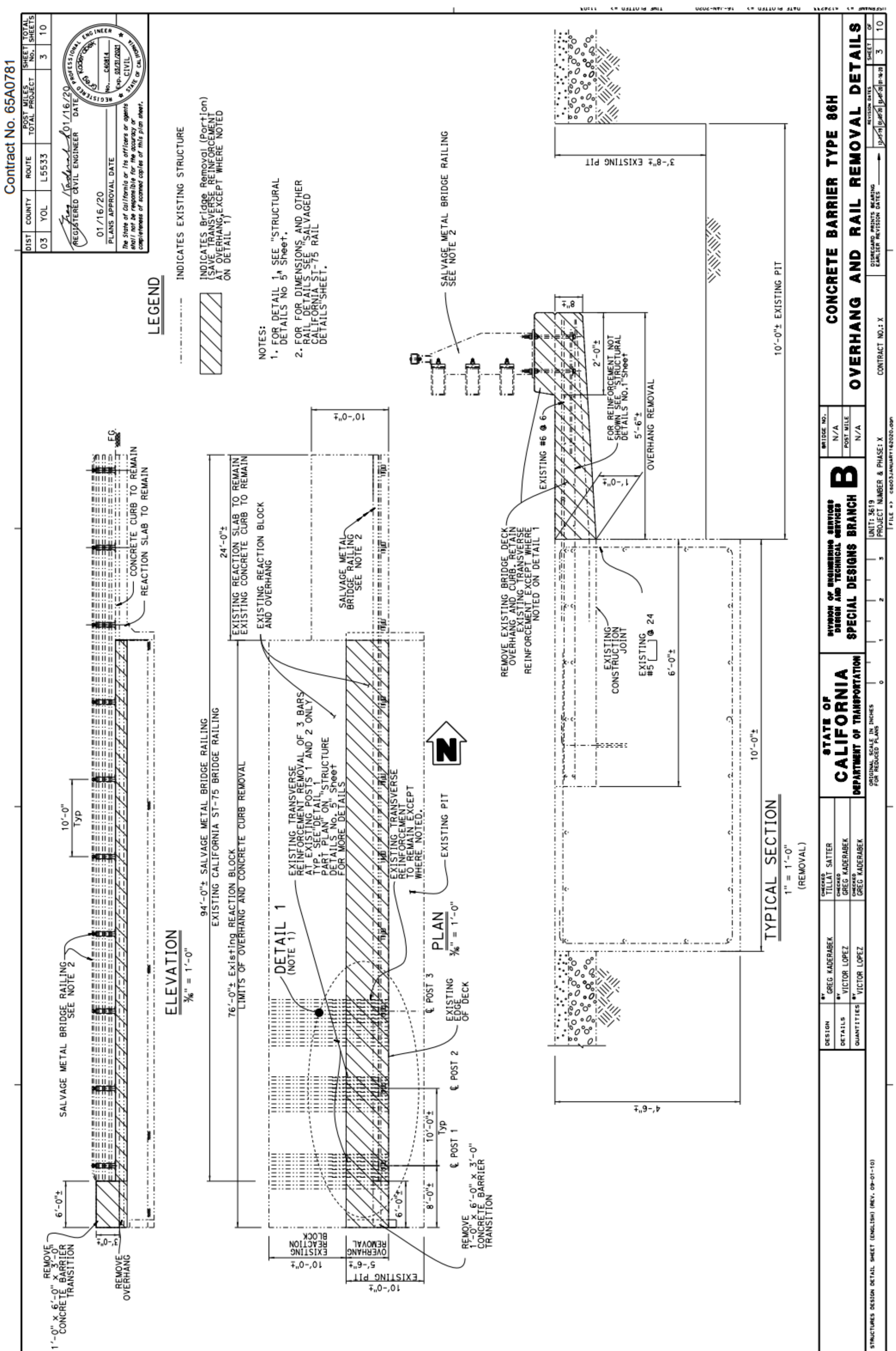


Figure 11-3 Type 86H Test Article Overhang and Rail Removal Details

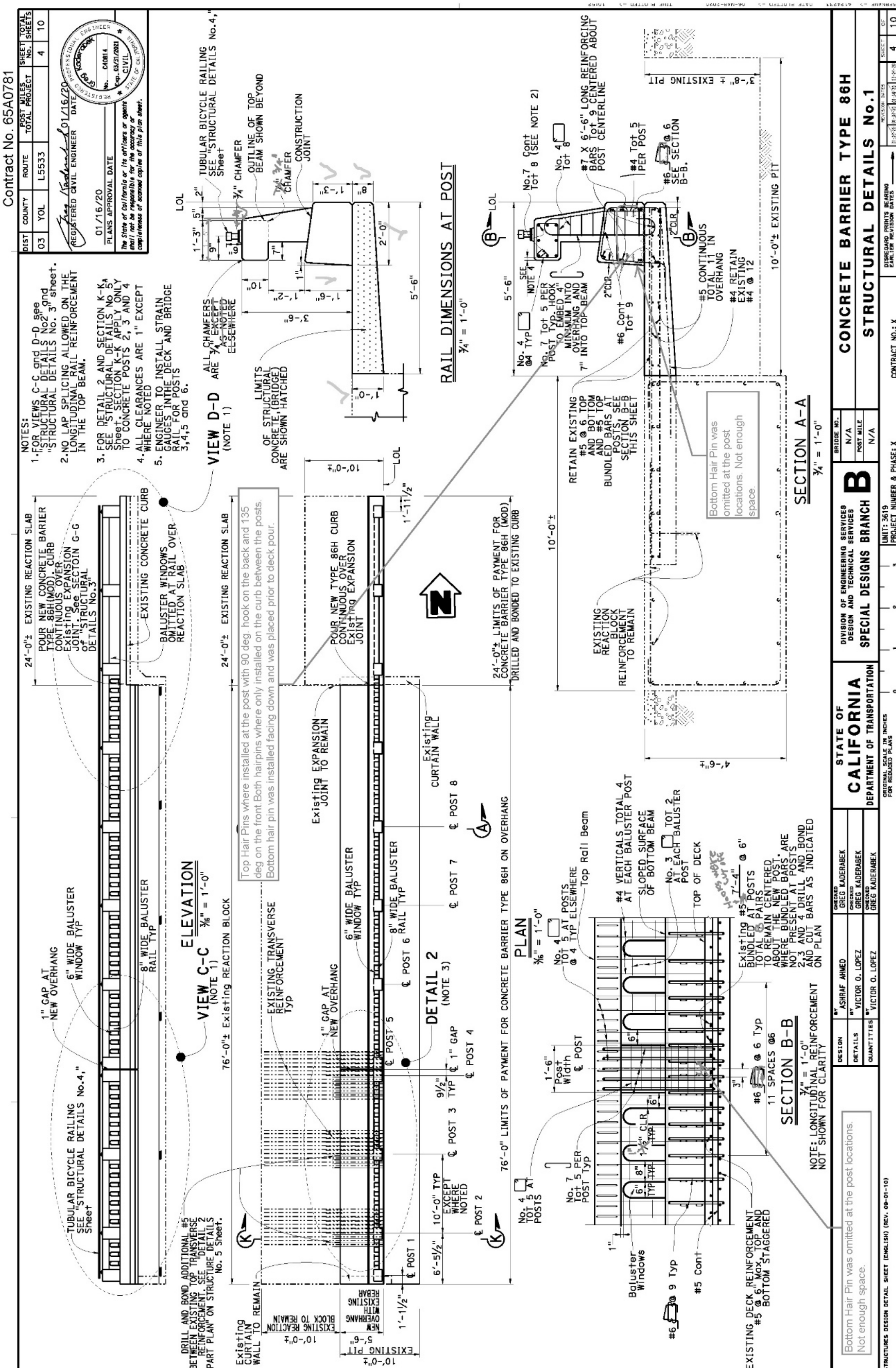


Figure 11-4 Type 86H Test Article Structural Details No.1

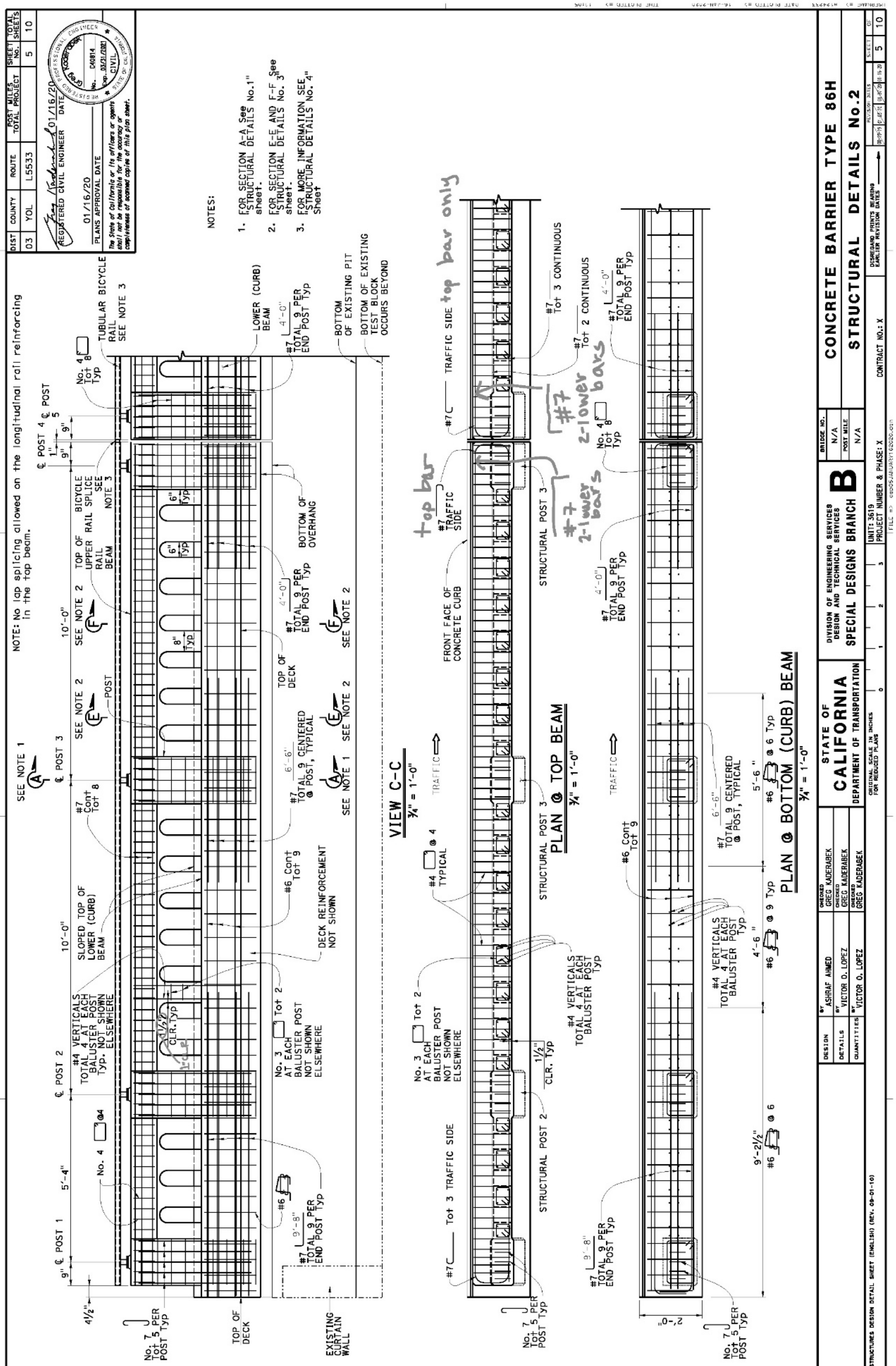


Figure 11-5 Type 86H Test Article Structural Details No.2

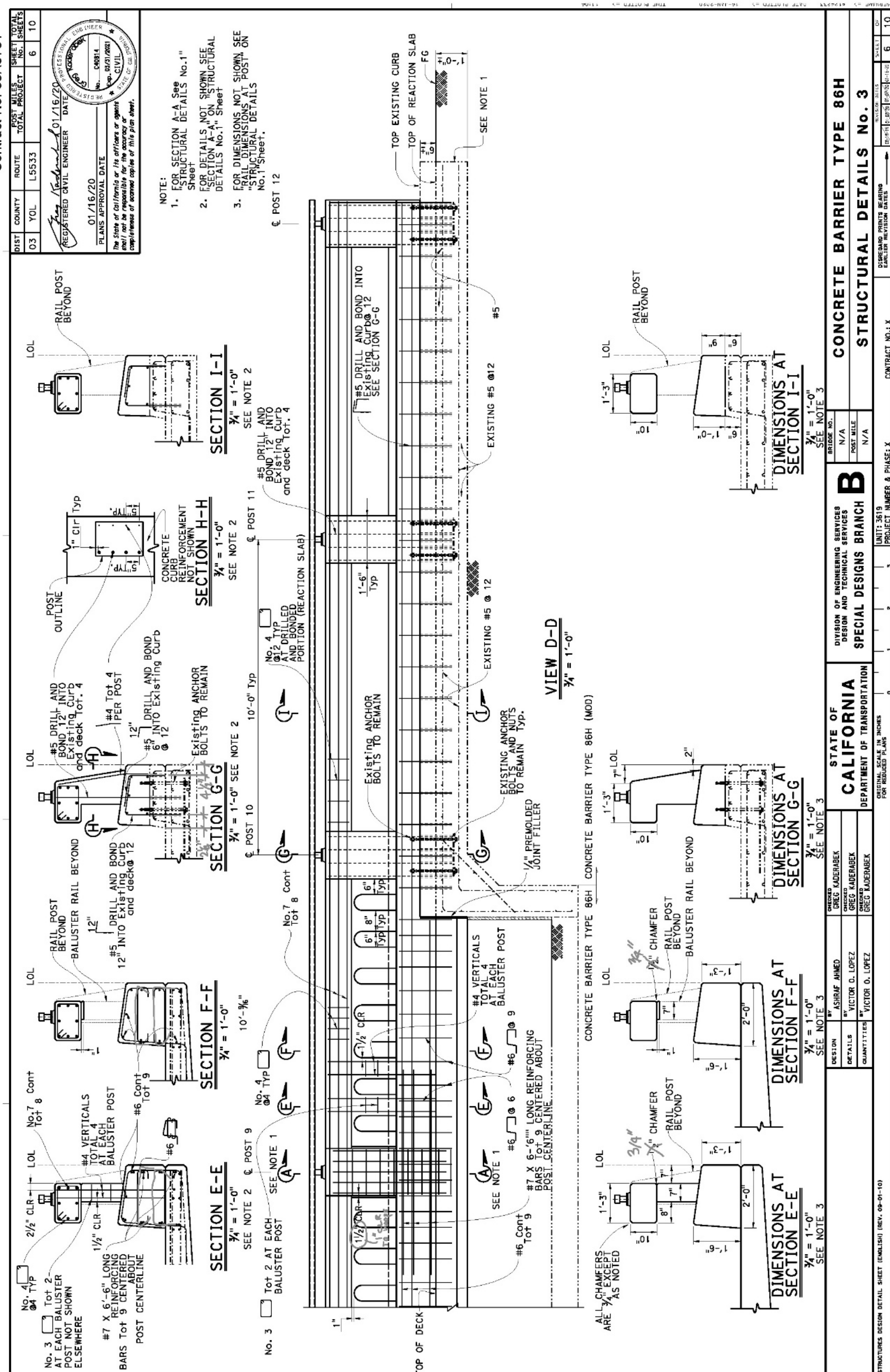


Figure 11-6 Type 86H Test Article Structural Details No.3

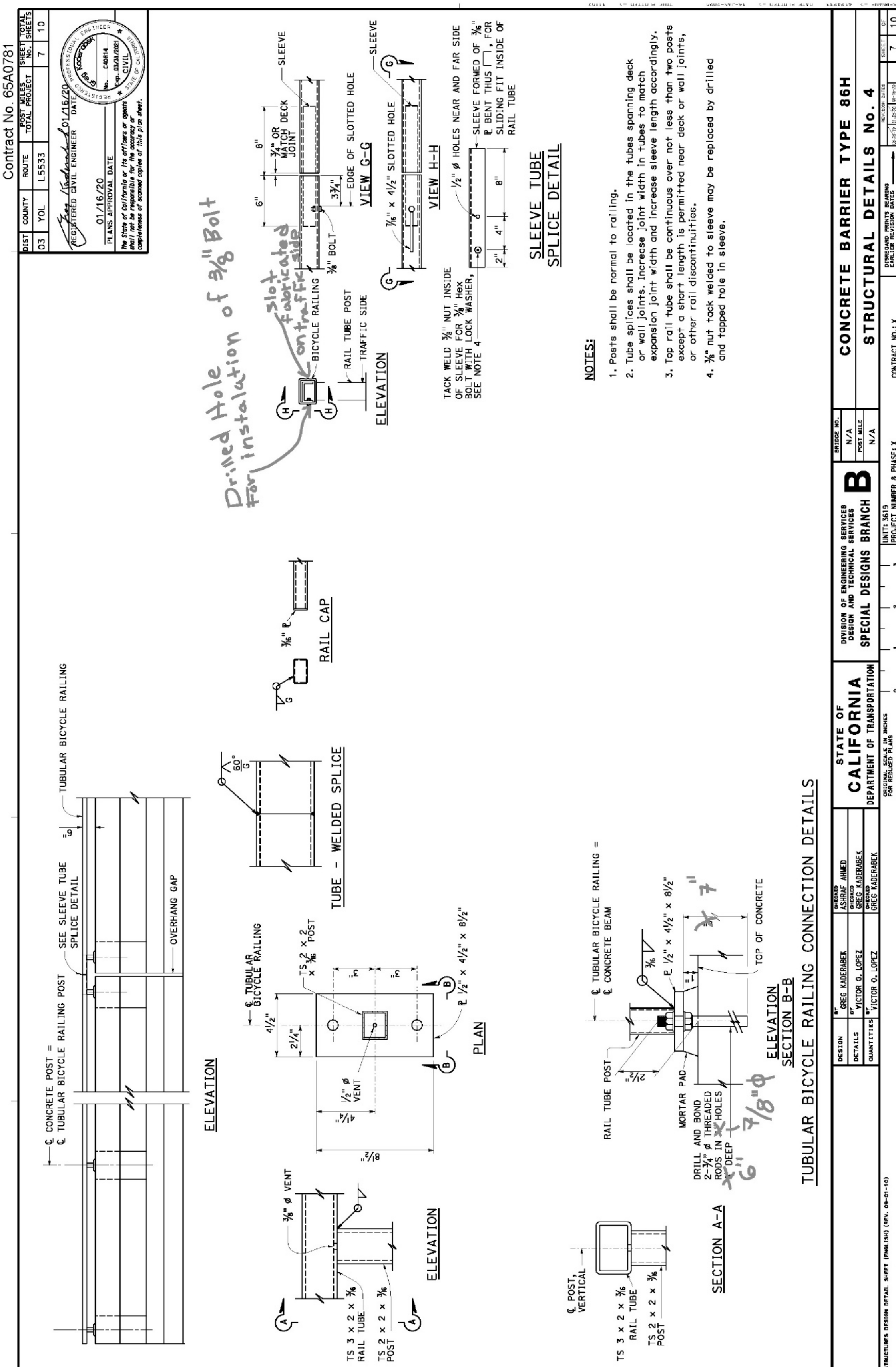


Figure 11-7 Type 86H Test Article Structural Details No.4

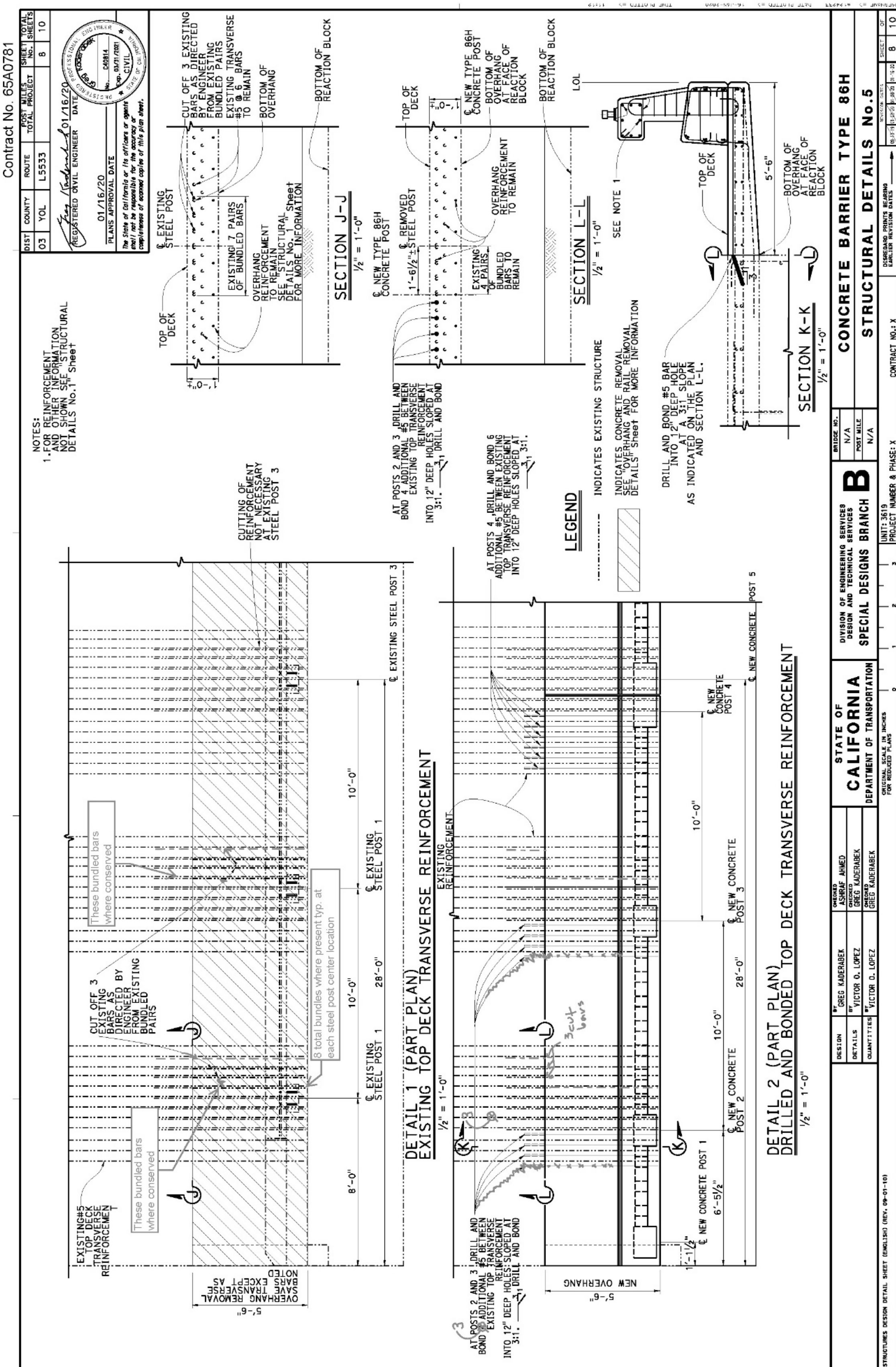


Figure 11-8 Type 86H Test Article Structural Details No.5

12. Appendix C: Material Properties and Certifications

The concrete cylinder breaks and material certifications in Appendix C are not within the Lab's Scope of Accreditation.

Concrete Barrier Type 86H Concrete Cylinder Break Results

(Average of Two Cylinders)

	Mix Z5685210 (Deck Pour) Date of Pour 11/24/2020	**Mix Z1754120 (Curb Pour) Date of Pour 12/03/2020**	**Mix Z1754120 (Post and Beam Pour) Date of Pour 12/21/2020**
Age (Days)	Compressive Strength (psi)	Compressive Strength (psi)	Compressive Strength (psi)
7	4020	4500	4800
14	4810	5030	5980
21	N/A	N/A	N/A
28	5250	5700	6590 (Age was 29 days)
56	5760	5820	6720 (Age was 57 days)

Certified Mill Test Report for Grade 60 #3 Rebar (1 of 5)

CUSTOMER CAMBLIN STEEL SERVICE, INC.
4175 CINCINNATI AVE
ROCKLIN, CA 95765

CASCADE STEEL Rolling Mills Inc.
A Schnitzer Company

CERTIFIED MILL TEST REPORT
(CMTR)
3200 NORTH HIGHWAY 99W
McMINNVILLE, OREGON 97128
(503) 472-4181 FAX (503) 434-5739

DATE 9-26-19
BILL OF LADING 10264810
PAGE 1 OF 1

DESCRIPTION	TEST NAME / UNIT OF MEASURE								
HEAT NO. / PRODUCT / GRADE	YIELD PSI	TENSILE PSI	ELONG. % 8 INCHES	NOM. WT %	BEND DEGREES	DEF.	Melted Rolled	Shipped Lbs/Tons	Melt Lbs Roll Lbs
*301219 #3 COILED REBAR 60D GRADE ASTM A615-18/A706-16 Gr60 AASHTO M31-17	65,500	105,000	14	99	180 OK	OK	08/08/19 08/10/19	22,666 11.3	230,753 217,416
*301119 #3 COILED REBAR 60D GRADE ASTM A615-18/A706-16 Gr60 AASHTO M31-17	60,500	103,000	15	99	180 OK	OK	08/08/19 08/10/19	22,640 11.3	235,463 227,498

CHEMICAL ANALYSIS

HEAT NO.	C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	V %	Mo %	Sn %	CE %
301219	.30	1.23	.015	.019	.25	.28	.06	.11	.033	.02	.016	.52
301119	.30	1.24	.016	.018	.25	.27	.06	.12	.032	.02	.011	.52

This material fully complies with the requirements of the indicated revision of each specification listed.
PO NUMBER(S): ROCK-16

CERTIFIED BY: Jeff Kramer
Jeff Kramer
Quality Assura Manager

* ALL MI NG AND MANUFACTURING PROCESSES FOR THE MATERIALS OCC ED IN THE UNITED STATES.

F016-1.02

Certified Mill Test Report for Grade 60 #4 Rebar (2 of 5)

KYOEI STEEL GROUP
VINTON STEEL
Spirit of Challenge

MILL TEST CERTIFICATE
MANUFACTURER: VINTON STEEL LLC

SOLD TO: MILLENNIUM REINFORCING INC/ DBA SAMSON METALS LLC
1044 CALLE RECODO STE A
SAN CLEMENTE CA 92673
SHIP TO: CAMBLING STEEL PORT OF STOCKTON - TRACK #9970
GILMORE AVENUE
STOCKTON CA 95203
MATERIAL: RV13706F13PA #4 X 60' GRADE 60 (ASTM A706) (ASTM A706/A706M)
DELIVERY LIST NUMBER:
P.O. CUSTOMER NUMBER: V10867

PROGRAM NUMBER: 0080684756

ISSUING DATE: 15.10.2020
CERTIFICATE NUMBER: 72501
PAGE: 1/1

MECHANICAL PROPERTIES

HEAT NUMBER	YIELD STRENGTH psi	TENSILE STRENGTH psi	PERCENT ELONGATION %	BEND	ACTUAL W. PER FOOT lb/ft
2011143	64844	89911	17	ACCEPTABLE	0.641
2011516	69220	92371	17	ACCEPTABLE	0.655
2021188	63389	93973	16	ACCEPTABLE	0.644
2021578	70430	98792	16	ACCEPTABLE	0.647
2021579	69768	96630	16	ACCEPTABLE	0.649

CHEMICAL COMPOSITION

HEAT NUMBER	C %	Mn %	P %	S %	Si %	Ni %	Cr %	Mo %	Cu %	V %	Cb %	CE %			
2011143	0.2564	1.1617	0.0124	0.0316	0.1974	0.1841	0.2210	0.0293	0.2561	0.0304	0.0022	0.4810			
2011516	0.2544	1.1629	0.0121	0.0325	0.2371	0.1055	0.2174	0.0220	0.3023	0.0321	0.0022	0.4759			
2021188	0.2457	1.2577	0.0128	0.0248	0.1859	0.1900	0.2536	0.0386	0.2130	0.0337	0.0036	0.4881			
2021578	0.2648	1.1787	0.0151	0.0185	0.1968	0.0826	0.2298	0.0197	0.2659	0.0331	0.0030	0.4880			
2021579	0.2691	1.2075	0.0161	0.0233	0.2132	0.0934	0.2077	0.0238	0.2759	0.0345	0.0025	0.4953			

WE HEREBY CERTIFY THAT THE ABOVE FIGURES ARE CORRECT AS CONTAINED IN THE RECORDS OF THE COMPANY.
MELTED AND MANUFACTURED IN THE U.S.A.
This reinforcing steel meets all the requirements of the Buy America Act requirements of 23 CFR 635.410

Approved by KSGVS Quality Assurance
Manual REV-20 10/09/2014 to Manufacturing
in accordance with the latest version of the Plan Quality Manual
MAILING ADDRESS
VINTON STEEL LLC VINTON P.O. BOX 12843

CERTIFIED BY THE QUALITY DEPARTMENT - SIGNATURE ON FILE

STREET ADDRESS
I-10 & VINTON ROAD

Certified Mill Test Report for Grade 60 #5 Rebar (3 of 5)

KYOEI STEEL GROUP
VINTON STEEL
Spirit of Challenge

MILL TEST CERTIFICATE
MANUFACTURER: VINTON STEEL LLC

SOLD TO: MILLENNIUM REINFORCING INC/ DBA SAMSON METALS LLC
1044 CALLE RECODO STE A
SAN CLEMENTE CA 92673
SHIP TO: TRISTAR FLC INC
9600 KAISER WAY
FONTANA CA 92335
MATERIAL: RV16706F17PA #5 X 60' GRADE 60 (ASTM A706) (ASTM A706/A706M)
DELIVERY LIST NUMBER: 910056215
P.O. CUSTOMER NUMBER: V10548

PROGRAM NUMBER: 0080680492

ISSUING DATE: 13.04.2020
CERTIFICATE NUMBER: 68953
PAGE: 1/1

MECHANICAL PROPERTIES

HEAT NUMBER	YIELD STRENGTH psi	TENSILE STRENGTH psi	PERCENT ELONGATION %	BEND	ACTUAL W. PER FOOT lb/ft
2010823	67842	89798	17	ACCEPTABLE	1.007
2020862	69630	90155	17	ACCEPTABLE	1.014
2020877	65313	89992	19	ACCEPTABLE	0.991
2020878	68753	96488	14	ACCEPTABLE	1.009
20R0403	63778	87344	19	ACCEPTABLE	1.006

CHEMICAL COMPOSITION

HEAT NUMBER	C %	Mn %	P %	S %	Si %	Ni %	Cr %	Mo %	Cu %	V %	Cb %	CE %			
2010823	0.2544	1.1882	0.0098	0.0297	0.2447	0.0927	0.1507	0.0208	0.2814	0.0309	0.0027	0.4726			
2020862	0.2765	1.1962	0.0143	0.0394	0.1914	0.1065	0.1681	0.0284	0.1997	0.0326	0.0027	0.4959			
2020877	0.2624	1.1842	0.0125	0.0262	0.2224	0.0760	0.2097	0.0192	0.1987	0.0346	0.0022	0.4822			
2020878	0.2836	1.1804	0.0122	0.0323	0.2271	0.0661	0.2424	0.0171	0.2218	0.0301	0.0020	0.5071			
20R0403	0.2700	1.1900	0.0160	0.0300	0.2000	0.0900	0.2100	0.0200	0.2400	0.0330	0.0000	0.4900			

WE HEREBY CERTIFY THAT THE ABOVE FIGURES ARE CORRECT AS CONTAINED IN THE RECORDS OF THE COMPANY.
MELTED AND MANUFACTURED IN THE U.S.A.
This reinforcing steel meets all the requirements of the Buy America Act requirements of 23 CFR 635.410

Hector De Aquino

Approved by KSGVS Quality Assurance
Manual REV-20 10/09/2014 to Manufacturing
in accordance with the latest version of the Plan Quality Manual
MAILING ADDRESS
VINTON S' L LLC VINTON P.O. BOX 12843

CERTIFIED BY THE QUALITY DEPARTMENT - SIGNATURE ON FILE

STREET ADDRESS
I-10 & VINTON ROA

Certified Mill Test Report for Grade 60 #6 Rebar (4 of 5)

CMC STEEL CALIFORNIA
12459 Arrow Route
Rancho Cucamonga CA
91739-9807

CERTIFIED MILL TEST REPORT
For additional copies call
909 646 7827

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

Michael R Mayer
Quality Assurance Manager

HEAT / SECTION	SOLD TO	SHIP TO	DELIVERY
HEAT NO.:3097836 SECTION: REBAR 19MM (#6) 60'0" A615/A706-60 GRADE: ASTM A615 GR A706-60 Dual Gr ROLL DATE: 08/26/2020 MELT DATE: 06/19/2020 Cert. No.: 83200920 / 097836N399	Camblin Steel Service Inc 4175 Cincinnati Ave Rocklin CA US 95765-1402 9166441300 9169251502	Alamillo Rebar - Stockton Yard 411 Gilmore Ave Stockton CA US 95203-0000 2099380264	Delivery#: 83200920 BOL#: 73760051 CUST PO#: STO-11 CUST P/N: DLVRY LBS / HEAT: 6128.000 LB DLVRY PCS / HEAT: 68 EA

Characteristic	Value	Characteristic	Value	Characteristic	Value
C	0.28%	Elongation test 1	18%		
Mn	1.18%	Elongation Gage Lgth test 1	8IN		
P	0.013%	Tensile to Yield ratio test1	1.34		
S	0.031%	Bend Test 1	Passed		
Si	0.23%	Rebar Deformation Avg. Spaci	0.481IN		
Cu	0.36%	Rebar Deformation Avg. Heigh	0.056IN		
Cr	0.12%	Rebar Deformation Max. Gap	0.132IN		
Ni	0.12%	Strain at Peak Stress test 1	12.5%		
Mo	0.033%				
V	0.030%				
Cb	0.002%				
Sn	0.011%				
Al	0.001%				
N	0.0127%				
Carbon Eq A706	0.50%				
Yield Strength test 1	72.9ksi				
Yield Strength test 1 (metri	503MPa				
Tensile Strength test 1	98.0ksi				
Tensile Strength 1 (metric)	676MPa				

The Following is true of the material represented by this MTR:
*Material is fully killed
*100% melted and rolled in the USA
*EN10204:2004 3.1 compliant
*Contains no weld repair
*Contains no Mercury contamination
*Manufactured in accordance with the latest version of the plant quality manual
*Meets the "Buy America" requirements of 23 CFR635.410, 49 CFR 661
*Warning: This product can expose you to chemicals which are known to the State of California to cause cancer, birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov

REMARKS :

Page 1 OF 1 09/04/2020 09:__:50

Certified Mill Test Report for Grade 60 #7 Rebar (5 of 5)

KYOEI STEEL GROUP
VINTON STEEL
Spirit of Challenge

MILL TEST CERTIFICATE
MANUFACTURER: VINTON STEEL LLC

SOLD TO: MILLENNIUM REINFORCING INC/ DBA SAMSON METALS LLC
1044 CALLE RECODO STE A
SAN CLEMENTE CA 92673

SHIP TO: CAMBLING STEEL PORT OF STOCKTON - TRACK #9970
GILMORE AVENUE
STOCKTON CA 95203

PROGRAM NUMBER: 0080683993

MATERIAL: RV22706060PA #7 X 60' GR60 Dual Standard A615/A706 (ASTM A706/A615)
DELIVERY LIST NUMBER:
P.O. CUSTOMER NUMBER: V10867

ISSUING DATE: 15.09.2020
CERTIFICATE NUMBER: 71855
PAGE: 1/1

MECHANICAL PROPERTIES

HEAT NUMBER	YIELD STRENGTH psi	TENSILE STRENGTH psi	PERCENT ELONGATION %	BEND	ACTUAL W. PER FOOT lb/ft
2011845	68108	96157	17	ACCEPTABLE	1.937
2011846	69179	102092	16	ACCEPTABLE	1.970
2011847	68050	103741	14	ACCEPTABLE	1.956
2011848	68654	100100	15	ACCEPTABLE	1.960

CHEMICAL COMPOSITION

HEAT NUMBER	C %	Mn %	P %	S %	Si %	Ni %	Cr %	Mo %	Cu %	V %	Cb %	CE %			
2011845	0.2495	1.3294	0.0220	0.0344	0.2263	0.1271	0.2305	0.0369	0.3174	0.0314	0.0031	0.5014			
2011846	0.2480	1.3515	0.0202	0.0310	0.1870	0.1412	0.2476	0.0368	0.3397	0.0342	0.0036	0.5060			
2011847	0.2639	1.3857	0.0212	0.0272	0.2240	0.1389	0.2212	0.0456	0.3223	0.0310	0.0030	0.5248			
2011848	0.2576	1.3510	0.0134	0.0376	0.2241	0.1280	0.2211	0.0384	0.2617	0.0315	0.0032	0.5108			

WE HEREBY CERTIFY THAT THE ABOVE FIGURES ARE CORRECT AS CONTAINED IN THE RECORDS OF THE COMPANY.
MELTED AND MANUFACTURED IN THE U.S.A.
This reinforcing steel meets all the requirements of the Buy America Act requirements of 23 CFR 635.410

Approved by KSGVS Quality Assurance
Manual to Manufacturing
in accordance with the latest version of the Plan Quality Manual

CERTIFIED BY THE QUALITY DEPARTMENT - SIGNATURE ON FILE

MAILING ADDRESS
VINTON S[illegible] LLC VINTON P.O. BOX 12843

STREET ADDRESS
I-10 & VINTON ROA[illegible]

Certified Mill Test Report for Grade 60 #7 Rebar For Tension Coupler Samples (1 of 1)

KYOEI STEEL GROUP
VINTON STEEL

MILL TEST CERTIFICATE
MANUFACTURER: VINTON STEEL LLC

SOLD TO: MILLENNIUM REINFORCING INC/ DBA SAMSON METALS LLC
1044 CALLE RECODO STE A
SAN CLEMENTE CA 92673

SHIP TO: CAMBLING STEEL PORT OF STOCKTON - TRACK #9970
GILMORE AVENUE
STOCKTON CA 95203

PROGRAM NUMBER: 0080683993

MATERIAL: RV22706060PA #7 X 60' GR60 Dual Standard A615/A706 (ASTM A706/A615)
DELIVERY LIST NUMBER:
P.O. CUSTOMER NUMBER: V10867

ISSUING DATE: 15.09.2020
CERTIFICATE NUMBER: 71855
PAGE: 1/1

MECHANICAL PROPERTIES

HEAT NUMBER	YIELD STRENGTH psi	TENSILE STRENGTH psi	PERCENT ELONGATION %	BEND	ACTUAL W. PER FOOT lb/ft
2011845	68108	96157	17	ACCEPTABLE	1.937
2011846	69179	102092	16	ACCEPTABLE	1.970
2011847	68050	103741	14	ACCEPTABLE	1.956
2011848	68654	100100	15	ACCEPTABLE	1.960

CHEMICAL COMPOSITION

HEAT NUMBER	C %	Mn %	P %	S %	Si %	Ni %	Cr %	Mo %	Cu %	V %	Cb %	CE %
2011845	0.2495	1.3294	0.0220	0.0344	0.2263	0.1271	0.2305	0.0369	0.3174	0.0314	0.0031	0.5014
2011846	0.2480	1.3515	0.0202	0.0310	0.1870	0.1412	0.2476	0.0368	0.3397	0.0342	0.0036	0.5060
2011847	0.2639	1.3857	0.0212	0.0272	0.2240	0.1389	0.2212	0.0456	0.3223	0.0310	0.0030	0.5248
2011848	0.2576	1.3510	0.0134	0.0376	0.2241	0.1280	0.2211	0.0384	0.2617	0.0315	0.0032	0.5108

WE HEREBY CERTIFY THAT THE ABOVE FIGURES ARE CORRECT AS CONTAINED IN THE RECORDS OF THE COMPANY.
MELTED AND MANUFACTURED IN THE U.S.A.
This reinforcing steel meets all the requirements of the Buy America Act requirements of 23 CFR 635.410

Hector De Aquino.

Approved by KSGVS Quality Assurance
Manual to Manufacturing
in accordance with the latest version of the Plan Quality Manual

CERTIFIED BY THE QUALITY DEPARTMENT - SIGNATURE ON FILE

MAILING ADDRESS
VINTON ST LLC VINTON P.O. BOX 12843

STREET ADDRESS
I-10 & VINTON ROAD

Certified Mill Test Report for Grade #7 ZAP Screwlock Type 2 Coupler Samples (1 of 3)

BarSplice PRODUCTS INC.
A SUBSIDIARY OF FC INDUSTRIES INC.

CERTIFICATE OF COMPLIANCE

FOR BPI® MECHANICAL SPLICES &
ASTM A970 HEADED DEVICES

DATE	CUSTOMER	PURCHASE ORDER	ITEM	PROJECT NAME
10/28/2020	CAMBLIN STEEL	DB-200126		MINOR B AT CHP ACADEMY CONT

QUANTITY	PRODUCT	IDENTIFICATION	HEAT LOT NO	ASTM Spec or Rebar Mill
24 EA	#7 ZAP SCREWLOK TYPE 2	7ZBA JW	A201871	ASTM A519-17

TOTAL
24 EA

This certifies the following:

1. Barsplice Products, Inc. (BPI) is engaged in designing, manufacturing and supplying mechanical splices and headed devices for reinforcing bars under a quality system program that is in accordance with ISO 9001:2015.
2. This Certificate of Compliance is issued upon the date shown above to the customer noted with reference to the customer purchase order and project name. Quantities shown above are broken down by heat lot number(s) for each product(s) listed. The identification code(s) shown are marked upon the finished parts and CMTR's and uniquely identify the product and the heat lot number.
3. The above referenced iron and steel product is provided in accordance with the following:
   - Illinois Department of Transportation Specification Section 106.01
   - Michigan Department of Transportation Specification Section 105.10
   - New York Department of Transportation Specification Section 709-10
4. Raw materials and parts used in the manufacture of these products were obtained and processed from qualified sources in accordance with ISO 9001:2015. Iron and steel products provided by BPI have been domestically manufactured, produced and fabricated in the United States of America in accordance with the Buy America Act. Chemical analyses, tests, examinations and heat treatments required by the material specification have been performed by the supplier(s) and this information has been verified as appearing upon Certified Material Test Reports (CMTR) included herewith. Any such test not performed (if applicable) is noted on the CMTR. Any operation not performed per specification (if applicable) is reported.
5. All requirements of BPI's material specification have been met and mechanical testing has been performed to verify that the above provided mechanical splices and/or headed devices are capable of meeting the applicable strength requirements. Type 1 mechanical splices are conforming to Section 25.5.7 of ACI 318-19 and capable of developing, in tension or compression, 125% x specified yield strength of the reinforcing bar. These tests pertain to the use of said products attached to **Grade 60** (metric Grade 420) reinforcing bars which have been manufactured to the latest requirements of ASTM A615/A615M or ASTM A706. For headed devices, in-air testing has verified conformance with Class A/HA strength requirement listed in ASTM A970.

NOTICE
The products described herein must be installed in accordance with the latest edition of **INSTALLATION INSTRUCTIONS** supplied to the project, which must be read and understood by the operator before use. In accordance with project specifications, tensile tests may be required before and during production splicing to verify correct usage, rebar grade, and operator proficiency. Other terms and conditions are applicable as may have been previously supplied on quotations and order acknowledgments, either directly or to the dealer, distributor or representative.

Signed E Pounds
Barsplice Products, Inc.
~~S.R. Pounds, Shipping Clerk~~

Date 10/28/2020
Shop Order # 187409

BPI 4 12-08 REV B 09/12/2016 Eff 03/10/2020

Certified Mill Test Report for Grade #7 ZAP Screwlock Type 2 Coupler Samples (2 of 3)

PLYMOUTH TUBE CO USA
572 W State Road 14, Winamac, Indiana 46996
Phone: (574) 946-3125

PRODUCT CERTIFICATION
SALES ORDER - LINE / RLS
183232 - 1 / 1

WORK ORDER 005139 PCS/HEAT 320
HEAT NUMBER A201871
MELT SOURCE Steel Dynamics - USA Melt/Mfg

SHIP TO

Barsplice Products, Inc.
4900 Webster
Dayton, OH 45414
USA

07ZBA JW	07SZBA JW	07SZSC JW	07ZEA JW*
07ZGA JW*	07ZFXA JW	07/06ZBA JW	07/06ZEA JW*
07/06ZFXA JW	07/05ZBA JW	07/05ZEA JW*	07/05ZFXA JW

ISO 9001:2015 Registered

CUSTOMER P.O.	CUSTOMER PART	QUANTITY	LADING NO	CERT ID / REV	CERT DATE
N0003923	N09TRZ	27,314.69 Lb	00115195	00170533 / 02	05/29/2020

PART DESCRIPTION EG20860354CR1320R40H
Spec: ASTM A-519 Seamless Mech.
Carbon Smls Mechanical, HF [B/C] Smls Long/Straight
Grade: 1026
OD: 2.0860" Tol+.0200" Tol-.0200"
Wall: 0.3540" Tol+.0354" Tol-.0354" AW
Lgth Type: Random
Lgth: 13.00' / 20.00'
End Finish: Debur ID & OD
Finish Type: Normalized
Oil: No Oil / Ship Dry

BarSplice REVIEWED BY ENG. & APPROVED FOR MANUFACTURE
DATE 5/29/2020 HT# A201871
SIG. [signature] CODE LISTED

CERTIFICATION REQUIREMENTS
ASTM A-519-17 / NCA 3800
This material is normalized annealed. The final (Cold Finish)annealing temperature was 1650 degrees fahrenheit.
This material was Eddy Current tested and conforms to the requirements of ASTM A-450 & E-309.
Material smelted, produced, and processed in the USA. Conforms with 10CFR PART 21 provisions. Material produced in accordance with to ASME Section III Div. 1 & 2. Subsection NCA3800(2019 ed.) Plymouth Tube Quality Manual 2018 Edition Rev.0 date 02/07/2018, as audited and approved by BPI.
Color Code: Orange

Chemical Analysis

	C	Mn	P	S	Si	Al	Cr	Mo	Ni	Pb	Cu	V	Ti
Ladle	.26	.76	.010	.019	.24	.024	.15	.02	.06	.000	.17	.002	.000
Check	.26	.72	.008	.015	.23	.021	.15	.02	.06		.17	.001	.001

	Sn	Cb	Ca	N	As	Sb	B
Ladle	.007	.001	.0009	.0066	.003	.002	-------
Check	.007	.000	.0008	.0056			

Physical Properties

Grain Size
7

Methods of Manufacturing

Method of Mfg 1	Method of Mfg 2	Method of Mfg 3
Electric Arc Furnace Melted	Continuous Cast	Vacuum Degassed

I certify that the described material has been manufactured, inspected, and tested in accordance with the above specification(s) and satisfies the requirements.

[signature]
Quality Assurance

Page 1 of 2 Date Printed: 05/29/2020

Certified Mill Test Report for Grade #7 ZAP Screwlock Type 2 Coupler Samples (3 of 3)

PLYMOUTH TUBE CO USA
672 W State Road 14, Winamac, Indiana 46996
Phone: (574) 946-3125

PRODUCT CERTIFICATION

SALES ORDER - LINE / RLS
183232 - 1 / 1

WORK ORDER 005139 PCS/HEAT 320
HEAT NUMBER A201871
MELT SOURCE Steel Dynamics - USA Melt/Mfg

SHIP TO

Barsplice Products, Inc.
4900 Webster
Dayton, OH 45414
USA

BarSplice REVIEWED BY ENG. & APPROVED FOR MANUFACTURE
DATE 5/29/2020 HT# A201871
SIG [signature] CODE LISTED

ISO 9001:2015 Registered

CUSTOMER P.O.	CUSTOMER PART	QUANTITY	LADING NO	CERT ID / REV	CERT DATE
N0003923	N09TRZ	27,314.69 Lb	00115195	00170533 / 02	05/29/2020

PART DESCRIPTION EG20860354CR1320R40H

Mechanical Properties

	Rb-High	Rb-Low	Tensile	Yield .5%	Elong%
1	81	81	70600	55090	54
2			69100	56440	43

This test report data is for the heat Chemistry Stated above.

The material in this test report is:

1) **Manufactured in the USA.**
2) **Free from Polybrominated Biphenyls (PBB), Polybrominated Diphenyl Ethers (PBDE), and Mercury contamination.**
3) **No Repairs by welding**
4) **Compliant with EN-10204 3.1B**

End of Certification

I certify that the described material has been manufactured, inspected, and tested in accordance with the above specification(s) and satisfies the requirements.

[signature]
Quality Assurance

Page 2 of 2 Date Printed: 05/29/2020

Mill Certificate for Bicycle Rail (1 of 3)

Customer Name	Customer PO#	Shipper No	Heat Number
BEKO'S WELDING, INC.	007	198929	813L72080

Sales Order No: 166318
Customer: SEAPORT STEEL : 210013
Specification: A500B/C-18
Article: 31328

MILL CERTIFICATE

THIS TUBING WAS MANUFACTURED IN THE U.S.A.

No:
Date: 09/03/20

SEARING INDUSTRIES Wyoming
5310 Clear Creek Pkwy · Cheyenne, WY 82009
(909) 948-3030

Size	Quantity		Chemical Composition (Ladle Analysis)										Tensile Test			(Heat No.)
	Number of Pieces	Calculated Weight per ft.	C (%) x 100	Mn (%) x 100	P (%) x 1000	S (%) x 1000	Si (%) x 1000	Cr (%) x 100	Cu (%) x 100	Mo (%) x 100	Ni (%) x 100	V (%) x 1000	Yield Strength (-)	Tensile Strength (-)	Elongation (%)	
SQ X .250 X HR 20'	50	8.800	19	80	17	5	18	4	3	1	1	3	68000	77000	29	930317 07/27/20
MELTED AND MFG IN THE USA																
SQ X .250 X HR 20'	50	8.800	20	84	11	3	24	3	1	1	1	1	63000	72000	25	041356 08/28/20
MELTED AND MFG IN THE USA																
SQ X .250 X HR 24'	50	8.800	21	81	12	5	15	2	1	0	1	2	65000	75000	29	821J10990 12/16/19
MELTED AND MFG IN THE USA																
SQ X .188 X HR 20'	100	6.860	20	81	10	3	9	3	2	1	1	1	64000	75000	24	937295 04/03/20
MELTED AND MFG IN THE USA																
SQ X .188 X HR 40'	30	6.860	21	85	10	4	9	2	2	0	1	1	59000	71000	30	813L72080 07/24/20
MELTED AND MFG IN THE USA																
X 2 X .188 X HR 20'	72	5.590	21	81	7	5	7	2	1	0	1	1	65000	75000	28	822L32060 08/19/20
MELTED AND MFG IN THE USA																
X 2 X .188 X HR 40'	48	5.590	20	84	9	3	22	3	2	1	1	2	64000	73000	27	032213 07/30/20

We hereby certify that the material described herein conforms fully to the said specification.
Unless noted this tubing does not meet the melted and manufactured specification for MADE IN AMERICA
⚠ Warning: Cancer and Reproductive Harm www.p65warnings.ca.gov

SEARING INDUSTRIES, INC.

Salvador Rodriguez-Quality Manager

Mill Certificate for Bicycle Rail (2 of 3)

MAC

MILL CERTIFICATE

ORIGINAL

BL No. SH0000079888
Destination FARWEST STEEL CORPORATION-E
Supplier

M/C No. MC0000072972
Date 06/20/2018
THIS PIPE AND TUBE MADE IN U.S.A.

MARUICHI AMERICAN CORPORATION
11529 GREENSTONE AVENUE
SANTA FE SPRINGS, CALIFORNIA
TEL: (562) 903-8600 FAX: (562) 903-8601

	SPEC / SIZE / CUSTOMER PO NO	No of PCS / Calculated Wt(MT)	Heat No	C (%) X 100	Si (%) X 100	Mn (%) X 100	P (%) X 1000	S (%) X 1000	Cu (%) X 1000	Ni (%) X 1000	Cr (%) X 1000	Mo (%) X 1000	V (%) X 1000	Yield Strength (PSI)	Tensile Strength (PSI)	Elongation (%)	Hydrostatic Test Pressure (PSI) / Result	Bending Test	Flattening Test	Remarks
1	ASTM A500/A500M-10a GRADE B ERW TUBING 3 1/2IN x 2 1/2IN x 0.188IN x 40FT 101-19268	4 0.498	C6936	15	1	45	14	6						51300	67500	36				SA0000112762 GR-C
2	ASTM A513-12 ERW TUBING 2 1/2IN x 1IN x 0.12IN x 20FT 101-19272	40 0.952	A7337	7	2	37	10	4												SA0000112809 M
3	ASTM A500/A500M-10a GRADE B ERW TUBING 2 1/2IN x 1 1/2IN x 0.25IN x 24FT 101-19272	24 1.411	C6824	10	1	49	15	8						55900	62500	28				SA0000112809 M , GR-C
4	ASTM A500/A500M-10a GRADE B ERW TUBING 2 1/2IN x 1 1/2IN x 0.25IN x 24FT 101-19272	12 0.706	C6825	9	2	48	17	4						60900	69500	25				SA0000112809 M , GR-C
5	ASTM A500/A500M-10a GRADE B ERW TUBING 4IN x 6IN x 0.12IN x 40FT 101-19280	12 1.709	C6882	17	1	75	15	2						52700	66400	36				SA0000113819 M , GR-C
6	ASTM A500/A500M-10a GRADE B ERW TUBING 7IN x 9IN x 0.25IN x 40FT 101-19285	6 2.808	F0530	18	2	77	14	5						54800	71500	35				SA0000114593 M , GR-C

We hereby certify that the material described herein conforms fully to the said specification.

Remarks: M - Domestic Coil
GR-C - Meet ASTM A500/A500M-10 GRADE C

MARUICHI AMERICAN CORPORATION

Y. Ikuta
(Quality Control)

Mill Certificate for Bicycle Rail (3 of 3)

Customer Name	Customer PO#	Shipper No	Heat Number
BEKO'S WELDING, INC.	007	193586	3500011093

NUCOR

Mill Certification
05/29/2020

MTR#:422421-12
Lot #:350001109320
2424 SW ANDOVER ST
SEATTLE, WA 98106 US
206-933-2222
Fax: 206-933-2207

Sold To: SEAPORT STEEL COMPANY
3660 E MARGINAL WAY S
SEATTLE, WA 98134 US

Ship To: SEAPORT STEEL COMPANY
A VARSTEEL COMPANY
3000 SE HIDDEN WAY #40A
VANCOUVER, WA 98661 US

Customer PO	30165	Sales Order #	35011553 - 3.1
Product Group	Hot Roll - Merchant Bar Quality	Product #	3050421
Grade	Nucor Multigrade	Lot #	350001109320
Size	0.5" x 5"	Heat #	3500011093
BOL #	BOL-506443	Load #	422421
Description	Hot Roll - Merchant Bar Quality Flat 1/2" x 5" Nucor Multigrade 20' 0" [240"] 4001-8000 lbs	Customer Part #	
Production Date	02/27/2020	Qty Shipped LBS	5104
Product Country Of Origin	United States	Qty Shipped EA	30
Original Item Description		Original Item Number	

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Melt Country of Origin : United States

Melting Date: 02/23/2020

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	V (%)	Nb (%)	Sn (%)
0.16	0.86	0.012	0.036	0.20	0.11	0.15	0.03	0.31	0.005	0.006	0.020

ASTM A529 S78 2 CE (%) : 0.40
ASTM A992 5.4 CE (%) : 0.37

Other Test Results

Yield (PSI) : 56550	Yield (PSI) : 56664	Tensile (PSI) : 75491
Tensile (PSI) : 75595	Elongation in 8" (%) : 29.7	Elongation in 8" (%) : 31.3

Comments:

ASTM A36/A36M-14, A529/A529M-14 GR50,
A572/A572M-15 GR50, A709/A709M-16A GR36/50 NO CVN,
CSA G40.21-13 GR44W/GR50W,
AASHTO M270/M270M-12 GR36/GR50, ASME SA36/SA36M-13
MEETS REPORTING REQUIREMENTS OF EN10204 SEC 3.1
Nucor-Seattle is ISO 9001-2015, 14001 and ABS certified. All manufacturing processes of the steel materials in this product, including melting, have occurred within the United States. Mercury, in any form has not been used in the production or testing of this material. Meets (FTA) Buy American Requirements (49 C.F.R. part 661). This material is free of HG contamination and is ROHS compliant. Manufactured in the US and complies with the Buy American Act. No weld repair was performed. Parts meet the requirements of the purchase order and have been produced under the Nucor Steel Seattle quality manual rev A5 dated 10/20/2017.

Erik Nissen, Plant Metallurgist

Page 1 of 1

3/4 in. Diameter Threaded Rods for Installation of Bicycle Rail (1 of 2)

04-29-20;11:52 ;Viking Bolt ;5036207062 # 1/ 4

NUCOR
Nucor Steel Nebraska

Mill Certification
07/27/2018

MTR#: 75895
Lot #:10089196423
2911 E NUCOR ROAD
PO BOX 309
NORFOLK, NE 68701 US
402-644-0200
Fax: 402-644-0329

Sold To: KING STEEL CORP
5225 E COOK RD
GRAND BLANC, MI 48439 US

Ship To: KING STEEL - CUSTOMER PICK UP
REFER TO DISPATCH
NORFOLK, NE 68701 US

Customer P.O	026082-JK-T/26	Sales Order #	10012027 - 1.2
Product Group	Hot Roll - Engineered Bar	Product #	1000934
Grade	4140DHA5 Vacuum Degassed H-Band Aluminum Treated	Lot #	10089196423
Size	0.68"	Heat #	100891964
BOL #	BOL-171205	Load #	75895
Description	Hot Roll - Engineered Bar Round 0.68" 4140 Vacuum Degassed H-Band Aluminum Treated 24' 6" [294"] 7001-9000 lbs	Customer Part #	1000934
Production Date	07/07/2018	Qty Shipped LBS	33308
Product Country Of Origin	United States	Qty Shipped EA	1100
Original Item Description		Original Item Number	

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed above and that it satisfies those requirements.

Melt Country of Origin : United States — Melting Date: 05/14/2018

C (%)	Mn (%)	P (%)	S (%)	Si (%)	Ni (%)	Cr (%)	Mo (%)	Cu (%)	Ti (%)	V (%)	B (%)
0.41	0.88	0.008	0.015	0.28	0.07	0.92	0.18	0.14	0.002	0.005	0.000
Nb (%)	Zr (%)	N (PPM)	Sn (%)	Al (%)	Pb (%)	Ca (%)	As (%)				
0.004	0.001	90	0.008	0.03	0.000	0.001	0.004				

Austenitic fine grain by chemical analysis per the latest revision of ASTM A29
Reduction Ratio 120.84 : 1

Jominy Calculated

J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	J12	J13	J14	J15	J16	J18	J20	J22	J24	J26	J28	J30	J32
57	57	57	57	57	57	55	53	52	50	49	48	47	46	45	44	43	42	41	40	39	38	37	36

ASTM E45 Method A (Average)
Sulfides:T: 1.3 H: 0.5 Alumina : T: 0.8 H: 0.0 Silicates T: 0.1 H: 0.0 Globular T: 1.0 H: 0.5
ASTM E45 Method A (Worst)
Sulfides:T: 1.5 H: 0.5 Alumina : T: 1.5 H: 0.0 Silicates T: 0.5 H: 0.0 Globular T: 1.0 H: 0.5

Other Test Results
Tensile (PSI) : 145400
Elongation in 8" (%) : 8.0
Macroetch E381 Surface : 1
Macroetch E381 Mid Radius : 1
Macroetch E381 Center : 2
Rockwell C (HRC) : 32
DI Calculated (IN) : 5.02

Comments:
All manufacturing processes of the steel materials in this product, including melting, have been performed in the United States.
All products produced are weld free.
Mercury, in any form, has not been used in the production or testing of this material.
Test conform to ASTM A29-15, ASTM E415 and ASTM E1019-resulphurized grades or applicable customer requirements.
All material melted at Nucor Steel Nebraska is produced in an Electric Arc Furnace.
Strand Cast

Jim Hill
Jim Hill, Division Metallurgist

NBMG-10 January 1, 2012

Page 1 of 2

3/4 in. Diameter Threaded Rods for Installation of Bicycle Rail (2 of 2)

04-29-20;11:52 ;Viking Bolt ;5036207062 # 2/ 4

NUCOR
Nucor Steel Nebraska

Mill Certification
07/27/2018

MTR#: 75895
Lot #:10089196423
2911 E NUCOR ROAD
PO BOX 309
NORFOLK, NE 68701 US
402-644-0200
Fax: 402-644-0329

VIKING BOLT PO-84742 SO-117111
35ea 3/4-10 X 12 FT DOM ASTM A193 B7 ATR MFG
HT 100891964

ISO-17025 LAB accreditation cert available upon request.
Exporting Country-USA
Sales@nucorna.com
California Proposition 65: This product contains chemicals known to the State of California to cause cancer, birth defects and other reproductive harm. The list of chemicals are available upon request. For more information, please call 402-644-0200.

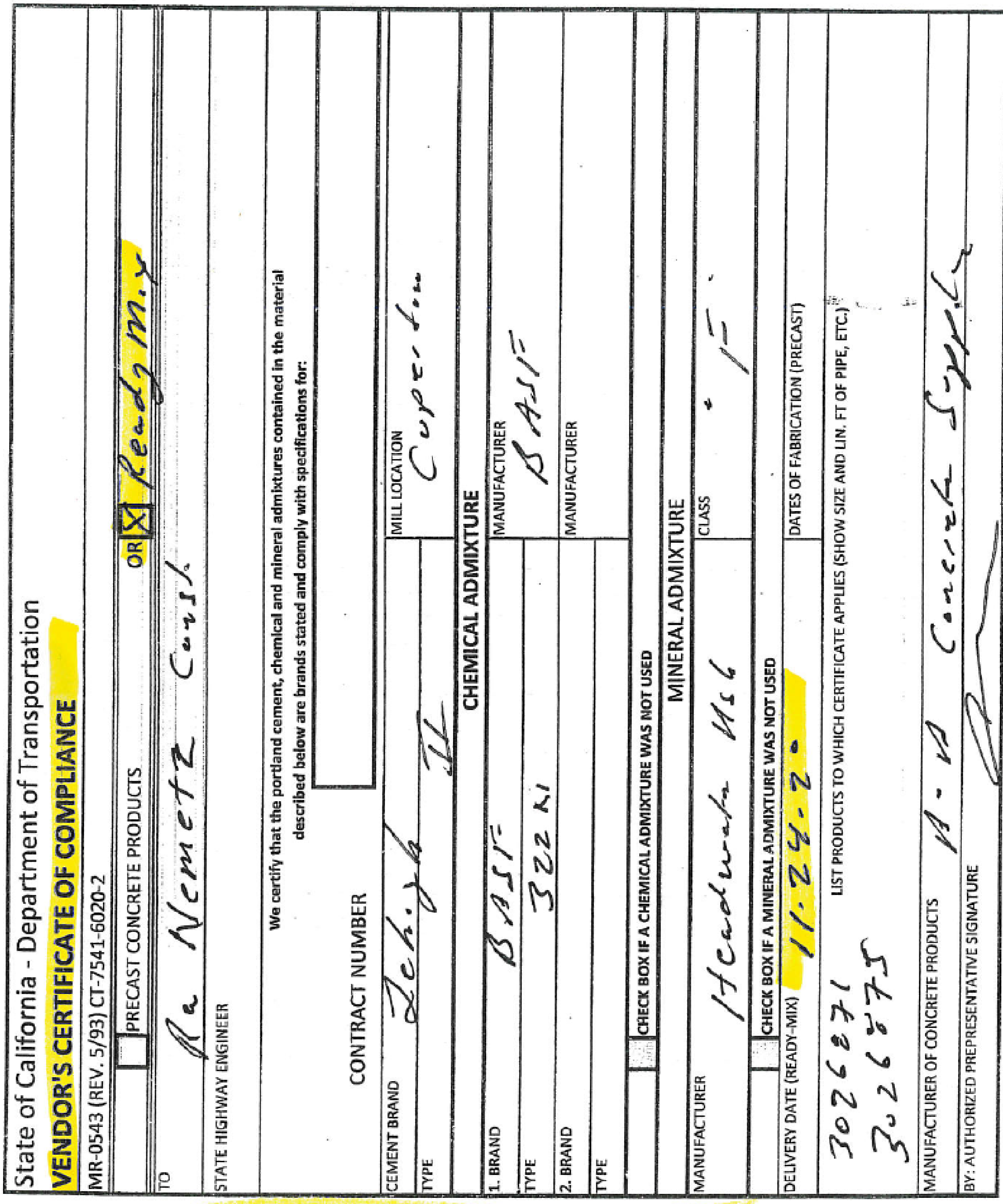
NBMG-10 January 1, 2012

Jim Hill

Jim Hill, Division Metallurgist

Page 2 of 2

Certificate of Compliance for Concrete Mix (Overhang) (1of 3)



State of California - Department of Transportation

VENDOR'S CERTIFICATE OF COMPLIANCE

MR-0543 (REV. 5/93) CT-7541-6020-2

☐ PRECAST CONCRETE PRODUCTS OR ☒ Ready Mix

TO: Ra Nemetz Const

STATE HIGHWAY ENGINEER

We certify that the portland cement, chemical and mineral admixtures contained in the material described below are brands stated and comply with specifications for:

CONTRACT NUMBER

CEMENT BRAND: Lehigh

TYPE: II

MILL LOCATION: Cupertino

CHEMICAL ADMIXTURE

1. BRAND: BASF
TYPE: 322 N
MANUFACTURER: BASF

2. BRAND:
TYPE:
MANUFACTURER:

☐ **CHECK BOX IF A CHEMICAL ADMIXTURE WAS NOT USED**

MINERAL ADMIXTURE

MANUFACTURER: Headwaters Hsb

CLASS: "F"

☐ **CHECK BOX IF A MINERAL ADMIXTURE WAS NOT USED**

DELIVERY DATE (READY-MIX): 11-24-20

DATES OF FABRICATION (PRECAST)

3026871
3026875

LIST PRODUCTS TO WHICH CERTIFICATE APPLIES (SHOW SIZE AND LIN. FT OF PIPE, ETC.)

MANUFACTURER OF CONCRETE PRODUCTS: A-A Concrete Supply

BY: AUTHORIZED PREPRESENTATIVE SIGNATURE

FM 93 1839 ORIGINAL TO RES. ENGR. RETAIN DUPLICATE OSP 08 107926

Certificate of Compliance for Concrete Mix (Barrier Curb) (2 of 3)

State of California - Department of Transportation

VENDOR'S CERTIFICATE OF COMPLIANCE

MR-0543 (REV. 5/93) CT-7541-6020-2

☐ PRECAST CONCRETE PRODUCTS OR ☒ Ready Mix

TO: RA - Nemetz Const

STATE HIGHWAY ENGINEER

We certify that the portland cement, chemical and mineral admixtures contained in the material described below are brands stated and comply with specifications for:

CONTRACT NUMBER

CEMENT BRAND	Lehigh	MILL LOCATION	Cupertino
TYPE	II		

CHEMICAL ADMIXTURE

1. BRAND	BASF	MANUFACTURER	BASF
TYPE	322N		
2. BRAND	BASF	MANUFACTURER	BASF
TYPE	Pelz 4025		

☐ **CHECK BOX IF A CHEMICAL ADMIXTURE WAS NOT USED**

MINERAL ADMIXTURE

MANUFACTURER	Headwaters Ash	CLASS	F

☐ **CHECK BOX IF A MINERAL ADMIXTURE WAS NOT USED**

DELIVERY DATE (READY-MIX)	12-3-20	DATES OF FABRICATION (PRECAST)	

LIST PRODUCTS TO WHICH CERTIFICATE APPLIES (SHOW SIZE AND LIN. FT OF PIPE, ETC.)

3027075
3027077

MANUFACTURER OF CONCRETE PRODUCTS: A & A Concrete Supply

BY: AUTHORIZED PREPRESENTATIVE SIGNATURE

FM 93 1839 ORIGINAL TO RES. ENGR. RETAIN DUPLICATE OSP 08 107926

Certificate of Compliance for Concrete Mix (Barrier Post and Beam) (3 of 3)

State of California - Department of Transportation
VENDOR'S CERTIFICATE OF COMPLIANCE
MR-0543 (REV. 5/93) CT-7541-6020-2

☐ PRECAST CONCRETE PRODUCTS OR ☒ Ready mix

TO: RA Nemetz Const Co
STATE HIGHWAY ENGINEER

We certify that the portland cement, chemical and mineral admixtures contained in the material described below are brands stated and comply with specifications for:

CONTRACT NUMBER

CEMENT BRAND: Two Rivers	MILL LOCATION: West Sacramento
TYPE: II/V	
CHEMICAL ADMIXTURE	
1. BRAND: BasF	MANUFACTURER: BasF
TYPE: 322N	
2. BRAND: BasF	MANUFACTURER: BasF
TYPE: Poly 1025	
☐ **CHECK BOX IF A CHEMICAL ADMIXTURE WAS NOT USED**	
MINERAL ADMIXTURE	
MANUFACTURER: Heat waters	CLASS: Fly Ash "F"
☐ **CHECK BOX IF A MINERAL ADMIXTURE WAS NOT USED**	
DELIVERY DATE (READY-MIX): 12-21-20	DATES OF FABRICATION (PRECAST)

302 74 98 LIST PRODUCTS TO WHICH CERTIFICATE APPLIES (SHOW SIZE AND LIN. FT OF PIPE, ETC.)

MANUFACTURER OF CONCRETE PRODUCTS: A3A Concrete Supply

BY: AUTHORIZED PREPRESENTATIVE SIGNATURE: [illegible]

FM 93 1839 ORIGINAL TO RES. ENGR. RETAIN DUPLICATE OSP 08 107926

Certificate of Compliance for Concrete Cure Compound (1 of 1)

Certificate of Compliance

'Batch Number: 0PF018

Certificate Number: 3216

Batch Volume: 1980 Gallons

Date Certificate Issued: 06/15/2020

Date of Manufacture: 06/09/2020

Issued To:

cc: California Department of Transportation
Chemical Testing Branch
5900 Folsom Boulevard
Sacramento, CA 95819

W. R MEADOWS, INC. certifies that the following batch of curing compound, 2250-White Poly-Alphamethyl Styrene, Batch# 0PF018, Type 2, Class B, meets or exceeds the requirements as specified in Section 90-1.01C(5) of the 2018 Standard Specifications, ASTM C309, and all rules and regulations concerning air pollution control in the State of California.

Batch Test Results

Tests	Test Method	Date Tested	Test Result	Tested By	Requirements
Moisture loss in 24 hours, $5.0 m^2/L$, average of 2 pans	CT 534	06/10/2020	.14	KN	$0.15\text{-}kg/m^2$, max
Viscosity, 2 Spindle, 50 RPM	ASTM D2196	06/10/2020	193	KN	
Nonvolatile Content	ASTM D2369	06/10/2020	42.3	KN	
Pigment Content	ASTM D3723	06/10/2020	5.0	KN	
Reflectance (ASTM C309 Type 2)	ASTM E1347	06/10/2020	71.8	KN	60%, min.

Shipping Container 'Fingerprint' Test Results[2]

Shipping Container Number: TOTE# 4624 Shipping Container Volume: 275 GALLON TOTE

Tests	Test Method	Date Tested	Test Result	Tested By	Requirements[1]
Viscosity, 2 Spindle, 50 RPM	ASTM D2196	06/10/2020	199	KN	+/- 21.6%, relative
Nonvolatile Content	ASTM D2369	06/10/2020	42.8	KN	+/- 2.5%, absolute
Pigment Content	ASTM D3723	06/10/2020	5.1	KN	+/- 1.5%, absolute

[1]Relative to test result of 'fingerprint' testing of batch samples.
[2]At minimum two of the three 'fingerprint' tests must meet the requirements.

Shipping Container 'Fingerprint' Test Results[2]

Shipping Container Number: TOTE# 4626 Shipping Container Volume: 275 GALLON TOTE

Tests	Test Method	Date Tested	Test Result	Tested By	Requirements[1]
Viscosity, 2 Spindle, 50 RPM	ASTM D2196	06/10/2020	196	KN	+/- 21.6%, relative
Nonvolatile Content	ASTM D2369	06/10/2020	42.9	KN	+/- 2.5%, absolute
Pigment Content	ASTM D3723	06/10/2020	5.1	KN	+/- 1.5%, absolute

[1]Relative to test result of 'fingerprint' testing of batch samples.
[2]At minimum two of the three 'fingerprint' tests must meet the requirements.

Certified By: Daniel Nelson, Technical Director

Executed By: Matthew Price, President

Modified 10/18/2019

13. Appendix D: Undercarriage Photos

Photos shown below are for the 1100C and the 2270P Pickup Truck. Undercarriage photos for the Van Body can be seen in Figures 7-14 and 7-16.

Figure 13-1 Undamaged Gasoline Tank for the 1100C vehicle

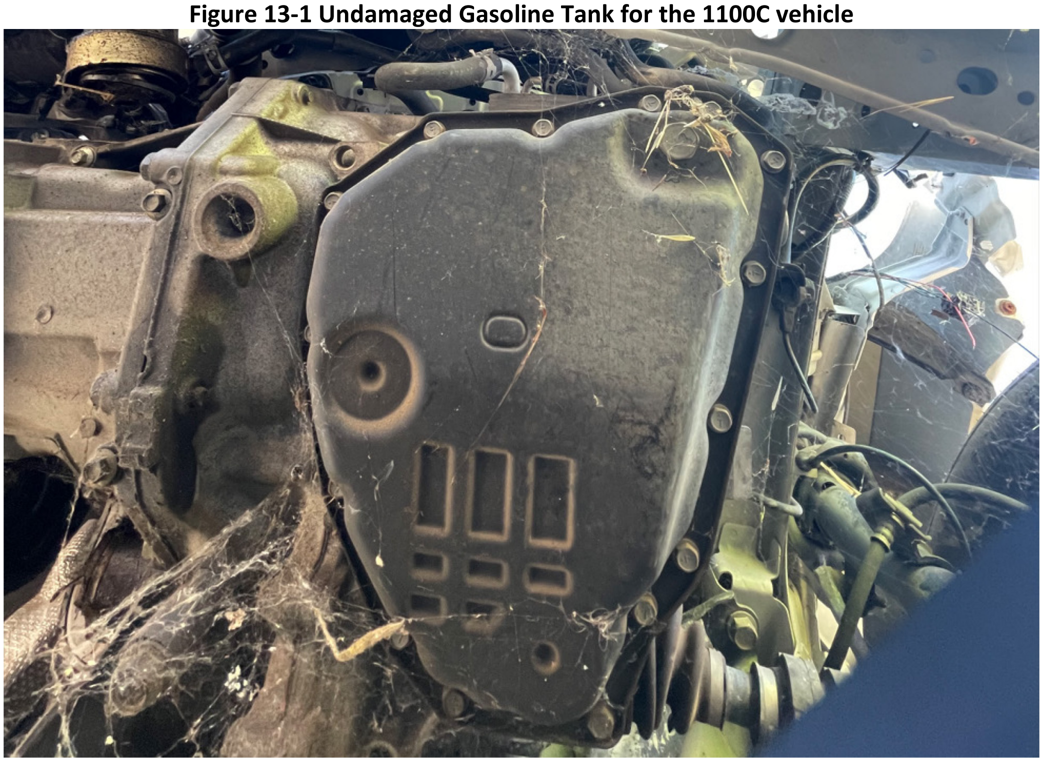


Figure 13-2 Undamaged Oil Pan for the 1100C vehicle

Figure 13-3 Undamaged Gasoline Tank for the 2270P Pick Up Truck

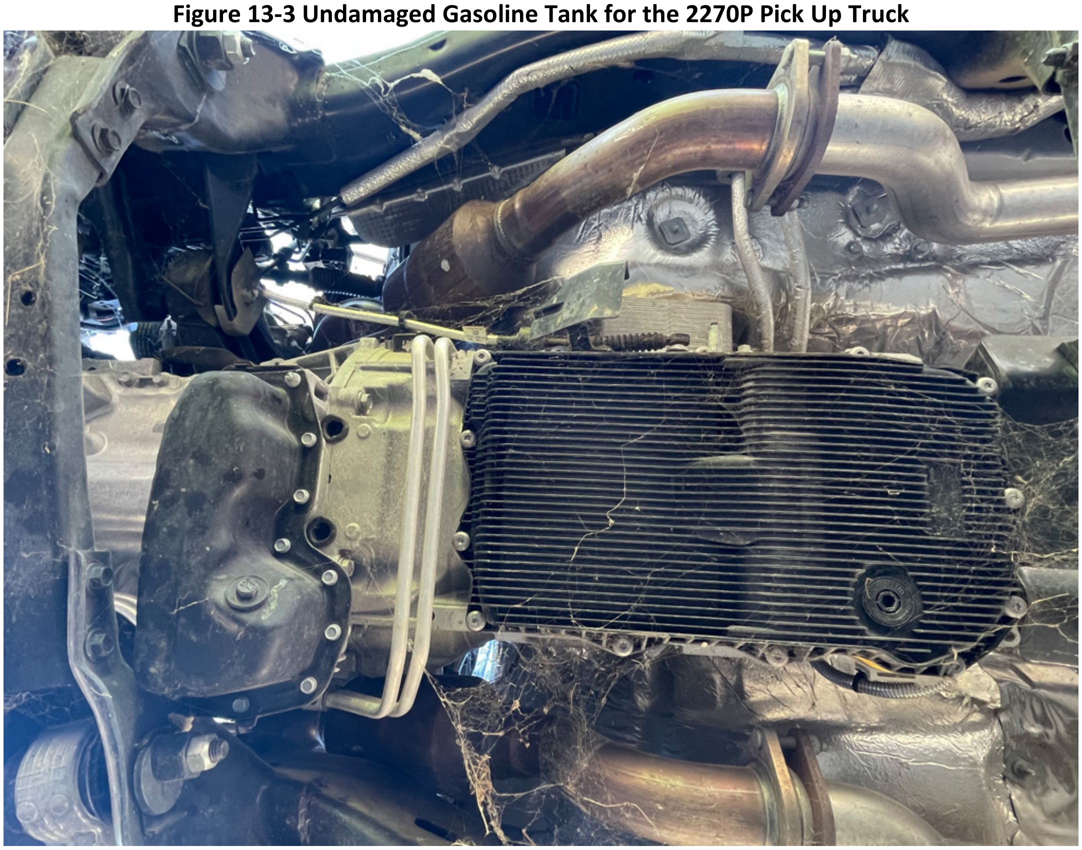


Figure 13-4 Undamaged Oil Pan for the 2270P Pick Up Truck

14. Document Revision History

Date	Description