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PERFORMANCE EVALUATION OF NEW JERSEY'S PORTABLE CONCRETE BARRIER WITH A PINNED CONFIGURATION AND GROUTED TOES – TEST NO. NJPCB-1

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16. Abstract

This report documents a full-scale crash test conducted in support of a study to investigate the performance of New Jersey Department of Transportation's (NJDOT) Precast Concrete Curb, Construction Barrier, which will be referred to as portable concrete barrier (PCB) in various configurations. This represents the first system as part of this study.

The primary objective of this research effort was to evaluate the safety performance of NJDOT's PCB, Type 4 (Alternative B) with a pinned configuration and grouted toes, corresponding to joint class C in the 2013 NJDOT *Roadway Design Manual*. Barrier nos. 1, 3, 5, 7, 9, and 10 were anchored to a concrete tarmac through the pin anchor recesses with nine 1-in. (25-mm) diameter by 15-in. (381-mm) long ASTM A36 steel pins inserted into 1¼-in. (32-mm) diameter drilled holes in the concrete tarmac. Non-shrink grout wedges were placed at the toe of each barrier segment in every joint between adjacent barrier segments. The barrier was evaluated according to the Test Level 3 (TL-3) criteria set forth in the *Manual for Assessing Safety Hardware* (MASH 2009). The research study included one full-scale vehicle crash test with a 2270P pickup truck. Following the successful redirection of the pickup truck, the safety performance of the system was determined to be acceptable according to TL-3 test designation no. 3-11 evaluation criteria specified in MASH 2009. The 1100C small car crash test was deemed unnecessary due to previous testing. The barrier successfully met MASH 2009 TL-3 criteria. This report is the first of nine documents in the nine-test series.

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This report was completed with funding from the New Jersey Department of Transportation. The contents of this report reflect the views and opinions of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the New Jersey Department of Transportation nor the Federal Highway Administration, U.S. Department of Transportation. This report does not constitute a standard, specification, regulation, product endorsement, or an endorsement of manufacturers.

UNCERTAINTY OF MEASUREMENT STATEMENT

The Midwest Roadside Safety Facility (MwRSF) has determined the uncertainty of measurements for several parameters involved in standard full-scale crash testing and non-standard testing of roadside safety features. Information regarding the uncertainty of measurements for critical parameters is available upon request by the sponsor and the Federal Highway Administration.

INDEPENDENT APPROVING AUTHORITY

The Independent Approving Authority (IAA) for the data contained herein was Mr. James Holloway, Research Engineer and Assistant Director – Physical Testing Division.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Background

The New Jersey Department of Transportation (NJDOT) currently uses a New Jersey shape, Precast Concrete Curb, Concrete Barrier, which will be referred to as portable concrete barrier (PCB), with a vertical, I-beam connection pin to attach barriers end to end within their work zones and construction areas. The 2013 NJDOT *Roadway Design Manual* [1] provided guidance on allowable barrier deflections for various classes of PCB joint treatments, as shown in Table 1. The current 2015 NJDOT *Roadway Design Manual* [2] provides guidance on allowable deflections for various connection types, as shown in Table 2.

Table 1. 2013 NJDOT Roadway Design Manual PCB Guidance [1]

Joint Class	Use	Joint Treatment
A	Allowable movement over 16 to 24 inches	Connection Key only
B	Allowable movement over 11 to 16 inches	Connection Key and grout in every joint
C	Allowable movement of 11 inches	Connection Key and grout in every joint and pin every other unit. In units to be anchored, pin should be required in every recess
D	No allowable movement (i.e., bridge parapet)	Connection Key and grout in every joint and bolt every anchor pocket hole in every unit.

Table 2. Current 2015 NJDOT Roadway Design Manual PCB Guidance [2]

Connection Type	Use	Joint Treatment*
A	Maximum allowable deflection of 41 inches	Connection Key and barrier end sections fully pinned
B	Maximum allowable deflection of 28 inches (Cannot be used with traffic on both sides of the barrier.)	Connection Key, 6" by 6" box beam, and barrier end sections fully pinned
C	Maximum allowable deflection of 11 inches	Connection Key, construction side of all sections pinned, and barrier end sections fully pinned

* Barrier end sections fully pinned – first and last barrier segments of the entire run regardless of connection type have pins in every anchor recess on both sides.

The guidance provided in both the 2013 and 2015 *Roadway Design Manual* was based on test data obtained from previous testing standards, which needs to be updated to be consistent with current crash testing standards and a changing vehicle fleet. Crash testing of other PCB systems under the Test Level 3 (TL-3) criteria of the *Manual for Assessing Safety Hardware* (MASH 2009) [3] has indicated that dynamic barrier deflections can increase significantly when compared to dynamic deflections based on older crash test data. Thus, a need exists to investigate the performance of the NJDOT PCB system in various configurations in order to provide updated design guidance. The NJDOT PCB standard plans are shown in Appendix A.

1.2 Objective

The objective of this research effort was to evaluate the safety performance of NJDOT's PCB, Type 4 (Alternative B) with a pinned configuration and grouted toes, corresponding to joint class C in the 2013 NJDOT *Roadway Design Manual* [1]. The system was to be evaluated according to the Test Level 3 (TL-3) criteria set forth in the *Manual for Assessing Safety Hardware* (MASH 2009) [3].

1.3 Scope

The research objective was achieved through completion of several tasks. One full-scale crash test was conducted on the PCB system according to MASH 2009 test designation no. 3-11. Next, the full-scale vehicle crash test results were analyzed, evaluated, and documented. Conclusions and recommendations were then made pertaining to the safety performance of the PCB system.

2 TEST REQUIREMENTS AND EVALUATION CRITERIA

2.1 Test Requirements

Longitudinal barriers, such as PCBs, must satisfy impact safety standards in order to be declared eligible for federal reimbursement by the Federal Highway Administration (FHWA) for use on the National Highway System (NHS). For new hardware, these safety standards consist of the guidelines and procedures published in MASH 2016 [4]. Note that there is no difference between MASH 2009 and MASH 2016 for most longitudinal barriers, such as the PCB system tested in this project, except that additional occupant compartment deformation measurements are required by MASH 2016. According to TL-3 of MASH 2009, longitudinal barrier systems must be subjected to two full-scale vehicle crash tests, as summarized in Table 3. However, only the 2270P crash test was deemed necessary as other prior small car tests were used to support a decision to deem the 1100C crash test not critical.

Table 3. MASH 2009 TL-3 Crash Test Conditions for Longitudinal Barriers

Test Article	Test Designation No.	Test Vehicle	Vehicle Weight, lb (kg)	Impact Conditions		Evaluation Criteria [1]
				Speed, mph (km/h)	Angle, deg.	
Longitudinal Barrier	3-10	1100C	2,420 (1,100)	62 (100)	25	A,D,F,H,I
	3-11	2270P	5,000 (2,268)	62 (100)	25	A,D,F,H,I

[1] Evaluation criteria explained in Table 4.

In test no. 7069-3, a rigid, F-shape, concrete bridge rail was successfully impacted by a small car weighing 1,800 lb (816 kg) at 60.1 mph (96.7 km/h) and 21.4 degrees according to the American Association of State Highway and Transportation Officials (AASHTO) *Guide Specifications for Bridge Railings* [5-6]. In the same manner, test nos. CMB-5 through CMB-10, CMB-13, and 4798-1 showed that rigid, New Jersey, concrete safety shape barriers struck by small cars have been shown to meet safety performance standards [7-8]. In additional, in test no. 2214NJ-1, a rigid, New Jersey, ½-section, concrete safety shape barrier was impacted by a passenger car weighing 2,579 lb (1,170 kg) at 60.8 mph (97.8 km/h) and 26.1 degrees according to the TL-3 standards set forth in MASH 2009 [9]. Furthermore, temporary, New Jersey safety shape, concrete median barriers have experienced only slight barrier deflections when impacted by small cars and behave similarly to rigid concrete barriers as seen in test no. 47 [10]. As such, the 1100C passenger car test was deemed not critical for testing and evaluating this PCB system.

It should be noted that the test matrix detailed herein represents the researchers' best engineering judgement with respect to the MASH 2009 safety requirements and their internal evaluation of critical tests necessary to evaluate the crashworthiness of the barrier system. However, the recent switch to new vehicle types as part of the implementation of the MASH 2009 criteria and the lack of experience and knowledge regarding the performance of the new vehicle types with certain types of hardware could result in unanticipated barrier performance. Thus, any tests within the evaluation matrix deemed non-critical may eventually need to be evaluated based on additional knowledge gained over time or revisions to the MASH 2009 criteria.

2.2 Evaluation Criteria

Evaluation criteria for full-scale vehicle crash testing are based on three appraisal areas: (1) structural adequacy; (2) occupant risk; and (3) vehicle trajectory after collision. Criteria for structural adequacy are intended to evaluate the ability of the PCB system to contain and redirect impacting vehicles. In addition, controlled lateral deflection of the test article is acceptable. Occupant risk evaluates the degree of hazard to occupants in the impacting vehicle. Post-impact vehicle trajectory is a measure of the potential of the vehicle to result in a secondary collision with other vehicles and/or fixed objects, thereby increasing the risk of injury to the occupants of the impacting vehicle and/or other vehicles. These evaluation criteria are summarized in Table 4 and defined in greater detail in MASH 2009. The full-scale vehicle crash test documented herein was conducted and reported in accordance with the procedures provided in MASH 2009.

In addition to the standard occupant risk measures, the Post-Impact Head Deceleration (PHD), the Theoretical Head Impact Velocity (THIV), and the Acceleration Severity Index (ASI) were determined and reported. Additional discussion on PHD, THIV and ASI is provided in MASH 2009.

Table 4. MASH 2009 Evaluation Criteria for Longitudinal Barrier

<table>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="3">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></tr>
<tr><td rowspan="10">Occupant Risk</td><td>D.</td><td colspan="3">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH 2009.</td></tr>
<tr><td>F.</td><td colspan="3">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">Occupant Impact Velocity (OIV) (see Appendix A, Section A5.3 of MASH 2009 for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></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>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.3 of MASH 2009 for calculation procedure) should satisfy the following limits:</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
</table>

3 DESIGN DETAILS

The test installation consisted of ten 20-ft (6.1-m) long NJDOT PCBs with a pinned configuration and grouted toes, as shown in Figures 1 through 14. This system uses NJDOT barriers, Type 4 (Alternative B) with joint class C as specified in the 2013 NJDOT *Roadway Design Manual*. Photographs of the test installation are shown in Figures 15 through 18. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B.

The concrete mix for the barrier sections required a minimum 28-day compressive strength of 3,700 psi (25.5 MPa). A minimum concrete cover of 1½ in. (38 mm) was used along all rebar in the barrier. All of the steel reinforcement in the barrier was ASTM A615 Grade 60 rebar and consisted of four No. 6 longitudinal bars, eight No. 4 bars for the vertical stirrups, four No. 6 lateral bars, and nine No. 4 bars for the anchor hole reinforcement loops. The section reinforcement details are shown in Figures 5 and 6.

The barrier sections used a connection key, as shown in Figures 7 through 11 and 16. The connection key assembly consisted of ½-in. (13-mm) thick, ASTM A36 steel plates welded together to form the key shape. A connection socket was configured at each end of the PCB section, as shown in Figures 2, 15, and 16. The connection socket consisted of three ASTM A36 steel plates welded on the sides of an ASTM A500 Grade B or C steel tube, as shown in Figures 9 and 10. The connection key was inserted into the steel tubes of two adjoining PCBs to form the connection, as shown in Figure 11.

Barrier nos. 1, 3, 5, 7, 9, and 10 were anchored to the concrete tarmac through the pin anchor recesses with nine 1-in. (25-mm) diameter by 15-in. (381-mm) long, ASTM A36 steel pins inserted into 1¼-in. (32-mm) diameter holes in the concrete tarmac, as shown in Figures 12 and 17. The steel pins were embedded to a depth of 5 in. (127 mm), as shown in Figure 1. During installation, the barrier segments were pulled in a direction parallel to their longitudinal axes, and slack was removed from all joints. After slack was removed from all the joints, 1¼-in. (32-mm) diameter holes were drilled for pin anchors at pin recess locations. Five samples of concrete tarmac were tested from five different locations of the MwRSF Outdoor Test Site. The concrete tarmac had a compressive strength ranging between 5,970 and 7,040 psi (41.2 and 48.5 MPa), as shown in Appendix C. Non-shrink grout wedges were placed at the toe of each barrier segment in every joint between adjacent barrier segments, as shown in Figure 18. The grout wedges consisted of a grout mix with a minimum 1-day compressive strength of 1,000 psi (6.9 MPa).

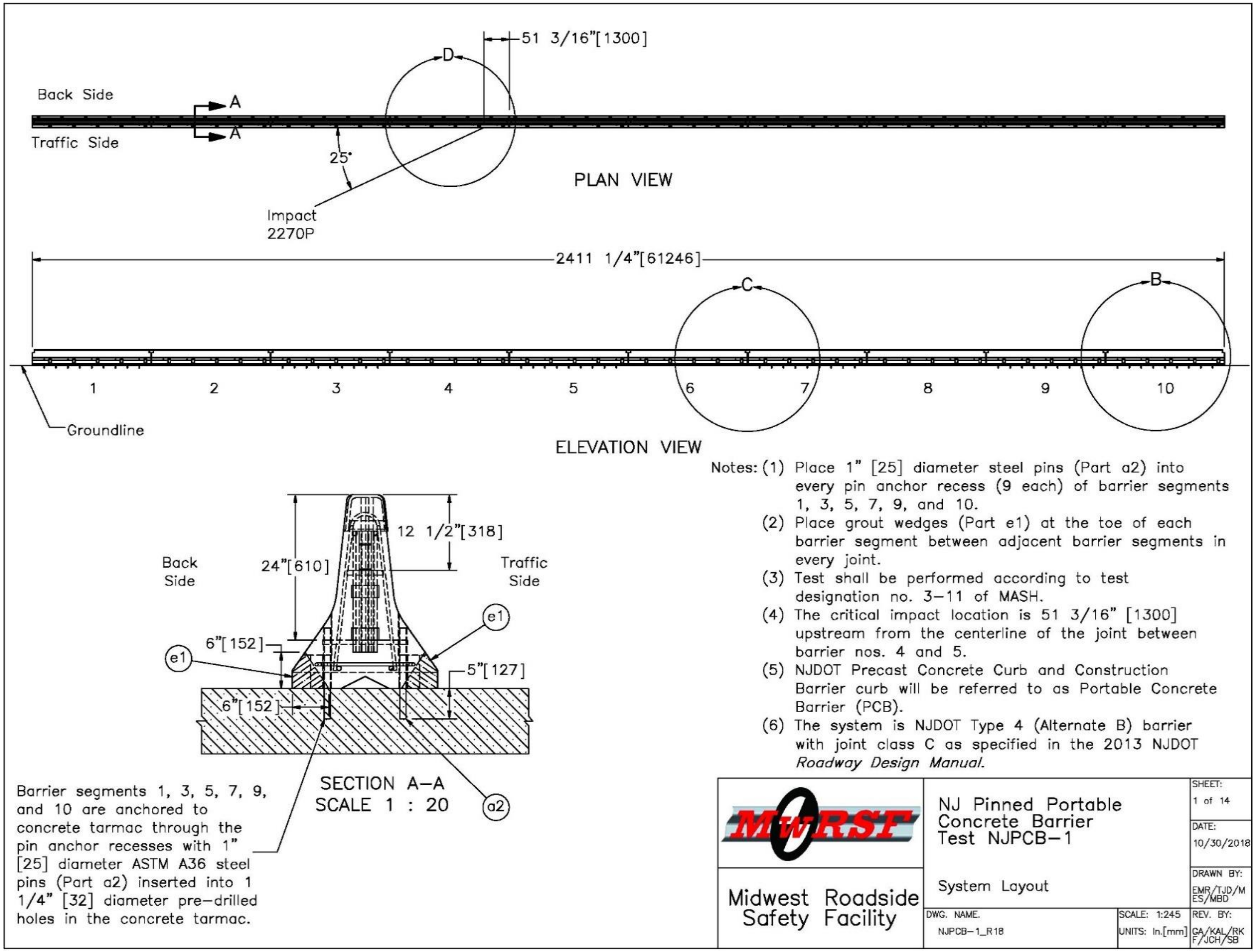


Figure 1. Test Installation Layout, Test No. NJPCB-1

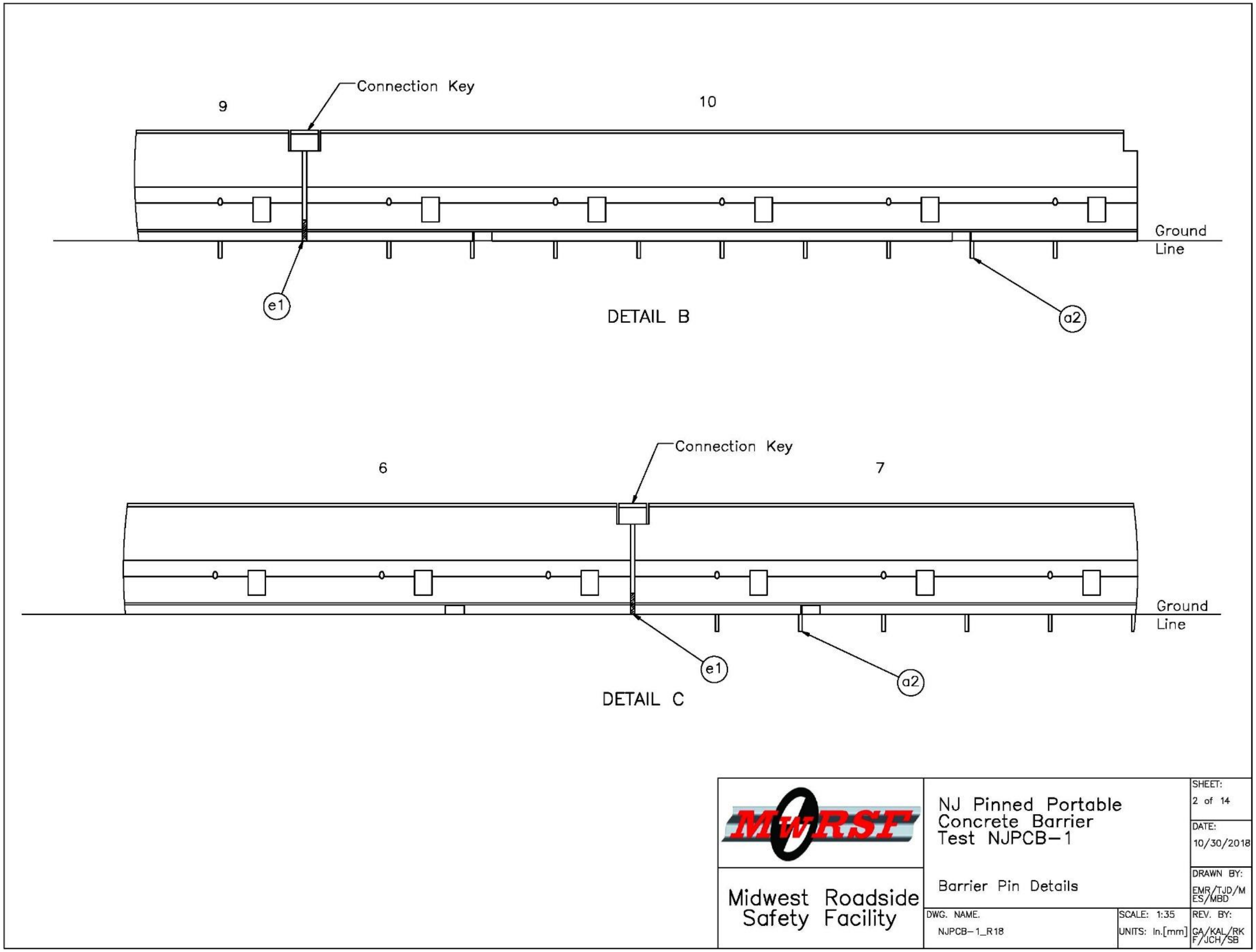


Figure 2. PCB Pin Anchor Details, Test No. NJPCB-1

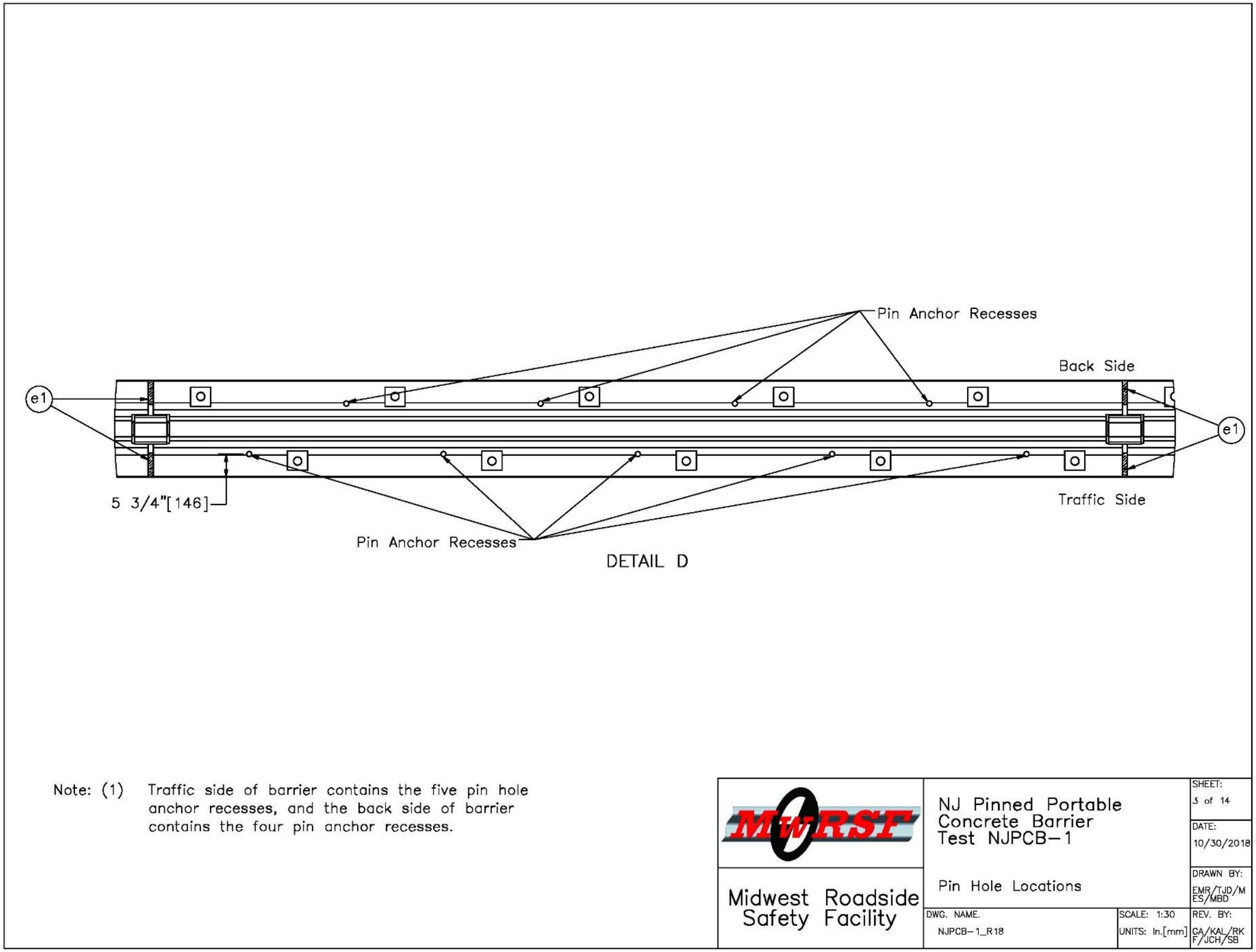


Figure 3. PCB Pin Anchor Locations, Test No. NJPCB-1

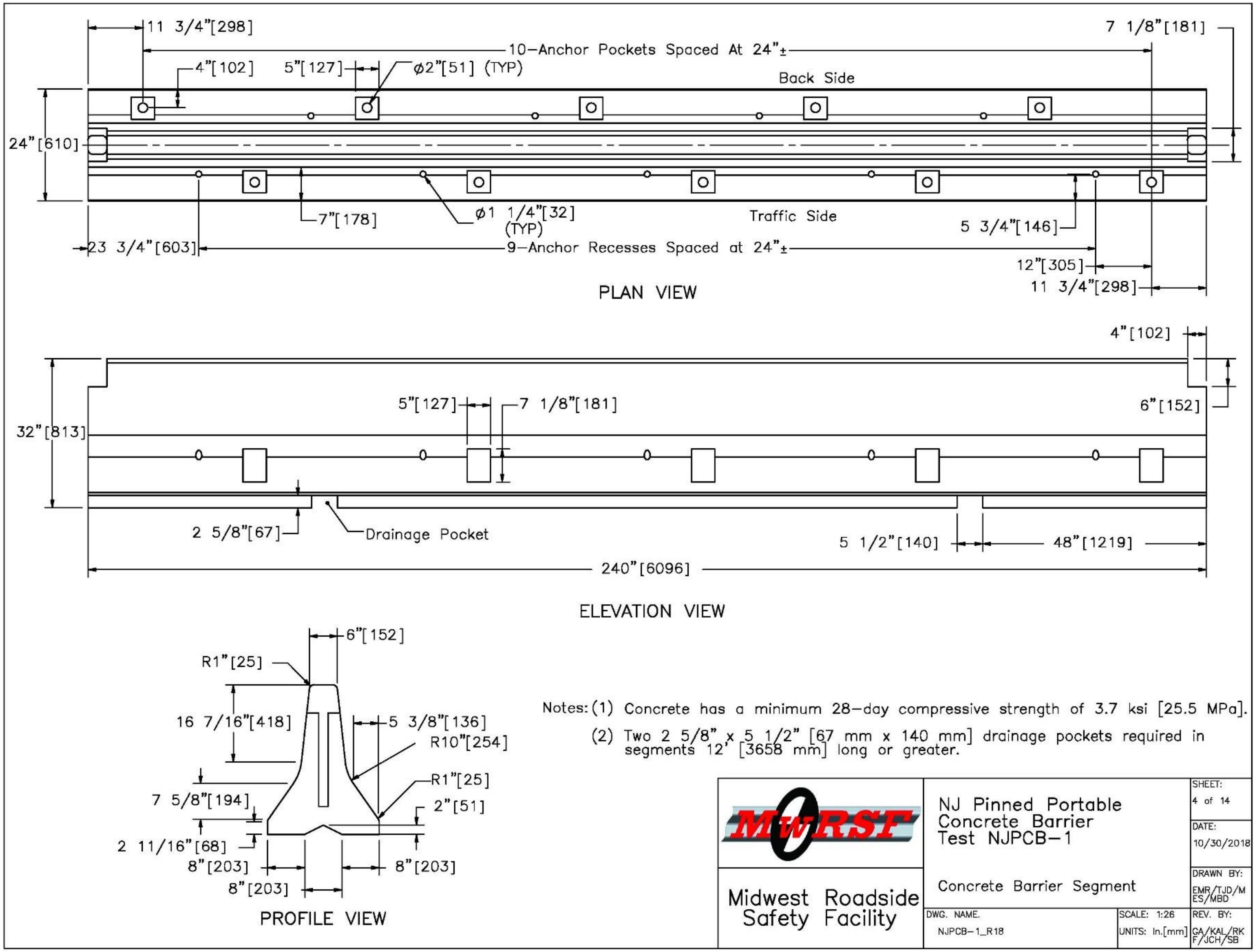


Figure 4. PCB Details, Test No. NJPCB-1

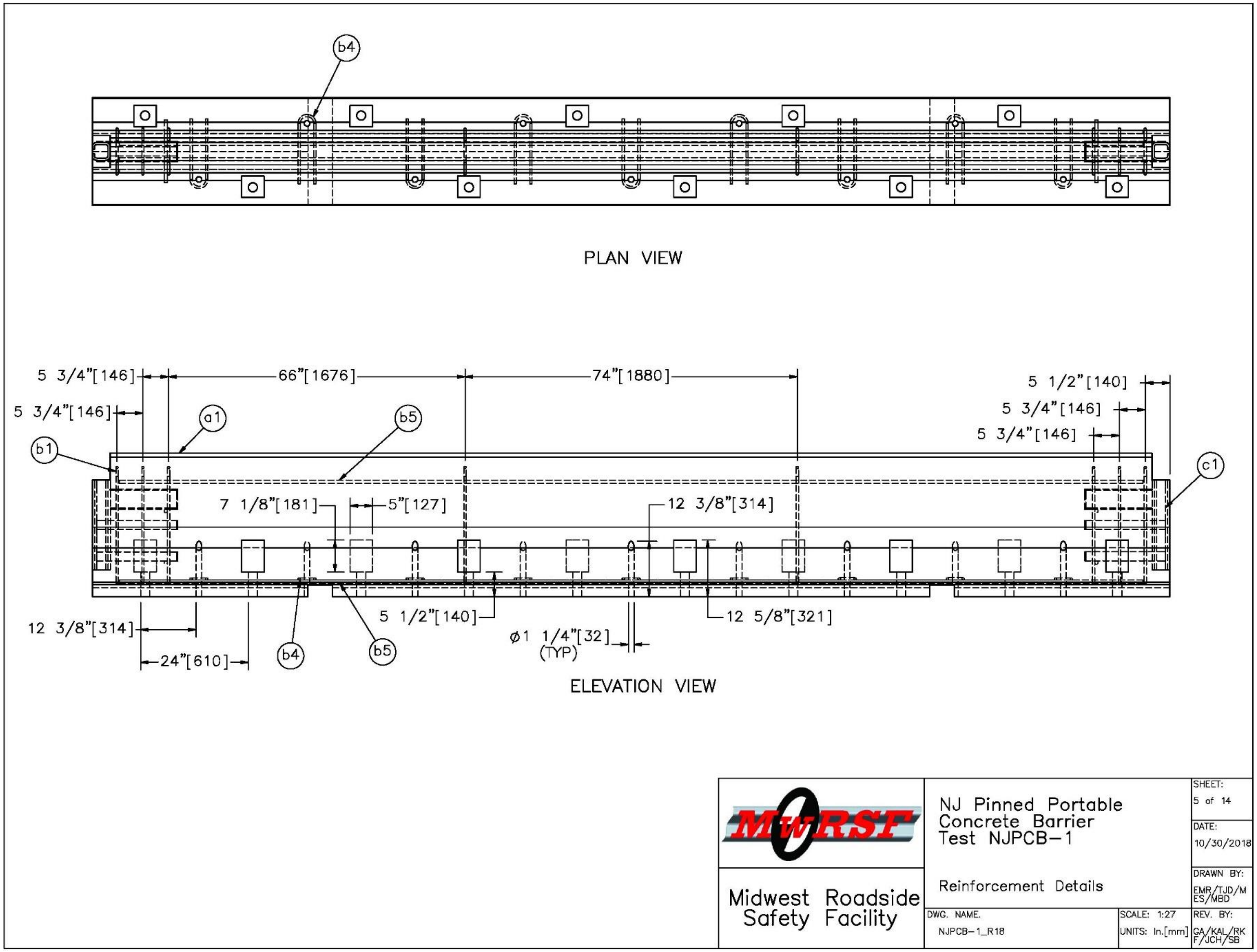


Figure 5. PCB Reinforcement Details, Test No. NJPCB-1

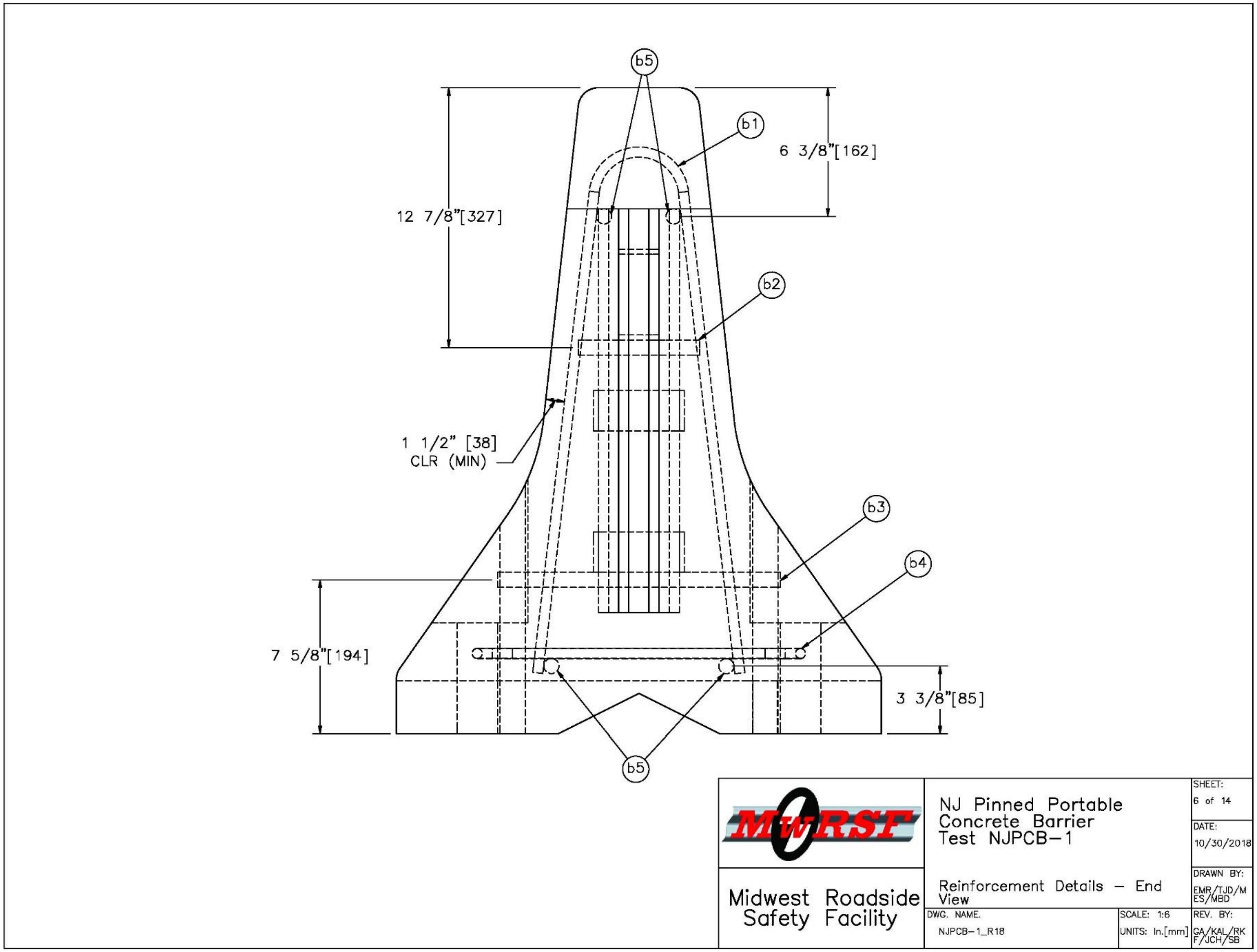


Figure 6. PCB Reinforcement Details – End View, Test No. NJPCB-1

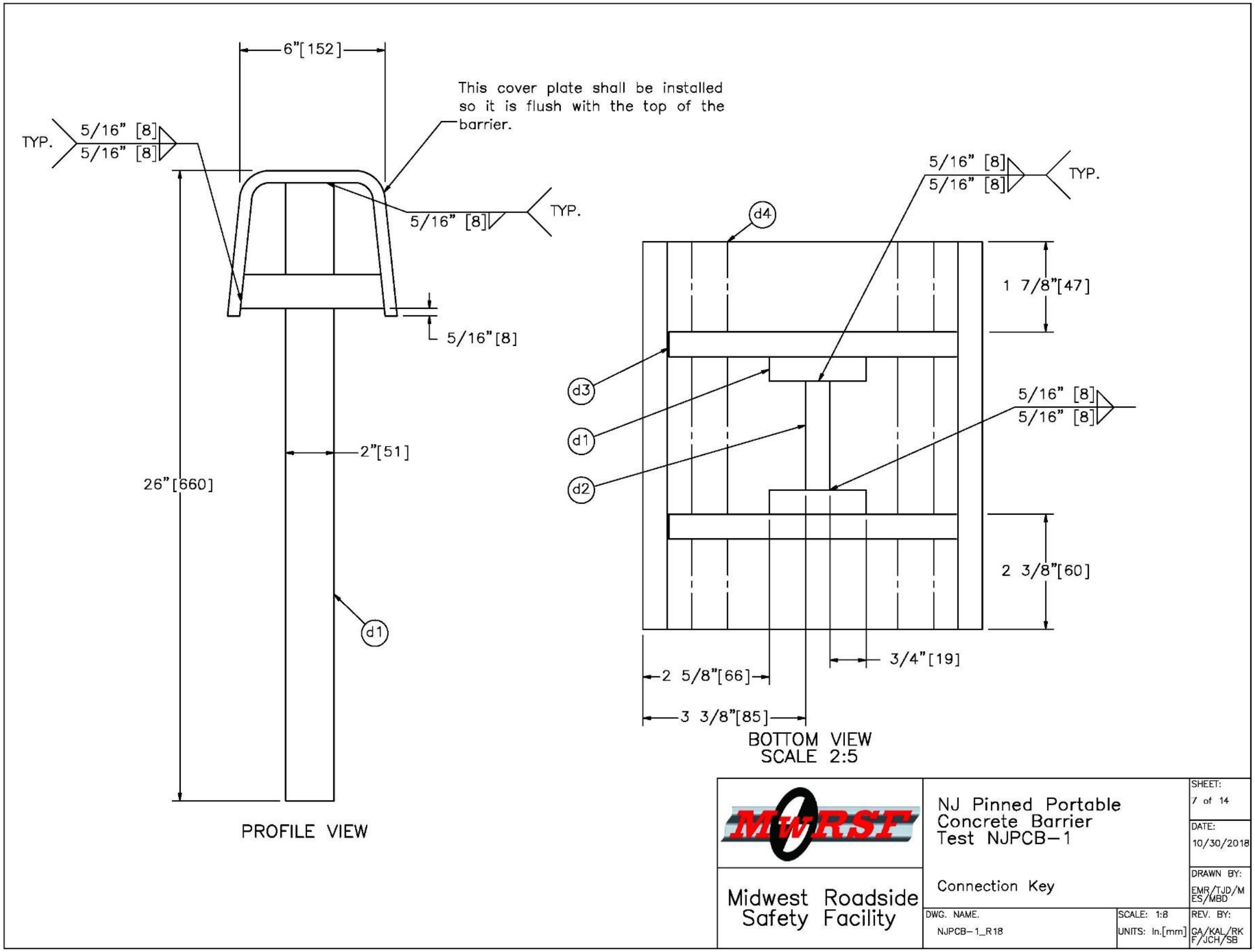


Figure 7. PCB Connection Key Assembly Details, Test No. NJPCB-1

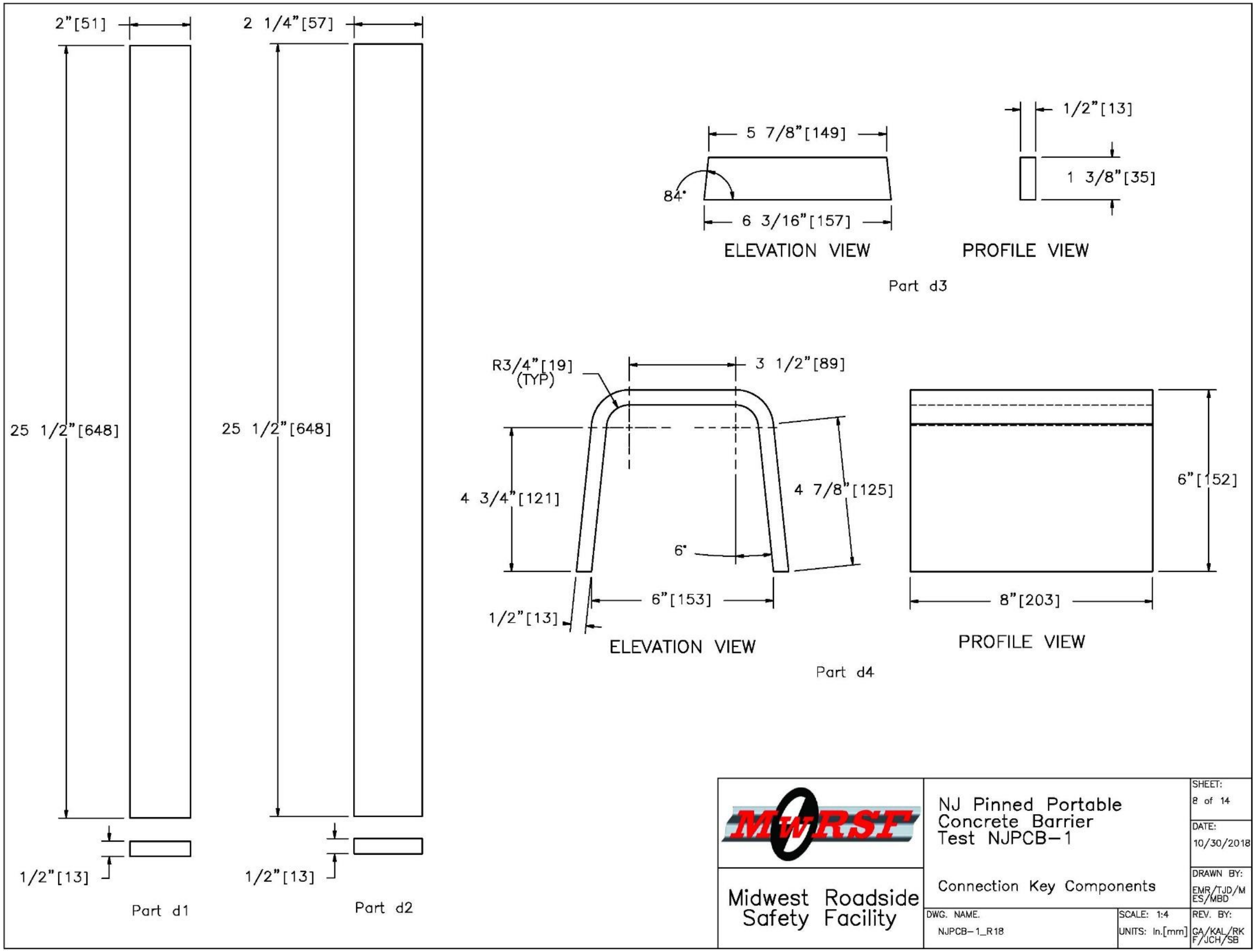


Figure 8. PCB Connection Key Component Details, Test No. NJPCB-1

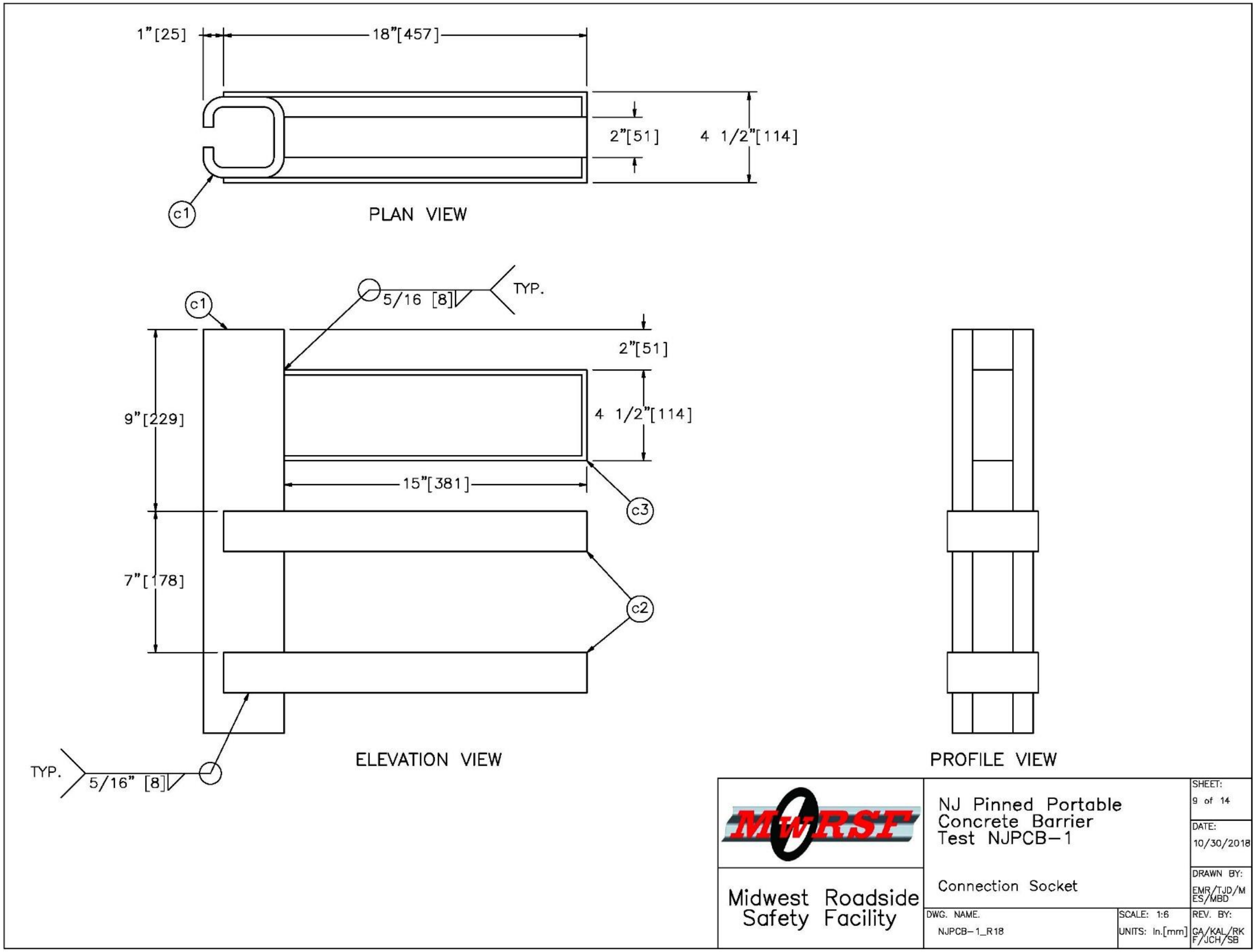


Figure 9. PCB Connection Socket Details, Test No. NJPCB-1

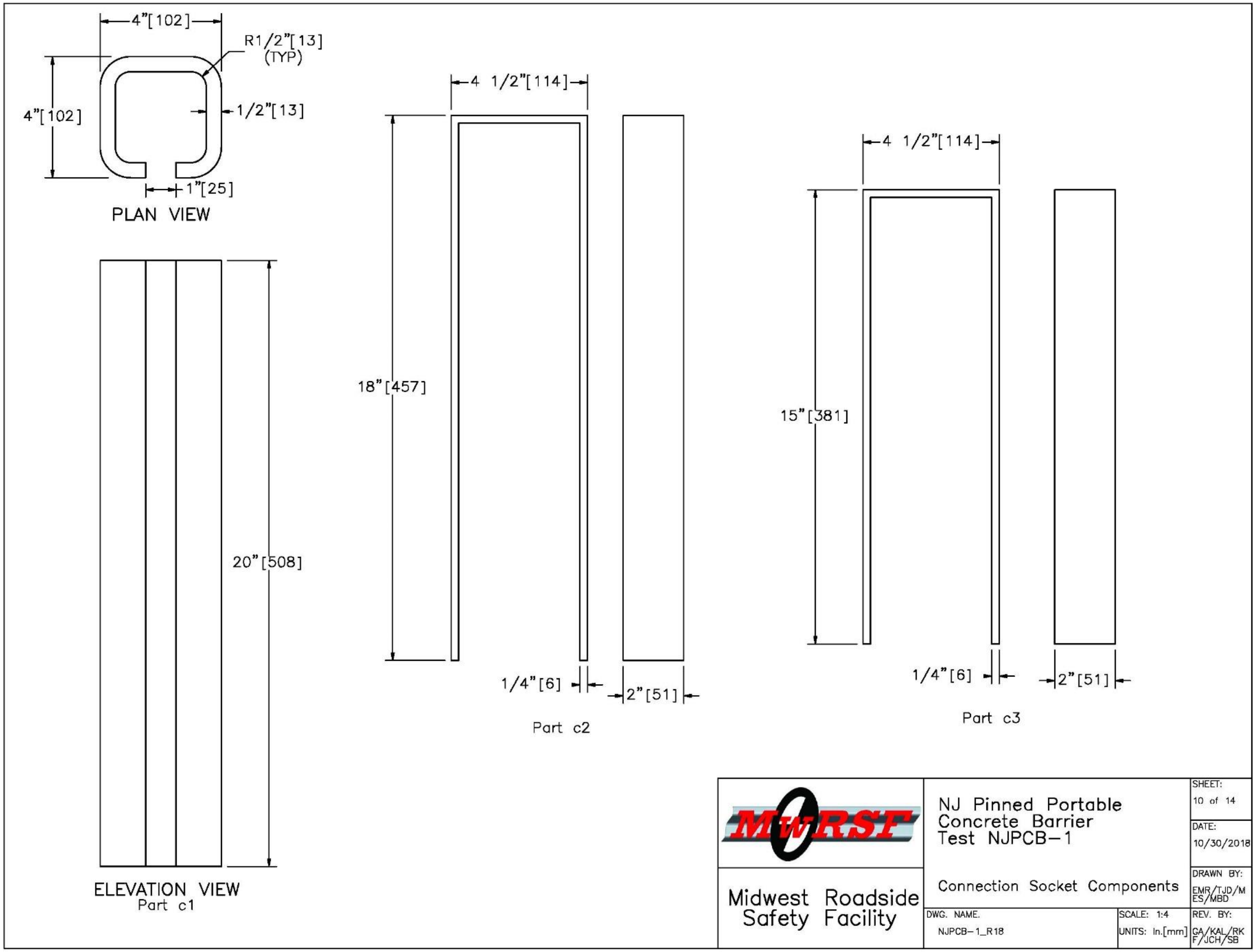


Figure 10. PCB Connection Socket Component Details, Test No. NJPCB-1

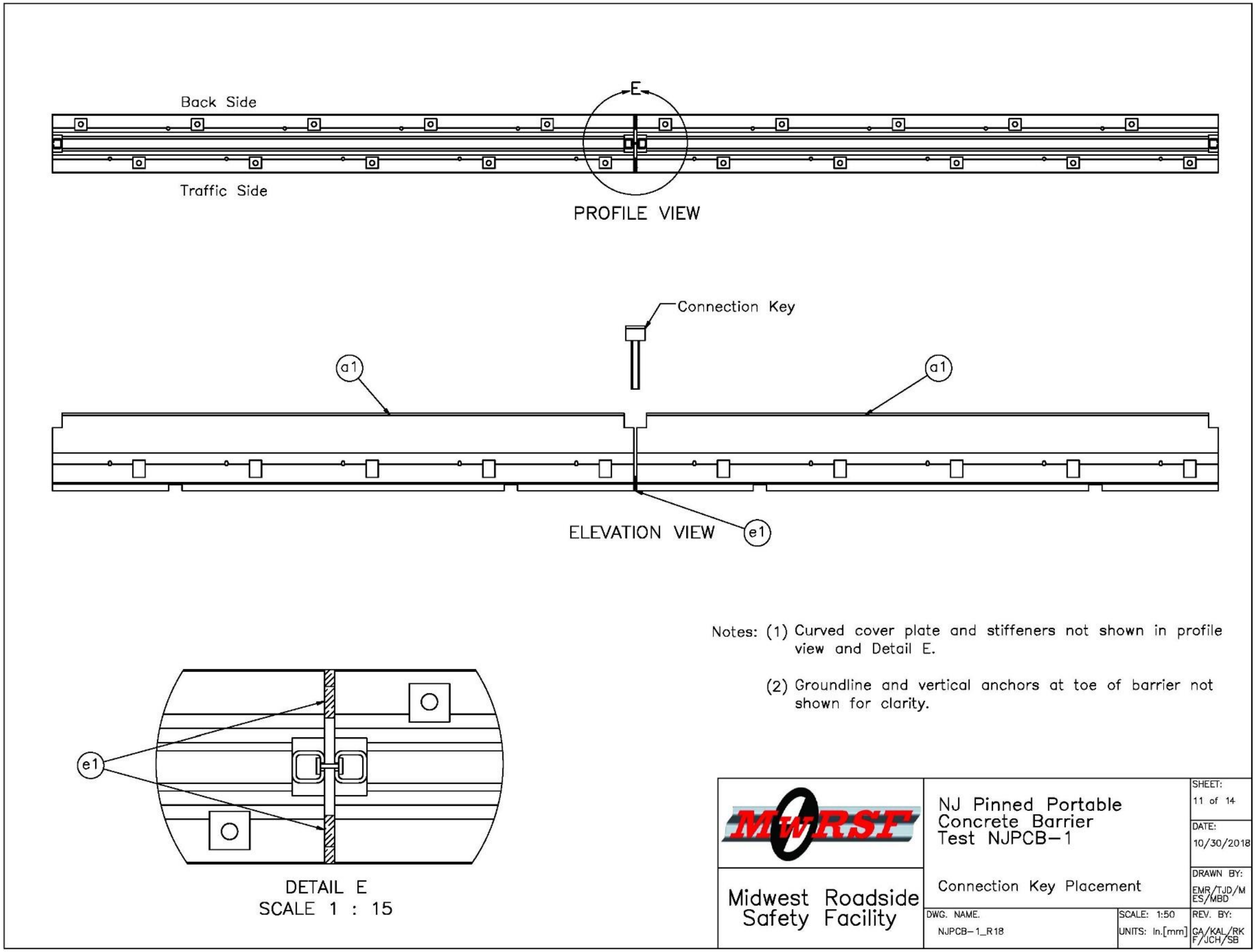


Figure 11. Connection Key Placement Details, Test No. NJPCB-1

BILL OF BARS

ITEM NO.	QTY.	BAR SIZE	UNBENT LENGTH	MATERIAL SPEC.
a2	54	ϕ1" [25]	15" [381]	A36
b1	80	#4 [13]	59" [1499]	A615 Gr. 60
b2	20	#6 [19]	6" [152]	A615 Gr. 60
b3	20	#6 [19]	14" [356]	A615 Gr. 60
b4	90	#4 [13]	37" [940]	A615 Gr. 60
b5	40	#6 [19]	19'-0" [5791]	A615 Gr. 60

Note: (1) Quantities in Bill of Bars represent a system with ten barriers.

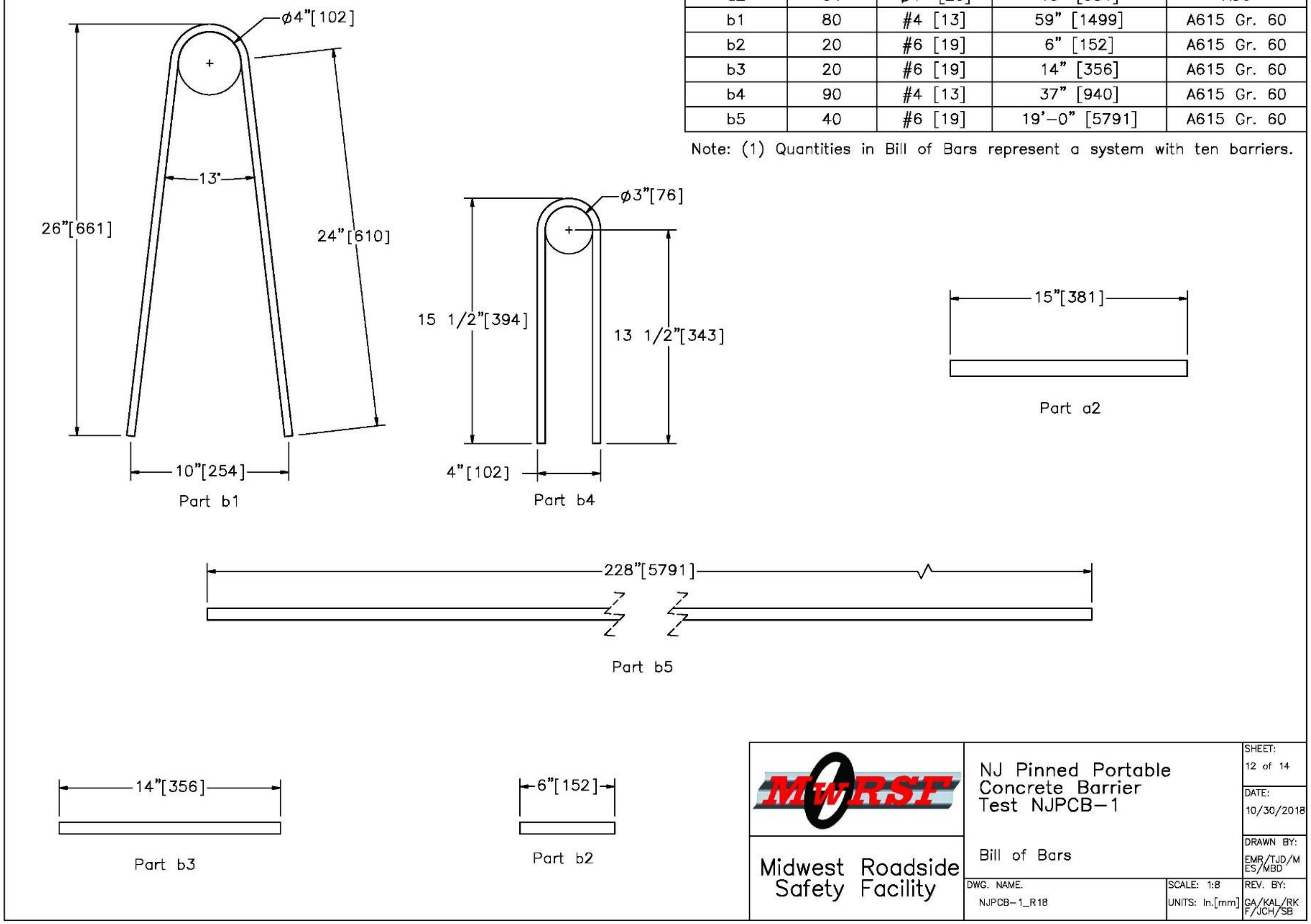


Figure 12. PCB Reinforcement Details, Test No. NJPCB-1

(1) Minimum concrete clear cover for reinforcement steel shall be 1 1/2" [38 mm].

(2) All end segments shall be pinned.

(3) After a segment has been placed and the connection key inserted, pull the unit in a direction parallel to its longitudinal axis to remove any slack in the joint.

(4) The portable concrete barrier shall be cast in steel forms.

(5) The portable concrete barrier shall be barrier segments of 20 feet [6,096 mm]. However, other lengths may be used to meet field conditions. The number and placement of the b2 and b3 reinforcement steel will vary with the length of the barrier segment as shown on the table of variable reinforcement steel. The b5 reinforcement steel shall be 10" [254 mm] shorter than the nominal length of the barrier segments.

(6) Reinforcing shown is the minimum required. Additional reinforcing necessary for handling shall be the option and responsibility of the contractor.

(7) Welding and fabrication of steel structures shall be in accordance with sections 1 thru 6 of the ANSI/AASHTO/AWS D1.5 bridge welding code and section 10 of the ANSI/AWS D1 structural welding code. Surfaces to be welded shall be free of scale, slag, rust, moisture, grease or any other material that will prevent proper welding or produce objectional fumes. Welding shall be shielded metal arc welding using properly dried 5/32" [4 mm] dia. E7018 electrodes.

(8) The length of the pins shall be such that a minimum embedment length of 5" [127 mm] is obtained when embedded into concrete pavement. When anchor pins are in place, they shall not project above the plane of the concrete surface of the barrier. Holes in bridge decks shall be 1 1/4" [32 mm] diameter maximum and made with a core drill or any other approved rotary drilling device that does not impart an impact force.

(9) Use non-shrink grout of a plastic consistency that is listed on the QPL and conforms to ASTM C 1107 with the following amendments:
1. Ensure that the grout has a working time of at least 30 minutes from the time the water is added.
2. Match the color of the hardened grout, where visible, to the color of the adjacent hardened concrete.
3. Include 1-day strength tests as part of the performance requirements of ASTM C 1107.
4. Ensure that the grout contains no more than 0.05 percent chlorides or 5.0 percent sulfates by weight.
5. Minimum 1-day compressive strength of 1,000 psi [6.9 MPa].

(10) Use connection key in every joint. Grout is placed at the toe of each barrier segment between adjacent barrier segments in every joint. Pin every other segment, except both end segments are pinned. In segments that are to be anchored, pins shall be required in every anchor pin recess.

MwRSF	NJ Pinned Portable Concrete Barrier Test NJPCB-1		SHEET: 13 of 14
			DATE: 10/30/2018
Midwest Roadside Safety Facility	General Notes		DRAWN BY: EMR/TJD/MES/MBD
	DWG. NAME. NJPCB-1_R18	SCALE: None UNITS: in.[mm]	REV. BY: GA/KAL/RKF/JCH/SB

Figure 13. General Notes, Test No. NJPCB-1

Item No.	QTY.	Description	Material Spec	Galvanization Spec
a1	10	Concrete Barrier Segment – NJDOT Type 4 Barrier (Alternate B)	f'c = 3,700 psi [25.5 MPa]	–
a2	54	1" [25] Dia., 15" [381] Long Anchor Steel Pin	ASTM A36	ASTM A123*
b1	80	1/2" [13] Dia., 59" [1,499] Long Bent Rebar	ASTM A615 Gr. 60	–
b2	20	3/4" [19] Dia., 6" [152] Long Rebar	ASTM A615 Gr. 60	–
b3	20	3/4" [19] Dia., 14" [356] Long Rebar	ASTM A615 Gr. 60	–
b4	90	1/2" [13] Dia., 37" [940] Long Bent Rebar	ASTM A615 Gr. 60	–
b5	40	3/4" [19] Dia., 228" [5,791] Long Rebar	ASTM A615 Gr. 60	–
c1	20	4"x4"x1/2" [102x102x13] x 20" [508] Long Tube	ASTM A500 Gr. B or C	–
c2	40	40 1/2"x2"x1/4" [1,029x51x6] Bent Steel Plate	ASTM A36	–
c3	20	34 1/2"x2"x1/4" [876x51x6] Bent Steel Plate	ASTM A36	–
d1	18	25 1/2"x2"x1/2" [648x51x13] Steel Plate	ASTM A36	–
d2	9	25 1/2"x2 1/4"x1/2" [648x57x13] Steel Plate	ASTM A36	–
d3	18	6 3/16"x1 3/8"x1/2" [157x35x13] Steel Plate – Stiffener	ASTM A36	–
d4	9	17"x8"x1/2" [432x203x13] Bent Steel Plate – Top Plate	ASTM A36	–
e1	18	Non-Shrink Grout	Min. 1-day Compressive Strength 1,000 psi [6.9 MPa]	–

*Component does not need to be galvanized for testing purposes.

MwRSF Midwest Roadside Safety Facility	NJ Pinned Portable Concrete Barrier Test NJPCB-1 Bill of Materials	SHEET: 14 of 14
		DATE: 10/30/2018
		DRAWN BY: EMR/TJD/MES/MBD
	DWG. NAME. NJPCB-1_R18	SCALE: None UNITS: In.[mm]
		REV. BY: GA/KAL/RKF/JCH/SB

Figure 14. Bill of Materials, Test No. NJPCB-1

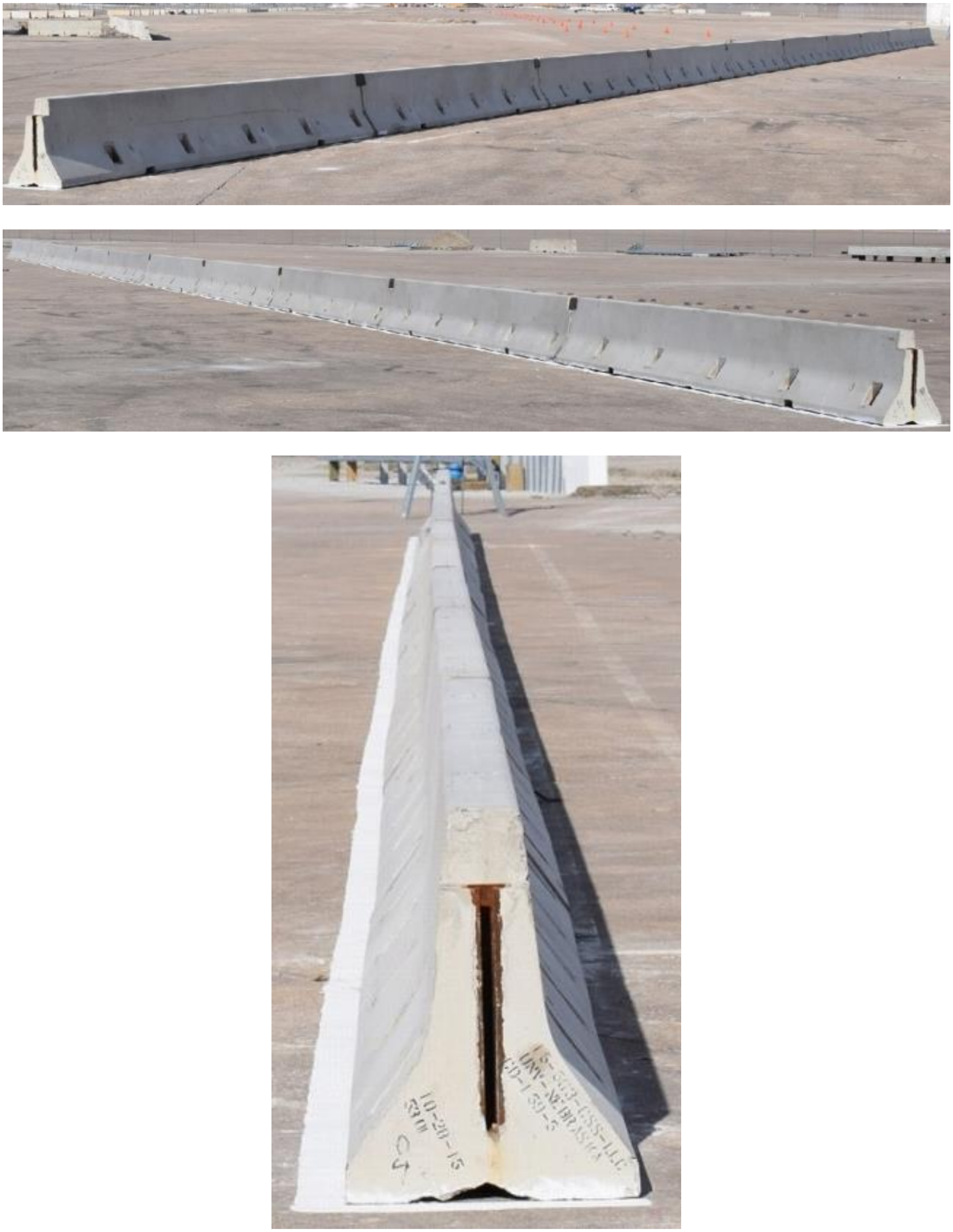


Figure 15. NJDOT PCB with Pinned Configuration and Grouted Toes Test Installation, Test No. NJPCB-1

Figure 16. PCB Connection Key and Connection Socket, Test No. NJPCB-1

Figure 17. PCB Pin Anchor Recesses, Test No. NJPCB-1

Figure 18. Grout at Toes between PCBs, Test No. NJPCB-1

4 TEST CONDITIONS

4.1 Test Facility

The Outdoor Test Site is located at the Lincoln Air Park on the northwest side of the Lincoln Municipal Airport and is approximately 5 miles (8.0 km) northwest of the University of Nebraska-Lincoln.

4.2 Vehicle Tow and Guidance System

A reverse-cable, tow system with a 1:2 mechanical advantage was used to propel the test vehicle. The distance traveled and the speed of the tow vehicle were one-half that of the test vehicle. The test vehicle was released from the tow cable before impact with the barrier system. A digital speedometer on the tow vehicle increased the accuracy of the test vehicle impact speed.

A vehicle guidance system developed by Hinch [11] was used to steer the test vehicle. A guide flag, attached to the right-front wheel and the guide cable, was sheared off before impact with the barrier system. The ⅜-in. (9.5-mm) diameter guide cable was tensioned to approximately 3,500 lb (15.6 kN) and supported both laterally and vertically every 100 ft (30.5 m) by hinged stanchions. The hinged stanchions stood upright while holding up the guide cable, but as the vehicle was towed down the line, the guide flag struck and knocked each stanchion to the ground.

4.3 Test Vehicle

For test no. NJPCB-1, a 2010 Dodge Ram 1500 quad cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,229 lb (2,372 kg), 5,013 lb (2,274 kg), and 5,174 lb (2,347 kg), respectively. The test vehicle is shown in Figure 19, and vehicle dimensions are shown in Figure 20.

The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights. The Suspension Method [12] was used to determine the vertical component of the c.g. for the pickup truck. This method is based on the principle that the c.g. of any freely suspended body is in the vertical plane through the point of suspension. The vehicle was suspended successively in three positions, and the respective planes containing the c.g. were established. The intersection of these planes pinpointed the final c.g. location for the test inertial condition. The location of the final c.g. is shown in Figures 20 and 21. Data used to calculate the location of the c.g. and ballast information are shown in Appendix D.

Square, black- and white-checkered targets were placed on the vehicle for reference to be viewed from the high-speed digital video cameras and aid in the video analysis, as shown in Figure 21. Round, checkered targets were placed on the c.g. on the left-side door, the right-side door, and the roof of the vehicle.

The front wheels of the test vehicle were aligned to vehicle standards except the toe-in value was adjusted to zero such that the vehicle would track properly along the guide cable. A 5B flash bulb was mounted under the vehicle's left-side windshield wiper and was fired by a pressure tape switch mounted at the impact corner of the bumper. The flash bulb was fired upon initial impact with the test article to create a visual indicator of the precise time of impact on the high-speed digital videos. A remote-controlled brake system was installed in the test vehicle to bring the vehicle safely to a stop after the test.

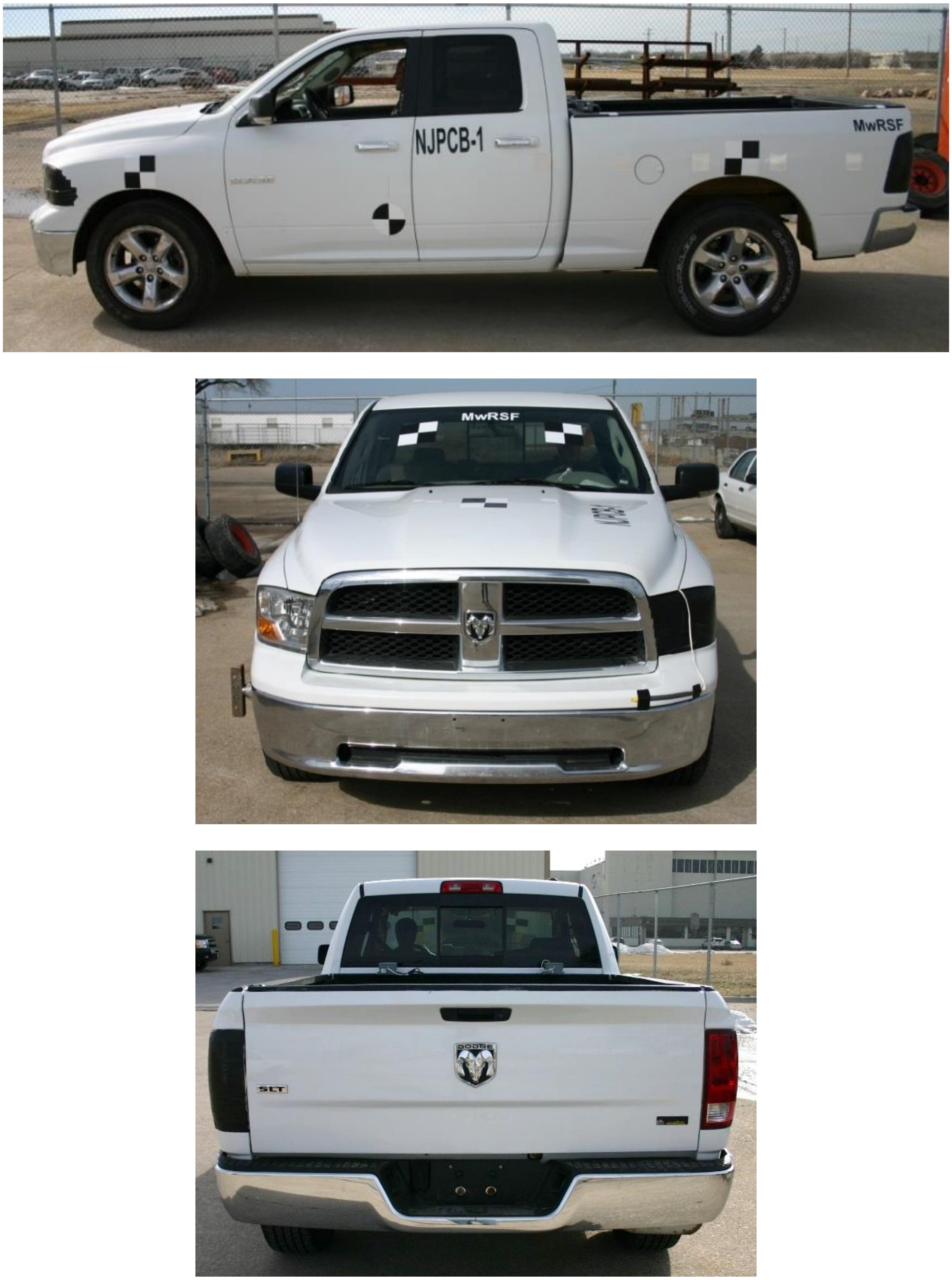


Figure 19. Test Vehicle, Test No. NJPCB-1

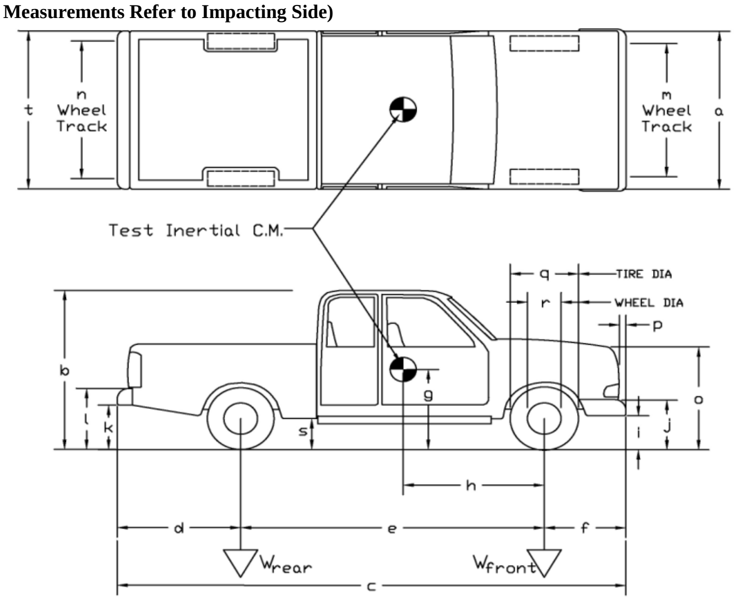
Date: 2/19/2016 **Test Number:** NJPCB-1 **Model:** RAM 1500

Make: Dodge **Vehicle I.D.#:** 1d7rb1gp4as138145

Tire Size: 275/60R20 **Year:** 2010 **Odometer:** 174257

Tire Inflation Pressure: 40

***(All Measurements Refer to Impacting Side)**



Vehicle Geometry -- in. (mm)

a	76 1/2	(1943)	b	74 3/4	(1899)
c	229 1/4	(5823)	d	46 1/2	(1181)
e	140 1/2	(3569)	f	38 1/8	(968)
g	28 1/2	(724)	h	59 3/4	(1519)
i	10 1/8	(257)	j	25 3/4	(654)
k	19	(483)	l	30 1/8	(765)
m	68	(1727)	n	68 3/8	(1737)
o	43 7/8	(1114)	p	4 5/8	(117)
q	32	(813)	r	21 1/2	(546)
s	14 3/4	(375)	t	75 3/8	(1915)

Wheel Center Height Front	15 1/2	(394)
Wheel Center Height Rear	15 7/8	(403)
Wheel Well Clearance (F)	35 3/8	(899)
Wheel Well Clearance (R)	38 5/8	(981)
Frame Height (F)	18 1/4	(464)
Frame Height (R)	26 1/2	(673)
Engine Type	Gasoline	
Engine Size	4.7L V8	
Transmission Type:	Automatic	
Drive Type:	RWD	

Mass Distribution lb (kg)

Gross Static	**LF**	1488 (675)	**RF**	1485 (674)
	LR	1098 (498)	**RR**	1103 (500)

Weights lb (kg)	**Curb**	**Test Inertial**	**Gross Static**
W-front	2972 (1348)	2879 (1306)	2973 (1349)
W-rear	2257 (1024)	2134 (968)	2201 (998)
W-total	5229 (2372)	5013 (2274)	5174 (2347)

GVWR Ratings

Front	3700 lb
Rear	3900 lb
Total	6700 lb

Dummy Data

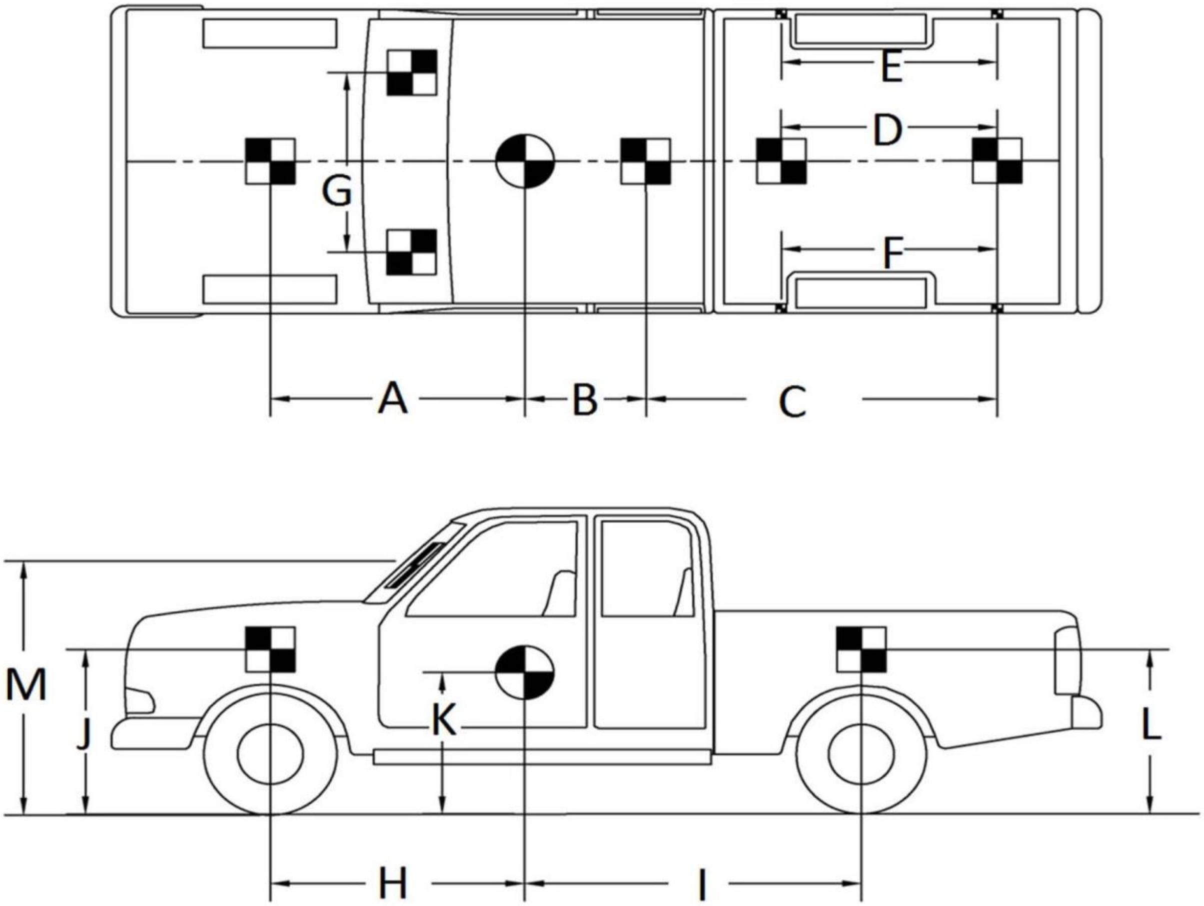
Type: Hybrid II

Mass: 161 lb

Seat Position: Driver

Note any damage prior to test:

Figure 20. Vehicle Dimensions, Test No. NJPCB-1



TEST #: NJPCB-1

TARGET GEOMETRY-- in. (mm)

A	72 7/8	(1851)	**E**	63 3/8	(1610)	**J**	39 1/2	(1003)
B	28 3/8	(721)	**F**	63 1/2	(1613)	**K**	28 5/8	(727)
C	79 7/8	(2029)	**G**	30 1/2	(775)	**L**	42 3/4	(1086)
D	48	(1219)	**H**	59 5/8	(1514)	**M**	64 1/4	(1632)
			I	80 7/8	(2054)			

Figure 21. Target Geometry, Test No. NJPCB-1

4.4 Simulated Occupant

For test no. NJPCB-1, A Hybrid II 50th-Percentile, Adult Male Dummy, equipped with clothing and footwear, was placed in the left-front seat of the test vehicle with the seat belt fastened. The dummy, which had a final weight of 161 lb (73 kg), was represented by model no. 572, serial no. 451, and was manufactured by Android Systems of Carson, California. As recommended by MASH 2009, the dummy was not included in calculating the c.g. location.

4.5 Data Acquisition Systems

4.5.1 Accelerometers

Two environmental shock and vibration sensor/recorder systems were used to measure the accelerations in the longitudinal, lateral, and vertical directions. Both accelerometers were mounted near the c.g. of the test vehicle. The electronic accelerometer data obtained in testing was filtered using the SAE Class 60 and the SAE Class 180 Butterworth filter conforming to the SAE J211/1 specifications [13].

The first accelerometer, the SLICE-1 unit, was a modular data acquisition system manufactured by Diversified Technical Systems, Inc. (DTS) of Seal Beach, California. The SLICE-1 unit was designated as the primary system. The acceleration sensors were mounted inside the body of a custom-built, SLICE 6DX event data recorder and recorded data at 10,000 Hz to the onboard microprocessor. The SLICE 6DX was configured with 7 GB of non-volatile flash memory, a range of ±500 g's, a sample rate of 10,000 Hz, and a 1,650 Hz (CFC 1000) anti-aliasing filter. The "SLICEWare" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

The second accelerometer system was a two-arm piezoresistive accelerometer system manufactured by Endevco of San Juan Capistrano, California. Three accelerometers were used to measure each of the longitudinal, lateral, and vertical accelerations independently at a sample rate of 10,000 Hz. The accelerometers were configured and controlled using a system developed and manufactured by DTS of Seal Beach, California. More specifically, data was collected using a DTS Sensor Input Module (SIM), Model TDAS3-SIM-16M. The SIM was configured with 16 MB SRAM and 8 sensor input channels with 250 kB SRAM/channel. The SIM was mounted on a TDAS3-R4 module rack. The module rack was configured with isolated power/event/communications, 10BaseT Ethernet and RS232 communication, and an internal backup battery. Both the SIM and module rack were crashworthy. The "DTS TDAS Control" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

4.5.2 Rate Transducers

The first angular rate sensor system, which was mounted inside the body of the SLICE-1 event data recorder, measured the rates of rotation of the test vehicle. The SLICE MICRO Triax ARS had a range of 1,500 degrees/sec in each of the three directions (roll, pitch, and yaw) and recorded data at 10,000 Hz to the onboard microprocessor. The raw data measurements were then downloaded, converted to the proper Euler angles for analysis, and plotted. The "SLICEWare" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the angular rate sensor data.

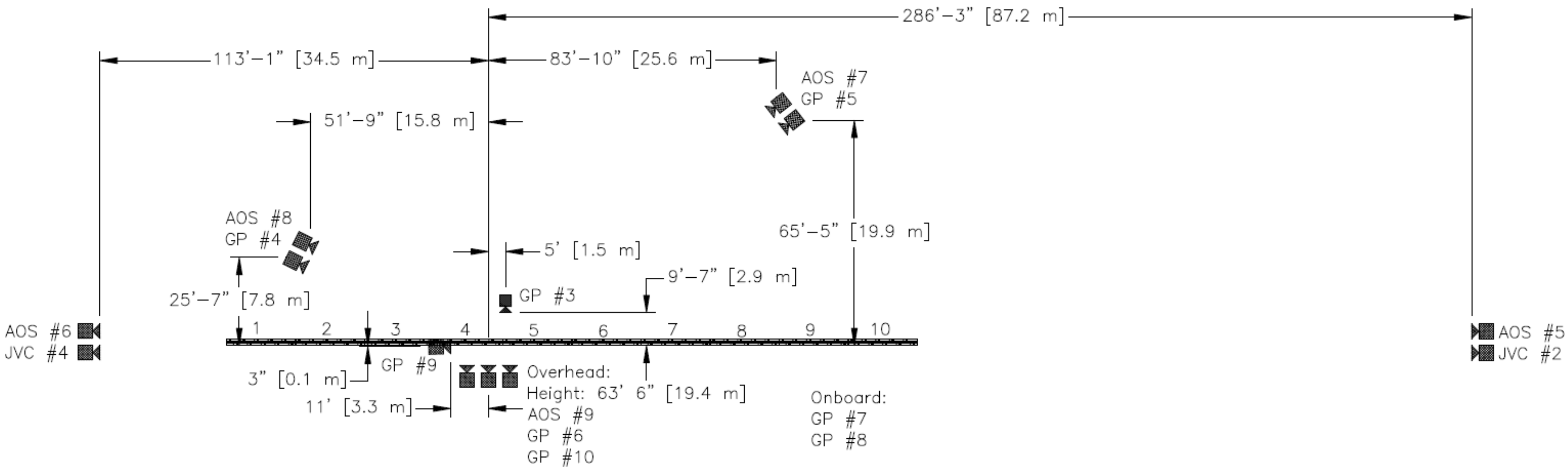
The second angular rate sensor, the ARS-1500, with a range of 1,500 degrees/sec in each of the three directions (roll, pitch, and yaw), measured the rates of rotation of the test vehicle. The angular rate sensor was mounted on an aluminum block inside the test vehicle near the c.g. and recorded data at 10,000 Hz to the DTS SIM. The raw data measurements were then downloaded, converted to the proper Euler angles for analysis, and plotted. The "DTS TDAS Control" computer software program and a customized Microsoft Excel worksheet were used to analyze and plot the angular rate sensor data.

4.5.3 Retroreflective Optic Speed Trap

The retroreflective optic speed trap was used to determine the speed of the test vehicle before impact. Five retroreflective targets, spaced at approximately 18-in. (457-mm) intervals, were applied to the side of the vehicle. When the emitted beam of light was reflected by the targets and returned to the Emitter/Receiver, a signal was sent to the data acquisition computer, recording at 10,000 Hz, as well as the external LED box activating the LED flashes. The speed was then calculated using the spacing between the retroreflective targets and the time between the signals. LED lights and high-speed digital video analysis are only used as a backup in the event that vehicle speeds cannot be determined from the electronic data.

4.5.4 Digital Photography

Five AOS high-speed digital video cameras, eight GoPro digital video cameras, and two JVC digital video cameras were utilized to film test no. NJPCB-1. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 22. The high-speed digital videos were analyzed using ImageExpress MotionPlus and RedLake MotionScope software programs. Actual camera speed and camera divergence factors were considered in the analysis of the high-speed digital videos. A Nikon digital still camera was also used to document pre- and post-test conditions for the test.



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-5	AOS X-PRI Gigabit	500	VIVITAR 135mm Fixed	-
AOS-6	AOS X-PRI Gigabit	500	Fujinon 50mm Fixed	-
AOS-7	AOS X-PRI Gigabit	500	SIGMA 28-70 DG	50
AOS-8	AOS S-VIT 1531	500	SIGMA 28-70	35
AOS-9	AOS TRI-VIT	500	KOWA 12mm Fixed	-
GP-3	GoPro Hero 3+	120		
GP-4	GoPro Hero 3+	120		
GP-5	GoPro Hero 3+	120		
GP-6	GoPro Hero 3+	120		
GP-7	GoPro Hero 4	240		
GP-8	GoPro Hero 4	240		
GP-9	GoPro Hero 4	120		
GP-10	GoPro Hero 4	240		
JVC-2	JVC – GZ-MG27u (Everio)	29.97		
JVC-4	JVC – GZ-MG27u (Everio)	29.97		

Figure 22. Camera Locations, Speeds, and Lens Settings, Test No. NJPCB-1

5 FULL-SCALE CRASH TEST NO. NJPCB-1

5.1 Weather Conditions

Test no. NJPCB-1 was conducted on February 19, 2016 at approximately 1:15 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 5.

Table 5. Weather Conditions, Test No. NJPCB-1

Temperature	66° F
Humidity	24%
Wind Speed	16 mph
Wind Direction	280° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.00 in.

5.2 Test Description

The 5,013-lb (2,274-kg) pickup truck impacted the NJDOT PCB, Type 4 (Alternative B) with a pinned configuration and grouted toes, corresponding to joint class C in the 2013 NJDOT *Roadway Design Manual*, at a speed of 62.6 mph (100.7 km/h) and at an angle of 24.7 degrees. A summary of the test results and sequential photographs are shown in Figure 24. Additional sequential photographs are shown in Figures 25 and 26. Documentary photographs of the crash test are shown in Figure 27.

Initial vehicle impact was to occur 4 ft – 3$^{3}/_{16}$ in. (1.3 m) upstream from the centerline of the joint between barrier nos. 4 and 5, as shown in Figure 28, which was selected using Table 2.6 of MASH 2009. The actual point of impact was 2⅛ in. (54 mm) downstream from the target location. A sequential description of the impact events is contained in Table 6. The vehicle came to rest 193 ft – 11 in. (59.1 m) downstream from the impact point and 9 ft – 4 in. (2.8 m) laterally away from the traffic side of the barrier. The vehicle trajectory and final position are shown in Figures 24 and 29.

Table 6. Sequential Description of Impact Events, Test No. NJPCB-1

TIME (sec)	EVENT
0.000	Vehicle's left-front corner impacted barrier no. 4 at 4 ft – 1$^{1}/_{16}$ in. (1.25 m) upstream from centerline of joint between barrier nos. 4 and 5.
0.004	Left corner of front bumper deformed inward.
0.008	Left headlight contacted top of barrier no. 4 and deformed.

0.020	Downstream end of barrier no. 4 deflected backward.
0.022	Vehicle's hood and grille contacted front face of barrier no. 4, and barrier deformed.
0.026	Vehicle's left-front door contacted downstream front face of barrier no. 4, and door deformed.
0.038	Vehicle yawed away from system.
0.044	Vehicle's airbags deployed, and upstream end of barrier no. 4 cracked.
0.046	Upstream end of barrier no. 5 deflected backward.
0.050	Downstream end of barrier no. 3 deflected backward.
0.058	Vehicle's left-rear door contacted downstream end of barrier no. 4, and door deformed.
0.064	Downstream end of barrier no. 5 cracked.
0.066	Center and upstream end of barrier no. 5 cracked.
0.068	Upstream end of barrier no. 6 deflected backward.
0.084	Downstream end of barrier no. 4 spalled.
0.088	Center and downstream portions of barrier no. 5 spalled.
0.092	Upstream end of barrier no. 5 spalled.
0.098	Vehicle's left-front window shattered from occupant's head, and vehicle rolled away from system.
0.110	Vehicle's right-front tire became airborne.
0.130	Upstream end toe on front side of barrier no. 4 cracked, and large piece of concrete separated from back side of barrier no. 5.
0.142	Large piece of concrete separated from downstream end of barrier no. 4.
0.192	Vehicle's left-rear tire contacted top of barrier no. 5.
0.200	Left headlight detached away from vehicle.
0.204	Vehicle was parallel to system at a speed of 46.5 mph (74.8 km/h).
0.226	Vehicle pitched downward.
0.278	Vehicle's right-rear tire became airborne.
0.344	Vehicle became airborne and exited system at a speed of 46.0 mph (74.1 km/h) and at an angle of 9.2 deg.
0.652	Vehicle's right-front tire regained contact with ground with vehicle exhibiting approximately 33.8 deg of roll.
0.990	Vehicle's left-front tire regained contact with ground.
1.020	Vehicle's left-front tire separated from left-front rim.
1.050	Left-front wheel detached from vehicle, and left-rear tire deflated.
1.104	Occupant's left arm contacted vehicle's A-pillar.

5.3 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 30 through 35. Barrier damage consisted of contact and gouge marks on the front face of the PCB segments, spalling of the concrete, and concrete cracking and fracture. The length of vehicle contact along the barrier was approximately 19 ft – 4½ in. (5.9 m), which spanned from 4 ft – 2½ in. (1.3 m) upstream from the center of the joint between barrier nos. 4 and 5 through 15 ft – 2 in. (4.6 m) downstream from the center of the joint between barrier nos. 4 and 5.

Tire marks were visible on the front face of barrier nos. 4 and 5. Scrape marks were also found on the front and top faces of barrier nos. 4 and 5. The traffic-side grout between barrier nos. 3 and 4 was displaced ¼ in. (6 mm) laterally toward back side. Grout between barrier nos. 4 and 5 had crumbled. A 26¼-in. (667-mm) long crack on the front face extended from the upstream end to the toe of barrier no. 4. An 18¼-in. (464-mm) long crack on the front face of barrier no. 4 extended from the downstream end to anchor pocket no. 9. Barrier no. 5 was fractured from top to bottom at 60½-in. (1,537-mm) downstream from the upstream end. A 32¾-in. (832-mm) long crack was found on the front face of barrier no. 5 beginning at the bottom of anchor pocket no. 3. A 15½-in. (394-mm) long crack near the bottom on the back side of barrier no. 5 was approximately 31-in. (787-mm) downstream from the upstream end. A 32½-in. (826-mm) long crack on the back side of barrier no. 5 extended vertically from anchor pocket no. 4. Minor cracks were found on the back side of barrier no. 6. A 2½-in. (64-mm) long vertical crack was found at the corner of the upstream connection key socket on barrier no. 6. A 16-in. (406-mm) long crack was found on the upstream end of the back face of barrier no. 6. Anchor pin nos. 2, 6 and 7 in barrier no. 5 were bent, and the concrete around those pin anchors were cracked.

Concrete spalling occurred on barrier nos. 3 through 6. A 2-in. × 2½-in. × ¼-in. (51-mm × 64-mm × 6-mm) concrete piece disengaged from barrier no. 3 at the lower-upstream corner on the front face. A 2⅞-in. × 1½-in. × ⅛-in. (73-mm × 38-mm × 3-mm) piece of concrete was removed from the upper-downstream end of barrier no. 3. Concrete spalling of 52¼ in. × 11½ in. × 4¾ in. (1,327 mm × 292 mm × 121 mm) and an 11⅜-in. (289-mm) long crack occurred at the lower-front upstream corner of barrier no. 4. The front side of barrier no. 4 experienced concrete spalling 30¼ in. × 15 in. × 10¾ in (768 mm × 381 mm × 273 mm) at the lower downstream corner. A 4¼-in. x 5½-in. x ⅝-in. (108-mm × 140-mm × 16-mm) piece of concrete was removed from the upper-downstream corner of barrier no. 4 below the connection key socket. Minor spalling occurred below the connection key socket on the front-upstream end of barrier no. 5. Concrete spalling occurred on the back side of barrier no. 5 at the upstream end from top to bottom, and a 24-in. (610 mm) long piece was removed, which exposed the connection key socket tube. Concrete spalling, measuring 42⅝ in. × 16 in. × 3⅝ in. (1,083 mm × 406 mm × 92 mm) occurred below the fractured section on the back side of barrier no. 5. Concrete spalling, measuring 67⅛ in. × 9⅛ in. × 1⅛ in. (1,705 mm × 232 mm × 29 mm) occurred at the back-side downstream end of barrier no. 5. The back side of barrier no. 6 experienced concrete spalling at the lower-downstream corner and near the middle of the barrier.

The maximum permanent set deflection of the barrier system was 6¼ in. (159 mm) at the downstream end of barrier no. 4, as measured in the field. The maximum lateral dynamic barrier deflection, including minor tipping of the barrier along the top surface, was 13.5 in. (343 mm) at the upstream end of barrier no. 5, as determined from high-speed digital video analysis. The working width of the system was found to be 37.5 in. (953 mm), also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 23. In addition, NJDOT identifies the clear space behind the barrier, which is defined as the maximum deflection of the back of the barrier from its original position. For this test, the clear space behind the barrier was 13.5 in. (343 mm).

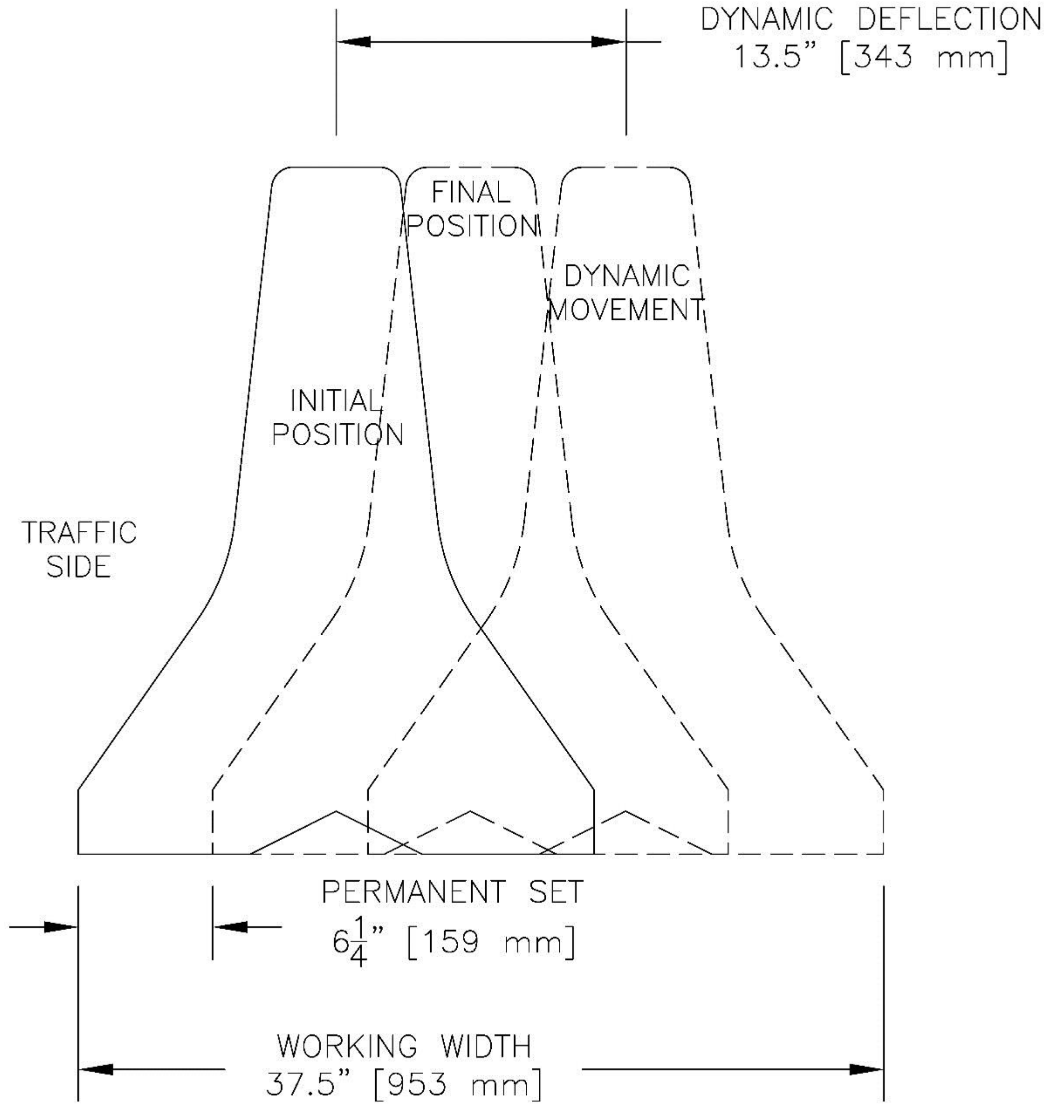


Figure 23. Permanent Set Deflection, Dynamic Deflection, and Working Width, Test No. NJPCB-1

5.4 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 36 through 40. The maximum occupant compartment deformations are listed in Table 7 along with the deformation limits established in MASH 2009 for various areas of the occupant compartment. Note that none of the MASH 2009 established deformation limits were violated. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix E.

The majority of the damage was concentrated on the left–front corner and left side of the vehicle where the impact had occurred. The left side of the bumper crushed inward. The plastic bumper portion separated from the left side and bent toward the right side of the vehicle. The hood separated from the right fender. The left-front fender was deformed 4 in. (102 mm) inward toward the engine compartment. A 2-in. × 3-in. (51-mm × 76-mm) dent was found on the rear of the left fender approximately 19 in. (483 mm) from the bottom of the fender. Denting, scraping, and gouging were observed on the entire left side of the cab. Gouging and contact marks were found at the bottom of the left-front door, starting from the front of the door and extending 4 in. (102 mm) backward. Scraping was found at the bottom of the left-front door, extending 21½ in. (546 mm) toward the rear of the door. Contact marks were found on the left-rear door, starting from the front of the left-rear door and extending 15 in. (381 mm) backward. The left-front headlight and tire disengaged from the vehicle. A tear was found on the left-rear tire extending from the outer side wall through the tread and two-thirds of the way around the tire. A 15-in. × 5-in. × 1-in. (381-mm × 127-mm × 25-mm) dent extended from the left edge of the front bumper and 3 in. (76 mm) from the bottom of the bumper. A 3-in. × 2-in. × ¼-in. (76-mm × 51-mm × 6-mm) dent was found 11 in. (279 mm) from the left edge of the bottom of the front bumper.

The lower-left control arm was scraped and crushed. The left-front lower control arm had a 2½-in. (64-mm) tear on the leading edge approximately 5½ in. (140 mm) from the lower ball joint. The left-front wheel and hub were disengaged. The brake disk disengaged from the overall assembly but remained attached. The rear transmission and rear axle were shifted toward the right of the vehicle. Scrape marks were found on the exhaust pipe. The left-front side window glass shattered. The roof remained undamaged. The windshield had 30-in. (762-mm) diameter spider web cracking and an additional crack extending from the spider-web crack to the left-bottom corner.

Table 7. Maximum Occupant Compartment Deformations by Location

LOCATION	MAXIMUM DEFORMATION in. (mm)	MASH 2009 ALLOWABLE DEFORMATION in. (mm)
Wheel Well & Toe Pan	4⅝ (117)	≤ 9 (229)
Floor Pan & Transmission Tunnel	1¼ (32)	≤ 12 (305)
Side Front Panel (in Front of A-Pillar)	¼ (6)	≤ 12 (305)
Side Door (Above Seat)	¾ (19)	≤ 9 (229)
Side Door (Below Seat)	¼ (6)	≤ 12 (305)
Roof	½ (13)	≤ 4 (102)
Windshield	0 (0)	≤ 3 (76)
Side Window	Shattered due to contact with dummy's head	No shattering resulting from contact with structural member of test article
Dash	½ (13)	N/A

N/A – Not applicable

5.5 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 8. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2009. The calculated THIV, PHD, and ASI values are also shown in Table 8. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 24. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix F.

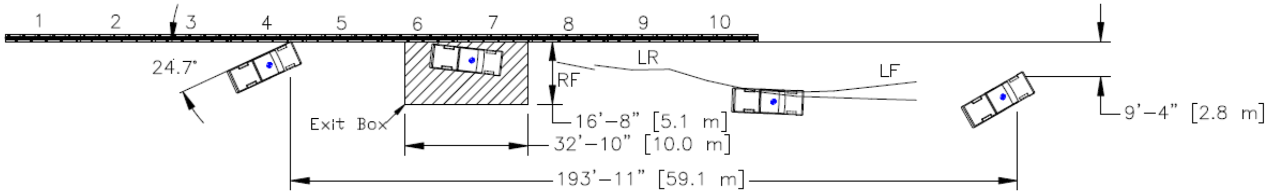
Table 8. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. NJPCB-1

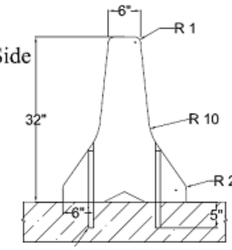
Evaluation Criteria		Transducer		MASH 2009 Limits
		SLICE-1 (Primary)	**DTS**	
OIV ft/s (m/s)	Longitudinal	-14.27 (-4.35)	-14.53 (-4.43)	± 40 (12.2)
	Lateral	19.33 (5.89)	17.38 (5.30)	± 40 (12.2)
ORA g's	Longitudinal	-9.97	-9.24	± 20.49
	Lateral	7.17	8.53	± 20.49
MAX. ANGULAR DISPL. deg.	Roll	-39.9	38.5	± 75
	Pitch	-12.8	10.5	±75
	Yaw	36.0	37.1	not required
THIV ft/s (m/s)		23.49 (7.16)	21.75 (6.63)	not required
PHD g's		10.23	10.20	not required
ASI		1.23	1.13	not required

5.6 Discussion

The analysis of the test results showed that the system adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix F, were deemed acceptable because they did not adversely influence occupant risk safety criteria nor cause rollover. After impact, the vehicle exited the barrier at an angle of 9.2 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. NJPCB-1 was determined to be acceptable according to the MASH 2009 safety performance criteria for test designation no. 3-11.

0.000 sec | 0.098 sec | 0.204 sec | 0.496 sec | 0.746 sec

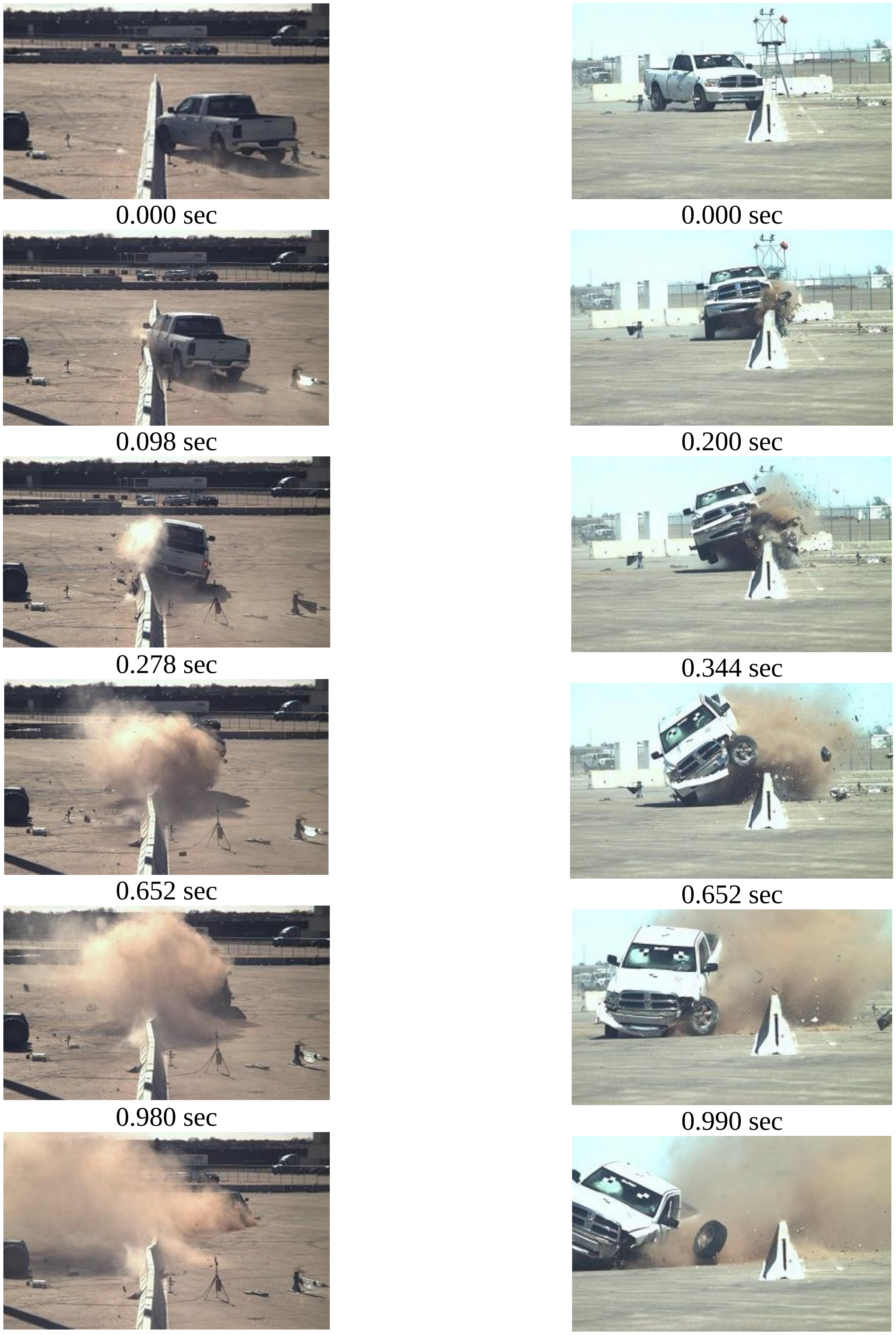




- Test Agency .... MwRSF
- Test Number NJPCB-1
- Date 2/19/2016
- MASH 2009 Test Designation 3-11
- Test Article .... NJDOT PCB with Pinned Configuration and Grouted Toes
- Total Length .... 200 ft (61.0 m)
- Key Component – NJDOT PCB
  - Length .... 20 ft (6.1 m)
  - Width .... 24 in. (610 mm)
  - Height .... 32 in. (813 mm)
- Key Component – Anchor Pins
  - Pin Size .... 1-in. (25-mm) diameter unthreaded rod
  - Pin Material .... ASTM A36 steel
  - Pin Length .... 15 in. (381 mm)
  - Embedment Depth .... 5 in. (127 mm)
  - Number of Pins per Barrier 9
  - Pinned Barrier Nos. .... 1, 3, 5, 7, 9, and 10
- Key Component – Grout
  - Specification .... Min. 1-day compressive strength 1,000 psi (6.9 MPa)
  - Location .... Toes at joints between barrier nos. 1-10 on traffic and back sides
- Type of Support Surface .... Concrete Tarmac
- Vehicle Make /Model .... 2010 Dodge Ram 1500 quad cab pickup truck
  - Curb .... 5,229 lb (2,372 kg)
  - Test Inertial .... 5,013 lb (2,274 kg)
  - Gross Static .... 5,174 lb (2,347 kg)
- Impact Conditions
  - Speed .... 62.6 mph (100.7 km/h)
  - Angle .... 24.7 deg
  - Impact Location .... $49^{1}/_{16}$ in. (1.25 m) upstream from joint 4-5
- Impact Severity .... 114.9 kip-ft (155.8 kJ) > 105.6 kip-ft (143.1 kJ) limit in MASH 2009
- Exit Conditions
  - Speed .... 46.0 mph (74.1 km/h)
  - Angle .... 9.2 deg
  - Exit Box Criterion .... Pass
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 193 ft – 11 in. (59.1 m) downstream
  9 ft – 4 in. (2.8 m) laterally in front
- Test Article Damage .... Moderate
- Vehicle Damage .... Moderate
  - VDS [14] 11-LFQ-4
  - CDC [15] 11-LYEW-4
  - Maximum Interior Deformation .... 4⅝ in. (117 mm)
- Maximum Test Article Deflections
  - Permanent Set .... 6¼ in. (159 mm)
  - Dynamic .... 13.5 in. (343 mm)
  - Working Width .... 37.5 in. (953 mm)
- Transducer Data

Evaluation Criteria		Transducer: SLICE-1 (Primary)	Transducer: DTS	MASH 2009 Limit
OIV ft/s (m/s)	Longitudinal	-14.27 (-4.35)	-14.53 (-4.43)	± 40 (12.2)
	Lateral	19.33 (5.89)	17.38 (5.30)	± 40 (12.2)
ORA g's	Longitudinal	-9.97	-9.24	± 20.49
	Lateral	7.17	8.53	± 20.49
MAX. ANGULAR DISPL. deg.	Roll	-39.9	38.5	± 75
	Pitch	-12.8	10.5	± 75
	Yaw	36.0	37.1	not required
THIV ft/s (m/s)		23.49 (7.16)	21.75 (6.63)	not required
PHD g's		10.23	10.20	not required
ASI		1.23	1.13	not required

Figure 24. Summary of Test Results and Sequential Photographs, Test No. NJPCB-1



0.000 sec

0.098 sec

0.278 sec

0.652 sec

0.980 sec

1.682 sec

0.000 sec

0.200 sec

0.344 sec

0.652 sec

0.990 sec

1.332 sec

Figure 25. Additional Sequential Photographs, Test No. NJPCB-1

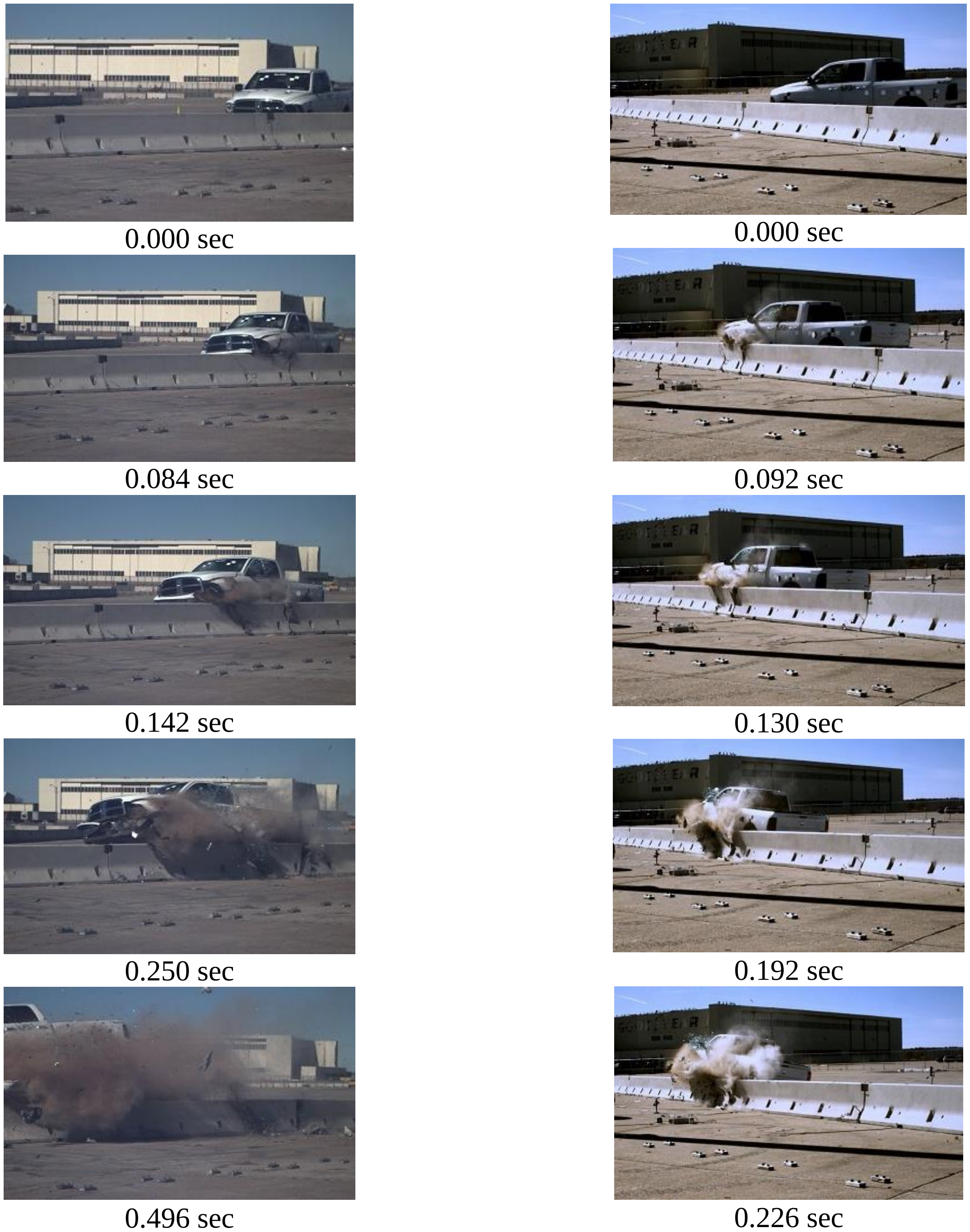


Figure 26. Additional Sequential Photographs, Test No. NJPCB-1

Figure 27. Documentary Photographs, Test No. NJPCB-1

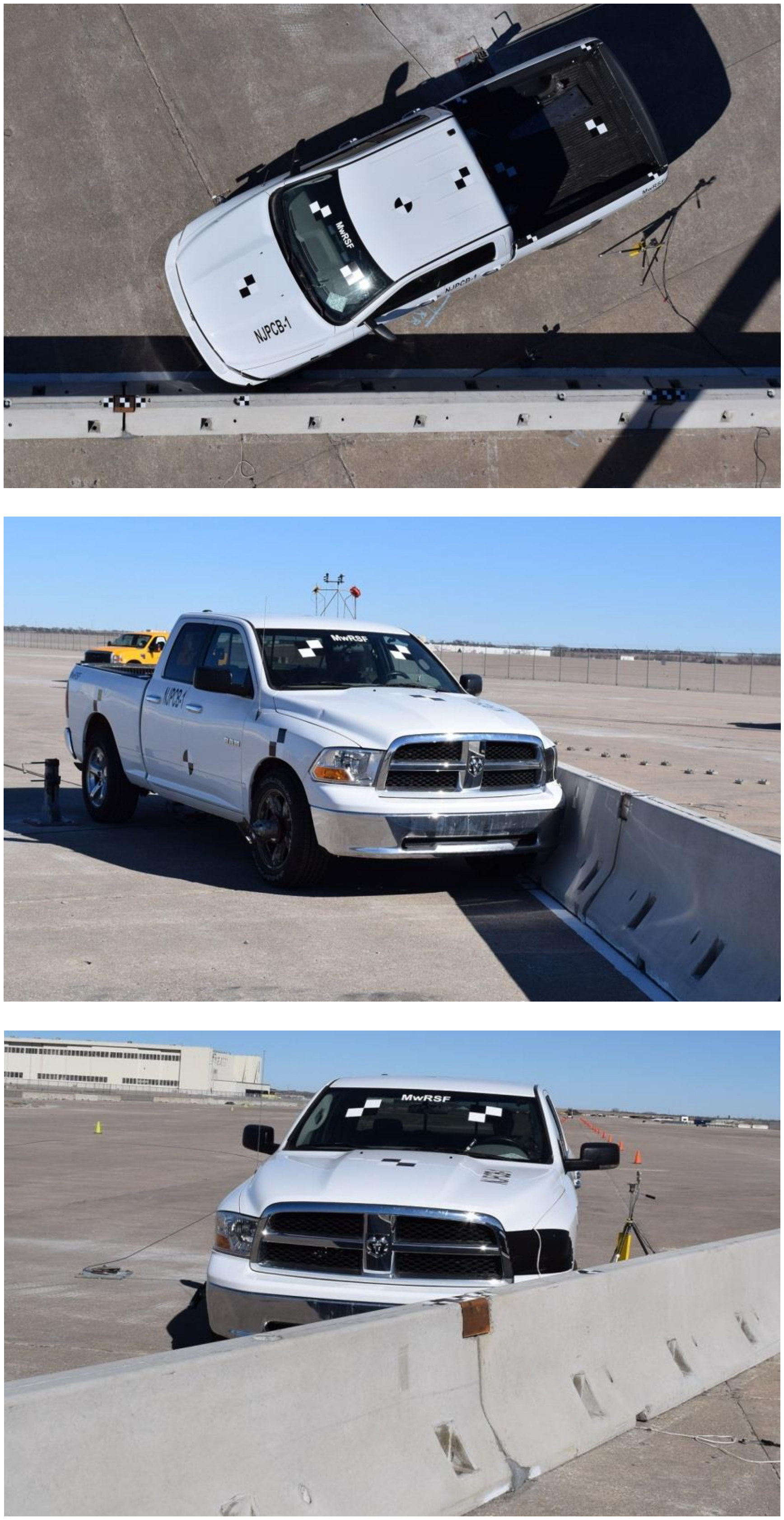


Figure 28. Impact Location, Test No. NJPCB-1

Figure 29. Vehicle Final Position and Trajectory Marks, Test No. NJPCB-1

Figure 30. System Damage – Front, Back, Upstream and Downstream Views, Test No. NJPCB-1

Figure 31. System Damage at Impact Location, Test No. NJPCB-1

Figure 32. Barrier No. 3 – Traffic and Back Side Damage, Test No. NJPCB-1

Figure 33. Barrier No. 4 – Traffic and Back Side Damage, Test No. NJPCB-1

Figure 34. Barrier No. 5 – Traffic and Back Side Damage, Test No. NJPCB-1

Figure 35. Barrier No. 6 – Traffic and Back Side Damage, Test No. NJPCB-1

Figure 36. Vehicle Damage, Test No. NJPCB-1

Figure 37. Vehicle Damage on Impact Side, Test No. NJPCB-1

Figure 38. Vehicle Windshield and Window Damage, Test No. NJPCB-1

Figure 39. Occupant Compartment Deformation, Test No. NJPCB-1

Figure 40. Undercarriage Damage, Test No. NJPCB-1

6 SUMMARY AND CONCLUSIONS

Test no. NJPCB-1 was conducted on the NJDOT PCB system with a pinned configuration and grouted toes according to MASH 2009 test designation no. 3-11. This system uses NJDOT barriers, Type 4 (Alternative B) with joint class C, as specified in the 2013 NJDOT *Roadway Design Manual*. Barrier nos. 1, 3, 5, 7, 9 and 10 were anchored to the rigid concrete tarmac through the nine pin anchor recesses with 1-in. (25-mm) diameter by 15-in. (381-mm) long ASTM A36 steel pins.

During test no. NJPCB-1, the 5,013-lb (2,274 kg) pickup truck impacted the NJDOT PCB system at a speed of 62.6 mph (100.7 km/h) and at an angle of 24.7 degrees, resulting in an impact severity of 114.9 kip-ft (155.8 kJ). After impacting the barrier system, the vehicle exited the system at a speed of 46.0 mph (74.1 km/h) and at an angle of 9.2 degrees. The vehicle was successfully contained and smoothly redirected with moderate damage to both the barrier and the vehicle. Barrier nos. 4, 5, and 6 experienced spalling and cracking. A dynamic deflection of 13.5 in. (343 mm) and working width of 37.5 in. (953 mm) were observed during the test, as shown in Figure 23. All occupant risk values were found to be within limits, and the occupant compartment deformations were also deemed acceptable. Subsequently, test no. NJPCB-1 was determined to satisfy the safety performance criteria for MASH 2009 test designation no. 3-11. A summary of the test evaluation is shown in Table 9.

Table 9. Summary of Safety Performance Evaluation

<table>
<tr><th>Evaluation Factors</th><th colspan="2">Evaluation Criteria</th><th>Test No. NJPCB-1</th></tr>
<tr><td>Structural Adequacy</td><td>A.</td><td>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>S</td></tr>
<tr><td rowspan="5">Occupant Risk</td><td rowspan="2">D.</td><td>1. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone.</td><td>S</td></tr>
<tr><td>2. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016.</td><td>S</td></tr>
<tr><td>F.</td><td>The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td><td>S</td></tr>
<tr><td>H.</td><td>Occupant Impact Velocity (OIV) (see Appendix A, Section A5.3 of MASH 2009 for calculation procedure) should satisfy the following limits:
<table><tr><th colspan="3">Occupant Impact Velocity Limits</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>S</td></tr>
<tr><td>I.</td><td>The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.3 of MASH 2009 for calculation procedure) should satisfy the following limits:
<table><tr><th colspan="3">Occupant Ridedown Acceleration Limits</th></tr><tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr><tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr></table></td><td>S</td></tr>
<tr><td colspan="3">MASH 2009 Test Designation No.</td><td>3-11</td></tr>
<tr><td colspan="3">Final Evaluation (Pass or Fail)</td><td>Pass</td></tr>
</table>

S – Satisfactory U – Unsatisfactory NA - Not Applicable

7 MASH IMPLEMENTATION

The objective of this research was to evaluate the safety performance of NJDOT's PCB, Type 4 (Alternative B) with a pinned configuration and grouted toes, corresponding to joint class C in the 2013 NJDOT *Roadway Design Manual*. The NJDOT barriers consisted of NJDOT PCBs joined with a connection key. Barrier nos. 1, 3, 5, 7, 9 and 10 were anchored to the concrete roadway surface through the nine pin anchor recesses with 1-in. (25-mm) diameter by 15-in. (381-mm) long, ASTM A36 steel pins. The barrier segments were pulled in a direction parallel to their longitudinal axes, and slack was removed from all joints prior to installation of the steel anchor pins. A wedge of grout was placed at the toe of each joint on both the traffic side and back side of the system.

According to TL-3 evaluation criteria in MASH 2009, two tests are required for evaluation of longitudinal barrier systems: (1) test designation no. 3-10 – an 1100C small car and (2) test designation no. 3-11 – a 2270P pickup truck. However, only the 2270P crash test was deemed necessary as other prior small car tests were used to support a decision to deem the 1100C crash test not critical.

In test no. 7069-3, a rigid, F-shape bridge rail was successfully impacted by a small car weighing 1,800 lb (816 kg) at 60.1 mph and 21.4 degrees according to the American Association of State Highway and Transportation Officials (AASHTO) *Guide Specifications for Bridge Railings* [5-6]. In the same manner, test nos. CMB-5 through CMB-10, CMB-13, and 4798-1 showed that rigid, New Jersey, concrete safety shape barriers struck by small cars have been shown to meet safety performance standards [7-9]. In addition, in test no. 2214NJ-1, a rigid, New Jersey, ½-section, concrete safety shape barrier was impacted by a passenger car weighing 2,579 lb (1,170 kg) at 60.8 mph and 26.1 degrees according to the TL-3 standards set forth in MASH 2009 [9]. Furthermore, temporary, New Jersey safety shape, concrete median barriers have experienced only slight barrier deflections when impacted by small cars and behave similarly to rigid concrete barriers as seen in test no. 47 [10]. Therefore, the 1100C passenger car test was deemed not critical for testing and evaluating this PCB system. It should be noted that any tests within the evaluation matrix deemed not critical may eventually need to be evaluated based on additional knowledge gained over time or additional FHWA eligibility letter requirements.

During test no. NJPCB-1, a 5,013-lb (2,274 kg) pickup truck with a simulated occupant seated in the left-front passenger seat, impacted the NJDOT PCB system with joint class C, as specified in the 2013 NJDOT *Roadway Design Manual*, at a speed of 62.6 mph (100.7 km/h) and at an angle of 24.7 degrees, resulting in an impact severity of 114.9 kip-ft (155.8 kJ). At 0.204 sec after impact, the vehicle became parallel to the system with a speed of 46.5 mph (74.8 km/h). At 0.344 sec, the vehicle became airborne and exited the system at a speed of 46.0 mph (74.1 km/h) and an angle of 9.2 degrees. The vehicle was successfully contained and smoothly redirected.

Exterior vehicle damage was moderate. Interior occupant compartment deformations were minimal with a maximum of 4⅝ in. (117 mm), which did not violate the limits established in MASH 2009. Damage to the barrier was also moderate, consisting of contact marks on the front face of the PCB segments, concrete spalling, and concrete cracking on barrier nos. 4, 5, and 6. The maximum dynamic barrier deflection was 13.5 in. (343 mm), which included minor tipping of the barrier at the top surface. The working width of the PCB system was 37.5 in. (953 mm). All occupant risk measures were within the recommended limits, and the occupant compartment deformations were also deemed acceptable. Therefore, NJDOT barriers, Type 4 (Alternative B) with joint class C as specified in the 2013 NJDOT *Roadway Design Manual*, successfully met all the safety performance criteria of MASH 2009 test designation no. 3-11.

The NJDOT barriers, Type 4 (Alternative B) with joint class C, as specified in the 2013 NJDOT *Roadway Design Manual*, consisting of NJDOT PCB barriers joined with a connection key, joint slack removed, grouted toes, and every other barrier pinned on both the traffic side and back side, was successfully crash tested and evaluated according to the AASHTO MASH 2009 TL-3 criteria. This barrier successfully met all the requirements of MASH 2009 test designation no. 3-11. In addition, the researchers consider the system MASH 2009 compliant based on the successful test designation no. 3-11 test and the previous justification for test designation no. 3-10 being deemed not critical. Further, since there is no difference between MASH 2009 and MASH 2016 for the evaluation of longitudinal barriers such as the PCB system tested in this project, except for the additional occupant compartment deformation measurements required by MASH 2016, this system also meets MASH 2016 TL-3 criteria.

While no previous comparison between crash tests exists, it is anticipated that little to no benefit would be observed in reduced barrier deflections and clear space requirements due to joint slack removal and/or use of grouted toes. The finding is primarily due to no barrier reinforcement in the toes of the New Jersey PCB segments. The lack of steel reinforcement led to concrete fracture near the barrier toes when they were loaded by adjacent barrier segments, which caused increased rotation of the barrier joints. This concrete toe disengagement reduced the expected benefit that would have been provided by the removal of joint slack and use of grouted toes. Further, the PCB segments used in this test have a relatively small gap between adjacent barrier segments. Thus, improvement of the joint response through removal of joint slack and use of grouted toes provided less benefit than would be expected for other PCB systems, which utilize joint spacings up to 4 in. (102 mm). Finally, barrier system behavior and associated barrier deflections can vary from test to test due to the natural variability of a wide variety of factors involved in full-scale crash testing. These factors would include slight differences in impact conditions, differing test vehicle model years, slight variations in steel and concrete strengths, and variation of the cracking and damage observed on the barrier segments, among others. Thus, some variability would be expected in barrier performance, even for basically identical systems.

In the 2013 NJDOT *Roadway Design Manual*, the allowable deflection is determined by the clear space behind the barrier, which is defined as the maximum deflection of the back of the barrier from its original position. For joint class C, as specified in the 2013 NJDOT *Roadway Design Manual* and utilized in this system, the NJDOT allowable movement guidance is 11 in. (279 mm). For this test, the clear space behind the barrier was 13.5 in. (343 mm).

8 REFERENCES

1. New Jersey Department of Transportation, *Roadway Design Manual*, Revised May 10, 2013.

2. New Jersey Department of Transportation, *Roadway Design Manual*, Revised 2015.

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

4. *Manual for Assessing Safety Hardware, Second Edition,* American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C., 2016.

5. Buth, C. E., Hirsch, T. J., and McDevitt, C. F., *Performance Level 2 Bridge Railings*, Transportation Research Record No. 1258, Transportation Research Board, National Research Council, Washington, D.C., 1990.

6. *Guide Specifications for Bridge Railings*, American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C., 1989

7. Bronstad, M. E., Calcote, L. R., and Kimball Jr, C. E., *Concrete Median Barrier Research-Vol.2 Research Report*, Report No. FHWA-RD-77-4, Submitted to the Office of Research and Development, Federal Highway Administration, Performed by Southwest Research Institute, San Antonio, TX, March 1976.

8. Buth, C. E., Campise, W. L., Griffin III, L. I., Love, M. L., and Sicking, D. L., *Performance Limits of Longitudinal Barrier Systems-Volume I: Summary Report,* FHWA/RD-86/153, Final Report to the Federal Highway Administration, Office of Safety and Traffic Operations R&D, Performed by Texas Transportation Institute, Texas A&M University, College Station, TX, May 1986.

9. Polivka, K.A., Faller, R.K., Sicking, D.L., Rohde, J.R., Bielenberg, B.W., Reid, J.D., and Coon, B.A., *Performance Evaluation of the Permanent New Jersey Safety Shape Barrier – Update to NCHRP 350 Test No. 3-10 (2214NJ-1),* Report No. TRP-03-177-06, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, October 13, 2006.

10. Fortuniewicz, J. S., Bryden, J. E., and Phillips, R. G., *Crash Tests of Portable Concrete Median Barrier for Maintenance Zones,* Report No. FHWA/NY/RR-82/102, Final Report to the Office of Research, Development, and Technology, Federal Highway Administration, Performed by the Engineering Research and Development Bureau, New York State Department of Transportation, December 1982.

11. Hinch, J., Yang, T.L., and Owings, R., *Guidance Systems for Vehicle Testing,* ENSCO, Inc., Springfield, Virginia, 1986.

12. *Center of Gravity Test Code - SAE J874 March 1981*, SAE Handbook Vol. 4, Society of Automotive Engineers, Inc., Warrendale, Pennsylvania, 1986.

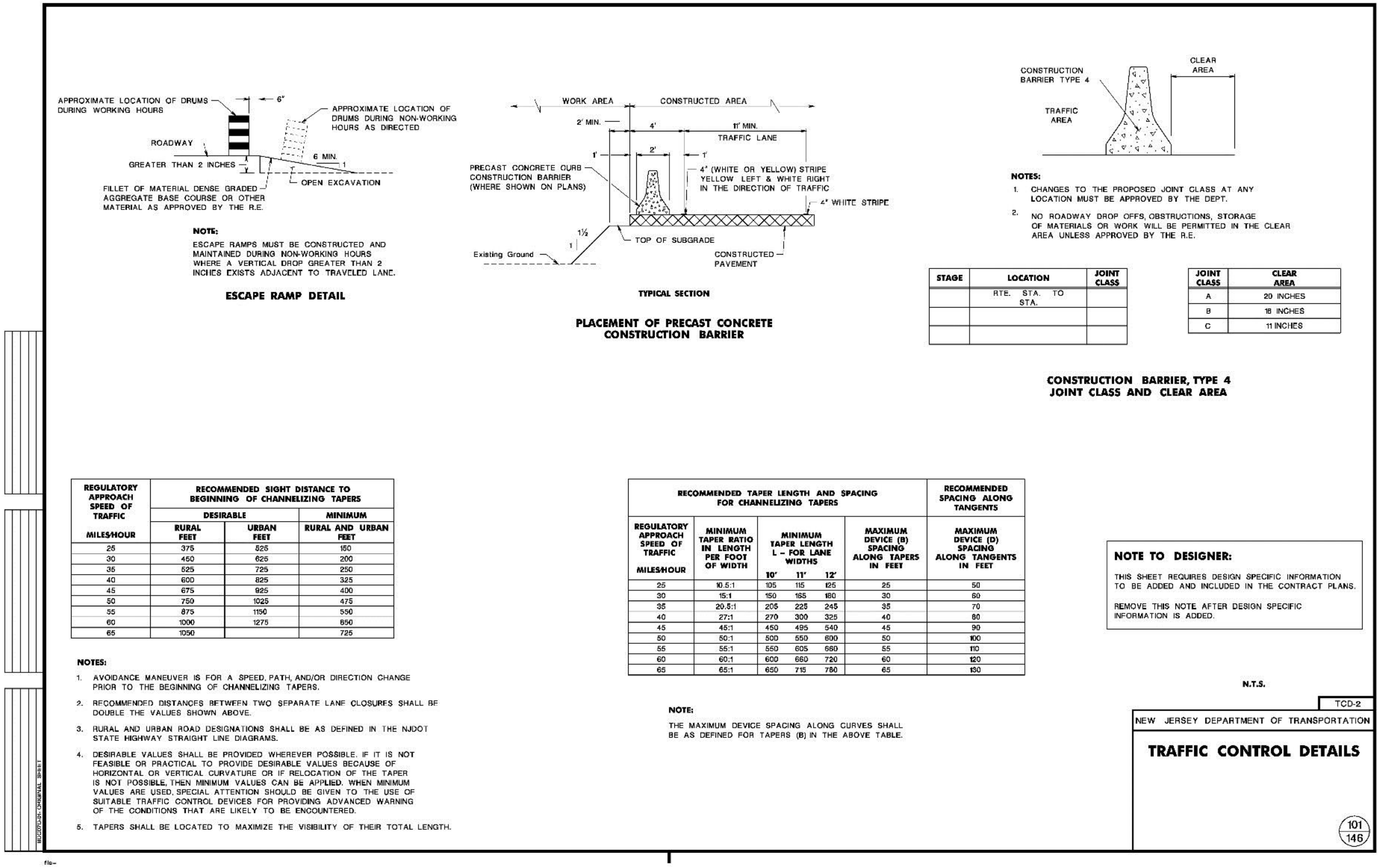
13. Society of Automotive Engineers (SAE), *Instrumentation for Impact Test – Part 1 – Electronic Instrumentation*, SAE J211/1 MAR95, New York City, NY, July, 2007.

14. *Vehicle Damage Scale for Traffic Investigators*, Second Edition, Technical Bulletin No. 1, Traffic Accident Data (TAD) Project, National Safety Council, Chicago, Illinois, 1971.

15. *Collision Deformation Classification – Recommended Practice J224 March 1980*, Handbook Volume 4, Society of Automotive Engineers (SAE), Warrendale, Pennsylvania, 1985.

9 APPENDICES

Appendix A. NJDOT PCB Standard Plans



NOTES:

1. CHANGES TO THE PROPOSED JOINT CLASS AT ANY LOCATION MUST BE APPROVED BY THE DEPT.
2. NO ROADWAY DROP OFFS, OBSTRUCTIONS, STORAGE OF MATERIALS OR WORK WILL BE PERMITTED IN THE CLEAR AREA UNLESS APPROVED BY THE R.E.

STAGE	LOCATION	JOINT CLASS
	RTE. STA. TO STA.	

JOINT CLASS	CLEAR AREA
A	20 INCHES
B	16 INCHES
C	11 INCHES

REGULATORY APPROACH SPEED OF TRAFFIC	RECOMMENDED SIGHT DISTANCE TO BEGINNING OF CHANNELIZING TAPERS		
	DESIRABLE		MINIMUM
MILES/HOUR	RURAL FEET	URBAN FEET	RURAL AND URBAN FEET
25	375	525	150
30	450	625	200
35	525	725	250
40	600	825	325
45	675	925	400
50	750	1025	475
55	875	1150	550
60	1000	1275	650
65	1050		725

NOTES:

1. AVOIDANCE MANEUVER IS FOR A SPEED, PATH, AND/OR DIRECTION CHANGE PRIOR TO THE BEGINNING OF CHANNELIZING TAPERS.
2. RECOMMENDED DISTANCES BETWEEN TWO SEPARATE LANE CLOSURES SHALL BE DOUBLE THE VALUES SHOWN ABOVE.
3. RURAL AND URBAN ROAD DESIGNATIONS SHALL BE AS DEFINED IN THE NJDOT STATE HIGHWAY STRAIGHT LINE DIAGRAMS.
4. DESIRABLE VALUES SHALL BE PROVIDED WHEREVER POSSIBLE. IF IT IS NOT FEASIBLE OR PRACTICAL TO PROVIDE DESIRABLE VALUES BECAUSE OF HORIZONTAL OR VERTICAL CURVATURE OR IF RELOCATION OF THE TAPER IS NOT POSSIBLE, THEN MINIMUM VALUES CAN BE APPLIED. WHEN MINIMUM VALUES ARE USED, SPECIAL ATTENTION SHOULD BE GIVEN TO THE USE OF SUITABLE TRAFFIC CONTROL DEVICES FOR PROVIDING ADVANCED WARNING OF THE CONDITIONS THAT ARE LIKELY TO BE ENCOUNTERED.
5. TAPERS SHALL BE LOCATED TO MAXIMIZE THE VISIBILITY OF THEIR TOTAL LENGTH.

RECOMMENDED TAPER LENGTH AND SPACING FOR CHANNELIZING TAPERS						RECOMMENDED SPACING ALONG TANGENTS
REGULATORY APPROACH SPEED OF TRAFFIC MILES/HOUR	MINIMUM TAPER RATIO IN LENGTH PER FOOT OF WIDTH	MINIMUM TAPER LENGTH L – FOR LANE WIDTHS 10'	11'	12'	MAXIMUM DEVICE (B) SPACING ALONG TAPERS IN FEET	MAXIMUM DEVICE (D) SPACING ALONG TANGENTS IN FEET
25	10.5:1	105	115	125	25	50
30	15:1	150	165	180	30	60
35	20.5:1	205	225	245	35	70
40	27:1	270	300	325	40	80
45	45:1	450	495	540	45	90
50	50:1	500	550	600	50	100
55	55:1	550	605	660	55	110
60	60:1	600	660	720	60	120
65	65:1	650	715	780	65	130

NOTE:

THE MAXIMUM DEVICE SPACING ALONG CURVES SHALL BE AS DEFINED FOR TAPERS (B) IN THE ABOVE TABLE.

NOTE TO DESIGNER:

THIS SHEET REQUIRES DESIGN SPECIFIC INFORMATION TO BE ADDED AND INCLUDED IN THE CONTRACT PLANS.

REMOVE THIS NOTE AFTER DESIGN SPECIFIC INFORMATION IS ADDED.

Figure A-1. NJDOT PCB Standard Plans

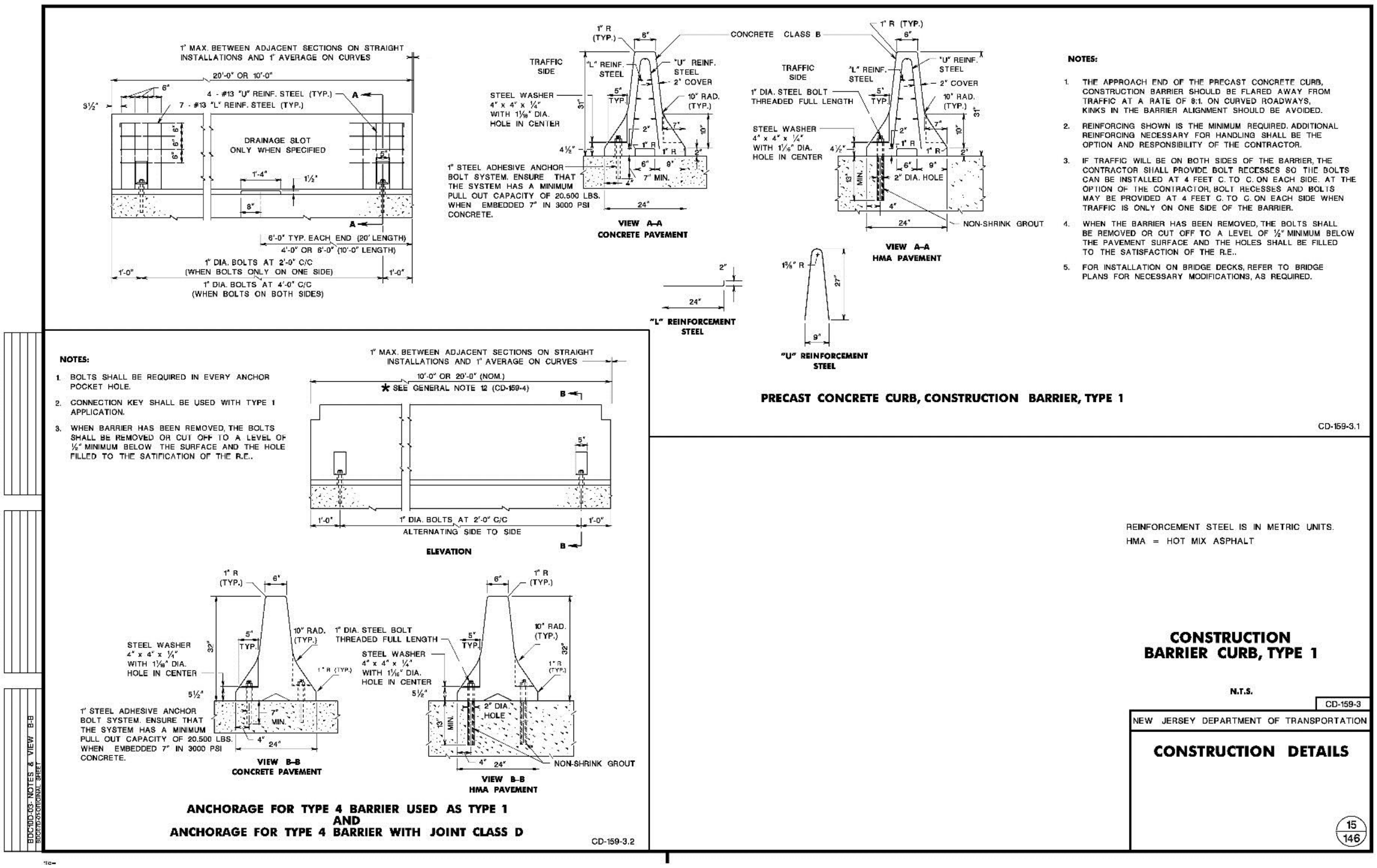


Figure A-2. NJDOT PCB Standard Plans

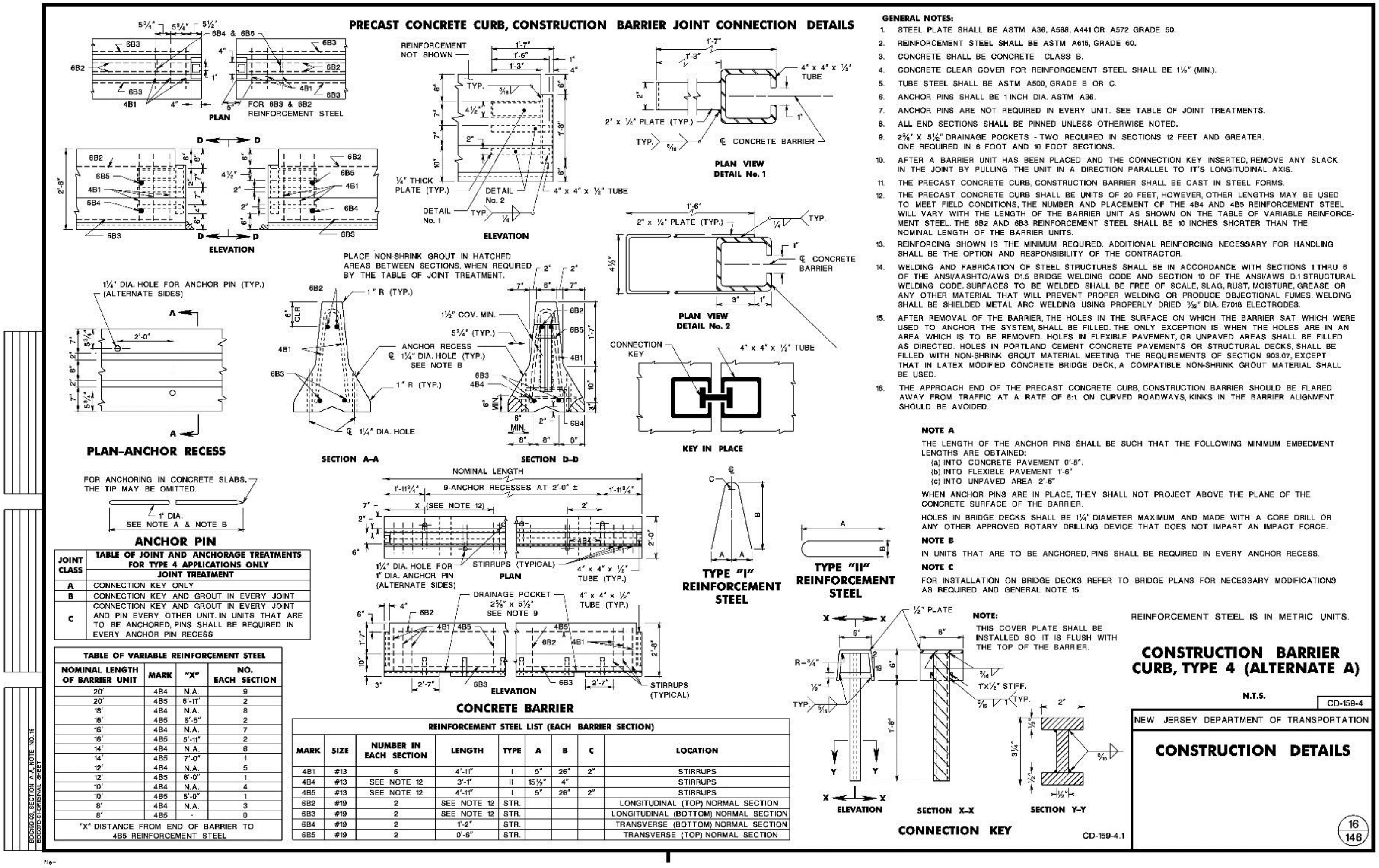


Figure A-3. NJDOT PCB Standard Plans

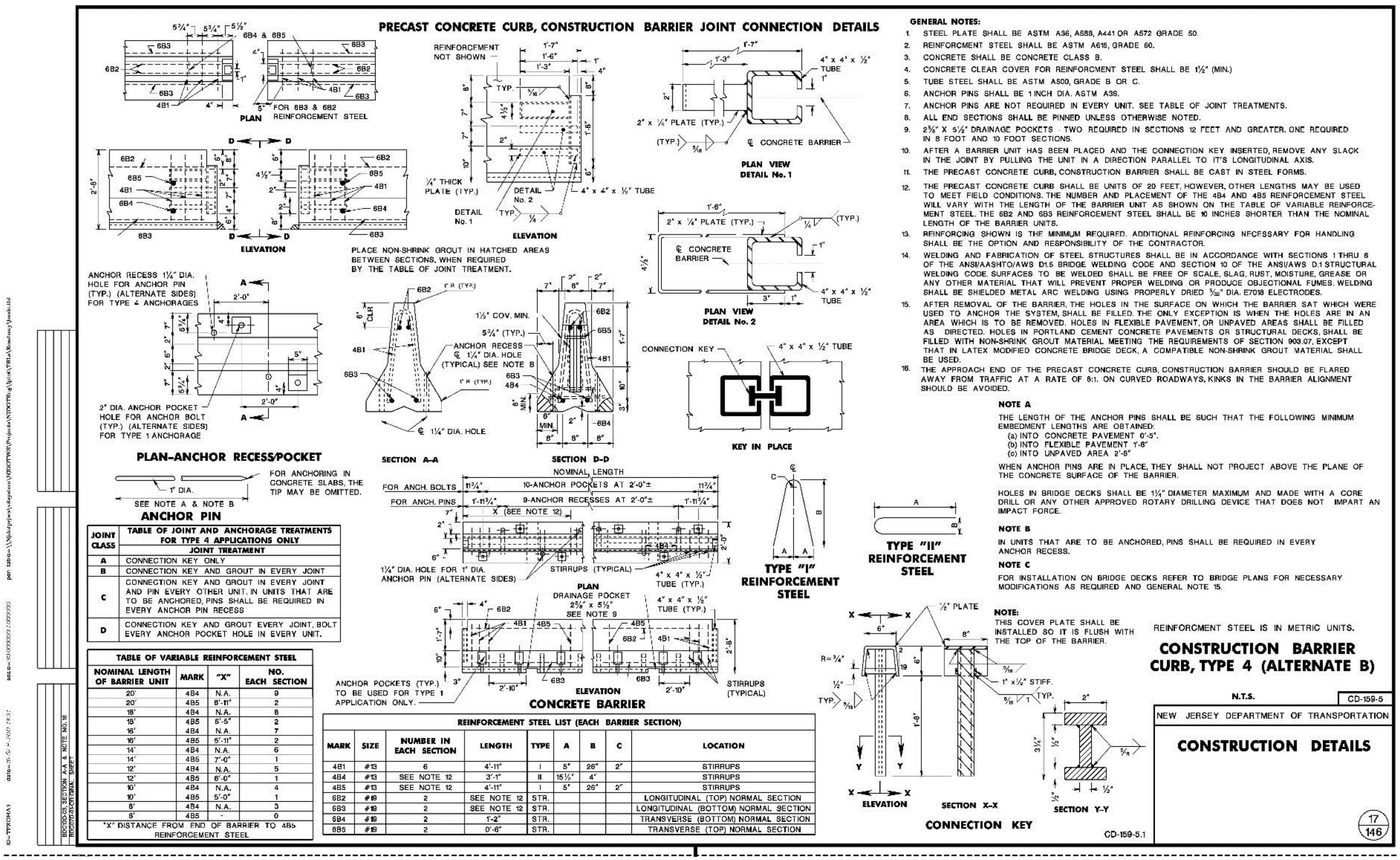


Figure A-4. NJDOT PCB Standard Plans

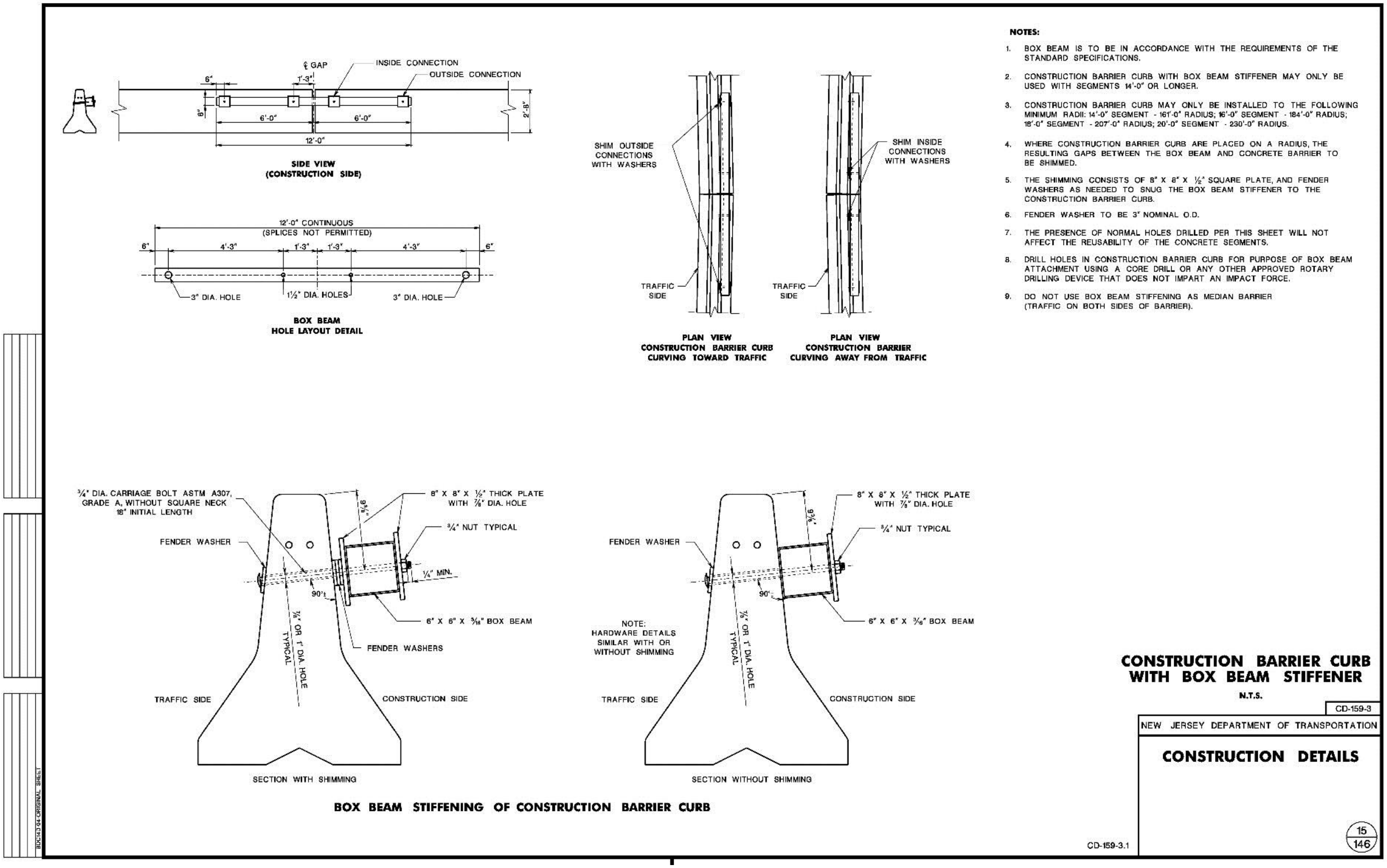


Figure A-5. NJDOT PCB Standard Plans

Appendix B. Material Specifications

Table B-1. Bill of Materials, Test No. NJPCB-1

Item No.	Description	Material Specification	Reference
A1	Concrete Barrier Segment	Min. f'c = 3,700 psi (25.5 MPa)	University of Nebraska 15-563
A2	Anchor Steel Pin	ASTM A36	Barrier #1: Heat #54147657 Other Barriers: Heat #54141812
B1	Rebar - #4 Vertical Stirrup	ASTM A615 Gr. 60	Heat #61101274, 61101493, 61101510, 61101492, 61101499, 61101772
B2, B3	Rebar - #6 Longitudinal Bar	ASTM A615 Gr. 60	Heat #6115448, 61105472
B4	Rebar - #4 Horizontal Anchor Recess, Reinforcement Stirrup	ASTM A615 Gr. 60	Heat #61101274, 61101493, 61101510, 61101492, 61101499, 61101772
B5	Rebar - #6 Top and Bottom Cross Bar	ASTM A615 Gr. 60	Heat #6115448, 61105472
C1	Steel Tube – 4”×4”×½” (102×102×12.7) thick × 20” (508) long	ASTM A500 Gr. B and C	Heat #821597, 1422428, M04495_1, T83539, SD5020
C2	Bent Steel Plate 1, 2”×¼”	ASTM A36	Heat #1129849
C3	Bent Steel Plate 2, 2”×¼”	ASTM A36	Heat #1129849
D1	Steel Plate 1, 2”×½”	ASTM A36	Heat #L99837
D2	Steel Plate 2, 2-¼”×½”	ASTM A36	Heat #54144612
D3	½” (13) Steel Plate – Stiffener	ASTM A36	Heat #54144612, L99837
D4	½” (13) Steel Plate – Top Plate	ASTM A36	Heat #54144612, L99837
E1	Non-Shrink Grout	Min. 1-day Compressive Strength 1,000 psi (6.9 MPa)	Advantage Grout ASTM C1107 Product Code: 67435

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15-563

Cast Date	Age (days)	Cylinder 1	Cylinder 2	Average	Age (days)	Cylinder 1	Cylinder 2	Average	Age (days)	Cylinder 1	Cylinder 2	Average	Air	Slump	Concrete Temp.	Ambient Temp	EMAIL, Mailed, etc
10/26/2015	1	4171	3869	4020	7	7805	7800	7803	28			0	5.5	6 3/4	60	58	
10/27/2015	1	3539	3883	3711	7	7343	7624	7484	28			0	6.8	5 3/4	62	60	
10/28/2015	1	4116	4311	4214	7	6223	6340	6282	28			0	6.0	6 1/2	64	64	
10/29/2015	1	3831	3544	3688	7	7046	6998	7022	28			0	5.8	6 1/2	67	68	
10/30/2015	3	4571	4608	4590	7	6337	6235	6286	28			0	6.0	6 1/2	64	63	
11/2/2015	1	3125	3062	3094	7	6887	6748	6818	28			0	6.2	5 3/4	64	62	
	1			0	7			0	28			0					
	1			0	7			0	28			0					
	1			0	7			0	28			0					
	1			0	7			0	28			0					
	1			0	7			0	28			0					
	1			0	7			0	28			0					
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	1			0	7			0	28			0					
	1			0	7			0	28			0					
	1			0	7			0	28			0					
	1			0	7			0	28			0					
	1			0	7			0	28			0					
	1			0	7			0	28			0					
	1			0	7			0	28			0					
	1			0	7			0	28			0					
	1			0	7			0	28			0					
	1			0	7			0	28			0					
	1			0	7			0	28			0					

Figure B-2. Concrete Barrier Segment – Concrete Strength, Test No. NJPCB-1

CERTIFIED MATERIAL TEST REPORT Page 1/1

GERDAU

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

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	
STEEL & PIPE SUPPLY CO INC 1003 FORT GIBSON RD CATOOSA,OK 74015-3033 USA	STEEL & PIPE SUPPLY CO INC MANHATTAN,KS 66505-1688 USA	A36/44W	Round Bar / 1"	
		LENGTH 20'00"	WEIGHT 9,836 LB	HEAT / BATCH 54147657/02
SALES ORDER 3112389/000010	CUSTOMER MATERIAL Nº 000000000009010020	SPECIFICATION / DATE or REVISION ASME SA36 ASTM A6-14, A36-14 ASTM A709-13A, AASHTO M270-12 CSA G40.20-13/G40.21-13		

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
4500255395	1321-0000036206	12/23/2015

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	V %	Nb %	Sn %
0.20	0.75	0.012	0.031	0.19	0.33	0.16	0.11	0.040	0.002	0.002	0.024

MECHANICAL PROPERTIES

Elong. %	G/L Inch	UTS PSI	UTS MPa	YS PSI	YS MPa
30.00	8.000	76810	530	53412	368

GEOMETRIC CHARACTERISTICS

R:R
32.00

COMMENTS / NOTES

R#16-0338 H#54147657
NJ PCB-1 Barrier #1 ONLY
1"x15" Round Pins

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

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

JORDAN FOSTER
QUALITY ASSURANCE MGR.

Figure B-3. Anchor Pins Material Certificate, Test No. NJPCB-1

GERDAU

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

CERTIFIED MATERIAL TEST REPORT

Page 1/1

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE
STEEL & PIPE SUPPLY CO INC JONESBURG INDUSTRIAL PARK JONESBURG,MO 63351 USA	STEEL & PIPE SUPPLY CO INC MANHATTAN,KS 66505-1688 USA	A36/44W	Round Bar / 1"

LENGTH	WEIGHT	HEAT / BATCH
20'00"	14,968 LB	54141812/02

SALES ORDER	CUSTOMER MATERIAL N°
1384530/000040	000000000009010020

SPECIFICATION / DATE or REVISION
1-ASTM A6/A6M-11, A36/A36M-08
2-A709/A709M-11 GR36
3-CSA G40.21-04(R2009) 44W

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
4500233654	1321-0000027245	12/18/2014

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	V %	Nb %	Sn %
0.17	0.69	0.018	0.031	0.19	0.41	0.13	0.11	0.030	0.001	0.001	0.014

MECHANICAL PROPERTIES

Elong. %	G/L Inch	UTS PSI	UTS MPa	YS PSI	YS MPa
23.20	8.000	77428	534	54195	374

GEOMETRIC CHARACTERISTICS

R:R
32.00

COMMENTS / NOTES

R#16-0230 ASTM A36 1"x15" Round Bar
New Jersey TCB Barrer Anchor Dowel Pins
H#54141812 R#16-0230 December 2015

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

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

JORDAN FOSTER
QUALITY ASSURANCE MGR

Figure B-4. Anchor Pins Material Certificate, Test No. NJPCB-1

CERTIFIED MATERIAL TEST REPORT

Page 1/1

GERDAU

US-ML-SAYREVILLE
NORTH CROSSMAN ROAD
SAYREVILLE, NJ 08872
USA

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE
RE STEEL SUPPLY CO INC 2000 EDDYSTONE INDUSTRIAL PARK EDDYSTONE,PA 19022 USA	RE STEEL SUPPLY CO INC 2000 EDDYSTONE INDUSTRIAL PARK EDDYSTONE,PA 19022-1588 USA	60 (420)	Rebar / #4 (13MM)

LENGTH	WEIGHT	HEAT / BATCH
40'00"	5,050 LB	61101274/02

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
1785955/000010		ASTM A615/A615M-14

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
BB 22777	1331-0000029243	01/23/2015

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqyA706 %
0.43	0.66	0.012	0.048	0.23	0.43	0.16	0.05	0.046	0.019	0.017	0.56

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
66850	461	93950	648	8.000	200.0
67400	465	95100	656	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
13.50	OK
13.50	OK

GEOMETRIC CHARACTERISTICS

%Light %	Def Hgt Inch	Def Gap Inch	DefSpace Inch
4.10	0.030	0.099	0.320
3.20	0.030	0.099	0.320

COMMENTS / NOTES

This grade meets the requirements for the following grades:

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

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

JOSEPH T HOMIC
QUALITY ASSURANCE MGR.

Figure B-5. Rebar No. 4 Material Certificate, Test No. NJPCB-1

GERDAU

US-ML-SAYREVILLE
NORTH CROSSMAN ROAD
SAYREVILLE, NJ 08872
USA

CERTIFIED MATERIAL TEST REPORT

Page 1/1

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE
RE STEEL SUPPLY CO INC 2000 EDDYSTONE INDUSTRIAL PARK EDDYSTONE,PA 19022 USA	RE STEEL SUPPLY CO INC 2000 EDDYSTONE INDUSTRIAL PARK EDDYSTONE,PA 19022-1588 USA	60 (420)	Rebar / #4 (13MM)

LENGTH	WEIGHT	HEAT / BATCH
40'00"	5,023 LB	61101493/04

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
1785955/000010		ASTM A615/A615M-14

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
BB 22777	1331-0000029243	01/23/2015

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqyA706 %
0.42	0.65	0.012	0.058	0.19	0.43	0.15	0.09	0.056	0.020	0.009	0.56

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
71350	492	104900	723	8.000	200.0
71250	491	105600	728	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
13.00	OK
11.50	OK

GEOMETRIC CHARACTERISTICS

%Light %	Def Hgt Inch	Def Gap Inch	DefSpace Inch
2.70	0.032	0.098	0.321
1.40	0.034	0.099	0.321

COMMENTS / NOTES

This grade meets the requirements for the following grades:

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

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

JOSEPH T HOMOC
QUALITY ASSURANCE MGR.

Figure B-6. Rebar No. 4 Material Certificate, Test No. NJPCB-1

GERDAU

US-ML-SAYREVILLE
NORTH CROSSMAN ROAD
SAYREVILLE, NJ 08872
USA

CERTIFIED MATERIAL TEST REPORT

Page 1/1

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE
RE STEEL SUPPLY CO INC 2000 EDDYSTONE INDUSTRIAL PARK EDDYSTONE,PA 19022 USA	RE STEEL SUPPLY CO INC 2000 EDDYSTONE INDUSTRIAL PARK EDDYSTONE,PA 19022-1588 USA	60 (420)	Rebar / #4 (13MM)

LENGTH	WEIGHT	HEAT / BATCH
40'00"	5,050 LB	61101510/03

SALES ORDER	CUSTOMER MATERIAL Nº	SPECIFICATION / DATE or REVISION
1785955/000010		ASTM A615/A615M-14

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
BB 22777	1331-0000029243	01/23/2015

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqyA706 %
0.42	0.66	0.018	0.046	0.21	0.30	0.11	0.06	0.035	0.018	0.015	0.55

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
73400	506	107150	739	8.000	200.0
75600	521	110500	762	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
12.00	OK
13.00	OK

GEOMETRIC CHARACTERISTICS

%Light %	Def Hgt Inch	Def Gap Inch	DefSpace Inch
2.40	0.032	0.080	0.322
2.30	0.032	0.080	0.322

COMMENTS / NOTES

This grade meets the requirements for the following grades:

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

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

JOSEPH T HOMIC
QUALITY ASSURANCE MGR.

Figure B-7. Rebar No. 4 Material Certificate, Test No. NJPCB-1

GERDAU

US-ML-SAYREVILLE
NORTH CROSSMAN ROAD
SAYREVILLE, NJ 08872
USA

CERTIFIED MATERIAL TEST REPORT

Page 1/1

CUSTOMER SHIP TO	CUSTOMER BILL TO
RE STEEL SUPPLY CO INC 2000 EDDYSTONE INDUSTRIAL PARK EDDYSTONE,PA 19022 USA	RE STEEL SUPPLY CO INC 2000 EDDYSTONE INDUSTRIAL PARK EDDYSTONE,PA 19022-1588 USA

GRADE	SHAPE / SIZE
60 (420)	Rebar / #4 (13MM)

LENGTH	WEIGHT	HEAT / BATCH
40'00"	10,020 LB	61101492/02

SALES ORDER	CUSTOMER MATERIAL N°
1785955/000010	

SPECIFICATION / DATE or REVISION
ASTM A615/A615M-14

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
BB 22777	1331-0000029243	01/23/2015

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqyA706 %
0.43	0.67	0.014	0.054	0.20	0.43	0.21	0.10	0.064	0.018	0.017	0.57

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
65150	449	96100	663	8.000	200.0
68450	472	99600	687	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
15.00	OK
15.50	OK

GEOMETRIC CHARACTERISTICS

%Light %	Def Hgt Inch	Def Gap Inch	DefSpace Inch
3.60	0.031	0.078	0.322
1.70	0.029	0.090	0.322

COMMENTS / NOTES

This grade meets the requirements for the following grades:

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

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

JOSEPH T HOMIC
QUALITY ASSURANCE MGR.

Figure B-8. Rebar No. 4 Material Certificate, Test No. NJPCB-1

CERTIFIED MATERIAL TEST REPORT

Page 1/1

GERDAU

US-ML-SAYREVILLE
NORTH CROSSMAN ROAD
SAYREVILLE, NJ 08872
USA

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE
RE STEEL SUPPLY CO INC 2000 EDDYSTONE INDUSTRIAL PARK EDDYSTONE,PA 19022 USA	RE STEEL SUPPLY CO INC 2000 EDDYSTONE INDUSTRIAL PARK EDDYSTONE,PA 19022-1588 USA	60 (420)	Rebar / #4 (13MM)

LENGTH	WEIGHT	HEAT / BATCH
40'00"	5,050 LB	61101499/04

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
1785955/000010		ASTM A615/A615M-14

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
BB 22777	1331-0000029243	01/23/2015

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqyA706 %
0.43	0.68	0.026	0.064	0.21	0.33	0.21	0.19	0.066	0.016	0.012	0.58

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
70900	489	105500	727	8.000	200.0
68950	475	103200	712	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
11.00	OK
11.00	OK

GEOMETRIC CHARACTERISTICS

%Light %	Def Hgt Inch	Def Gap Inch	DefSpace Inch
1.90	0.032	0.088	0.321
1.90	0.032	0.086	0.321

COMMENTS / NOTES

This grade meets the requirements for the following grades:

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

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

JOSEPH T HOMIC
QUALITY ASSURANCE MGR.

Figure B-9. Rebar No. 4 Material Certificate, Test No. NJPCB-1

GERDAU

US-ML-SAYREVILLE
NORTH CROSSMAN ROAD
SAYREVILLE, NJ 08872
USA

CERTIFIED MATERIAL TEST REPORT

Page 1/1

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	
RE STEEL SUPPLY CO INC 2000 EDDYSTONE INDUSTRIAL PARK EDDYSTONE,PA 19022 USA	RE STEEL SUPPLY CO INC 2000 EDDYSTONE INDUSTRIAL PARK EDDYSTONE,PA 19022-1588 USA	60 (420)	Rebar / #4 (13MM)	
		LENGTH 40'00"	WEIGHT 4,008 LB	HEAT / BATCH 61101772/04

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
1785955/000010		ASTM A615/A615M-14

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
BB 22777	1331-0000029243	01/23/2015

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqyA706 %
0.44	0.67	0.019	0.059	0.20	0.38	0.16	0.06	0.047	0.017	0.016	0.57

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
66400	458	96900	668	8.000	200.0
65850	454	97700	674	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
16.00	OK
17.00	OK

GEOMETRIC CHARACTERISTICS

%Light %	Def Hgt Inch	Def Gap Inch	DefSpace Inch
1.10	0.025	0.099	0.320
0.80	0.029	0.115	0.320

COMMENTS / NOTES

This grade meets the requirements for the following grades:

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

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

JOSEPH T HOMIC
QUALITY ASSURANCE MGR.

Figure B-10. Rebar No. 4 Material Certificate, Test No. NJPCB-1

GERDAU

US-ML-SAYREVILLE
NORTH CROSSMAN ROAD
SAYREVILLE, NJ 08872
USA

CERTIFIED MATERIAL TEST REPORT

Page 1/1

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE
RE STEEL SUPPLY CO INC 2000 EDDYSTONE INDUSTRIAL PARK EDDYSTONE,PA 19022 USA	RE STEEL SUPPLY CO INC 2000 EDDYSTONE INDUSTRIAL PARK EDDYSTONE,PA 19022-1588 USA	60 (420)	Rebar / #6 (19MM)

LENGTH	WEIGHT	HEAT / BATCH
40'00"	30,282 LB	**61105448**/03

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
2886827/000020		ASTM A615/A615M-15

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
BB-23635	1331-0000038904	10/08/2015

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqyA706 %
0.48	0.75	0.010	0.064	0.23	0.33	0.18	0.09	0.036	0.028	0.018	0.65

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
70159	484	107318	740	8.000	200.0
70590	487	108364	747	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
14.00	OK
13.00	OK

GEOMETRIC CHARACTERISTICS

%Light %	Def Hgt Inch	Def Gap Inch	DefSpace Inch
5.80	0.040	0.090	0.477
5.80	0.040	0.090	0.477

COMMENTS / NOTES

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

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

JOSEPH T HOMIC
QUALITY ASSURANCE MGR.

Figure B-11. Rebar No. 6 Material Certificate, Test No. NJPCB-1

Page 1/1

CERTIFIED MATERIAL TEST REPORT

GERDAU

US-ML-SAYREVILLE
NORTH CROSSMAN ROAD
SAYREVILLE, NJ 08872
USA

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE
RE STEEL SUPPLY CO INC 2000 EDDYSTONE INDUSTRIAL PARK EDDYSTONE,PA 19022 USA	RE STEEL SUPPLY CO INC 2000 EDDYSTONE INDUSTRIAL PARK EDDYSTONE,PA 19022-1588 USA	60 (420)	Rebar / #6 (19MM)

LENGTH	WEIGHT	HEAT / BATCH
40'00"	4,987 LB	**61105472**/03

SALES ORDER	CUSTOMER MATERIAL Nº	SPECIFICATION / DATE or REVISION
2886827/000020		ASTM A615/A615M-15

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
BB-23635	1331-0000038904	10/08/2015

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqyA706 %
0.46	0.72	0.019	0.048	0.21	0.38	0.15	0.14	0.036	0.017	0.022	0.63

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
73296	505	106977	738	8.000	200.0
73386	506	107455	741	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
13.00	OK
15.00	OK

GEOMETRIC CHARACTERISTICS

%Light %	Def Hgt Inch	Def Gap Inch	DefSpace Inch
4.20	0.058	0.072	0.481
4.50	0.058	0.072	0.481

COMMENTS / NOTES

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

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

JOSEPH T HOMIC
QUALITY ASSURANCE MGR.

Figure B-12. Rebar No. 6 Material Certificate, Test No. NJPCB-1

Customer Name	Customer PO#	Shipper No	Heat Number
Seibel Modern Mfg.	Leon	273924	821597

Atlas Tube Canada ULC
200 Clark St.
Harrow, Ontario, Canada
N0R 1G0
Tel: 519-738-3541
Fax: 519-738-3537

Atlas Tube
JMC STEEL GROUP

Ref.B/L: 80664351
Date: 05.08.2015
Customer: 1497

MATERIAL TEST REPORT

Sold to

Triad Metals International
1 Village Road
HORSHAM PA 19044-3812
USA

Shipped to

Triad Metals International
3507 Grand Avenue
PITTSBURGH PA 15225
USA

Material: 3.0x3.0x125x24'0"0(7x7). Material No: 300301252400 Made In: Canada
Sales order: 989576 Purchase Order: 75461 Melted in: Canada

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
821195	0.190	0.810	0.009	0.007	0.019	0.044	0.060	0.006	0.006	0.026	0.045	0.002	0.002	0.000	0.003

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M101451859	49	063780 Psi	077160 Psi	26.6 %	ASTM A500-13 GRADE B&C	0.34

Material Note:
Sales Or.Note:

Material: 4.0x4.0x500x40'0"0(4x2). Material No: 400405004000 Made in: Canada
Sales order: 995107 Purchase Order: 76312 Melted in: Canada

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
775533	0.200	0.810	0.012	0.010	0.015	0.031	0.032	0.006	0.002	0.011	0.032	0.002	0.002	0.000	0.003

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M101454130	1	066980 Psi	075080 Psi	27.0 %	ASTM A500-13 GRADE B&C	0.35

Material Note:
Sales Or.Note:

Material: 4.0x4.0x500x40'0"0(4x2). Material No: 400405004000 Made in: Canada
Sales order: 995107 Purchase Order: 76312 Melted in: Canada

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
821597	0.210	0.780	0.011	0.009	0.013	0.040	0.026	0.006	0.004	0.013	0.031	0.002	0.002	0.000	0.004

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M101454130	7	069700 Psi	078390 Psi	27.2 %	ASTM A500-13 GRADE B&C	0.35

Material Note:
Sales Or.Note:

Marvin Phillips

Authorized by Quality Assurance:
The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
CE calculated using the AWS D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Page : 1 Of 4

Metals Service Center Institute

Figure B-13. Steel Tube Material Certificate, Test No. NJPCB-1

Customer Name	Customer PO#	Shipper No	Heat Number
Seibel Modern Mfg.	Leon	273924	821597

Atlas Tube Canada ULC
200 Clark St.
Harrow, Ontario, Canada
N0R 1G0
Tel: 519-738-3541
Fax: 519-738-3537

Atlas Tube
JMC STEEL GROUP

Ref.B/L: 80664351
Date: 05.08.2015
Customer: 1497

MATERIAL TEST REPORT

Sold to
Triad Metals International
1 Village Road
HORSHAM PA 19044-3812
USA

Shipped to
Triad Metals International
3507 Grand Avenue
PITTSBURGH PA 15225
USA

Material: 4.0x4.0x500x40'0"0(4x2). Material No: 400405004000 Made in: Canada Melted in: Canada
Sales order: 995107 Purchase Order: 76312

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
821597	0.210	0.780	0.011	0.009	0.013	0.040	0.026	0.006	0.004	0.013	0.031	0.002	0.002	0.000	0.004

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M101454131	8	069700 Psi	078390 Psi	27.2 %	ASTM A500-13 GRADE B&C	0.35

Material Note:
Sales Or.Note:

Material: 6.0x2.0x188x24'0"0(3x9). Material No: 600201882400 Made in: Canada Melted in: Canada
Sales order: 995107 Purchase Order: 76312

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
821679	0.180	0.790	0.010	0.008	0.015	0.040	0.047	0.002	0.005	0.023	0.038	0.002	0.002	0.000	0.004

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M101453723	27	058410 Psi	069080 Psi	33.3 %	ASTM A500-13 GRADE B&C	0.33

Material Note:
Sales Or.Note:

Material: 6.0x6.0x188x40'0"0(3x3). Material No: 600601884000 Made in: Canada Melted in: Canada
Sales order: 1001173 Purchase Order: 77498

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
821531	0.190	0.810	0.013	0.006	0.017	0.059	0.051	0.005	0.004	0.015	0.036	0.002	0.002	0.000	0.004

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M101456164	9	063160 Psi	078380 Psi	30.5 %	ASTM A500-13 GRADE B&C	0.34

Material Note:
Sales Or.Note:

Authorized by Quality Assurance:
The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
Calculated using the AWS D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Page : 2 Of 4

Metals Service Center Institute

Figure B-14. Steel Tube Material Certificate, Test No. NJPCB-1

Customer Name	Customer PO#	Shipper No	Heat Number
Seibel Modern Mfg.	Leon	273924	1422428

Atlas ABC Corp (Atlas Tube Chicago)
1855 East 122nd Street
Chicago, Illinois, USA
60633
Tel: 773-646-4500
Fax: 773-646-6128

Atlas Tube
JMC STEEL GROUP

Ref.B/L: 80660765
Date: 04.15.2015
Customer: 1497

MATERIAL TEST REPORT

Sold to
Triad Metals International
1 Village Road
HORSHAM PA 19044-3812
USA

Shipped to
Triad Metals International
3507 Grand Avenue
PITTSBURGH PA 15225
USA

Material: 4.0x4.0x500x40'0"0(4x2). Material No: 400405004000 Made in: USA
Sales order: 989623 Purchase Order: 75462 Melted in: Russian Fed.

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
1422428	0.200	0.930	0.007	0.010	0.013	0.043	0.040	0.000	0.000	0.020	0.030	0.000	0.000	0.000	0.006

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800549020	3	070619 Psi	081004 Psi	36 %	ASTM A500-13 GRADE B&C	0.37

Material Note:
Sales Or.Note:

Material: 4.0x4.0x500x40'0"0(4x2). Material No: 400405004000 Made in: USA
Sales order: 989623 Purchase Order: 75462 Melted in: Russian Fed.

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
1422428	0.200	0.930	0.007	0.010	0.013	0.043	0.040	0.000	0.000	0.020	0.030	0.000	0.000	0.000	0.006

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800549017	8	070619 Psi	081004 Psi	36 %	ASTM A500-13 GRADE B&C	0.37

Material Note:
Sales Or.Note:

Material: 20.0x4.0x313x48'0"0(1x4). Material No: 2000403134800 Made in: USA
Sales order: 994677 Purchase Order: 75051-replacement Melted in: USA

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
A73575	0.200	0.490	0.009	0.002	0.030	0.034	0.120	0.000	0.020	0.060	0.050	0.001	0.002	0.000	0.009

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M900754817	4	057121 Psi	074148 Psi	30 %	ASTM A500-13 GRADE B&C	0.31

Material Note:
Sales Or.Note:

Authorized by Quality Assurance:
The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
Calculated using the AWS D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Page : 3 Of 3

Metals Service Center Institute

Figure B-15. Steel Tube Material Certificate, Test No. NJPCB-1

Customer Name	Customer PO#	Shipper No	Heat Number
Seibel Modern Mfg.	Leon	273924	M04495_1

Atlas ABC Corp (Atlas Tube Chicago)
1855 East 122nd Street
Chicago, Illinois, USA
60633
Tel: 773-646-4500
Fax: 773-646-6128

Atlas Tube
JMC STEEL GROUP

Ref.B/L: 80665303
Date: 05.18.2015
Customer: 1497

MATERIAL TEST REPORT

Sold to

Triad Metals International
1 Village Road
HORSHAM PA 19044-3812
USA

Shipped to

Triad Metals International
3507 Grand Avenue
PITTSBURGH PA 15225
USA

Material: 4.0x4.0x500x48'0"0(3x2). Material No: 400405004800 Made in: USA
Melted in: USA

Sales order: 989623 Purchase Order: 75462

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
M04495_1	0.190	0.750	0.014	0.010	0.019	0.050	0.050	0.004	0.004	0.010	0.040	0.001	0.001	0.000	0.005

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification
M800554030	2	072918 Psi	082550 Psi	35 %	ASTM A500-13 GRADE B&C

CE: 0.33

Material Note:
Sales Or.Note:

Authorized by Quality Assurance:
The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
CE calculated using the AWS D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Page : 4 Of 4

Metals Service Center Institute

Figure B-16. Steel Tube Material Test Certificate, Test No. NJPCB-1

Customer Name	Customer PO#	Shipper No	Heat Number
Seibel Modern Mfg.	Leon	273924	T83539

Atlas ABC Corp (Atlas Tube Chicago)
1855 East 122nd Street
Chicago, Illinois, USA
60633
Tel: 773-646-4500
Fax: 773-646-6128

Atlas *Tube*
JMC STEEL GROUP

Ref.B/L: 80619794
Date: 08.22.2014
Customer: 1497

MATERIAL TEST REPORT

Sold to
Triad Metals International
1 Village Road
HORSHAM PA 19044-3812
USA

Shipped to
Triad Metals International
3500 Neville Road
NEVILLE ISLAND PA 15225
USA

Material: 4.0x4.0x375x48'0"0(4x2). Material No: 400403754800 Made in: USA Melted in: USA

Sales order: 934921 Purchase Order: 67358

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
E84203	0.190	0.800	0.015	0.011	0.021	0.050	0.040	0.005	0.006	0.010	0.040	0.001	0.001	0.000	0.004

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800504131	8	071476 Psi	081675 Psi	32 %	ASTM A500-13 GRADE B&C	0.34

Material Note:
Sales Or.Note:

Material: 4.0x4.0x500x40'0"0(4x2). Material No: 400405004000 Made in: USA Melted in: USA

Sales order: 934921 Purchase Order: 67358

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
T83539	0.200	0.820	0.012	0.007	0.015	0.054	0.020	0.007	0.004	0.010	0.040	0.001	0.001	0.000	0.005

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M800500342	8	072654 Psi	085933 Psi	29 %	ASTM A500-13 GRADE B&C	0.35

Material Note:
Sales Or.Note:

Material: 12.0x12.0x250x40'0"0(2x2). Material No: 1201202504000 Made in: USA Melted in: USA

Sales order: 933979 Purchase Order: 67228

Heat No	C	Mn	P	S	Si	Al	Cu	Cb	Mo	Ni	Cr	V	Ti	B	N
T84047	0.180	0.800	0.008	0.007	0.015	0.045	0.020	0.003	0.003	0.010	0.040	0.001	0.001	0.000	0.007

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE
M900697115	4	055286 Psi	073956 Psi	28 %	ASTM A500-13 GRADE B&C	0.33

Material Note:
Sales Or.Note:

Marvin Phillips

Authorized by Quality Assurance:
The results reported on this report represent the actual attributes of the material furnished and indicate full compliance with all applicable specification and contract requirements.
CE calculated using the AWS D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Page : 1 Of 4

Metals Service Center Institute

Figure B-17. Steel Tube Material Certificate, Test No. NJPCB-1

Customer Name	Customer PO#	Shipper No	Heat Number
Seibel Modern Mfg.	Leon	273924	SD5020

Independence Tube

6226 W. 74th St
Chicago, IL 60638
708-496-0380
Fax: 708-563-1950

independencetube.com
itctube.com
Certificate Number: DCR 250913

Sold By:
INDEPENDENCE TUBE CORPORATION
6226 W. 74th St.
Chicago, IL 60638
Tel: 708-496-0380
Fax: 708-563-1950

Purchase Order No: 70783
Sales Order No: DCR 64130 - 5
Bill of Lading No: DCR 43787 - 94
Invoice No:

Shipped: 1/16/2015
Invoiced:

Sold To:
2103 - TRIAD METALS
1 VILLAGE ROAD
HORSHAM, PA 19044-3812

Ship To:
39 - TRIAD METALS BARGE
MILE MARKER 7.3
OHIO RIVER
NEVILLE ISLAND, PA 15225

CERTIFICATE of ANALYSIS and TESTS

Customer Part No:

TUBING A500 GRADE B(C)
4" SQ X 1/2" X 48'

Certificate No: DCR 250913
Test Date: 1/14/2015

Total Pieces	Total Weight
36	37,376

Bundle Tag	Mill	Heat	Pieces	Weight
844458	40	SD5020	9	9,344
844459	40	SD5020	9	9,344
844460	40	SD5020	9	9,344
844461	40	SD5020	9	9,344

Mill #: 40 Heat #: SD5020 Yield: 72,300 psi Tensile: 78,800 psi Elongation: 28.50 % Y/T Ratio: 0.9175 Carbon Eq: 0.1352

C	Mn	P	S	Si	Al	Cu	Cr	Mo	V	Ni	Nb
0.0500	0.3900	0.0090	0.0040	0.2240	0.0260	0.0900	0.0400	0.0200	0.0010	0.0300	0.0080

Certification:

I certify that the above results are a true and correct copy of records prepared and maintained by Independence Tube Corporation. Sworn this day, 1/14/2015

WE PROUDLY MANUFACTURE ALL OF OUR HSS IN THE USA.
INDEPENDENCE TUBE PRODUCT IS MANUFACTURED, TESTED, AND INSPECTED IN ACCORDANCE WITH ASTM STANDARDS.

CURRENT STANDARDS:
..............................A500/A500M-13
..............................A513-12
..............................A252-10
..............................A847/A847M-12

MATERIAL IDENTIFIED AS A500 GRADE B(C) MEETS BOTH ASTM A500 GRADE B AND A500 GRADE C SPECIFICATIONS.

Jose Martinez, QMS Manager

Figure B-18. Steel Tube Material Certificate, Test No. NJPCB-1

MID-AMERICA STEEL CORPORATION
TEST REPORT

No. F33822

TO: SEIBEL MODERN MFG & WELDING

DATE: 02/19/13
P.O. #: SBJ-40

ATTN:

TAG#	SIZE	SPEC
K78419	1/4 x 48.000 x 144.000	A-36
K78420	1/4 x 48.000 x 144.000	A-36
K78421	1/4 x 48.000 x 144.000	A-36
K78422	1/4 x 48.000 x 144.000	A-36

CHEMICAL ANALYSIS

TAG#	HEAT#	C	Mn	P	S
K78419	1129849	0.063	0.760	0.012	0.004
K78420	1129849	0.063	0.760	0.012	0.004
K78421	1129849	0.063	0.760	0.012	0.004
K78422	1129849	0.063	0.760	0.012	0.004

PHYSICAL ANALYSIS

TAG#	HEAT#	TENSILE	YIELD	ELONGATION
K78419	1129849	75,102	58,422	26%
K78420	1129849	75,102	58,422	26%
K78421	1129849	75,102	58,422	26%
K78422	1129849	75,102	58,422	26%

All material made and melted in the U.S.

Thank you,

JOHN RATICA
MID-AMERICA STEEL CORPORATION

Figure B-19. 2-in. × ¼-in. (51-mm × 6-mm) Bent Steel Plate, Test No. NJPCB-1

ArcelorMittal

ArcelorMittal LaPlace
(HARRIMAN)
2404 S. ROANE STREET
HARRIMAN, TENNESSEE 37748
Telephone (865) 882-5100

MATERIAL CERTIFICATION REPORT
METAL TRADER INC. (TRIAD METAL)
1 Village Road
HORSHAM PA 19044
ETATS-UNIS

TRIAD METALS INTERNATIONAL
(WASSELL LAND)
3507 Grand Avenue
PITTSBURGH PA 15225
USA

Tested in Accordance
With: ASTM A6

Sales Order 148953-4
Product Flat bars
Heat NO. L99837
Cust.Mat.
Size 2" X1/2" X3.404

Date 09/09/2015
Cust 40008882
Grade A3652950
Length 20' 00"

PO: 81536
Ref. 80833851
Pieces 288
Weight 19607.04

CHEMICAL ANALYSIS	
C	0.13
Mn	0.88
P	0.007
S	0.018
Si	0.19
Cu	0.24
Ni	0.17
Cr	0.14
Mo	0.065
Cb	0.020
V	0
B	
Al	
Sn	0.012
N	
Ti	
Ci	
CE	

MECHANICAL PROPERTIES	TEST 1 IMPERIAL	TEST 1 METRIC	TEST 2 IMPERIAL	TEST 2 METRIC	TEST 3 IMPERIAL	TEST 3 METRIC
YIELD STRENGTH	52710 PSI	363 MPa	53770 PSI	371 MPa		
TENSILE STRENGTH	72220 PSI	498 MPa	74560 PSI	514 MPa		
ELONGATION	25 %	25 %	25 %	25 %		
GAUGE LENGTH	8 IN	203 mm	8 IN	203 mm		
BEND TEST DIAMETER						
BEND TEST RESULTS						
SPECIMEN AREA						
REDUCTION OF AREA						
IMPACT STRENGTH						

IMPACT STRENGTH	IMPERIAL	METRIC	INTERNAL CLEANLINESS		GRAIN SIZE	
AVERAGE			SEVERITY		HARDNESS	
TEST TEMP			FREQUENCY		GRAIN PRACTICE	
ORIENTATION			RATING		REDUCTION RATIO	

This heat makes the following grades: A36-08,A52950-05,G40.21-CSA50W,CSA44W,A70936-09a, ASME SA36-2010, A57250-07, A70950-10, AASHTO M270 Grade 36,AASHTO M270 Grade 50, AASHTO M270M Grade 345.

I hereby certify that the material test results presented here are from the reported heat and are correct. All tests were performed in accordance to the specification reported above. All steel is electric arc furnace melted (billets), manufactured, processed, tested in the U.S.A with satisfactory results. No weld repair was performed on this heat.

Notarized upon request:
Sworn to and subscribed before me on 9th day of September, 2015

Signed ________ KEITH D. LIMBURG, QUALITY ASSURANCE MANAGER

________________ Notary Public ________________ County

Direct any questions or necessary clarifications concerning this report to the Sales Department 1-800-535-7692(USA)

Figure B-20. ½-in. (13-mm) Thick Steel Plate Material Certificate, Test No. NJPCB-1

CERTIFIED MATERIAL TEST REPORT

Page 1/1

GERDAU

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

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE
TRIAD METALS 3507 GRAND AVE PITTSBURGH,PA 15225 USA	TRIAD METALS INTERNATIONAL MET 1 VILLAGE RD HORSHAM,PA 19044-3800 USA	GGMULTI	Flat / 1/2 X 2 1/4

LENGTH	WEIGHT	HEAT / BATCH
20'00"	4,979 LB	54144612/03

SALES ORDER	CUSTOMER MATERIAL N°
2819476/000010	

SPECIFICATION / DATE or REVISION
A6-13A,A36-12, ASME SA36-13
ASTM A529-05(2009), A572-13A
ASTM A709-13A, AASHTO M270-12
CSA G40.20-13/G40.21-13

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
83055W	1321-0000034345	09/24/2015

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	V %	Nb %	Sn %
0.17	0.71	0.011	0.033	0.20	0.47	0.14	0.17	0.030	0.015	0.002	0.013

MECHANICAL PROPERTIES

Elong. %	G/L Inch	UTS PSI	UTS MPa	YS PSI	YS MPa
29.40	8.000	74174	511	51422	355

GEOMETRIC CHARACTERISTICS

R:R
22.00

COMMENTS / NOTES

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

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

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

JORDAN FOSTER
QUALITY ASSURANCE MGR.

Figure B-21. ½-in. (13-mm) Thick Steel Plate Material Certificate, Test No. NJPCB-1

DAYTON SUPERIOR

1107 Advantage Grout

Cement Based Grout

TECHNICAL DATA SHEET

DESCRIPTION

The 1107 Advantage Grout is a non-shrink, non-metallic, non-corrosive, cementitious grout that is designed to provide a controlled, positive expansion to ensure an excellent bearing area. The 1107 Advantage Grout can be mixed from a fluid to a dry pack consistency.

USE

Exterior grouting of structural column base plates, pump and machinery bases, anchoring bolts, dowels, bearing pads and keyway joints. It finds applications in paper mills, oil refineries, food plants, chemical plants, sewage and water treatment plants etc.

FEATURES

- Controlled, net positive expansion
- Non shrink
- Non metallic/non corrosive
- Pourable, pumpable or dry pack consistency
- Interior/exterior applications

PROPERTIES

Corps of Engineers Specification for non-shrink grout:

CRD-C 621 Grades A, B, C

ASTM C-1107 Grades A, B, C

ASTM C-827 - 1107 Advantage Grout yielded a controlled positive expansion

Expansion - ASTM C-1090:

1 day: 0-0.3

3 days: 0-0.3

14 days: 0-0.3

28 days: 0-0.3

Test Results

	@ 1 Day		@ 3 Days		@ 7 Days		@ 28 Days	
Fluidity	PSI	MPa	PSI	MPa	PSI	MPa	PSI	MPa
Dry-Pack	5000	34.5	7000	48.2	9000	62.0	10000	68.9
Flowable	2500	17.2	5000	34.5	6000	41.4	8000	55.1
Fluid	2000	13.8	4000	27.6	5000	34.5	7500	51.7

Note:
The data shown is typical for controlled laboratory conditions. Reasonable variation from these results can be expected due to interlaboratory precision and bias. When testing the field mixed material, other factors such as variations in mixing, water content, temperature and curing conditions should be considered.

Estimating Guide

Yield (Flowable Consistency):
0.43 cu. ft./50 lbs. (0.0122 cu. M/22.67 kg) bag
0.59 cu. ft./50 lbs. (0.017 cu. M/22.67 kg) bag extended with 25 lbs. (11.34 kg) of washed 3/8 in. (1cm) pea gravel

Packaging

PRODUCT CODE	PACKAGE	SIZE	
		lbs	kg
67435	Bag	50	22.67
67437	Supersack	3,000	1,360.78

STORAGE

Store in a cool, dry area free from direct sunlight. Shelf life of unopened bags, when stored in a dry facility, is 12 months. Excessive temperature differential and /or high humidity can shorten the shelf life expectancy.

APPLICATION

Surface Preparation:

Thoroughly clean all contact surfaces. Existing concrete should be strong and sound. Surface should be roughened to insure bond. Metal base plates should be clean and free of oil and other contaminants. Maintain contact areas between 45°F (7°C) and 90°F (32°C) before grouting and during curing period.

Thoroughly wet concrete contact area 24 hours prior to grouting, keep wet and remove all surface water just prior to placement. If 24 hours is not possible, then saturate with water for at least 4 hours. Seal forms to prevent water or grout loss. On the placement side, provide an angle in the form high enough to assist in grouting and to maintain head pressure on the grout during the entire grouting process. Forms should be at least 1 in. (2.5 cm) higher than the bottom of the base plate.

Water Requirements:

Desired Mix Water / 50 lbs. (22.67 kg) Bag
Dry Pack: 5 pints (2.4 L)
Flowable: 8 pints (3.8 L)
Fluid: 9 pints (4.2 L)

Mixing:

A mechanical mixer with rotating blades like a mortar mixer is best. Small quantities can be mixed with a drill and paddle. When mixing less than a full bag, always first agitate the bag thoroughly so that a representative sample is obtained.

Sec 16

Grouts

Visit www.daytonsuperior.com for the most up to date technical information

Page 1 of 3

File Date: 3/27/2015

Figure B-22. Non-Shrink Grout Specifications, Test No. NJPCB-1

DAYTON SUPERIOR

1107 Advantage Grout

Cement Based Grout

TECHNICAL DATA SHEET

Place approximately 3/4 of the anticipated mix water into the mixer and add the grout mix, adding the minimum additional water necessary to achieve desired consistency.
Mix for a total of five minutes ensuring uniform consistency. For placements greater in depth than 3 in. (7.6 cm), up to 25 lbs. (11.34 kg) of washed 3/8 in. (1 cm) pea gravel must be added to each 50 lbs. (22.67 kg) bag of grout. The approximate working time (pot life) is 30 minutes but will vary somewhat with ambient conditions.

For hot weather conditions, greater than 85°F (29°C), mix with cold water approximately 40°F (4°C).
For cold weather conditions, less than 50°F (10°C), mix with warm water, approximately 90°F (29°C). For additional hot and cold weather applications, contact Dayton Superior.

Placement:
Grout should be placed preferably from one side using a grout box to avoid entrapping air. Grout should not be over-worked or over-watered causing segregation or bleeding. Vent holes should be provided where necessary.
When possible, grout bolt holes first. Placement and consolidation should be continuous for any one section of the grout. When nearby equipment causes vibration of the grout, such equipment should be shut down for a period of 24 hours. Forms may be removed when grout is completely self-supporting. For best results, grout should extend downward at a 45 degree angle from the lower edge of the steel base plates or similar structures.

Sec 16 Grouts

CLEAN UP

Use clean water. Hardened material will require mechanical removal methods.

CURING

Exposed grout surfaces must be cured. Dayton Superior recommends using a Dayton Superior curing compound, cure & seal or a wet cure for 3 days. Maintain the temperature of the grout and contact area at 45°F (7°C) to 90°F (32°C) for a minimum of 24 hours.

LIMITATIONS

FOR PROFESSIONAL USE ONLY

Do not re-temper after initial mixing
Do not add other
cements or additives
Setting time for the 1107 Advantage Grout will slow during cooler weather, less than 50°F (10°C) and speed up during hot weather, greater than 80°F (27°C)
Prepackaged material segregates while in the bag, thus when mixing less than a full bag it is recommended to first agitate the bag to assure it is blended prior to sampling.

PRECAUTIONS

READ SDS PRIOR TO USING PRODUCT

- Product contains Crystalline Silica and Portland Cement Avoid breathing dust Silica may cause serious lung problems
- Use with adequate ventilation
  n Wear protective clothing, gloves and eye protection (goggles, safety glasses and/or face shield)
- Keep out of the reach of children
- Do not take internally
- In case of ingestion, seek medical help immediately
- May cause skin irritation upon contact, especially prolonged or repeated. If skin contact occurs, wash immediately with soap and water and seek medical help as needed.
- If eye contact occurs, flush immediately with clean water and seek medical help as needed
- Dispose of waste material in accordanc

MANUFACTURER

Dayton Superior Corporation
1125 Byers Road
Miamisburg, OH 45342
Customer Service: 888-977-9600
Technical Services: 877-266-7732
Website: www.daytonsuperior.com

WARRANTY

Dayton Superior Corporation ("Dayton") warrants for 12 months from the date of manufacture or for the duration of the published product shelf life, whichever is less, that at the time of shipment by Dayton, the product is free of manufacturing defects and conforms to Dayton's product properties in force on the date of acceptance by Dayton of the order. Dayton shall only be liable under this warranty if the product has been applied, used, and stored in accordance with Dayton's instructions, especially surface preparation and installation, in force on the date of acceptance by Dayton of the order. The purchaser must examine the product when received and promptly notify Dayton in writing of any non-conformity before the product is used and no later than 30 days after such non-conformity is first discovered. If Dayton, in its sole discretion, determines that the product breached the above warranty, it will, in its sole discretion, replace the non-conforming product, refund the purchase price or issue a credit in the amount of the purchase price. This is the sole and exclusive remedy for breach of this warranty. Only a Dayton officer is authorized to modify this warranty. The information in this data sheet supersedes all other sales information received by the customer during the sales process. THE FOREGOING WARRANTY SHALL BE EXCLUSIVE AND IN LIEU OF ANY OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, AND ALL OTHER WARRANTIES OTHERWISE ARISING BY OPERATION OF LAW, COURSE OF DEALING, CUSTOM, TRADE OR OTHERWISE.

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Page 2 of 3
File Date: 3/27/2015

Figure B-23. Non-Shrink Grout Specifications, Test No. NJPCB-1

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LINCOLN OFFICE
825 "M" Street, Suite 100
Lincoln, NE 68508
Phone: (402) 479-2200
Fax: (402) 479-2276

COMPRESSION TEST OF CYLINDRICAL CONCRETE SPECIMENS - 4x8

ASTM Designation: C 39

Client Name: Midwest Roadside Safety Facility **Date** 25-Feb-16
Project Name: New Jersey PCB
Placement Location: Grout Test A

Mix Designation: **Required Strength:** 1000

Laboratory Test Data

Laboratory Identification	Field Identification	Date Cast	Date Received	Date Tested	Days Cured in Field	Days Cured in Laboratory	Age of Test, Days	Length of Specimen, in.	Diameter of Specimen, in.	Cross-Sectional Area, sq.in.	Maximum Load, lbf	Compressive Strength, psi.	Required Strength, psi.	Type of Fracture	ASTM Practice for Capping Specimen
PCB- 1		2/17/2016	2/24/2016	2/25/2016	7	1	8	8	4.03	12.76	89,005	6,980	1,000	5	C 1231

1 cc: Shaun Tighe
Midwest Roadside Safety Facility

Remarks:

Concrete test specimens along with documentation and test data were submitted by Midwest Roadside Safety Facility.

Test results presented relate only to the concrete specimens as received from Midwest Roadside Safety

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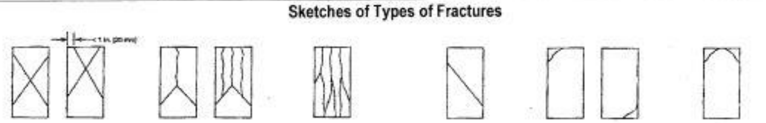
Report Number 2147368164
Page 1

Sketches of Types of Fractures



Type 1: Reasonably well-formed cones on both ends, less than 1 in. [25 mm] of cracking through caps

Type 2: Well-formed cone on one end, vertical cracks running through caps, no well-defined cone on other end

Type 3: Columnar vertical cracking through both ends, no well-formed cones

Type 4: Diagonal fracture with no cracking through ends; tap with hammer to distinguish from Type 1

Type 5: Side fractures at top or bottom (occur commonly with unbonded caps)

Type 6: Similar to Type 5 but end of cylinder is pointed

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By
Brant Wells, Field/Lab Operations Manager

Figure B-24. Non-shrink Grout Compressive Test Certificate, Test No. NJPCB-1

Appendix C. Concrete Tarmac Strength

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825 J Street
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COMPRESSION TEST OF Cylindrical CONCRETE SPECIMENS
ASTM Designation: C39-03

Client:	UNL	Date:	December 10, 2010
Project:	MwRSF		
Placement Location:	WI - East 1, 2, 3		
Mix Type:	Class:	Mix No.:	
Type of Forms		Cement Factor, Sks/Yd	na
		Water-Cement Ratio	na
Admixture Quantity	na	Slump Inches	na
Admixture Type	na	Unit Wt, lbs/cu. Ft.	na
Admixture Quantity	na	Air Content, %	na
Average Field Temperature	na	Batch Volume, Cu. Yds.	na
Temperature of Concrete F	na	Ticket No.	na

Identification Laboratory	East 1	East 2	East 3			
Date Cast						
Date Received in Laboratory	11/30/2010	11/30/2010	11/30/2010			
Date Tested						
Days Cured in Field						
Days Cured in Laboratory						
Age of Test, Days						
Length, in.	7.78	7.81	7.75			
Average Width (1), in.	3.72	3.72	3.72			
Cross-Sectional Area, sq. in.	10.874	10.869	10.874			
Maximum Load, lbf	71,030	76,470	73,310			
Compressive Stength, psi	6,530	7,040	6,740			
Length/Diameter Ratio	2.091	2.099	2.083			
Correction						
Corrected Compressive Strength,psi	0	0	0			
Type of Fracture	4	4	4			
Required Strength,psi						

Remarks:

All concrete break data in this report was produced by Benesch personnel using ASTM Standard Methods and Practices unless otherwise noted.

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CONSTRUCTION MATERIALS LABORATORY

By: Raymond E. Delka, Manager

Figure C-1. Concrete Tarmac Strength Test

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LINCOLN OFFICE
825 J Street
Lincoln, NE 68508
402/479-2200

COMPRESSION TEST OF Cylindrical CONCRETE SPECIMENS
ASTM Designation: C39-03

Client:	UNL		Date:	December 13, 2010
Project:	MwRSF			
Placement Location:	WI - Epoxy West 4 &5			
Mix Type:	Class:		Mix No.:	
Type of Forms		Cement Factor, Sks/Yd		na
		Water-Cement Ratio		na
Admixture Quantity	na	Slump Inches		na
Admixture Type	na	Unit Wt, lbs/cu. Ft.		na
Admixture Quantity	na	Air Content, %		na
Average Field Temperature	na	Batch Volume, Cu. Yds.		na
Temperature of Concrete F	na	Ticket No.		na

Identification Laboratory	4	5				
Date Cast						
Date Received in Laboratory	12/13/2010	12/13/2010				
Date Tested						
Days Cured in Field						
Days Cured in Laboratory						
Age of Test, Days	na	na				
Length, in.	8.05	8.06				
Average Width (1), in.	3.91	3.90				
Cross-Sectional Area, sq. in.	11.977	11.952				
Maximum Load, lbf	71,500	71,630				
Compressive Stength, psi	5,970	5,990				
Length/Diameter Ratio	2.061	2.065				
Correction						
Corrected Compressive Strength,psi	0	0				
Type of Fracture	3	3				
Required Strength,psi						

Remarks:

All concrete break data in this report was produced by Benesch personnel using ASTM Standard Methods and Practices unless otherwise noted.

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By: Raymond E. Delka, Manager

Figure C-2. Concrete Tarmac Strength Test

Appendix D. Vehicle Center of Gravity Determination

Test: NJPCB-1 Vehicle: Dodge RAM 1500

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb.)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unbalasted Truck (Curb)	5229	28.4969	149010.31
+	Hub	19	15.625	296.875
+	Brake activation cylinder & frame	7	28.125	196.875
+	Pneumatic tank (Nitrogen)	27	26.125	705.375
+	Strobe/Brake Battery	5	23.875	119.375
+	Brake Reciever/Wires	5	53.125	265.625
+	CG Plate including DAS	47	30.375	1427.625
-	Battery	-46	40.875	-1880.25
-	Oil	-9	26.875	-241.875
-	Interior	-95	33.875	-3218.125
-	Fuel	-169	20.875	-3527.875
-	Coolant	-12	33.875	-406.5
-	Washer fluid	-8	32.875	-263
+	Water Ballast	0	0	0
+	Onboard Battery	14	24.875	348.25
				0
				142832.69

Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle

Estimated Total Weight (lb.)	5014
Vertical CG Location (in.)	28.48677

Wheel Base (in.) 140.5

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb.)	5000 ± 110	5013	13.0
Longitudinal CG (in.)	63 ± 4	59.81	-3.19011
Lateral CG (in.)	NA	0.727714	NA
Vertical CG (in.)	28 or greater	28.49	0.48677

Note: Long. CG is measured from front axle of test vehicle

Note: Lateral CG measured from centerline - positive to vehicle right (passenger) side

CURB WEIGHT (lb.)

	Left	Right
Front	1510	1462
Rear	1093	1164

FRONT	2972 lb.
REAR	2257 lb.
TOTAL	5229 lb.

TEST INERTIAL WEIGHT (lb.)

	Left	Right
Front	1399	1480
Rear	1054	1080

FRONT	2879 lb.
REAR	2134 lb.
TOTAL	5013 lb.

Figure D-1. Vehicle Mass Distribution, Test No. NJPCB-1

Appendix E. Vehicle Deformation Records

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 1

TEST: NJPCB-1
VEHICLE: Dodge RAM 1500

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)	Total Δ (in.)	Crush (in.)
1	30.568	-27.416	4.249	27.045	-26.637	6.632	-3.523	0.779	2.383	4.324	4.253
2	32.098	-23.025	1.584	28.547	-22.305	4.496	-3.551	0.720	2.912	4.649	4.593
3	31.751	-18.961	0.356	29.065	-18.969	2.123	-2.687	-0.009	1.767	3.215	3.215
4	30.184	-14.121	0.732	29.790	-14.032	0.826	-0.394	0.090	0.094	0.414	0.405
5	28.337	-27.925	1.355	25.614	-27.261	3.180	-2.723	0.665	1.826	3.345	3.278
6	29.156	-23.687	-0.364	26.751	-23.130	1.441	-2.405	0.557	1.805	3.058	3.007
7	28.664	-19.315	-1.104	26.344	-18.912	0.215	-2.320	0.403	1.318	2.699	2.668
8	28.038	-14.371	-1.455	27.430	-14.218	-1.266	-0.608	0.153	0.188	0.655	0.636
9	24.992	-28.644	-1.808	23.852	-27.698	-1.344	-1.139	0.946	0.464	1.552	0.464
10	24.860	-23.776	-2.451	23.988	-23.210	-1.258	-0.871	0.566	1.193	1.582	1.193
11	25.517	-19.227	-2.698	24.640	-18.983	-2.061	-0.877	0.244	0.637	1.111	0.637
12	25.122	-14.544	-3.447	24.719	-14.214	-3.336	-0.403	0.330	0.110	0.532	0.110
13	21.323	-29.576	-3.580	20.918	-29.115	-3.312	-0.406	0.461	0.268	0.670	0.268
14	21.390	-24.178	-4.132	21.027	-23.922	-3.962	-0.363	0.257	0.170	0.476	0.170
15	21.838	-19.749	-4.430	21.523	-19.506	-4.422	-0.315	0.242	0.008	0.397	0.008
16	22.115	-14.926	-4.880	21.854	-14.822	-4.961	-0.262	0.104	-0.081	0.293	-0.081
17	17.398	-29.621	-3.950	17.266	-29.346	-4.171	-0.132	0.275	-0.221	0.377	-0.221
18	17.870	-23.847	-4.537	17.520	-23.630	-4.679	-0.350	0.217	-0.141	0.435	-0.141
19	17.843	-19.687	-5.019	17.682	-19.624	-5.170	-0.162	0.064	-0.151	0.230	-0.151
20	17.429	-14.628	-5.453	17.146	-14.472	-5.623	-0.283	0.156	-0.170	0.365	-0.170
21	6.718	-29.371	-3.643	6.592	-29.175	-3.730	-0.126	0.197	-0.087	0.249	-0.087
22	6.522	-22.830	-4.338	6.352	-22.716	-4.499	-0.170	0.114	-0.161	0.261	-0.161
23	6.839	-18.095	-4.888	6.597	-17.985	-5.049	-0.243	0.110	-0.161	0.311	-0.161
24	6.890	-13.553	-5.415	6.693	-13.369	-5.557	-0.197	0.184	-0.142	0.305	-0.142
25	0.520	-27.452	0.288	0.477	-27.287	0.341	-0.043	0.165	0.052	0.178	0.052
26	0.593	-21.377	-0.297	0.498	-21.161	-0.336	-0.095	0.217	-0.039	0.240	-0.039
27	0.603	-17.462	-0.748	0.535	-17.170	-0.835	-0.067	0.292	-0.087	0.312	-0.087
28	0.856	-12.172	-1.336	0.574	-12.014	-1.509	-0.282	0.158	-0.173	0.367	-0.173

Note: Crush column is deformation perpendicular to the plane area of interest

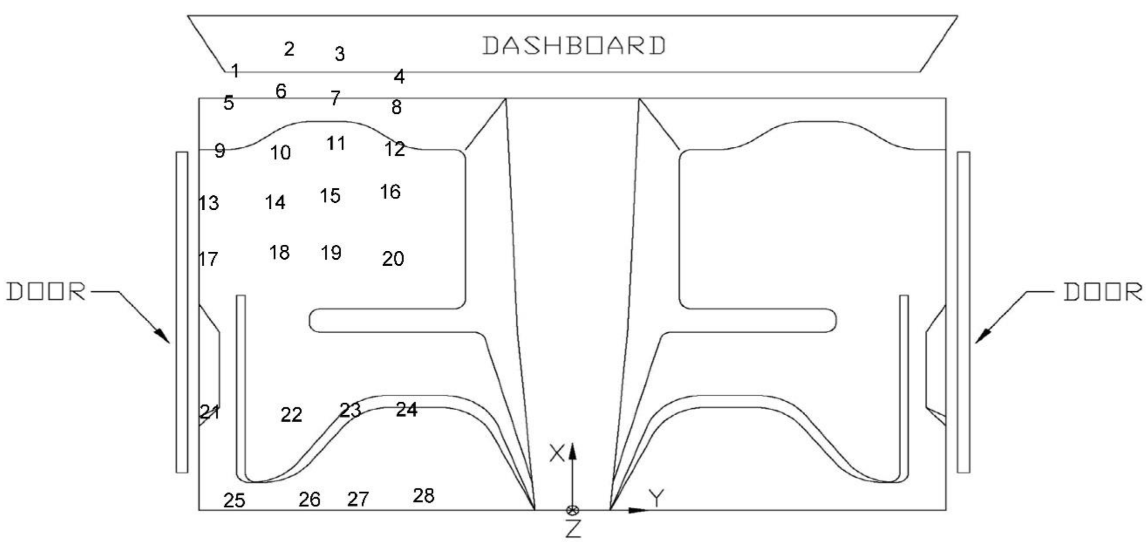


Figure E-1. Floor Pan Deformation Data – Set 1, Test No. NJPCB-1

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 2

TEST: NJPCB-1
VEHICLE: Dodge RAM 1500

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)	Total Δ (in.)	Crush (in.)
1	56.544	-33.693	2.138	52.755	-33.624	4.227	-3.789	0.068	2.088	4.327	4.327
2	58.038	-29.033	0.095	54.434	-29.073	2.768	-3.604	-0.040	2.674	4.488	4.487
3	57.610	-24.770	-0.673	54.997	-25.089	0.851	-2.613	-0.319	1.524	3.042	3.025
4	55.984	-20.039	0.330	55.759	-20.458	0.250	-0.225	-0.419	-0.080	0.482	0.239
5	54.406	-33.741	-0.874	51.447	-33.761	0.779	-2.960	-0.020	1.653	3.390	3.390
6	55.132	-29.372	-2.035	52.680	-29.413	-0.422	-2.452	-0.040	1.613	2.935	2.935
7	54.555	-24.946	-2.211	52.843	-24.243	-0.898	-1.712	0.704	1.313	2.269	2.157
8	53.856	-19.989	-1.889	53.462	-19.867	-1.578	-0.393	0.122	0.310	0.516	0.501
9	51.159	-34.118	-4.143	50.104	-33.343	-3.597	-1.056	0.774	0.546	1.419	0.546
10	50.858	-29.298	-4.207	49.812	-29.416	-3.253	-1.046	-0.117	0.954	1.421	0.954
11	51.388	-24.802	-3.861	50.497	-24.978	-3.443	-0.891	-0.176	0.419	1.000	0.419
12	50.997	-19.884	-3.971	50.679	-20.234	-4.017	-0.319	-0.350	-0.045	0.475	-0.045
13	47.421	-34.910	-6.108	47.002	-34.976	-5.931	-0.419	-0.066	0.177	0.460	0.177
14	47.442	-29.437	-5.927	47.044	-29.457	-5.908	-0.398	-0.021	0.020	0.400	0.020
15	47.783	-25.036	-5.688	47.549	-25.029	-5.794	-0.233	0.007	-0.106	0.256	-0.106
16	47.922	-20.133	-5.508	47.682	-20.301	-5.830	-0.240	-0.169	-0.322	0.436	-0.322
17	43.505	-34.834	-6.554	43.199	-34.984	-6.915	-0.306	-0.150	-0.361	0.497	-0.361
18	43.890	-29.266	-6.358	43.477	-29.257	-6.644	-0.413	0.009	-0.285	0.502	-0.285
19	43.868	-24.940	-6.298	43.470	-25.044	-6.437	-0.398	-0.104	-0.139	0.434	-0.139
20	43.317	-19.885	-6.057	43.025	-19.799	-6.315	-0.292	0.086	-0.258	0.399	-0.258
21	32.762	-34.838	-6.349	32.486	-34.810	-6.605	-0.276	0.029	-0.256	0.378	-0.256
22	32.560	-28.328	-6.187	32.346	-28.328	-6.531	-0.215	0.000	-0.344	0.405	-0.344
23	32.716	-23.583	-6.107	32.612	-23.573	-6.430	-0.104	0.011	-0.323	0.339	-0.323
24	32.794	-18.934	-6.032	32.651	-19.118	-6.336	-0.143	-0.184	-0.304	0.383	-0.304
25	26.564	-33.580	-2.290	26.308	-33.529	-2.427	-0.256	0.051	-0.137	0.295	-0.137
26	26.567	-27.474	-2.072	26.460	-27.286	-2.251	-0.108	0.188	-0.179	0.281	-0.179
27	26.539	-23.583	-2.000	26.361	-23.354	-2.238	-0.177	0.230	-0.238	0.375	-0.238
28	26.746	-18.237	-1.883	26.646	-18.158	-2.197	-0.099	0.079	-0.315	0.339	-0.315

Note: Crush column is deformation perpendicular to the plane area of interest

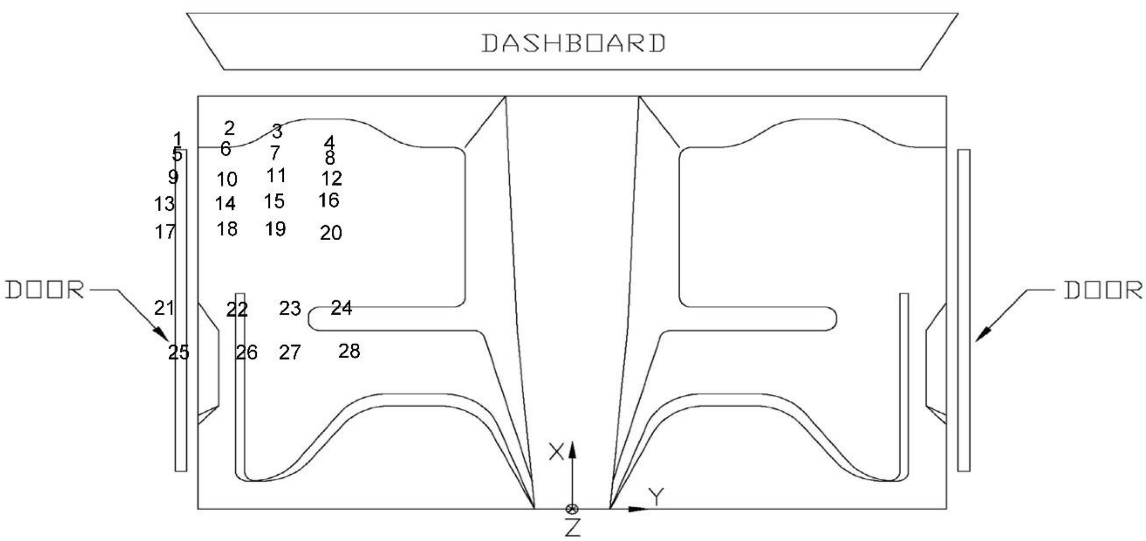


Figure E-2. Floor Pan Deformation Data – Set 2, Test No. NJPCB-1

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 1

TEST: NJPCB-1
VEHICLE: Dodge RAM 1500

	POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)	Total Δ (in.)	Crush (in.)
DASH	1	17.269	-24.339	27.307	16.894	-24.313	27.668	-0.375	0.026	0.361	0.521	0.521
	2	14.744	-15.650	29.775	14.393	-15.505	30.084	-0.351	0.145	0.309	0.490	0.490
	3	16.747	2.405	25.586	16.372	2.310	25.667	-0.375	-0.094	0.081	0.395	0.395
	4	12.447	-25.773	17.117	12.127	-25.937	17.515	-0.319	-0.164	0.399	0.536	0.536
	5	10.998	-17.269	15.251	10.687	-17.365	15.508	-0.311	-0.096	0.257	0.415	0.415
	6	9.981	1.320	13.560	9.643	1.080	13.721	-0.339	-0.240	0.162	0.446	0.446
SIDE PANEL	7	21.211	-32.273	4.819	20.944	-32.040	5.195	-0.267	0.233	0.376	0.517	0.233
	8	24.045	-32.373	4.017	23.651	-32.111	4.742	-0.394	0.262	0.725	0.865	0.262
	9	22.979	-32.494	2.819	22.660	-32.312	3.438	-0.319	0.182	0.619	0.719	0.182
IMPACT SIDE DOOR	10	-15.370	-31.550	25.889	-15.688	-32.305	26.311	-0.318	-0.755	0.422	0.922	-0.755
	11	-1.178	-31.317	25.005	-1.590	-31.824	25.527	-0.412	-0.507	0.522	0.836	-0.507
	12	13.230	-31.410	24.345	12.887	-31.683	24.783	-0.343	-0.274	0.437	0.620	-0.274
	13	-15.095	-33.220	10.387	-15.327	-33.197	10.719	-0.232	0.024	0.333	0.406	0.024
	14	-1.248	-34.673	10.119	-1.586	-34.709	10.546	-0.338	-0.036	0.428	0.546	-0.036
	15	12.463	-33.063	11.082	12.183	-32.903	11.642	-0.280	0.159	0.560	0.646	0.159
ROOF	1	6.170	-17.589	42.893	5.880	-17.728	43.358	-0.290	-0.140	0.465	0.565	0.465
	2	7.888	-11.760	42.341	7.650	-11.788	42.741	-0.238	-0.028	0.400	0.466	0.400
	3	8.883	-6.656	41.827	8.649	-6.695	42.193	-0.234	-0.039	0.365	0.436	0.365
	4	9.556	-0.792	41.250	9.306	-0.725	41.573	-0.250	0.067	0.323	0.414	0.323
	5	9.673	4.034	40.784	9.362	3.936	41.121	-0.311	-0.098	0.337	0.469	0.337
	6	-4.215	-16.171	46.576	-4.559	-16.146	46.974	-0.344	0.024	0.397	0.526	0.397
	7	-3.683	-11.122	46.259	-3.867	-11.136	46.611	-0.184	-0.014	0.352	0.397	0.352
	8	-3.310	-6.821	45.948	-3.667	-6.921	46.307	-0.357	-0.100	0.359	0.516	0.359
	9	-3.380	-1.847	45.655	-3.703	-1.846	45.975	-0.323	0.000	0.320	0.454	0.320
	10	-3.232	3.022	45.169	-3.719	3.106	45.473	-0.487	0.083	0.304	0.580	0.304
	11	-13.216	-15.771	47.444	-13.498	-15.856	47.789	-0.282	-0.085	0.345	0.453	0.345
	12	-13.623	-11.438	47.275	-13.904	-11.381	47.599	-0.280	0.058	0.324	0.432	0.324
	13	-13.889	-8.119	47.087	-14.240	-8.103	47.400	-0.351	0.016	0.313	0.470	0.313
	14	-14.048	-3.144	46.723	-14.443	-3.283	47.023	-0.394	-0.139	0.300	0.514	0.300
	15	-14.266	0.967	46.360	-14.489	0.889	46.627	-0.224	-0.077	0.267	0.356	0.267

Note: Crush column is deformation perpendicular to the plane area of interest

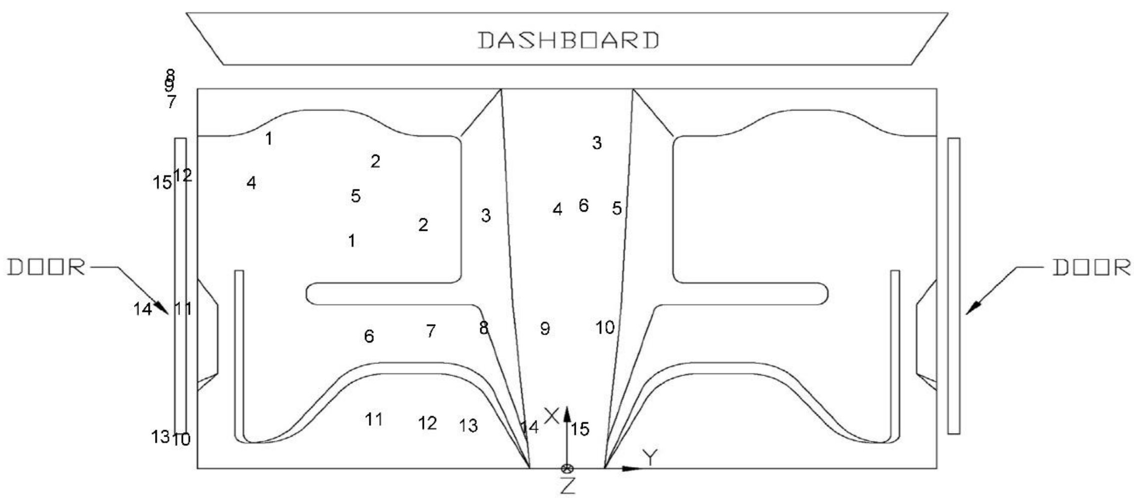


Figure E-3. Occupant Compartment Deformation Data – Set 1, Test No. NJPCB-1

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 2

TEST: NJPCB-1
VEHICLE: Dodge RAM 1500

	POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)	Total Δ (in.)	Crush (in.)
DASH	1	42.961	-33.887	25.153	42.445	-34.172	25.281	-0.517	-0.285	0.128	0.604	0.604
	2	40.209	-25.506	28.694	39.728	-25.793	28.763	-0.481	-0.287	0.068	0.564	0.564
	3	41.975	-7.087	26.902	41.943	-7.561	26.781	-0.032	-0.473	-0.121	0.490	0.490
	4	38.228	-34.007	14.761	37.786	-34.326	14.944	-0.441	-0.319	0.183	0.575	0.575
	5	36.704	-25.289	13.965	36.384	-25.690	14.073	-0.319	-0.402	0.108	0.524	0.524
	6	35.416	-6.650	14.862	35.387	-6.938	14.653	-0.029	-0.288	-0.209	0.357	0.357
SIDE PANEL	7	47.241	-38.684	1.803	46.657	-38.765	2.135	-0.584	-0.081	0.333	0.677	-0.081
	8	50.112	-38.646	1.172	49.518	-38.763	1.376	-0.593	-0.117	0.204	0.638	-0.117
	9	49.098	-38.619	-0.145	48.435	-38.801	0.385	-0.663	-0.181	0.530	0.868	-0.181
IMPACT SIDE DOOR	10	10.356	-41.227	22.310	9.846	-41.773	22.488	-0.510	-0.545	0.178	0.768	-0.545
	11	24.548	-40.679	21.736	23.984	-41.241	21.882	-0.565	-0.562	0.146	0.810	-0.562
	12	39.039	-40.520	21.205	38.503	-41.044	21.374	-0.537	-0.523	0.168	0.768	-0.523
	13	10.938	-40.837	6.814	10.423	-40.609	6.983	-0.515	0.228	0.169	0.588	0.228
	14	24.800	-42.060	6.515	24.176	-42.121	6.759	-0.624	-0.061	0.244	0.673	-0.061
	15	38.524	-40.409	7.841	37.960	-40.504	8.122	-0.564	-0.095	0.281	0.637	-0.095
ROOF	1	31.509	-29.464	41.282	31.249	-29.612	41.550	-0.260	-0.149	0.268	0.402	0.268
	2	33.178	-23.594	41.517	33.027	-23.740	41.733	-0.151	-0.146	0.216	0.301	0.216
	3	34.191	-18.198	41.683	34.016	-18.488	41.899	-0.175	-0.290	0.215	0.402	0.215
	4	34.693	-12.400	41.934	34.772	-12.604	42.029	0.079	-0.204	0.096	0.239	0.096
	5	34.724	-7.537	42.120	34.669	-7.768	42.287	-0.055	-0.231	0.167	0.290	0.167
	6	21.050	-28.543	45.006	20.910	-28.633	45.187	-0.140	-0.090	0.181	0.246	0.181
	7	21.552	-23.514	45.356	21.413	-23.484	45.534	-0.139	0.030	0.178	0.228	0.178
	8	21.799	-19.194	45.628	21.638	-19.226	45.787	-0.162	-0.032	0.159	0.229	0.159
	9	21.717	-14.295	45.979	21.664	-14.337	46.114	-0.053	-0.043	0.135	0.152	0.135
	10	21.701	-9.295	46.156	21.628	-9.345	46.277	-0.073	-0.050	0.121	0.150	0.121
	11	12.025	-28.358	45.800	11.843	-28.312	45.940	-0.182	0.046	0.140	0.234	0.140
	12	11.531	-24.035	46.199	11.418	-23.889	46.329	-0.113	0.146	0.130	0.226	0.130
	13	11.117	-20.772	46.449	10.968	-20.532	46.578	-0.149	0.241	0.129	0.311	0.129
	14	11.019	-15.846	46.718	10.775	-15.717	46.824	-0.244	0.129	0.106	0.295	0.106
	15	10.764	-11.640	46.901	10.822	-11.586	46.986	0.057	0.053	0.085	0.116	0.085

Note: Crush column is deformation perpendicular to the plane area of interest

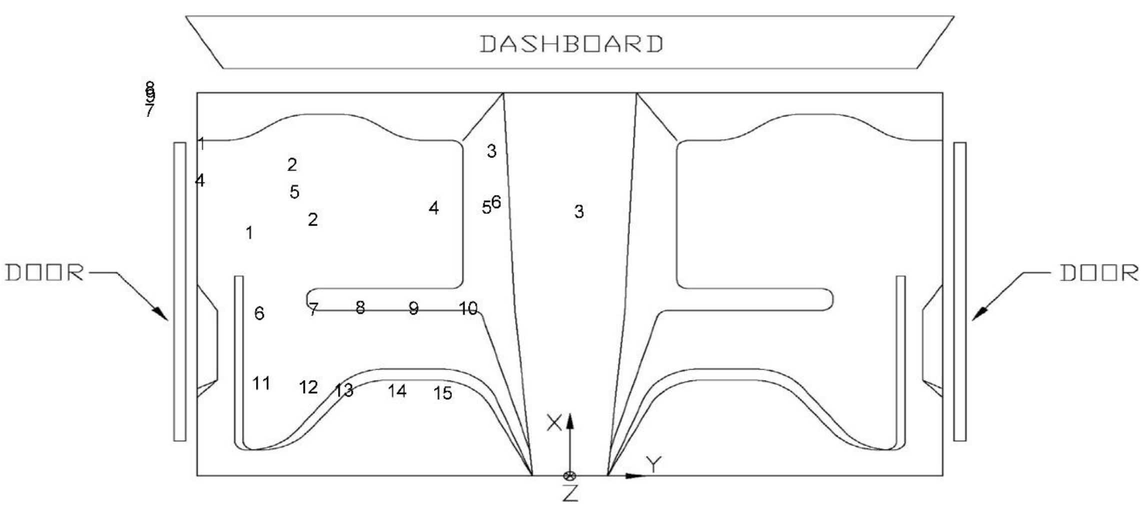
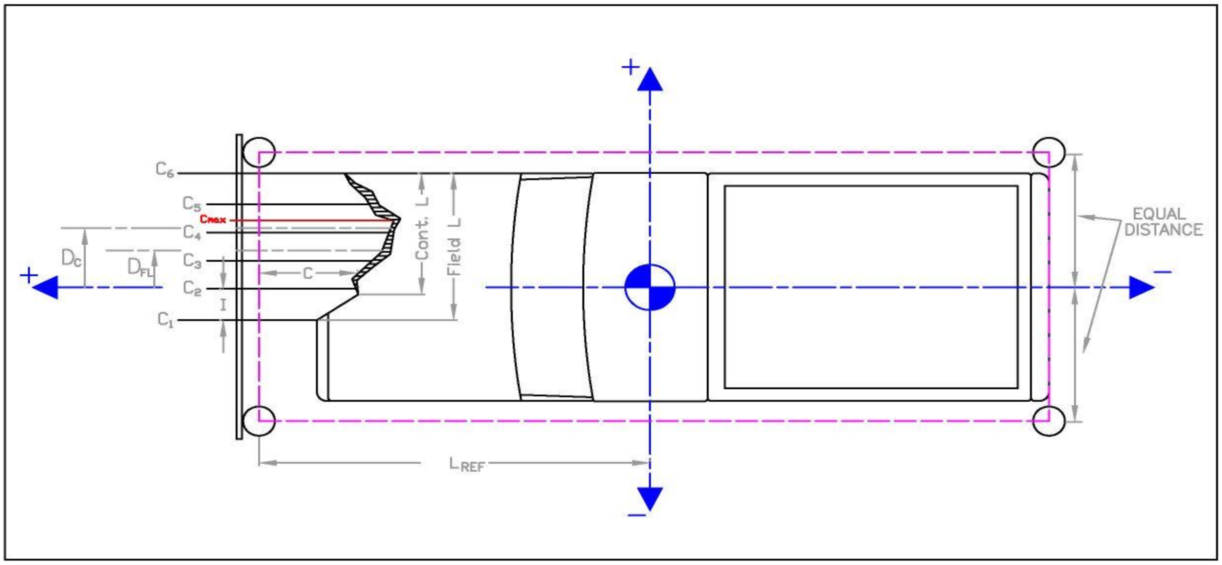


Figure E-4. Occupant Compartment Deformation Data – Set 2, Test No. NJPCB-1

Date: 2/23/2016 **Test Number:** NJPCB-1

Make: Dodge **Model:** RAM 1500 **Year:** 2010



Blue Cells to be filled out Before Test
Orange Cells to Be filled out After Test

	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	109 1/8	(2772)
Total Vehicle Width:	76.5	(1943)
Width of contact and induced crush - Field L:	76 1/2	(1943)
Crush measurement spacing interval (L/5) - I:	15.3	(389)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	21 1/4	(540)
Distance from center of vehicle to center of contact damage - D_C:	27 5/8	(702)

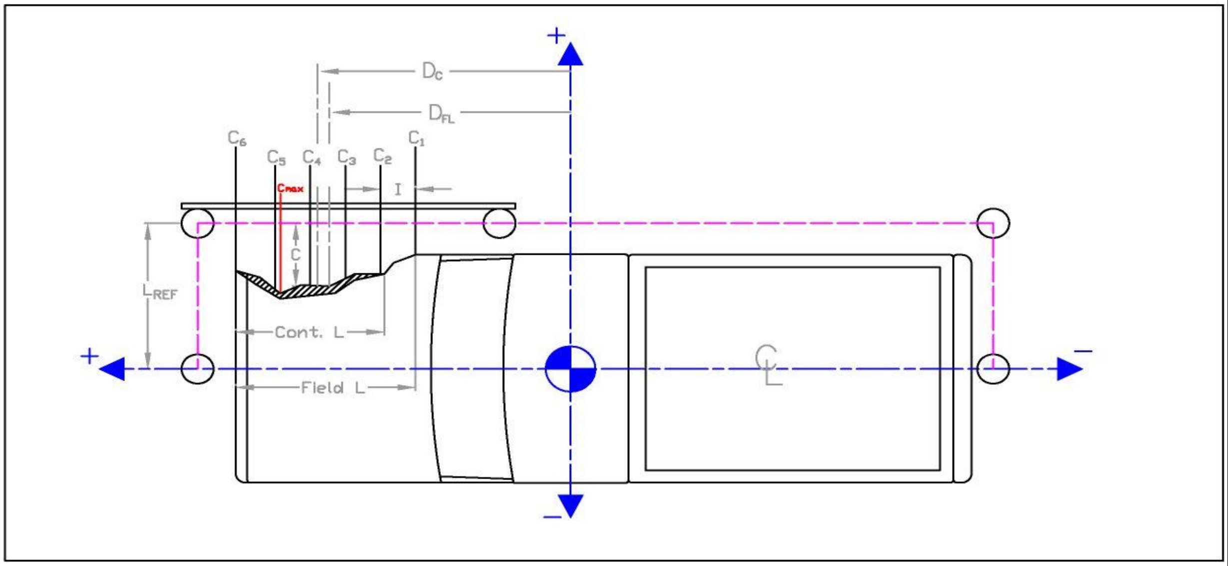
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Lateral Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual	Crush
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	na	NA	-38 1/4	-(972)	22 1/2	(572)	5 1/3	(135)	NA	NA
C_2	22	(559)	-23	-(583)	6 4/9	(164)			10 1/4	(260)
C_3	9	(229)	-7 2/3	-(194)	4 1/4	(108)			- 5/9	-(14)
C_4	9	(229)	7 2/3	(194)	4 2/9	(107)			- 1/2	-(14)
C_5	11	(279)	23	(583)	6	(154)			- 3/8	-(10)
C_6	na	NA	38 1/4	(972)	20 1/2	(521)			NA	NA
C_{MAX}	29	(737)	27 1/2	(699)	7 3/4	(197)			16	(405)

Figure E-5. Exterior Vehicle Crush (NASS) - Front, Test No. NJPCB-1

Date: 2/23/2016 **Test Number:** NJPCB-1

Make: Dodge **Model:** RAM 1500 **Year:** 2010



Blue Cells to be filled out Before Test
Orange Cells to Be filled out After Test

	in.	(mm)
Distance from centerline to reference line - L_{REF}:	47 5/8	(1210)
Total Vehicle Length:	229.25	(5823)
Width of contact and induced crush - Field L:	160 3/4	(4083)
Crush measurement spacing interval (L/5) - I:	32.15	(817)
Distance from vehicle c.g. to center of Field L - D_{FL}:	17 5/8	(448)
Width of Contact Damage:	160 3/4	(4083)
Distance from vehicle c.g. to center of contact damage - D_C:	17 5/8	(448)

NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., front of vehicle has been pushed inward or tire has been removed)
NOTE: All values must be filled out above before crush measurements are filled out.

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual	Crush
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	8	(203)	-62 3/4	-(1594)	5 1/2	(140)	3 5/8	(92)	-1 1/8	-(29)
C_2	9 1/4	(235)	-30 3/5	-(777)	5 1/8	(130)			1/2	(13)
C_3	9 1/8	(232)	1 5/9	(39)	5	(127)			1/2	(13)
C_4	7 3/4	(197)	33 2/3	(856)	5 2/9	(133)			-1	-(28)
C_5	na	NA	65 6/7	(1673)	5 2/9	(133)			NA	NA
C_6	31 3/4	(806)	98	(2489)	33 1/2	(851)			-5 3/8	-(137)
C_{MAX}	21 3/4	(552)	77	(1956)	5 7/8	(149)			12 1/4	(311)

Figure E-6. Exterior Vehicle Crush (NASS) - Side, Test No. NJPCB-1

Appendix F. Accelerometer and Rate Transducer Data Plots, Test No. NJPCB-1

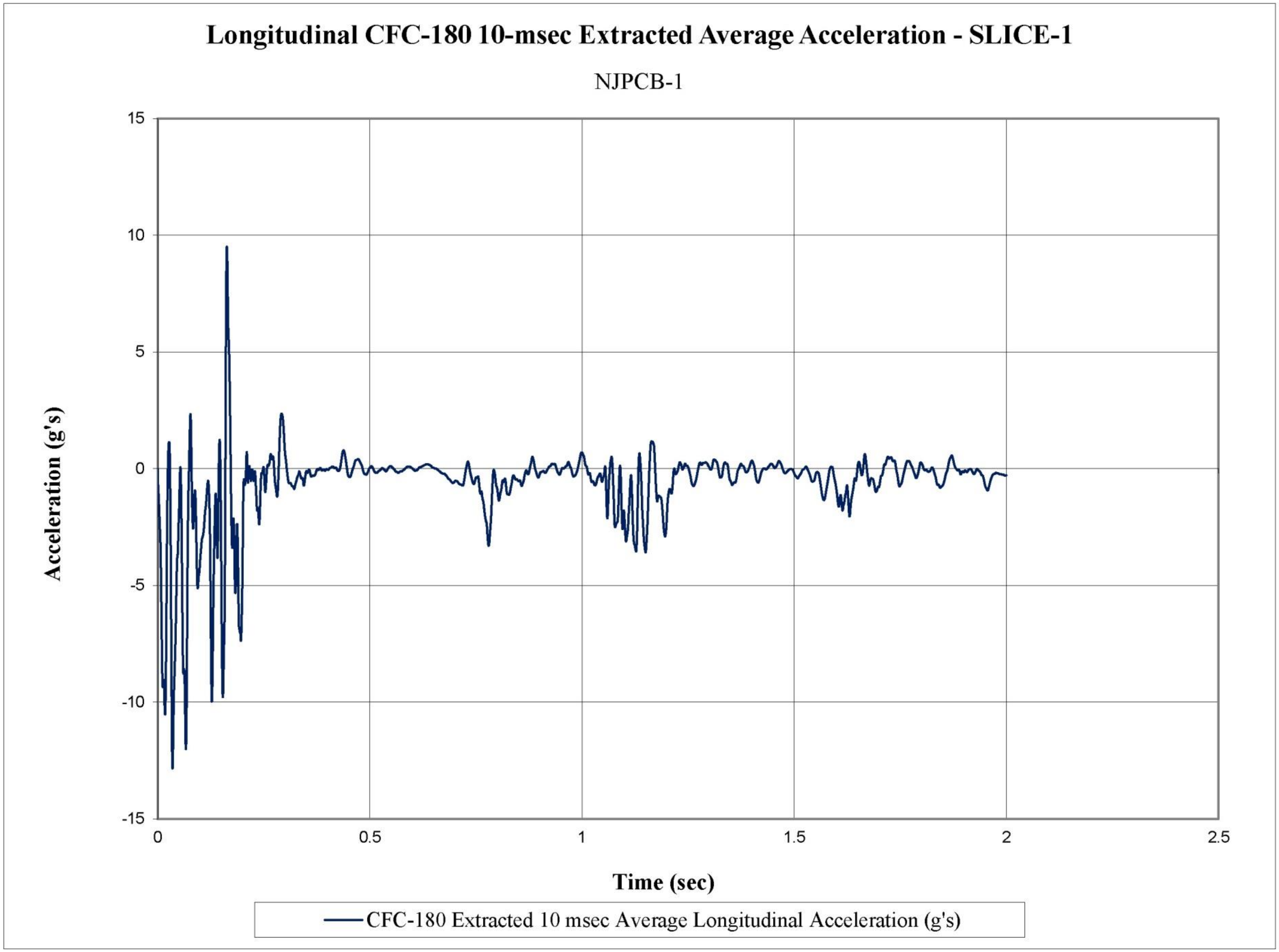


Figure F-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. NJPCB-1

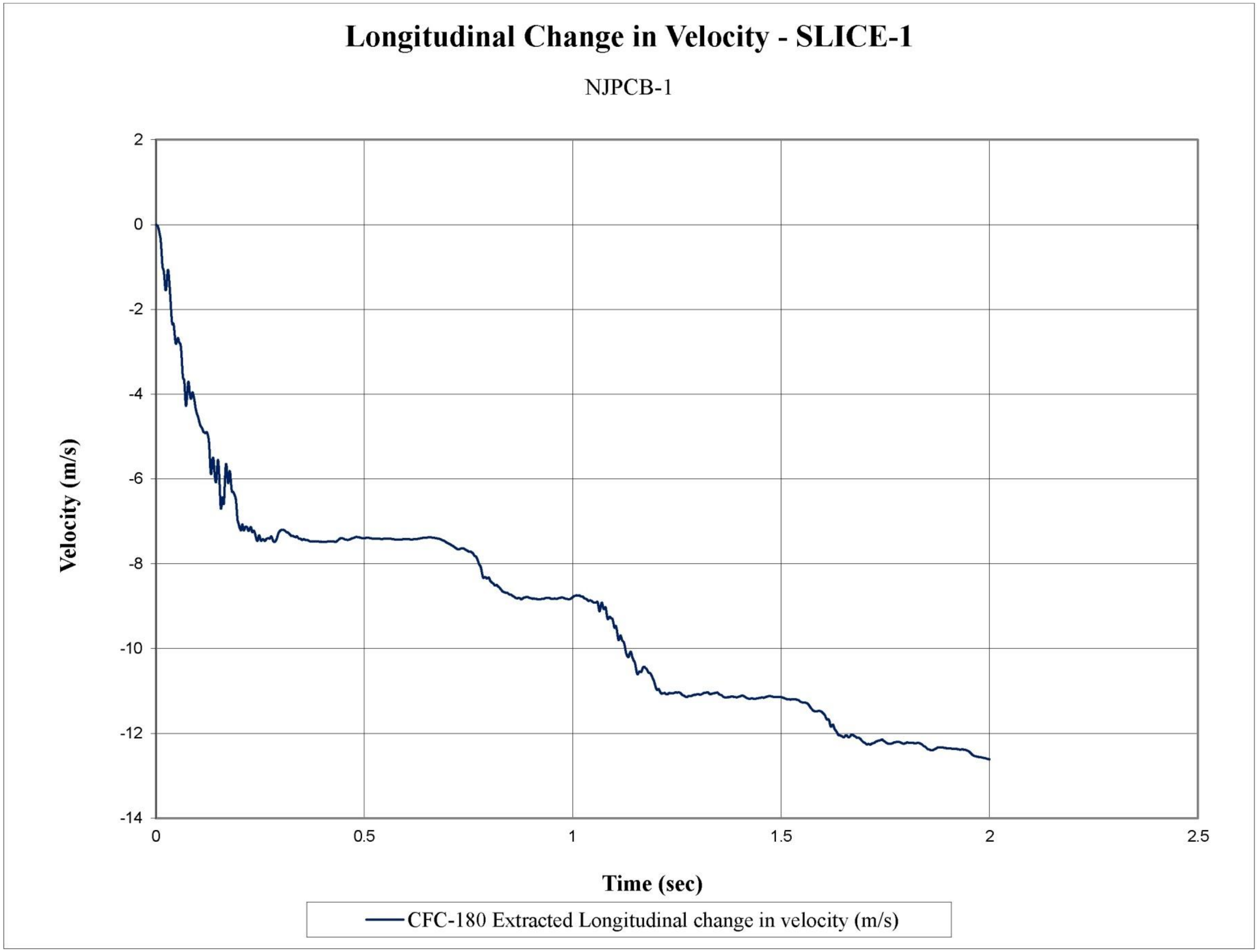


Figure F-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. NJPCB-1

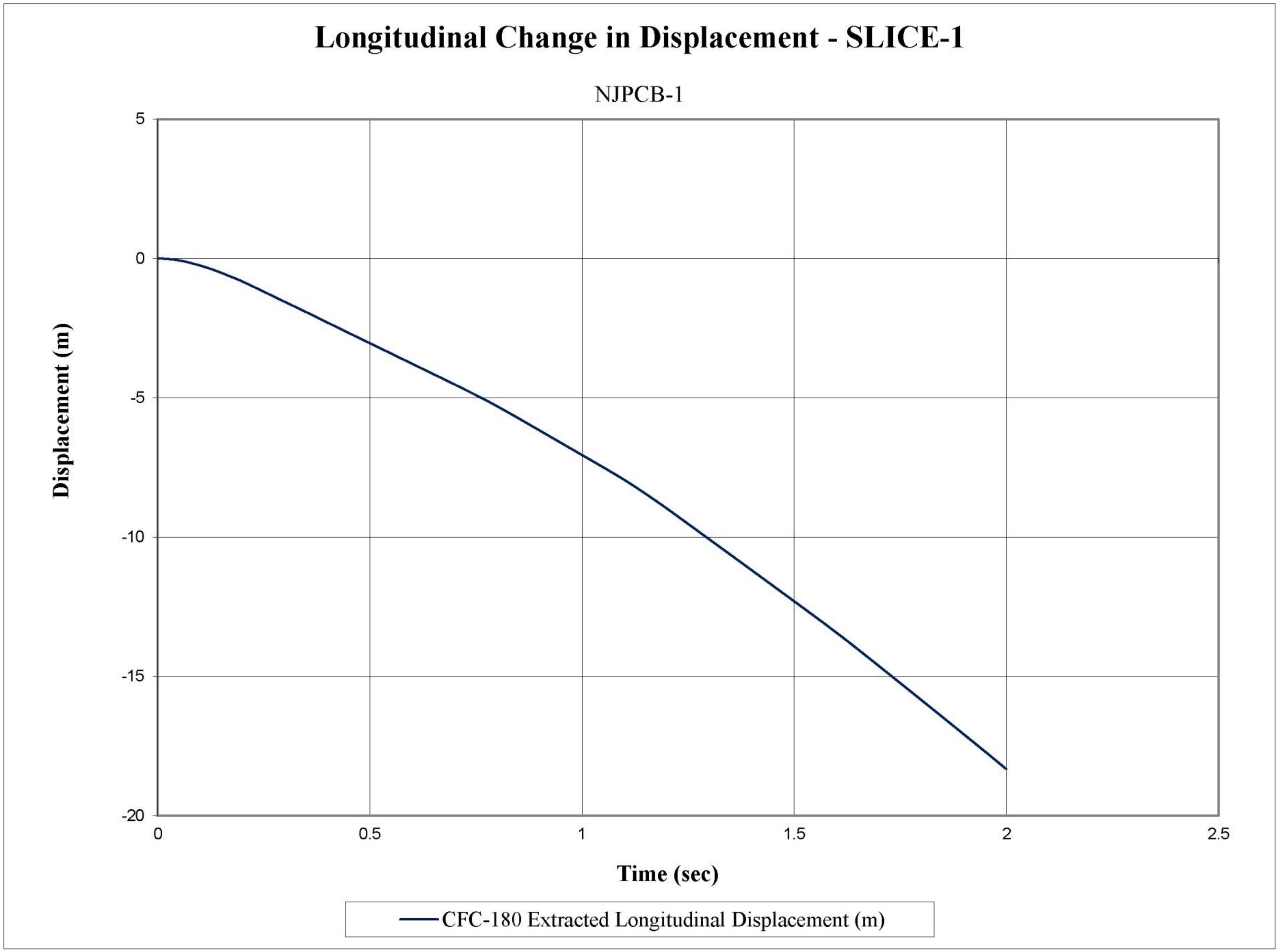


Figure F-3. Longitudinal Occupant Displacement (SLICE-1), Test No. NJPCB-1

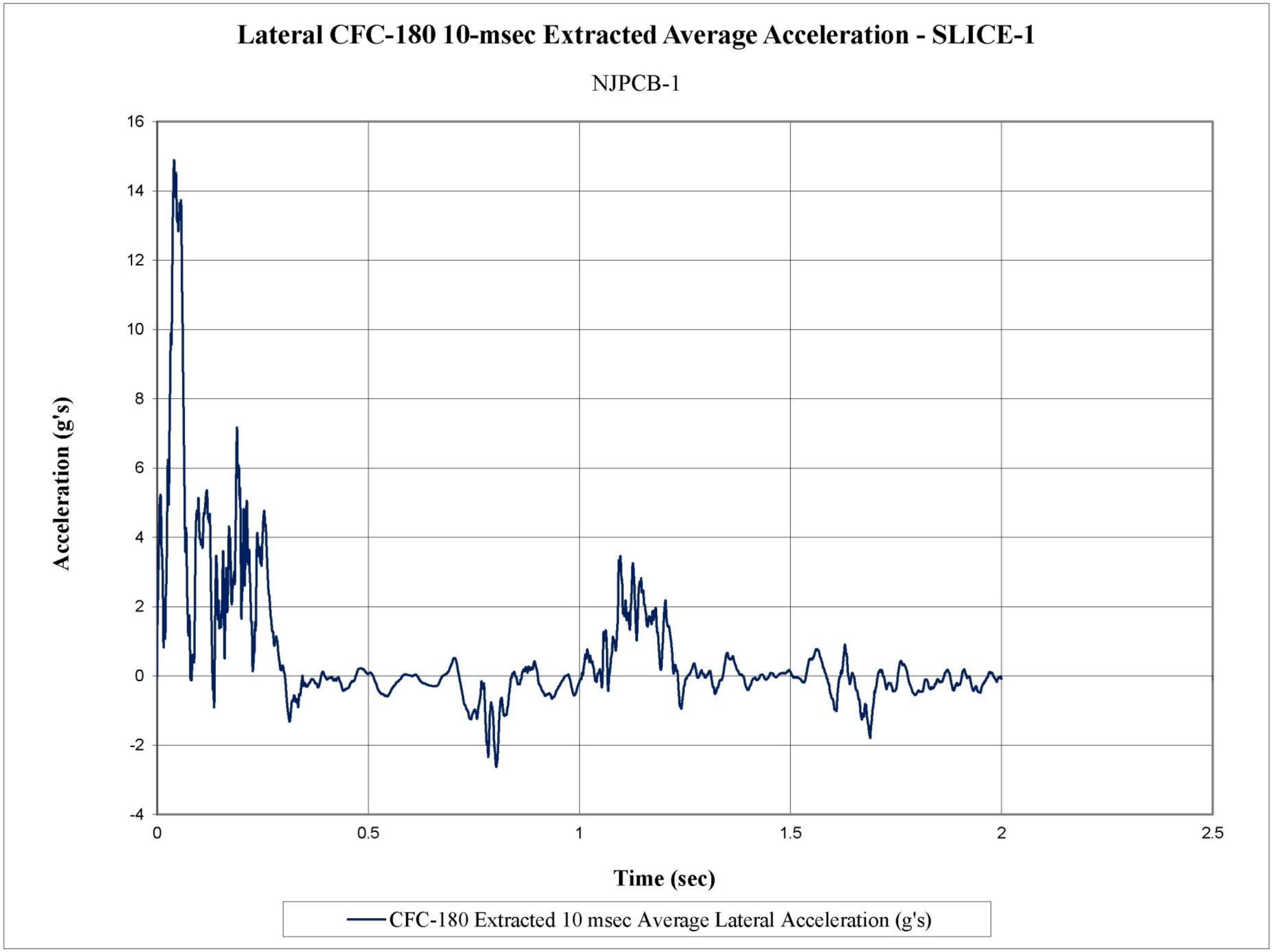


Figure F-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. NJPCB-1

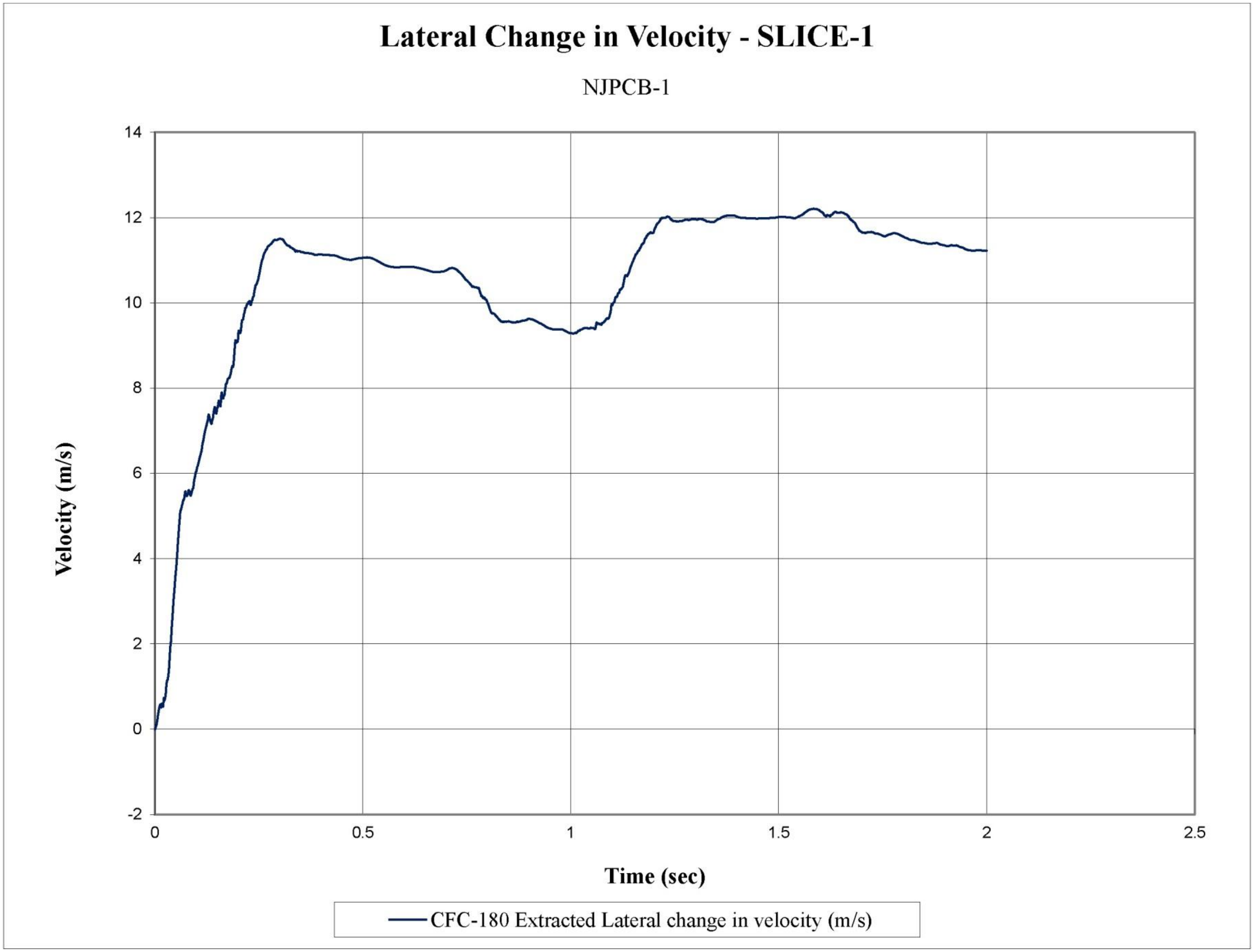


Figure F-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. NJPCB-1

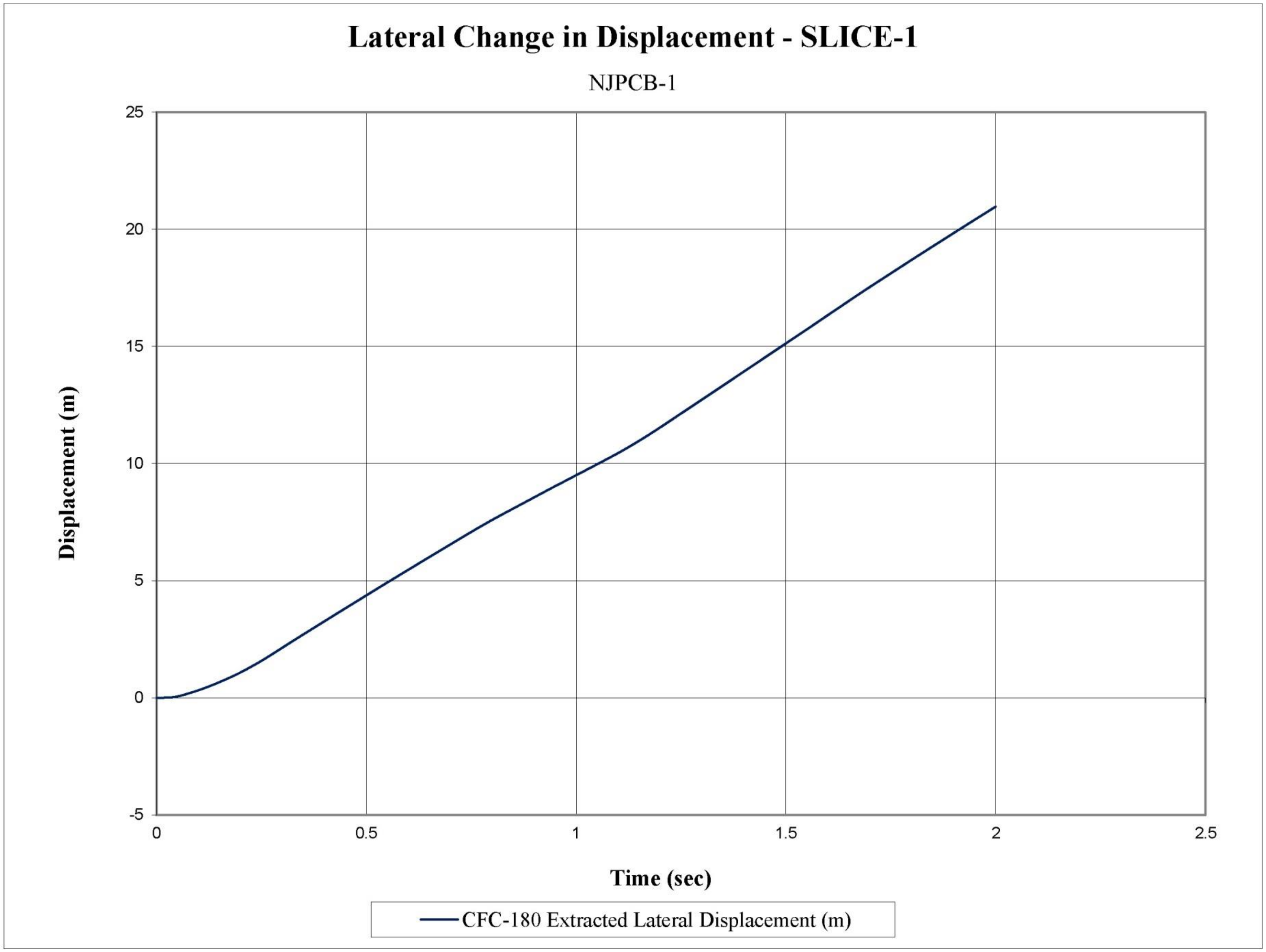


Figure F-6. Lateral Occupant Displacement (SLICE-1), Test No. NJPCB-1

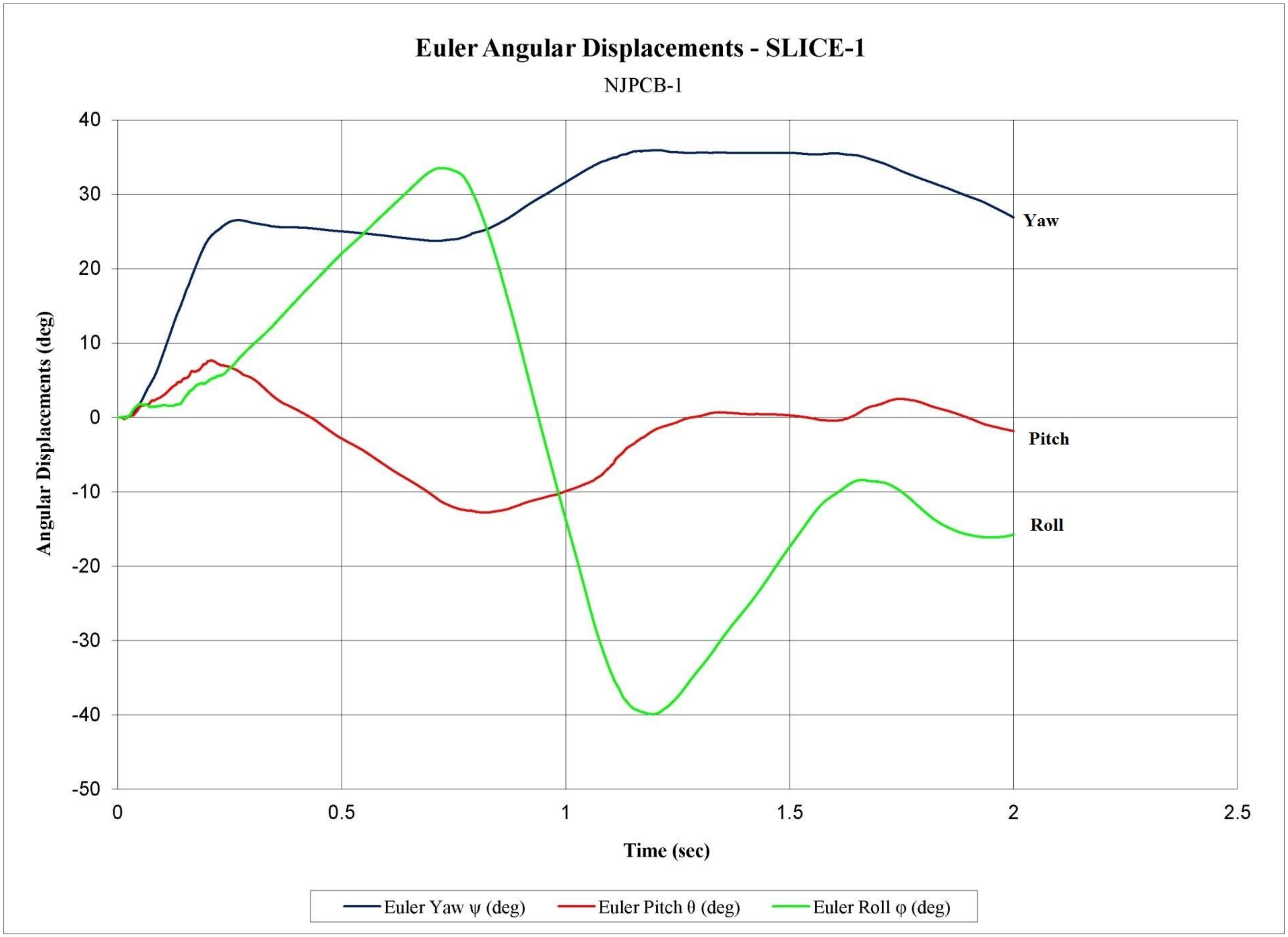


Figure F-7. Vehicle Angular Displacements (SLICE-1), Test No. NJPCB-1

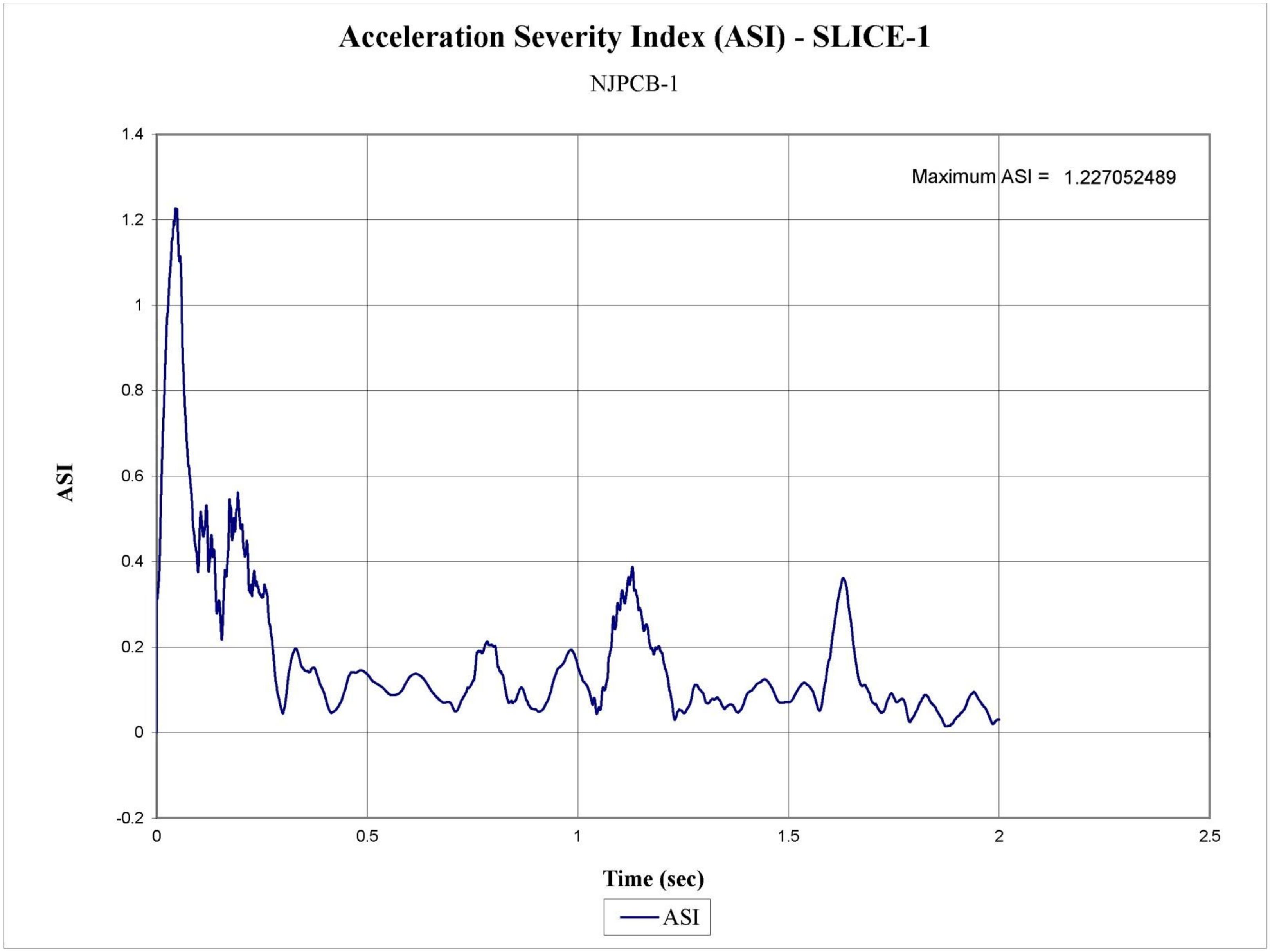


Figure F-8. Acceleration Severity Index (SLICE-1), Test No. NJPCB-1

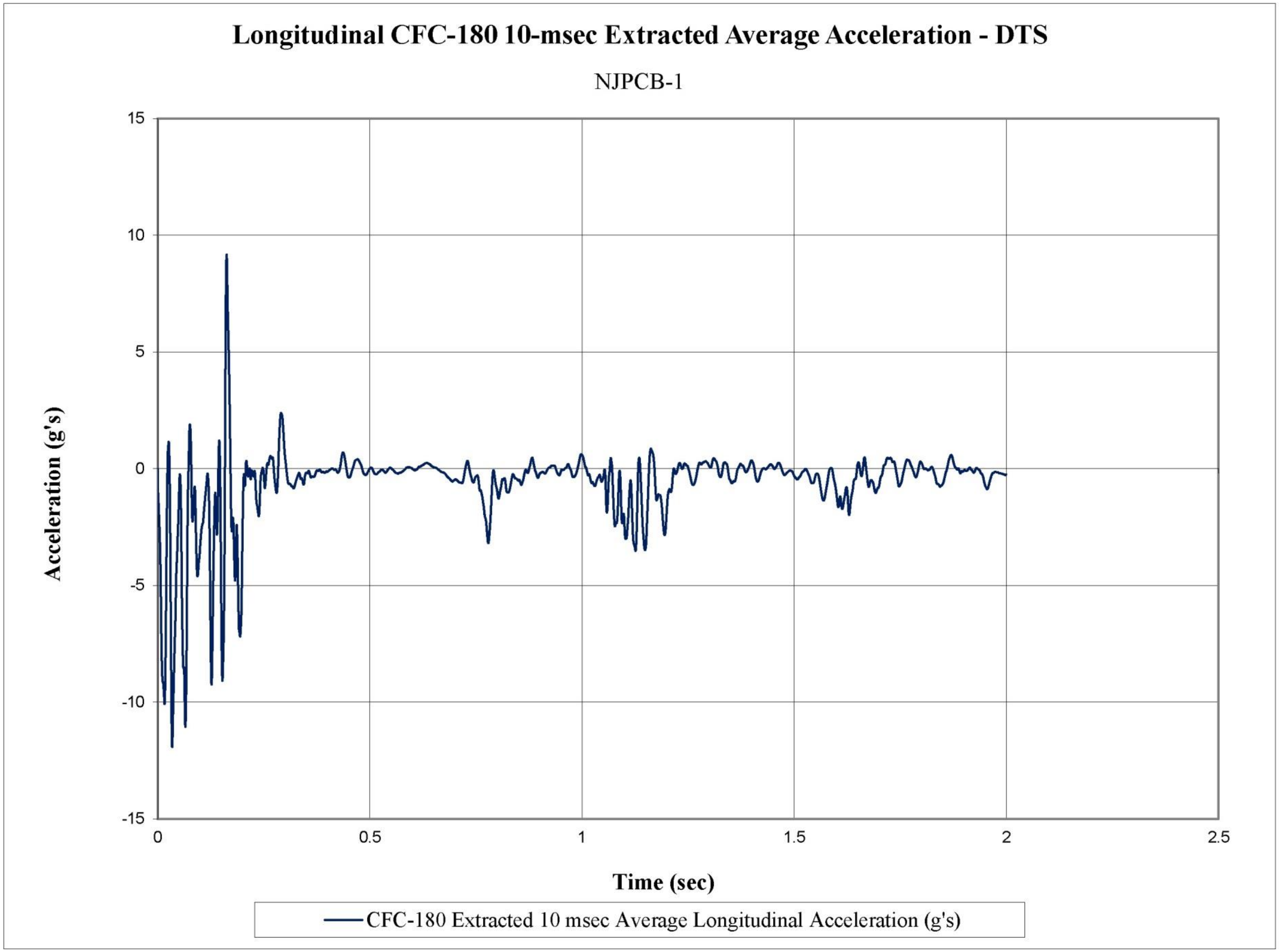


Figure F-9. 10-ms Average Longitudinal Deceleration (DTS), Test No. NJPCB-1

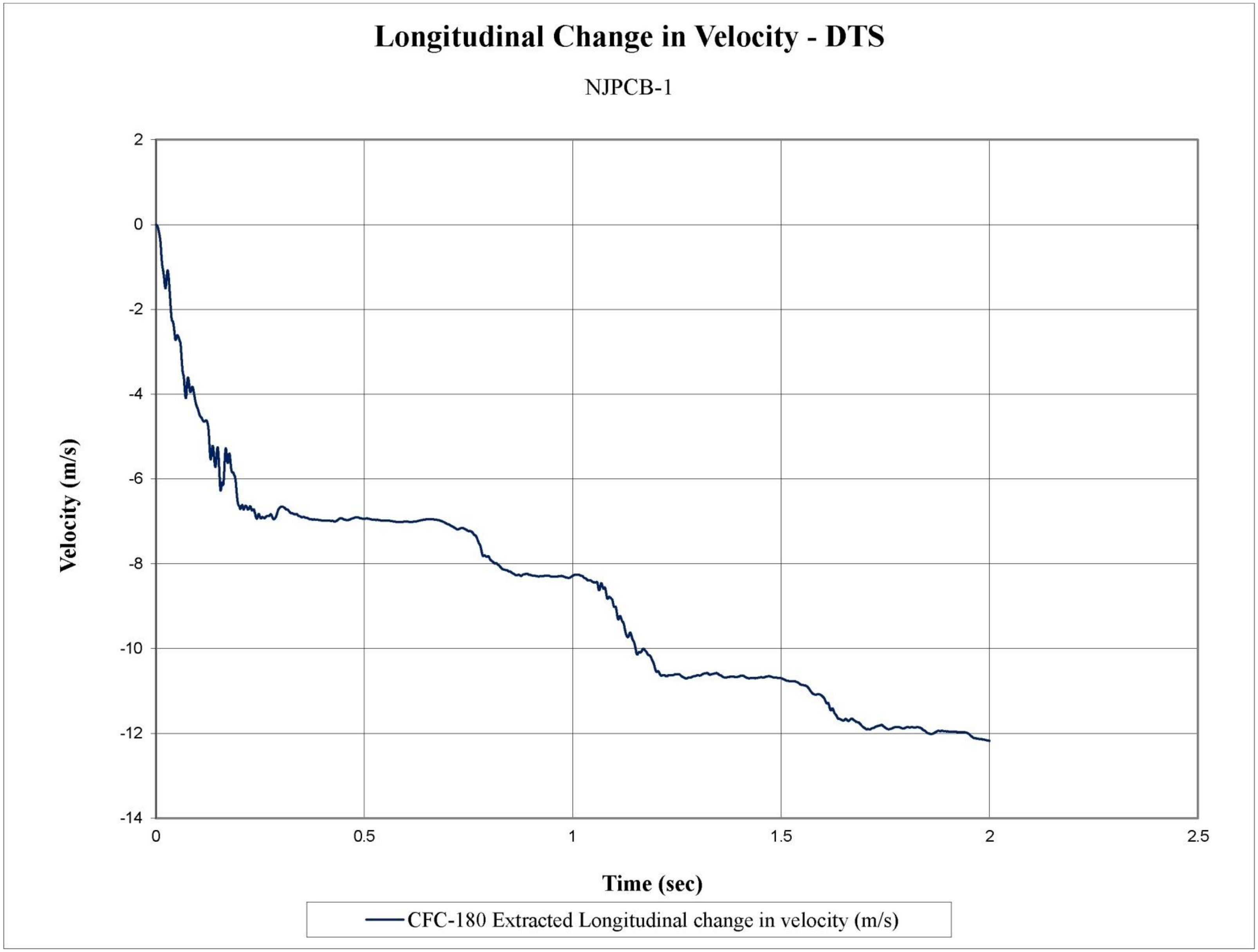


Figure F-10. Longitudinal Occupant Impact Velocity (DTS), Test No. NJPCB-1

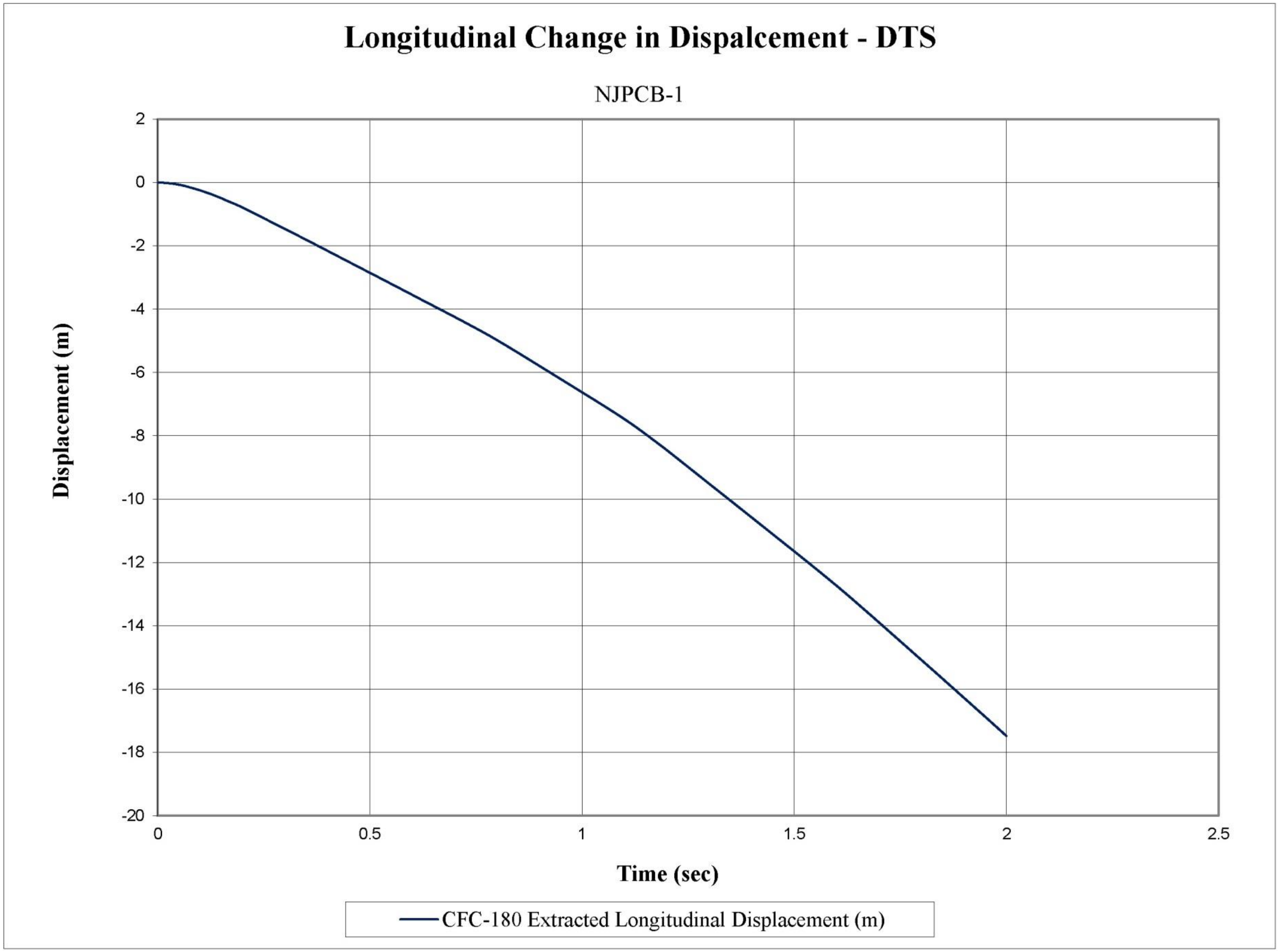


Figure F-11. Longitudinal Occupant Displacement (DTS), Test No. NJPCB-1

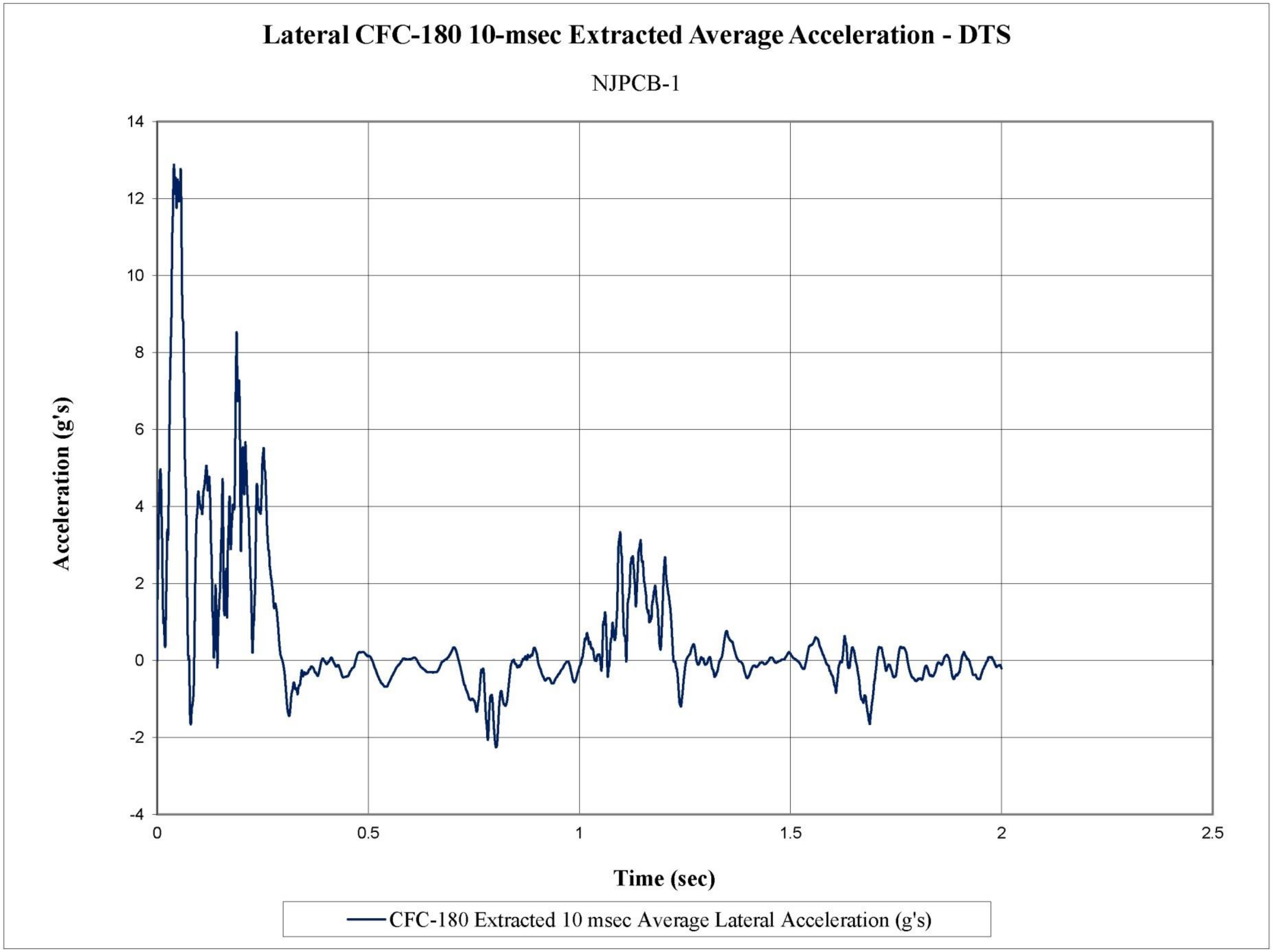


Figure F-12. 10-ms Average Lateral Deceleration (DTS), Test No. NJPCB-1

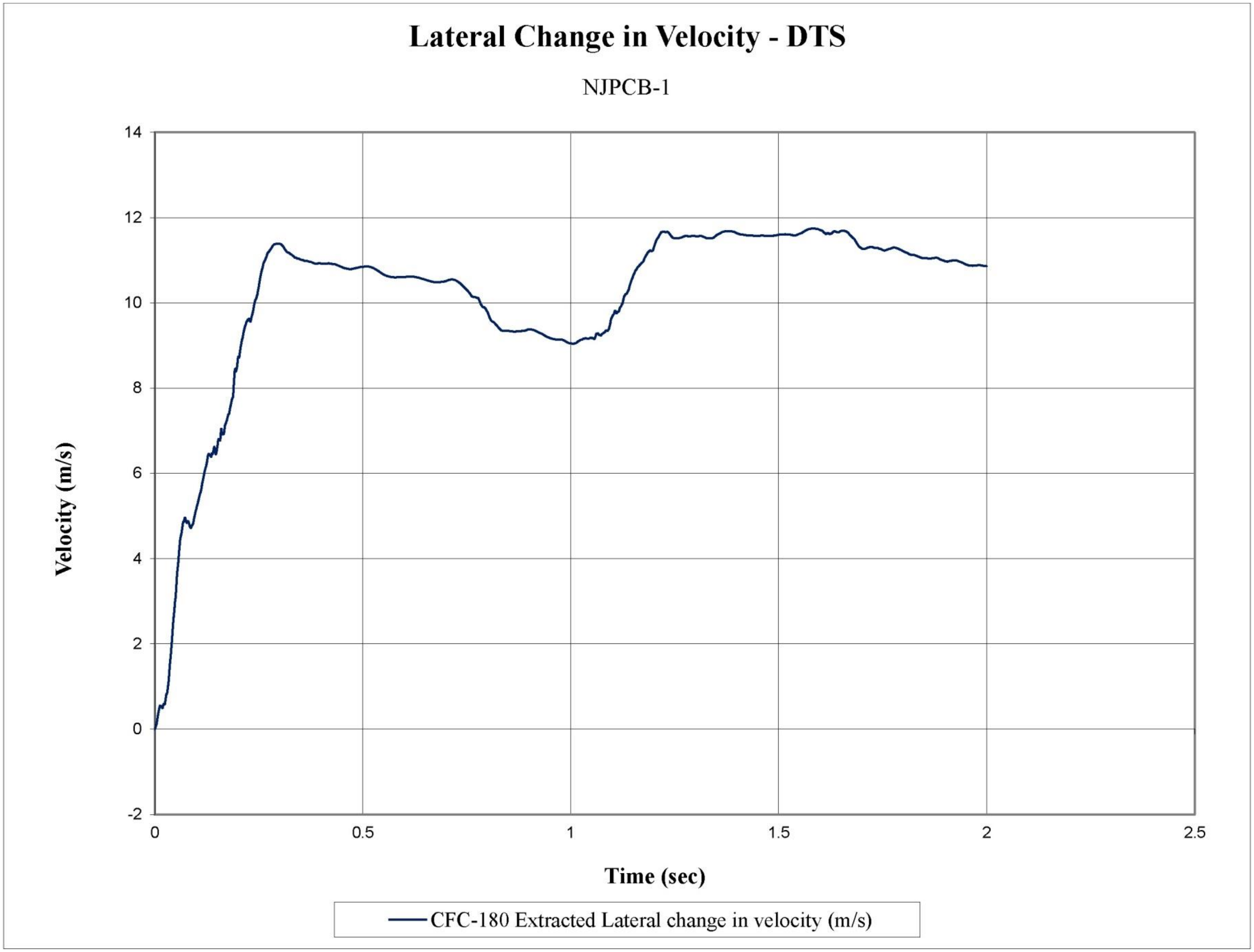


Figure F-13. Lateral Occupant Impact Velocity (DTS), Test No. NJPCB-1

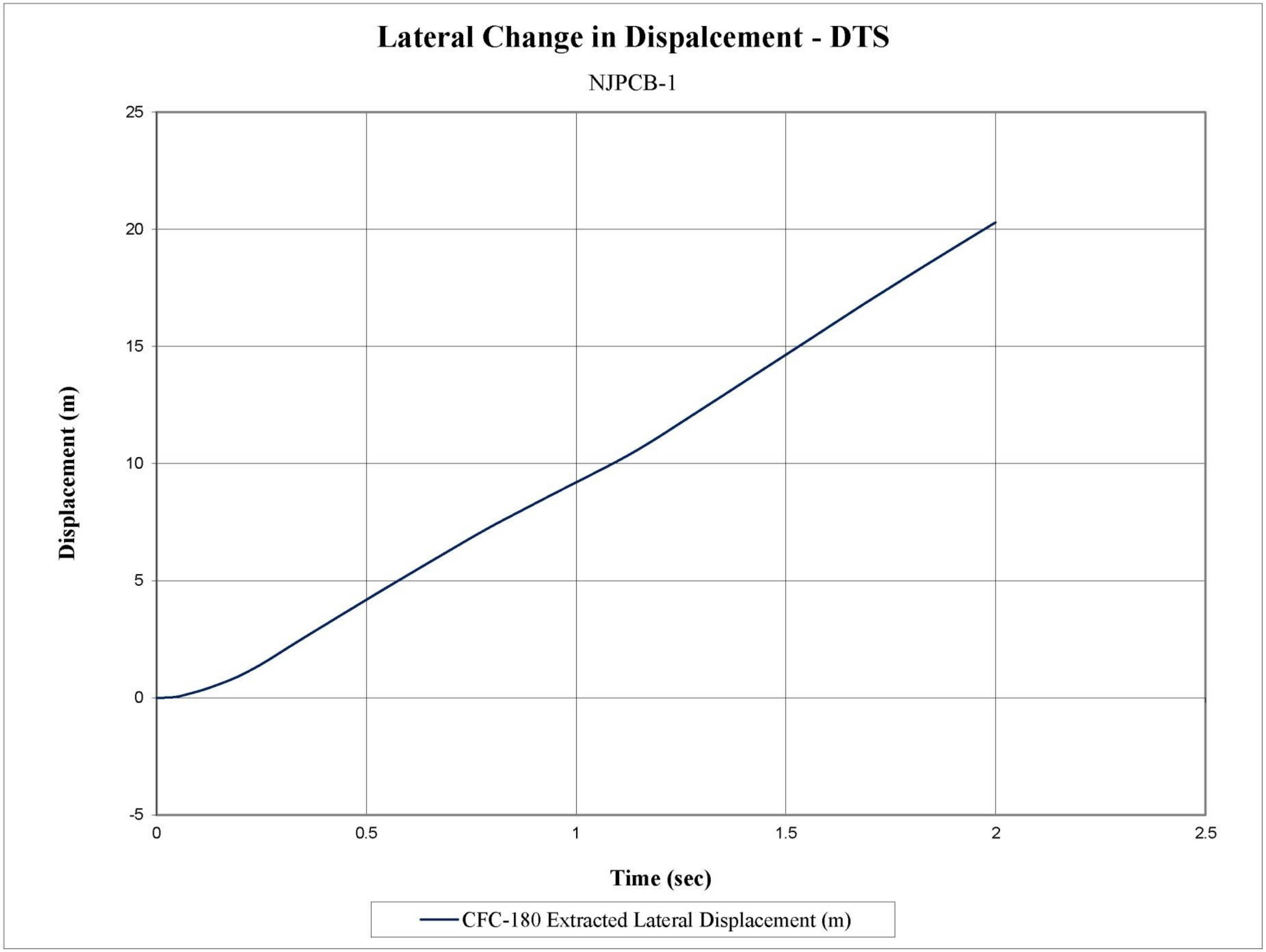


Figure F-14. Lateral Occupant Displacement (DTS), Test No. NJPCB-1

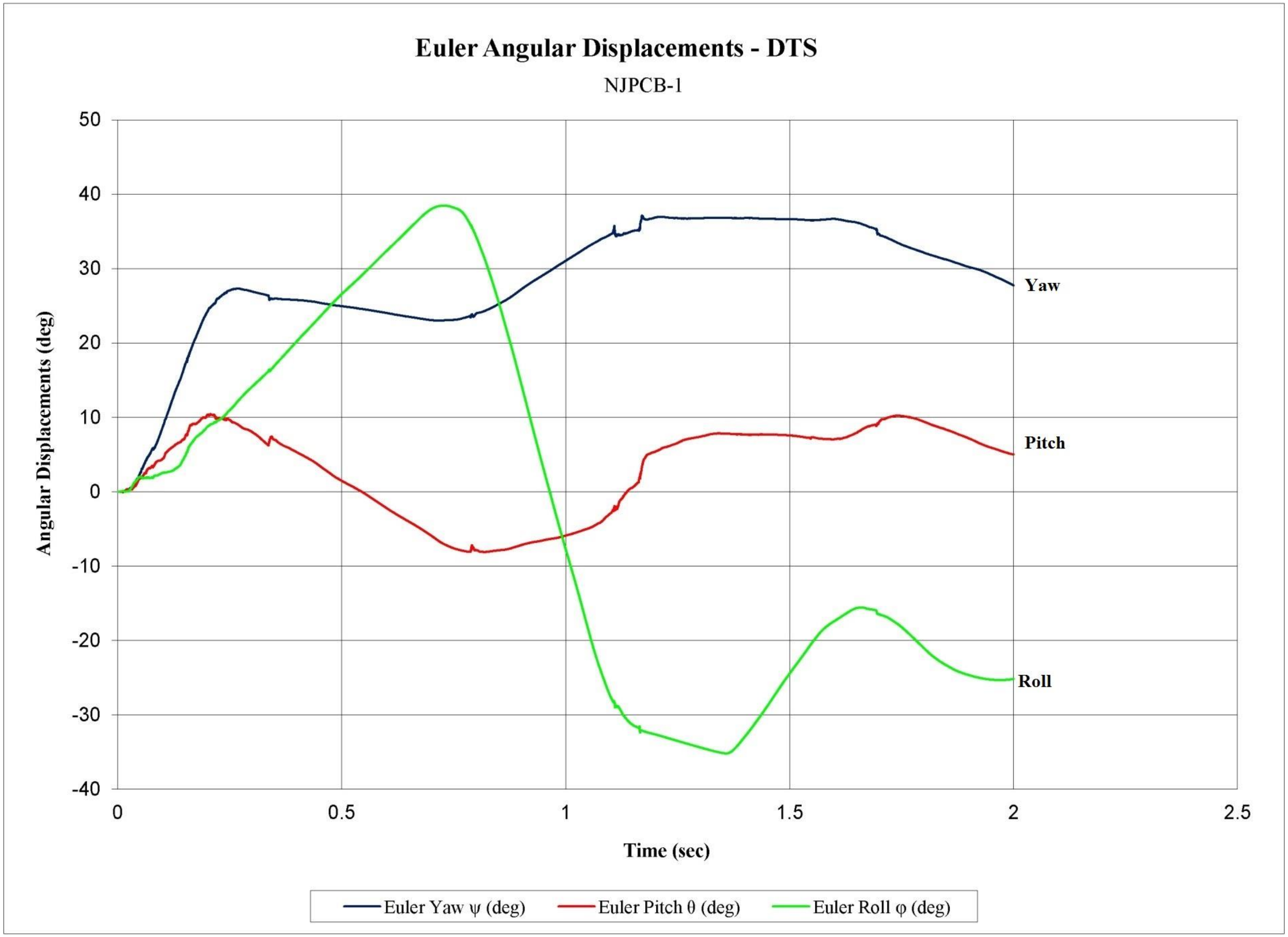


Figure F-15. Vehicle Angular Displacements (DTS), Test No. NJPCB-1

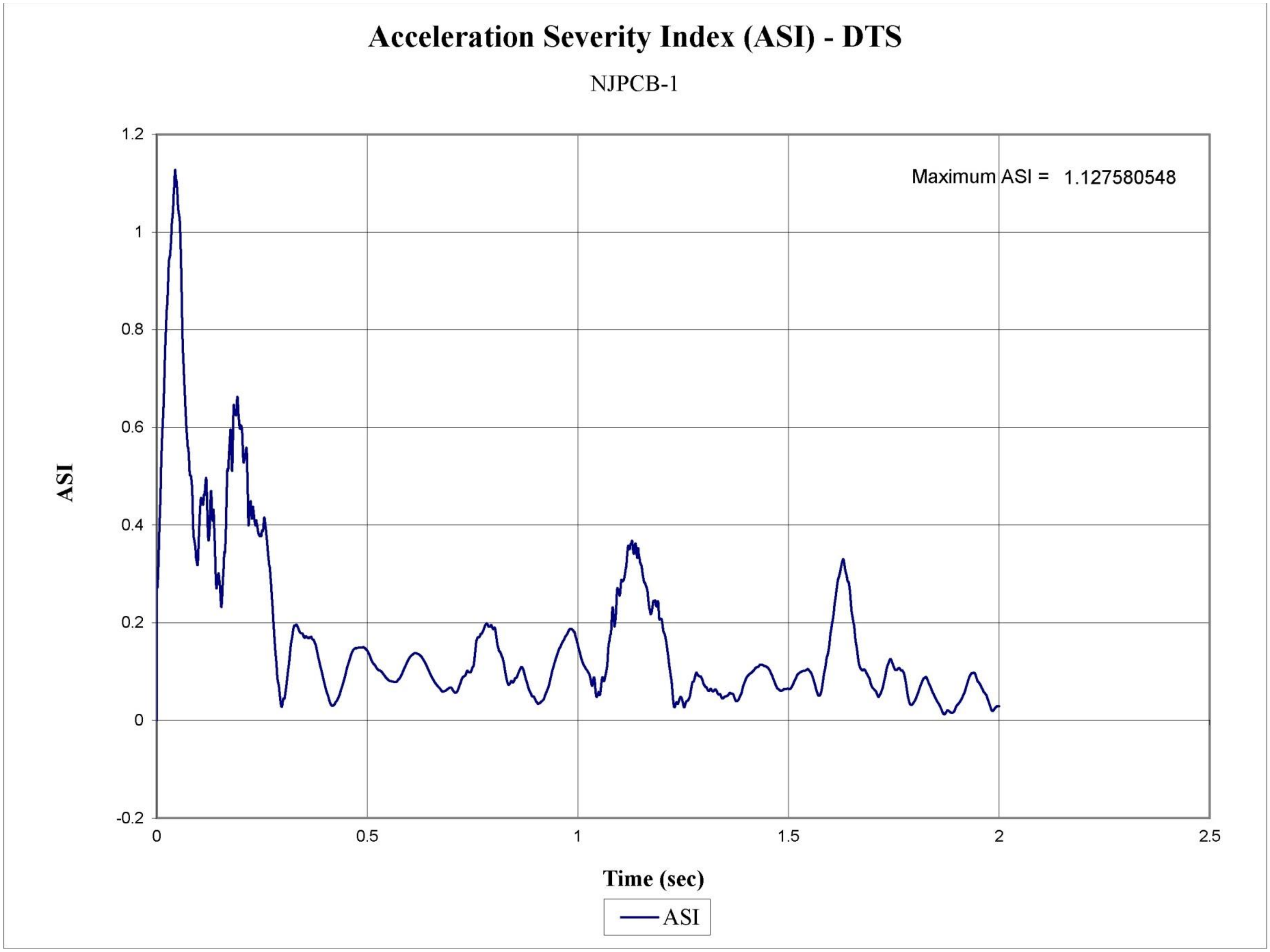


Figure F-16. Acceleration Severity Index (DTS), Test No. NJPCB-1

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