Research Project Number TPF-5(193) Supplement #88

PERFORMANCE EVALUATION OF NEW JERSEY'S PORTABLE CONCRETE BARRIER WITH A FREE-STANDING CONFIGURATION – TEST NO. NJPCB-3

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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's) Precast Concrete Curb, Construction Barrier, which will be referred as portable concrete barrier (PCB) in various configurations. This represents the third system as part of this study.
The primary objective of this research effort was to evaluate the safety performance of the NJDOT PCB, Type 4 (Alternative B) with a free-standing configuration, corresponding to joint class A in the 2013 NJDOT Roadway Design Manual and connection type A in the 2015 NJDOT Roadway Design Manual. Barrier nos. 1 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. 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 the 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 third of nine documents in the nine-test series.</td></tr>
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DISCLAIMER STATEMENT

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 Dr. Jennifer Schmidt, Research Assistant Professor.

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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) system with a free-standing configuration, corresponding to joint class A in the 2013 NJDOT *Roadway Design Manual* [1] and connection type A in the 2015 NJDOT *Roadway Design Manual* [2]. 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 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 (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 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 Barriers

<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 free-standing configuration, as shown in Figures 1 through 14. This system uses NJDOT barriers, Type 4 (Alternative B) with joint class A as specified in the 2013 NJDOT *Roadway Design Manual* and connection type A in the 2015 NJDOT *Roadway Design Manual*. Photographs of the test installation are shown in Figures 15 through 17. 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, 15, 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, 11, 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 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 drilled holes in the concrete tarmac, as shown in Figure 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 MwRSF's Outdoor Test Site. The concrete tarmac had a compressive strength between 5,970 and 7,040 psi (41.2 and 48.5 MPa), as shown in Appendix C.

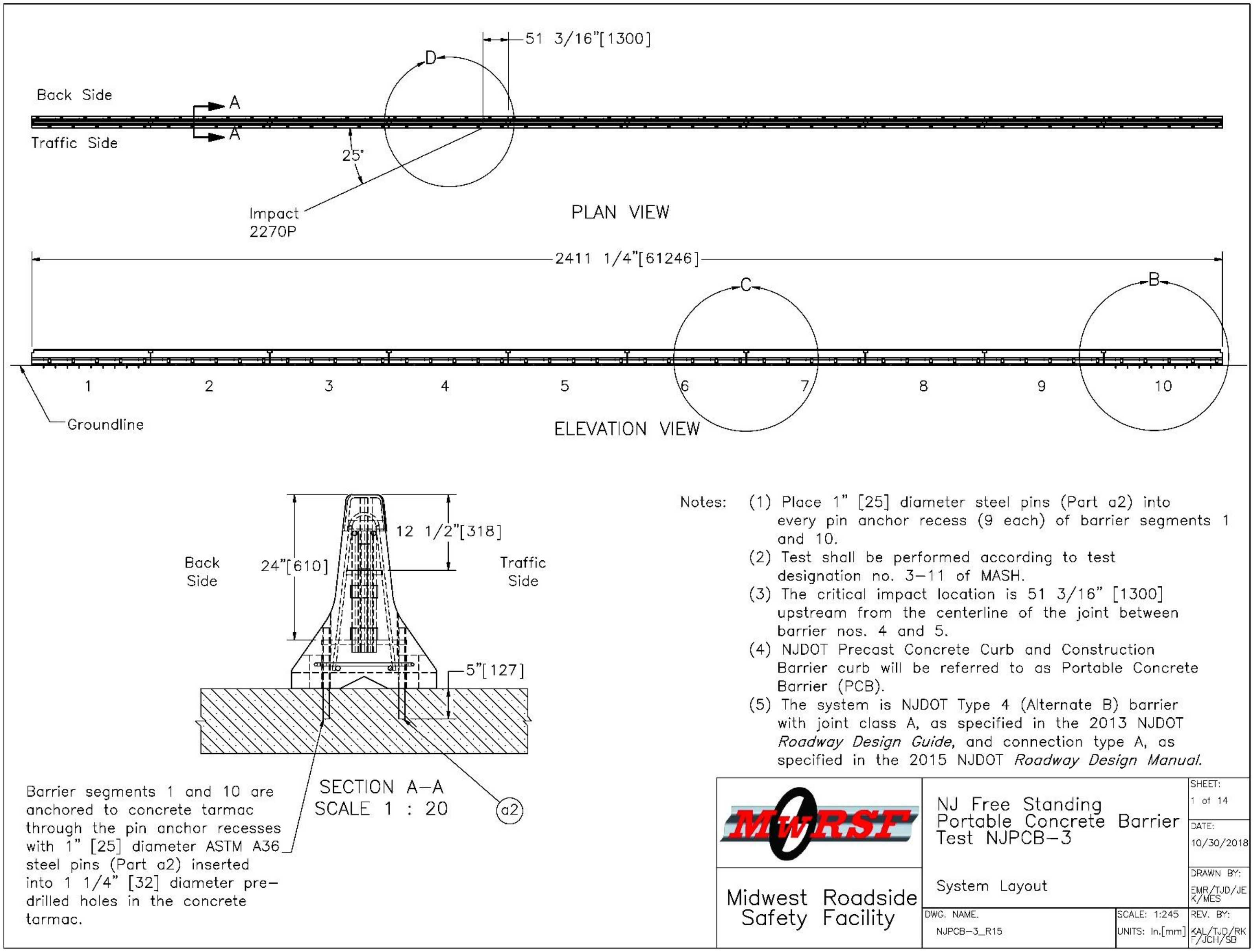


Figure 1. Test Installation Layout, Test No. NJPCB-3

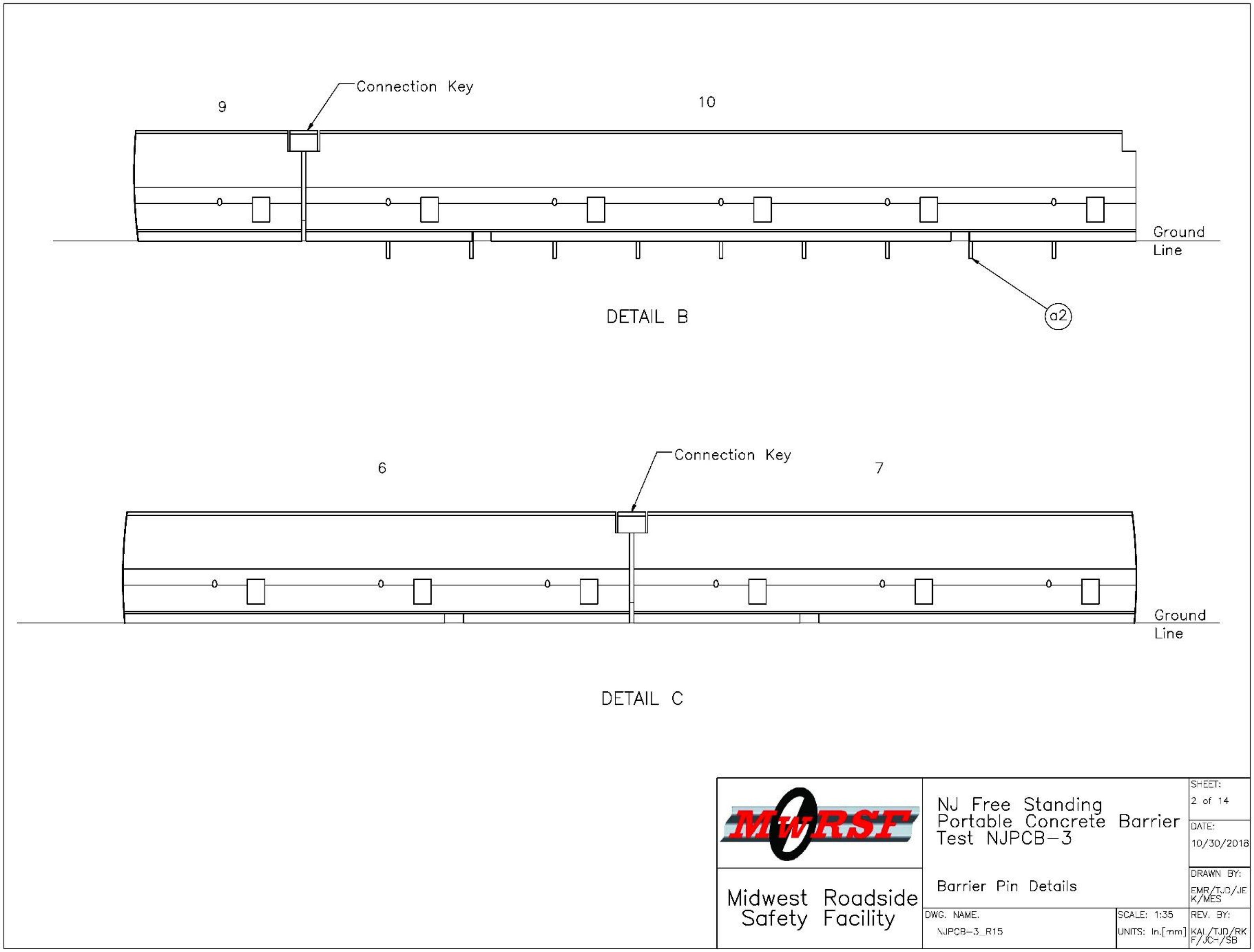


Figure 2. PCB Pin Anchor Details, Test No. NJPCB-3

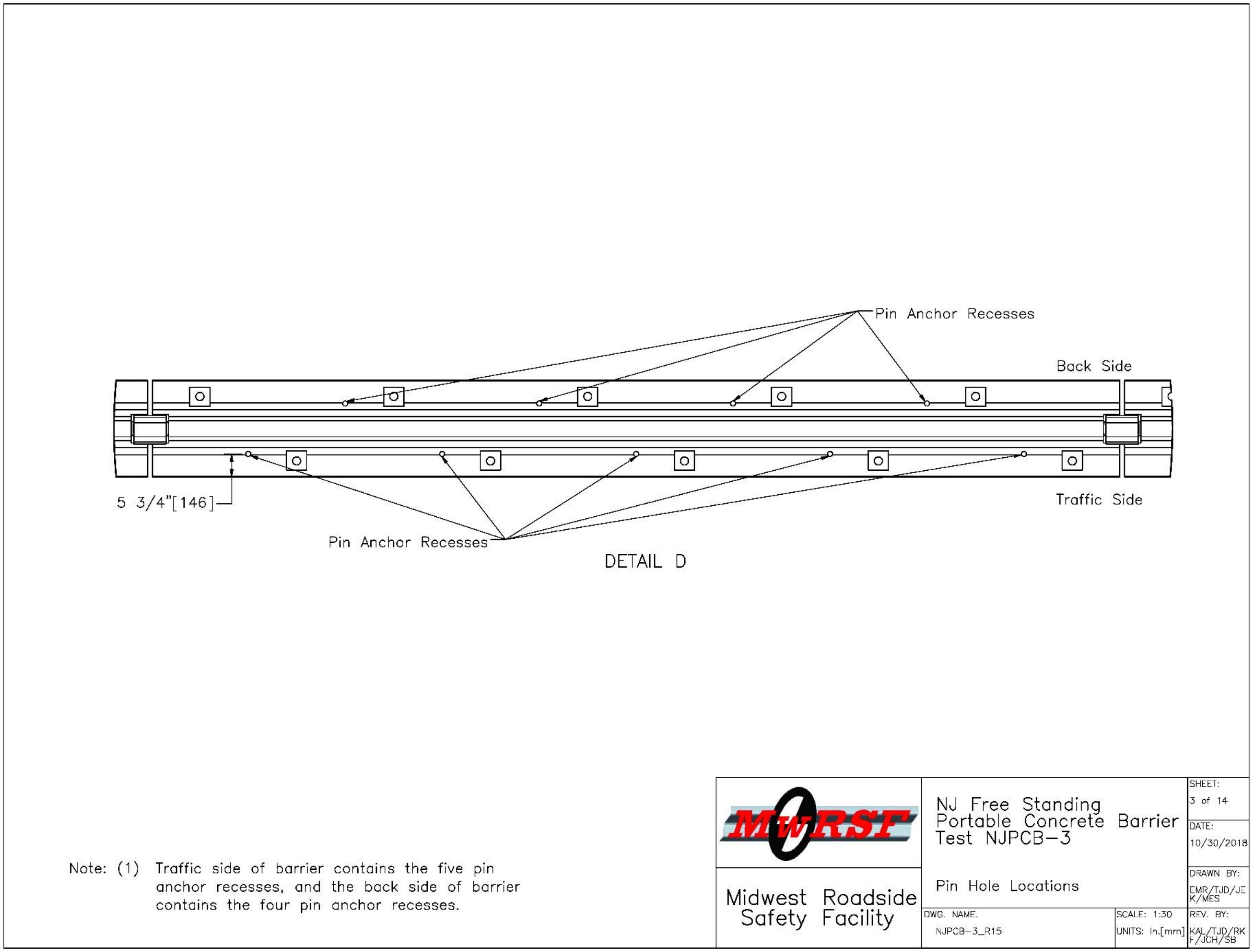


Figure 3. PCB Pin Anchor Locations, Test No. NJPCB-3

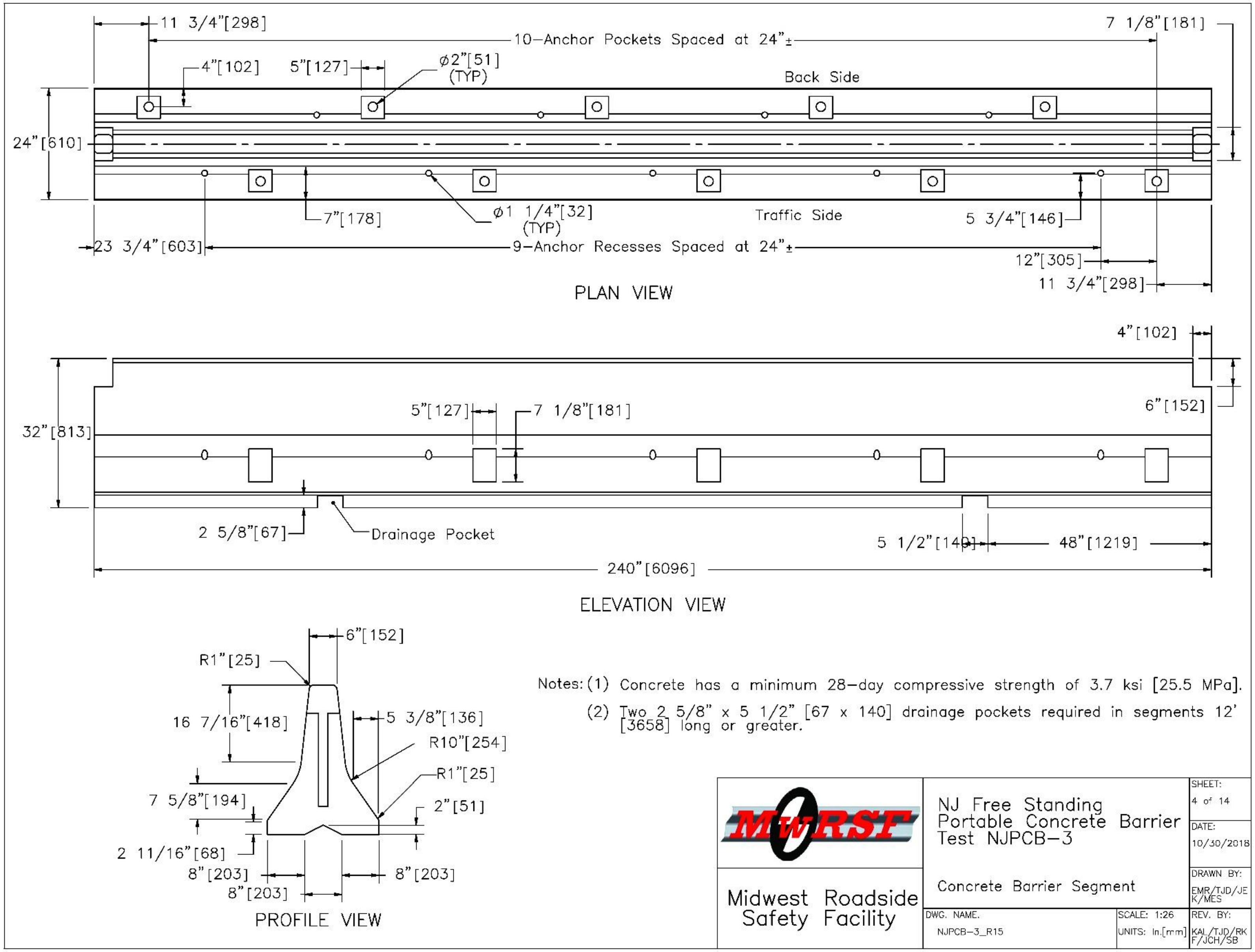


Figure 4. PCB Details, Test No. NJPCB-3

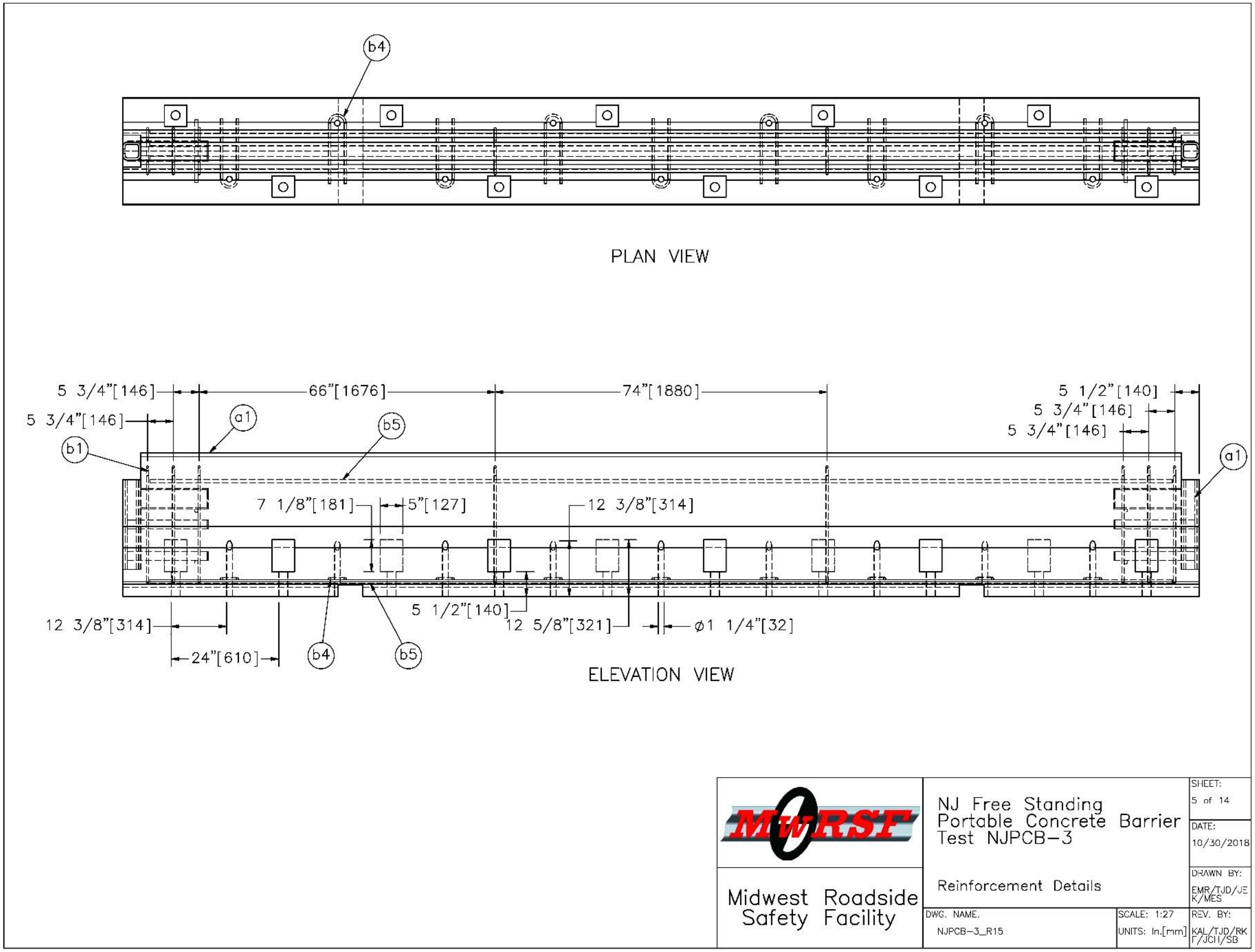


Figure 5. PCB Reinforcement Details, Test No. NJPCB-3

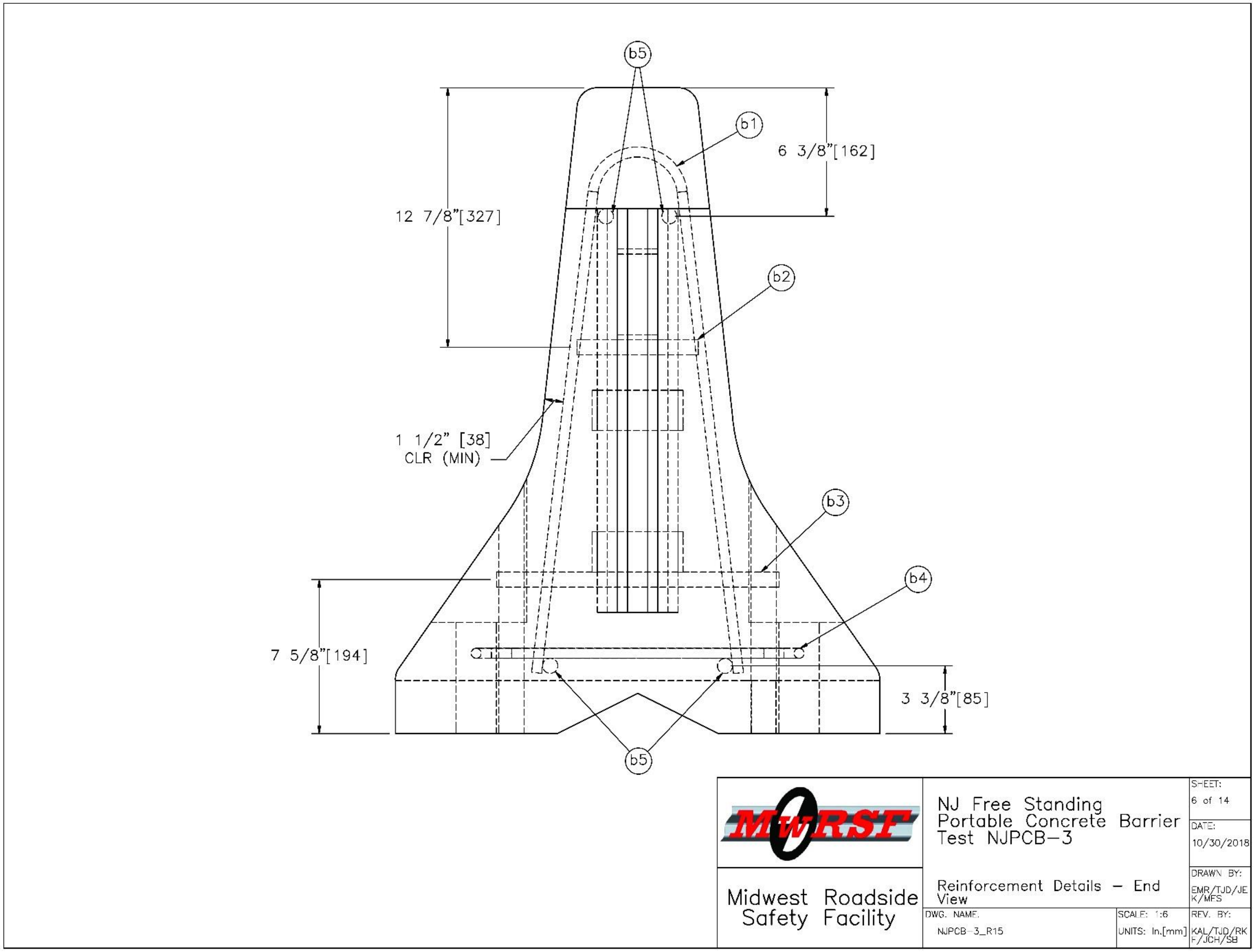


Figure 6. PCB Reinforcement Details – End View, Test No. NJPCB-3

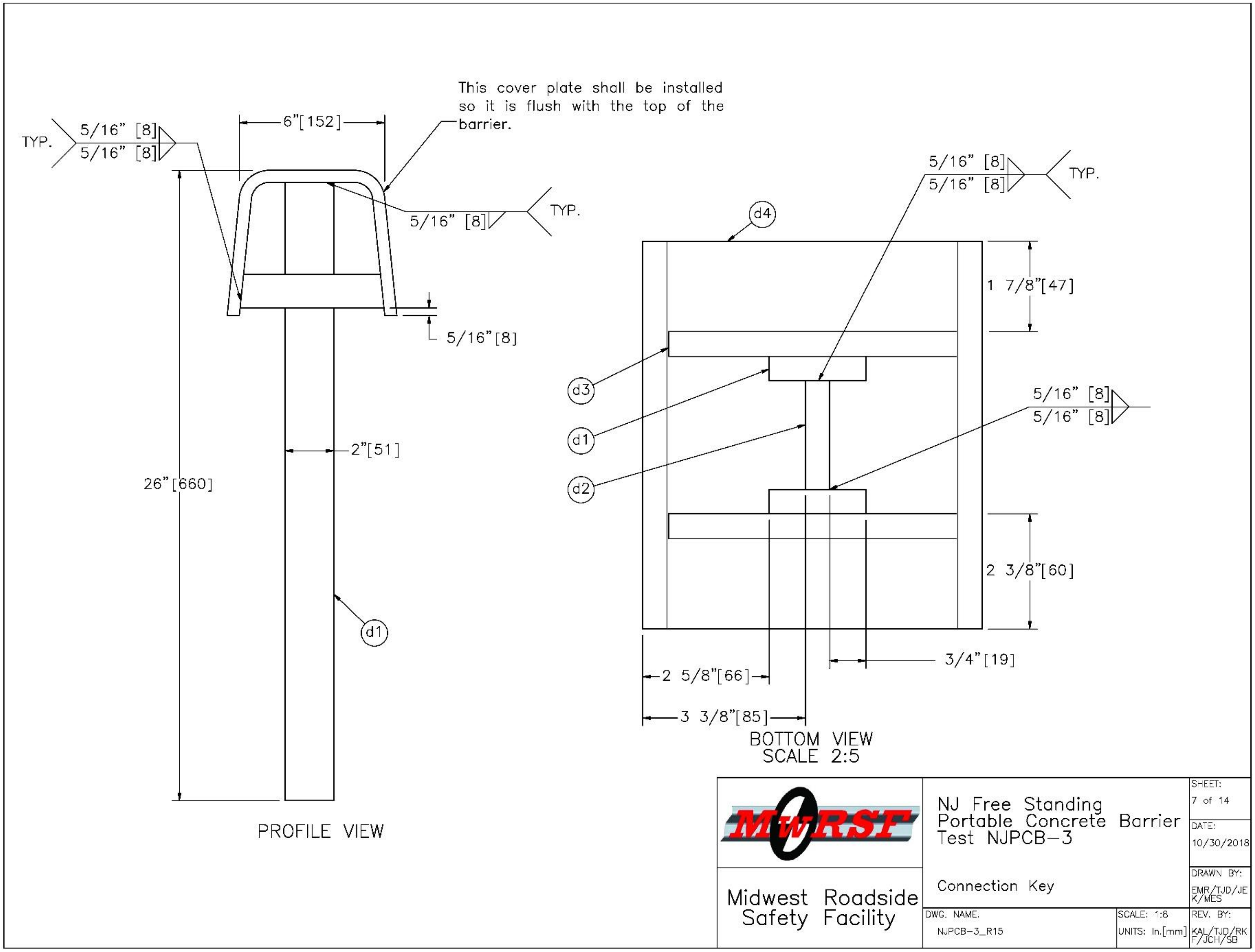


Figure 7. PCB Connection Key Assembly Details, Test No. NJPCB-3

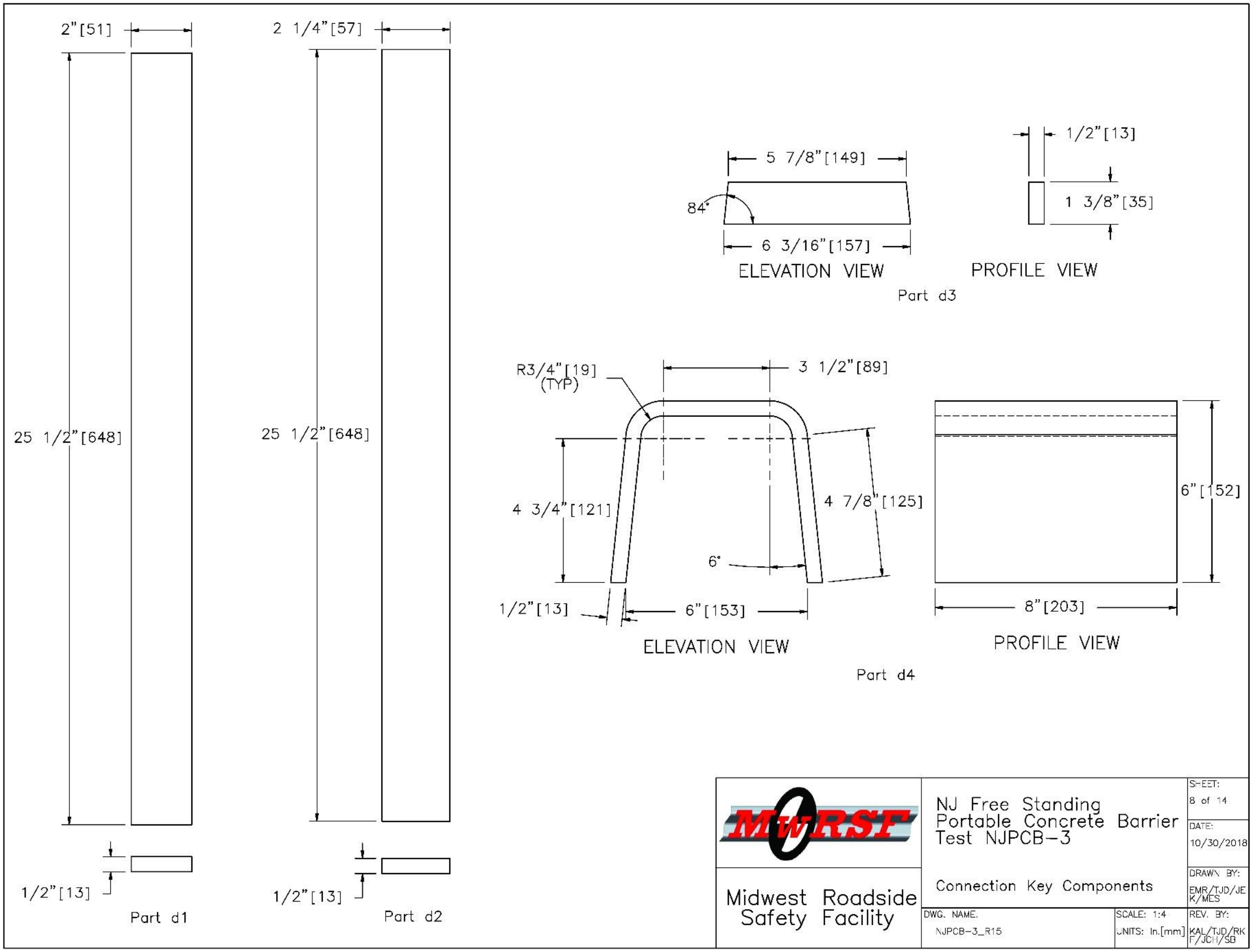


Figure 8. PCB Connection Key Component Details, Test No. NJPCB-3

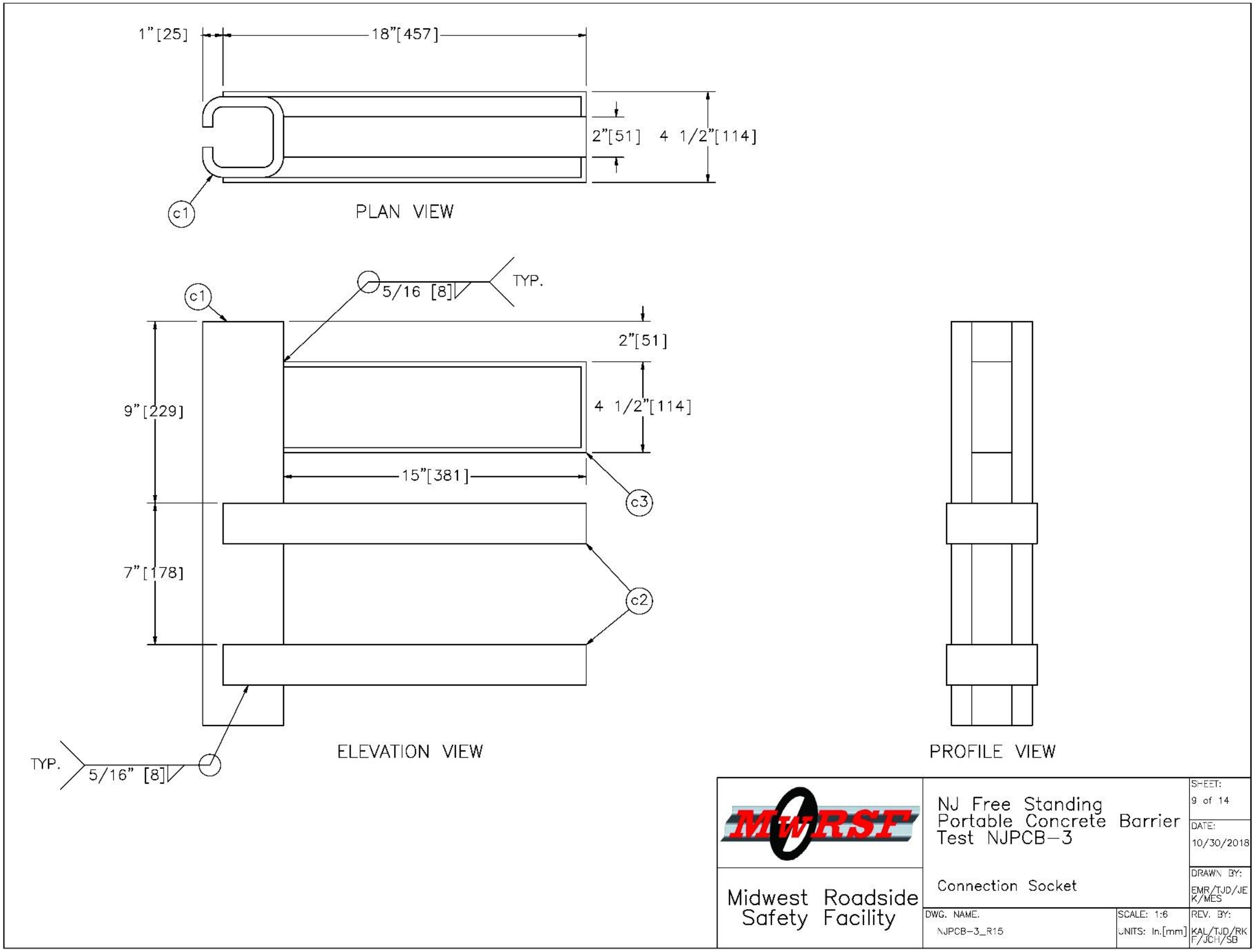


Figure 9. PCB Connection Socket Details, Test No. NJPCB-3

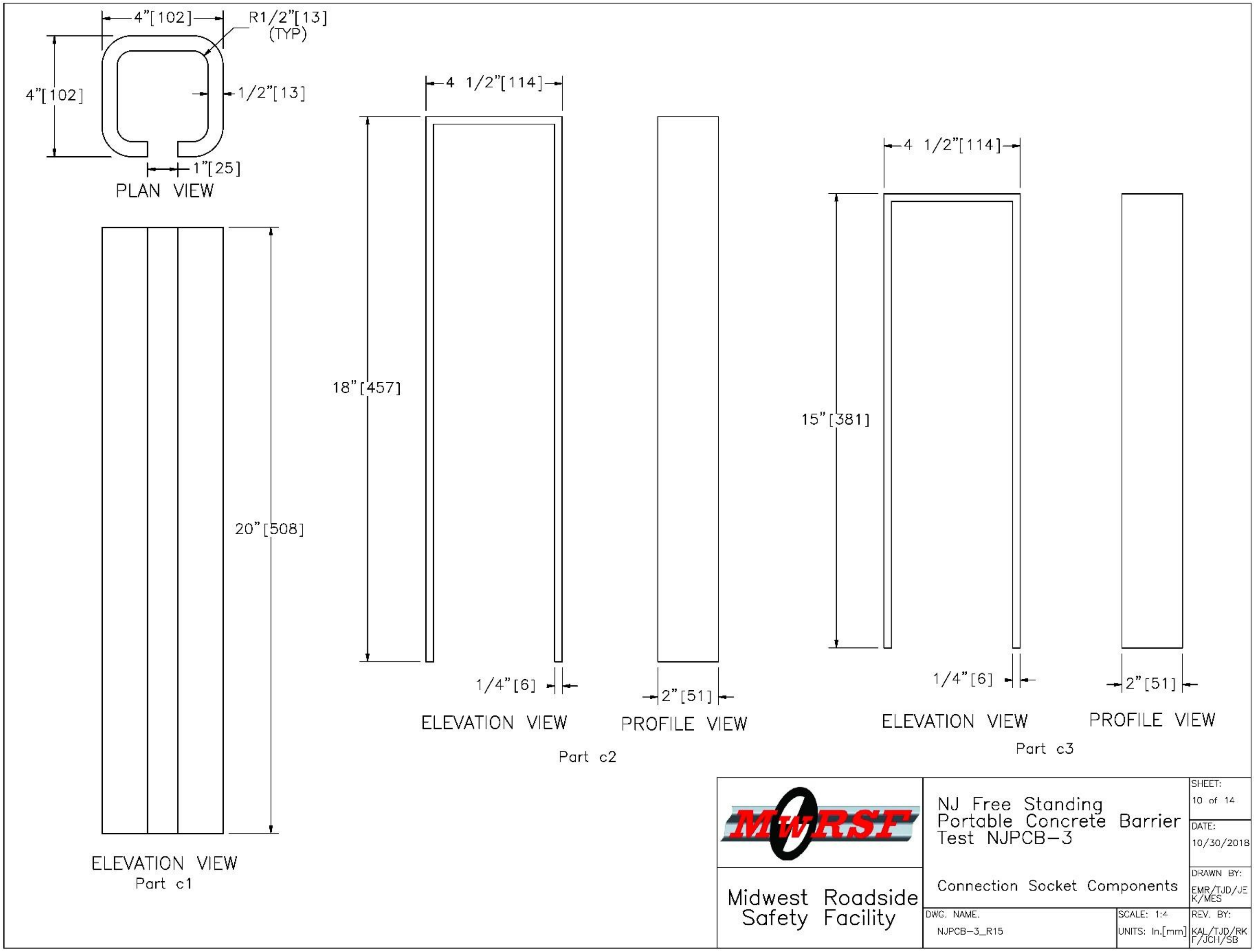


Figure 10. PCB Connection Socket Component Details, Test No. NJPCB-3

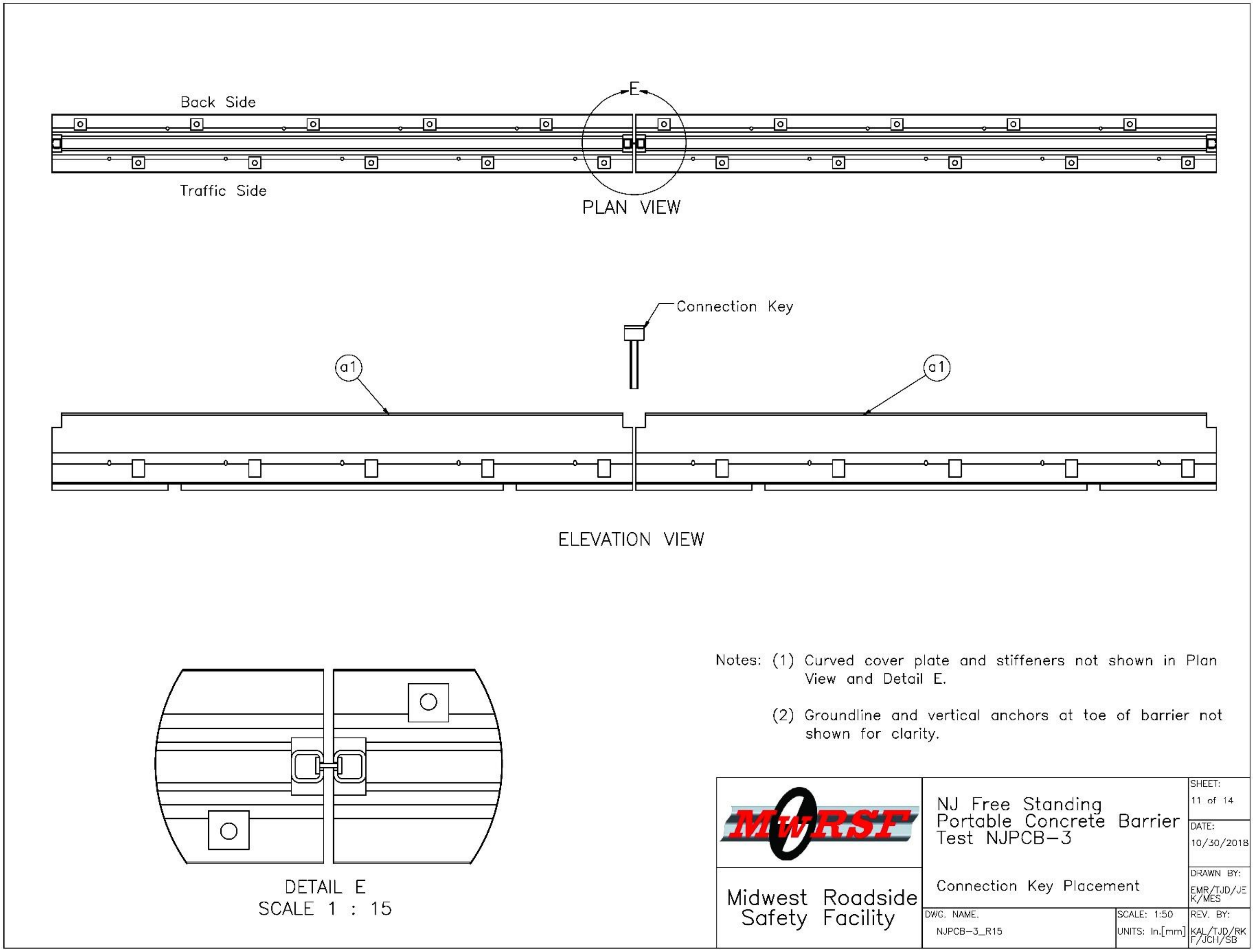
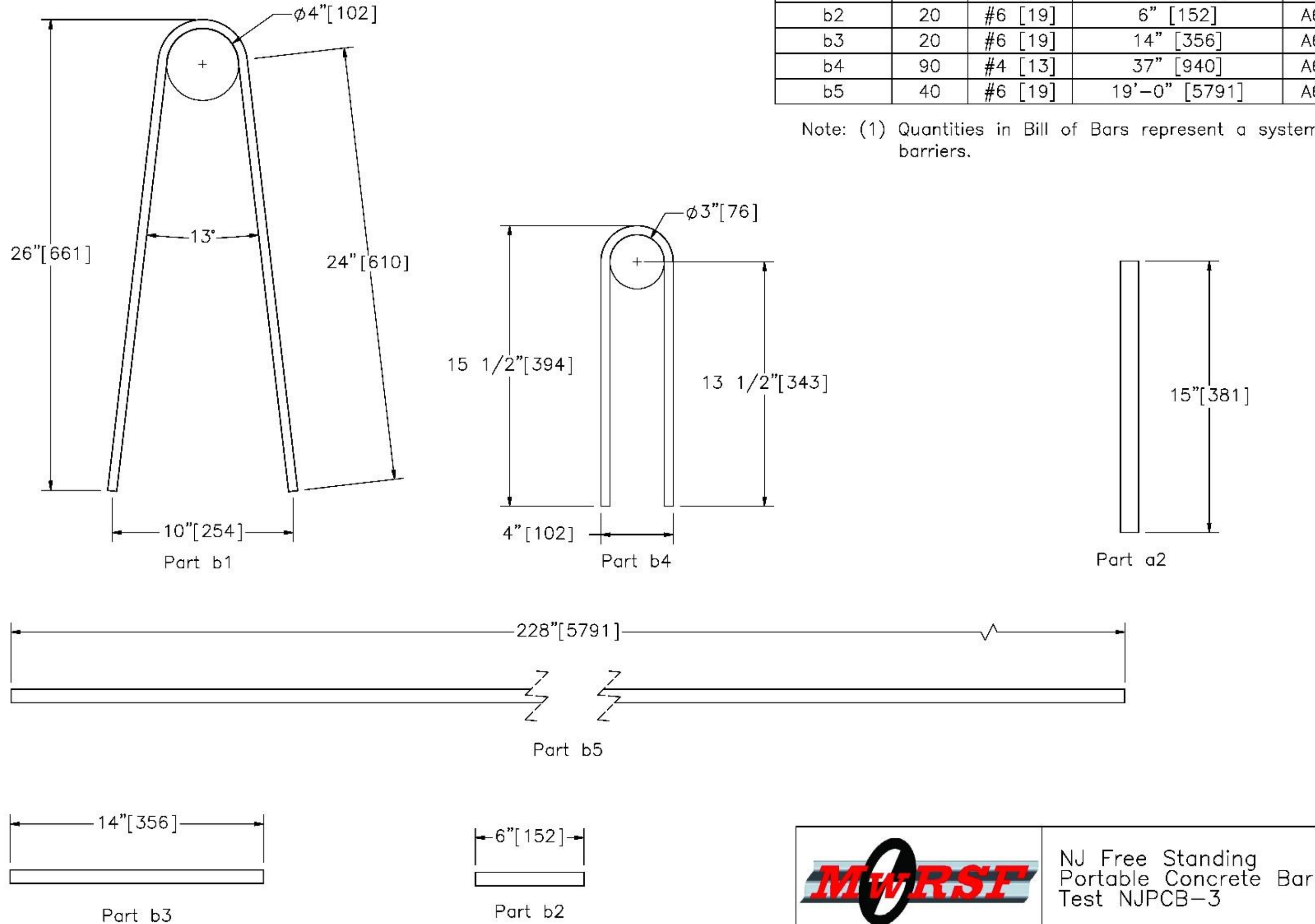


Figure 11. Connection Key Placement Details, Test No. NJPCB-3

BILL OF BARS				
ITEM NO.	QTY.	BAR SIZE	UNBENT LENGTH	MATERIAL SPEC.
a2	18	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.



MwRSF Midwest Roadside Safety Facility	NJ Free Standing Portable Concrete Barrier Test NJPCB-3 Bill of Bars	SHEET: 12 of 14 DATE: 10/30/2018 DRAWN BY: EMR/TJD/JEK/MFS
	DWG. NAME. NJPCB-3_R15 | SCALE: 1:8 UNITS: in.[mm]	REV. BY: KAL/TJD/RKF/JCH/SB

Figure 12. PCB Reinforcement Details, Test No. NJPCB-3

(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 connection key in every joint. Pin end segments with pins in every anchor pin recess.

Midwest Roadside Safety Facility	NJ Free Standing Portable Concrete Barrier Test NJPCB-3	SHEET: 13 of 14
		DATE: 10/30/2018
	General Notes	DRAWN BY: EMR/TJD/JEK/MES
	DWG. NAME. NJPCB-3_R15 / SCALE: None / UNITS: In.[mm]	REV. BY: KAL/TJD/RKF/JCH/SB

Figure 13. General Notes, Test No. NJPCB-3

Item No.	QTY.	Description	Material Spec	Galvanization Spec
a1	10	Concrete Barrier Segment – NJDOT Type 4 Barrier (Alternate B)	Min. f'c = 3,700 psi [25.5 MPa]	–
a2	18	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	–

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

Midwest Roadside Safety Facility

NJ Free Standing Portable Concrete Barrier Test NJPCB-3

Bill of Materials

SHEET: 14 of 14
DATE: 10/30/2018
DRAWN BY: EMR/TJD/JEK/MES
DWG. NAME. NJPCB-3_R15
SCALE: None
UNITS: In.[mm]
REV. BY: KAL/TJD/RKF/JCH/SB

Figure 14. Bill of Materials, Test No. NJPCB-3

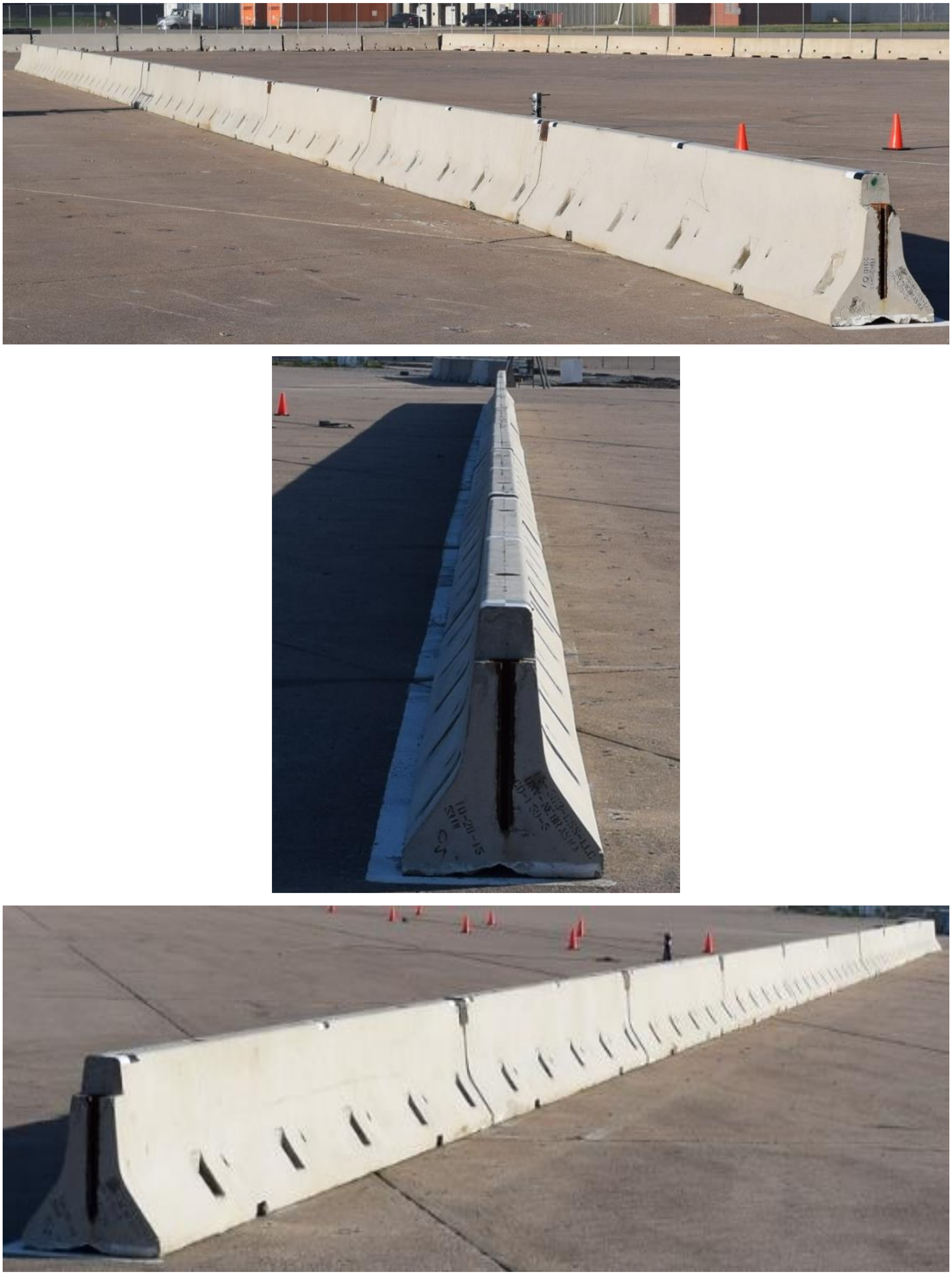


Figure 15. NJDOT PCB with Free-Standing Configuration Test Installation, Test No. NJPCB-3

Figure 16. PCB Connection Key and Connection Socket, Test No. NJPCB-3

Figure 17. PCB Pin Anchor Recesses (Barrier Nos. 1 and 10), Test No. NJPCB-3

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-3, 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 5,093 lb (2,310 kg), 4,999 lb (2,268 kg), and 5,154 lb (2,338 kg), respectively. The test vehicle is shown in Figure 18, and vehicle dimensions are shown in Figure 19.

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 19 and 20. 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 20. 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 so 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 so the vehicle could be brought safely to a stop after the test.

Figure 18. Test Vehicle, Test No. NJPCB-3

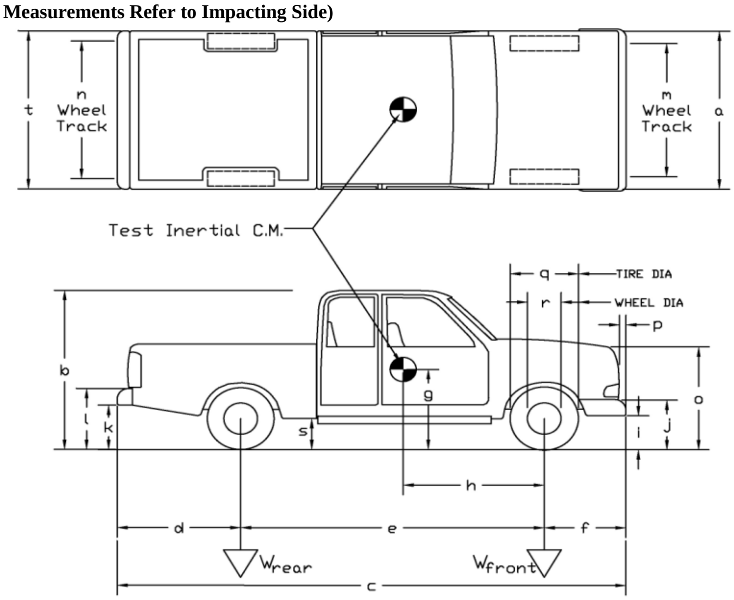
Date: 4/22/2016 **Test Number:** NJPCB-3 **Model:** Ram

Make: Dodge **Vehicle I.D.#:** 1D3HB18P79S813848

Tire Size: P 265/70R17 113T M+S **Year:** 2010 **Odometer:** 171791

Tire Inflation Pressure: 35

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



Vehicle Geometry -- in. (mm)

a	77 1/8	(1959)	b	74 5/8	(1895)
c	229	(5817)	d	46 3/8	(1178)
e	140 3/4	(3575)	f	41 3/8	(1051)
g	28 1/8	(716)	h	62	(1574)
i	12 1/4	(311)	j	26	(660)
k	21	(533)	l	30 3/8	(772)
m	67 3/4	(1721)	n	67 1/2	(1715)
o	45 1/8	(1146)	p	4 1/2	(114)
q	31 1/2	(800)	r	18 5/8	(473)
s	14 3/4	(375)	t	77 1/8	(1959)

Wheel Center Height Front	14 7/8	(378)
Wheel Center Height Rear	15 3/8	(391)
Wheel Well Clearance (F)	35 1/8	(892)
Wheel Well Clearance (R)	38 1/2	(978)
Frame Height (F)	18 1/8	(460)
Frame Height (R)	26 1/4	(667)
Engine Type	Gasoline	
Engine Size	4.7 L V8	
Transmission Type:	Automatic	
Drive Type:	RWD	

Mass Distribution lb (kg)

Gross Static	LF	1458	(661)	RF	1432	(650)
	LR	1154	(523)	RR	1110	(503)

Weights lb (kg)	Curb		Test Inertial		Gross Static	
W-front	2856	(1295)	2798	(1269)	2890	(1311)
W-rear	2237	(1015)	2201	(998)	2264	(1027)
W-total	5093	(2310)	4999	(2268)	5154	(2338)

GVWR Ratings

Front	3700
Rear	3900
Total	6700

Dummy Data

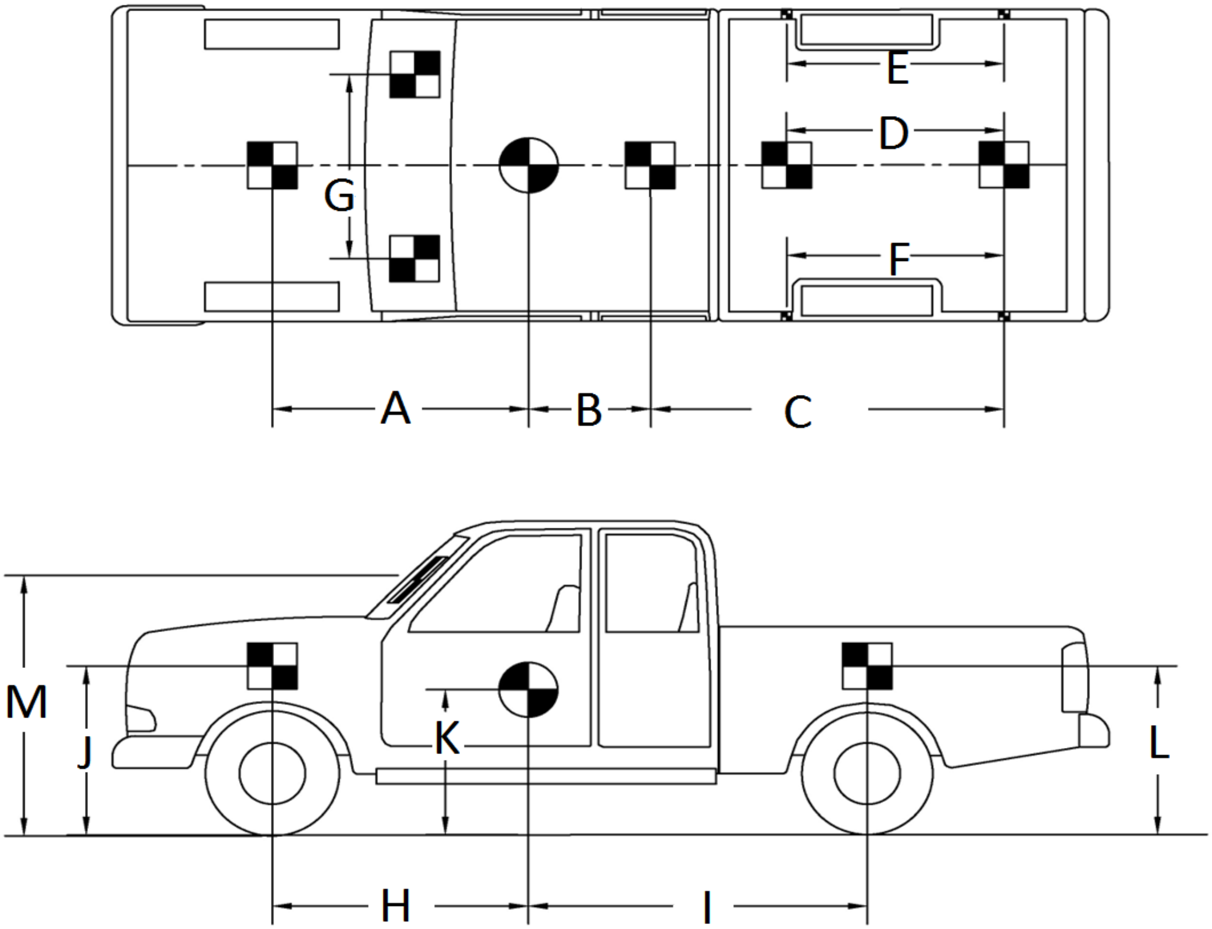
Type: Hybrid II

Mass: 155 lb

Seat Position: Driver Seat

Note any damage prior to test: Dent on rear diver side near MwRSF sticker, Dent near back passenger door handle, protrusion middle back passenger side door

Figure 19. Vehicle Dimensions, Test No. NJPCB-3



TEST #: NJPCB-3

TARGET GEOMETRY-- in. (mm)

A	76 1/4	(1937)	E	63 1/4	(1607)	J	38 3/4	(984)
B	27 1/4	(692)	F	63 1/4	(1607)	K	28 1/8	(716)
C	74 1/2	(1892)	G	23	(584)	L	42 1/8	(1070)
D	48	(1219)	H	62 7/8	(1597)	M	65 1/8	(1654)
			I	77 5/8	(1972)			

Figure 20. Target Geometry, Test No. NJPCB-3

4.4 Simulated Occupant

For test no NJPCB-3, 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 155 lb (70 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. All of the 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 two systems, the SLICE-1 and SLICE-2 units, were modular data acquisition systems manufactured by Diversified Technical Systems, Inc. (DTS) of Seal Beach, California. The SLICE-2 unit was designated as the primary system. The acceleration sensors were mounted inside the bodies of custom-built, SLICE 6DX event data recorders and recorded data at 10,000 Hz to the onboard microprocessor. Each 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 programs and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

4.5.2 Rate Transducers

Two identical angular rate sensor systems, which were mounted inside the bodies of the SLICE-1 and SLICE-2 event data recorders, measured the rates of rotation of the test vehicle. Each 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 microprocessors. 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.

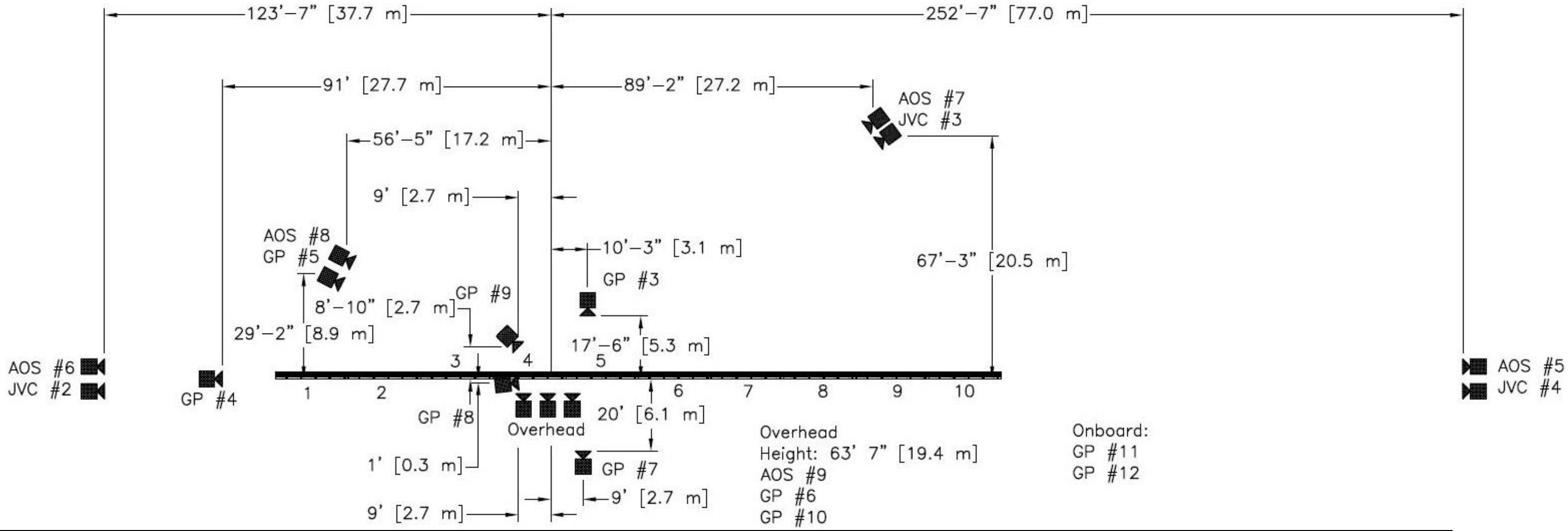
4.5.3 Retroreflective Optic Speed Trap

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, ten GoPro digital video cameras, and three JVC digital video cameras were utilized to film test no. NJPCB-3. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 21. Due to technical difficulties, JVC-3 did not collect data.

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	Nikon 28-70	50
AOS-7	AOS X-PRI Gigabit	500	Fujinon 50mm Fixed	-
AOS-8	AOS S-VIT 1531	500	Sigma 28-70 DG	35
AOS-9	AOS TRI-VIT 2236	500	Kowa 12 mm 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		
GP-11	GoPro Hero 4	120		
GP-12	GoPro Hero 4	120		
JVC-2	JVC – GZ-MG27u (Everio)	29.97		
JVC-3	JVC – GZ-MG27u (Everio)	29.97		
JVC-4	JVC – GZ-MG27u (Everio)	29.97		

Figure 21. Camera Locations, Speeds, and Lens Settings, Test No. NJPCB-3

5 FULL-SCALE CRASH TEST NO. NJPCB-3

5.1 Weather Conditions

Test no. NJPCB-3 was conducted on April 22, 2016 at approximately 12:30 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-3

Temperature	63° F
Humidity	45%
Wind Speed	3 mph
Wind Direction	0° from True North
Sky Conditions	Sunny
Visibility	9 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	1.26 in.
Previous 7-Day Precipitation	2.24 in.

5.2 Test Description

The 4,999-lb (2,268-kg) pickup truck impacted the NJDOT PCB, Type 4 (Alternative B) with a free-standing configuration, corresponding to joint class A in the 2013 NJDOT *Roadway Design Manual* and connection type A in the 2015 NJDOT *Roadway Design Manual*, at a speed of 62.3 mph (100.2 km/h) and at an angle of 25.8 degrees. A summary of the test results and sequential photographs are shown in Figure 23. Additional sequential photographs are shown in Figures 24 and 25. Documentary photographs of the crash test are shown in Figure 26.

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 27, which was selected using Table 2.6 of MASH 2009. The actual point of impact was 5 in. (127 mm) downstream from the target location. A sequential description of the impact events is contained in Table 6. The vehicle came to rest 194 ft (59.1 m) downstream from the impact point and 44 ft – 1 in. (13.4 m) laterally away from the traffic side of the barrier after brakes were applied. The vehicle trajectory and final position are shown in Figures 23 and 28.

Table 6. Sequential Description of Impact Events, Test No. NJPCB-3

TIME (sec)	EVENT
0.000	Vehicle's left-front tire impacted barrier no. 4 at 3 ft – $10^{3}/_{16}$ in. (1,173 mm) upstream from centerline of joint between barrier nos. 4 and 5.
0.006	Left corner of front bumper deformed inward after contact with barrier no. 4.
0.012	Vehicle's left headlight and left fender deformed.

0.020	Vehicle’s hood contacted barrier no. 4 at downstream end and deformed.
0.022	Vehicle’s grille contacted barrier no. 4 at downstream end and deformed.
0.028	Vehicle’s right headlight and left-front door deformed.
0.032	Downstream end of barrier no. 4 deflected backward while upstream end deflected forward. Upstream end of barrier no. 5 deflected backward while downstream end deflected forward.
0.044	Vehicle’s right-side airbag deployed.
0.048	Vehicle yawed away from system.
0.050	Vehicle’s left-rear door contacted system and deformed, and vehicle rolled away from system.
0.056	Upstream end of barrier no. 4 cracked.
0.062	Vehicle’s left-side mirror deformed.
0.064	Upstream end of barrier no. 4 spalled.
0.070	Vehicle pitched upward, barrier no. 5 cracked from the center, and downstream end of barrier no. 3 deflected forward.
0.072	Upstream end of barrier no. 6 deflected backward.
0.088	Upstream end of barrier no. 6 deflected forward.
0.114	Concrete cracked near center target on barrier no. 5.
0.122	Vehicle’s right-front tire became airborne.
0.172	Upstream end of barrier no. 6 deflected backward.
0.206	Left headlight detached from vehicle, and upstream end of barrier no. 7 deflected backward.
0.216	Vehicle was parallel to system at a speed of 50.1 mph (80.7 km/h).
0.232	Downstream end of barrier no. 3 deflected backward.
0.238	Vehicle’s left-rear tire contacted barrier no. 5.
0.268	Vehicle’s left-rear quarter panel contacted barrier no. 5. Vehicle’s rear bumper contacted barrier no. 5. Vehicle’s left-rear quarter panel deformed.
0.296	Vehicle’s right-rear tire became airborne.
0.312	Vehicle pitched downward.
0.342	Vehicle rolled toward system.
0.380	Vehicle lost contact with system at a speed of 49.0 mph (78.9 km/h) and an angle of 5.4 degrees.
0.418	Upstream end of barrier no. 7 deflected backward.
0.602	Vehicle’s right-front tire regained contact with ground.
0.698	Vehicle’s left-front tire regained contact with ground.
0.712	Vehicle’s front bumper contacted ground.
0.724	Vehicle’s left-front tire deflated.
0.838	Vehicle’s left quarter panel contacted barrier no. 7.
1.232	Vehicle’s left-rear tire deflated.

5.3 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 29 through 32. Barrier damage consisted of contact marks on the front face of the PCB segments, spalling of concrete, and concrete cracking. The length of vehicle contact along the barrier was approximately 21 ft – 2 in. (6.4 m), which spanned from 3 ft – 8 in. (1.1 m) upstream from the center of the joint between barrier nos. 4 and 5 through 17 ft – 6 in. (5.3 m) downstream from the center of the joint between barrier nos. 4 and 5. The vehicle contacted the system again starting from the upstream end on the top face of barrier no. 7 which spanned approximately 11 ft – 6 in. (3.5 m).

Tire marks were visible on the front face of barrier nos. 4 and 5. Contact marks were found on the front faces of barrier nos. 7 and 8 as well as on the connection keys between barrier nos. 4 and 5. A 14-in. (356-mm) long gouge on the front face of barrier no. 4 began 57 in. (1,448 mm) upstream from the downstream end. A 41-in. (1,041-mm) long scrape was found on barrier no. 4 beginning 44 in. (1,118 mm) upstream from the downstream end. A 14-in. (356-mm) long gouge was found on barrier no. 4 that began 40 in. (1,016 mm) upstream from the downstream target and 17 in. (432 mm) from the ground.

Concrete spalling was found on barrier nos. 3 through 8. The lower back corner on the downstream end of barrier no. 3 spalled. A 5½-in. × 13½-in. × 2-in. (140-mm × 343-mm × 51-mm) piece of concrete was removed from the upper-downstream corner on the front face of barrier no. 4. A 10½-in. × 4½-in. (267-mm × 114-mm) piece of concrete was removed from the lower-downstream corner on the front face of barrier no. 4. Concrete spalling, measuring 29 in. × 11 in. × 4 in. (737 mm × 279 mm × 102 mm), was found 41⅝ in. (1,057 mm) upstream from the downstream end on the back face of barrier no. 4. A 32-in. × 10-in × 3-in. (813-mm × 254-mm × 76-mm) piece of concrete was removed from the bottom-upstream corner on the front face of barrier no. 5. A 13½-in. × 8-in. (343-mm × 203-mm) piece of concrete was removed from the bottom of barrier no. 5, approximately 46½ in. (1,181 mm) downstream from the upstream end. A 15-in. × 4-in × 4½-in. (381-mm × 102-mm × 114-mm) piece of concrete disengaged from the back side of barrier no. 5 approximately 17 in. (432 mm) downstream from the center target. An 8-in. × 12-in. × 5-in. (203-mm × 305-mm × 127-mm) piece of concrete was removed from the lower-downstream corner of barrier no. 6. Concrete spalling, measuring 16½ in. × 4½ in. (419 mm × 114 mm), occurred at the bottom on the front side of barrier no. 7 approximately 48 in. (1,219 mm) downstream from the upstream end. A 2½-in. × 3-in. (64-mm × 76-mm) piece of concrete was removed from the upper-upstream corner on the back side of barrier no. 8 below the connection key socket.

Minor cracks were found on barrier nos. 3, 7 and 8. A 10¾-in. (273-mm) long vertical crack that began 11½ in. (292 mm) from the bottom of barrier no. 4 extended toward the downstream edge. A crack spanning the front, top, and back faces was found 4¼ in. (108 mm) downstream of the center target on barrier no. 4. A 32-in. (813-mm) long crack was found 47 in. (1,194 mm) upstream from downstream edge of barrier no. 5 on the front face. Vertical cracks were found on the front and back faces of barrier no. 5 at 48 in. (1,219 mm), 101 in. (2,565 mm), and 224 in. (5,690 mm) downstream from the upstream end of the barrier. A 23½-in. (597-mm) long vertical crack was found on the back face of barrier no. 5 that began 7 in. (178 mm) from the bottom and 5 in. (127 mm) upstream from the downstream end. A 19-in. (483-mm) long vertical crack was found 4 in. (102 mm) downstream from the upstream end of barrier no. 6. A 26-in. (660-

mm) long crack was found 7 in. (178 mm) from the top and 6½ in. (165 mm) downstream from the upstream end on the back face of barrier no. 6. A vertical crack was also found on the front, top, and back faces of barrier no. 6 near the center target.

The maximum permanent set deflection of the barrier system was 36⅝ in. (930 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 38.1 in. (968 mm) at the downstream end of barrier no. 4, as determined from high-speed digital video analysis. The working width of the system was found to be 62.1 in. (1,577 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 22. 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 38.1 in. (968 mm).

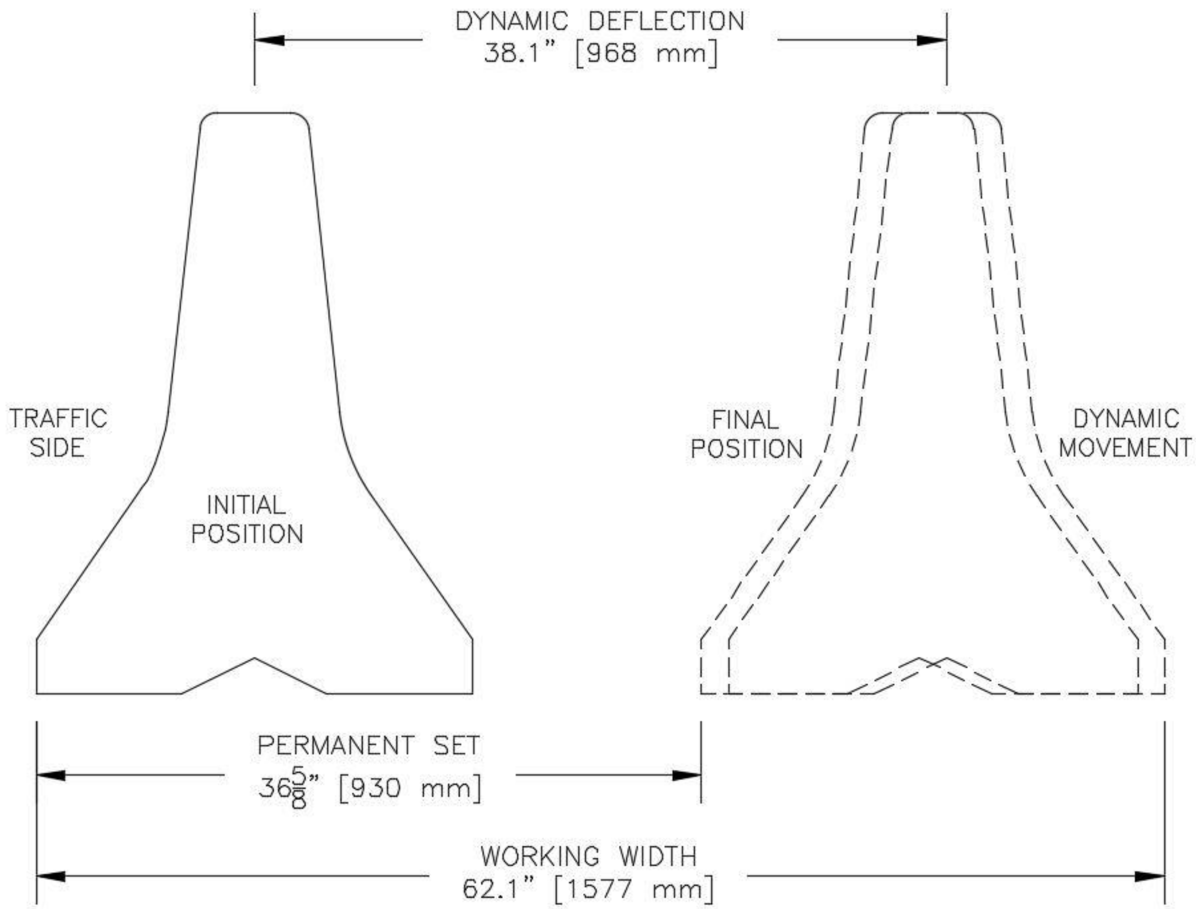


Figure 22. Permanent Set Deflection, Dynamic Deflection and Working Width, Test No. NJPCB-3

5.4 Vehicle Damage

Damage to the vehicle was moderate, as shown in Figures 33 through 36. 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 was crushed inward and back. The left-front fender was pushed upward near the door panel, torn, and had a dent behind the left-front wheel. The left-rear steel rim was severely deformed with tears and significant crushing. The left-front and left-rear tires were torn and deformed. The grille was fractured around the left-side headlight assembly. A 20-in. × 6-in. (508-mm × 152-mm) scrape was found on the left side of the front bumper. A 6-in. (152-mm) kink was found on the bottom-front of the left fender, and the front of the fender deformed inward. A 2½-in. (64-mm) gap was found between the vehicle's hood and the left fender. A 2½-in. × 10-in. (64-mm × 254-mm) buckle was found on the rear of the left fender approximately 15 in. (381 mm) above the bottom of the fender. A 71-in. (1,803-mm) scrape and contact marks were found along the left side of the vehicle cab. The left-rear door was dented and was ajar approximately ¼ in. (6 mm) at the top. A 5-in. × 6-in. (127-mm × 152-mm) dent was found on the bottom of the C-pillar at the rear of the cab.

Table 7. Maximum Occupant Compartment Deformations by Location

LOCATION	MAXIMUM DEFORMATION in. (mm)	MASH 2009 ALLOWABLE DEFORMATION in. (mm)
Wheel Well & Toe Pan	3⅛ (79)	≤ 9 (229)
Floor Pan & Transmission Tunnel	¼ (6)	≤ 12 (305)
Side Front Panel (in Front of A-Pillar)	¾ (19)	≤ 12 (305)
Side Door (Above Seat)	¼ (6)	≤ 9 (229)
Side Door (Below Seat)	⅜ (10)	≤ 12 (305)
Roof	¼ (6)	≤ 4 (102)
Windshield	0 (0)	≤ 3 (76)
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	¼ (6)	N/A

N/A – Not applicable

The left-side quarter panel experienced scraping, buckling, and denting. The left-side headlight and foglight disengaged from the vehicle. The left side of the radiator was pushed backward. The left-front and left-rear tires were deflated. The left-rear tire had a tear 3 in. (76 mm) away from the edge of the tire's outer face. The left-rear rim had a 1-in. (25-mm) scrape. A 1-in. (25-mm) gap was found between the left-front fender and the left-front door. The left-front anti-roll bar end links contacted the tie rod and were scraped. The left-front steering knuckle assembly was gouged underneath the lower control arm. The middle of the left-rear upper brake caliper was torn. The left side of the steering rack fractured from the mount. The right side of the windshield had a hairline crack, and the lower-left side encountered minor cracking. The roof and remaining window glass remained undamaged.

5.5 Occupant Risk

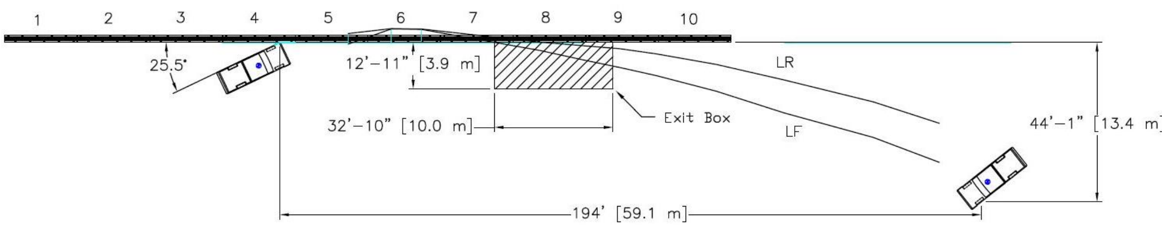
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 8. Note that the OIVs and ORAs were within the suggested limits, as provided in MASH 2009. The calculated THIV, PHD, 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 23. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix F.

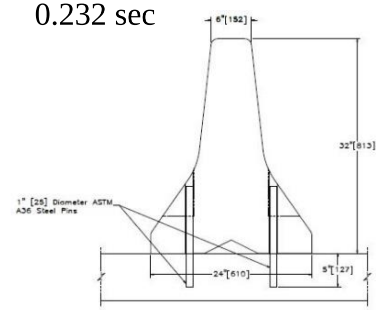
Table 8. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. NJPCB-3

Evaluation Criteria		Transducer		MASH 2009 Limits
		SLICE-1	SLICE-2 (primary)	
OIV ft/s (m/s)	Longitudinal	-13.58 (-4.14)	-13.52 (-4.12)	± 40 (12.2)
	Lateral	15.65 (4.77)	18.01 (5.49)	± 40 (12.2)
ORA g's	Longitudinal	-4.89	-5.23	± 20.49
	Lateral	10.67	9.61	± 20.49
MAX. ANGULAR DISPL. deg.	Roll	-20.7	-17.2	± 75
	Pitch	-7.3	-9.0	± 75
	Yaw	105.5	105.0	not required
THIV ft/s (m/s)		19.58 (5.97)	23.16 (7.06)	not required
PHD g's		10.68	9.61	not required
ASI		1.09	1.23	not required

5.6 Discussion

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 11.9 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. NJPCB-3 was determined to be acceptable according to the MASH 2009 safety performance criteria for test designation no. 3-11.

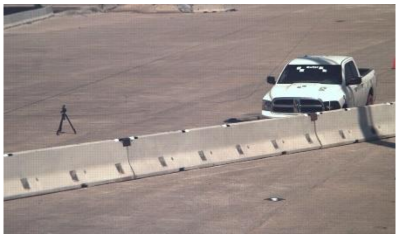




- Test Agency .... MwRSF
- Test Number NJPCB-3
- Date 04/22/2016
- MASH 2009 Test Designation 3-11
- Test Article .... Free-standing NJDOT PCB with Joint Class A [1]/Connection Type A [2]
- Total Length .... 200 ft (61.0 m)
- Key Component – NJDOT PCB
  - Length .... 20 ft (6.1 m)
  - Width .... 24 in. (610 mm)
  - Height .... 32 in. (813 mm)
- Key Component – Anchor Pins
  - Pin Size & Length .... 1-in. (25-mm) diameter × 15-in. (381-mm) long unthreaded rod
  - Pin Material .... ASTM A36 steel
  - Embedment Depth .... 5 in. (127 mm)
  - Number of Pins per Barrier 9
  - Pinned Barrier Nos. .... 1 and 10
- Type of Support Surface .... Concrete Tarmac
- Vehicle Make/Model .... 2010 Dodge Ram 1500 quad cab pickup truck
  - Curb .... 5,093 lb (2,310 kg)
  - Test Inertial .... 4,999 lb (2,268 kg)
  - Gross Static .... 5,154 lb (2,338 kg)
- Impact Conditions
  - Speed .... 62.3 mph (100.2 km/h)
  - Angle .... 25.8 deg
  - Impact Location .... $46^3/_{16}$ in. (1,173 mm) upstream from joint 4-5
- Impact Severity .... 122.9 kip-ft (166.6 kJ) > 105.6 kip-ft (143.1 kJ) limit in MASH 2009
- Exit Conditions
  - Speed .... 49.0 mph (78.9 km/h)
  - Angle .... 11.9 deg
  - Exit Box Criterion .... Pass
- Vehicle Stability .... Satisfactory
- Test Article Damage .... Moderate
- Vehicle Stopping Distance .... 194 ft (59.1 m) downstream
  44 ft – 1 in. (13.4 m) laterally in front
- Vehicle Damage .... Moderate
  - VDS [14] 11-LFQ-4
  - CDC [15] 11-LYEW-4
  - Maximum Interior Deformation .... 3⅛ in. (79 mm)
- Maximum Test Article Deflections
  - Permanent Set .... 36⅝ in. (930 mm)
  - Dynamic .... 38.1 in. (968 mm)
  - Working Width .... 62.1 in. (1,577 mm)
- Transducer Data

Evaluation Criteria		Transducer		MASH 2009 Limit
		SLICE-1	SLICE-2 (primary)	
OIV ft/s (m/s)	Longitudinal	-13.58 (-4.14)	-13.52 (-4.12)	± 40 (12.2)
	Lateral	15.65 (4.77)	18.01 (5.49)	± 40 (12.2)
ORA g's	Longitudinal	-4.89	-5.23	± 20.49
	Lateral	10.67	9.61	± 20.49
MAX. ANGULAR DISP. deg.	Roll	-20.7	-17.2	± 75
	Pitch	-7.3	-9.0	± 75
	Yaw	105.5	105.0	not required
THIV – ft/s (m/s)		19.58 (5.97)	23.16 (7.06)	not required
PHD – g's		10.68	9.61	not required
ASI		1.09	1.23	not required

Figure 23. Summary of Test Results and Sequential Photographs, Test No. NJPCB-3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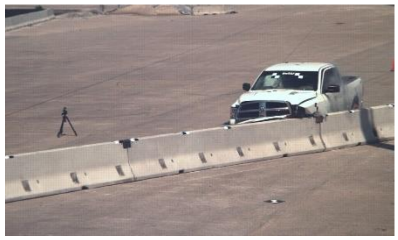
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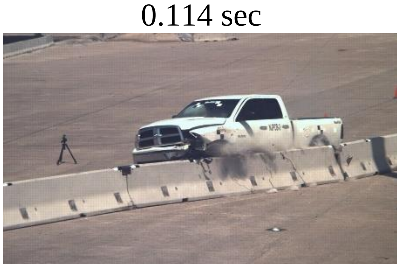
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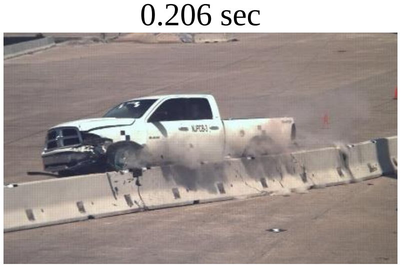
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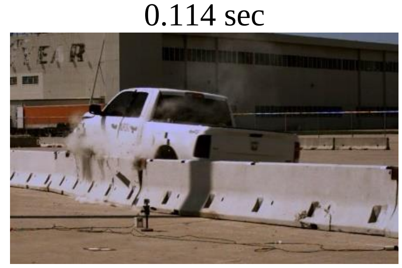
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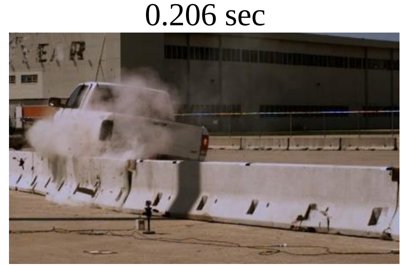
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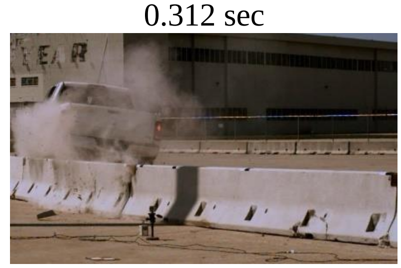
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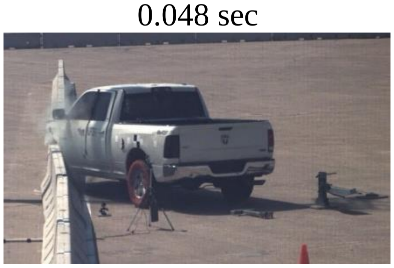
Figure 24. Additional Sequential Photographs, Test No. NJPCB-3

0.000 sec

0.028 sec

0.048 sec



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0.232 sec

0.268 sec

0.296 sec

0.342 sec

0.622 sec

0.796 sec

2.944 sec

Figure 25. Additional Sequential Photographs, Test No. NJPCB-3

Figure 26. Documentary Photographs, Test No. NJPCB-3

Figure 27. Impact Location, Test No. NJPCB-3

Figure 28. Vehicle Final Position and Trajectory Marks, Test No. NJPCB-3

Figure 29. System Damage – Front, Back, Upstream, and Downstream views, Test No. NJPCB-3

Figure 30. Barrier No. 3 Traffic-side and Back-side Damage, Test No. NJPCB-3

Figure 31. Barrier Nos. 4 and 5 Damage, Test No. NJPCB-3

Figure 32. Barrier No. 5 Damage, Test No. NJPCB-3

Figure 33. Vehicle Damage, Test No. NJPCB-3

Figure 34. Vehicle Damage on Impact Side, Test No. NJPCB-3

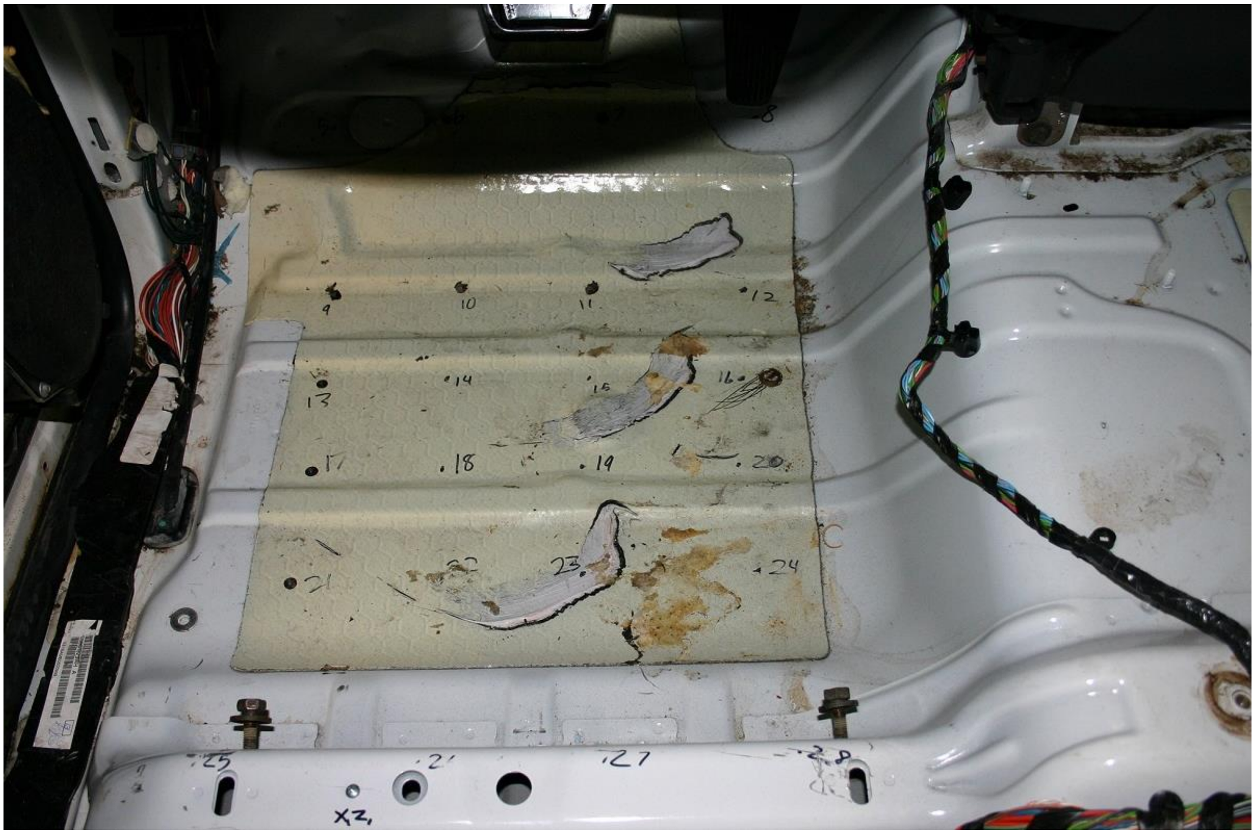


Figure 35. Occupant Compartment Deformation, Test No. NJPCB-3

Figure 36. Undercarriage Deformations, Test No. NJPCB-3

6 SUMMARY AND CONCLUSIONS

Test no. NJPCB-3 was conducted on the NJDOT PCB system with a free-standing configuration according to MASH 2009 test designation no. 3-11. This system uses NJDOT barriers, Type 4 (Alternative B) with joint class A as specified in the 2013 NJDOT *Roadway Design Manual* and connection type A in the 2015 NJDOT *Roadway Design Manual*. Barrier nos. 1 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-3, the 4,999-lb (2,268 kg) pickup truck impacted the NJDOT PCB system at a speed of 62.3 mph (100.2 km/h) and at an angle of 25.8 degrees, resulting in an impact severity of 122.9 kip-ft (166.6 kJ). After impacting the barrier system, the vehicle exited the system at a speed of 49.0 mph (78.9 km/h) and at an angle of 11.9 degrees. The vehicle was successfully contained and smoothly redirected with moderate damage to both the barrier and the vehicle. Barrier nos. 3, 4, 5, and 6 experienced concrete spalling and cracking, with most of the damage concentrated on the downstream end of barrier no. 4 and upstream end of barrier no. 5. A dynamic deflection of 38.1 in. (968 mm) and working width of 62.1 in. (1,577 mm) were observed during the test, as shown in Figure 22. All occupant risk values were found to be within limits, and the occupant compartment deformations were also deemed acceptable. Subsequently, test no. NJPCB-3 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="4">Evaluation Criteria</th><th>Test No. NJPCB-3</th></tr>
<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><td>S</td></tr>
<tr><td rowspan="12">Occupant Risk</td><td rowspan="2">D.</td><td colspan="3">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 colspan="3">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 colspan="3">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 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><td rowspan="4">S</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><td rowspan="4">S</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>
<tr><td colspan="5">MASH 2009 Test Designation No.</td><td>3-11</td></tr>
<tr><td colspan="5">Final Evaluation (Pass or Fail)</td><td>Pass</td></tr>
</table>

S – Satisfactory U – Unsatisfactory NA - Not Applicable

7 COMPARISON TO TEST NO. NYTCB-2

A summary of full-scale crash testing of the two free-standing configurations of the NJ PCB system is shown in Table 10. One system included removing the joint slack (test no. NJPCB-3), as described herein. The other system consisted of removing joint slack and grouted toes (test no. NJPCB-4) [16]. These tests were compared to the full-scale crash testing of a similar New York PCB system without removal of joint slack or grouted toes (test no. NYTCB-2) [17]. Results from these tests included the actual impact conditions and impact severity as well as dynamic barrier deflection, permanent set barrier deflection, working width (as measured from the original front face of the barrier), and the clear space behind the barrier. The clear space behind the barrier is used by NJDOT to define the maximum deflection of the back of the barrier from its original position. In addition, the schematic diagrams shown in Figure 37 indicate how the dynamic deflection, permanent set deflection, and working width for each crash test was defined.

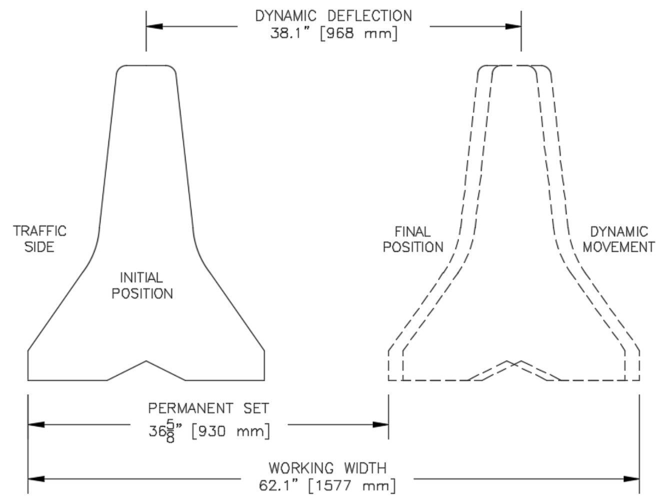
A review of the results from test nos. NJPCB-3, NJPCB-4, and NYTCB-2 revealed little to no benefit in terms of barrier deflection and clear space requirements for free-standing PCBs due to the removal of joint slack and/or the use of grouted barrier toes. This finding can be seen in the fact that dynamic deflections and the clear space behind barrier for all three tests are very similar. The primary cause of the lack of observed benefit for the modified PCB joints was the absence of barrier reinforcement in the toes of both the New York and New Jersey PCB segments. The lack of reinforcement led to disengagement of the barrier toes when they were loaded by adjacent barrier segments, which caused increased rotation and motion of the barrier joints. This toe disengagement overcame the expected benefit that would have been provided by the removal of joint slack and use of grouted toes, which resulted in similar joint rotation and displacement for both the New Jersey and New York PCB crash tests. Secondly, the PCB segments used in these tests 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 segment, among others. Thus, some variability would be expected in barrier performance even for basically identical systems.

Smaller reductions in PCB deflections and clear space behind the barrier were observed with the removal of joint slack and use of grouted toes. This finding was primarily due to the fracture and disengagement of the barrier toes. If larger reductions in PCB deflections and clear space are desired, PCB redesign or modification would be required, including reinforcement of the barrier toes, which may improve effectiveness of joint slack removal and the use of grouted toes.

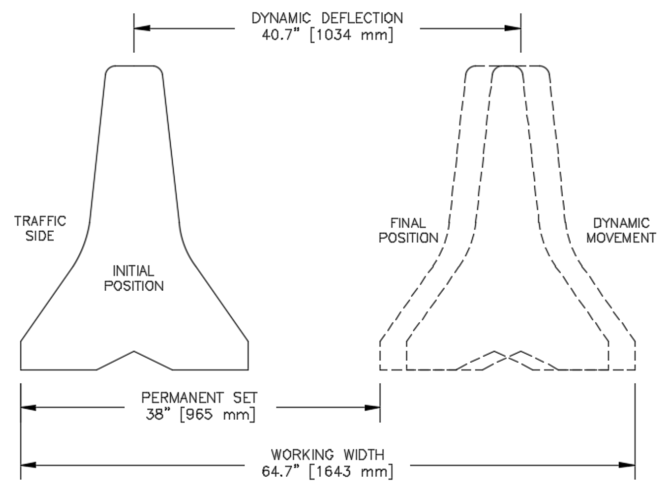
Table 10. Comparison of Free-Standing Systems

Test No.	Joint Class [1]	Connection Type [2]	System Details	Permanent Set	Dynamic Deflection (DD)	Working Width (WW)	Clear Space Behind Barrier	Vehicle Roll (deg)	Vehicle Pitch (deg)	Vehicle Mass lb (kg)	Impact Speed mph (km/h)	Impact Angle (deg)	Impact Severity kip-ft (kJ)
NJPCB-3	A	A	Free-standing system, barriers 1 and 10 pinned, remove slack, no grouted toes	36⅝ in. (930 mm)	38.1 in. (968 mm)	62.1 in. (1,577 mm)	38.1 in. (968 mm)	-17.2	-9.0	4,999 (2,268)	62.3 (100.2)	25.8	122.9 (166.6)
NJPCB-4 [16]	B	N/A	Free-standing system, barriers 1 and 10 pinned, remove slack, grouted toes	38 in. (962 mm)	40.7 in. (1,034 mm)	64.7 in. (1,643 mm)	40.7 in. (1,034 mm)	-16.2	-14.2	5,000 (2,268)	62.8 (101.3)	24.5	113.4 (153.7)
NYTCB-2 [17]	A	A	Free-standing system, barriers 1 and 10 pinned, slack not removed, no grouted toes	39½ in. (1,003 mm)	40.3 in. (1,023 mm)	64.3 in. (1,633 mm)	40.3 in. (1,023 mm)	-12.4	-10.6	5,024 (2,279)	61.2 (98.5)	25.8	119.2 (161.6)

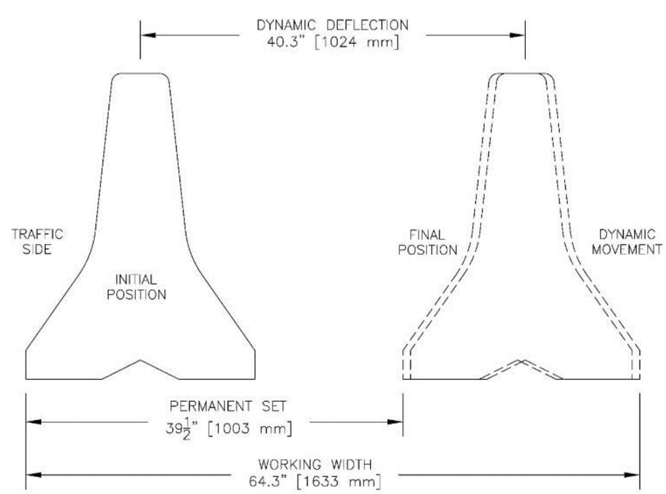
N/A = Not Applicable



NJPCB-3 – Free-Standing, Joint Slack Removed, No Grouted Toes



NJPCB-4 – Free-Standing, Joint Slack Removed, Grouted Toes



NYTCB-2 – Free-Standing, Joint Slack Not Removed, No Grouted Toes

Figure 37. Deflection Comparisons – Test Nos. NJPCB-3, NJPCB-4, and NYTCB-2

8 MASH IMPLEMENTATION

The objective of this research was to evaluate the safety performance of NJDOT's PCB, Type 4 (Alternative B) with a free-standing configuration, corresponding to joint class A in the 2013 NJDOT *Roadway Design Manual* and connection type A in the 2015 NJDOT *Roadway Design Manual*. The NJDOT barriers consisted of NJDOT PCBs joined with a connection key. Barrier nos. 1 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.

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 (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 [7-9]. 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 (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]. 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-3, a 4,999-lb (2,268 kg) pickup truck with a simulated occupant seated in the left-front seat impacted the NJDOT PCB system with joint class A, as specified in the 2013 NJDOT *Roadway Design Manual,* and connection type A in the 2015 NJDOT *Roadway Design Manual*, at a speed of 62.3 mph (100.2 km/h) and at an angle of 25.8 degrees, resulting in an impact severity of 122.9 kip-ft (165.2 kJ). At 0.216 sec after impact, the vehicle became parallel to the system with a speed of 50.1 mph (80.7 km/h). At 0.380 sec, the vehicle exited the system at a speed of 49.0 mph (78.9 km/h) and at an angle of 5.4 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. 3, 4, 5, and 6. The maximum dynamic barrier deflection was 38.1 in. (968 mm), which included minor tipping of the barrier at the top surface. The working width of the PCB system was 62.1 in. (1,577 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 A, as specified in the 2013 NJDOT *Roadway Design Manual,* and connection type A in the 2015 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 A, as specified in the 2013 NJDOT *Roadway Design Manual,* and connection type A in the 2015 NJDOT *Roadway Design Manual*, consisting of NJDOT PCB barriers joined with a connection key, joint slack removed, and barrier nos. 1 and 10 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.

A comparison of similar systems for the free-standing configuration included three systems: (1) a NJ PCB system with the joint slack removed (test no. NJPCB-3); (2) a NJ PCB system with the joint slack removed and grouted toes (test no. NJPCB-4) [16]; and (3) a New York PCB system without removal of joint slack or grouted toes (test no. NYTCB-2) [17]. A review of these test results (test nos. NJPCB-3, NJPCB-4, and NYTCB-2) revealed little to no benefit would be observed in reduced barrier deflections and clear space requirements for free-standing PCBs due to joint slack removal and/or use of grouted toes as dynamic deflections and the clear space behind barrier for all three tests are very similar. The finding is primarily due to no barrier reinforcement in the toes of both the New York and 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. Secondly, the PCB segments used in these tests 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 inches. 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 other. 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 A, as specified in the 2013 NJDOT *Roadway Design Manual* and utilized in this system, the NJDOT allowable movement guidance is 16 to 24 in. (406 to 610 mm). For connection type A, as specified in the 2015 NJDOT *Roadway Design Manual,* the NJDOT maximum allowable deflection is 41 in. (1,041 mm). For this test, the clear space behind the barrier was 38.1 in. (968 mm). Limited reductions in PCB deflections and clear space behind the barrier were observed with joint slack removal and use of grouted toes. Again, this finding is primarily due to the fracture and disengagement of the barrier toes. If larger reductions in PCB deflections and clear space are desired, PCB redesign or modification would be required, including reinforcement of the barrier toes, which may improve the effectiveness of joint slack removal and the use of grouted toes.

9 REFERENCES

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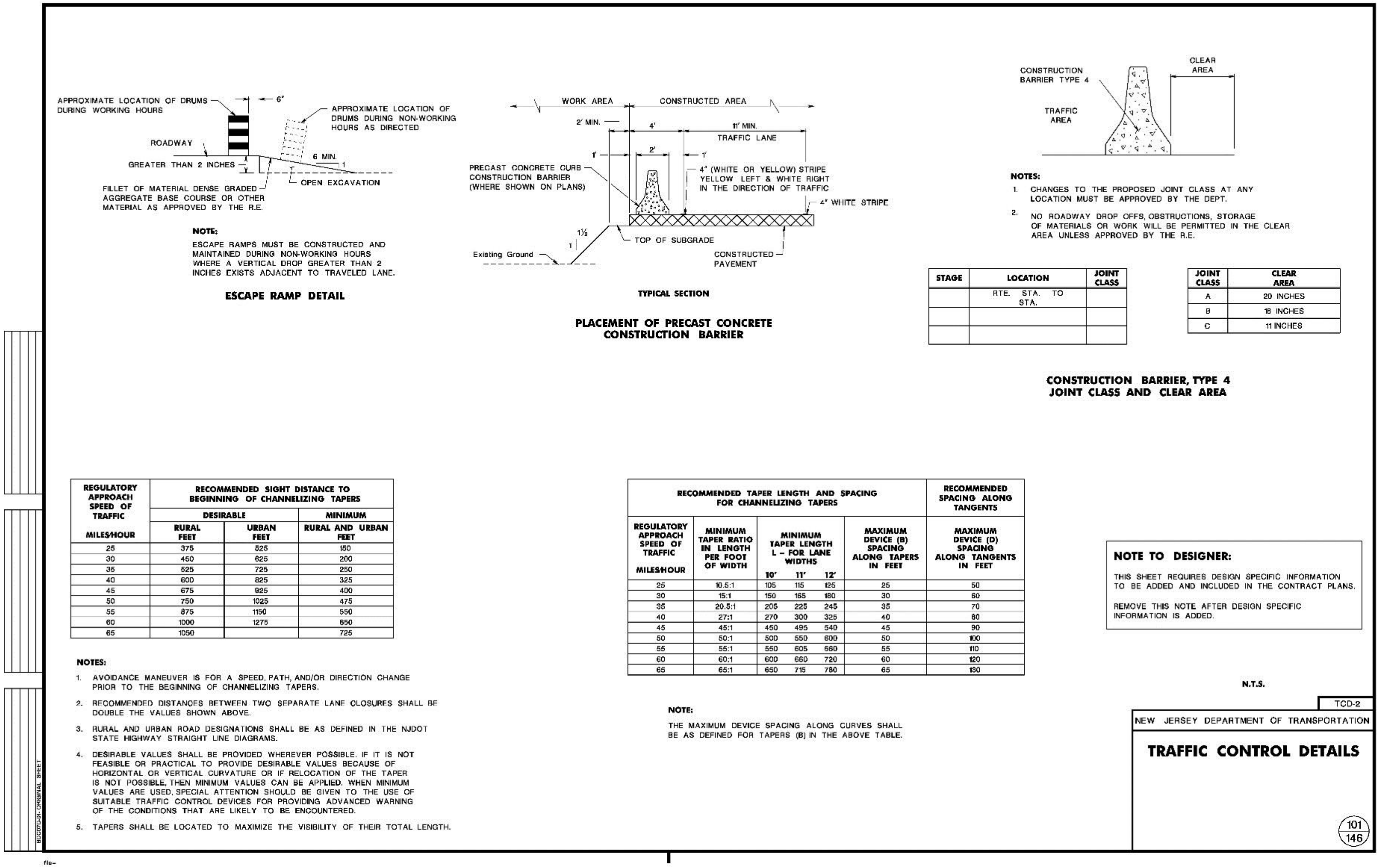
10 APPENDICES

Appendix A. NJDOT PCB Standard Plans



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 MILES/HOUR	RECOMMENDED SIGHT DISTANCE TO BEGINNING OF CHANNELIZING TAPERS		
	DESIRABLE		MINIMUM
	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.

Figure A-1. NJDOT PCB Standard Plans

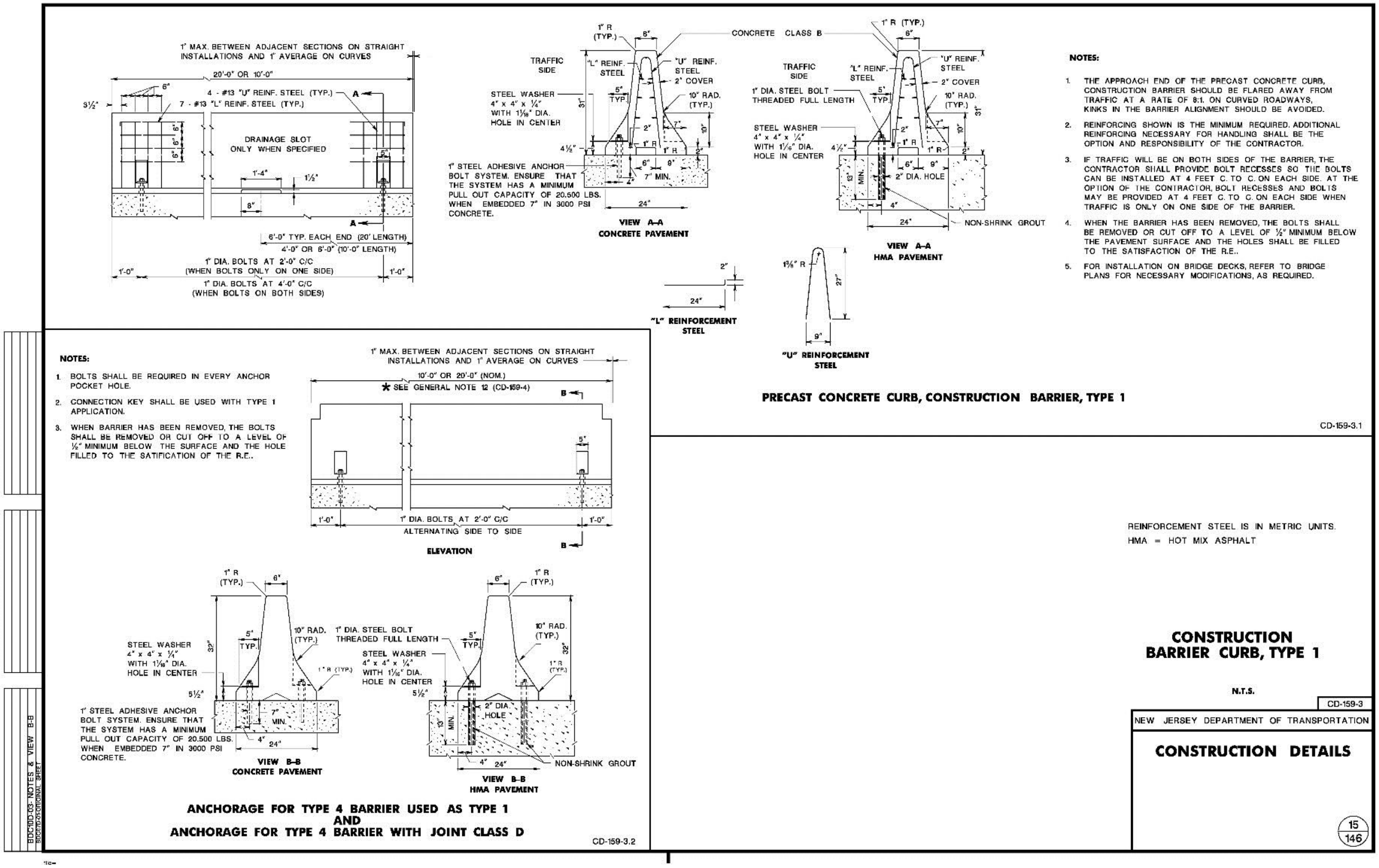


Figure A-2. NJDOT PCB Standard Plans

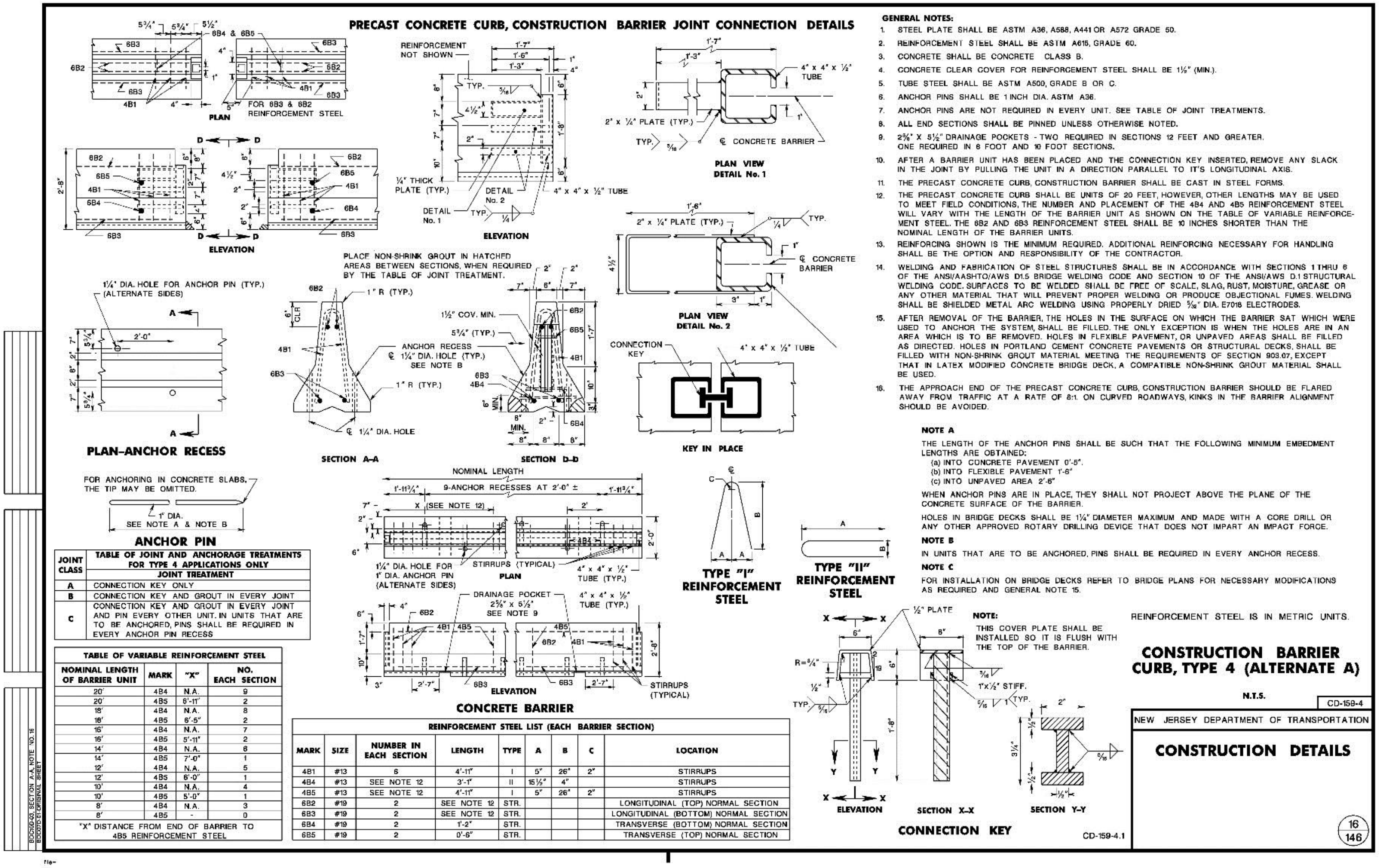


Figure A-3. NJDOT PCB Standard Plans

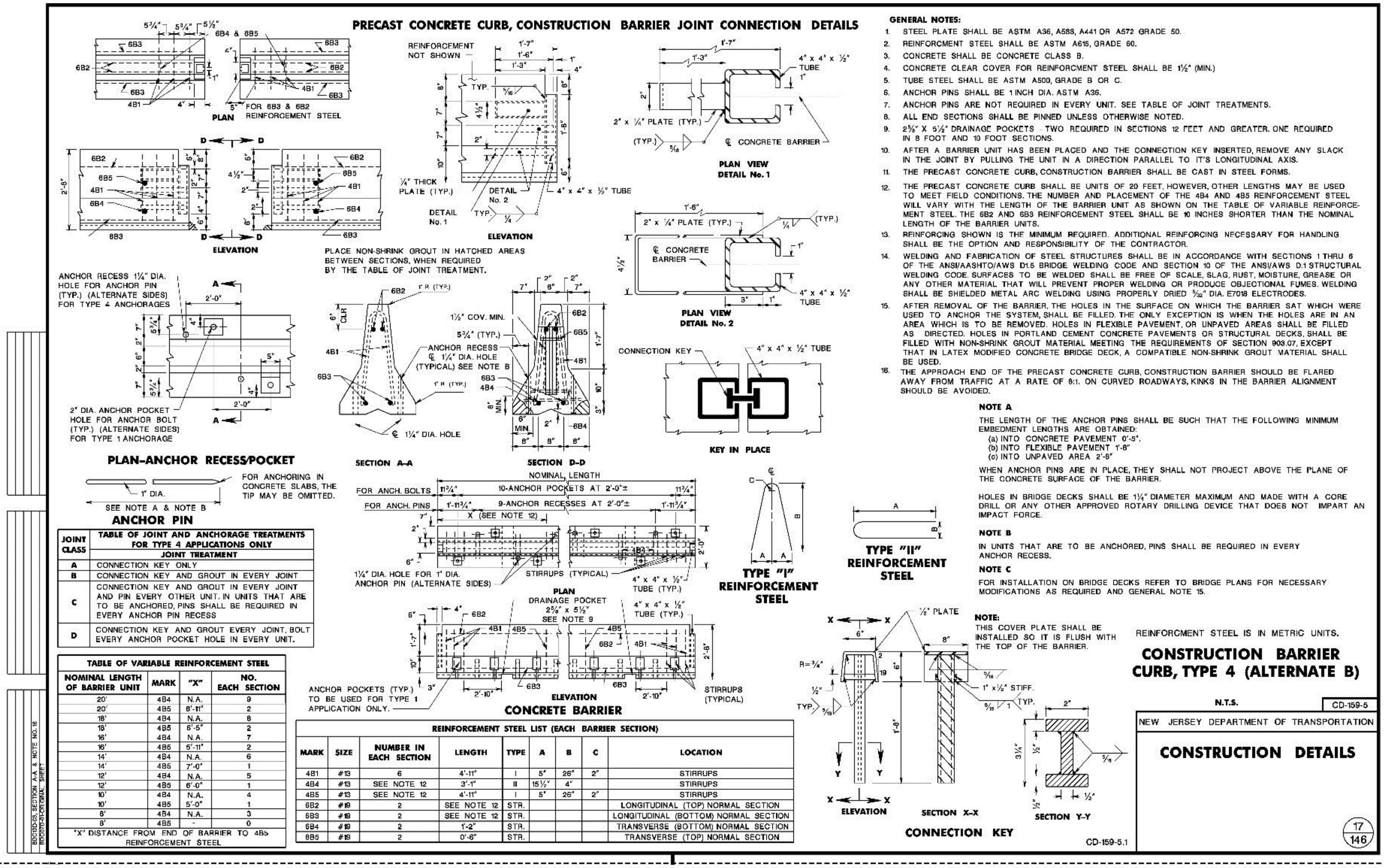


Figure A-4. NJDOT PCB Standard Plans

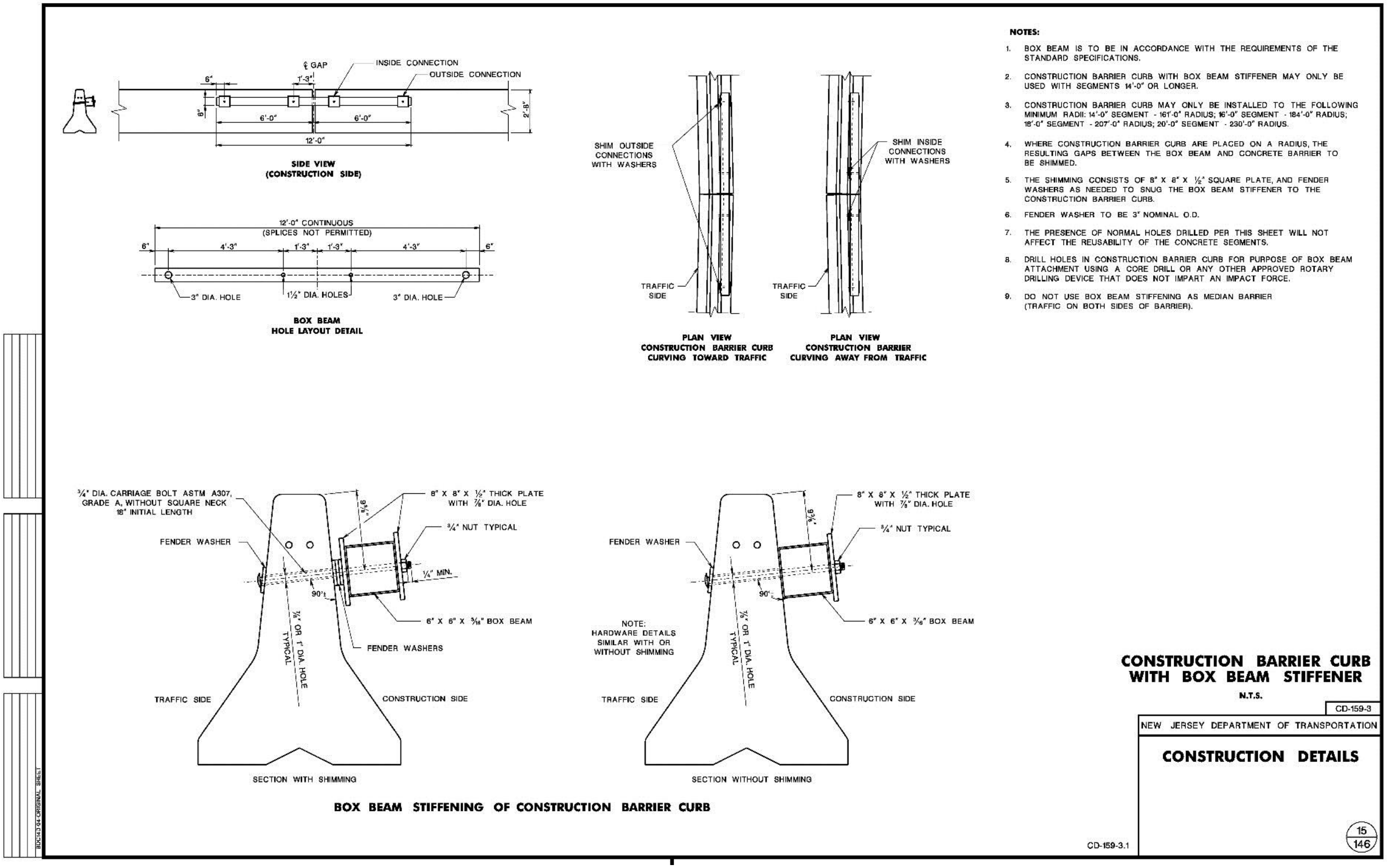


Figure A-5. NJDOT PCB Standard Plans

Appendix B. Material Specifications

Table B-1. Bill of Materials, Test No. NJPCB-3

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 Pins	ASTM A36	H #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” (51×6)	ASTM A36	Heat #1129849
C3	Bent Steel Plate 2, 2”×¼” (51×6)	ASTM A36	Heat #1129849
D1	Steel Plate 1, 2”×½” (51×13)	ASTM A36	Heat #L99837
D2	Steel Plate 2, 2¼”×½” (57×13)	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

UNIVERSITY OF NEBRASKA

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					
	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					
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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					
	1			0	7			0	28			0					
	1			0	7			0	28			0					

Figure B-2. Concrete Barrier Segment – Concrete Strength, Test No. NJPCB-3

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 Nº
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-3. Anchor Pins Material Certificate, Test No. NJPCB-3

GERDAU

CERTIFIED MATERIAL TEST REPORT

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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-4. Rebar No. 4 Material Certificate, Test No. NJPCB-3

CERTIFIED MATERIAL TEST REPORT

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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"	5,023 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-5. Rebar No. 4 Material Certificate, Test No. NJPCB-3

GERDAU

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

CERTIFIED MATERIAL TEST REPORT

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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 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 %	CEqvA706 %
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-6. Rebar No. 4 Material Certificate, Test No. NJPCB-3

GERDAU

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

CERTIFIED MATERIAL TEST REPORT

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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"	10,020 LB	61101492/02

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	0.67	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-7. Rebar No. 4 Material Certificate, Test No. NJPCB-3

CERTIFIED MATERIAL TEST REPORT

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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-8. Rebar No. 4 Material Certificate, Test No. NJPCB-3

GERDAU

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

CERTIFIED MATERIAL TEST REPORT

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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"	4,008 LB	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-9. Rebar No. 4 Material Certificate, Test No. NJPCB-3

CERTIFIED MATERIAL TEST REPORT

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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"	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-10. Rebar No. 6 Material Certificate, Test No. NJPCB-3

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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-11. Rebar No. 6 Material Certificate, Test No. NJPCB-3

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	CE: 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	CE: 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	CE: 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-12. Steel Tube Material Certificate, Test No. NJPCB-3

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
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
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
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
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
Sales order: 1001173 Purchase Order: 77498 Melted in: Canada

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-13. Steel Tube Material Certificate, Test No. NJPCB-3

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.
CE calculated using the AWS D1.1 method.

Steel Tube Institute OF NORTH AMERICA

Page : 3 Of 3

Metals Service Center Institute

Figure B-14. Steel Tube Material Certificate, Test No. NJPCB-3

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	CE: 0.33
M800554030	2	072918 Psi	082550 Psi	35 %	ASTM A500-13 GRADE B&C	

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 : 4 Of 4

Metals Service Center Institute

Figure B-15. Steel Tube Material Test Certificate, Test No. NJPCB-3

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-16. Steel Tube Material Certificate, Test No. NJPCB-3

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

Jose Martinez, QMS Manager

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

Figure B-17. Steel Tube Material Certificate, Test No. NJPCB-3

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-18. 2-in. × ¼-in. (51-mm × 6-mm) Bent Steel Plate, Test No. NJPCB-3

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	Date	09/09/2015	PO:	81536
Product	Flat bars	Cust	40008882	Ref.	80833851
Heat NO.	L99837	Grade	A3652950	Pieces	288
Cust.Mat.		Length	20' 00"	Weight	19607.04
Size	2" X1/2" X3.404				

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		TEST 2		TEST 3	
	IMPERIAL	METRIC	IMPERIAL	METRIC	IMPERIAL	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-19. ½-in. (13-mm) Thick Steel Plate Material Certificate

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

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
2819476/000010		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-20. ½-in (13-mm) Thick Steel Plate Material Certificate, Test No. NJPCB-3

Appendix C. Concrete Tarmac Strength

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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 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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ALFRED BENESCH & COMPANY
CONSTRUCTION MATERIALS LABORATORY

By: Raymond E. Delka
Raymond E. Delka, Manager

Figure C-1. Concrete Tarmac Strength Test, Test No. NJPCB-3

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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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CONSTRUCTION MATERIALS LABORATORY

By: Raymond E. Delka, Manager

Figure C-2. Concrete Tarmac Strength Test, Test No. NJPCB-3

Appendix D. Vehicle Center of Gravity Determination

Test: NJPCB-3 Vehicle: Dodge Ram

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb.)	Vertical CG (in.)	Vertical M (lb-in.)
+	Unbalasted Truck (Curb)	5093	28.20623	143654.34
+	Hub	19	15.0625	286.1875
+	Brake activation cylinder & frame	7	28.25	197.75
+	Pneumatic tank (Nitrogen)	27	25.25	681.75
+	Strobe/Brake Battery	5	26.5	132.5
+	Brake Reciever/Wires	5	52	260
+	CG Plate including DAS	42	30 3/8	1275.75
-	Battery	-38	40	-1520
-	Oil	-7	29	-203
-	Interior	-84	27	-2268
-	Fuel	-164	19	-3116
-	Coolant	-12	34	-408
-	Washer fluid	0	35	0
+	Water Ballast	114	19	2166
+	Onboard Battery	14	24.25	339.5
				0
				141478.77

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

Estimated Total Weight (lb.)	5021
Vertical CG Location (in.)	28.17741

Wheel Base (in.) 140.75

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb.)	5000 ± 110	4999	-1.0
Longitudinal CG (in.)	63 ± 4	61.97	-1.02946
Lateral CG (in.)	NA	0.290846	NA
Vertical CG (in.)	28 or greater	28.18	0.17741

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	1471	1385
Rear	1127	1110

FRONT	2856 lb.
REAR	2237 lb.
TOTAL	5093 lb.

TEST INERTIAL WEIGHT (lb.)

	Left	Right
Front	1375	1423
Rear	1103	1098

FRONT	2798 lb.
REAR	2201 lb.
TOTAL	4999 lb.

Figure D-1. Vehicle Mass Distribution, Test No. NJPCB-3

Appendix E. Deformation Records

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 1

TEST: NJPCB-3
VEHICLE: Dodge Ram

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	27.724	-26.885	3.666	26.391	-26.216	4.540	-1.332	0.669	0.874	1.728	1.593
2	29.354	-22.754	2.006	26.622	-21.264	3.237	-2.733	1.490	1.231	3.347	2.997
3	29.583	-16.664	1.359	28.104	-15.858	2.589	-1.479	0.806	1.231	2.086	1.924
4	28.205	-11.414	2.085	28.274	-11.021	2.241	0.069	0.394	0.156	0.429	0.171
5	24.632	-26.805	-0.287	25.028	-26.080	-0.126	0.395	0.724	0.161	0.840	0.427
6	24.727	-22.770	-0.643	25.110	-22.213	-0.466	0.383	0.557	0.177	0.699	0.422
7	24.767	-17.380	-1.197	25.206	-16.770	-1.252	0.440	0.610	-0.055	0.754	0.443
8	24.931	-11.969	-1.905	25.287	-11.403	-1.956	0.356	0.566	-0.051	0.670	0.360
9	18.778	-26.619	-2.972	19.299	-26.007	-2.873	0.521	0.613	0.100	0.810	0.100
10	18.916	-22.385	-3.478	19.461	-21.938	-3.357	0.544	0.446	0.122	0.714	0.122
11	18.894	-18.105	-3.949	19.401	-17.603	-3.915	0.507	0.502	0.033	0.714	0.033
12	18.917	-13.144	-4.550	19.200	-12.509	-4.528	0.284	0.635	0.022	0.696	0.022
13	14.902	-26.550	-3.101	15.294	-26.057	-3.019	0.392	0.493	0.082	0.635	0.082
14	14.936	-22.664	-3.563	15.402	-22.180	-3.419	0.466	0.484	0.144	0.687	0.144
15	14.937	-18.230	-4.086	15.281	-17.715	-3.997	0.344	0.515	0.089	0.625	0.089
16	14.979	-13.556	-4.627	15.248	-13.060	-4.609	0.269	0.497	0.018	0.565	0.018
17	11.448	-26.286	-3.234	11.943	-25.944	-3.202	0.495	0.342	0.032	0.602	0.032
18	11.523	-22.470	-3.678	11.875	-22.161	-3.583	0.352	0.309	0.094	0.477	0.094
19	11.508	-18.471	-4.145	11.793	-18.055	-4.070	0.285	0.416	0.074	0.509	0.074
20	11.518	-13.888	-4.688	11.783	-13.547	-4.656	0.265	0.342	0.032	0.433	0.032
21	7.631	-26.396	-3.348	8.147	-25.988	-3.268	0.516	0.408	0.081	0.663	0.081
22	7.670	-22.284	-3.803	8.080	-21.877	-3.758	0.411	0.408	0.046	0.580	0.046
23	7.708	-18.448	-4.223	8.148	-18.052	-4.181	0.441	0.396	0.042	0.594	0.042
24	7.741	-13.667	-4.829	8.168	-13.203	-4.821	0.428	0.463	0.008	0.631	0.008
25	0.556	-26.098	0.412	0.922	-25.754	0.478	0.366	0.344	0.067	0.507	0.067
26	0.635	-21.391	-0.137	0.906	-20.938	-0.100	0.271	0.453	0.037	0.529	0.037
27	0.573	-17.365	-0.599	0.807	-17.131	-0.564	0.234	0.234	0.035	0.333	0.035
28	0.586	-13.292	-1.080	0.899	-13.029	-1.086	0.313	0.263	-0.006	0.408	-0.006

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

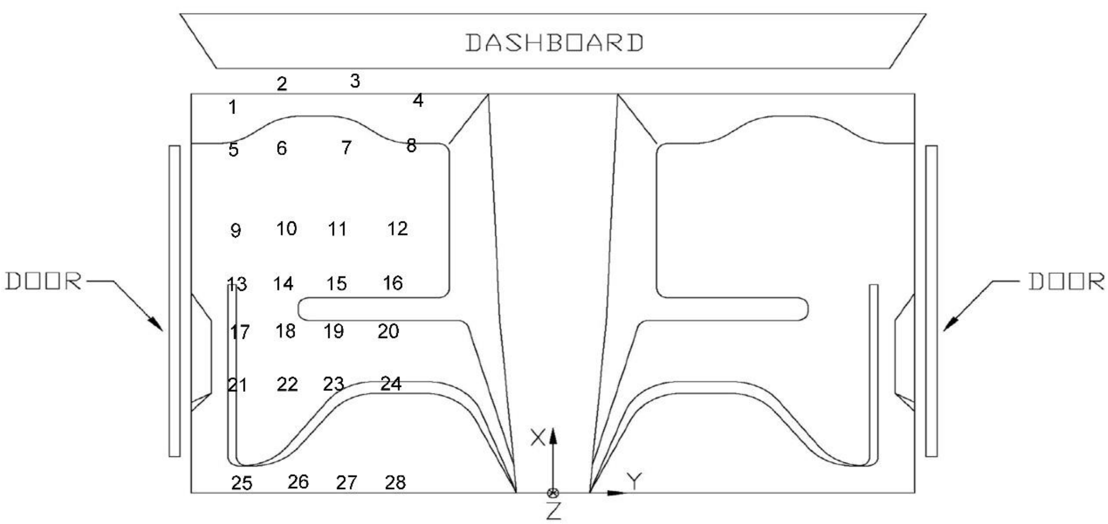


Figure E-1. Floor Pan Deformation Data – Set 1, Test No. NJPCB-3

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 2

TEST: NJPCB-3
VEHICLE: Dodge Ram

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	50.021	-33.470	1.477	48.387	-33.013	2.046	-1.634	0.457	0.568	1.790	1.730
2	51.462	-28.823	0.093	48.601	-27.890	1.364	-2.861	0.933	1.270	3.266	3.130
3	51.822	-22.901	0.313	50.039	-22.537	1.183	-1.783	0.364	0.871	2.017	1.984
4	50.484	-17.717	1.708	50.234	-17.563	1.391	-0.250	0.154	-0.317	0.432	0.404
5	46.845	-32.784	-2.344	46.850	-32.426	-2.551	0.005	0.358	-0.207	0.413	0.207
6	46.872	-28.745	-2.253	46.902	-28.461	-2.433	0.031	0.284	-0.180	0.338	0.183
7	47.015	-23.223	-2.209	47.099	-22.882	-2.555	0.085	0.341	-0.345	0.493	0.356
8	47.105	-17.906	-2.223	47.171	-17.582	-2.584	0.066	0.324	-0.361	0.489	0.367
9	40.970	-32.406	-4.828	41.033	-32.026	-5.111	0.063	0.381	-0.283	0.479	-0.283
10	41.041	-28.184	-4.835	41.202	-27.799	-5.064	0.161	0.384	-0.229	0.475	-0.229
11	40.912	-23.781	-4.844	41.168	-23.452	-5.086	0.256	0.329	-0.241	0.481	-0.241
12	40.939	-18.776	-4.843	40.968	-18.436	-5.074	0.029	0.340	-0.231	0.412	-0.231
13	37.012	-32.288	-4.845	37.102	-31.946	-5.123	0.091	0.342	-0.278	0.450	-0.278
14	37.103	-28.352	-4.853	37.162	-28.006	-5.016	0.059	0.345	-0.164	0.387	-0.164
15	37.102	-23.916	-4.861	37.047	-23.579	-5.041	-0.055	0.337	-0.179	0.386	-0.179
16	37.009	-19.163	-4.852	36.953	-18.809	-5.091	-0.056	0.354	-0.239	0.430	-0.239
17	33.627	-32.051	-4.854	33.710	-31.762	-5.108	0.083	0.288	-0.254	0.393	-0.254
18	33.650	-28.246	-4.843	33.650	-27.947	-5.045	0.000	0.298	-0.202	0.360	-0.202
19	33.668	-24.103	-4.840	33.653	-23.819	-5.030	-0.015	0.284	-0.189	0.342	-0.189
20	33.571	-19.526	-4.850	33.553	-19.151	-5.062	-0.019	0.375	-0.212	0.431	-0.212
21	29.638	-32.024	-4.887	29.799	-31.885	-5.077	0.161	0.139	-0.190	0.285	-0.190
22	29.802	-28.022	-4.845	29.855	-27.639	-5.048	0.052	0.384	-0.203	0.437	-0.203
23	29.859	-24.181	-4.816	29.858	-23.840	-5.002	-0.001	0.341	-0.186	0.389	-0.186
24	29.833	-19.364	-4.855	29.886	-18.911	-5.052	0.053	0.453	-0.197	0.496	-0.197
25	22.764	-32.334	-0.912	22.750	-32.075	-1.053	-0.014	0.259	-0.141	0.295	-0.141
26	22.732	-27.529	-0.905	22.712	-27.164	-1.034	-0.020	0.365	-0.130	0.388	-0.130
27	22.712	-23.651	-0.915	22.654	-23.311	-1.036	-0.058	0.340	-0.121	0.365	-0.121
28	22.747	-19.441	-0.930	22.745	-19.132	-1.056	-0.002	0.310	-0.126	0.334	-0.126

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

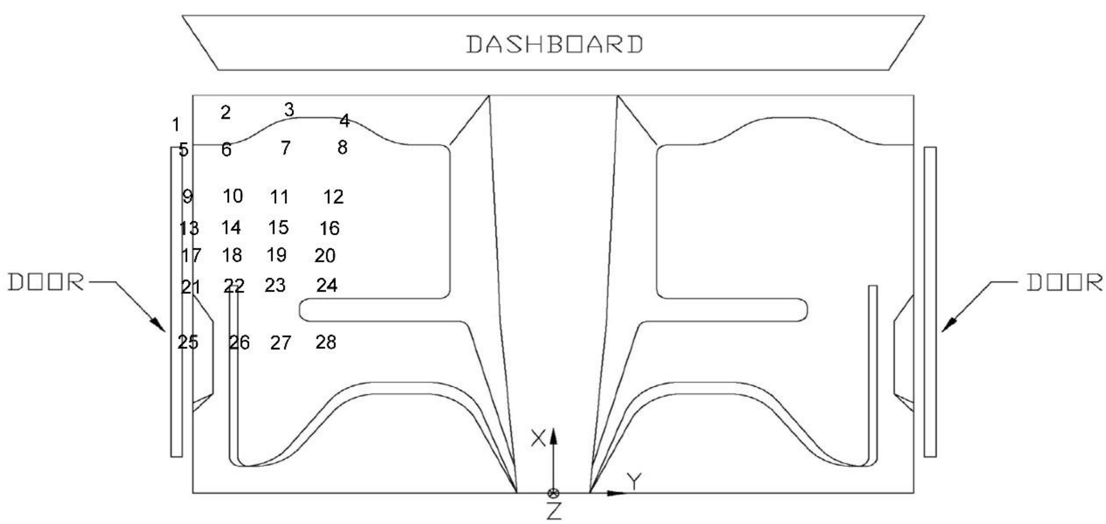


Figure E-2. Floor Pan Deformation Data – Set 2, Test No. NJPCB-3

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 1

TEST: NJPCB-3
VEHICLE: Dodge Ram

	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	12.349	-20.049	30.376	12.391	-19.763	30.396	0.042	0.287	0.020	0.291	0.291
	2	13.876	-6.626	27.428	13.954	-6.284	27.442	0.078	0.342	0.014	0.351	0.351
	3	13.822	3.990	26.377	13.934	4.364	26.364	0.112	0.374	-0.013	0.391	0.391
	4	14.230	-21.941	11.332	14.409	-21.459	11.514	0.179	0.482	0.182	0.545	0.545
	5	13.615	-9.539	9.666	13.813	-9.335	9.716	0.198	0.204	0.050	0.289	0.289
	6	11.779	1.942	7.294	12.061	2.158	7.106	0.282	0.216	-0.188	0.402	0.402
SIDE PANEL	7	20.243	-30.851	9.347	20.680	-30.208	9.738	0.437	0.643	0.391	0.870	0.643
	8	23.145	-31.013	8.828	23.451	-30.336	9.126	0.306	0.677	0.298	0.800	0.677
	9	21.917	-31.283	6.375	22.226	-30.578	6.564	0.309	0.704	0.189	0.792	0.704
IMPACT SIDE DOOR	10	-11.291	-32.745	18.825	-11.048	-32.996	18.870	0.242	-0.250	0.045	0.351	-0.250
	11	-2.920	-32.351	19.332	-2.591	-32.443	19.244	0.330	-0.092	-0.089	0.354	-0.092
	12	9.933	-32.126	19.330	10.161	-31.893	19.577	0.228	0.233	0.248	0.409	0.233
	13	-10.729	-33.700	8.217	-10.573	-33.579	8.043	0.156	0.121	-0.174	0.263	0.121
	14	-2.237	-34.107	8.862	-1.833	-33.874	8.959	0.403	0.233	0.097	0.476	0.233
	15	3.422	-34.386	6.521	3.683	-33.990	6.624	0.261	0.396	0.103	0.485	0.396
ROOF	1	2.410	-16.631	43.258	2.499	-16.130	43.265	0.089	0.501	0.007	0.509	0.007
	2	4.102	-11.207	42.791	4.183	-10.735	42.775	0.082	0.472	-0.016	0.479	-0.016
	3	5.109	-5.354	42.282	5.150	-4.891	42.245	0.040	0.464	-0.037	0.467	-0.037
	4	5.648	0.120	41.778	5.669	0.646	41.695	0.021	0.525	-0.083	0.532	-0.083
	5	5.644	5.234	41.306	5.808	5.749	41.107	0.164	0.514	-0.199	0.575	-0.199
	6	-6.835	-16.299	46.128	-6.842	-15.893	46.086	-0.007	0.406	-0.042	0.408	-0.042
	7	-6.048	-11.323	45.906	-5.951	-11.004	45.832	0.097	0.319	-0.074	0.341	-0.074
	8	-5.543	-5.946	45.527	-5.450	-5.470	45.413	0.093	0.476	-0.115	0.498	-0.115
	9	-5.033	-1.330	45.117	-5.031	-0.783	44.971	0.002	0.547	-0.146	0.566	-0.146
	10	-5.056	3.449	44.649	-5.028	3.900	44.473	0.028	0.450	-0.176	0.484	-0.176
	11	-17.993	-15.559	46.557	-17.840	-15.089	46.444	0.153	0.470	-0.113	0.507	-0.113
	12	-17.778	-10.262	46.294	-17.593	-9.903	46.149	0.185	0.359	-0.144	0.429	-0.144
	13	-17.573	-5.424	45.958	-17.453	-5.078	45.777	0.120	0.346	-0.182	0.409	-0.182
	14	-17.592	-0.122	45.488	-17.662	0.401	45.247	-0.070	0.523	-0.242	0.580	-0.242
	15	-17.794	4.987	44.952	-17.787	5.440	44.688	0.007	0.453	-0.264	0.525	-0.264

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

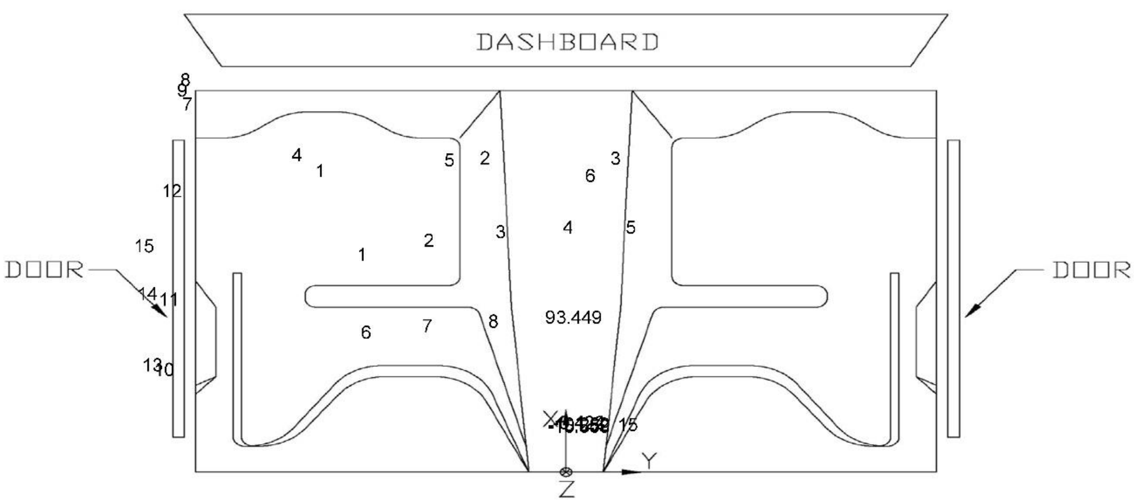


Figure E-3. Occupant Compartment Deformation Data – Set 1, Test No. NJPCB-3

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 2

TEST: NJPCB-3
VEHICLE: Dodge Ram

	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	35.378	-29.723	29.192	35.429	-29.646	29.054	0.052	0.077	-0.138	0.167	0.167
	2	36.916	-16.061	27.840	36.933	-15.988	27.613	0.017	0.073	-0.227	0.240	0.240
	3	36.834	-5.382	28.017	36.915	-5.364	27.819	0.081	0.018	-0.198	0.215	0.215
	4	36.738	-29.391	10.074	36.819	-29.300	9.760	0.081	0.090	-0.315	0.337	0.337
	5	35.973	-16.953	9.966	36.195	-16.943	9.518	0.222	0.010	-0.447	0.499	0.499
	6	34.144	-5.238	8.907	34.311	-5.179	8.509	0.166	0.059	-0.398	0.436	0.436
SIDE PANEL	7	42.786	-38.024	6.851	42.804	-37.593	6.680	0.018	0.431	-0.171	0.464	0.431
	8	45.518	-38.115	6.433	45.472	-37.659	6.093	-0.046	0.456	-0.339	0.571	0.456
	9	44.257	-38.101	3.852	44.264	-37.579	3.717	0.007	0.523	-0.135	0.540	0.523
IMPACT SIDE DOOR	10	11.422	-41.135	16.876	11.400	-41.421	16.701	-0.022	-0.286	-0.175	0.336	-0.286
	11	19.796	-40.767	17.261	19.785	-40.940	17.007	-0.011	-0.172	-0.254	0.307	-0.172
	12	32.751	-40.491	16.943	32.700	-40.446	16.675	-0.051	0.045	-0.268	0.277	0.045
	13	11.701	-40.867	6.297	11.548	-40.680	5.997	-0.153	0.187	-0.299	0.385	0.187
	14	20.245	-41.297	6.591	20.303	-41.099	6.382	0.058	0.198	-0.209	0.294	0.198
	15	25.852	-41.277	4.121	25.831	-40.942	3.912	-0.021	0.335	-0.209	0.395	0.335
ROOF	1	25.871	-27.795	42.707	25.976	-27.659	42.516	0.105	0.136	-0.191	0.257	-0.191
	2	27.608	-22.423	42.771	27.673	-22.311	42.591	0.065	0.112	-0.180	0.222	-0.180
	3	28.569	-16.518	42.930	28.626	-16.348	42.769	0.057	0.170	-0.161	0.241	-0.161
	4	29.022	-11.073	43.052	29.139	-10.838	42.880	0.117	0.235	-0.172	0.314	-0.172
	5	29.082	-6.076	43.134	29.324	-5.657	42.894	0.242	0.418	-0.240	0.539	-0.240
	6	16.619	-28.018	45.821	16.732	-27.762	45.686	0.113	0.256	-0.135	0.311	-0.135
	7	17.576	-23.053	46.111	17.603	-22.790	46.000	0.027	0.263	-0.111	0.286	-0.111
	8	18.229	-17.481	46.329	18.268	-17.385	46.202	0.038	0.096	-0.127	0.163	-0.127
	9	18.682	-12.941	46.427	18.691	-12.711	46.318	0.008	0.230	-0.109	0.254	-0.109
	10	18.707	-8.116	46.505	18.676	-7.906	46.395	-0.032	0.211	-0.110	0.240	-0.110
	11	5.750	-27.316	46.618	5.649	-27.036	46.526	-0.102	0.280	-0.092	0.312	-0.092
	12	5.905	-21.973	46.971	5.896	-21.871	46.853	-0.009	0.102	-0.118	0.156	-0.118
	13	6.220	-17.089	47.190	6.122	-17.098	47.028	-0.098	-0.009	-0.162	0.190	-0.162
	14	6.103	-11.801	47.349	6.024	-11.556	47.180	-0.078	0.245	-0.170	0.308	-0.170
	15	5.921	-6.756	47.420	5.792	-6.541	47.244	-0.129	0.215	-0.176	0.307	-0.176

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

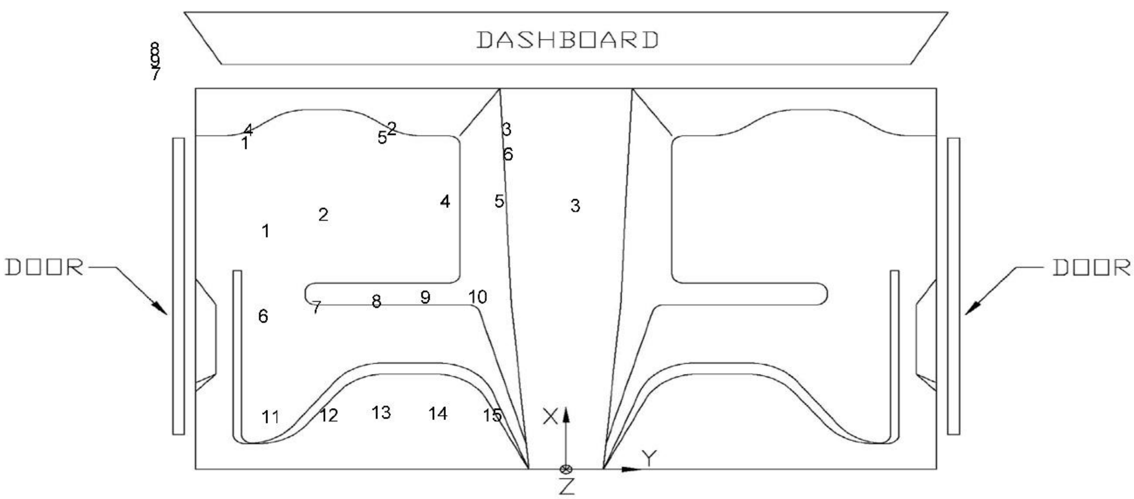
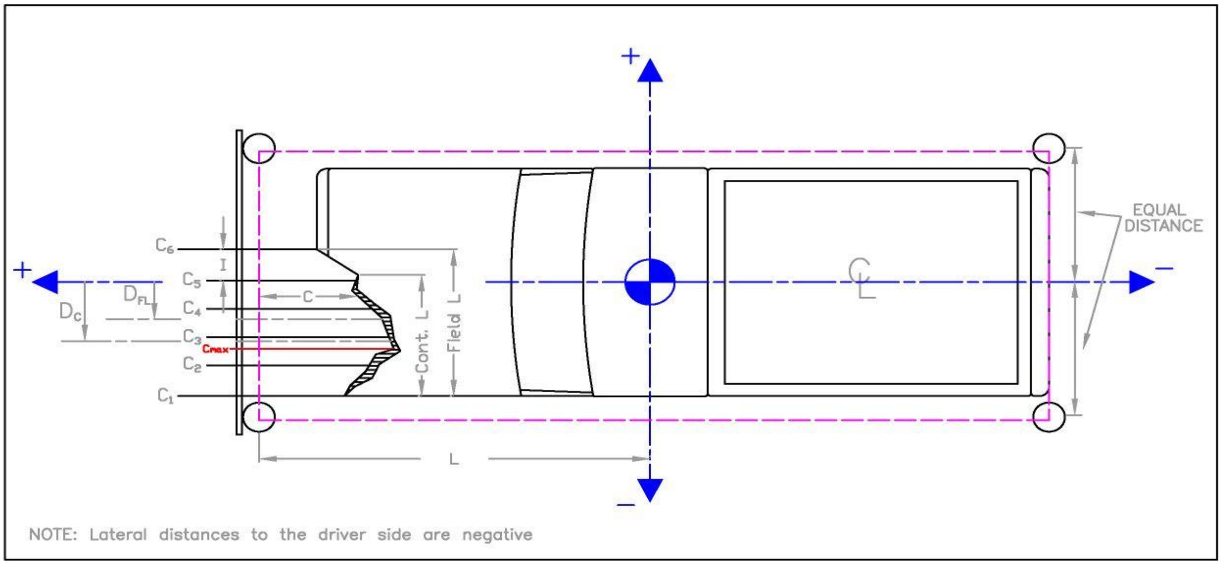


Figure E-4. Occupant Compartment Deformation Data – Set 2, Test No. NJPCB-3

Date: 6/20/2016 **Test Number:** NJPCB-3

Make: Dodge **Model:** Ram **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 1/2	(2781)
Total Vehicle Width:	77.125	(1959)
Width of contact and induced crush - Field L:	55 1/2	(1410)
Crush measurement spacing interval (L/5) - I:	11.1	(282)
Distance from center of vehicle to center of Field L - D_{FL}:	-10.8125	-(275)
Width of Contact Damage:	18	(457)
Distance from center of vehicle to center of contact damage - D_C:	-29 4/7	-(751)

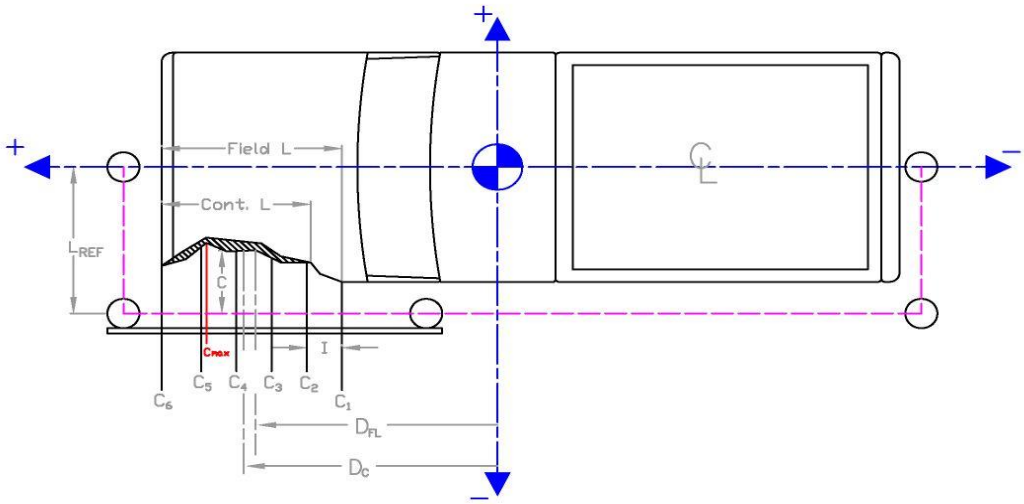
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)
NOTE: All values must be filled out above before crush measurements are filled out.

	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 4/7	-(979)	22 1/2	(572)	3 7/9	(96)	NA	NA
C_2	27 3/4	(705)	-27 1/2	-(698)	7 3/4	(197)			16 2/9	(412)
C_3	8 3/4	(222)	-16 1/3	-(416)	5	(129)			-0	-(2)
C_4	5 1/2	(140)	-5 1/4	-(134)	4	(104)			-2 3/8	-(60)
C_5	5 1/4	(133)	5 5/6	(148)	4 1/9	(104)			-2 2/3	-(67)
C_6	7 1/4	(184)	17	(430)	5	(129)			-1 5/8	-(41)
C_{MAX}	28	(711)	-25	-(635)	7	(176)			17 2/7	(439)

Figure E-5. Exterior Vehicle Crush (NASS) - Front, Test No. NJPCB-3

Date: 6/20/2016 **Test Number:** NJPCB-3

Make: Dodge **Model:** Ram **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 3/4	(1213)
Total Vehicle Length:	229	(5817)
Width of contact and induced crush - Field L:	229	(5817)
Crush measurement spacing interval (L/5) - I:	45.8	(1163)
Distance from vehicle c.g. to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	229	(5817)
Distance from vehicle c.g. to center of contact damage - D_C:	0	()

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	13 1/2	(343)	-114 1/2	-(2908)	6	(152)	3 3/4	(95)	3 3/4	(95)
C_2	NA	NA	-68 5/7	-(1745)	1347 7/8	(34236)			NA	NA
C_3	6 1/2	(165)	-23	-(582)	5 1/8	(130)			-2 3/8	-(60)
C_4	7 1/8	(181)	22 8/9	(582)	5 1/8	(130)			-1 3/4	-(44)
C_5	NA	NA	68 2/3	(1745)	5 4/5	(148)			NA	NA
C_6	NA	NA	114 1/2	(2908)	33 1/2	(851)			NA	NA
C_{MAX}	23 3/4	(603)	27	(686)	5 1/8	(130)			14 7/8	(378)

Figure E-6. Exterior Vehicle Crush (NASS) - Side, Test No. NJPCB-3

Appendix F. Accelerometer and Rate Transducer Data Plots, Test No. NJPCB-3

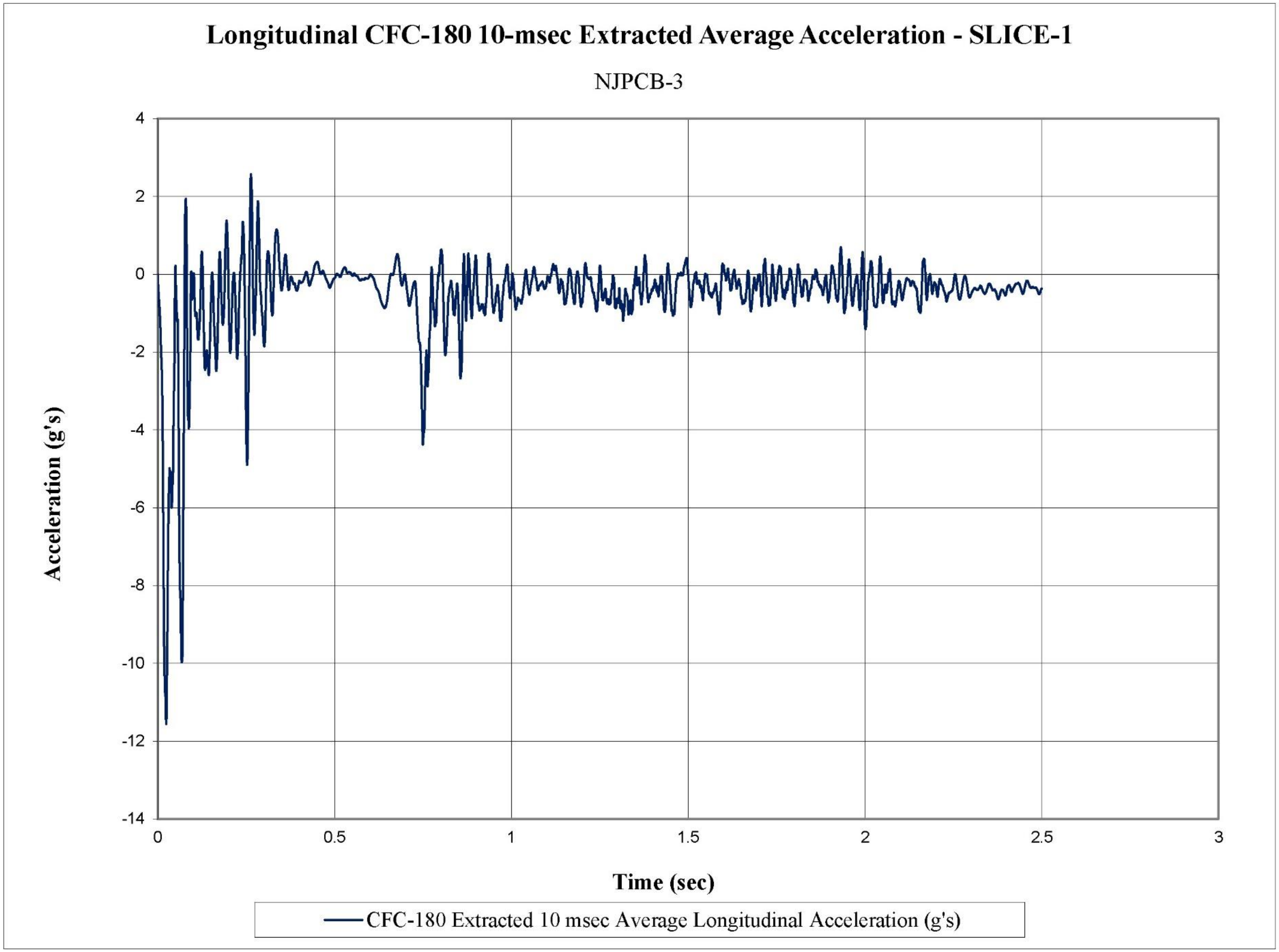


Figure F-1. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. NJPCB-3

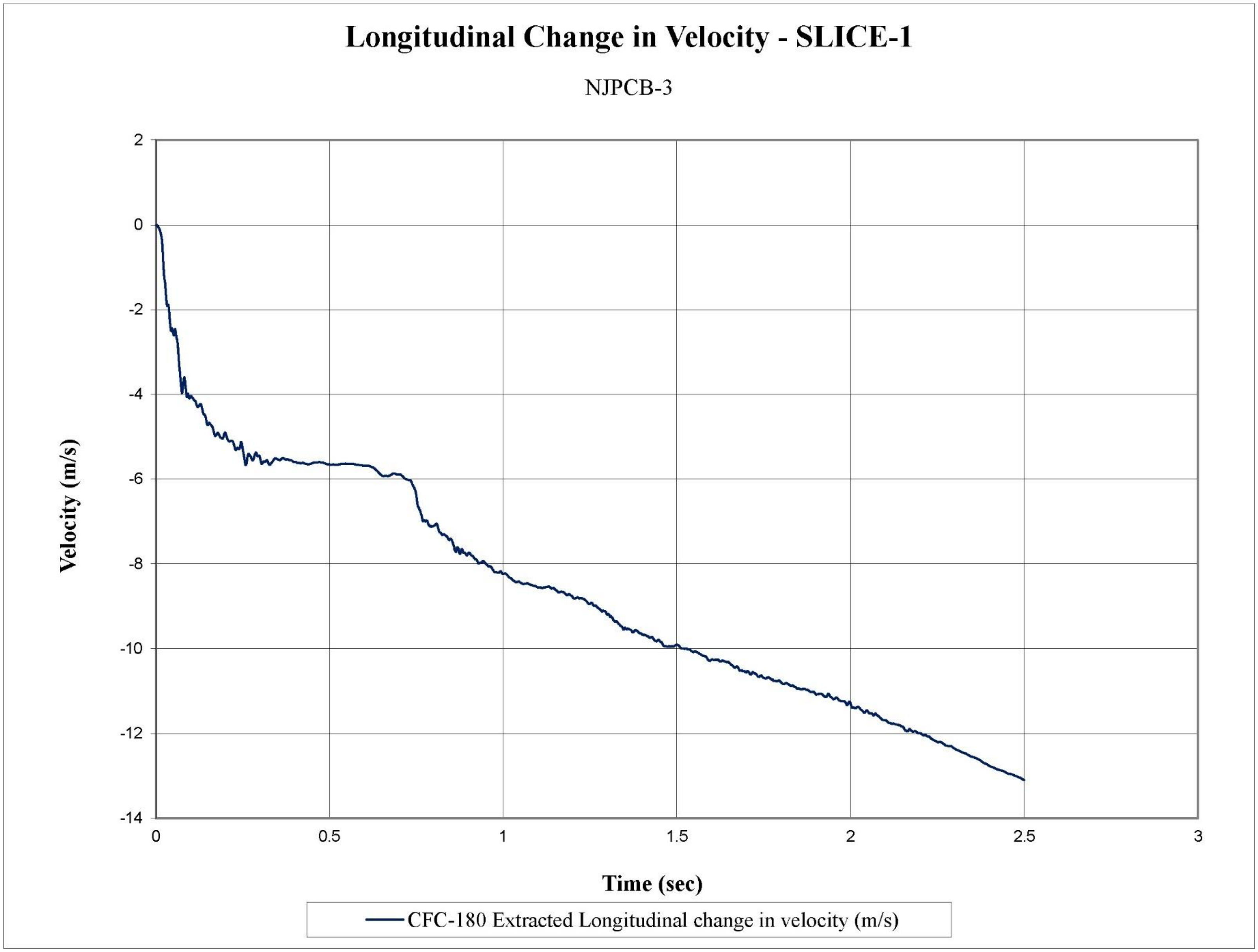


Figure F-2. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. NJPCB-3

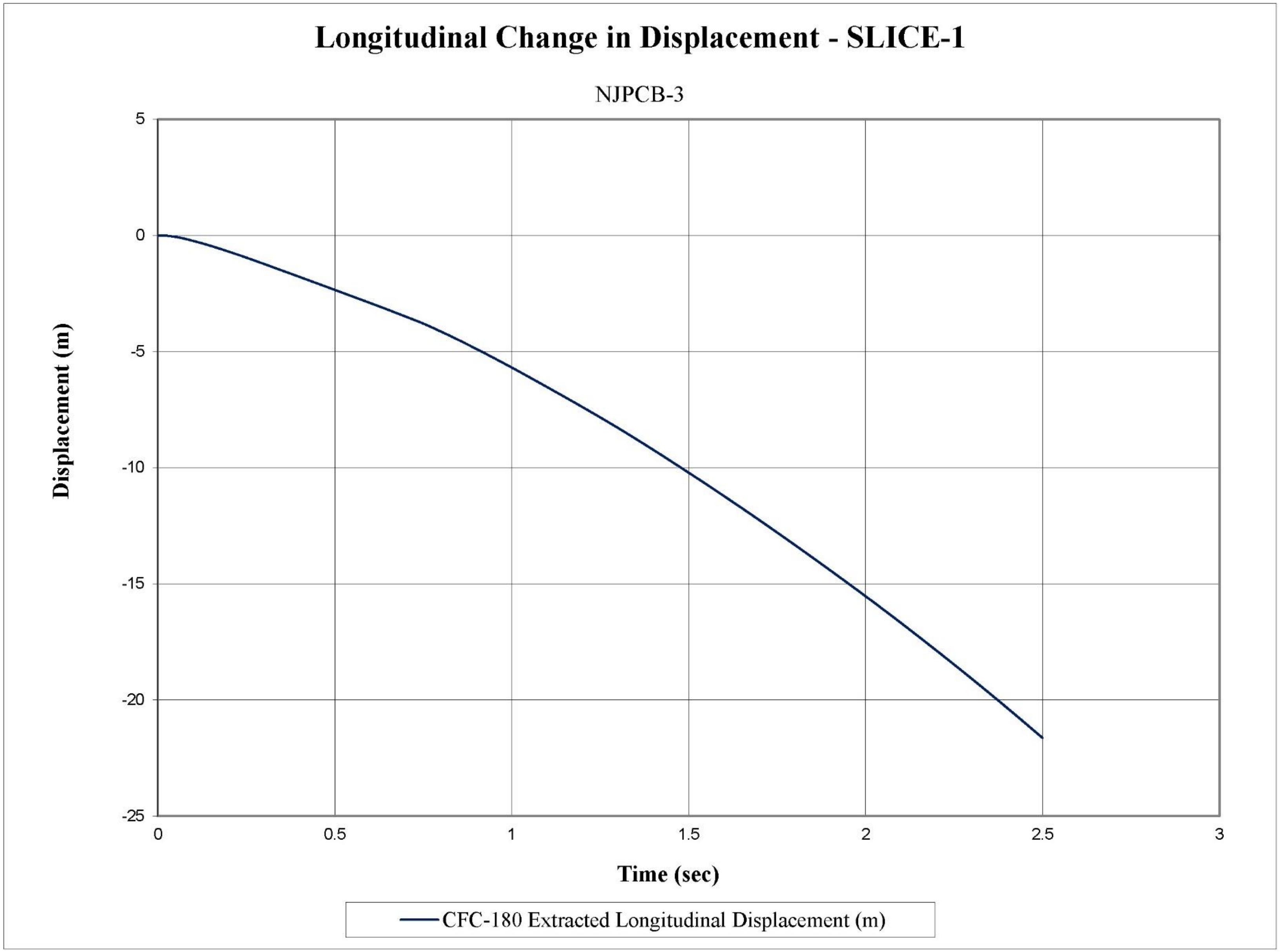


Figure F-3. Longitudinal Occupant Displacement (SLICE-1), Test No. NJPCB-3

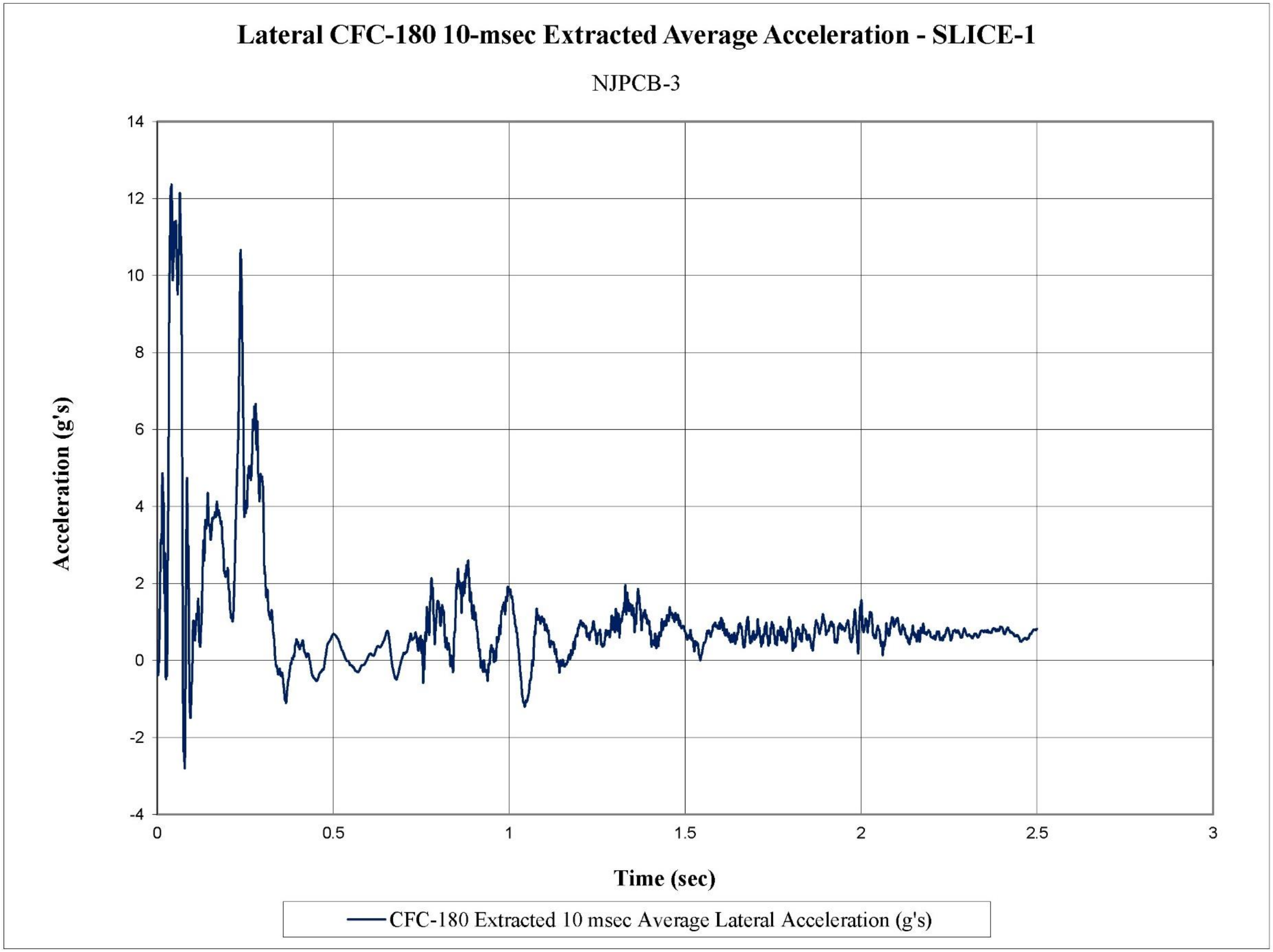


Figure F-4. 10-ms Average Lateral Deceleration (SLICE-1), Test No. NJPCB-3

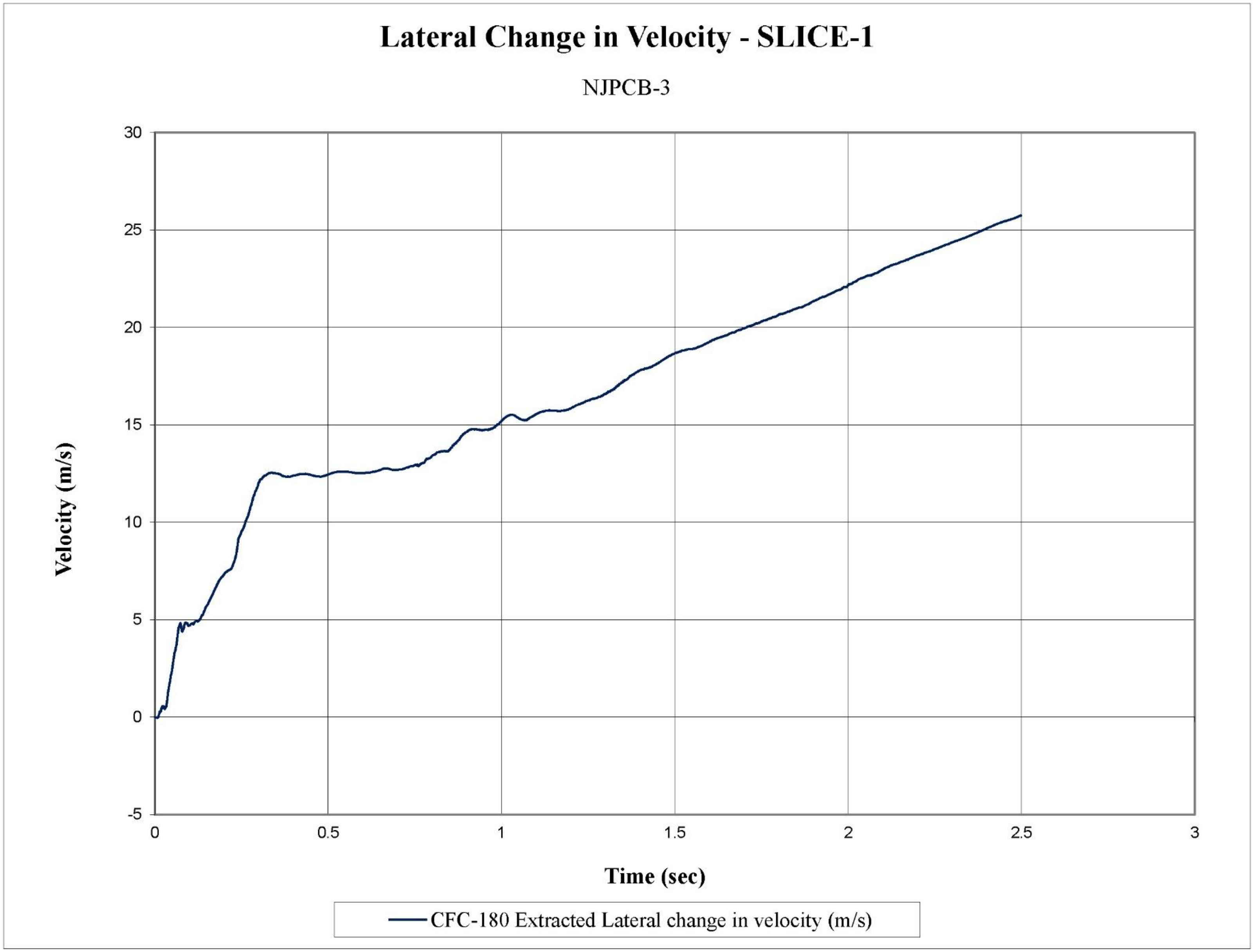


Figure F-5. Lateral Occupant Impact Velocity (SLICE-1), Test No. NJPCB-3

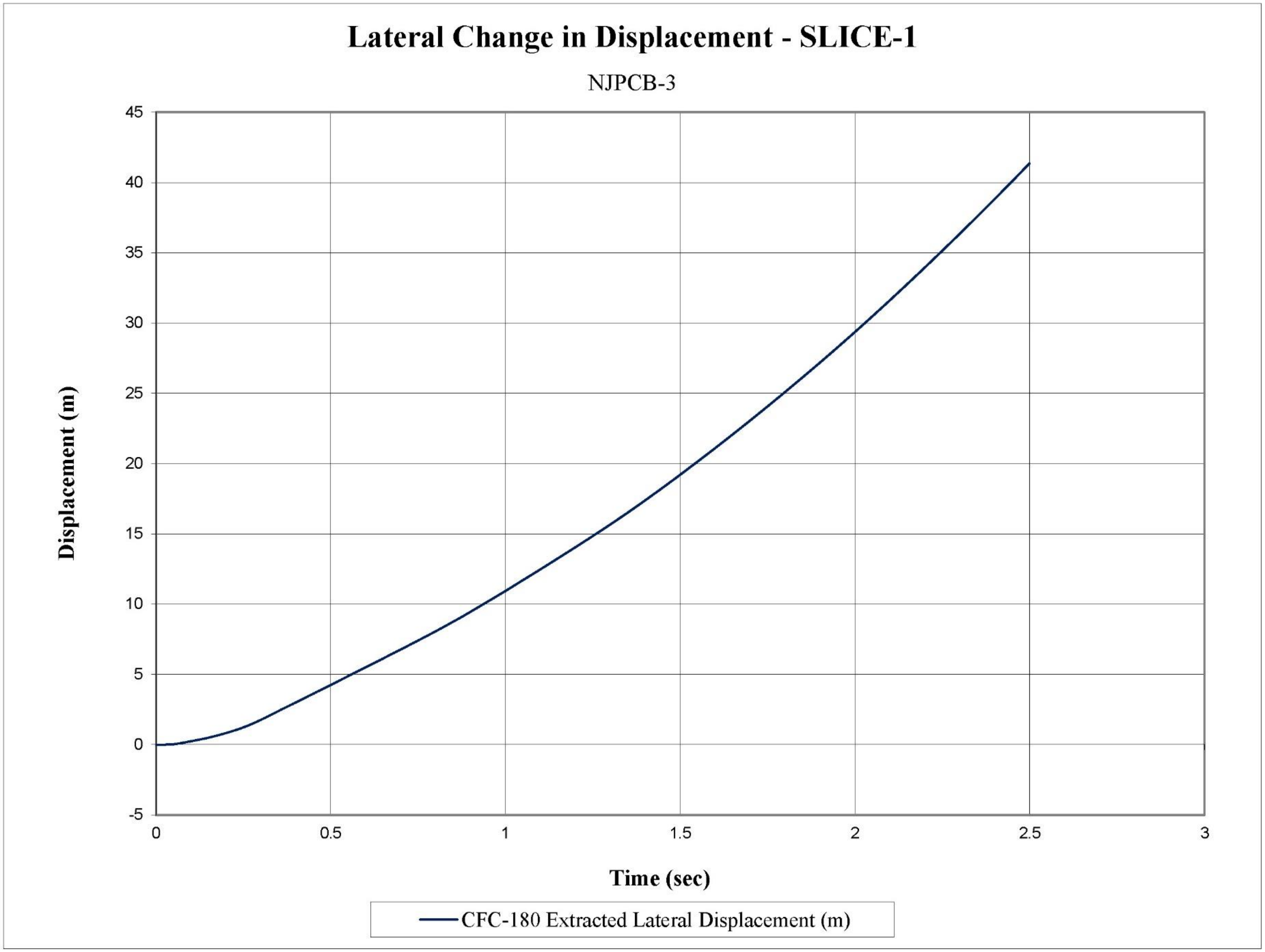


Figure F-6. Lateral Occupant Displacement (SLICE-1), Test No. NJPCB-3

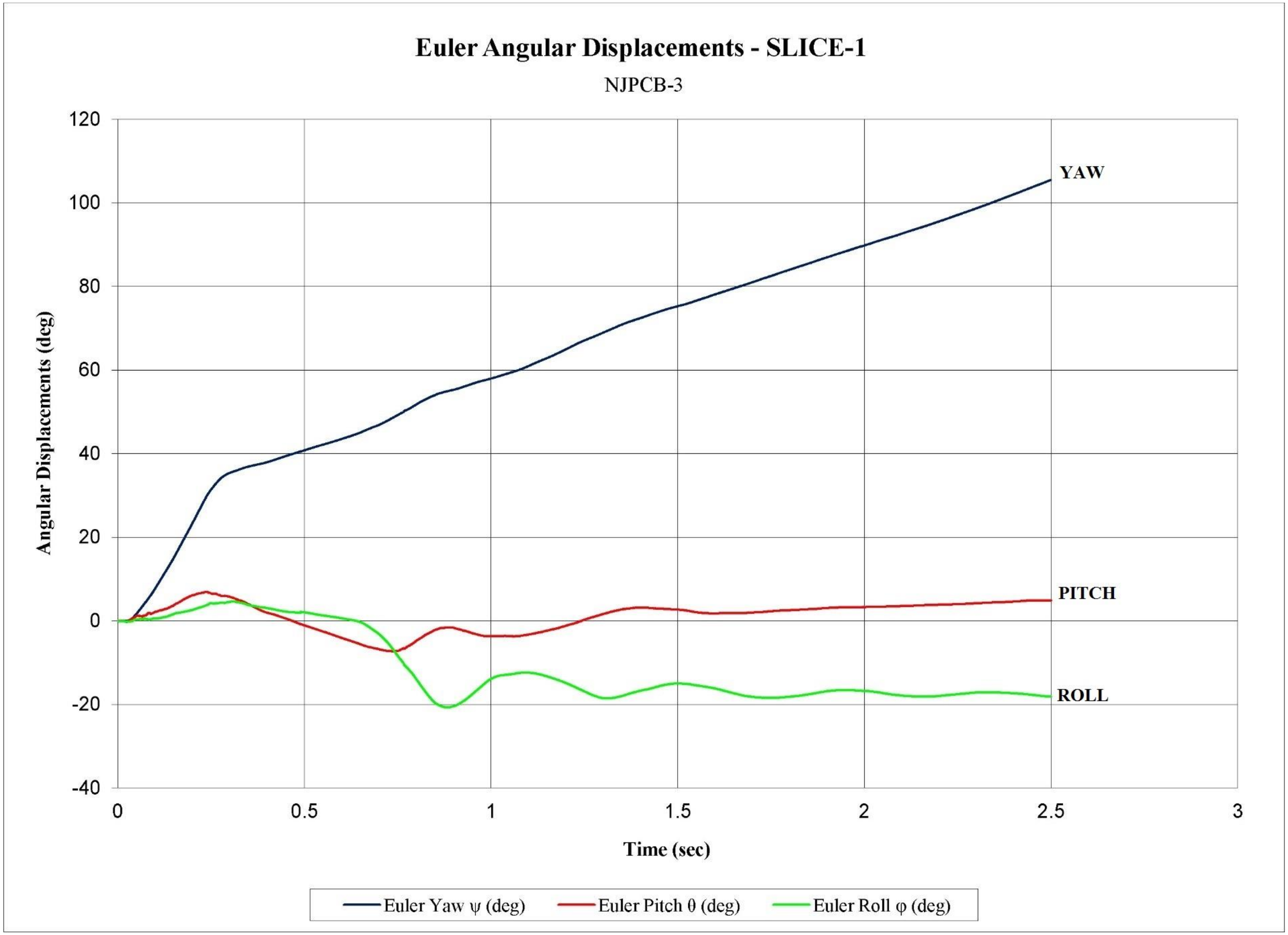


Figure F-7. Vehicle Angular Displacements (SLICE-1), Test No. NJPCB-3

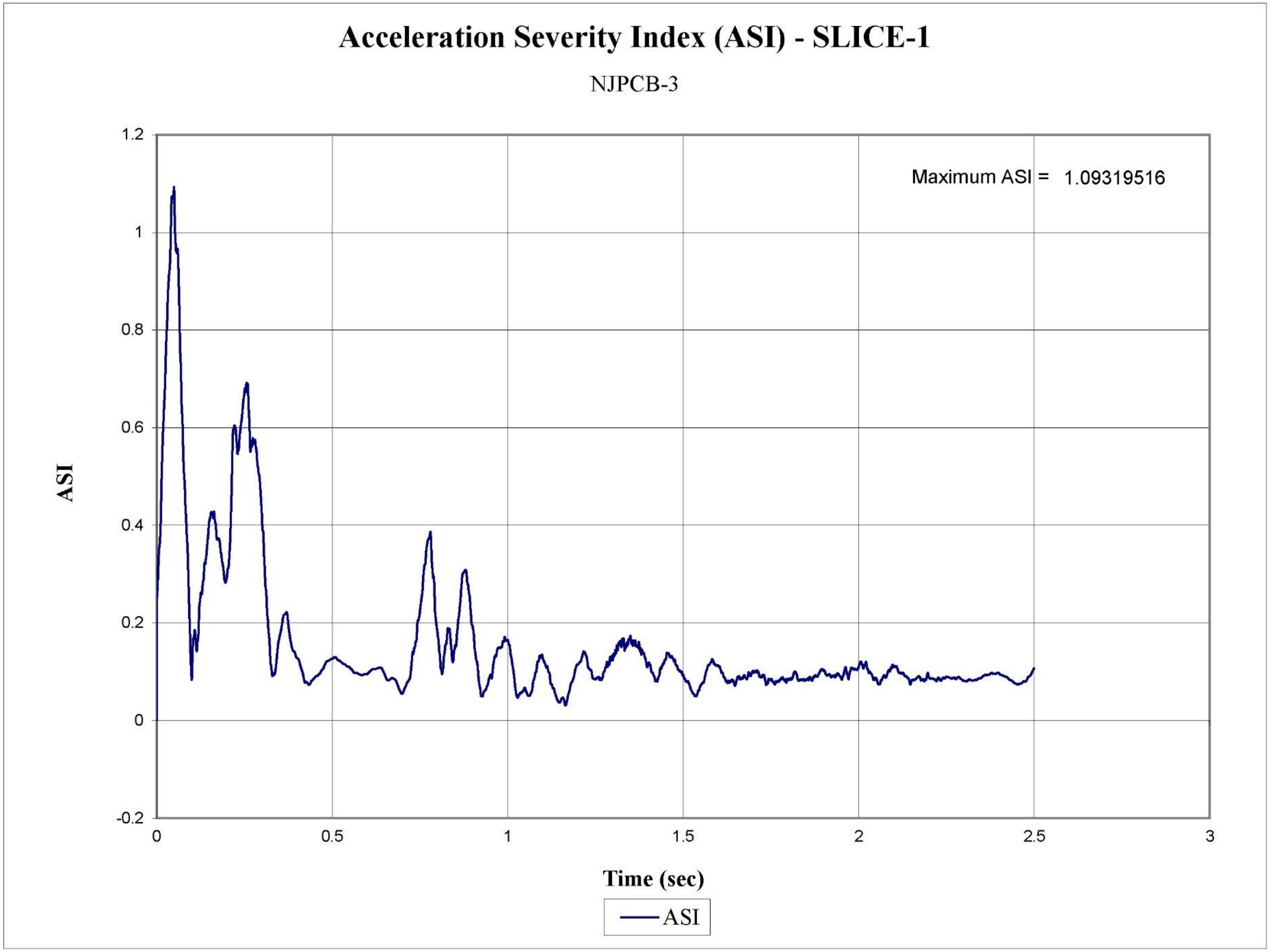


Figure F-8. Acceleration Severity Index (SLICE-1), Test No. NJPCB-3

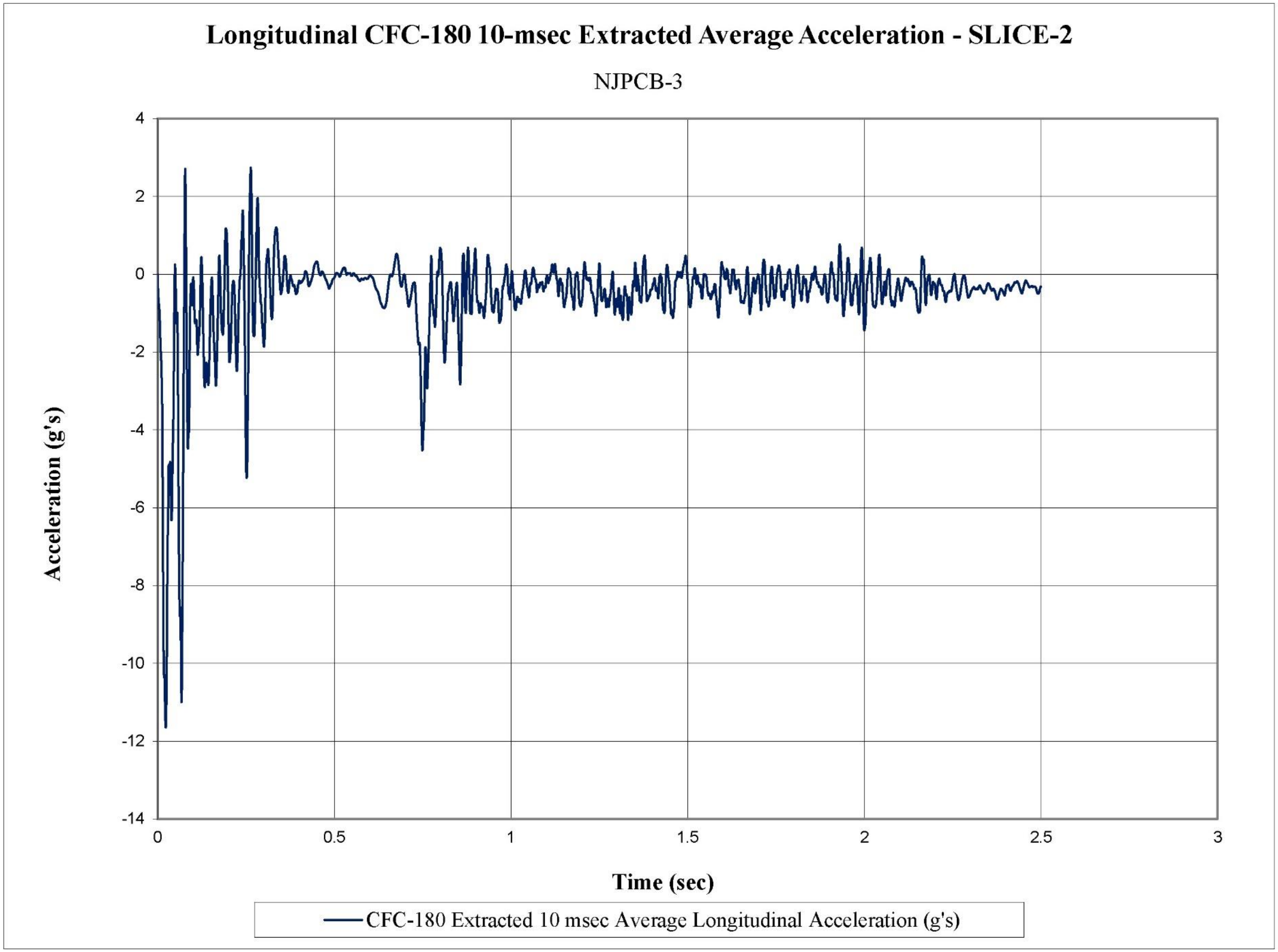


Figure F-9. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. NJPCB-3

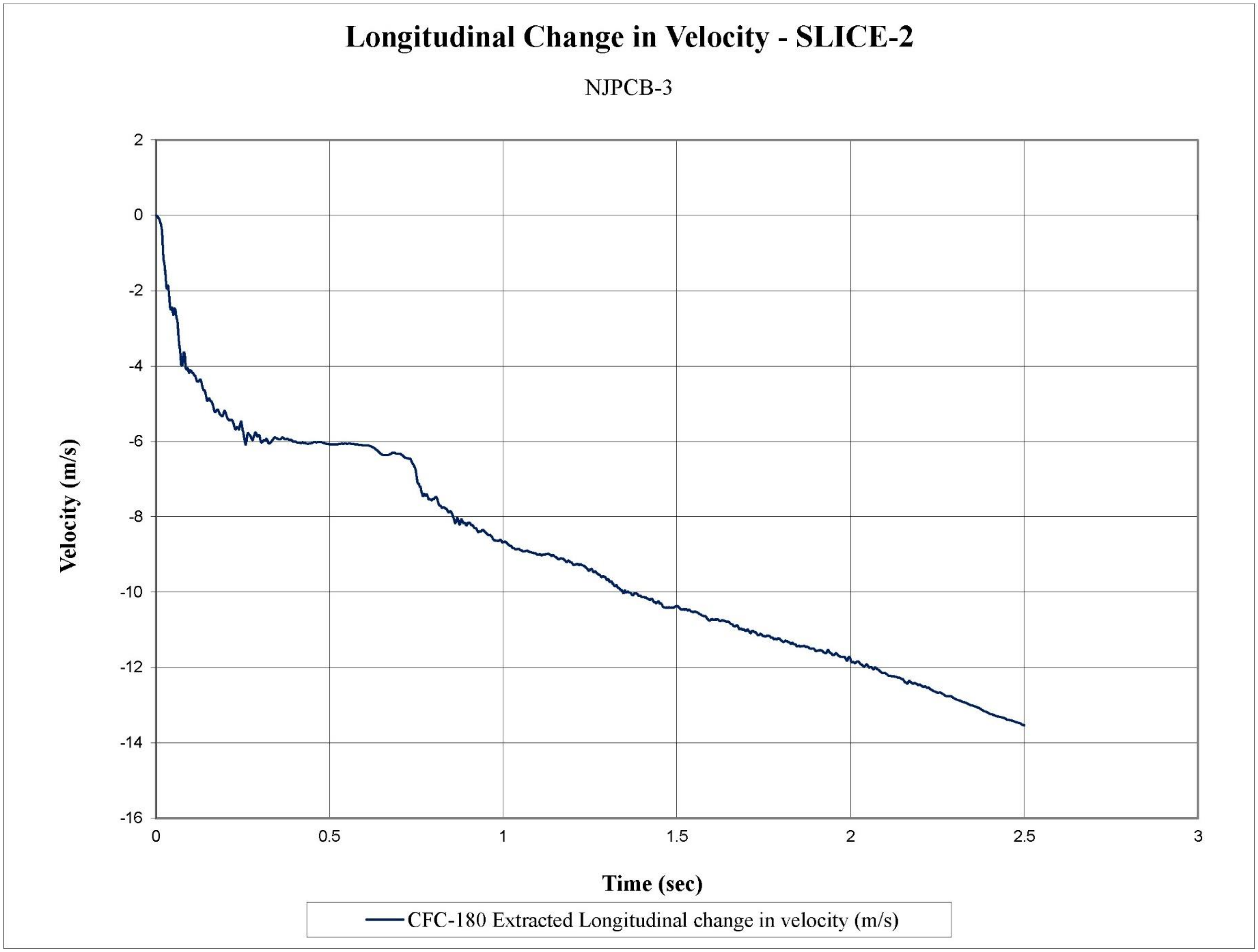


Figure F-10. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. NJPCB-3

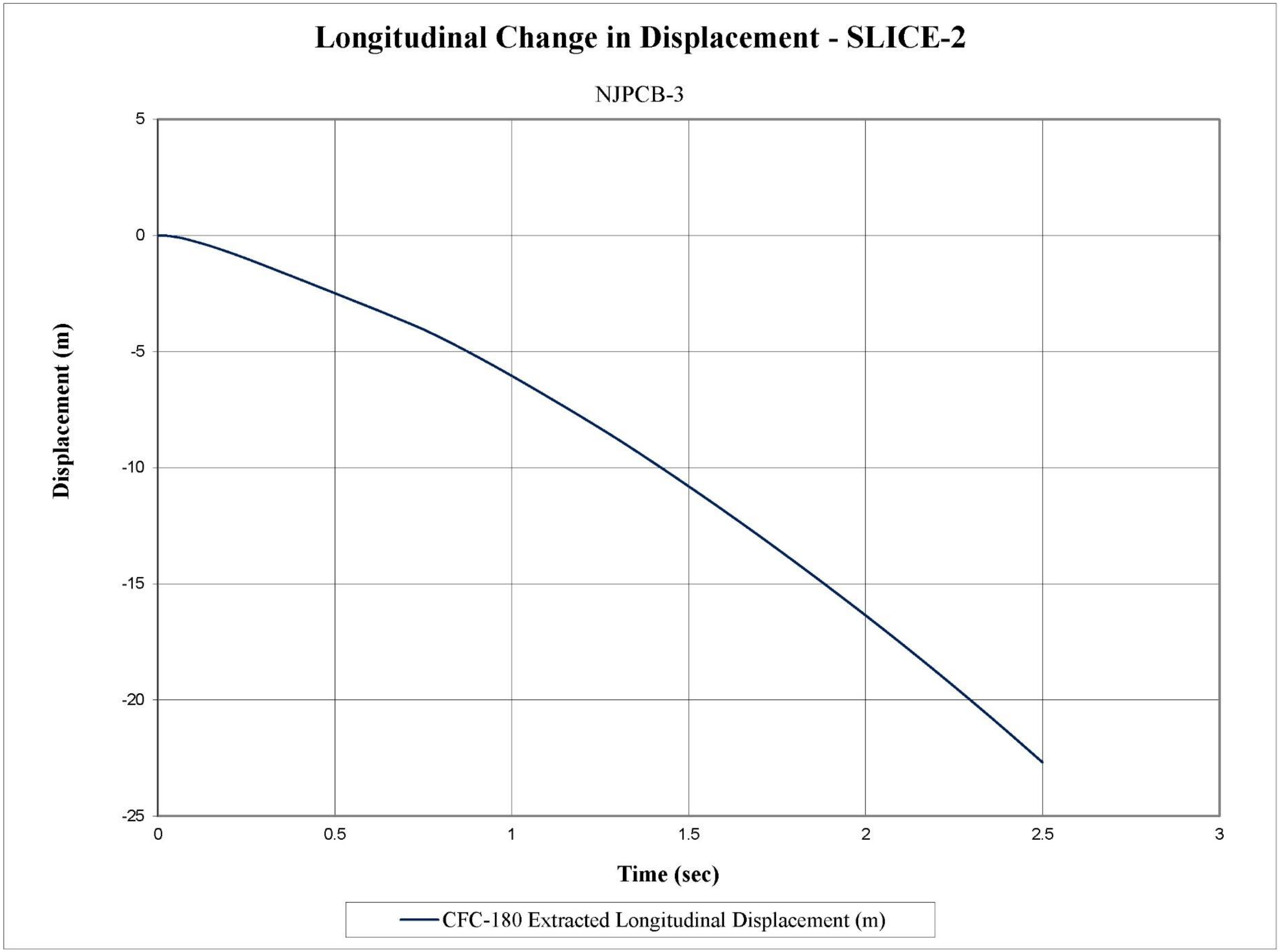


Figure F-11. Longitudinal Occupant Displacement (SLICE-2), Test No. NJPCB-3

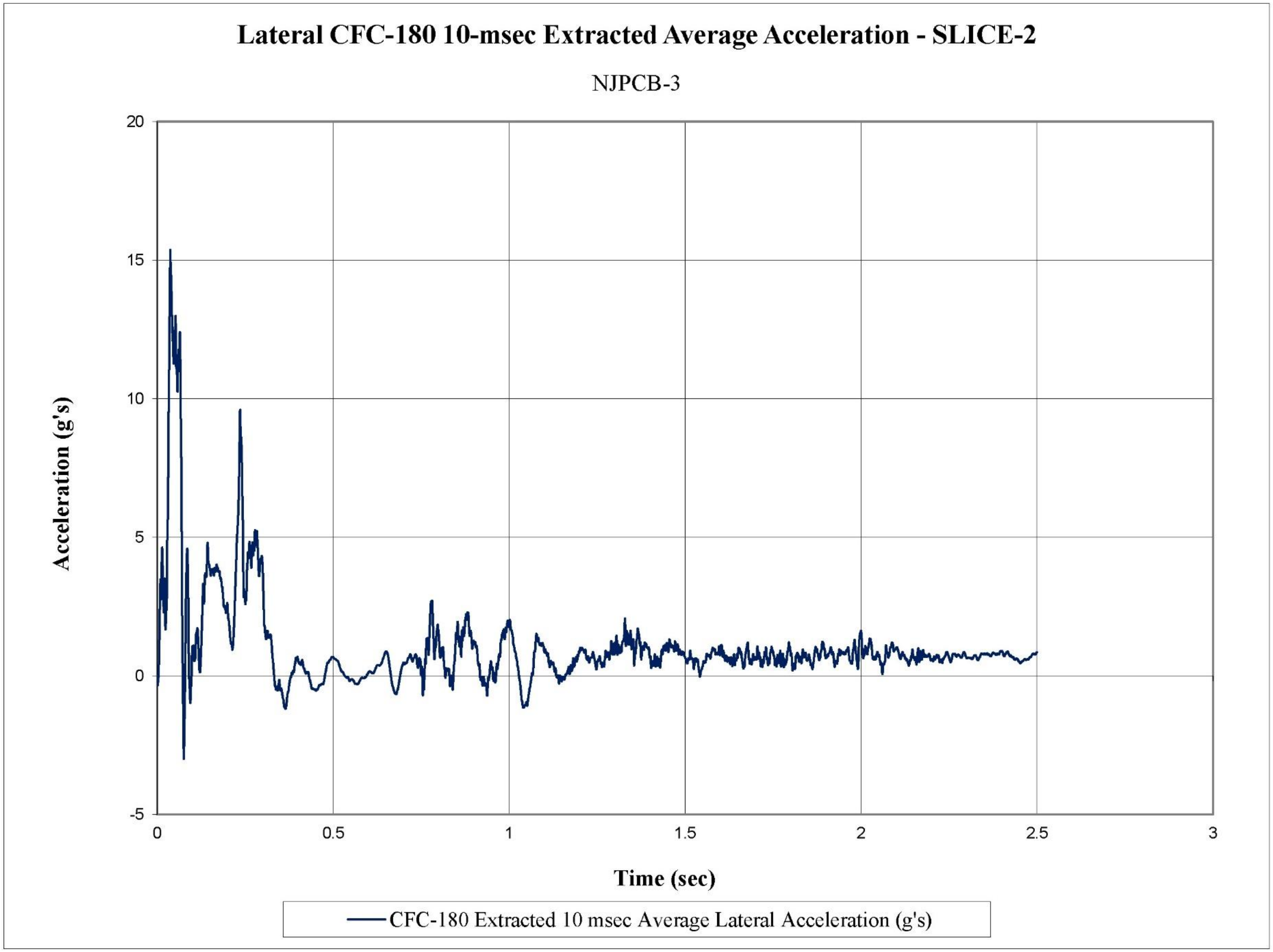


Figure F-12. 10-ms Average Lateral Deceleration (SLICE-2), Test No. NJPCB-3

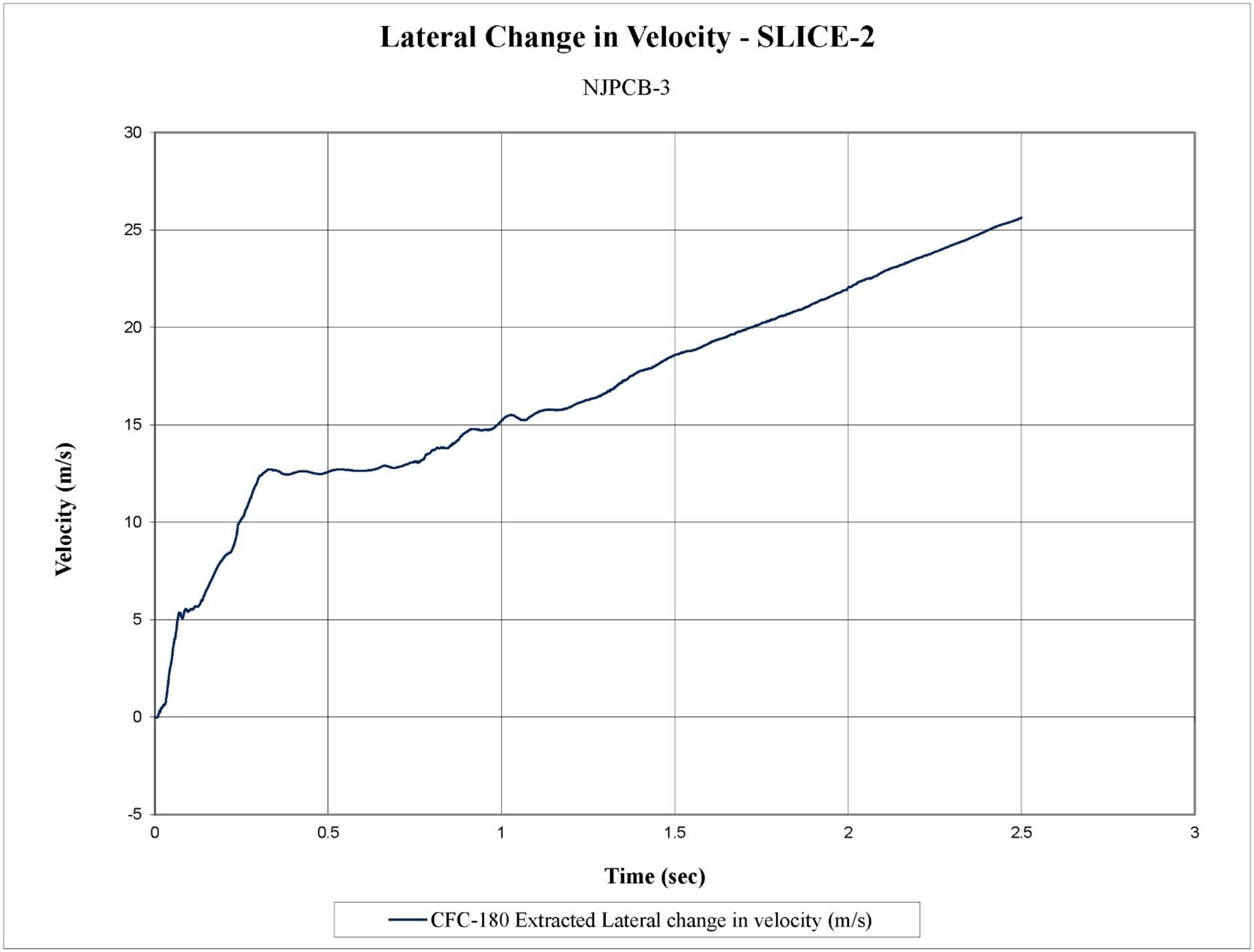


Figure F-13. Lateral Occupant Impact Velocity (SLICE-2), Test No. NJPCB-3

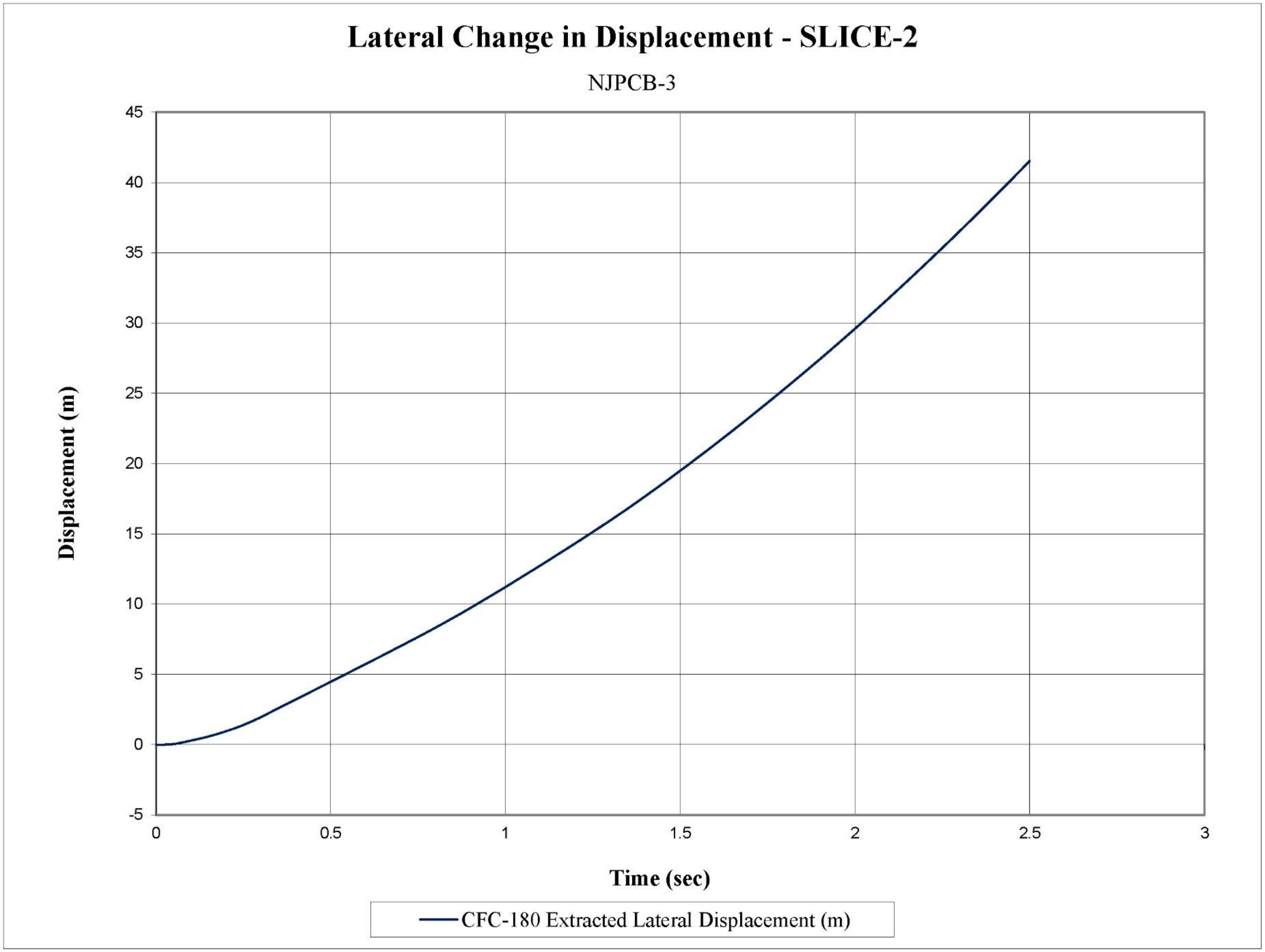


Figure F-14. Lateral Occupant Displacement (SLICE-2), Test No. NJPCB-3

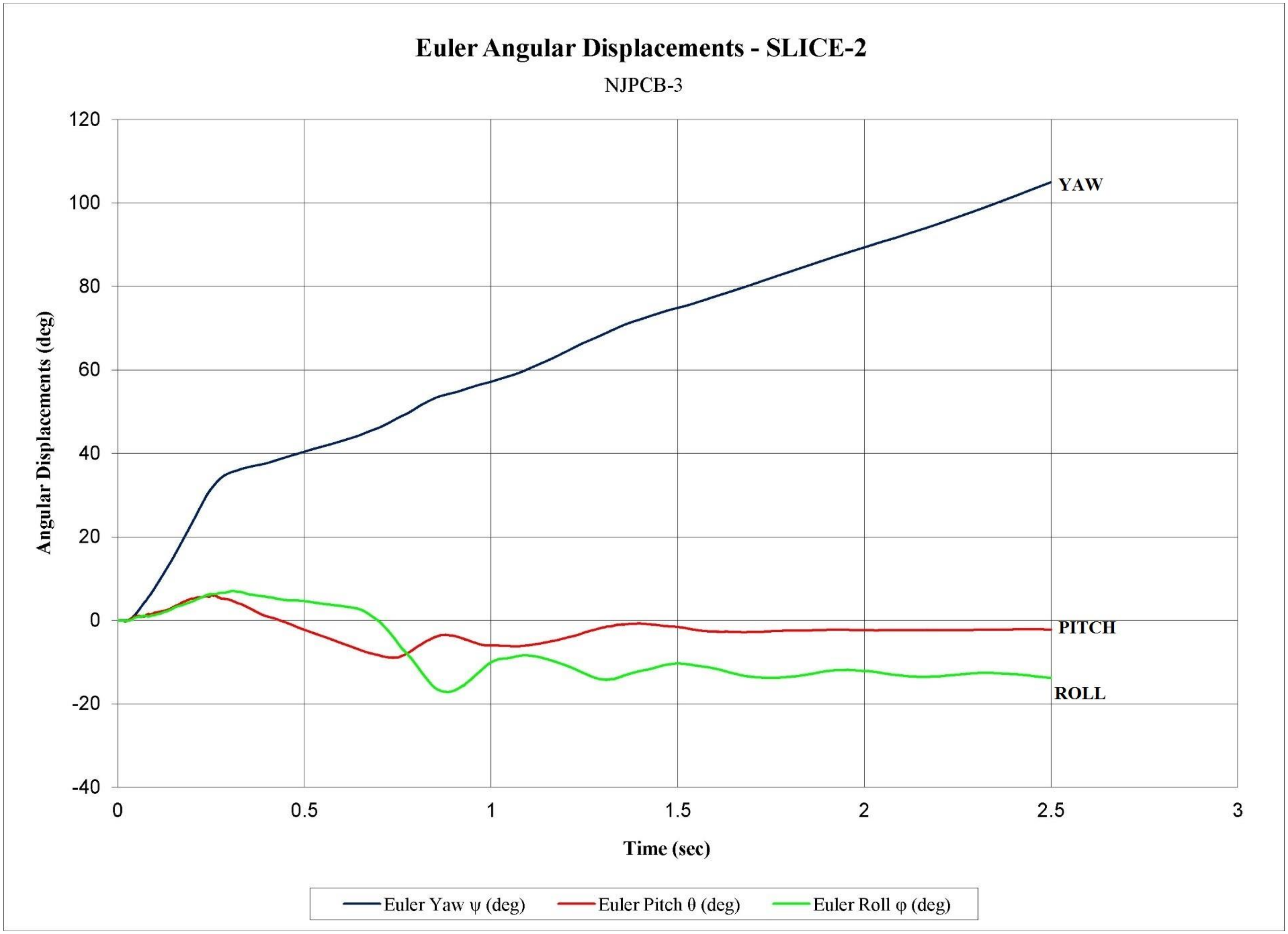


Figure F-15. Vehicle Angular Displacements (SLICE-2), Test No. NJPCB-3

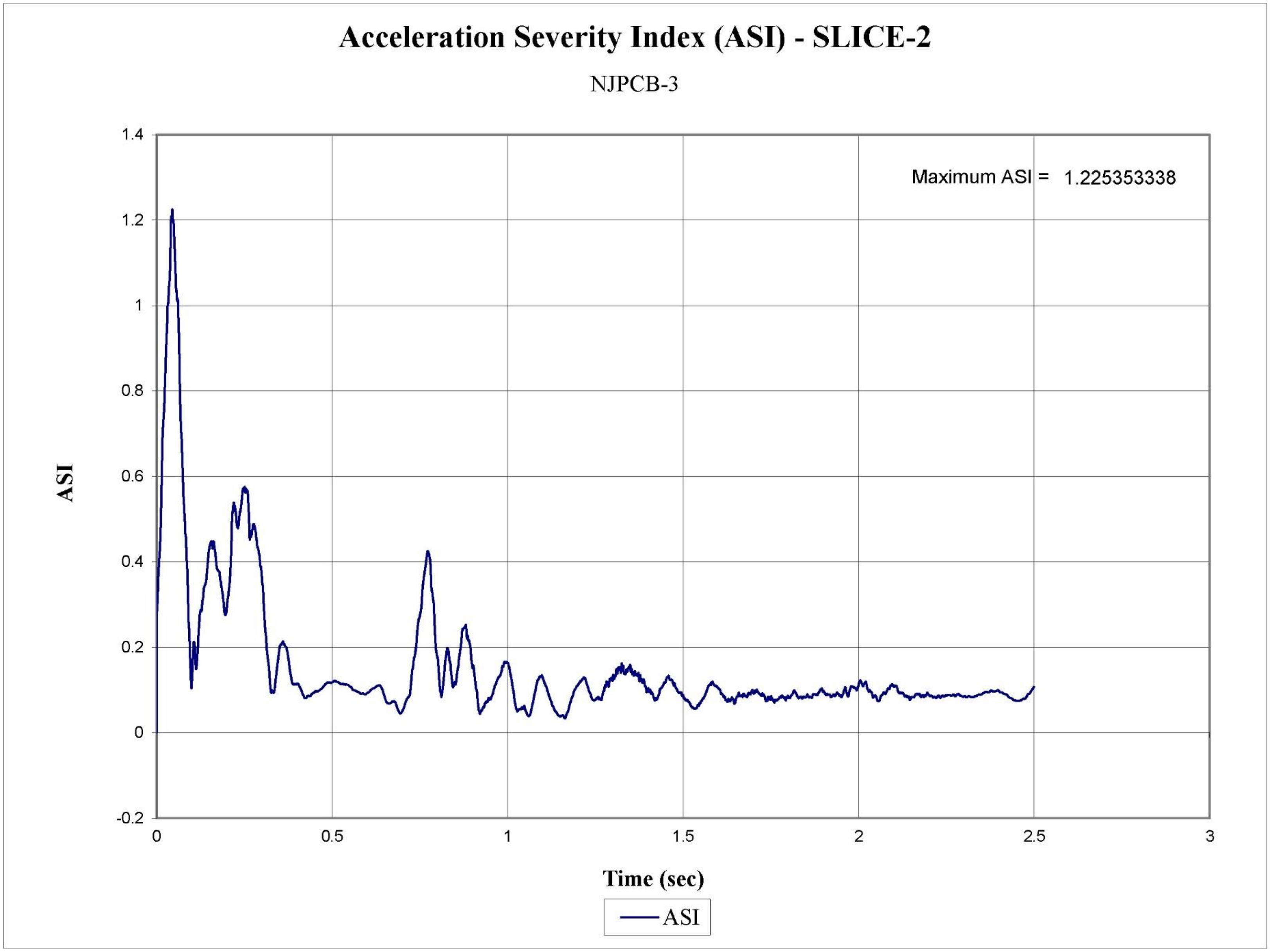


Figure F-16. Acceleration Severity Index (SLICE-2), Test No. NJPCB-3

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