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PERFORMANCE EVALUATION OF NEW JERSEY'S PORTABLE CONCRETE BARRIER WITH A TRAFFIC-SIDE PINNED CONFIGURATION AND GROUTED TOES – TEST NO. NJPCB-7

Submitted by

Surajkumar K. Bhakta, M.S.M.E.
Former Graduate Research Assistant

Karla A. Lechtenberg, M.S.M.E., E.I.T.
Research Engineer

Ronald K. Faller, Ph.D., P.E.
Research Professor
MwRSF Director

John D. Reid, Ph.D.
Professor

Robert W. Bielenberg, M.S.M.E., E.I.T.
Research Engineer

Erin L. Urbank, B.A.
Research Communication Specialist

MIDWEST ROADSIDE SAFETY FACILITY
Nebraska Transportation Center
University of Nebraska-Lincoln

Main Office
Prem S. Paul Research Center at Whittier School
Room 130, 2200 Vine Street
Lincoln, Nebraska 68583-0853
(402) 472-0965

Outdoor Test Site
4630 N.W. 36th Street
Lincoln, Nebraska 68524

Submitted to

NEW JERSEY DEPARTMENT OF TRANSPORTATION
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16. Abstract

This report documents a full-scale crash test conducted in support of a study to investigate the performance of New Jersey Department of Transportation's (NJDOT) Precast Concrete Curb, Construction Barrier, which will be referred to as portable concrete barrier (PCB) in various configurations. This represents the seventh 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 traffic-side pinned configuration and grouted toes. Barrier nos. 1 and 10 were anchored on both sides, and barrier nos. 2 through 9 were anchored only to the concrete tarmac through the traffic-side pin anchor recesses with 1-in. (25-mm) diameter by 15-in. (381-mm) long, ASTM A36 steel pins inserted into 1¼-in. (32-mm) diameter holes drilled in the concrete tarmac. Non-shrink grout wedges were placed at the toe of each barrier segment in every joint between adjacent barrier segments. The barrier was evaluated according to the Test Level 3 (TL-3) criteria set forth in the *Manual for Assessing Safety Hardware, Second Edition* (MASH 2016). 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 2016. The 1100C small car crash test was deemed unnecessary due to previous testing. The barrier successfully met MASH 2016 TL-3 criteria. This report is the seventh of nine documents in the nine-test series.

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

UNCERTAINTY OF MEASUREMENT STATEMENT

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

INDEPENDENT APPROVING AUTHORITY

The Independent Approving Authority (IAA) for the data contained herein was Dr. Jennifer Schmidt, Research Assistant Professor.

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S.K. Rosenbaugh, M.S.C.E., E.I.T., Research Engineer
M. Asadollahi Pajouh, Ph.D., former Post-Doctoral Research Associate
S.A. Ranjha, Ph.D., former Post-Doctoral Research Associate
A.T. Russell, B.S.B.A., Testing and Maintenance Technician II
E.W. Krier, B.S., Construction and Testing Technician II
S.M. Tighe, Construction and Testing Technician I
D.S. Charroin, Construction and Testing Technician I
M.A. Rasmussen, Construction and Testing Technician I
M.T. Ramel, B.S.C.M., former Construction and Testing Technician I
R.M. Novak, Construction and Testing Technician I
J.E. Kohtz, B.S.M.E., CAD Technician
Undergraduate and Graduate Research Assistants

New Jersey Department of Transportation

Dave Bizuga, former Senior Executive Manager, Roadway Design Group 1
Giri Venkiteela, Research Project Manager, NJDOT Bureau of Research
Hung Tang, Design Standards Bureau, Roadway Standards Unit
Lee Steiner, Project Engineer, Bureau of Traffic Engineering

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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] provides 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, Second Edition* (MASH 2016) [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 included an evaluation of the safety performance of NJDOT's PCB, Type 4 (Alternative B) with a traffic-side pinned configuration and grouted toes. The system was evaluated according to the Test Level 3 (TL-3) criteria set forth in the *Manual for Assessing Safety Hardware, Second Edition* (MASH 2016) [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 2016 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 [3]. Note that there is no difference between MASH 2009 [4] 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 2016, 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 2016 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 2016 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 2016 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 2016 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 2016. The full-scale vehicle crash test documented herein was conducted and reported in accordance with the procedures provided in MASH 2016.

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 2016.

Table 4. MASH 2016 Evaluation Criteria for Longitudinal Barrier

<table>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="3">Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td></tr>
<tr><td rowspan="10">Occupant Risk</td><td>D.</td><td colspan="3">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.2.2 and Appendix E of MASH 2016.</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 A5.2.2 of MASH 2016 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 A5.2.2 of MASH 2016 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 traffic-side pinned configuration and grouted toes, as shown in Figures 1 through 14. This system uses NJDOT barriers, Type 4 (Alternative B). Photographs of the test installation are shown in Figures 15 through 18. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B.

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

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

Barrier nos. 1 and 10 were anchored to the concrete tarmac on both the traffic side and the back side, while barrier nos. 2 through 9 were anchored to the concrete tarmac only on the traffic side through the pin anchor recesses with 1-in. (25-mm) diameter by 15-in. (381-mm) long, ASTM A36 steel pins inserted into 1¼-in. (32-mm) diameter holes drilled in the concrete tarmac, as shown in Figures 12 and 17. The steel pins were embedded to a depth of 5 in. (127 mm), as shown in Figure 1. During installation, the barrier segments were pulled in a direction parallel to their longitudinal axes, and slack was removed from all joints. After slack was removed from all the joints, the 1¼-in. (32-mm) diameter holes were drilled for the 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 ranging between 5,970 and 7,040 psi (41.2 and 48.5 MPa), as shown in Appendix C. Non-shrink grout wedges were placed at the toe of each barrier segment in every joint between adjacent barrier segments on both traffic and back sides, as shown in Figures 1, 2, and 18. The grout wedges consisted of a grout mix with a minimum 1-day compressive strength of 1,000 psi (6.9 MPa).

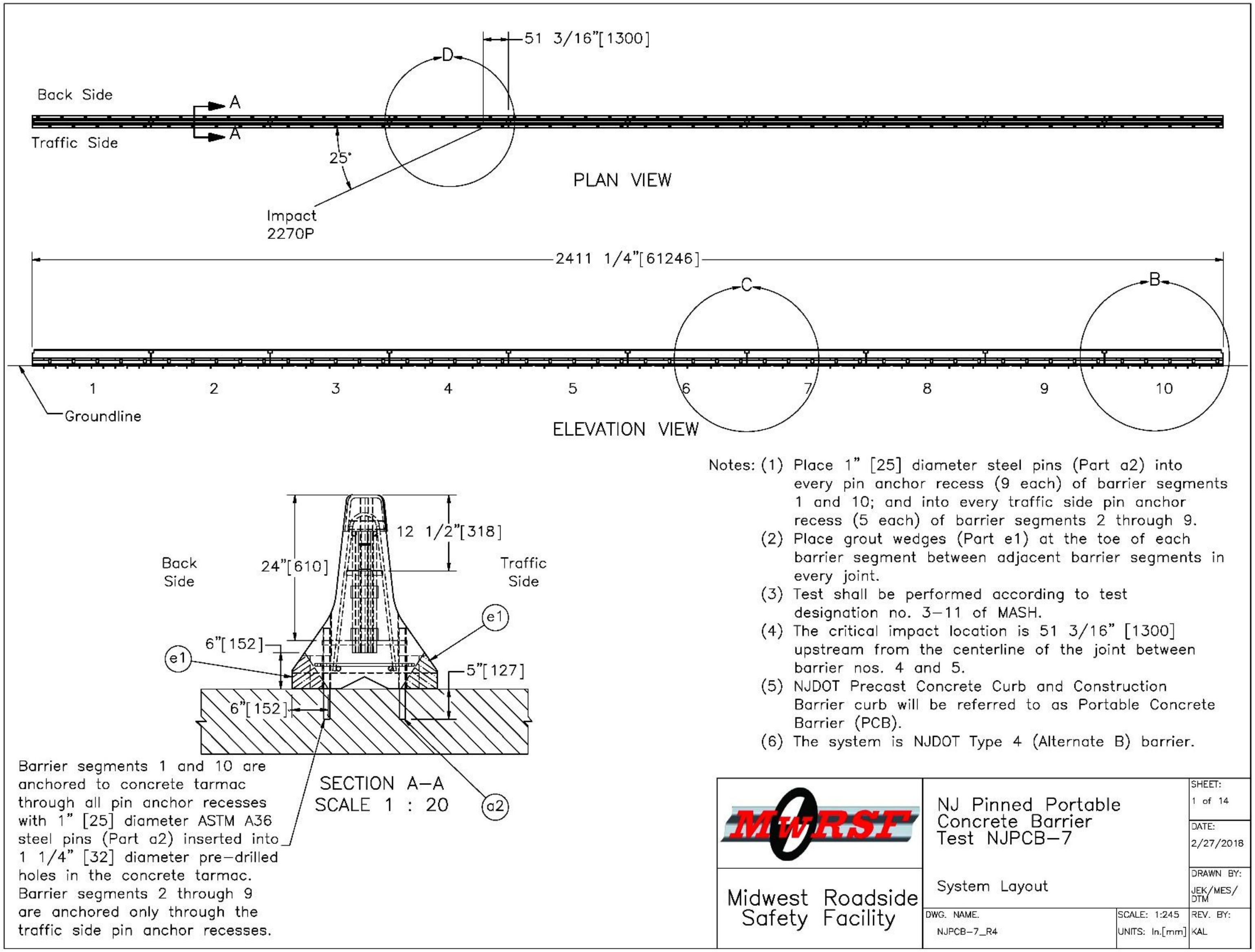


Figure 1. Test Installation Layout, Test No. NJPCB-7

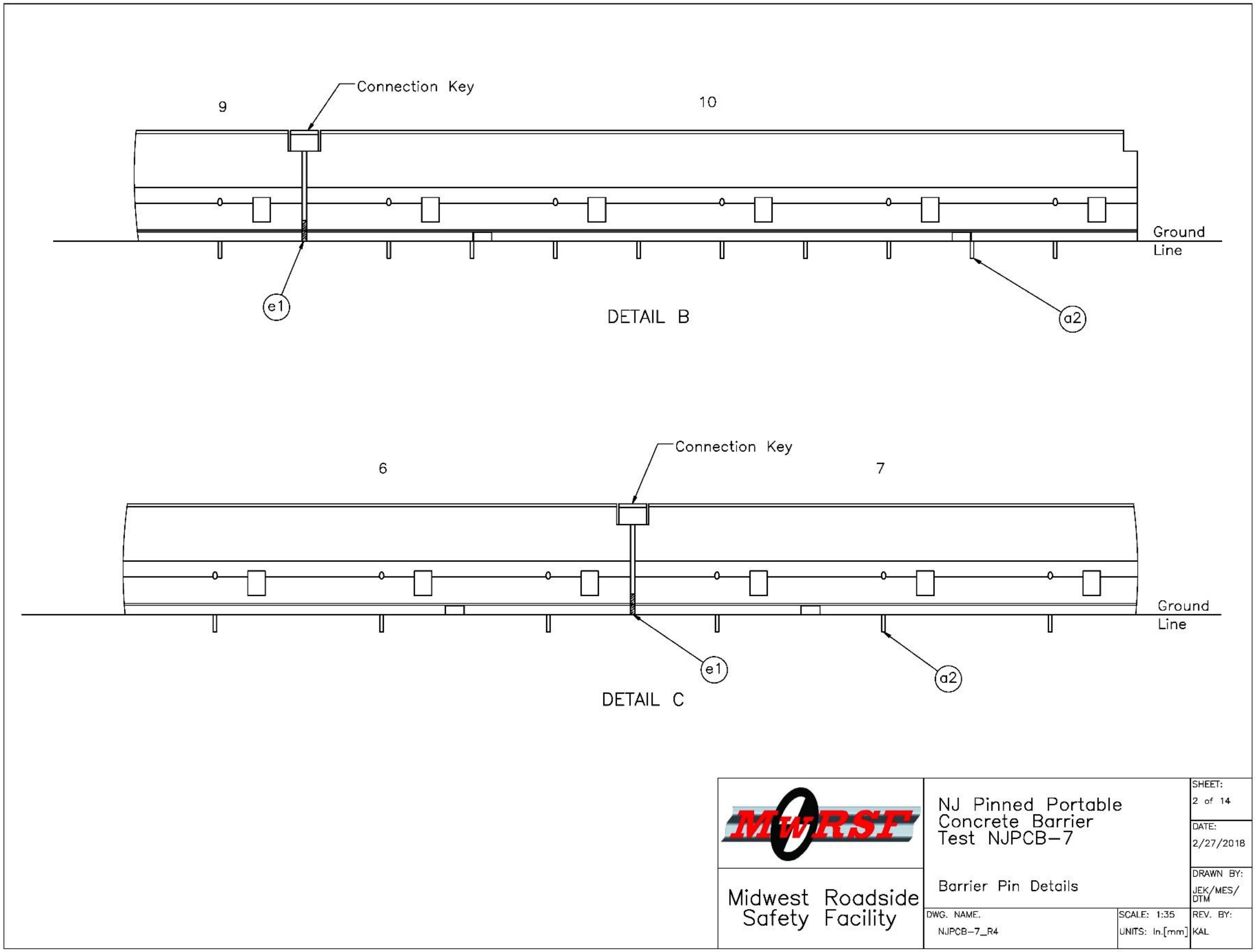


Figure 2. PCB Pin Anchor Details, Test No. NJPCB-7

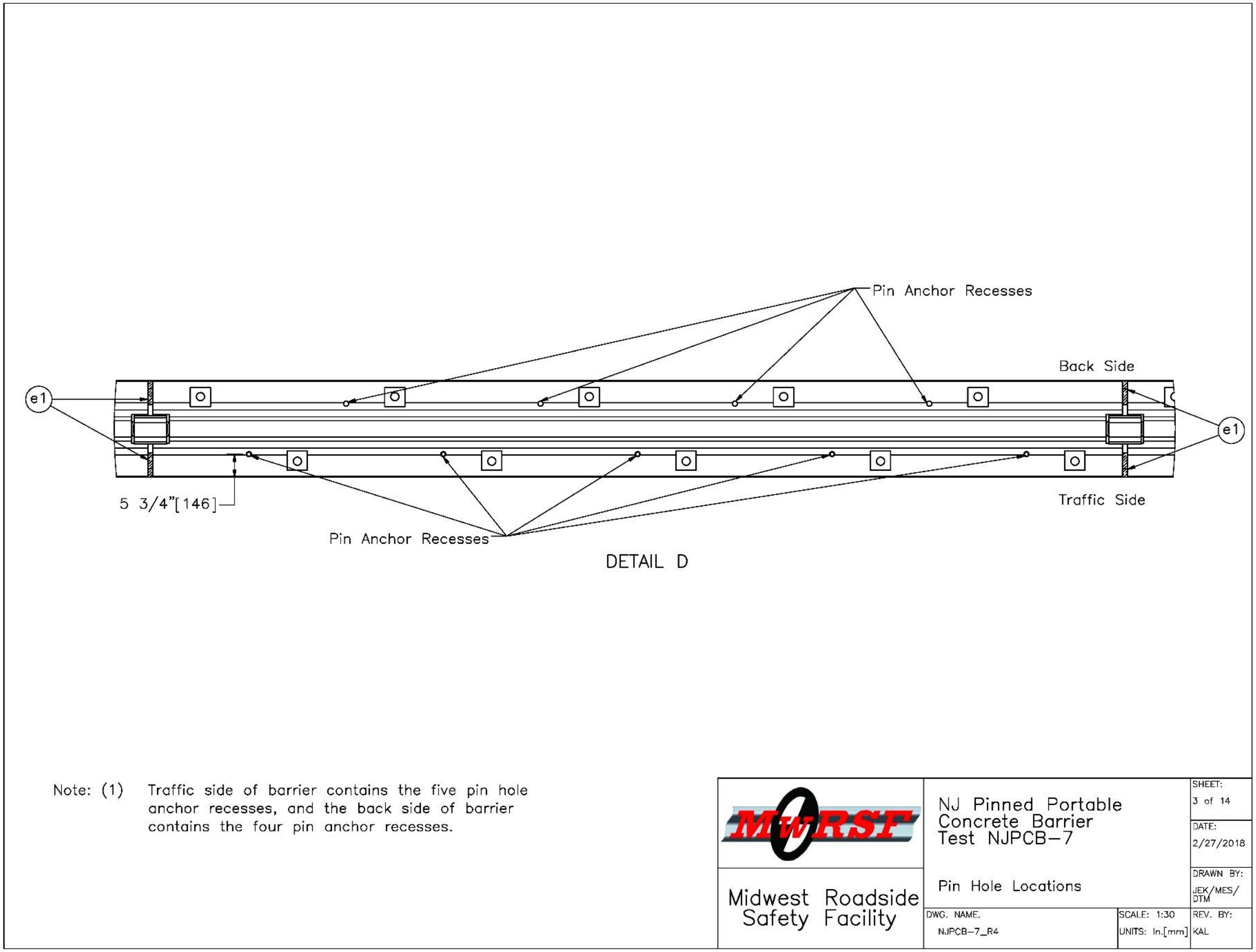


Figure 3. PCB Pin Anchor Locations, Test No. NJPCB-7

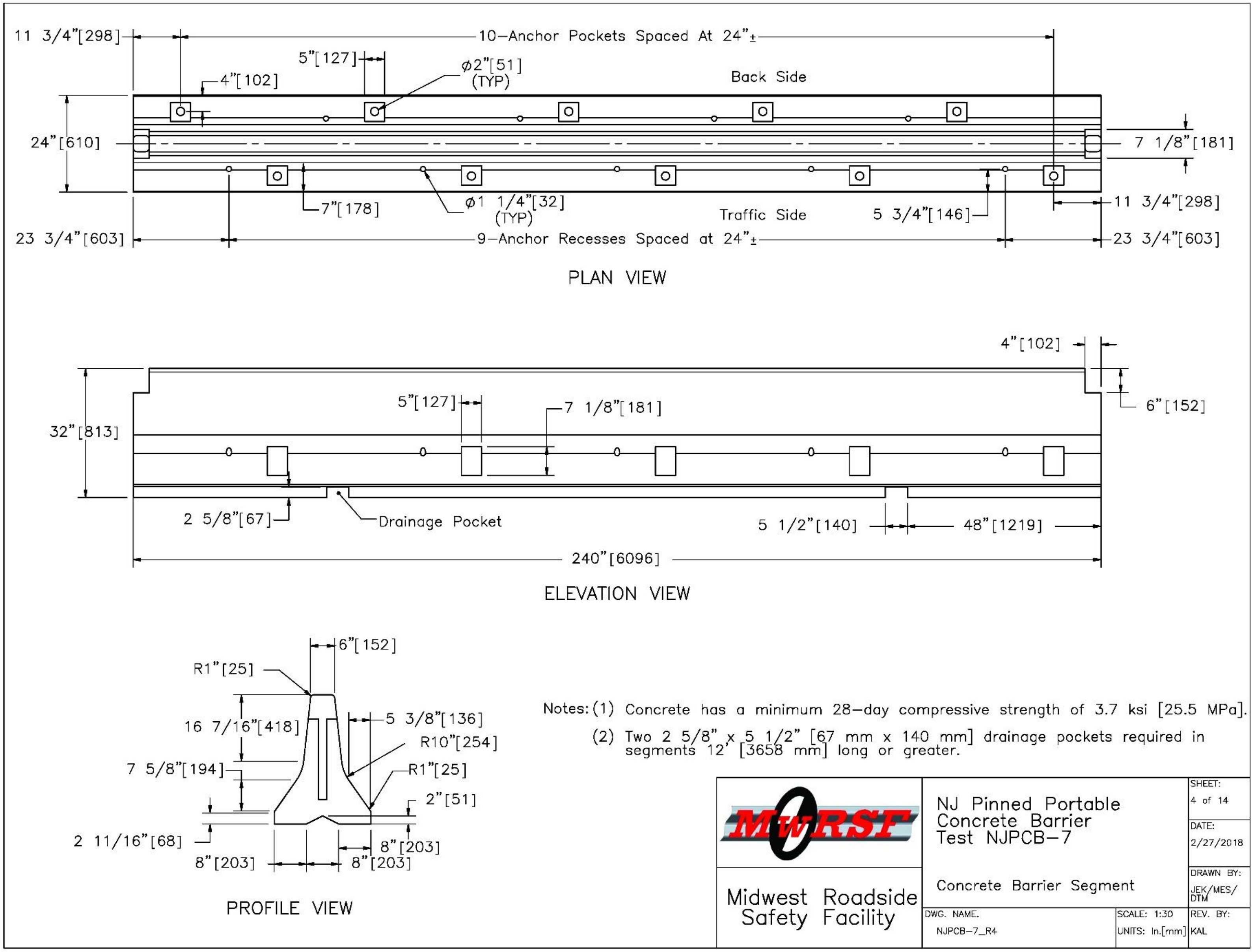


Figure 4. PCB Details, Test No. NJPCB-7

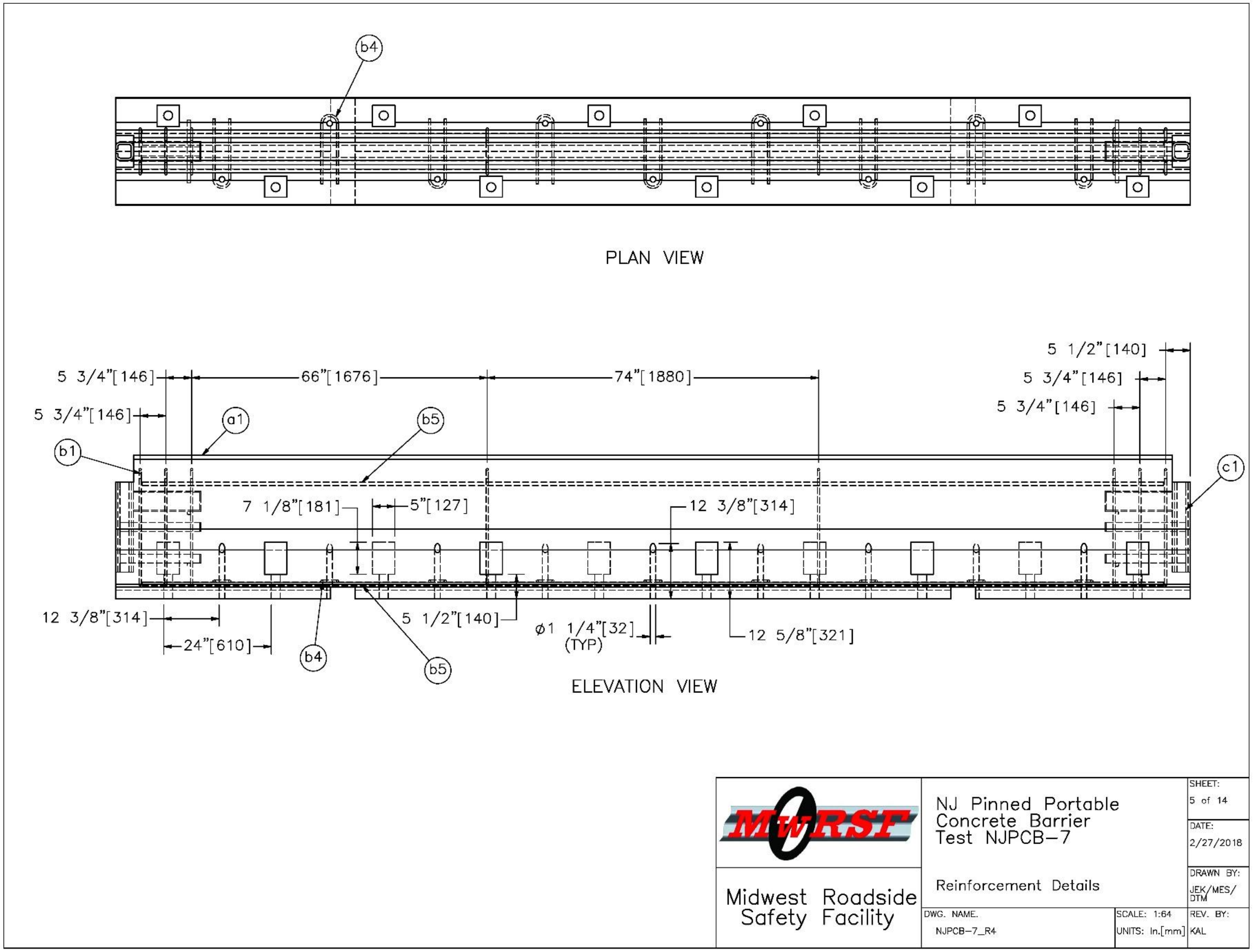


Figure 5. PCB Reinforcement Details, Test No. NJPCB-7

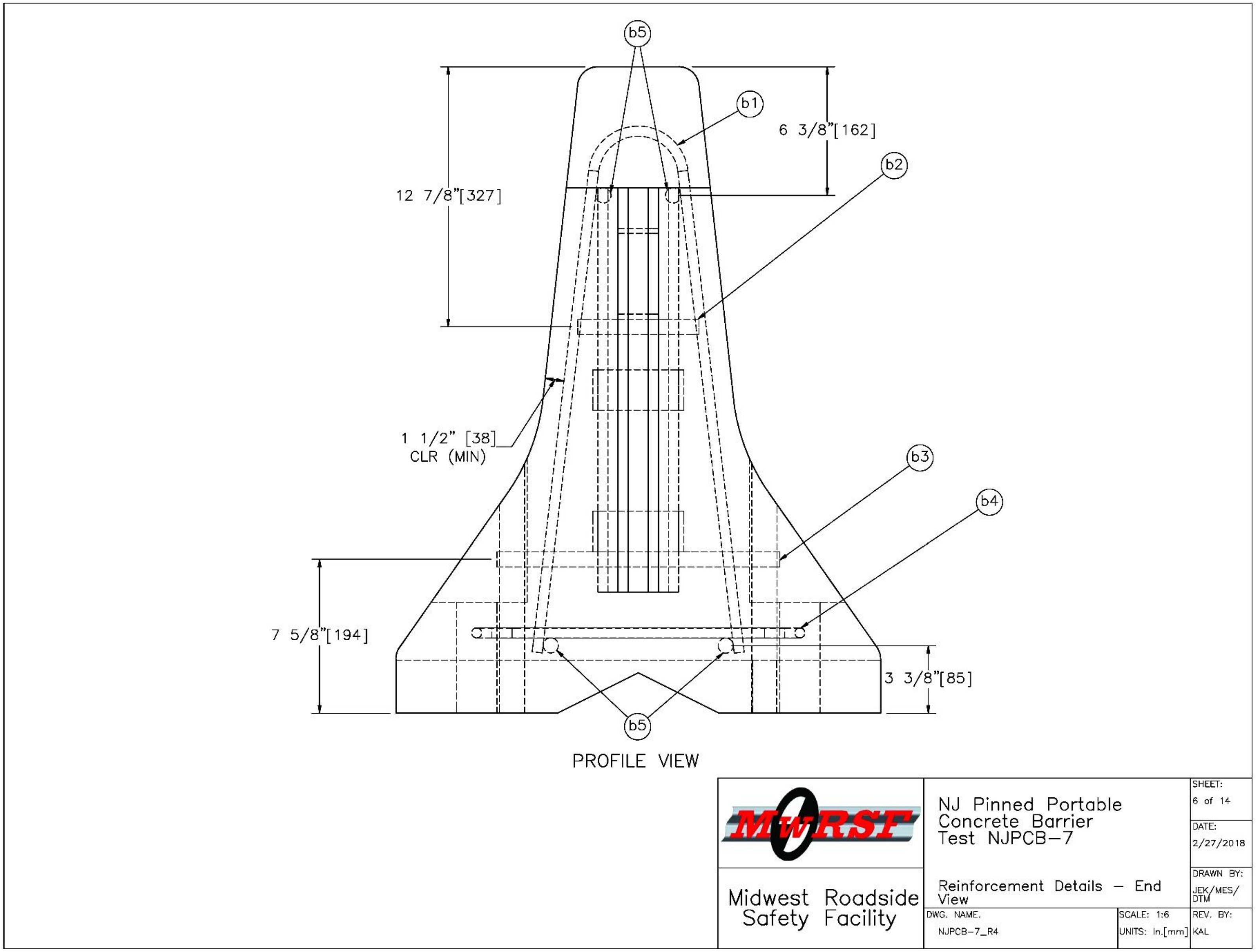


Figure 6. PCB Reinforcement Details – End View, Test No. NJPCB-7

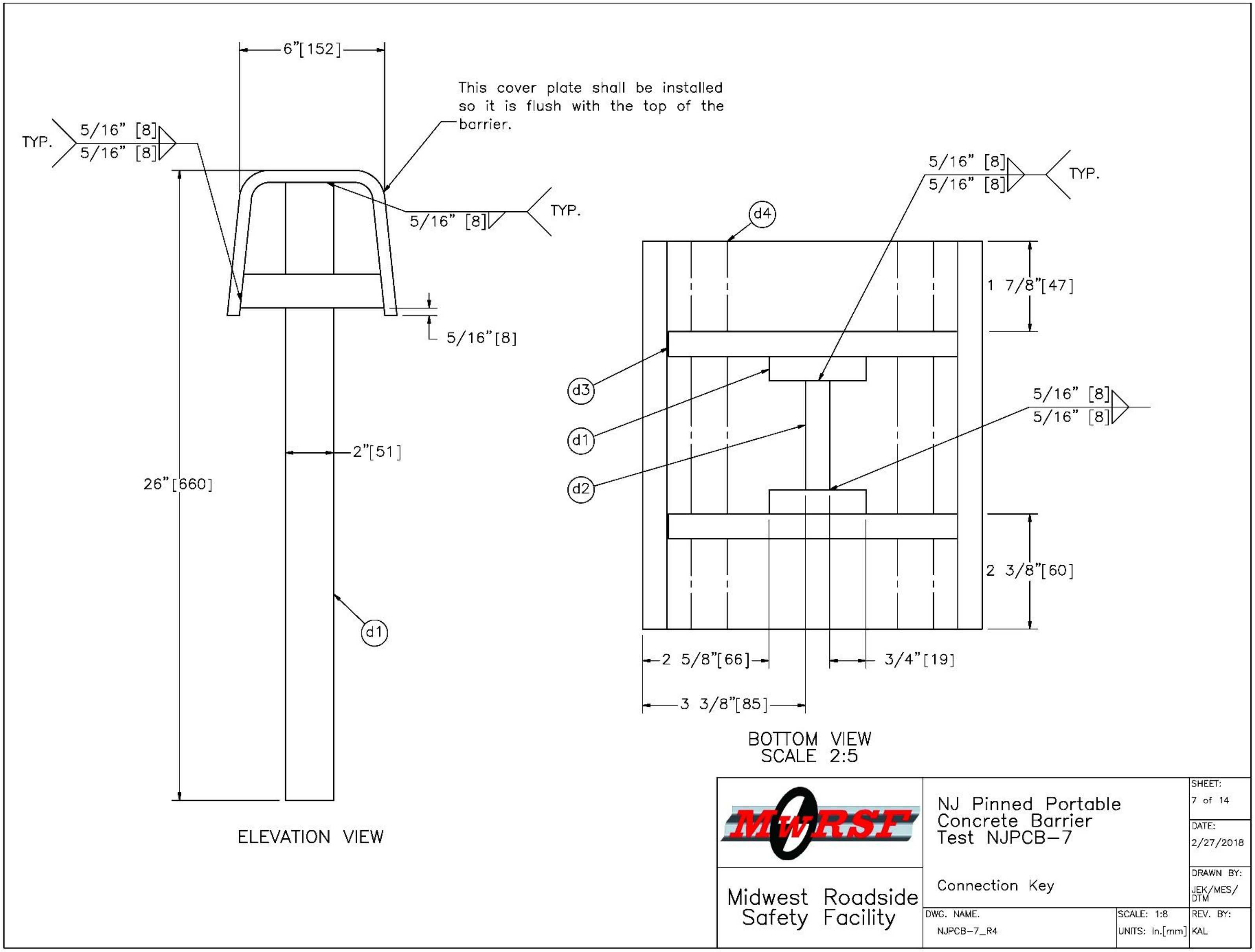


Figure 7. PCB Connection Key Assembly Details, Test No. NJPCB-7

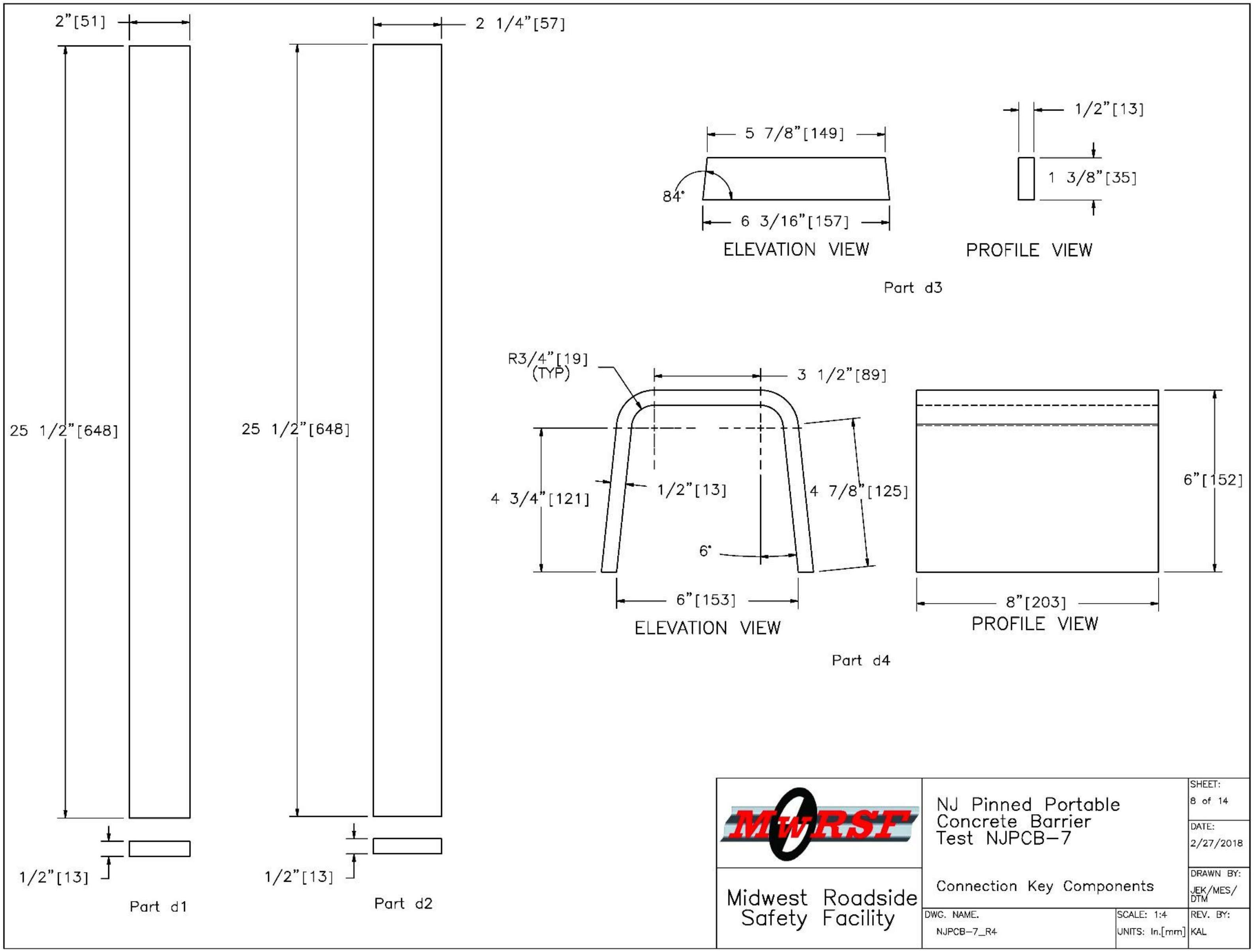


Figure 8. PCB Connection Key Component Details, Test No. NJPCB-7

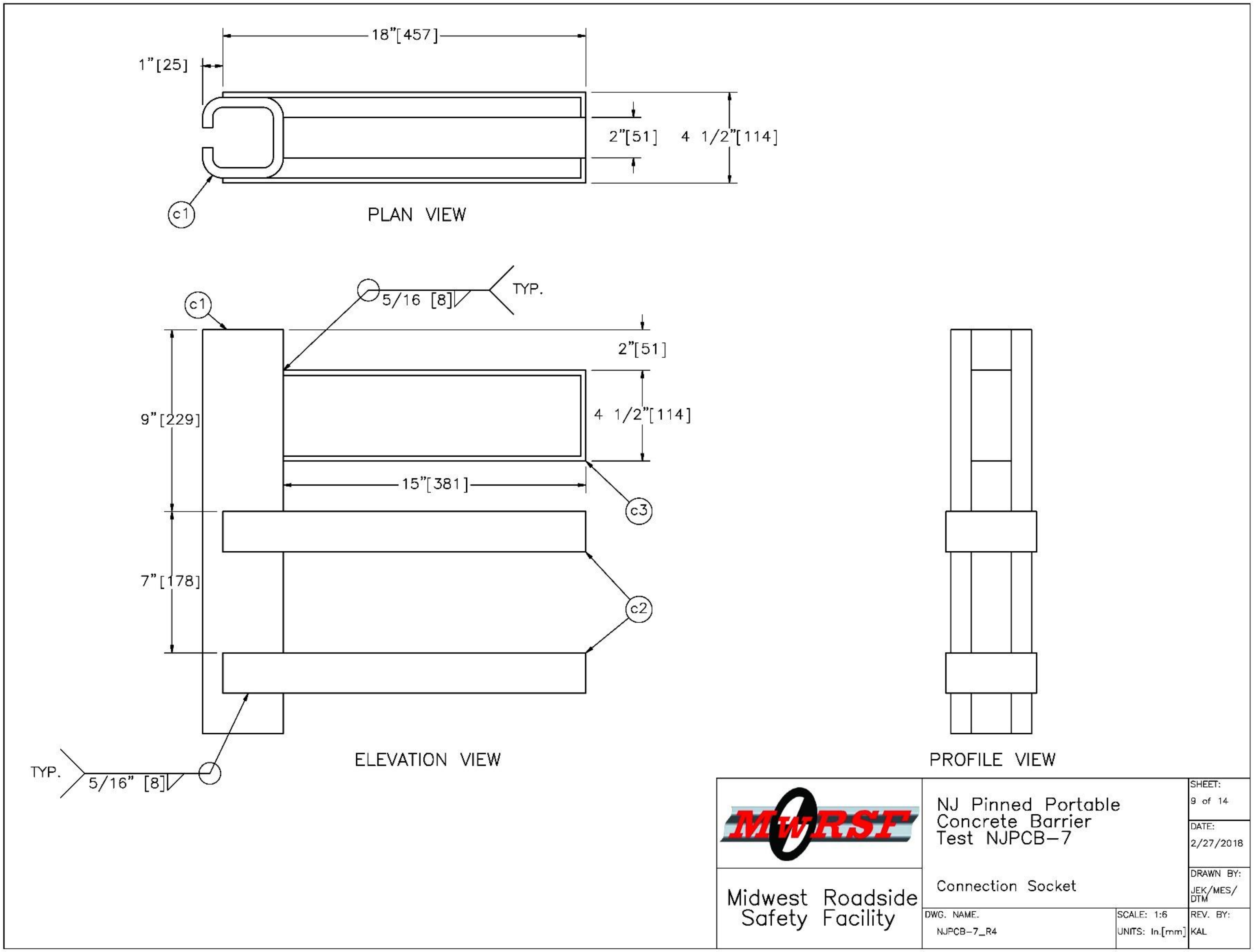


Figure 9. PCB Connection Socket Details, Test No. NJPCB-7

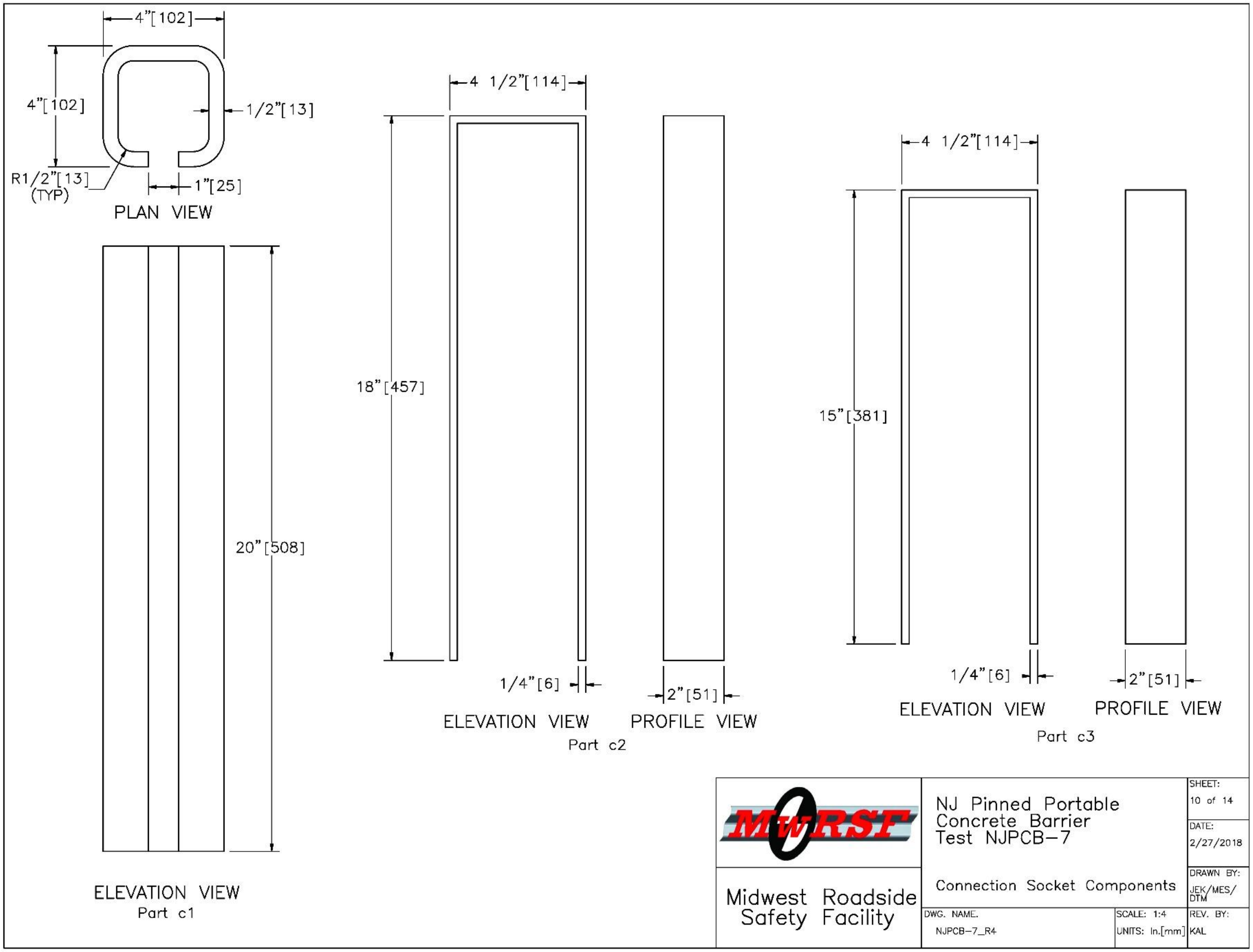


Figure 10. PCB Connection Socket Component Details, Test No. NJPCB-7

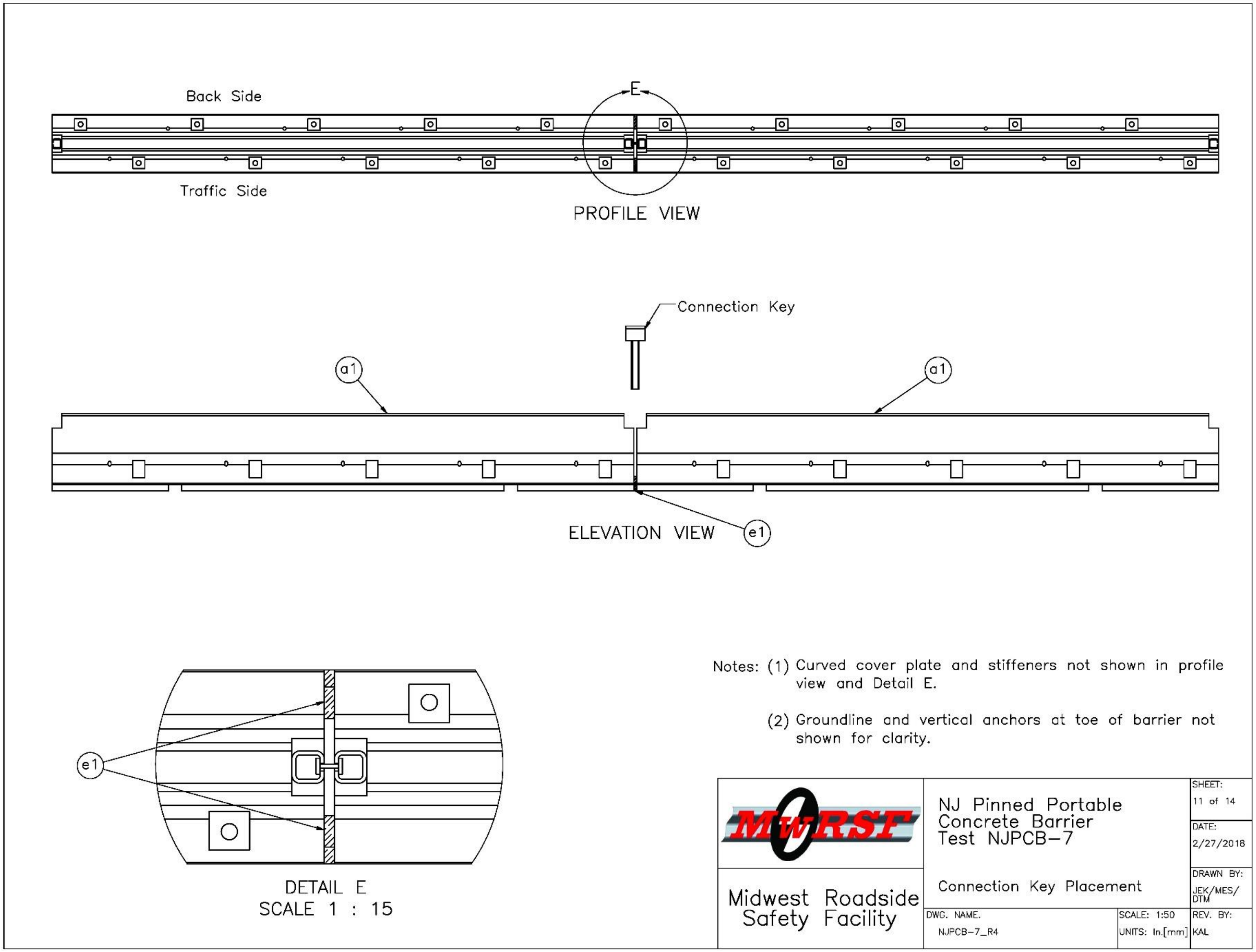


Figure 11. Connection Key Placement Details, Test No. NJPCB-7

BILL OF BARS				
ITEM NO.	QTY.	BAR SIZE	UNBENT LENGTH	MATERIAL SPEC.
a2	58	ø1" [25]	15" [381]	ASTM A36
b1	80	#4 [13]	59" [1499]	ASTM A615 Gr. 60
b2	20	#6 [19]	6" [152]	ASTM A615 Gr. 60
b3	20	#6 [19]	14" [356]	ASTM A615 Gr. 60
b4	90	#4 [13]	37" [940]	ASTM A615 Gr. 60
b5	40	#6 [19]	19'-0" [5791]	ASTM A615 Gr. 60

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

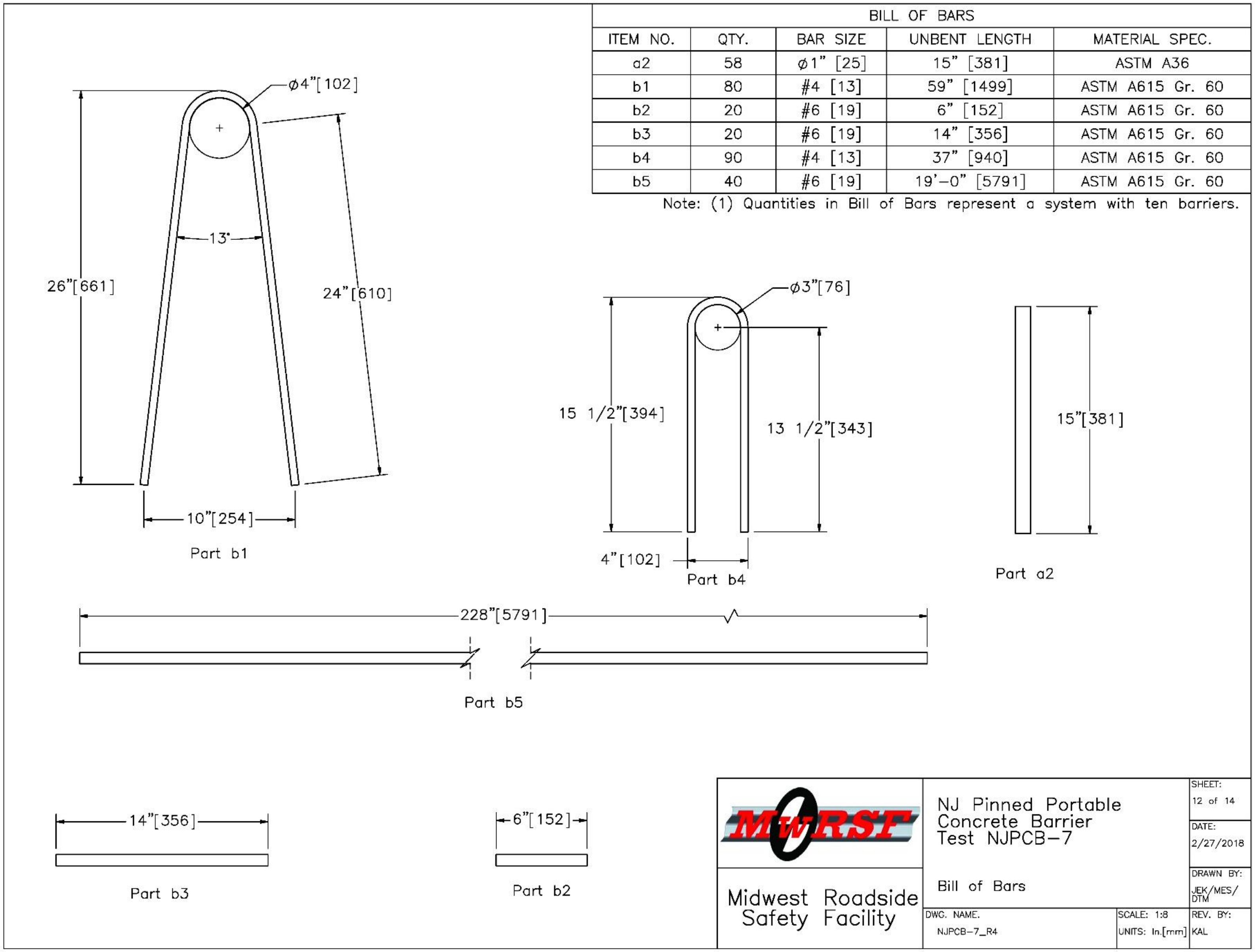


Figure 12. PCB Reinforcement Details, Test No. NJPCB-7

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

(2) All end segments shall be pinned.

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

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

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

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

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

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

(9) Use non-shrink grout of a plastic consistency that is listed on the QPL and conforms to ASTM C 1107 with the following amendments:
1. Ensure that the grout has a working time of at least 30 minutes from the time the water is added.
2. Match the color of the hardened grout, where visible, to the color of the adjacent hardened concrete.
3. Include 1-day strength tests as part of the performance requirements of ASTM C 1107.
4. Ensure that the grout contains no more than 0.05 percent chlorides or 5.0 percent sulfates by weight.
5. Minimum 1-day compressive strength of 1,000 psi [7.0 MPa].

(10) Use connection key in every joint. Grout is placed at the toe of each barrier segment between adjacent barrier segments in every joint. Pin every segment in all traffic side anchor pin recesses, and pin both end segments in every anchor pin recess.

MwRSF Midwest Roadside Safety Facility	NJ Pinned Portable Concrete Barrier Test NJPCB-7 General Notes		SHEET: 13 of 14 DATE: 2/27/2018 DRAWN BY: JEK/MES/DTM
	DWG. NAME. NJPCB-7_R4	SCALE: None UNITS: In.[mm]	REV. BY: KAL

Figure 13. General Notes, Test No. NJPCB-7

Item No.	QTY.	Description	Material Spec	Galvanization Spec
a1	10	Concrete Barrier Segment – NJDOT Type 4 Barrier (Alternate B)	f'c = 3,700 psi [25.5 MPa]	–
a2	58	1" [25] Dia., 15" [381] Long Steel Anchor Pin	ASTM A36	ASTM A123*
b1	80	1/2" [13] Dia., 59" [1499] 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" [5791] Long Rebar	ASTM A615 Gr. 60	–
c1	20	4"x4"x1/2" [102x102x13] x 20" [508] Long Tube	ASTM A500 Gr. B or C	–
c2	40	40 1/2"x2"x1/4" [1,029x51x6] Bent Steel Plate	ASTM A36	–
c3	20	34 1/2"x2"x1/4" [876x51x6] Bent Steel Plate	ASTM A36	–
d1	18	25 1/2"x2"x1/2" [648x51x13] Steel Plate	ASTM A36	–
d2	9	25 1/2"x2 1/4"x1/2" [648x57x13] Steel Plate	ASTM A36	–
d3	18	6 3/16"x1 3/8"x1/2" [157x35x13] Steel Plate – Stiffener	ASTM A36	–
d4	9	17"x8"x1/2" [432x203x13] Bent Steel Plate – Top Plate	ASTM A36	–
e1	1	Non-Shrink Grout	Min. 1-day Compressive Strength 1,000 psi [7.0 MPa]	–

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

MwRSF
Midwest Roadside Safety Facility

NJ Pinned Portable Concrete Barrier Test NJPCB-7

Bill of Materials

SHEET:	14 of 14
DATE:	2/27/2018
DRAWN BY:	JEK/MES/DTM
DWG. NAME.	NJPCB-7_R4
SCALE:	None
UNITS:	in.[mm]
REV. BY:	KAL

Figure 14. Bill of Materials, Test No. NJPCB-7

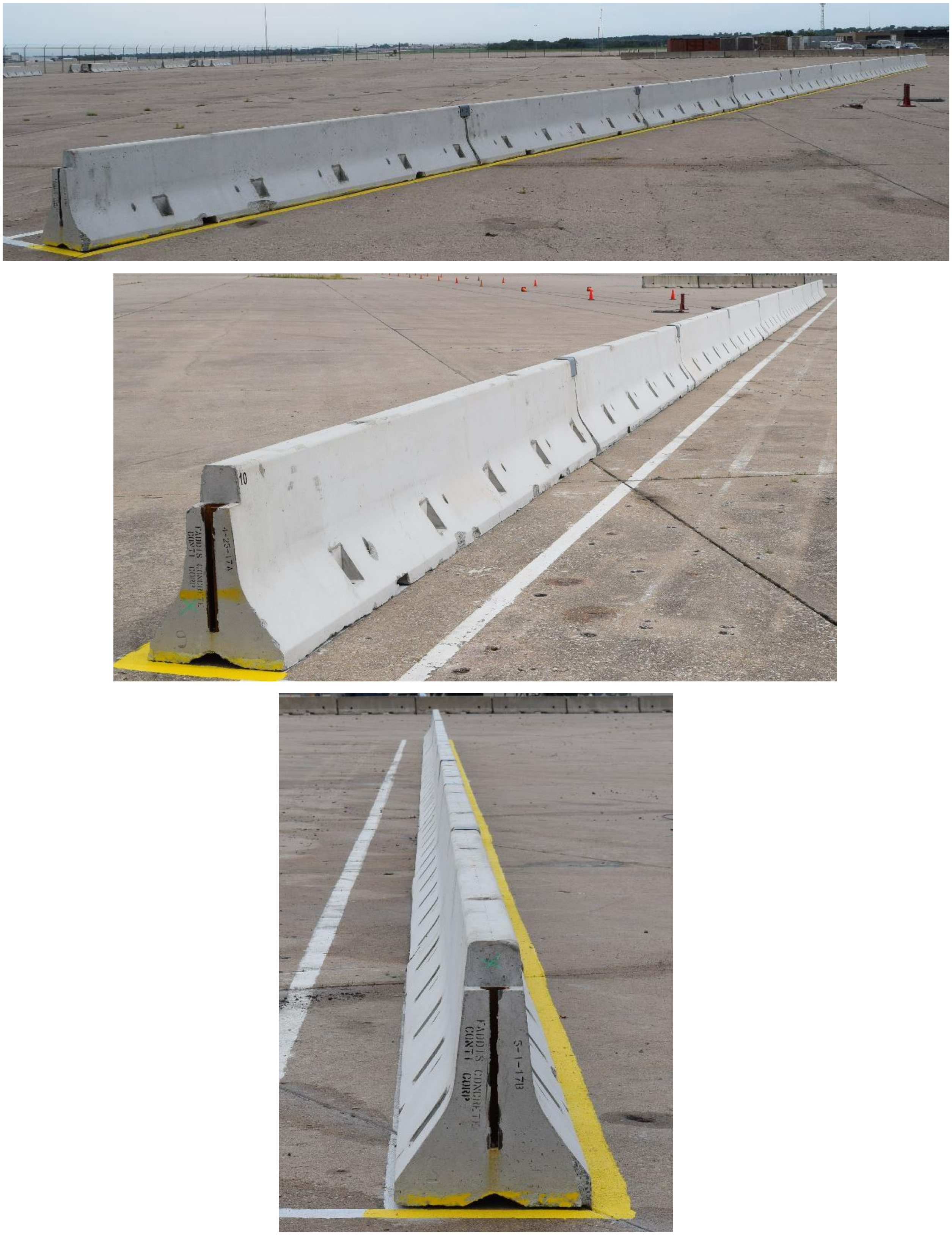


Figure 15. NJDOT PCB with Traffic-Side Pinned Configuration and Grouted Toes Test Installation, Test No. NJPCB-7

Figure 16. PCB Connection Key and Connection Socket, Test No. NJPCB-7

Figure 17. PCB Traffic-Side Pin Anchor Recesses, Test No. NJPCB-7

Figure 18. Grout at Toes between PCBs, Test No. NJPCB-7

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

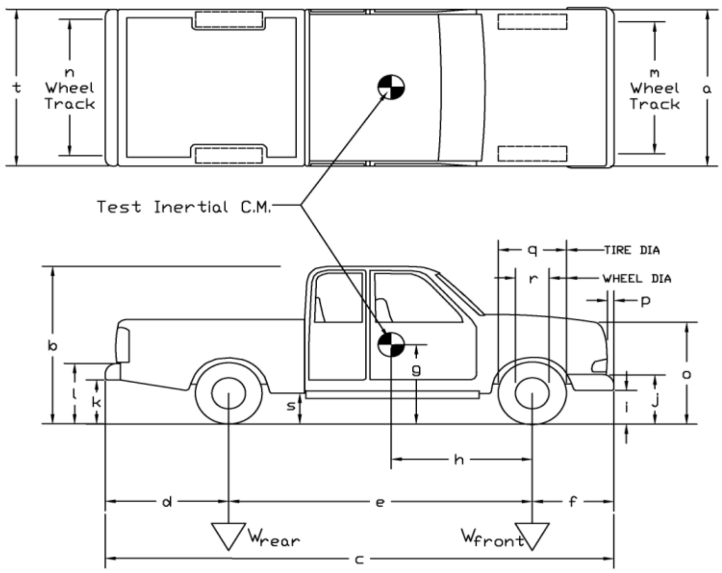
For test no. NJPCB-7, a 2010 Dodge Ram 1500 quad cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,053 lb (2,292 kg), 5,000 lb (2,268 kg), and 5,155 lb (2,338 kg), respectively. The test vehicle is shown in Figure 19, and vehicle dimensions are shown in Figure 20. Note that pre-test photographs of the vehicle's interior floorboards and undercarriage are not available.

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

Square, black- and white-checkered targets were placed on the vehicle for reference to be viewed from the high-speed digital video cameras and aid in the video analysis, as shown in Figure 21. Round, checkered targets were placed on the c.g. on the left-side door, the right-side door, and the roof of the vehicle. The front wheels of the test vehicle were aligned to vehicle standards except the toe-in value was adjusted to zero such that the vehicles would track properly along the guide cable. A 5B flash bulb was mounted under the vehicle's left-side windshield wiper and was fired by a pressure tape switch mounted at the impact corner of the bumper. The flash bulb was fired upon initial impact with the test article to create a visual indicator of the precise time of impact on the high-speed digital videos. A remote-controlled brake system was installed in the test vehicle to bring the vehicle safely to a stop after the test.

Figure 19. Test Vehicle, Test No. NJPCB-7

Date:	6/9/2017	**Test Name:**	NJPCB-7	**VIN No:**	1D7RB1GP7AS162701
Year:	2010	**Make:**	Dodge	**Model:**	Ram 1500
Tire Size:	P265/70R17	**Tire Inflation Pressure:**	40 Psi	**Odometer:**	207988



Vehicle Geometry - in. (mm)
Target Ranges listed below

a:	77 1/2	(1969)	b:	74 3/8	(1889)
	78±2 (1950±50)				
c:	228 3/4	(5810)	d:	47 5/8	(1210)
	237±13 (6020±325)				
e:	140 1/4	(3562)	f:	40 1/4	(1022)
	148±12 (3760±300)			39±3 (1000±75)	
g:	28 1/16	(713)	h:	62 1/8	(1578)
	min: 28 (710)			63±4 (1575±100)	
i:	12 3/8	(314)	j:	24 1/4	(616)
k:	22 5/8	(575)	l:	28 1/2	(724)
m:	68 3/8	(1737)	n:	68 1/4	(1734)
	67±1.5 (1700±38)			67±1.5 (1700±38)	
o:	46 1/8	(1172)	p:	3 5/8	(92)
	43±4 (1100±75)				
q:	32 3/8	(822)	r:	18 5/8	(473)
s:	14 3/8	(365)	t:	79 1/4	(2013)

Wheel Center Height (Front):	15 1/4	(387)
Wheel Center Height (Rear):	15 1/4	(387)
Wheel Well Clearance (Front):	35 1/4	(895)
Wheel Well Clearance (Rear):	37 5/8	(956)
Bottom Frame Height (Front):	18 1/8	(460)
Bottom Frame Height (Rear):	25 3/8	(645)
Engine Type:	Gasoline	
Engine Size:	4.7L V8	
Transmission Type:	Automatic	
Drive Type:	RWD	
Cab Style:	Quad Cab	
Bed Length:	76"	

Mass Distribution lb (kg)

Gross Static	LF	1459 (662)	RF	1412 (640)
	LR	1146 (520)	RR	1138 (516)

Weights lb (kg)	Curb	Test Inertial	Gross Static
W-front	2825 (1281)	2786 (1264)	2871 (1302)
W-rear	2228 (1011)	2214 (1004)	2284 (1036)
W-total	5053 (2292)	5000 (2268)	5155 (2338)
		5000±110 (2270±50)	5165±110 (2343±50)

GVWR Ratings lb

Front	3600
Rear	3900
Total	6800

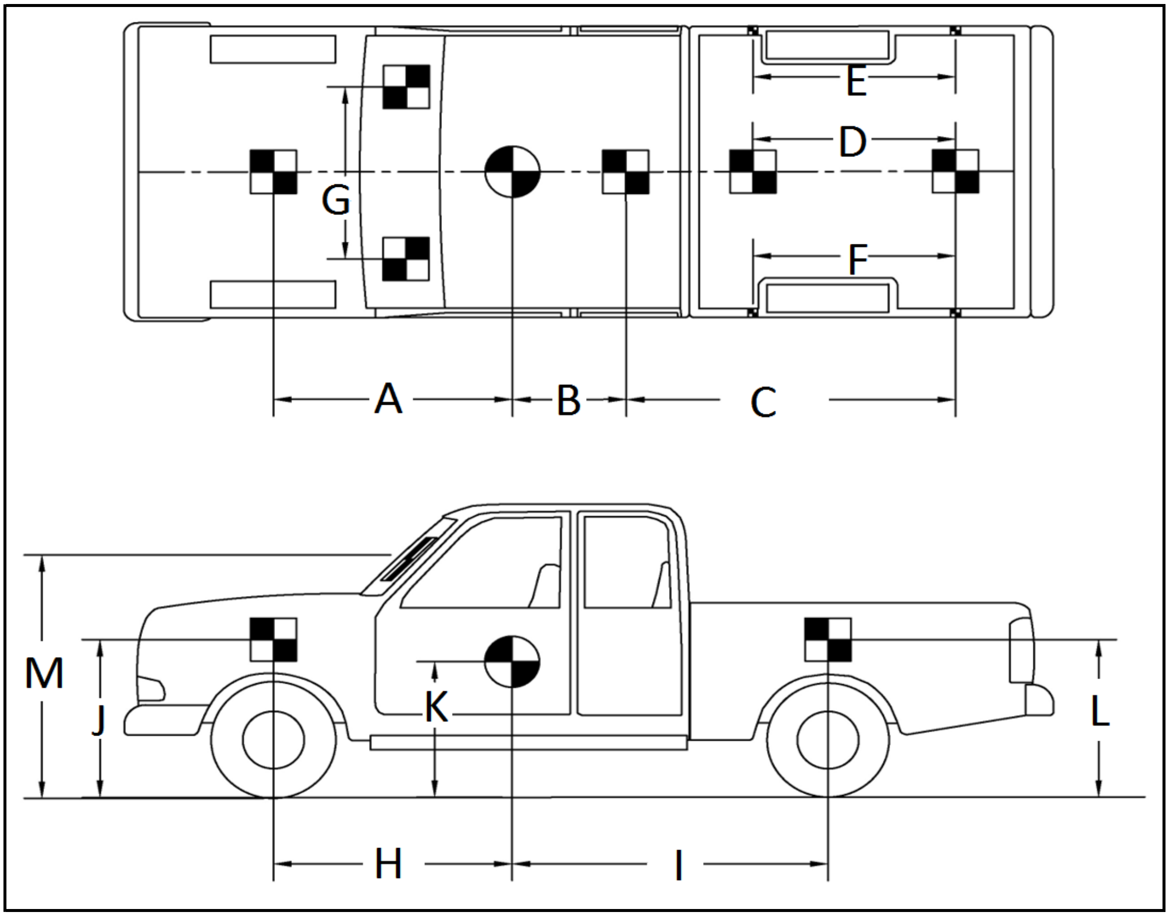
Dummy Data

Type:	Hybrid II
Mass:	155 lb
Seat Position:	Driver

Note any damage prior to test: NONE

Figure 20. Vehicle Dimensions, Test No. NJPCB-7

Date:	6/9/2017	Test Name:	NJPCB-7	VIN:	1D7RB1GP7AS162701
Year:	2010	Make:	Dodge	Model:	Ram 1500



TARGET GEOMETRY-- in. (mm)

A:	76	(1930)	E:	63 3/8	(1610)	J:	39	(991)
B:	24 3/16	(614)	F:	63 1/4	(1607)	K:	28	(711)
C:	75 5/8	(1921)	G:	35 7/8	(911)	L:	41 5/8	(1057)
D:	37 7/8	(962)	H:	62 1/8	(1578)	M:	64 1/2	(1638)
			I:	77 7/8	(1978)			

Figure 21. Target Geometry, Test No. NJPCB-7

4.4 Simulated Occupant

For test no. NJPCB-7, 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 2016, the dummy was not included in calculating the c.g. location.

4.5 Data Acquisition Systems

4.5.1 Accelerometers

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

The 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, based on mounting location. 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.

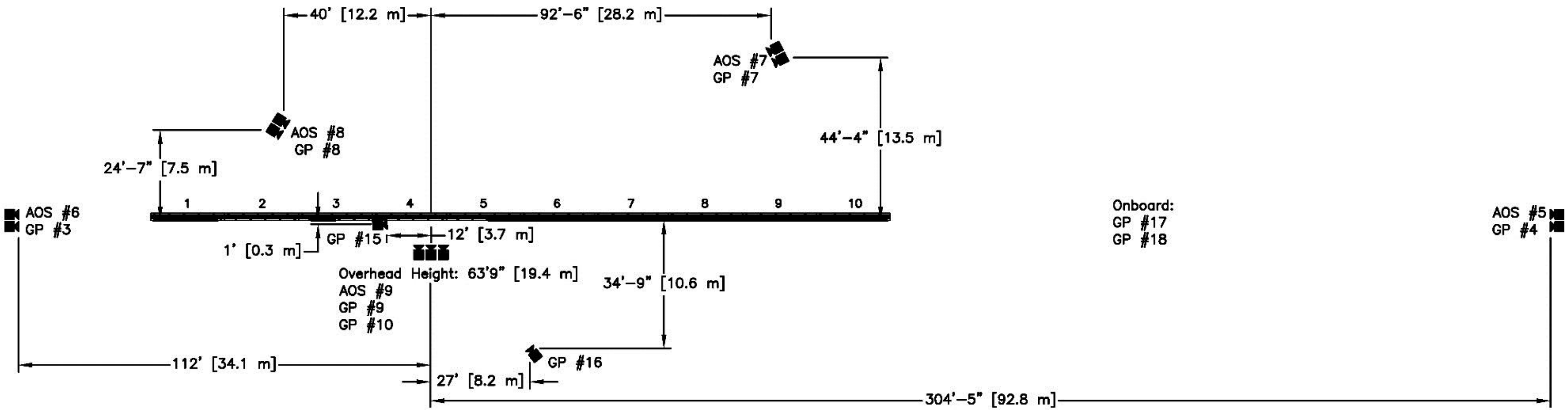
4.5.3 Retroreflective Optic Speed Trap

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 and ten GoPro digital video cameras were utilized to film test no. NJPCB-7. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 22.

The high-speed digital videos were analyzed using TEMA Motion and RedLake MotionScope software programs. Actual camera speed and camera divergence factors were considered in the analysis of the high-speed digital videos. A Nikon digital still camera was also used to document pre- and post-test conditions for the test.



No.	Type	Operating Speed (frames/sec)	Lens	Lens Setting
AOS-5	AOS X-PRI Gigabit	500	VIVITAR 135mm Fixed	-
AOS-6	AOS X-PRI Gigabit	500	Fujinon 50mm Fixed	-
AOS-7	AOS X-PRI Gigabit	500	Fujinon 35mm Fixed	-
AOS-8	AOS S-VIT 1531	500	KOWA 25mm Fixed	-
AOS-9	AOS TRI-VIT 2236	1000	KOWA 12mm Fixed	-
GP-3	GoPro Hero 3+	120		
GP-4	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-15	GoPro Hero 4	240		
GP-16	GoPro Hero 4	240		
GP-17	GoPro Hero 4	120		
GP-18	GoPro Hero 4	120		

Figure 22. Camera Locations, Speeds, and Lens Settings, Test No. NJPCB-7

5 FULL-SCALE CRASH TEST NO. NJPCB-7

5.1 Weather Conditions

Test no. NJPCB-7 was conducted on July 12, 2017 at approximately 11:30 a.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-7

Temperature	83° F
Humidity	71%
Wind Speed	5 mph
Wind Direction	180° from True North
Sky Conditions	Overcast
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.01 in.
Previous 7-Day Precipitation	0.01 in.

5.2 Test Description

The 5,000-lb (2,268-kg) pickup truck impacted the NJDOT PCB, Type 4 (Alternative B) with a traffic-side pinned configuration and grouted toes at a speed of 62.8 mph (101.0 km/h) and at an angle of 25.2 degrees. A summary of the test results and sequential photographs are shown in Figure 24. Additional sequential photographs are shown in Figures 25 and 26. Documentary photographs of the crash test are shown in Figures 27 through 30.

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 31, which was selected using Table 2.7 of MASH 2016. The actual point of impact was 4⅞ in. (124 mm) downstream from the target location. A sequential description of the impact events is contained in Table 6. The vehicle came to rest 229 ft – 11 in. (70.1 m) downstream from the impact point and 34 ft – 3 in. (10.4 m) laterally away from the traffic side of the barrier, after brakes were applied. The vehicle trajectory and final position are shown in Figures 24 and 32.

Table 6. Sequential Description of Impact Events, Test No. NJPCB-7

TIME (sec)	EVENT
0.000	Vehicle’s left-front corner impacted barrier no. 4 at 3 ft – 10$^{5}/_{16}$ in. (1.2 m) upstream from centerline of joint between barrier nos. 4 and 5.
0.003	Left-front corner of bumper deformed inward.
0.010	Vehicle’s left fender contacted barrier no. 4 and deformed. Vehicle’s left headlight contacted top of barrier no. 4.

0.014	Vehicle's left headlight deformed.
0.024	Downstream end of barrier no. 4 rolled backward. Vehicle's grille contacted barrier no. 4.
0.028	Vehicle's grille deformed.
0.034	Vehicle's front bumper contacted barrier no. 5. Upstream end of barrier no. 5 rolled backward.
0.036	Vehicle yawed away from system. Vehicle's grille contacted barrier no. 5. Barrier no. 5 rotated clockwise.
0.042	Vehicle pitched upward.
0.044	Vehicle rolled away from system.
0.046	Vehicle's airbags deployed. Vehicle's left-front door contacted barrier no. 4 and deformed. Vehicle's left fender contacted barrier no. 5.
0.055	Downstream end of barrier no. 5 spalled.
0.068	Midspan of barrier no. 4 fractured.
0.084	Vehicle's left-front door contacted barrier no. 5.
0.100	Barrier nos. 6 and 7 rolled backward.
0.114	Vehicle's right-front tire became airborne.
0.126	Midspan of barrier no. 5 fractured.
0.144	Vehicle's left-rear tire contacted barrier no. 4.
0.197	Vehicle was parallel to system at a speed of 50.5 mph (81.3 km/h).
0.200	Vehicle's left-rear quarter panel contacted barrier no. 4, and left taillight deformed.
0.240	Vehicle pitched downward.
0.244	Vehicle's right-rear tire became airborne.
0.257	Barrier no. 4 rolled forward.
0.268	Vehicle's left-front tire became airborne.
0.290	Vehicle exited system at a speed of 50.3 mph (80.9 km/h) and at an angle of 7.1 degrees.
0.330	Barrier nos. 6 and 7 rolled forward.
0.616	Vehicle's right-front tire regained contact with ground.
0.658	Vehicle's front bumper contacted ground.
0.680	Vehicle rolled toward system.
0.716	Vehicle's left headlight disengaged.
0.740	Vehicle's left-front tire regained contact with ground.
0.794	Vehicle pitched upward.
1.002	Vehicle's left-rear tire regained contact with ground.
1.104	Vehicle rolled away from system.

5.3 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 33 through 37. Barrier damage consisted of contact and gouge marks on the front face of PCB segments, spalling of the concrete, and concrete cracking and fracture. The length of vehicle contact along the barrier was approximately 22 ft – ⅜ in. (6.7 m), which spanned from 5 ft – 8⅞ in. (1.7 m) upstream from the center of the joint between barrier nos. 4 and 5 through 16 ft – 3½ in. (5.0 m) downstream from the center of the joint between barrier nos. 4 and 5.

Tire marks were visible on the front face of barrier nos. 4 and 5. Scrape marks were also found on the front and top faces of barrier nos. 4 and 5. Grout between barrier nos. 3 and 4 and barrier nos. 4 and 5 crumbled. A 31½-in. (800-mm) long vertical crack was found on the front face of barrier no. 4 that started 56⅞ in. (1,445 mm) downstream from the upstream end and 4⅛ in. (105 mm) from the bottom. A 33¾-in. (857-mm) long vertical crack was found on the front face of barrier no. 4 that started 89¾ in. (2,280 mm) downstream from the upstream end. A 45-in. (1,143-mm) long crack was found on the front face of barrier no. 4 located 12⅞ in. (327 mm) downstream from the midspan of the barrier. A 36⅝-in. (930-mm) long crack was found on the front face of barrier no. 4 located 70¼ in. (1,784 mm) upstream from the downstream end of the barrier. A 26½-in. (673-mm) long crack was found on the back face of barrier no. 4 located 21½ in. (546 mm) downstream from the midspan of the barrier. A 38¼-in. (972-mm) long crack was found on the front face of barrier no. 5 located 35¾ in. (908 mm) upstream from the midspan of the barrier. A 38½-in. (978-mm) long crack was found on the front face of barrier no. 5 located 11¼ in. (286 mm) downstream from the midspan of the barrier. A 23½-in. (597-mm) long vertical crack was found on the back face of barrier no. 5 starting 62 in. (1,575 mm) downstream from the upstream end and 2 in. (51 mm) from the bottom. A 46-in. (1,168-mm) long crack was found on the back face of barrier no. 5 located 13⅛ in. (333 mm) upstream from the midspan of the barrier. Minor cracks were found on the traffic side of barrier nos. 3, 6, and 7. A 35½-in. long × ½-in. wide (902-mm × 13-mm) gouge was found 23½ in. (597 mm) upstream from the downstream end on the front face of barrier no. 5.

Concrete spalling occurred on barrier nos. 4 through 6. The front side of barrier no. 4 experienced 57 in. × 11¾ in. × 9 in. (1,448 mm × 298 mm × 229 mm) concrete spalling at the lower downstream corner. A 17¼-in. × 13½-in. × 3½-in. (438-mm × 343-mm × 89-mm) concrete piece disengaged from barrier no. 4 at the lower-upstream corner on the back face. A 29-in. × 5¾-in. × 4-in. (737-mm × 146-mm × 102-mm) concrete piece disengaged from the front face of barrier no. 5, 57½ in. (1,461 mm) downstream from the upstream end of the barrier. A 4¼-in. × 9⅛-in. × 3¼-in. (108-mm × 232-mm × 83-mm) concrete piece disengaged from the back face of barrier no. 5 at the lower-upstream corner. A 22¾-in. × 9½-in. × 3¾-in. (578-mm × 241-mm × 95-mm) concrete piece disengaged from the back face of barrier no. 5 at the lower-downstream corner. A 5⅜-in. × 2-in. × ¼-in. (137-mm × 51-mm × 6-mm) concrete piece disengaged from the front face of barrier no. 6 at the lower-upstream corner. A 7¼-in. × 3¼-in. (184-mm × 83-mm) concrete piece partially disengaged from the back face of barrier no. 6 at 19½ in. (495 mm) upstream from the downstream end.

The maximum permanent set deflection of the barrier system was 6¼ in. (159 mm) at the downstream end of barrier no. 4, as measured in the field. The maximum lateral dynamic barrier deflection, including tipping of the barrier along the top surface, was 11.4 in. (290 mm) at the upstream end of barrier no. 5, as determined from high-speed digital video analysis. The working width of the system was found to be 35.4 in. (899 mm), also determined from high-speed digital video analysis. A schematic of the permanent set deflection, dynamic deflection, and working width is shown in Figure 23. In addition, NJDOT identifies the clear space behind the barrier, which is defined as the maximum deflection of the back of the barrier from its original position. For this test, the clear space behind the barrier was 11.4 in. (290 mm).

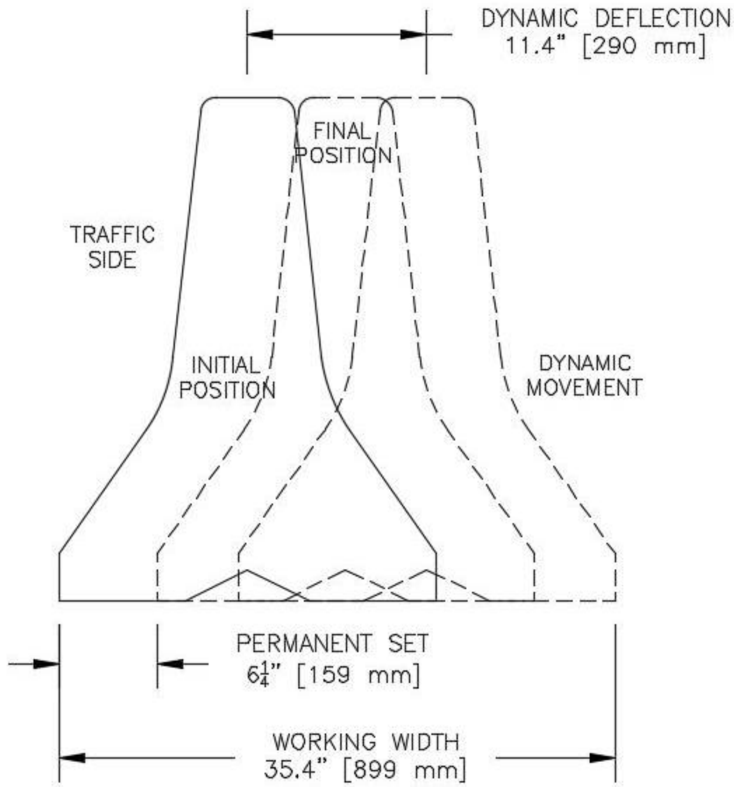


Figure 23. Permanent Set Deflection, Dynamic Deflection, and Working Width, Test No. NJPCB-7

5.4 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 39 through 43. The maximum occupant compartment deformations are listed in Table 7 along with the deformation limits established in MASH 2016 for various areas of the occupant compartment. Note that none of the MASH 2016 established deformation limits were violated. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix E.

The majority of the damage was concentrated on the left-front corner and left side of the vehicle where the impact had occurred. The left side of the bumper crushed inward. The engine hood separated from the left fender. The left-front fender was deformed inward toward the engine compartment. The left corner of the front bumper was bent inward from the left side. The left-front corner of the frame rail buckled inward. A 2-in. (51-mm) gap occurred between the fender and the front bumper. Kinks and scrapes were observed on the entire front bumper. Denting, scraping, and gouging were observed on the entire left side of the cab. Gouging and contact marks were found at the bottom of the left-front door, starting at the front of the door and extending across the entire cab and quarter panel. A 13-in. × 10-in. (330-mm × 254-mm) dent was found on the rear of the left-front door. The left headlight disengaged away from the vehicle.

The lower-left control arm was scraped and bent. The left-front upper control arm was bent 2 in. (51 mm) upward. The left-front wheel and hub partially disengaged. Tears were found in the left-front tire extending from the outer wall through the tread, and the rim buckled. Scrapes were found on the left-rear tire. The right-side engine cross member was bent. The right side of the windshield had 14-in. (356-mm) diameter spider-web cracking from the deployment of the right-side airbag. A crack extended from the spider-web crack to the lower-left corner, and two additional cracks were found in the lower-left corner of the windshield. The roof and the remaining window glass were undamaged.

Table 7. Maximum Occupant Compartment Deformations by Location

LOCATION	MAXIMUM DEFORMATION in. (mm)	MASH 2016 ALLOWABLE DEFORMATION in. (mm)
Wheel Well & Toe Pan	3¼ (83)	≤ 9 (229)
Floor Pan & Transmission Tunnel	⅜ (10)	≤ 12 (305)
A-Pillar	2⅜ (60)	≤ 5 (127)
A-Pillar (Lateral)	1⅝ (41)	≤ 3 (76)
B-Pillar	2⅜ (60)	≤ 5 (127)
B-Pillar (Lateral)	⅜ (10)	≤ 3 (76)
Side Front Panel (in Front of A-Pillar)	2 (51)	≤ 12 (305)
Side Door (Above Seat)	⅞ (22)	≤ 9 (229)
Side Door (Below Seat)	1⅜ (35)	≤ 12 (305)
Roof	⅛ (3)	≤ 4 (102)
Windshield	0 (0)	≤ 3 (76)
Side Window	Intact	No shattering resulting from contact with structural member of test article
Dash	1½ (38)	N/A

N/A – Not applicable

5.5 Occupant Risk

The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 8. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and ASI values are also shown in Table 8. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 24. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix F.

Table 8. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. NJPCB-7

Evaluation Criteria		**Transducer**		**MASH 2016 Limits**
		SLICE-1	**SLICE-2 (Primary)**	
OIV ft/s (m/s)	Longitudinal	-14.34 (-4.37)	-14.09 (-4.30)	± 40 (12.2)
	Lateral	19.23 (5.86)	21.56 (6.57)	± 40 (12.2)
ORA g's	Longitudinal	-3.39	-3.65	± 20.49
	Lateral	9.52	7.98	± 20.49
MAX. ANGULAR DISPL. deg.	Roll	-33.7	-29.2	± 75
	Pitch	-17.0	-18.6	±75
	Yaw	41.2	40.2	not required
THIV ft/s (m/s)		24.31 (7.41)	26.81 (8.17)	not required
PHD g's		9.64	8.08	not required
ASI		1.25	1.41	not required

5.6 Discussion

The analysis of the test results showed that the system adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. Detached elements, fragments, or other debris from the test article did not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or work-zone personnel. Deformations of, or intrusions into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the barrier and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements, as shown in Appendix F, were deemed acceptable because they did not adversely influence occupant risk safety criteria nor cause rollover. After impact, the vehicle exited the barrier at an angle of 7.1 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. NJPCB-7 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-11.

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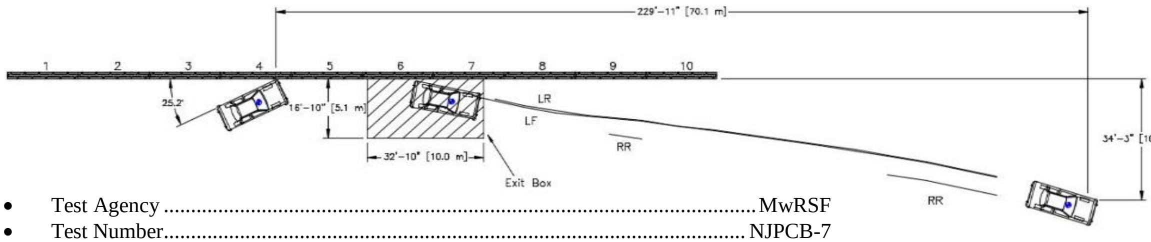

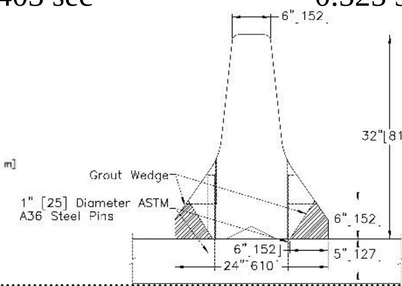

- Test Agency .... MwRSF
- Test Number NJPCB-7
- Date 7/12/2017
- MASH 2016 Test Designation 3-11
- Test Article........NJDOT PCB with Traffic Side Pinned Configuration and Grouted Toes
- Total Length .... 200 ft (61.0 m)
- Key Component – NJDOT PCB
  - Length .... 20 ft (6.1 m)
  - Width........ 24 in. (610 mm)
  - Height........ 32 in. (813 mm)
- Key Component – Anchor Pins
  - Pin Size........ 1-in. (25-mm) diameter unthreaded rod
  - Pin Material .... ASTM A36 steel
  - Pin Length .... 15 in. (381 mm)
  - Embedment Depth .... 5 in. (127 mm)
  - Pinned Barrier Nos. – Traffic Side........ 2-9
  - Pinned Barrier Nos. – Traffic and Back Side. .... 1 and 10
  - Grout Minimum Bond Strength .... 1,000 psi (6.9 MPa)
- Type of Support Surface........ Concrete Tarmac
- Vehicle Make /Model........ 2010 Dodge Ram 1500 quad cab pickup truck
  - Curb........ 5,053 lb (2,292 kg)
  - Test Inertial........ 5,000 lb (2,268 kg)
  - Gross Static........ 5,155 lb (2,338 kg)
- Impact Conditions
  - Speed .... 62.8 mph (101.0 km/h)
  - Angle .... 25.2 deg
  - Impact Location........ $46^5/_{16}$ in. (1.2 m) upstream from joint 4-5
- Impact Severity .... 119.5 kip-ft (162.0 kJ) > 105.6 kip-ft (143.1 kJ) limit in MASH 2016
- Exit Conditions
  - Speed .... 50.3 mph (80.9 km/h)
  - Angle .... 7.1 deg
  - Exit Box Criterion .... Pass
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance........ 229 ft – 11 in. (70.1 m) downstream
  34 ft – 3 in. (10.4 m) laterally in front
- Test Article Damage .... Moderate
- Vehicle Damage........ Moderate
  - VDS [14] 11-LFQ-4
  - CDC [15]........ 11-LYEW-4
  - Maximum Interior Deformation .... 3¼ in. (83 mm)
- Maximum Test Article Deflections
  - Permanent Set .... 6¼ in. (159 mm)
  - Dynamic........ 11.4 in. (290 mm)
  - Working Width........ 35.4 in. (899 mm)
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limit
		SLICE-1	SLICE-2 (Primary)	
OIV ft/s (m/s)	Longitudinal	-14.34 (-4.37)	-14.09 (-4.30)	± 40 (12.2)
	Lateral	19.23 (5.86)	21.56 (6.57)	± 40 (12.2)
ORA g's	Longitudinal	-3.39	-3.65	± 20.49
	Lateral	9.52	7.98	± 20.49
MAX. ANGULAR DISPL. deg.	Roll	-33.7	-29.2	± 75
	Pitch	-17.0	-18.6	± 75
	Yaw	41.2	40.2	not required
THIV ft/s (m/s)		24.31 (7.41)	26.81 (8.17)	not required
PHD g's		9.64	8.08	not required
ASI		1.25	1.41	not required

Figure 24. Summary of Test Results and Sequential Photographs, Test No. NJPCB-7

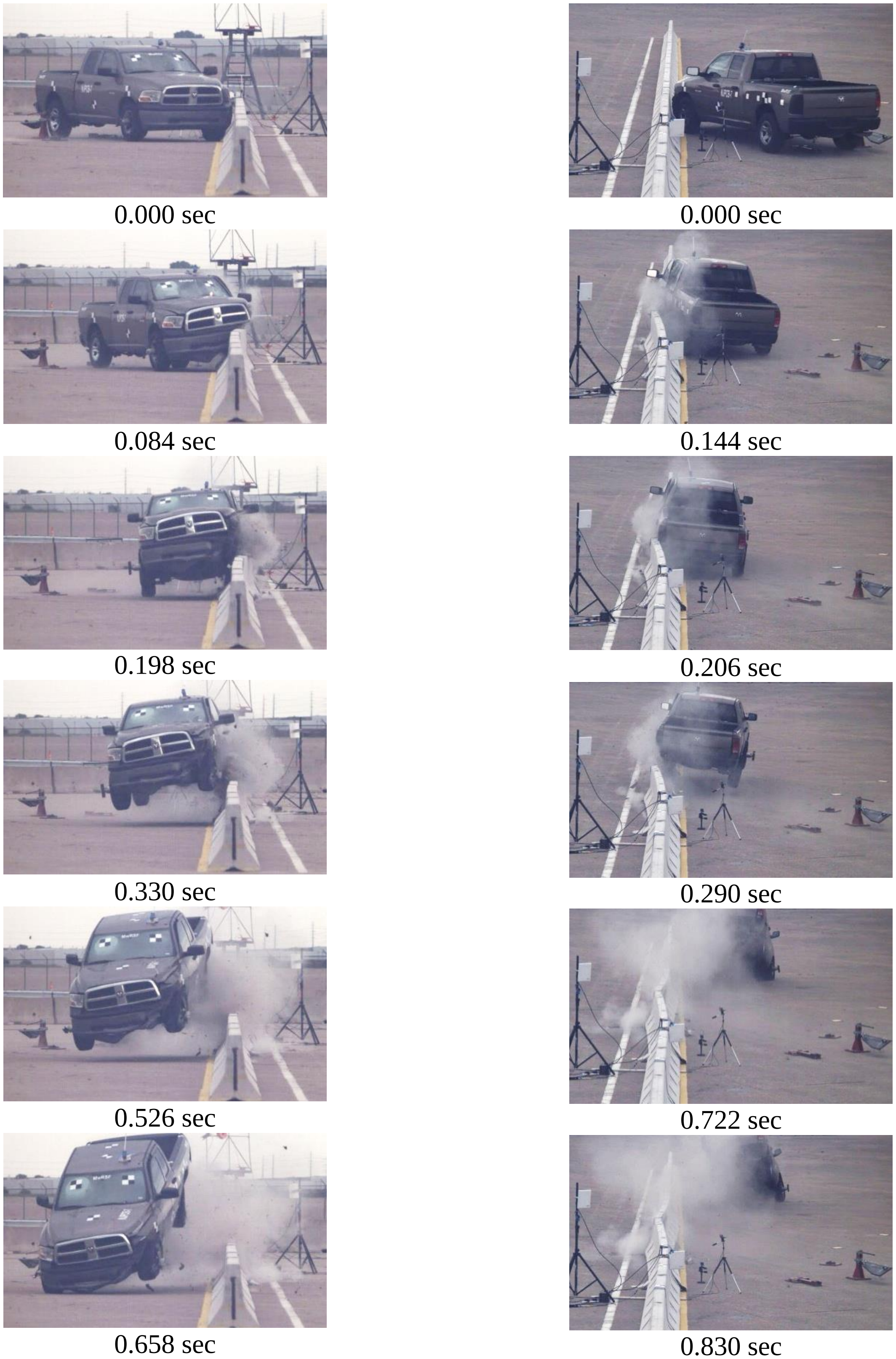

Figure 25. Additional Sequential Photographs, Test No. NJPCB-7


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0.258 sec


0.526 sec


0.000 sec


0.100 sec


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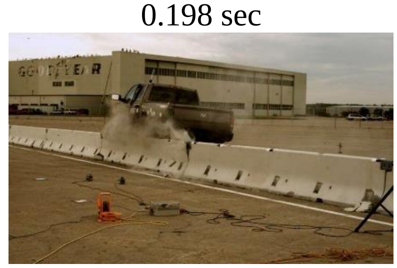
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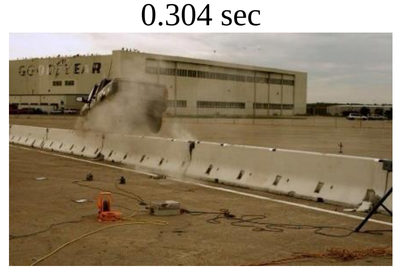
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1.326 sec

Figure 26. Additional Sequential Photographs, Test No. NJPCB-7

Figure 27. Documentary Photographs, Test No. NJPCB-7

Figure 28. Documentary Photographs, Test No. NJPCB-7

Figure 29. Documentary Photographs, Test No. NJPCB-7

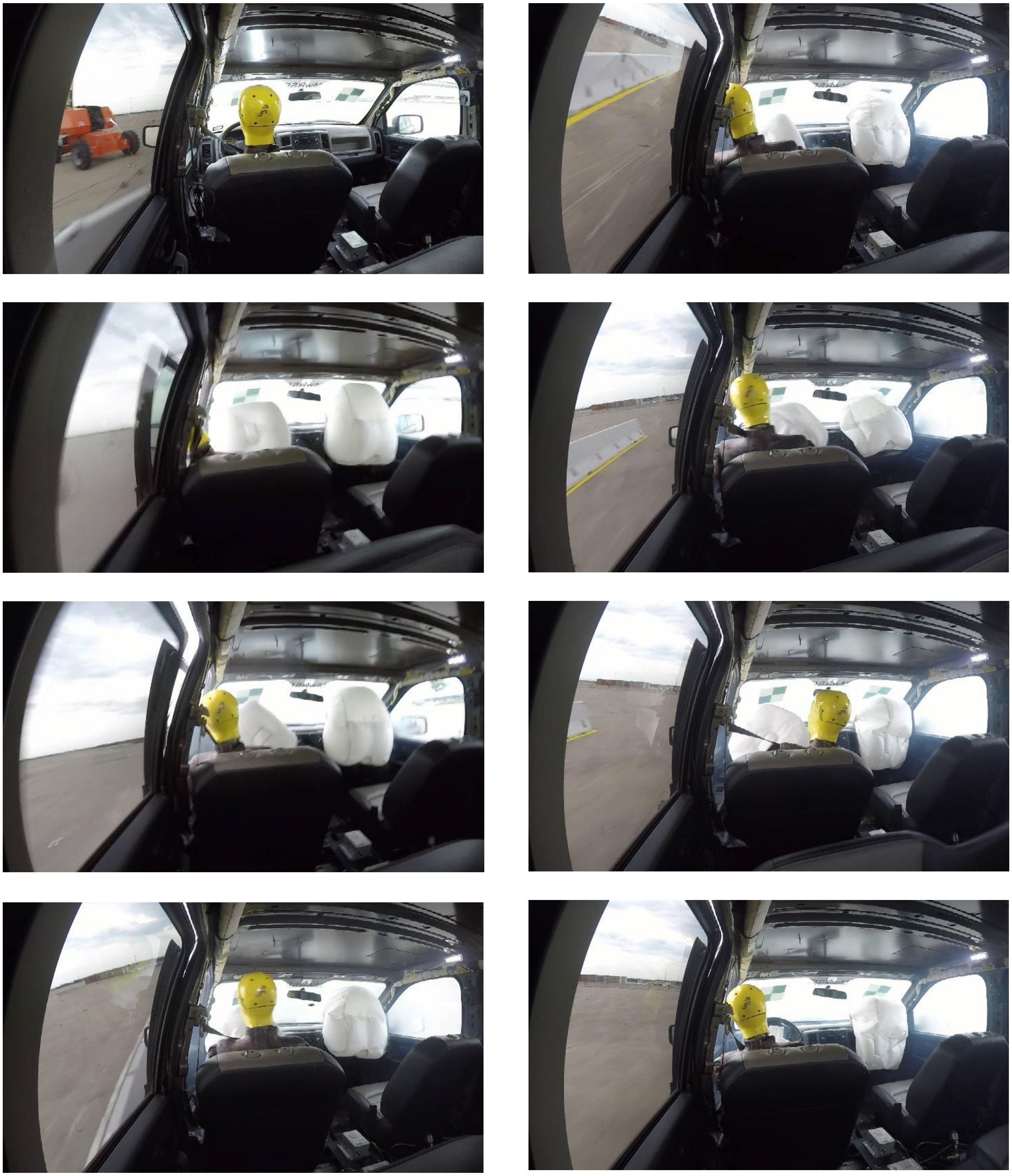


Figure 30. Documentary Photographs, Test No. NJPCB-7

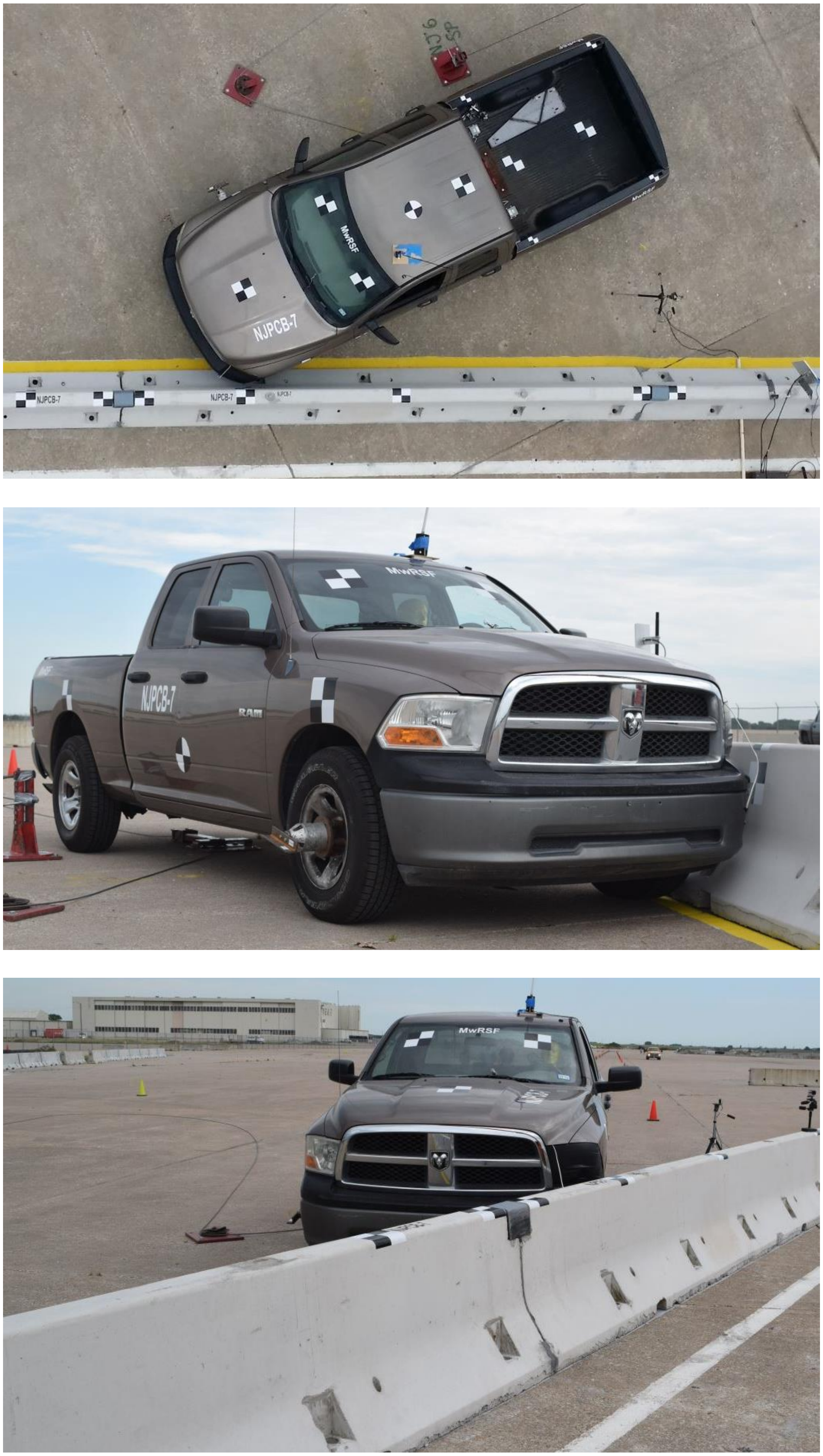
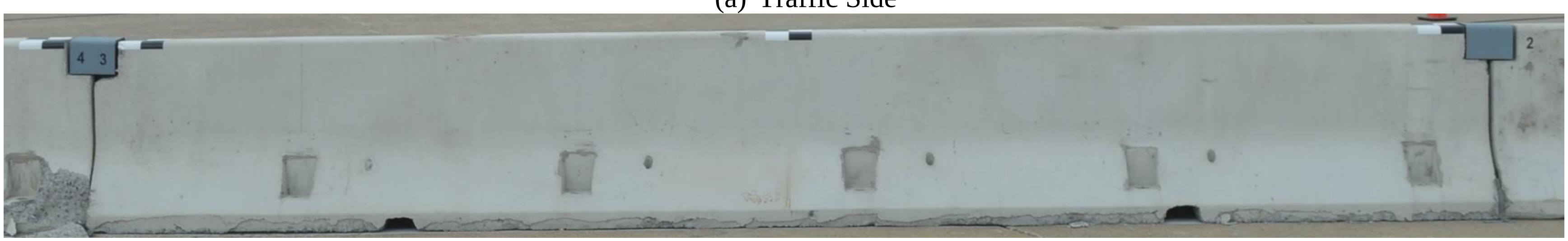


Figure 31. Impact Location, Test No. NJPCB-7

Figure 32. Vehicle Final Position and Trajectory Marks, Test No. NJPCB-7

Figure 33. System Damage – Front, Back, Upstream and Downstream Views, Test No. NJPCB-7

(a) Traffic Side



(b) Back Side

Figure 34. Barrier No. 3 – Traffic and Back Side Damage, Test No. NJPCB-7

Figure 35. Barrier Nos. 4 and 5 Damage, Test No. NJPCB-7

(a) Traffic Side

(b) Back Side

Figure 36. Barrier No. 4 – Traffic and Back Side Damage, Test No. NJPCB-7

(a) Traffic Side

(b) Back Side

Figure 37. Barrier No. 5 - Traffic and Back Side Damage, Test No. NJPCB-7

(a) Traffic Side

(b) Back Side

Figure 38. Barrier No. 6 – Traffic and Back Side Damage, Test No. NJPCB-7

Figure 39. Vehicle Damage, Test No. NJPCB-7

Figure 40. Vehicle Damage on Impact Side, Test No. NJPCB-7

Figure 41. Vehicle Windshield Damage, Test No. NJPCB-7

Figure 42. Occupant Compartment Deformation, Test No. NJPCB-7

Figure 43. Undercarriage Damage, Test No. NJPCB-7

6 SUMMARY AND CONCLUSIONS

Test no. NJPCB-7 was conducted on the NJDOT PCB system with a traffic-side pinned configuration and grouted toes according to MASH 2016 test designation no. 3-11. This system uses NJDOT barriers, Type 4 (Alternative B). Barrier nos. 1 and 10 were anchored on both sides, and barrier nos. 2 through 9 were anchored to the concrete tarmac on the traffic side through pin anchor recesses with 1-in. (25-mm) diameter by 15-in. (381-mm) long, ASTM A36 steel pins. Non-shrink grout wedges were placed at the toe of each barrier segment in every joint between adjacent barrier segments on the traffic and back sides.

During test no. NJPCB-7, the 5,000-lb (2,268 kg) pickup truck impacted the NJDOT PCB system at a speed of 62.8 mph (101.0 km/h) and at an angle of 25.2 degrees, resulting in an impact severity of 119.5 kip-ft (162.0 kJ). After impacting the barrier system, the vehicle exited the system at a speed of 50.3 mph (80.9 km/h) and at an angle of 7.1 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 spalling and cracking. A dynamic deflection of 11.4 in. (290 mm) and working width of 35.4 in. (899 mm) were observed during the test, as shown in Figure 23. All occupant risk values were found to be within limits, and the occupant compartment deformations were also deemed acceptable. Subsequently, test no. NJPCB-7 was determined to satisfy the safety performance criteria for MASH 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-7</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 A5.2.2 of MASH 2016 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 A5.2.2 of MASH 2016 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 2016 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-5

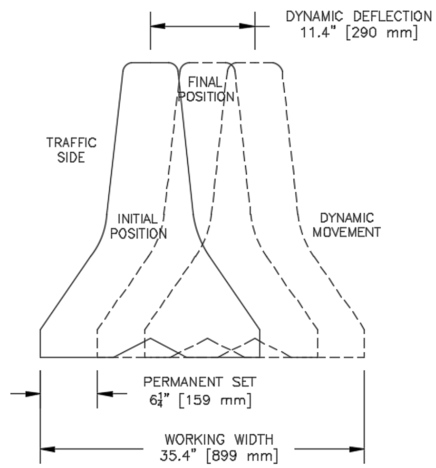
A summary of full-scale crash testing on the two pinned configurations with only one side of the NJ PCB system pinned, joint slack removed, and grouted toes is shown in Table 10. Test no. NJPCB-7 evaluated the use of steel pins placed through the front side of every barrier segment in order to anchor the PCBs and reduce barrier deflections. This test was compared to the NJ PCB system with only the back side pinned, joint slack removed, and grouted toes, corresponding to connection type C in the 2015 NJDOT *Roadway Design Manual* (test no. NJPCB-6) [16] and a similar New York PCB system also with only the back side pinned and without removal of joint slack or grouted toes (test no. NYTCB-5) [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 44 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-6, NJPCB-7, and NYTCB-5 would suggest that pinning the barriers on the front of the PCB segments provides two benefits as compared to pinning on only the back side. First, pinning the front of the PCBs produced lower deflections for test no. NJPCB-7 as compared to test no. NJPCB-6. Second, in both tests of the back-side pinned barriers, the impacting vehicle climbed the barrier face significantly and rolled away from the barrier face as it was redirected. This finding was due to the back-side pins providing increased constraint to the back of the PCB segments, thus causing increased barrier rotation, which promotes vehicle climb and instability. Test no. NJPCB-7 with the barrier pinned on the front face of the barrier showed improved vehicle stability with less roll and vehicle climb, while the vehicle was in contact with the barrier. Previous research by CALTRANS and MwRSF has noted that anchoring of PCB segments on the front side of the barrier improved stability as well. Thus, pinning the front side versus the back side of NJ PCB segments seems to be slightly more effective in reducing barrier deflections while providing improved vehicle stability.

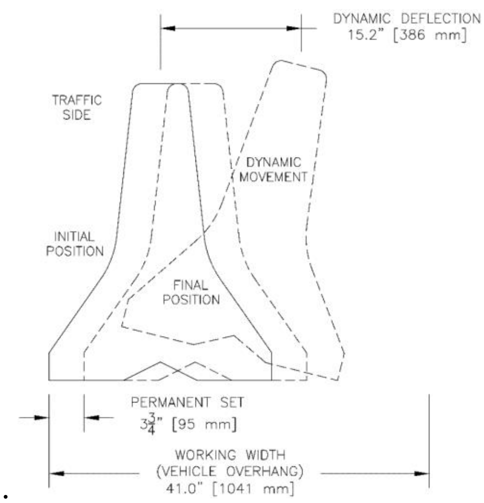
Table 10. Comparison of Pinned Systems on One Side Only

Test No.	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-6 [16]	C	Barriers 1 and 10 pinned, Barriers 2-9 pinned back side only, remove slack, grouted toes	3¾ in. (95 mm)	15.2 in. (386 mm)	41.0 in. (1,041 mm) Vehicle	15.2 in. (386 mm)	28.9	-12.2	5,000 (2,268)	62.9 (101.3)	25.1	119.0 (161.3)
NYTCB-5 [17]	N/A	Barriers 1-10 pinned back side only, slack not removed, no grouted toes	9 in. (229 mm)	20.5 in. (521 mm)	35.0 in. (889 mm)	11 in. (279 mm)	41.8	-21.2	4,953 (2247)	64.3 (103.5)	26.2	133.4 (180.9)
NJPCB-7	N/A	Barriers 1 and 10 pinned, Barriers 2-9 pinned front side only, remove slack, grouted toes	6¼ in. (159 mm)	11.4 in. (290 mm)	35.4 in. (899 mm)	11.4 in. (290 mm)	-29.2	-18.6	5,000 (2,268)	62.8 (101.0)	25.2	119.5 (162.0)

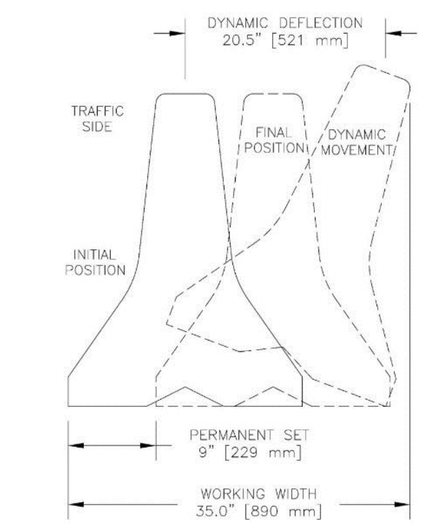
N/A = Not Applicable



NJPCB-7 – Only Front Side Pinned, Joint Slack Removed, Grouted Toes



NJPCB-6 – Only Back Side Pinned, Joint Slack Removed, Grouted Toes



NYTCB-5 – Only Back Side Pinned, Joint Slack Not Removed, No Grouted Toes

Figure 44. Deflection Comparisons – Test Nos. NJPCB-7, NJPCB-6 and NYTCB-5

8 MASH IMPLEMENTATION

The objective of this research was to evaluate the safety performance of NJDOT's PCB system with a traffic-side pinned configuration and grouted toes. The NJDOT barriers, Type 4 (Alternative B), 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. Barrier nos. 2 through 9 were anchored to the concrete surface through only the five traffic-side pin anchor recesses. The barrier segments were pulled in a direction parallel to their longitudinal axes, and slack was removed from all joints prior to installation of the steel anchor pins. A wedge of grout was placed at the toe of each joint on both the traffic side and back side of the system.

According to TL-3 evaluation criteria in MASH 2016, 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-7, a 5,000-lb (2,268 kg) pickup truck with a simulated occupant seated in the left-front seat impacted the NJDOT PCB system at a speed of 62.8 mph (101.0 km/h) and at an angle of 25.2 degrees, resulting in an impact severity of 119.5 kip-ft (162.0 kJ). At 0.197 sec after impact, the vehicle became parallel to the system with a speed of 50.5 mph (81.3 km/h). At 0.290 sec, the vehicle exited the system at a speed of 50.3 mph (80.9 km/h) and at an angle of 7.1 degrees. The vehicle was successfully contained and smoothly redirected.

Exterior vehicle damage was moderate. Interior occupant compartment deformations were moderate with a maximum of 3¼ in. (83 mm), which did not violate the limits established in MASH 2016. Damage to the barrier was also moderate, consisting of contact and gouge marks on the front face of the PCB segments as well as concrete spalling, cracking, and fracture on barrier nos. 4 and 5. The maximum dynamic barrier deflection was 11.4 in. (290 mm), which included minor tipping of the barrier at the top surface. The working width of the PCB system was 35.4 in. (899 mm). All occupant risk measures were within the recommended limits, and the occupant compartment deformations were also deemed acceptable. Therefore, the NJDOT barriers, Type 4

(Alternative B) pinned only on the traffic side, successfully met all the safety performance criteria of MASH 2016 test designation no. 3-11.

The NJDOT barriers, Type 4 (Alternative B), consisting of NJDOT PCB barriers joined with a connection key, joint slack removed, grouted toes, barrier nos. 1 and 10 pinned on both the traffic side and back side, and barrier nos. 2 through 9 pinned only on the traffic side, were successfully crash tested and evaluated according to the AASHTO MASH 2016 TL-3 criteria. This barrier successfully met all the requirements of MASH 2016 test designation no. 3-11. In addition, the researchers consider the system MASH 2016 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.

A comparison of similar PCB systems with only one side of the system pinned included three systems: (1) a NJ PCB system with barrier nos. 1 and 10 pinned on both front and back sides, pin anchors only on the traffic side of barrier nos. 2 through 9, joint slack removed, and grouted toes (test no. NJPCB-7); (2) a NJ PCB system with barrier nos. 1 and 10 pinned on both front and back sides, pin anchors only on the back side of barrier nos. 2 through 9, joint slack removed, and grouted toes (test no. NJPCB-6) [16]; and (3) a New York PCB system with pin anchors only on the back side of all barriers and without removal of joint slack or grouted toes (test no. NYTCB-5) [17]. A review of these test results (test nos. NJPCB-6, NJPCB-7, and NYTCB-5) revealed benefits to pinning the barriers on the traffic side of the PCB segments when compared to pinning only n the back side. First, pinning the traffic side of the PCBs produced lower deflections for test no. NJPCB-7 as compared to test no. NJPCB-6. Second, in both tests of the back-side pinned barriers, the impacting vehicle climbed the barrier face significantly and rolled away from the traffic-side face of the barrier as it was redirected. This finding is primarily due to the back-side pins providing increased constraint to the back of the PCB segments, thus causing increased barrier rotation and subsequently, promotes vehicle climb and instability. In test no. NJPCB-7, the vehicle showed improved vehicle stability with less climb and roll when in contact with the pinned only on the traffic-side barrier. In addition, previous research by CALTRANS and MwRSF has noted that anchoring of PCB segments on the traffic side of the barrier improved stability as well. Thus, pinning only the traffic side of NJ PCB segments appears to be slightly more effective in reducing barrier deflections while providing improved vehicle stability.

Barrier system behavior and associated barrier deflections can vary from test to test due to the natural variability of a wide variety of factors involved in full-scale crash testing. These factors would include slight differences in impact conditions, differing test vehicle model years, slight variations in steel and concrete strengths, and variation of the cracking and damage observed on the barrier segments, among others. Thus, some variability would be expected in barrier performance even for basically identical systems.

In both the 2013 and 2015 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 this test, the clear space behind the barrier was 11.4 in. (290 mm).

9 REFERENCES

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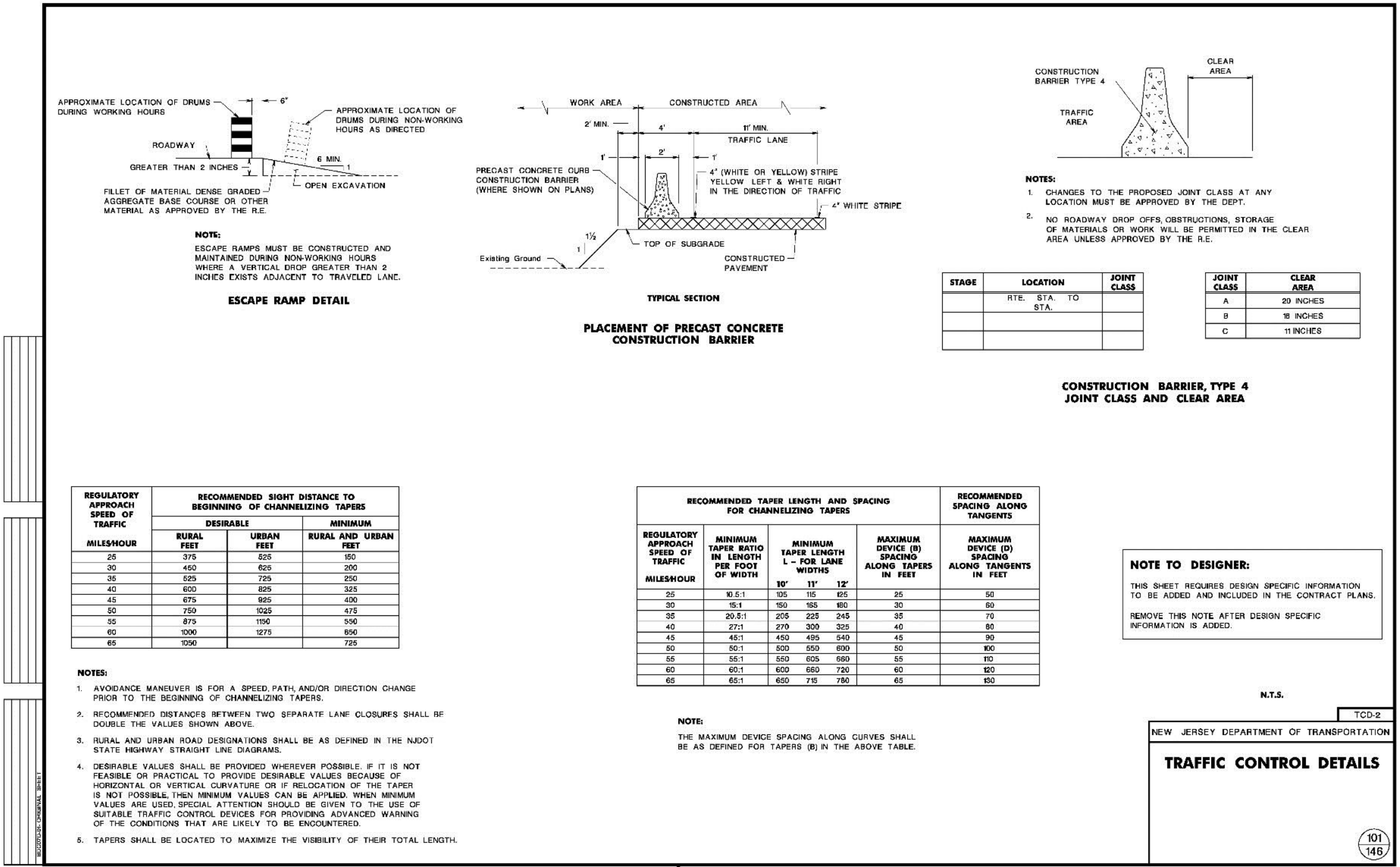
10 APPENDICES

Appendix A. NJDOT PCB Standard Plans



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

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			MAXIMUM DEVICE (B) SPACING ALONG TAPERS IN FEET	MAXIMUM DEVICE (D) SPACING ALONG TANGENTS IN FEET
		10'	11'	12'		
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

Figure A-1. NJDOT PCB Standard Plans

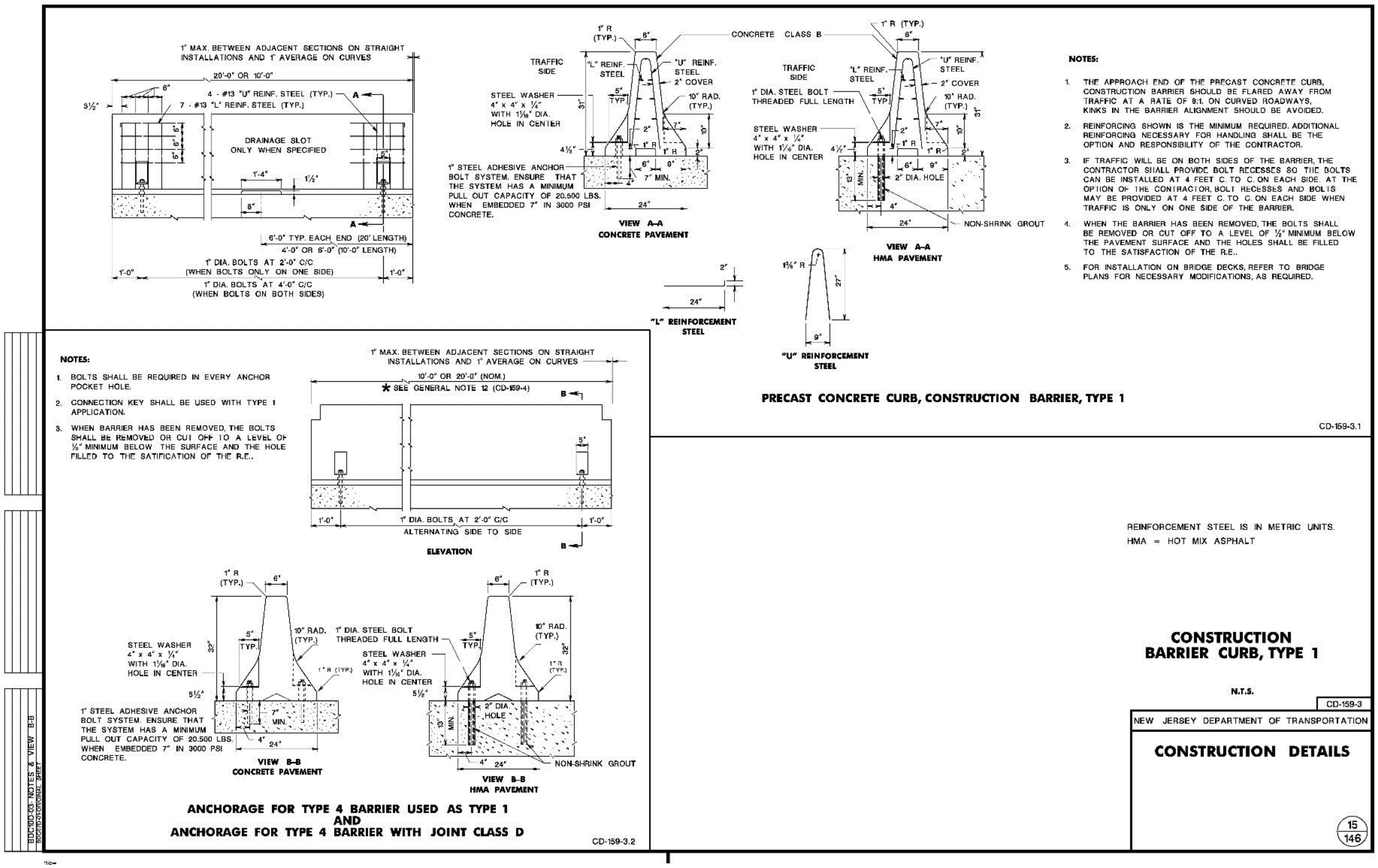


Figure A-2. NJDOT PCB Standard Plans

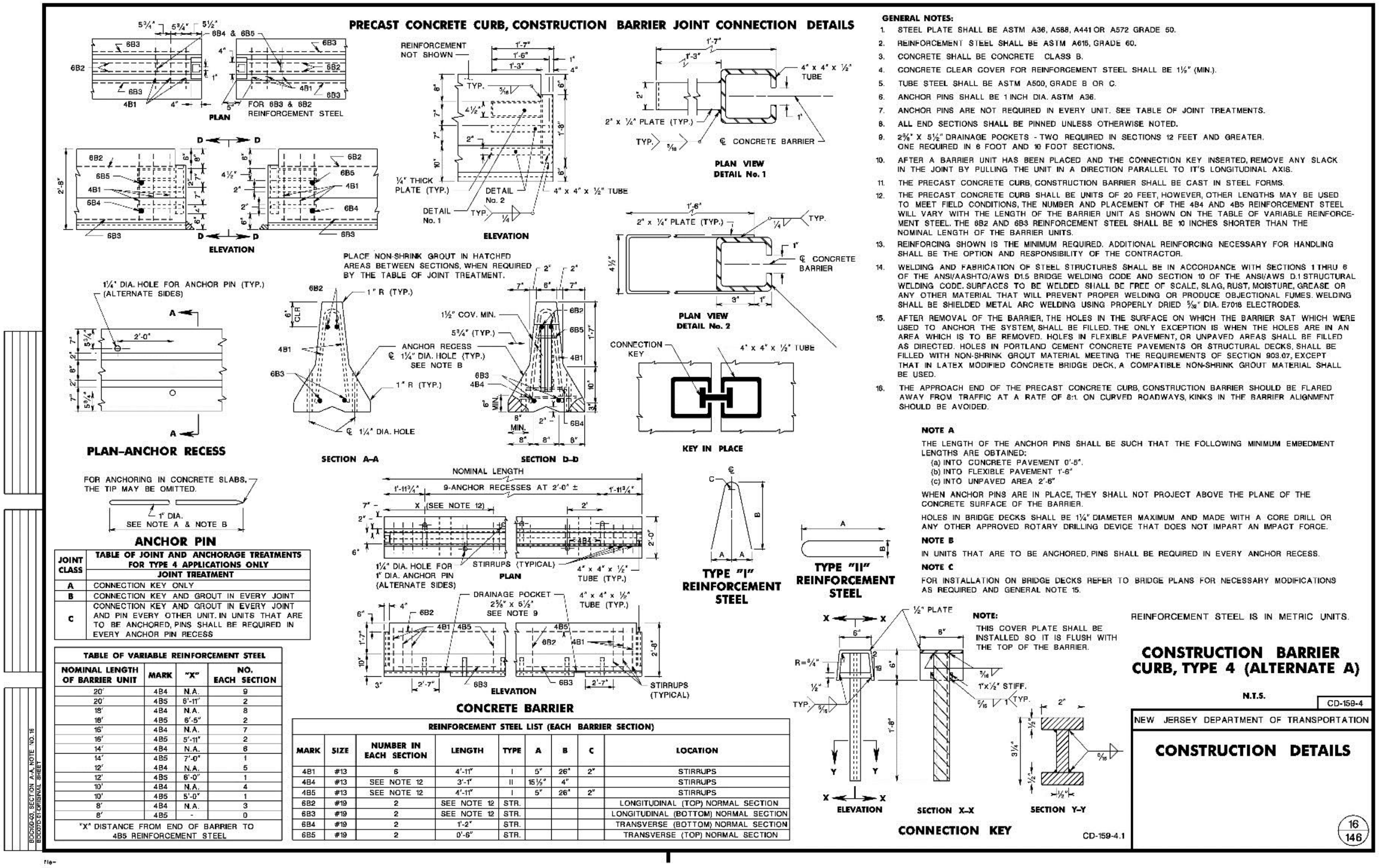


Figure A-3. NJDOT PCB Standard Plans

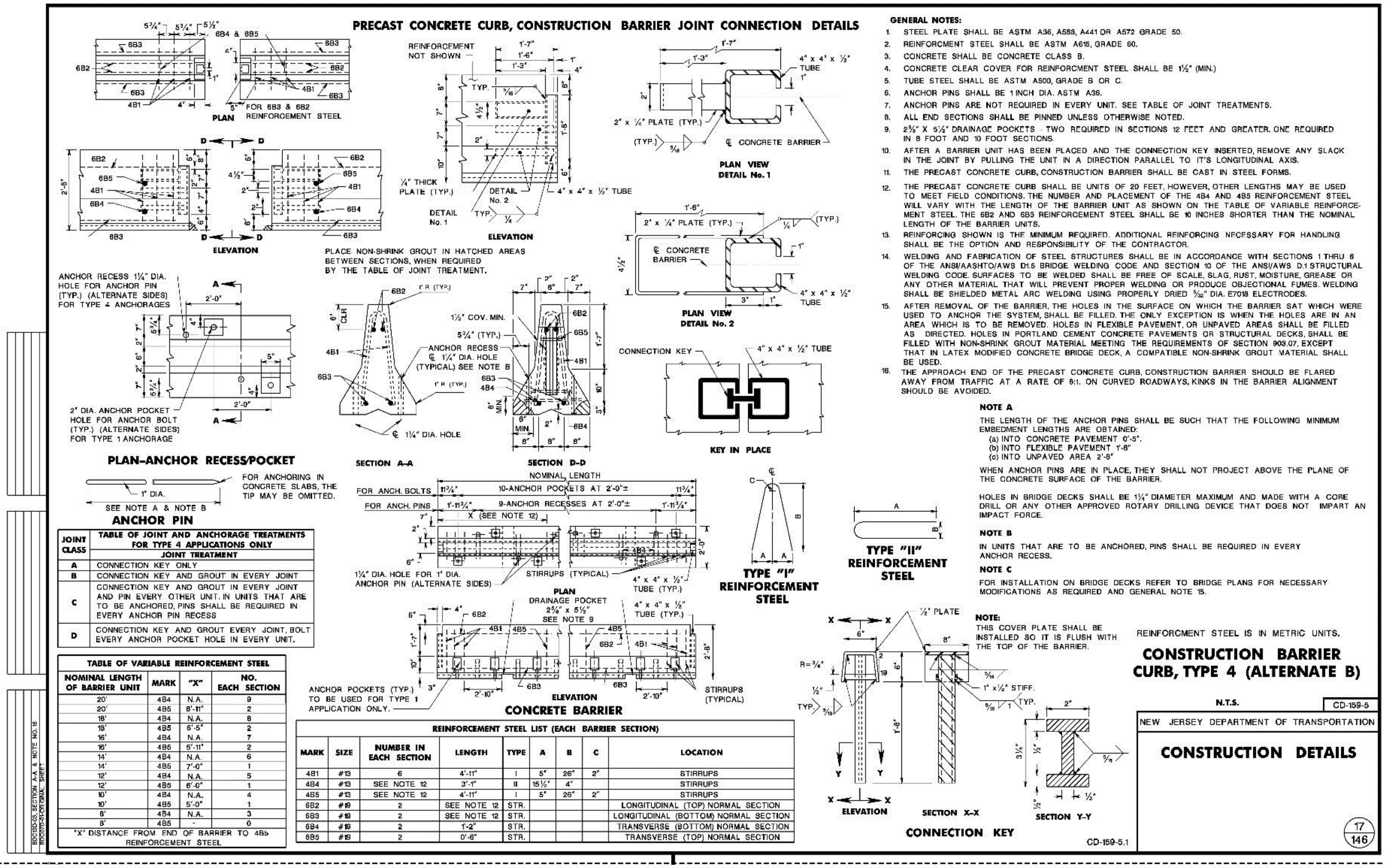


Figure A-4. NJDOT PCB Standard Plans

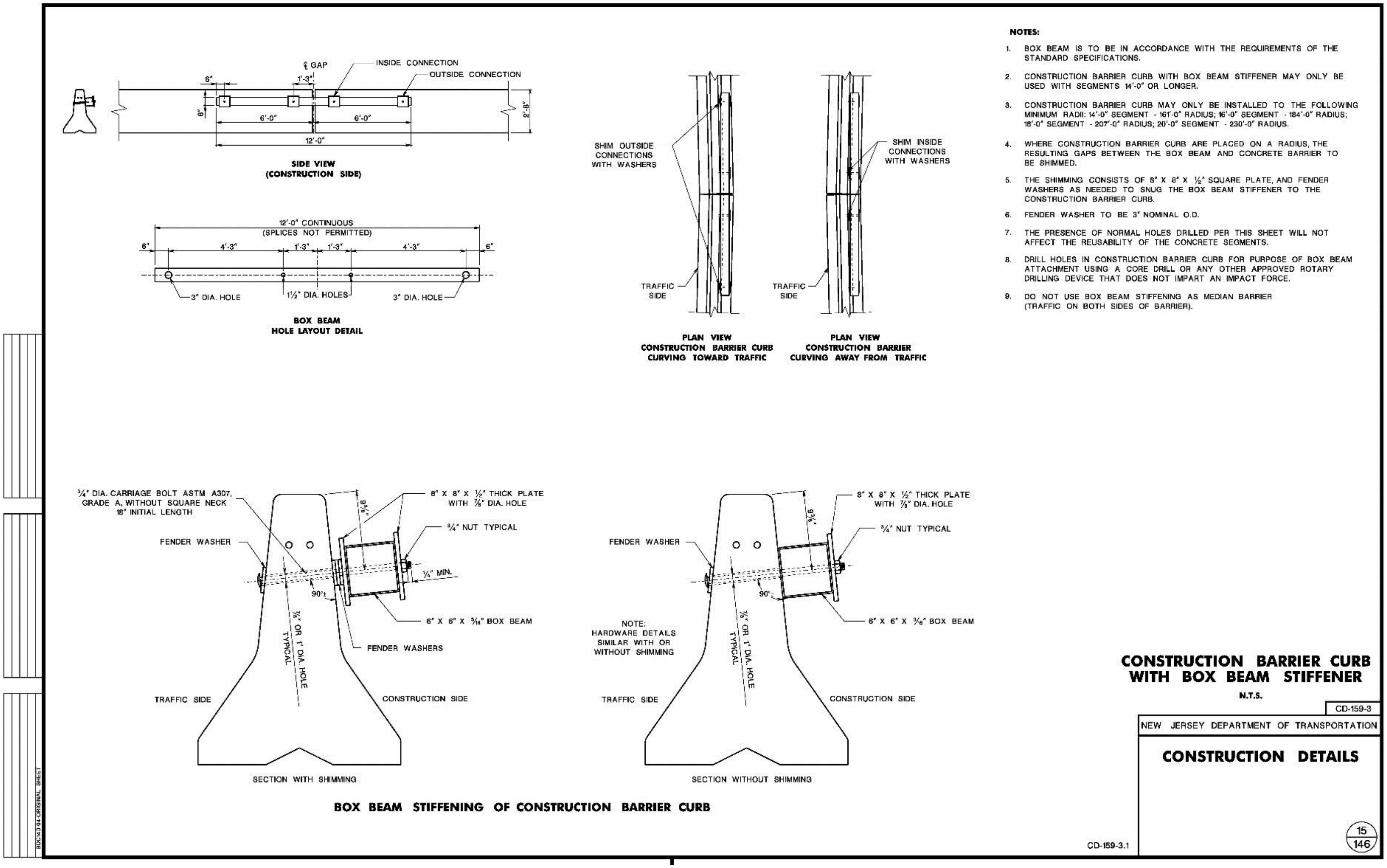


Figure A-5. NJDOT PCB Standard Plans

Appendix B. Material Specifications

Table B-1. Bill of Materials, Test No. NJPCB-7

Item No.	Description	Material Specification	Reference
A1	Concrete Barrier Segment	Min. f 'c = 3,700 psi (25.5 MPa)	KU3325
A2	Anchor Steel Pin	ASTM A36	Heat #54153853
B1	Rebar - #4 Vertical Stirrup	ASTM A615 Gr. 60	Heat #JL1000, JK9068, 61108687
B2, B3	Rebar - #6 Longitudinal Bar	ASTM A615 Gr. 60	Heat #61110285, 61110265, JL3511, JL3506, JL3505
B4	Rebar - #4 Horizontal Anchor Recess, Reinforcement Stirrup	ASTM A615 Gr. 60	Heat #JL1000, JK9068, 61108687
B5	Rebar - #6 Top and Bottom Cross Bar	ASTM A615 Gr. 60	Heat #61110285, 61110265, JL3511, JL3506, JL3505
C1	Steel Tube – 4”×4”×½” (102×102×12.7) thick × 20” (508) long	ASTM A500 Gr. B and C	Heat #SF1424, SF4193
C2	Bent Steel Plate 1, 2”×¼”	ASTM A36	Heat #269878
C3	Bent Steel Plate 2, 2”×¼”	ASTM A36	Heat #269878
D1	Steel Plate 1, 2”×½”	ASTM A36	Heat #54148807
D2	Steel Plate 2, 2¼”×½”	ASTM A36	Heat #54148805
D3	½” (13) Steel Plate – Stiffener	ASTM A36	Heat #SF2550
D4	½” (13) Steel Plate – Top Plate	ASTM A36	Heat #SF2550
E1	Non-Shrink Grout	Min. 1-day Compressive Strength 1,000 psi (6.9 MPa)	Advantage Grout ASTM C1107 Product Code: 67435, R#2147369273

KU3325 Midwest Roadside Safety
University of Nebraska

20' Temporary Barrier with socket and key connection

Production date	Quantity to ship	Cylinder Breaks - 3 Day Results
5-1-17B	3	5199
4-13-17B	1	5130
4-28-17B	3	5024
4-27-17B	3	4834
4-27-17A	3	4697
4-26-17A	3	5134
4-25-17B	3	5516
4-25-17A	1	5223

Figure B-2. Concrete Barrier Segment – Concrete Strength, Test No. NJPCB-7

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

CERTIFIED MATERIAL TEST REPORT

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CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
STEEL & PIPE SUPPLY CO INC 401 NEW CENTURY PKWY NEW CENTURY,KS 66031-1127 USA	STEEL & PIPE SUPPLY CO INC MANHATTAN,KS 66505-1688 USA	A36/44W	Round Bar / 1"	0000021046

LENGTH	WEIGHT	HEAT / BATCH
20'00"	14,968 LB	54153853/02

SALES ORDER	CUSTOMER MATERIAL N°
4875117/000010	000000000009010020

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
4500284124	1321-0000046146	04/07/2017

SPECIFICATION / DATE or REVISION
ASME SA36
ASTM A6-14, A36-14
ASTM A709-15, AASHTO M270-12
CSA G40.20-13/G40.21-13

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	V %	Nb %	Sn %
0.16	0.66	0.009	0.022	0.18	0.32	0.16	0.09	0.040	0.002	0.002	0.009

MECHANICAL PROPERTIES

Elong. %	G/L Inch	UTS PSI	UTS MPa	YS PSI	YS MPa
24.40	8.000	72118	497	51028	352

GEOMETRIC CHARACTERISTICS

R:R
32.00

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
Phone: (409) 769-1014 Email: Bhaskar.Yalamanchili@gerdau.com

JORDAN FOSTER
QUALITY ASSURANCE MGR.
Phone: (704) 596-0361 EX3708 Email: Jordan.Foster@gerdau.com

Figure B-3. Anchor Pins Material Certificate, Test No. NJPCB-7

Steel Dynamics®
Roanoke Bar Division

P.O. Box 13948
Roanoke, VA 24038-3934

Office: (540) 342-1831
(800) 753-3532
Fax: (540) 342-9437
www.roanokesteel.com

PRODUCT CERTIFICATION

MFG LOT NBR	HEAT NUMBER
JL1000-376202	JL1000
BILL OF LADING	**SALES ORDER/LINE**
00514980	121669 / 001
	CERT ID / REV
	00049973 / 01

SOLD TO	SHIP TO
Metal Partners International 55 South Main Street Suite 304 Naperville, IL 60540 USA	Metal Partners International 55 South Main Street Suite 304 Naperville, IL 60540 USA

CUSTOMER P.O.	CUSTOMER PART	QUANTITY	BUNDLE(S)	TOTAL PIECES	GRADE	SHIPMENT DATE
8495	N/A	25,956	3	288	A615-60	12/12/2016

PART NUMBER : RB019796000CA DESCRIPTION : Rebar # 06 (19) 60'0" A615-60

Alt Certs

ASTM A615/A615M-16 GR60 | AASHTO M31/M31M-15 GR60

Chemical

C	Mn	S	P	Si	Cr	Ni	Mo	Cu	V	Nb	CE
0.42	1.02	0.043	0.012	0.26	0.11	0.10	0.03	0.26	0.003	0.001	0.68

Yield Tensile Elongation

	Yld-1 (KSI)	Yld-1 (MPa)	Ultimate-1 (KSI)	Ultimate-1 (MPa)	Elong8" (%)
Sample-1	64.8	447	103.4	713	18
	Yld-2 (KSI)	**Yld-2 (MPa)**	**Ultimate-2 (KSI)**	**Ultimate-2 (MPa)**	**Elong8" (%)**
Sample-2	64.3	443	102.2	705	16.6

Mechanical

TEST	RESULT
Bend Test	Pass

Approved ABS QA Mill. Certificate No. 12-MMPQA-676. This Material was melted and manufactured in our plant located in Roanoke, VA, USA, by basic Electric Furnace process(es) to meet the "ordered" Grade. Mercury, Radium or other Alpha source materials in any form have not been used in the production of this material. No Weld repair has been performed. Any tensile values stated herein either inch-pound units or SI units are to be regarded as separate as defined in the ASTM scope for this material. All samples tested are full size. Unless a metric specification is ordered, this material has been tested and meets the requirements of the inch-pound ranges.

This is to certify the above to be a true and accurate report as contained in the records of this company.

END OF CERTIFICATION

Engineer of Tests: Lewis E. Leftwich Jr.

qtc302 (v6.0) Page 1 of 1 Date Printed: 12/12/2016

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

Steel Dynamics®
Roanoke Bar Division

P.O. Box 13948
Roanoke, VA 24038-3934

Office: (540) 342-1831
(800) 753-3532
Fax: (540) 342-9437
www.roanokesteel.com

PRODUCT CERTIFICATION

MFG LOT NBR	HEAT NUMBER
JK9068-171121	JK9068
BILL OF LADING	SALES ORDER/LINE
00505081	105043 / 002
	CERT ID / REV
	00014678 / 01

SOLD TO
Metal Partners International
55 South Main Street
Suite 304
Naperville, IL 60540
USA

SHIP TO
Metal Partners International
55 South Main Street
Suite 304
Naperville, IL 60540
USA

CUSTOMER P.O.	CUSTOMER PART	QUANTITY	BUNDLE(S)	TOTAL PIECES	GRADE	SHIPMENT DATE
5410	N/A	17,304	2	192	A615-60	05/05/2016

PART NUMBER : RB019796000CA DESCRIPTION : Rebar # 06 (19) 60'0" A615-60

Alt Certs

ASTM A615/A615M-16 GR60 | AASHTO M31/M31M-15 GR60

Chemical

C	Mn	S	P	Si	Cr	Ni	Mo	Cu	V	Nb
0.44	1.02	0.028	0.015	0.24	0.16	0.09	0.02	0.36	0.003	0.002

CE
0.71

Yield Tensile Elongation

	Yld-1 (KSI)	Yld-1 (MPa)	Ultimate-1 (KSI)	Ultimate-1 (MPa)	% Elong (%)
Sample-1	69.5	479	109.3	754	17.5
	Yld-2 (KSI)	Yld-2 (MPa)	Ultimate-2 (KSI)	Ultimate-2 (MPa)	% Elong (%)
Sample-2	68.8	475	109.5	755	16.3

Mechanical

TEST	RESULT
Bend Test	Pass

Approved ABS QA Mill. Certificate No. 12-MMPQA-676. This Material was melted and manufactured in our plant located in Roanoke, VA, USA, by basic Electric Furnace process(es) to meet the "ordered" Grade. Mercury, Radium or other Alpha source materials in any form have not been used in the production of this material. No Weld repair has been performed. Any tensile values stated herein either inch-pound units or SI units are to be regarded as separate as defined in the ASTM scope for this material. All samples tested are full size. Unless a metric specification is ordered, this material has been tested and meets the requirements of the inch-pound ranges.

This is to certify the above to be a true and accurate report as contained in the records of this company.

END OF CERTIFICATION Engineer of Tests: Lewis E. Leftwich Jr.

qtc302 (v6.0) Page 1 of 1 Date Printed: 05/05/2016

Figure B-5. Rebar No. 4 Material Certificate, Test No. NJPCB-7

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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	DOCUMENT ID:
TYE BAR LLC 1050 OHIO AVE GLASSPORT,PA 15045-1675 USA	TYE BAR LLC 1050 OHIO AVE GLASSPORT,PA 15045-1675 USA	60 (420)	Rebar / #5 (16MM)	0000000000

LENGTH	WEIGHT	HEAT / BATCH
60'00"	8,636 LB	**61108687**/02

SALES ORDER	CUSTOMER MATERIAL Nº	SPECIFICATION / DATE or REVISION
4209659/000010		ASTM A615/A615M-15 E1

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
160122	1331-0000048641	09/15/2016

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqyA706 %
0.44	0.62	0.012	0.061	0.19	0.31	0.17	0.14	0.057	0.016	0.015	0.56

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
65742	453	97290	671	8.000	200.0
64419	444	96645	666	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
15.00	OK
15.00	OK

GEOMETRIC CHARACTERISTICS

%Light %	Def Hgt Inch	Def Gap Inch	DefSpace Inch
4.50	0.035	0.095	0.400
4.60	0.035	0.095	0.400

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-6. Rebar No. 4 Material Certificate, Test No. NJPCB-7

GERDAU

CERTIFIED MATERIAL TEST REPORT

Page 1/1

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

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
TYE BAR LLC 1050 OHIO AVE GLASSPORT,PA 15045-1675 USA	TYE BAR LLC 1050 OHIO AVE GLASSPORT,PA 15045-1675 USA	60 (420)	Rebar / #6 (19MM)	0000000000

LENGTH	WEIGHT	HEAT / BATCH
41'00"	9,606 LB	61110285/09

SALES ORDER	CUSTOMER MATERIAL Nº	SPECIFICATION / DATE or REVISION
4699099/000020		ASTM A615/A615M-15 E1

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
170014	1331-0000052907	02/13/2017

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqyA706 %
0.45	0.64	0.014	0.041	0.20	0.28	0.14	0.21	0.044	0.011	0.019	0.61

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
68669	473	102440	706	8.000	200.0
68520	472	102170	704	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
13.00	OK
13.00	OK

GEOMETRIC CHARACTERISTICS

%Light %	Def Hgt Inch	Def Gap Inch	DefSpace Inch
4.00	0.051	0.074	0.453
4.10	0.051	0.074	0.453

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
Phone: (409) 769-1014 Email: Bhaskar.Yalamanchili@gerdau.com

JOSEPH T HOMIC
QUALITY ASSURANCE MGR.
Phone: 732 259 7660 Email: joe.homic@gerdau.com

Figure B-7. Rebar No. 6 Material Certificate, Test No. NJPCB-7

GERDAU

CERTIFIED MATERIAL TEST REPORT

Page 1/1

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

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
TYE BAR LLC 1050 OHIO AVE GLASSPORT,PA 15045-1675 USA	TYE BAR LLC 1050 OHIO AVE GLASSPORT,PA 15045-1675 USA	60 (420)	Rebar / #5 (16MM)	0000000000

LENGTH	WEIGHT	HEAT / BATCH
41'00"	35,576 LB	**61110265**/06

SALES ORDER	CUSTOMER MATERIAL Nº	SPECIFICATION / DATE or REVISION
4699099/000010		ASTM A615/A615M-15 E1

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
170014	1331-0000052911	02/13/2017

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqyA706 %
0.48	0.63	0.010	0.030	0.18	0.34	0.13	0.13	0.032	0.012	0.012	0.60

MECHANICAL PROPERTIES

YS PSI	YS MPa	UTS PSI	UTS MPa	G/L Inch	G/L mm
67134	463	102850	709	8.000	200.0
66752	460	101950	703	8.000	200.0

MECHANICAL PROPERTIES

Elong. %	BendTest
13.00	OK
13.00	OK

GEOMETRIC CHARACTERISTICS

%Light %	Def Hgt Inch	Def Gap Inch	DefSpace Inch
4.50	0.033	0.130	0.400
4.70	0.033	0.130	0.400

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

Phone: (409) 769-1014 Email: Bhaskar.Yalamanchili@gerdau.com

JOSEPH T HOMIC
QUALITY ASSURANCE MGR.

Phone: 732 259 7660 Email: joe.homic@gerdau.com

Figure B-8. Rebar No. 6 Material Certificate, Test No. NJPCB-7

Steel Dynamics®
Roanoke Bar Division

P.O. Box 13948
Roanoke, VA 24038-3934
Office: (540) 342-1831
(800) 753-3532
Fax: (540) 342-9437
www.roanokesteel.com

PRODUCT CERTIFICATION

MFG LOT NBR	HEAT NUMBER
JL3511-479027	JL3511
BILL OF LADING	SALES ORDER/LINE
00520094	129426 / 001
	CERT ID / REV
	00063374 / 01

SOLD TO
Metal Partners International
55 South Main Street
Suite 304
Naperville, IL 60540
USA

SHIP TO
Metal Partners International
55 South Main Street
Suite 304
Naperville, IL 60540
USA

CUSTOMER P.O.	CUSTOMER PART	QUANTITY	BUNDLE(S)	TOTAL PIECES	GRADE	SHIPMENT DATE
9579	N/A	17,315	3	432	A615-60	03/08/2017

PART NUMBER : RB019776000CA DESCRIPTION : Rebar # 04 (13) 60'0" A615-60

Chemical

C	Mn	S	P	Si	Cr	Ni	Mo	Cu	V	Nb	CE
0.41	1.05	0.024	0.012	0.22	0.16	0.10	0.02	0.21	0.002	0.001	0.68

Yield Tensile Elongation

	Yld (KSI)	Yld (MPa)	Ultimate (KSI)	Ultimate (MPa)	Elong8" (%)
Sample-1	68.9	475	107.6	742	15.6
Sample-2	69.5	479	108.2	746	14

Mechanical

TEST	RESULT
Bend Test	Pass

Approved ABS QA Mill. Certificate No. 12-MMPQA-676. This Material was melted and manufactured in our plant located in Roanoke, VA, USA, by basic Electric Furnace process(es) to meet the "ordered" Grade. Mercury, Radium or other Alpha source materials in any form have not been used in the production of this material. No Weld repair has been performed. Any tensile values stated herein either inch-pound units or SI units are to be regarded as separate as defined in the ASTM scope for this material. All samples tested are full size. Unless a metric specification is ordered, this material has been tested and meets the requirements of the inch-pound ranges.

This is to certify the above to be a true and accurate report as contained in the records of this company.

END OF CERTIFICATION

Engineer of Tests: Lewis E. Leftwich Jr.

qtc302 (v6.0) Page 1 of 1 Date Printed: 03/08/2017

Figure B-9. Rebar No. 6 Material Certificate, Test No. NJPCB-7

Steel Dynamics®
Roanoke Bar Division

P.O. Box 13948
Roanoke, VA 24038-3934

Office: (540) 342-1831
(800) 753-3532
Fax: (540) 342-9437
www.roanokesteel.com

PRODUCT CERTIFICATION

MFG LOT NBR	HEAT NUMBER
JL3506-479027	JL3506
BILL OF LADING	SALES ORDER/LINE
00520481	130004 / 001
	CERT ID / REV
	00064145 / 01

SOLD TO
Metal Partners International
55 South Main Street
Suite 304
Naperville, IL 60540
USA

SHIP TO
Metal Partners International
55 South Main Street
Suite 304
Naperville, IL 60540
USA

CUSTOMER P.O.	CUSTOMER PART	QUANTITY	BUNDLE(S)	TOTAL PIECES	GRADE	SHIPMENT DATE
9726	N/A	15,390	2	384	A615-60	03/13/2017

PART NUMBER : **RB019776000CA** DESCRIPTION : **Rebar # 04 (13) 60'0" A615-60**

Chemical

C	Mn	S	P	Si	Cr	Ni	Mo	Cu	V	Nb	CE
0.42	1.11	0.025	0.010	0.24	0.11	0.09	0.02	0.21	0.003	0.001	0.69

Yield Tensile Elongation

	Yld (KSI)	Yld (MPa)	Ultimate (KSI)	Ultimate (MPa)	Elong8" (%)
Sample-1	67.7	467	105.2	725	15.6
Sample-2	69.9	482	109.0	752	15.6

Mechanical

TEST	RESULT
Bend Test	Pass

Approved ABS QA Mill. Certificate No. 12-MMPQA-676. This Material was melted and manufactured in our plant located in Roanoke, VA, USA, by basic Electric Furnace process(es) to meet the "ordered" Grade. Mercury, Radium or other Alpha source materials in any form have not been used in the production of this material. No Weld repair has been performed. Any tensile values stated herein either inch-pound units or SI units are to be regarded as separate as defined in the ASTM scope for this material. All samples tested are full size. Unless a metric specification is ordered, this material has been tested and meets the requirements of the inch-pound ranges.

This is to certify the above to be a true and accurate report as contained in the records of this company.

END OF CERTIFICATION

Engineer of Tests: Lewis E. Leftwich Jr.

qtc302 (v6.0) Page 1 of 1 Date Printed: 03/13/2017

Figure B-10. Rebar No. 6 Material Certificate, Test No. NJPCB-7

Steel Dynamics®
Roanoke Bar Division

P.O. Box 13948
Roanoke, VA 24038-3934

Office: (540) 342-1831
(800) 753-3532
Fax: (540) 342-9437
www.roanokesteel.com

PRODUCT CERTIFICATION

MFG LOT NBR	HEAT NUMBER
JL3505-479027	JL3505
BILL OF LADING	SALES ORDER/LINE
00520481	130004 / 001
	CERT ID / REV
	00064144 / 01

SOLD TO	SHIP TO
Metal Partners International 55 South Main Street Suite 304 Naperville, IL 60540 USA	Metal Partners International 55 South Main Street Suite 304 Naperville, IL 60540 USA

CUSTOMER P.O.	CUSTOMER PART	QUANTITY	BUNDLE(S)	TOTAL PIECES	GRADE	SHIPMENT DATE
9726	N/A	30,540	4	762	A615-60	03/13/2017

PART NUMBER : RB019776000CA DESCRIPTION : Rebar # 04 (13) 60'0" A615-60

Chemical

C	Mn	S	P	Si	Cr	Ni	Mo	Cu	V	Nb	CE
0.42	1.04	0.034	0.010	0.24	0.08	0.08	0.02	0.24	0.003	0.001	0.68

Yield Tensile Elongation

	Yld-1 (KSI)	Yld-1 (MPa)	Ultimate-1 (KSI)	Ultimate-1 (MPa)	Elong8" (%)
Sample-1	70.5	486	110.0	759	12.5

	Yld-2 (KSI)	Yld-2 (MPa)	Ultimate-2 (KSI)	Ultimate-2 (MPa)	Elong8" (%)
Sample-2	69.5	479	110.7	763	14.4

Mechanical

TEST	RESULT
Bend Test	Pass

Approved ABS QA Mill. Certificate No. 12-MMPQA-676. This Material was melted and manufactured in our plant located in Roanoke, VA, USA, by basic Electric Furnace process(es) to meet the "ordered" Grade. Mercury, Radium or other Alpha source materials in any form have not been used in the production of this material. No Weld repair has been performed. Any tensile values stated herein either inch-pound units or SI units are to be regarded as separate as defined in the ASTM scope for this material. All samples tested are full size. Unless a metric specification is ordered, this material has been tested and meets the requirements of the inch-pound ranges.

This is to certify the above to be a true and accurate report as contained in the records of this company.

END OF CERTIFICATION

Engineer of Tests: Lewis E. Leftwich Jr.

qtc302 (v6.0) Page 1 of 1 Date Printed: 03/13/2017

Figure B-11. Rebar No. 6 Material Certificate, Test No. NJPCB-7

Independence Tube

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

independencetube.com
itctube.com
Certificate Number: DCR 493504

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

Purchase Order No: 01033424
Sales Order No: DCR 87576 - 3
Bill of Lading No: DCR 58409 - 3
Invoice No:

Shipped: 10/28/2016
Invoiced:

Sold To:
1214 - LIVINGSTON PIPE & TUBE
P.O. BOX 300
STAUNTON, IL 62088

Ship To:
1 - LIVINGSTON PIPE & TUBE
1612 ROUTE 4 NORTH
STAUNTON, IL 62088

CERTIFICATE of ANALYSIS and TESTS

Customer Part No:

Certificate No: DCR 493504
Test Date: 10/27/2016

TUBING A500B MIN MIXED HEAT
4" SQ X 1/2" X 40'

Total Pieces	Total Weight
9	7,787

* DO NOT SWITCH TAGS *

Bundle Tag	Mill	Heat	Specs	Y/T Ratio	Pieces	Weight
921690	40	SF1425	YLD=82600/TEN=87100/ELG=26.5	0.9483	9	7,787
	40	SF1424	YLD=83800/TEN=88900/ELG=24	0.9426		

Mill #: 40 Heat #: SF1424 Carbon Eq: 0.1714 Heat Src Origin: MELTED AND MANUFACTURED IN THE USA

C	Mn	P	S	Si	Al	Cu	Cr	Mo	V	Ni	Nb	Cb
0.0600	0.5700	0.0080	0.0020	0.2140	0.0220	0.0900	0.0300	0.0100	0.0020	0.0300	0.0100	0.0100

Sn	N	B	Ti	Ca
0.0090	0.0066	0.0002	0.0010	0.0013

LEED Information (based on the most recent LEED information from the producing mill)

Method	Location	Recycled Content	Post Consumer	Post Industrial
EAF	Decatur, AL	66.1%	54.8%	11.2%

Mill #: 40 Heat #: SF1425 Carbon Eq: 0.1631 Heat Src Origin: MELTED AND MANUFACTURED IN THE USA

C	Mn	P	S	Si	Al	Cu	Cr	Mo	V	Ni	Nb	Cb
0.0500	0.5800	0.0080	0.0020	0.2160	0.0230	0.0900	0.0300	0.0100	0.0020	0.0300	0.0100	0.0100

Sn	N	B	Ti	Ca
0.0080	0.0068	0.0002	0.0010	0.0012

LEED Information (based on the most recent LEED information from the producing mill)

Method	Location	Recycled Content	Post Consumer	Post Industrial
EAF	Decatur, AL	66.1%	54.8%	11.2%

Page - 1

Figure B-12. Steel Tube Material Certificate, Test No. NJPCB-7

Independence Tube

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

independencetube.com
itctube.com
Certificate Number: DCR 493505

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

Purchase Order No: 01033424
Sales Order No: DCR 87579 - 1
Bill of Lading No: DCR 58409 - 4
Invoice No:

Shipped: 10/28/2016
Invoiced:

Sold To:
1214 - LIVINGSTON PIPE & TUBE
P.O. BOX 300
STAUNTON, IL 62088

Ship To:
1 - LIVINGSTON PIPE & TUBE
1612 ROUTE 4 NORTH
STAUNTON, IL 62088

CERTIFICATE of ANALYSIS and TESTS

Customer Part No:

Certificate No: DCR 493505
Test Date: 10/27/2016

REJECT TUBING
4" SQ X 1/2" X 34'

Total Pieces	Total Weight
2	1,471

Bundle Tag	Mill	Heat	Specs	Y/T Ratio	Pieces	Weight
947721	40	SF4193	YLD=77600/TEN=83000/ELG=25.5	0.9349	2	1,471

Mill #: 40 Heat #: SF4193 Carbon Eq: 0.1776 Heat Src Origin: MELTED AND MANUFACTURED IN THE USA

C	Mn	P	S	Si	Al	Cu	Cr	Mo	V	Ni	Nb	Cb
0.0600	0.5900	0.0090	0.0020	0.2380	0.0320	0.1000	0.0400	0.0100	0.0030	0.0300	0.0100	0.0100

Sn	N	B	Ti	Ca
0.0060	0.0057	0.0004	0.0020	0.0012

LEED Information (based on the most recent LEED information from the producing mill)

Method	Location	Recycled Content	Post Consumer	Post Industrial
EAF	Decatur, AL	66.1%	54.8%	11.2%

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, 10/27/2016

WE PROUDLY MANUFACTURE ALL OUR PRODUCT IN THE USA.
INDEPENDENCE TUBE PRODUCT IS MANUFACTURED, TESTED, AND INSPECTED IN ACCORDANCE WITH ASTM STANDARDS.
MATERIAL IDENTIFIED AS A500 GRADE B(C) MEETS BOTH ASTM A500 GRADE B AND A500 GRADE C SPECIFICATIONS.

Chris Allen

Chris Allen, ASQ CMQ/OE
Quality Management Systems Manager

CURRENT STANDARDS:
A252-10
A500/A500M-13
A513-13
ASTM A53/A53M-12 | ASME SA-53/SA-53M-13
A847/A847M-14
A1085/A1085M-15

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Figure B-13. Steel Tube Material Certificate, Test No. NJPCB-7

CERTIFICATE OF CONFORMANCE

*PHOENIX STEEL SERVICE INC.
4679 JOHNSTON PARKWAY
CLEVELAND, OHIO 44128
216-332-0600

DATE: 9/07/16

SOLD TO: SEIBEL MODERN MFG. & WELDING
38 PALMER PLACE
LANCASTER, NY 14086

SHIP TO: SEIBEL MODERN MFG. & WELDING
38 PALMER PLACE
LANCASTER, NEW YORK 14086

Cust P/O# SBS-16

SIZE: .250 X 49.00 X 144.00

GRADE: HR A709 GR50

DATE SHPPD: 9/07/16

Wt.Shipped 43300

CHEMICAL ANALYSIS

Heat Number 269878

C : .05	Mn: 1.020	P : .007	S : .001
Si: .019	Ti: .003	Cr: .038	
Cu: .129	Al: .027	Cb: .001	V : .080
	Sn: .007		N : .017
B : .001		Ni: .053	Mo: .019

PHYSICAL PROPERTIES

Yield: 63700 Tensile: 77700 Elongation: 30.1%

Misc Info TAG#: C40123909-10-11-12-13
Misc Info *MELTED AND MANUFACTURED IN THE USA*

THE ABOVE IS IN ACCORDANCE WITH OUR RECORDS.

CONFORMANCE FORM REV. 10/04/12 DJD

Figure B-14. 2-in. × ¼-in. (51-mm × 6-mm) Bent Steel Plate, Test No. NJPCB-7

CERTIFIED MATERIAL TEST REPORT Page 1/1

GERDAU

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

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
TRIAD METALS 3507 GRAND AVE PITTSBURGH,PA 15225 USA	TRIAD METALS INTERNATIONAL MET 1 VILLAGE RD HORSHAM,PA 19044-3800 USA	GGMULTI	Flat Bar / 1/2 X 2	0000000000

LENGTH	WEIGHT	HEAT / BATCH
20'00"	16,728 LB	54148807/02

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
3566020/000020		ASTM A529-14, A572-15 ASTM A6-14,A36-14, ASME SA-36 ASTM A709-13A, AASHTO M270-12 CSA G40.20-13/G40.21-13

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
90844W	1321-0000039076	05/10/2016

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	V %	Nb %	Sn %
0.17	0.79	0.011	0.035	0.21	0.31	0.18	0.15	0.060	0.017	0.001	0.015

MECHANICAL PROPERTIES

Elong. %	G/L Inch	UTS PSI	UTS MPa	YS PSI	YS MPa
25.00	8.000	78985	545	56738	391

GEOMETRIC CHARACTERISTICS

R R
25.00

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-15. ½-in. (13-mm) Thick Steel Plate Material Certificate, Test No. NJPCB-7

GERDAU

CERTIFIED MATERIAL TEST REPORT

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

CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE	DOCUMENT ID:
TRIAD METALS 3507 GRAND AVE PITTSBURGH,PA 15225 USA	TRIAD METALS INTERNATIONAL MET 1 VILLAGE RD HORSHAM,PA 19044-3800 USA	GGMULTI	Flat Bar / 1/2 X 2 1/4	0000000000

LENGTH	WEIGHT	HEAT / BATCH
20'00"	4,979 LB	54148805/02

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
3806947/000010		ASTM A529-14, A572-15 ASTM A6-14,A36-14, ASME SA-36 ASTM A709-13A, AASHTO M270-12 CSA G40.20-13/G40.21-13

CUSTOMER PURCHASE ORDER NUMBER	BILL OF LADING	DATE
93494W	1321-0000039836	06/08/2016

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	V %	Nb %	Sn %
0.18	0.77	0.013	0.033	0.21	0.31	0.23	0.16	0.050	0.013	0.001	0.016

MECHANICAL PROPERTIES

Elong. %	G/L Inch	UTS PSI	UTS MPa	YS PSI	YS MPa
25.00	8.000	75435	520	53469	369

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-16. ½-in. (13-mm) Thick Steel Plate Material Certificate, Test No. NJPCB-7

CERTIFICATE OF CONFORMANCE

*PHOENIX STEEL SERVICE INC.
4679 JOHNSTON PARKWAY
CLEVELAND, OHIO 44128
216-332-0600

DATE:

SOLD TO: SEIBEL MODERN MFG. & WELDING
38 PALMER PLACE
LANCASTER, NY 14086

SHIP TO: SEIBEL MODERN MFG. & WELDING
38 PALMER PLACE
LANCASTER, NEW YORK 14086

Cust P/O# SBR-41

SIZE: .500 X 40.00 X 144.00

GRADE: HR A36 *MELTED & MANUFACTURED IN THE USA*

DATE SHPPD:

CHEMICAL ANALYSIS

Heat Number SF2550

C : .216	Mn: .548	P : .008	S : .002
Si: .222	Ti: .002	Cr: .033	
Cu: .076	Al: .027	Cb: .007	V : .002
	Sn: .0051	Ca: .0012	N : .0054
B : .0002		Ni: .0232	Mo: .0103

PHYSICAL PROPERTIES

Yield: 38700 Tensile: 72000 Elongation: 33%

Misc Info TAG#: PS149410A-B-C-D

THE ABOVE IS IN ACCORDANCE WITH OUR RECORDS.

CONFORMANCE FORM REV. 10/04/12 DJD

Figure B-17. ½-in. (13-mm) Thick Steel Plate Material Certificate, Test No. NJPCB-7

DAYTON SUPERIOR

1107 Advantage Grout

Cement Based Grout

TECHNICAL DATA SHEET

DESCRIPTION

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

USE

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

FEATURES

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

PROPERTIES

Corps of Engineers Specification for non-shrink grout:

CRD-C 621 Grades A, B, C

ASTM C-1107 Grades A, B, C

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

Expansion - ASTM C-1090:

1 day: 0-0.3

3 days: 0-0.3

14 days: 0-0.3

28 days: 0-0.3

Test Results

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

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

Estimating Guide

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

Packaging

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

STORAGE

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

APPLICATION

Surface Preparation:

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

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

Water Requirements:

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

Mixing:

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

Sec 16

Grouts

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

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File Date: 3/27/2015

Figure B-18. Non-Shrink Grout Specifications, Test No. NJPCB-7

DAYTON SUPERIOR

1107 Advantage Grout

Cement Based Grout

TECHNICAL DATA SHEET

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

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

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

Sec 16 Grouts

CLEAN UP

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

CURING

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

LIMITATIONS

FOR PROFESSIONAL USE ONLY

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

PRECAUTIONS

READ SDS PRIOR TO USING PRODUCT

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

MANUFACTURER

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

WARRANTY

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

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File Date: 3/27/2015

Figure B-19. Non-Shrink Grout Specifications, Test No. NJPCB-7

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

COMPRESSION TEST OF CYLINDRICAL CONCRETE SPECIMENS - 4x8

ASTM Designation: C 39

Client Name: Midwest Roadside Safety Facility **Date** 28-Jun-17
Project Name: NJPCB-7
Placement Location: None Given

Mix Designation: N/A **Required Strength:** N/A

Laboratory Test Data

Laboratory Identification	Field Identification	Date Cast	Date Received	Date Tested	Days Cured in Field	Days Cured in Laboratory	Age of Test, Days	Length of Specimen, in.	Diameter of Specimen, in.	Cross-Sectional Area,sq.in.	Maximum Load, lbf	Compressive Strength, psi.	Required Strength, psi.	Type of Fracture	ASTM Practice for Capping Specimen
NCB- 1	A	6/27/2017	6/27/2017	6/28/2017	0	1	1	8	4.01	12.63	54,291	4,300		6	C 1231
NCB- 2	B	6/27/2017	6/27/2017	6/28/2017	0	1	1	8	4.01	12.63	56,844	4,500		6	C 1231

Remarks:

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

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

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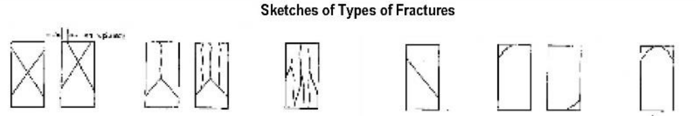
Sketches of Types of Fractures



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

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

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

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

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

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

ALFRED BENESCH & COMPANY
CONSTRUCTION MATERIALS LABORATORY

By____________________________
Brant Wells, Field/Lab Operations Manager

Figure B-20. Non-shrink Grout Compressive Test Certificate, Test No. NJPCB-7

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.

ALFRED BENESCH & COMPANY
CONSTRUCTION MATERIALS LABORATORY

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

Figure C-1. Concrete Tarmac Strength Test

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

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

Client:	UNL			Date:	December 13, 2010	
Project:	MwRSF					
Placement Location:	WI - Epoxy West 4 &5					
Mix Type:	Class:			Mix No.:		
Type of Forms			Cement Factor, Sks/Yd		na	
			Water-Cement Ratio		na	
Admixture Quantity	na		Slump Inches		na	
Admixture Type	na		Unit Wt, lbs/cu. Ft.		na	
Admixture Quantity	na		Air Content, %		na	
Average Field Temperature	na		Batch Volume, Cu. Yds.		na	
Temperature of Concrete F	na		Ticket No.		na	
Identification Laboratory	4	5				
Date Cast						
Date Received in Laboratory	12/13/2010	12/13/2010				
Date Tested						
Days Cured in Field						
Days Cured in Laboratory						
Age of Test, Days	na	na				
Length, in.	8.05	8.06				
Average Width (1), in.	3.91	3.90				
Cross-Sectional Area, sq. in.	11.977	11.952				
Maximum Load, lbf	71,500	71,630				
Compressive Stength, psi	5,970	5,990				
Length/Diameter Ratio	2.061	2.065				
Correction						
Corrected Compressive Strength,psi	0	0				
Type of Fracture	3	3				
Required Strength,psi						

Remarks:

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

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CONSTRUCTION MATERIALS LABORATORY

By: Raymond E. Delka, Manager

Figure C-2. Concrete Tarmac Strength Test

Appendix D. Vehicle Center of Gravity Determination

Date:	**6/9/2017**	**Test Name:**	**NJPCB-7**	**VIN:**	**1D7RB1GP7AS162701**
Year:	**2010**	**Make:**	**Dodge**	**Model:**	**Ram 1500**

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb.)	Vertical CG (in.)	Vertical M (lb.-in.)
+	Unballasted Truck (Curb)	5053	28 1/8	142115.63
+	Hub	19	15 1/4	289.75
+	Brake activation cylinder & frame	7	24 1/2	171.5
+	Pneumatic tank (Nitrogen)	27	28	756
+	Strobe/Brake Battery	5	26 1/4	131.25
+	Brake Receiver/Wires	5	52 1/2	262.5
+	CG Plate including DAS	42	30 1/2	1281
-	Battery	-44	42 1/4	-1859
-	Oil	-7	26 1/2	-185.5
-	Interior	-96	29 1/2	-2832
-	Fuel	-172	19 1/2	-3354
-	Coolant	-3	33 1/2	-100.5
-	Washer fluid	-1	33	-33
+	Water Ballast (In Fuel Tank)	99	16 3/4	1658.25
+	Onboard Supplemental Battery	12	26 1/2	318
	Steel Truck Bed Plate	33	33 1/4	1097.25
				139717.13

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

Estimated Total Weight (lb.) 4979
Vertical CG Location (in.) 28.0613

Vehicle Dimensions for C.G. Calculations

Wheel Base: 140 1/4 in.
Front Track Width: 68 3/8 in.
Rear Track Width: 68 1/4 in.

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb.)	5000 ± 110	5000	0.0
Longitudinal CG (in.)	63 ± 4	62.1027	-0.89730
Lateral CG (in.)	NA	0.4781875	NA
Vertical CG (in.)	28 or greater	28.06	0.06128

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	1439	1386
Rear	1116	1112

FRONT	2825	lb.
REAR	2228	lb.
TOTAL	5053	lb.

TEST INERTIAL WEIGHT (lb.)

	Left	Right
Front	1372	1414
Rear	1093	1121

FRONT	2786	lb.
REAR	2214	lb.
TOTAL	5000	lb.

Figure D-1. Vehicle Mass Distribution, Test No. NJPCB-7

Appendix E. Vehicle Deformation Records

Date: 2/27/2018 Test Name: NJPCB-7 VIN: 1D7RB1GP7AS162701
Year: 2010 Make: Dodge Model: Ram 1500

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 1

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	29.577	-34.638	2.449	28.298	-33.618	3.449	-1.279	1.020	1.001	1.918	1.624
2	31.409	-30.025	0.658	28.788	-28.315	2.598	-2.621	1.710	1.940	3.682	3.261
3	32.221	-26.016	-0.329	30.140	-24.342	1.723	-2.081	1.674	2.051	3.368	2.922
4	32.048	-22.114	-0.307	30.674	-20.851	1.164	-1.374	1.263	1.470	2.376	2.012
5	27.272	-35.032	-1.133	26.895	-34.058	-0.546	-0.377	0.974	0.588	1.198	0.698
6	28.780	-30.467	-2.172	27.900	-29.194	-1.056	-0.880	1.273	1.116	1.908	1.421
7	28.555	-25.958	-2.262	27.819	-24.864	-1.303	-0.737	1.095	0.959	1.631	1.210
8	28.056	-21.101	-2.366	28.060	-20.036	-2.348	0.004	1.065	0.019	1.065	0.019
9	24.697	-35.352	-4.173	25.046	-34.348	-3.882	0.348	1.004	0.291	1.102	0.291
10	24.638	-30.604	-4.146	24.759	-29.521	-3.808	0.121	1.083	0.338	1.141	0.338
11	24.616	-25.446	-4.354	24.615	-24.334	-4.089	-0.001	1.113	0.265	1.144	0.265
12	24.692	-20.070	-4.349	24.963	-19.198	-4.549	0.271	0.872	-0.200	0.935	-0.200
13	19.013	-35.233	-6.866	19.567	-34.214	-6.962	0.553	1.018	-0.096	1.163	-0.096
14	18.941	-29.912	-6.820	19.329	-28.930	-6.888	0.388	0.982	-0.069	1.058	-0.069
15	18.645	-24.625	-6.840	19.080	-23.747	-6.926	0.435	0.878	-0.086	0.984	-0.086
16	18.470	-19.017	-6.839	18.818	-18.102	-6.962	0.348	0.914	-0.123	0.986	-0.123
17	13.590	-34.661	-6.878	14.120	-33.790	-7.174	0.530	0.871	-0.297	1.062	-0.297
18	13.158	-29.611	-6.816	13.632	-28.797	-7.045	0.474	0.814	-0.229	0.969	-0.229
19	13.142	-22.666	-6.822	13.546	-21.794	-6.962	0.404	0.872	-0.140	0.972	-0.140
20	13.045	-18.368	-6.910	13.249	-17.541	-7.052	0.204	0.827	-0.142	0.864	-0.142
21	6.748	-35.482	-6.863	7.305	-34.763	-7.066	0.557	0.719	-0.204	0.932	-0.204
22	6.966	-30.710	-6.863	7.485	-29.987	-7.113	0.519	0.724	-0.250	0.925	-0.250
23	7.047	-24.640	-6.875	7.469	-23.902	-7.037	0.421	0.738	-0.162	0.865	-0.162
24	6.870	-19.022	-6.909	7.145	-18.268	-7.046	0.275	0.754	-0.137	0.814	-0.137
25	-0.024	-31.739	-2.889	0.621	-31.108	-3.031	0.645	0.630	-0.142	0.913	-0.142
26	0.086	-27.767	-2.871	0.593	-27.207	-3.009	0.507	0.560	-0.138	0.767	-0.138
27	0.002	-24.569	-2.884	0.426	-23.991	-3.019	0.424	0.578	-0.135	0.730	-0.135
28	-0.045	-19.611	-2.906	0.308	-19.008	-3.065	0.353	0.603	-0.159	0.717	-0.159

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

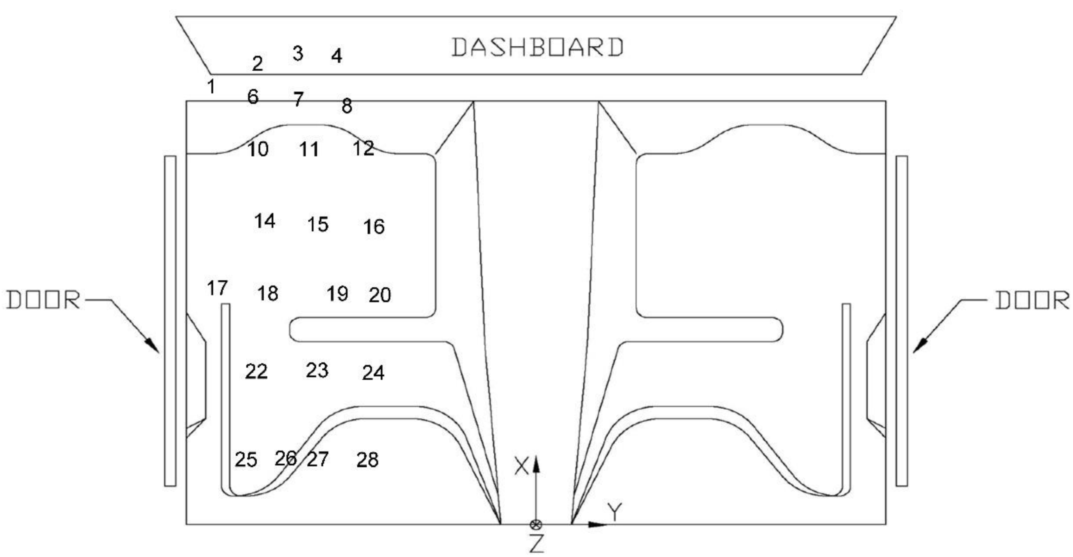


Figure E-1. Floor Pan Deformation Data – Set 1, Test No. NJPCB-7

Date: 2/27/2018 Test Name: NJPCB-7 VIN: 1D7RB1GP7AS162701
Year: 2010 Make: Dodge Model: Ram 1500

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 2

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)	Total Δ (in.)	Crush (in.)
1	56.526	-34.264	2.717	55.208	-33.926	3.108	-1.318	0.338	0.391	1.415	1.374
2	58.261	-29.707	0.910	55.684	-28.614	2.313	-2.578	1.093	1.403	3.132	2.935
3	59.137	-25.465	-0.048	57.024	-24.617	1.449	-2.114	0.849	1.497	2.726	2.590
4	58.923	-21.765	-0.043	57.772	-21.210	0.763	-1.151	0.555	0.806	1.511	1.405
5	54.142	-34.657	-0.787	53.651	-34.347	-0.842	-0.491	0.310	-0.056	0.583	0.494
6	55.613	-30.057	-1.845	54.650	-29.449	-1.332	-0.963	0.608	0.513	1.249	1.091
7	55.385	-25.532	-1.898	54.552	-25.094	-1.524	-0.833	0.438	0.374	1.013	0.913
8	54.868	-20.687	-1.964	54.741	-20.258	-2.566	-0.126	0.428	-0.602	0.749	0.615
9	51.484	-35.010	-3.755	51.621	-34.586	-4.130	0.137	0.425	-0.375	0.583	-0.375
10	51.407	-30.233	-3.716	51.349	-29.863	-3.932	-0.058	0.370	-0.216	0.432	-0.216
11	51.385	-25.074	-3.885	51.181	-24.672	-4.158	-0.205	0.402	-0.273	0.528	-0.273
12	51.442	-19.776	-3.862	51.601	-19.410	-4.599	0.158	0.366	-0.737	0.838	-0.737
13	45.672	-34.756	-6.299	46.060	-34.461	-6.965	0.388	0.295	-0.666	0.825	-0.666
14	45.582	-29.442	-6.225	45.802	-29.169	-6.825	0.220	0.273	-0.601	0.695	-0.601
15	45.317	-24.191	-6.212	45.531	-23.900	-6.796	0.214	0.291	-0.585	0.687	-0.585
16	45.141	-18.574	-6.187	45.266	-18.275	-6.765	0.125	0.299	-0.578	0.663	-0.578
17	40.280	-34.310	-6.163	40.582	-33.988	-6.974	0.302	0.322	-0.810	0.923	-0.810
18	39.849	-29.314	-6.065	40.120	-29.056	-6.776	0.271	0.258	-0.710	0.803	-0.710
19	39.858	-22.281	-6.038	39.977	-21.982	-6.623	0.119	0.299	-0.585	0.668	-0.585
20	39.686	-18.060	-6.104	39.761	-17.756	-6.647	0.075	0.304	-0.543	0.627	-0.543
21	33.474	-35.106	-5.965	33.848	-34.909	-6.638	0.374	0.197	-0.673	0.795	-0.673
22	33.674	-30.285	-5.949	33.960	-30.154	-6.636	0.286	0.131	-0.686	0.755	-0.686
23	33.719	-24.231	-5.936	33.902	-24.079	-6.492	0.182	0.151	-0.556	0.605	-0.556
24	33.500	-18.619	-5.940	33.597	-18.421	-6.425	0.097	0.198	-0.485	0.533	-0.485
25	26.894	-31.407	-1.793	27.178	-31.323	-2.329	0.285	0.083	-0.536	0.613	-0.536
26	26.955	-27.481	-1.759	27.212	-27.369	-2.263	0.257	0.112	-0.504	0.577	-0.504
27	26.828	-24.226	-1.756	27.091	-24.199	-2.231	0.263	0.027	-0.475	0.543	-0.475
28	26.767	-19.307	-1.752	26.909	-19.240	-2.218	0.142	0.067	-0.466	0.492	-0.466

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

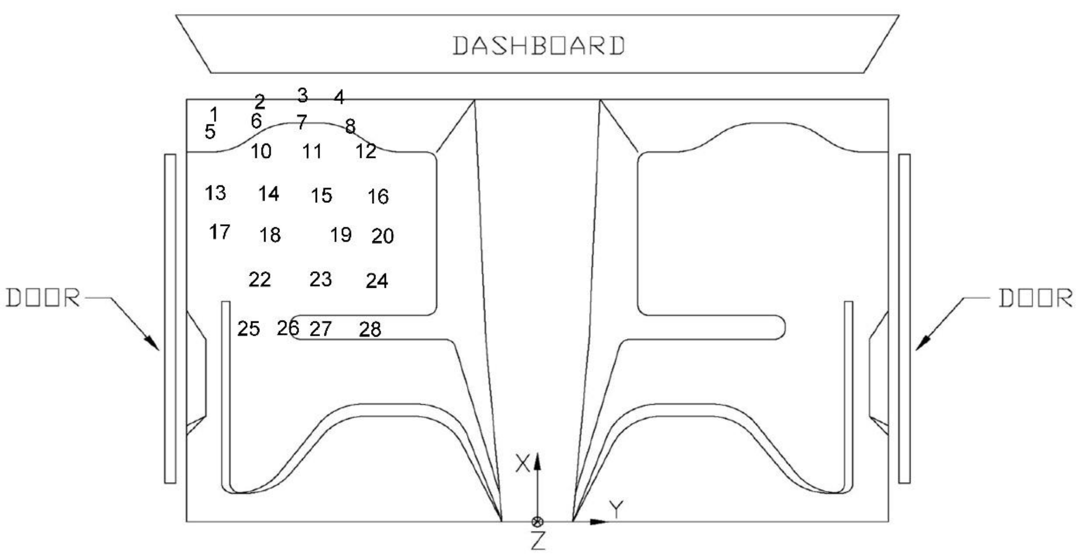


Figure E-2. Floor Pan Deformation Data – Set 2, Test No. NJPCB-7

Date: 2/27/2018 Test Name: NJPCB-7 VIN: 1D7RB1GP7AS162701
Year: 2010 Make: Dodge Model: Ram 1500

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 1

	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	12.411	-25.051	27.691	13.292	-23.867	27.702	0.881	1.184	0.011	1.476	1.476
	2	14.357	-16.028	25.402	14.936	-14.849	25.373	0.579	1.180	-0.029	1.314	1.314
	3	11.151	-6.412	24.989	11.450	-5.261	24.962	0.299	1.151	-0.027	1.189	1.189
	4	9.984	-25.410	12.896	11.010	-24.327	12.888	1.026	1.083	-0.008	1.492	1.492
	5	11.052	-16.641	12.210	11.764	-15.523	12.226	0.712	1.118	0.016	1.326	1.326
	6	8.549	-6.589	13.220	8.920	-5.611	13.216	0.371	0.978	-0.004	1.046	1.046
SIDE PANEL	7	21.988	-38.766	5.024	23.545	-36.878	5.232	1.557	1.888	0.208	2.456	1.888
	8	22.404	-38.632	0.837	24.003	-36.648	1.062	1.599	1.984	0.225	2.558	1.984
	9	25.142	-38.727	4.506	26.657	-36.742	4.717	1.514	1.986	0.212	2.506	1.986
IMPACT SIDE DOOR	10	-13.495	-40.512	21.402	-11.633	-41.736	21.164	1.862	-1.223	-0.238	2.240	-1.223
	11	-0.759	-40.266	21.210	1.015	-40.477	21.189	1.774	-0.211	-0.021	1.787	-0.211
	12	12.503	-40.136	21.004	14.303	-39.251	21.066	1.800	0.885	0.062	2.007	0.885
	13	-8.632	-41.873	2.699	-6.523	-41.535	2.513	2.109	0.339	-0.186	2.144	0.339
	14	-0.394	-41.987	2.314	1.723	-41.187	2.217	2.117	0.801	-0.097	2.266	0.801
	15	7.151	-41.820	-0.018	9.147	-40.444	-0.006	1.996	1.376	0.013	2.424	1.376
ROOF	16	3.994	-28.835	40.601	5.289	-27.810	40.611	1.295	1.024	0.010	1.651	0.010
	17	5.843	-21.619	40.820	6.837	-20.482	40.845	0.995	1.137	0.025	1.511	0.025
	18	6.601	-17.116	40.889	7.337	-15.937	40.952	0.735	1.179	0.063	1.391	0.063
	19	7.170	-10.433	41.010	7.741	-9.227	41.014	0.571	1.206	0.005	1.334	0.005
	20	7.222	-6.659	41.031	7.582	-5.434	41.058	0.360	1.226	0.027	1.278	0.027
	21	-3.518	-29.028	43.553	-2.184	-28.224	43.504	1.334	0.805	-0.049	1.559	-0.049
	22	-2.604	-21.671	44.037	-1.603	-20.825	43.992	1.001	0.846	-0.045	1.312	-0.045
	23	-2.061	-16.954	44.197	-1.168	-16.123	44.122	0.893	0.831	-0.076	1.222	-0.076
	24	-1.624	-13.172	44.253	-0.920	-12.274	44.198	0.705	0.898	-0.055	1.143	-0.055
	25	-1.336	-7.360	44.285	-0.918	-6.441	44.241	0.418	0.919	-0.044	1.010	-0.044
	26	-7.096	-28.187	44.115	-5.796	-27.575	44.035	1.299	0.612	-0.079	1.438	-0.079
	27	-6.350	-21.357	44.538	-5.286	-20.723	44.460	1.064	0.635	-0.078	1.241	-0.078
	28	-5.752	-16.472	44.703	-4.970	-15.816	44.636	0.782	0.655	-0.066	1.022	-0.066
	29	-5.267	-12.626	44.763	-4.636	-11.942	44.693	0.630	0.684	-0.070	0.933	-0.070
	30	-4.952	-7.164	44.785	-4.533	-6.414	44.719	0.419	0.750	-0.066	0.862	-0.066
A PILLAR	31	4.154	-34.017	38.358	5.571	-32.917	38.391	1.417	1.101	0.033	1.795	1.101
	32	9.152	-35.100	35.621	10.625	-33.814	35.665	1.473	1.286	0.044	1.956	1.286
	33	15.181	-36.383	31.468	16.795	-34.890	31.541	1.614	1.494	0.073	2.201	1.494
	34	19.063	-37.176	28.404	20.741	-35.540	28.542	1.677	1.636	0.137	2.347	1.636
B PILLAR	35	-22.919	-38.621	21.202	-20.539	-38.450	21.059	2.380	0.171	-0.142	2.390	0.171
	36	-19.309	-38.559	21.398	-16.944	-38.206	21.280	2.365	0.353	-0.118	2.394	0.353
	37	-23.146	-37.942	27.538	-20.876	-37.800	27.463	2.270	0.143	-0.076	2.276	0.143
	38	-20.098	-37.972	27.066	-17.810	-37.703	26.948	2.289	0.269	-0.118	2.307	0.269
	39	-23.927	-34.091	39.069	-21.929	-34.104	38.860	1.998	-0.013	-0.209	2.009	-0.013
	40	-21.029	-33.945	39.390	-19.046	-33.793	39.285	1.983	0.152	-0.105	1.992	0.152

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

Figure E-3. Occupant Compartment Deformation Data – Set 1, Test No. NJPCB-7

Date: 2/27/2018 Test Name: NJPCB-7 VIN: 1D7RB1GP7AS162701
Year: 2010 Make: Dodge Model: Ram 1500

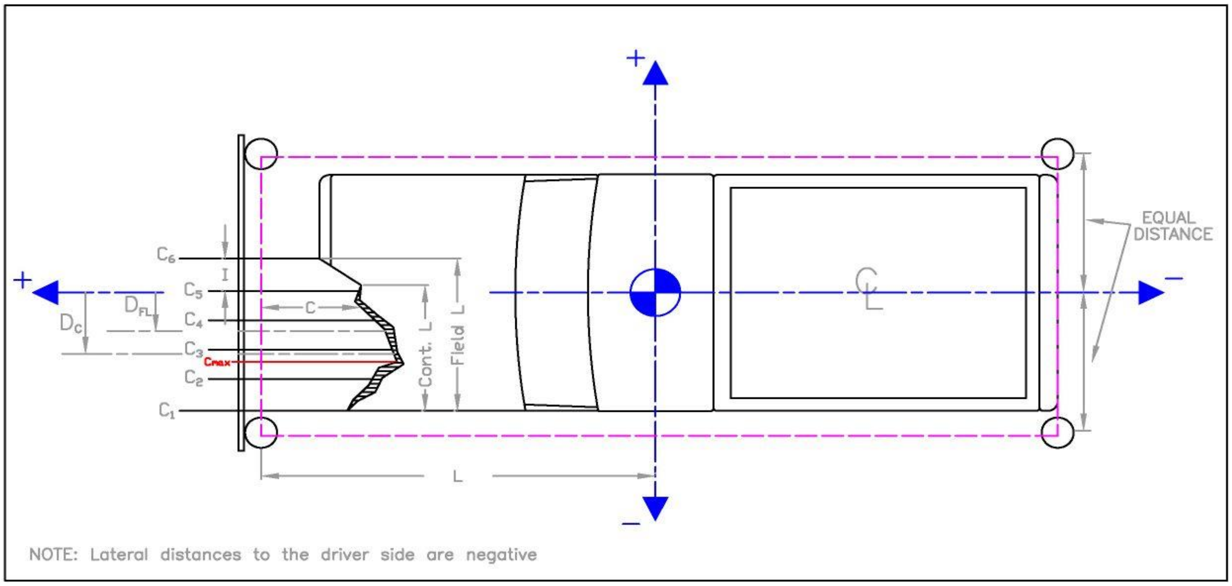
VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 2

	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	40.050	-24.777	28.462	40.842	-24.635	28.051	0.791	0.142	-0.411	0.903	0.903
	2	41.903	-15.809	26.156	42.527	-15.661	25.744	0.624	0.148	-0.412	0.762	0.762
	3	38.670	-6.148	25.873	39.082	-6.017	25.534	0.412	0.132	-0.339	0.549	0.549
	4	37.222	-25.132	13.786	38.016	-24.877	13.364	0.794	0.254	-0.422	0.935	0.935
	5	38.242	-16.346	13.129	38.900	-16.116	12.641	0.657	0.229	-0.487	0.850	0.850
	6	35.750	-6.334	14.251	36.166	-6.181	13.907	0.417	0.153	-0.344	0.562	0.562
SIDE PANEL	7	49.104	-38.396	5.472	50.118	-37.482	5.072	1.014	0.914	-0.400	1.422	0.914
	8	49.310	-38.243	1.325	50.349	-37.213	0.896	1.038	1.029	-0.428	1.524	1.029
	9	52.176	-38.347	4.902	53.251	-37.361	4.409	1.075	0.986	-0.494	1.540	0.986
IMPACT SIDE DOOR	10	14.004	-40.315	22.800	15.142	-42.245	22.340	1.138	-1.930	-0.460	2.287	-1.930
	11	26.752	-40.037	22.269	27.867	-41.216	21.780	1.115	-1.179	-0.489	1.695	-1.179
	12	40.032	-39.891	21.698	41.084	-40.217	21.207	1.052	-0.325	-0.491	1.206	-0.325
	13	18.454	-41.571	3.998	19.570	-41.950	3.481	1.116	-0.379	-0.517	1.287	-0.379
	14	26.659	-41.669	3.342	27.720	-41.741	2.801	1.061	-0.072	-0.541	1.193	-0.072
	15	34.040	-41.475	0.915	35.202	-41.096	0.312	1.162	0.379	-0.603	1.363	0.379
ROOF	16	31.959	-28.706	41.604	32.946	-28.843	41.199	0.987	-0.137	-0.405	1.076	-0.405
	17	33.808	-21.526	41.796	34.634	-21.556	41.446	0.826	-0.031	-0.350	0.898	-0.350
	18	34.557	-16.991	41.869	35.601	-16.648	41.560	1.044	0.343	-0.309	1.142	-0.309
	19	35.108	-10.278	42.013	35.997	-10.021	41.709	0.889	0.257	-0.303	0.974	-0.303
	20	35.112	-6.506	42.075	35.908	-6.214	41.777	0.796	0.292	-0.298	0.899	-0.298
	21	24.565	-28.843	44.746	26.045	-28.971	44.341	1.480	-0.128	-0.405	1.540	-0.405
	22	25.433	-21.484	45.248	26.684	-21.549	44.890	1.251	-0.065	-0.358	1.303	-0.358
	23	25.971	-16.836	45.413	27.162	-16.898	45.050	1.191	-0.062	-0.363	1.247	-0.363
	24	26.454	-13.079	45.463	27.432	-13.078	45.157	0.978	0.001	-0.306	1.025	-0.306
	25	26.643	-7.275	45.533	27.496	-7.261	45.257	0.853	0.014	-0.275	0.897	-0.275
	26	21.073	-28.169	45.379	22.507	-28.326	44.996	1.434	-0.157	-0.383	1.492	-0.383
	27	21.782	-21.245	45.833	22.992	-21.383	45.494	1.210	-0.138	-0.339	1.264	-0.339
	28	22.312	-16.343	46.013	23.367	-16.620	45.702	1.055	-0.277	-0.311	1.134	-0.311
	29	22.875	-12.529	46.066	23.786	-12.653	45.781	0.912	-0.124	-0.284	0.963	-0.284
	30	23.109	-7.024	46.118	23.837	-7.135	45.871	0.728	-0.111	-0.247	0.777	-0.247
A PILLAR	31	32.076	-33.838	39.304	33.745	-33.579	38.829	1.669	0.259	-0.474	1.754	0.259
	32	37.040	-34.905	36.402	38.724	-34.467	35.942	1.684	0.438	-0.460	1.800	0.438
	33	42.909	-36.151	32.164	44.712	-35.510	31.574	1.803	0.641	-0.590	2.002	0.641
	34	46.656	-36.907	29.022	48.492	-36.134	28.493	1.836	0.773	-0.529	2.061	0.773
B PILLAR	35	4.549	-38.446	22.862	6.434	-38.869	22.425	1.885	-0.423	-0.437	1.980	-0.423
	36	8.191	-38.376	22.971	9.997	-38.682	22.531	1.806	-0.306	-0.440	1.884	-0.306
	37	4.515	-37.781	29.302	6.419	-38.306	28.812	1.905	-0.525	-0.490	2.036	-0.525
	38	7.546	-37.809	28.701	9.416	-38.227	28.243	1.871	-0.418	-0.458	1.971	-0.418
	39	4.052	-34.006	40.765	5.817	-34.694	40.379	1.765	-0.688	-0.385	1.933	-0.688
	40	6.879	-33.847	41.044	8.633	-34.448	40.656	1.754	-0.601	-0.387	1.895	-0.601

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

Figure E-4. Occupant Compartment Deformation Data – Set 2, Test No. NJPCB-7

Date:	7/13/2017	Test Name:	NJPCB-7	VIN:	1D7RB1GP7AS162701
Year:	2010	Make:	Dodge	Model:	Ram 1500



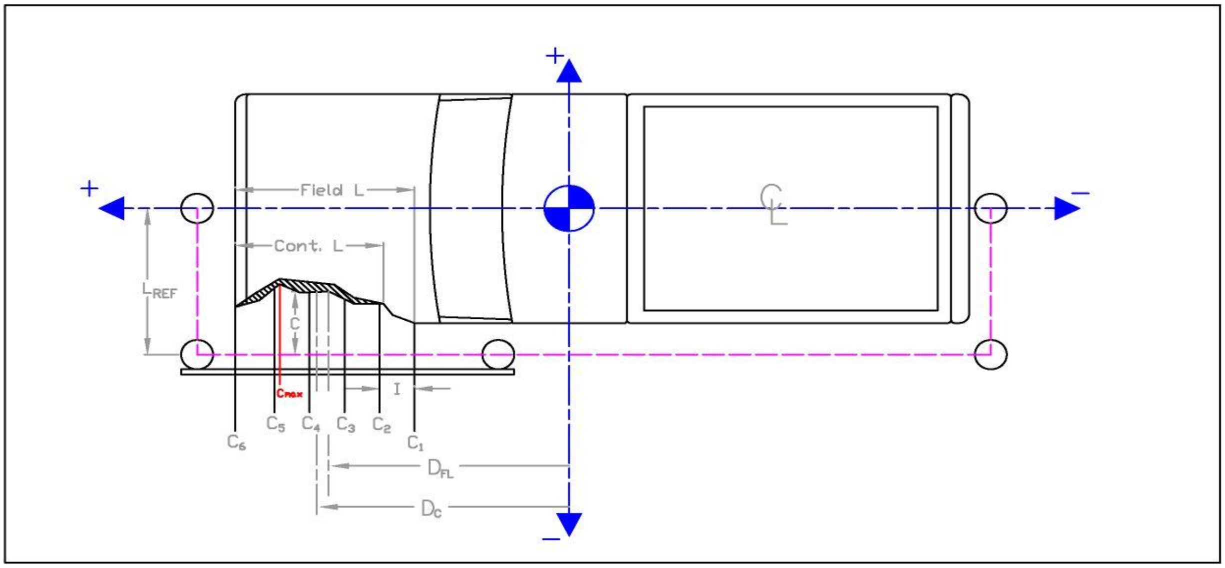
	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	108 1/4	(2750)
Total Vehicle Width:	77 1/2	(1969)
Width of contact and induced crush - Field L:	58 1/8	(1476)
Crush measurement spacing interval (L/5) - I:	11 5/8	(295)
Distance from center of vehicle to center of Field L - D_{FL}:	-9 3/4	-(248)
Width of Contact Damage:	19 3/8	(492)
Distance from center of vehicle to center of contact damage - D_C:	-29	-(737)

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 7/8	-(987)	22 1/2	(572)	1 7/8	(48)	NA	NA
C_2	NA	NA	-27 1/4	-(692)	7 5/8	(194)			NA	NA
C_3	9 7/8	(251)	-15 5/8	-(397)	5	(127)			3	(76)
C_4	6 1/8	(156)	-4	-(102)	4	(102)			1/4	(6)
C_5	6	(152)	7 5/8	(194)	4 1/4	(108)			- 1/8	-(3)
C_6	7 1/4	(184)	19 1/4	(489)	5 1/2	(140)			- 1/8	-(3)
C_{MAX}	27 3/4	(705)	-27 1/4	-(692)	7 5/8	(194)			18 1/4	(464)

Figure E-5. Exterior Vehicle Crush (NASS) - Front, Test No. NJPCB-7

Date:	7/13/2017	Test Name:	NJPCB-7	VIN:	1D7RB1GP7AS162701
Year:	2010	Make:	Dodge	Model:	Ram 1500



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	45	(1143)
Total Vehicle Length:	228 3/4	(5810)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-12	-(305)
Width of contact and induced crush - Field L:	228 3/4	(5810)
Crush measurement spacing interval (L/5) - I:	45 3/4	(1162)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-12	-(305)
Width of Contact Damage:	228 3/4	(5810)
Distance from vehicle c.g. to center of contact damage - D_C:	-12	-(305)

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	NA	NA	-126 3/8	-(3210)	33 1/2	(851)	1	(25)	NA	NA
C_2	6 7/8	(175)	-80 5/8	-(2048)	5 1/4	(133)			5/8	(16)
C_3	5	(127)	-34 7/8	-(886)	5 1/2	(140)			-1 1/2	-(38)
C_4	3 7/8	(98)	10 7/8	(276)	5 1/8	(130)			-2 1/4	-(57)
C_5	9	(229)	56 5/8	(1438)	5	(127)			3	(76)
C_6	NA	NA	102 3/8	(2600)	33 1/2	(851)			NA	NA
C_{MAX}	19 7/8	(505)	73 3/8	(1864)	5 1/4	(133)			13 5/8	(346)

Figure E-6. Exterior Vehicle Crush (NASS) - Side, Test No. NJPCB-7

Appendix F. Accelerometer and Rate Transducer Data Plots

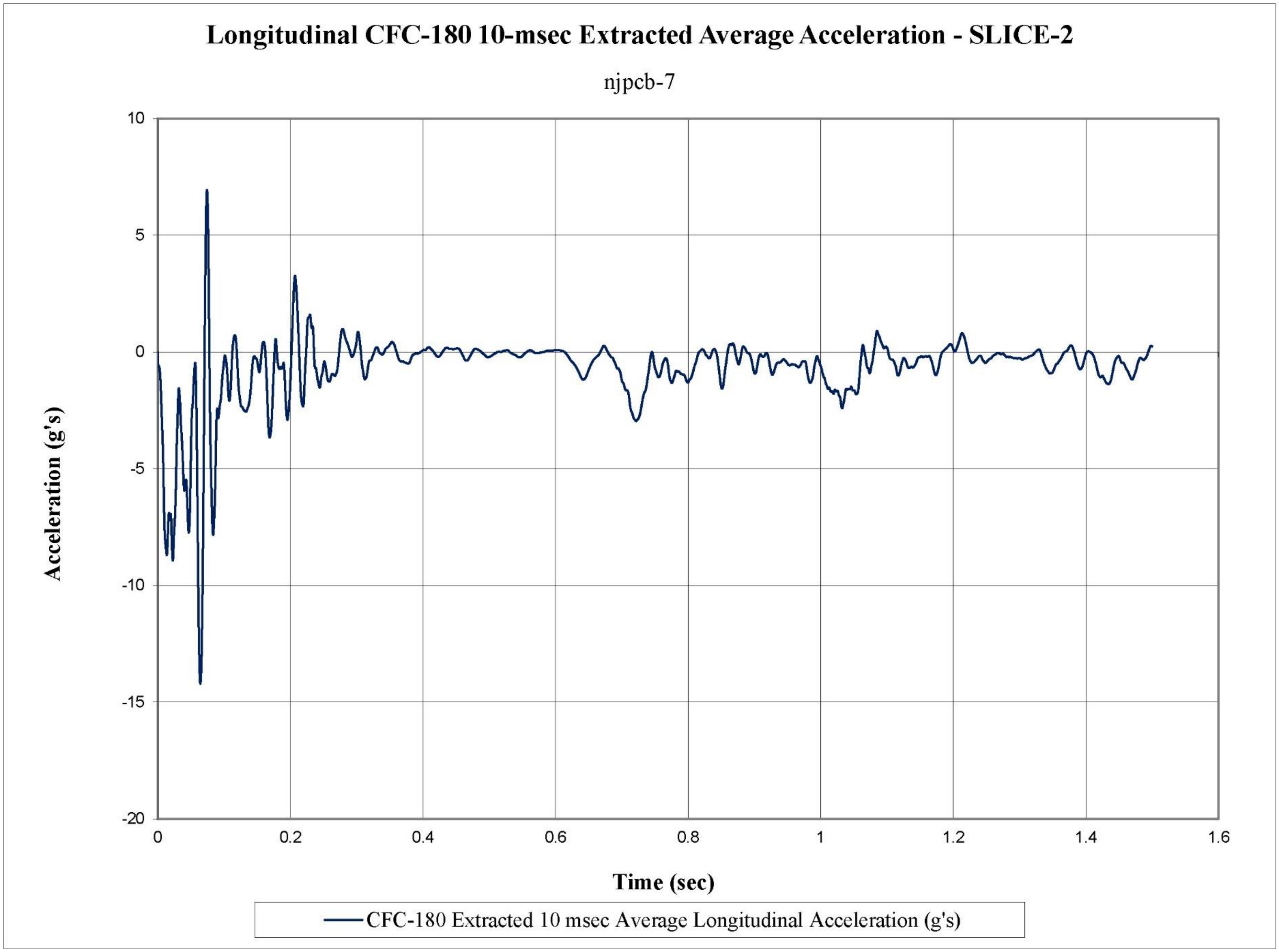


Figure F-1. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. NJPCB-7

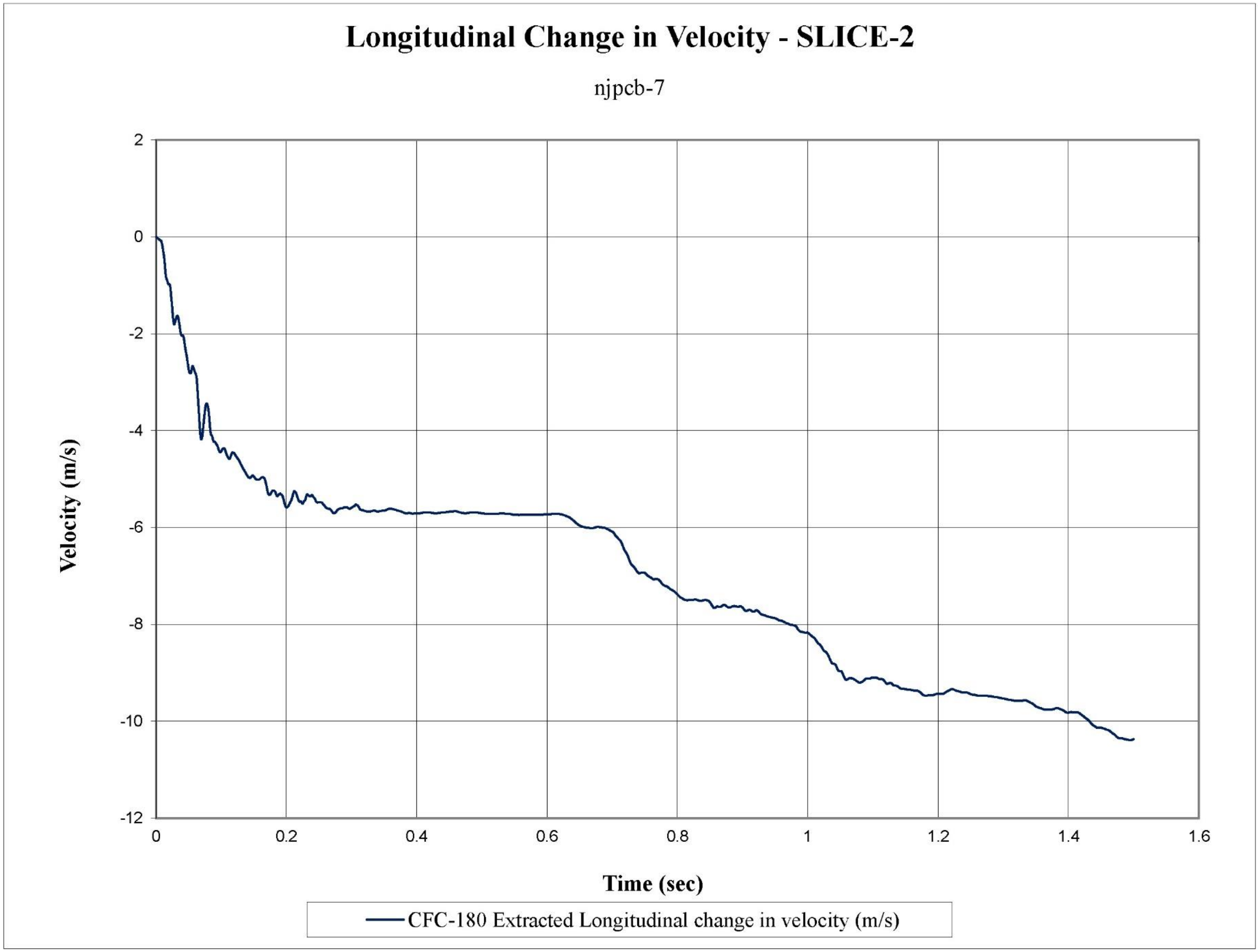


Figure F-2. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. NJPCB-7

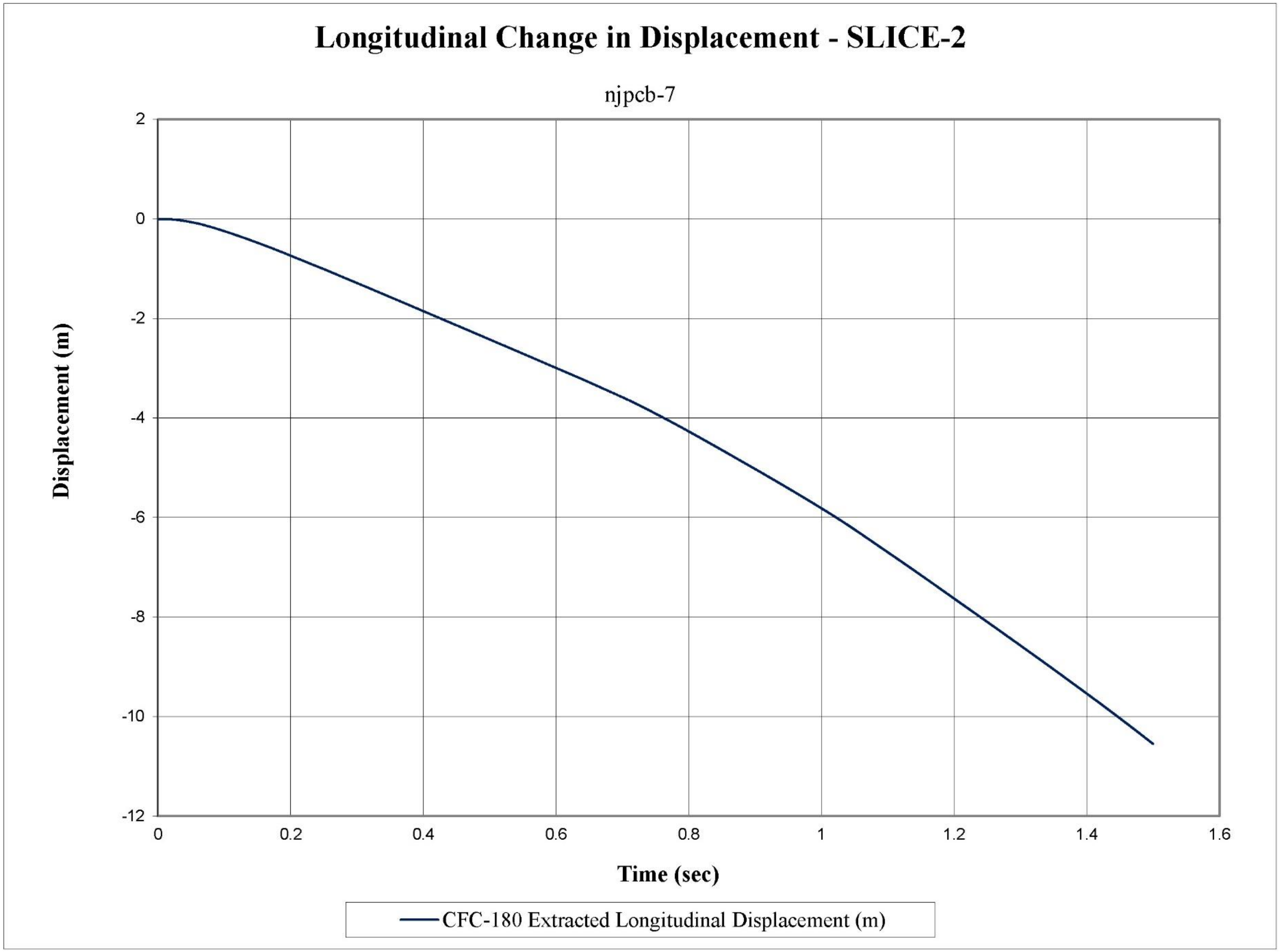


Figure F-3. Longitudinal Occupant Displacement (SLICE-2), Test No. NJPCB-7

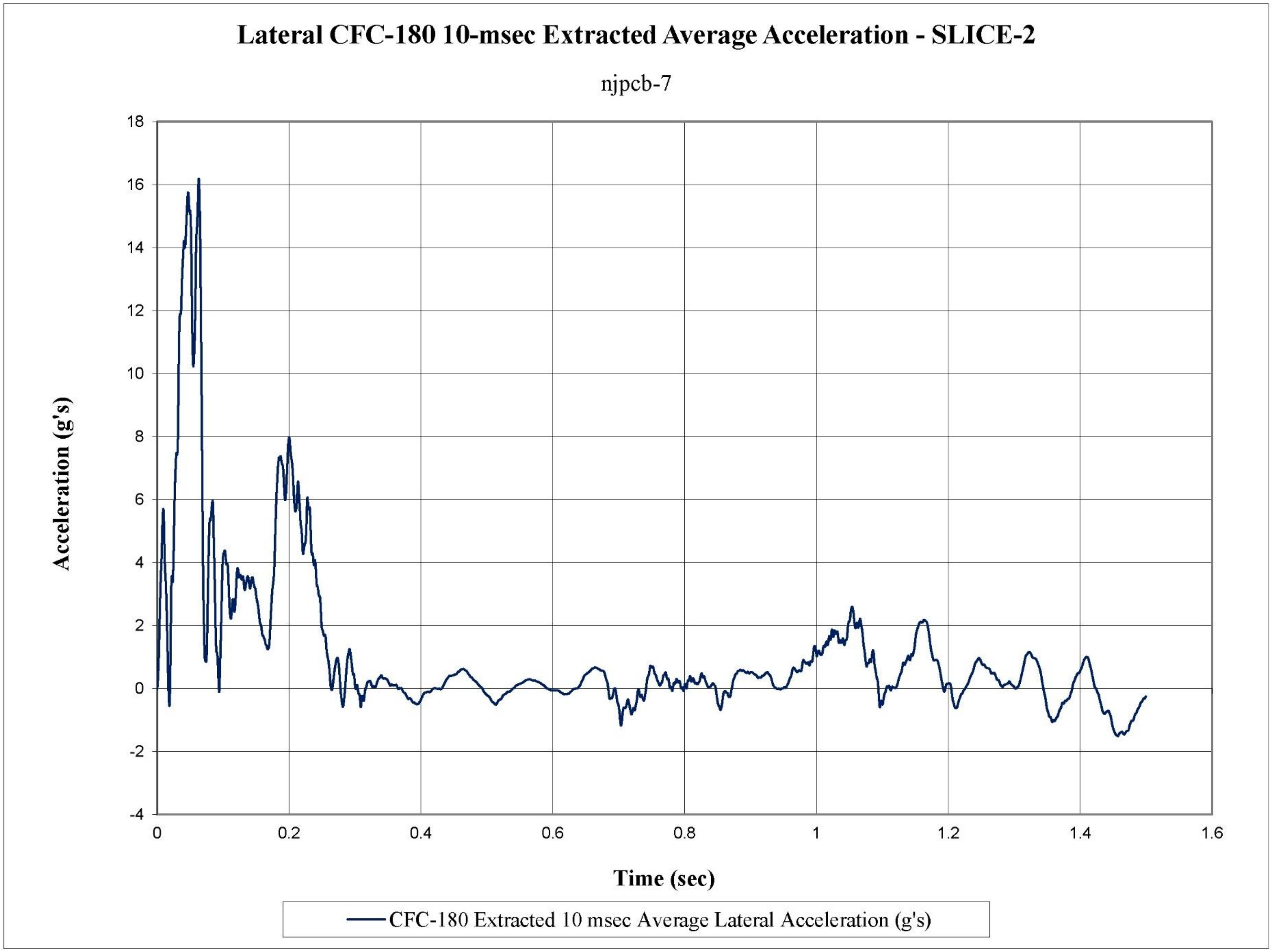


Figure F-4. 10-ms Average Lateral Deceleration (SLICE-2), Test No. NJPCB-7

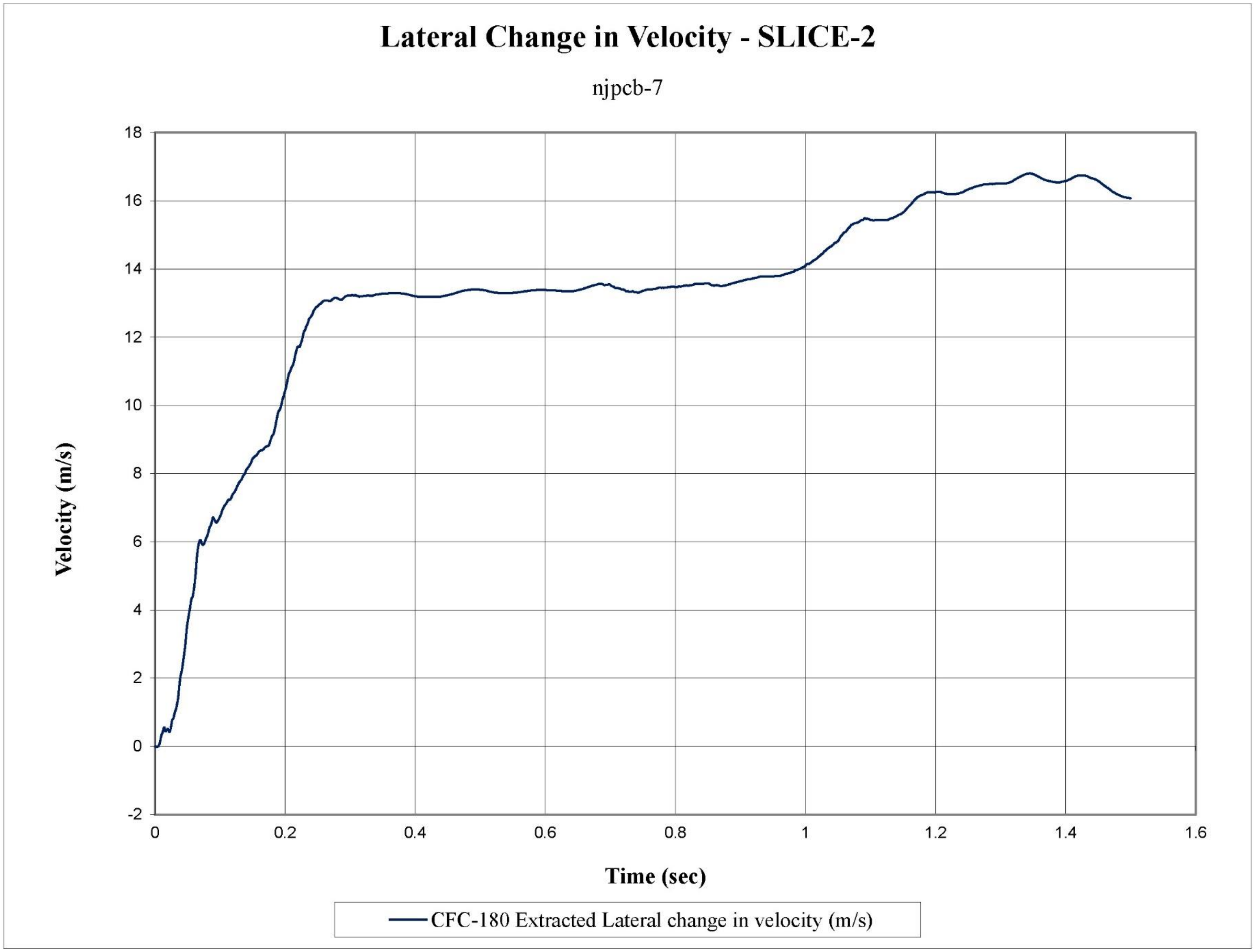


Figure F-5. Lateral Occupant Impact Velocity (SLICE-2), Test No. NJPCB-7

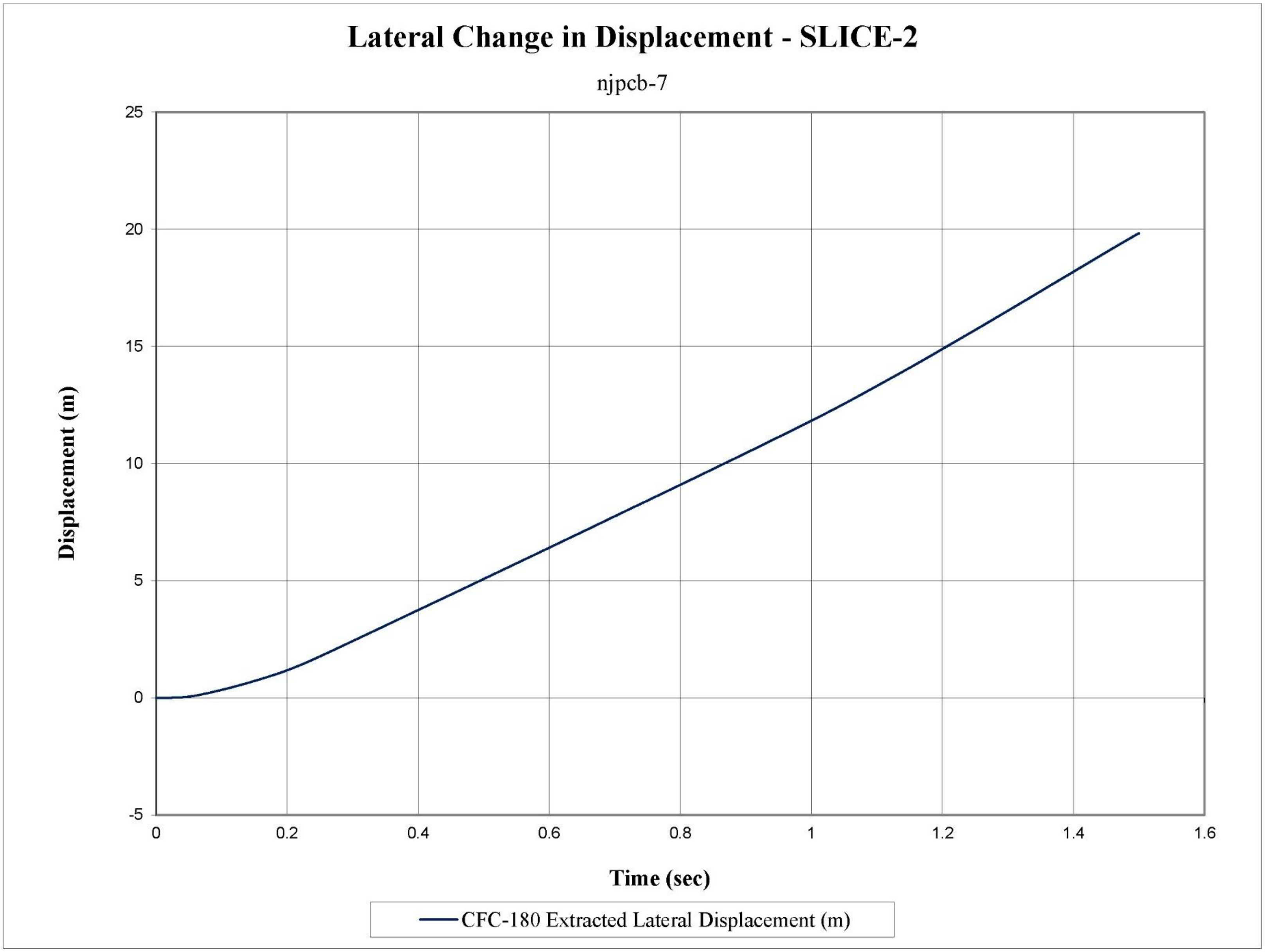


Figure F-6. Lateral Occupant Displacement (SLICE-2), Test No. NJPCB-7

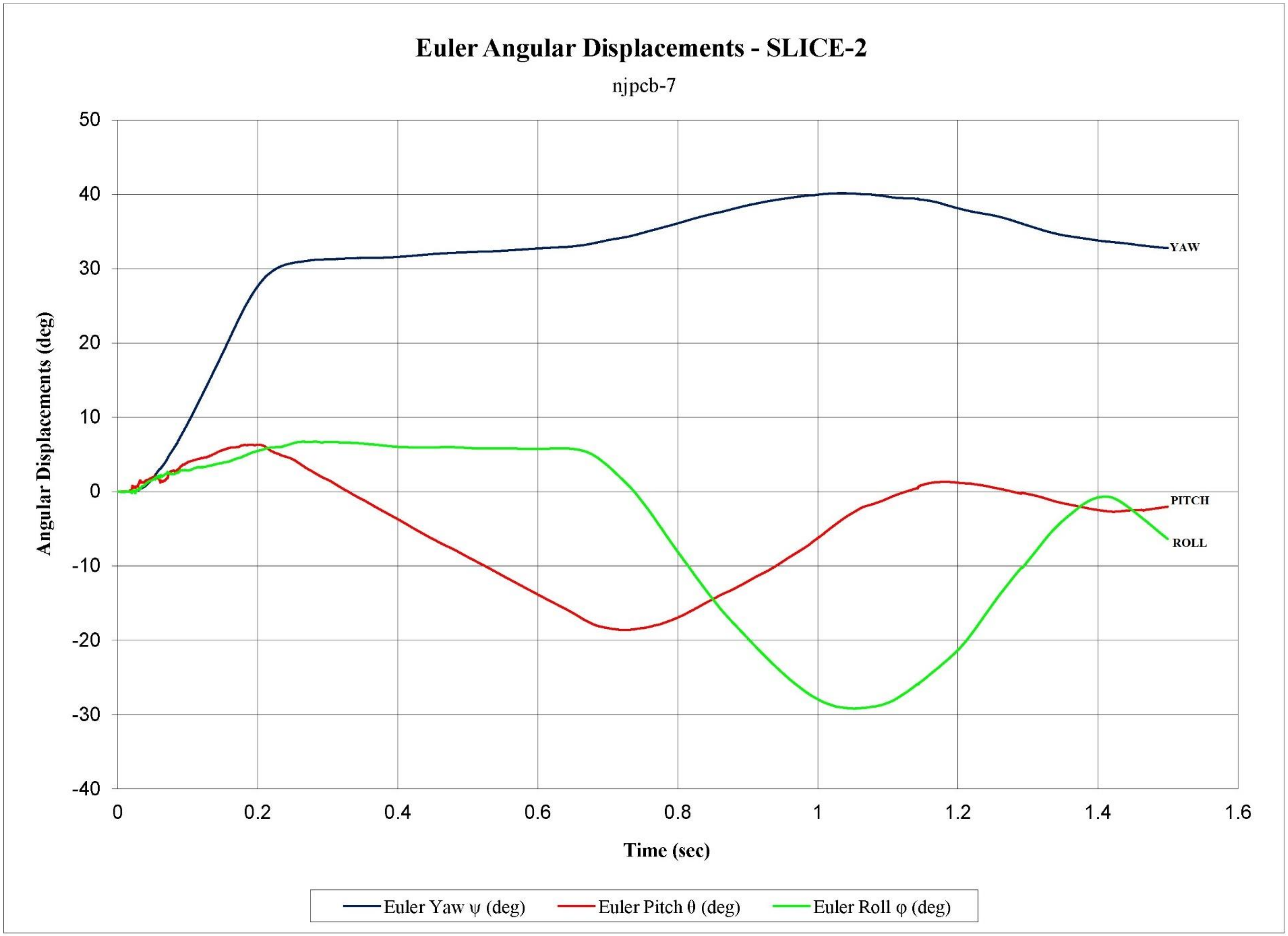


Figure F-7. Vehicle Angular Displacements (SLICE-2), Test No. NJPCB-7

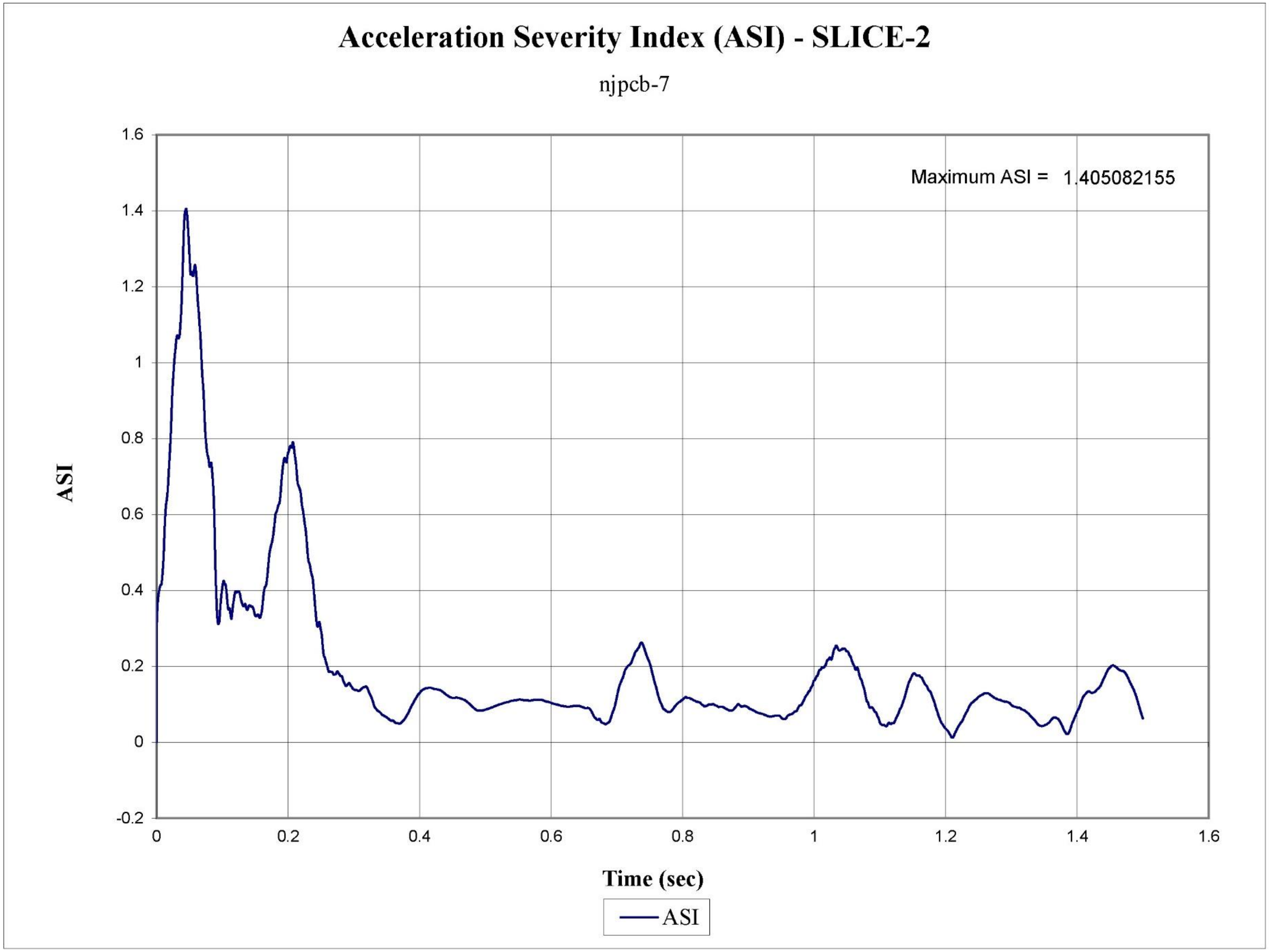


Figure F-8. Acceleration Severity Index (SLICE-2), Test No. NJPCB-7

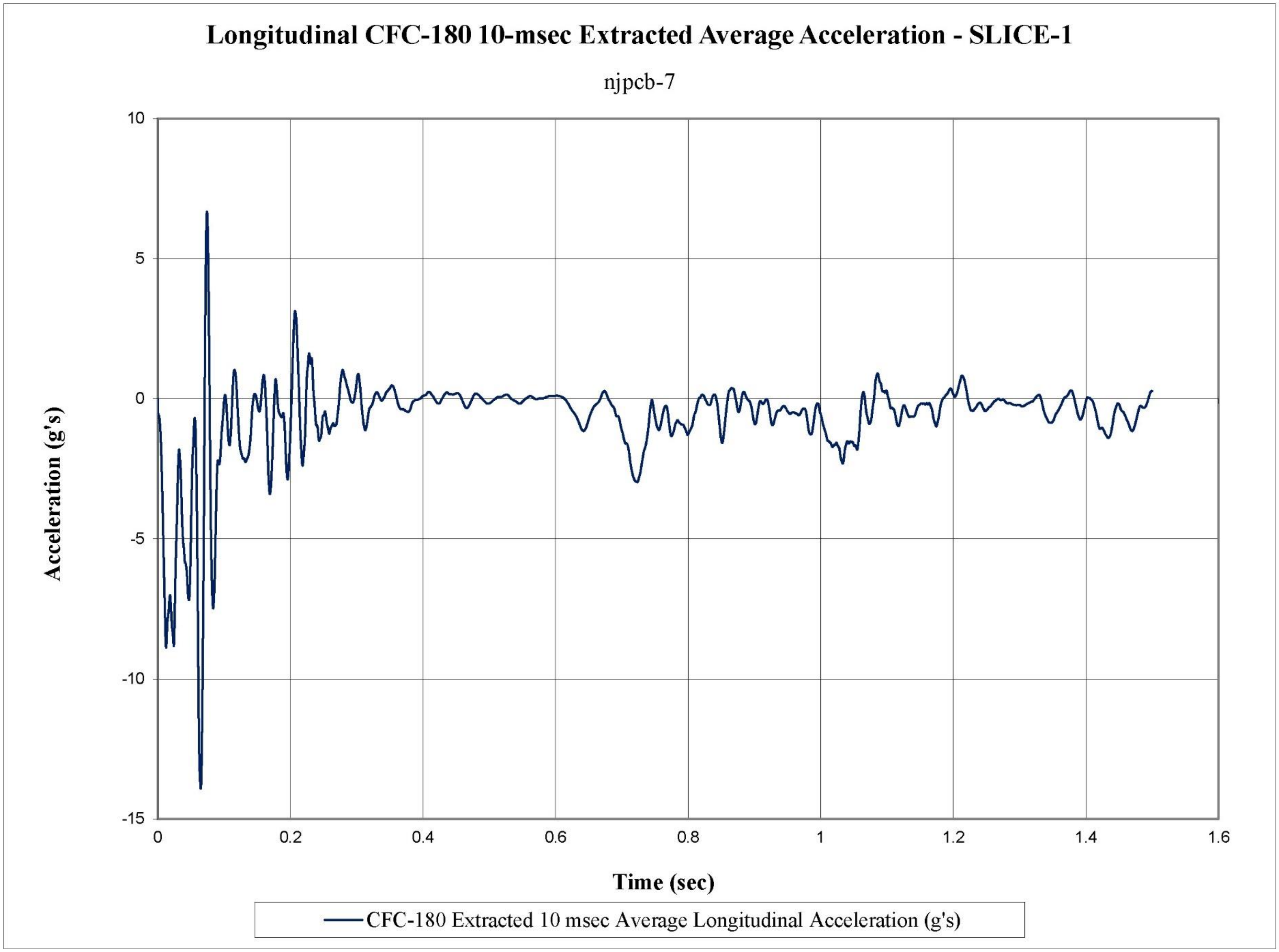


Figure F-9. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. NJPCB-7

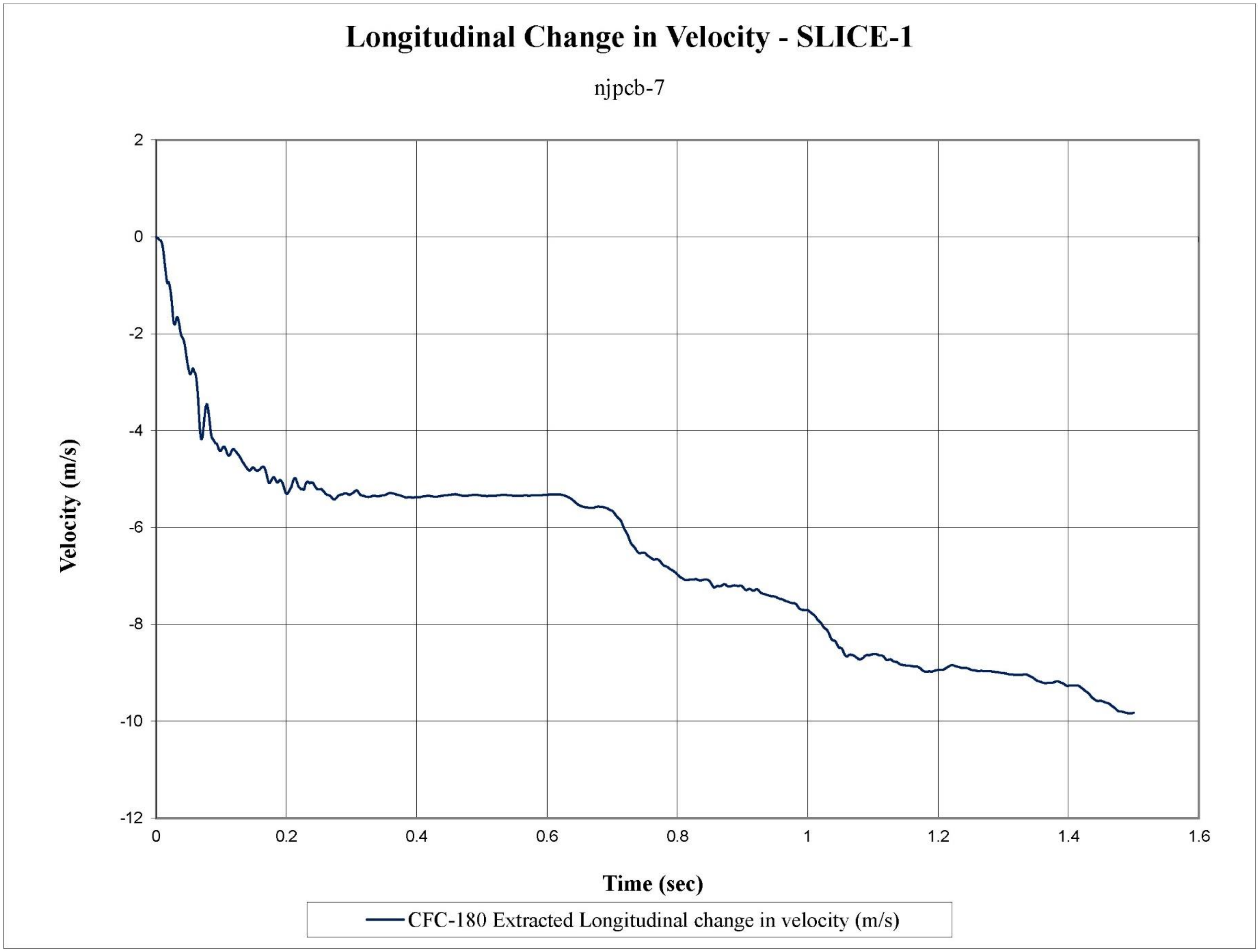


Figure F-10. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. NJPCB-7

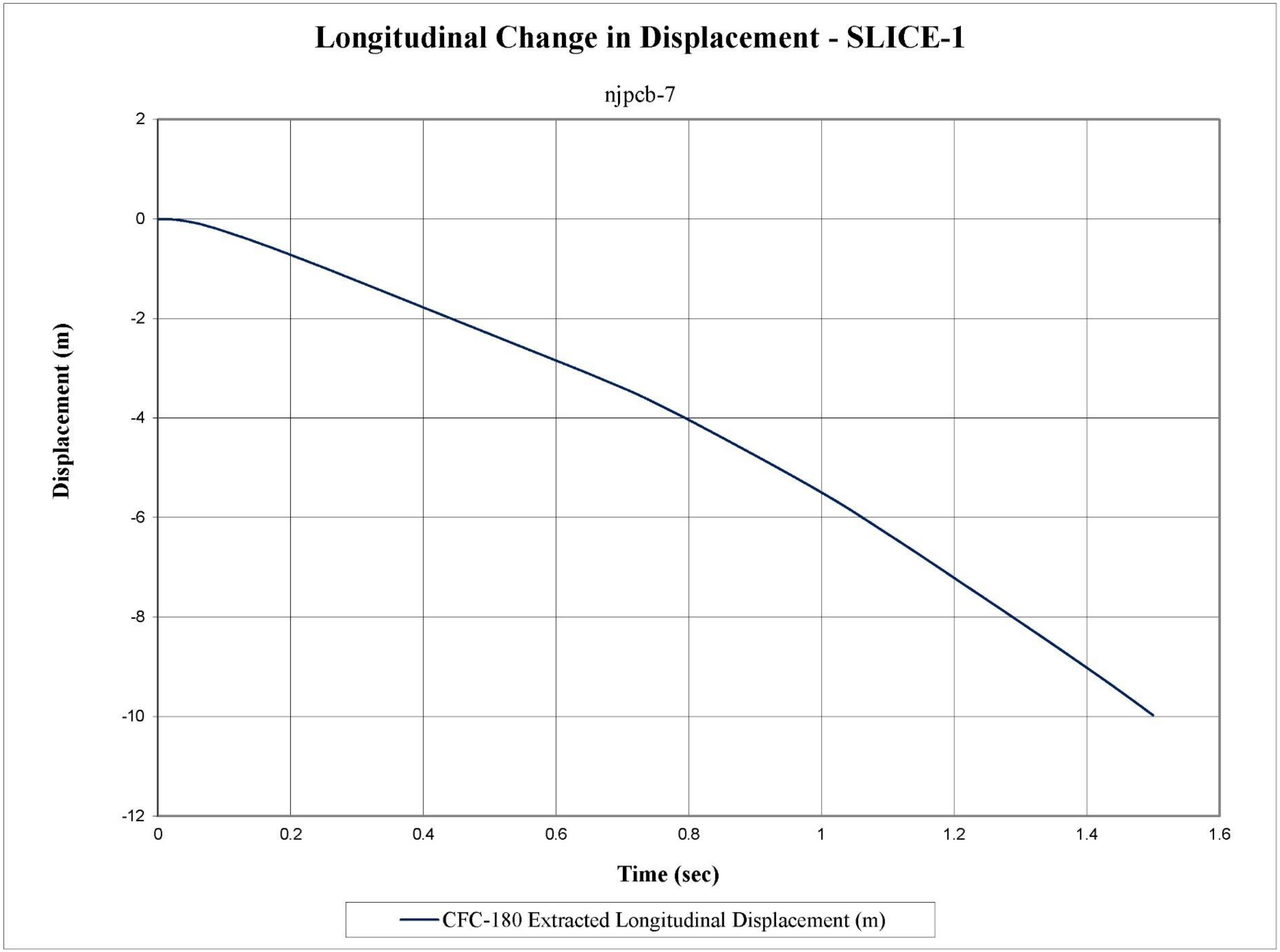


Figure F-11. Longitudinal Occupant Displacement (SLICE-1), Test No. NJPCB-7

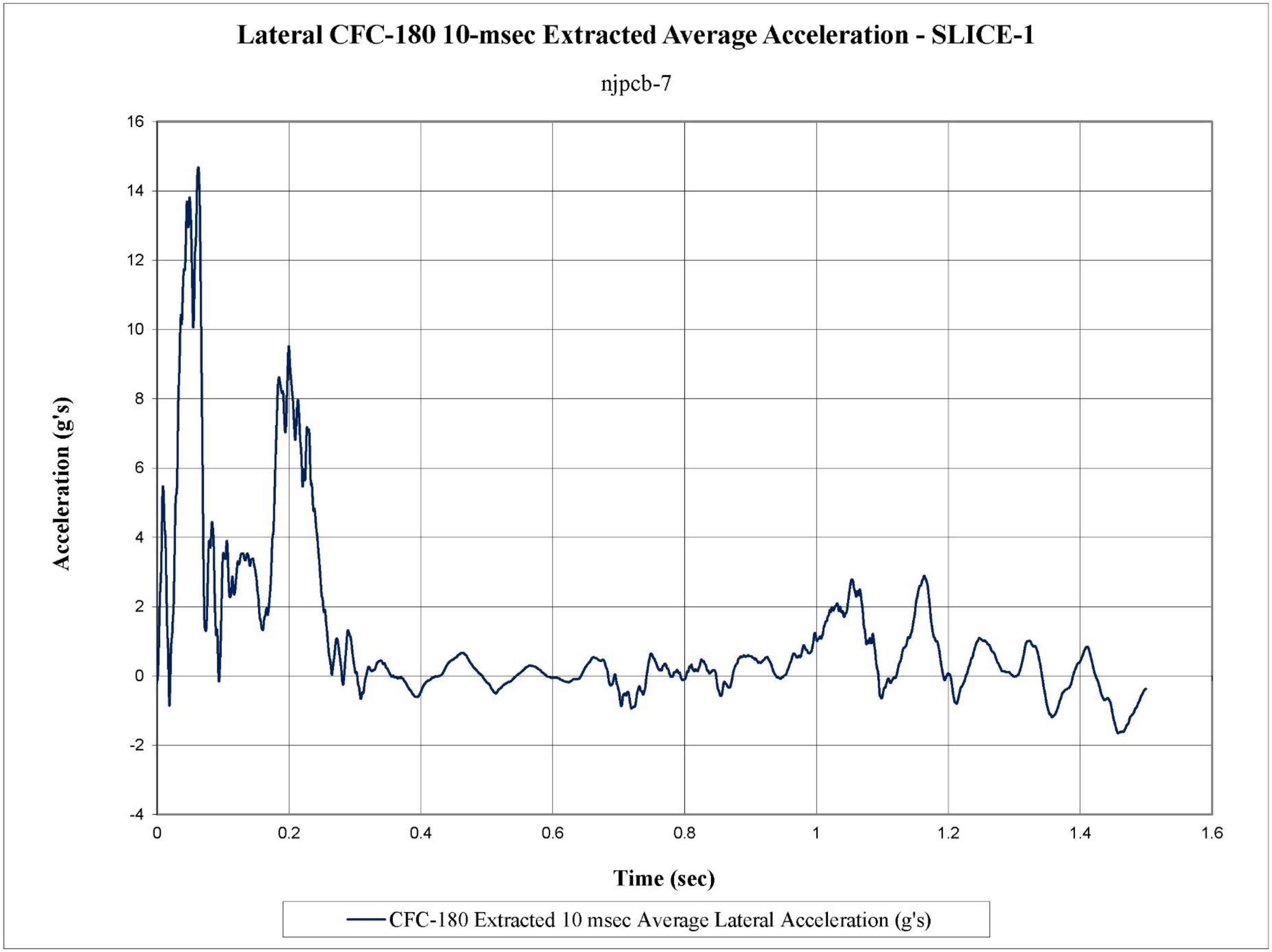


Figure F-12. 10-ms Average Lateral Deceleration (SLICE-1), Test No. NJPCB-7

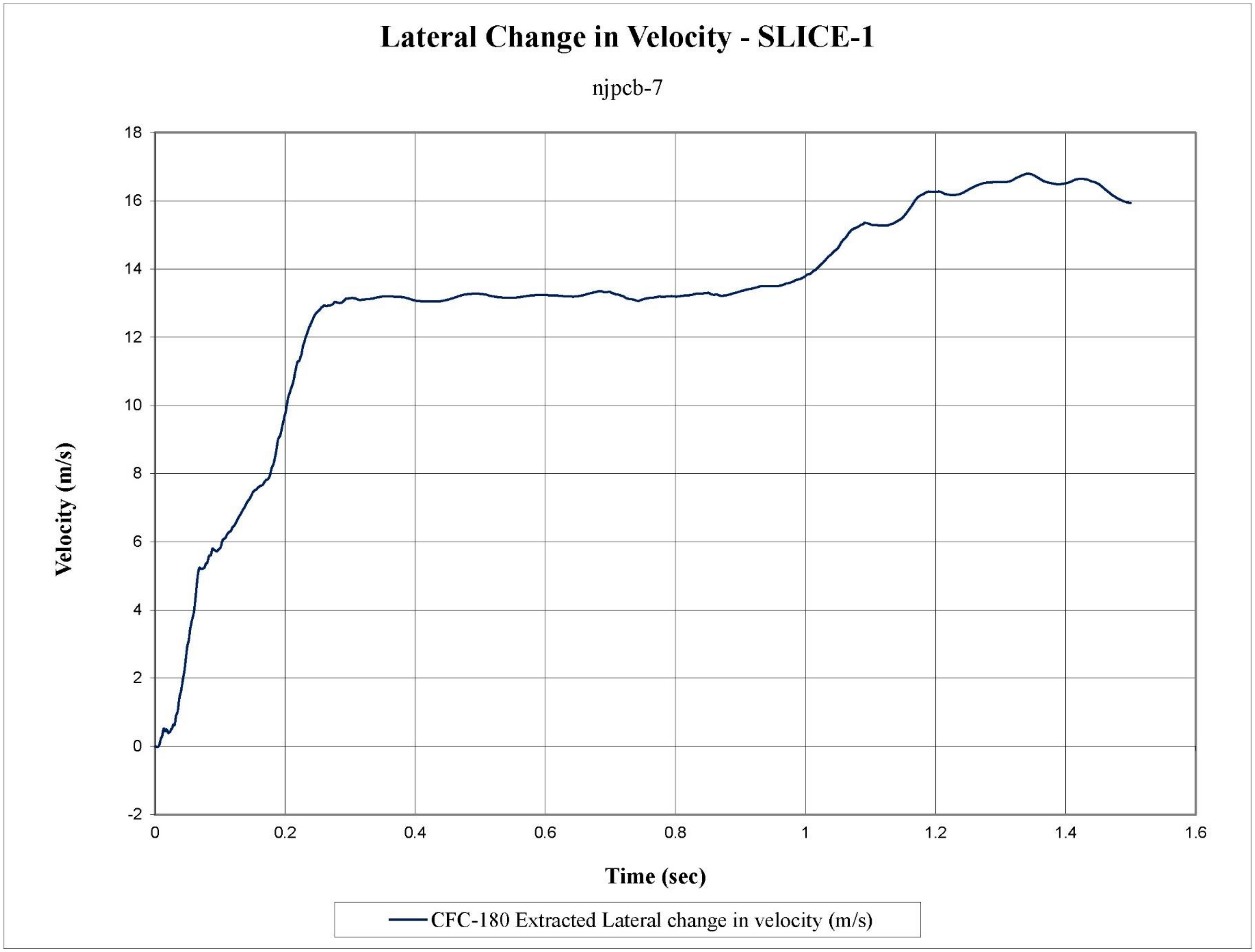


Figure F-13. Lateral Occupant Impact Velocity (SLICE-1), Test No. NJPCB-7

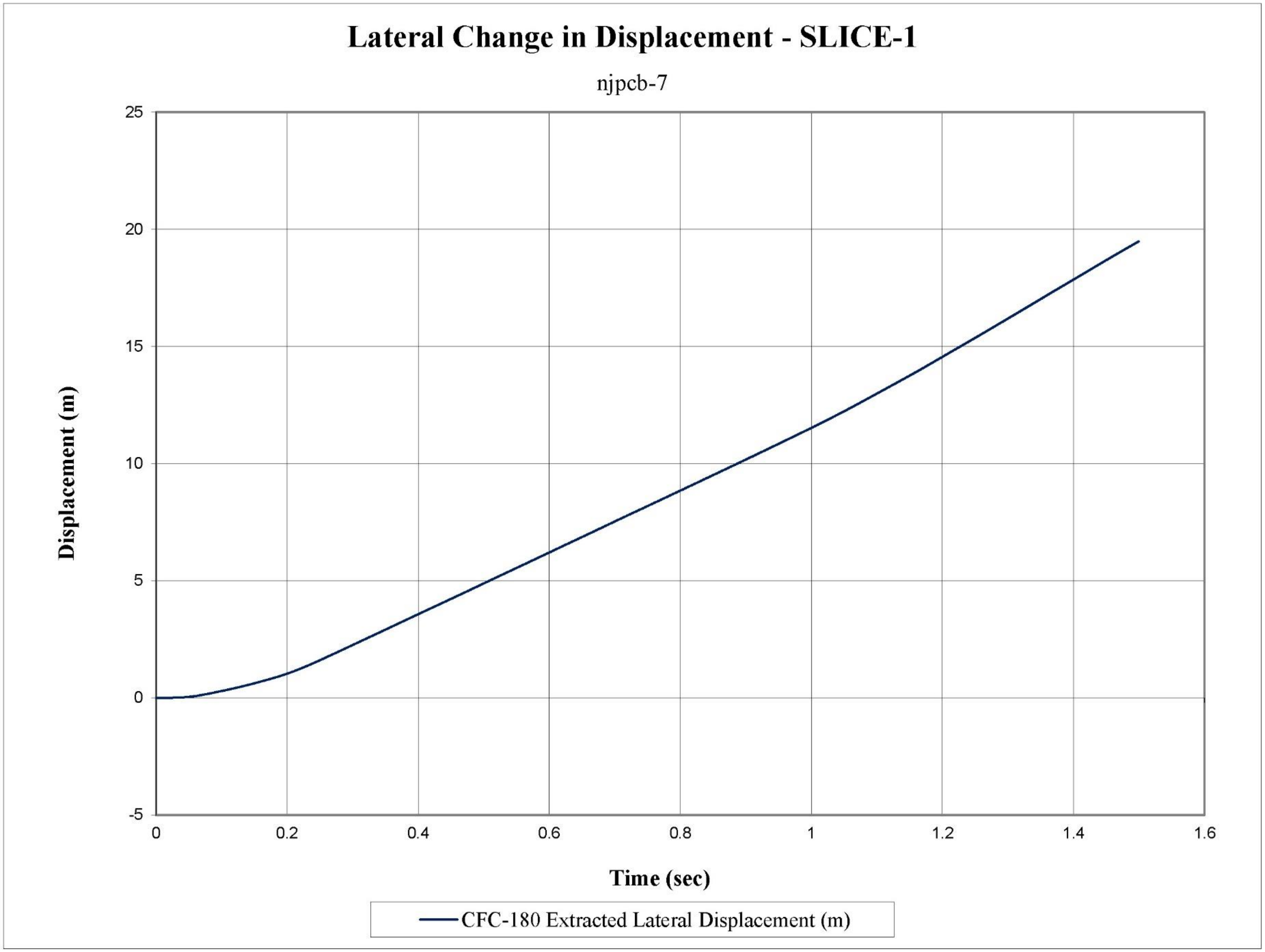


Figure F-14. Lateral Occupant Displacement (SLICE-1), Test No. NJPCB-7

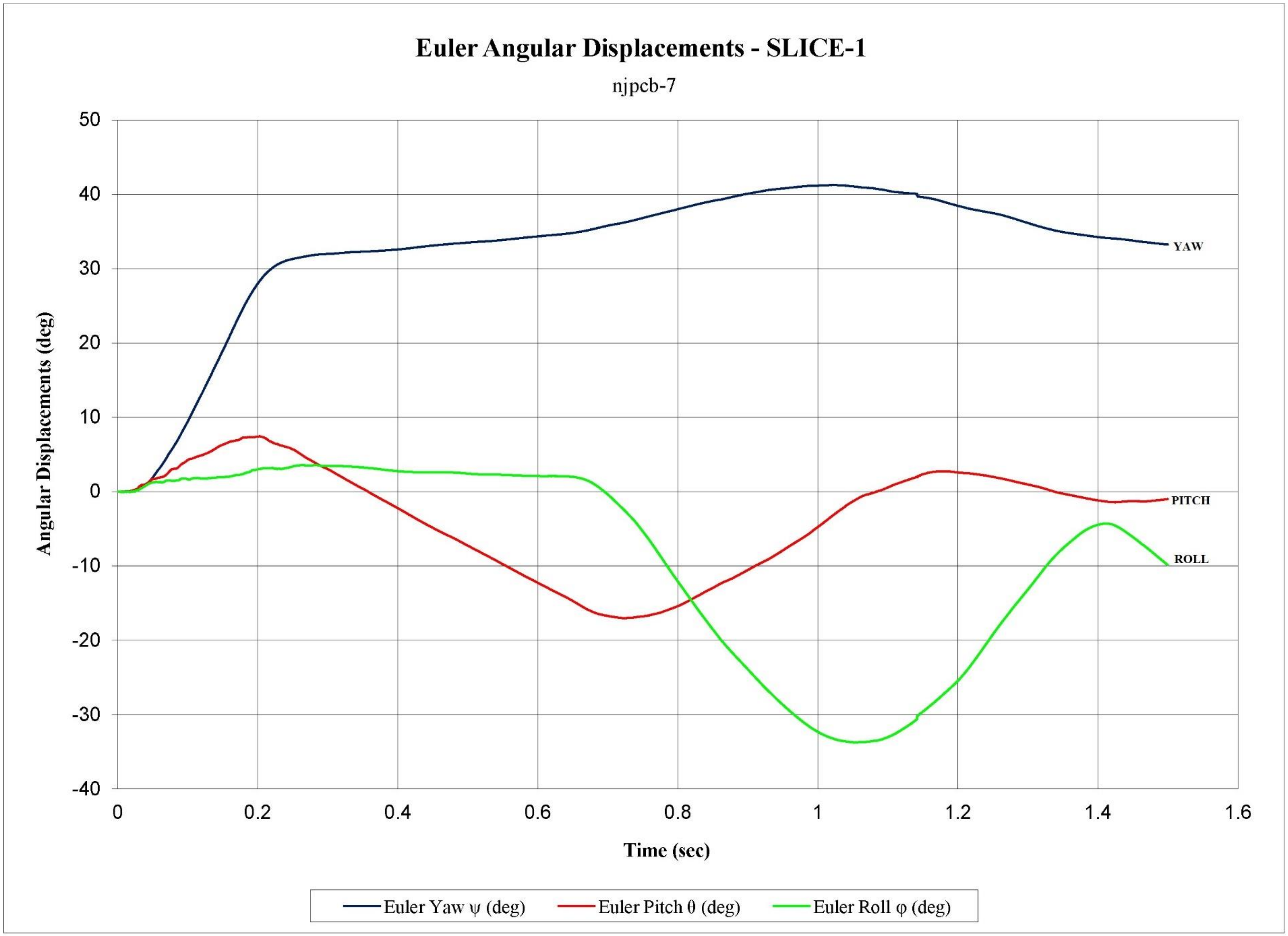


Figure F-15. Vehicle Angular Displacements (SLICE-1), Test No. NJPCB-7

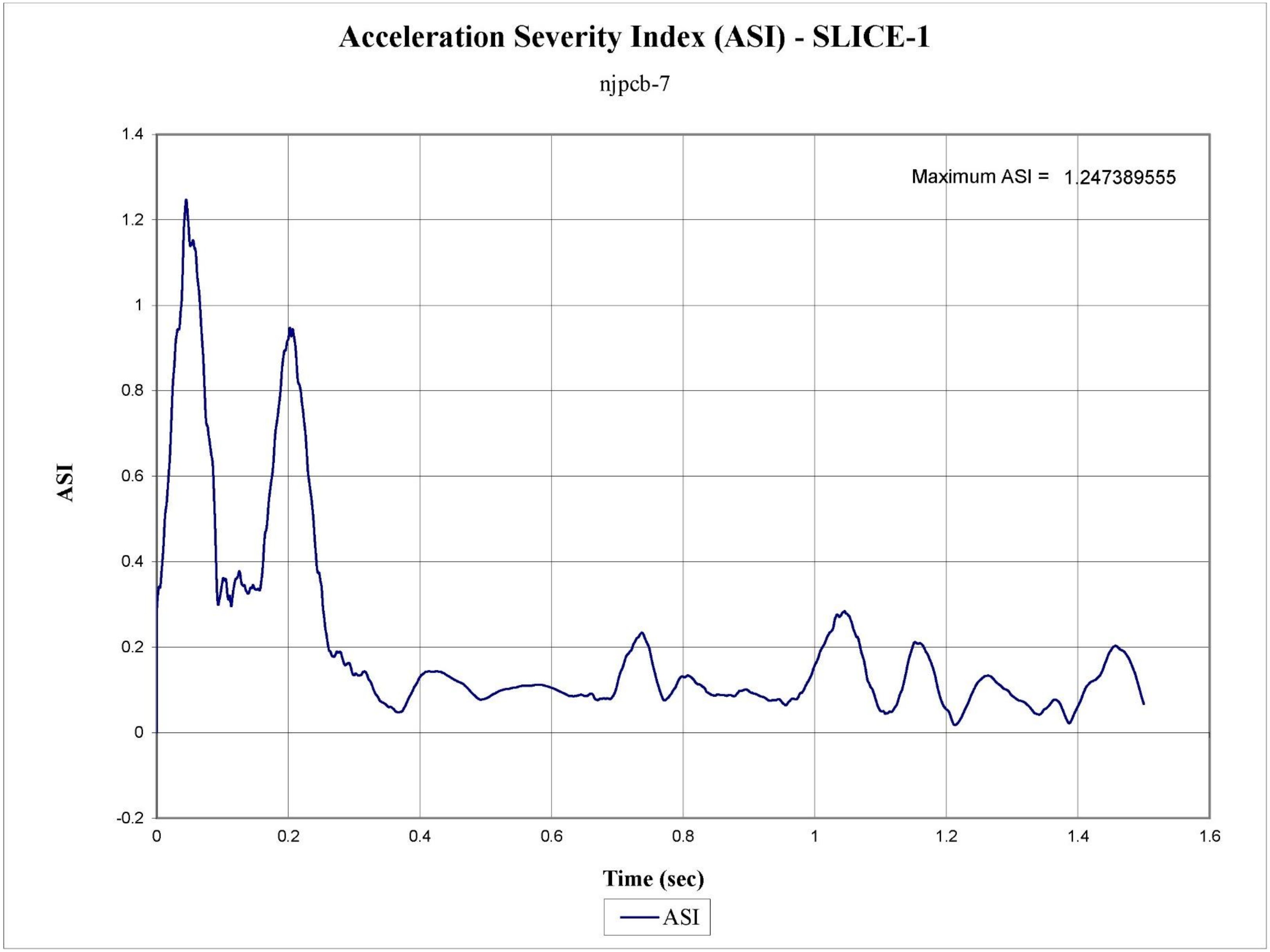


Figure F-16. Acceleration Severity Index (SLICE-1), Test No. NJPCB-7

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