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PERFORMANCE EVALUATION OF NEW JERSEY'S PORTABLE CONCRETE BARRIER WITH A BACK-SIDE PINNED CONFIGURATION AND GROUTED TOES – TEST NO. NJPCB-6

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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 sixth 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 back-side pinned configuration and grouted toes, corresponding connection type C in the 2015 NJDOT *Roadway Design Manual*. Barrier nos. 1 and 10 were anchored on both sides, and barrier nos. 2 through 9 were anchored only on the back side to the concrete tarmac 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 drilled holes in the concrete tarmac. Non-shrink grout wedges were placed at the toe of each barrier segment in every joint between adjacent barrier segments. The barrier was evaluated according to the Test Level 3 (TL-3) criteria set forth in the *Manual for Assessing Safety Hardware, 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 sixth of nine documents in the nine-test series.

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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.

ACKNOWLEDGEMENTS

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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 was to evaluate the safety performance of NJDOT's PCB, Type 4 (Alternative B) with a back-side pinned configuration and grouted toes, corresponding to connection type C in the 2015 NJDOT *Roadway Design Manual*. The system was to be 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="5">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="3">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"><table>
<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>
</table></td></tr>
<tr><td rowspan="2">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"><table>
<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></td></tr>
</table>

3 DESIGN DETAILS

The test installation consisted of ten 20-ft (6.1-m) long NJDOT PCBs with a back-side pinned configuration and grouted toes as shown in Figures 1 through 14. This system uses NJDOT barriers, Type 4 (Alternative B) with connection type C, as specified in the 2015 NJDOT *Roadway Design Manual*. Photographs of the test installation are shown in Figures 15 through 18. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix B.

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

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

Barrier nos. 1 and 10 were anchored to the concrete tarmac on the traffic side and back side, while barrier nos. 2 through 9 were anchored to the concrete tarmac on the back side only. All anchored barriers were anchored 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 in the concrete tarmac, as shown in Figures 1, 12 and 17. The steel pins were embedded to a depth of 5 in. (127 mm), as shown in Figure 1. During installation, the barrier segments were pulled in a direction parallel to their longitudinal axes, and slack was removed from all joints. After slack was removed from all the joints, 1¼-in. (32-mm) diameter holes were drilled for pin anchors at pin recess locations. Five samples of concrete tarmac were tested from five different locations of 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).

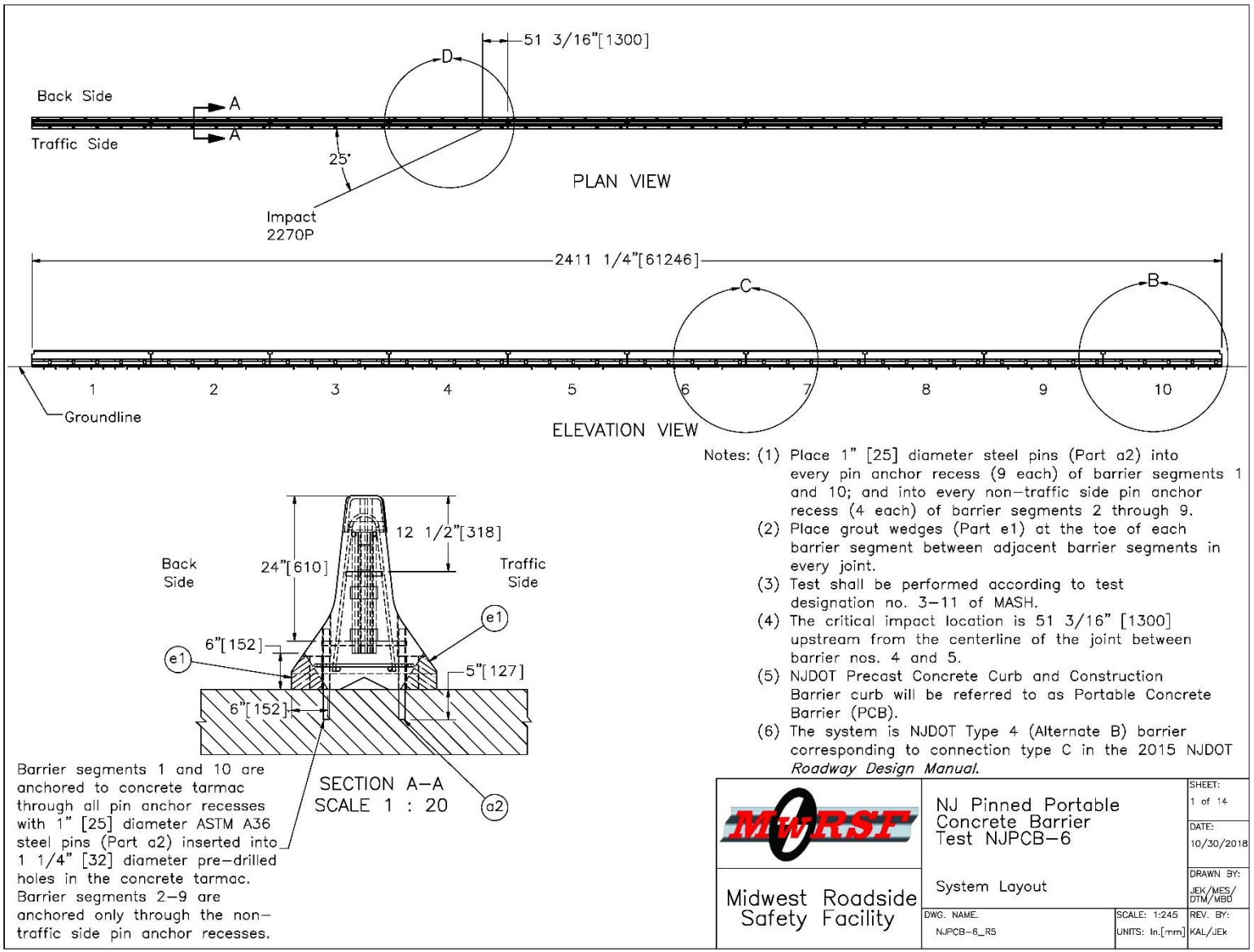


Figure 1. Test Installation Layout, Test No. NJPCB-6

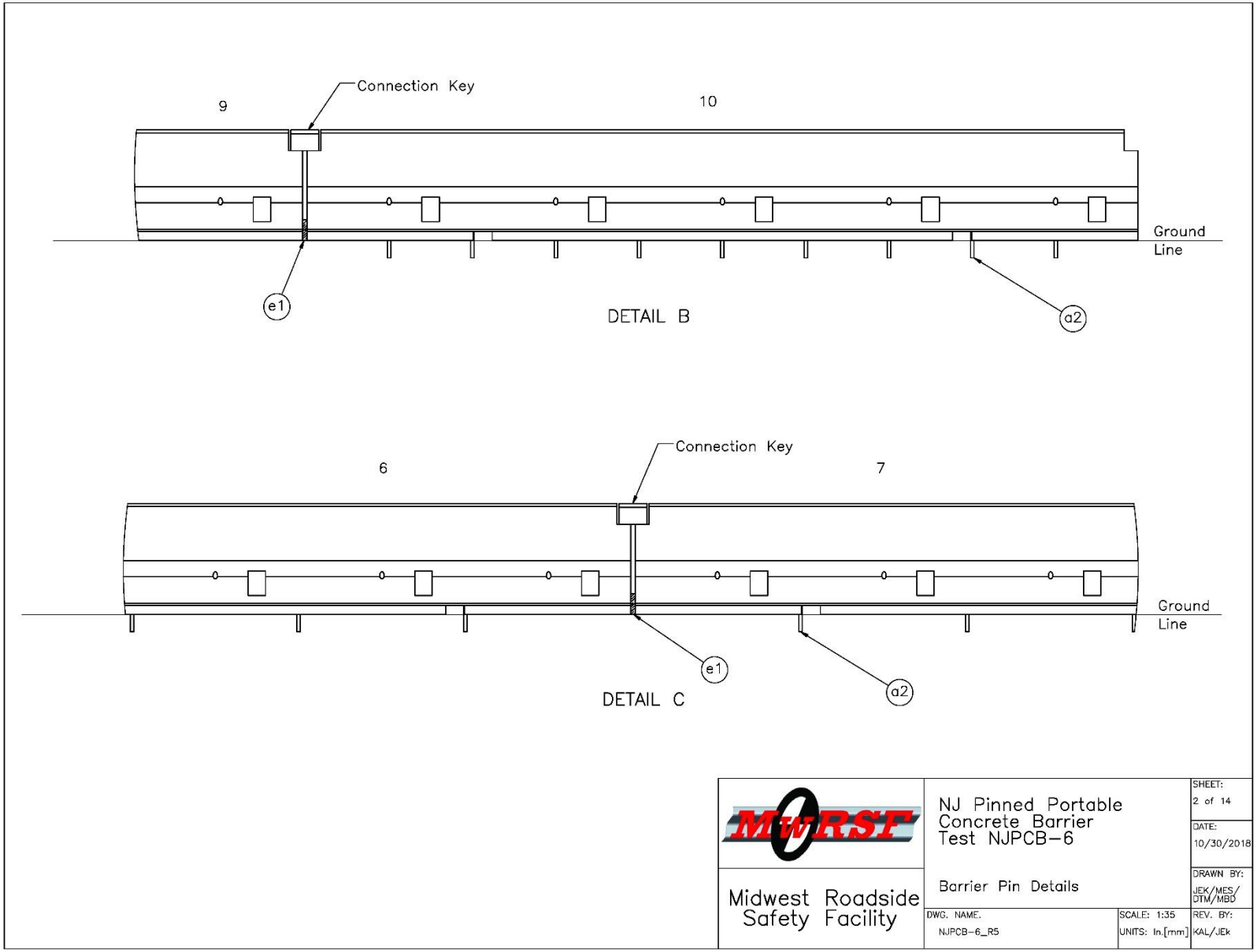


Figure 2. PCB Pin Anchor Details, Test No. NJPCB-6

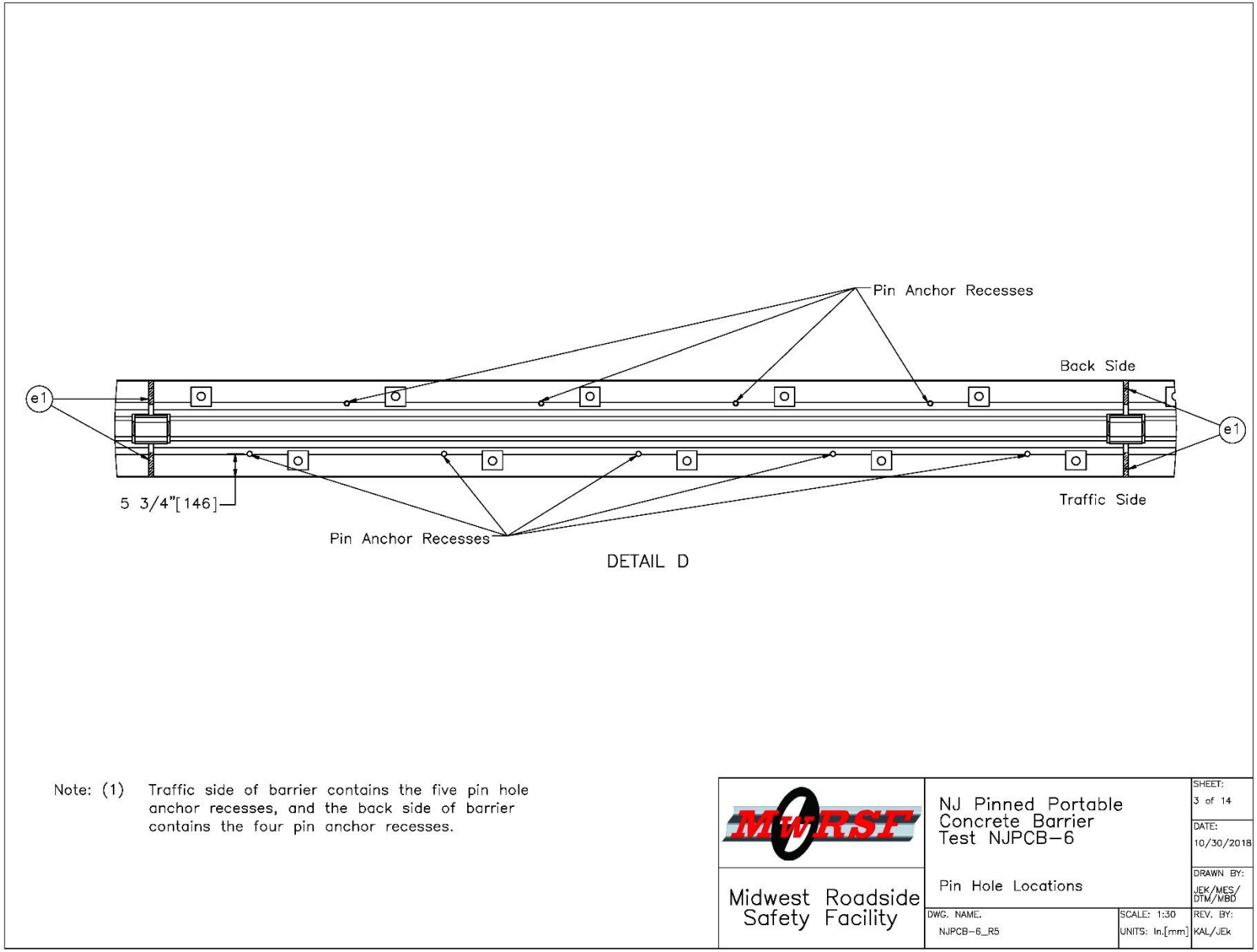


Figure 3. PCB Pin Anchor Locations, Test No. NJPCB-6

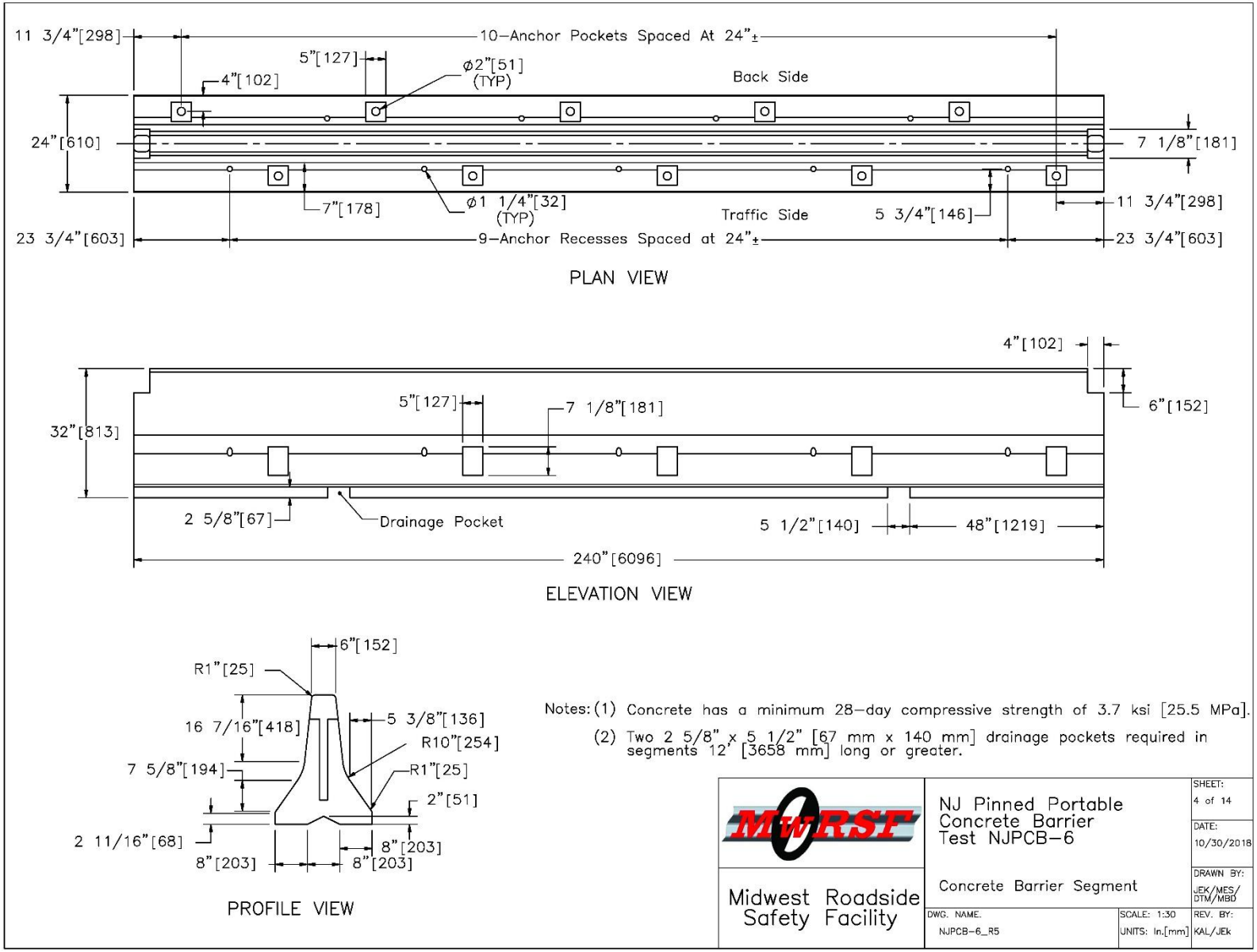


Figure 4. PCB Details, Test No. NJPCB-6

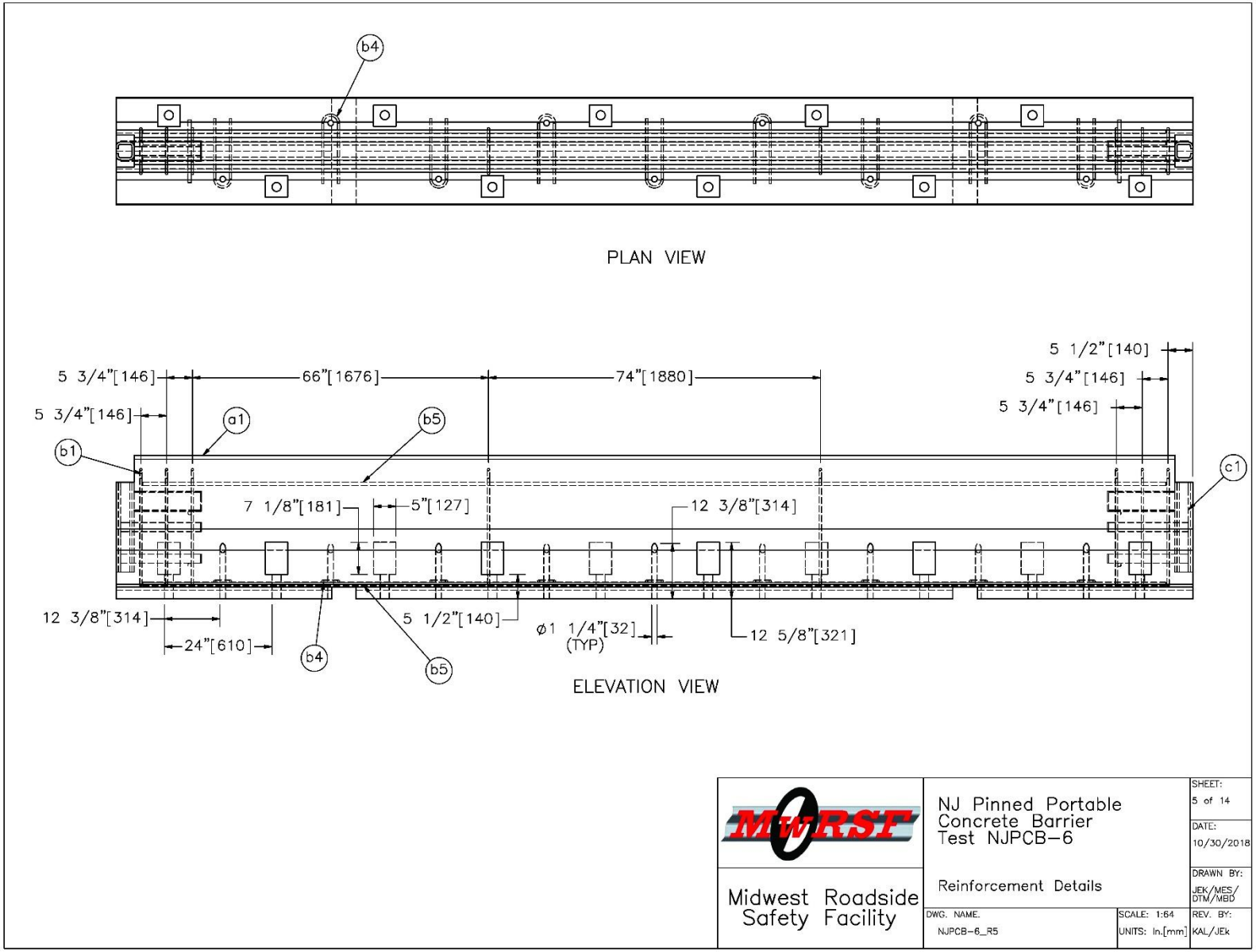


Figure 5. PCB Reinforcement Details, Test No. NJPCB-6

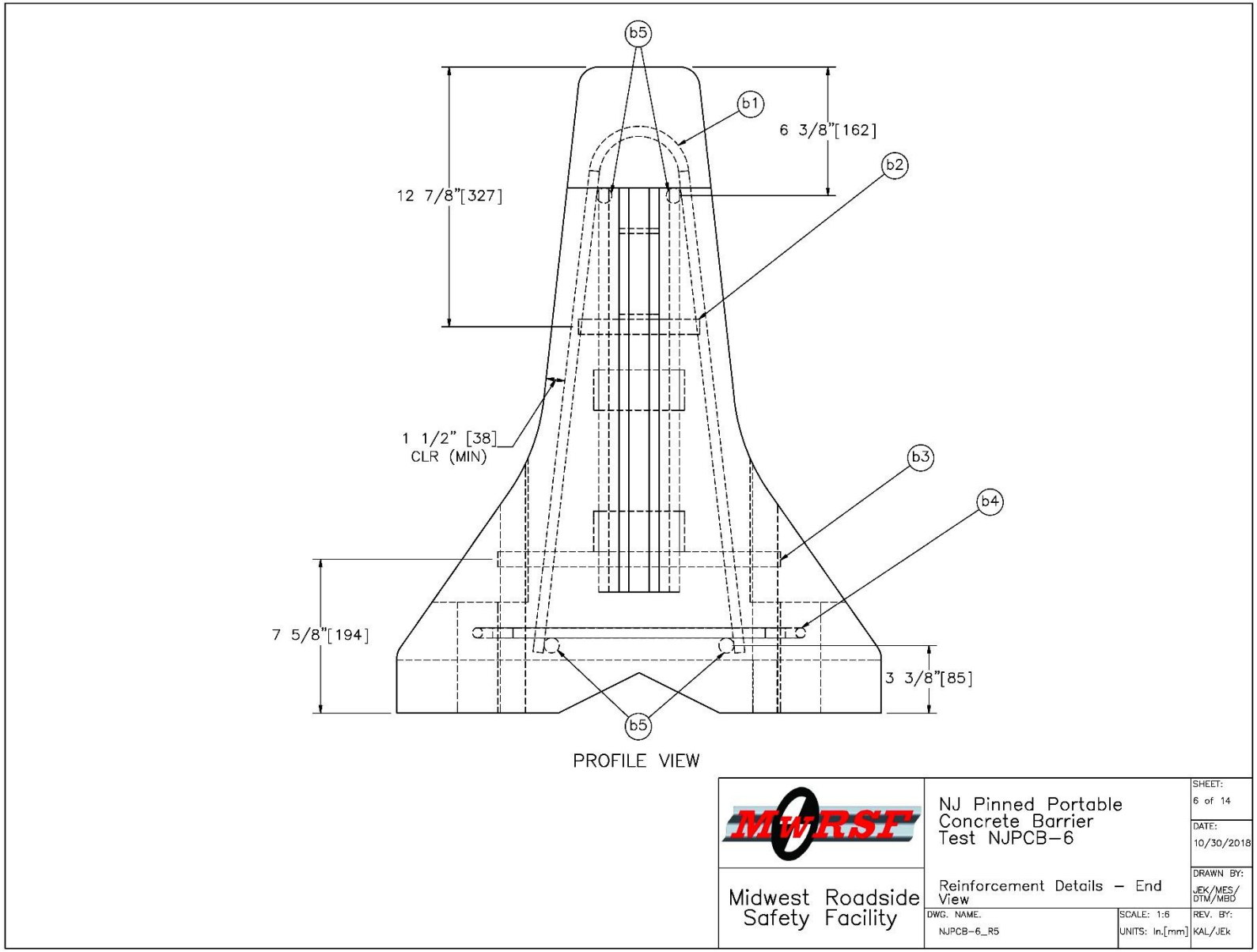


Figure 6. PCB Reinforcement Details – End View, Test No. NJPCB-6

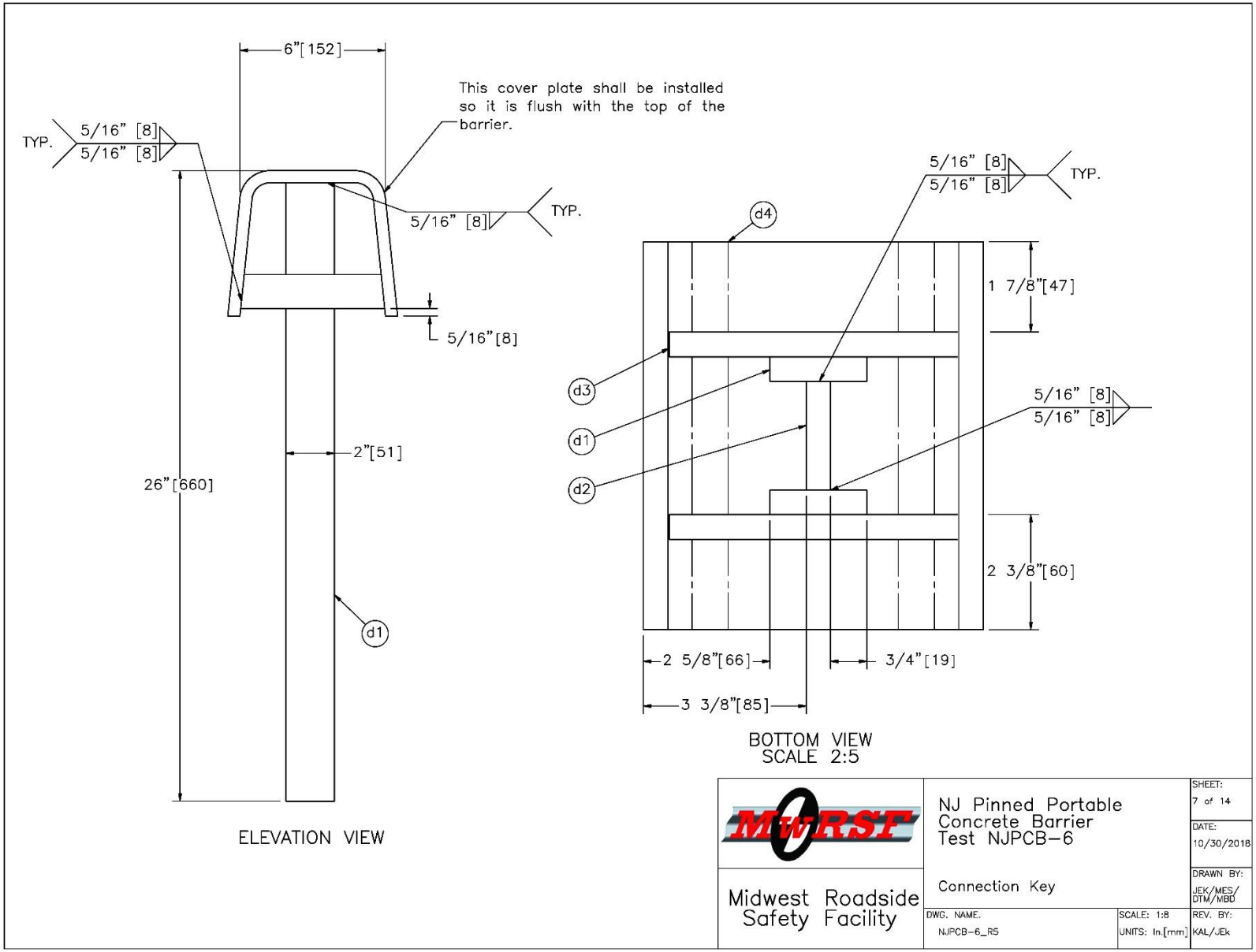


Figure 7. PCB Connection Key Assembly Details, Test No. NJPCB-6

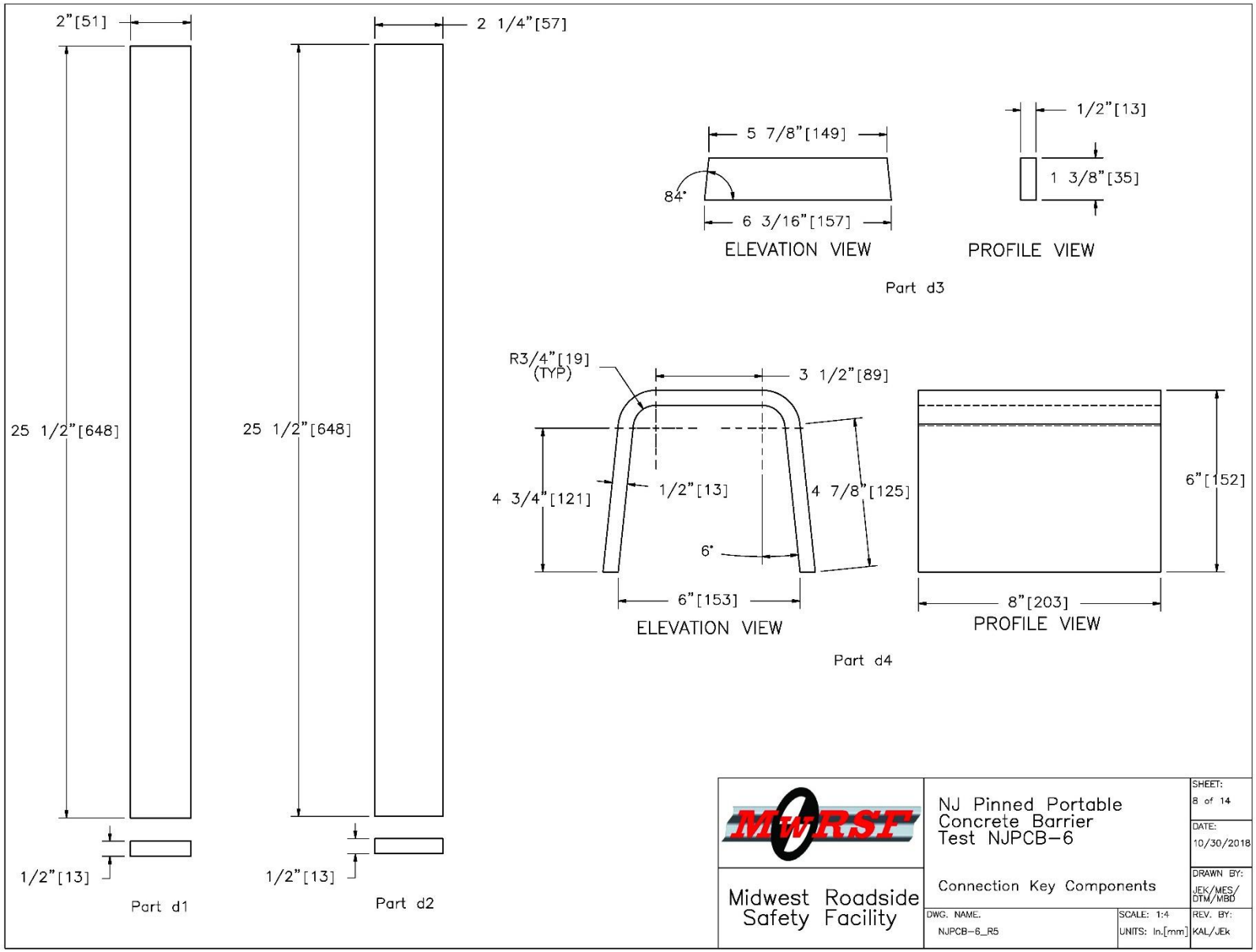


Figure 8. PCB Connection Key Component Details, Test No. NJPCB-6

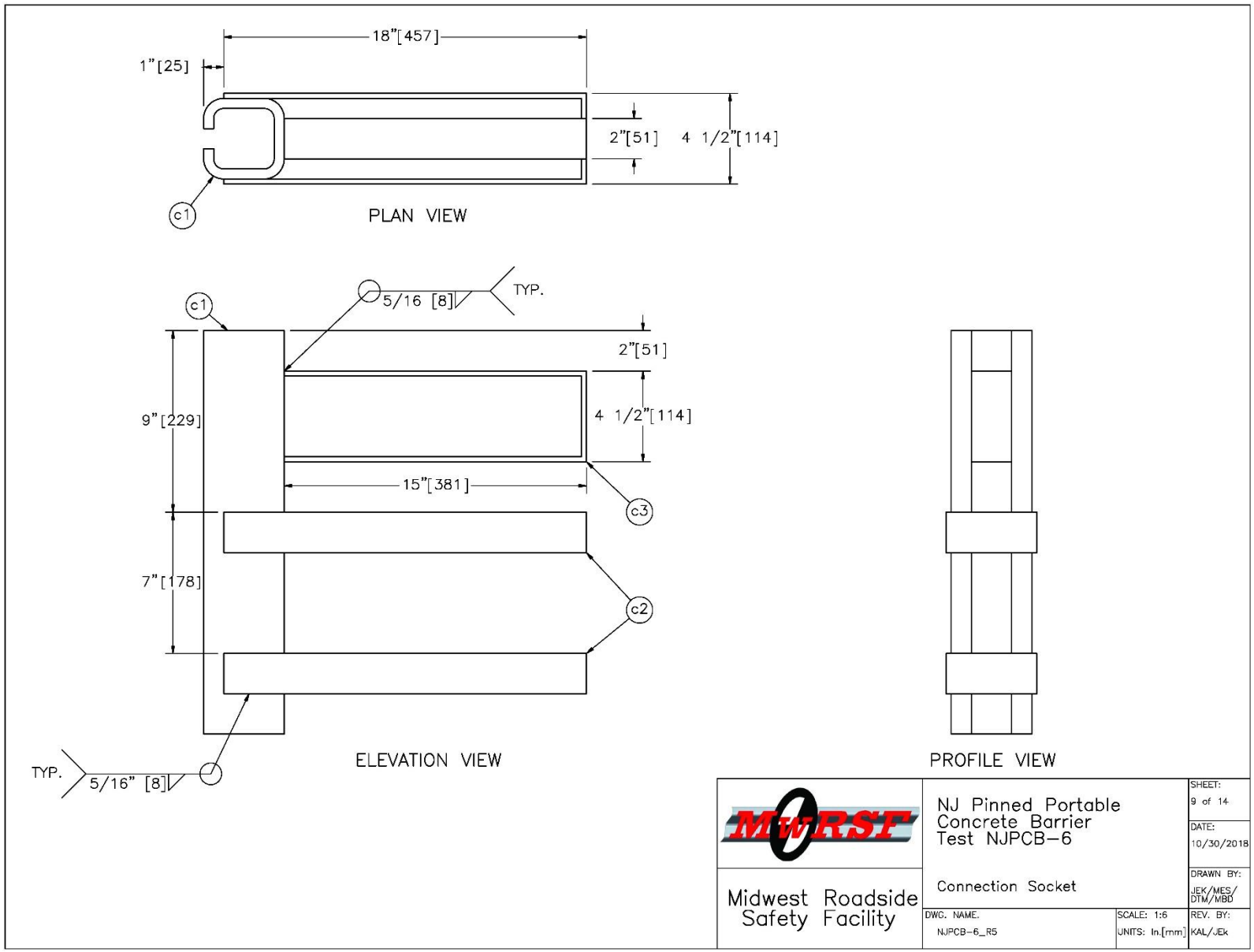


Figure 9. PCB Connection Socket Details, Test No. NJPCB-6

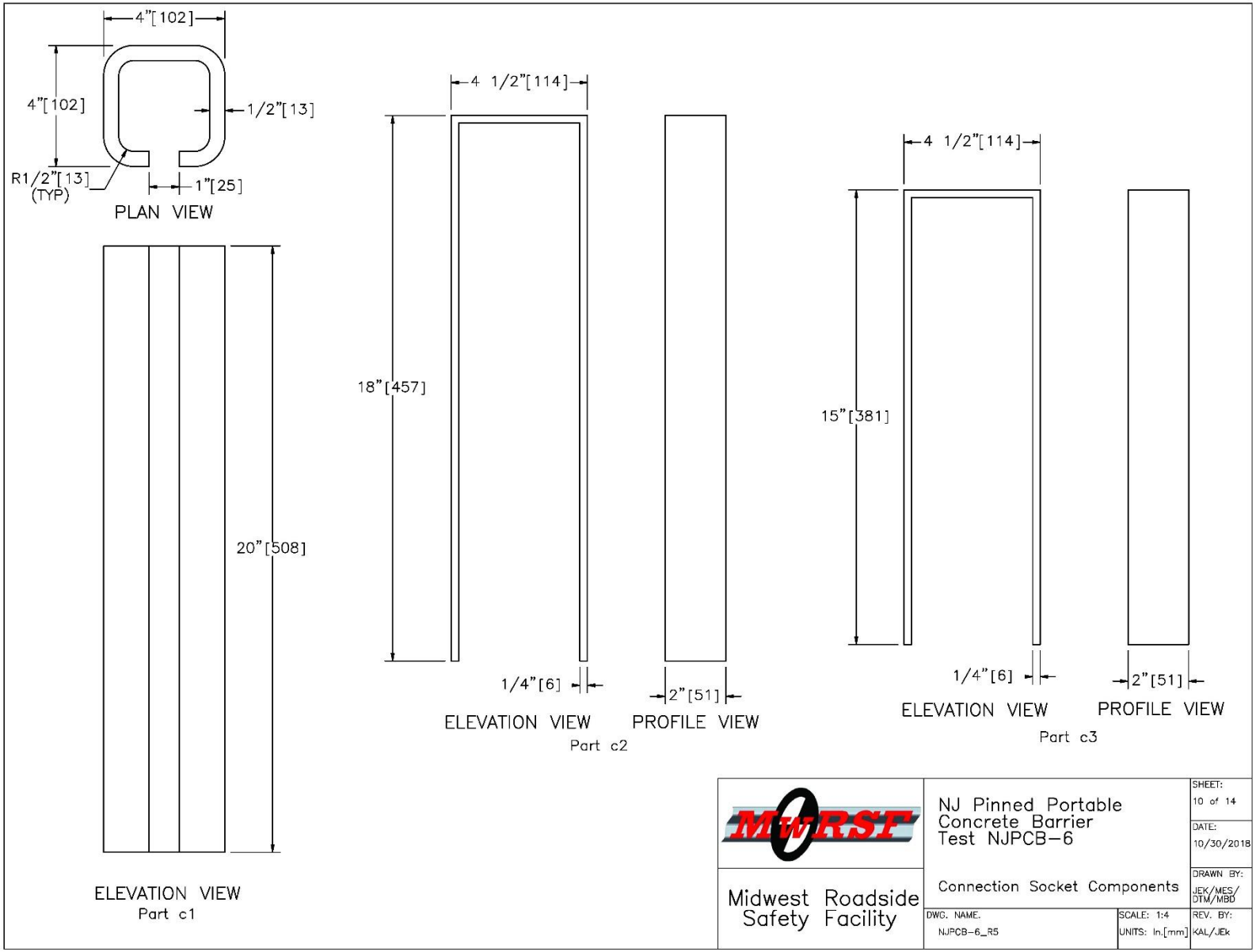


Figure 10. PCB Connection Socket Component Details, Test No. NJPCB-6

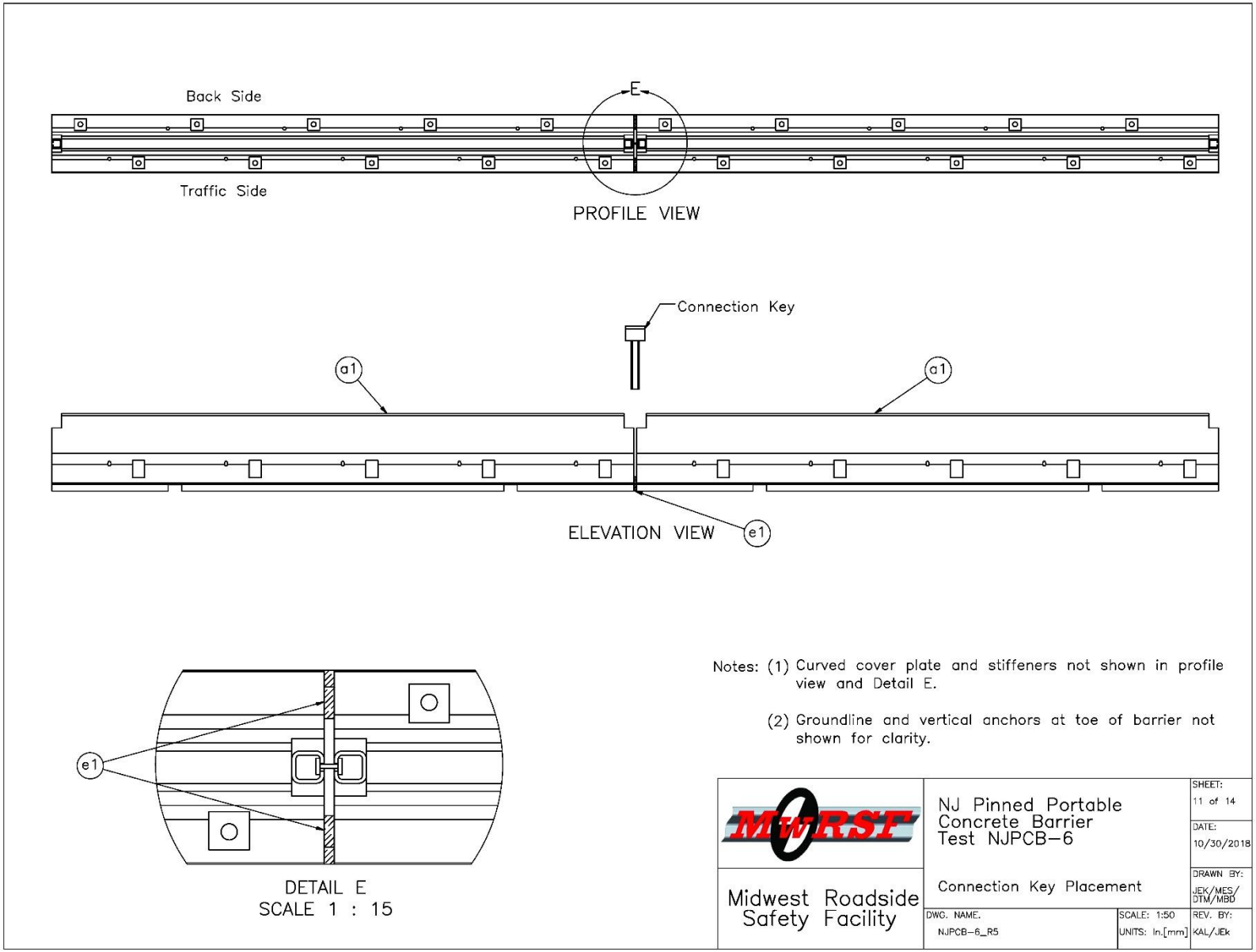


Figure 11. Connection Key Placement Details, Test No. NJPCB-6

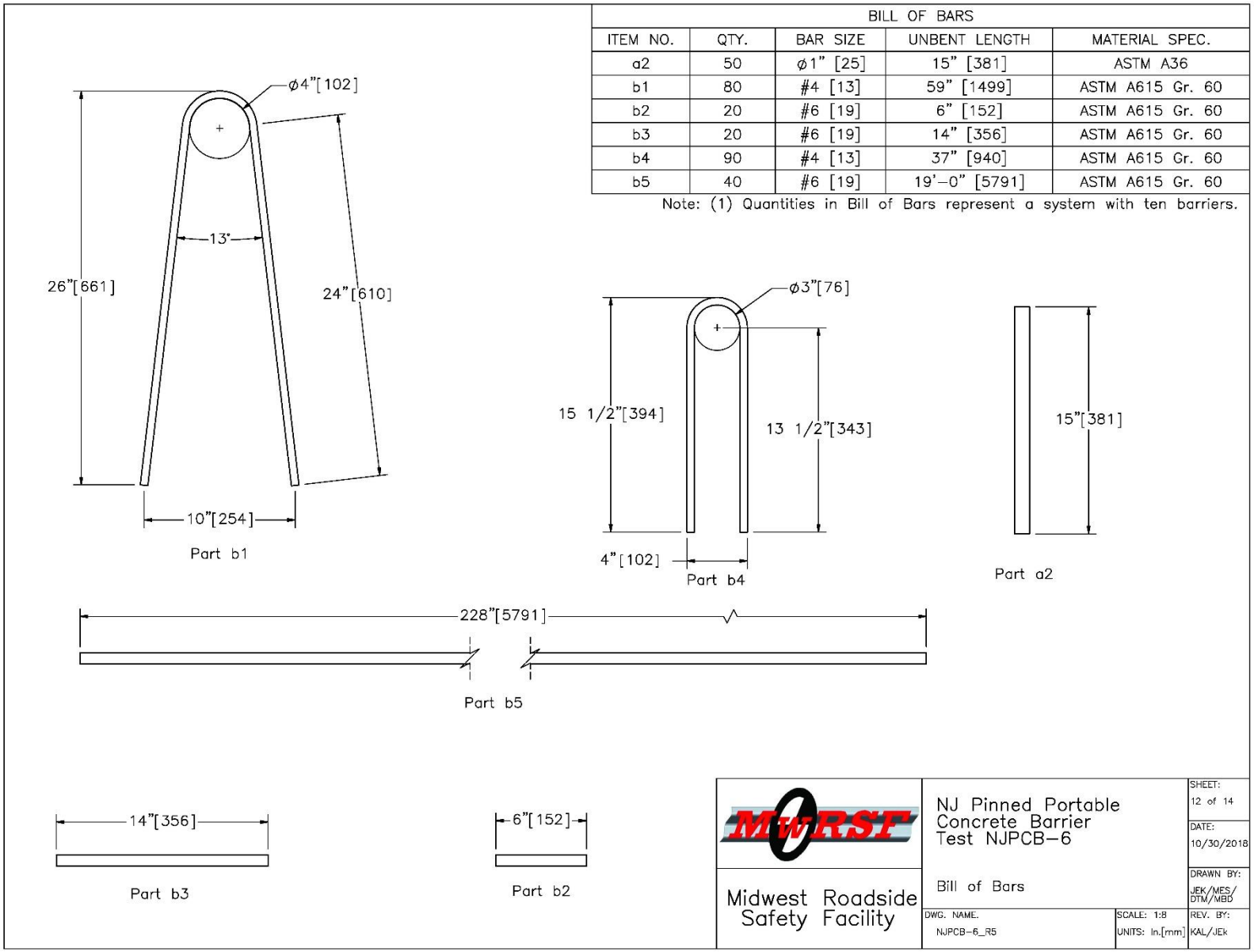


Figure 12. PCB Reinforcement Details, Test No. NJPCB-6

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

(2) All end segments shall be pinned.

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

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

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

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

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

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

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

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

MwRSF	NJ Pinned Portable Concrete Barrier Test NJPCB-6	SHEET: 13 of 14
		DATE: 10/30/2018
Midwest Roadside Safety Facility	General Notes	DRAWN BY: JEK/MES/ DTM/MBD
	DWG. NAME. NJPCB-6_R5 / SCALE: None / UNITS: In.[mm]	REV. BY: KAL/JEk

Figure 13. General Notes, Test No. NJPCB-6

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	50	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 [6.9 MPa]	–

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

Midwest Roadside Safety Facility

NJ Pinned Portable Concrete Barrier
Test NJPCB-6

Bill of Materials

SHEET: 14 of 14
DATE: 10/30/2018
DRAWN BY: JEK/MES/DTM/MBD
REV. BY: KAL/JEk
DWG. NAME. NJPCB-6_R5
SCALE: None
UNITS: In.[mm]

Figure 14. Bill of Materials, Test No. NJPCB-6

Figure 15. NJDOT PCB with Back-Side Pinned Configuration and Grouted Toes Test Installation, Test No. NJPCB-6

Figure 16. PCB Connection Key and Connection Socket, Test No. NJPCB-6

Figure 17. PCB Back-Side Pin Anchor Recesses, Test No. NJPCB-6

Figure 18. Grout at Toes Between PCBs, Test No. NJPCB-6

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-6, a 2009 Dodge Ram 1500 crew cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,221 lb (2,368 kg), 5,000 lb (2,268 kg), and 5,159 lb (2,340 kg), respectively. The test vehicle is shown in Figures 19 and 20, and vehicle dimensions are shown in Figure 21. Note that pre-test photographs of the vehicle's 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 21 and 22. 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 22. Round, checkered targets were placed on the c.g. on the left-side door, the right-side door, and the roof of the vehicle.

The front wheels of the test vehicle were aligned to vehicle standards except the toe-in value was adjusted to zero such that the vehicle would track properly along the guide cable. A 5B flash bulb was mounted under the vehicle's left-side windshield wiper and was fired by a pressure tape switch mounted at the impact corner of the bumper. The flash bulb was fired upon initial

impact with the test article to create a visual indicator of the precise time of impact on the high-speed digital videos. A remote-controlled brake system was installed in the test vehicle to bring the vehicle safely to a stop after the test.

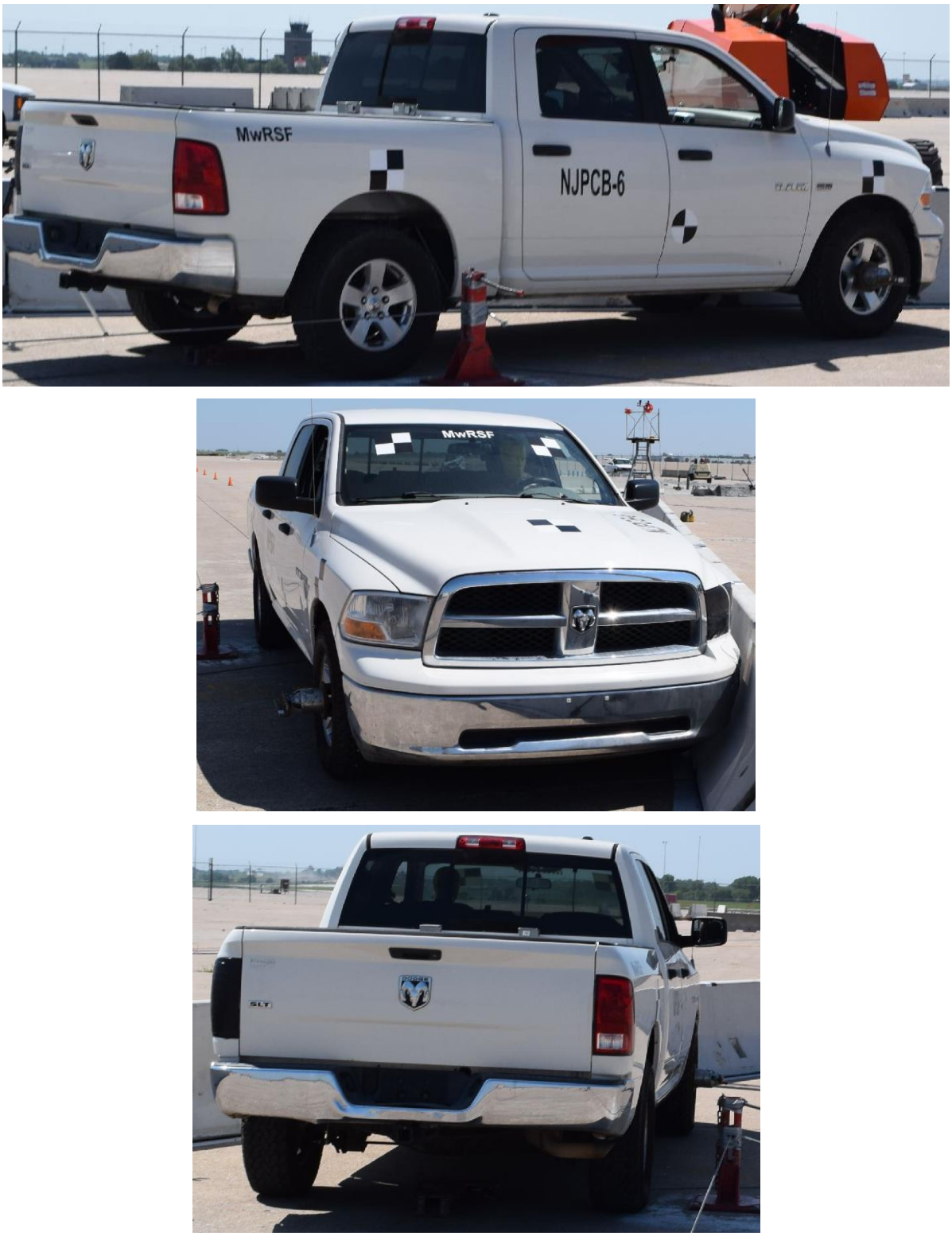
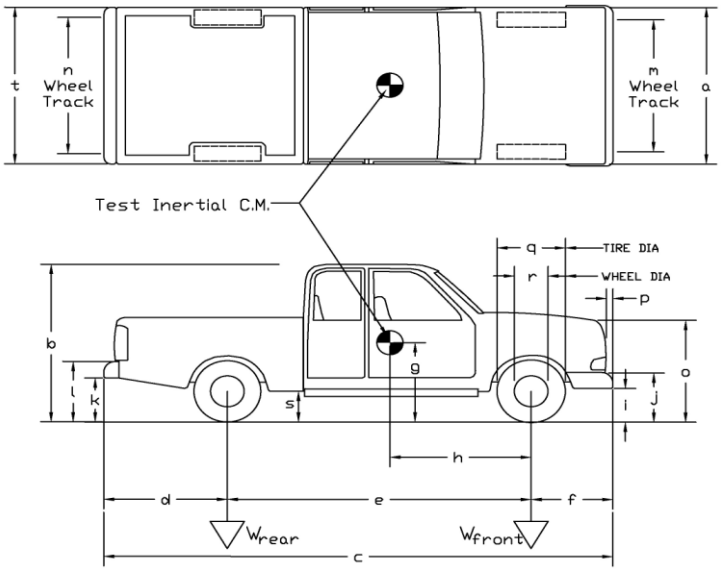


Figure 19. Test Vehicle, Test No. NJPCB-6

Figure 20. Test Vehicle's Interior Floorboards, Test No. NJPCB-6

Date:	6/2/2017	**Test Name:**	NJPCB-6	**VIN No:**	1D3HB13T69S750827
Year:	2009	**Make:**	Dodge	**Model:**	Ram 1500 Hemi
Tire Size:	265/70R17 115	**Tire Inflation Pressure:**	35 Psi	**Odometer:**	171070



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

a:	76 1/2 (1943) 78±2 (1950±50)	**b:**	74 3/8 (1889)
c:	230 1/8 (5845) 237±13 (6020±325)	**d:**	49 3/8 (1254)
e:	140 1/8 (3559) 148±12 (3760±300)	**f:**	39 7/8 (1013) 39±3 (1000±75)
g:	28 5/8 (727) min: 28 (710)	**h:**	60 11/16 (1541) 63±4 (1575±100)
i:	12 (305)	**j:**	24 (610)
k:	20 1/8 (511)	**l:**	29 1/2 (749)
m:	66 1/4 (1683) 67±1.5 (1700±38)	**n:**	68 (1727) 67±1.5 (1700±38)
o:	45 1/2 (1156) 43±4 (1100±75)	**p:**	4 1/2 (114)
q:	31 1/2 (800)	**r:**	18 3/8 (467)
s:	14 1/8 (359)	**t:**	77 7/8 (1978)

Mass Distribution lb (kg)

Gross Static	**LF**	1465 (665)	**RF**	1466 (665)
	LR	1121 (508)	**RR**	1107 (502)

Weights lb (kg)	**Curb**	**Test Inertial**	**Gross Static**
W-front	2937 (1332)	2834 (1285)	2931 (1329)
W-rear	2284 (1036)	2166 (982)	2228 (1011)
W-total	5221 (2368)	5000 (2268) 5000±110 (2270±50)	5159 (2340) 5165±110 (2343±50)

GVWR Ratings lb

Front	3700
Rear	3900
Total	6800

Dummy Data

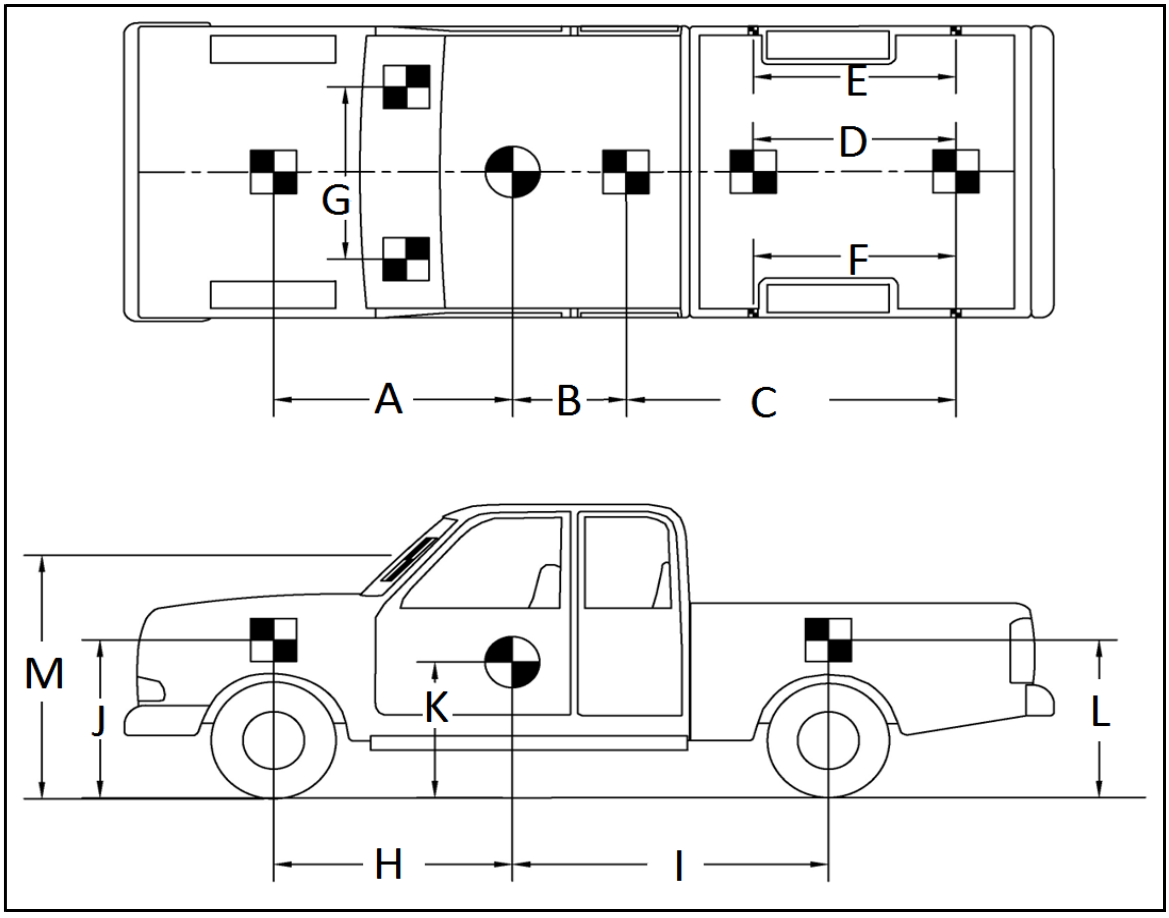
Type:	Hybrid II
Mass:	159 lb
Seat Position:	Driver

Wheel Center Height (Front):	15 (381)
Wheel Center Height (Rear):	15 (381)
Wheel Well Clearance (Front):	4 7/8 (124)
Wheel Well Clearance (Rear):	7 7/8 (200)
Bottom Frame Height (Front):	9 1/2 (241)
Bottom Frame Height (Rear):	26 1/8 (664)
Engine Type:	Gasoline
Engine Size:	5.7L
Transmission Type:	Automatic
Drive Type:	RWD
Cab Style:	Crew Cab
Bed Length:	67"

Note any damage prior to test: none

Figure 21. Vehicle Dimensions, Test No. NJPCB-6

Date:	**6/2/2017**	**Test Name:**	**NJPCB-6**	**VIN:**	**1D3HB13T69S750827**
Year:	**2009**	**Make:**	**Dodge**	**Model:**	**Ram 1500 Hemi**



TARGET GEOMETRY-- in. (mm)

A:	**82 1/4**	**(2089)**	**E:**	**54 1/8**	**(1375)**	**J:**	**39 5/8**	**(1006)**
B:	**36 1/4**	**(921)**	**F:**	**54 1/8**	**(1375)**	**K:**	**28 5/8**	**(727)**
C:	**72 3/8**	**(1838)**	**G:**	**36 1/8**	**(918)**	**L:**	**42 3/8**	**(1076)**
D:	**48**	**(1219)**	**H:**	**60 3/4**	**(1543)**	**M:**	**64 7/8**	**(1648)**
			I:	**80 1/4**	**(2038)**			

Figure 22. Target Geometry, Test No. NJPCB-6

4.4 Simulated Occupant

For test no. NJPCB-6, 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 159 lb (72 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.

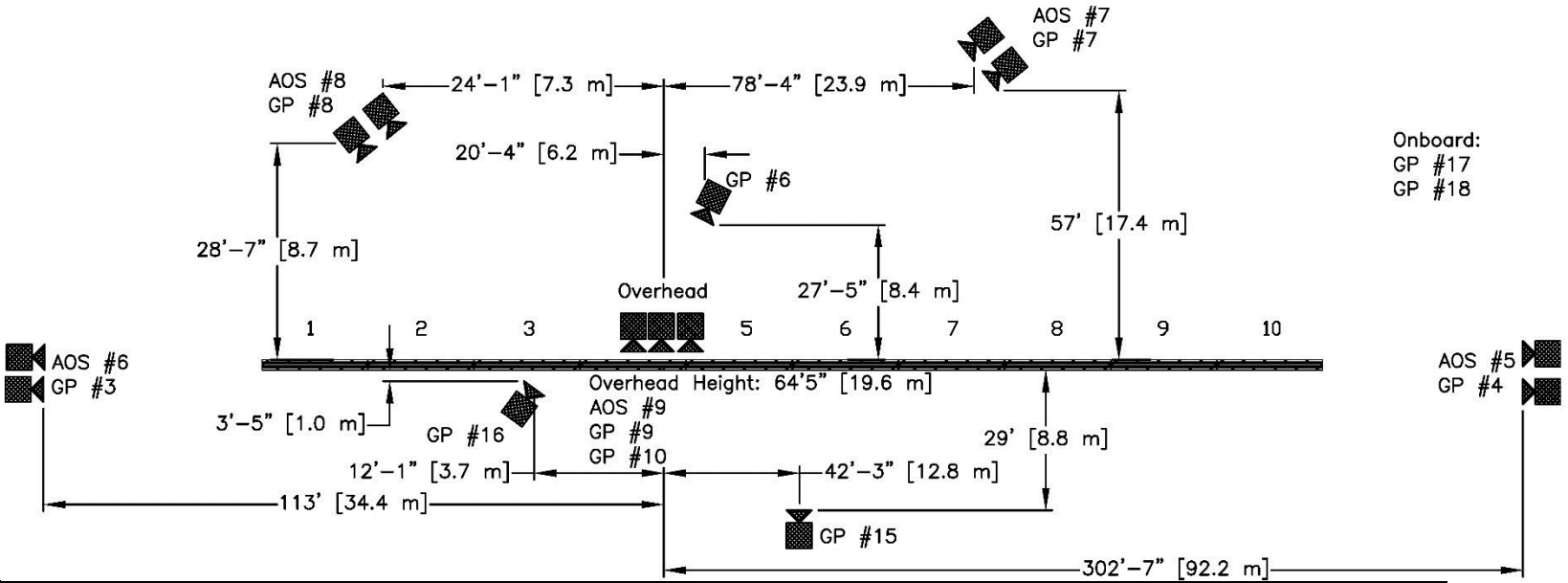
4.5.3 Retroreflective Optic Speed Trap

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 eleven GoPro digital video cameras were utilized to film test no. NJPCB-6. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 23.

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	500	KOWA 12mm Fixed	-
GP-3	GoPro Hero 3+	120		
GP-4	GoPro Hero 3+	120		
GP-6	GoPro Hero 3+	120		
GP-7	GoPro Hero 4	240		
GP-8	GoPro Hero 4	240		
GP-9	GoPro Hero 4	120		
GP-10	GoPro Hero 4	240		
GP-15	GoPro Hero 4	240		
GP-16	GoPro Hero 4	240		
GP-17	GoPro Hero 4	120		
GP-18	GoPro Hero 4	120		

Figure 23. Camera Locations, Speeds, and Lens Settings, Test No. NJPCB-6

5 FULL-SCALE CRASH TEST NO. NJPCB-6

5.1 Weather Conditions

Test no. NJPCB-6 was conducted on June 2, 2017 at approximately 1:45 p.m. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported and are shown in Table 5.

Table 5. Weather Conditions, Test No. NJPCB-6

Temperature	87° F
Humidity	36%
Wind Speed	13 mph
Wind Direction	200° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0.00 in.
Previous 7-Day Precipitation	0.42 in.

5.2 Test Description

The 5,000-lb (2,268-kg) pickup truck impacted the NJDOT PCB, Type 4 (Alternative B) with a back-side pinned configuration and grouted toes, corresponding to connection type C in the 2015 NJDOT *Roadway Design Manual*, at a speed of 62.9 mph (101.3 km/h) and at an angle of 25.1 degrees. A summary of the test results and sequential photographs are shown in Figure 25. Additional sequential photographs are shown in Figures 26 and 27. Documentary photographs of the crash test are shown in Figure 28 through 31.

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 32, which was selected using Table 2.7 of MASH 2016. The actual point of impact was 5½ in. (140 mm) downstream from the target location. A sequential description of the impact events is contained in Table 6. The vehicle came to rest 205 ft – 3 in. (62.5 m) downstream from the impact point and 21 ft – 2 in. (6.4 m) laterally behind the traffic side of the barrier, after brakes were applied. The vehicle trajectory and final position are shown in Figures 25 and 33.

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

TIME (sec)	EVENT
0.000	Vehicle's left-front corner impacted barrier no. 4 at 3 ft – $9^{11}/_{16}$ in. (1.2 m) upstream from the centerline of joint between barrier nos. 4 and 5.
0.002	Vehicle's left-front bumper contacted barrier no. 4.
0.004	Left corner of front bumper deformed inward.
0.008	Vehicle's left headlight contacted top of barrier no. 4.

0.012	Vehicle's left fender contacted barrier no. 4 and deformed.
0.014	Vehicle's left headlight, hood, and grille deformed.
0.022	Downstream end of barrier no. 4 deflected backward.
0.034	Vehicle's front bumper contacted barrier no. 5. Upstream end of barrier no. 5 deflected backward.
0.038	Upstream end of barrier no. 4 spalled. Vehicle yawed away from system.
0.040	Barrier nos. 4 and 5 rolled backward.
0.044	Vehicle's airbags deployed.
0.046	Vehicle's windshield cracked from airbag deployment.
0.054	Vehicle pitched upward and vehicle rolled away from system.
0.062	Downstream end of barrier no. 5 spalled.
0.064	Vehicle's left-front door contacted barrier no. 4 and deformed.
0.084	Upstream end of barrier no. 3 spalled.
0.088	Vehicle's left fender contacted barrier no. 5.
0.098	Vehicle's left-front door contacted barrier no. 5.
0.100	Midspan of barrier no. 5 spalled. Midspan of barrier no. 4 fractured.
0.120	Barrier no. 6 deflected backward.
0.138	Barrier no. 7 deflected backward and vehicle's right-front tire became airborne.
0.160	Vehicle's left-rear tire contacted barrier no. 4.
0.182	Vehicle's rear bumper deformed.
0.194	Vehicle's left headlight disengaged.
0.228	Vehicle was parallel to system at a speed of 47.8 mph (76.9 km/h).
0.276	Vehicle's right-rear tire became airborne.
0.282	Vehicle pitched downward and barrier no. 4 rolled toward traffic side of system.
0.298	Vehicle's left-front tire became airborne.
0.398	Vehicle's left-rear tire became airborne. Vehicle exited system at a speed of 46.9 mph (75.4 km/h) and at an angle of 8.0 degrees.
0.610	Vehicle's right-front tire regained contact with ground.
0.640	System came to rest.
0.720	Vehicle rolled toward system.
0.744	Vehicle's front bumper contacted ground.
0.752	Vehicle pitched upward.
0.970	Vehicle's right-front tire became airborne.
1.012	Vehicle's left-rear tire regained contact with ground.
1.044	Vehicle's left-front tire regained contact with ground.
1.100	Vehicle's left-rear quarter panel deformed.
1.120	Vehicle rolled away from system.
1.164	Occupant's head contacted left-front window and window shattered.
1.252	Vehicle pitched downward.
1.376	Vehicle pitched upward.
1.386	Vehicle yawed toward system.
1.410	Vehicle rolled toward system.
1.414	Vehicle's plastic bumper fascia contacted ground.
1.644	Vehicle rolled away from system.

5.3 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 34 through 39. 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 23 ft – 10¼ in. (7.3 m), which spanned from 5 ft – 11¼ in. (1.8 m) upstream from the center of the joint between barrier nos. 4 and 5 through 17 ft – 9 in. (5.4 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 9¾-in. (248-mm) long crack was found on the front face of barrier no. 4 that started at the top corner of the upstream end. A 35½-in. (902-mm) long vertical crack was found on front face of barrier no. 4, 35 in. (889 mm) downstream from the midspan of the barrier. A 13-in. (330-mm) long vertical crack was found on the front face of barrier no. 4 that started 2½ in. (64 mm) upstream from the downstream end and ended 17½ in. (445 mm) from the top. A 36-in. (914-mm) long crack was found on the front face of barrier no. 5, 55½ in. (1,410 mm) downstream from the upstream end of the barrier. A 38½-in. (978-mm) long vertical crack that extended onto the front face and back face of barrier no. 5 was located 73 in. (1,854 mm) downstream from the upstream end. Minor cracks were found on the back side of barrier nos. 3, 6, and 7. Barrier no. 4 was fractured from top to bottom 9½-in. (241-mm) downstream from the midspan, originating from the bottom of the front face, extending vertically toward the center target, and terminating 46 in. (1,168 mm) downstream from the midspan on the back face. A 36¾-in. long × 6-in. wide (933-mm × 152-mm) gouge was found 57½ in. (1,461 mm) upstream from the downstream end of barrier no. 4, and extended diagonally toward the upper-downstream corner. Barrier no. 5 was fractured from top to bottom at 8⅝-in. (219-mm) downstream from the midspan. A 19½-in. long × 1½-in. wide (495-mm × 38-mm) gouge was found 9½ in. (241 mm) downstream from the upstream end of barrier no. 5 and 9¼ in. (235 mm) from the top on the front face. A 77-in. (1,956-mm) long gouge was found on barrier no. 5 that began 55½ in. (1,410 mm) downstream from the upstream end.

A 6⅜-in. × 7¼-in. × ⅞-in. (162-mm × 184-mm × 22-mm) concrete piece disengaged from the back face of barrier no. 3 at the lower-upstream corner. A 17-in. × 6-in. (432-mm × 152-mm) concrete piece partially disengaged from the back face of barrier no. 5, 43¾ in. (1,111 mm) downstream from the upstream end. A 56¼-in. × 7¼-in. × 9½-in. (1,429-mm × 184-mm × 241-mm) piece of concrete was removed from the lower-downstream end of barrier no. 4. Concrete spalling measuring 32¾ in. × 12¾ in. × 3½ in. (832 mm × 324 mm × 89 mm) and a 7-in. (178-mm) long crack occurred at the lower-back upstream corner of barrier no. 4. The front side of barrier no. 5 experienced 21-in. × 6½-in. × 9½-in. (533-mm × 165-mm × 241-mm) concrete spalling at the lower-upstream corner. A 6½-in. × 6-in. × ½-in. (165-mm × 152-mm × 13-mm) piece of concrete was removed from the upper-downstream corner on the front face of barrier no. 5 below the connection key socket. A 4-in. × 3½-in. × 1-in. (102-mm × 89-mm × 25-mm) concrete piece disengaged from the back face of barrier no. 5 at the lower-upstream corner. The back side of barrier no. 5 experienced concrete spalling near the midspan of the barrier. Concrete spalling, measuring 37 in. × 12 in. × 3 in. (940 mm × 305 mm × 76 mm) occurred at the back-side downstream end of barrier no. 5. An 8-in. × 2-in. × 2-in. (203-mm × 51-mm × 51-mm) concrete piece disengaged from the back face of barrier no. 6 at the lower-upstream corner. A 10-in. × 4-

in. (254-mm × 102-mm) concrete piece disengaged from the back face of barrier no. 6, 22 in. (559 mm) downstream from the midspan of the barrier. Concrete spalling, measuring 11½ in. × 10 in. × 2 in. (292 mm × 254 mm × 51 mm), occurred at the back-side downstream end of barrier no. 6. Minor spalling occurred on the back side of barrier nos. 2 and 7.

The maximum permanent set deflection of the barrier system was 3¾ in. (95 mm) at the upstream end of barrier no. 5, as measured in the field. The maximum lateral dynamic barrier deflection, including tipping of the barrier along the top surface, was 15.2 in. (386 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 41.0 in. (1,041 mm), also determined from high-speed digital video analysis. A schematic of the permanent set, dynamic deflection, and working width is shown in Figure 25. 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 15.2 in. (386 mm).

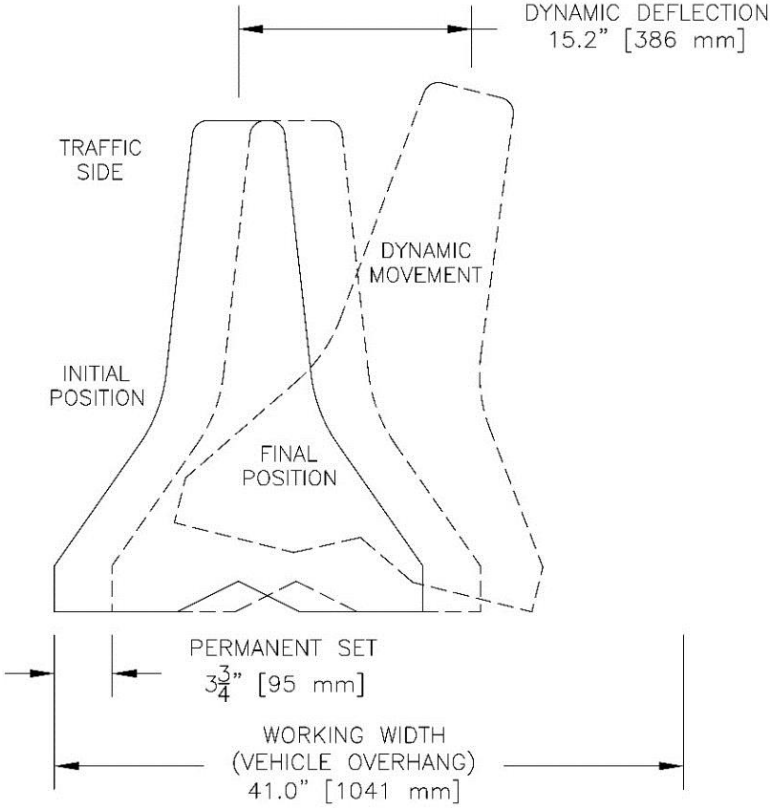


Figure 24. Permanent Set Deflection, Dynamic Deflection, and Working Width, Test No. NJPCB-6

5.4 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 40 through 44. 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 plastic bumper portion separated from the left side and bent toward the right side of the vehicle. The engine hood separated from the right fender. The left-front fender was deformed inward toward the engine compartment. The left corner of the front bumper was bent inward approximately 28 in. (711 mm) 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 left side of the cab. Gouging and contact marks were found at the bottom of the left-front door, starting from the front of the door and extending across the cab. A 9½-in. × 8-in. (241-mm × 203-mm) dent was found on the rear of the left-front door. The left headlight disengaged away from the vehicle. A tear was found on the left-rear tire extending from the outside wall through the tread and two-thirds of the way around the tire. The top of left-front door was bent outward.

The lower-left control arm was scraped, bent, and disengaged away from the steering knuckle at the joint. The left-front upper control arm was bent 6½ in. (165 mm) upward. The left-front wheel and hub partially disengaged. The right-side engine cross member was bent. The left-front window glass shattered. The roof remained undamaged. The windshield had spider web cracking on the right side and additional cracks extending from the spider-web crack across the left side.

Table 7. Maximum Occupant Compartment Deformations by Location

LOCATION	MAXIMUM DEFORMATION in. (mm)	MASH 2016 ALLOWABLE DEFORMATION in. (mm)
Wheel Well & Toe Pan	4⅝ (117)	≤ 9 (229)
Floor Pan & Transmission Tunnel	⅝ (16)	≤ 12 (305)
A-Pillar	⅝ (16)	≤ 5 (127)
A-Pillar (Lateral)	−⅜ (−10)	≤ 3 (76)
B-Pillar	¾ (19)	≤ 5 (127)
B-Pillar (Lateral)	−⅝ (−16)	≤ 3 (76)
Side Front Panel (in Front of A-Pillar)	1⅜ (35)	≤ 12 (305)
Side Door (Above Seat)	−2½ (−64)	≤ 9 (229)
Side Door (Below Seat)	−1⅜ (−35)	≤ 12 (305)
Roof	−¼ (−6)	≤ 4 (102)
Windshield	0 (0)	≤ 3 (76)
Side Window	Shattered due to contact with dummy's head	No shattering resulting from contact with structural member of test article
Dash	½ (13)	N/A

Note: Negative values denote outward deformation
N/A – Not applicable

5.5 Occupant Risk

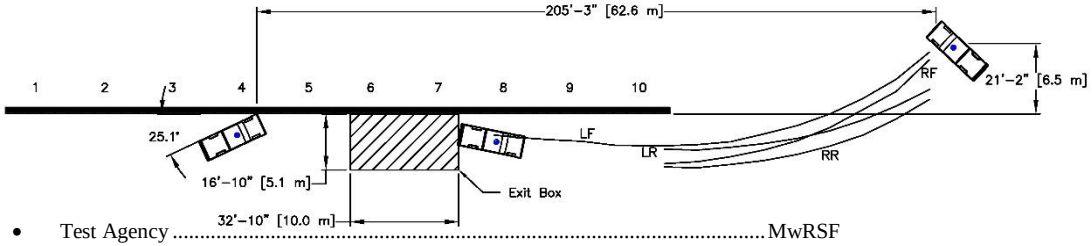
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec average occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 8. Note that the OIVs and ORAs were within suggested limits, as provided in MASH 2016. The calculated THIV, PHD, and 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 25. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix F.

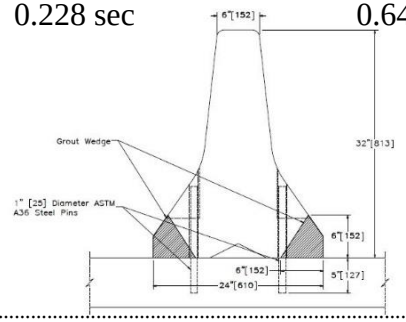
Table 8. Summary of OIV, ORA, THIV, PHD, and ASI Values, Test No. NJPCB-6

Evaluation Criteria		Transducer		MASH 2016 Limits
		SLICE-1	SLICE-2 (Primary)	
OIV ft/s (m/s)	Longitudinal	-17.74 (-5.41)	-17.30 (-5.27)	± 40 (12.2)
	Lateral	18.89 (5.76)	20.67 (6.30)	± 40 (12.2)
ORA g's	Longitudinal	-9.84	-9.73	± 20.49
	Lateral	9.87	8.43	± 20.49
MAX. ANGULAR DISPL. deg.	Roll	-28.2	28.9	± 75
	Pitch	-9.8	-12.2	±75
	Yaw	40.1	39.5	not required
THIV ft/s (m/s)		25.95 (7.91)	27.00 (8.23)	not required
PHD g's		9.11	8.19	not required
ASI		1.14	1.26	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 8.0 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. NJPCB-6 was determined to be acceptable according to the MASH 2016 safety performance criteria for test designation no. 3-11.

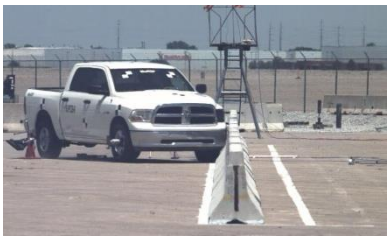




- Test Agency ..... MwRSF
- Test Number..... NJPCB-6
- Date..... 6/02/2017
- MASH 2016 Test Designation 3-11
- Test Article.....Back-Side Pinned NJDOT PCB with Grouted Toes, Connection Type C [2]
- Total Length ..... 200 ft (61.0 m)
- Key Component – NJDOT PCB
  - Length ..... 20 ft (6.1 m)
  - Width..... 24 in. (610 mm)
  - Height..... 32 in. (813 mm)
- Key Component – Anchor Pins
  - Pin Size..... 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. – Back Side (4 per barrier) 2-9
  - Pinned Barrier Nos. – Traffic and Back Side..... 1 and 10
- Key Component – Grout
  - Specification..... Min. 1-day compressive strength 1,000 psi (6.9 MPa)
  - Location..... Toes at joints between barrier nos. 1-10 on traffic and back sides
- Type of Support Surface..... Concrete Tarmac
- Vehicle Make /Model..... 2009 Dodge Ram 1500 crew cab pickup truck
  - Curb..... 5,221 lb (2,368 kg)
  - Test Inertial..... 5,000 lb (2,268 kg)
  - Gross Static..... 5,159 lb (2,340 kg)
- Impact Conditions
  - Speed..... 62.9 mph (101.3 km/h)
  - Angle..... 25.1 deg
  - Impact Location..... $45^{11}/_{16}$ in. (1.2 m) upstream from joint 4-5
- Impact Severity ..... 119.0 kip-ft (161.3 kJ) > 105.6 kip-ft (143.1 kJ) limit in MASH 2016
- Exit Conditions
  - Speed..... 46.9 mph (75.4 km/h)
  - Angle..... 8.0 deg
  - Exit Box Criterion ..... Pass
- Vehicle Stability ..... Satisfactory
- Vehicle Stopping Distance..... 205 ft – 3 in. (62.5 m) downstream
  21 ft – 2 in. (6.4 m) laterally behind
- Test Article Damage ..... Moderate
- Vehicle Damage..... Moderate
  - VDS [14] 11-LFQ-4
  - CDC [15]..... 11-LYEW-4
  - Maximum Interior Deformation ..... 4⅝ in. (117 mm)
- Maximum Test Article Deflections
  - Permanent Set ..... 3¾ in. (95 mm)
  - Dynamic..... 15.2 in. (386 mm)
  - Working Width..... 41.0 in. (1,041 mm)
- Transducer Data

Evaluation Criteria		Transducer		MASH 2016 Limit
		SLICE-1	SLICE-2 (Primary)	
OIV ft/s (m/s)	Longitudinal	-17.74 (-5.41)	-17.30 (-5.27)	± 40 (12.2)
	Lateral	18.89 (5.76)	20.67 (6.30)	± 40 (12.2)
ORA g's	Longitudinal	-9.84	-9.73	± 20.49
	Lateral	9.87	8.43	± 20.49
MAX. ANGULAR DISPL. deg.	Roll	-28.2	28.9	± 75
	Pitch	-9.8	-12.2	± 75
	Yaw	40.1	39.5	not required
THIV ft/s (m/s)		25.95 (7.91)	27.00 (8.23)	not required
PHD g's		9.11	8.19	not required
ASI		1.14	1.26	not required

Figure 25. Summary of Test Results and Sequential Photographs, Test No. NJPCB-6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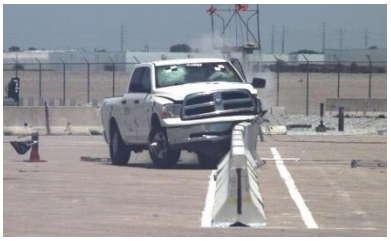
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0.054 sec


0.276 sec


0.160 sec


0.398 sec


0.282 sec


0.640 sec


0.752 sec


0.970 sec


1.410 sec

Figure 26. Additional Sequential Photographs, Test No. NJPCB-6


0.000 sec


0.000 sec


0.038 sec


0.098 sec


0.062 sec


0.228 sec


0.228 sec


0.398 sec


0.398 sec


0.720 sec

Figure 27. Additional Sequential Photographs, Test No. NJPCB-6

Figure 28. Documentary Photographs, Test No. NJPCB-6

Figure 29. Documentary Photographs, Test No. NJPCB-6

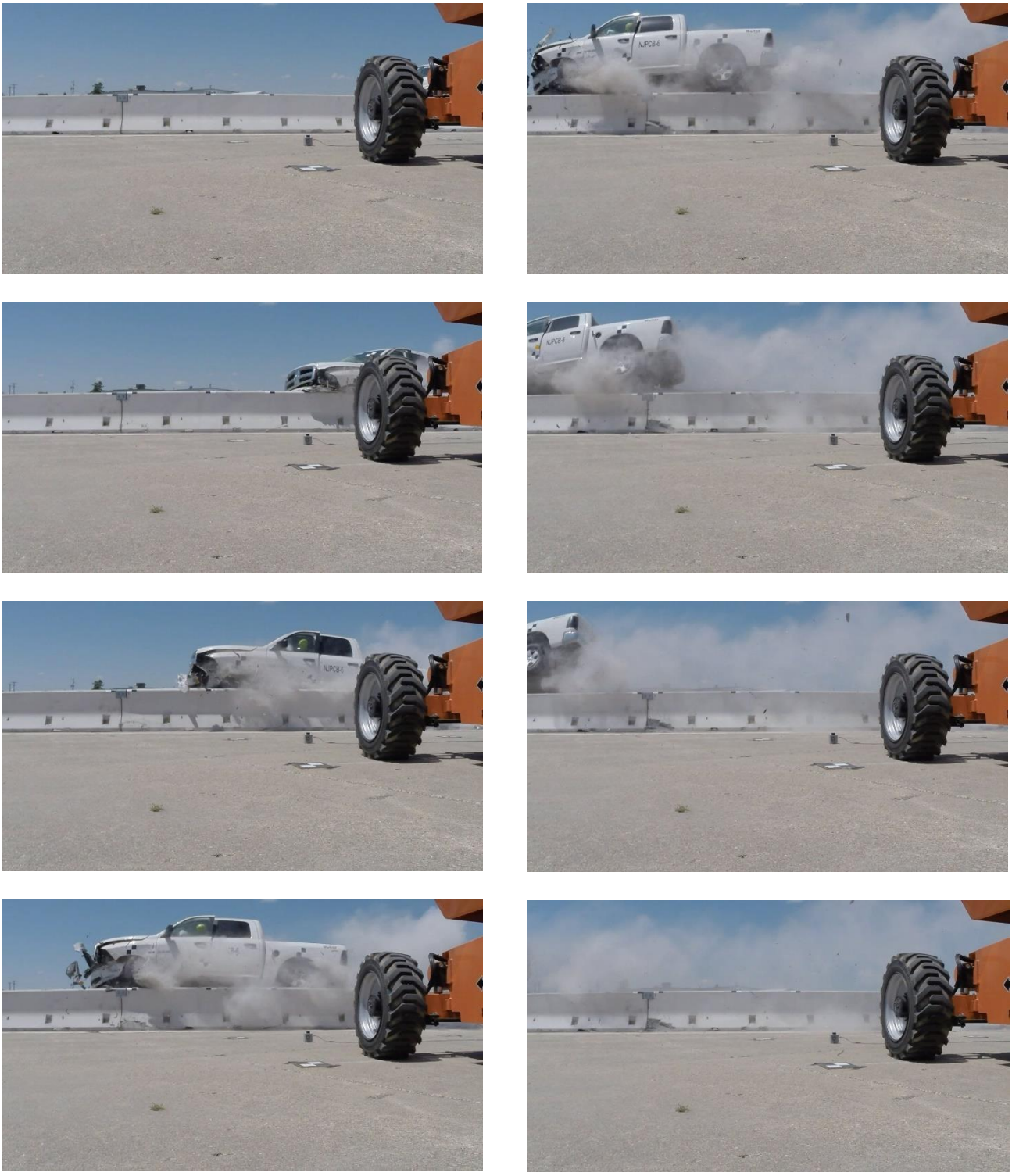


Figure 30. Documentary Photographs, Test No. NJPCB-6

Figure 31. Documentary Photographs, Test No. NJPCB-6

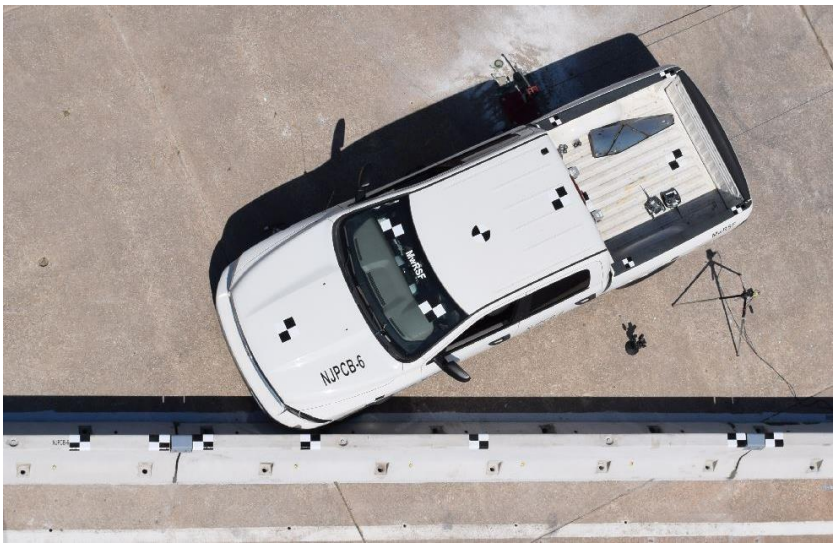


Figure 32. Impact Location, Test No. NJPCB-6

Figure 33. Vehicle Final Position and Trajectory Marks, Test No. NJPCB-6

Figure 34. System Damage – Front, Back, Upstream and Downstream Views, Test No. NJPCB-6

(a) Traffic Side

(b) Back Side

(c) Traffic Side

(d) Back Side

Figure 35. Barrier Nos. 2 and 3 – Traffic and Back Side Damage, Test No. NJPCB-6

Figure 36. Barrier Nos. 4 and 5 Damage, Test No. NJPCB-6

(a) Traffic Side

(b) Back Side

(c) Back Side

Figure 37. Barrier No. 4 – Traffic and Back Side Damage, Test No. NJPCB-6

(a) Traffic Side

(b) Back Side

(c) Back Side

Figure 38. Barrier No. 5 – Traffic and Back Side Damage, Test No. NJPCB-6

(a) Traffic Side

(b) Back Side

(c) Back Side

(d) Back Side

(e) Back Side

Figure 39. Barrier Nos. 6 and 7 - Traffic and Back Side Damage, Test No. NJPCB-6

Figure 40. Vehicle Damage, Test No. NJPCB-6

Figure 41. Vehicle Damage on Impact Side, Test No. NJPCB-6

Figure 42. Vehicle Windshield and Side Window Damage, Test No. NJPCB-6

Figure 43. Occupant Compartment Deformation, Test No. NJPCB-6

Figure 44. Undercarriage Damage, Test No. NJPCB-6

6 SUMMARY AND CONCLUSIONS

Test no. NJPCB-6 was conducted on the NJDOT PCB system with a back-side pinned configuration and grouted toes according to MASH 2016 test designation no. 3-11. This system uses NJDOT barriers, Type 4 (Alternative B) with connection type C, as specified in the 2015 NJDOT *Roadway Design Manual*. Barrier nos. 1 and 10 were anchored on both sides, and barrier nos. 2 through 9 were anchored on the back side to the rigid concrete tarmac through pin anchor recesses with 1-in. (25-mm) diameter by 15-in. (381-mm) long ASTM A36 steel pins.

During test no. NJPCB-6, the 5,000-lb (2,268 kg) pickup truck impacted the NJDOT PCB system at a speed of 62.9 mph (101.3 km/h) and at an angle of 25.1 degrees, resulting in an impact severity of 119.0 kip-ft (161.3 kJ). After impacting the barrier system, the vehicle exited the system at a speed of 46.9 mph (75.4 km/h) and at an angle of 8.0 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 15.2 in. (386 mm) and working width of 41.0 in. (1,041 mm) were observed during the test, as shown in Figure 24. All occupant risk values were found to be within limits, and the occupant compartment deformations were also deemed acceptable. Subsequently, test no. NJPCB-6 was determined to satisfy the safety performance criteria for MASH 2016 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-6</th></tr>
<tr><td>Structural Adequacy</td><td colspan="4">A. Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td><td>S</td></tr>
<tr><td rowspan="6">Occupant Risk</td><td colspan="4">D. 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="4">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 colspan="4">F. 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 colspan="4">H. 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="3">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 colspan="4">I. 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="3">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 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 one NJ PCB system (test no. NJPCB-6) and one New York PCB system (test no. NYTCB-5) [16], which were pinned only through the back-side pin anchor recesses of each barrier segment to reduce the deflection of the PCB system, is shown in Table 10. Results from these tests included the 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 45 indicate how the dynamic deflection, permanent set deflection, and working width for each crash test was defined.

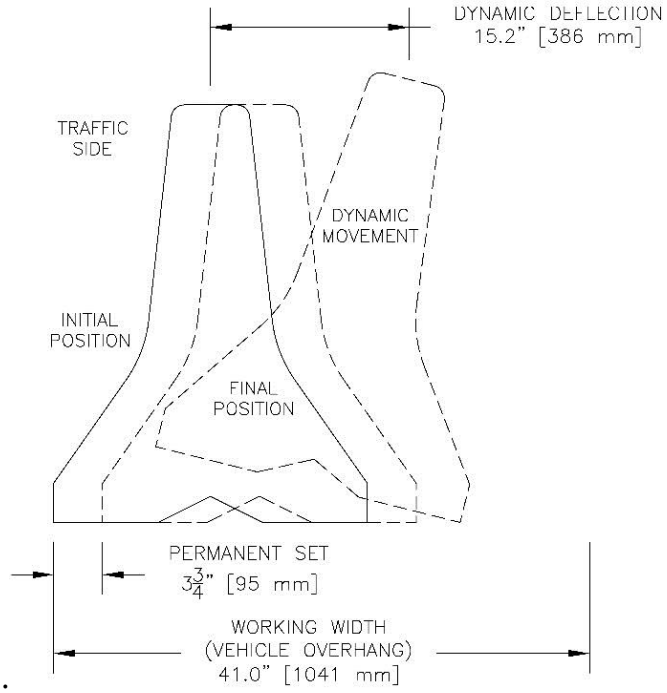
A review of the results from test nos. NJPCB-6 and NYTCB-5 revealed little to no benefit in terms of barrier deflection and clear space requirements for PCBs with only back-side pins due to removal of joint slack and/or the use of grouted barrier toes. Test no. NJPCB-6, with removal of joint slack and use of grouted toes, demonstrated lower dynamic and permanent set deflections when compared to test no. NYTCB-5. Additionally, test no. NJPCB-6 demonstrated higher working width and required clear space behind the barrier due to vehicle intrusion over the top of the barrier compared to test no. NYTCB-5. This finding likely occurred in test no. NJPCB-6 as the PCBs primarily translated laterally, while the barrier segments in test no. NYTCB-5 translated laterally and had more rotation backward. Fracture and disengagement of the barrier toes was observed in both the New Jersey DOT and New York DOT crash tests, which negated the effectiveness of the joint modifications. Second, the PCB segments used in these tests have a relatively small gap between adjacent barrier segments. Thus, improvement of the joint response through removal of joint slack and use of grouted toes provided less benefit than would be expected for other PCB systems that utilize joint spacings up to 4 inches. Finally, barrier system behavior and associated barrier deflections can vary from test to test due to the natural variability of a wide variety of factors involved in full-scale crash testing. These factors would include slight differences in impact conditions, differing test vehicle model years, slight variations in steel and concrete strengths, and variation of the cracking and damage observed on the barrier segment, among others. Thus, some variability would be expected in barrier performance, even for basically identical systems.

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

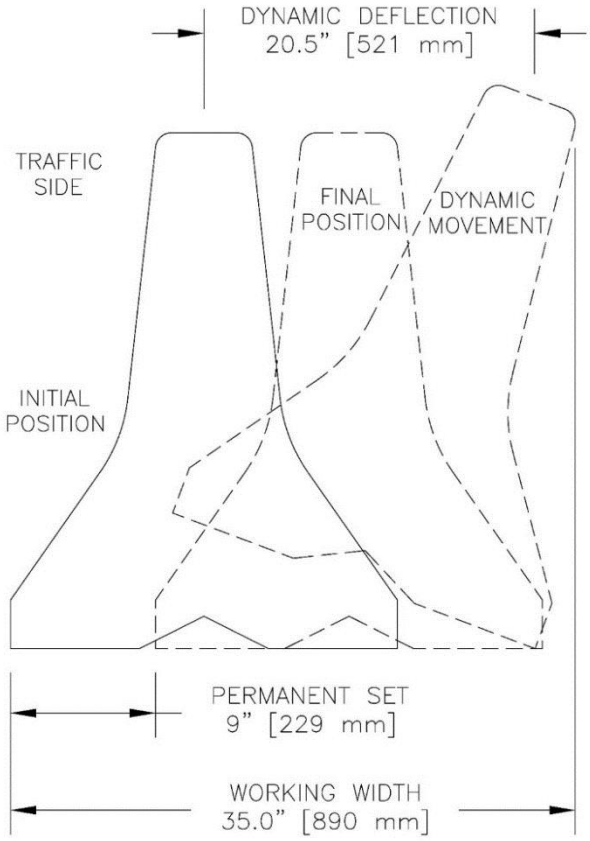
Table 10. Comparison of Pinned Back Side Only Systems

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	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 [16]	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)

N/A = Not Applicable



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 45. Deflection Comparisons – Test Nos. NJPCB-6 and NYTCB-5

8 MASH IMPLEMENTATION

The objective of this research was to evaluate the safety performance of NJDOT's PCB, Type 4 (Alternative B) system with a back-side pinned configuration and grouted toes, corresponding to connection type C in the 2015 NJDOT *Roadway Design Manual*. The NJDOT barriers consisted of NJDOT PCBs joined with a connection key. Barrier nos. 1 and 10 were anchored to the concrete roadway surface through the nine pin anchor recesses with 1-in. (25-mm) diameter by 15-in. (381-mm) long ASTM A36 steel pins. Barrier nos. 2 through 9 were anchored to the concrete surface through only the four back-side pin anchor recessed. The barrier segments were pulled in a direction parallel to their longitudinal axes, and slack was removed in 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-6, 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 62.9 mph (101.3 km/h) and at an angle of 25.1 degrees, resulting in an impact severity of 119.0 kip-ft (161.3 kJ). At 0.228 sec after impact, the vehicle became parallel to the system with a speed of 47.8 mph (76.9 km/h). At 0.398 sec, the vehicle exited the system at a speed of 46.9 mph (75.4 km/h) and at an angle of 8.0 degrees. The vehicle was successfully contained and smoothly redirected.

Exterior vehicle damage was moderate. Interior occupant compartment deformations were moderate with a maximum of 4⅝ in. (117 mm), which did not violate the limits established in MASH 2016. Damage to the barrier was also moderate, consisting of contact marks on the front face of the PCB segments as well as concrete spalling and cracking on barrier nos. 3, 4, 5, and 6. The maximum dynamic barrier deflection was 15.2 in. (386 mm), which included minor tipping of the barrier at the top surface. The working width of the PCB system was 41.0 in. (1,041 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 back 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 back side, corresponding to connection type C in the 2015 NJDOT *Roadway Design Manual*, was successfully crash tested and evaluated according to 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 pinned only on the back side included two systems: (1) 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) and (2) 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) [16]. A review of these test results (test nos. NJPCB-6 and NYTCB-5) revealed little to no benefit would be observed in reduced barrier deflections and clear space requirements for PCBs with only the back-side pinned due to joint slack removal and/or use of grouted toes as dynamic deflections and the clear space behind barrier for both tests are very similar. The finding is primarily due to no barrier reinforcement in the toes of both the New York and New Jersey PCB segments. The lack of steel reinforcement led to concrete fracture near the barrier toes when they were loaded by adjacent barrier segments, which caused increased rotation of the barrier joints. This concrete toe disengagement reduced the expected benefit that would have been provided by the removal of joint slack and use of grouted toes. Second, the PCB segments used in these tests have a relatively small gap between adjacent barrier segments. Thus, improvement of the joint response through removal of joint slack and use of grouted toes provided less benefit than would be expected for other PCB systems, which utilize joint spacings up to 4 in. (102 mm). Finally, barrier system behavior and associated barrier deflections can vary from test to test due to the natural variability of a wide variety of factors involved in full-scale crash testing. These factors would include slight differences in impact conditions, differing test vehicle model years, slight variations in steel and concrete strengths, and variation of the cracking and damage observed on the barrier 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 connection type C, as specified in the 2015 NJDOT *Roadway Design Manual* and utilized in this system, the NJDOT maximum allowable deflection is 11 in. (279 mm). For this test, the clear space behind the barrier was 15.2 in. (386 mm). Limited reductions in PCB deflections and clear space behind the barrier were observed with joint slack removal and use of grouted toes. Again, this finding is primarily due to the fracture and disengagement of the barrier toes. If larger reductions in PCB deflections and clear space are desired, PCB redesign or modification would be required, including reinforcement of the barrier toes, which may improve the effectiveness of joint slack removal and the use of grouted toes.

9 REFERENCES

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

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

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

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

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

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

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

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

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

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

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

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

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

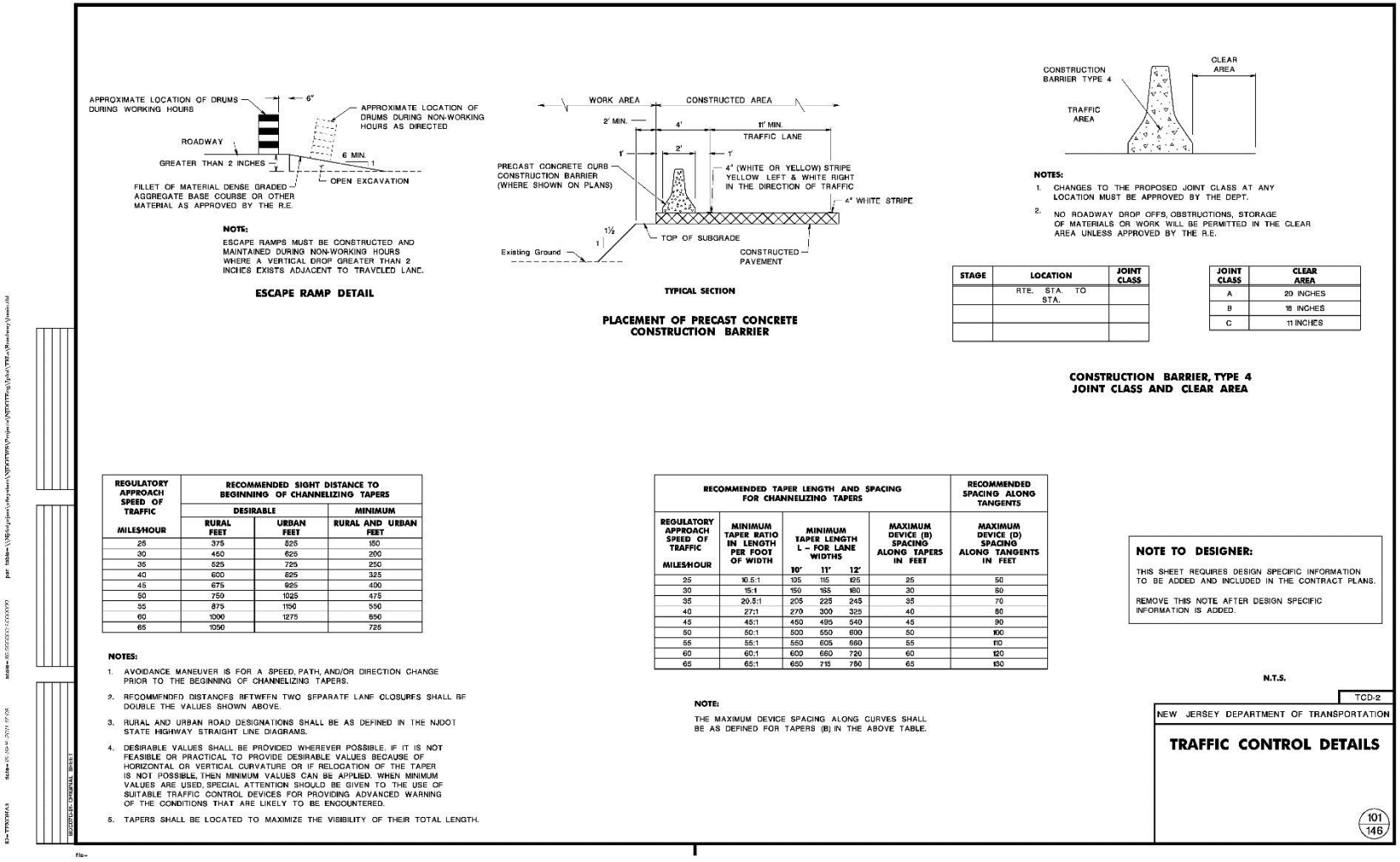
14. *Vehicle Damage Scale for Traffic Investigators*, Second Edition, Technical Bulletin No. 1, Traffic Accident Data (TAD) Project, National Safety Council, Chicago, Illinois, 1971.

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

16. Lechtenberg, K.A., Faller, R.K., Reid, J.D., and Sicking, D.L., *Dynamic Evaluation of a Pinned Anchoring System for New York State's Temporary Concrete Barriers – Phase II*, Report No. TRP-03-224-10, Project No. TPF-5(193), Supplement #11, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, January 27, 2010.

10 APPENDICES

Appendix A. NJDOT PCB Standard Plans



STAGE	LOCATION	JOINT CLASS
	RTE. STA. TO STA.	

JOINT CLASS	CLEAR AREA
A	20 INCHES
B	18 INCHES
C	11 INCHES

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

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

Figure A-1. NJDOT PCB Standard Plans

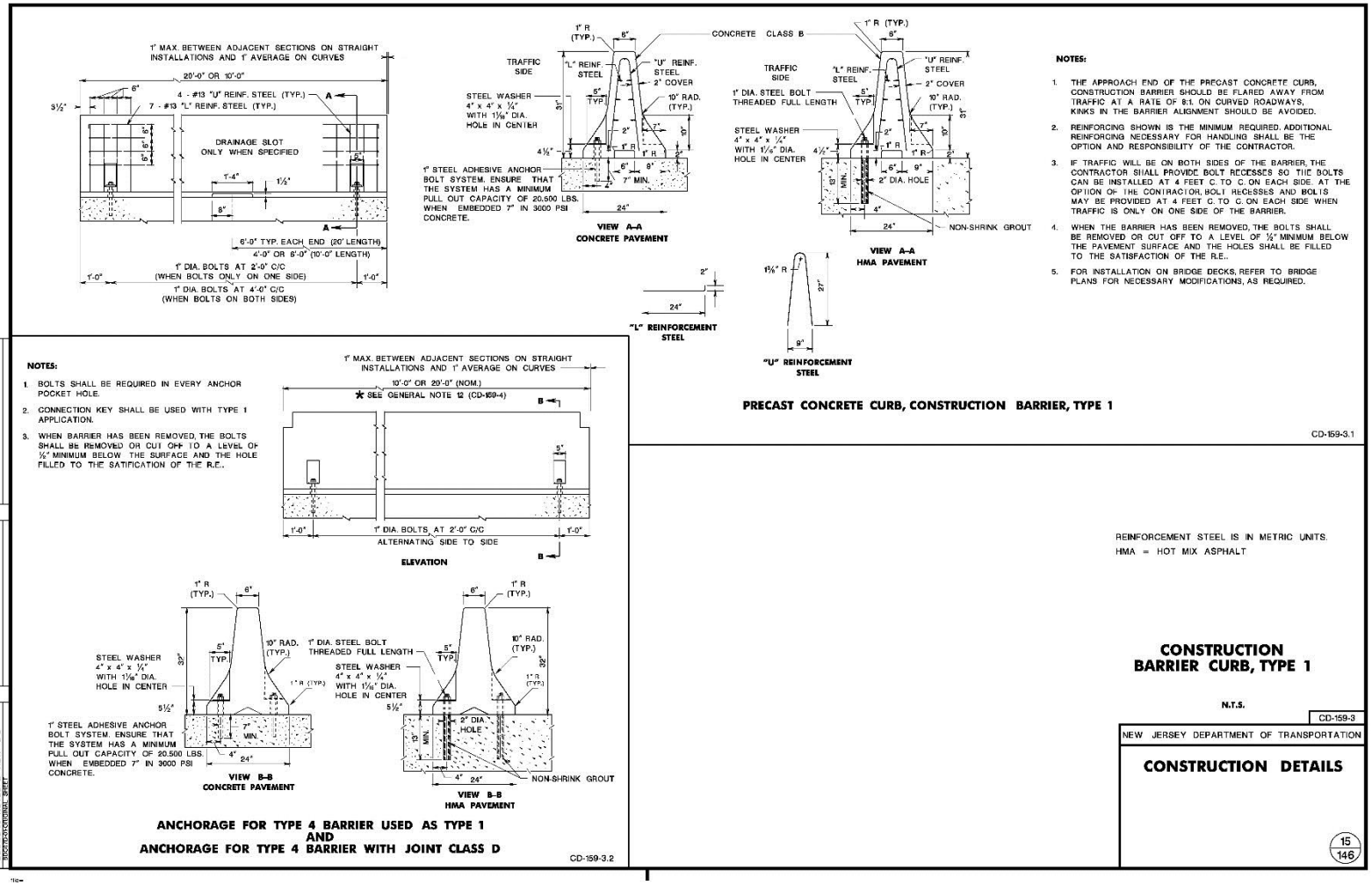
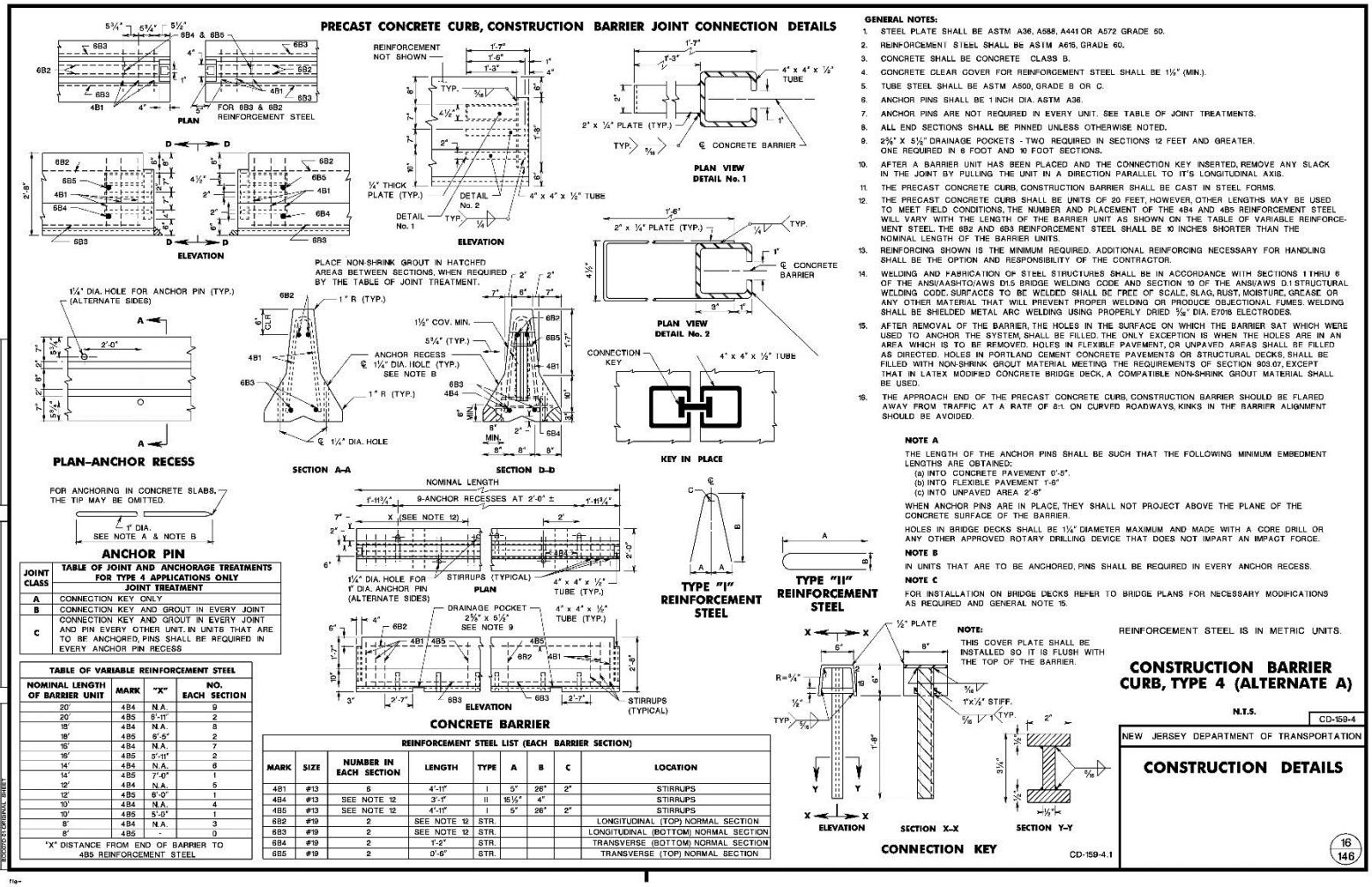


Figure A-2. NJDOT PCB Standard Plans



JOINT CLASS	TABLE OF JOINT AND ANCHORAGE TREATMENTS FOR TYPE 4 APPLICATIONS ONLY — JOINT TREATMENT
A	CONNECTION KEY ONLY
B	CONNECTION KEY AND GROUT IN EVERY JOINT
C	CONNECTION KEY AND GROUT IN EVERY JOINT AND PIN EVERY OTHER UNIT. IN UNITS THAT ARE TO BE ANCHORED, PINS SHALL BE REQUIRED IN EVERY ANCHOR PIN RECESS

TABLE OF VARIABLE REINFORCEMENT STEEL			
NOMINAL LENGTH OF BARRIER UNIT	MARK	"X"	NO. EACH SECTION
20'	4B4	N.A.	9
20'	4B5	5'-11"	2
18'	4B4	N.A.	8
18'	4B5	6'-5"	2
16'	4B4	N.A.	7
16'	4B5	5'-11"	2
14'	4B4	N.A.	6
14'	4B5	7'-0"	1
12'	4B4	N.A.	5
12'	4B5	6'-0"	1
10'	4B4	N.A.	4
10'	4B5	5'-0"	1
8'	4B4	N.A.	3
8'	4B5	-	0
"X" DISTANCE FROM END OF BARRIER TO 4B5 REINFORCEMENT STEEL			

REINFORCEMENT STEEL LIST (EACH BARRIER SECTION)								
MARK	SIZE	NUMBER IN EACH SECTION	LENGTH	TYPE	A	B	C	LOCATION
4B1	#13	6	4'-11"	I	5"	26"	2"	STIRRUPS
4B4	#13	SEE NOTE 12	3'-1"	II	15½"	4"		STIRRUPS
4B5	#13	SEE NOTE 12	4'-11"	I	5"	26"	2"	STIRRUPS
6B2	#19	2	SEE NOTE 12	STR.				LONGITUDINAL (TOP) NORMAL SECTION
6B3	#19	2	SEE NOTE 12	STR.				LONGITUDINAL (BOTTOM) NORMAL SECTION
6B4	#19	2	1'-2"	STR.				TRANSVERSE (BOTTOM) NORMAL SECTION
6B5	#19	2	0'-6"	STR.				TRANSVERSE (TOP) NORMAL SECTION

Figure A-3. NJDOT PCB Standard Plans

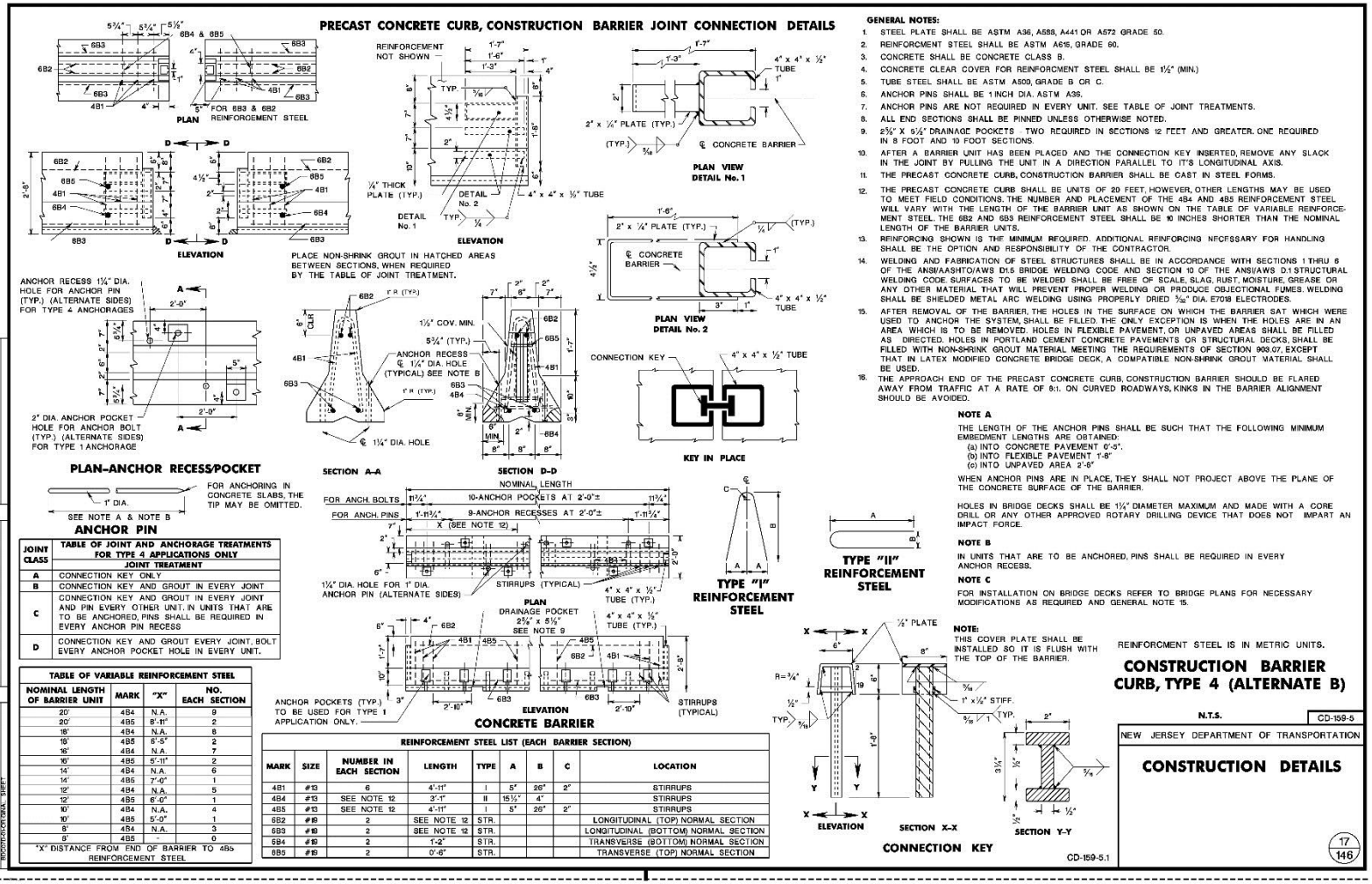


Figure A-4. NJDOT PCB Standard Plans

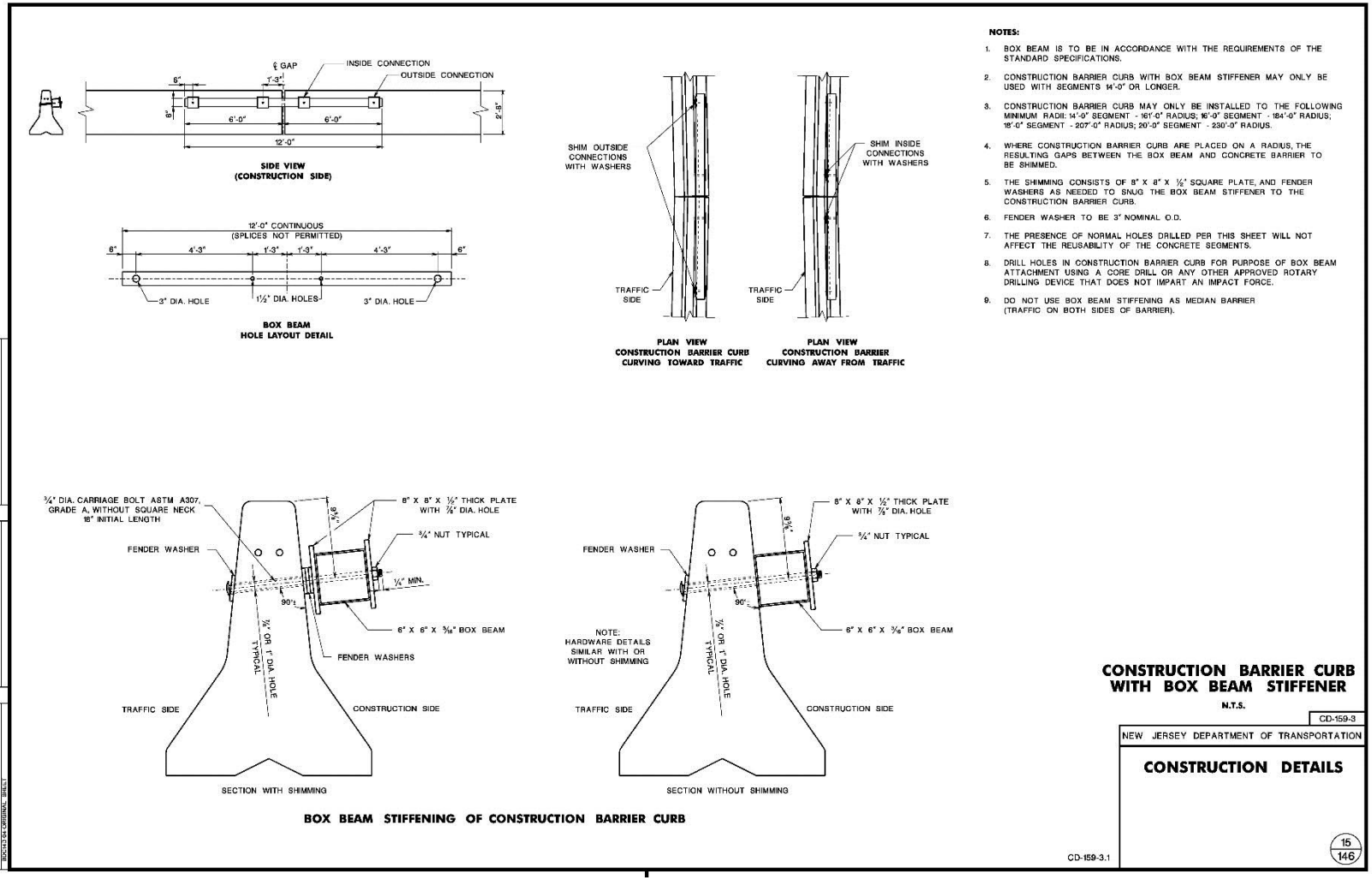


Figure A-5. NJDOT PCB Standard Plans

Appendix B. Material Specifications

Table B-1. Bill of Materials, Test No. NJPCB-6

Item No.	Description	Material Specification	Reference
A1	Concrete Barrier Segment	Min. f 'c = 3,700 psi (25.5 MPa)	Barrier Nos. 1, 4, 5, 6 and 10: University of Nebraska 15-563; Barrier Nos. 2, 3, 7, 8 and 9: KU3325
A2	Anchor Steel Pin	ASTM A36	Heat #54153853
B1	Rebar - #4 Vertical Stirrup	ASTM A615 Gr. 60	Barrier Nos. 1, 4, 5, 6 and 10: H#61101274, 61101493, 61101510, 61101492, 61101499, 61101772 Barrier Nos. 2, 3, 7, 8 and 9: H#JL1000, JK9068, 61108687
B2, B3	Rebar - #6 Longitudinal Bar	ASTM A615 Gr. 60	Barrier Nos. 1, 4, 5, 6 and 10: H#6115448, 61105472 Barrier Nos. 2, 3, 7, 8 and 9: H#61110285, 61110265, JL3511, JL3506, JL3505
B4	Rebar - #4 Horizontal Anchor Recess, Reinforcement Stirrup	ASTM A615 Gr. 60	Barrier Nos. 1, 4, 5, 6 and 10: H#61101274, 61101493, 61101510, 61101492, 61101499, 61101772 Barrier Nos. 2, 3, 7, 8 and 9: H#JL1000, JK9068, 61108687
B5	Rebar - #6 Top and Bottom Cross Bar	ASTM A615 Gr. 60	Barrier Nos. 1, 4, 5, 6 and 10: H#6115448, 61105472 Barrier Nos. 2, 3, 7, 8 and 9: H#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	Barrier Nos. 1, 4, 5, 6 and 10: H#821597, 1422428, M04495_1, T83539, SD5020 Barrier Nos. 2, 3, 7, 8 and 9: H#SF1424, SF4193
C2	Bent Steel Plate 1, 2”×¼” (51×6)	ASTM A36	Barrier Nos. 1, 4, 5, 6 and 10: H#1129849 Barrier Nos. 2, 3, 7, 8 and 9: H#269878
C3	Bent Steel Plate 2, 2”×¼” (51×6)	ASTM A36	Barrier Nos. 1, 4, 5, 6 and 10: H#1129849 Barrier Nos. 2, 3, 7, 8 and 9: H#269878
D1	Steel Plate 1, 2”×½” (51×13)	ASTM A36	Barrier Nos. 1, 4, 5, 6 and 10: H#L99837 Barrier Nos. 2, 3, 7, 8 and 9: H#54148807
D2	Steel Plate 2, 2-¼”×½” (51×13)	ASTM A36	Barrier Nos. 1, 4, 5, 6 and 10: H#54144612 Barrier Nos. 2, 3, 7, 8 and 9: H#54148805
D3	½” (13) Steel Plate – Stiffener	ASTM A36	Barrier Nos. 1, 4, 5, 6 and 10: H#54144612, L99837 Barrier Nos. 2, 3, 7, 8 and 9: H#SF2550
D4	½” (13) Steel Plate – Top Plate	ASTM A36	Barrier Nos. 1, 4, 5, 6 and 10: H#54144612, L99837 Barrier Nos. 2, 3, 7, 8 and 9: H#SF2550
E1	Non-Shrink Grout	Min. 1-day Compressive Strength 1,000 psi (6.9 MPa)	Advantage Grout ASTM C1107 Product Code: 67435 R: 2147369180

UNIVERSITY OF NEBRASKA

15-563

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

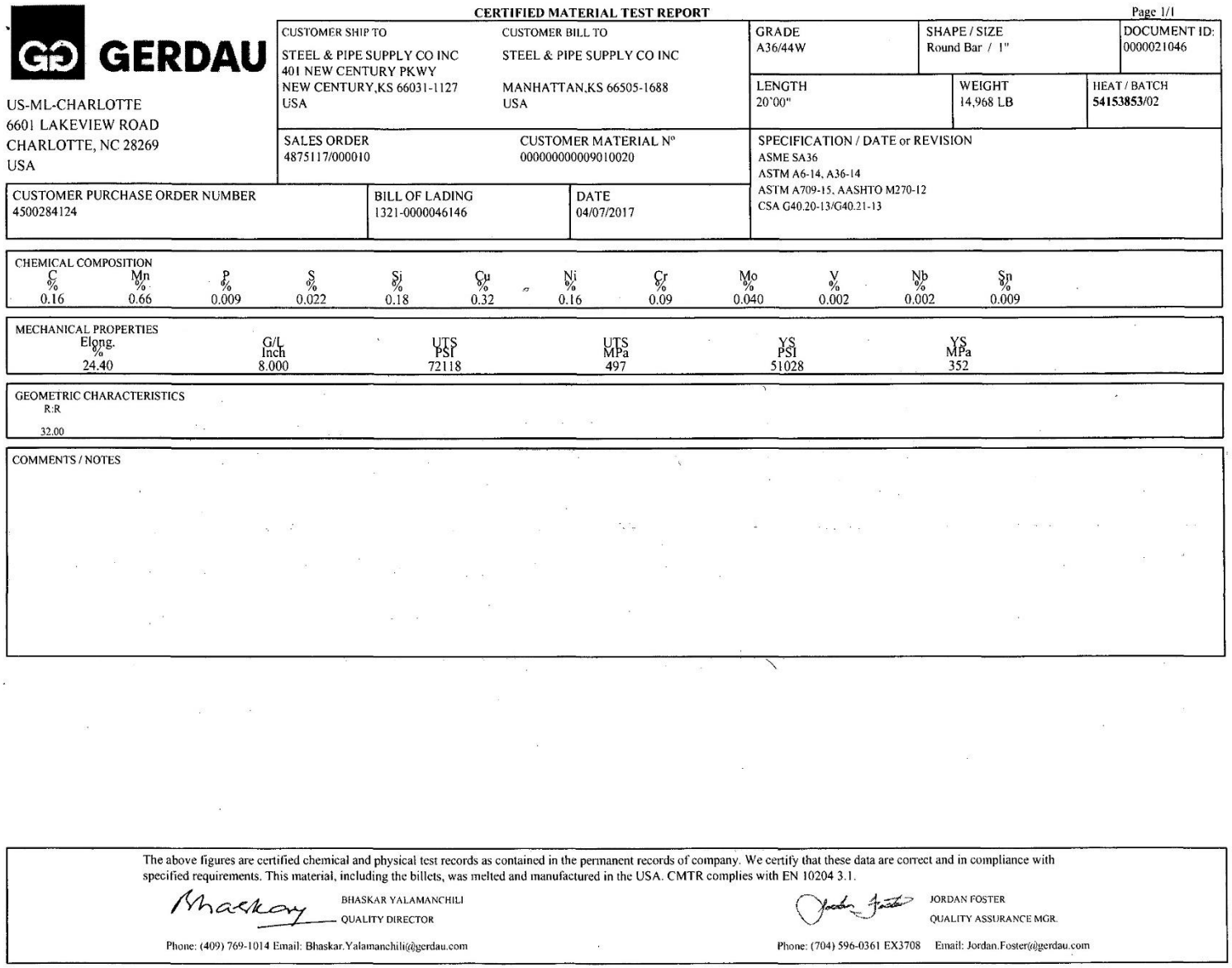
Figure B-2. Concrete Barrier Segment – Concrete Strength, Test No. NJPCB-6

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-3. Concrete Barrier Segment – Concrete Strength, Test No. NJPCB-6



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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
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

GRADE	SHAPE / SIZE	DOCUMENT ID:
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

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

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

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.

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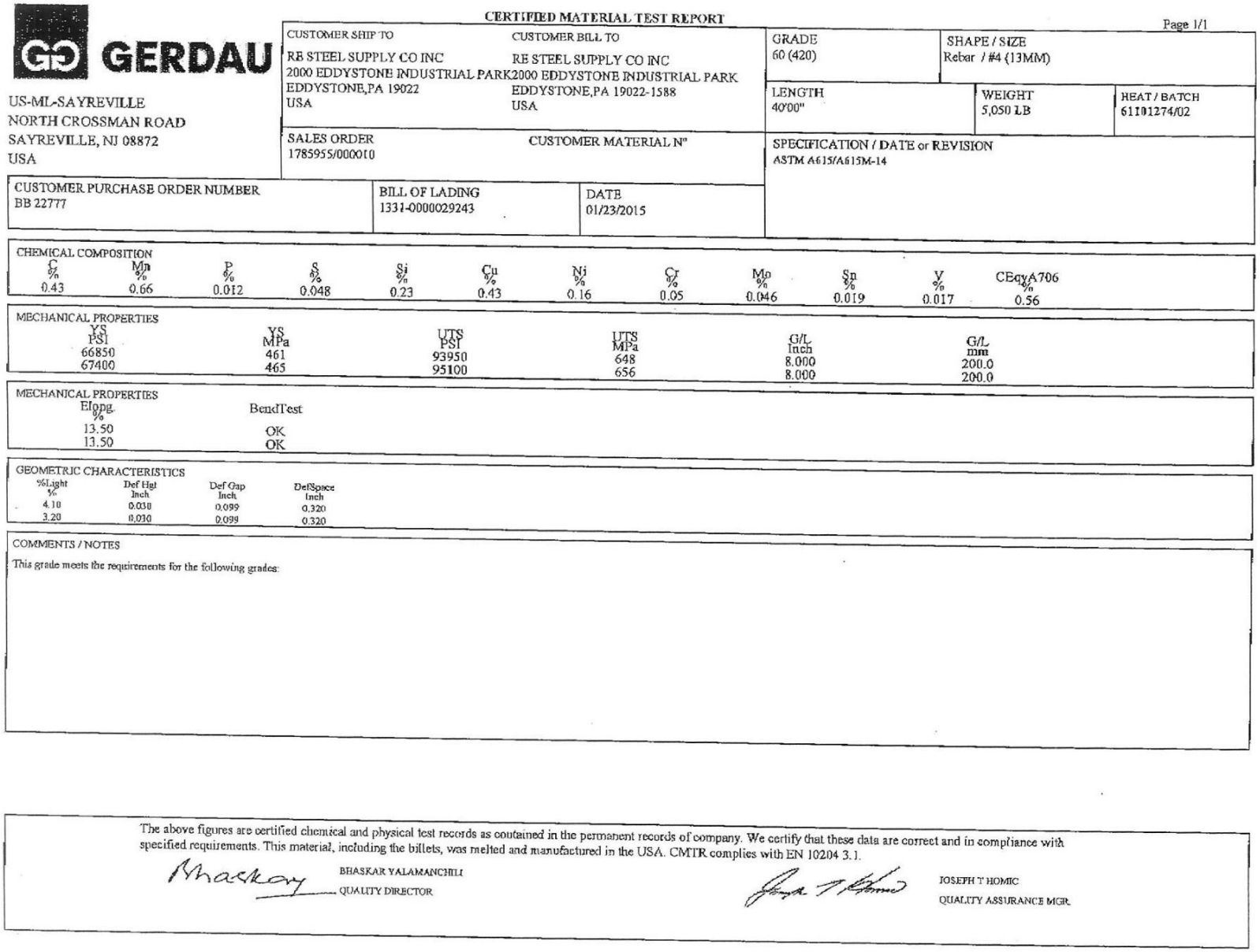
Figure B-4. Anchor Pins Material Certificate, Test No. NJPCB-6



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SAYREVILLE, NJ 08872
USA

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

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

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

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

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

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqvA706 %
0.43	0.66	0.012	0.048	0.23	0.43	0.16	0.05	0.046	0.019	0.017	0.56

MECHANICAL PROPERTIES

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

MECHANICAL PROPERTIES

Elong. %	BendTest
13.50	OK
13.50	OK

GEOMETRIC CHARACTERISTICS

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

COMMENTS / NOTES

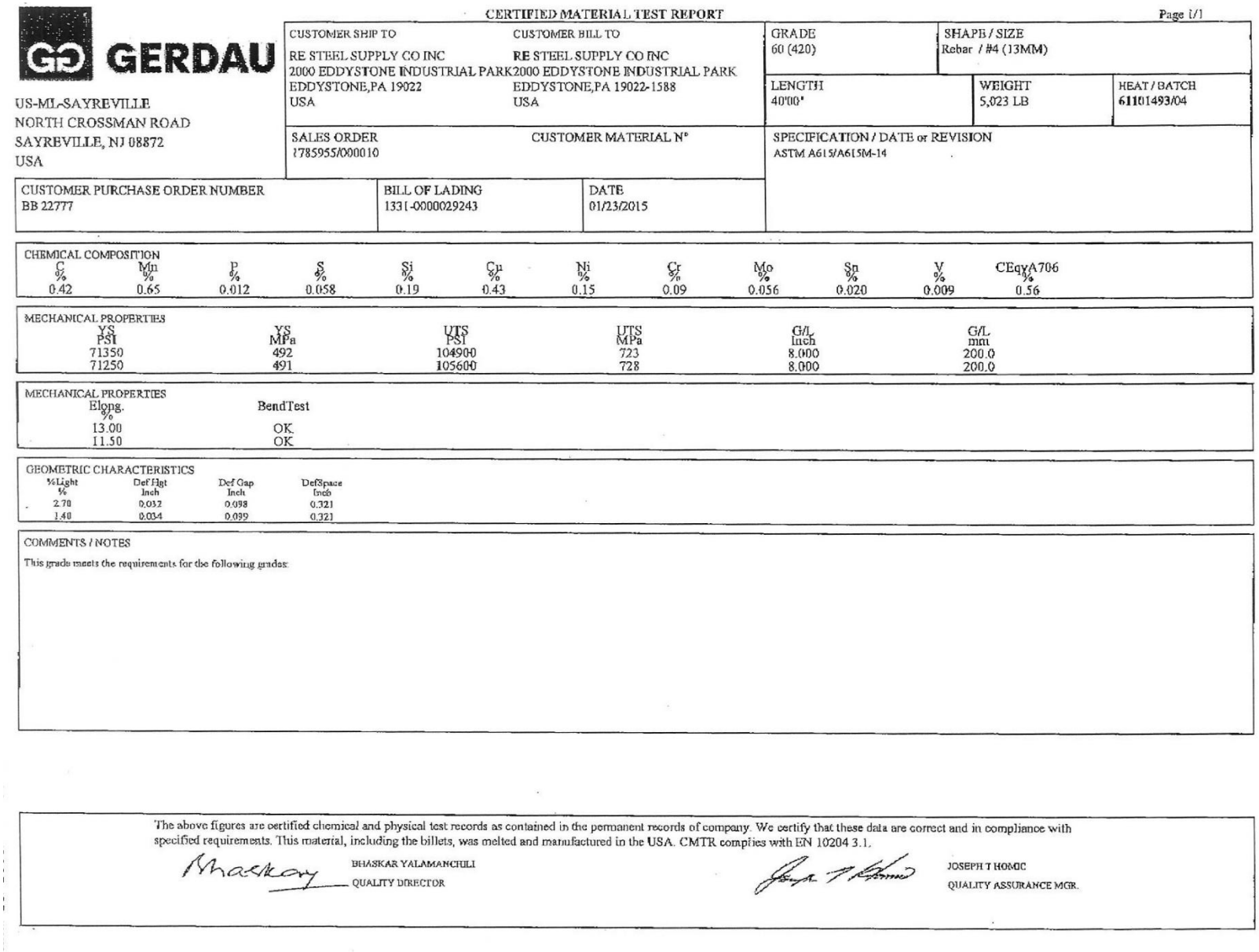
This grade meets the requirements for the following grades:

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

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

JOSEPH T HOMIC
QUALITY ASSURANCE MGR.

Figure B-5. Rebar No. 4 Material Certificate, Test No. NJPCB-6



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

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

GRADE	SHAPE / SIZE		
60 (420)	Rebar / #4 (13MM)		
LENGTH	WEIGHT	HEAT / BATCH	
40'00"	5,023 LB	61101493/04	

SALES ORDER	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION
785955/000010		ASTM A615/A615M-14

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

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqvA706 %
0.42	0.65	0.012	0.058	0.19	0.43	0.15	0.09	0.056	0.020	0.009	0.56

MECHANICAL PROPERTIES

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

MECHANICAL PROPERTIES

Elong. %	BendTest
13.00	OK
11.50	OK

GEOMETRIC CHARACTERISTICS

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

COMMENTS / NOTES

This grade meets the requirements for the following grades:

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

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

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NORTH CROSSMAN ROAD
SAYREVILLE, NJ 08872
USA

CERTIFIED MATERIAL TEST REPORT Page 1/1

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

GRADE	SHAPE / SIZE		
60 (420)	Rebar / #4 (13MM)		
LENGTH	WEIGHT	HEAT / BATCH	
40'00"	5,050 LB	61101510/03	

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

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

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqvA706 %
0.42	0.66	0.018	0.046	0.21	0.30	0.11	0.06	0.035	0.018	0.015	0.55

MECHANICAL PROPERTIES

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

MECHANICAL PROPERTIES

Elong. %	BendTest
12.00	OK
13.00	OK

GEOMETRIC CHARACTERISTICS

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

COMMENTS / NOTES

This grade meets the requirements for the following grades:

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

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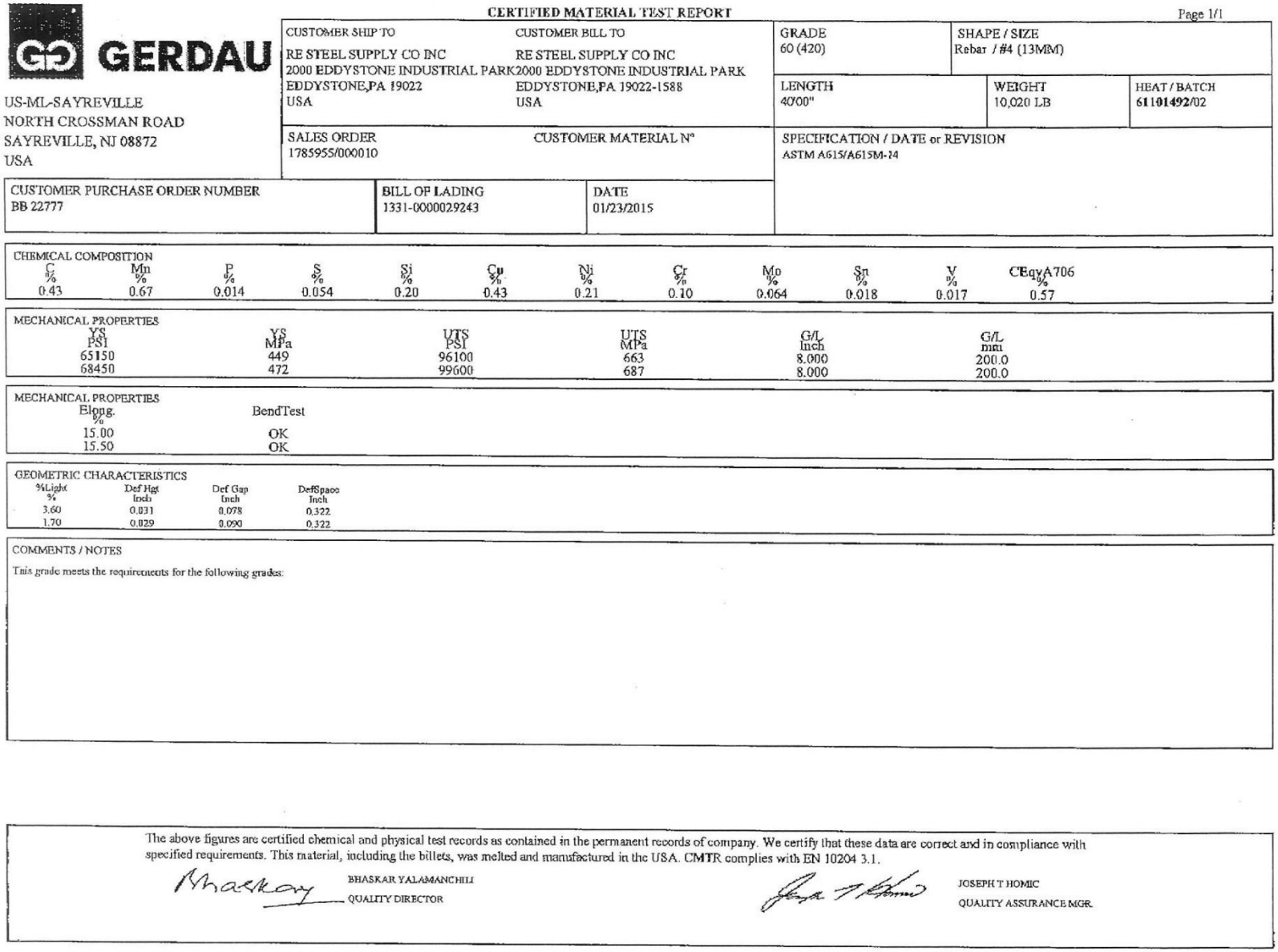
Figure B-7. Rebar No. 4 Material Certificate, Test No. NJPCB-6



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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
RE STEEL SUPPLY CO INC
2000 EDDYSTONE INDUSTRIAL PARK
EDDYSTONE,PA 19022
USA

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

GRADE: 60 (420)

SHAPE / SIZE: Rebar / #4 (13MM)

LENGTH: 40'00"

WEIGHT: 10,020 LB

HEAT / BATCH: 61101492/02

SALES ORDER: 1785955/000010

CUSTOMER MATERIAL N°:

SPECIFICATION / DATE or REVISION: ASTM A615/A615M-14

CUSTOMER PURCHASE ORDER NUMBER: BB 22777

BILL OF LADING: 1331-0000029243

DATE: 01/23/2015

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqvA706 %
0.43	0.67	0.014	0.054	0.20	0.43	0.21	0.10	0.064	0.018	0.017	0.57

MECHANICAL PROPERTIES

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

MECHANICAL PROPERTIES

Elong. %	BendTest
15.00	OK
15.50	OK

GEOMETRIC CHARACTERISTICS

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

COMMENTS / NOTES

This grade meets the requirements for the following grades:

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

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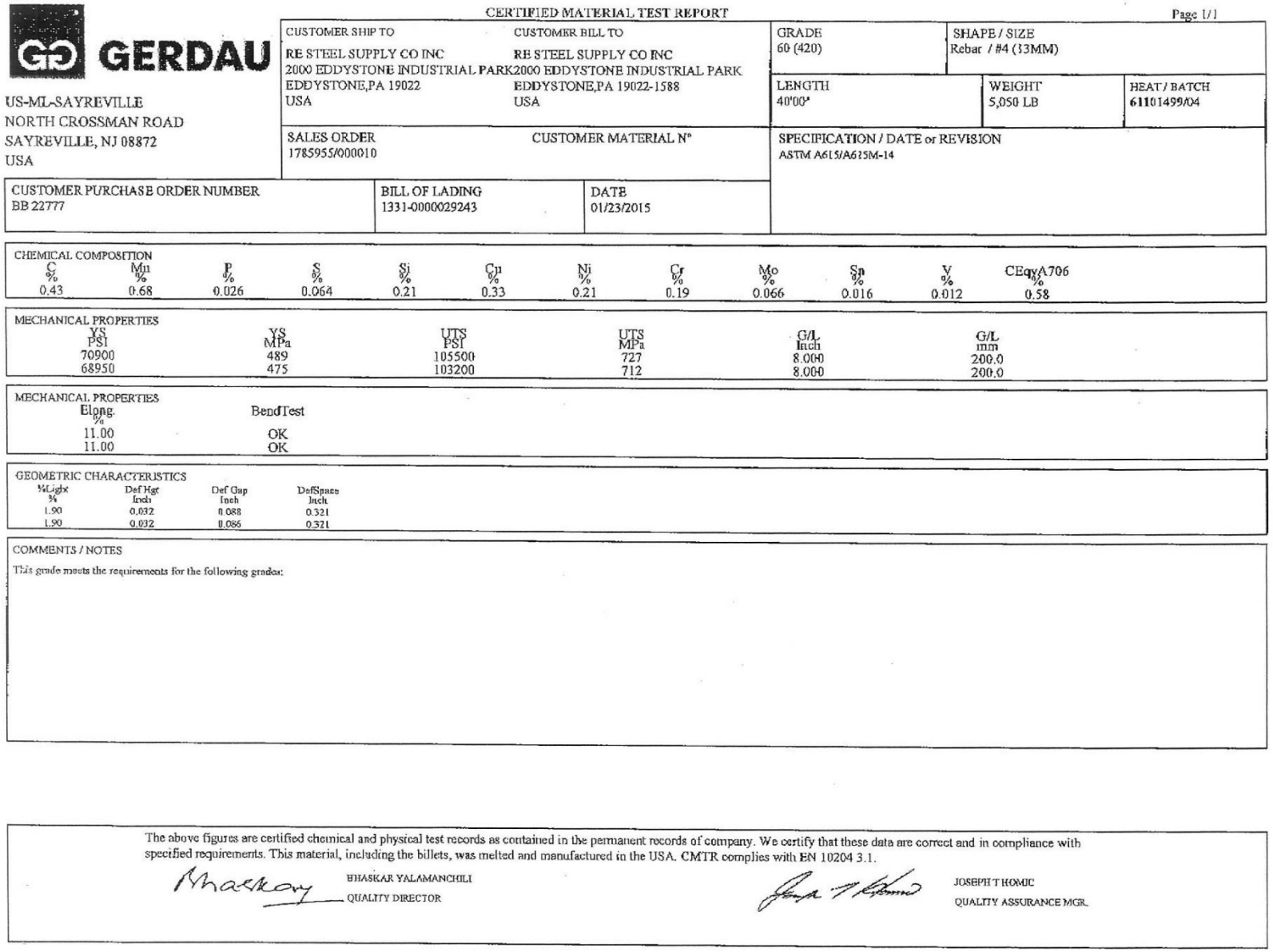
QUALITY ASSURANCE MGR.

Figure B-8. Rebar No. 4 Material Certificate, Test No. NJPCB-6



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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
RE STEEL SUPPLY CO INC
2000 EDDYSTONE INDUSTRIAL PARK
EDDYSTONE,PA 19022
USA

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

GRADE: 60 (420)

SHAPE / SIZE: Rebar / #4 (13MM)

LENGTH: 40'00"

WEIGHT: 5,050 LB

HEAT / BATCH: 61101499/04

SALES ORDER: 1785955/000010

CUSTOMER MATERIAL N°:

SPECIFICATION / DATE or REVISION: ASTM A615/A615M-14

CUSTOMER PURCHASE ORDER NUMBER: BB 22777

BILL OF LADING: 1331-0000029243

DATE: 01/23/2015

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqvA706 %
0.43	0.68	0.026	0.064	0.21	0.33	0.21	0.19	0.066	0.016	0.012	0.58

MECHANICAL PROPERTIES

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

MECHANICAL PROPERTIES

Elong. %	BendTest
11.00	OK
11.00	OK

GEOMETRIC CHARACTERISTICS

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

COMMENTS / NOTES

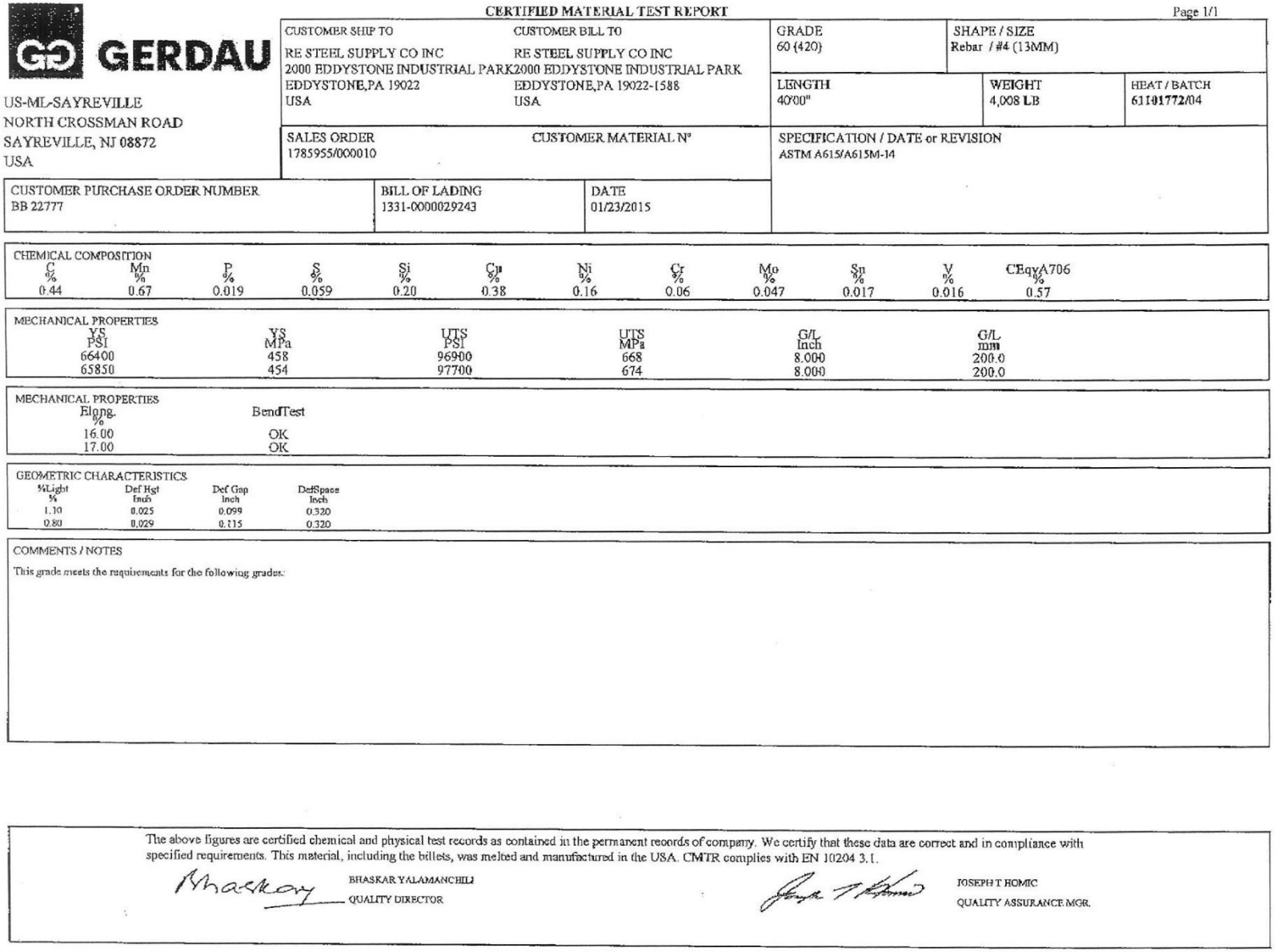
This grade meets the requirements for the following grades:

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

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

JOSEPH T HOMJC
QUALITY ASSURANCE MGR.

Figure B-9. Rebar No. 4 Material Certificate, Test No. NJPCB-6



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

CERTIFIED MATERIAL TEST REPORT

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CUSTOMER SHIP TO	CUSTOMER BILL TO	GRADE	SHAPE / SIZE		
RE STEEL SUPPLY CO INC 2000 EDDYSTONE INDUSTRIAL PARK EDDYSTONE,PA 19022 USA	RE STEEL SUPPLY CO INC 2000 EDDYSTONE INDUSTRIAL PARK EDDYSTONE,PA 19022-1588 USA	60 (420)	Rebar / #4 (13MM)		
		LENGTH 40'00"	WEIGHT 4,008 LB	HEAT / BATCH 61101772/04	
SALES ORDER 1785955/000010	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION ASTM A615/A615M-14			
CUSTOMER PURCHASE ORDER NUMBER BB 22777	BILL OF LADING 1331-0000029243	DATE 01/23/2015			

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqvA706 %
0.44	0.67	0.019	0.059	0.20	0.38	0.16	0.06	0.047	0.017	0.016	0.57

MECHANICAL PROPERTIES

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

MECHANICAL PROPERTIES

Elong. %	BendTest
16.00	OK
17.00	OK

GEOMETRIC CHARACTERISTICS

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

COMMENTS / NOTES

This grade meets the requirements for the following grades:

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

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

JOSEPH T HOMIC
QUALITY ASSURANCE MGR.

Figure B-10. Rebar No. 4 Material Certificate, Test No. NJPCB-6

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: JL1000-376202
HEAT NUMBER: JL1000
BILL OF LADING: 00514980
SALES ORDER/LINE: 121669 / 001
CERT ID / REV: 00049973 / 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
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.

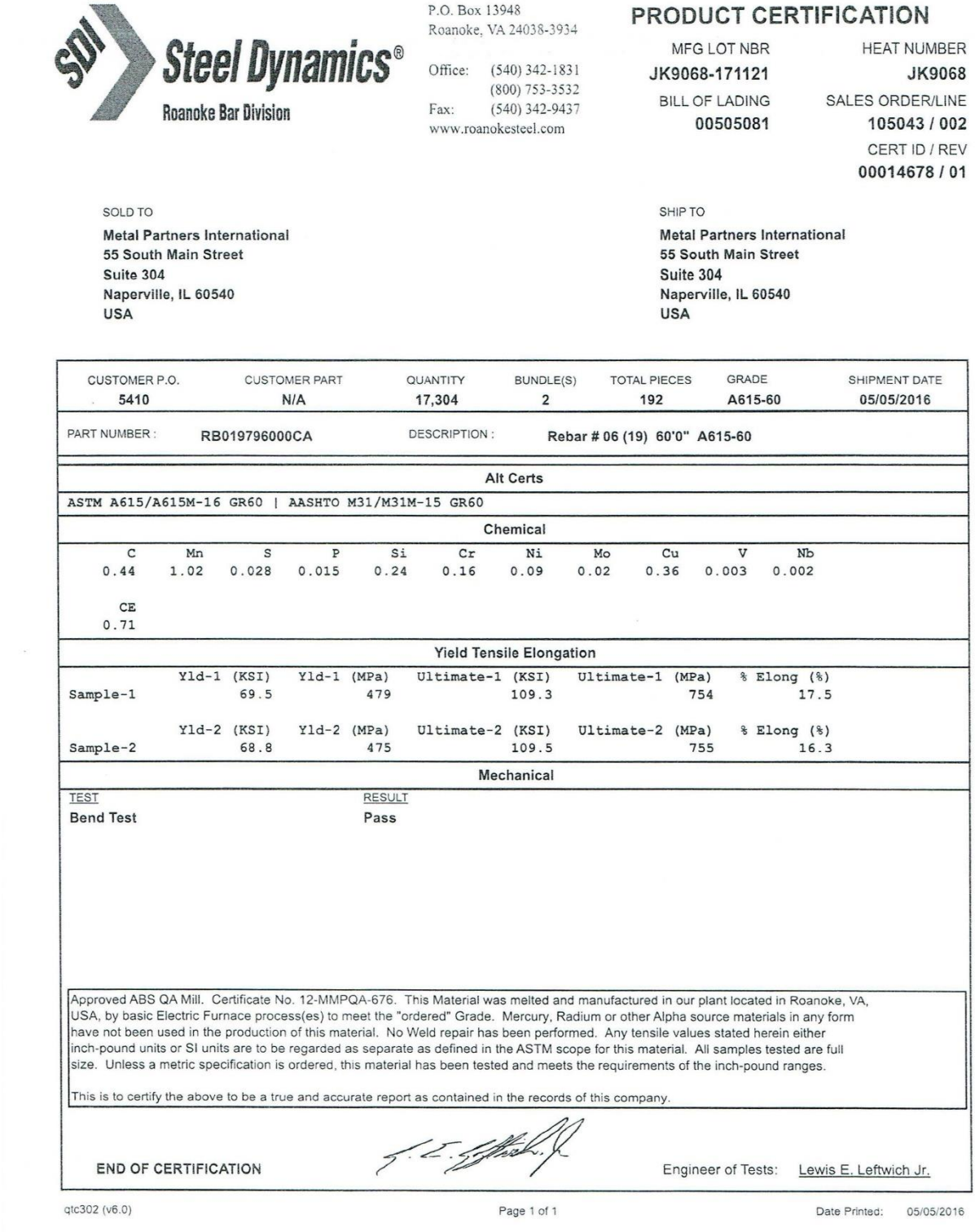
This is to certify the above to be a true and accurate report as contained in the records of this company.

END OF CERTIFICATION

Engineer of Tests: Lewis E. Leftwich Jr.

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

Figure B-11. Rebar No. 4 Material Certificate, Test No. NJPCB-6



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.

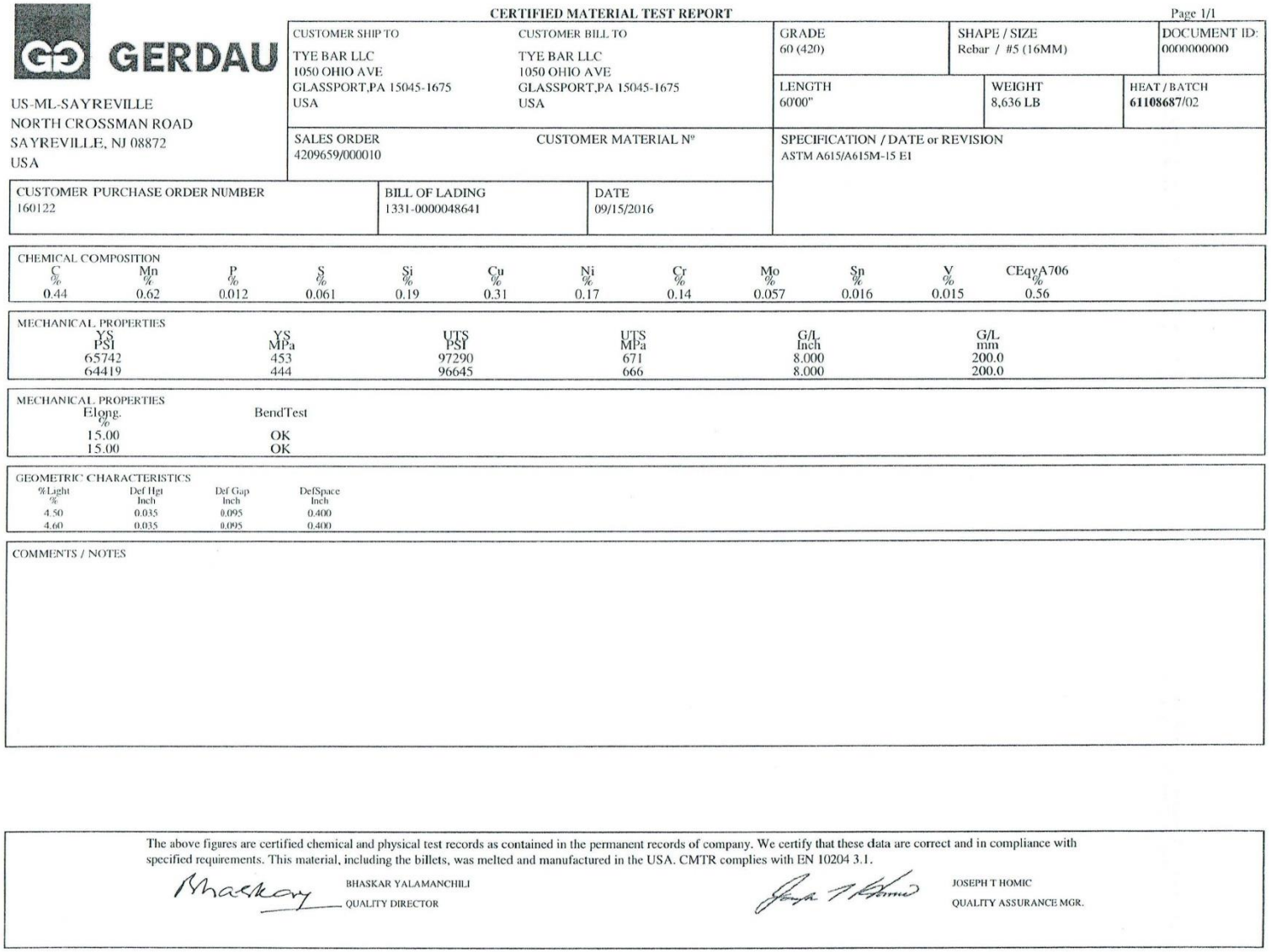
This is to certify the above to be a true and accurate report as contained in the records of this company.

END OF CERTIFICATION

Engineer of Tests: Lewis E. Leftwich Jr.

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

Figure B-12. Rebar No. 4 Material Certificate, Test No. NJPCB-6



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CERTIFIED MATERIAL TEST REPORT Page 1/1

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

CUSTOMER SHIP TO	CUSTOMER BILL TO
TYE BAR LLC 1050 OHIO AVE GLASSPORT,PA 15045-1675 USA	TYE BAR LLC 1050 OHIO AVE GLASSPORT,PA 15045-1675 USA

GRADE	SHAPE / SIZE	DOCUMENT ID:
60 (420)	Rebar / #5 (16MM)	0000000000

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

SALES ORDER	CUSTOMER MATERIAL Nº
4209659/000010	

SPECIFICATION / DATE or REVISION
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 %	CEqvA706 %
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

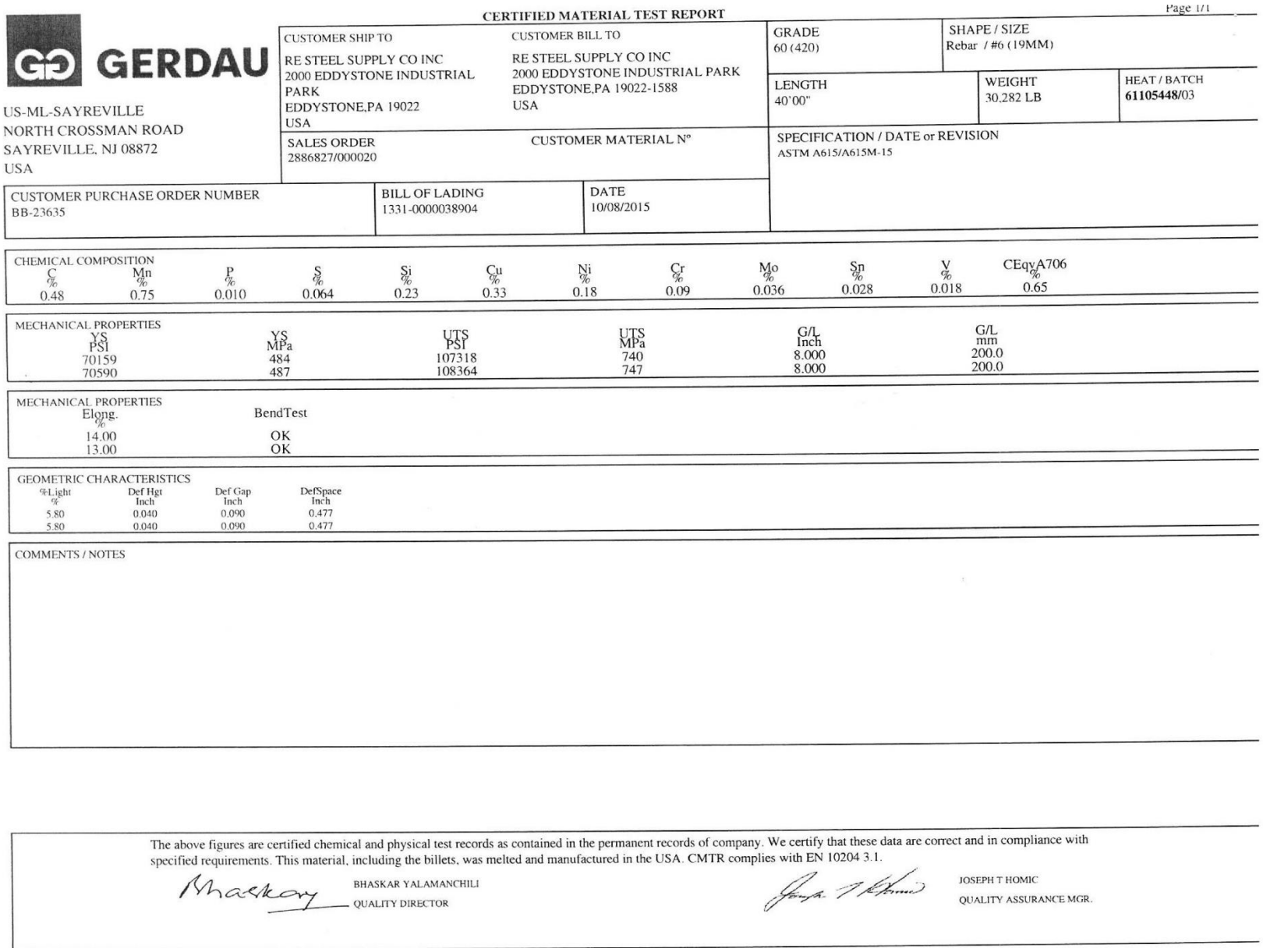
COMMENTS / NOTES

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-13. Rebar No. 4 Material Certificate, Test No. NJPCB-6



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

CERTIFIED MATERIAL TEST REPORT

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

GRADE	SHAPE / SIZE
60 (420)	Rebar / #6 (19MM)

LENGTH	WEIGHT	HEAT / BATCH
40'00"	30.282 LB	**61105448**/03

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

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

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqvA706 %
0.48	0.75	0.010	0.064	0.23	0.33	0.18	0.09	0.036	0.028	0.018	0.65

MECHANICAL PROPERTIES

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

MECHANICAL PROPERTIES

Elong. %	BendTest
14.00	OK
13.00	OK

GEOMETRIC CHARACTERISTICS

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

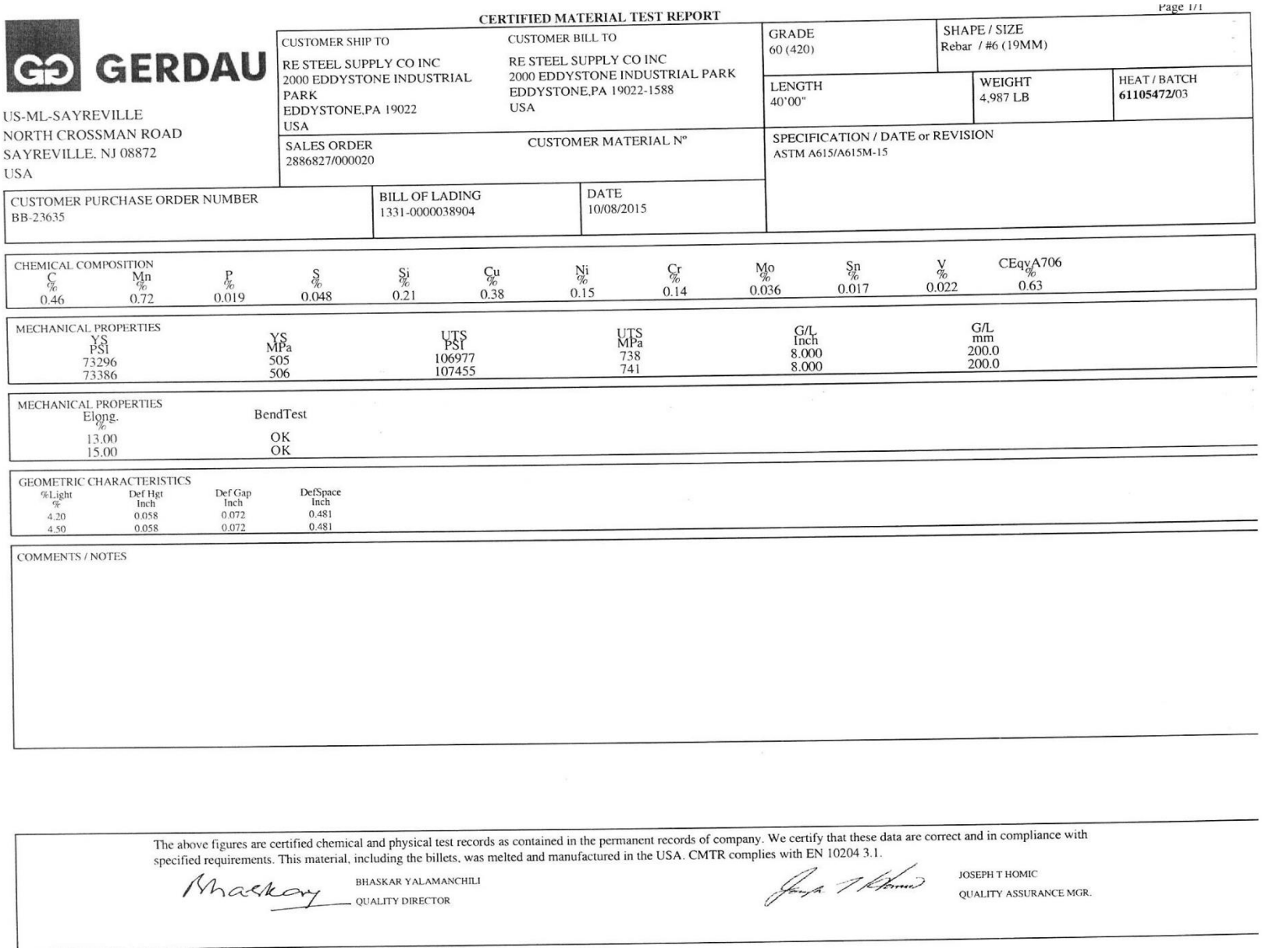
COMMENTS / NOTES

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

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

JOSEPH T HOMIC
QUALITY ASSURANCE MGR.

Figure B-14. Rebar No. 6 Material Certificate, Test No. NJPCB-6



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

CERTIFIED MATERIAL TEST REPORT

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

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

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

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

CHEMICAL COMPOSITION

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	Mo %	Sn %	V %	CEqvA706 %
0.46	0.72	0.019	0.048	0.21	0.38	0.15	0.14	0.036	0.017	0.022	0.63

MECHANICAL PROPERTIES

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

MECHANICAL PROPERTIES

Elong. %	BendTest
13.00	OK
15.00	OK

GEOMETRIC CHARACTERISTICS

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

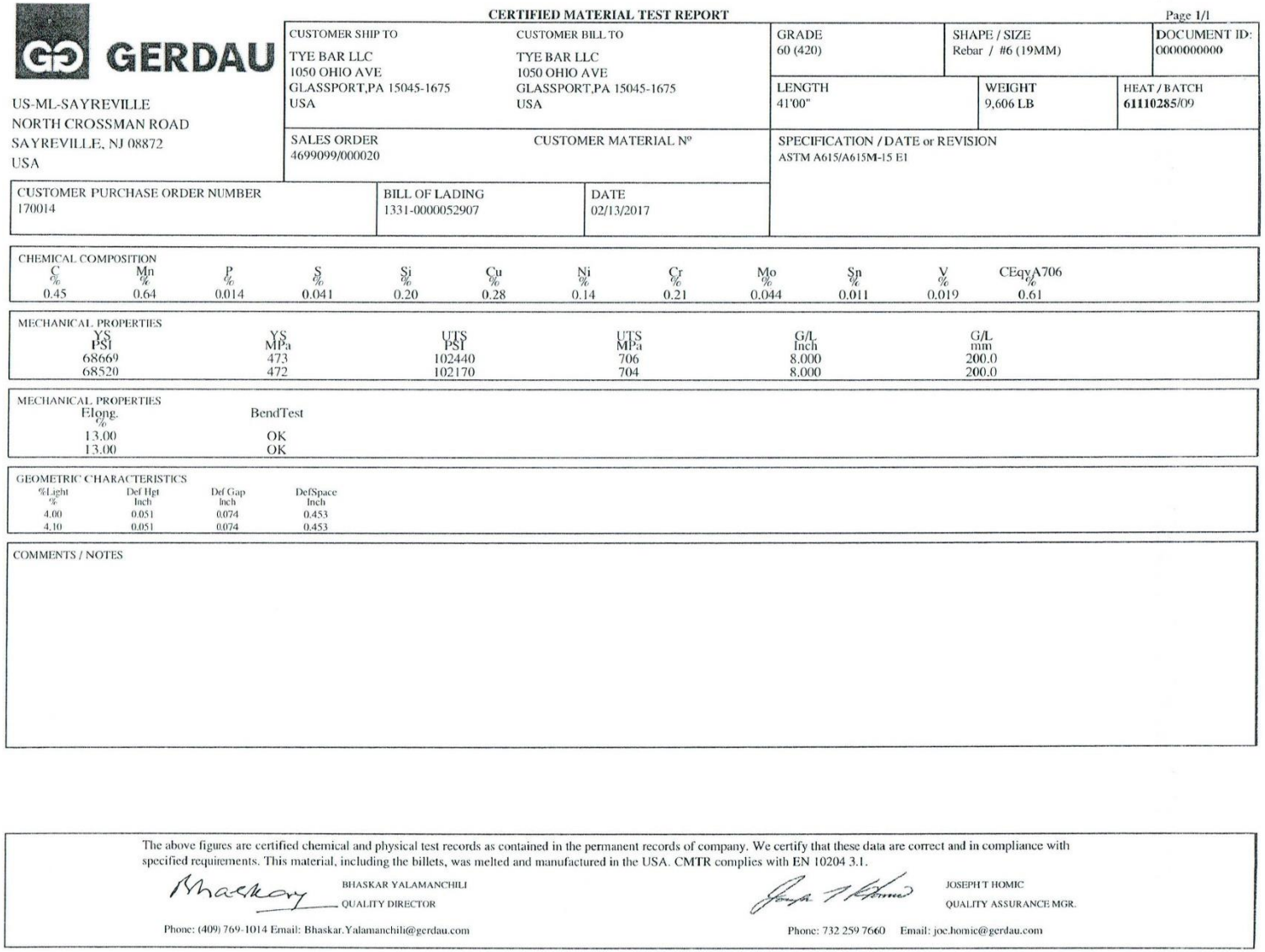
COMMENTS / NOTES

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

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

JOSEPH T HOMIC
QUALITY ASSURANCE MGR.

Figure B-15. Rebar No. 6 Material Certificate, Test No. NJPCB-6



CERTIFIED MATERIAL TEST REPORT Page 1/1

GERDAU

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

CUSTOMER SHIP TO	CUSTOMER BILL TO
TYE BAR LLC 1050 OHIO AVE GLASSPORT,PA 15045-1675 USA	TYE BAR LLC 1050 OHIO AVE GLASSPORT,PA 15045-1675 USA

GRADE	SHAPE / SIZE	DOCUMENT ID:
60 (420)	Rebar / #6 (19MM)	0000000000

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

SALES ORDER: 4699099/000020
CUSTOMER MATERIAL Nº:
SPECIFICATION / DATE or REVISION: 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 %	CEqvA706 %
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

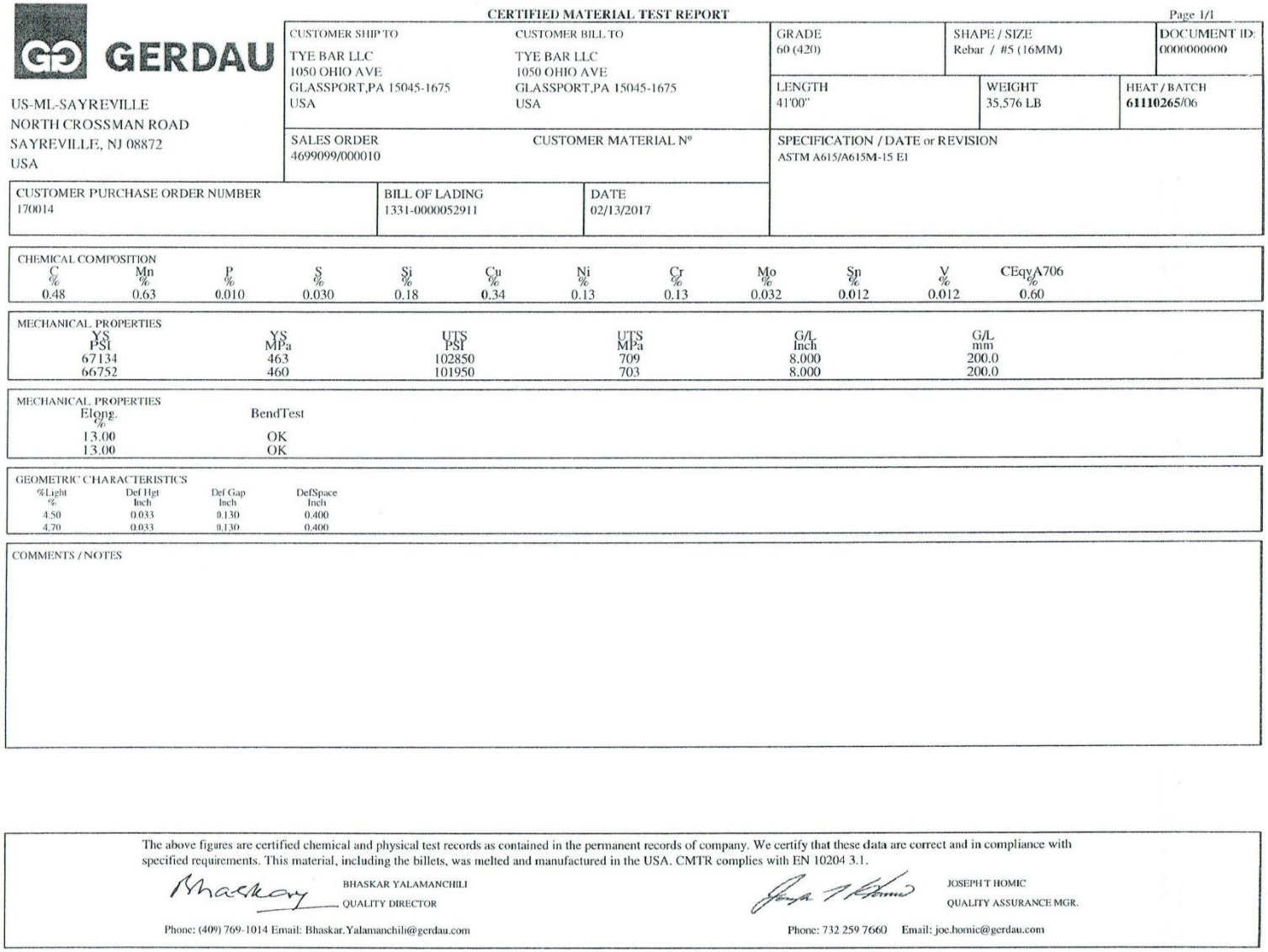
COMMENTS / NOTES

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-16. Rebar No. 6 Material Certificate, Test No. NJPCB-6



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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
TYE BAR LLC 1050 OHIO AVE GLASSPORT,PA 15045-1675 USA	TYE BAR LLC 1050 OHIO AVE GLASSPORT,PA 15045-1675 USA

GRADE	SHAPE / SIZE	DOCUMENT ID:
60 (420)	Rebar / #5 (16MM)	0000000000

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

SALES ORDER	CUSTOMER MATERIAL Nº
4699099/000010	

SPECIFICATION / DATE or REVISION
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 %	CEqvA706 %
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

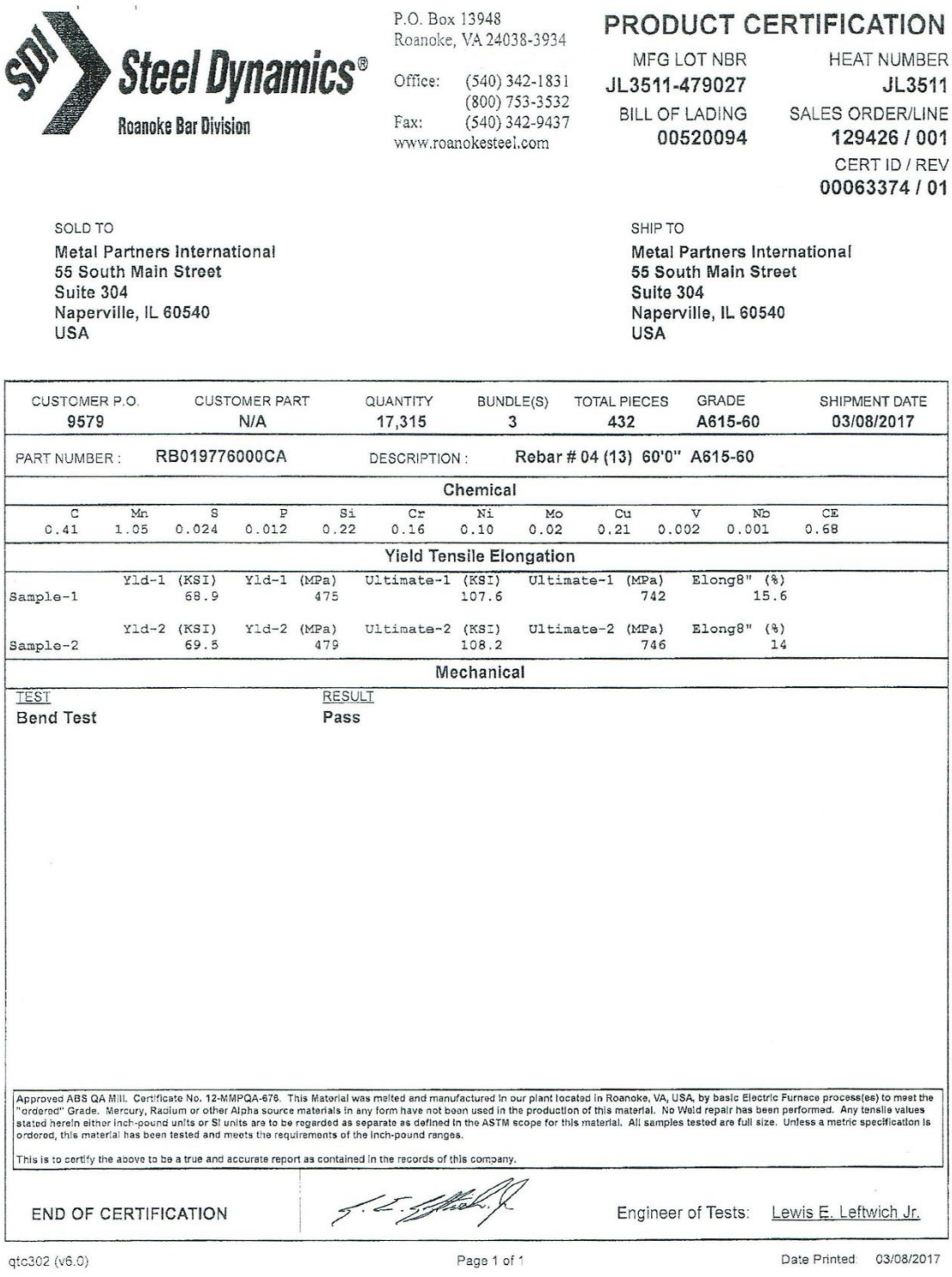
COMMENTS / NOTES

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-17. Rebar No. 6 Material Certificate, Test No. NJPCB-6



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: JL3511-479027
HEAT NUMBER: JL3511
BILL OF LADING: 00520094
SALES ORDER/LINE: 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-1 (KSI)	Yld-1 (MPa)	Ultimate-1 (KSI)	Ultimate-1 (MPa)	Elong8" (%)
Sample-1	68.9	475	107.6	742	15.6
	Yld-2 (KSI)	Yld-2 (MPa)	Ultimate-2 (KSI)	Ultimate-2 (MPa)	Elong8" (%)
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.

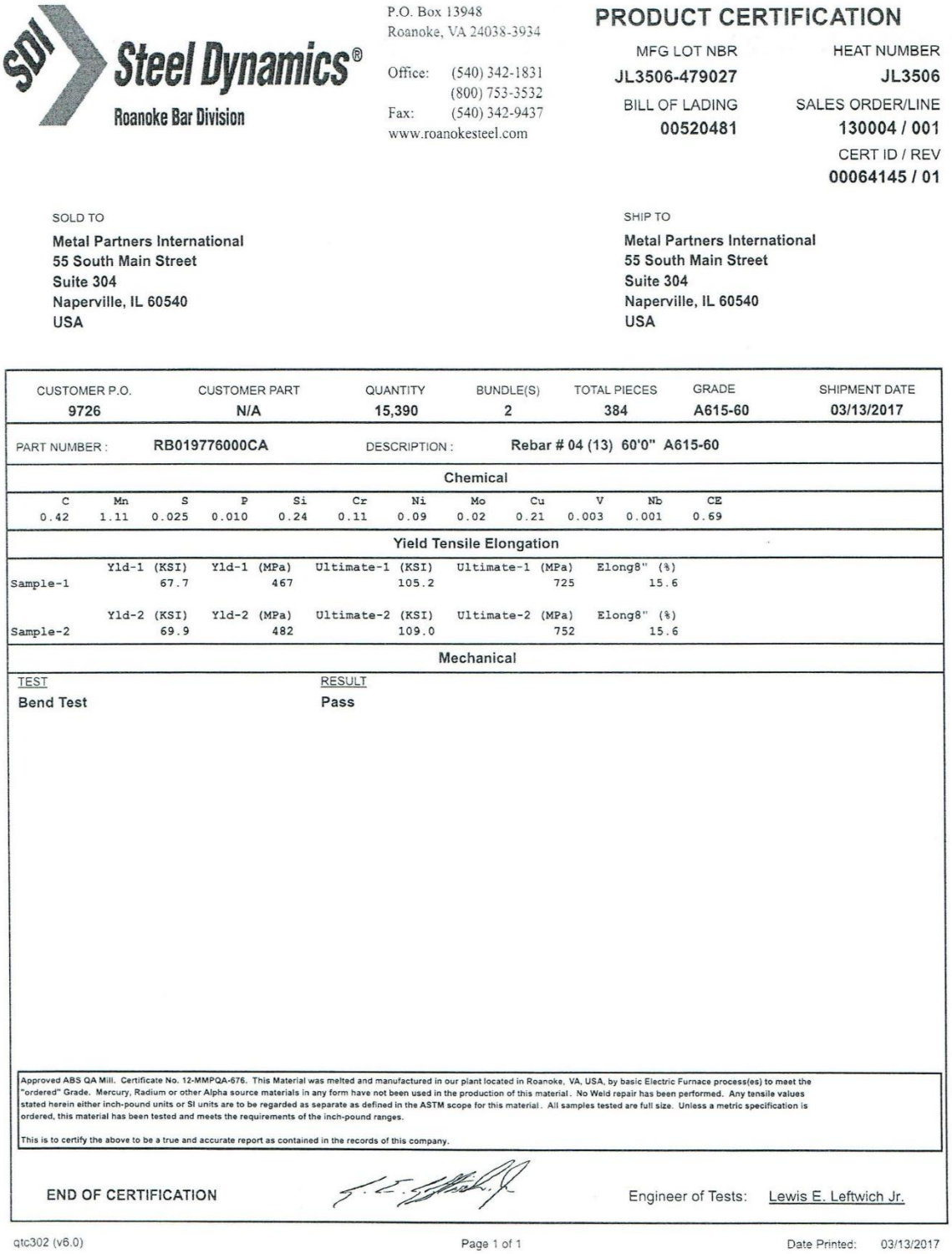
This is to certify the above to be a true and accurate report as contained in the records of this company.

END OF CERTIFICATION

Engineer of Tests: Lewis E. Leftwich Jr.

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

Figure B-18. Rebar No. 6 Material Certificate, Test No. NJPCB-6



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: JL3506-479027
HEAT NUMBER: JL3506
BILL OF LADING: 00520481
SALES ORDER/LINE: 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-1 (KSI)	Yld-1 (MPa)	Ultimate-1 (KSI)	Ultimate-1 (MPa)	Elong8" (%)
Sample-1	67.7	467	105.2	725	15.6

	Yld-2 (KSI)	Yld-2 (MPa)	Ultimate-2 (KSI)	Ultimate-2 (MPa)	Elong8" (%)
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.

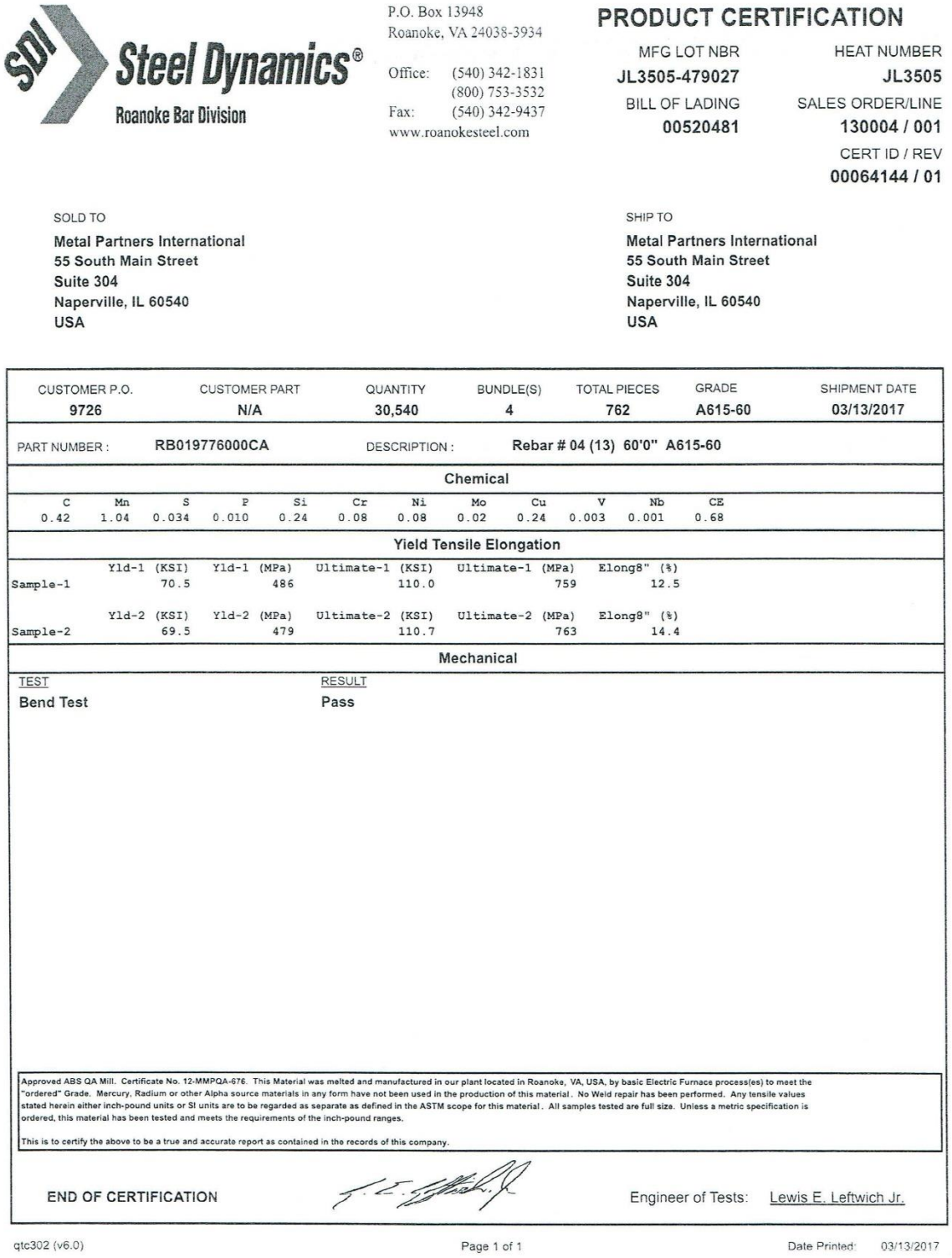
This is to certify the above to be a true and accurate report as contained in the records of this company.

END OF CERTIFICATION

Engineer of Tests: Lewis E. Leftwich Jr.

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

Figure B-19. Rebar No. 6 Material Certificate, Test No. NJPCB-6



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: JL3505-479027
HEAT NUMBER: JL3505
BILL OF LADING: 00520481
SALES ORDER/LINE: 130004 / 001
CERT ID / REV: 00064144 / 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	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-20. Rebar No. 6 Material Certificate, Test No. NJPCB-6

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

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

Atlas Tube
JMC STEEL GROUP

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

MATERIAL TEST REPORT

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

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

Material: 3.0x3.0x125x24'0"0(7x7). Material No: 300301252400 Made In: Canada Melted in: Canada

Sales order: 989576 Purchase Order: 75461

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

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

Material Note:
Sales Or.Note:

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

Sales order: 995107 Purchase Order: 76312

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

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

Material Note:
Sales Or.Nota:

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

Sales order: 995107 Purchase Order: 76312

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

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

Material Note:
Sales Or.Nota:

Marvin Phillips

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

Steel Tube Institute OF NORTH AMERICA

Page : 1 Of 4

Metals Service Center Institute

Figure B-21. Steel Tube Material Certificate, Test No. NJPCB-6

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

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

Atlas Tube
JMC STEEL GROUP

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

MATERIAL TEST REPORT

Sold to

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

Shipped to

Triad Metals International
3507 Grand Avenue
PITTSBURGH PA 15225
USA

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

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

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

Material Note:
Sales Or.Note:

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

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

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

Material Note:
Sales Or.Note:

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

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

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

Material Note:
Sales Or.Note:

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

Steel Tube Institute OF NORTH AMERICA

Metals Service Center Institute

Figure B-22. Steel Tube Material Certificate, Test No. NJPCB-6

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

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

Atlas Tube
JMC STEEL GROUP

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

MATERIAL TEST REPORT

Sold to

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

Shipped to

Triad Metals International
3507 Grand Avenue
PITTSBURGH PA 15225
USA

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

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

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

Material Note:
Sales Or.Note:

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

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

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

Material Note:
Sales Or.Note:

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

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

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

Material Note:
Sales Or.Note:

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

Steel Tube Institute OF NORTH AMERICA

Page : 3 Of 3

Metals Service Center Institute

Figure B-23. Steel Tube Material Certificate, Test No. NJPCB-6

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

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

Atlas Tube
JMC STEEL GROUP

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

MATERIAL TEST REPORT

Sold to

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

Shipped to

Triad Metals International
3507 Grand Avenue
PITTSBURGH PA 15225
USA

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

Sales order: 989623 Purchase Order: 75462

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

Bundle No	PCs	Yield	Tensile	Eln.2in	Certification	CE: 0.33
M800554030	2	072918 Psi	082550 Psi	35 %	ASTM A500-13 GRADE B&C	

Material Note:
Sales Or.Note:

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

Steel Tube Institute of North America

Page : 4 Of 4

Metals Service Center Institute

Figure B-24. Steel Tube Material Certificate, Test No. NJPCB-6

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

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

Atlas Tube
JMC STEEL GROUP

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

MATERIAL TEST REPORT

Sold to

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

Shipped to

Triad Metals International
3500 Neville Road
NEVILLE ISLAND PA 15225
USA

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

Sales order: 934921 Purchase Order: 67358

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

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

Material Note:
Sales Or.Note:

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

Sales order: 934921 Purchase Order: 67358

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

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

Material Note:
Sales Or.Note:

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

Sales order: 933979 Purchase Order: 67228

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

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

Material Note:
Sales Or.Note:

Marvin Phillips

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

Steel Tube Institute OF NORTH AMERICA

Page : 1 Of 4

Metals Service Center Institute

Figure B-25. Steel Tube Material Certificate, Test No. NJPCB-6

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

Independence Tube

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

independencetube.com
itctube.com
Certificate Number: DCR 250913

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

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

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

Shipped: 1/16/2015
Invoiced:

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

CERTIFICATE of ANALYSIS and TESTS

Customer Part No:

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

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

Total Pieces	Total Weight
36	37,376

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

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

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

Certification:

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

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

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

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

Jose Martinez, QMS Manager

Figure B-26. Steel Tube Material Certificate, Test No. NJPCB-6

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

Certificate No: DCR 493504
Customer Part No:
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%

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Figure B-27. Steel Tube Material Certificate, Test No. NJPCB-6

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:

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

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

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-28. Steel Tube Material Certificate, Test No. NJPCB-6

MID-AMERICA STEEL CORPORATION
TEST REPORT

No. F33822

TO: SEIBEL MODERN MFG & WELDING
DATE: 02/19/13
P.O. #: SBJ-40

ATTN:

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

CHEMICAL ANALYSIS

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

PHYSICAL ANALYSIS

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

All material made and melted in the U.S.

Thank you,

JOHN RATICA
MID-AMERICA STEEL CORPORATION

Figure B-29. 2-in. × ¼-in. (51-mm × 6-mm) Bent Steel Plate, Test No. NJPCB-6

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

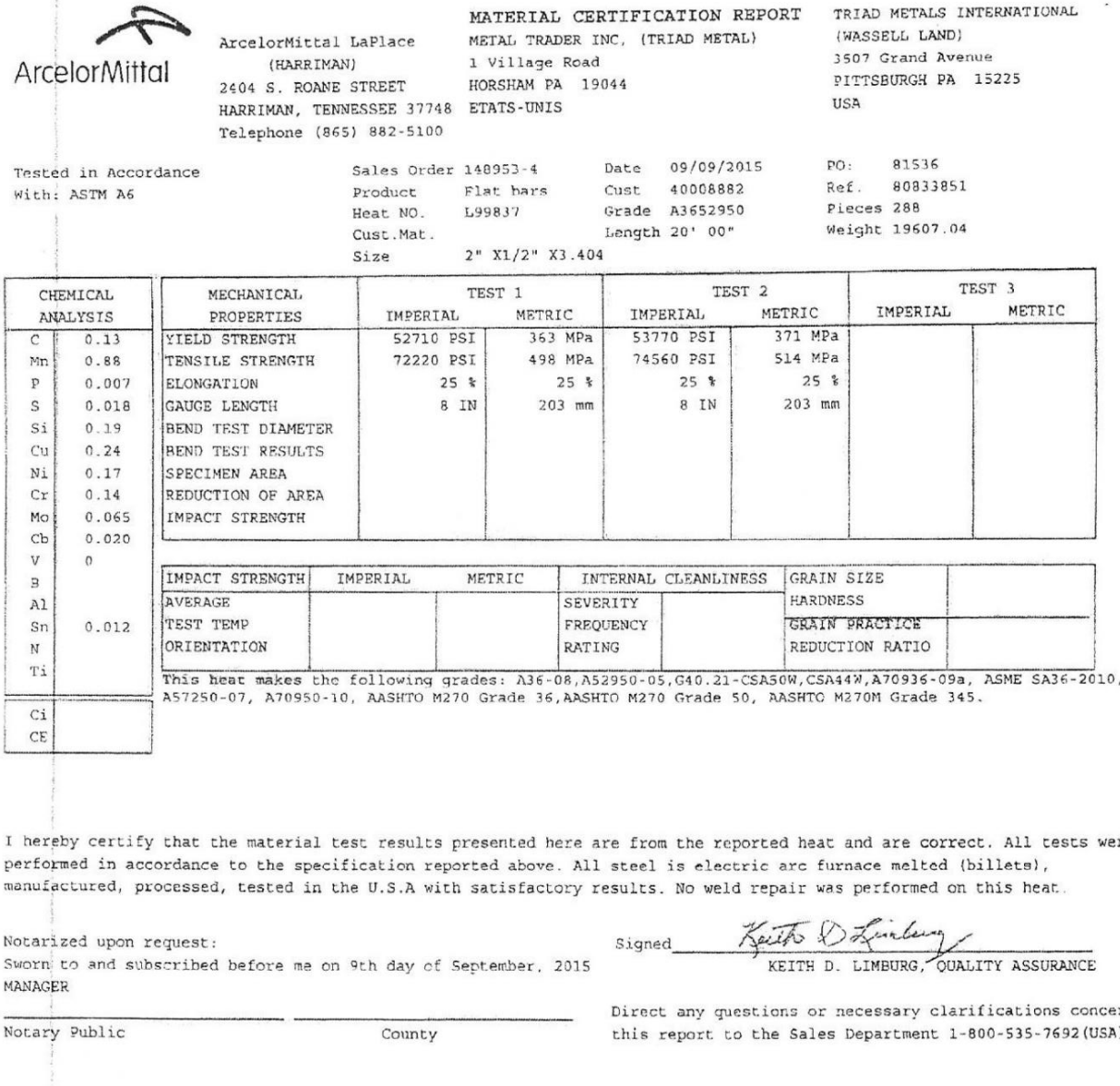
Yield: 63700 Tensile: 77700 Elongation: 30.1%

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-30. 2-in. × ¼-in. (51-mm × 6-mm) Bent Steel Plate, Test No. NJPCB-6



ArcelorMittal

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

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

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

Tested in Accordance With: ASTM A6

Sales Order 140953-4 Date 09/09/2015 PO: 81536
Product Flat bars Cust 40008882 Ref. 80833851
Heat NO. L99837 Grade A3652950 Pieces 288
Cust.Mat. Length 20' 00" Weight 19607.04
Size 2" X1/2" X3.404

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

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

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

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

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

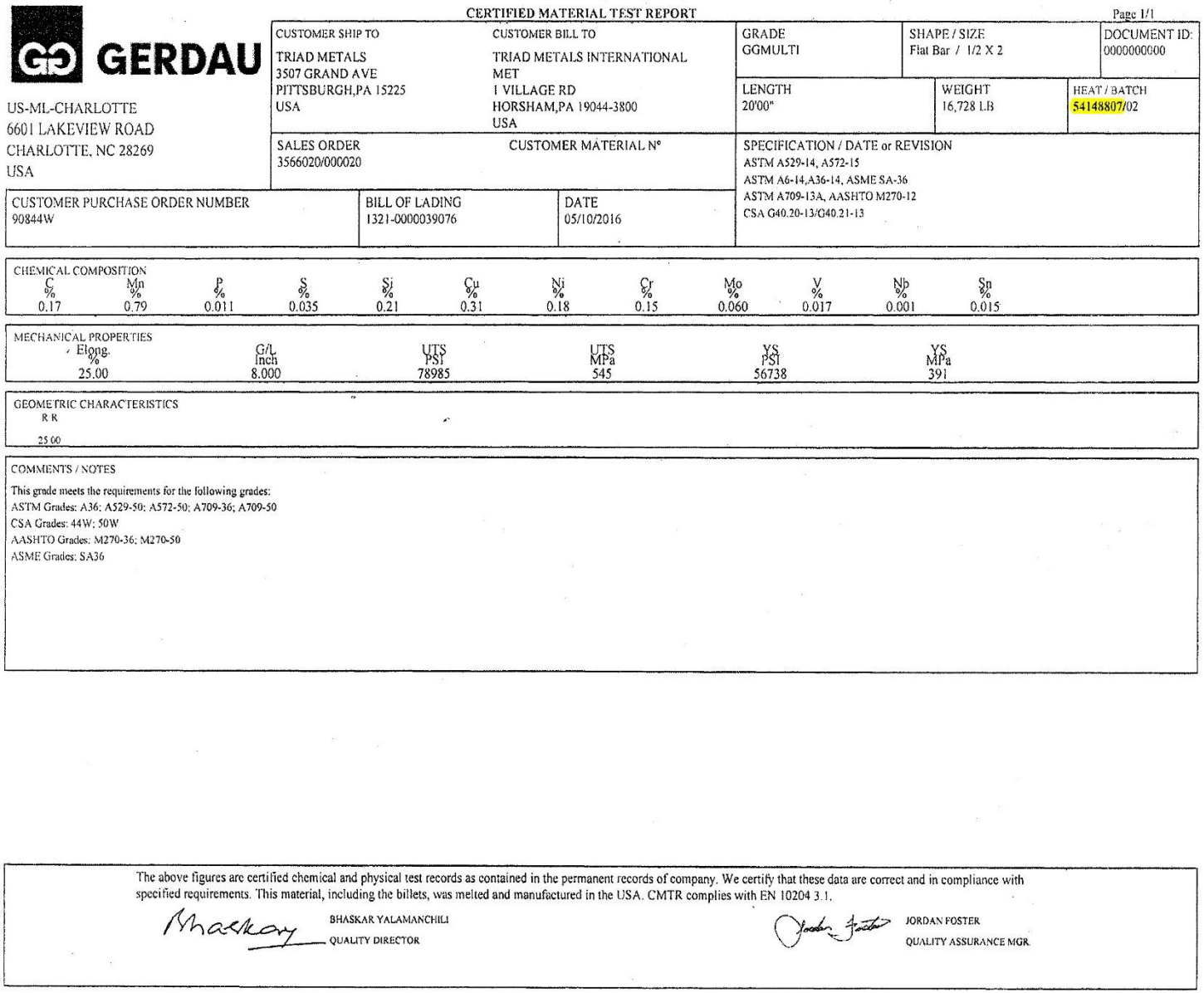
Notarized upon request:
Sworn to and subscribed before me on 9th day of September, 2015
MANAGER

Notary Public _____ County _____

Signed Keith D Limburg
KEITH D. LIMBURG, QUALITY ASSURANCE

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

Figure B-31. ½-in. (13-mm) Thick Steel Plate Material Certificate, Test No. NJPCB-6



GERDAU

CERTIFIED MATERIAL TEST REPORT

Page 1/1

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

CUSTOMER SHIP TO	CUSTOMER BILL TO
TRIAD METALS 3507 GRAND AVE PITTSBURGH,PA 15225 USA	TRIAD METALS INTERNATIONAL MET 1 VILLAGE RD HORSHAM,PA 19044-3800 USA

GRADE	SHAPE / SIZE	DOCUMENT ID:
GGMULTI	Flat Bar / 1/2 X 2	0000000000

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

SALES ORDER	CUSTOMER MATERIAL N°
3566020/000020	

SPECIFICATION / DATE or REVISION
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

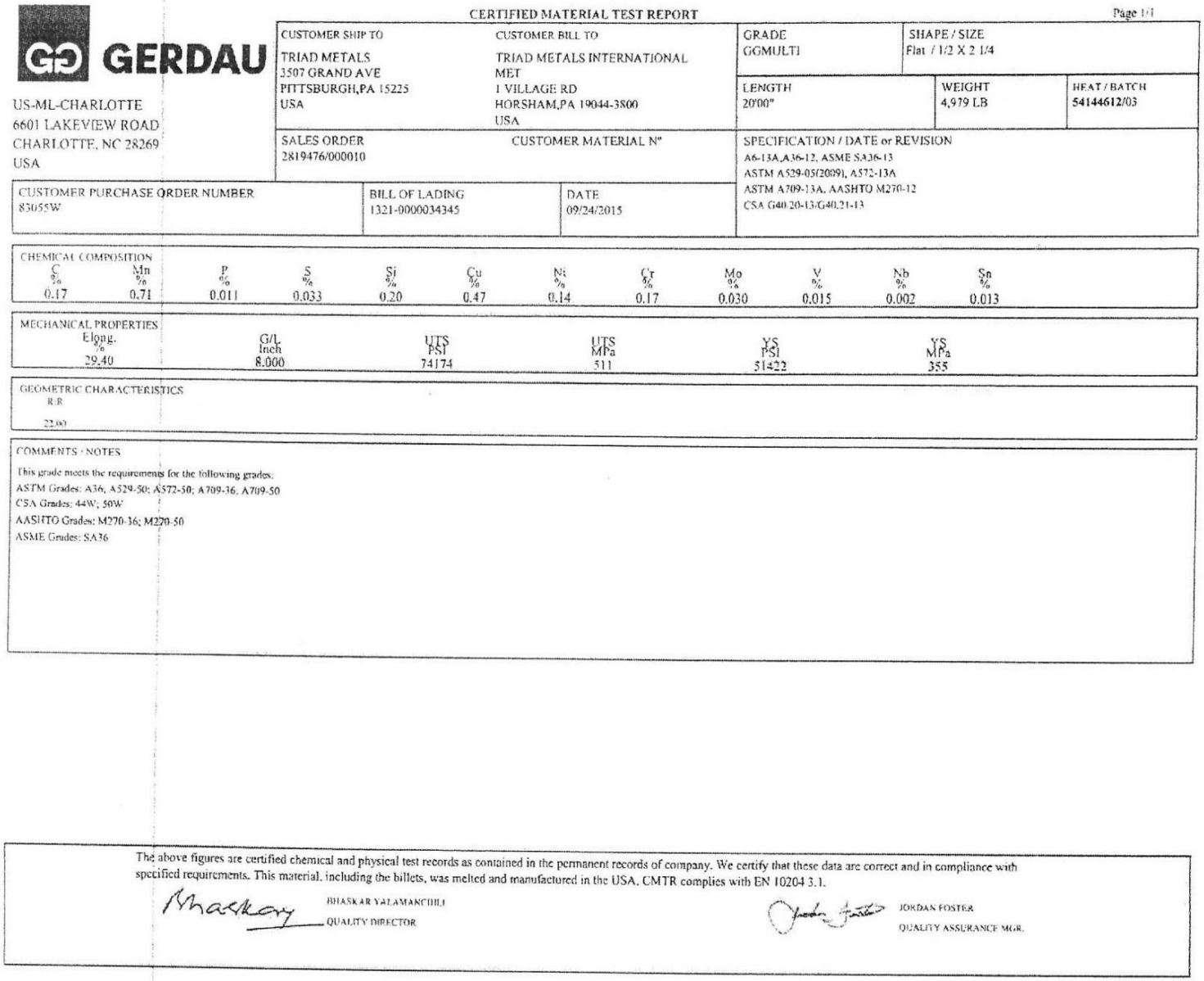
This grade meets the requirements for the following grades:
ASTM Grades: A36; A529-50; A572-50; A709-36; A709-50
CSA Grades: 44W; 50W
AASHTO Grades: M270-36; M270-50
ASME Grades: SA36

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-32. ½-in. (13-mm) Thick Steel Plate Material Certificate, Test No. NJPCB-6



GERDAU

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	
TRIAD METALS 3507 GRAND AVE PITTSBURGH,PA 15225 USA	TRIAD METALS INTERNATIONAL MET 1 VILLAGE RD HORSHAM,PA 19044-3800 USA	GGMULTI	Flat / 1/2 X 2 1/4	
		LENGTH 20'00"	WEIGHT 4,979 LB	HEAT / BATCH 54144612/03
SALES ORDER 2819476/000010	CUSTOMER MATERIAL N°	SPECIFICATION / DATE or REVISION A6-13A,A36-12, ASME SA36-13 ASTM A529-05(2009), A572-13A ASTM A709-13A, AASHTO M270-12 CSA G40.20-13/G40.21-13		

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

CHEMICAL COMPOSITION

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

MECHANICAL PROPERTIES

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

GEOMETRIC CHARACTERISTICS

R/R
22.00

COMMENTS / NOTES

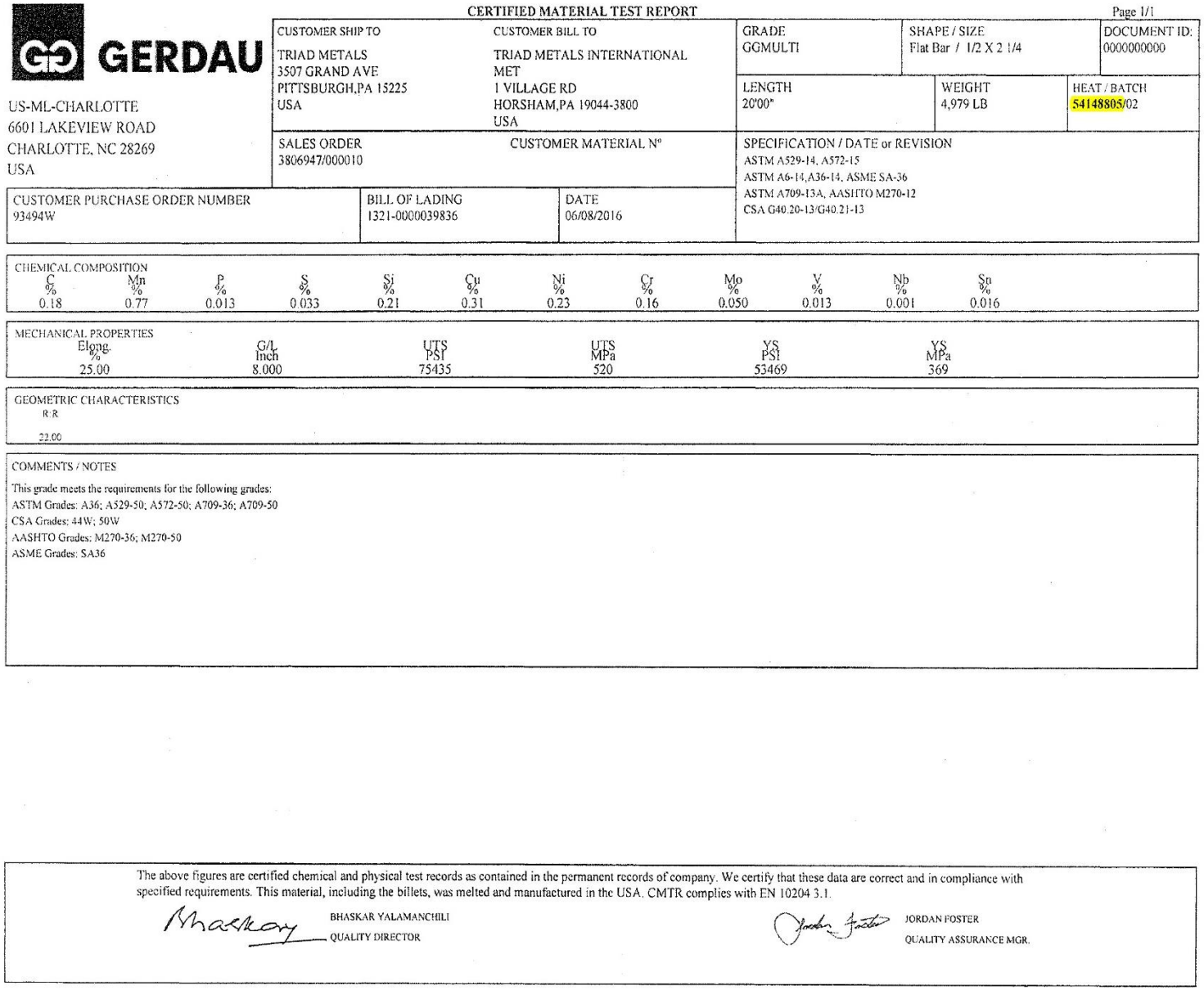
This grade meets the requirements for the following grades:
ASTM Grades: A36, A529-50; A572-50; A709-36, A709-50
CSA Grades: 44W; 50W
AASHTO Grades: M270-36; M270-50
ASME Grades: SA36

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

BHASKAR YALAMANCHILI
QUALITY DIRECTOR

JORDAN FOSTER
QUALITY ASSURANCE MGR.

Figure B-33. ½-in. (13-mm) Thick Steel Plate Material Certificate, Test No. NJPCB-6



GERDAU

CERTIFIED MATERIAL TEST REPORT

Page 1/1

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

CUSTOMER SHIP TO	CUSTOMER BILL TO
TRIAD METALS 3507 GRAND AVE PITTSBURGH,PA 15225 USA	TRIAD METALS INTERNATIONAL MET 1 VILLAGE RD HORSHAM,PA 19044-3800 USA

GRADE	SHAPE / SIZE	DOCUMENT ID:
GGMULTI	Flat Bar / 1/2 X 2 1/4	0000000000

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

SALES ORDER: 3806947/000010

CUSTOMER MATERIAL N°:

SPECIFICATION / DATE or REVISION:
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-34. ½-in. (13-mm) Thick Steel Plate Material Certificate, Test No. NJPCB-6

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-35. ½-in. (13-mm) Thick Steel Plate Material Certificate, Test No. NJPCB-6

DAYTON® SUPERIOR

1107 Advantage Grout

Cement Based Grout

TECHNICAL DATA SHEET

DESCRIPTION

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

USE

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

FEATURES

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

PROPERTIES

Corps of Engineers Specification for non-shrink grout:

CRD-C 621 Grades A, B, C

ASTM C-1107 Grades A, B, C

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

Expansion - ASTM C-1090:

1 day: 0-0.3

3 days: 0-0.3

14 days: 0-0.3

28 days: 0-0.3

Test Results

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

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

Estimating Guide

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

Packaging

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

STORAGE

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

APPLICATION

Surface Preparation:

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

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

Water Requirements:

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

Mixing:

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

Sec 16 Grouts

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

Page 1 of 3

File Date: 3/27/2015

Figure B-36. Non-Shrink Grout Specifications, Test No. NJPCB-6

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.

Figure B-37. Non-Shrink Grout Specifications, Test No. NJPCB-6

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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
Project Name: NJPCB-6
Placement Location: Cylinder A Cast 6/1

Date 02-Jun-17

Mix Designation: C1107 Grout

Required Strength: 1000

Laboratory Test Data

Laboratory Identification	Field Identification	Date Cast	Date Received	Date Tested	Days Cured in Field	Days Cured in Laboratory	Age of Test, Days	Length of Specimen, in.	Diameter of Specimen, in.	Cross-Sectional Area,sq.in.	Maximum Load, lbf	Compressive Strength, psi.	Required Strength, psi.	Type of Fracture	ASTM Practice for Capping Specimen
RSF- 1	A	6/1/2017	6/2/2017	6/2/2017	1	0	1	8	4.02	12.69	41,272	3,250		5	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

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By _____
Brant Wells, Field/Lab Operations Manager

Figure B-38. Non-shrink Grout Compressive Test Certificate, Test No. NJPCB-6

Appendix C. Concrete Tarmac Strength

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

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

Client:	UNL			Date:	December 10, 2010	
Project:	MwRSF					
Placement Location:	WI - East 1, 2, 3					
Mix Type:	Class:			Mix No.:		
Type of Forms			Cement Factor, Sks/Yd		na	
			Water-Cement Ratio		na	
Admixture Quantity	na		Slump Inches		na	
Admixture Type	na		Unit Wt, lbs/cu. Ft.		na	
Admixture Quantity	na		Air Content, %		na	
Average Field Temperature	na		Batch Volume, Cu. Yds.		na	
Temperature of Concrete F	na		Ticket No.		na	
Identification Laboratory	East 1	East 2	East 3			
Date Cast						
Date Received in Laboratory	11/30/2010	11/30/2010	11/30/2010			
Date Tested						
Days Cured in Field						
Days Cured in Laboratory						
Age of Test, Days						
Length, in.	7.78	7.81	7.75			
Average Width (1), in.	3.72	3.72	3.72			
Cross-Sectional Area, sq. in.	10.874	10.869	10.874			
Maximum Load, lbf	71,030	76,470	73,310			
Compressive Stength, psi	6,530	7,040	6,740			
Length/Diameter Ratio	2.091	2.099	2.083			
Correction						
Corrected Compressive Strength,psi	0	0	0			
Type of Fracture	4	4	4			
Required Strength,psi						

Remarks:

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

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CONSTRUCTION MATERIALS LABORATORY

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

Figure C-1. Concrete Tarmac Strength Test

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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:	6/2/2017	Test Name:	NJPCB-6	VIN:	1D3HB13T69S750827
Year:	2009	Make:	Dodge	Model:	Ram 1500 Hemi

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb.)	Vertical CG (in.)	Vertical M (lb.-in.)
+	Unballasted Truck (Curb)	5221	28 3/8	148145.88
+	Hub	19	15	285
+	Brake activation cylinder & frame	7	26 3/4	187.25
+	Pneumatic tank (Nitrogen)	27	27	729
+	Strobe/Brake Battery	5	25	125
+	Brake Receiver/Wires	5	51 1/2	257.5
+	CG Plate including DAS	50	29 3/4	1487.5
-	Battery	-47	41 1/2	-1950.5
-	Oil	-10	28	-280
-	Interior	-111	26 1/4	-2913.75
-	Fuel	-163	16	-2608
-	Coolant	-23	31	-713
-	Washer fluid	-1	35	-35
+	Water Ballast (In Fuel Tank)	0	16	0
+	Onboard Supplemental Battery	12	25 1/4	303
				0
Note: (+) is added equipment to vehicle, (-) is removed equipment from vehicle				143019.88

Estimated Total Weight (lb.)	4991
Vertical CG Location (in.)	28.6556

Vehicle Dimensions for C.G. Calculations

Wheel Base:	140 1/8	in.	Front Track Width:	66 1/4	in.
			Rear Track Width:	68	in.

Center of Gravity	2270P MASH Targets	Test Inertial	Difference
Test Inertial Weight (lb.)	5000 ± 110	5000	0.0
Longitudinal CG (in.)	63 ± 4	60.70215	-2.29785
Lateral CG (in.)	NA	0.604125	NA
Vertical CG (in.)	28 or greater	28.66	0.65555

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	1511	1426	
Rear	1142	1142	
FRONT	2937		lb.
REAR	2284		lb.
TOTAL	5221		lb.

TEST INERTIAL WEIGHT (lb.)

	Left	Right	
Front	1380	1454	
Rear	1075	1091	
FRONT	2834		lb.
REAR	2166		lb.
TOTAL	5000		lb.

Figure D-1. Vehicle Mass Distribution, Test No. NJPCB-6

Appendix E. Vehicle Deformation Records

Date: 2/27/2017 Test Name: NJPCB-6 VIN: 1D3HB13T69S750827
Year: 2009 Make: Dodge Model: Ram 1500 Quad Cab

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	28.771	-28.482	4.709	27.227	-27.600	5.751	-1.544	0.882	1.042	2.061	1.863
2	30.856	-24.186	3.215	26.819	-22.576	5.830	-4.037	1.610	2.614	5.072	4.810
3	31.271	-16.991	1.126	27.628	-15.555	3.718	-3.643	1.436	2.592	4.696	4.471
4	29.228	-12.182	2.502	27.741	-12.332	3.135	-1.488	-0.149	0.633	1.624	1.617
5	27.150	-28.955	1.862	26.038	-27.865	2.637	-1.113	1.090	0.775	1.740	1.356
6	28.175	-24.386	0.247	25.287	-22.937	2.118	-2.889	1.449	1.871	3.734	3.442
7	27.832	-17.492	-0.637	25.518	-16.217	0.493	-2.315	1.274	1.130	2.874	2.576
8	27.154	-12.738	-0.772	25.617	-12.458	-0.247	-1.537	0.280	0.525	1.648	1.625
9	24.055	-29.532	-1.241	23.621	-28.485	-0.892	-0.434	1.047	0.349	1.185	0.349
10	24.052	-24.564	-1.731	22.710	-23.836	-1.164	-1.341	0.728	0.567	1.628	0.567
11	24.230	-17.323	-2.569	23.348	-16.451	-2.290	-0.883	0.872	0.279	1.272	0.279
12	24.131	-13.086	-3.078	23.704	-12.300	-3.359	-0.428	0.786	-0.281	0.938	-0.281
13	20.013	-29.882	-3.469	20.156	-28.943	-3.787	0.144	0.939	-0.318	1.002	-0.318
14	19.912	-24.844	-3.637	19.583	-23.978	-3.579	-0.330	0.866	0.058	0.928	0.058
15	19.844	-18.355	-4.337	19.682	-17.503	-4.792	-0.162	0.852	-0.455	0.979	-0.455
16	19.900	-13.271	-4.899	19.719	-12.514	-5.186	-0.180	0.757	-0.287	0.830	-0.287
17	16.346	-29.388	-3.364	16.465	-28.604	-3.807	0.119	0.785	-0.443	0.909	-0.443
18	16.356	-24.636	-3.792	16.361	-23.877	-4.179	0.006	0.759	-0.387	0.852	-0.387
19	16.275	-18.386	-4.463	16.191	-17.613	-4.784	-0.083	0.773	-0.321	0.841	-0.321
20	16.348	-12.950	-5.108	16.107	-12.155	-5.382	-0.241	0.795	-0.275	0.875	-0.275
21	9.416	-29.243	-3.605	9.568	-28.712	-4.024	0.152	0.531	-0.419	0.693	-0.419
22	9.031	-24.315	-4.045	9.117	-23.747	-4.441	0.086	0.568	-0.397	0.698	-0.397
23	9.158	-18.303	-4.666	9.011	-17.699	-4.876	-0.147	0.604	-0.210	0.656	-0.210
24	9.506	-12.807	-5.314	9.136	-12.182	-5.451	-0.370	0.625	-0.137	0.739	-0.137
25	0.130	-26.589	0.101	0.360	-26.245	0.119	0.229	0.344	0.018	0.414	0.018
26	0.165	-21.671	-0.383	0.285	-21.252	-0.377	0.121	0.418	0.006	0.435	0.006
27	0.136	-16.295	-0.951	0.083	-15.886	-0.982	-0.053	0.410	-0.031	0.414	-0.031
28	0.148	-12.233	-1.375	-0.043	-11.831	-1.471	-0.191	0.402	-0.096	0.455	-0.096

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

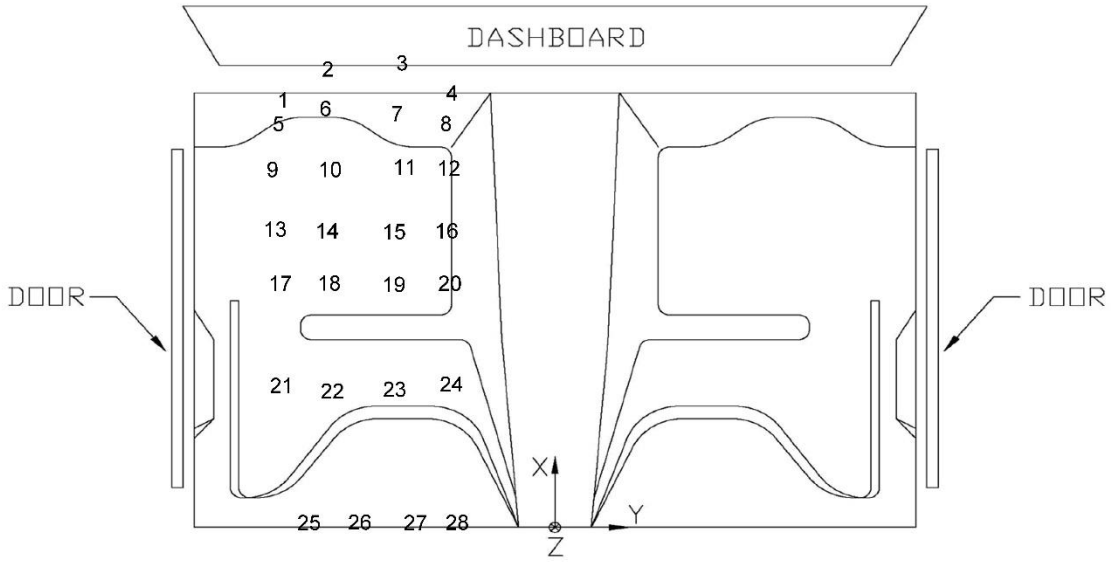


Figure E-1. Floor Pan Deformation Data – Set 1, Test No. NJPCB-6

Date: 2/27/2017 Test Name: NJPCB-6 VIN: 1D3HB13T69S750827
Year: 2009 Make: Dodge Model: Ram 1500 Quad Cab

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	59.004	-34.824	2.062	57.464	-34.407	2.726	-1.541	0.417	0.664	1.729	1.678
2	61.027	-30.395	0.977	57.138	-29.468	3.501	-3.889	0.926	2.525	4.728	4.637
3	61.431	-23.003	-0.197	58.017	-22.139	2.262	-3.414	0.864	2.458	4.295	4.207
4	59.493	-18.419	1.818	58.193	-18.946	2.132	-1.300	-0.527	0.314	1.437	1.337
5	57.288	-34.996	-0.862	56.229	-34.279	-0.377	-1.060	0.717	0.485	1.368	1.165
6	58.348	-30.311	-1.911	55.524	-29.239	-0.263	-2.823	1.072	1.649	3.441	3.269
7	57.992	-23.258	-1.972	55.876	-22.404	-1.032	-2.116	0.855	0.940	2.468	2.316
8	57.336	-18.486	-1.541	55.990	-18.566	-1.219	-1.346	-0.080	0.322	1.386	1.384
9	54.155	-35.109	-4.009	53.806	-34.299	-3.887	-0.349	0.810	0.123	0.891	0.123
10	54.146	-30.094	-3.891	53.155	-29.575	-3.488	-0.991	0.520	0.403	1.189	0.403
11	54.409	-22.887	-3.807	53.625	-22.225	-3.745	-0.784	0.662	0.062	1.028	0.062
12	54.239	-18.601	-3.749	54.023	-18.019	-4.272	-0.215	0.582	-0.524	0.812	-0.524
13	50.147	-35.307	-6.213	50.250	-34.416	-6.763	0.103	0.891	-0.549	1.052	-0.549
14	50.050	-30.269	-5.719	49.721	-29.514	-5.920	-0.329	0.755	-0.201	0.847	-0.201
15	50.001	-23.731	-5.634	49.877	-22.968	-6.297	-0.125	0.764	-0.663	1.019	-0.663
16	50.049	-18.646	-5.576	49.991	-17.933	-6.048	-0.057	0.713	-0.471	0.857	-0.471
17	46.381	-34.749	-5.997	46.568	-34.055	-6.686	0.186	0.694	-0.689	0.996	-0.689
18	46.473	-29.958	-5.831	46.479	-29.344	-6.447	0.006	0.614	-0.616	0.870	-0.616
19	46.413	-23.692	-5.724	46.355	-23.044	-6.239	-0.057	0.649	-0.515	0.831	-0.515
20	46.501	-18.183	-5.693	46.465	-17.514	-6.133	-0.036	0.669	-0.440	0.802	-0.440
21	39.478	-34.588	-6.135	39.709	-34.080	-6.805	0.231	0.509	-0.670	0.873	-0.670
22	39.180	-29.556	-5.957	39.267	-29.099	-6.567	0.086	0.457	-0.610	0.767	-0.610
23	39.271	-23.554	-5.831	39.298	-23.003	-6.216	0.027	0.551	-0.385	0.673	-0.385
24	39.618	-18.029	-5.807	39.461	-17.464	-6.083	-0.157	0.565	-0.276	0.648	-0.276
25	30.314	-32.266	-2.019	30.542	-32.002	-2.212	0.228	0.264	-0.194	0.399	-0.194
26	30.392	-27.374	-1.892	30.503	-27.064	-2.070	0.111	0.311	-0.179	0.375	-0.179
27	30.310	-21.960	-1.795	30.423	-21.639	-1.973	0.112	0.321	-0.178	0.384	-0.178
28	30.312	-17.845	-1.718	30.344	-17.469	-1.936	0.031	0.376	-0.218	0.435	-0.218

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

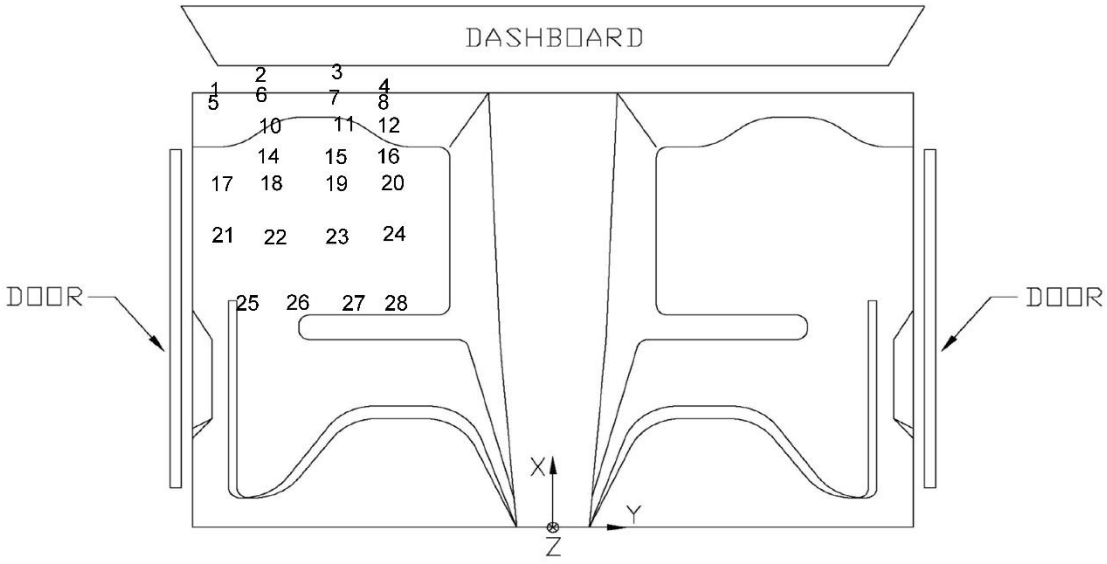


Figure E-2. Floor Pan Deformation Data – Set 2, Test No. NJPCB-6

Date: 2/27/2017 Test Name: NJPCB-6 VIN: 1D3HB13T69S750827
Year: 2009 Make: Dodge Model: Ram 1500 Quad Cab

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	14.593	-27.832	27.246	14.737	-27.779	27.235	0.144	0.053	-0.011	0.154	0.154
	2	12.506	-15.920	29.798	12.521	-15.781	29.774	0.015	0.139	-0.024	0.142	0.142
	3	11.201	2.939	25.024	11.048	3.019	24.942	-0.154	0.079	-0.082	0.191	0.191
	4	11.739	-28.418	17.184	11.900	-28.339	17.178	0.161	0.079	-0.006	0.180	0.180
	5	9.838	-16.843	15.322	9.794	-16.767	15.353	-0.044	0.076	0.031	0.093	0.093
	6	8.732	1.630	13.116	8.549	1.615	13.100	-0.183	-0.015	-0.015	0.185	0.185
SIDE PANEL	7	20.621	-31.681	8.226	20.800	-30.574	8.175	0.179	1.107	-0.051	1.123	1.107
	8	25.328	-31.801	8.204	25.480	-30.698	8.078	0.152	1.103	-0.126	1.121	1.103
	9	22.405	-32.057	4.408	22.583	-30.725	4.300	0.179	1.332	-0.108	1.348	1.332
IMPACT SIDE DOOR	10	-16.011	-31.859	25.088	-16.024	-34.236	25.464	-0.013	-2.377	0.376	2.406	-2.377
	11	-0.778	-31.480	24.830	-0.763	-33.254	25.183	0.016	-1.774	0.353	1.809	-1.774
	12	12.084	-31.375	24.670	12.111	-32.501	24.825	0.027	-1.126	0.155	1.137	-1.126
	13	-14.850	-33.288	11.970	-14.855	-34.141	12.204	-0.005	-0.852	0.234	0.884	-0.852
	14	1.682	-33.863	10.694	1.576	-34.866	10.894	-0.106	-1.004	0.200	1.029	-1.004
	15	11.502	-32.944	11.227	11.134	-33.268	11.309	-0.368	-0.325	0.082	0.498	-0.325
ROOF	16	2.807	-21.631	43.162	2.928	-21.646	43.126	0.121	-0.016	-0.036	0.127	-0.036
	17	5.330	-14.063	42.709	5.353	-14.150	42.641	0.023	-0.087	-0.068	0.113	-0.068
	18	6.361	-8.882	42.344	6.327	-8.895	42.253	-0.034	-0.014	-0.091	0.098	-0.091
	19	7.312	-1.426	41.692	7.217	-1.459	41.560	-0.095	-0.033	-0.132	0.166	-0.132
	20	7.464	3.617	41.212	7.287	3.554	41.078	-0.177	-0.063	-0.134	0.231	-0.134
	21	-2.894	-19.143	45.815	-2.882	-19.224	45.797	0.012	-0.081	-0.018	0.084	-0.018
	22	-1.642	-12.792	45.576	-1.673	-12.895	45.523	-0.031	-0.103	-0.053	0.120	-0.053
	23	-0.608	-7.961	45.211	-0.635	-8.031	45.119	-0.027	-0.070	-0.092	0.119	-0.092
	24	0.554	-1.084	44.538	0.460	-1.084	44.403	-0.094	0.001	-0.135	0.164	-0.135
	25	0.531	3.751	44.106	0.376	3.648	43.960	-0.154	-0.103	-0.146	0.236	-0.146
	26	-10.752	-18.312	46.655	-10.771	-18.461	46.623	-0.019	-0.149	-0.033	0.153	-0.033
	27	-9.807	-12.506	46.504	-9.821	-12.608	46.442	-0.013	-0.101	-0.063	0.120	-0.063
	28	-9.193	-7.804	46.220	-9.246	-7.928	46.134	-0.053	-0.124	-0.086	0.160	-0.086
	29	-8.964	-1.632	45.762	-9.011	-1.791	45.645	-0.047	-0.160	-0.117	0.203	-0.117
	30	-8.537	3.390	45.280	-8.644	3.239	45.142	-0.107	-0.152	-0.138	0.232	-0.138
A PILLAR	31	3.693	-23.332	41.726	3.786	-23.388	41.734	0.093	-0.056	0.008	0.109	-0.056
	32	9.523	-24.960	38.682	9.532	-24.960	38.688	0.009	0.001	0.006	0.011	0.001
	33	15.285	-26.468	33.987	15.347	-26.472	33.976	0.062	-0.003	-0.011	0.063	-0.003
	34	19.857	-27.885	30.548	19.955	-27.876	30.525	0.099	0.009	-0.022	0.102	0.009
B PILLAR	35	-22.694	-29.702	24.769	-22.507	-30.227	24.929	0.186	-0.525	0.160	0.580	-0.525
	36	-19.203	-29.643	24.944	-19.073	-30.149	25.084	0.130	-0.506	0.140	0.541	-0.506
	37	-23.191	-28.364	31.001	-23.044	-28.813	31.141	0.146	-0.449	0.140	0.493	-0.449
	38	-19.893	-28.180	31.464	-19.730	-28.603	31.665	0.162	-0.422	0.200	0.495	-0.422
	39	-23.594	-24.970	38.625	-23.461	-25.317	38.691	0.133	-0.347	0.067	0.378	-0.347
	40	-20.755	-24.829	38.809	-20.642	-25.159	38.862	0.112	-0.329	0.053	0.352	-0.329

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

Figure E-3. Occupant Compartment Deformation Data – Set 1, Test No. NJPCB-6

Date: 2/27/2017 Test Name: NJPCB-6 VIN: 1D3HB13T69S750827
Year: 2009 Make: Dodge Model: Ram 1500 Quad Cab

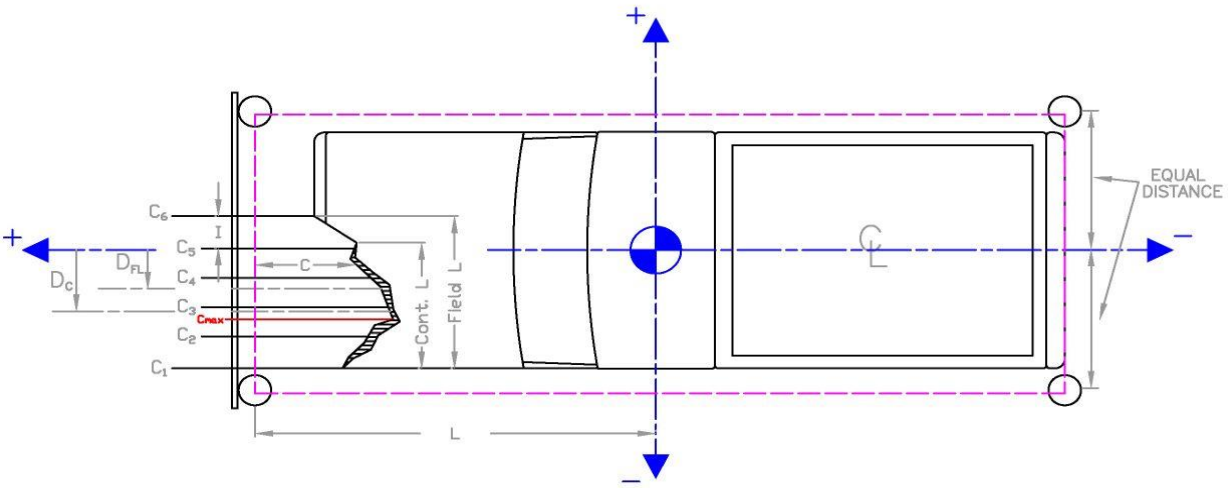
VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 2

	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	45.043	-36.976	24.558	45.327	-37.197	24.290	0.285	-0.221	-0.268	0.449	0.449
	2	43.060	-25.445	28.586	43.324	-25.558	28.410	0.264	-0.113	-0.177	0.337	0.337
	3	41.787	-6.128	26.157	42.045	-6.277	26.008	0.259	-0.149	-0.149	0.334	0.334
	4	42.059	-36.276	14.539	42.309	-36.410	14.268	0.250	-0.134	-0.271	0.392	0.392
	5	40.221	-24.518	14.121	40.331	-24.697	13.983	0.110	-0.179	-0.138	0.251	0.251
	6	39.189	-5.982	14.279	39.306	-6.151	14.141	0.117	-0.169	-0.137	0.247	0.247
SIDE PANEL	7	50.817	-38.439	5.189	51.040	-37.582	4.826	0.223	0.857	-0.363	0.957	0.857
	8	55.524	-38.565	4.996	55.742	-37.751	4.669	0.218	0.814	-0.327	0.904	0.814
	9	52.544	-38.345	1.313	52.728	-37.261	1.005	0.184	1.085	-0.308	1.142	1.085
IMPACT SIDE DOOR	10	14.300	-40.512	22.334	14.464	-42.999	22.142	0.164	-2.488	-0.192	2.500	-2.488
	11	29.619	-40.170	21.953	29.699	-42.181	21.732	0.080	-2.011	-0.221	2.025	-2.011
	12	42.481	-40.116	21.578	42.571	-41.527	21.303	0.090	-1.411	-0.275	1.440	-1.411
	13	15.422	-40.324	9.108	15.465	-41.225	9.006	0.043	-0.901	-0.102	0.907	-0.901
	14	31.858	-40.819	7.627	31.813	-41.969	7.359	-0.045	-1.150	-0.268	1.182	-1.150
	15	41.669	-40.016	8.109	41.423	-40.543	7.791	-0.246	-0.527	-0.318	0.663	-0.527
ROOF	16	33.502	-32.677	41.254	33.800	-33.004	41.023	0.298	-0.326	-0.230	0.499	-0.230
	17	36.071	-25.110	41.709	36.403	-25.480	41.423	0.332	-0.370	-0.286	0.574	-0.286
	18	37.093	-19.984	41.977	37.425	-20.304	41.691	0.332	-0.320	-0.286	0.542	-0.286
	19	38.071	-12.544	42.235	38.374	-12.794	41.962	0.303	-0.251	-0.273	0.479	-0.273
	20	38.211	-7.487	42.405	38.543	-7.774	42.106	0.332	-0.286	-0.299	0.531	-0.299
	21	27.808	-30.559	44.267	28.159	-30.875	44.042	0.351	-0.315	-0.226	0.523	-0.226
	22	29.050	-24.191	44.815	29.441	-24.518	44.570	0.391	-0.327	-0.245	0.565	-0.245
	23	30.153	-19.389	45.022	30.473	-19.688	44.786	0.320	-0.299	-0.236	0.498	-0.236
	24	31.299	-12.414	45.204	31.699	-12.700	44.937	0.401	-0.286	-0.266	0.560	-0.266
	25	31.253	-7.648	45.378	31.616	-7.951	45.120	0.363	-0.303	-0.258	0.538	-0.258
	26	19.940	-29.774	45.304	20.287	-30.101	45.111	0.347	-0.327	-0.193	0.514	-0.193
	27	20.960	-23.914	45.863	21.323	-24.299	45.664	0.363	-0.385	-0.199	0.565	-0.199
	28	21.523	-19.296	46.152	21.913	-19.611	45.952	0.389	-0.316	-0.199	0.539	-0.199
	29	21.846	-13.169	46.451	22.246	-13.495	46.248	0.400	-0.326	-0.203	0.554	-0.203
	30	22.268	-8.058	46.593	22.649	-8.433	46.390	0.382	-0.375	-0.203	0.572	-0.203
A PILLAR	31	34.305	-34.201	39.687	34.674	-34.564	39.389	0.369	-0.363	-0.297	0.597	-0.363
	32	40.029	-35.449	36.385	40.399	-35.818	36.050	0.370	-0.370	-0.335	0.621	-0.370
	33	45.807	-36.411	31.423	46.092	-36.766	31.053	0.285	-0.355	-0.370	0.587	-0.355
	34	50.285	-37.400	27.803	50.570	-37.753	27.389	0.286	-0.353	-0.415	0.615	-0.353
B PILLAR	35	7.668	-38.281	22.394	8.000	-38.879	22.275	0.332	-0.598	-0.119	0.694	-0.598
	36	11.211	-38.263	22.514	11.511	-38.857	22.470	0.300	-0.595	-0.044	0.667	-0.595
	37	7.278	-37.717	28.718	7.562	-38.265	28.631	0.284	-0.548	-0.087	0.623	-0.548
	38	10.599	-37.610	29.161	10.898	-38.171	29.080	0.300	-0.561	-0.080	0.641	-0.561
	39	6.974	-35.285	36.697	7.294	-35.759	36.587	0.320	-0.473	-0.110	0.582	-0.473
	40	9.806	-35.190	36.847	10.209	-35.663	36.709	0.402	-0.473	-0.138	0.636	-0.473

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

Figure E-4. Occupant Compartment Deformation Data – Set 2, Test No. NJPCB-6

Date:	6/13/2017	**Test Name:**	NJPCB-6	**VIN:**	1D3HB13T69S750827
Year:	2009	**Make:**	Dodge	**Model:**	Ram 1500 Hemi



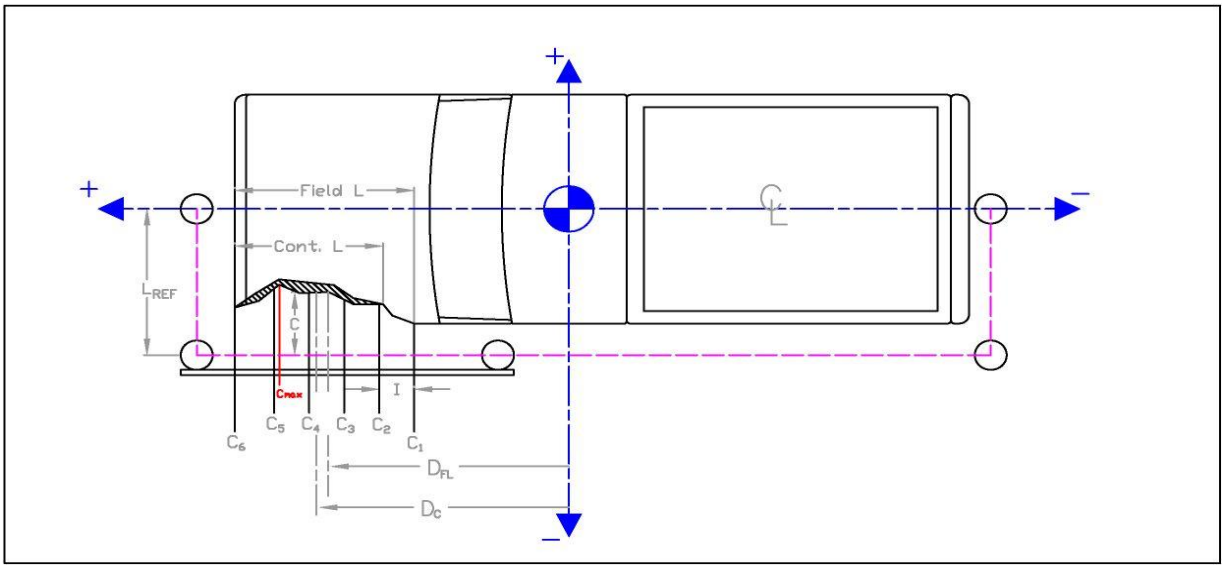
	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	106 1/4	(2699)
Total Vehicle Width:	76 1/2	(1943)
Width of contact and induced crush - Field L:	76 1/2	(1943)
Crush measurement spacing interval (L/5) - I:	15 1/4	(387)
Distance from center of vehicle to center of Field L - D_{FL}:	0	()
Width of Contact Damage:	38 1/4	(972)
Distance from center of vehicle to center of contact damage - D_C:	-19 1/8	-(486)

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	N/A	N/A	-38 1/4	-(972)	22 1/2	(572)	1 1/5	(30)	N/A	N/A
C_2	33	(838)	-23	-(584)	6 1/2	(165)			25 1/3	(643)
C_3	6	(152)	-7 3/4	-(197)	4 1/4	(108)			4/7	(14)
C_4	4 3/8	(111)	7 1/2	(191)	4 1/4	(108)			-1	-(27)
C_5	7 7/8	(200)	22 3/4	(578)	6 1/8	(156)			4/7	(14)
C_6	N/A	N/A	38	(965)	20 1/2	(521)			N/A	N/A
C_{MAX}	35 1/8	(892)	-23 1/2	-(597)	6 5/8	(168)			27 1/3	(694)

Figure E-5. Exterior Vehicle Crush (NASS) - Front, Test No. NJPCB-6

Date:	6/13/2017	**Test Name:**	NJPCB-6	**VIN:**	1D3HB13T69S750827
Year:	2009	**Make:**	Dodge	**Model:**	Ram 1500 Hemi



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	42 1/4	(1073)
Total Vehicle Length:	230 1/8	(5845)
Distance from vehicle c.g. to 1/2 of Vehicle total length:	-14 1/2	-(368)
Width of contact and induced crush - Field L:	172 3/5	(4384)
Crush measurement spacing interval (L/5) - I:	34 1/2	(876)
Distance from vehicle c.g. to center of Field L - D_{FL}:	14 2/7	(363)
Width of Contact Damage:	172 3/5	(4384)
Distance from vehicle c.g. to center of contact damage - D_C:	14 2/7	(363)

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	5 3/8	(137)	-72	-(1829)	5 1/2	(140)	-1 3/4	-(44)	1 5/8	(41)
C_2	3 1/4	(83)	-37 1/2	-(953)	5 5/8	(143)			- 5/8	-(16)
C_3	3 1/4	(83)	-3	-(76)	5	(127)			0	()
C_4	4 1/8	(105)	31 1/2	(800)	5 1/8	(130)			3/4	(19)
C_5	19 5/8	(498)	66	(1676)	5 7/8	(149)			15 1/2	(394)
C_6	32 5/8	(829)	100 1/2	(2553)	30	(762)			4 3/8	(111)
C_{MAX}	19 5/8	(498)	66	(1676)	5 7/8	(149)			15 1/2	(394)

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

Appendix F. Accelerometer and Rate Transducer Data Plots

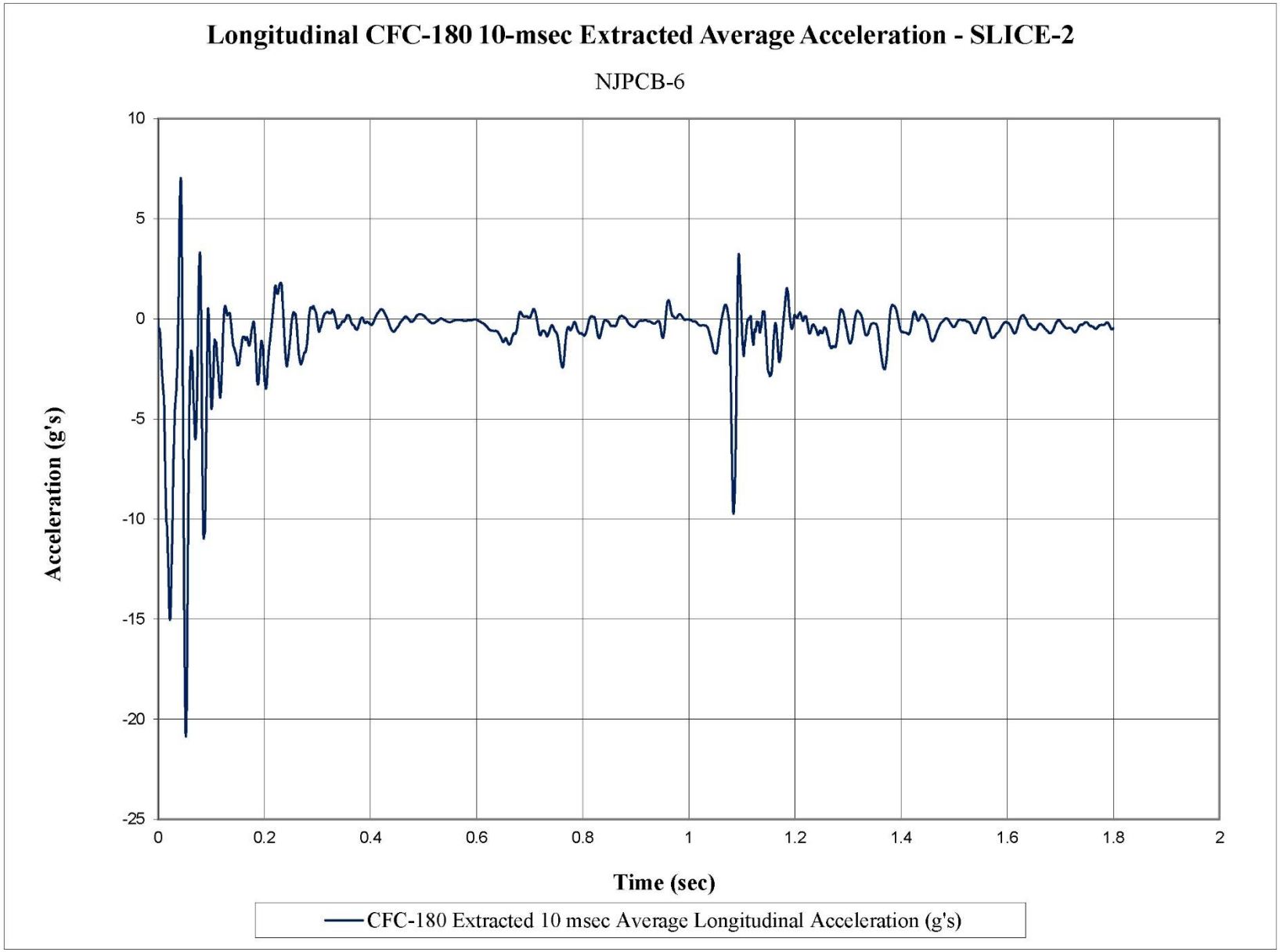


Figure F-1. 10-ms Average Longitudinal Deceleration (SLICE-2), Test No. NJPCB-6

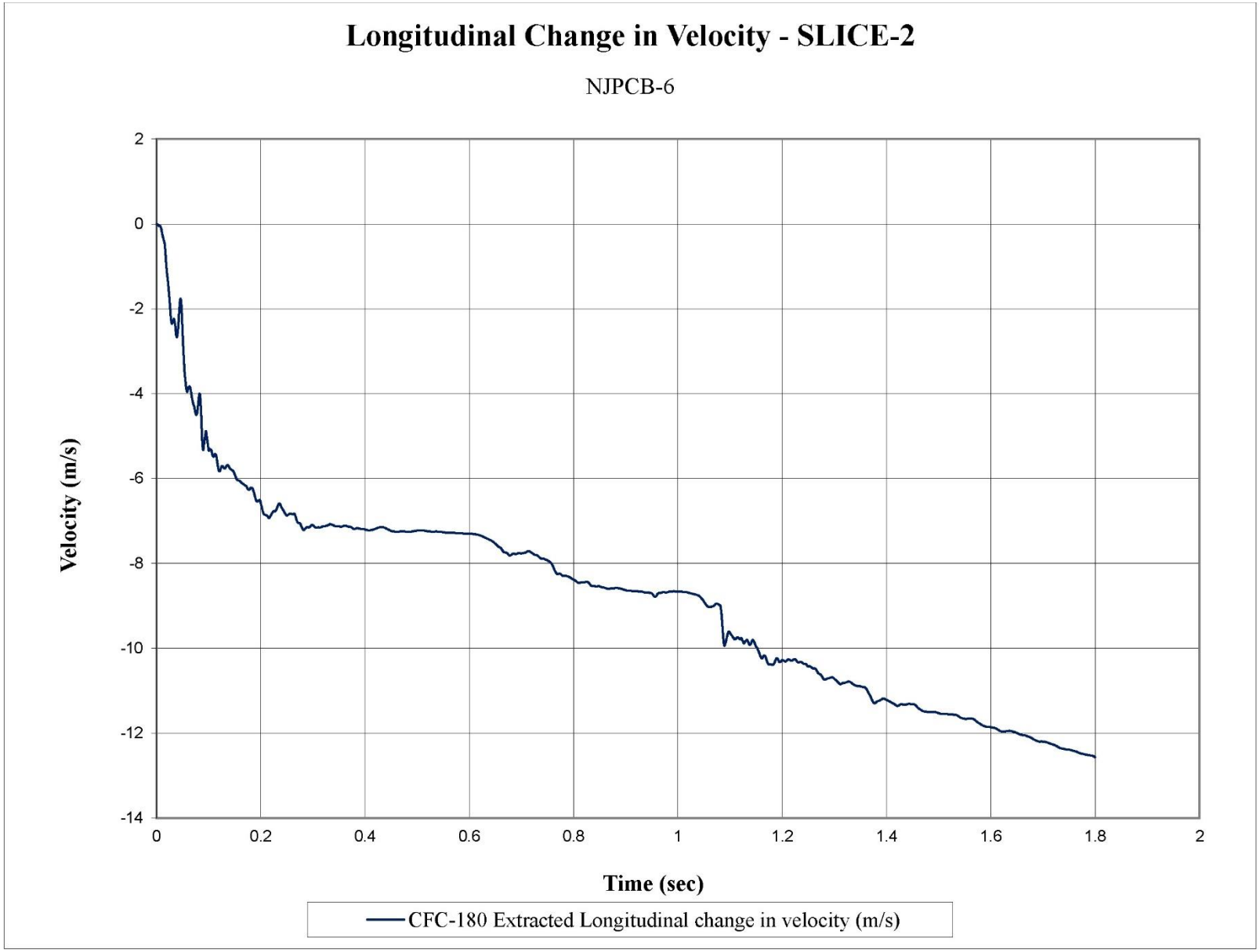


Figure F-2. Longitudinal Occupant Impact Velocity (SLICE-2), Test No. NJPCB-6

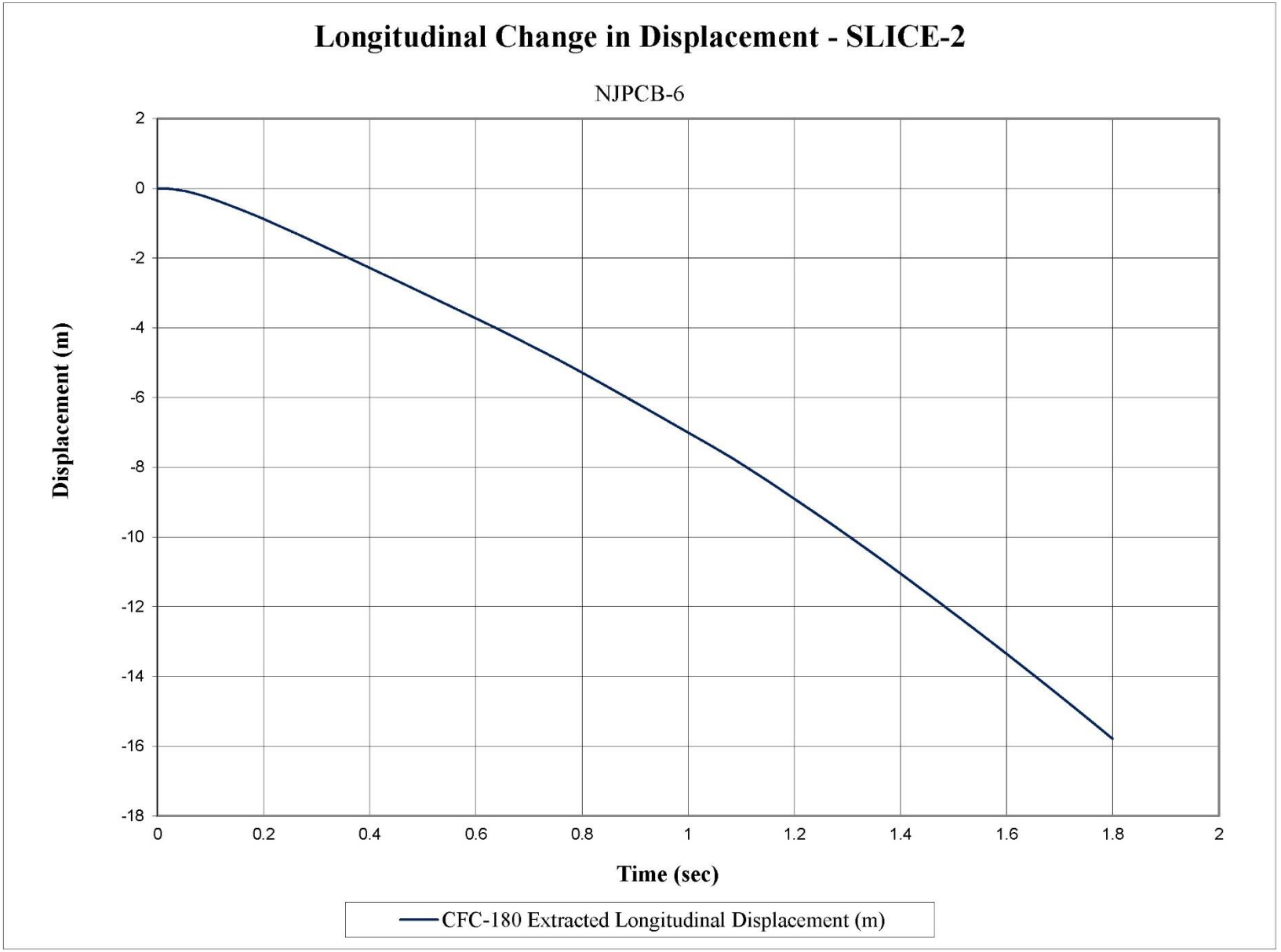


Figure F-3. Longitudinal Occupant Displacement (SLICE-2), Test No. NJPCB-6

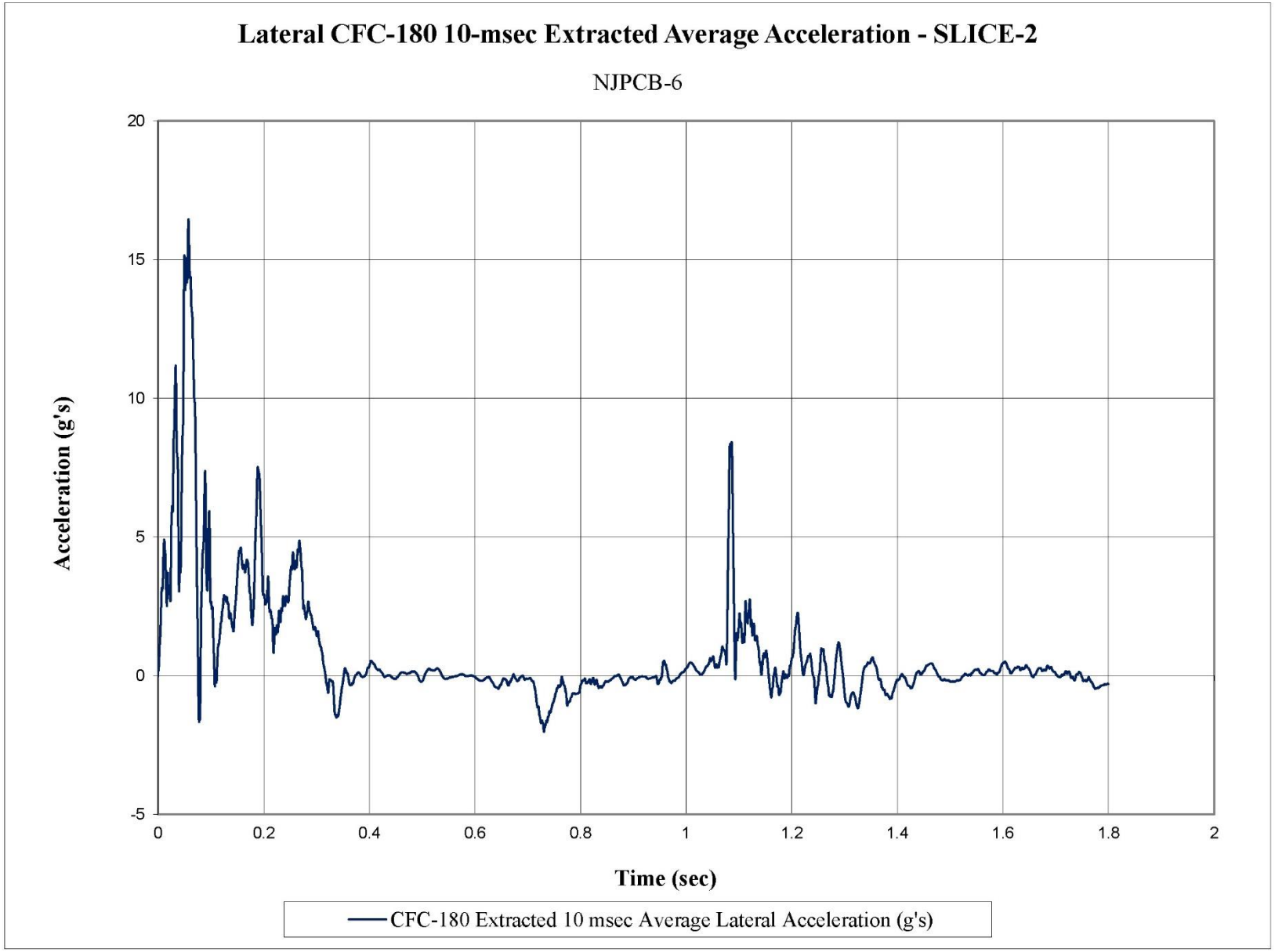


Figure F-4. 10-ms Average Lateral Deceleration (SLICE-2), Test No. NJPCB-6

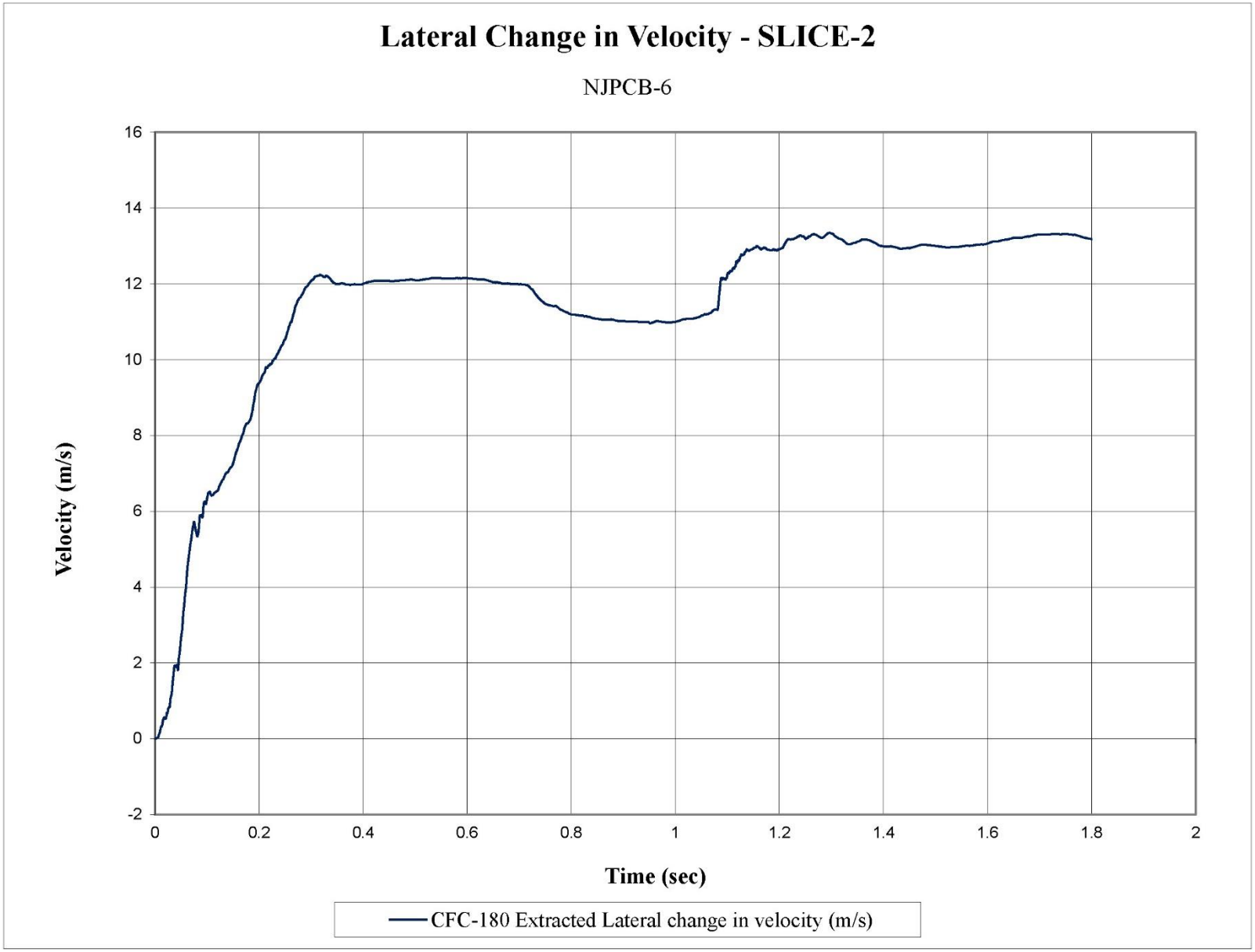


Figure F-5. Lateral Occupant Impact Velocity (SLICE-2), Test No. NJPCB-6

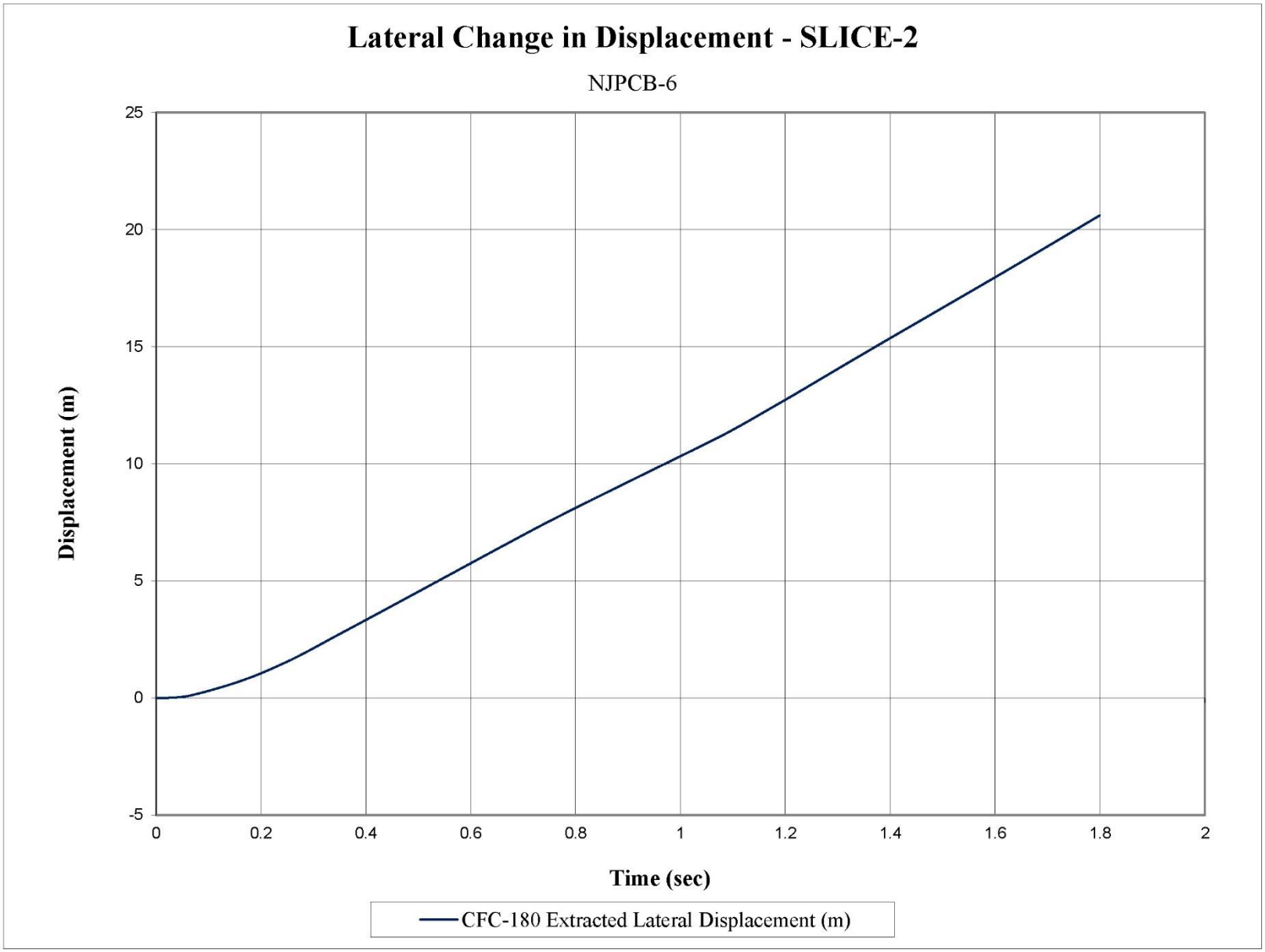


Figure F-6. Lateral Occupant Displacement (SLICE-2), Test No. NJPCB-6

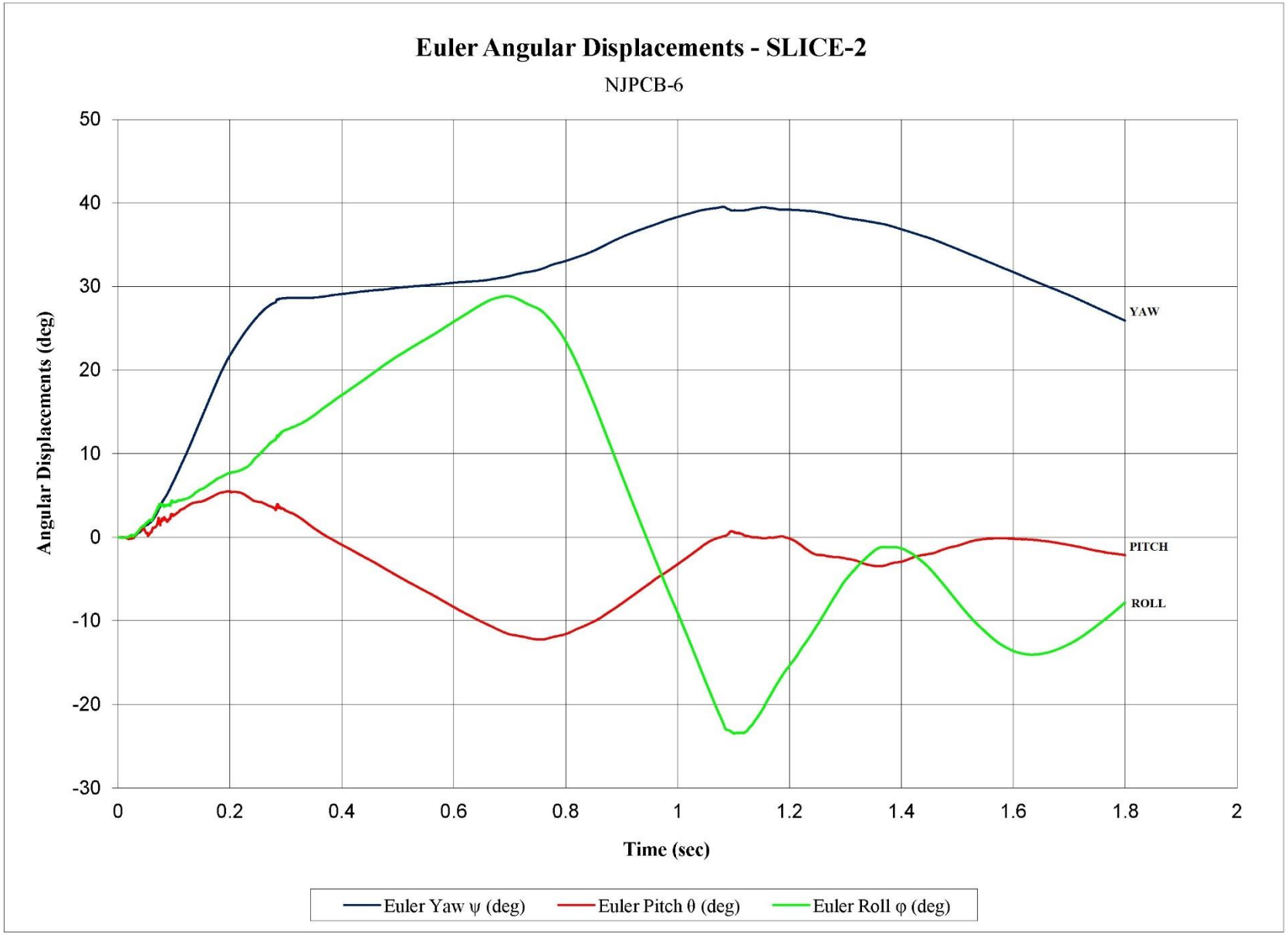


Figure F-7. Vehicle Angular Displacements (SLICE-2), Test No. NJPCB-6

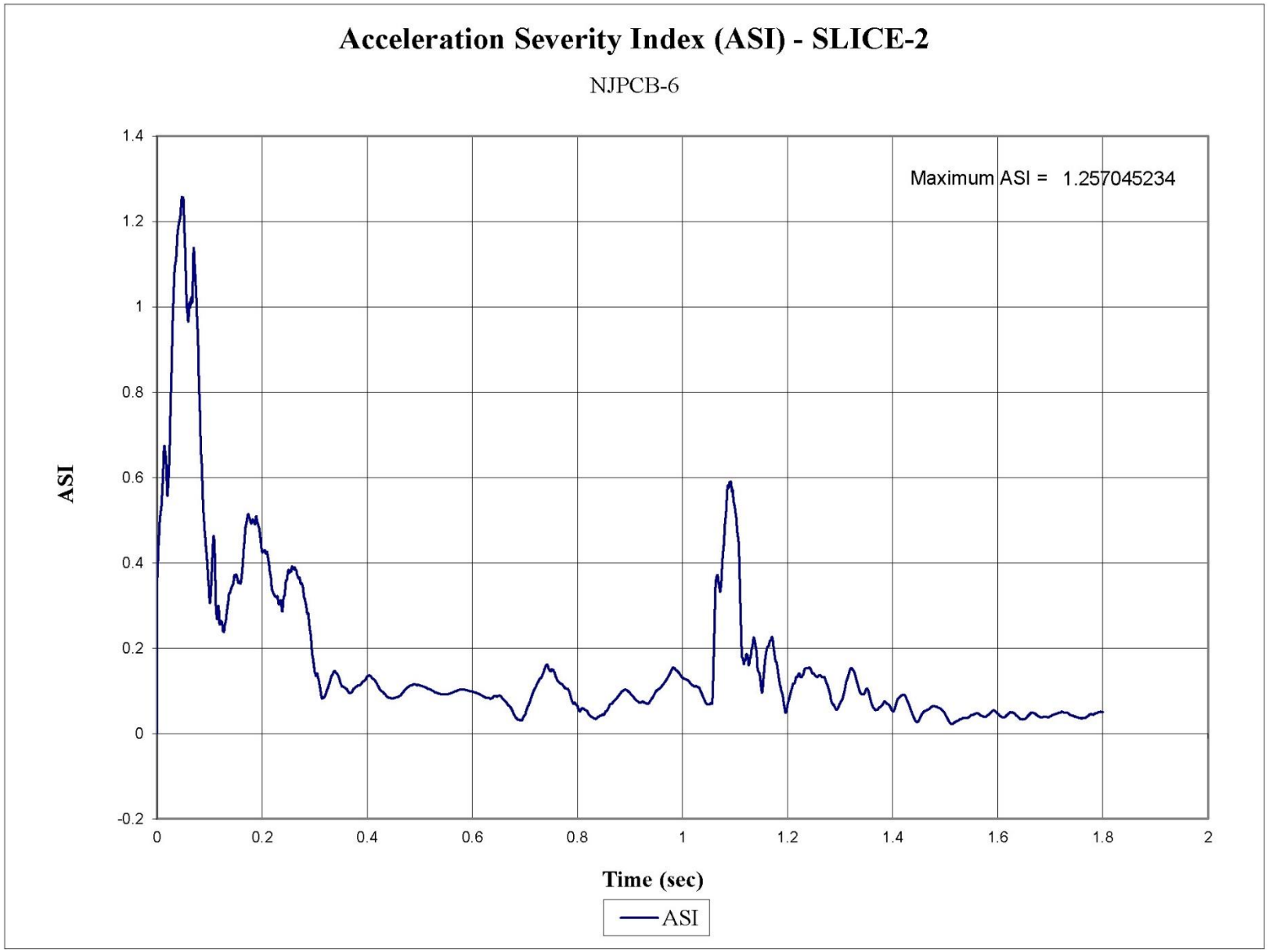


Figure F-8. Acceleration Severity Index (SLICE-2), Test No. NJPCB-6

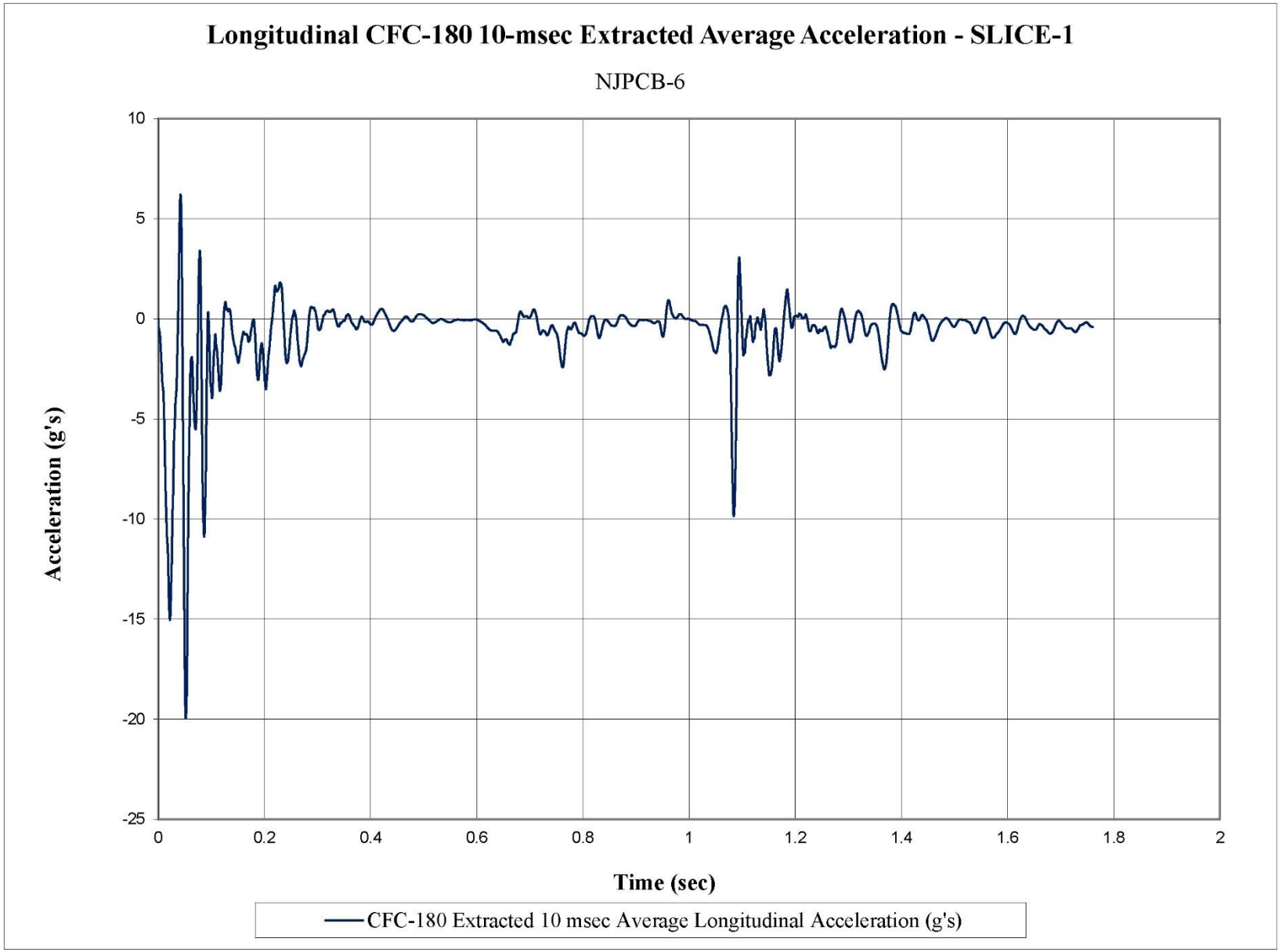


Figure F-9. 10-ms Average Longitudinal Deceleration (SLICE-1), Test No. NJPCB-6

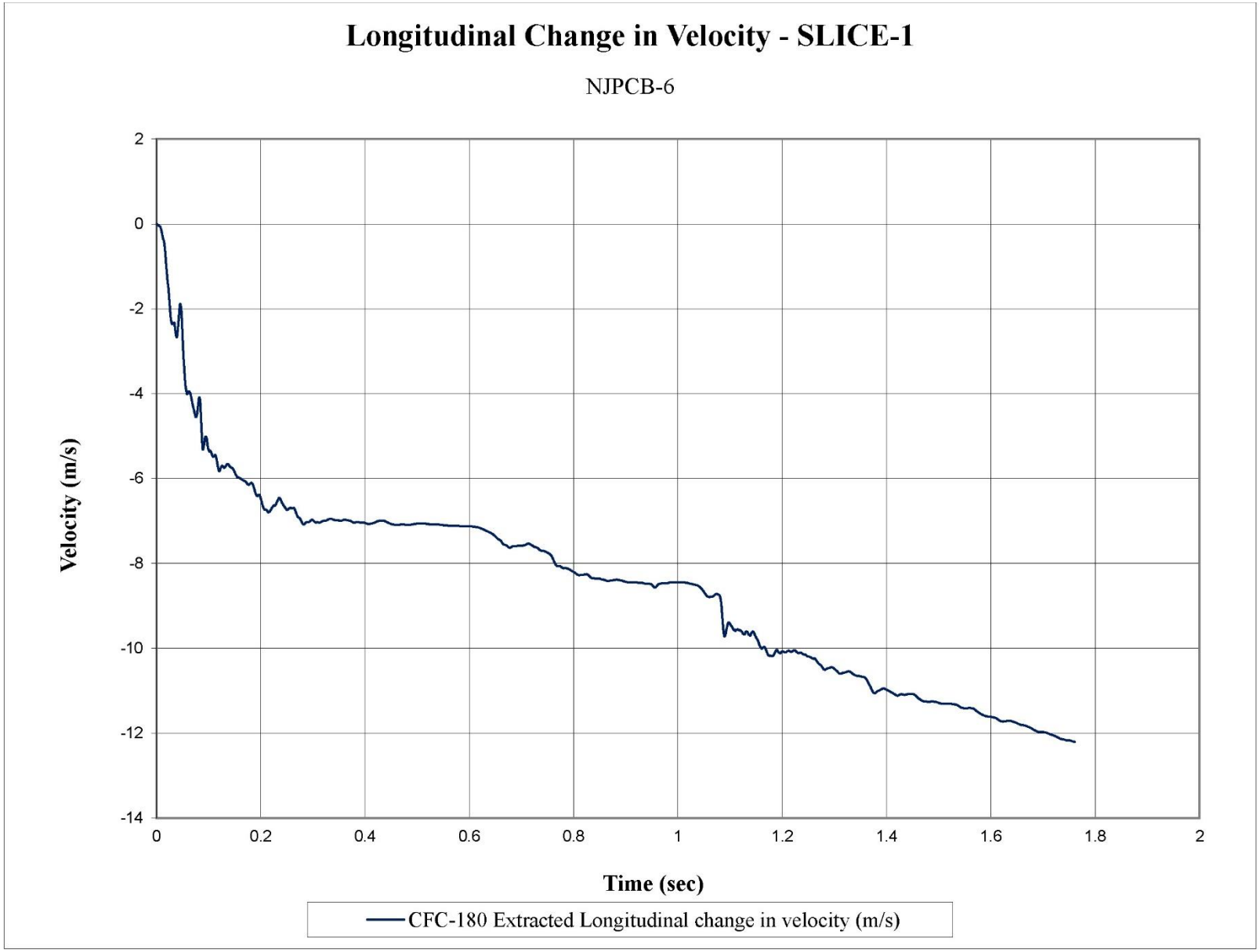


Figure F-10. Longitudinal Occupant Impact Velocity (SLICE-1), Test No. NJPCB-6

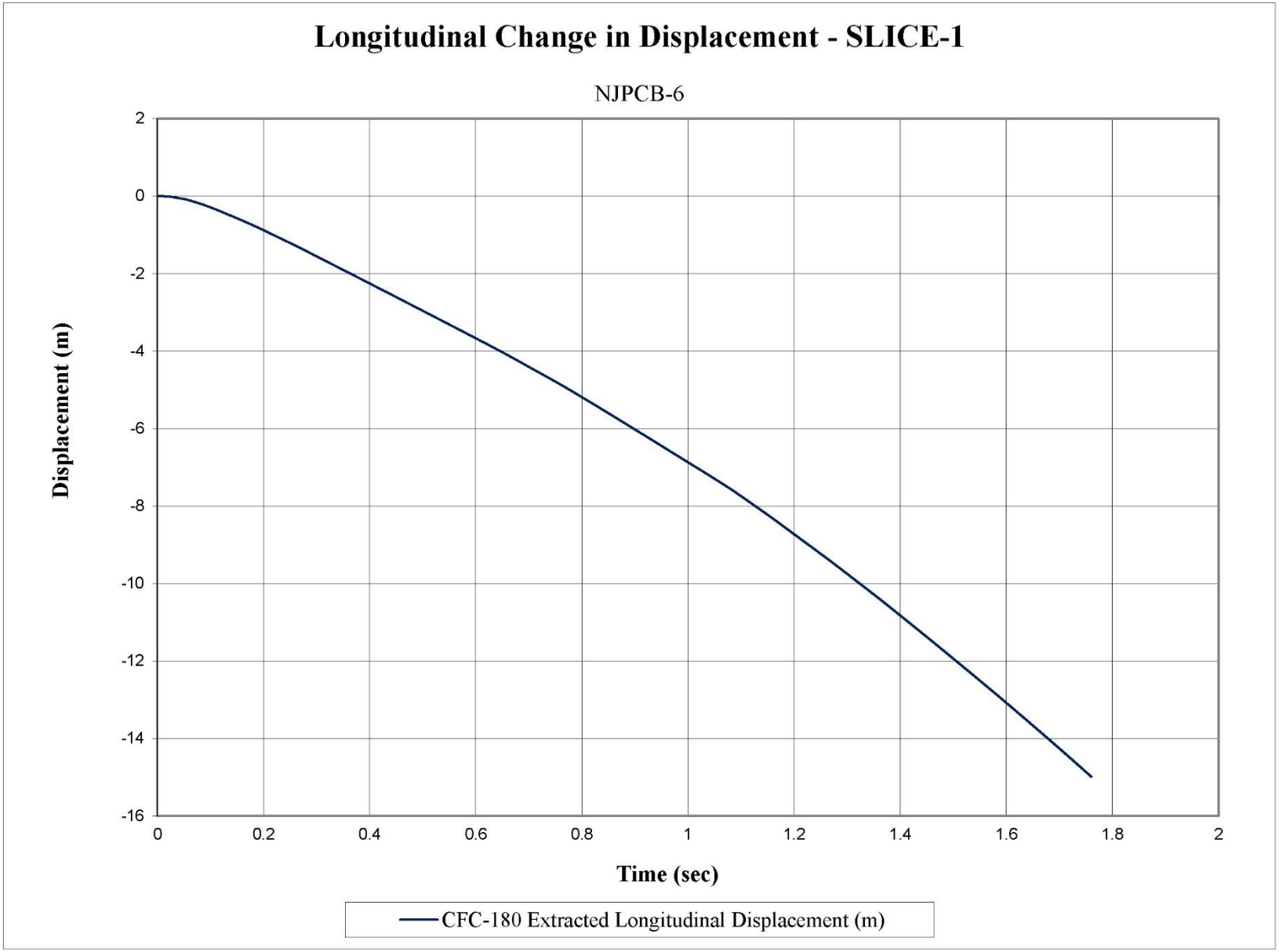


Figure F-11. Longitudinal Occupant Displacement (SLICE-1), Test No. NJPCB-6

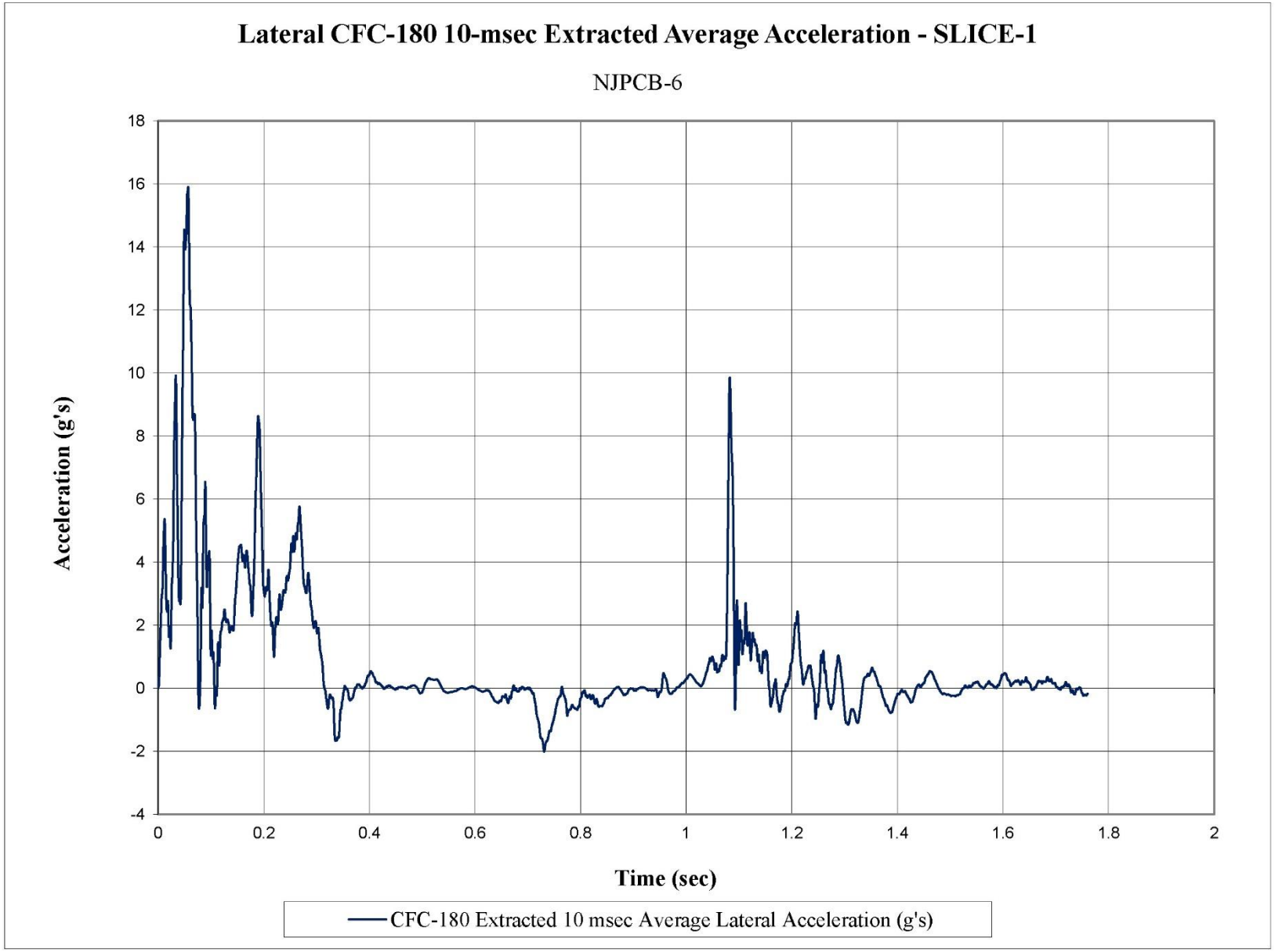


Figure F-12. 10-ms Average Lateral Deceleration (SLICE-1), Test No. NJPCB-6

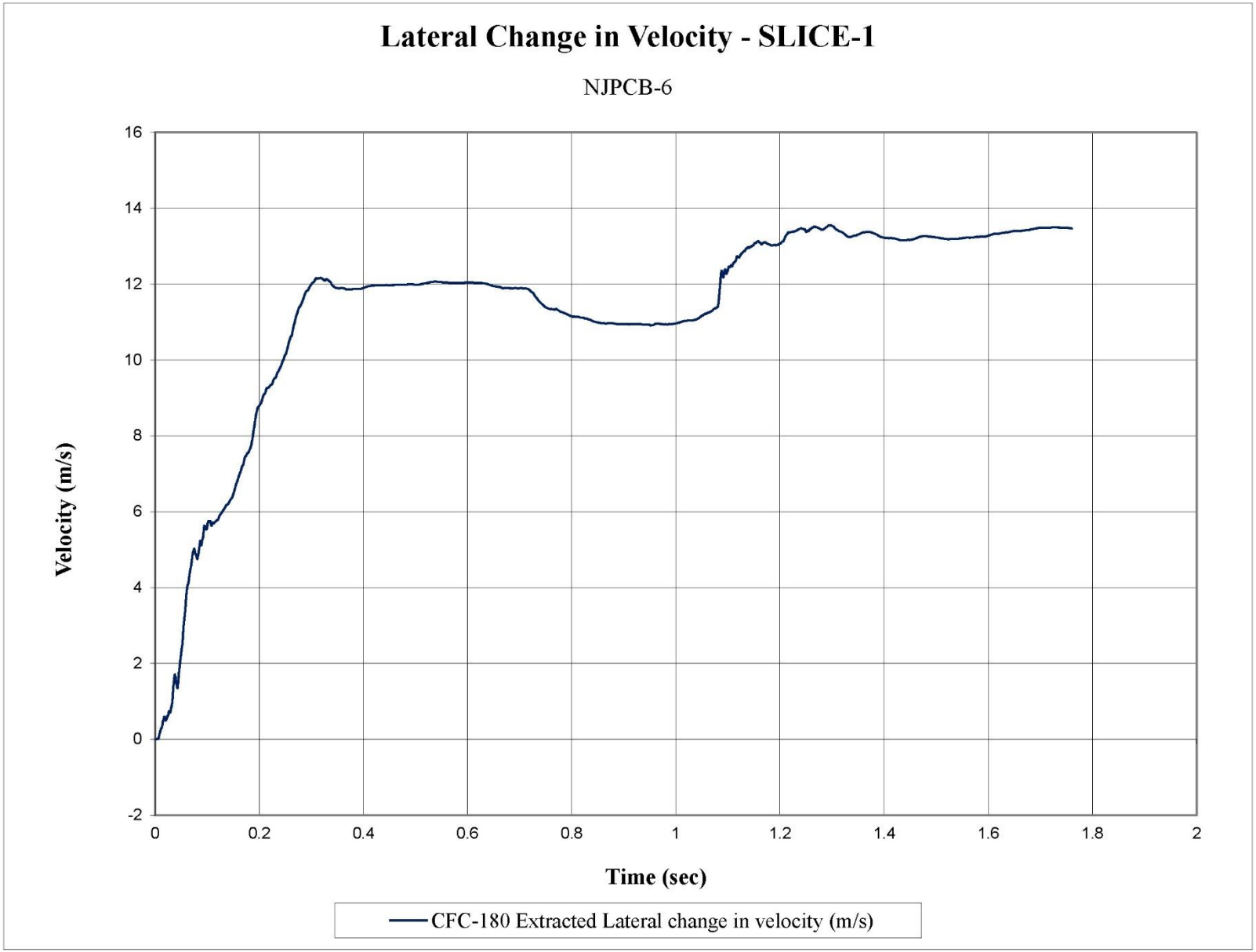


Figure F-13. Lateral Occupant Impact Velocity (SLICE-1), Test No. NJPCB-6

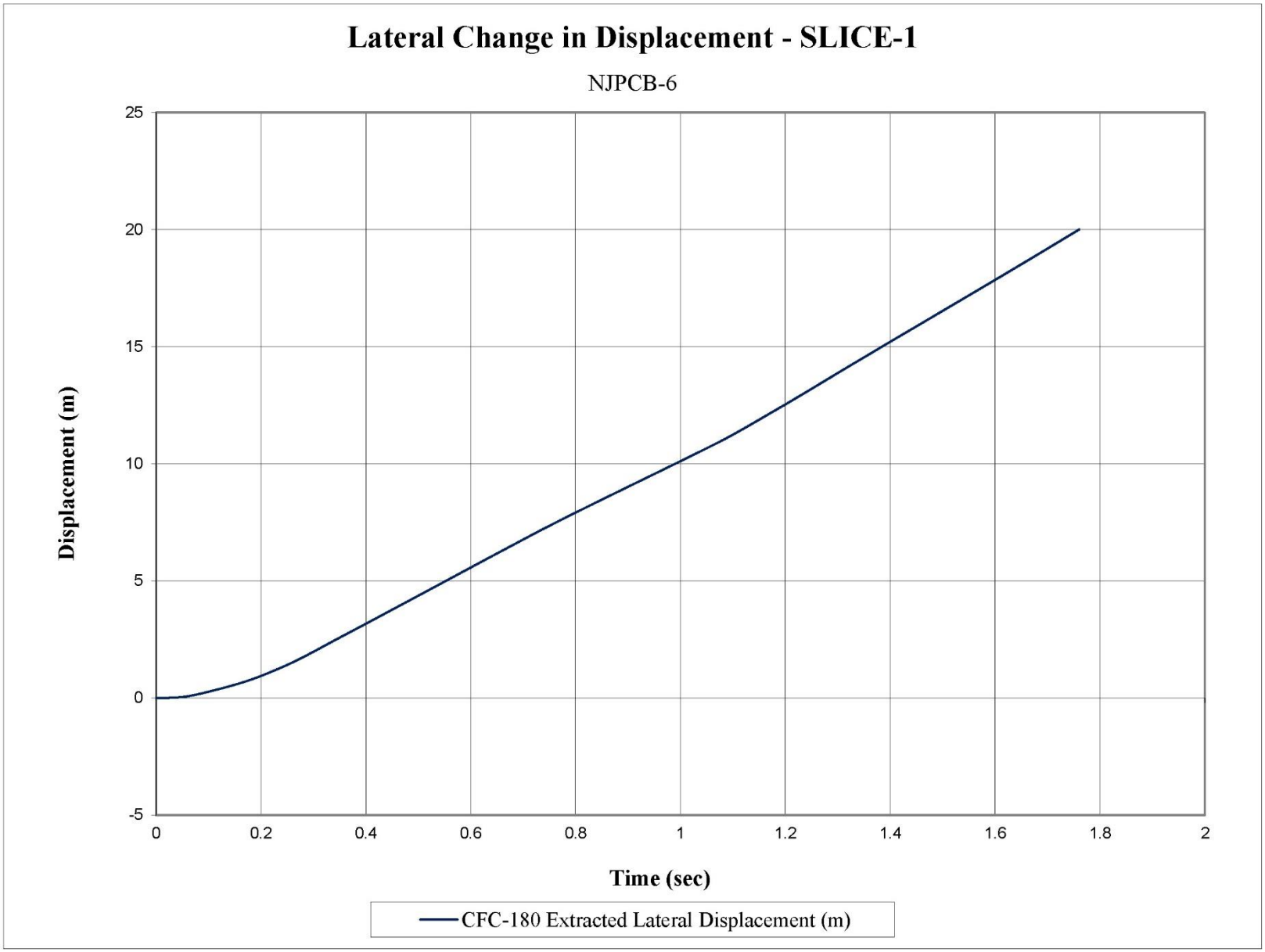


Figure F-14. Lateral Occupant Displacement (SLICE-1), Test No. NJPCB-6

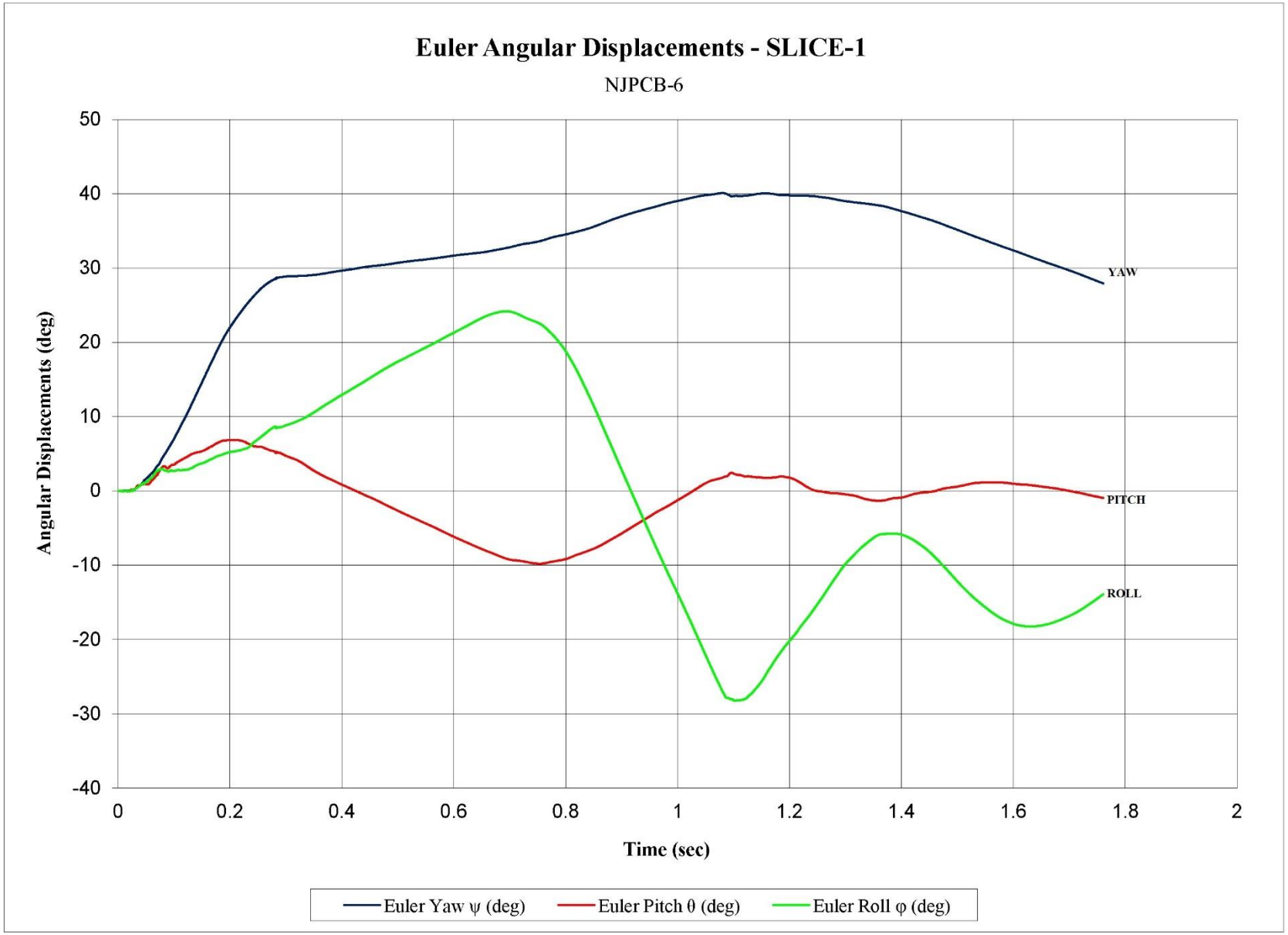


Figure F-15. Vehicle Angular Displacements (SLICE-1), Test No. NJPCB-6

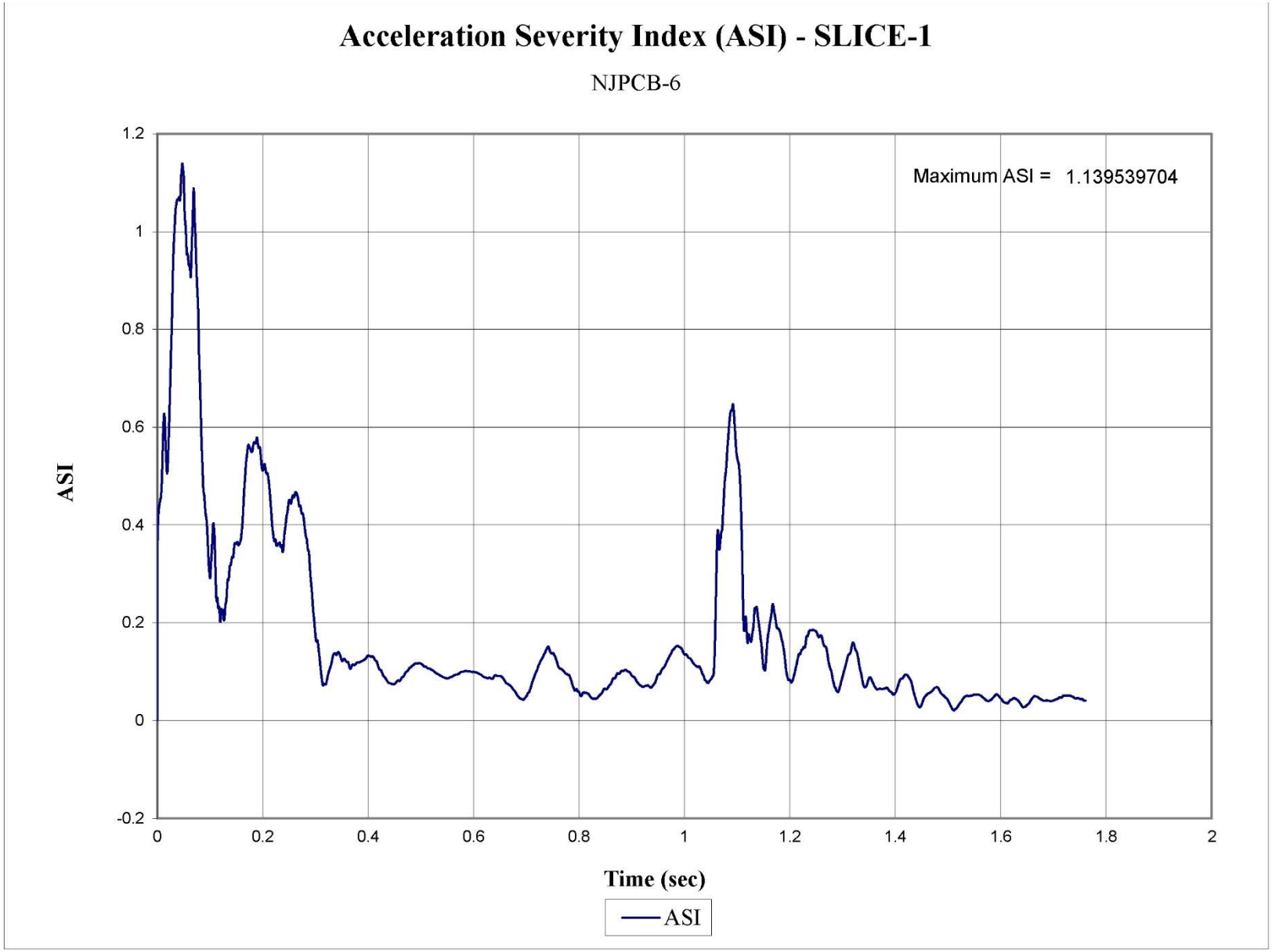


Figure F-16. Acceleration Severity Index (SLICE-1), Test No. NJPCB-6

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