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PERFORMANCE LIMITS FOR 6-IN. (152-MM) HIGH CURBS PLACED IN ADVANCE OF THE MGS USING MASH VEHICLES

PART III: FULL-SCALE CRASH TESTING (TL-2)

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16. Abstract (Limit: 200 words)

A full-scale crash test utilizing the Test Level 2 (TL-2) safety performance criteria of the Manual for Assessing Safety Hardware (MASH) was performed on the Midwest Guardrail System (MGS) offset 6 ft (1.8 m) behind a 6-in. (152-mm) high AASHTO Type B curb with a top mounting height of 31 in. (787 mm) relative to the ground [37 in. (940 mm) relative to the roadway]. In the test, the 2270P vehicle was redirected by the guardrail, and all safety performance criteria were met. Thus, the MGS offset 6 ft (1.8 mm) behind a 6-in. (152-mm) high curb with a top mounting height of 31 in. (787 mm) was deemed to be acceptable according to TL-2 of MASH. Based on test results and prior research, preliminary guidelines were developed for use of the MGS when offset behind curbs.

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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.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Problem Statement

Highway design policy typically discourages the use of 6- to 8-in. (152- to 203-mm) vertical curbs on high-speed roadways because of their potential to cause drivers to lose control in a crash [1]. Curbs can also affect the interaction of errant vehicles with roadside barriers by causing vaulting or underride of the barrier. However, the use of curbs is often required because of restricted right-of-way, drainage considerations, access control, and other functions. Often, there is a desire to offset the guardrail from the curb to reduce the propensity for snow plows to gouge and/or damage the W-beam rail sections or to allow for placement of sidewalks between the road and a barrier or other roadside features.

When curbs are required, the offset of the barrier from the curb has been shown to be critical in the performance of the system through modeling and crash testing. Previous work with steel-post, nested W-beam guardrail has shown that a 4-in. (102-mm) high sloped curb with the toe of the curb placed at the front face of the guardrail is capable of meeting National Cooperative Highway Research Program (NCHRP) Report No. 350 safety requirements [2-4]. Further research with standard wood-post W-beam guardrail has shown that a 4-in. (102-mm) high sloped curb with its toe set out 1 in. (25 mm) from the front face of the guardrail is also capable of meeting TL-3 requirements [5].

Investigation of curb-barrier combinations was reported in NCHRP Report No. 537, *Recommended Guidelines for Curbs and Curb-Barrier Combinations* [6]. This study developed guidelines for the use of curbs and curb-barrier combinations on roadways with operating speeds greater than 37.3 mph (60 km/h). The study recommended that guardrail be installed flush with the face of the sloped curb or offset more than 8.2 ft (2.5 m) behind the curb for operating speeds in excess of 37.3 mph (60 km/h). In addition, the study recommended that guardrail should not be offset behind sloped curbs for speeds greater than 62.1 mph (100 km/h).

The recent development and testing of the Midwest Guardrail System (MGS) has demonstrated that this system can be used with a 6-in. (152-mm) tall, American Association of State Highway Transportation Officials (AASHTO) Type B curb positioned 6 in. (152 mm) in front of the face of the guardrail element [7-8]. Although this guardrail-to-curb configuration provides increased hydraulic flow for roadway runoff as well as reduced guardrail maintenance arising from snow plowing operations, state departments of transportation (DOTs) often desire to locate roadside curbs farther away from the front face of the guardrail. Thus, a research effort was begun with the goal of determining placement guidelines for the MGS in relation to curbs.

1.2 Background

In 2008, testing was performed with the small car and pickup truck vehicles specified in the *Manual for Assessing Safety Hardware (MASH)* [9]. The test vehicles impacted a 6-in. (152-mm) high AASTHO Type B curb under Test Level 3 (TL-3) conditions [i.e., 62 mph (100 km/h) and 25 degrees]. The main goal of the tests was to determine the vehicle behavior following the impact, with particular attention focused on the pitch angles and the bumper trajectories of the vehicles [10-11].

By comparing the critical bumper impact point trajectories against the MGS top/bottom corrugation heights, the critical override/underride offset for placing the MGS behind the curb was determined. Results of this analysis created offset guidelines for placement of the MGS with a 6-in. (152-mm) high curb [10-11].

To further investigate the critical offset distance for MGS placement behind an AASHTO Type B curb, finite element analysis was performed. The MGS was offset from a 6-in. (152-mm) high AASTHO Type B curb at various distances and impacted with the 2000P test vehicle.

Based on previous vehicle-curb simulation results and to ensure reliability of the model, the offset distance under investigation was limited to the range of 0.0 ft (0.0 m) to 7.35 ft (2.24 m) behind the curb. Simulation results indicated that the current pickup model (2000P) was fairly accurate in predicting the vehicle trajectory within 7.35 ft (2.24 m) behind the curb. Details of this research effort are documented in prior MwRSF research reports [10-11].

Based on the simulation results, a full-scale crash test was then performed on the MGS with a top mounting height of 37 in. (940 mm) above the roadway, offset 8 ft (2.44 m) behind a 6-in. (152-mm) high AASHTO Type B Curb [12]. In the test, the 2270P vehicle was contained by the guardrail, but it became unstable and rolled over. Analysis of the test revealed that the right-front tire snagged on a post and detached. The right-rear tire of the pickup traversed over the detached tire, causing the rear of the vehicle to pitch upward. The vehicle subsequently became unstable and rolled over. Thus, the MGS offset 8 ft (2.44 mm) behind a 6-in. (152-mm) high curb with a top mounting height of 37 in. (940 mm) relative to the roadway was deemed to be unacceptable according to TL-3 of MASH.

Simulation of this crash test was then performed with the newly released 2270P vehicle model. Simulation results also showed the 2270P rolling over in the same impact scenario as the first crash test.

1.3 Objective

Following the unsuccessful full-scale crash test, the original project was modified based on a survey of the states in the Midwest States Regional Pooled Fund Program. The new objective was to determine a range of distances for which the MGS could be offset behind a 6-in. (152-mm) high AASHTO Type B curb and satisfy the TL-2 safety performance criteria of MASH.

1.4 Scope

The research objective was achieved through the completion of several tasks. First, finite element simulations of the system were performed to determine the critical offset distance of the MGS relative to the curb. This configuration would represent the highest probability of system failure under TL-2 conditions for the range of offsets. Then, a full-scale vehicle crash test was performed on the MGS offset 6 ft (1.83 m) behind a 6-in. (152-mm) high AASHTO Type B curb. The MGS was raised 6 in. (152 mm) resulting in a top mounting height of 37 in. (940 mm) relative to the roadway. The crash test utilized a pickup truck, weighing approximately 5,000 lb (2,268 kg). Target impact conditions for the test were an impact speed of 44 mph (70 km/h) and an impact angle of 25 degrees. Next, the test results were analyzed, evaluated, and documented. Finally, conclusions and recommendations were made that pertain to the safety performance of the MGS and curb system relative to the test performed.

2 BARRIER DESIGN AND ANALYSIS

Researchers concluded that the critical offset distance for the MGS behind the curb was the distance which would provide the most probable conditions for override of the pickup truck test vehicle. It was believed that the worst-case placement for the MGS relative to the curb would be at the location where the front bumper of the truck reached the apex of its trajectory following impact with the curb. The truck would be at its maximum height at this location, and its momentum would not yet be going downward. It was believed an acceptable range for placing the MGS behind the curb could be achieved by testing the worst-case location for the MGS with the pickup truck and using previous knowledge concerning the small car.

Finite element analysis was performed using LS-DYNA to determine the critical offset of the MGS relative to the curb [13]. The vehicle model used for the simulation was the National Crash Analysis Center (NCAC) Silverado V2 model released in March 2009, while the MGS model used in the simulations was developed by MwRSF in previous studies [11].

To determine the critical offset distance for TL-2 conditions, simulations with only the pickup truck and the curb were initially conducted. Results from this study showed the apex of the trajectory of the front bumper occurred at a distance of approximately 6 ft (1.83 m) behind the toe of the curb.

Further simulations were then performed in which the Silverado impacted the MGS at various offsets from the curb. These offsets ranged from 4 ft (1.22 m) to 10 ft (3.05 m) at 1-ft (0.30-m) increments. Results from the 6-ft (1.83-m) and 8-ft (2.44-m) offset simulations, which are shown in Figure 1, clearly indicated that the 6-ft (1.83-m) offset produced the worst-case impact. However, in this scenario, the truck was smoothly redirected by the MGS. Therefore, the system was expected to perform successfully in full-scale crash testing.

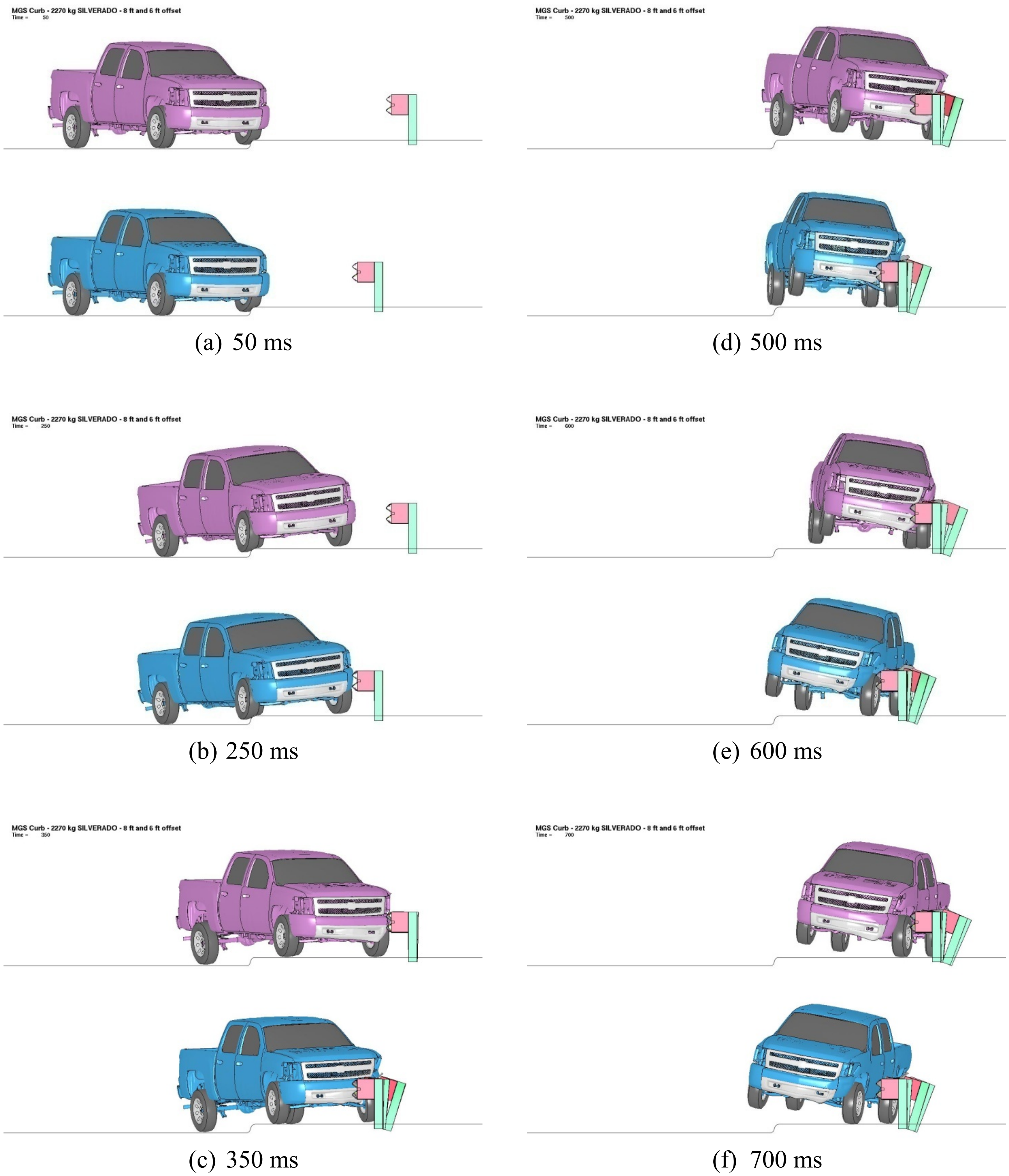


Figure 1. 8-ft Offset (Top Vehicle in Each Frame) vs. 6-ft Offset (Bottom Vehicle in Each Frame)

3 DESIGN DETAILS

The barrier system test installation was comprised of 175 ft (53.34 m) of MGS guardrail supported by steel posts and positioned 6 ft (1.83 m) behind a 6-in. (152-mm) tall, AASHTO Type B curb, as shown in Figures 2 through 11. Photographs of the test installation are shown in Figures 12 through 14. Material specifications, mill certifications, and certificates of conformity for the system materials are shown in Appendix A.

The MGS was constructed with twenty-nine guardrail posts. Post nos. 3 through 27 were galvanized ASTM A36 steel W6x8.5 (W152x12.6) sections measuring 72 in. (1,829 mm) long and embedded in 40 in. (1016 mm) of soil, as shown in Figures 3 and 6. Post nos. 1, 2, 28, and 29 were timber posts measuring 5½ in. wide x 7½ in. deep x 46 in. long (140 mm x 190 mm x 1,168 mm) and were placed in 72-in. (1,829-mm) long steel foundation tubes, as shown in Figures 4 and 7. The timber posts and foundation tubes were part of the anchor system designed to replicate the capacity of a tangent guardrail terminal.

Post nos. 1 through 29 were spaced 75 in. (1,905 mm) on center, as shown in Figure 2. The posts were placed in a compacted, coarse, crushed limestone material that met Grading B of AASHTO M147-65 (1990) as described in MASH. For post nos. 3 through 27, 6-in. wide x 12-in. deep x 14¼-in. long (152-mm x 305-mm x 362-mm) wood spacer blockouts were used to block the rail away from the front face of the steel posts, as shown in Figures 3 and 6.

Standard 12-gauge (2.66-mm thick) W-beam rails were placed between post nos. 1 and 29, as shown in Figures 2, 4, and 10. The top mounting height of the W-beam rail was 31 in. (787 mm) above the ground surface with a 24⅞-in. (632-mm) center mounting height, or 37 in. (940 mm) above the roadway surface. Rail splices were placed at midspan locations between guardrail posts, as shown in Figures 2 and 4. All lap splice connections between the rail sections were configured to reduce vehicle snag at the splice during the crash test.

A 6-in. (152-mm) tall, AASHTO Type B curb was placed in front of the MGS. The concrete curb was 73 ft - 6 in. (22.40 m) long, beginning at the midspan between post nos. 8 and 9 to post no. 20, as shown in Figure 2. The toe of the curb was offset 6 ft (1.83 m) in front of the front face of the guardrail. The concrete mix had a minimum 28-day compressive strength of 4,000 psi (27.6 MPa). All steel reinforcement was specified as ASTM A615 Grade 40 rebar and consisted of No. 4 longitudinal and vertical bars, as shown in Figure 3.

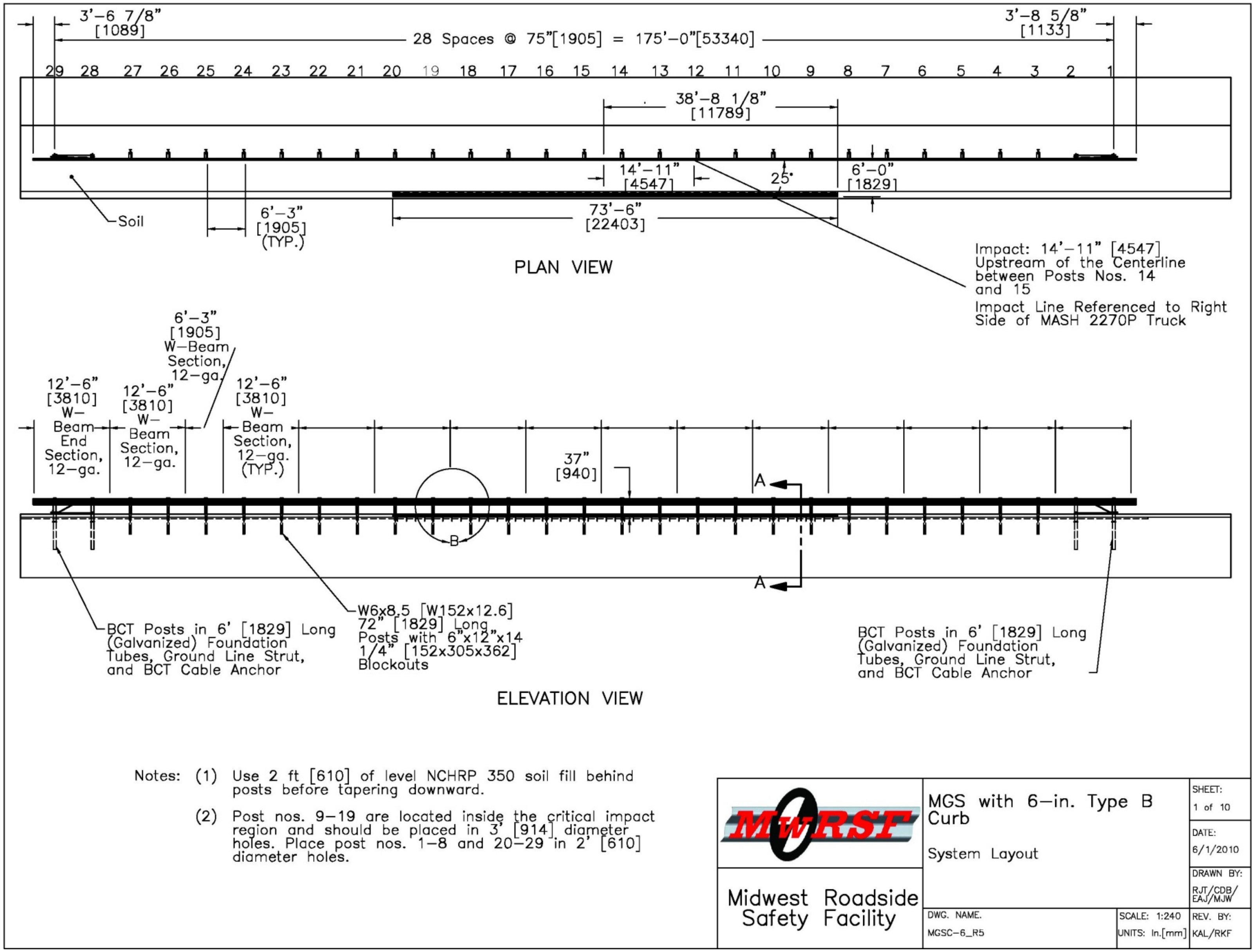


Figure 2. Test Installation Layout, Test No. MGSC-6

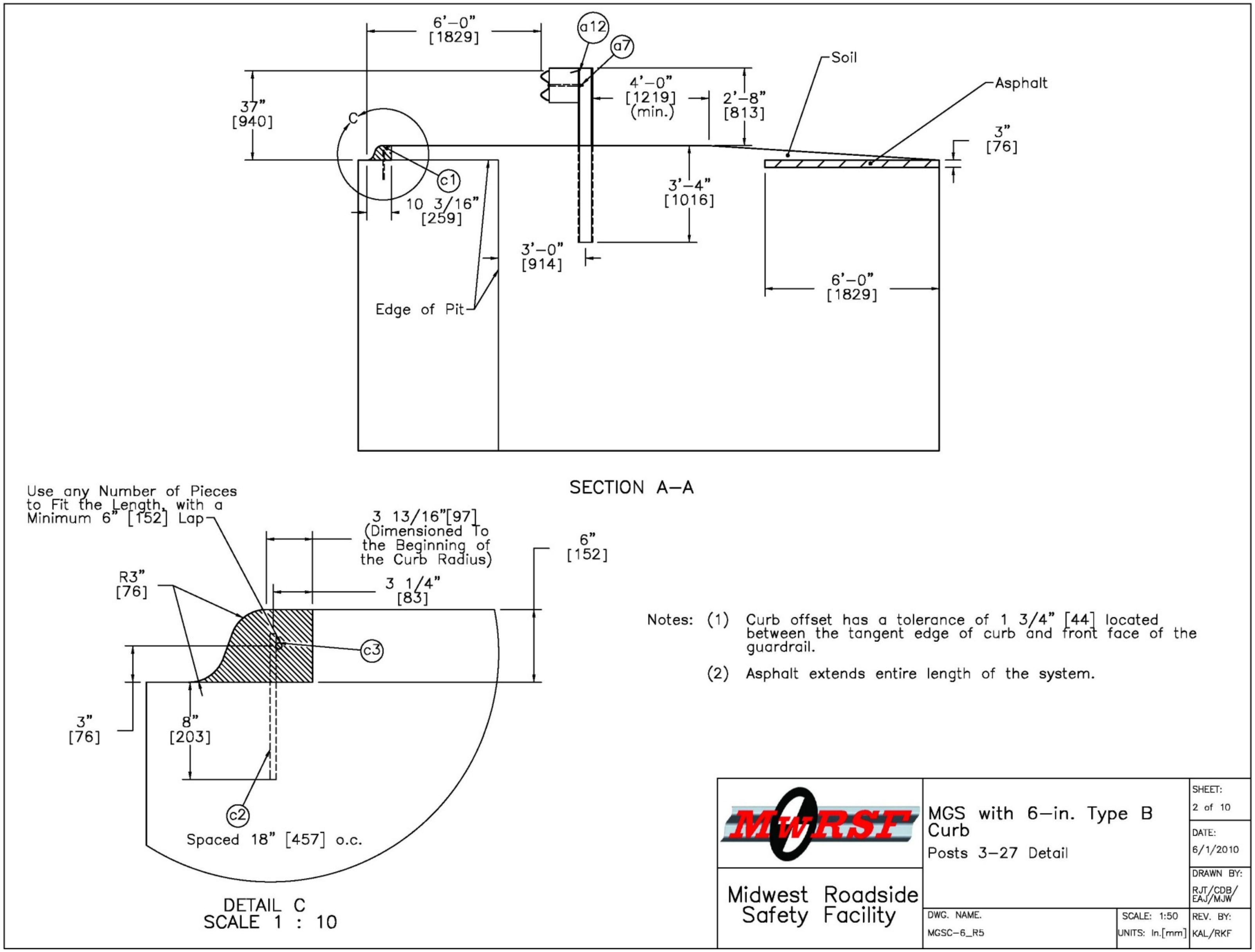


Figure 3. Post and Curb Details, Test No. MGSC-6

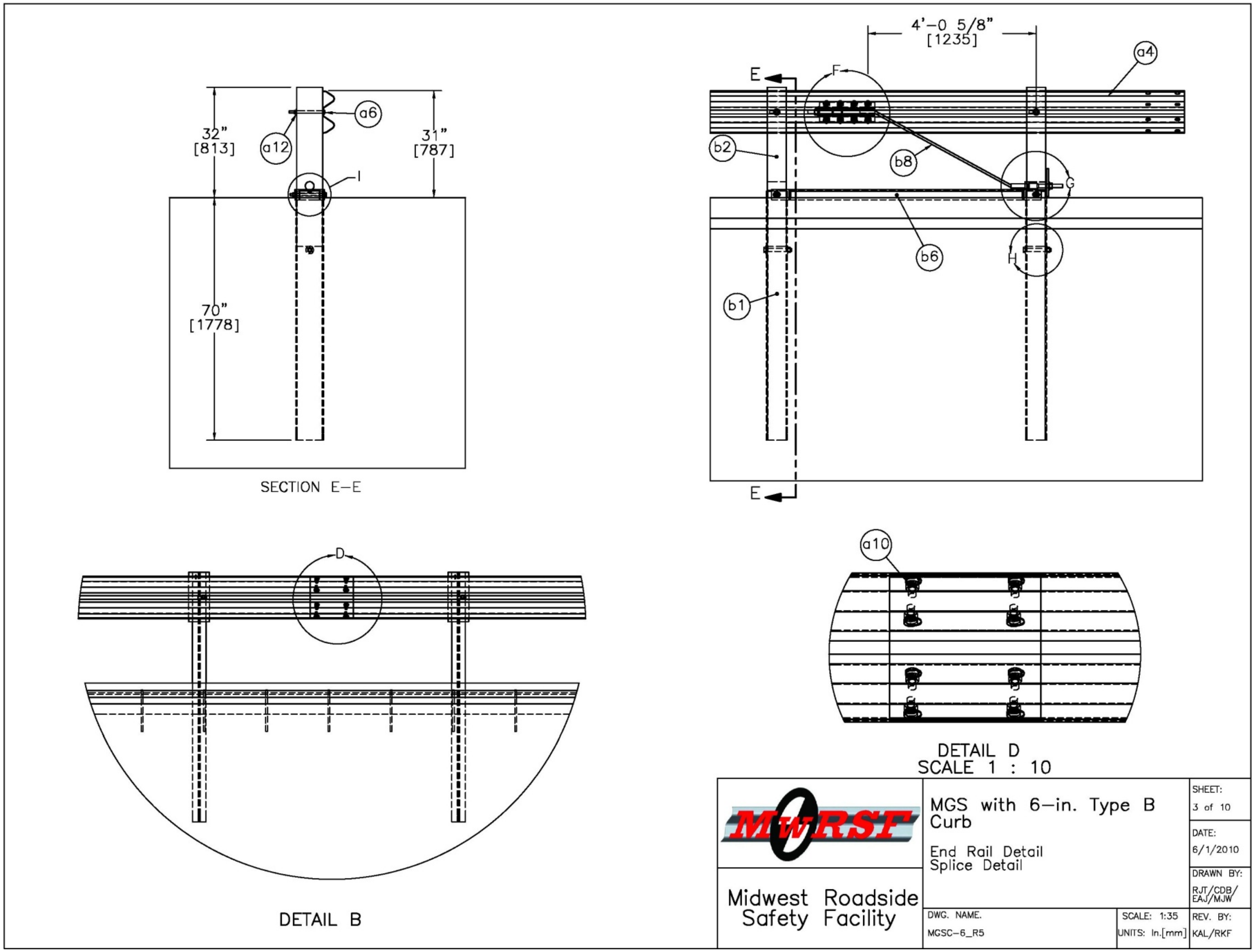


Figure 4. End Rail and Splice Details, Test No. MGSC-6

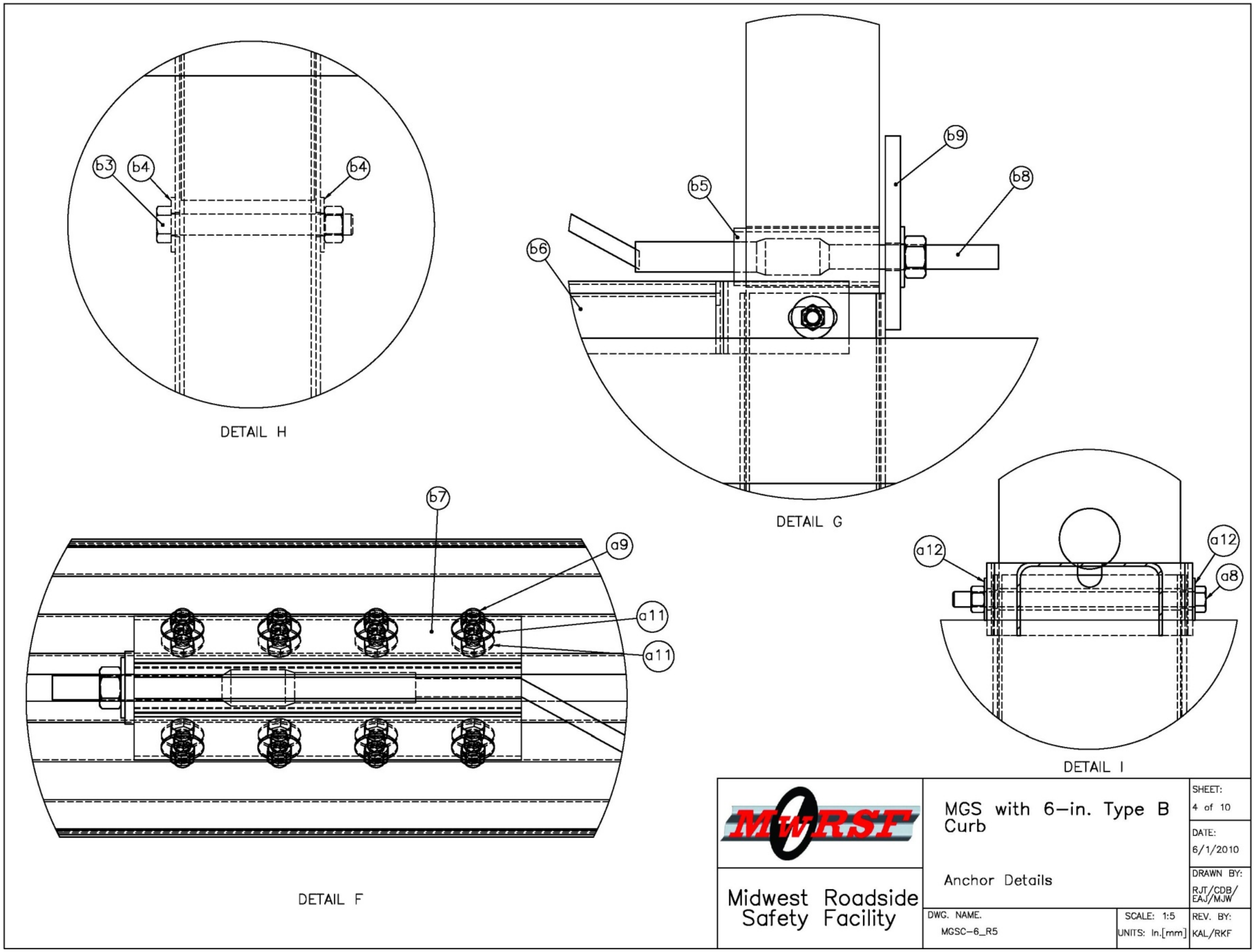


Figure 5. Anchor Details, Test No. MGSC-6

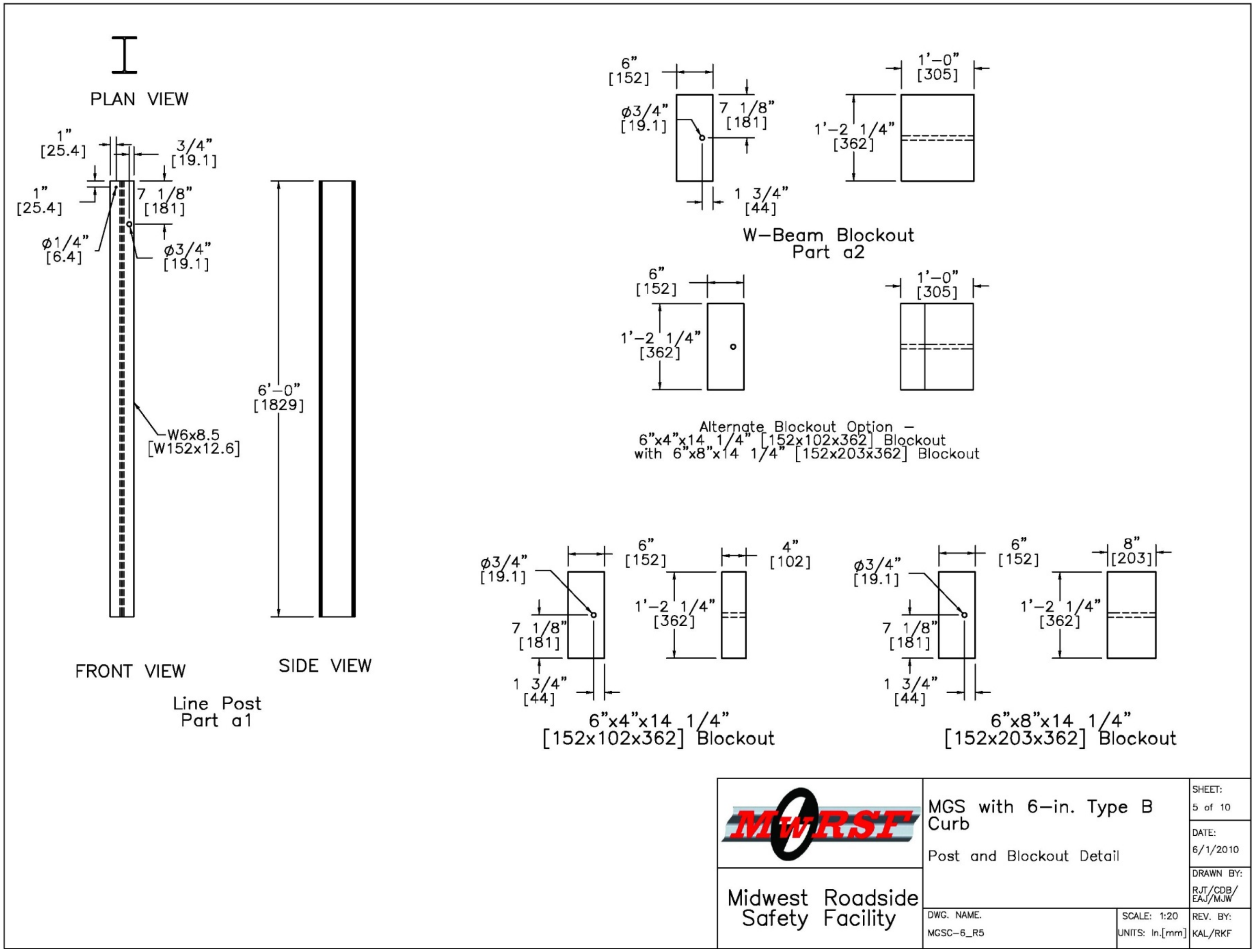


Figure 6. Post and Blockout Details, Test No. MGSC-6

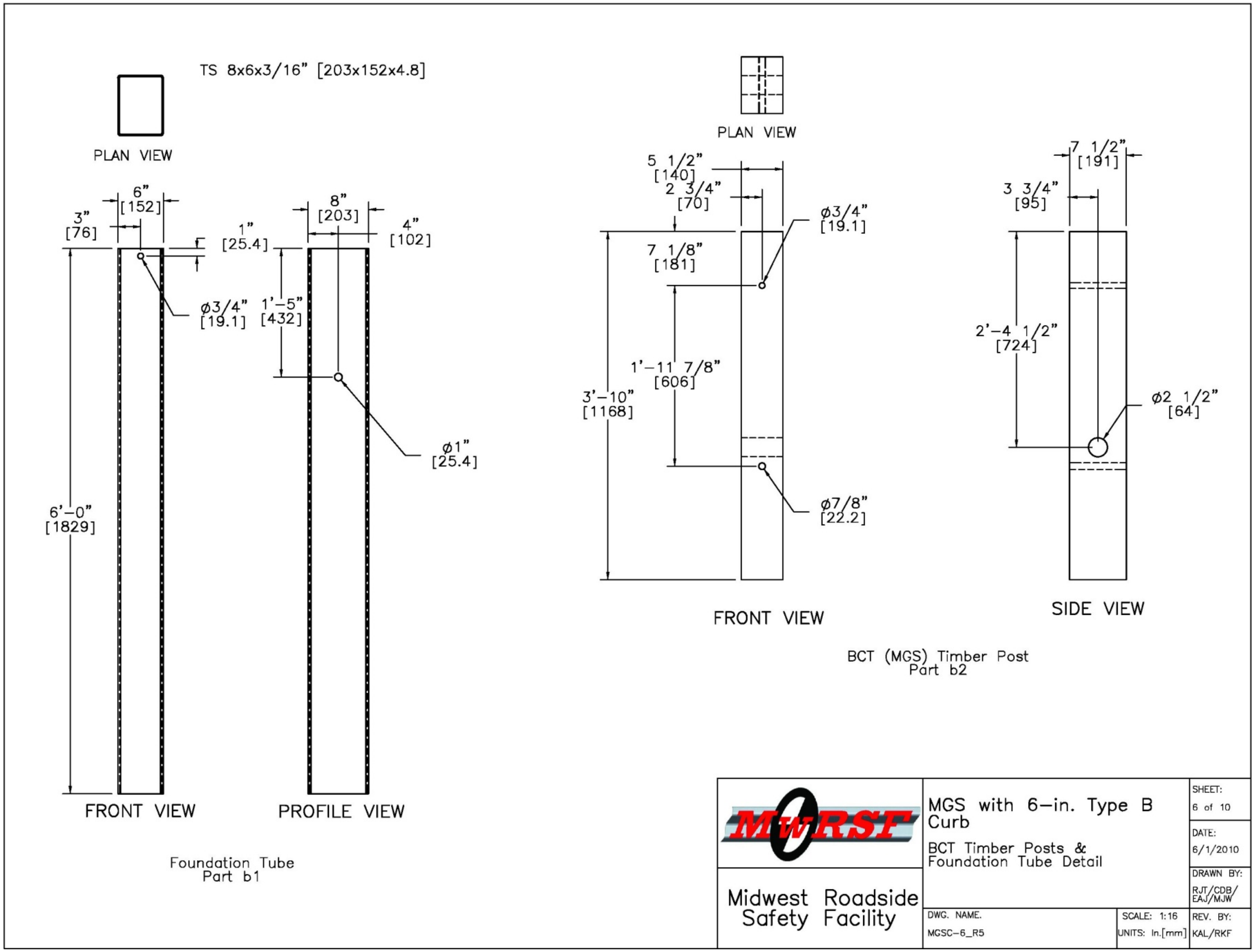


Figure 7. BCT Timber Post and Foundation Tube Details, Test No. MGSC-6

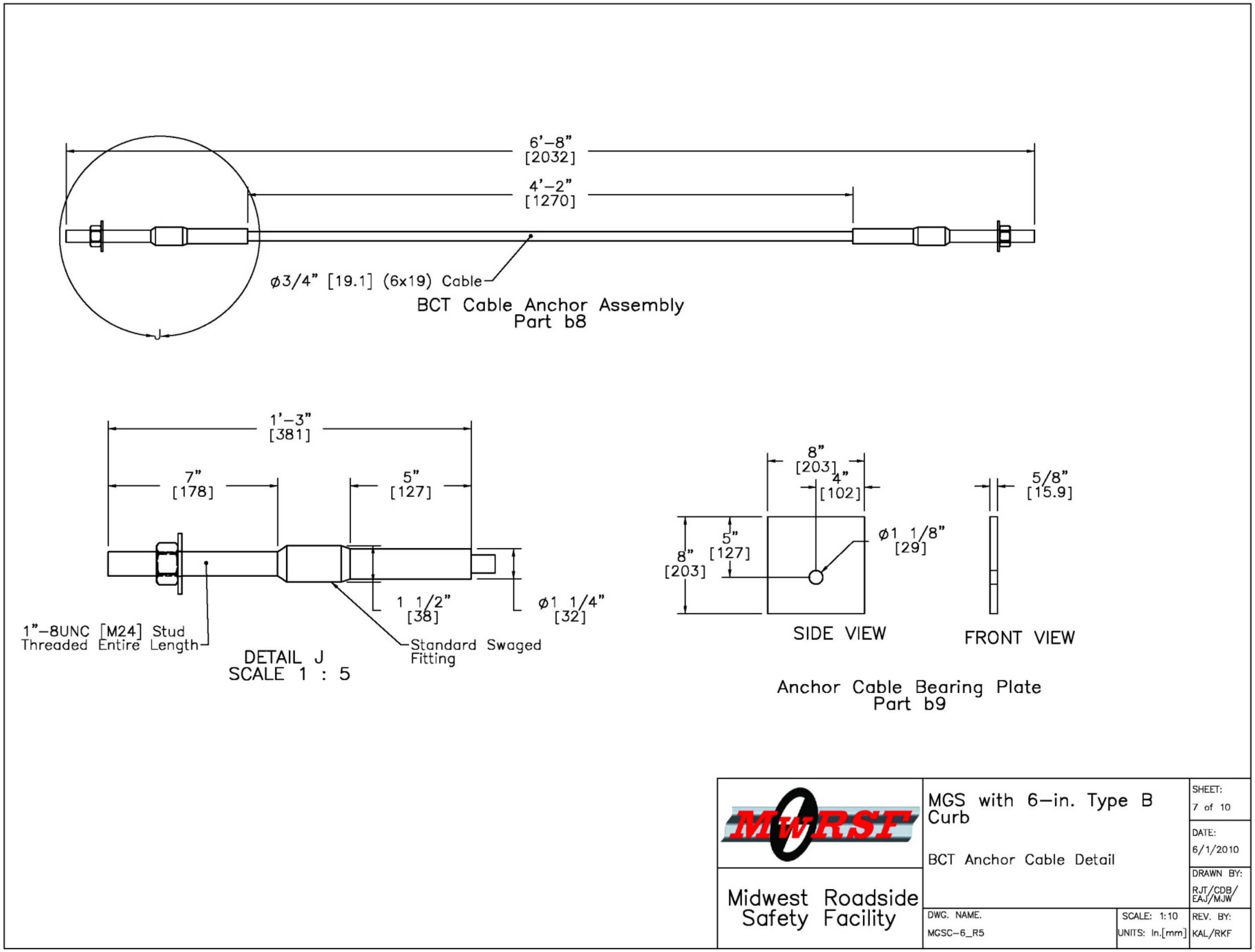


Figure 8. BCT Anchor Cable Details, Test No. MGSC-6

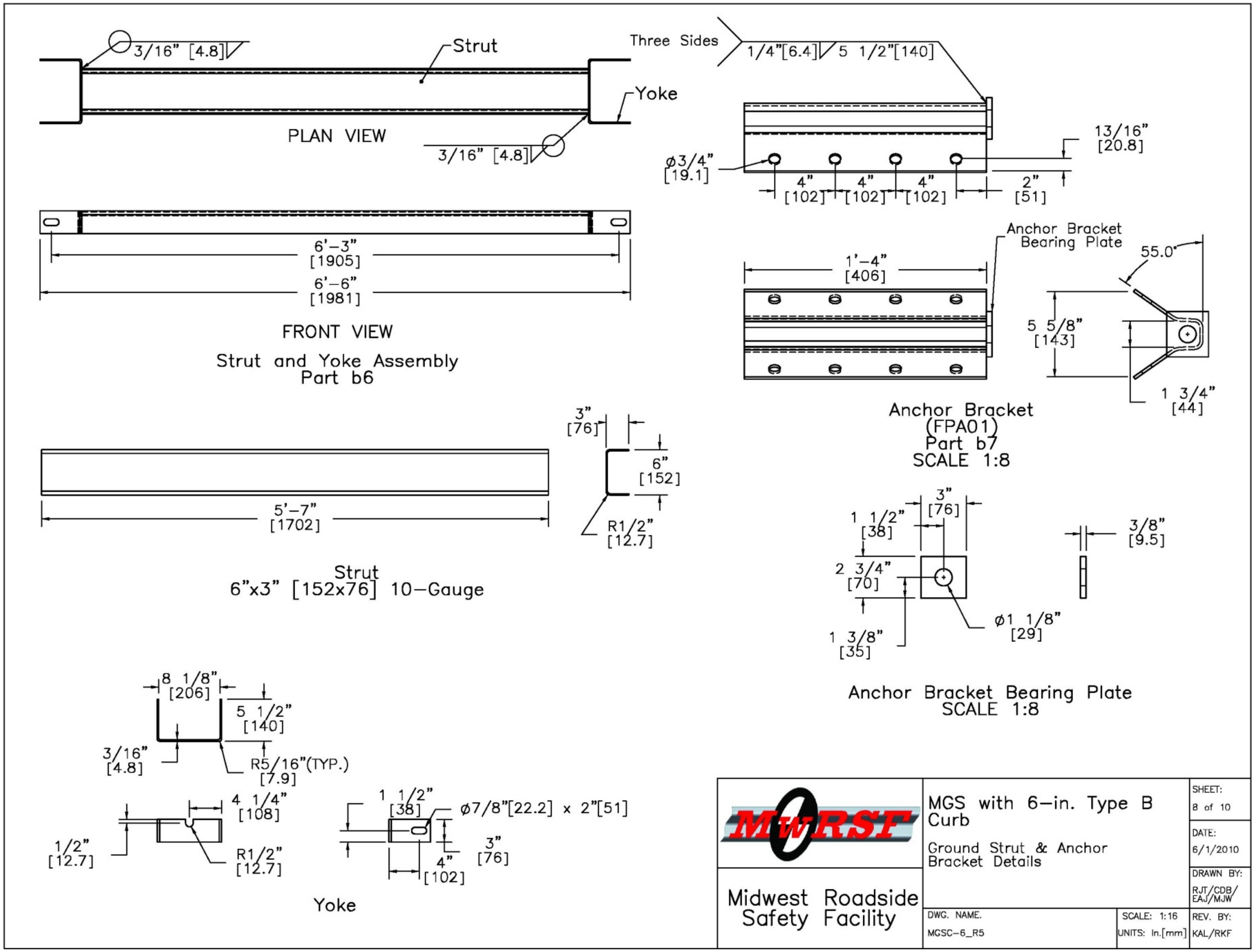


Figure 9. Ground Strut and Anchor Bracket Details, Test No. MGSC-6

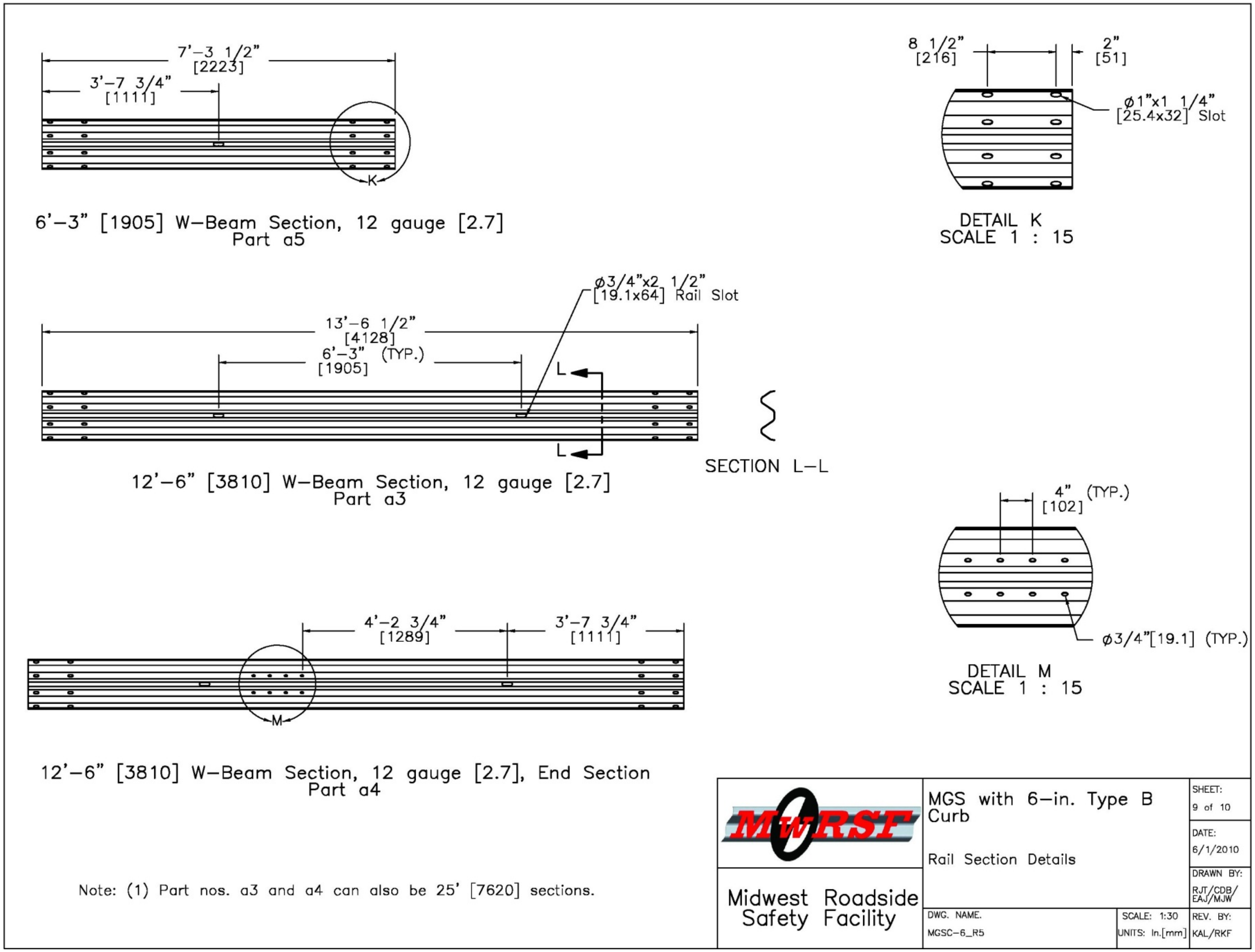


Figure 10. Rail Section Details, Test No. MGSC-6

Item No.	QTY.	Description	Material Specifications	Hardware Guide
a1	25	W6x8.5 [W152x12.6] 72" [1829] long	ASTM A36 Steel	–
a2	25	6x12x14 1/4" [152x305x362] Blockout	SYP Grade No.1 or better	PDB10a–b
a3	12	12'–6" [3810] W–Beam MGS Section	12 gauge [2.7] AASHTO M180	RWM04a
a4	2	12'–6" [3810] W–Beam MGS End Section	12 gauge [2.7] AASHTO M180	RWM14a
a5	1	6'–3" [1905] W–Beam MGS Section	12 gauge [2.7] AASHTO M180	RWM01a
a6	4	5/8" [15.9] Dia. x 10" [254] long Guardrail Bolt and Nut	ASTM A307	FBB03
a7	25	5/8" [15.9] Dia. x 14" [356] long Guardrail Bolt and Nut	ASTM A307	FBB06
a8	4	5/8" [15.9] Dia. x 10" [254] long Hex Head Bolt and Nut	ASTM A307	FBX16a
a9	16	5/8" [15.9] Dia. x 1 1/2" [38] long Hex Head Bolt and Nut	ASTM A307	FBX16a
a10	112	5/8" [15.9] Dia. x 1 1/2" [38] long Guardrail Bolt and Nut	ASTM A307	FBB01
a11	44	5/8" [15.9] Dia. Flat Washer	ASTM F436 Grade 1	FWC16a
a12	25	16D Double Head Nail	–	–
b1	4	72" [1829] Foundation Tube	ASTM A500 Gr. B	PTE06
b2	4	BCT Timber Post	SYP Grade No. 1 or better (No knots, 18" [457] above or below ground tension face)	PDF01
b3	4	7/8" [22.2] Dia. x 7 1/2" [191] long Hex Head Bolt and Nut	ASTM A307	FBX22a
b4	8	7/8" [22.2] Dia. Flat Washer	ASTM F436 Grade 1	FWC22a
b5	2	2 3/8" [60] O.D.x 6" [152] long BCT Post Sleeve	ASTM A53 Grade B Schedule 40	FMM02
b6	2	Strut and Yoke Assembly	ASTM A36 Steel Galvanized	–
b7	2	Anchor Bracket Assembly	ASTM A36 Steel Galvanized	FPA01
b8	2	BCT Cable Anchor Assembly	ϕ3/4" [19] 6x19 IWRC IPS Galvanized Wire Rope	FCA01–02
b9	2	8"x8"x5/8" [203x203x16] Anchor Bearing Plate	ASTM A36 Steel Galvanized	FPB01
c1	1	Curb	Concrete (s/g mix) – Min. 4000 psi [27.6 MPa] Comp. Strength	–
c2	49	#4 Rebar 12" [305] Long	ASTM A615 Grade 40	–
c3	1	#4 Rebar 73' [22.3 m] Long	ASTM A615 Grade 40	–

Midwest Roadside Safety Facility	MGS with 6–in. Type B Curb Bill of Materials		SHEET: 10 of 10 DATE: 6/1/2010 DRAWN BY: RJT/CDB/EAJ/MJW
	DWG. NAME. MGSC–6_R5	SCALE: None UNITS: in.[mm]	REV. BY: KAL/RKF

Figure 11. Bill of Materials, Test No. MGSC-6

Figure 12. Test Installation Photographs, Test No. MGSC-6

Figure 13. Test Installation Photographs, Test No. MGSC-6

Figure 14. Test Installation Photographs, Test No. MGSC-6

4 TEST REQUIREMENTS AND EVALUATION CRITERIA

4.1 Test Requirements

Longitudinal barriers, such as W-beam guardrails with curbs, must satisfy impact safety standards in order to be accepted by the Federal Highway Administration (FHWA) for use on National Highway System (NHS) new construction projects or as a replacement for existing designs not meeting current safety standards. In recent years, these safety standards have consisted of the guidelines and procedures published in NCHRP Report 350. However, NCHRP Project 22-14(2) generated revised testing procedures and guidelines for use in the evaluation of roadside safety appurtenances and are provided in MASH. According to TL-2 of MASH, longitudinal barrier systems must be subjected to two full-scale vehicle crash tests. The two full-scale crash tests are as follows:

1. Test Designation 2-10 consisting of a 2,425-lb (1,100-kg) passenger car impacting the system at a nominal speed and angle of 44 mph (70 km/h) and 25 degrees, respectively.

2. Test Designation 2-11 consisting of a 5,000-lb (2,268-kg) pickup truck impacting the system at a nominal speed and angle of 44 mph (70 km/h) and 25 degrees, respectively.

The test conditions of TL-2 longitudinal barriers are summarized in Table 1.

Table 1. MASH TL-2 Crash Test Conditions

Test Article	Test Designation	Test Vehicle	Impact Conditions			Evaluation Criteria [1]
			Speed		Angle (deg)	
			mph	km/h		
Longitudinal Barrier	2-10	1100C	44	70	25	A,D,F,H,I
	2-11	2270P	44	70	25	A,D,F,H,I

[1] Evaluation criteria explained in Table 2.

4.2 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 guardrail to contain and redirect impacting vehicles. Occupant risk evaluates the degree of hazard to occupants in the impacting vehicle. Vehicle trajectory after collision is a measure of the potential for the post-impact trajectory of the vehicle to result in secondary collisions with other vehicles or fixed objects, thereby increasing the risk of injury to the occupant of the impacting vehicle and to other vehicles. These evaluation criteria are summarized in Table 2 and defined in greater detail in MASH. The full-scale vehicle crash test was conducted and reported in accordance with the procedures provided in MASH.

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 on the test summary sheet. Additional discussion on PHD, THIV and ASI is provided in Reference 9.

4.3 Soil Strength Requirements

In order to limit the variation of soil strength among testing agencies, foundation soil must satisfy the recommended performance characteristics set forth in Chapter 3 and Appendix B of MASH. Testing facilities must first subject their soil to a dynamic post test to demonstrate a minimum dynamic load of 7.5 kips (33.4 kN) at deflections between 5 and 20 in. (127 and 508 mm). If satisfactory results are observed, a static test is conducted using an identical test installation. The results of this static test become the baseline requirement for soil strength in future full-scale testing. On the full-scale test day, an additional post installed near the impact point is statically tested in the same manner as the baseline test. The full-scale test can be conducted only if the static test results show a resistance greater than or equal to 90 percent of the baseline test at deflections of 5, 10, and 15 in. (127, 254, and 381 mm). Otherwise, testing must be postponed until the soil demonstrates adequate strength.

Table 2. MASH Evaluation Criteria for Longitudinal Barrier

<table>
<tr><td>Structural Adequacy</td><td>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></tr>
<tr><td rowspan="4">Occupant Risk</td><td>D. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.</td></tr>
<tr><td>F. 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>H. Occupant Impact Velocities (OIV) (see Appendix A, Section A5.3 of MASH for calculation procedure) should satisfy the following limits:
<table>
<tr><th colspan="3">Occupant Impact Velocity Limits</th></tr>
<tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s
(9.1 m/s)</td><td>40 ft/s
(12.2 m/s)</td></tr>
</table></td></tr>
<tr><td>I. The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.3 of MASH for calculation procedure) should satisfy the following limits:
<table>
<tr><th colspan="3">Occupant Ridedown Acceleration Limits</th></tr>
<tr><th>Component</th><th>Preferred</th><th>Maximum</th></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g's</td><td>20.49 g's</td></tr>
</table></td></tr>
</table>

5 TEST CONDITIONS

5.1 Test Facility

The testing facility 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.

5.2 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 [14] was used to steer the test vehicle. A guide-flag, attached to the left-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 (30.48 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.

5.3 Test Vehicle

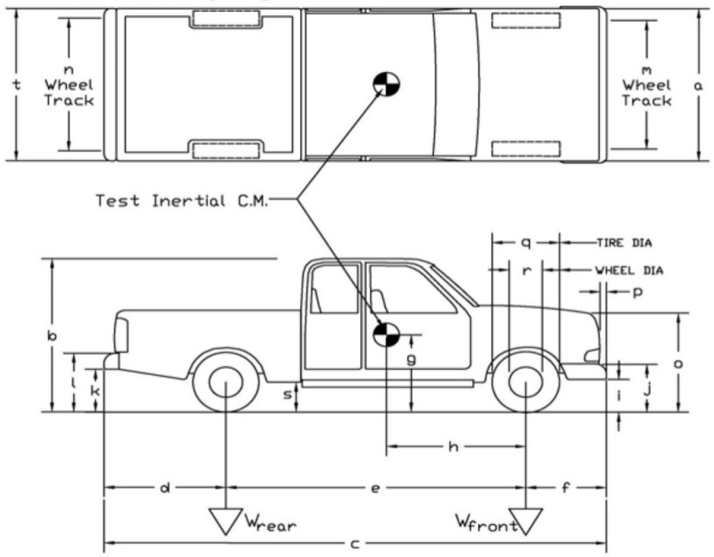
For test no. MGSC-6, a 2003 Dodge Ram 1500 Quad Cab pickup truck was used as the test vehicle. The curb, test inertial, and gross static vehicle weights were 5,100 lb (2,313 kg), 4,974 lb (2,256 kg), and 5,144 lb (2,333 kg), respectively. The test vehicle is shown in Figure 15, and vehicle dimensions are shown in Figure 16.

Figure 15. Test Vehicle, Test No. MGSC-6

Date:	11/10/2009	Test Number:	MGSC-6	Model:	2270P (RAM 1500)
Make:	Dodge	Vehicle I.D.#:	1D7HA18N73S229425		
Tire Size:	265/70 R17	Year:	2003	Odometer:	111866

Tire Inflation Pressure: 35psi

*(All Measurements Refer to Impacting Side)



Vehicle Geometry -- in. (mm)

a	78	(1981)	b	74	(1880)
c	227	(5766)	d	47.5	(1207)
e	140.25	(3562)	f	39.25	(997)
g	28.76	(730)	h	62.91	(1598)
i	15	(381)	j	27	(686)
k	20.5	(521)	l	28.75	(730)
m	68	(1727)	n	67.5	(1715)
o	44	(1118)	p	3	(76)
q	32	(813)	r	18.5	(470)
s	15.25	(387)	t	74.5	(1892)

Wheel Center Height Front	15	(381)
Wheel Center Height Rear	14.75	(375)
Wheel Well Clearance (F)	35.5	(902)
Wheel Well Clearance (R)	37.75	(959)
Frame Height (F)	18	(457)
Frame Height (R)	25	(635)
Engine Type	Gas V-8	
Engine Size	4.7L	

Transmition Type:

Automatic Manual

FWD RWD 4WD

Mass Distribution

Gross Static	LF	1405	RF	1432
	LR	1113	RR	1194

Weights lbs (kg)	Curb	Test Inertial	Gross Static
W-front	2838 (1287)	2735 (1241)	2837 (1287)
W-rear	2262 (1026)	2239 (1016)	2307 (1046)
W-total	5100 (2313)	4974 (2256)	5144 (2333)

GVWR Ratings

Front	3650
Rear	3900
Total	6650

Dummy Data

Type:	Hybrid II
Mass:	170 lbs
Seat Position:	Passenger

Note any damage prior to test: None

Figure 16. Vehicle Dimensions, Test No. MGSC-6

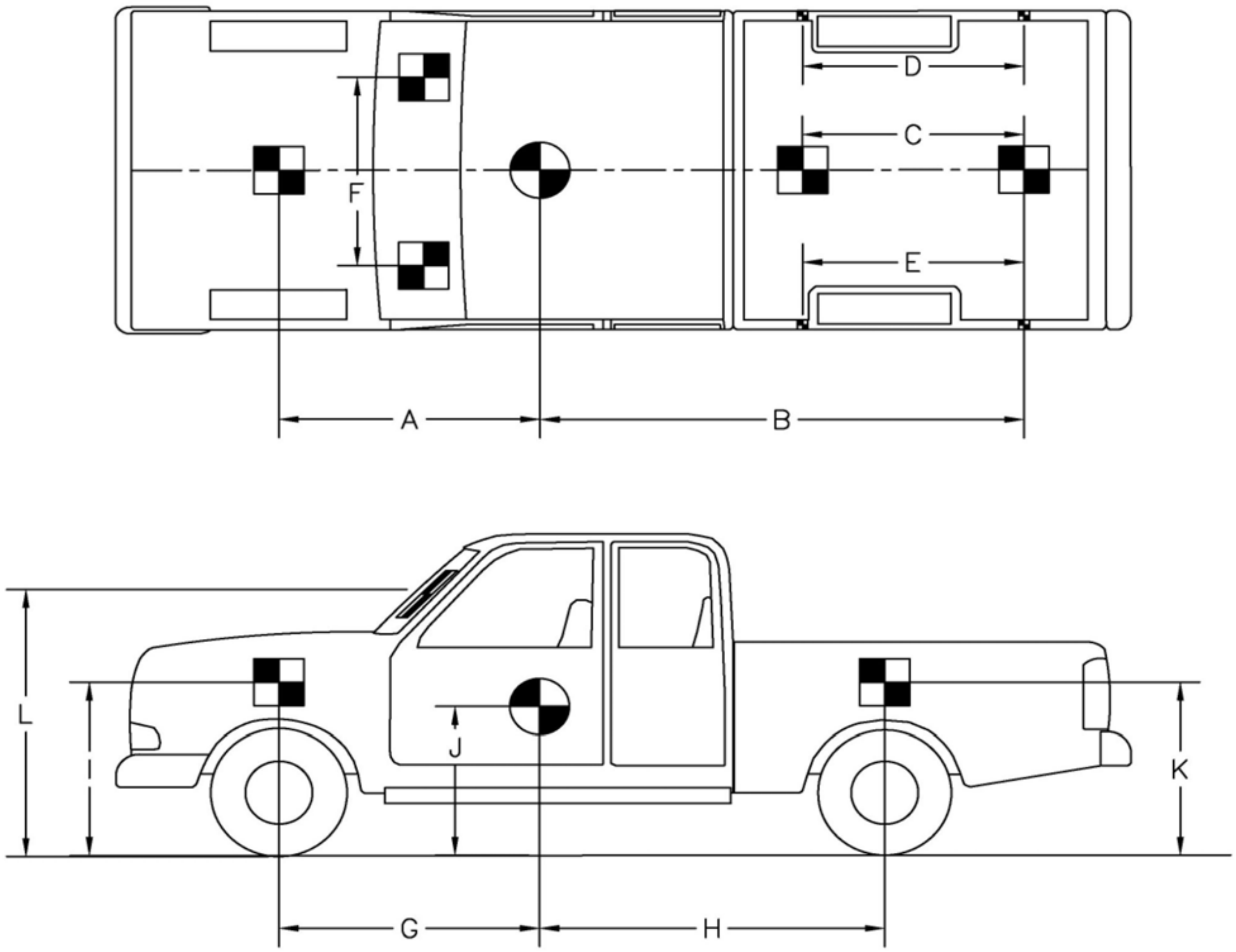
The longitudinal component of the center of gravity (c.g.) was determined using the measured axle weights, while the Suspension Method [15] was used to determine the vertical component of the c.g. for the pickup truck. The latter method is based on the principle that the c.g. of any freely suspended 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 16 and 17. Data used to calculate the location of the c.g. and ballast information are shown in Appendix B.

Square, black- and white-checkered targets were placed on the vehicle to aid in the analysis of the high-speed videos, as shown in Figure 17. Round, checkered targets were placed on the center of gravity on the left-side door, the right-side door, and the roof of the vehicle. The remaining targets were located for references so that they could be viewed from the high-speed cameras for video analysis.

The front wheels of the test vehicle were aligned for camber, caster, and toe-in values of zero so that the vehicles would track properly along the guide cable. A 5B flash bulb was mounted on the right side of the vehicle's dash 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 videos. A remote controlled brake system was installed in the test vehicle so the vehicle could be brought safely to a stop after the test.

5.4 Simulated Occupant

For test no. MGSC-6, A Hybrid II 50th Percentile Adult Male Dummy, equipped with clothing and footware, was placed in the right-front seat of the test vehicle with the seat belt



TEST #: MGSC-6

TARGET GEOMETRY-- in. (mm)

A	75	(1905)	**E**	69.25	(1759)	**I**	39.75	(1010)
B	105.5	(2680)	**F**	37	(940)	**J**	28.76	(731)
C	48	(1219)	**G**	62.91	(1598)	**K**	42.25	(1073)
D	69.5	(1765)	**H**	77.34	(1964)	**L**	61	(1549)

Figure 17. Target Geometry, Test No. MGSC-6

fastened. The dummy, which had a final weight of 170 lb (77 kg), was represented by model no. 572, serial no. 451, and was manufactured by Android Systems of Carson, California. As recommended by MASH, the dummy was not included in calculating the c.g location.

5.5 Data Acquisition Systems

5.5.1 Accelerometers

Two environmental shock and vibration sensor/recorder systems were used to measure the accelerations in the longitudinal, lateral, and vertical directions. Both of the accelerometers were mounted near the center of gravity of the test vehicle.

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

The second system, Model EDR-3, was a triaxial piezoresistive accelerometer system developed and manufactured by Instrumented Sensor Technology (IST) of Okemos, Michigan. The EDR-3 was configured with 256 kB of RAM memory, a range of ±200 g's, a sample rate of

3,200 Hz, and a 1,120 Hz low-pass filter. The computer software program “DynaMax 1 (DM-1)” and a customized Microsoft Excel worksheet were used to analyze and plot the accelerometer data.

5.5.2 Rate Transducers

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

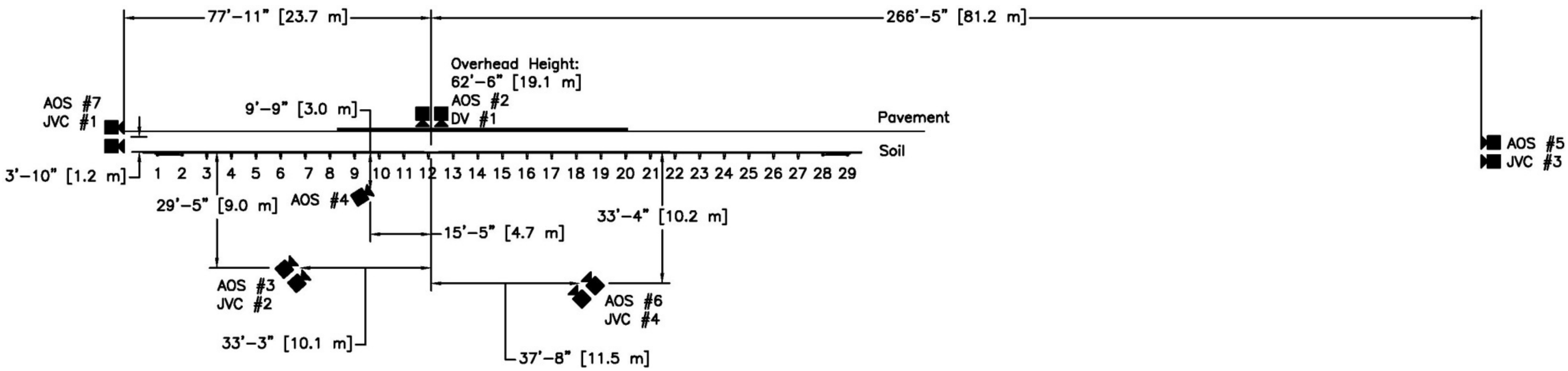
5.5.3 Pressure Tape Switches

For test no. MGSC-6, five pressure-activated tape switches, spaced at approximately 6.56 ft (2 m) intervals, were used to determine the speed of the vehicle before impact. Each tape switch fired a strobe light which sent an electronic timing signal to the data acquisition system as the right-front tire of the test vehicle passed over it. Test vehicle speed was determined from electronic timing mark data recorded using TestPoint and LabVIEW computer software programs. Strobe lights and high-speed video analysis are used only as a backup in the event that vehicle speed cannot be determined from the electronic data.

5.5.4 High-Speed Photography

Three AOS VITcam high-speed digital video cameras, three AOS X-PRI high-speed digital video cameras, four JVC digital video cameras, and one Canon digital video camera were used to film the crash test. Camera details, camera operating speeds, lens information, and a schematic of the camera locations relative to the system are shown in Figure 18.

The high-speed videos were analyzed using ImageExpress MotionPlus and RedLake MotionScope software programs. Actual camera speed and camera divergence factors were considered in the analysis of the high-speed videos. A Nikon D50 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
High-Speed Video	2	AOS Vitcam CTM	500	Cosmicar 12.5-mm Fixed	-
	3	AOS Vitcam CTM	500	TV Zoom V6x17 17-102 mm	50 mm
	4	AOS Vitcam CTM	500	Kowa 8-mm Fixed	-
	5	AOS X-PRI Gigabit	500	Telesar 135-mm Fixed	-
	6	AOS X-PRI Gigabit	500	Sigma 50-mm Fixed	-
	7	AOS X-PRI Gigabit	500	Fujinon 50-mm Fixed	-
Digital Video	1	JVC – GZ-MC500 (Everio)	29.97		
	2	JVC – GZ-MG27u (Everio)	29.97		
	3	JVC – GZ-MG27u (Everio)	29.97		
	4	JVC – GZ-MG27u (Everio)	29.97		
	1	Canon ZR90	29.97		

Figure 18. Camera Locations, Speeds, and Lens Settings, Test No. MGSC-6

6 FULL-SCALE CRASH TEST NO. MGSC-6

6.1 Static Soil Test

Before full-scale test no. MGSC-6 was conducted, the strength of the foundation soil was evaluated with a static test, as described in MASH. The static test results, as shown in Appendix C, demonstrated a soil resistance above the baseline test limits. Thus, the soil provided adequate strength, and the barrier system was approved for full-scale testing.

6.2 Test No. MGSC-6

The 5,144-lb (2,333-kg) pickup truck, with a simulated occupant seated in the right-front seat, impacted the curb at a speed of 45.6 mph (73.4 km/h) and at an angle of 25.3 degrees. After mounting the curb, the vehicle impacted the guardrail at an angle of 22.5 degrees. A summary of the test results and sequential photographs are shown in Figure 19. Additional sequential photographs are shown in Figures 20 through 22. Documentary photographs of the crash test are shown in Figures 23 through 25.

6.3 Weather Conditions

Test no. MGSC-6 was conducted on November 10, 2009 at approximately 2:30 pm. The weather conditions as per the National Oceanic and Atmospheric Administration (station 14939/LNK) were reported as shown in Table 3.

Table 3. Weather Conditions, Test No. MGSC-6

Temperature	62° F
Humidity	46%
Wind Speed	11 mph
Wind Direction	120° from True North
Sky Conditions	Sunny
Visibility	10 Statute Miles
Pavement Surface	Dry
Previous 3-Day Precipitation	0 in.
Previous 7-Day Precipitation	0 in.

6.4 Test Description

Initial vehicle impact with the guardrail was to occur 14 ft - 11 in. (4.6 m) upstream of the centerline of the splice between post nos. 14 and 15, as shown in Figure 26. The actual point of impact was 15 ft - 2½ in. (4.6 m) upstream of the centerline of the splice between post nos. 14 and 15. A sequential description of the impact events is contained in Table 4. The vehicle came to rest 211 ft - 8 in. (64.5 m) downstream from impact and 87 ft (26.5 m) laterally behind the front face of the guardrail. The vehicle trajectory and final position are shown in Figures 19 and 27, respectively.

Table 4. Sequential Description of Impact Events, Test No. MGSC-6

TIME (sec)	EVENT
-0.180	The right-front tire contacted the front face of the mountable curb.
-0.004	The left-front tire contacted the front face of the mountable curb.
0.000	The right-front bumper corner impacted the front face of the rail.
0.036	The rail upstream of impact deflected downstream, and the upstream posts rotated downstream.
0.064	The vehicle began to redirect.
0.082	The rail disengaged from post no. 13 due to bolt pullout.
0.086	The right headlight disengaged from the vehicle.
0.126	The right-front tire of the vehicle contacted the upstream side of post no. 13.
0.232	The rail disengaged from post no. 14 due to bolt pullout.
0.246	The right-front tire contacted the upstream side of post no. 14.
0.248	The right-front tire disengaged from the vehicle.
0.258	The right-rear tire contacted the upstream side of post no. 14.
0.288	The right-rear quarter panel of the vehicle contacted the rail near the impact location.
0.318	The vehicle was parallel to the system at a speed of 31.6 mph (50.9 km/h).
0.436	The rail upstream of impact relaxed, and the upstream posts rotated upstream.
0.582	The right taillight disengaged from the vehicle.
0.592	The vehicle exited the system at a speed of 30.1 mph (48.4 km/h) and at an angle of 18.7 degrees as the right-rear quarter panel lost contact with the system at the midpoint between post nos. 14 and 15.

6.5 Barrier Damage

Damage to the barrier was moderate, as shown in Figures 28 through 33. Barrier damage consisted of contact marks and deformation of the W-beam rail, deformed guardrail posts, and disengaged post-to-rail connections. The length of vehicle contact along the barrier was approximately 19 ft - 5 in. (5.92 m) which spanned from 2 in. (51 mm) downstream of post no. 12 to 10 in. (254 mm) downstream of post no. 15.

Post nos. 3 through 15 posts showed varying degrees of damage. Post nos. 3 through 11 twisted slightly downstream. Post nos. 12 and 15 rotated slightly backward and sustained minor twisting. Post nos. 13 and 14 sustained large downstream and backward rotations while twisting upstream. Tire marks were found on post no. 13.

Post nos. 13 and 14 were disengaged from the rail due to pullout of the guardrail bolt and deformation of the guardrail slot. A small tear was found in the slot at post no. 13. Gaps of ⅛ in. (3 mm) were present at the splices located between post nos. 2 and 3, 10 and 11, and 12 and 13.

General deformation and flattening of the W-beam rail occurred from post no. 12 to slightly downstream of post no. 15. Contact and tire marks were visible on the guardrail beginning 2 in. (51 mm) downstream of post no. 12 to 10 in. (254 mm) downstream of post no. 15. Slight buckling occurred at post no. 11 and between post nos. 11 and 12. More severe buckling occurred at post nos. 12 and 15.

A 1¼-in. (32-mm) soil gap was present at the upstream edge of post no. 1, and a ½-in. (13-mm) soil gap was present on the downstream edge of post no. 2. A soil gap of ½ in. (13 mm) was present at the downstream edge of post no. 29.

The maximum permanent set rail and post deflections were 14 in. (356 mm) at the midspan between post nos. 13 and 14 and 18 in. (457 mm) at post no. 13, respectively, as measured at the test site. The maximum lateral dynamic rail and post deflections were 24.4 in.

(621 mm) at post no. 13 and 23.6 in. (600 mm) at post no. 13, respectively, as determined from high-speed digital video analysis. The working width of the system was 45.1 in. (1,146 mm), also determined from high-speed video analysis.

6.6 Vehicle Damage

The damage to the vehicle was moderate, as shown in Figures 34 and 35. The maximum occupant compartment deformations are listed in Table 5 along with the deformation limits established in MASH for various areas of the occupant compartment. It should be noted that none of the MASH established deformation limits were violated. Complete occupant compartment and vehicle deformations and the corresponding locations are provided in Appendix D.

Table 5. Maximum Occupant Compartment Deformations by Location

LOCATION	MAXIMUM DEFORMATION in. (mm)	MASH ALLOWABLE DEFORMATION in. (mm)
Wheel Well & Toe Pan	¾ (19)	≤ 9 (229)
Floor Pan & Transmission Tunnel	¼ (6)	≤ 12 (305)
Side Front Panel (in Front of A-Pillar)	¼ (6)	≤ 12 (305)
Side Door (Above Seat)	½ (13)	≤ 9 (229)
Side Door (Below Seat)	½ (13)	≤ 12 (305)
Roof	0	≤ 4 (102)
Windshield	0	≤ 3 (76)

The majority of the damage was concentrated on the right-front corner and right side of the vehicle where the impact occurred. The right side of the front bumper was crushed inward and back. The right-front fender was dented and scraped. The right-front wheel was detached from the vehicle, and the right-front rim was scraped and deformed. The right-front brake lines were cut, and the right-upper control arm was bent inward. The right-side headlight and foglight were disengaged from the vehicle. Denting and scraping were observed on the entire right side of the vehicle. The right-rear corner of the vehicle and right side of the rear bumper were slightly crushed inward. The right-side taillight was removed. The hood was ajar and slightly crushed inward. Slight deformation to the front of the vehicle frame was observed. The roof and all window glass remained undamaged.

6.7 Occupant Risk

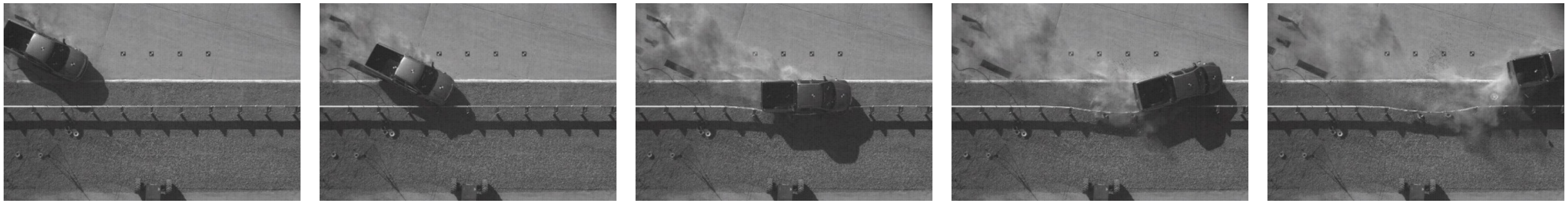
The calculated occupant impact velocities (OIVs) and maximum 0.010-sec occupant ridedown accelerations (ORAs) in both the longitudinal and lateral directions are shown in Table 6. The OIVs and ORAs were within the suggested limits provided in MASH. The calculated THIV, PHD, and ASI values are also shown in Table 6. The results of the occupant risk analysis, as determined from the accelerometer data, are summarized in Figure 19. The recorded data from the accelerometers and the rate transducers are shown graphically in Appendix E.

Table 6. Summary of OIV, ORA, THIV, and PHD Values, Test No. MGSC-6

Evaluation Criteria		**Transducer**			**MASH Limits**
		EDR-3	**DTS Set 1**	**DTS Set 2**	
OIV ft/s (m/s)	Longitudinal	-11.60 (-3.54)	-13.94 (-4.25)	-14.22 (-4.34)	≤ 40 (12.2)
	Lateral	-13.91 (-4.24)	-13.55 (-4.13)	-14.06 (-4.29)	≤ 40 (12.2)
ORA g's	Longitudinal	-10.40	-10.71	-11.02	≤ 20.49
	Lateral	-6.60	-7.02	-6.84	≤ 20.49
THIV ft/s (m/s)		NA	18.35 (5.59)	NA	not required
PHD g's		NA	11.08	NA	not required
ASI		0.45	0.49	NA	not required

6.8 Discussion

The analysis of the test results for test no. MGSC-6 showed that the MGS and curb configuration adequately contained and redirected the 2270P vehicle with controlled lateral displacements of the barrier. There were no detached elements nor fragments which showed potential for penetrating the occupant compartment nor presented undue hazard to other traffic. 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 E, were well below the limit of 75 degrees recommended by MASH. After impact, the vehicle exited the barrier at an angle of 18.7 degrees, and its trajectory did not violate the bounds of the exit box. Therefore, test no. MGSC-6 conducted on the MGS offset 6 ft (1.83 m) behind a 6-in. (152-mm) high AASHTO Type B curb was determined to be acceptable according to the MASH TL-2 safety performance criteria for test designation no. 2-11.



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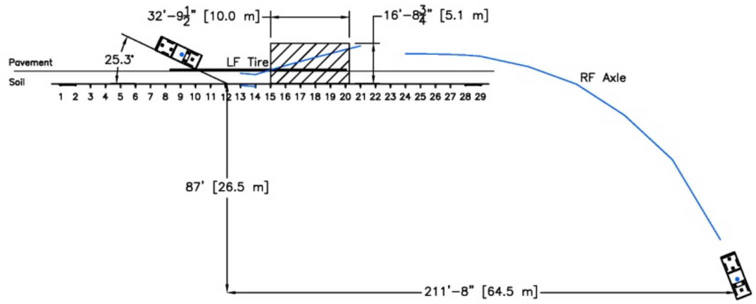
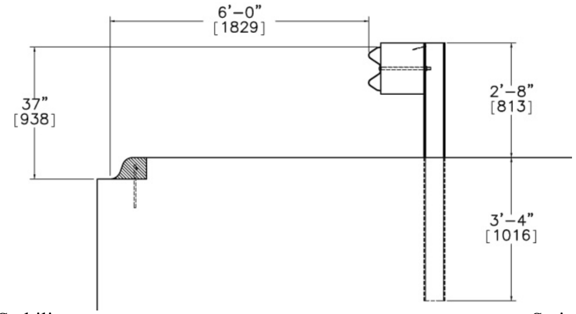
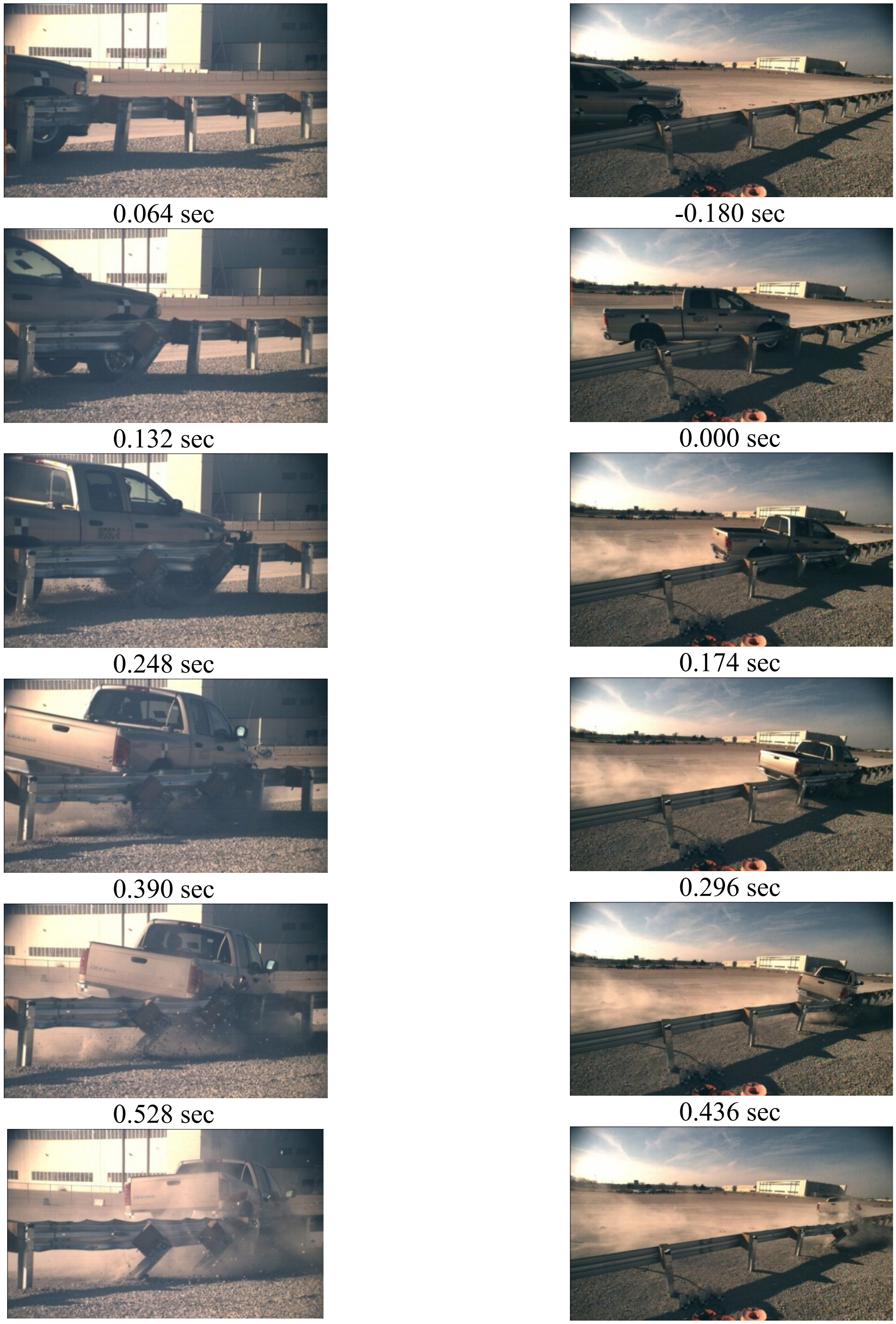




- Test Agency .... MwRSF
- Test Number MGSC-6
- Date 11/10/2009
- MASH Test Designation 2-11
- Test Article .... MGS offset 6 ft (1.83 m) behind 6-in. (152-mm) high curb
- Total Length .... 175 ft (53.3 m)
- Key Component – Midwest Guardrail System
  - Length .... 175 ft (53.3 m)
  - Post Spacing .... 75 in. (1,905 mm)
- Key Component – AASHTO Type B Curb
  - Length .... 73 ft - 6 in. (22.40 m)
  - Height .... 6 in. (152 mm)
- Soil Type .... Grade B of AASHTO M147-65 (1990)
- Vehicle Make /Model .... 2003 Dodge Ram 1500 Quad Cab
  - Curb .... 5,100 lb (2,313 kg)
  - Test Inertial .... 4,974 lb (2,256 kg)
  - Gross Static .... 5,144 lb (2,333 kg)
- Impact Conditions
  - Speed .... 45.6 mph (73.4 km/h)
  - Angle (Curb) .... 25.3 deg
  - Angle (Guardrail) .... 22.5 deg
  - Location ..... 15 ft - 2½ in. (4.6 m) US of splice between posts 14 and 15
- Exit Conditions
  - Speed .... 30.1 mph (48.4 km/h)
  - Angle .... 18.7 deg
- Exit Box Criterion .... Pass
- Vehicle Damage .... Moderate
  - VDS[16] 1-RFQ-3
  - CDC[17] 1-RYEW-3
  - Maximum Interior Deformation...... ¾ in. (19 mm)at wheel well/toe pan
- Vehicle Stability .... Satisfactory
- Vehicle Stopping Distance .... 211 ft - 8 in. (64.5 m) downstream of impact
  87 ft (26.5 m) laterally behind barrier
- Test Article Damage .... Moderate
- Test Article Deflections
  - Permanent Set .... 18 in. (457 mm)
  - Dynamic .... 24.4 in. (621 mm)
  - Working Width .... 45.1 in. (1,146 mm)
- Maximum Angular Displacements
  - Roll .... 13.6° < 75°
  - Pitch .... 6.6° < 75°
  - Yaw .... -41.5°
- Impact Severity .... 65.3 kip-ft (88.5 kJ) > 52 kip-ft (70.5 kJ)
- Transducer Data

Evaluation Criteria		Transducer			MASH Limit
		EDR-3	DTS (1)	DTS (2)	
OIV ft/s (m/s)	Longitudinal	-11.60 (-3.54)	-13.94 (-4.25)	-14.22 (-4.34)	≤ 40 (12.2)
	Lateral	-13.91 (-4.24)	-13.55 (-4.13)	-14.06 (-4.29)	≤ 40 (12.2)
ORA g's	Longitudinal	-10.40	-10.71	-11.02	≤ 20.49
	Lateral	-6.60	-7.02	-6.84	≤ 20.49
THIV – ft/s (m/s)		NA	18.35 (5.59)	NA	not required
PHD – g's		NA	11.08	NA	not required
ASI		0.45	0.49	NA	not required

Figure 19. Summary of Test Results and Sequential Photographs, Test No. MGSC-6



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0.528 sec

0.710 sec

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0.174 sec

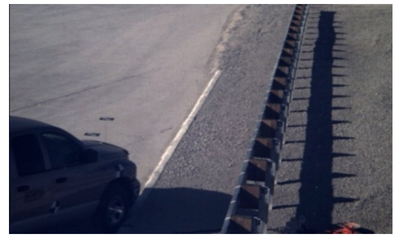
0.296 sec

0.436 sec

0.778 sec

Figure 20. Additional Sequential Photographs, Test No. MGSC-6

0.000 sec



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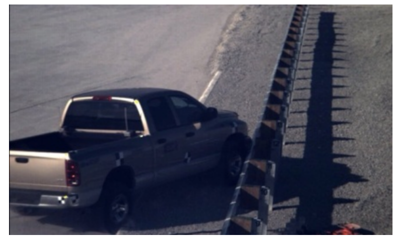

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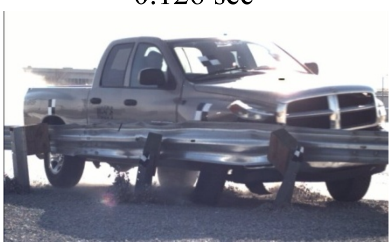

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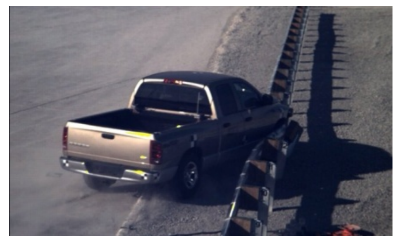

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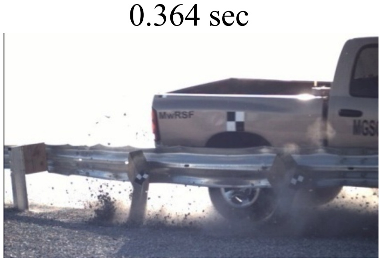

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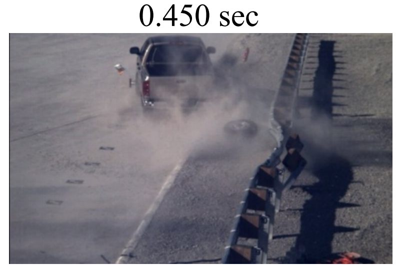
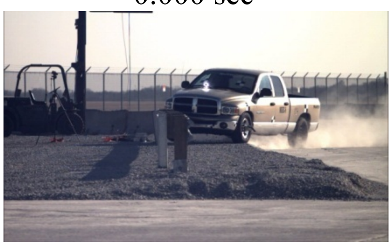


1.044 sec

Figure 21. Additional Sequential Photographs, Test No. MGSC-6


-0.180 sec


0.000 sec


0.058 sec


0.112 sec

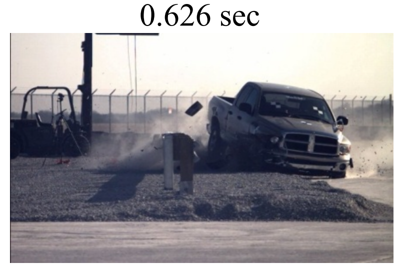

0.214 sec

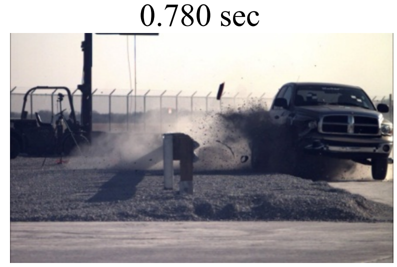

0.324 sec


0.408 sec


0.486 sec


0.626 sec


0.780 sec


1.008 sec

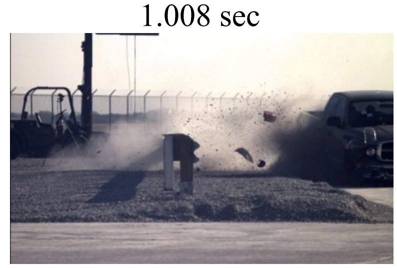

1.356 sec

Figure 22. Additional Sequential Photographs, Test No. MGSC-6

Figure 23. Documentary Photographs, Test No. MGSC-6

Figure 24. Documentary Photographs, Test No. MGSC-6

Figure 25. Documentary Photographs, Test No. MGSC-6

Figure 26. Impact Location, Test No. MGSC-6

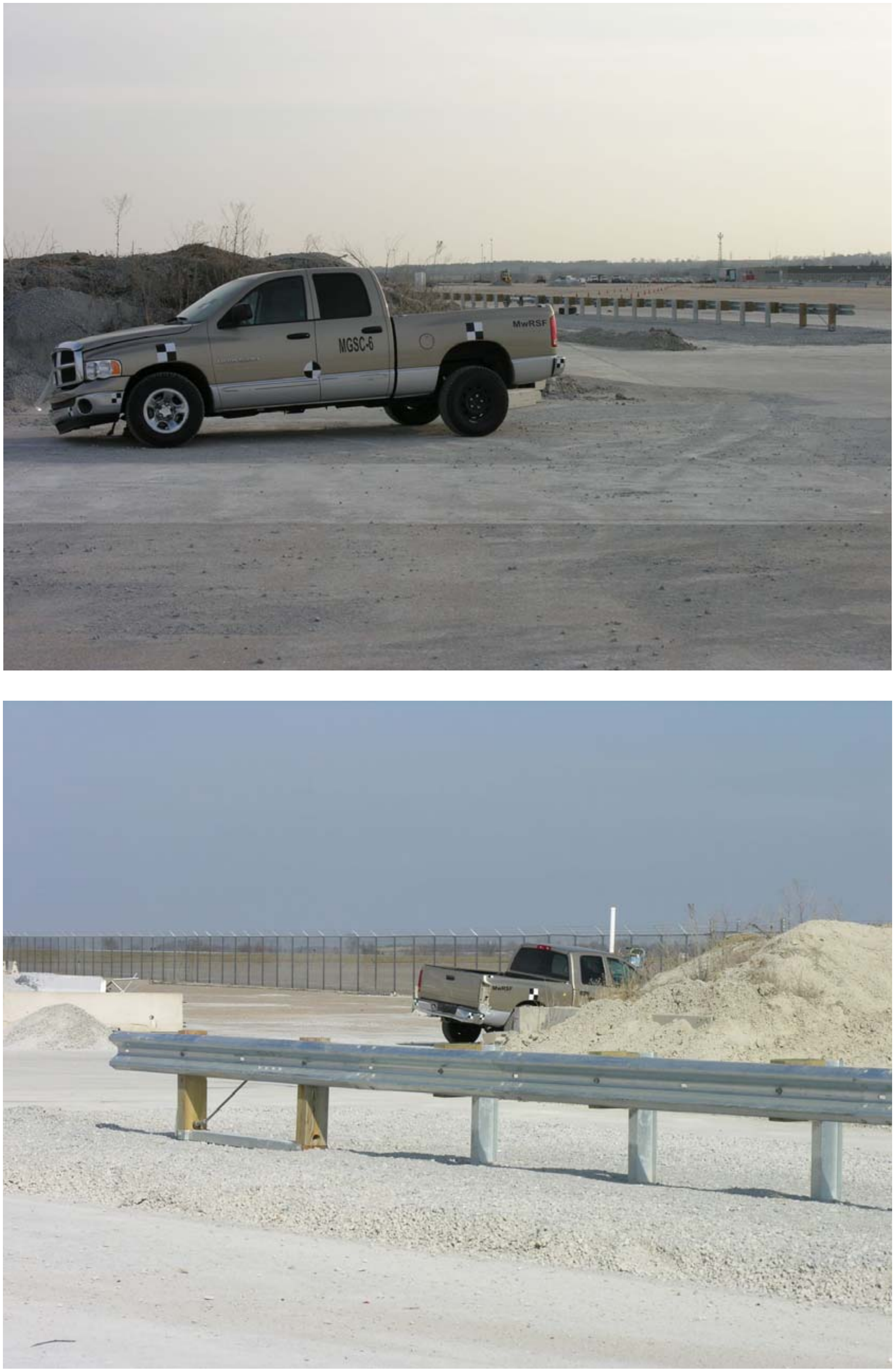


Figure 27. Vehicle Final Position and Trajectory Marks, Test No. MGSC-6

Figure 28. System Damage, Test No. MGSC-6

Figure 29. Post No. 12 Damage, Test No. MGSC-6

Figure 30. Post No. 13 Damage, Test No. MGSC-6

Figure 31. Post No. 14 Damage, Test No. MGSC-6

Figure 32. Post No. 15 Damage, Test No. MGSC-6

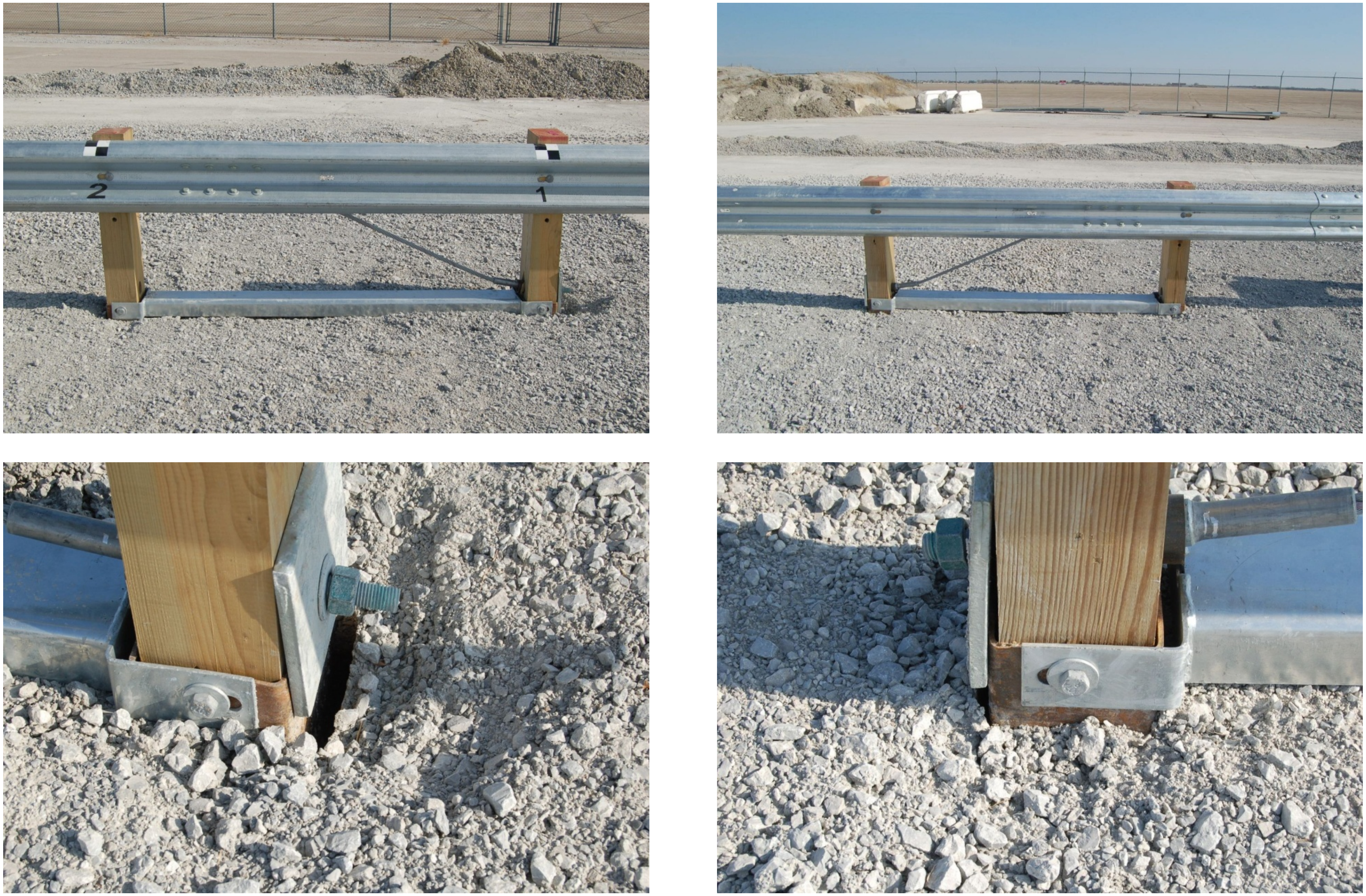


Figure 33. Anchorage Damage, Test No. MGSC-6

Figure 34. Vehicle Damage, Test No. MGSC-6

Figure 35. Undercarriage Damage, Test No. MGSC-6

7 DISCUSSION OF FINDINGS

Two items must be considered in determining the lateral placement of a 6-in. (152-mm) high curb relative to the MGS when installed with a 37-in. (940-mm) top rail height relative to the roadway at the toe of the curb.

First, if there is a zero offset (i.e., the rail face is aligned directly over the face of the curb), then a vehicle (2270P or 1100C) would impact the rail with its tires still on the roadway. The vehicle could wedge beneath the raised rail (i.e., the MGS installed at 37 in. (940 mm) relative to the roadway) with potentially severe consequences. This behavior cannot be accurately predicted and would require full-scale crash testing to fully understand the phenomena. For greater lateral offsets between the MGS and the curb, the relationship between the vehicle and the MGS becomes more like the standard 31-in. (787-mm) tall MGS placed over the curb.

Second, it is believed that vehicles cannot become wedged beneath the rail for offsets of at least 4 ft (1.22 m) from the curb, as the curb and ground geometry lower the effective rail height. Note that the small car (1100C), which becomes airborne following impact with the curb, may wedge itself under the rail due to front end suspension compression upon landing on the ground. Based on previous 25-degree angle vehicle-to-curb impact studies performed by MwRSF [10-11] and NCAC [unpublished work], it is believed that the 1100C vehicle bumper will have returned at least to its normal static equilibrium height when the vehicle has reached the 4-ft (1.22-m) lateral offset. Thus, a minimum lateral offset of 4 ft (1.22 m) is recommended for raising the MGS rail height from 31 in. (787 mm) to 37 in. (940 mm) relative to the roadway at the toe of the curb. The 37 in. (940-mm) rail height was determined by combining the heights of the 6-in. (152-mm) curb with that for the 31 in. (787 mm) MGS.

8 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The Midwest Guardrail System was installed 6 ft (1.83 m) behind a 6-in. (152-mm) high, AASHTO Type B curb and was subjected to full-scale crash testing under TL-2 conditions, as defined in MASH. The lateral offset and impact conditions were selected after the system failed to meet the TL-3 criteria with an 8-ft (2.44-m) lateral offset behind the same curb. LS-DYNA simulations demonstrated that a 6-ft (1.83-m) lateral offset produced the greatest propensity for truck override of the barrier at the TL-2 impact conditions.

Full-scale crash testing demonstrated that the MGS with a 37-in. (940-mm) top rail height relative to the roadway is valid for MASH TL-2 for lateral offsets ranging between 4 and 12 ft (1.22 and 3.66 m) behind a 6-in. (152-mm) high, AASHTO Type B curb. Note that no relevant TL-2 crash tests were available for 1100C and/or 2270P vehicles striking a curb without other barriers located behind the curb. Thus, a maximum 12-ft (3.66-m) lateral offset is recommended; since, prior TL-3 curb testing indicated potential vehicle problems beyond a 12-ft (3.66-m) lateral offset. As discussed in References 10 and 11, the Type B curb is considered the worst-case geometry for sloped curbs. Thus, this recommendation is also valid for other sloped curbs with heights of 6 in. (152 mm) or less. For lower-height curbs, the rail height should be reduced in order to maintain the 31-in. (787-mm) top rail height relative to the ground behind the curb.

The full-scale crash testing was conducted with level terrain in front of and behind the curb. However, the research sponsors have indicated that the actual terrain is rarely level in front of and behind the curb. A common roadway slope found in front of curbs consists of a 6 percent slope toward the curb. Typical slopes found behind curbs include a 2 percent slope toward the curb for adjacent sidewalks and a 4 percent slope toward or away from the curb for grass terrain.

The researchers are not concerned with a traveled way sloped downward toward the gutter region found in front of curbs. However, it is the researchers' opinion that sloped terrain behind the curb can significantly affect a guardrail system's redirective capability. In order to address that concern, it is recommended that the top rail height relative to the top of the curb range between 31 and 32 in. (787 and 813 mm), while at the same time the rail height relative to the ground directly below the rail be no higher than 34 inches (864 mm). Thus, the desired lateral offset from the curb as well as the two criteria noted in the previous sentence must be used to determine an acceptable ground slope.

The researchers have no evidence to make any other statements regarding the use of the MGS with 6-in. (152-mm) high curbs under the TL-2 impact conditions. For example, there is no point where the rail height makes the change from 31 in. (787 mm) to 37 in. (940 mm) relative to the roadway because the valid range for the 31-in. (787-mm) rail height relative to the roadway is unknown.

Currently, there are neither plans nor budget to determine any other valid scenarios for MGS placement relative to a curb. It is believed that any such determination would require additional full-scale vehicle crash testing.

Table 7. Summary of Safety Performance Evaluation Results

<table>
<tr><th>Evaluation Factors</th><th colspan="4">Evaluation Criteria</th><th>Test No. MGSC-6</th></tr>
<tr><td>Structural Adequacy</td><td>A.</td><td colspan="3">Test article should contain and redirect the vehicle or bring the vehicle to a controlled stop; the vehicle should not penetrate, underride, or override the installation although controlled lateral deflection of the test article is acceptable.</td><td>S</td></tr>
<tr><td rowspan="10">Occupant Risk</td><td>D.</td><td colspan="3">Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment should not exceed limits set forth in Section 5.3 and Appendix E of MASH.</td><td>S</td></tr>
<tr><td>F.</td><td colspan="3">The vehicle should remain upright during and after collision. The maximum roll and pitch angles are not to exceed 75 degrees.</td><td>S</td></tr>
<tr><td rowspan="4">H.</td><td colspan="3">Occupant Impact Velocities (OIV) (see Appendix A, Section A5.3 of MASH for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</td></tr>
<tr><td colspan="3">Occupant Impact Velocity Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>30 ft/s (9.1 m/s)</td><td>40 ft/s (12.2 m/s)</td></tr>
<tr><td rowspan="4">I.</td><td colspan="3">The Occupant Ridedown Acceleration (ORA) (see Appendix A, Section A5.3 of MASH for calculation procedure) should satisfy the following limits:</td><td rowspan="4">S</td></tr>
<tr><td colspan="3">Occupant Ridedown Acceleration Limits</td></tr>
<tr><td>Component</td><td>Preferred</td><td>Maximum</td></tr>
<tr><td>Longitudinal and Lateral</td><td>15.0 g’s</td><td>20.49 g’s</td></tr>
</table>

S – Satisfactory U – Unsatisfactory NA - Not Applicable

9 REFERENCES

1. *A Policy on Geometric Design of Highways and Streets 2004*, Fifth Edition, American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C., 2004.

2. Polivka, K.A., Faller, R.K., Sicking, D.L., Rohde, J.R., Reid, J.D., and Holloway, J.C., *Guardrail and Guardrail Terminals Installed Over Curbs*, Final Report to the Midwest States Regional Pooled Fund, MwRSF Research Report No. TRP-03-83-99, Project No. SPR-3(017)-Year 8, Project Code RPFP-98-03, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, March 21, 2000.

3. Polivka, K.A., Faller, R.K., Sicking, D.L., Rohde, J.R., Reid, J.D., and Holloway, J.C., *Guardrail and Guardrail Terminals Installed Over Curbs – Phase II*, Final Report to the Midwest States Regional Pooled Fund, MwRSF Research Report No. TRP-03-105-00, Project No. SPR-3(017)-Year 10, Project Code RPFP-98-03, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, November 5, 2001.

4. Ross, H.E., Sicking, D.L., Zimmer, R.A., and Michie, J.D., *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, National Cooperative Highway Research Program (NCHRP) Report 350, Transportation Research Board, Washington, D.C., 1993.

5. Bullard, D.L. and Menges, W.L., *NCHRP Report 350 Test 3-11 on the G4(2W) Strong Post W-Beam Guardrail with 100 mm High Asphaltic Curb*, Report No. FHWA-RD-00, Federal Highway Administration, Washington, D.C., June, 2000.

6. Eccles, K., Council, F., McGee, H. ,Tiso, P., Orengo, F., Weir, J.A., Ray, M.H., and Plaxico, C.A., *Recommended Guidelines for Curbs and Curb-Barrier Installations*, National Cooperative Highway Research Program (NCHRP) Report 537, Transportation Research Board, Washington, D.C., 2005.

7. Polivka, K.A, Faller, R.K., Sicking, D.L., Reid, J.D., Rohde, J.R., Holloway, J.C., Bielenberg, R.W., and Kuipers, B.D., *Development of the Midwest Guardrail System (MGS) for Standard and Reduced Post Spacing and in Combination with Curbs*, Final Report to the Midwest States Regional Pooled Fund Program, Transportation Research Report No. TRP-03-139-04, Project No. SPR-3(017)-Years 10, 12, and 13, Project Codes RPFP-00-02, 02-01, and 03-05, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, September 1, 2004.

8. Faller, R.K., Polivka, K.A., Kuipers, B.D., Bielenberg, R.W., Reid, J.D., Rohde, J.R., and Sicking, D.L., *Midwest Guardrail System for Standard and Special Applications*, Paper No. 04-4778, Transportation Research Record No. 1890, Transportation Research Board, Washington D.C., January 2004.

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

10. Zhu, L., Critical Offset of the Midwest Guardrail System Behind a Curb, Thesis, University of Nebraska-Lincoln, Lincoln, Nebraska, June 2008.

11. Zhu, L., Reid, J.D., Faller, R.K., Bielenberg, R.W., Sicking, D.L., Polivka, K.A., Rohde, J.R., *Installation Guidelines for MGS and 6-in. High, AASHTO Type B Curb Combination – Part I: Vehicle-Curb Testing and LS-DYNA Analysis*, Final Report to the Midwest States Regional Pooled Fund Program, Transportation Research Report No. TRP-03-205-09, Project No. SPR-3(017)-Year 17, Project Code RPFP-07-03, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, May 6, 2009.

12. Thiele, J.C., Lechtenberg, K.A., Reid, J.D., Faller, R.K., Sicking, D.L., and Bielenberg, R.W., *Performance Limits for 6-in. (152-mm) High Curbs Placed in Advance of the MGS Using MASH Vehicles Part II: Full-Scale Crash Testing*, Final Report to the Midwest States Regional Pooled Fund Program, Transportation Research Report No. TRP-03-221-09, Project No. SPR-3(017)-Year 17, Project Code RPFP-07-03, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, October 30, 2009.

13. Halquist, J.O., LS-DYNA Keyword User's Manual, Version 971, Livermore Software Technology Corporation, Livermore, California, May 2007.

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

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

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

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

10 APPENDICES

Appendix A. Material Specifications

Certified Analysis

Trinity Highway Products , LLC
425 E. O'Connor
Lima, OH
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097
Project: RESALE

Order Number: 1114174
Customer PO: 2213
BOL Number: 51169
Document #: 1
Shipped To: NE
Use State: NE

As of: 9/16/09

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
750	545G	6'0 POST/DB:DDR	A-36			J86489	50,565	68,830	26.1	0.090	0.950	0.010	0.040	0.200	0.290	0.00	0.160	0.003	4
50	14662G	6'6 POST/8.5#/DB:DDR NB	A-36			J86489	50,565	68,830	26.1	0.090	0.950	0.010	0.040	0.200	0.290	0.00	0.160	0.003	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM-123, UNLESS OTHERWISE STATED.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 49100 LB

State of Ohio, County of Allen. Sworn and subscribed before me this 16th day of September, 2009
Notary Public:
Commission Expires 1/28/2012

Trinity Highway Products , LLC
Certified By:
Quality Assurance

1 of 1

Figure A-1. W6x8.5 (W152x12.6) Posts Material Specification

Jun-16-2009 08:12am From-Porteous Denver 1 303 576 0533 T-510 P.002/003 F-448

1"

Certification provided by:PFC, To:NEBRASKA BOLT Order:124841

FASTENER DIVISION

Telephone 260/337-1600

CUSTOMER NO/NAME
267 PORTEOUS FASTENER CO.
NUCOR ORDER # 600934
TEST REPORT SERIAL# FB285160
CUST PART # 00219-4000-004
TEST REPORT ISSUE DATE 4/20/07
DATE SHIPPED 10/04/07
CUSTOMER P.O. # 17070232
NAME OF LAB SAMPLER: SHIRRI STANTZ, LAB TECHNICIAN
****************CERTIFIED MATERIAL TEST REPORT******************
NUCOR PART NO QUANTITY LOT NO. DESCRIPTION
175407 7200 822445A 1-8 CR DH HV H.D.G.
MANUFACTURE DATE 1/29/07 HEX NUT H.D.G.

DH

--CHEMISTRY MATERIAL GRADE -1045L
MATERIAL HEAT **CHEMISTRY COMPOSITION (WT% HEAT ANALYSIS) BY MATERIAL SUPPLIER

MATERIAL NUMBER	HEAT NUMBER		C	MN	P	S	SI
RH023446	NU 838828		.45	.69	.015	.021	.18
		MIN	.20	.60			
NU 838828		MAX	.55		.040	.050	

NUCOR STEEL - NEBRASKA
A2LA NO: 780.01 EXP: 2008-11-30
FOR CHEMICAL TESTING

--MECHANICAL PROPERTIES IN ACCORDANCE WITH ASTM A563-04A

SURFACE HARDNESS (R30N)	CORE HARDNESS (RC)	PROOF LOAD 90900 LBS	TENSILE STRENGTH DEG-WEDGE (LBS)	STRESS (PSI)
N/A	28.1	PASS	N/A	N/A
N/A	30.0	PASS	N/A	N/A
N/A	31.0	PASS	N/A	N/A
N/A	28.5	PASS	N/A	N/A
N/A	28.0	PASS	N/A	N/A

AVERAGE VALUES FROM TESTS PRODUCTION LOT SIZE 67000 PCS
29.3
ROTATIONAL CAPACITY TESTED IN ACCORDANCE WITH A325, A563 AND F606 TO 360 DEGREES OF ROTATION.
SAMPLE #1 PASSED SAMPLE #2 PASSED

--VISUAL INSPECTION IN ACCORDANCE WITH ASTM A563-04a 80 PCS. SAMPLED LOT PASSED

--COATING - Hot Dip Galvanized.

1. 0.00433	2. 0.00404	3. 0.00356	4. 0.00331	5. 0.00354	6. 0.00468	7. 0.00617
8. 0.00567	9. 0.00341	10. 0.00637	11. 0.00426	12. 0.00495	13. 0.00387	14. 0.00399
15. 0.00395	16. 0.00344	17. 0.00409	18. 0.00342	19. 0.00364	20. 0.00399	

AVERAGE THICKNESS FROM 20 TESTS .00415
HEAT TREATMENT - AUSTENITIZED, OIL QUENCHED & TEMPERED (MIN 800 DEG F)

--DIMENSIONS PER ASME B18.2.6-2003

CHARACTERISTIC	#SAMPLES TESTED	MINIMUM	MAXIMUM
Width Across Corners	8	1.8190	1.8300
Thickness	32	0.9670	0.9830

ALL TESTS ARE IN ACCORDANCE WITH THE LATEST REVISIONS OF THE METHODS PRESCRIBED IN THE APPLICABLE SAE AND ASTM SPECIFICATIONS. THE SAMPLES TESTED CONFORM TO THE SPECIFICATIONS AS DESCRIBED/LISTED ABOVE AND WERE MANUFACTURED FREE OF MERCURY CONTAMINATION.
THE STEEL WAS MELTED AND MANUFACTURED IN THE U.S.A. AND THE PRODUCT WAS MANUFACTURED AND TESTED IN THE U.S.A.
WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY. THIS CERTIFIED MATERIAL TEST REPORT RELATES ONLY TO THE ITEMS LISTED ON THIS DOCUMENT AND MAY NOT BE REPRODUCED EXCEPT IN FULL.

ACCREDITED

MECHANICAL FASTENER
CERTIFICATE NO. A2LA 139-01
EXPIRATION DATE 12/31/07

NUCOR FASTENER
A DIVISION OF NUCOR CORPORATION

Chris Ramer
CHRIS RAMER
QUALITY ASSURANCE SUPERVISOR

Page 1 of 1

Jun 17 2009 9:22 HP LASERJET FAX p.3

Figure A-2. W6x8.5 (W152x12.6) Posts Material Specification (Continued)

S.L. Storey
LUMBER COMPANY, INC.

CERTIFICATE OF COMPLIANCE

MARCH 12, 2009.

MIDWEST MACHINERY & SUPPLY
P O BOX 81097
LINCOLN, NE 68501

THE FOLLOWING MATERIAL DELIVERED ON 3/12/09 ON BILL OF LADING NUMBER 19216 HAS BEEN INSPECTED BEFORE AND AFTER TREATMENT AND IS IN FULL COMPLIANCE WITH APPLICABLE NEBRASKA DEPARTMENT OF ROADS REQUIREMENTS FOR SOUTHERN YELLOW PINE TIMBER GUARDRAIL COMPONENTS, PRESERVATIVE TREATED WITH CHROMATED-COPPER-ARSENATE (CCA-C) TO A MINIMUM RETENTION OF .60 LBS/CU.FT. THE ACCEPTANCE OF EACH PIECE BY COMPANY QUALITY CONTROL IS INDICATED BY A HAMMER BRAND ON THE END OF EACH PIECE.

MATERIAL		CHARGE #	DATE	RETENTION	QUANTITY
6x8x14"	Blockout (CD)	09-26	1/29/09	0.66	70
6x8x14"	Blockout (CD)	09-67	2/19/09	0.60	70
6x8x14"	OCD Blockout	09-95	3/5/09	0.62	140
6x8x6'	CRT Post	09-94	3/5/09	0.69	70
6x8x6'	Line Post	09-94	3/5/08	0.69	70
5½X7½X42½"	BCT Post	08-74	1/29/08	0.67	48
6x8x18"	Blockout	09-95	3/5/00	0.62	70
6x8x18"	Blockout	09-95	3/5/09	0.62	70

THIS CERTIFICATE APPLIES TO MATERIAL ORDERED FOR your order no.: 2117

FOR ANY INQUIRIES, PLEASE RETAIN THIS DOCUMENT FOR FUTURE REFERENCE.

THANK YOU FOR YOUR ORDER.

SINCERELY,

Karen L Storey

Karen Storey

SIGNED BEFORE ME THIS 12 DAY OF MARCH 2009.

Notary: William S. Houston
Notary Public Floyd County Georgia
My Commission Expires Oct. 15, 2010

WILLIAM S. HOUSTON NOTARY PUBLIC FLOYD COUNTY, GA.

11/02/2009 09:59 402-761-3288 MIDWEST MACHINERY

Figure A-3. Post Blockouts Certificate of Compliance

Charge Report

Plant No. : 1

Address

S.I. Storey Lumber Co.
235 Sike Storey Rd.
Armuchee, GA 30105
PH: 706 234-1605
Fax706 235-8132

EPA Reg. No. 3008-36

Charge : 95
Treatment : Guardrail Type 1
Date : 3/5/09 1:39:01PM
Chemical : CCA
Target Retention : .60
Cylinder : 1 (9,090)
Tank : 3
Operator : Richard
Total Time : 2:08:41
Turn Around Time (min) : 35
Time/Date Off Drip Pad :

Total Board Ft : 6,824
Total Cubic Ft : 513
Total Treatable Cubic Ft : 513
Displaced Volume In : 482
Displaced Volume Out : 556
Volume Start : 8,604
Volume Finish : 7,754
Volume Used : 850
Penetration Sampled : 0
Penetration Failed : 0
Treat By Tally : True

Step	Time			Pressure			Injection			Retention			Flow Rate			Time			Volume	Reason
	Min	Max	Act	Min	Max	Act	Min	Max	Act	Min	Max	Act	Min	Max	Act	Ramp	Start	End	End	
Initial Vacuum	0	17	17	0	-23	-23	0.00	0.00	0.00	.00	.00	.00	0.00	0.00	0.00	0	13:39:01	13:56:03	8,603	Time
Fill	0	10	7	0	-23	6	0.00	0.00	0.45	.00	.00	.07	0.00	0.00	0.00	0	13:56:04	14:02:58	3,121	Full
Raise Press	0	2	1	0	75	78	0.00	0.00	1.12	.00	.00	.18	0.00	0.00	0.00	0	14:02:59	14:03:43	2,777	PSI
Pressure	1	45	46	75	140	110	0.00	3.20	2.07	.00	.00	.33	0.00	0.00	0.00	1	14:03:43	14:48:45	2,202	Time
Press Relief	0	1	1	0	25	19	0.00	0.00	2.00	.00	.00	.32	0.00	0.00	0.00	1	14:48:45	14:49:45	2,329	PSI
Empty	0	10	8	0	8	-1	0.00	0.00	2.62	.00	.00	.41	0.00	0.00	0.00	0	14:49:46	14:57:25	7,259	Empty
Final Vacuum	0	45	45	0	-29	-27	0.00	1.75	1.67	.00	.00	.28	0.00	0.00	0.00	0	14:57:25	15:42:27	7,747	Time
Final Empty	0	1	2	-1	-1	-1	0.00	0.00	1.66	.00	.00	.28	0.00	0.00	0.00	0	15:42:28	15:44:40	7,754	Empty
Finish	0	1	1	0	-1	0	0.00	0.00	1.66	.00	.00	.26	0.00	0.00	0.00	0	15:44:41	15:45:42	7,754	Time

	Solution Percent		Lbs. Per Gallon			Total Lbs.		Retention		Assay	
Chemical	Start	Finish	Start	Finish	Absorbed	Gauge	Absorbed	Gauge	Absorbed	Min Retion	Wood
CCA	1.85 %	1.84 %	.1581	.1573	.1649	134	140	.262	.273	-	-
Totals :	1.85 %	1.84 %	.1581	.1573	.1649	134	140	.262	.273	.60	-

Additive List

Additives	Solution %

Automatic Mix Information

Chemical	Current Value	Target Value	Required	Actual	Difference
Water	7,809 Gals.	8,600 Gals.	777 Gals.	788 Gals.	0 Gals.
CCA	1.84 %	1.85 %	14 Gals.	14 Gals.	[illegible] Gals.

1	021.001009.60	Pieces: 336	Packs/Size : 2 @ 168	Desc: 6 x 8 x 0-14 Blockout (CD)S4S	BF: 1,579	CF: 114	HW: - %	Moist. Cont.: - %
	Std.: .60	Mill:	Cust Num: None	Retreat?: False	Chg#: 0	Species: SYP	Rem1: None
2	9999	Pieces: 252	Packs/Size : 3 @ 84	Desc: 6 x 8 x 0-23 Rub Block S4S CD - Kansas	BF: 1,933	CF: 139	HW: - %	Moist. Cont.: - %
	Std.: .60	Mill:	Cust Num: None	Retreat?: False	Chg#: 0	Species: SYP	Rem1: None
3	9999	Pieces: 20	Packs/Size : 1 @ 20	Desc: 6 x 8 x 0-23 Rub Block RTDS4S CD - Kansas	BF: 153	CF		
	Std.: .60	Mill:	Cust Num: None	Retreat?: False	Chg#: 0	Species: SYP		
4	021.001008.60	Pieces: 140	Packs/Size : 2 @ 70	Desc: 6 x 8 x 0-14 Blockout Rough	BF: 658	C		
	Std.: .60	Mill:	Cust Num: None	Retreat?: False	Chg#: 0	Species: SYP		
5	021.001012.60	Pieces: 140	Packs/Size : 2 @ 70	Desc: 6 x 8 x 0-14 OCD Blockout Rough	BF: 658	C		
	Std.: .60	Mill:	Cust Num: None	Retreat?: False	Chg#: 0	Species: SYP		
6	9999	Pieces: 70	Packs/Size : 1 @ 70	Desc: 6 x 8 x 0-18 Blockout (GR01.4.3.1)	BF: 329	C		
	Std.: .60	Mill:	Cust Num: None	Retreat?: False	Chg#: 0	Species: SYP		
[illegible]	9999	Pieces: 70	Packs/Size : 1 @ 70	Desc: 6 x 8 x 0-18 Blockout (GR01.4.3.4)	BF: 329	C		
	Std.: .60	Mill:	Cust Num: None	Retreat?: False	Chg#: 0	Species: SYP		

ANALYSIS REPORT
RETENTION
CrO_3 = 0.30 PCF
CuO = 0.10 PCF
As_2O_5 = 0.22 PCF
TOTAL RETENTION
0.62 PCF

Figure A-4. Post Blockouts Certificate of Compliance (Continued)

03/09/2009 14:21 4024722022 MWRSF PAGE 01

RECEIVED
OCT 05 2005
UNL FMP

GREGORY HIGHWAY PRODUCTS, INC.
4100 13th St. P.O. Box 80508
Canton, Ohio 44708

Customer: UNIVERSITY OF NEBRASKA-LINCOLN
401 CANFIELD ADMIN BLDG
P O BOX 880439
LINCOLN, NE. 68588-0439

Test Report
B.O.L. # 15808 DATE SHIPPED: 09/27/05
Customer P.O.: VERBAL JOHN ROHDE
Shipped to: UNIVERSITY OF NEBRASKA-LINCOLN
Project: STOCK
GHP Order No.: 44822

HEAT #	C.	Mn.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
3390	0.21	0.8	0.013	0.007	0.01	81660	62520	20.76	160		2	12GA 12FT6IN/3FT1 1/2IN WB T2

Bolts comply with ASTM A-307 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
Nuts comply with ASTM A-563 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
All other galvanized material conforms with ASTM-123 & ASTM-525
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
All Guardrail and Terminal Sections meets AASHTO M-180, All structural steel meets AASHTO M-183 & M270
All Bolts and Nuts are of Domestic Origin

By: [signature]
Andrew Artar
Vice President of Sales and Marketing
Gregory Highway Products, Inc.

UNL ACCOUNTING
OCT - 3 2005
RECEIVED

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by Andrew Artar this 28th day of September, 2005
[signature]
Dawn R. Batton
Notary Public, State of Ohio
My Commission Expires February 24, 2008

Figure A-5. 12-ft 6-in. (3.81-m) W-Beam Guardrail Material Specification

GREGORY HIGHWAY PRODUCTS, INC.
4100 13th St. P.O. Box 80508
Canton, Ohio 44708

MAY 14 2009

Test Report

Customer: UNIVERSITY OF NEBRASKA-LINCOLN
401 CANFIELD ADMIN BLDG
P O BOX 880439
LINCOLN, NE. 68588-0439

B.O.L. # 39963 DATE SHIPPED: 05/07/09
Customer P.O. 4500204081/ 04/06/2009
Shipped to: UNIVERSITY OF NEBRASKA-LINCOLN
Project : TEST PANELS
GHP Order No 105271

HT # code	C.	Mn.	P.	S.	Si.	Tensile	Yield	Elong.	Quantity	Class	Type	Description
4614	0.21	0.84	0.011	0.003	0.03	89432	67993	19.8	160	A	2	12GA 12FT6IN/3FT1 1/2IN WB T2

Bolts comply with ASTM A-307 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
Nuts comply with ASTM A-563 specifications and are galvanized in accordance with ASTM A-153, unless otherwise stated.
All other galvanized material conforms with ASTM-123 & ASTM-525
All steel used in the manufacture is of Domestic Origin, "Made and Melted in the United States"
All Guardrail and Terminal Sections meets AASHTO M-180, All structural steel meets AASHTO M-183 & M270
All Bolts and Nuts are of Domestic Origin
All material fabricated in accordance with Nebraska Department of Transportation
All controlled oxidized/corrosion resistant Guardrail and terminal sections meet ASTM A606, Type 4.

By: Andrew Artar
Andrew Artar
Vice President of Sales & Marketing
Gregory Highway Products, Inc.

STATE OF OHIO: COUNTY OF STARK
Sworn to and subscribed before me, a Notary Public, by Andrew Artar this 8th day of May, 2009.
Cynthia K Crawford
Notary Public, State of Ohio

NOTARIAL SEAL STATE OF OHIO

CYNTHIA K. CRAWFORD
Notary Public, State of Ohio
My Commission Expires 09-16-2012

Figure A-6. Additional 12-ft 6-in. (3.81-m) W-Beam Guardrail Material Specification

Certified Test Report

NORTH STAR BLUESCOPE STEEL LLC
6767 County Road 9
Delta, Ohio 43515
Telephone: (888) 822-2112

Customer:
Lawson Steel, Inc.

3238 E. 82nd St.	**Order Number**	171137	**Ordered Width (mm/in)**	1454.150 / 57.250
Cleveland, OH 44104	**Line Item Number**	1	**Ordered Gauge (mm/in)**	2.438 / 0.096
Customer P.O.: 021336	**Heat Number**	111813	**Material Description**	ASTM A568, 1018 CQ Modified
Cust. Ref/Part # n/a	**Coil Number**	842536	**Production Date/Time**	Mar 1 2008 5:41PM

Heat Chemical Analysis (wt%)

Type	C	Mn	P	S	Si	Al	Cu	Cr	Ni	Mo	Sn	N	B	V	Nb	Ti	Ca
Heat	0.19	0.73	0.012	0.003	0.03	0.02	0.09	0.04	0.03	0.01	0.00	0.005	0.0000	0.000	0.000	0.002	0.002

Mechanical Test Report

All mechanical tests are performed on a sample from the tail of a coil.

Yield Strength	Tensile Strength	% Elongation in 2 inches
64,860 psi	83,230 psi	23.5%

This material has been produced and tested in accordance with each of the following applicable standards: ASTM E 1806-96, ASTM E 415-99a, ASTM A 751-01, ASTM A 370-03a, JIS Z2201:1998, JIS Z 2241:1998. This report certifies that the above test results are representative of those contained in the records of North Star BlueScope Steel LLC for the material identified in this test report and is intended to comply with the requirements of the material description. North Star BlueScope Steel LLC is not responsible for the inability of this material to meet specific applications. Any modifications to this certification as provided negates the validity of this test report. All reproductions must have the written approval of North Star BlueScope Steel. This product was manufactured, melted, cast, and hot-rolled (min. 3:1 reduction ratio), entirely within the U.S.A at North Star BlueScope Steel LLC, Delta, Ohio. This material was not exposed to Mercury or any alloy which is liquid at ambient temperature during processing or while in North Star BlueScope Steel LLC possession. Test equipment calibration certificates are available upon request. NIST traceability is established through test equipment calibration certificates which are available upon request. Uncertainty calculations are calculated in accordance with NIST standards and are maintained at a 4:1 ratio in accordance with NIST standards. Uncertainty data is available upon request.

Tim Mitchell **Manager Quality Assurance and Technology**

Date Issued: Mar 12, 2008 11:00:32
Revision#: 01

Figure A-7. 6-ft 3-in. (1.91-m) W-Beam Guardrail Material Specification

06/04/2009 16:36 402-761-3288 MIDWEST MACHINERY PAGE 06/32

MID WEST
FABRICATING CO.

CERTIFICATE OF COMPLIANCE
WE CERTIFY THAT ALL BOLTS ARE MADE AND MANUFACTURED IN THE USA.

TO: TRINITY INDUSTRIES INC.
Plant #55
425 E. O'Connor 419-222-7398
Lima,Ohio 45801
SHIP DATE: .11/6/2008
MANUFACTURER: MID WEST FABRICATING CO.
ASTM: A307A
GALVANIZERS: Columbus/Piolt TO A-153 CLASS C

QTY	PART NO.	HEAT NO.	LOT NO.	P.O.NO.
3,524	5/8 X 10-6"	7261134	85204	126266BR80
1,076	5/8 X 10-6"	7261134	85204	126266BR78
8,900	5/8 X 10-6"	7261134	85204	126266BR74
4,500	5/8 X 10-6"	7261611	85217	126266BR74
2,550	5/8 X 10W-6"	7261286	85180	126266BR84
4,500	5/8 X 14-6"	7366618	85199	126266BR68
6,000	5/8 X 18-6"	7366618	85157	126266BR84
1,536	5/8 X 18-6"	7366618	85157	126266BR74
130	5/8 X 18-6"	7366618	85156	126266BR74
2,964	5/8 X 18-6"	7366618	85149	126266BR74
4,370	5/8 X 18-6"	7261611	85146	126266BR74
400	5/8 X 3.5"	5978691	85016	126266BR82

Signature D. Smith D. Smith
TITLE: QUALITY CONTROL
DATE: 11/6/2008

313 North Johns Street • Amanda, Ohio 43102 • 740/969-4411 • FAX: 740/969-4433

Figure A-8. ⅝-in. (15.9-mm) x 10-in. (254-mm) Guardrail Bolt/Nut Material Specification

06/04/2009 16:36 402-761-3288 MIDWEST MACHINERY PAGE 15/52

04/14/2009 10:14 FAX 740 681 4433 MID WEST FAB: ROCKMILL 002

35406

MID WEST
FABRICATING CO.

CERTIFICATE OF COMPLIANCE

WE CERTIFY THAT ALL BOLTS ARE MADE AND MANUFACTURED IN THE USA

TO: TRINITY INDUSTRIES INC.
Plant #55
550 East Robb Ave. 419-222-7398
Lima, Ohio 45801
SHIP DATE: 4/13/2009
MANUFACTURER: MID WEST FABRICATING CO.
ASTM: A307A
GALVANIZERS: Bristol/Pilot/Columbus TO A-153 CLASS C

QTY	PART NO.	HEAT NO.	LOT NO.	P.O.NO.
5,250	5/8 X 10-6"	20060370	95055	130236BR25
2,625	5/8 X 10-6"	20060370	95052	130236BR25
28,500	5/8 X14-6"	7366618	85199	126266BR114

Signature D. Smith D. Smith
TITLE: QUALITY CONTROL
DATE: 4/13/2009

313 North Johns Street • Amanda, Ohio 43102 • 740/969-4411 • FAX: 740/969-4433

Figure A-9. ⅝-in. (15.9-mm) Dia. x 14-in. (356-mm) Long Bolt/Nut Material Specification

PAGE 44/52

425 E. O'Connor
Lima, OH

Customer: MIDWEST MACH.& SUPPLY CO. P. O. BOX 81097 LINCOLN, NE 68501-1097	Sales Order: 1093497 Customer PO: 2030 BOL # 43073 Document # 1	Print Date: 6/30/08 Project: RESALE Shipped To: NE Use State: KS

Trinity Highway Products. LLC

Certificate Of Compliance For Trinity Industries, Inc. ** SLOTTED RAIL TERMINAL **

NCHRP Report 350 Compliant

MIDWEST MACHINERY

Pieces	Description
32	12/12'6/S SRT-1
32	12/25'0/SPEC/S SRT-2
32	3/16X12.5X16 CAB ANC BRKT
32	2" X 5 1/2" PIPE (LONG)
64	6'0 TUBE SL/.188X8X6
32	5/8 X 6 X 8 BEARING PLATE
32	12/BUFFER/ROLLED
32	CBL 3/4X6'6/DBL SWG/NOHWD
640	5/8" RD WASHER 1 3/4 OD
1,728	5/8" GR HEX NUT
1,152	5/8"X1.25" GR BOLT
256	5/8"X1.5" HEX BOLT A307
64	5/8"X9.5" HEX BOLT A307

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

402-761-3288

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL OTHER GALVANIZED MATERIAL CONFORMS WITH ASTM-123.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 49100 LB

State of Ohio, County of Allen. Sworn and Subscribed before me this 30th day of June, 2008

Notary Public: [signature]
Commission Expires [illegible]

Trinity Highway Products, LLC
Certified By: [signature]

1 of 1

Figure A-10. ⅝-in. (15.9-mm) Dia. Bolts, Washers, and Nuts Certificate of Compliance

06/04/2009 16:36 402-761-3288 MIDWEST MACHINERY

TRINITY HIGHWAY PRODUCTS, LCC.
Plant #55
425 E. O' CONNOR AVENUE
Lima, OH 45801
419-227-1296

MATERIAL CERTIFICATION

CUSTOMER: STOCK	DATE: March 10, 2009
	INVOICE #
	LOT NUMBER: 081128B
PART NUMBER: 3360G	QUANTITY: 107,458
DESCRIPTION: 5/8"x 1 ¼" GR BOLT	DATE SHIPPED:
SPECIFICATIONS: ASTM A307-A /A153	HEAT#: 7366484,7262312

MATERIAL CHEMISTRY

C	MN	P	S	SI	NI	CR	MO	CU	SN	V	AL	N	B	TI	NB
.13 .15	.38 .48	.007 .006	.002 .007	.10 .06	.04 .02	.06 .04	.02 .02	.03 .02	.001 .001	.002 .002	.037 .024	.004 .0039	.000 .000	.000 .000	.000 .000

PLATING AND/OR PROTECTIVE COATING

HOT DIP GALVANIZED (OZ. PER SQ. FT.)		1.25 Avg.

****THIS PRODUCT WAS MANUFACTURED IN THE UNITED STATES OF AMERICA****

THE MATERIAL USED IN THIS PRODUCT WAS MELTED AND MANUFACTURED IN THE U.S.A

WE HEREBY CERTIFY THAT TO THE BEST OF OUR KNOWLEDGE ALL INFORMATION CONTAINED HEREIN IS CORRECT.

TRINITY HIGHWAY PRODUCTS, LLC.

STATE OF OHIO, COUNTY OF ALLEN
SWORN AND SUBSCRIBED BEFORE ME
THIS 10TH DAY OF MARCH, 2009

NOTARY PUBLIC

425 E. O 'CONNOR AVENUE LIMA, OH 45801 419-227-1296

Figure A-11. ⅝-in. (15.9-mm) Guardrail Splice Bolts Material Specification

06/04/2009 16:36 402-761-3288 MIDWEST MACHINERY PAGE 05/52

Apr. 21. 2009 2:44PM Trinity Industries, Inc. No. 1357 P. 31/31

Trinity Metals Laboratory
A DIVISION OF TRINITY INDUSTRIES
4001 IRVING BLVD. 75247 • P.O. BOX 568887
DALLAS, TX 75356-8887
Phone: 214.589.7591 FAX: 214.589.7594

NVLAP LAB CODE 200554-0

Lab No: S110344P

CHERITY A. MASON
TRINITY HWY PRODUCTS, LLC #55
ROLLFORM
LIMA, OH 45801

Received Date: 11/21/2008
Heat Code:
Heat Number: 545770
PO or Work Order: Lot#: 081031N2
Test Spec: F606 ASTM METHODS
Other Information: SO#: 55-45667

Completion Date: 12/01/2008
Weld Spec:
Material Type: A 563 A
Material Size: 5/8" GR Nuts

OTHER TEST:

Seq: 1

Type: NUT PROOF LOAD — Quantity Amount: 5

SAMPLES PASSED PROOF LOADS OF 16,950 LBS.

Seq: 2

Type: HEAD MARKINGS — Quantity Amount: 0

TRN L

We certify the above results to be a true and accurate representation of the sample(s) submitted. Alteration or partial reproduction of this report will void certification. NVLAP Certificate of Accreditation effective through 12-31-08. This report may not be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the federal government.

Lab Director, Michael S. Borden, PE

Page 2 of 2

Figure A-12. ⅝-in. (15.9-mm) Guardrail Splice Nuts Material Specification

06/04/2009 16:36 402-761-3288 MIDWEST MACHINERY PAGE 04/52
Apr. 21. 2009 3:44PM Trinity Industries, Inc. No. 1357 P. 30/31

Trinity Metals Laboratory
A DIVISION OF TRINITY INDUSTRIES
4001 IRVING BLVD. 75247 - P.O. BOX 568887
DALLAS, TX 75356-8887
Phone: 214.589.7591 FAX: 214.589.7594

NVLAP LAB CODE 200084-0

Lab No: 8110344F
CHERITY A. MASON
TRINITY HWY PRODUCTS, LLC #55
ROLLFORM
LIMA, OH 45801

Received Date: 11/21/2008
Heat Code:
Heat Number: 545770
PO or Work Order: Lot#: 081031N2
Test Spec: F606 ASTM METHODS
Other Information: SO#: 55-45857

Completion Date: 12/01/2008
Weld Spec:
Material Type: A 563 A
Material Size: 5/8" GR Nuts

HARDNESS TEST:

Seq:1 — PASSED
Hardness Type: HARDNESS ROCKWELL BW
Hardness Location: SURFACE of WRENCH FLAT - A
Hardness Average: 88

Measured Value	Measured Amt
Measured Value	88
Measured Value	88

Seq:2 — PASSED
Hardness Type: HARDNESS ROCKWELL BW
Hardness Location: SURFACE of WRENCH FLAT - B
Hardness Average: 89

Measured Value	Measured Amt
Measured Value	88
Measured Value	90

Seq:3 — PASSED
Hardness Type: HARDNESS ROCKWELL BW
Hardness Location: SURFACE of WRENCH FLAT - C
Hardness Average: 89.5

Measured Value	Measured Amt
Measured Value	89
Measured Value	90

Seq:4 — PASSED
Hardness Type: HARDNESS ROCKWELL BW
Hardness Location: SURFACE of WRENCH FLAT - D
Hardness Average: 90

Measured Value	Measured Amt
Measured Value	90
Measured Value	90

Seq:5 — PASSED
Hardness Type: HARDNESS ROCKWELL BW
Hardness Location: SURFACE of WRENCH FLAT - E
Hardness Average: 92

Measured Value	Measured Amt
Measured Value	91
Measured Value	93

We certify the above results to be a true and accurate representation of the sample(s) submitted. Alteration or partial reproduction of this report will void certification. NVLAP Certificate of Accreditation effective through 12-31-08. This report may not be used to claim product certification, approval, or endorsement by NVLAP, NIST, or any agency of the federal government.

Lab Director, Michael S. Boston, PE

Page 1 of 2

Figure A-13. ⅝-in. (15.9-mm) Guardrail Splice Nuts Material Specification (Continued)

06/04/2009 16:36 402-761-3288 MIDWEST MACHINERY PAGE 01/02

Apr. 21. 2009 3:43PM Trinity Industries, Inc. No. 1357 P. 27/31

TRINITY HIGHWAY PRODUCTS, LLC.
425 E. O'CONNOR AVENUE
LIMA, OHIO 45801
419-227-1296

3340 G

MATERIAL CERTIFICATION

CUSTOMER: STOCK	DATE: NOVEMBER 18, 2008
	INVOICE #:
	LOT #: 081031N2
PART NUMBER: 3340G	QUANTITY: 110,000
DESCRIPTION: 5/8" GR NUT	DATE SHIPPED:
SPECIFICATIONS: ASTM A563-A/A153	HEAT #: 545770

MATERIAL CHEMISTRY

C	MN	P	S	SI	CU	NI	CR	MO	AL	V	N	CB	SN	B	TI	NB
.11	.45	.008	.013	.090	.07	.04	.08	.01	.023	.001	.0080	.000	.005	.0001	.001	.001

PLATING AND/OR PROTECTIVE COATING

HOT DIP GALVANIZING (OZ. PER SQ. FT.)	1.25 AVG.

****THIS PRODUCT WAS MANUFACTURED IN THE UNITED STATES OF AMERICA***

THE MATERIAL USED IN THIS PRODUCT WAS MELTED AND MANUFACTURED IN THE U.S.A.

WE HEREBY CERTIFY THAT TO THE BEST OF OUR KNOWLEDGE ALL INFORMATION CONTAINED HEREIN IS CORRECT.

TRINITY HIGHWAY PRODUCTS, LLC.

STATE OF OHIO, COUNTY OF ALLEN
SWORN AND SUBSCRIBED BEFORE ME
THIS 18TH DAY OF NOVEMBER 2008
NOTARY PUBLIC

425 E. O'CONNOR AVENUE LIMA, OHIO 45801 419-227-1296

Figure A-14. ⅝-in. (15.9-mm) Guardrail Splice Nuts Material Specification (Continued)

PAGE 02/02

06/04/2009 16:36 402-761-3288 MIDWEST MACHINERY No. 1357 P. 28/31

Apr. 21. 2009 3:43PM Trinity Industries, Inc.

JUN-05-2008 THU 11:20 AM CHARTER ROLLING Q/C DEPT +1 262 268 2554 P. 05

FAX

CHARTER STEEL

A Division of
Charter Manufacturing Company, Inc.

CHARTER STEEL TEST REPORT
Reverse Has Text And Codes

1658 Cold Springs Road
Saukville, Wisconsin 53080
(262) 268-2400
1-800-437-8789
FAX (262) 268-2570

Trinity Highway Prod, LLC
425 E. O Conner Ave
Lima,OH 45801-
Attn: Attn: Sue Henline

[illegible]	127896
[illegible]	1009449
[illegible]	273108
[illegible]	646770
[illegible]	397211
[illegible]	1010 A AK FG RHQ
[illegible]	HR
[illegible]	1-7/32

I hereby certify that the material described herein has been manufactured in accordance with the specifications and standards listed below and on the reverse side, and that it satisfies those requirements.

Test Results of Heat Lot# 646770

Lab Code: 7388

Chemistry	C	MN	P	S	SI	NI	CR	MO	CU	SN	V
Wt%	0.11	0.45	0.008	0.013	0.050	0.04	0.06	0.01	0.07	0.005	0.001

	AL	N	B	TI	NB
	0.023	0.0080	0.0001	0.001	0.001

CHEM. DEVIATION EXT.-GREEN = N/R

Test Results of Rolling Lot # 397211

	# of Tests	Min Value	Max Value	Mean Value	
ROCKWELL B (HRBW)	2	81	82	81	RB LAB = 0368-02
ROCKWELL C (HRC)	0	0	0	0	RC LAB = N/R

QC DEVIATION EXT.-GREEN = N/R

Test Results of Processing Lot #

QC DEVIATION EXT.-PROCESSED = N/R

Specifications: Manufactured per Charter Steel Quality Manual Rev 8, 12-05-07
Meets customer specifications with any applicable Charter Steel exceptions for the following customer documents:
Customer Document = Revision = Dated =

Additional Comments: MELTED AND MANUFACTURED IN THE USA

Charter Steel
Saukville, WI, USA

Fax number: (419) 222-7388 Rem: Lead1,Mail0,Fax1

A2LA ACCREDITED Testing Laboratory

Janice Barnard
Manager of Quality Assurance
06/04/2008

Figure A-15. ⅝-in. (15.9-mm) Guardrail Splice Nuts Material Specification (Continued)

PAGE 03/52

MIDWEST MACHINERY

16/04/2009 16:36 402-761-3288 No. 1357 P. 29/31

Apr. 21. 2009 3:43PM Trinity Industries, Inc.

JUN-05-2008 THU 11:23 AM CHARTER ROLLING Q/C DEPT +1 262 268 2554 P. 14

The following statements are applicable to the material described on the front of this Test Report:

1. Except as noted, the steel supplied for this order was melted, rolled and processed in the United States.
2. Mercury was not used during the manufacture of this product, nor was the steel contaminated with mercury during processing.
3. Unless directed by the customer, there are no welds in any of the coils produced for this order.
4. The laboratory that generated the analytical or test results can be identified by the following key:

Certificate Number	Lab Code		Laboratory	Address
0358-01	7388	CSMD	Charter Steel Melting Division	1658 Cold Springs Road, Saukville, WI 53080
0358-02	8171	CSRD/CSPD	Charter Steel Rolling/Processing Division	1658 Cold Springs Road, Saukville, WI 53080
0358-03	123633	P4	Charter Steel Ohio Processing Division	6255 US Highway 23, Risingsun, OH 43457
0358-04	125544	CSC	Charter Steel Cleveland	4300 E. 49th St., Cuyahoga Heights, OH 44125-1004
0358-05	128003	CSDT	Charter Steel Detroit	23860 Sherwood Ave, Center Line, MI 48015
*	**	--	Subcontracted test performed by laboratory not in Charter Steel system	

5. When run by a Charter Steel laboratory, the following tests were performed according to the latest revisions of the specifications listed below, as noted in the Charter Steel Laboratory Quality Manual:

Test	Possible Laboratory	Specification
Chemistry Analysis	CSMD, CSC	ASTM E415; ASTM E1019
X-ray Fluorescence Stainless and Alloy Steel	CSC	ASTM E572
Macroetch	CSMD, CSC	ASTM E381
Hardenability (Jominy)	CSMD, CSC	ASTM A255; SAE J406; JIS G0561
Grain Size	CSMD	ASTM E112
Tensile Test	CSRD/CSPD, P4, CSC, CSDT	ASTM E8; ASTM A370
Rockwell Hardness	CSMD, CSRD/CSPD, P4, CSC, CSDT	ASTM E18; ASTM A370
Microstructure (spheroidization)	CSRD/CSPD, P4	ASTM A892
Inclusion Content (Methods A, E)	CSRD/CSPD, CSC	ASTM E45

Charter Steel has been accredited to perform all of the above tests by the American Association for Laboratory Accreditation (A2LA). These accreditations expire 01/31/09

All other test results associated with a Charter Steel laboratory that appear on the front of this report, if any, were performed according to documented procedures developed by Charter Steel and are not accredited by A2LA.

6. The test results on the front of this report are the true values measured on the samples taken from the production lot. They do not apply to any other sample.
7. This test report cannot be reproduced or distributed except in full without the written permission of Charter Steel. The primary customer whose name and address appear on the front of this form may reproduce this test report, subject to the following restrictions:
   - It may be distributed only to their customers
   - Both sides of all pages must be reproduced in full
8. This certification is given subject to the terms and conditions of sale provided in Charter Steel's acknowledgment (designated by our Sales Order number) to the customer's purchase order. Both Order numbers appear on the front page of this Report.
9. Where the customer has provided a specification, the results on the front of this test report conform to that specification unless otherwise noted on this test report.

A2LA Accredited Testing Laboratory

Figure A-16. ⅝-in. (15.9-mm) Guardrail Splice Nuts Material Specification (Continued)

MATERIAL TEST REPORT

\TE: 09/25/07

PAGE: 1

BILL OF LADING: 164358

LEAVIT(JBE COMPANY, LLC

LEAVITT

The Tube People

Leavitt Tube Co., LLC
1717 W. 115th St.
Chicago, IL 60643

Phone: 773-239-7700
Phone: 1-800-LEAVITT
Fax: 773-239-1023
www.leavitt-tube.com
QA1002-0003 Rev. 0

CUST: STEEL & PIPE SUPPLY - CATOOSA OK
1050 FORT GIBSON ROAD
CATOOSA OK 74015

TUBING MANUFACTURED IN USA

ATTN: * Test Report Desk

106201 8027185

ITEM NO.	PIECES	SIZE, GAUGE,LENGTH	QTY. SHIPPED	CUSTOMER P.O.	ORDER NUMBER	CUSTOMER PART NBR	ASTM SPECIFICATION	GRADE
1	7	8.625-322HRB 252	147	4500088611	1015580 1.000		A500-03b	B
2	6	12X2-188HRB 480	240	4500088813	1016034 1.000		A500-03b	B
3. - 4	28	8.625-322HRB 504	1,176	4500091471	1025579 1.000		A500-03b	B
5	9	8X6-188HRB 480	360	4500092386	1029189 1.000		A500-03b	B

ITEM NO.	1	2	3	4	5
COIL NO.	395453	395532	395813	395460	391232
HEAT NO.	722562	722551	722564	722564	A13386
CORRECTED COIL					
CARBON	.210	.210	.210	.210	.220
MANGANESE	.820	.860	.820	.820	.700
PHOSPHORUS	.004	.006	.004	.004	.006
SULFUR	.006	.004	.006	.006	.003
ALUMINUM	.047	.050	.047	.047	.024
SILICON	.020	.030	.020	.020	.030
WELD TESTING	FLATTEN	FLARE	FLATTEN	FLATTEN	FLARE
YIELD STRENGTH (PSI)	47,297			52,000	55,056
TENSILE STRENGTH (PSI)	62,162			70,666	70,787
ELONGATION IN 2" (%)	29.0			31.0	27.0

Item(s)- 1 2 3 4 5 Are

Made and Melted
In The U.S.A.

I HEREBY CERTIFY THAT THE ABOVE IS CORRECT
AS CONTAINED IN THE RECORDS OF THE COMPANY.

Figure A-17. Foundation Tube Material Specification

S.I. Storey
LUMBER COMPANY, INC.

CERTIFICATE OF COMPLIANCE

AUGUST 4, 2009

MIDWEST MACHINERY & SUPPLY
PO BOX 81097
LINCOLN, NE 68501

THE FOLLOWING MATERIAL DELIVERED ON 8/3/09 ON BILL OF LADING NUMBER 19477 HAS BEEN INSPECTED BEFORE AND AFTER TREATMENT AND IS IN FULL COMPLIANCE WITH APPLICABLE NEBRASKA DEPARTMENT OF ROADS REQUIREMENTS FOR SOUTHERN YELLOW PINE TIMBER GUARDRAIL COMPONENTS, PRESERVATIVE TREATED WITH CHROMATED-COPPER-ARSENATE (CCA-C) TO A MINIMUM RETENTION OF .60 LBS/CU.FT. THE ACCEPTANCE OF EACH PIECE BY COMPANY QUALITY CONTROL IS INDICATED BY A HAMMER BRAND ON THE END OF EACH PIECE.

	MATERIAL		CHARGE #	DATE	RETENTION	QUANTITY
X	6x8x14"	Blockout (CD)	09-283	7/29/09	0.67	70
	6x8x6'	Line Post	09-283	7/29/09	0.67	175
X	51/2x71/2-46"	TB Bullnose	09-283	7/29/09	0.67	48
	6x6x8"	Blockout	09-283	7/29/09	0.67	100
	6x8x22"	Blockout	09-283	7/29/09	0.67	70

THIS CERTIFICATE APPLIES TO MATERIAL ORDERED FOR your order no.: .2191

FOR ANY INQUIRIES, PLEASE RETAIN THIS DOCUMENT FOR FUTURE REFERENCE.

THANK YOU FOR YOUR ORDER.

SINCERELY,

Karen L Storey

Karen Storey

SIGNED BEFORE ME THIS 4 DAY OF AUGUST 2009.

Notary: William S. Houston
Notary Public Floyd County Georgia
My Commission Expires Oct. 19, 2010

WILLIAM S. HOUSTON
NOTARY
PUBLIC
EXP. Oct. 19, 2010
FLOYD COUNTY, GA

Phone: 706-234-1605 P.O. Box 99, Armuchee, GA 30105 Fax: 706-235-8132

Figure A-18. BCT Timber Posts Certificate of Compliance

Charge Report

Plant No. : 1

Address

S.I. Storey Lumber Co.
285 Sike Storey Rd.
Armuchee, GA 30105
PH: 706 234-1605
Fax:706 235-8132

EPA Reg. No. 3008-36

Charge : 283
Treatment : drail Type 1
Date : 7/29/09 12:42:23PM
Chemical : CCA
Target Retention : .60
Cylinder : 1 (9,090)
Tank : 3
Operator : Richard
Total Time : 2:06:43
Turn Around Time (min) : 2,676
Time/Date Off Drip Pad :

Total Board Ft : 6,037
Total Cubic Ft : 491
Total Treatable Cubic Ft : 491
Displaced Volume In : 502
Displaced Volume Out : 535
Volume Start : 8,616
Volume Finish : 7,598
Volume Used : 1,018
Penetration Sampled : 0
Penetration Failed : 0
Treat By Tally : True

Step	Time			Pressure			Injection			Retention			Flow Rate			Time			Volume	Reason
	Min	Max	Act	Min	Max	Act	Min	Max	Act	Min	Max	Act	Min	Max	Act	Ramp	Start	End	End	
Initial Vacuum	0	17	17	0	-23	-23	0.00	0.00	0.00	.00	.00	.00	0.00	0.00	0.00	0	12:42:23	12:59:25	8,616	Time
Fill	0	10	7	0	-23	10	0.00	0.00	0.00	.00	.00	.00	0.00	0.00	0.00	0	12:59:25	13:06:05	3,281	Full
Raise Press	0	2	0	0	75	78	0.00	0.00	0.08	.00	.00	.01	0.00	0.00	0.00	0	13:06:06	13:06:26	3,159	PSI
Pressure	1	45	45	75	140	128	0.00	3.20	1.97	.00	.00	.32	0.00	0.00	0.01	1	13:06:26	13:51:27	2,229	Time
Press Relief	0	1	1	0	25	13	0.00	0.00	1.93	.00	.00	.31	0.00	0.00	0.00	1	13:51:27	13:52:15	2,249	PSI
Empty	0	10	9	0	0	0	0.00	0.00	2.61	.00	.00	.42	0.00	0.00	0.00	0	13:52:15	14:00:55	7,334	Empty
Final Vacuum	0	45	45	0	-29	-26	0.00	1.75	2.10	.00	.00	.34	0.00	0.00	0.01	0	14:00:55	14:45:57	7,588	Time
Final Empty	0	1	2	-1	-1	-1	0.00	0.00	2.09	.00	.00	.34	0.00	0.00	0.00	0	14:45:57	14:48:02	7,593	Empty
Finish	0	1	1	0	-1	0	0.00	0.00	2.07	.00	.00	.34	0.00	0.00	0.00	0	14:48:03	14:49:06	7,598	Time

	Solution Percent		Lbs. Per Gallon			Total Lbs.		Retention		Assay	
Chemical	Start	Finish	Start	Finish	Absorbed	Gauge	Absorbed	Gauge	Absorbed	Min Reten	Wood
CCA	1.90 %	1.90 %	.1624	.1624	.1624	165	165	.337	.337	-	-
Totals :	1.90 %	1.90 %	.1624	.1624	.1624	165	165	.337	.337	.60	-

Additive List

Additives	Solution %

Automatic Mix Information

Chemical	Current Value	Target Value	Required	Actual	Difference
Water	- Gals.	- Gals.	1,319 Gals.	1,311 Gals.	-8 Gals.
CCA	1.88 %	1.90 %	25 Gals.	25 Gals.	- Gals.

1 021.001021.60 Pieces: 175 Packs/Size : 5 @ 35 Desc: 6 x 8 x 6 Line Post Rough Nebraska #1 Dense BF: 4,200 CF: 350 HW: - % Moist. Cont.: - %
Std.: .60 Mill: Cust Num: None Retreat?: False Chg#: 0 Species: SYP Rem1: None

2 021.001008.60 Pieces: 70 Packs/Size : 1 @ 70 Desc: 6 x 8 x 0-14 Blockout Rough BF: 329 CF: 27 HW: - % Moist. Cont.: - %
Std.: .60 Mill: Cust Num: None Retreat?: False Chg#: 0 Species: SYP Rem1: None

3 9999 Pieces: 48 Packs/Size : 1 @ 48 Desc: 5-1/2 x 7-1/2 x 0-46 TB Bullnose Post BF: 720 CF: _
Std.: .60 Mill: Cust Num: None Retreat?: False Chg#: 0 Species: SYP

4 9999 Pieces: 70 Packs/Size : 1 @ 70 Desc: 6 x 8 x 0-22" Rough Blockout BF: 513 CF: _
Std.: .60 Mill: Cust Num: None Retreat?: False Chg#: 0 Species: SYP

5 9999 Pieces: 100 Packs/Size : 1 @ 100 Desc: 6 x 6 x 8" Post Block CCA .60 BF: 275 CF: _
Std.: .40 Mill: Cust Num: None Retreat?: False Chg#: 0 Species: SYP

ANALYSIS REPORT
****
RETENTION

CRO3 = 0.32 PCF
CUO = 0.12 PCF
AS2O5 = 0.23 PCF

TOTAL RETENTION
0.67 PCF
****

Printed on: 8/4/09 9:34:53AM Plant Number : 1 Charge Number : 283 Page 1 of 1

Figure A-19. BCT Timber Posts Certificate of Compliance (Continued)

EXLTUBE

905 ATLANTIC STREET, NORTH KANSAS CITY, MO 64116 1-816-474-5210 TOLL FREE 1-800-892-TUBE

STEEL VENTURES, LLC dba EXLTUBE

CERTIFIED TEST REPORT

Customer:	Size:	Spec No:	Date:
SPS - New Century 401 New Century Parkway New Century KS 66031	02.375	ASTM A500-07, A53E-07	05/22/2008
	Gauge: .154	Grade: A500B,C, A53BNT	Customer Order No: 4500104158
			B/L No: 81162893

Heat No	Yield P.S.I.	Tensile P.S.I.	Elongation % 2 Inch
280638	61,500	66,400	23.00

SLEEVE MAT CRT

Heat No	C	MN	P	S	SI	CU	NI	CR	MO	V
280638	0.040	0.330	0.010	0.000	0.034	0.098	0.039	0.042	0.015	0.003

We hereby certify that the above material was manufactured in the U.S.A and that all test results shown in this report are correct as contained in the records of our company. All testing and manufacturing is in accordance to A.S.T.M. parameters encompassed within the scope of the specifications denoted in the specification and grade tiles above.

BNT=Grade B not tested - meets tensile properties ONLY.

STEEL VENTURES, LLC dba EXLTUBE

Steve Frerichs
Quality Assurance Manager

104158

Figure A-20. BCT Post Sleeves Material Specification

725 E. O'Connor
Lima, OH

Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097

Sales Order: 1093497
Customer PO: 2030
BOL # 43073
Document # 1

Print Date: 6/30/08
Project: RESALE
Shipped To: NE
Use State: KS

Trinity Highway Products. LLC

Certificate Of Compliance For Trinity Industries, Inc. ** SLOTTED RAIL TERMINAL **

NCHRP Report 350 Compliant

Pieces	Description
64	5/8"X10" GR BOLT A307
192	5/8"X18" GR BOLT A307
32	1" ROUND WASHER F844
64	1" HEX NUT A563
192	WD 6'0 POST 6X8 CRT
192	WD BLK 6X8X14 DR
64	NAIL 16d SRT
64	WD 3'9 POST 5.5X7.5 BAND
32	STRUT & YOKE ASSY
128	SLOT GUARD '98
32	3/8 X 3 X 4 PL WASHER

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

06/04/2009 16:36 402-761-3288

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL OTHER GALVANIZED MATERIAL CONFORMS WITH ASTM-123.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM449 AASHTO M30, TYPE II BREAKING STRENGTH – 49100 LB

State of Ohio, County of Allen. Sworn and Subscribed before me this 30th day of June, 2008

Notary Public:
Commission Expires

Trinity Highway Products, LLC
Certified By:

2 of 4

Figure A-21. Strut and Yoke Assembly Certificate of Compliance

Certified Analysis

Trinity Highway Products , LLC
2548 N.E. 28th St.
Ft Worth, TX
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097
Project: RESALE

Order Number: 1095199
Customer PO: 2041
BOL Number: 24481
Document #: 1
Shipped To: NE
Use State: KS

As of: 6/20/08

Qty	Part#	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
25	6G	12/6'3/S	M-180	A		84964	64,230	81,300	25.4	0.180	0.720	0.012	0.001	0.040	0.080	0.000	0.060	0.000	4
20	701A	.25X11.75X16 CAB ANC	A-36			4153095	44,900	60,800	34.0	0.240	0.750	0.012	0.003	0.020	0.020	0.000	0.040	0.002	4
10	742G	6'0 TUBE SL/.188X8X6	A-500			A8P1160	74,000	87,000	25.2	0.050	0.670	0.013	0.005	0.030	0.220	0.000	0.060	0.021	4
20	782G	5/8"X8"X8" BEAR PL/OF	A-36			6106195	46,700	69,900	23.5	0.180	0.830	0.010	0.005	0.020	0.230	0.000	0.070	0.006	4
40	907G	12/BUFFER/ROLLED	M-180	A		L0049	54,200	73,500	25.0	0.160	0.700	0.011	0.008	0.020	0.200	0.000	0.100	0.000	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL OTHER GALVANIZED MATERIAL CONFORMS WITH ASTM-123.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH -- 49100 LB

State of Texas, County of Tarrant. Sworn and subscribed before me this 20th day of June, 2008

Notary Public:
Commission Expires: RACHEL R. MEDINA Notary Public State of Texas My Commission Expires

Trinity Highway Products , LLC
Certified By: Stefanie Onnl.a

Figure A-22. Anchor Bracket Material Specification

Certifie' \nalysis

Trinity Highway Products , LLC
425 E. O'Connor
Lima, OH
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097
Project: RESALE

Order Number: 1114174
Customer PO: 2213
BOL Number: 51169
Document #: 1
Shipped To: NE
Use State: NE

As of: 9/16/09

Qty	Part #	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
750	545G	6'0 POST/DB:DDR	A-36			J86489	50,565	68,830	26.1	0.090	0.950	0.010	0.040	0.200	0.290	0.00	0.160	0.003	4
50	14662G	6'6 POST/8.5#/DB:DDR NB	A-36			J86489	50,565	68,830	26.1	0.090	0.950	0.010	0.040	0.200	0.290	0.00	0.160	0.003	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL GALVANIZED MATERIAL CONFORMS WITH ASTM-123, UNLESS OTHERWISE STATED.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 49100 LB

State of Ohio, County of Allen. Sworn and subscribed before me this 16th day of September, 2009
Notary Public:
Commission Expires 1/28/2012

Trinity Highway Products , LLC
Certified By:
Quality Assurance

1 of 1

Figure A-23. BCT Cable Anchor Assembly Certificate of Compliance

Jun-15-2009 08:12am From-Porteous Denver 1 303 576 0533 T-510 P.002/003 F-448

1"

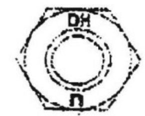
Certification provided by:PFC, To;NEBRASKA BOLT Order:124841

FASTENER DIVISION

Telephone 260/337-1600

CUSTOMER NO/NAME
267 PORTEOUS FASTENER CO.
TEST REPORT SERIAL# FB285160
TEST REPORT ISSUE DATE 4/20/07
DATE SHIPPED 10/04/07
NAME OF LAB SAMPLER: SHIRRI STANTZ, LAB TECHNICIAN

NUCOR ORDER # 600934
CUST PART # 00219-4000-004
CUSTOMER P.O. # 17070232



******************CERTIFIED MATERIAL TEST REPORT*******************

NUCOR PART NO	QUANTITY	LOT NO.	DESCRIPTION
175407	7200	222445A 1-8	CR DH HV M.D.C. HEX NUT H.D.G.

MANUFACTURE DATE 1/29/07

--CHEMISTRY MATERIAL GRADE -1045L

**CHEMISTRY COMPOSITION (WT% HEAT ANALYSIS) BY MATERIAL SUPPLIER

MATERIAL NUMBER	HEAT NUMBER		C	MN	P	S	SI
RM023445	NU 838828		.45	.69	.013	.021	.18
		MIN	:20	.60			
NU 838828		MAX	.55		.040	.050	

NUCOR STEEL - NEBRASKA
A2LA NO: 780.01 EXP: 2008-11-30
FOR CHEMICAL TESTING

--MECHANICAL PROPERTIES IN ACCORDANCE WITH ASTM A563-04A

SURFACE HARDNESS (R30N)	CORE HARDNESS (RC)	PROOF LOAD 90900 LBS	TENSILE STRENGTH DEG-WEDGE (LBS)	STRESS (PSI)
N/A	28.1	PASS	N/A	N/A
N/A	30.0	PASS	N/A	N/A
N/A	31.0	PASS	N/A	N/A
N/A	28.5	PASS	N/A	N/A
N/A	28.0	PASS	N/A	N/A
AVERAGE VALUES FROM TESTS	29.3			

PRODUCTION LOT SIZE 67000 PCS

ROTATIONAL CAPACITY TESTED IN ACCORDANCE WITH A325, A563 AND F606 TO 360 DEGREES OF ROTATION.
SAMPLE #1 PASSED SAMPLE #2 PASSED

--VISUAL INSPECTION IN ACCORDANCE WITH ASTM A563-04a 80 PCS. SAMPLED LOT PASSED

--COATING - Hot Dip Galvanized.

1.	0.00433	2.	0.00404	3.	0.00356	4.	0.00331	5.	0.00354	6.	0.00468	7.	0.00617
8.	0.00567	9.	0.00341	10.	0.00637	11.	0.00426	12.	0.00495	13.	0.00387	14.	0.00399
15.	0.00395	16.	0.00344	17.	0.00409	18.	0.00342	19.	0.00364	20.	0.00399		

AVERAGE THICKNESS FROM 20 TESTS .00413
HEAT TREATMENT - AUSTENITIZED, OIL QUENCHED & TEMPERED (MIN 800 DEG F)

--DIMENSIONS PER ASME B18.2.6-2003

CHARACTERISTIC	#SAMPLES TESTED	MINIMUM	MAXIMUM
Width Across Corners	8	1.8190	1.8300
Thickness	32	0.9670	0.9830

ALL TESTS ARE IN ACCORDANCE WITH THE LATEST REVISIONS OF THE METHODS PRESCRIBED IN THE APPLICABLE SAE AND ASTM SPECIFICATIONS. THE SAMPLES TESTED CONFORM TO THE SPECIFICATIONS AS DESCRIBED/LISTED ABOVE AND WERE MANUFACTURED FREE OF MERCURY CONTAMINATION.
THE STEEL WAS MELTED AND MANUFACTURED IN THE U.S.A. AND THE PRODUCT WAS MANUFACTURED AND TESTED IN THE U.S.A.
WE CERTIFY THAT THIS DATA IS A TRUE REPRESENTATION OF INFORMATION PROVIDED BY THE MATERIAL SUPPLIER AND OUR TESTING LABORATORY. THIS CERTIFIED MATERIAL TEST REPORT RELATES ONLY TO THE ITEMS LISTED ON THIS DOCUMENT AND MAY NOT BE REPRODUCED EXCEPT IN FULL.

ACCREDITED

MECHANICAL FASTENER
CERTIFICATE NO. A2LA 139-01
EXPIRATION DATE 12/31/07

NUCOR FASTENER
A DIVISION OF NUCOR CORPORATION

Chris Ramer
CHRIS RAMER
QUALITY ASSURANCE SUPERVISOR

Page 1 of 1

Jun 17 2009 9:22 HP LASERJET FAX p.3

Figure A-24. BCT Cable Anchor Assembly Certificate of Compliance (Continued)

Certified Analysis

Trinity Highway Products , LLC
2548 N.E. 28th St.
Ft Worth, TX
Customer: MIDWEST MACH.& SUPPLY CO.
P. O. BOX 81097

LINCOLN, NE 68501-1097

Project: RESALE

Order Number: 1095199
Customer PO: 2041
BOL Number: 24481
Document #: 1
Shipped To: NE
Use State: KS

As of: 6/20/08

Qty	Part#	Description	Spec	CL	TY	Heat Code/ Heat #	Yield	TS	Elg	C	Mn	P	S	Si	Cu	Cb	Cr	Vn	ACW
25	6G	12/6'3/S	M-180	A		84964	64,230	81,300	25.4	0.180	0.720	0.012	0.001	0.040	0.080	0.000	0.060	0.000	4
20	701A	.25X11.75X16 CAB ANC	A-36			4153095	44,900	60,800	34.0	0.240	0.750	0.012	0.003	0.020	0.020	0.000	0.040	0.002	4
10	742G	6' 0 TUBE SL/.188X8X6	A-500			A8P1160	74,000	87,000	25.2	0.050	0.670	0.013	0.005	0.030	0.220	0.000	0.060	0.021	4
20	782G	5/8"X8"X8" BEAR PL/OF	A-36			6106195	46,700	69,900	23.5	0.180	0.830	0.010	0.005	0.020	0.230	0.000	0.070	0.006	4
40	907G	12/BUFFER/ROLLED	M-180	A		L0049	54,200	73,500	25.0	0.160	0.700	0.011	0.008	0.020	0.200	0.000	0.100	0.000	4

Upon delivery, all materials subject to Trinity Highway Products , LLC Storage Stain Policy No. LG-002.

ALL STEEL USED WAS MELTED AND MANUFACTURED IN USA AND COMPLIES WITH THE BUY AMERICA ACT.
ALL GUARDRAIL MEETS AASHTO M-180, ALL STRUCTURAL STEEL MEETS ASTM A36
ALL OTHER GALVANIZED MATERIAL CONFORMS WITH ASTM-123.
BOLTS COMPLY WITH ASTM A-307 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.
NUTS COMPLY WITH ASTM A-563 SPECIFICATIONS AND ARE GALVANIZED IN ACCORDANCE WITH ASTM A-153, UNLESS OTHERWISE STATED.

3/4" DIA CABLE 6X19 ZINC COATED SWAGED END AISI C-1035 STEEL ANNEALED STUD 1" DIA ASTM 449 AASHTO M30, TYPE II BREAKING STRENGTH – 49100 LB

State of Texas, County of Tarrant. Sworn and subscribed before me this 20th day of June, 2008

Notary Public:
Commission Expires

RACHEL R. MEDINA
Notary Public
State of Texas
My Commission Expires

Trinity Highway Products , LLC
Certified By: Stefania Ornel.a

Figure A-25. Anchor Bearing Plate Certificate of Compliance

CAUTION
FRESH CONCRETE

Body and or eye contact with fresh (moist) concrete should be avoided because it contains alkali and is caustic.

Ready Mixed Concrete Company
6200 Cornhusker Highway, P.O. Box 29288
Lincoln, Nebraska 68529
Telephone 402-434-1844

ANT	MIX CODE	YARDS	TRUCK	DRIVER	DESTINATION	CLASS	TIME	DATE	TICKET
01	13013000	1.25	0135	056	N01		01:27PM	03/05/09	1117450

ISTOMER	JOB	CUSTOMER NAME	TAX CODE	PARTIAL	NIGHT R.	LOADS
00003		COD----MIDWEST ROADSIDE				1

LIVERY ADDRESS	SPECIAL INSTRUCTIONS	P.O. NUMBER
4800 NW 35TH	N/ OF THE NO. GOODYEAR HANGER INSIDE FENCE	450-6250

LOAD QUANTITY	CUMULATIVE QUANTITY	ORDERED QUANTITY	PRODUCT CODE	PRODUCT DESCRIPTION		UNIT PRICE	AMOUNT
1.25	1.25	1.25	13013000	SG 3000	2.00	86.50	108.13
				MINIMUM HAUL			57.50
				WINTER SERVICE			5.00

TER ADDED ON JOB
CUSTOMER'S REQUEST 0 GAL

RECEIVED BY

SUBTOTAL	170.63
TAX	11.94
TOTAL	182.57

182.57

Figure A-26. Concrete Material Specification

CONCRETE INDUSTRIES, INC.
6300 Cornhusker Highway, Lincoln, NE 6 ‑0529
402-434-1800 Fax: 402-434-1899
www.ConcreteIndustries.com

Customer Receipt

Driver:
Truck #:
Ordered By: CALL

Bill To:
5 CASH SALES-CONCRETE INDUSTRIES

Ship To:
UNL MIDWEST ROADSIDE SAFETY
CURT MEYER

Ship From:
CONCRETE INDUSTRIES
6300 CORNHUSKER HWY
LINCOLN NE 68507

Delivery Directions:

09:28 Order Number: SP 1102642 0 Delivery Date: 02/10/09 Customer PO Number:

Line	Item Description	Picked	Ordered	Back Order	Units	Unit Price	Discount	Extension
1	#4 STOCK REBAR GRADE 60 20'-0" R46020		7.00		EA	6.0200		42.14
	Heat #							
	M644041							
	Gerdau Ameristeel							

Received by

Print Name/Company

Returns: No returns w/o invoice. No returns on unusable material, seconds, architectural, decorative, all special order materials, and fractional units. All returnable materials subject to 50% restocking charge. No returns accepted after 30 days from date of purchase.

Terms: All invoices must be paid within 30 days of invoice. Past due accounts will be charged an interest rate of 1.33% per month which is 16% per year.

Tax Code:CINTE Nebraska Tax Exempt
Total Weight: 93.52
Total Cubic:

Sub Total:	42.14
Sales Tax:	
Total Amount:	42.14
Down Payment:	
Balance Due:	42.14

Document: 0 0 Print Date: 02/10/09 Print Time: 09:28 Page: 1 bobb

Figure A-27. Reinforcing Steel Material Specification

GERDAU AMERISTEEL

Chemical and Physical Test Report

MADE IN UNITED STATES

ATTN CURT

M-058717

ST PAUL STEEL MILL
1678 RED ROCK ROAD
ST PAUL MN 55119 USA
(651) 731-5600

PRODUCED IN: ST PAUL

SHIP TO	INVOICE TO	SHIP DATE
CONCRETE INDUSTRIES INC 6300 CORNHUSKER HWY LINCOLN, NE 68521	CONCRETE INDUSTRIES INC PO BOX 29529 LINCOLN, NE 68529-0529	05/21/08 CUST. ACCOUNT NO 60062172

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
X13MM REBAR (# 4)	280 (40)	A615/A615M-07 Grade 40/280 A6/A6M-07	8054869-01	70692-01

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	N	Sn	Al	Ti	Ca	Zn	Co
M644041	.15	.66	.010	.030	.18	.38	.14	.13	.027	.002	.001	.0104	.013	.002	.00100	.00080	.01100	.008

Mechanical Test: Yield 49000 PSI, 337.84 MPA Tensile: 67500 PSI, 465.4 MPA %El: 25.0/8in, 25.0/203.2mm Bend: OK Red R 155.69 Std Dev:0 Id Diam: .492

Customer Requirements SOURCE: GA-STP CASTING: STRAND CAST

Comment Steel not exposed to mercury, no weld repairment performed, Melt shop heat #81491M

SHAPE + SIZE	GRADE	SPECIFICATION	SALES ORDER	CUST P.O. NUMBER
X13MM REBAR (# 4)	280 (40)	A615/A615M-07 Grade 40/280 A6/A6M-07	8054869-01	70692-01

HEAT I.D.	C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V	Nb	N	Sn	Al	Ti	Ca	Zn	Co
M644042	.16	.64	.012	.030	.19	.31	.13	.14	.027	.002	.003	.0183	.016	.002	.00200	.00020	.00700	.008

Mechanical Test: Yield 49500 PSI, 341.29 MPA Tensile: 68000 PSI, 468.84 MPA %El: 28.8/8in, 28.8/203.2mm Bend: OK Red R 155.69 Std Dev:0 Id Diam: .495

Customer Requirements SOURCE: GA-STP CASTING: STRAND CAST

Comment Steel not exposed to mercury, no weld repairment performed.
melt shop heat #81489M

This material, including the billets, was produced and manufactured in the United States of America

THE ABOVE FIGURES ARE CERTIFIED EXTRACTS FROM THE ORIGINAL CHEMICAL AND PHYSICAL TEST RECORDS AS CONTAINED IN THE PERMANENT RECORDS OF COMPANY.

Bhaskar Yalamanchili
Quality Director
Gerdau Ameristeel

Mgr. Metallurg. Svcs.
ST PAUL STEEL MILL

Seller warrants that all material furnished shall comply with specifications subject to standard published manufacturing variations. NO OTHER WARRANTIES, EXPRESSED OR IMPLIED, ARE MADE BY THE SELLER, AND SPECIFICALLY EXCLUDED ARE WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.
In no event shall seller be liable for indirect, consequential or punitive damages arising out of or related to the materials furnished by seller.
Any claim for damages for materials that do not conform to specifications must be made from buyer to seller immediately after delivery of same in order to allow the seller the opportunity to inspect the material in question.

Figure A-28. Reinforcing Steel Material Specification (Continued)

Appendix B. Vehicle Center of Gravity Determination

Test: MGSC-6 Vehicle: 2270P (RAM 1500)

Vehicle CG Determination

VEHICLE	Equipment	Weight (lb)	Long CG (in.)	Lat CG (in.)	Vert CG (in.)	Long M (lb-in.)	Lat M (lb-in.)	Vert M (lb-in.)
+	Unbalasted Truck(Curb)	5100	62.2047	-0.03985	28.74069	317244	-203.25	146577.5
+	Brake receivers/wires	6	108	0	53	648	0	318
+	Brake Frame	5	40	-19	25	200	-95	125
+	Brake Cylinder (Nitrogen)	28	73	17	28	2044	784	784
+	Strobe/Brake Battery	6	78	3	32	468	192	192
+	Hub	27	0	-41	15.125	0	-1107	408.375
+	CG Plate (EDRs)	8	54	0	31	432	0	248
-	Battery	-47	-7.5	-25	39	352.5	1175	-1833
-	Oil	-10	8.5	0	17	-85	0	-170
-	Interior	-60	52	0	22	-3120	0	-1320
-	Fuel	-161	112	-11	20	-18032	1771	-3220
-	Coolant	-21	-26	0	36	546	0	-756
-	Washer fluid	-9	-26	17	33	234	-153	-297
BALLAST	Water	110	112	-11	20	12320	-1210	2200
	DTS Rack	18	71	0	29	1278	0	522
	Misc.					0	0	0
						314529.5	1153.75	143778.9
	TOTAL WEIGHT	5000 lb			CG location (in.)	62.90589	0.23075	28.75578

wheel base 140.25

Calculated Test Inertial Weight

MASH Targets	Targets	CURRENT	Difference
Test Inertial Weight (lb)	5000 ± 110	5000	0.0
Long CG (in.)	63 ± 4	62.91	-0.09411
Lat CG (in.)	NA	0.23	NA
Vert CG (in.)	28 min.	28.76	0.75578

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)

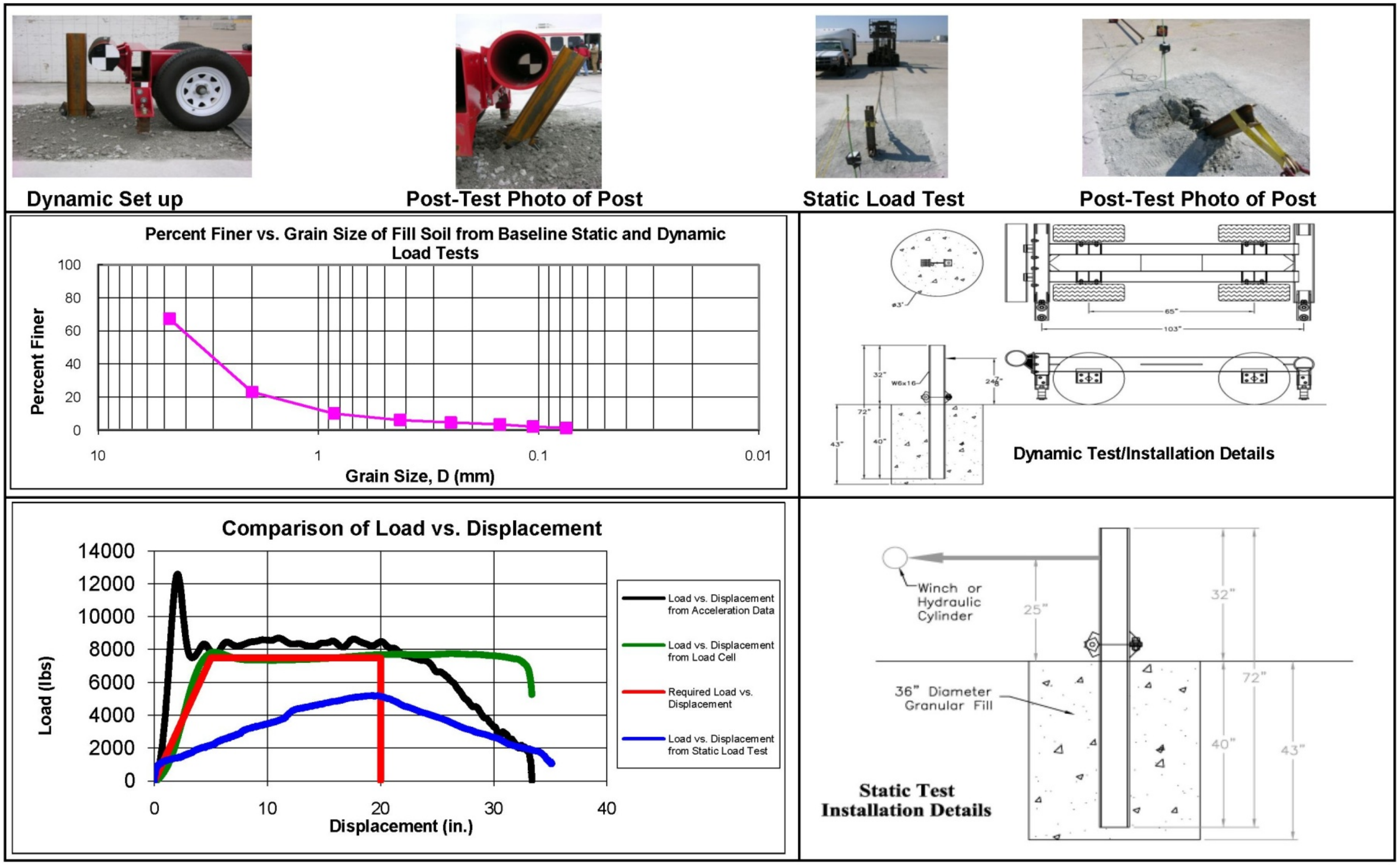
	Left	Right
Front	1416	1422
Rear	1137	1125
FRONT	2838 lb	
REAR	2262 lb	
TOTAL	5100 lb	

Actual test inertial weight (lb)
(from scales)

	Left	Right
Front	1402	1333
Rear	1084	1155
FRONT	2735 lb	
REAR	2239 lb	
TOTAL	4974 lb	

Figure B-1. Vehicle Mass Distribution, Test No. MGSC-6

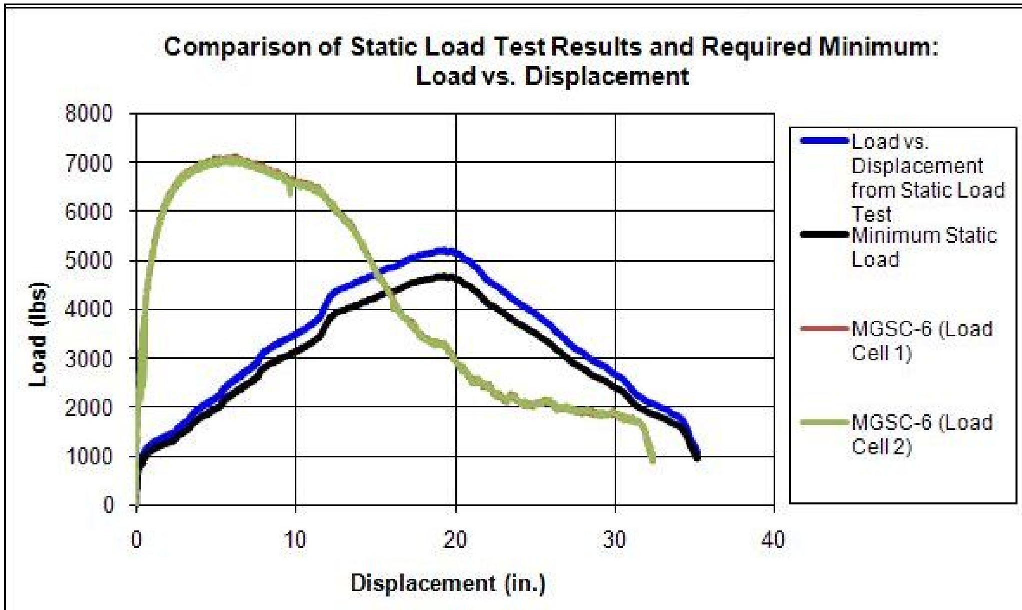
Appendix C. Static Soil Tests



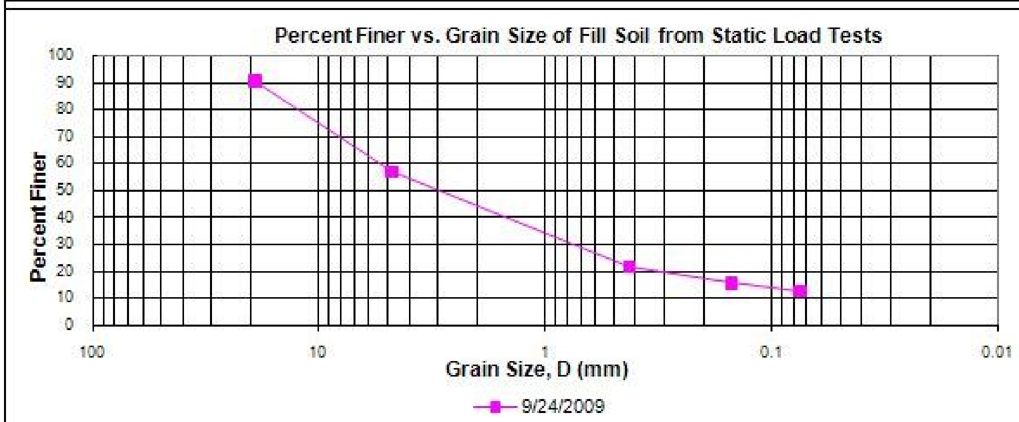
Date……………………………………………………………………	7/7/2005
Test Facility & Site Location……………………………………………	Midwest Road Side Safety Facility
In situ soil description (ASTM D2487)………………………………	Well Graded Gravel (GW)
Fill material description (ASTM D2487) & sieve analysis…………	Well Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure……………………………	6-inch lifts tamped with a pneumatic compactor
Bogie Weight…………………………………………………………	1605 lbs
Impact Velocity………………………………………………………	19.08 mph

Figure C-1. Soil Strength, Initial Calibration Tests

November 24, 2010
MwRSF Report No. TRP-03-237-10



Static Load Test Setup



Post-Test Photo of Post

Date	11/10/2009
Test Facility & Site Location	Midwest Road Side Safety Facility
In situ soil description (ASTM D2487)	Well Graded Gravel (GW)
Fill material description (ASTM D2487) & sieve analysis	Well Graded Gravel (GW) (see sieve analyses above)
Description of fill placement procedure	8-inch lifts tamped with a pneumatic compactor

Figure C-2. Static Soil Test, Test No. MGSC-6

November 24, 2010
MwRSF Report No. TRP-03-237-10

Appendix D. Vehicle Deformation Records

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 1

TEST: MGSC-6
VEHICLE: 2270P (RAM 1500)

Note: If impact is on driver side need to enter negative number for Y

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
1	26.25	10.5	0	26.5	11	0	0.25	0.5	0
2	29.5	15.25	-1	29.5	15.75	-1	0	0.5	0
3	32	20.75	-1.5	31.75	21	-1.5	-0.25	0.25	0
4	30.75	27.75	0	30.5	28	0	-0.25	0.25	0
5	24.75	12.25	-1.25	25	12.25	-1	0.25	0	0.25
6	26.5	18.75	-6.25	26.25	18	-6.25	-0.25	-0.75	0
7	26.5	24.75	-6.25	26.5	24.25	-6	0	-0.5	0.25
8	26.5	30	-5.5	26.5	29.5	-5.5	0	-0.5	0
9	19	7.5	-2	19.25	7.75	-2.25	0.25	0.25	-0.25
10	20.5	13.25	-5.25	20.75	13.75	-5.25	0.25	0.5	0
11	22	19.75	-9	22	20.25	-8.75	0	0.5	0.25
12	22.25	28.25	-8.75	22	28.25	-8.5	-0.25	0	0.25
13	14	3.75	-2.75	14	3.75	-3	0	0	-0.25
14	14	7.25	-2.75	13.75	7.25	-2.75	-0.25	0	0
15	16.5	13	-9.25	16.5	13.75	-9.25	0	0.75	0
16	16.75	21.25	-9.25	16.75	22	-9.25	0	0.75	0
17	16.75	28.5	-9	16.75	28.75	-9	0	0.25	0
18	8.75	3.75	-3.25	8.75	3.75	-3.25	0	0	0
19	12.5	11.5	-9.5	12.5	12	-9.5	0	0.5	0
20	12.5	17.5	-9.25	12.5	18.25	-9.25	0	0.75	0
21	12.75	25	-9.25	12.75	25.75	-9.25	0	0.75	0
22	5.25	7	-3.5	5.25	7	-3.5	0	0	0
23	7	17.25	-9.25	6.75	17.75	-9.5	-0.25	0.5	-0.25
24	7.25	27.25	-9	7	27.75	-9	-0.25	0.5	0
25	0.75	4	-2.75	0.75	4	-2.75	0	0	0
26	0.75	11.5	-5	0.75	11.5	-5	0	0	0
27	1	19.5	-5	1	19.25	-4.75	0	-0.25	0.25
28	1	26.75	-4.75	1	26.5	-4.75	0	-0.25	0
29							0	0	0
30							0	0	0
31							0	0	0

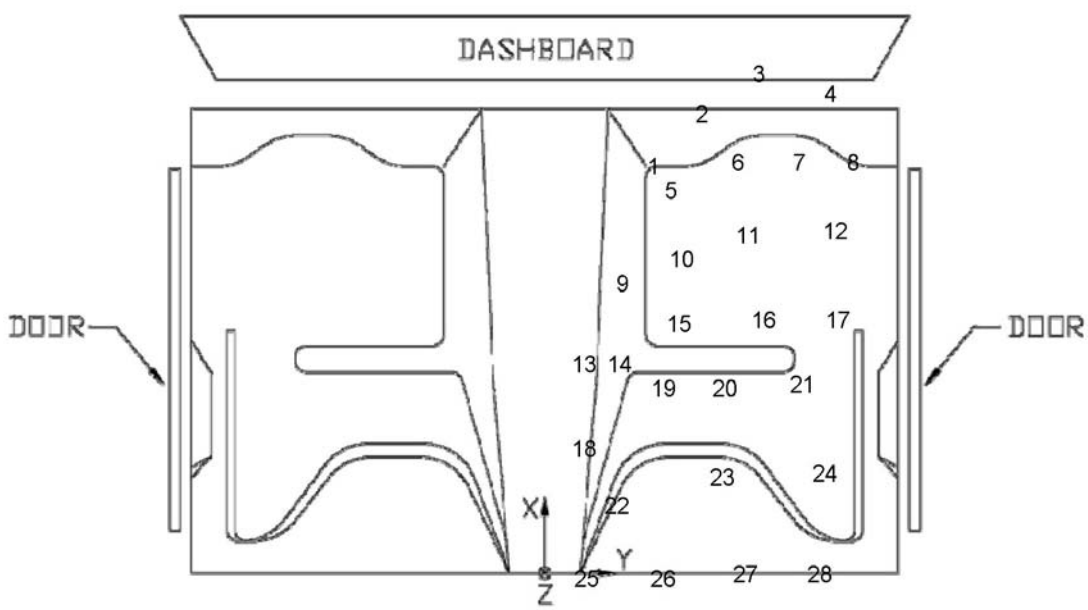


Figure D-1. Floor Pan Deformation Data – Set 1, Test No. MGSC-6

VEHICLE PRE/POST CRUSH
FLOORPAN - SET 2

TEST: MGSC-6
VEHICLE: 2270P (RAM 1500)

Note: If impact is on driver side need to enter negative number for Y

POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
1	49	17	0	48.75	17.75	0	-0.25	0.75	0
2	52	22	-1.25	52	22.5	-1	0	0.5	0.25
3	54.75	28.25	-1.5	54.75	28.25	-1.5	0	0	0
4	53.25	34.75	0	53.25	35	0	0	0.25	0
5	47.5	18.5	-1.25	47.5	19	-1	0	0.5	0.25
6	49.25	24.75	-6.25	49.25	25	-6.25	0	0.25	0
7	49.5	30.5	-6.25	49.5	31	-6.25	0	0.5	0
8	49.25	37	-5.5	49.5	36.25	-5.5	0.25	-0.75	0
9	42	14	-2.25	42	14.25	-2.25	0	0.25	0
10	43.5	20.25	-5.25	43.5	20.5	-5.25	0	0.25	0
11	45	26.25	-9	45	27	-9	0	0.75	0
12	45	35.5	-8.75	45	35	-8.75	0	-0.5	0
13	36.75	10.5	-3	37	10.5	-3	0.25	0	0
14	37	14.25	-3	36.75	14.25	-3	-0.25	0	0
15	39.5	20	-9.5	39.5	20.5	-9.25	0	0.5	0.25
16	39.75	28.25	-9.25	39.75	28.75	-9.25	0	0.5	0
17	39.75	36	-9.25	39.75	36	-9.25	0	0	0
18	32	10.5	-3.5	31.75	10.75	-3.5	-0.25	0.25	0
19	34.75	18.5	-9.75	34.5	18.75	-9.75	-0.25	0.25	0
20	35	24.75	-9.5	34.75	25.25	-9.5	-0.25	0.5	0
21	35	32	-9.25	34.75	32.75	-9.25	-0.25	0.75	0
22	28.25	13.75	-3.25	28.5	13.75	-3.75	0.25	0	-0.5
23	30	24.25	-9.25	29.5	24.5	-9.25	-0.5	0.25	0
24	30.75	34	-9	30	34.5	-9	-0.75	0.5	0
25	23.75	11	-3	23.75	10.75	-3	0	-0.25	0
26	23.5	18.5	-5.25	23.5	18.5	-5.25	0	0	0
27	24	26.25	-5	24	26.25	-5	0	0	0
28	24	33.75	-4.75	24	33.5	-4.75	0	-0.25	0
29							0	0	0
30							0	0	0
31							0	0	0

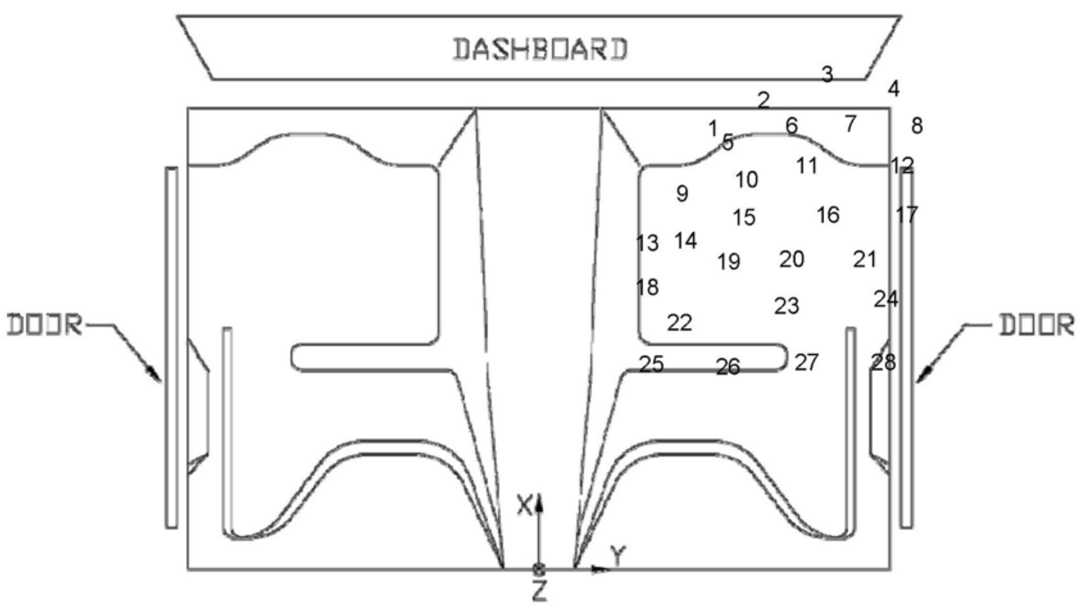


Figure D-2. Floor Pan Deformation Data – Set 2, Test No. MGSC-6

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 1

TEST: MGSC-6
VEHICLE: 2270P (RAM 1500)

Note: If impact is on driver side need to enter negative number for Y

	POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
DASH	A1	12	1.5	21.5	11.75	1.5	21.75	-0.25	0	0.25
	A2	12	11.5	21.75	11.75	11.5	21.5	-0.25	0	-0.25
	A3	12	21	21	12	20.25	21	0	-0.75	0
	A4	9.5	1.5	15	9.75	1.5	15	0.25	0	0
	A5	9.75	11.5	15.5	9.75	11	15.25	0	-0.5	-0.25
	A6	10.25	21	15.5	10.25	20.75	15.5	0	-0.25	0
SIDE PANEL	B1	23	23.25	0.25	23	23.25	0.5	0	0	0.25
	B2	19.25	23.25	-3.5	19	23.25	-3.5	-0.25	0	0
	B3	17.5	23.25	1	17.5	23.25	1	0	0	0
IMPACT SIDE DOOR	C1		25.5	17.25		26	17.25	0	0.5	0
	C2		25.5	17.75		26	17.75	0	0.5	0
	C3		25.5	18.25		26	18.25	0	0.5	0
	C4		24.75	0.5		25	0.5	0	0.25	0
	C5		25	3.75		25.25	3.75	0	0.25	0
	C6		25	3.75		25.25	3.75	0	0.25	0
ROOF	D1							0	0	0
	D2							0	0	0
	D3							0	0	0
	D4	Not needed due to low probability of damge						#VALUE!	0	0
	D5							0	0	0
	D6							0	0	0
	D7							0	0	0
	D8							0	0	0
	D9							0	0	0
	D10							0	0	0
	D11							0	0	0
	D12							0	0	0
	D13							0	0	0
	D14							0	0	0
	D15							0	0	0

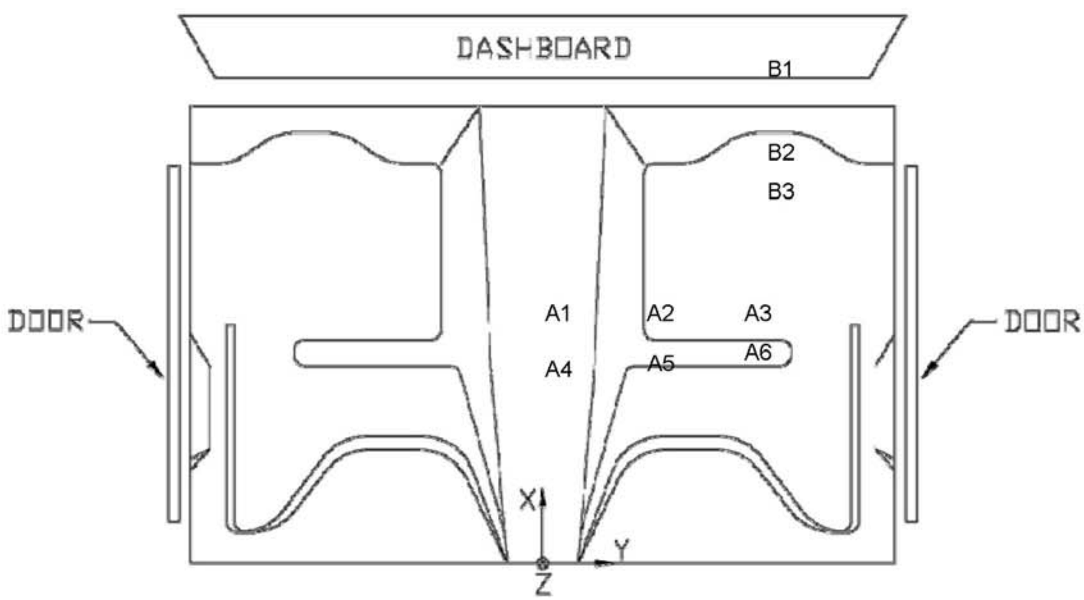


Figure D-3. Occupant Compartment Deformation Data – Set 1, Test No. MGSC-6

VEHICLE PRE/POST CRUSH
INTERIOR CRUSH - SET 2

TEST: MGSC-6
VEHICLE: 2270P (RAM 1500)

Note: If impact is on driver side need to enter negative number for Y

	POINT	X (in.)	Y (in.)	Z (in.)	X' (in.)	Y' (in.)	Z' (in.)	ΔX (in.)	ΔY (in.)	ΔZ (in.)
DASH	A1	29.5	18.5	21.25	30	18.5	21.5	0.5	0	0.25
	A2	29.5	28.5	21.5	29.5	28.75	21.25	0	0.25	-0.25
	A3	29.5	37.5	21	29.5	38	21	0	0.5	0
	A4	27.25	19	15	27.5	18.75	14.75	0.25	-0.25	-0.25
	A5	27.5	27.75	15.25	27.5	28.5	15	0	0.75	-0.25
	A6	27.5	37.75	15.5	27.75	38.5	15.5	0.25	0.75	0
SIDE PANEL	B1	40	41.75	0.25	40	41.5	0.5	0	-0.25	0.25
	B2	36.25	41.75	-3.75	36	41.5	-3.75	-0.25	-0.25	0
	B3	34.75	41.75	1	34.75	41.5	1	0	-0.25	0
IMPACT SIDE DOOR	C1	24.25	43	17.25	24.25	43.5	17	0	0.5	-0.25
	C2	12.5	43.25	17.5	12.25	43.75	17.5	-0.25	0.5	0
	C3	1.25	43.25	18	1	43.75	18	-0.25	0.5	0
	C4	25.75	43.25	0.25	25.25	43.25	0.5	-0.5	0	0.25
	C5	15.5	43.25	3.5	15.25	43.25	3.5	-0.25	0	0
	C6	3	43.5	3.5	3	43.25	3.5	0	-0.25	0
ROOF	D1							0	0	0
	D2							0	0	0
	D3							0	0	0
	D4	Not needed due to low probability of damge						#VALUE!	0	0
	D5							0	0	0
	D6							0	0	0
	D7							0	0	0
	D8							0	0	0
	D9							0	0	0
	D10							0	0	0
	D11							0	0	0
	D12							0	0	0
	D13							0	0	0
	D14							0	0	0
	D15							0	0	0

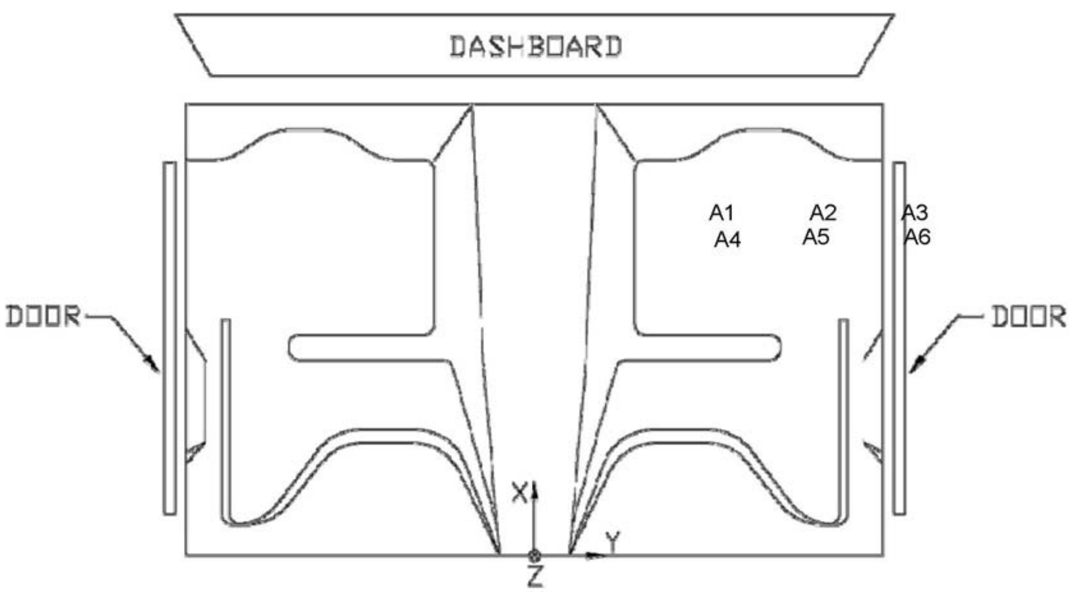
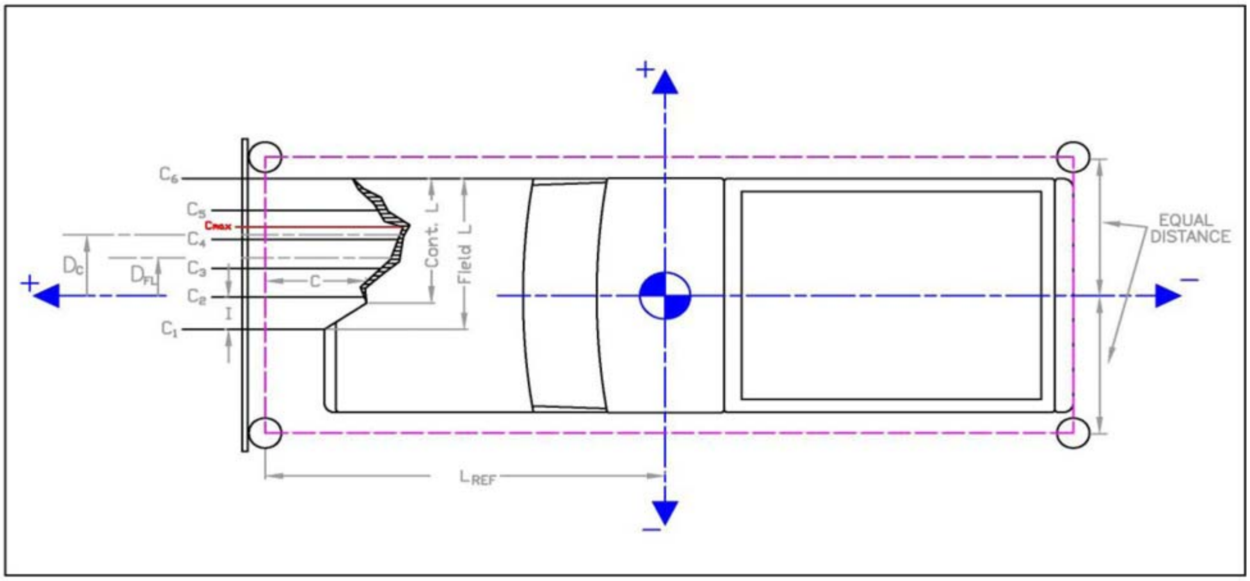


Figure D-4. Occupant Compartment Deformation Data – Set 2, Test No. MGSC-6

Date:	11/23/2009	**Test Number:**	MGSC-6		
Make:	Dodge	**Model:**	2270P (RAM 1500)	**Year:**	2003



	in.	(mm)
Distance from C.G. to reference line - L_{REF}:	110	(2794)
Width of contact and induced crush - Field L:	21.5	(546)
Crush measurement spacing interval (L/5) - I:	4.3	(109)
Distance from center of vehicle to center of Field L - D_{FL}:	28.25	(718)
Width of Contact Damage:	21.5	(546)
Distance from center of vehicle to center of contect damage - D_C:	28.25	(718)

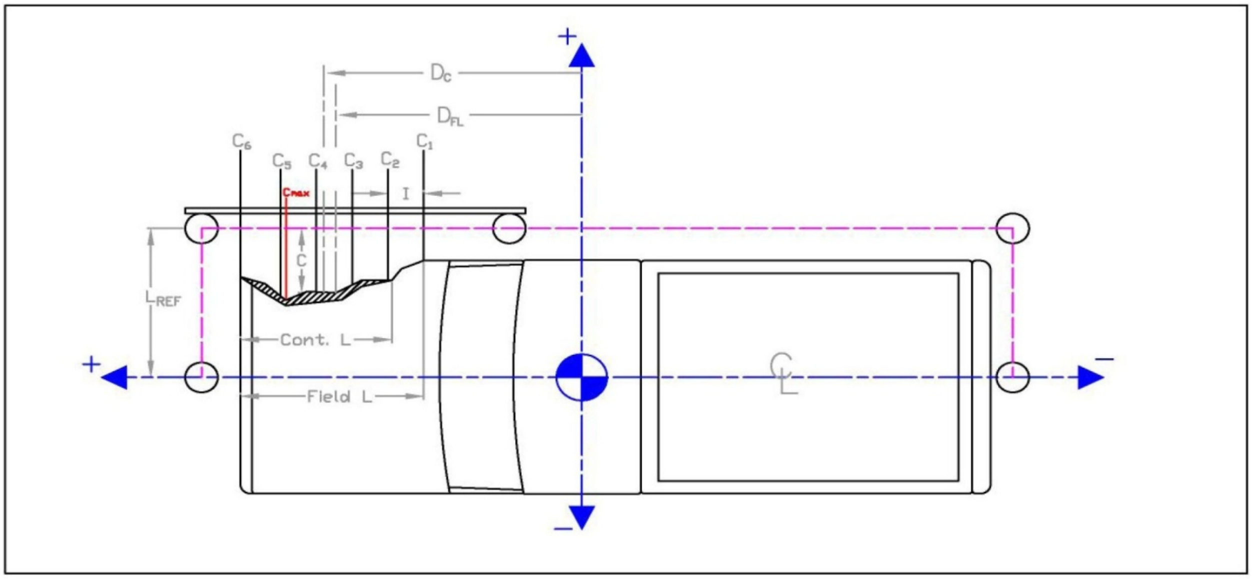
NOTE: Enter "NA" for crush measurement if distance can not be measured (i.e., side of vehicle has been pushed inward)

	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	8.75	(222)	17.5	(445)	12.0313	(306)	-2.655892	-(67)	-0.625358	-(16)
C_2	11	(279)	21.8	(554)	12.9375	(329)			0.718392	(18)
C_3	16	(406)	26.1	(663)	14.5	(368)			4.155892	(106)
C_4	23.5	(597)	30.4	(772)	16.2969	(414)			9.859017	(250)
C_5	NA	#VALUE!	34.7	(881)	19.9375	(506)			#VALUE!	#VALUE!
C_6	NA	#VALUE!	39	(991)	29	(737)			#VALUE!	#VALUE!
C_{MAX}	28.25	(718)	35	(889)	20.625	(524)			10.28089	(261)

Figure D-5. Exterior Vehicle Crush (NASS) - Front, Test No. MGSC-6

Date: 11/23/2009 **Test Number:** MGSC-6

Make: Dodge **Model:** 2270P (RAM 1500) **Year:** 2003



	in.	(mm)
Distance from centerline to reference line - L_{REF}:	46.25	(1175)
Width of contact and induced crush - Field L:	227	(5766)
Crush measurement spacing interval (L/5) - I:	45.4	(1153)
Distance from vehicle c.g. to center of Field L - D_{FL}:	-11.34	-(288)
Width of Contact Damage:	227	(5766)
Distance from vehicle c.g. to center of contect damage - D_C:	11.34	(288)

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 remeoved)

	Crush Measurement		Longitudinal Location		Original Profile Measurement		Dist. Between Ref. Lines		Actual Crush	
	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)	in.	(mm)
C_1	NA	#VALUE!	-124.84	-(3171)	14.75	(375)	-3.75	-(95)	#VALUE!	#VALUE!
C_2	10	(254)	-79.44	-(2018)	10.5	(267)			3.25	(83)
C_3	7.75	(197)	-34.04	-(865)	11.60417	(295)			-0.10417	-(3)
C_4	7.5	(191)	11.36	(289)	11.25	(286)			0	()
C_5	NA	#VALUE!	56.76	(1442)	10.5	(267)			#VALUE!	#VALUE!
C_6	NA	#VALUE!	102.16	(2595)	37	(940)			#VALUE!	#VALUE!
C_{MAX}	16	(406)	76.75	(1949)	10.875	(276)			8.875	(225)

Figure D-6. Exterior Vehicle Crush (NASS) - Side, Test No. MGSC-6

Appendix E. Accelerometer and Rate Transducer Data Plots, Test No. MGSC-6

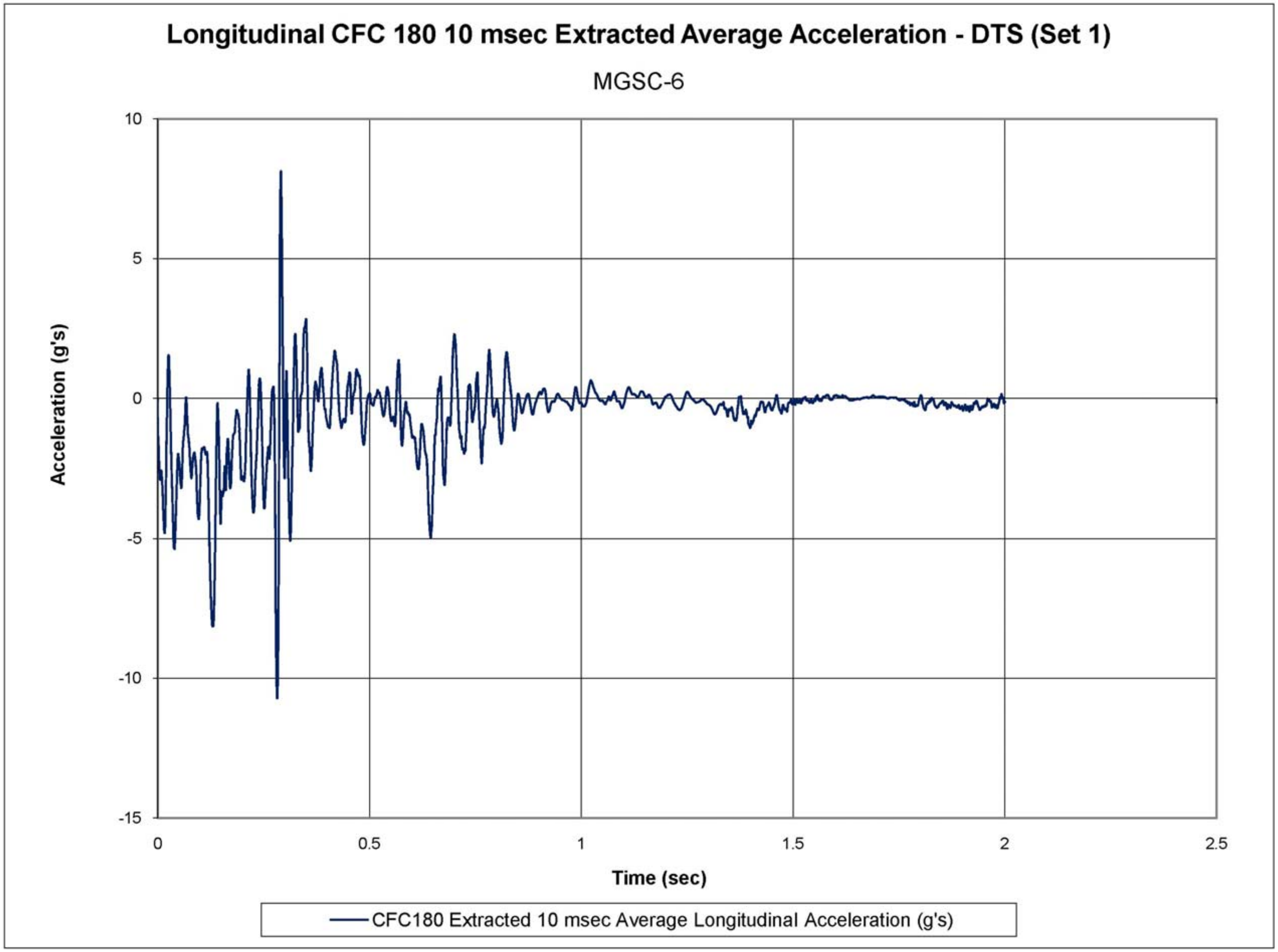


Figure E-1. 10-ms Average Longitudinal Deceleration (DTS, Set 1), Test No. MGSC-6

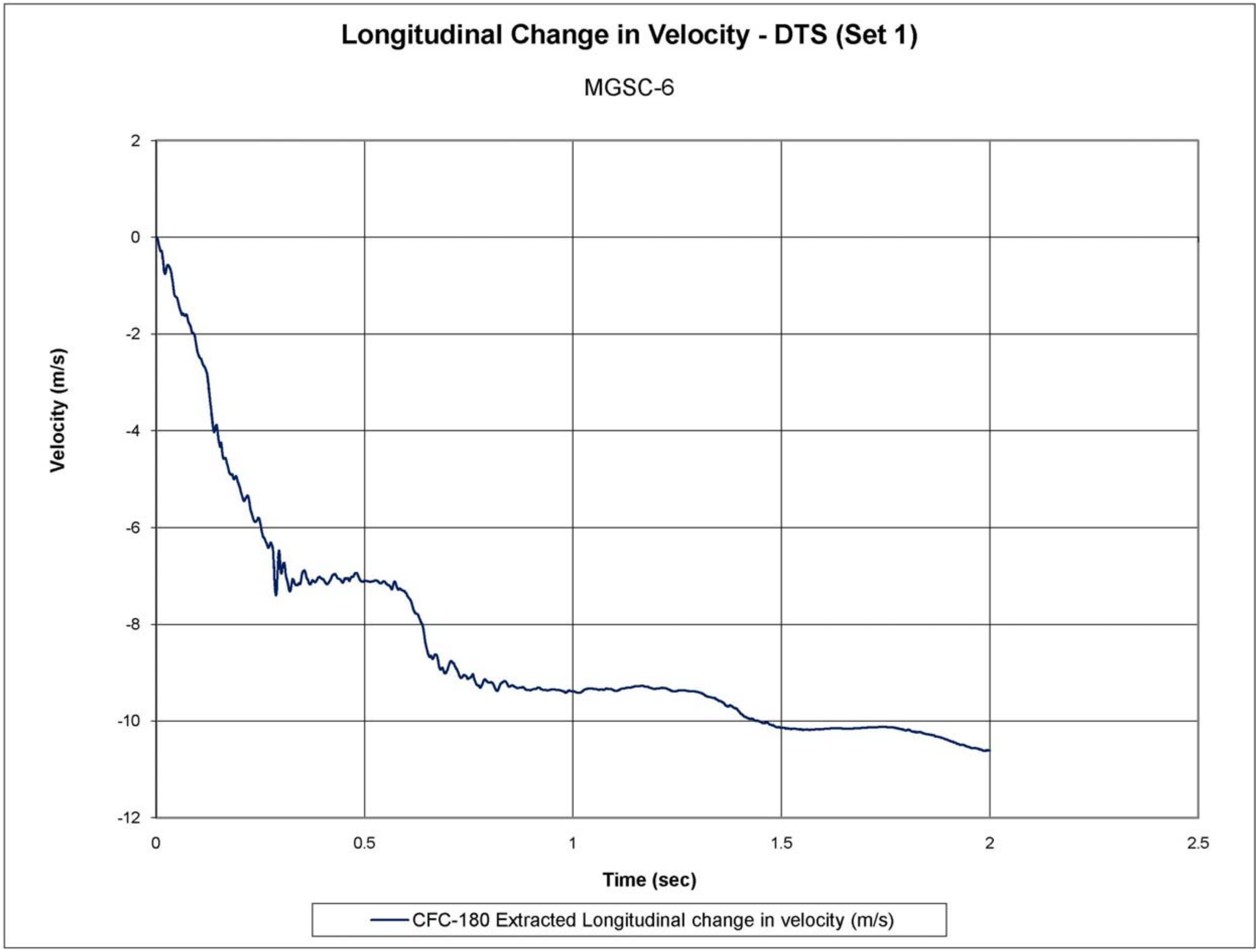


Figure E-2. Longitudinal Occupant Impact Velocity (DTS, Set 1), Test No. MGSC-6

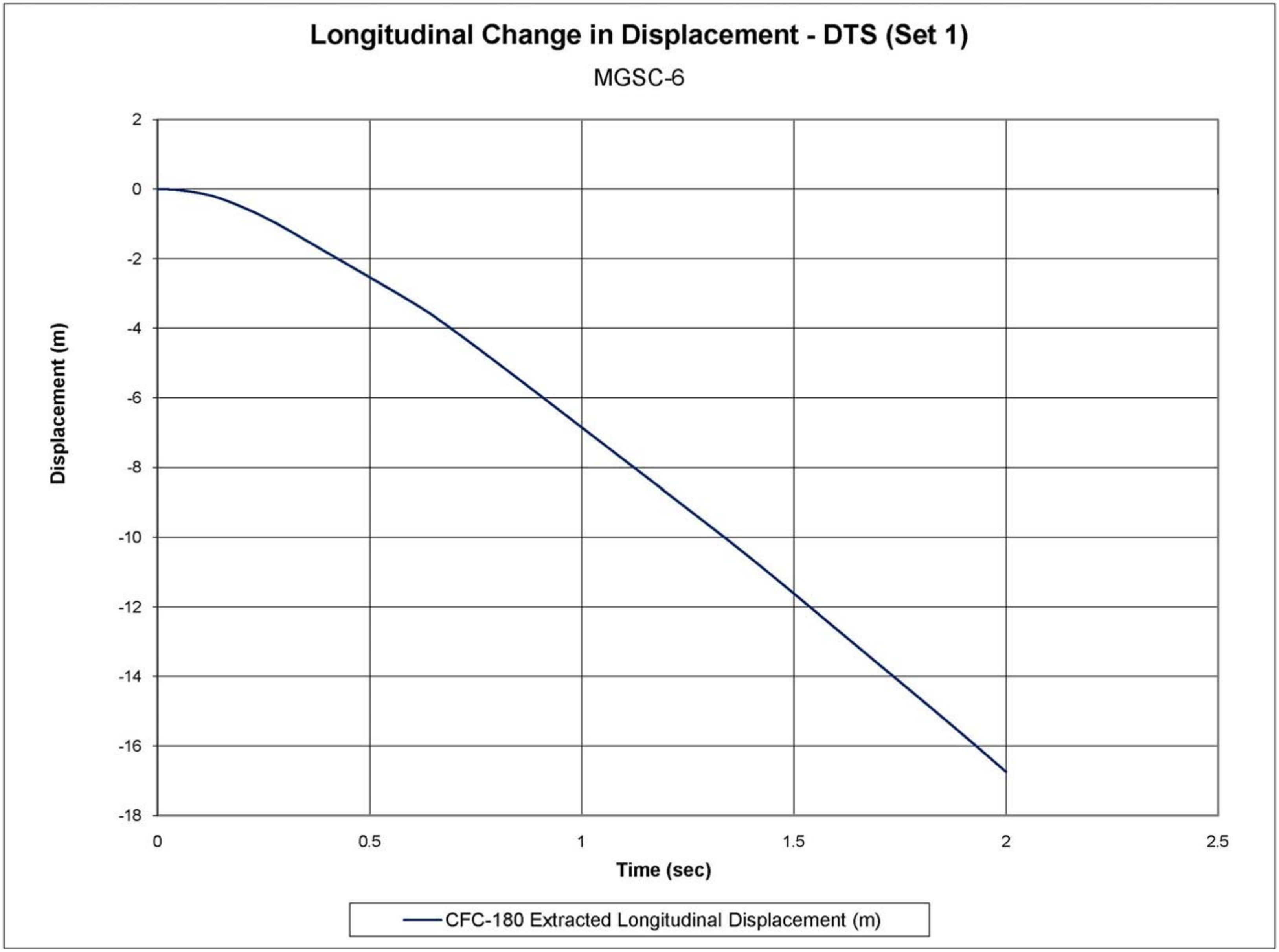


Figure E-3. Longitudinal Occupant Displacement (DTS, Set 1), Test No. MGSC-6

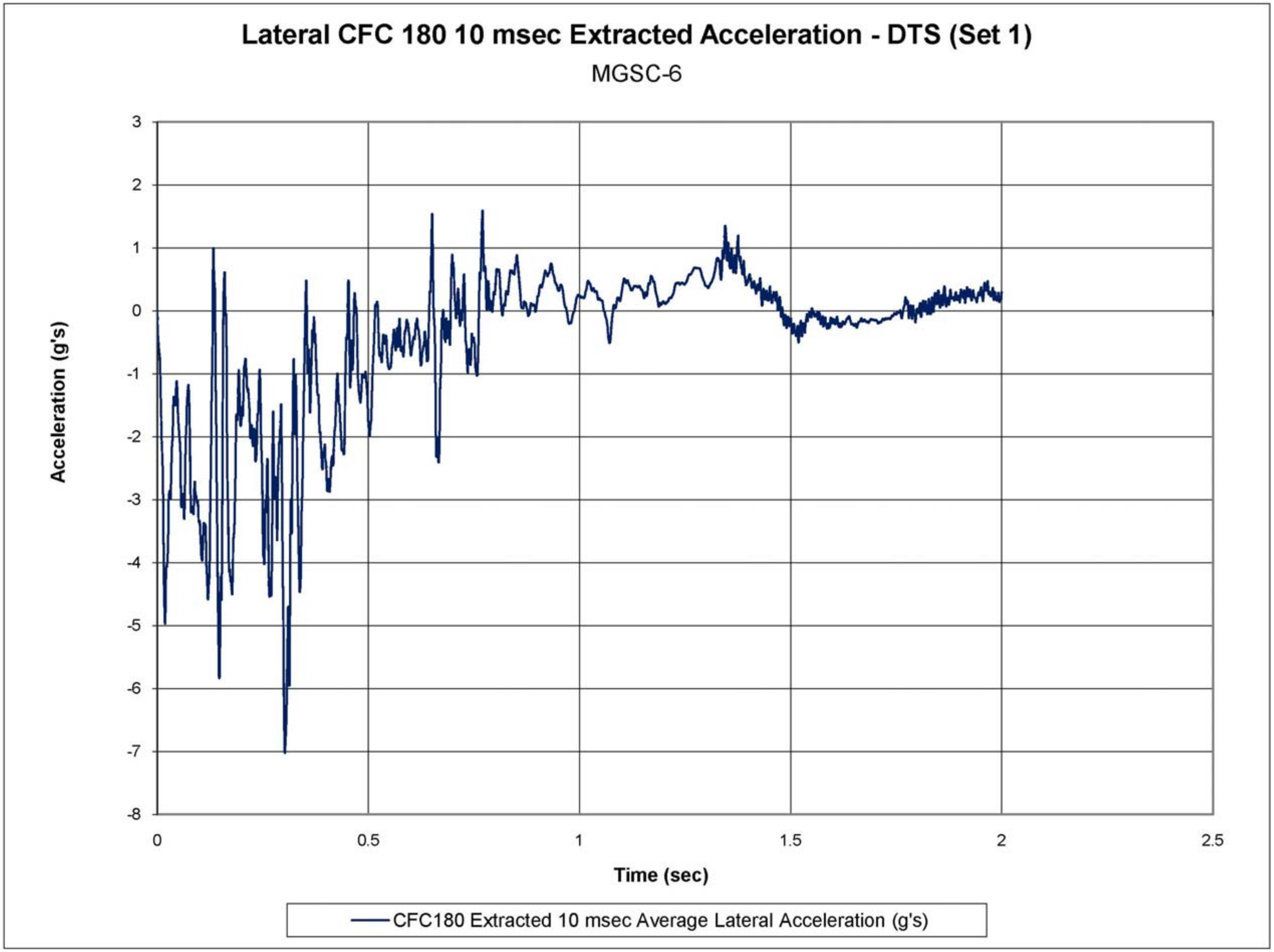


Figure E-4. 10-ms Average Lateral Deceleration (DTS, Set 1), Test No. MGSC-6

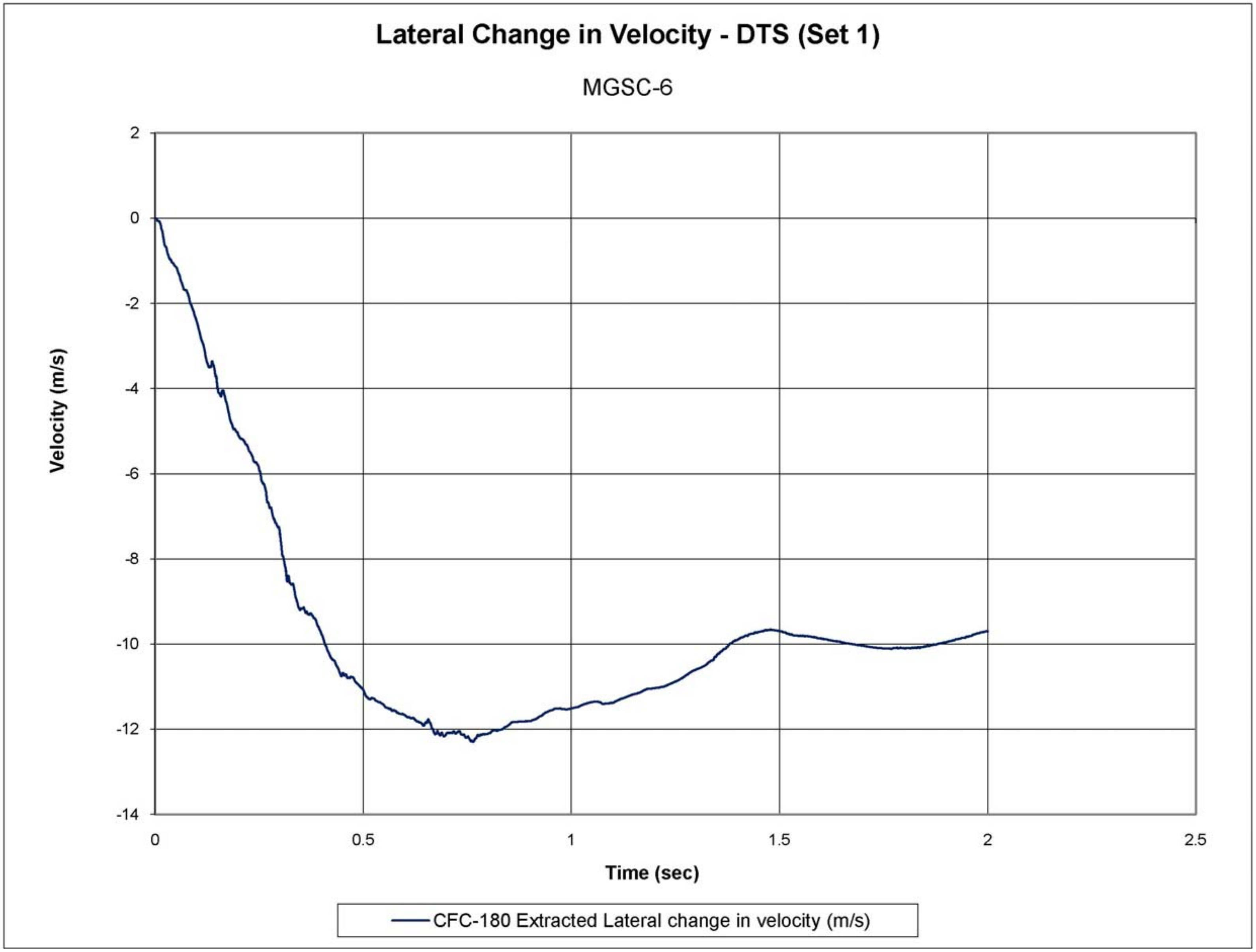


Figure E-5. Lateral Occupant Impact Velocity (DTS, Set 1), Test No. MGSC-6

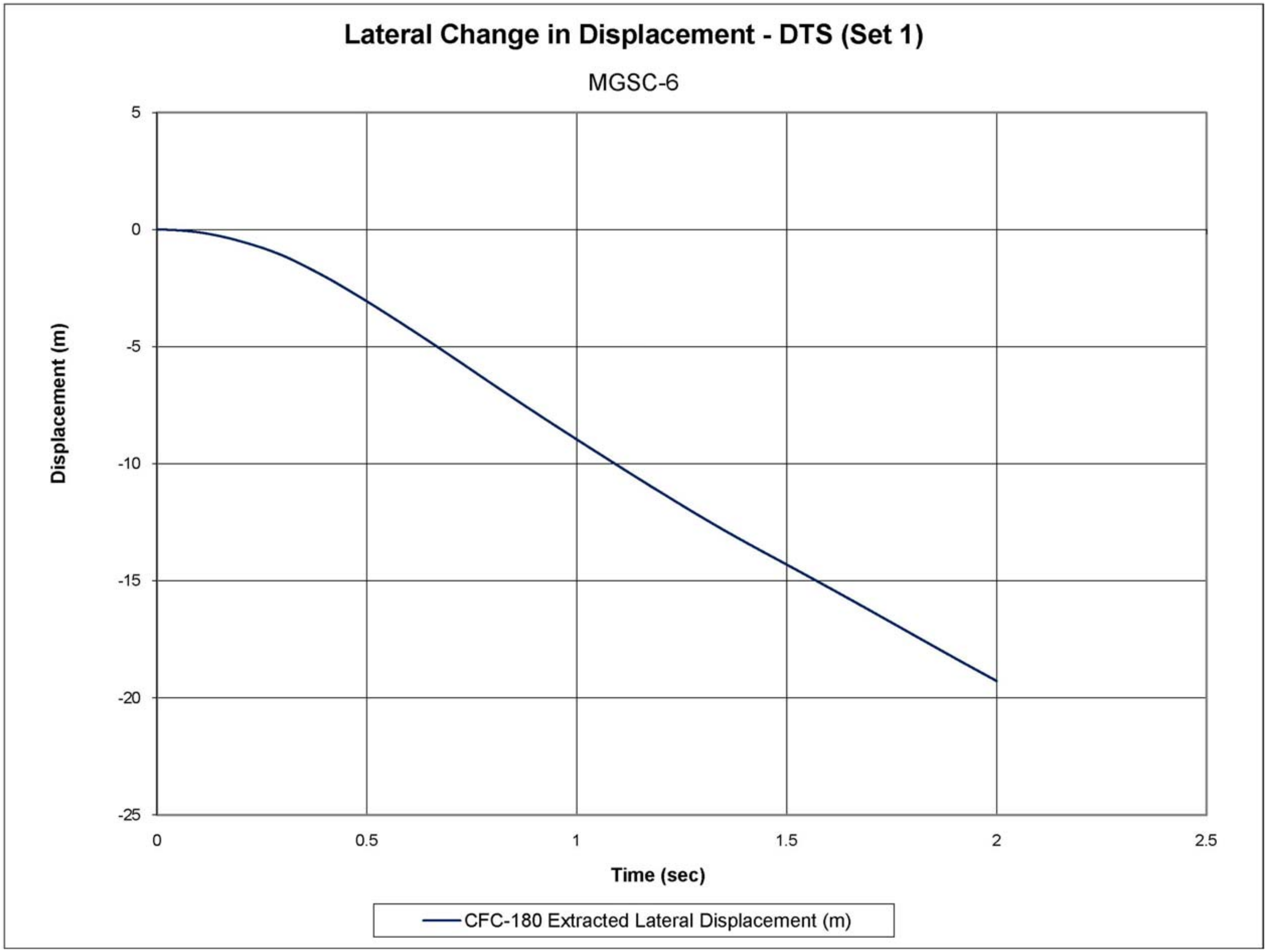


Figure E-6. Lateral Occupant Displacement (DTS, Set 1), Test No. MGSC-6

Figure E-7. Vehicle Angular Displacements (DTS), Test No. MGSC-6

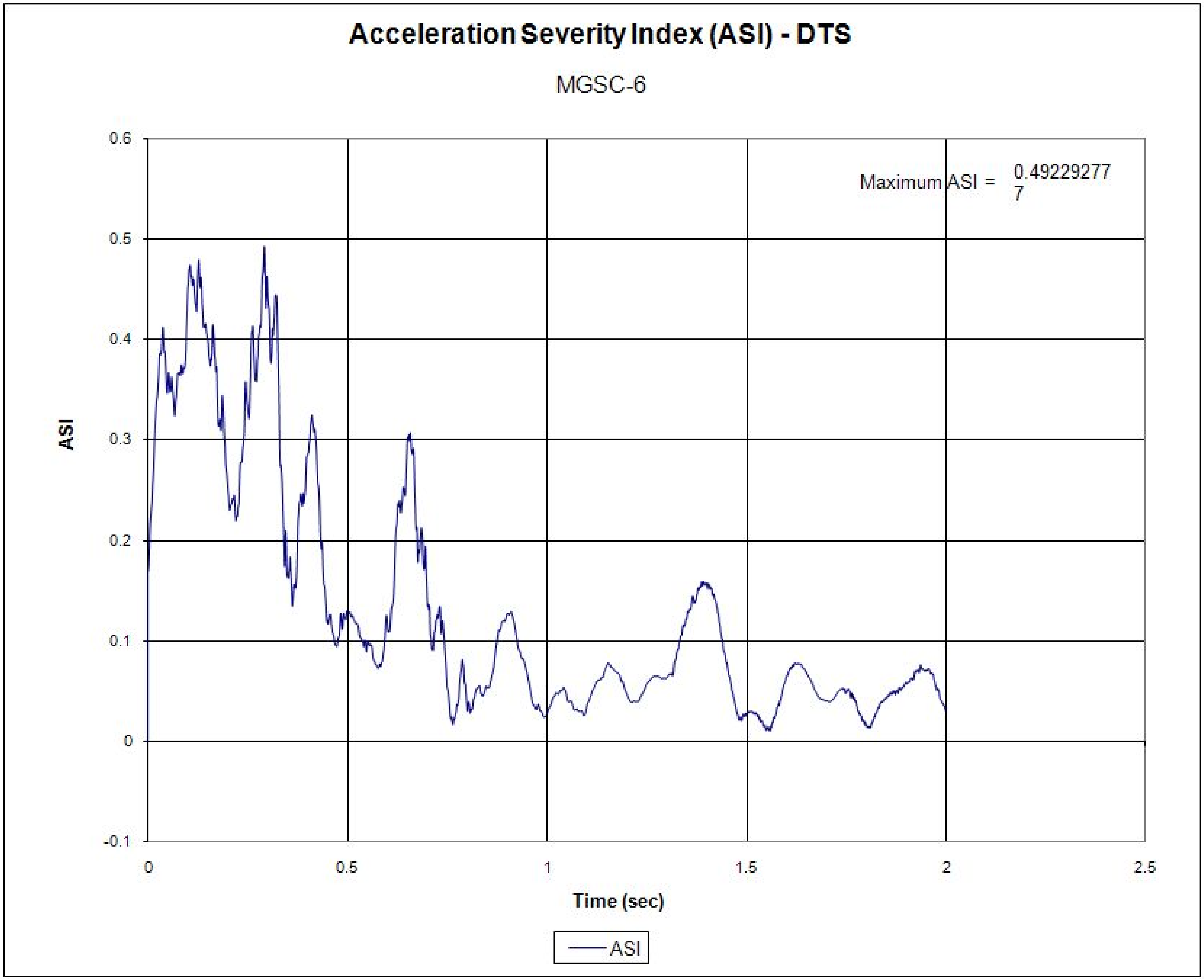


Figure E-8. Acceleration Severity Index (DTS Set 1), Test No. MGSC-6

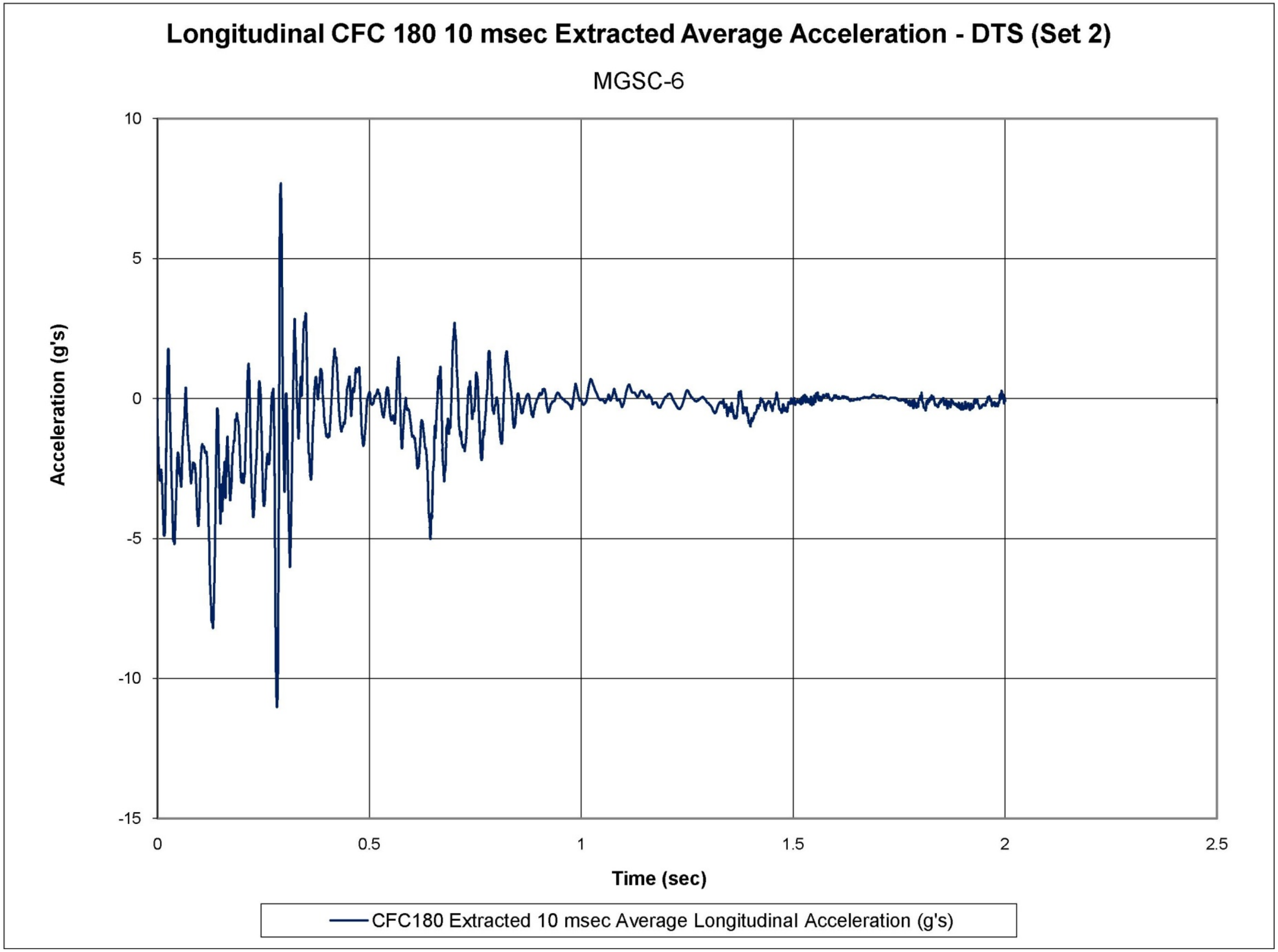


Figure E-9. 10-ms Average Longitudinal Deceleration (DTS, Set 2), Test No. MGSC-6

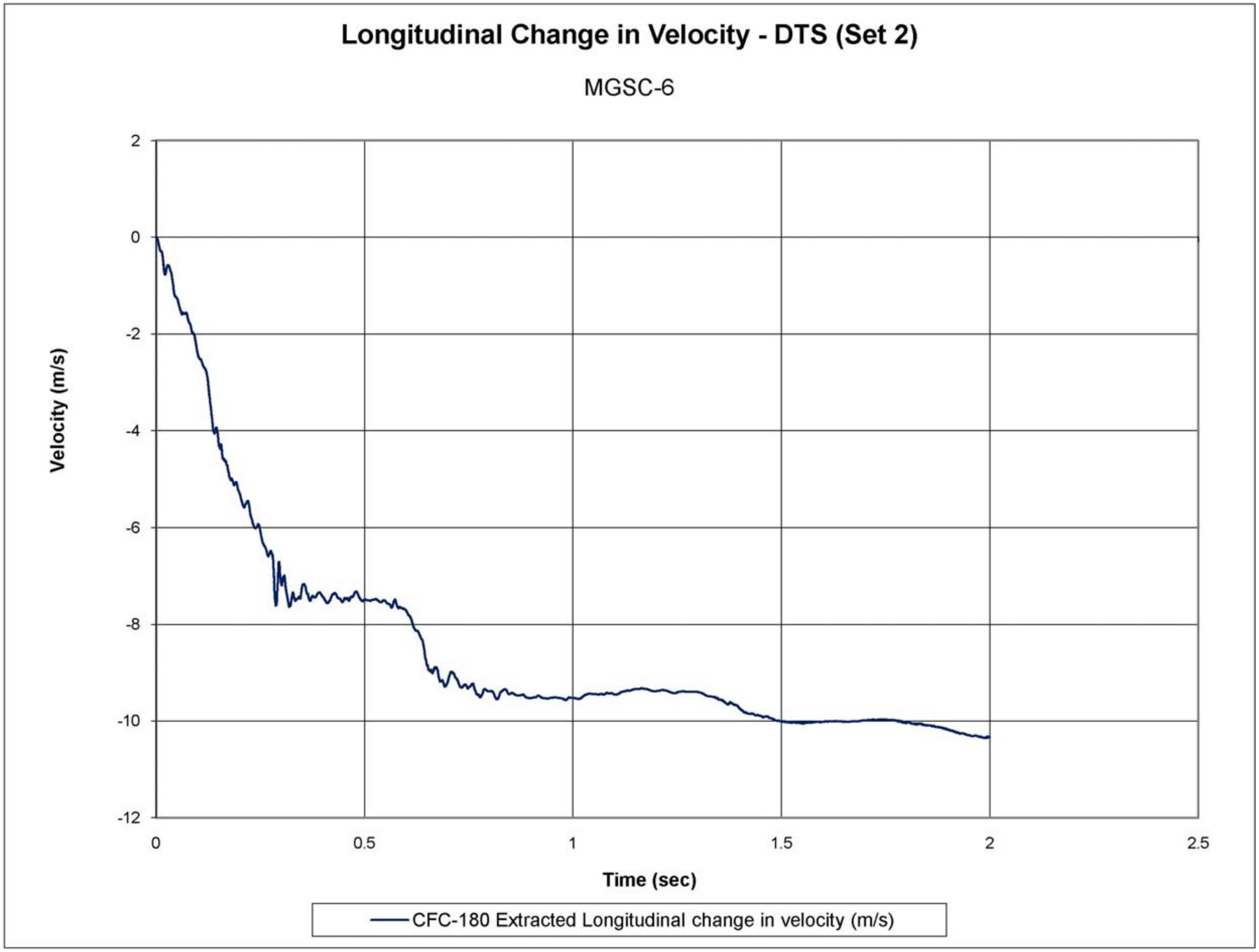


Figure E-10. Longitudinal Occupant Impact Velocity (DTS, Set 2), Test No. MGSC-6

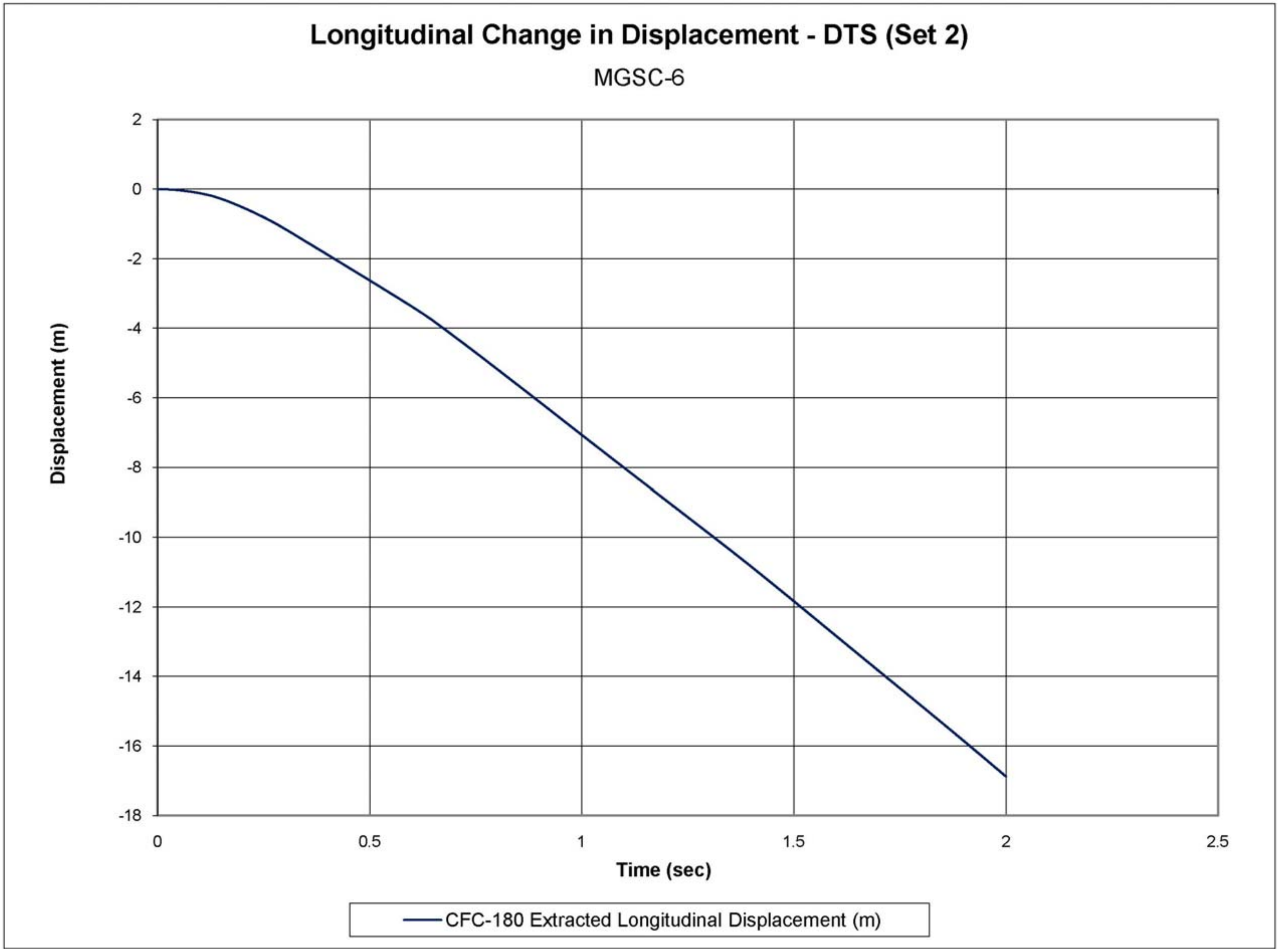


Figure E-11. Longitudinal Occupant Displacement (DTS, Set 2), Test No. MGSC-6

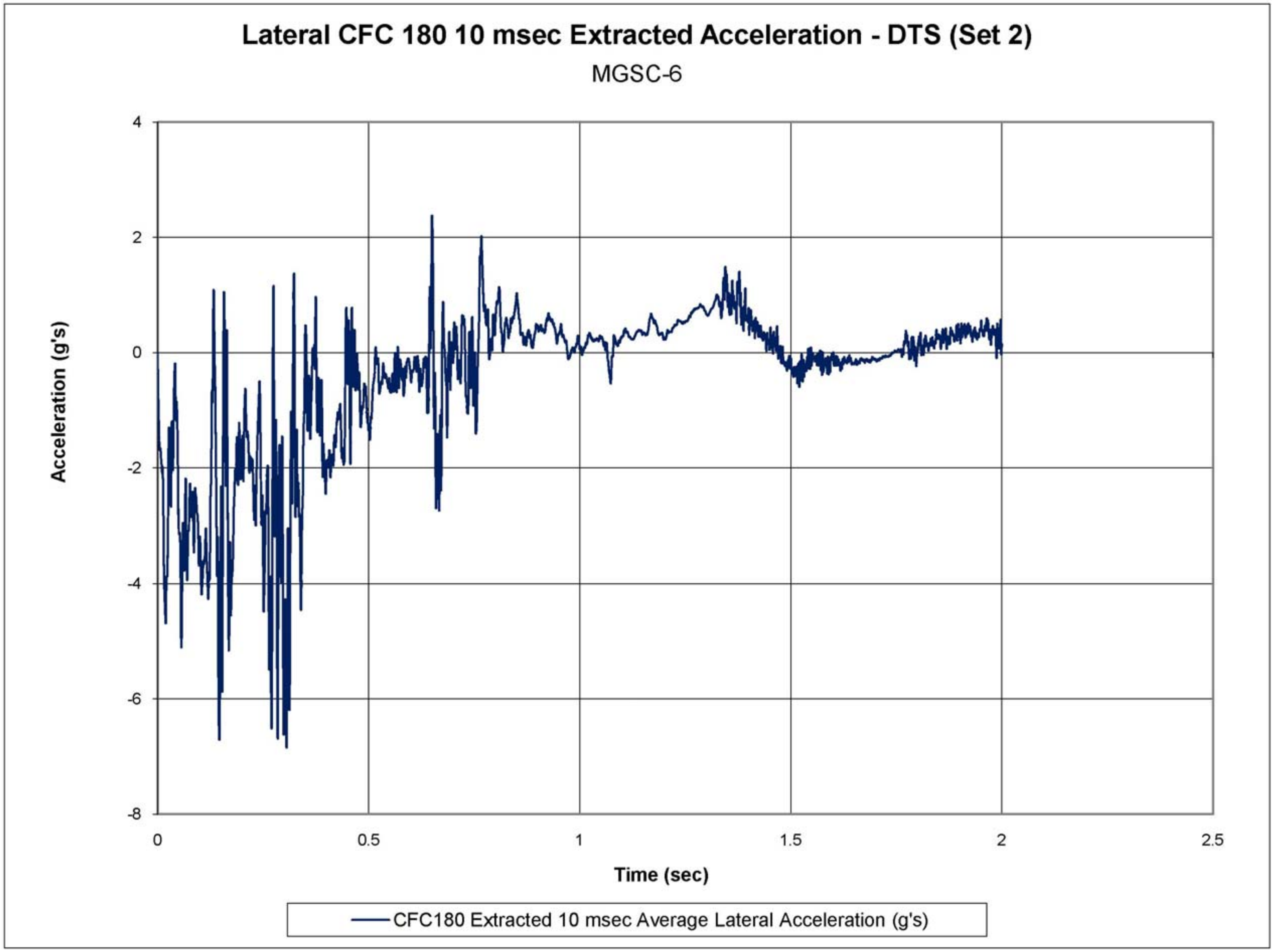


Figure E-12. 10-ms Average Lateral Deceleration (DTS, Set 2), Test No. MGSC-6

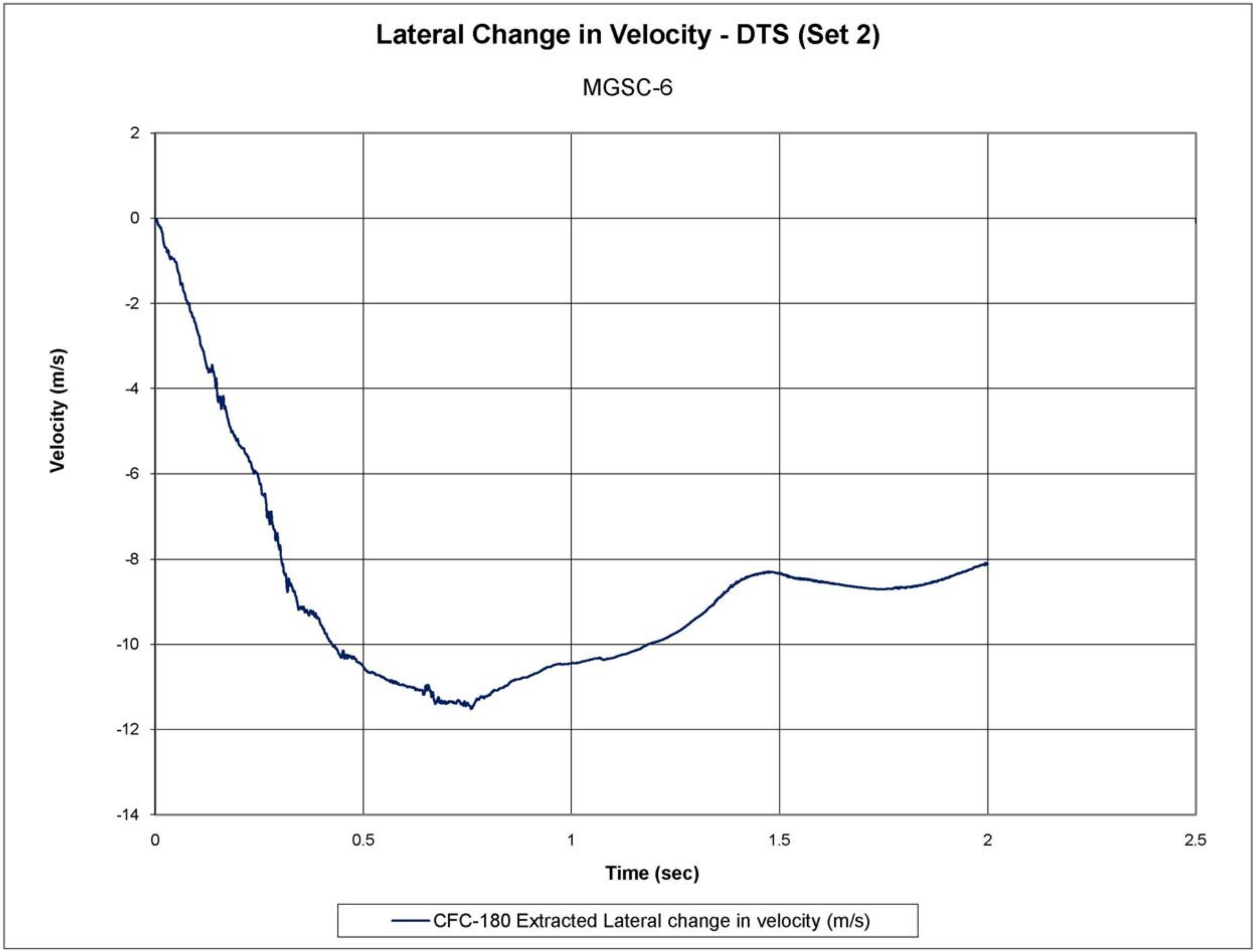


Figure E-13. Lateral Occupant Impact Velocity (DTS, Set 2), Test No. MGSC-6

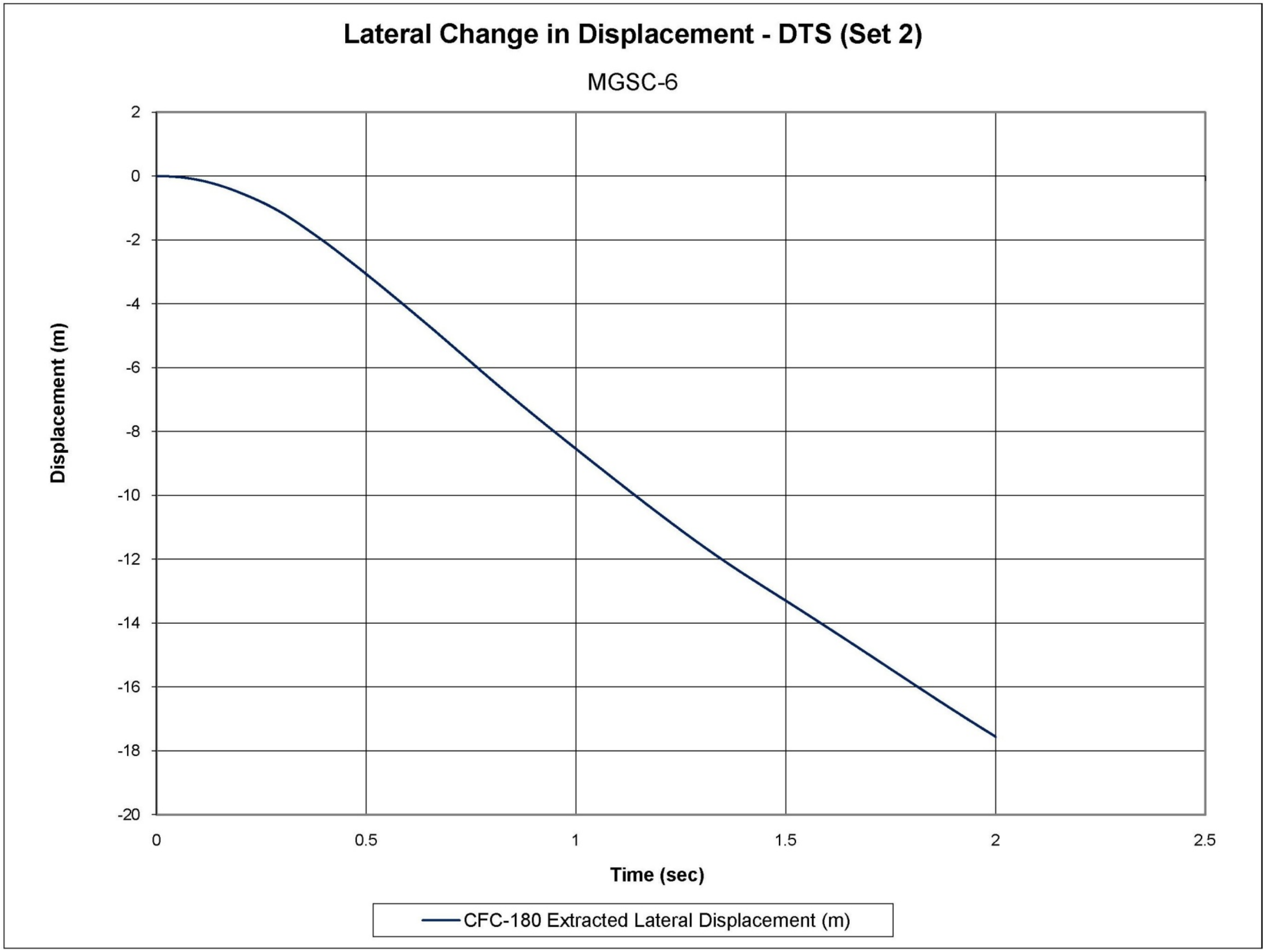


Figure E-14. Lateral Occupant Displacement (DTS, Set 2), Test No. MGSC-6

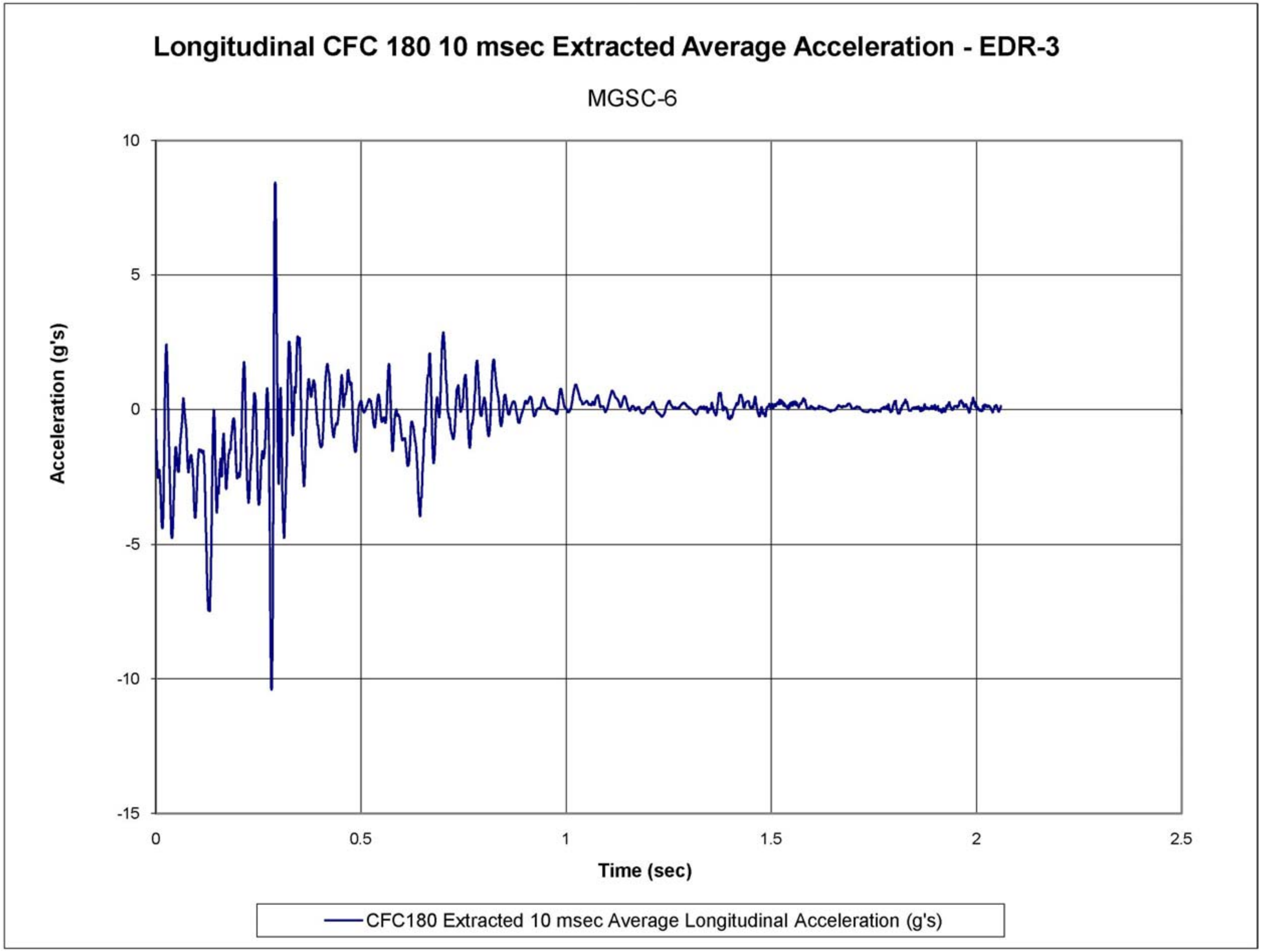


Figure E-15. 10-ms Average Longitudinal Deceleration (EDR-3), Test No. MGSC-6

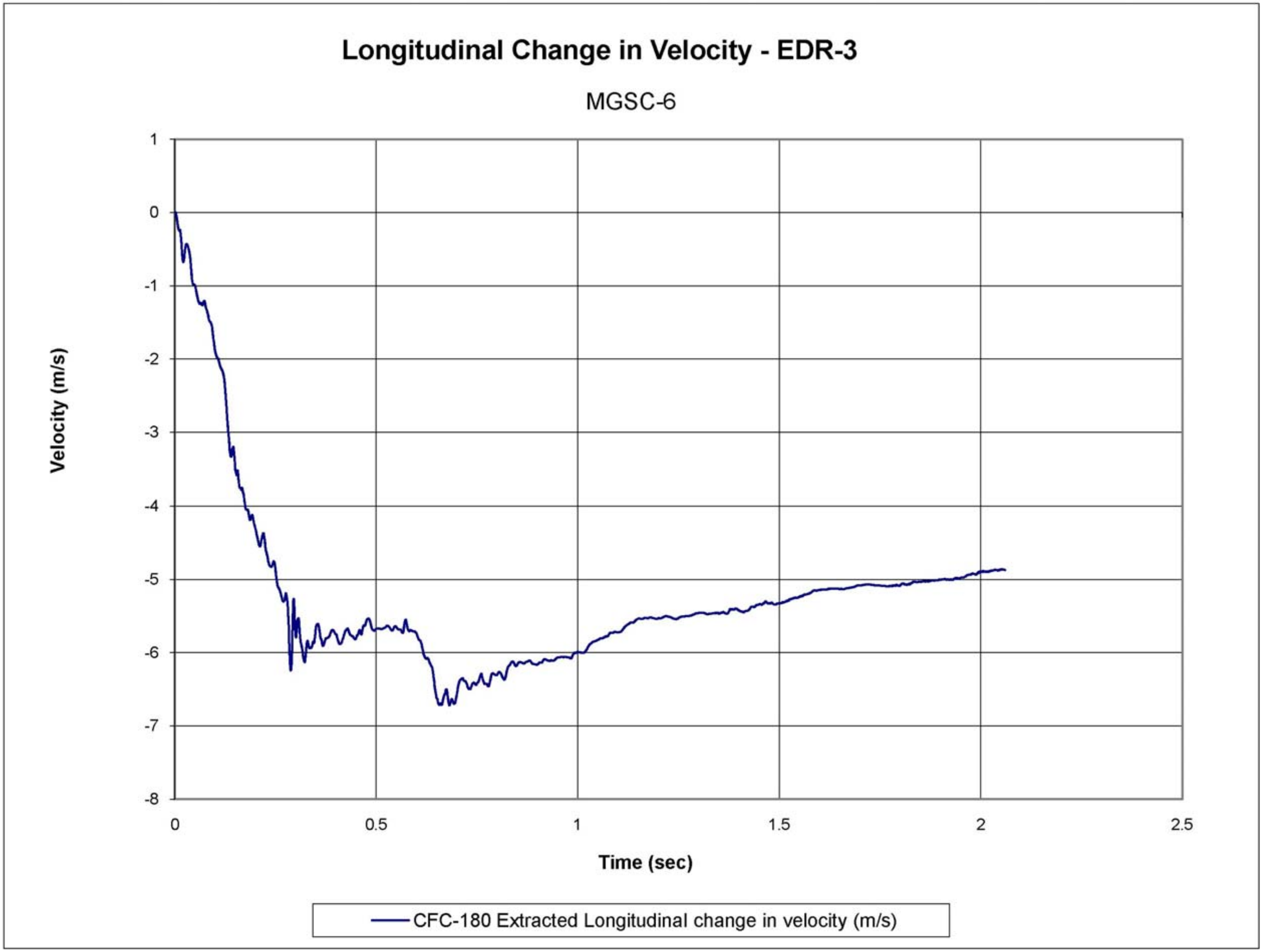


Figure E-16. Longitudinal Occupant Impact Velocity (EDR-3), Test No. MGSC-6

Figure E-17. Longitudinal Occupant Displacement (EDR-3), Test No. MGSC-6

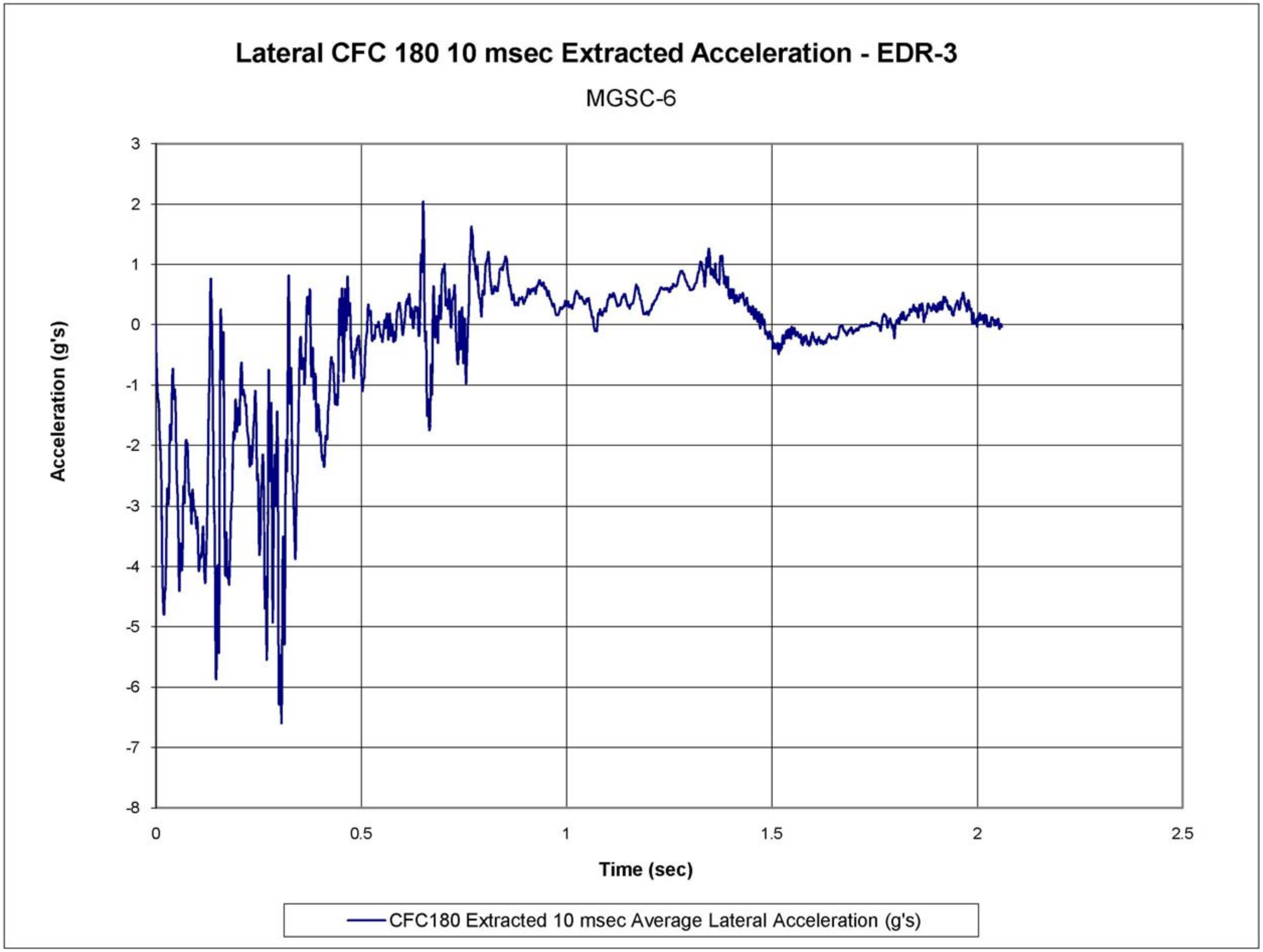


Figure E-18. 10-ms Average Lateral Deceleration (EDR-3), Test No. MGSC-6

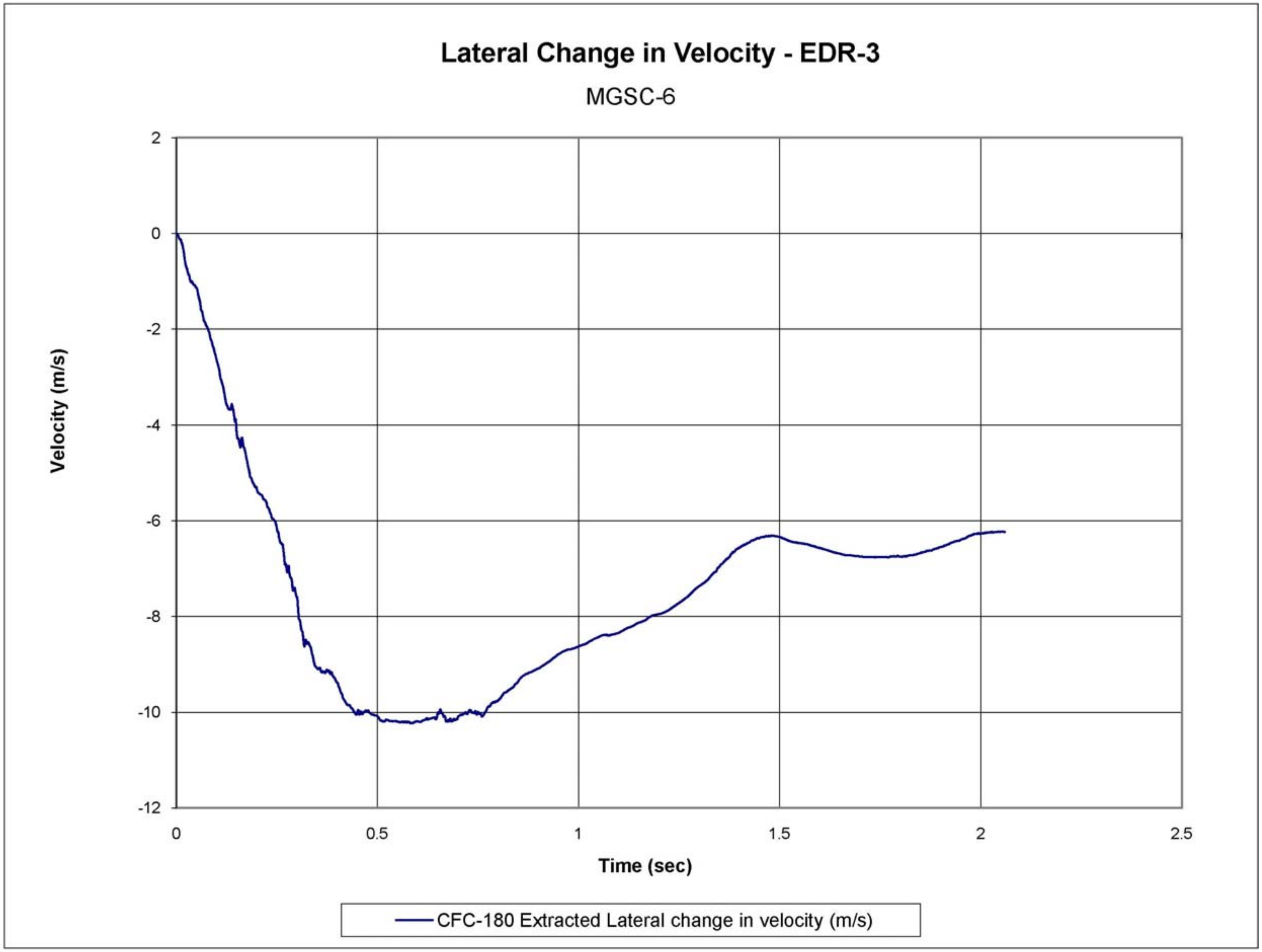


Figure E-19. Lateral Occupant Impact Velocity (EDR-3), Test No. MGSC-6

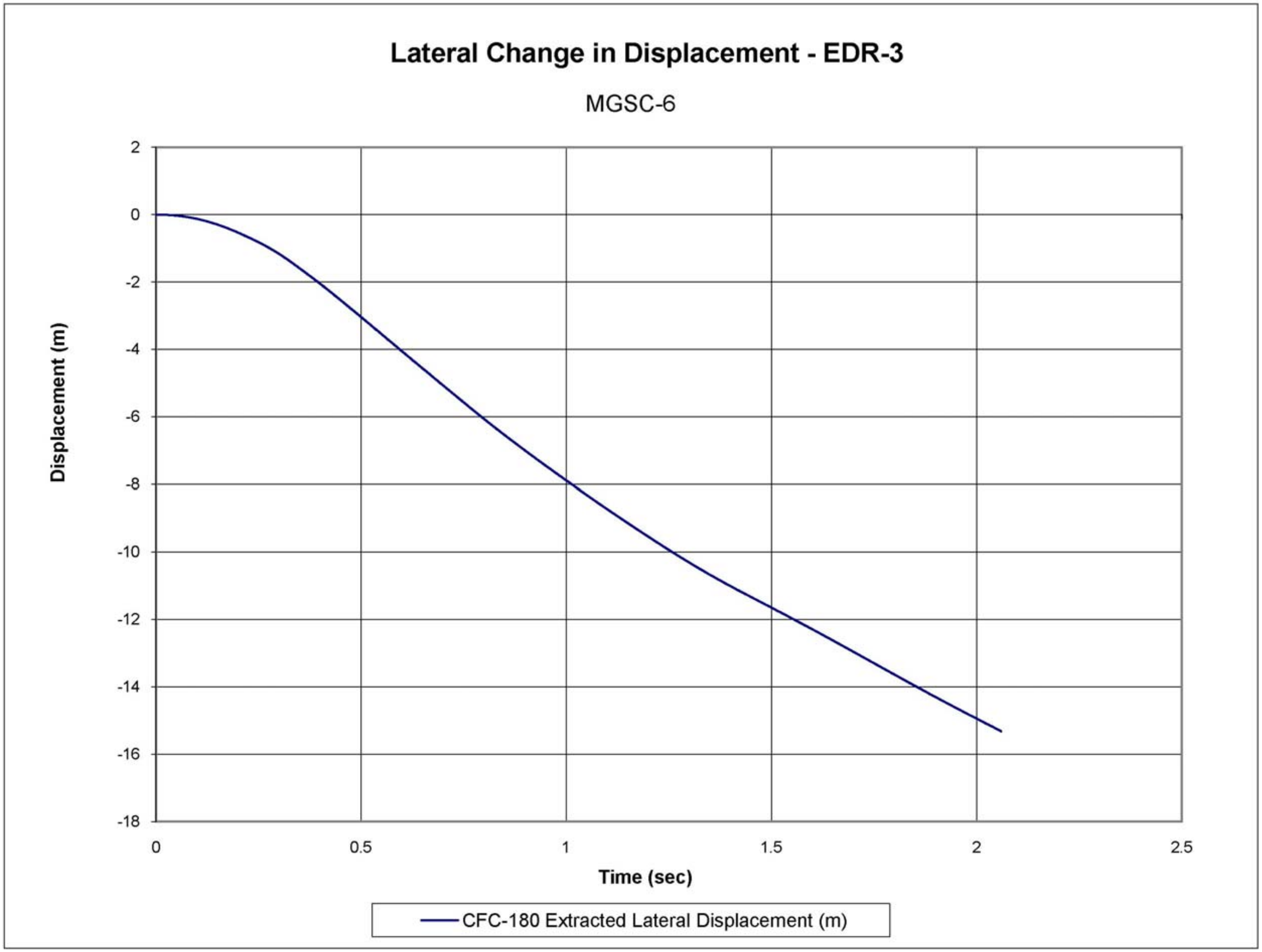


Figure E-20. Lateral Occupant Displacement (EDR-3), Test No. MGSC-6

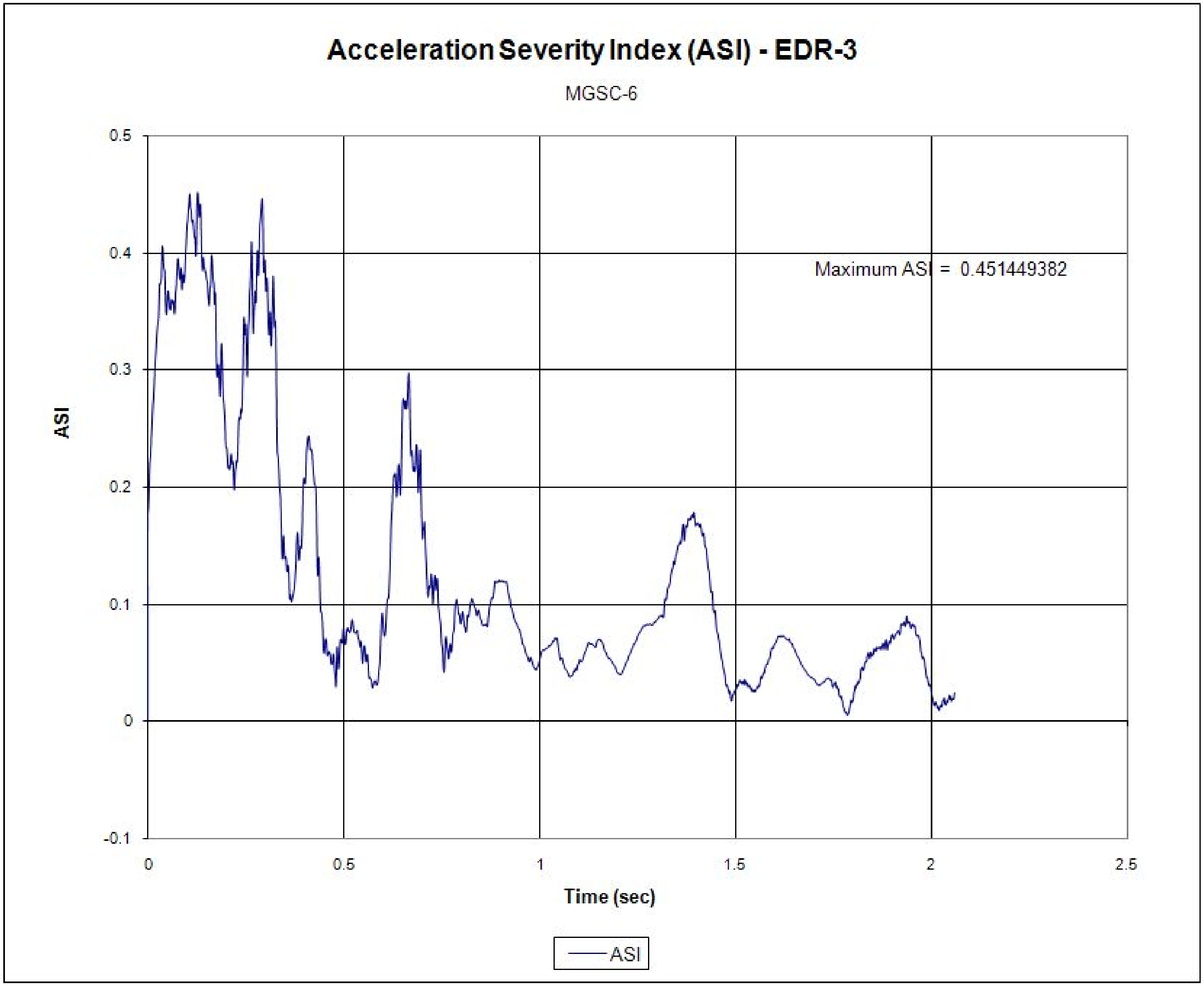


Figure E-21. Acceleration Severity Index (EDR-3), Test No. MGSC-6

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