PERFORMANCE EVALUATION OF THE PERMANENT NEW JERSEY SAFETY SHAPE BARRIER – UPDATE TO NCHRP 350 TEST NO. 3-10 (2214NJ-1)

Submitted by

Karla A. Polivka, M.S.M.E., E.I.T.
Research Associate Engineer

Ronald K. Faller, Ph.D., P.E.
Research Assistant Professor

Dean L. Sicking, Ph.D., P.E.
Professor and MwRSF Director

John R. Rohde, Ph.D., P.E.
Associate Professor

Bob W. Bielenberg, M.S.M.E., E.I.T.
Research Associate Engineer

John D. Reid, Ph.D.
Associate Professor

Brian A. Coon, Ph.D., P.E.
Research Associate Engineer

MIDWEST ROADSIDE SAFETY FACILITY
University of Nebraska-Lincoln
527 Nebraska Hall
Lincoln, Nebraska 68588-0529
(402) 472-6864

Submitted to

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

MwRSF Research Report No. TRP-03-177-06

October 13, 2006

Technical Report Documentation Page

1. Report No.	2.	3. Recipient's Accession No.
TRP-03-177-06		

4. Title and Subtitle

Performance Evaluation of the Permanent New Jersey Safety Shape Barrier – Update to NCHRP 350 Test No. 3-10 (2214NJ-1)

5. Report Date

October 13, 2006

6.

7. Author(s)

Polivka, K.A., Faller, R.K., Sicking, D.L., Rohde, J.R., Bielenberg, B.W., Reid, J.D., and Coon, B.A.

8. Performing Organization Report No.

TRP-03-177-06

9. Performing Organization Name and Address

Midwest Roadside Safety Facility (MwRSF)
University of Nebraska-Lincoln
527 Nebraska Hall
Lincoln, NE 68588-0529

10. Project/Task/Work Unit No.

11. Contract © or Grant (G) No.

NCHRP 22-14(2)

12. Sponsoring Organization Name and Address

National Cooperative Highway Research Program
Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

13. Type of Report and Period Covered

Final Report 2004-2006

14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with U.S. Department of Transportation, Federal Highway Administration

16. Abstract (Limit: 200 words)

Based on the proposed changes to the National Cooperative Highway Research Program (NCHRP) Report No. 350 guidelines, NCHRP Project 22-14(2) researchers deemed it appropriate to evaluate permanent safety shape barrier systems prior to finalizing the new crash testing procedures and guidelines. For this effort, the permanent New Jersey Safety Shape barrier was selected for evaluation. One full-scale vehicle crash test was performed on the longitudinal barrier system in accordance with the Test Level 3 (TL-3) requirements presented in the Update to NCHRP Report No. 350. For the permanent barrier testing program, an 1100C small car vehicle was used.

The permanent safety shape barrier provided an acceptable safety performance when impacted by the small car, thus meeting the proposed TL-3 requirements presented in the Update to NCHRP Report No. 350.

17. Document Analysis/Descriptors

Highway Safety, Roadside Appurtenances, Longitudinal Barriers, Permanent Barrier, Safety Shape, Crash Test, Compliance Test, NCHRP 350 Update

18. Availability Statement

No restrictions. Document available from: National Technical Information Services, Springfield, Virginia 22161

19. Security Class (this report)	20. Security Class (this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	65	

DISCLAIMER STATEMENT

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views nor policies of the National Research Council of the Transportation Research Board nor the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

ACKNOWLEDGMENTS

The authors wish to acknowledge several sources that made a contribution to this project: (1) the National Research Council of the Transportation Research Board for sponsoring this project; and (2) MwRSF personnel for constructing the barrier and conducting the crash test.

A special thanks is also given to the following individuals who made a contribution to the completion of this research project.

Midwest Roadside Safety Facility

J.C. Holloway, M.S.C.E., E.I.T., Research Manager
C.L. Meyer, B.S.M.E., E.I.T., Research Engineer II
A.T. Russell, B.S.B.A., Laboratory Mechanic II
K.L. Krenk, B.S.M.A, Field Operations Manager
A.T. McMaster, Laboratory Mechanic I
Undergraduate and Graduate Assistants

Transportation Research Board

Charles W. Niessner, Senior Program Officer
NCHRP 22-14(2) Panel Members

Federal Highway Administration

John Perry, P.E., Nebraska Division Office
Danny Briggs, Nebraska Division Office

Dunlap Photography

James Dunlap, President and Owner

TABLE OF CONTENTS

Page

List of Figures

Page

List of Tables

Page

1 INTRODUCTION

1.1 Problem Statement

In the late 1990s, roadside safety experts, State DOT representatives, Federal government officials, and industry personnel began discussions and preparations for updating the National Cooperative Highway Research Program (NCHRP) Report No. 350 safety performance guidelines (1). The new guidelines would improve upon existing test procedures, consider changes in the vehicle fleet, provide criteria for new roadside hardware categories and re-evaluate the appropriateness of the impact conditions.

In 1997, NCHRP Project 22-14, entitled *Improvement of the Procedures for the Safety Performance Evaluation of Roadside Features*, was initiated with the intent to: (1) evaluate the relevance and efficacy of the crash testing procedures, (2) assess the needs for updating NCHRP Report No. 350, and (3) provide recommended strategies for their implementation. Following the completion of this NCHRP study at the Texas Transportation Institute (TTI) in 2001, a follow-on research study was begun in 2002. NCHRP Project 22-14(2), entitled *Improved Procedures for Safety Performance Evaluation of Roadside Features*, was undertaken by Midwest Roadside Safety Facility (MwRSF) researchers with the objectives to: (1) prepare the revised crash testing guidelines, (2) assess the effects of any proposed guidelines, and (3) identify research needs for future improvements to the procedures.

Consequently, it was anticipated that a number of revisions would be incorporated into the Update of NCHRP Report No. 350 guidelines (2). For example, changes in the vehicle fleet have resulted in the need to reassess the small car and pickup truck test vehicles. Accordingly, new, heavier test vehicles have been selected for both the small car and light truck classes of vehicles.

Additionally, during the second study, researchers determined that the 100 km/h (62.1 mph) impact speed and 25 degree impact angle would remain the same as used in NCHRP Report No. 350 for the large passenger vehicle class impacting longitudinal barriers. However, the impact angle for the small car impact condition would increase from 20 to 25 degrees for evaluating longitudinal barriers and the length-of-need for guardrail terminals. The effects of any changes to vehicle specifications or impact conditions must be understood before the safety performance evaluation guidelines are finalized. Therefore, a series of full-scale crash tests on NCHRP Report No. 350 approved systems were to be conducted with the new test vehicles and impact conditions.

1.2 Objective

The objective of the research project was to evaluate the safety performance of the permanent New Jersey safety shape barrier when full-scale vehicle crash tested according to the test designation no. 3-10 criteria presented in the Update of NCHRP Report No. 350 guidelines (2).

1.3 Scope

The research objective was achieved through the completion of several tasks. First, a full-scale vehicle crash test was performed on the permanent safety shape barrier. The crash test utilized a small car, weighing approximately 1,100 kg (2,425 lbs). The target impact conditions for the test were an impact speed of 100.0 km/h (62.1 mph) 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 permanent safety shape barrier relative to the test performed.

2 TEST REQUIREMENTS AND EVALUATION CRITERIA

2.1 Test Requirements

Historically, longitudinal barriers, such as W-beam guardrail systems, have been required to satisfy impact safety standards in order to be accepted by the Federal Highway Administration (FHWA) for use on National Highway System (NHS) 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 No. 350 (1). However, NCHRP Project 22-14(2) generated revised testing procedures and guidelines for use in the evaluation of roadside safety appurtenances and were presented in the draft report entitled, *NCHRP Report 350 Update* (2). Therefore, according to Test Level 3 (TL-3) of the Update to NCHRP Report No. 350, 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 3-10. An 1,100-kg (2,425-lb) passenger car impacting at a nominal speed and angle of 100.0 km/h (62.1 mph) and 25 degrees, respectively.

2. Test Designation 3-11. A 2,270-kg (5,004-lb) pickup truck impacting at a nominal speed and angle of 100.0 km/h (62.1 mph) and 25 degrees, respectively.

The test conditions for TL-3 longitudinal barriers are summarized in Table 1. Test Designation 3-10 was conducted for the permanent safety shape barrier described herein.

2.2 Evaluation Criteria

According to the Update to NCHRP Report No. 350, the 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 barrier to contain, redirect, or allow controlled vehicle penetration in a predictable manner. 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 cause subsequent multi-vehicle accidents. This criterion also indicates the potential safety hazard for the occupants of other vehicles or the occupants of the impacting vehicle when subjected secondary collisions with other fixed objects. These three evaluation criteria are summarized in Table 2 and defined in greater detail in the Update to NCHRP Report No. 350 report (2). The full-scale vehicle crash tests were conducted and reported in accordance with the procedures provided in the Update to NCHRP Report No. 350.

Table 1. Update to NCHRP Report No. 350 Test Level 3 Crash Test Conditions

Test Article	Test Designation	Test Vehicle	Impact Conditions			Evaluation Criteria [1]
			Speed		Angle (degrees)	
			(km/h)	(mph)		
Longitudinal Barrier	3-10	1100C	100	62.1	25	A,D,F,H,I,M
	3-11	2270P	100	62.1	25	A,D,F,H,I,M

[1] Evaluation criteria explained in Table 2.

Table 2. Update to NCHRP Report No. 350 Evaluation Criteria for Crash Tests

Structural Adequacy	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.
Occupant Risk	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 the Update to NCHRP Report No. 350.
	F. The vehicle should remain upright during and after collision.
	H. Longitudinal and lateral occupant impact velocities should fall below the preferred value of 9.0 m/s (29.5 ft/s), or at least below the maximum allowable value of 12.0 m/s (39.4 ft/s).
	I. Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15 Gs, or at least below the maximum allowable value of 20.0 Gs.
Vehicle Trajectory	M. After impact, the vehicle shall exit the barrier within the exit box.

3 TEST CONDITIONS

3.1 Test Facility

The testing facility is located at the Lincoln Air Park on the northwest side of the Lincoln Municipal Airport and is approximately 8.0 km (5 mi.) northwest of the University of Nebraska-Lincoln.

3.2 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 was located on the tow vehicle to increase the accuracy of the test vehicle impact speed.

A vehicle guidance system developed by Hinch (3) was used to steer the test vehicle. A guide-flag, attached to the front-right wheel and the guide cable, was sheared off before impact with the barrier system. The 9.5-mm (0.375-in.) diameter guide cable was tensioned to approximately 15.6 kN (3,500 lbf), and supported laterally and vertically every 30.48 m (100 ft) 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. For test 2214NJ-1, the vehicle guidance system was 244 m (800 ft) long.

3.3 Test Vehicles

For test 2214NJ-1, a 2002 Kia Rio was used as the test vehicle. The test inertial and gross static weights were 1,095 kg (2,413 lbs) and 1,170 kg (2,579 lbs), respectively. The test vehicle is shown in Figure 1, and vehicle dimensions are shown in Figure 2.

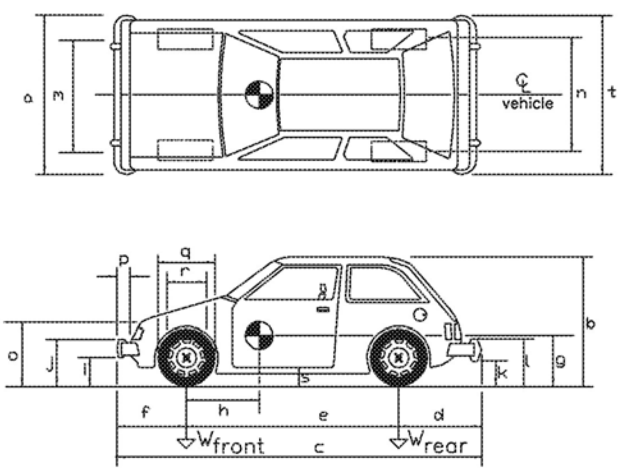
Figure 1. Test Vehicle, Test 2214NJ-1

Date: 5/28/04 Test Number: 2214NJ-1 Model: Rio

Make: Kia Vehicle I.D.#: KAJADC123526145867

Tire Size: P175/165 R15 Year: 2002 Odometer: 19500

*(All Measurements Refer to Impacting Side)



Vehicle Geometry – mm (in.)

a	1635 (64.375)	b	1353 (53.25)
c	4223 (166.25)	d	965 (38.0)
e	2426 (95.5)	f	832 (32.75)
g	546 (21.5)	h	978 (38.5)
i	216 (8.5)	j	521 (20.5)
k	254 (10.0)	l	521 (20.5)
m	1413 (55.625)	n	1445 (56.875)
o	559 (22.0)	p	76 (3.0)
q	565 (22.25)	r	391 (15.375)
s	286 (11.25)	t	1619 (63.75)

Wheel Center Height 270 (10.625)

Engine Type 3 CYL. GAS

Engine Size 1.0 L

Transmission Type:

Automatic or (Manual)

(FWD) or RWD or 4WD

Weights kg (lbs)	Curb (No Fuel)	Stripped	Test Inertial	Gross Static
W_{front}	653 (1439)	606 (1335)	653 (1439)	690 (1521)
W_{rear}	400 (882)	375 (826)	442 (974)	480 (1048)
W_{total}	1053 (2321)	980 (2161)	1095 (2413)	1170 (2579)

Note any damage prior to test: None

Figure 2. Vehicle Dimensions, Test 2214NJ-1

The longitudinal component of the center of gravity was determined using the measured axle weights. The location of the final center of gravity is shown in Figures 1 and 2.

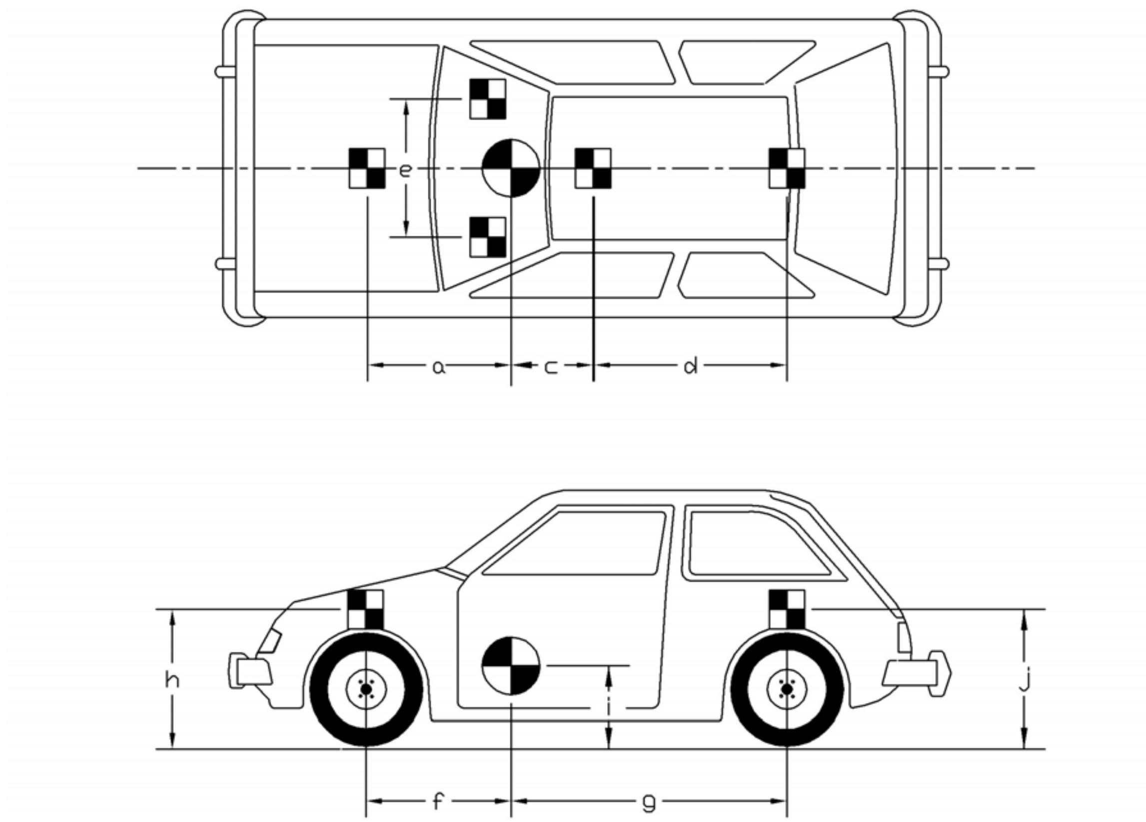
Square black and white-checkered targets were placed on the vehicle to aid in the analysis of the high-speed film and E/cam and Photron video, as shown in Figure 3. Checkered targets were placed on the center of gravity, on the driver's side door, on the passenger's side door, and on the roof of the vehicle. The remaining targets were located for reference so that they could be viewed from the high-speed cameras for film analysis.

The front wheels of the test vehicle were aligned for camber, caster, and toe-in values of zero so that the vehicle would track properly along the guide cable. Two 5B flash bulbs were mounted on both the hood and roof of the vehicle to pinpoint the time of impact with the barrier on the high-speed film, E/cam video, and Photron video. The flash bulbs were fired by a pressure tape switch mounted on the front face of the bumper. A remote-controlled brake system was installed in the test vehicle so the vehicle could be brought safely to a stop after the test.

3.4 Data Acquisition Systems

3.4.1 Accelerometers

One triaxial piezoresistive accelerometer system with a range of ±200 Gs was used to measure the acceleration in the longitudinal, lateral, and vertical directions at a sample rate of 10,000 Hz. The environmental shock and vibration sensor/recorder system, Model EDR-4M6, was developed by Instrumented Sensor Technology (IST) of Okemos, Michigan and includes three differential channels as well as three single-ended channels. The EDR-4 was configured with 6 MB of RAM memory and a 1,500 Hz lowpass filter. Computer software, "DynaMax 1 (DM-1)" and "DADiSP", was used to analyze and plot the accelerometer data.



TEST #: 2214NJ–1

TARGET GEOMETRY -- mm (in.)

a 1083 (42.625)	b –	c 889 (35.0)	d 1216 (47.875)
e 610 (24.0)	f 978 (38.5)	g 1448 (57.0)	h 727 (28.625)
	i 546 (21.5)	j 695 (27.375)	

Figure 3. Vehicle Target Locations, Test 2214NJ-1

Another triaxial piezoresistive accelerometer system with a range of ±200 Gs was also used to measure the acceleration in the longitudinal, lateral, and vertical directions at a sample rate of 3,200 Hz. The environmental shock and vibration sensor/recorder system, Model EDR-3, was developed by Instrumental Sensor Technology (IST) of Okemos, Michigan. The EDR-3 was configured with 256 kB of RAM memory and a 1,120 Hz lowpass filter. Computer software, "DynaMax 1 (DM-1)" and "DADiSP", was used to analyze and plot the accelerometer data.

3.4.2 Rate Transducers

An Analog Systems 3-axis rate transducer with a range of 1,200 degrees/sec in each of the three directions (pitch, roll, and yaw) was used to measure the rates of motion of the test vehicle. The rate transducer was mounted inside the body of the EDR-4M6 and recorded data at 10,000 Hz to a second data acquisition board inside the EDR-4M6 housing. The raw data measurements were then downloaded, converted to the appropriate Euler angles for analysis, and plotted. Computer software, "DynaMax 1 (DM-1)" and "DADiSP", was used to analyze and plot the rate transducer data.

3.4.3 High-Speed Photography

For test 2214NJ-1, one high-speed 16-mm Red Lake Locam camera, with operating speed of approximately 500 frames/sec, was used to film the crash test. Two high-speed Photron video camera and three high-speed Red Lake E/cam video cameras, all with operating speeds of 500 frames/sec, and five Canon digital video cameras, with a standard operating speed of 29.97 frames/sec, were also used to film the crash test. Camera details and a schematic of all twelve camera locations for test 2214NJ-1 is shown in Figure 4. The Locam films, Photron video, and E/cam videos were analyzed using the Vanguard Motion Analyzer, ImageExpress MotionPlus software, and Redlake Motion Scope software, respectively. Actual camera speed and camera divergence factors were considered in the analysis of the high-speed film.

3.4.4 Pressure Tape Switches

For test 2214NJ-1, five pressure-activated tape switches, spaced at 2-m (6.56-ft) 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 software. Strobe lights and high-speed film analysis are used only as a backup in the event that vehicle speed cannot be determined from the electronic data.

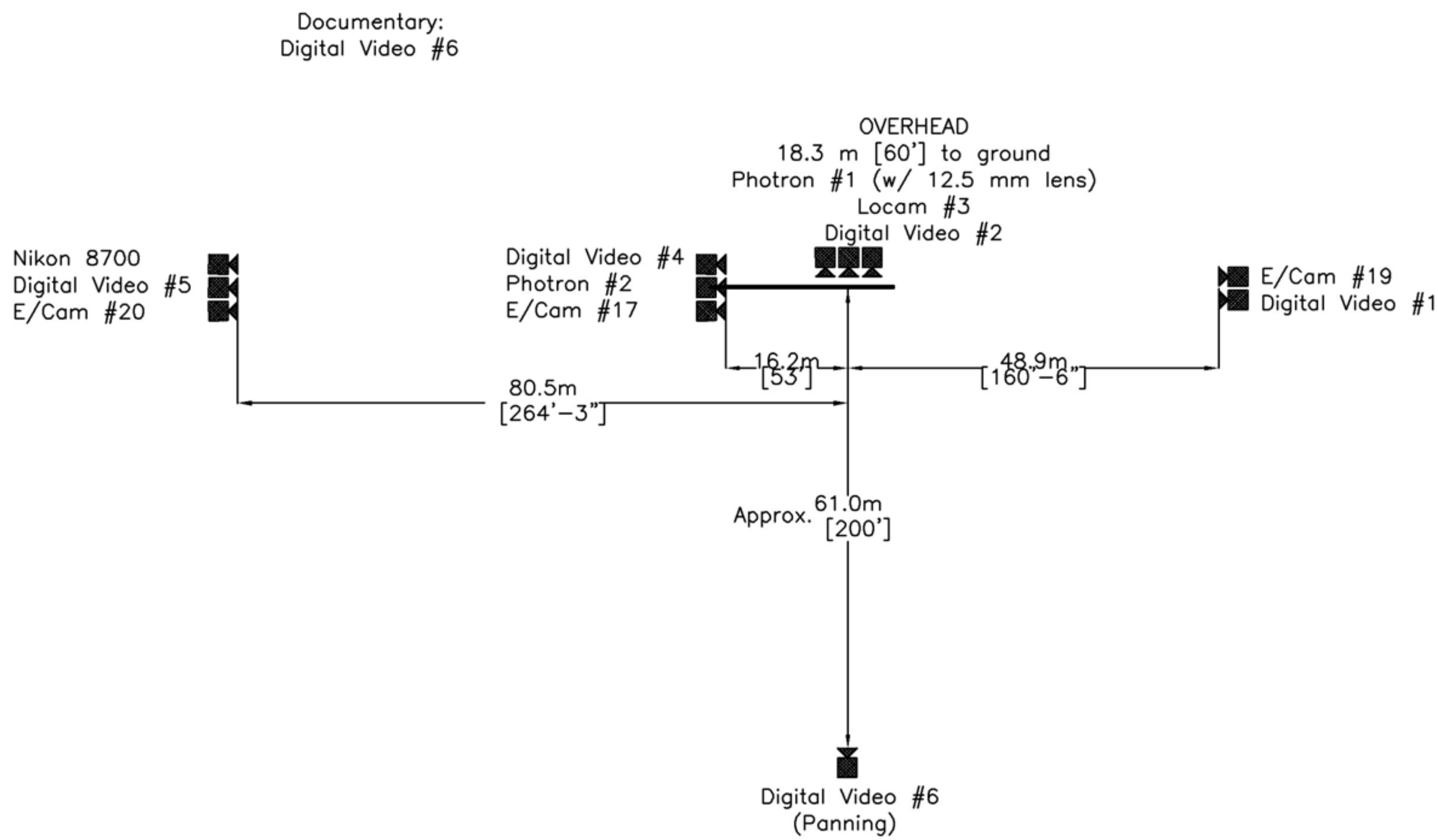


Figure 4. Location of High-Speed Cameras, Test 2214NJ-1

4 DESIGN DETAILS

The installation consisted of a reinforced, permanent New Jersey safety shape concrete barrier, as shown in Figures 5 through 8. The 24.38-m (80-ft) long half-section New Jersey shape barrier was 381 mm and 152 mm (15 in. and 6 in.) wide at the base and at the top, respectively, with an 813-mm (32-in.) top mounting height, as measured from the top of the concrete tarmac to the top of the barrier. The corresponding English-unit drawings are shown in Appendix A. Photographs of the test installation are shown in Figures 9 through 12.

The concrete used for the barrier consisted of Nebraska 47-BD Mix Type 3, with a minimum 28-day concrete compressive strength of 31.03 MPa (4,500 psi). The 21-day concrete compressive strength for the barrier, as determined from concrete cylinder testing, was found to be approximately 32.22 MPa (4,673 psi). A minimum concrete cover of 38 mm (1.5 in.) was used along the front and back sides of the barrier. A minimum concrete cover of 51 mm (2 in.) was used along the top of the vertical stirrups within the barrier. All the steel reinforcement in the barier was ASTM A615 Grade 60 rebar. The barrier reinforcement details are shown in Figures 5 through 9.

Barrier reinforcement consisted of No. 4 longitudinal bars and No. 5 bars for both the vertical stirrups and the barrier-to-tarmac angled and straight bars. Each of the eight longitudinal rebar measured 24.31 m (79 ft - 9 in.) long with minimum 305-mm (12-in.) long laps along each one. The vertical spacings of the lower, lower middle, upper middle, and upper longitudinal bars were 210 mm (8.25 in.), 387 mm (15.25 in.), 565 m (22.25 in.), and 743 mm (29.25 in.) from the ground to their centers, respectively. The vertical stirrups measured 1,422 mm (56 in.) long and were bent into a U-shape. Their longitudinal spacings were 203 mm (8 in.) on center, as shown in Figure 7. The barrier-to-tarmac attachment utilized straight bars and angled bars, which were bent into the shape of the lower front face of the barrier, as shown in Figures 5 and 6. The straight bars utilized on the back face were 711 mm (28 in.) long, while the angled bars utilized on the front face were 787 mm (31 in.) long. The longitudinal spacing of these bars was also 203 mm (8 in.) on center, as shown in Figure 7. The transverse spacing of the straight and angled bars was 289 mm (11.375 in.) on center, as shown in Figure 5. The barrier-to-tarmac attachment bars were epoxied into the concrete to an embedment depth of 254 mm (10 in.), as shown in Figure 5. The epoxy used was the Fast Set Formula Power-Fast High Strength Epoxy Anchorage System.

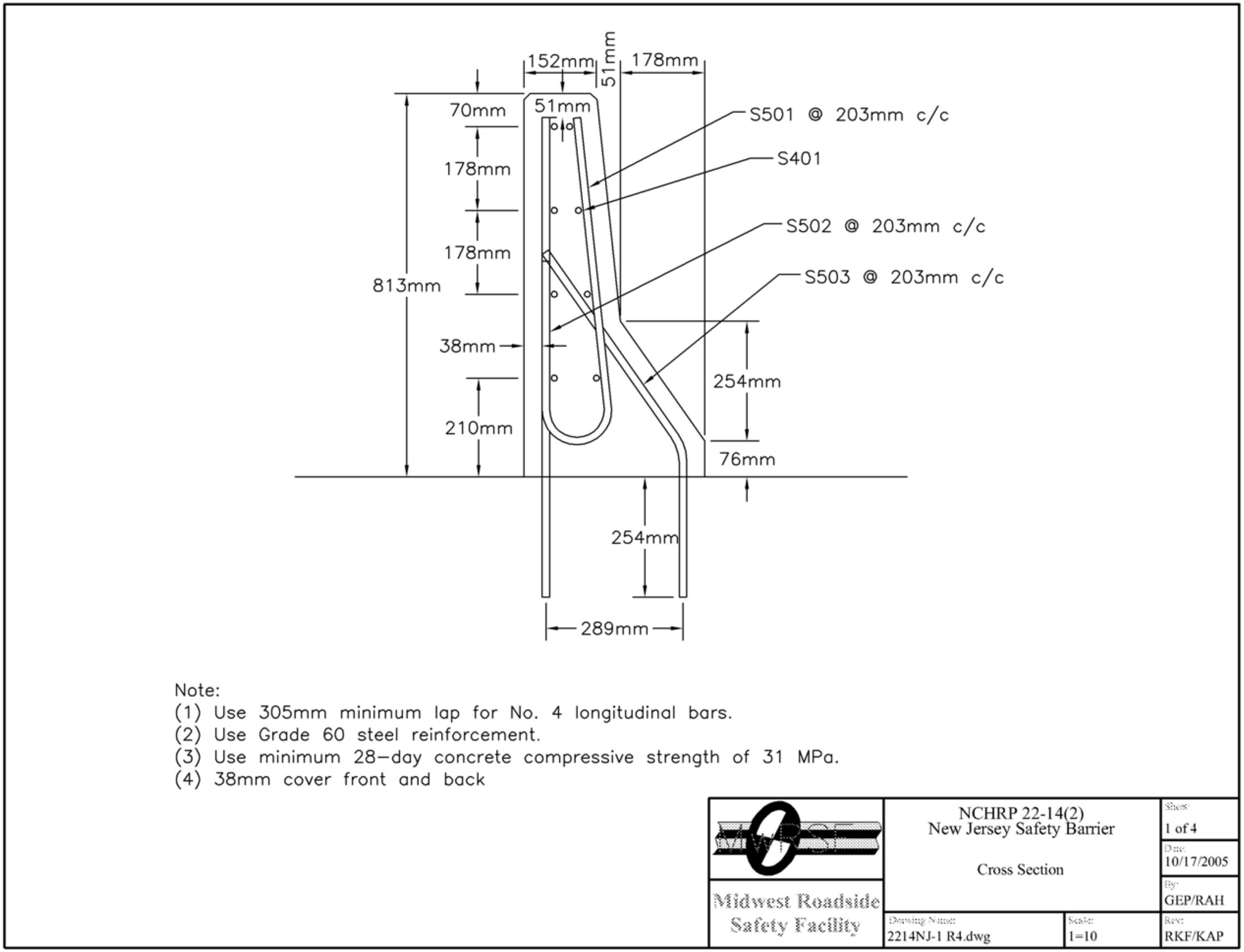
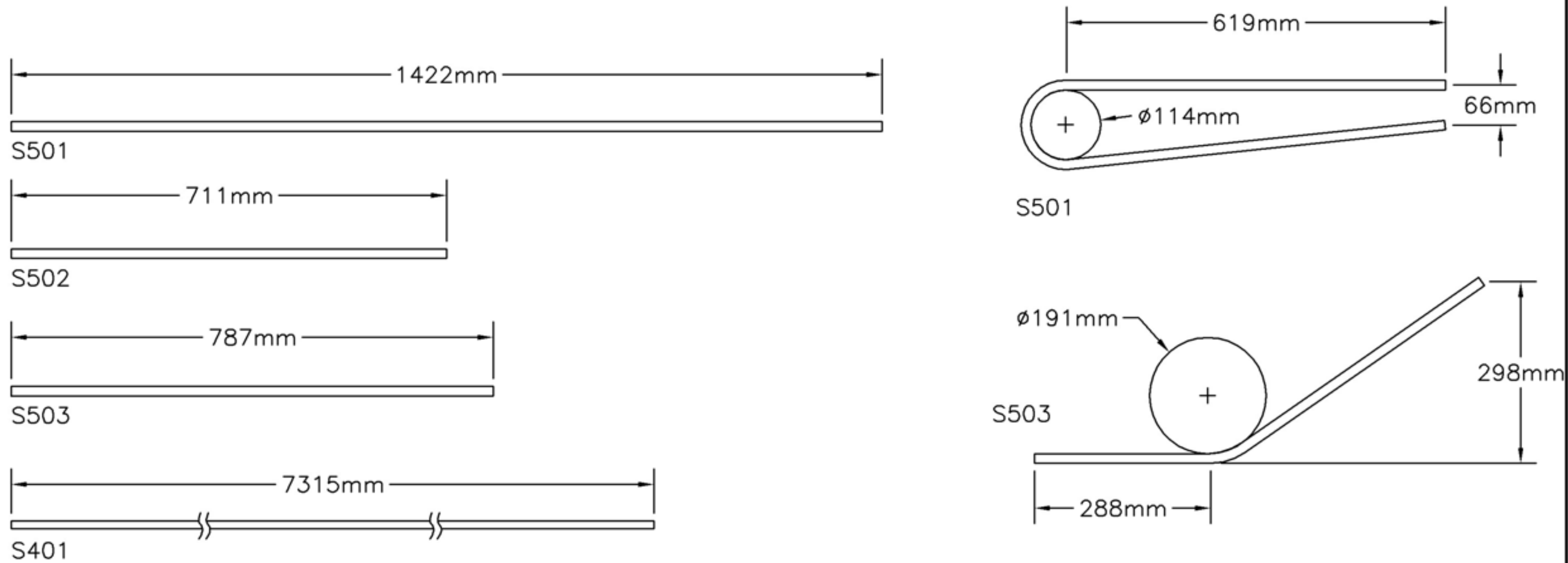


Figure 5. Cross Section of Permanent New Jersey Safety Shape Barrier



BILL OF BARS						
Mark	Bar No.	No.	Length		Pin Dia.	Hook Length
S501	5	120	1422mm		114mm	
S502	5	120	711mm			
S503	5	120	787mm		191mm	
S401	4	24	7315mm			

Midwest Roadside Safety Facility

NCHRP 22-14(2)
New Jersey Safety Barrier

Bar Detail

Sheet: 2 of 4
Date: 10/17/2005
By: GEP/RAH
Drawing Name: 2214NJ-1 R4.dwg
Scale: 1=10
Rev: RKF/KAP

Figure 6. Permanent New Jersey Safety Shape Reinforcement Details

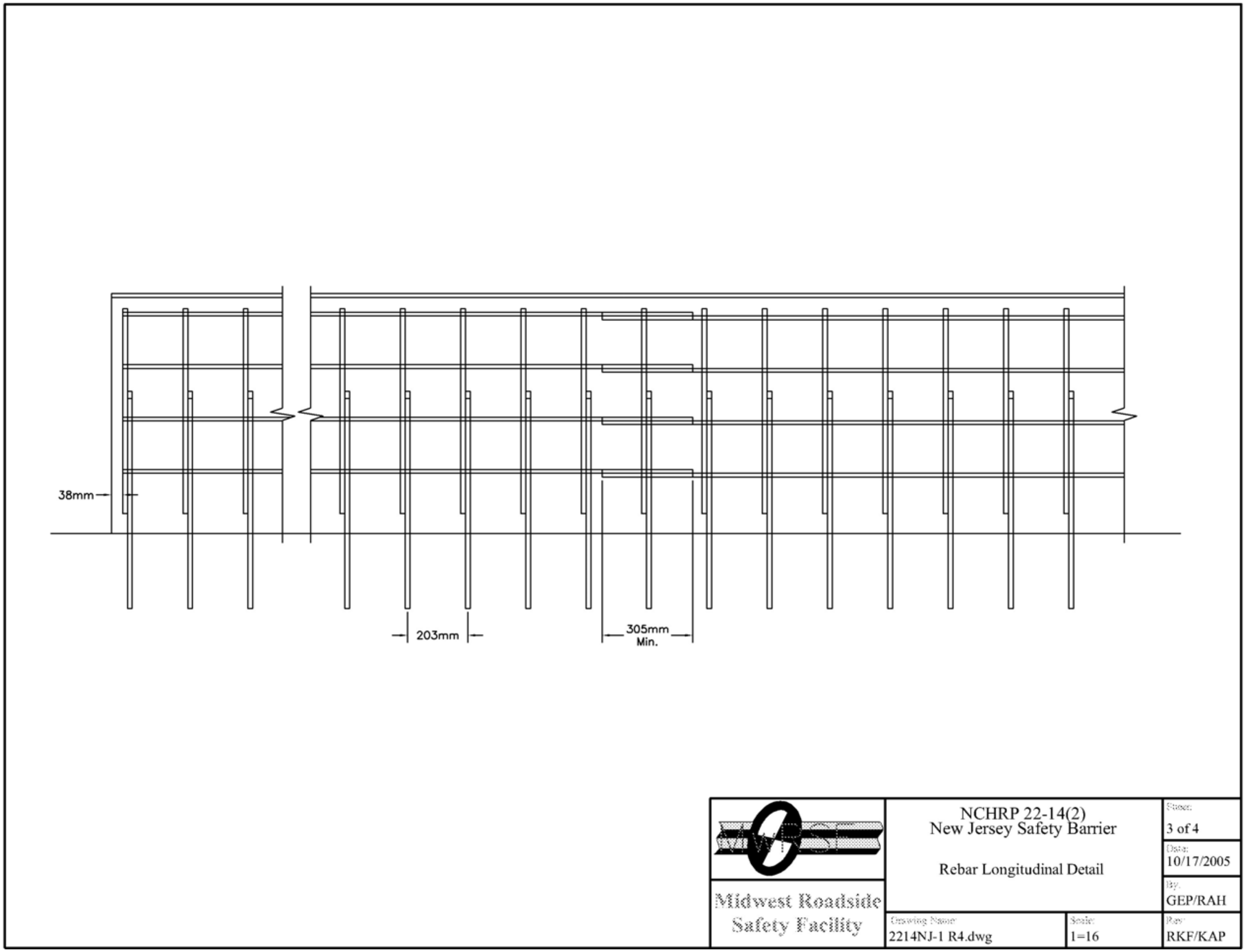


Figure 7. Permanent New Jersey Safety Shape Barrier Reinforcement Layout Details

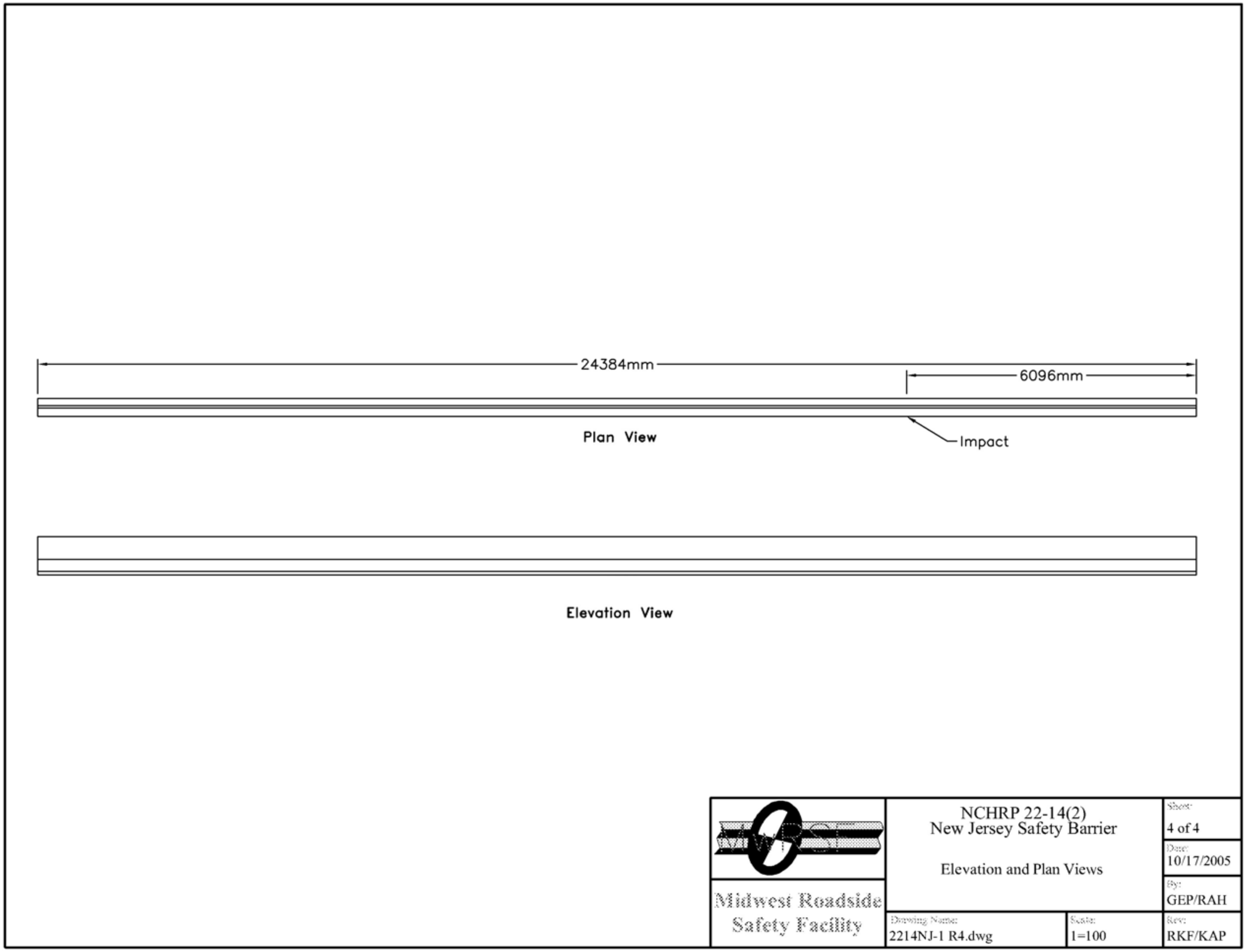


Figure 8. Layout of Permanent New Jersey Safety Shape Barrier

Figure 9. Permanent New Jersey Safety Shape Barrier System Reinforcement

Figure 10. Permanent New Jersey Safety Shape Barrier System Construction

Figure 11. Permanent New Jersey Safety Shape Barrier System

Figure 12. Permanent New Jersey Safety Shape Barrier System

5 CRASH TEST

5.1 Test 2214NJ-1

The 1,170-kg (2,579-lb) small car impacted the permanent New Jersey shape barrier system at a speed of 97.9 km/h (60.8 mph) and at an angle of 26.1 degrees. A summary of the test results and sequential photographs are shown in Figure 13. The summary of the test results and sequential photographs in English units are shown in Appendix B. Additional sequential photographs are shown in Figures 14 through 17. Documentary photographs of the crash test are shown in Figures 18 and 19.

5.2 Test Description

Initial vehicle impact was to occur 6.10 m (20 ft) downstream from the upstream end of the barrier, as shown in Figure 20. Actual vehicle impact occurred approximately 5.63 m (18 ft - 5.5 in.) downstream from the upstream end of the barrier. At 0.012 sec after impact, the right-front corner of the hood deformed inward as the bumper deflected backward. At 0.028 sec, the right-front quarter panel deformed inward. At this same time, the hood continued to buckle as the left side of the bumper deformed out away from the vehicle. At 0.046 sec, the right-front hood protruded over the top of the barrier. At this same time, a dent in the roof become apparent. At 0.058 sec, the top of the right-side door was ajar. At 0.062 sec, the left-front side of the bumper disengaged from the front of the vehicle. At this same time, the vehicle began to redirect. At 0.076 sec, a second dent in the roof appeared. At 0.098 sec, the right-front tire climbed the front face of the barrier. At 0.103 sec, the front of the right-side door was in contact with the barrier. At this same time, the front of the vehicle pitched upward. At 0.148 sec, the vehicle became parallel to the barrier with a resultant velocity of 78.9 km/h (49.0 mph). At this same time, the entire right side of the vehicle was in contact with the barrier. At 0.160 sec, the right rear of the vehicle contacted the barrier. At 0.176 sec, the vehicle continued to redirect as the front of the vehicle lost contact with the barrier. At 0.180 sec, the right-rear tire was airborne and in contact with the barrier. At 0.238 sec, the vehicle was completely airborne. At 0.300 sec, the vehicle exited the barrier at a trajectory angle of 6.6 degrees and at a resultant velocity of 79.4 km/h (49.3 mph). At 0.366 sec, the vehicle began to descend toward the ground. At 0.390 sec, the vehicle continued to yaw away from the barrier. At 0.562 sec, the left-front tire contacted the ground. At 0.608 sec, the right-front tire contacted the ground. At 0.642 sec, the bumper was deformed back into the engine compartment. At 0.706 sec, the right-rear tire contacted the ground. At 0.806 sec, the left-rear tire contacted the ground. At 0.830 sec, the vehicle became airborne again. At 0.868 sec, the right-rear bumper was in contacted with the ground. At 0.992 sec, both front tires re-contacted the ground. At 1.172 sec, the vehicle continued on its path away from the system. At 1.352 sec, the vehicle yawed back toward the system. The vehicle came to rest 75.69 m (245 ft - 9 in.) downstream from impact and 0.64 m (2 ft - 1 in.) laterally away from the traffic-side face of the concrete barrier system. The trajectory and final position of the small car are shown in Figures 13 and 21.

5.3 Barrier Damage

Damage to the barrier was minimal, as shown in Figure 22. Barrier damage consisted of contact and gouge marks. The length of vehicle contact along the concrete barrier system was approximately 3.35 m (11 ft), which spanned from 5,626 mm (221.5 in.) downstream from the upstream end of the barrier through 8,979 mm (353.5 in.) downstream from the upstream end of the barrier.

A 3,353-mm (132-in.) long tire mark began at the bottom face of the barrier 5,626 mm (221.5

in.) downstream from the upstream end of barrier and ended 508 mm (20 in.) above the ground. Another tire mark began 5,944 mm (234 in.) downstream from the upstream end of the barrier at a height of 508 mm (20 in.) above the ground and continued downstream for a length of 3,035 mm (119.5 in.). A thin, black bumper contact mark began 5,994 mm (236 in.) downstream from the upstream end of the barrier at a height of 660 mm (26 in.) above the ground.

A 51-mm (2-in.) wide wheel gouge began 343 mm (13.5 in.) upstream from targeted impact at a height of 127 mm (5 in.) above the ground and ended 114 mm (4.5 in.) downstream from targeted impact at a height of 343 mm (13.5 in.) above the ground. A 6-mm (0.25-in.) wide wheel gouge began 70 mm (2.75 in.) upstream from targeted impact and 102 mm (4 in.) above the ground. This mark ended 991 mm (39 in.) downstream from targeted impact and 400 mm (15.75 in.) above the ground. A 1,505-mm (59.25-in.) long wheel gouge began 171 mm (6.75 in.) downstream from impact at a height of 406 mm (16 in.) above the ground and ended 1,651 mm (65 in.) downstream from impact at a height of 610 mm (24 in.) above the ground. A 140-mm (5.5-in.) long wheel gouge began 1,270 mm (50 in.) downstream from impact and 597 mm (23.5 in.) above the ground. This gouge ended 1,378 mm (54.25 in.) downstream from impact and 622 mm (24.5 in.) above the ground.

The permanent set of the barrier system was negligible. The working width of the system was found to be 485 mm (19 in.).

5.4 Vehicle Damage

Exterior vehicle damage was moderate, as shown in Figures 23 through 25. Occupant compartment deformations to the right side and center of the floorboard were judged insufficient to cause serious injury to the vehicle occupants. Maximum longitudinal deflections of 57 mm (2.25 in.)

were located near the right-front corner of the right-side floor pan. Maximum lateral deflections of 38 mm (1.5 in.) were located near the right-front corner of the right-side floor pan. Maximum vertical deflections of 19 mm (0.75 in.) were located near the right-front corner of the right-side floor pan. Complete occupant compartment deformations and the corresponding locations are provided in Appendix C.

Damage was concentrated on the right side of the vehicle. The right-front quarter panel was deformed inward and downward toward the engine compartment. Contact marks were found on the right-rear quarter panel. The right side of the front bumper was flattened and bent back toward the engine compartment and also encountered scratches and cracks. The left side of the front bumper disengaged from the frame and buckled inward toward the engine compartment. The front bumper disengaged from the front mounting bolts. The right-rear door encountered a small dent directly in front of the rear tire. The top of the right-front door was ajar. The trim on the right-front door was bent and encountered a large abrasion. The molding behind the right-front tire was crushed inward. Scratches were found along the entire right side moldings at the bottom of the doors. The hood buckled and deformed backward on the right side. The right half of the roof buckled slightly. The right-side engine mount buckled severely. The radiator was bent and deformed. Contact marks were observed on the muffler. The right-front control arm connection to the frame was bent 51 mm (2 in.) away from the frame. Scratches were found on the skid plate, three of the lug nuts on the right-front tire, and two of the lug nuts on the right-rear tire. Contact marks were also found on the lower-right-rear control arm and on the inside of the right-rear wheel well .The right-front and right-rear steel rims were deformed and dented. The right-front tire pulled away from the bead and was deflated. The right-side headlight assembly was broken and pushed inward. The lower-right side of the windshield encountered minor cracking. All other window glass remained undamaged. The left-side and rear of the vehicle remained undamaged.

5.5 Occupant Risk Values

The longitudinal and lateral occupant impact velocities were determined to be 5.02 m/s (16.47 ft/s) and 10.67 m/s (35.01 ft/s), respectively. The maximum 0.010-sec average occupant ridedown decelerations in the longitudinal and lateral directions were 5.49 Gs and 8.08 Gs, respectively. It is noted that the occupant impact velocities (OIVs) and occupant ridedown decelerations (ORDs) were within the suggested limits provided in NCHRP Report No. 350. The THIV and PHD values were determined to be 12.38 m/s (40.62 ft/s) and 8.10 Gs, respectively. The results of the occupant risk, as determined from the accelerometer data, are summarized in Figure 13. Results are shown graphically in Appendix D. The results from the rate transducer are shown graphically in Appendix D.

5.6 Discussion

The analysis of the test results for test no. 2214NJ-1 showed that the permanent New Jersey safety shape concrete barrier system impacted with the 1100C vehicle of the Update to NCHRP Report No. 350 adequately contained and redirected the vehicle with controlled lateral displacements of the barrier system. 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 intrusion into, the occupant compartment that could have caused serious injury did not occur. The test vehicle did not penetrate nor ride over the permanent concrete barrier system and remained upright during and after the collision. Vehicle roll, pitch, and yaw angular displacements were noted, but they were deemed acceptable because they did not adversely influence occupant risk safety criteria nor cause rollover. After collision, the vehicle's trajectory revealed minimum intrusion into adjacent traffic lanes. In addition, the vehicle exited the barrier within the exit box. Therefore, test no. 2214NJ-1 conducted on the permanent New Jersey safety shape concrete barrier system was determined to be acceptable according to the TL-3 safety performance criteria found in Update to NCHRP Report No. 350.

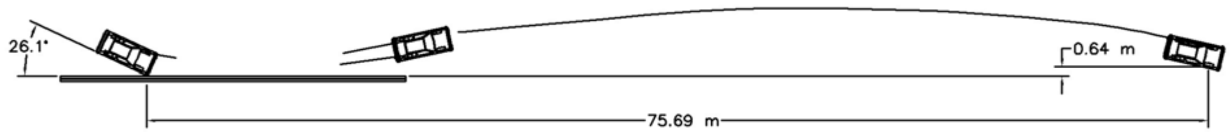
0.000 sec

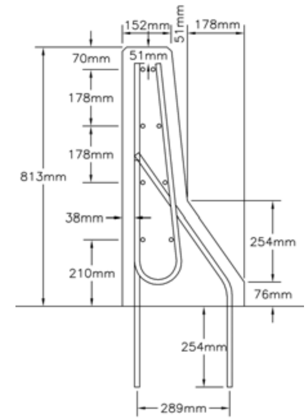
0.102 sec

0.160 sec

0.196 sec

0.390 sec





- Test Agency . . . . MwRSF
- Test Number 2214NJ-1
- Date 5/28/04
- NCHRP 350 Update Test Designation . . 3-10
- Appurtenance . . . . Permanent New Jersey Safety Shape Barrier
- Total Length . . . . 24.38 m
- Key Elements - Barrier
  - Description . . . . Half-Section New Jersey Shape Barrier
  - Base Width . . . . 381 mm
  - Height . . . . 813 mm
  - Concrete Material . . . . Nebraska 47-BD Mix
  - Reinforcing Steel Material . . . . Grade 60 Rebar
- Type of Soil . . . . NA
- Test Vehicle
  - Type/Designation 1170C
  - Make and Model . . . . 2002 Kia Rio
  - Curb . . . . 1,053 kg
  - Test Inertial . . . . 1,095 kg
  - Gross Static . . . . 1,170 kg
- Impact Conditions
  - Speed . . . . 97.9 km/h
  - Angle . . . . 26.1 degrees
  - Impact Location . . . . 5.63 m downstream from upstream end
- Exit Conditions
  - Speed . . . . 79.4 km/h
  - Angle . . . . 6.6 degrees
  - Exit Box Criterion . . . . Pass
- Post-Impact Trajectory
  - Vehicle Stability . . . . Satisfactory
  - Stopping Distance . . . . 75.69 m downstream
    0.64 m traffic-side face
- Occupant Impact Velocity (350 Update)
  - Longitudinal . . . . 5.02 m/s < 12 m/s
  - Lateral . . . . 10.67 m/s < 12 m/s
- Occupant Ridedown Deceleration (350 Update)
  - Longitudinal . . . . 5.49 Gs < 20 Gs
  - Lateral . . . . 8.08 Gs < 20 Gs
- THIV (not required) . . . . 12.38 m/s
- PHD (not required) . . . . 8.10 Gs
- Test Article Damage . . . . Minimal
- Test Article Deflections
  - Permanent Set . . . . NA
  - Dynamic . . . . NA
  - Working Width . . . . 485 mm
- Vehicle Damage . . . . Moderate
  - VDS[4] 1-RFQ-4
  - CDC[5] 1-RYEW5
  - Maximum Deformation . . . . 57 mm at right-front floorpan

Figure 13. Summary of Test Results and Sequential Photographs, Test 2214NJ-1

0.000 sec

0.062 sec

0.100 sec

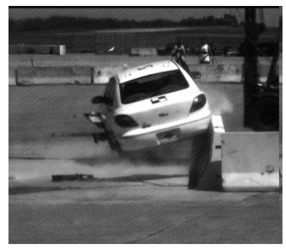
0.150 sec

0.214 sec

0.358 sec

0.000 sec

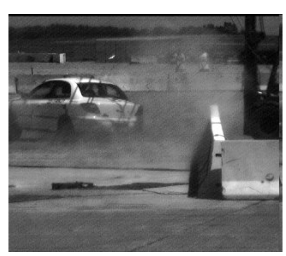
0.126 sec



0.220 sec

0.434 sec

0.706 sec



0.992 sec

Figure 14. Additional Sequential Photographs, Test 2214NJ-1

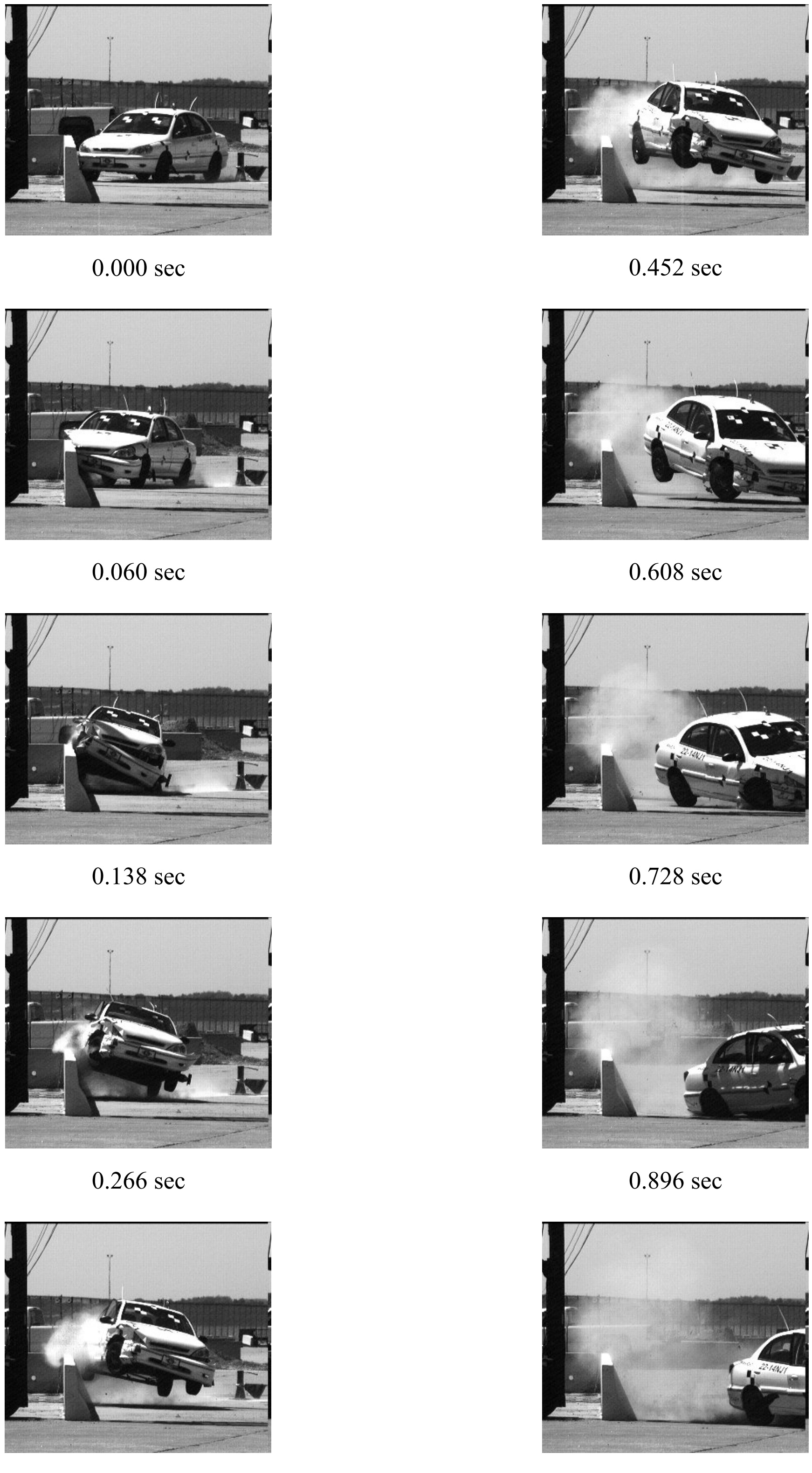


Figure 15. Additional Sequential Photographs, Test 2214NJ-1

0.000 sec

0.000 sec

0.067 sec

0.200 sec

0.167 sec

0.434 sec

0.267 sec

0.801 sec

0.400 sec

1.301 sec

Figure 16. Additional Sequential Photographs, Test 2214NJ-1

0.000 sec

0.200 sec

0.434 sec

0.701 sec

0.934 sec

1.201 sec

1.568 sec

2.002 sec

Figure 17. Additional Sequential Photographs, Test 2214NJ-1

Figure 18. Documentary Photographs, Test 2214NJ-1

Figure 19. Documentary Photographs, Test 2214NJ-1

Figure 20. Impact Location, Test 2214NJ-1

Figure 21. Vehicle Final Position and Trajectory Marks, Test 2214NJ-1

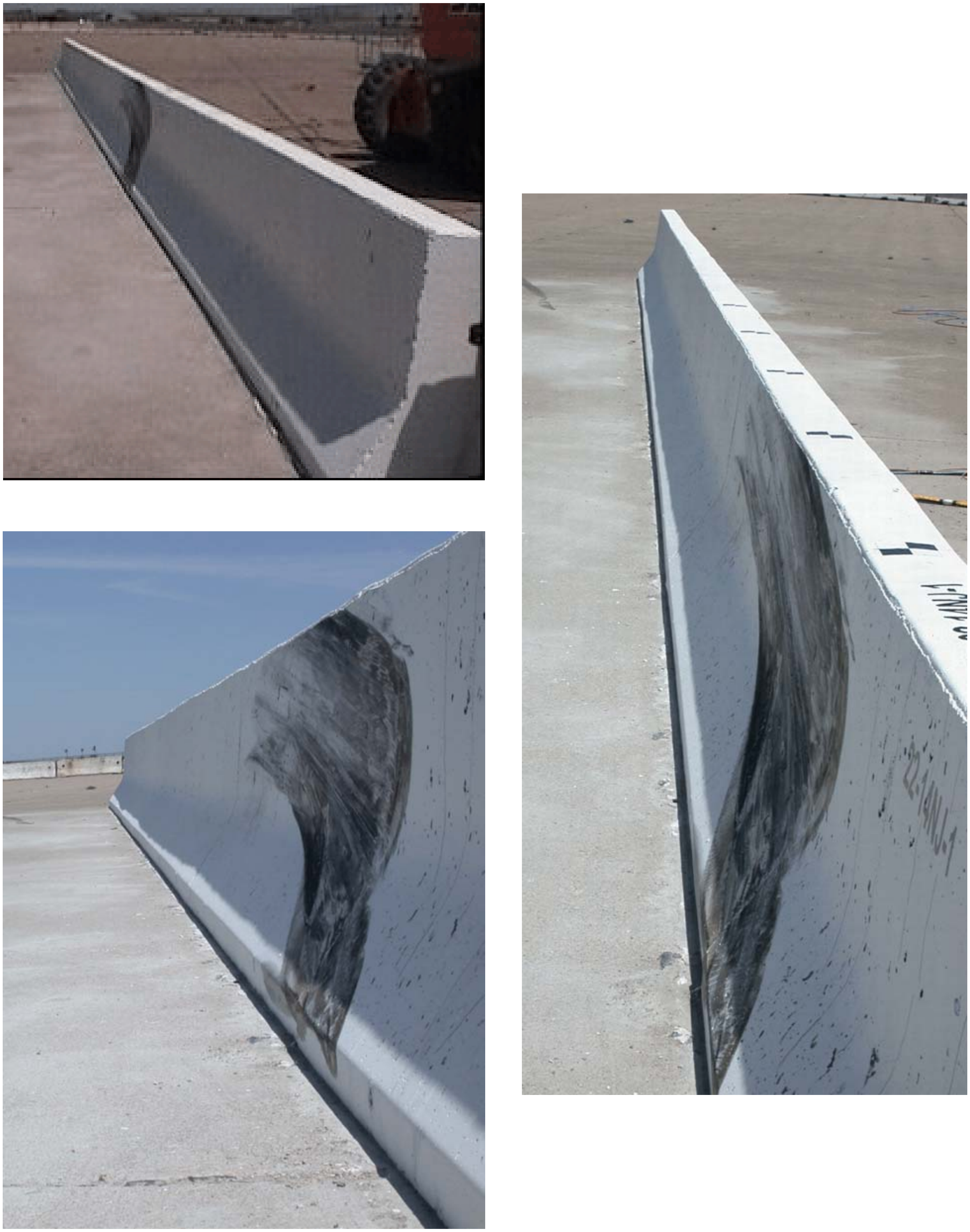


Figure 22. Permanent New Jersey Safety Shape Barrier Damage, Test 2214NJ-1

Figure 23. Vehicle Damage, Test 2214NJ-1

Figure 24. Vehicle Damage, Test 2214NJ-1

Figure 25. Windshield Damage, Test 2214NJ-1

6 SUMMARY AND CONCLUSIONS

A permanent New Jersey safety shape barrier was constructed and full-scale vehicle crash tested. One full-scale vehicle crash test, using a small car vehicle, was performed on the longitudinal barrier system and was determined to be acceptable according to the TL-3 safety performance criteria presented in the Update to NCHRP Report No. 350. A summary of the safety performance evaluation is provided in Table 3.

Table 3. Summary of Safety Performance Evaluation Results

Evaluation Factors	Evaluation Criteria		Test 2214NJ-1
Structural Adequacy	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.	S
Occupant Risk	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 the Update to NCHRP Report No. 350.	S
	F.	The vehicle should remain upright during and after collision.	S
	H.	Longitudinal and lateral occupant impact velocities should fall below the preferred value of 9.0 m/s (29.5 ft/s), or at least below the maximum allowable value of 12.0 m/s (39.4 ft/s).	S
	I.	Longitudinal and lateral occupant ridedown accelerations should fall below the preferred value of 15 Gs, or at least below the maximum allowable value of 20.0 Gs.	S
Vehicle Trajectory	M.	After impact, the vehicle shall exit the barrier within the exit box.	S

S - Satisfactory
U - Unsatisfactory
NA - Not Available

7 REFERENCES

1. 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 Research Program (NCHRP) Report No. 350, Transportation Research Board, Washington, D.C., 1993.

2. Sicking, D.L., Mak, K.K., and Rohde, J.R., *NCHRP Report No. 350 Update - Chapters 1 through 7, Draft Report*, Presented to the Transportation Research Board, Prepared by the Midwest Roadside Safety Facility, University of Nebraska-Lincoln, July 2005 [Privileged Document].

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

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

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

8 APPENDICES

APPENDIX A

English-Unit System Drawings

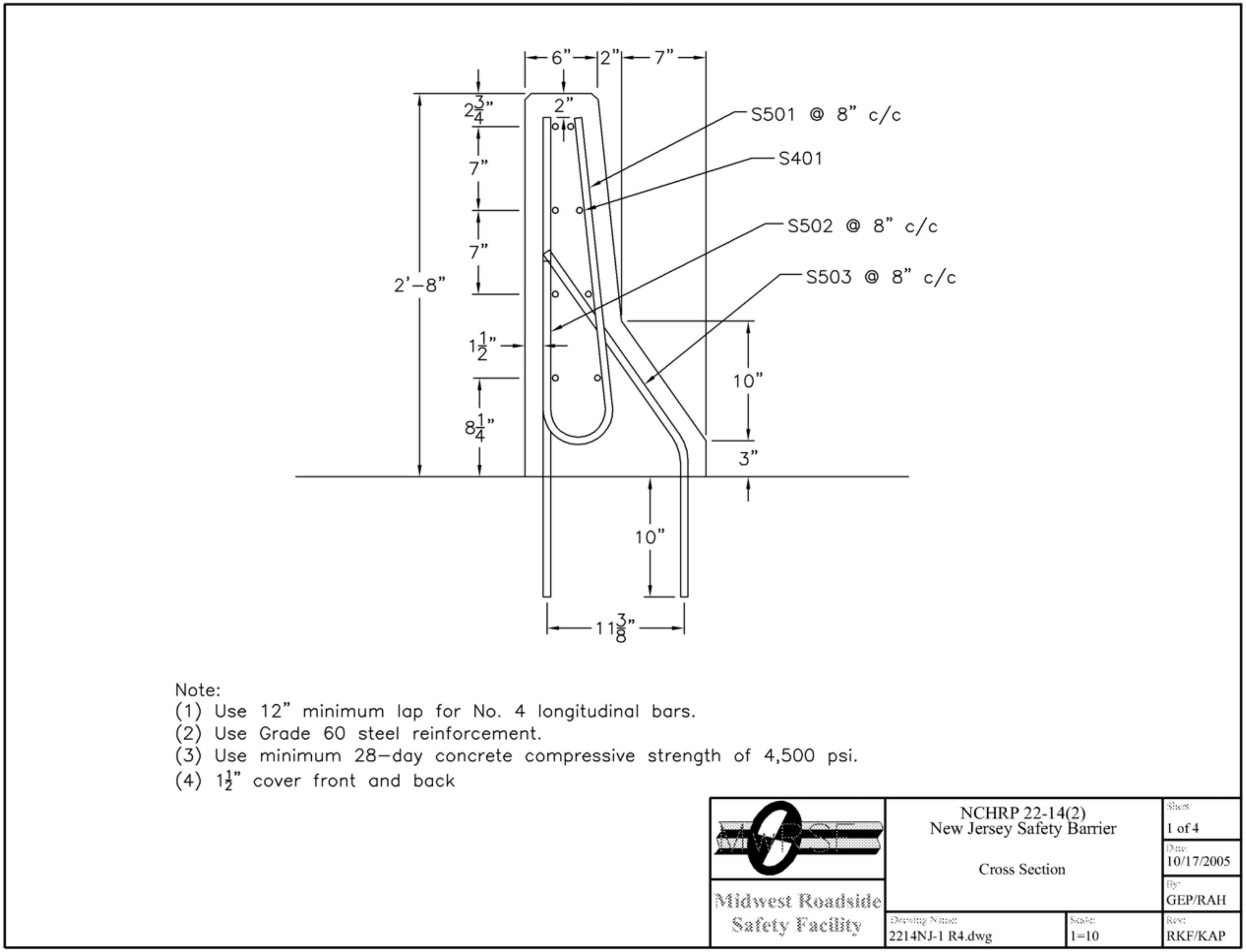
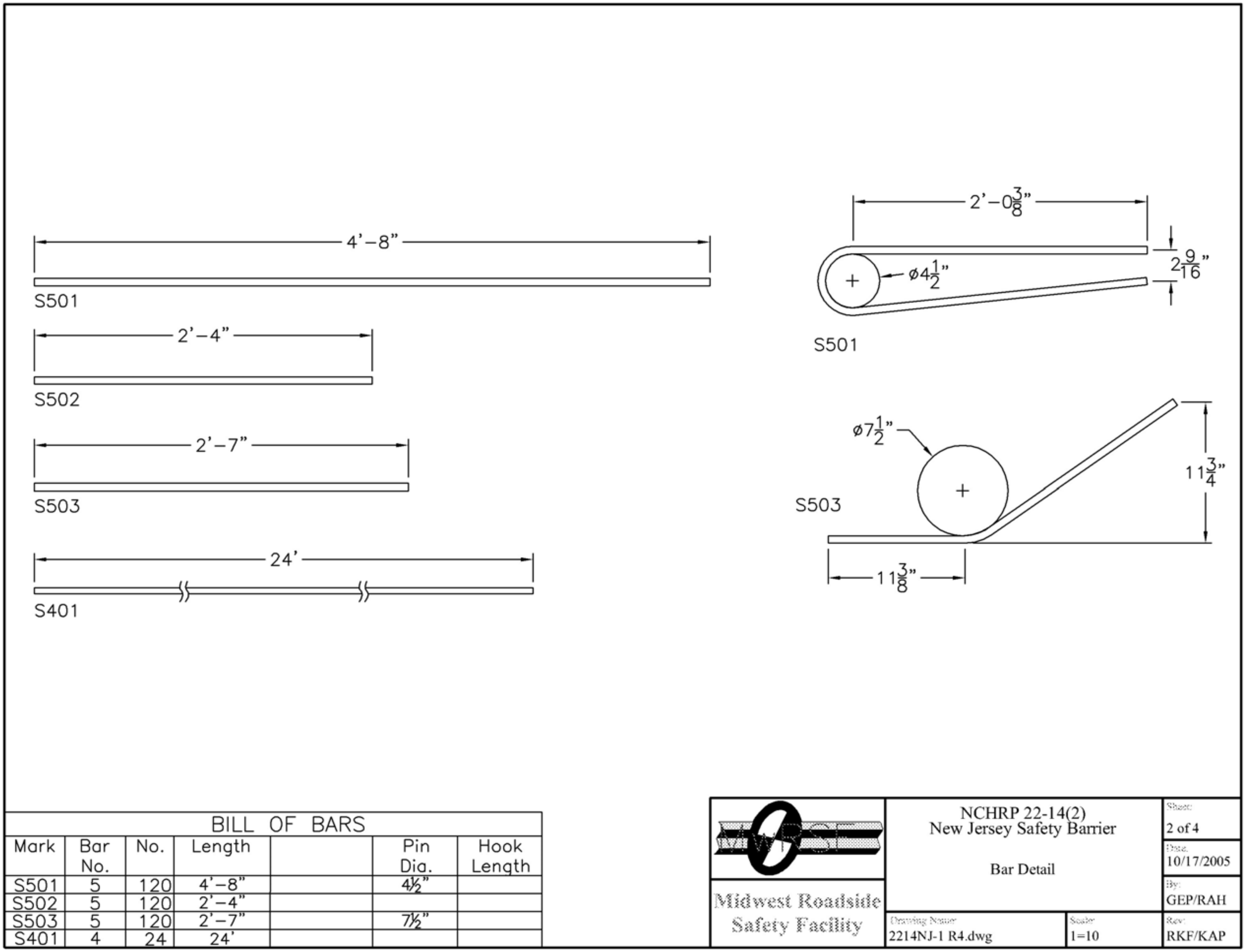


Figure A-1. Cross Section of Permanent New Jersey Safety Shape Barrier (English)



BILL OF BARS

Mark	Bar No.	No.	Length		Pin Dia.	Hook Length
S501	5	120	4'–8"		4½"	
S502	5	120	2'–4"			
S503	5	120	2'–7"		7½"	
S401	4	24	24'			

Figure A-2. Permanent New Jersey Safety Shape Barrier Reinforcement Details (English)

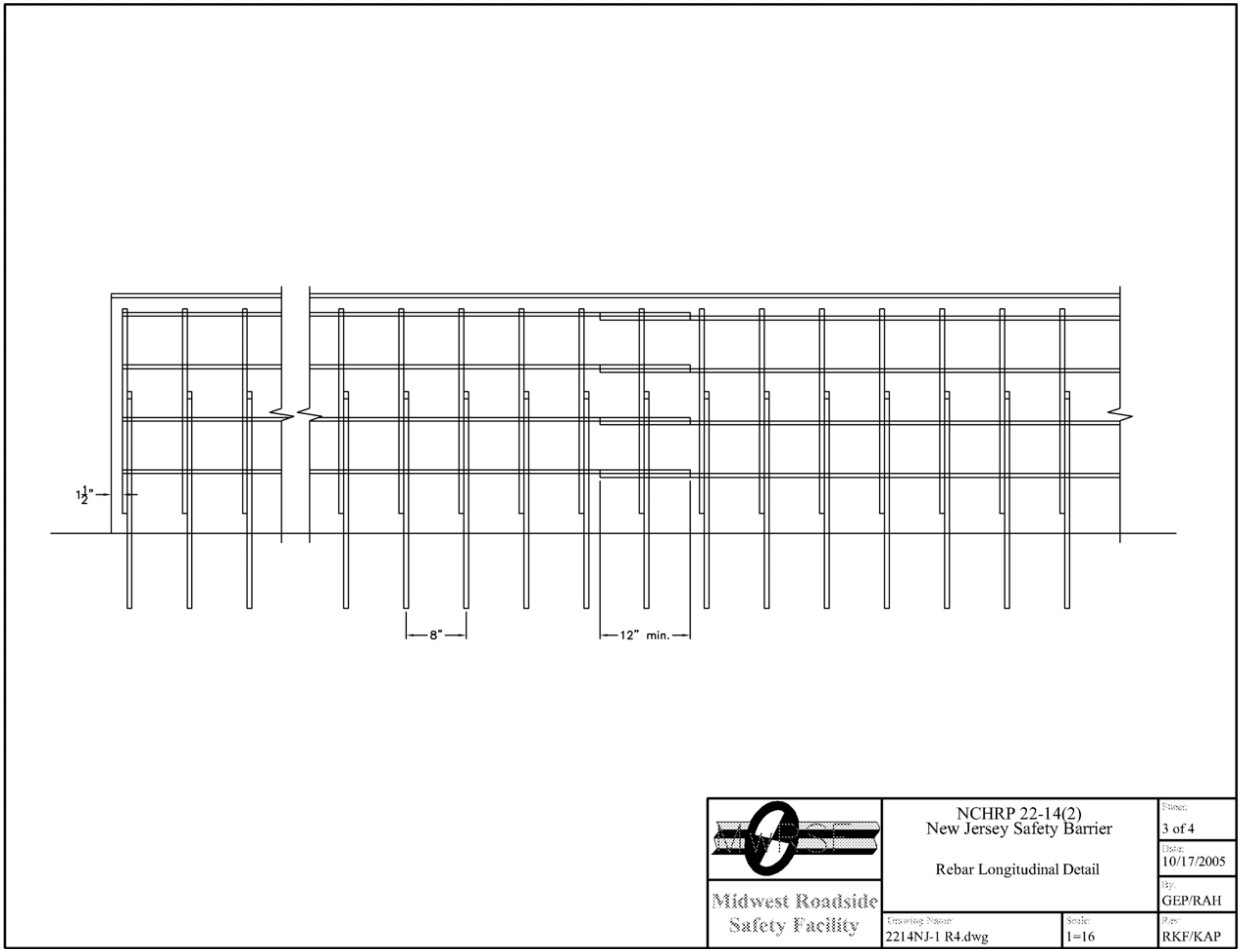


Figure A-3. Permanent New Jersey Safety Shape Barrier Reinforcement Layout Details (English)

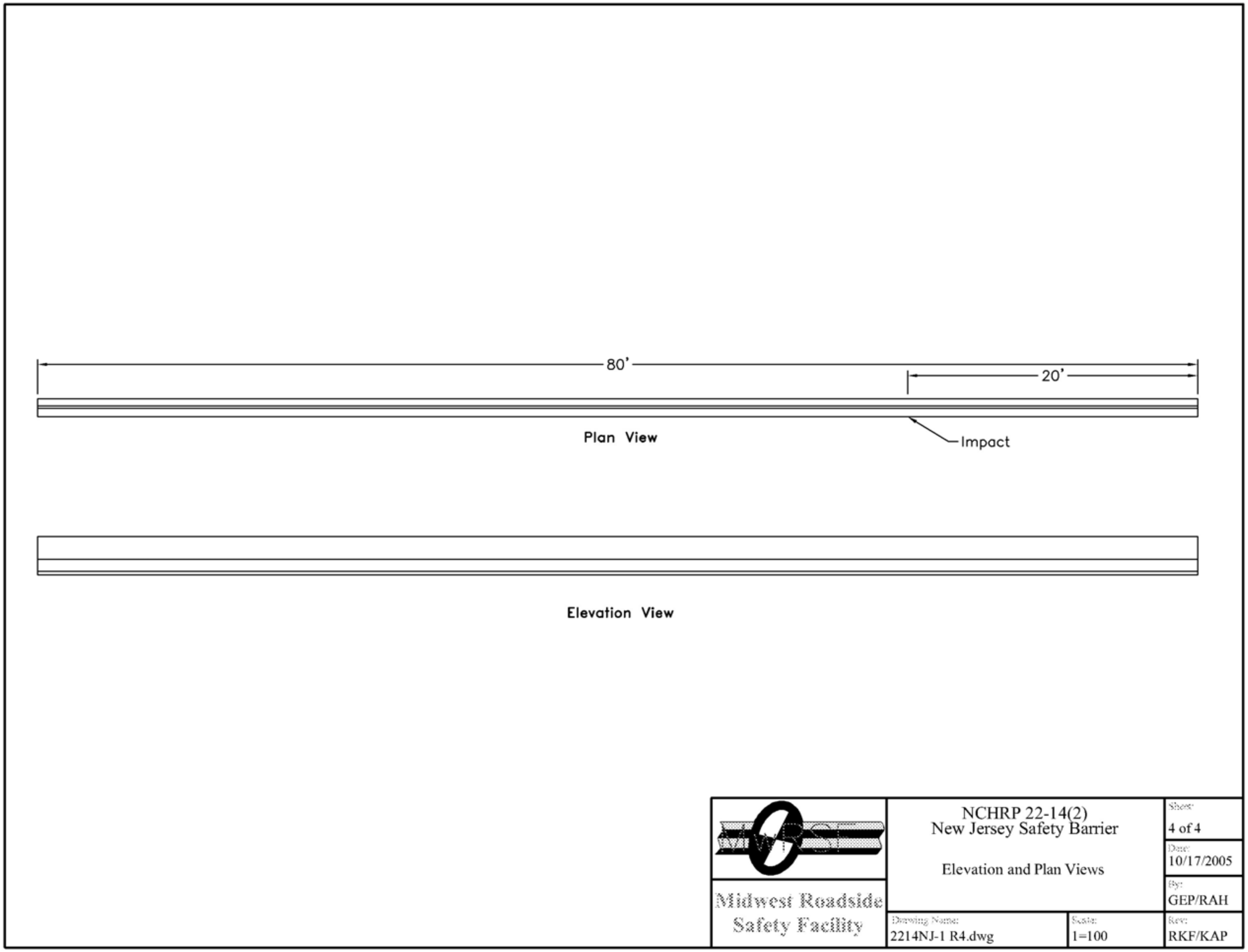


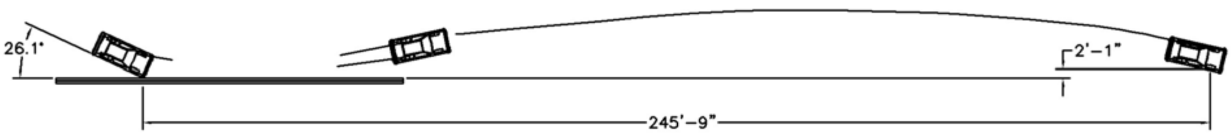
Figure A-4. Layout of Permanent New Jersey Safety Shape Barrier (English)

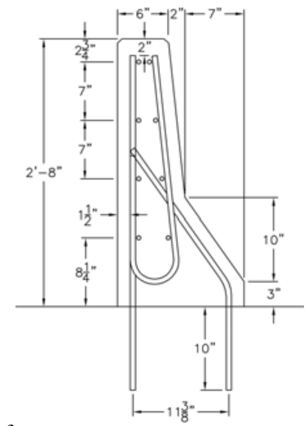
APPENDIX B

Test Summary Sheet in English Units

Figure B-1. Summary of Test Results and Sequential Photographs (English), Test 2214NJ-1

0.000 sec | 0.102 sec | 0.160 sec | 0.196 sec | 0.390 sec





- Test Agency . . . . MwRSF
- Test Number 2214NJ-1
- Date 5/28/04
- NCHRP 350 Update Test Designation . . 3-10
- Appurtenance . . . . Permanent New Jersey Safety Shape Barrier
- Total Length . . . . 80 ft
- Key Elements - Barrier
  - Description . . . . Half-Section New Jersey Shape Barrier
  - Base Width . . . . 15 in.
  - Height . . . . 32 in.
  - Concrete Material . . . . Nebraska 47-BD Mix
  - Reinforcing Steel Material . . . . Grade 60 Rebar
- Type of Soil . . . . NA
- Test Vehicle
  - Type/Designation 1170C
  - Make and Model . . . . 2002 Kia Rio
  - Curb . . . . 2,321 lbs
  - Test Inertial . . . . 2,413 lbs
  - Gross Static . . . . 2,579 lbs
- Impact Conditions
  - Speed . . . . 60.8 mph
  - Angle . . . . 26.1 degrees
  - Impact Location . . . . 18 ft - 5.5 in. downstream from upstream end
- Exit Conditions
  - Speed . . . . 49.3 mph
  - Angle . . . . 6.6 degrees
  - Exit Box Criterion . . . . Pass
- Post-Impact Trajectory
  - Vehicle Stability . . . . Satisfactory
  - Stopping Distance . . . . 245 ft - 9 in. downstream
    2 ft - 1 in. traffic-side face
- Occupant Impact Velocity (350 Update)
  - Longitudinal . . . . 16.47 ft/s < 39.4 ft/s
  - Lateral . . . . 35.01 ft/s < 39.4 ft/s
- Occupant Ridedown Deceleration (350 Update)
  - Longitudinal . . . . 5.49 Gs < 20 Gs
  - Lateral . . . . 8.08 Gs < 20 Gs
- THIV (not required) . . . . 40.62 ft/s
- PHD (not required) . . . . 8.10 Gs
- Test Article Damage . . . . Minimal
- Test Article Deflections
  - Permanent Set . . . . NA
  - Dynamic . . . . NA
  - Working Width . . . . 19 in.
- Vehicle Damage . . . . Moderate
  - VDS[4] 1-RFQ-4
  - CDC[5] 1-RYEW5
  - Maximum Deformation . . . . 2.25 in. at right-front floorpan

Figure B-1. Summary of Test Results and Sequential Photographs (English), Test 2214NJ-1

APPENDIX C

Occupant Compartment Deformation Data, Test 2214NJ-1

VEHICLE PRE/POST CRUSH INFO

TEST: 2214NJ-1
VEHICLE: 2002 Kia Rio

										Secondary points					
POINT	**X**	**Y**	**Z**	**X'**	**Y'**	**Z'**	**DEL X**	**DEL Y**	**DEL Z**	**X2**	**Z2**	**X2'**	**Z2'**	**Del X2**	**Del Z2**
1	57.25	0.5	1.75	56.75	0.5	0.5	-0.5	0	**-1.25**	53.75	1	53.25	1.25	-0.5	**0.25**
2	59	4.75	1.25	58	4.75	0	-1	0	**-1.25**	55.5	1.25	54.5	1	-1	**-0.25**
3	58.75	8.5	0.75	56.75	7.75	-0.25	-2	-0.75	**-1**	55.25	1.5	53	1	-2.25	**-0.5**
4	57.25	12.25	0.5	55.75	11.5	0	-1.5	-0.75	**-0.5**	53.75	1	52.25	0.5	-1.5	**-0.5**
5	55.5	15.52	0.5	53.25	14.25	0	-2.25	-1.27	**-0.5**	52	0.5	50	0	-2	**-0.5**
6	53.25	19.25	0.75	51.25	17.75	-0.5	-2	-1.5	**-1.25**	49.75	0	47.5	-0.75	-2.25	**-0.75**
7	53.25	0.25	-1.25	53	0.25	-3	-0.25	0	**-1.75**	49.75	-4	49.5	-4.25	-0.25	**-0.25**
8	53.5	3.75	-4	53.5	4	-5.5	0	0.25	**-1.5**	50	-6.25	49.5	-6.5	-0.5	**-0.25**
9	53	9	-3.5	52.75	9	-5	-0.25	0	**-1.5**	49.5	-5.25	49	-5.5	-0.5	**-0.25**
10	52.25	13.25	-4.5	52	13	-5	-0.25	-0.25	**-0.5**	48.75	-5.5	48.5	-5.25	-0.25	**0.25**
11	51.5	18.25	-4.5	51.25	17.5	-5	-0.25	-0.75	**-0.5**	48	-5.25	47.75	-5	-0.25	**0.25**
12	48.25	-1.25	-3.5	48.25	-0.75	-5	0	0.5	**-1.5**	44.75	-6	44.75	-6.5	0	**-0.5**
13	48.5	3.25	-4.25	48.5	4	-5.75	0	0.75	**-1.5**	45	-6.25	44.75	-6.75	-0.25	**-0.5**
14	48.5	8.25	-4.5	48.75	8.75	-5.75	0.25	0.5	**-1.25**	45	-5.75	45	-6.25	0	**-0.5**
15	48.25	13.25	-4.75	48.5	13	-6.25	0.25	-0.25	**-1.5**	44.75	-5.75	45	-6.25	0.25	**-0.5**
16	47.5	17.75	-5.25	47.25	17.25	-5.25	-0.25	-0.5	**0**	44	-5.75	43.75	-5.25	-0.25	**0.5**
17	39.25	-0.5	-4	39.25	0	-5.25	0	0.5	**-1.25**	35.75	-5.75	35.5	-6.25	-0.25	**-0.5**
18	39.5	5	-4.75	39.5	5.5	-6.25	0	0.5	**-1.5**	36	-6.25	35.5	-6.75	-0.5	**-0.5**
19	39.5	8.75	-4.5	39.75	9.25	-5.75	0.25	0.5	**-1.25**	36	-5.5	35.75	-6	-0.25	**-0.5**
20	39.5	14.25	-5	39.5	15	-6.5	0	0.75	**-1.5**	36	-5.75	35.75	-6.25	-0.25	**-0.5**
21	39	18	-5.5	39	18.25	-6.5	0	0.25	**-1**	35.5	-5.75	35.5	-6	0	**-0.25**
22	29.5	18.25	-2	29	18.75	-2.5	-0.5	0.5	**-0.5**	26	-1.75	25.5	-2	-0.5	**-0.25**
23	29.25	8.5	-2	29.25	9	-2.75	0	0.5	**-0.75**	25.75	-2.75	25.75	-3	0	**-0.25**
24	17	15.5	-5.25	17	16.5	-5.25	0	1	**0**	13.5	-5.75	13.5	-5.25	0	**0.5**
25	16.5	7.5	-5	16.5	7.75	-5.5	0	0.25	**-0.5**	13	-5.75	13	-5.5	0	**0.25**
26															
27															
28															
29															
30															

ORIENTATION AND REFERENCE INFO

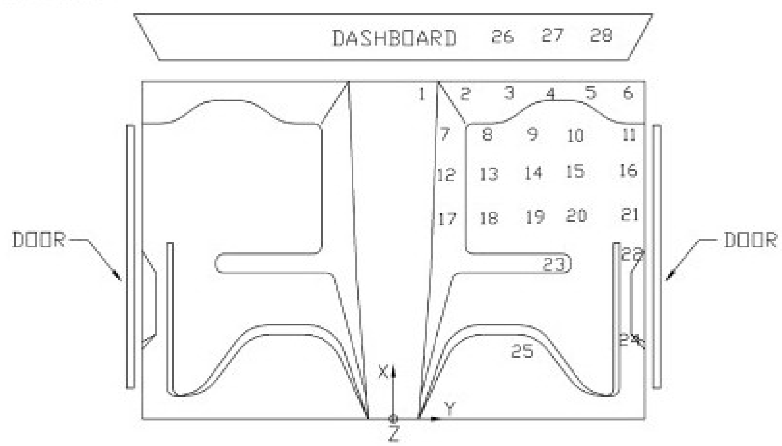


Figure C-1. Occupant Compartment Deformation Data, Test 2214NJ-1

Occupant Compartment Deformation Index (OCDI)

Test No. 2214NJ-1
Vehicle Type: 2002 Kia Rio

OCDI = XXABCDEFGHI

XX = location of occupant compartment deformation

A = distance between the dashboard and a reference point at the rear of the occupant compartment, such as the top of the rear seat or the rear of the cab on a pickup

B = distance between the roof and the floor panel

C = distance between a reference point at the rear of the occupant compartment and the motor panel

D = distance between the lower dashboard and the floor panel

E = interior width

F = distance between the lower edge of right window and the upper edge of left window

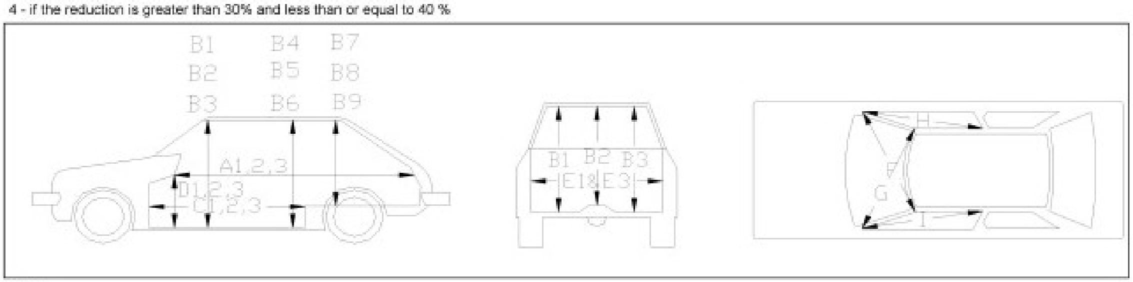
G = distance between the lower edge of left window and the upper edge of right window

H= distance between bottom front corner and top rear corner of the passenger side window

I= distance between bottom front corner and top rear corner of the driver side window

Severity Indices

0 - if the reduction is less than 3%
1 - if the reduction is greater than 3% and less than or equal to 10 %
2 - if the reduction is greater than 10% and less than or equal to 20 %
3 - if the reduction is greater than 20% and less than or equal to 30 %
4 - if the reduction is greater than 30% and less than or equal to 40 %



where,
1 = Passenger Side
2 = Middle
3 = Driver Side

Location:

Measurement	Pre-Test (in.)	Post-Test (in.)	Change (in.)	% Difference	Severity Index
A1	64.75	64.50	-0.25	-0.39	0
A2	65.75	65.50	-0.25	-0.38	0
A3	64.75	64.00	-0.75	-1.16	0
B1	40.88	41.00	0.13	0.31	0
B2	40.50	41.00	0.50	1.23	0
B3	43.50	44.00	0.50	1.15	0
C1	55.50	55.75	0.25	0.45	0
C2	58.50	58.25	-0.25	-0.43	0
C3	55.50	54.00	-1.50	-2.70	0
D1	13.25	13.25	0.00	0.00	0
D2	12.13	12.50	0.38	3.09	1
D3	13.00	13.00	0.00	0.00	0
E1	52.75	51.25	-1.50	-2.84	0
E3	53.75	54.00	0.25	0.47	0
F	51.00	52.75	1.75	3.43	1
G	50.50	50.50	0.00	0.00	0
H	36.75	35.75	-1.00	-2.72	0
I	36.88	37.00	0.13	0.34	0

Note: Maximum sevrity index for each variable (A-I) is used for determination of final OCDI value

	XX	A	B	C	D	E	F	G	H	I
Final OCDI:		0	0	0	1	0	1	0	0	0

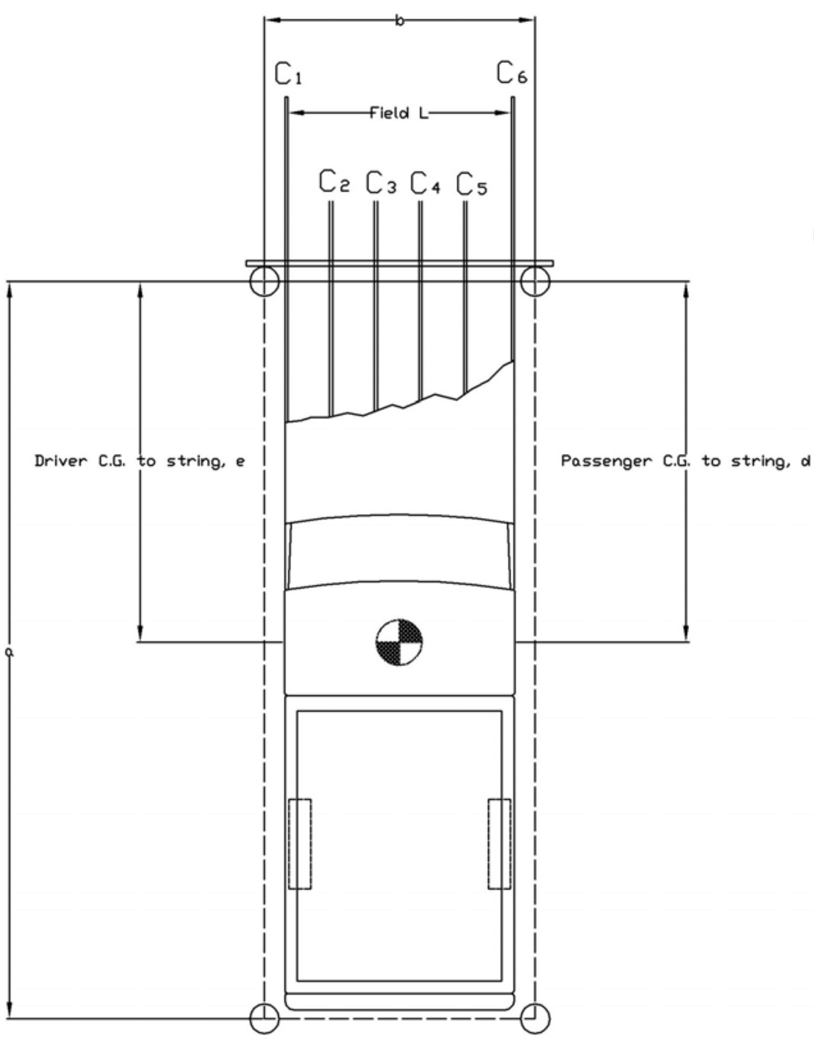
Figure C-2. Occupant Compartment Deformation Index (OCDI), Test 2214NJ-1

Date: 5/28/04 Test Number: 2214NJ-1 Model: KIA Rio

Make: KIA Vehicle I.D.#: KNADC123526145862

Tire Size: LT 245/75 R16 Year: 2002 Odometer: 19500

*(All Measurements Refer to Impacting Side) Vehicle Geometry -- mm (in.)



a 4826 (190)

b 2153 (84.75)

Field L 1448 (57)

Bumper Height 305 (12)

d 2184 (86)

e 2146 (84.5)

C_1 483 (19)

C_2 394 (15.5)

C_3 400 (15.75)

C_4 438 (17.25)

C_5 533 (21)

C_6 984 (38.75)

Figure C-3. NASS Crush Data, Test 2214NJ-1

APPENDIX D

Accelerometer and Rate Transducer Data Analysis, Test 2214NJ-1

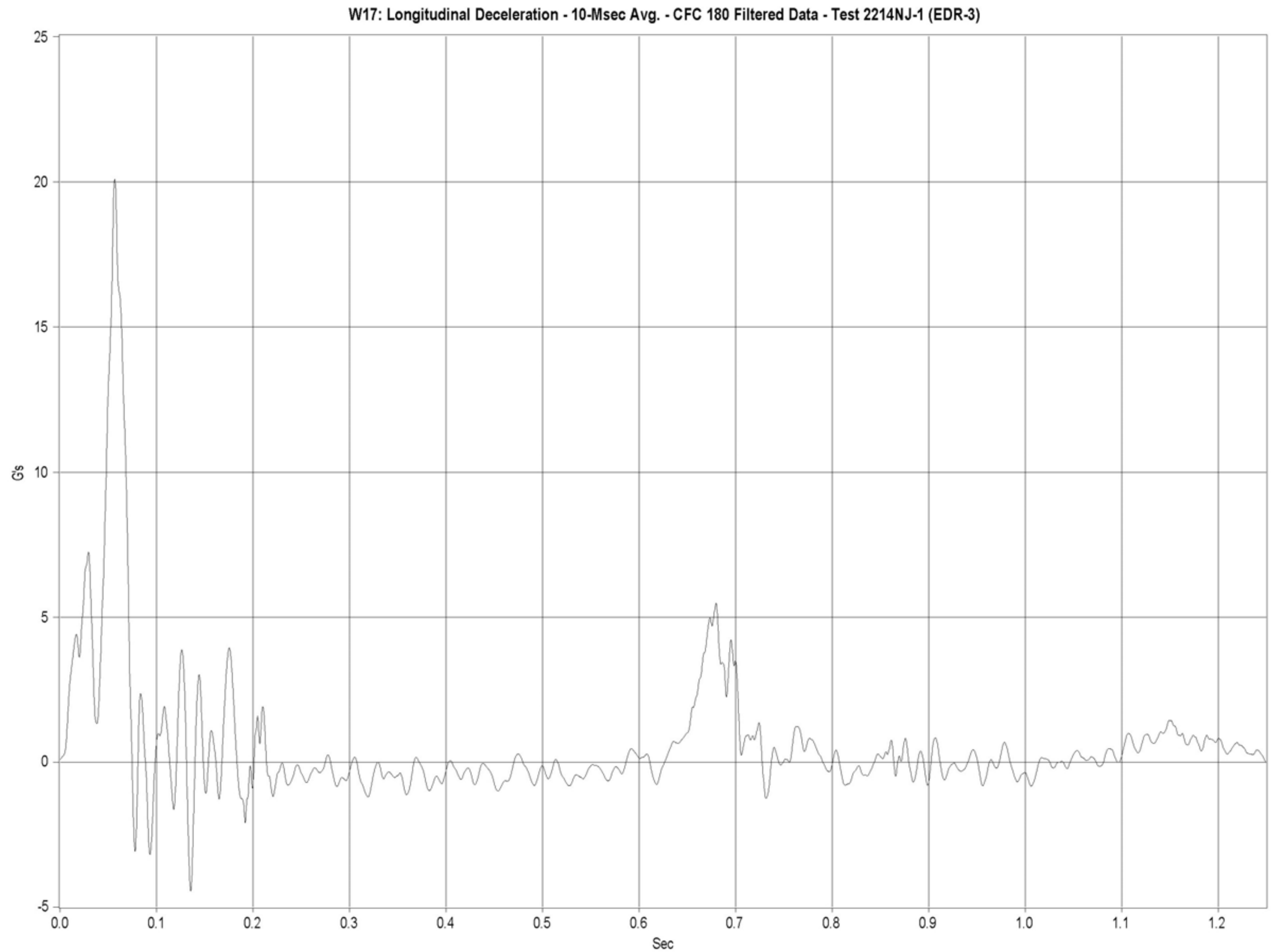


Figure D-1. Graph of Longitudinal Deceleration, Test 2214NJ-1

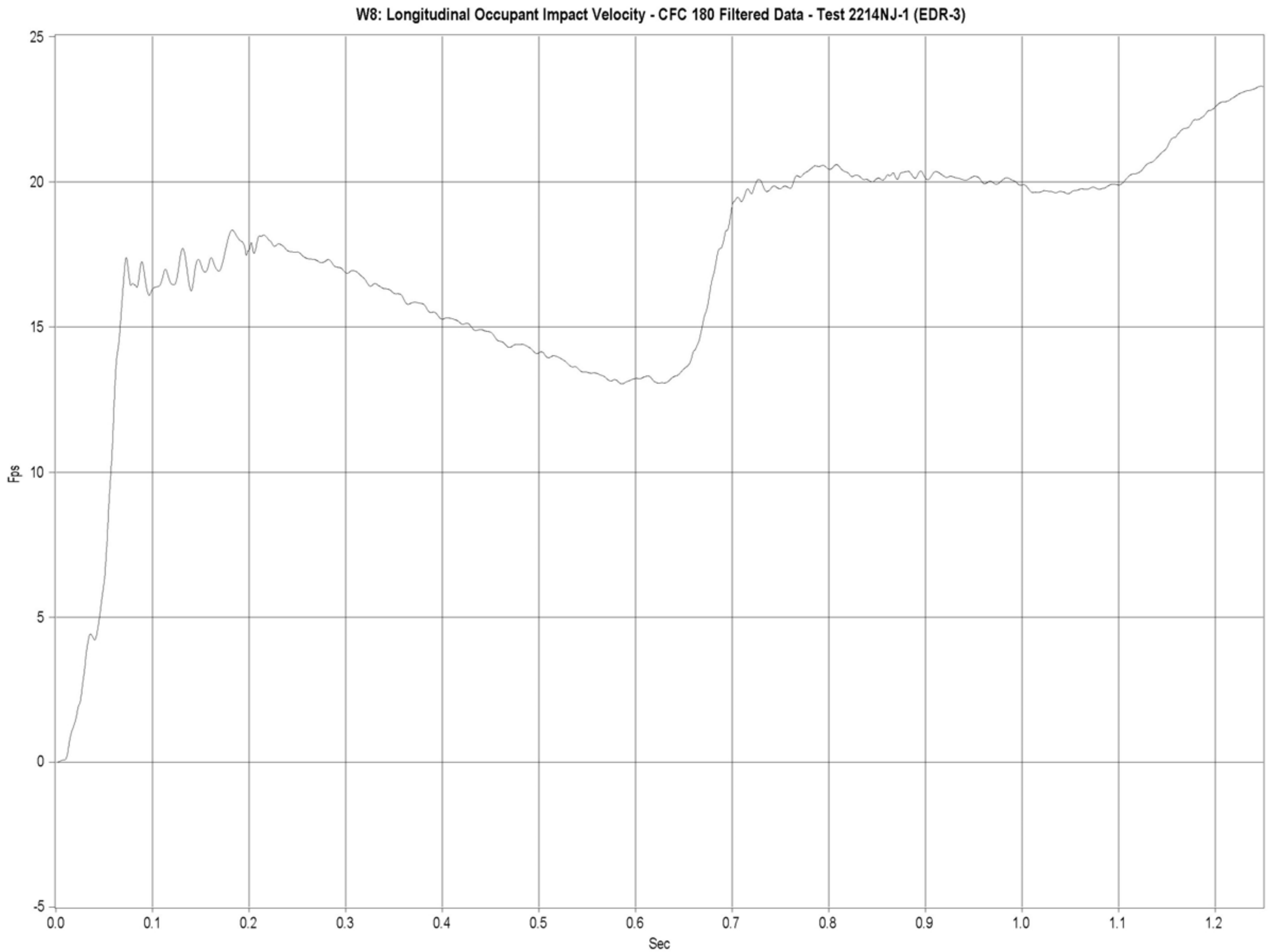


Figure D-2. Graph of Longitudinal Occupant Impact Velocity, Test 2214NJ-1

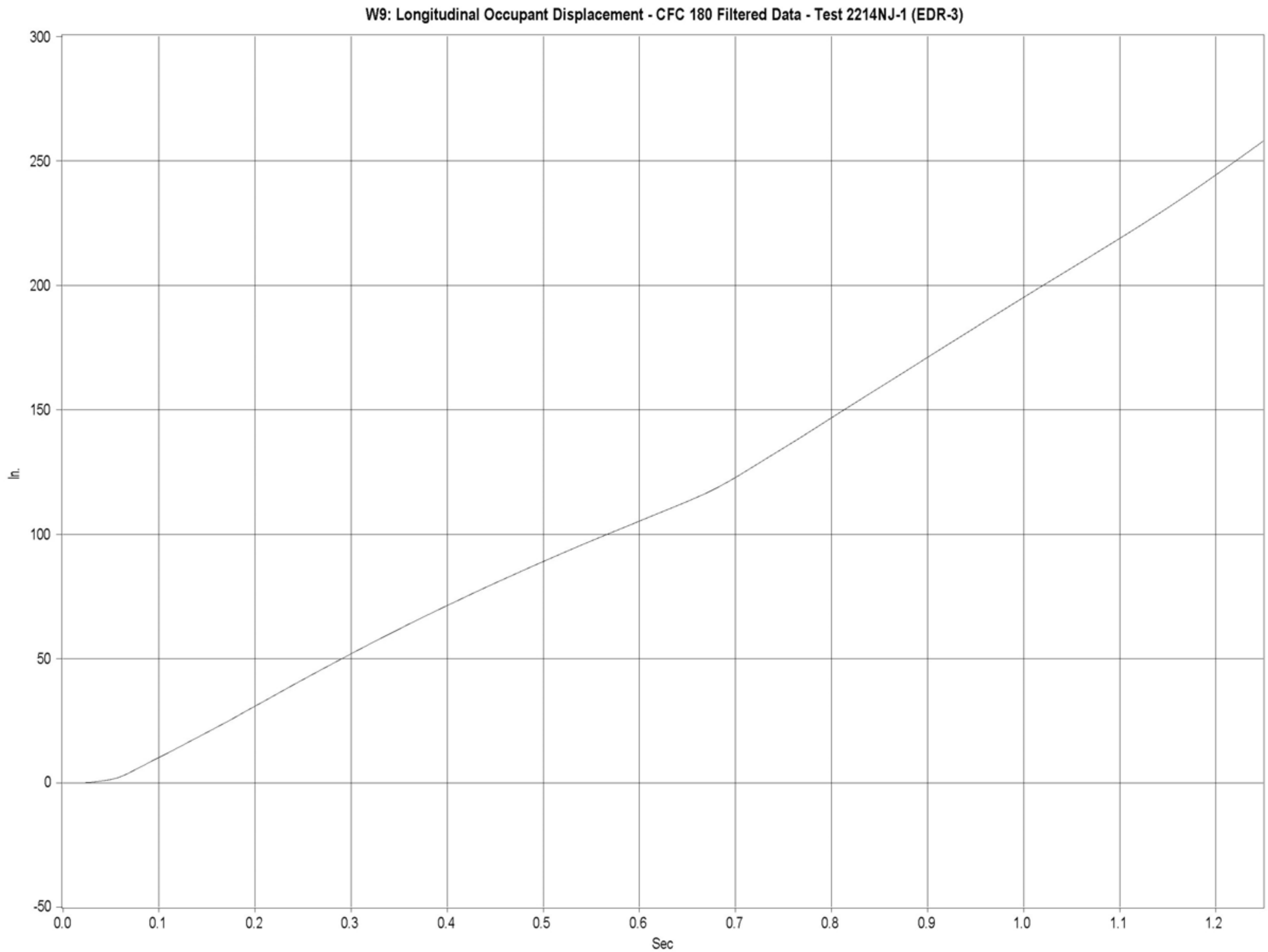


Figure D-3. Graph of Longitudinal Occupant Displacement, Test 2214NJ-1

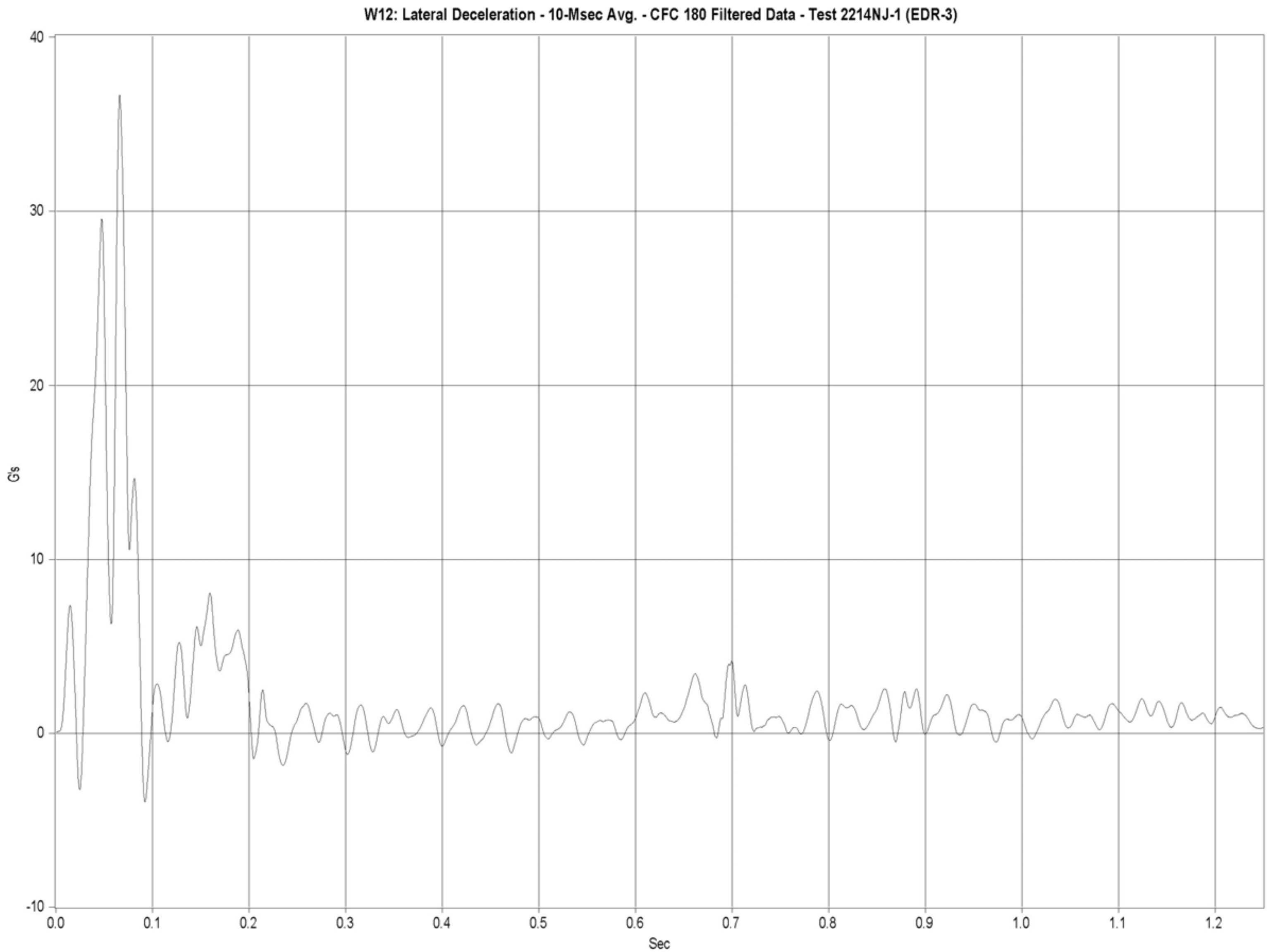


Figure D-4. Graph of Lateral Deceleration, Test 2214NJ-1

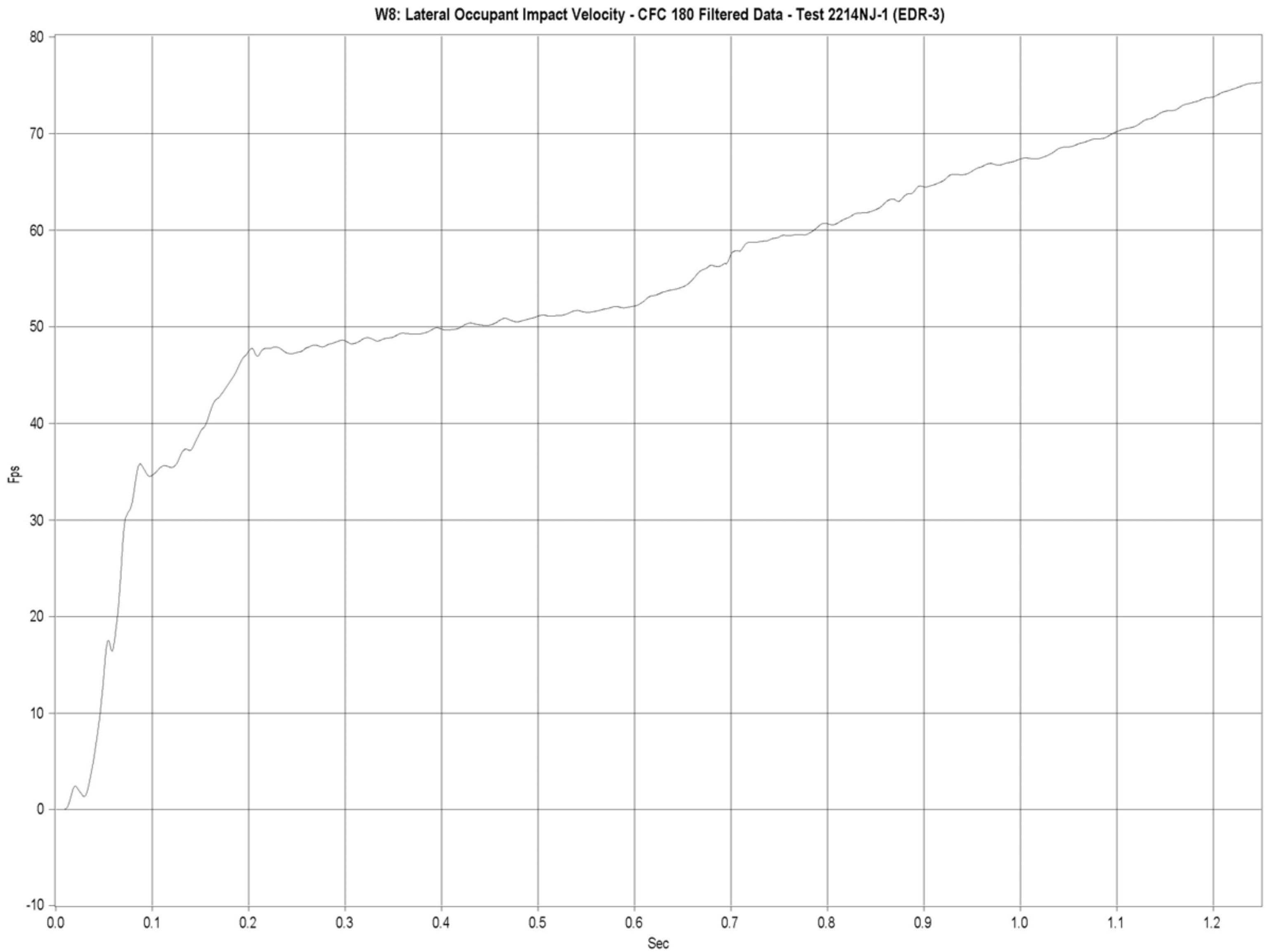


Figure D-5. Graph of Lateral Occupant Impact Velocity, Test 2214NJ-1

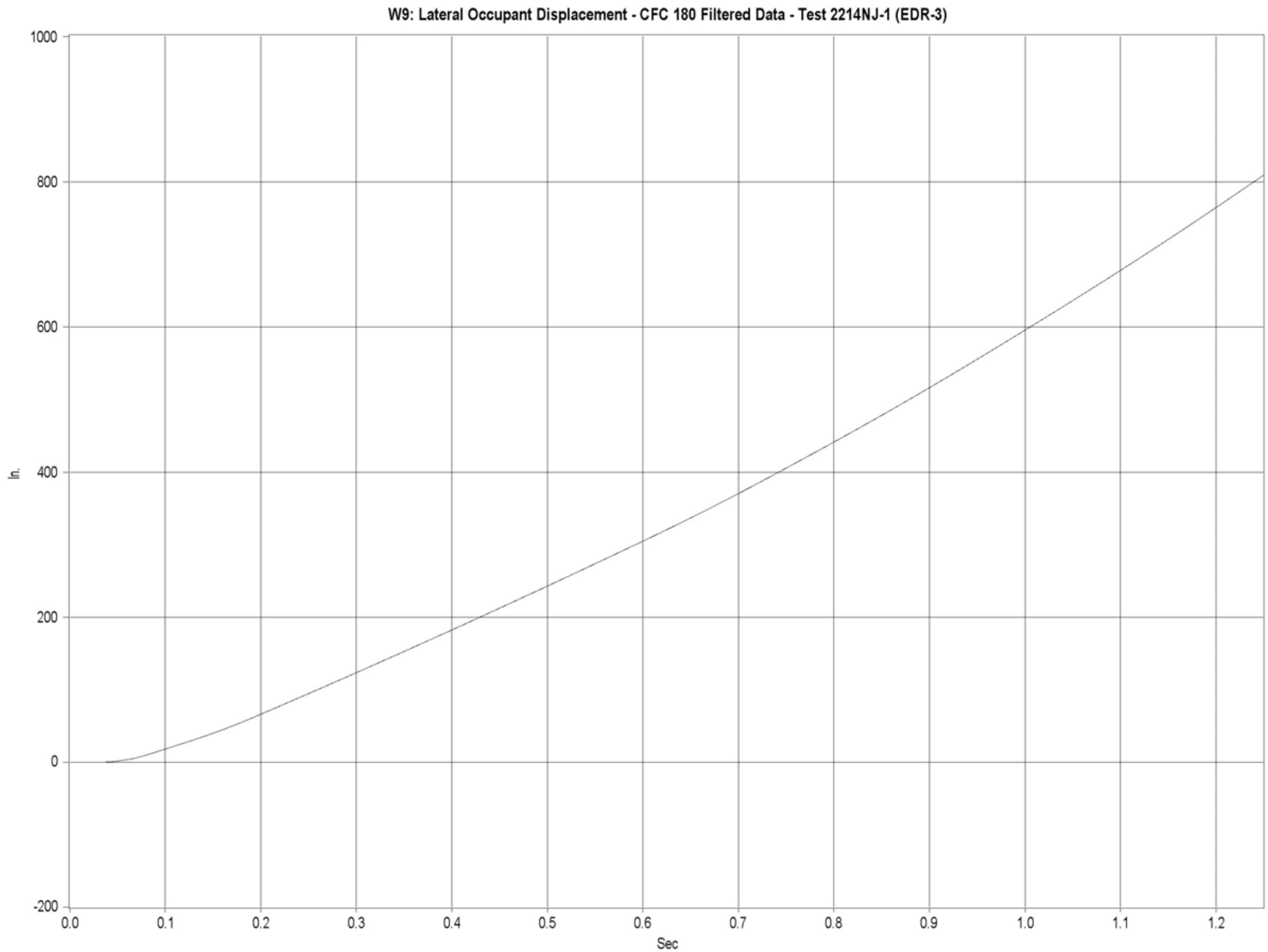


Figure D-6. Graph of Lateral Occupant Displacement, Test 2214NJ-1

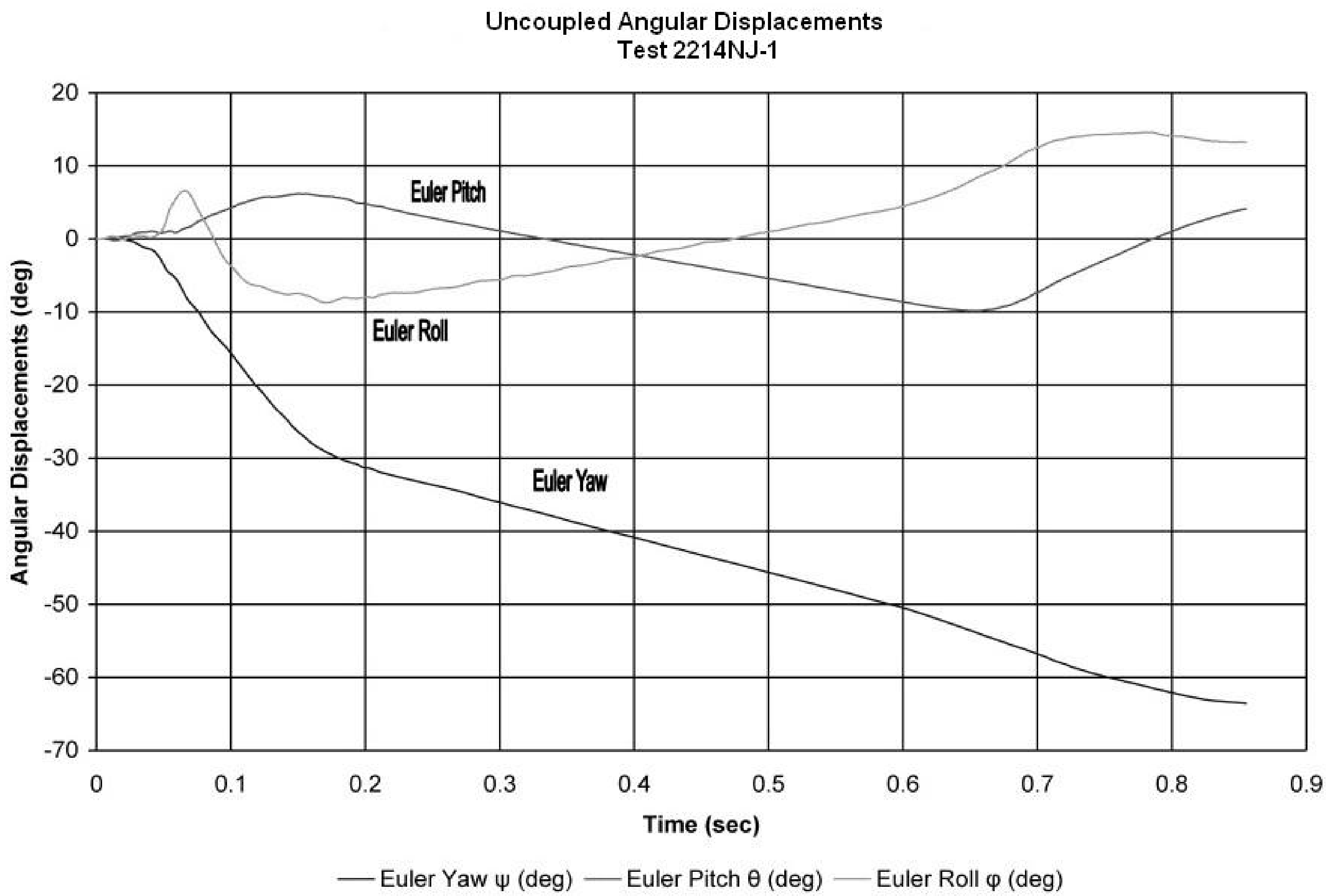


Figure D-7. Graph of Roll, Pitch, and Yaw Angular Displacements, Test 2214NJ-1