Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-01/1792-2		

4. Title and Subtitle	5. Report Date
IMPACT PERFORMANCE EVALUATION OF WORK ZONE TRAFFIC CONTROL DEVICES	December 2000
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Roger P. Bligh, D. Lance Bullard, Wanda L. Menges, and Sandra K. Schoeneman	Report 1792-2
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	11. Contract or Grant No. Study No. 0-1792
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas Department of Transportation Construction Division Research and Technology Transfer Section P. O. Box 5080 Austin, Texas 78763-5080	Research: September 1998-August 1999
	14. Sponsoring Agency Code

15. Supplementary Notes

Research performed in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.
Research Project Title: Roadside Safety Hardware for Traffic Control Devices

16. Abstract

The goal of this project and related previous projects is to provide traffic control devices for use in work zones that would perform satisfactorily when impacted by errant vehicles in accordance with national safety performance guidelines set forth in *National Cooperative Highway Research Program Report 350* (NCHRP Report 350). The specific objective of this project is to test and evaluate additional work zone sign supports and barricades to determine those that would perform satisfactorily when impacted by errant vehicles at 0 degrees (head-on).

This report consists of four chapters describing the performance of full-scale testing on work zone barricades. Chapter I introduces the problem, background, objectives and scope. Chapter II outlines the research approach of the project, including descriptions of the work zone traffic control devices tested, the crash test matrix, and the evaluation criteria. Results of the crash tests are presented in Chapter III. A summary of findings, conclusions, and recommendations is presented in Chapter IV.

17. Key Words	18. Distribution Statement
Work Zone Devices, Barricades, Sign Supports, Portable Sign Stands, Mailboxes, Crash Testing, Roadside Safety	No restrictions. This document is available to the public through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	418	

Form DOT F 1700.7 (8-72) **Reproduction of completed page authorized**

IMPACT PERFORMANCE EVALUATION
OF WORK ZONE TRAFFIC CONTROL DEVICES

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Report 1792-2
Project Number 0-1792
Research Project Title: Roadside Safety Hardware
for Traffic Control Devices

Sponsored by the
Texas Department of Transportation
In Cooperation with the
U.S. Department of Transportation
Federal Highway Administration

December 2000

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ACKNOWLEDGMENTS

This research project was conducted under a cooperative program between the Texas Transportation Institute, the Texas Department of Transportation, and the U.S. Department of Transportation, Federal Highway Administration. The TxDOT project director for this research was Mr. Greg Brinkmeyer. His assistance is acknowledged and appreciated.

Special thanks goes to the project panel:

- Greg Brinkmeyer
- Dan Maupin
- Paul Frerich
- Larry Colclasure
- Manny Aguilera
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- David Mitchell
- Billy Wehring
- Bill Yates
- Randy Lloyd
- Garry Silagi

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I. INTRODUCTION

PROBLEM

Safety of work zones is a major concern since it is not always possible to maintain a level of safety comparable to that of a normal highway not under construction. Proper traffic control is critical to the safety of work zones. However, traffic control devices themselves may pose a safety hazard when impacted by errant vehicles. Thus, the Federal Highway Administration (FHWA) and the Texas Manual on Uniform Traffic Control Devices (TxMUTCD) require that work zone traffic control devices be crashworthy.

FHWA has formally adopted the performance evaluation guidelines for highway safety features set forth in National Cooperative Highway Research Program (*NCHRP*) *Report 350* for the impact performance evaluation of work zoned traffic control devices.[(1)] FHWA has also mandated that, starting in October 2000, only Category II work zone devices (such as portable sign stands with signs, Type I, II and III barricades, vertical panels, intrusion alarms, and other devices not expected to cause significant velocity change) that have successfully met the performance evaluation guidelines set forth in *NCHRP Report 350* may be used on the National Highway System (NHS) for new installations.

BACKGROUND

Little is known about the impact performance of many work zone traffic control devices. TxDOT has, in recent years, sponsored a number of studies at the TTI to assess the impact performance of various work zone traffic control devices, including plastic drums, sign substrates, temporary sign supports, and barricades.[(2-6)] Results from these studies are being incorporated by the department into the compliant work zone traffic control device (CWZTD) list and barricade and construction (BC) standard sheets for construction projects. However, additional design, evaluation, and testing of work zone sign supports and barricades are needed to address the needs of TxDOT and its contractors.

OBJECTIVES/SCOPE OF RESEARCH

The goal of this project is to identify traffic control devices for use in work zones that perform satisfactorily when impacted by errant vehicles in accordance with national safety performance guidelines set forth in *NCHRP Report 350*. The specific objective of this project is to test and evaluate additional work zone sign supports and barricades to determine those that would perform satisfactorily when impacted by errant vehicles and to develop devices for those applications for which acceptable alternatives are not available.

This report consists of four chapters. Chapter II outlines the research approach of the study, including descriptions of the work zone traffic control devices tested, the crash test matrix, and the evaluation criteria. Chapter III presents results of the crash tests. A summary of findings, conclusions, and recommendations is presented in Chapter IV.

II. STUDY APPROACH

WORK ZONE CONTROL DEVICES TESTED

A total of 24 work zone traffic control devices were crashed tested under this project. The following section presents descriptions of these devices.

TYPE I BARRICADES

Previous TxDOT research focused primarily on the testing and evaluation of Type III barricades. Type III barricades are widely used and are generally more critical in regard to impact performance. Several crashworthy designs were successfully developed and tested. Design principles learned during this effort were used to develop Type I barricades under this project.

Type I Plastic A-frame Barricade (Test No. 417928-6)

Fender Enterprises supplied the Type I Plastic A-frame Barricade tested, and Figure 1 shows details of the barricade. A 25 mm × 204 mm × 2428 mm (1 inch × 8 inch × 96 inch) hollow core plastic rail was supported by an A-frame consisting of two pairs of 38 mm × 140 mm (1.5 inch × 5.5 inch) plastic legs. The panel was attached at four places with four 8 mm (5/16 inch) diameter × 89 mm (3.5 inch) long A307 bolts and washers. Horizontal braces 25 mm × 114 mm (1 inch × 4.5 inch) were attached to each pair of legs with 8 mm (5/16 inch) diameter × 102 mm (4 inch) long A307 bolts with washers. The lower brace was 822 mm (32 inch) long and was 169 mm (6.6 inch) above the ground to the bottom of the brace. The upper brace was 391 mm (15 inch) long and was 748 mm (30 inch) from the ground to the bottom of the brace. Height to the top of the A-frame was 1060 mm (42 inch).

Type I Perforated Steel Tube Skid Mount Barricade (Test No. 417928-7)

Figure 2 shows details of the Type I perforated steel tube skid mount barricade tested. This design has similar construction and is an adaptation of a Type III barricade system that was evaluated under a previous study.[2,3] The vertical supports were a pair of 38 mm (1.5 inch) square perforated tubes which telescoped into 45 mm square × 102 mm long (1.75 inch × 4 inch) stubs that were welded to skids. The skids were 45 mm square perforated tubes 1523 mm (60 in) long. A 19 mm × 185 mm × 1220 mm (1 inch × 8 inch × 48 inch) wood panel was attached to the vertical supports using four (two each support) 10 mm (3/8 inch) diameter bolts. Height to the top of the barricade rail was 930 mm (36.6 inch).

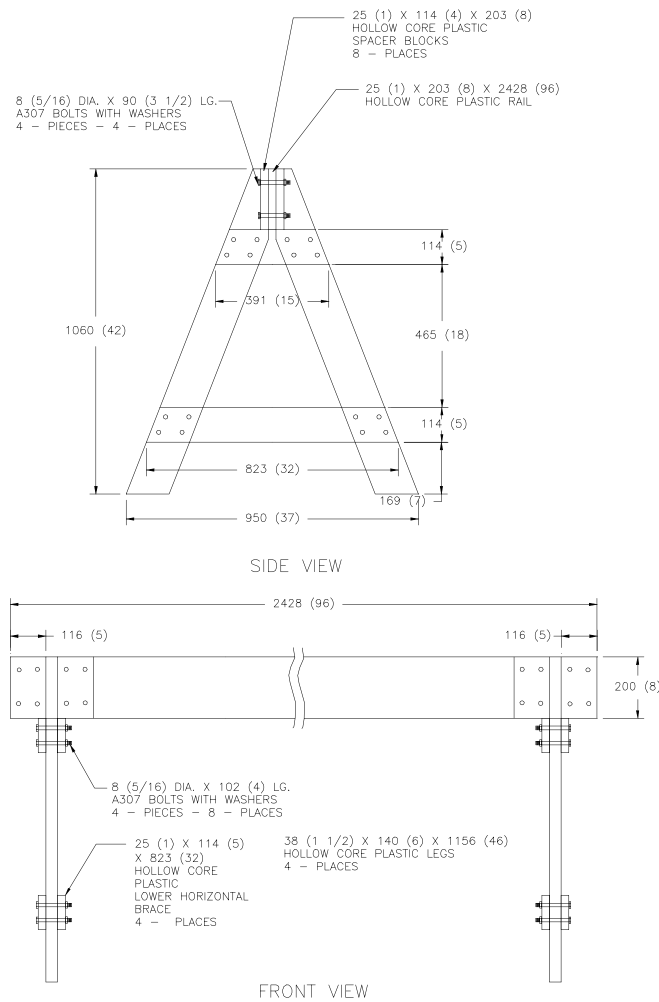


Figure 1. Type I Plastic A-Frame Barricade as Used in Test 417928-6.

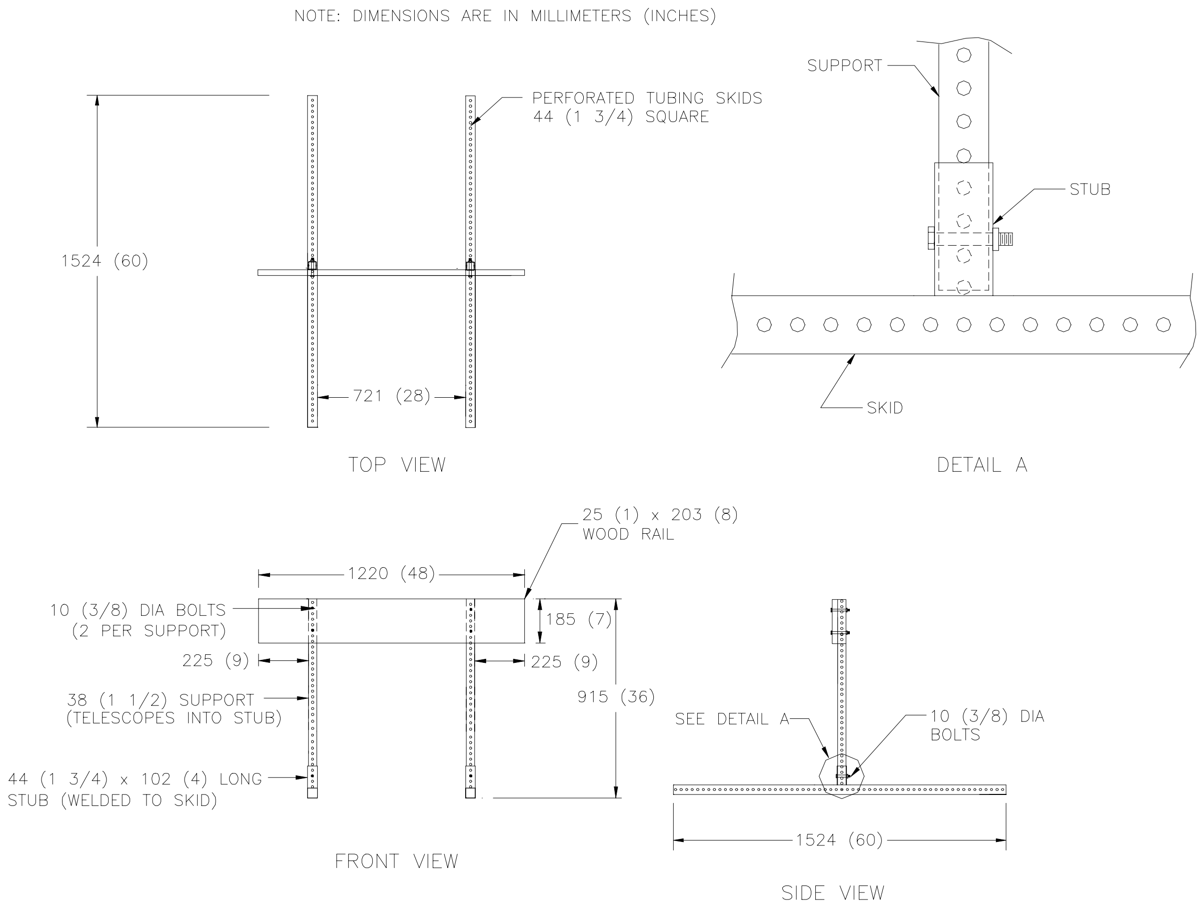


Figure 2. Type I Perforated Steel Tube Skid Mount Barricade as Used in Test 417928-7.

Type I Hollow Profile Plastic Skid Mount Barricade (Test No. 417928-8)

The Type I hollow profile plastic skid mount barricade was tested, and Figure 3 shows details of the barricade. This design is an adaptation of a Type III barricade concept that was developed and tested under previous research.[2,3] The 915 mm (36 inch) long wood skids for this barricade consisted of two pairs of 51 mm × 152 mm (2 inch × 6 inch) with four 90 mm × 90 mm × 102 mm (3.5 inch × 3.5 inch × 4 inch) tall wood spacer blocks. Each skid supports a 102 mm × 102 mm (4 inch × 4 inch) hollow profile plastic support 910 mm (36 inch) long. A plastic cap was placed on the top of each support. A 20 mm × 203 mm × 1220 mm (1 inch × 8 inch × 48 inch) wood panel was attached to the hollow profile plastic supports with four 10 mm (3/8 inch) diameter bolts, two per support. The height to the top of the barricade was 910 mm (36 inch).

Type I Hollow Profile Plastic Folding A-Frame (Test No. 417928-9)

Figure 4 shows details of a folding Type I hollow profile plastic A-frame tested under this project. Both the front and back sections of the A-frame consisted of an upper wooden rail measuring 20 mm × 184 mm × 815 mm (1 inch × 8 inch × 32 inch) long and a lower wooden rail measuring 20 mm × 146 mm × 815 mm (1 inch × 6 inch × 32 inch) long. These rails were mounted on a pair of 51 mm × 89 mm (2 inch × 4 inch) hollow profile plastic tubes with 3 mm (1/8 inch) wall thickness using two bolts and washers per support. The two sections were then bolted together near the top to form a hinge. Height to the top of the upper barricade rail was 910 mm (36 inch), and the height of the top of the hollow profile 51 mm × 89 mm (2 inch × 4 inch) supports was 991 mm (39 inch).

Type I Wood Fixed A-Frame Barricade (Test No. 417928-17)

Figure 5 shows details of a Type I wood fixed A-frame barricade. A 25 mm × 203 mm × 1220 mm (1 inch × 8 inch × 48 inch) wood rail was supported by an A-frame consisting of two pairs of 51 mm × 152 mm (2 inch × 6 inch) wood legs. The panel fits into a 29 mm (1 inch) opening between the legs. A pair of horizontal braces 51 mm × 102 mm (2 inch × 4 inch) was attached to each pair of legs with 10 mm (3/8 inch) diameter bolts with washers. The top edge of the lower brace was 305 mm (12 inch) above the ground, while the top edge of the upper brace was 185 mm (29.4 inch) above ground. Height to the top of the barricade rail was 925 mm (36.4 inch).

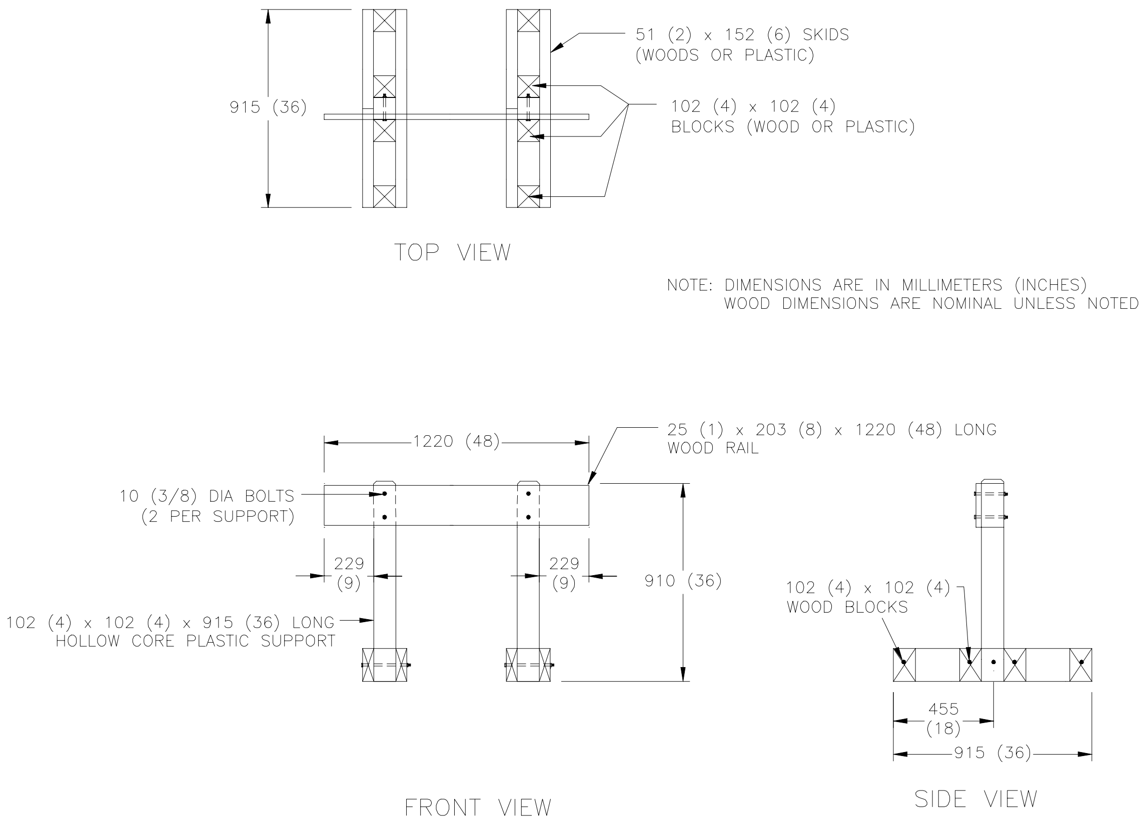


Figure 3. Type I Hollow Profile Plastic Skid Mount Barricade as Used in Test 417928-8.

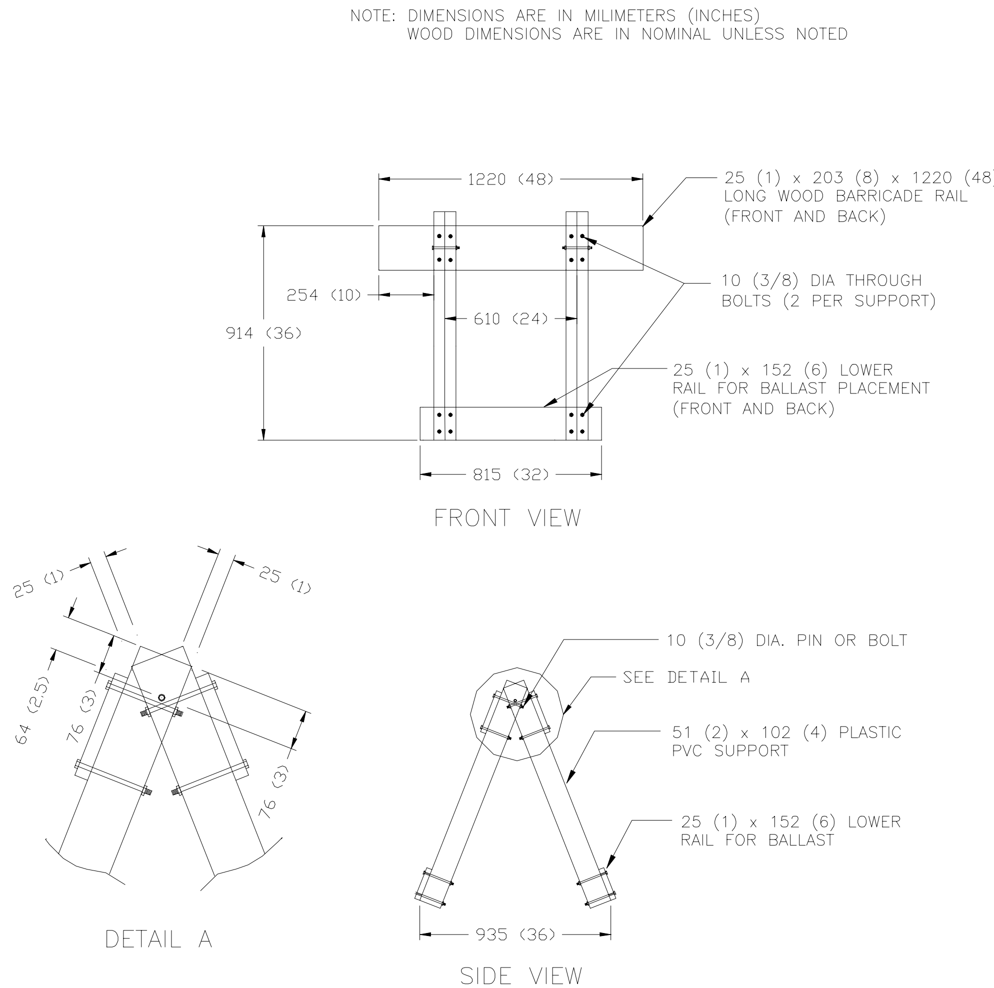


Figure 4. Type I Hollow Core Plastic Folding A-Frame Barricade for Test 417928-9.

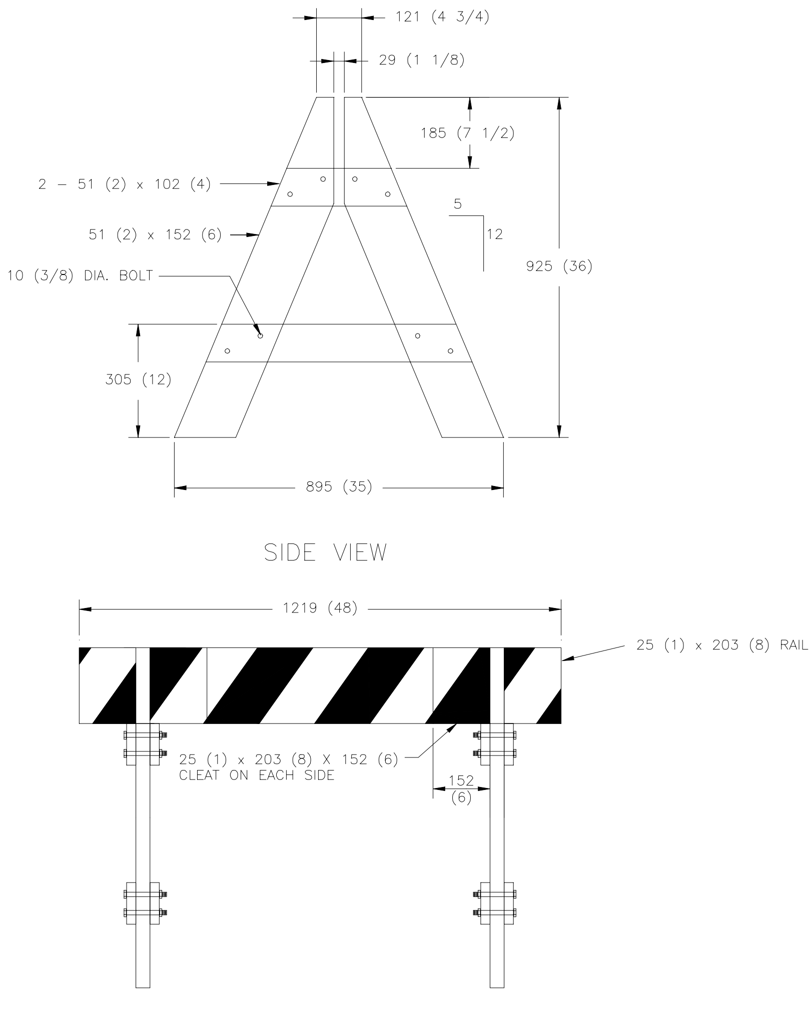


Figure 5. Type I Wood Fixed A-Frame Barricade for Test 417928-17.

TYPE III BARRICADES

The testing of Type III barricades under this project is intended to complement the work performed under previous TxDOT projects.

Type III Barricade with FRP Supports in Dual-Purpose Base (Test No. 417928-2)

Figure 6 shows details of the Type III barricade with Fiber Reinforced Plastic (FRP) supports in dual-purpose base. This test is intended to verify the performance of FRP tubes as barricade supports in a new dual-purpose base, thereby providing TxDOT with another acceptable construction alternative for Type III barricades. The barricade consisted of two 1524 mm (60 inch) long fiberglass reinforced plastic supports, with a lumber dual-purpose base with 51 mm × 152 mm (2 inch x 6 inch) outriggers 1524 mm (60 inch) long. Each of the three horizontal rail elements consisted of two 25 mm × 152 mm (1 inch × 6 inch) hollow core plastic panels each 1220 mm (48 inch) long placed on top the other for a total width of 308 mm (12 inch). Each panel was attached to the support with 10 mm (3/8 inch) diameter x 130 mm (5 inch) long through bolts with washers. Height to the top of the barricade was 1524 mm (60 inch).

Type III Perforated Steel Tube Barricade (Test No. 417928-14)

Based on testing performed under a previous TxDOT research project, a Type III barricade with a perforated steel tube frame was approved for use with wooden and hollow profile plastic rail elements. In these tests, both supports of the 1220 mm (48 inch) barricade were impacted by the test vehicle. While this is believed to be the most critical configuration for testing, some concern was expressed regarding the performance of a longer barricade unit impacted between the supports. Specifically, this test is intended to evaluate whether the use of hollow-profile rails in such situations would be detrimental to impact performance since these rails do not fracture (as do wooden rails) or readily release from their supports.

Figure 7 shows details of the Type III perforated steel tube barricade that was tested. The barricade consisted of two 38 mm (1.5 inch) square perforated tube vertical supports with 38 mm (1.5 inch) square perforated tube stiffeners inserted and bolted to 45 mm (1.75 inch) square × 102 mm (4 inch) long perforated tube stubs welded to 45 mm (1.75 inch) square perforated tube skids. Each of the three 25 mm × 203 mm (1 inch × 8 inch) hollow core plastic vertical panels 2435 mm (96 inch) long were attached to the vertical supports with two 10 mm (3/8 inch) diameter by 130 mm (5 inch) long through bolts in each support. Height to the top of the barricade was 1527 mm (60 inch).

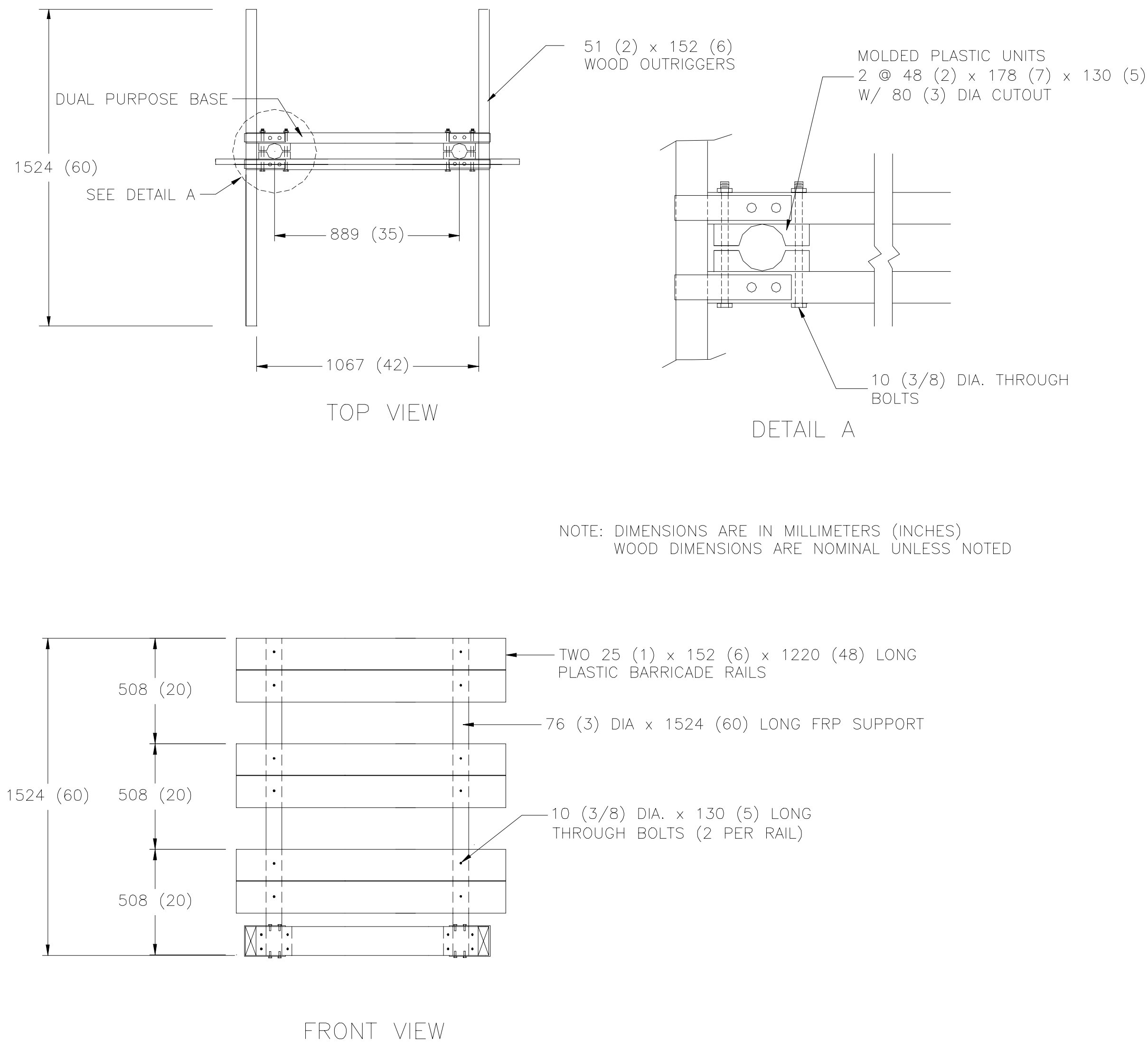


Figure 6. Type III Barricade with FRP Supports in Dual Purpose Base as Used in Test 417928-2.

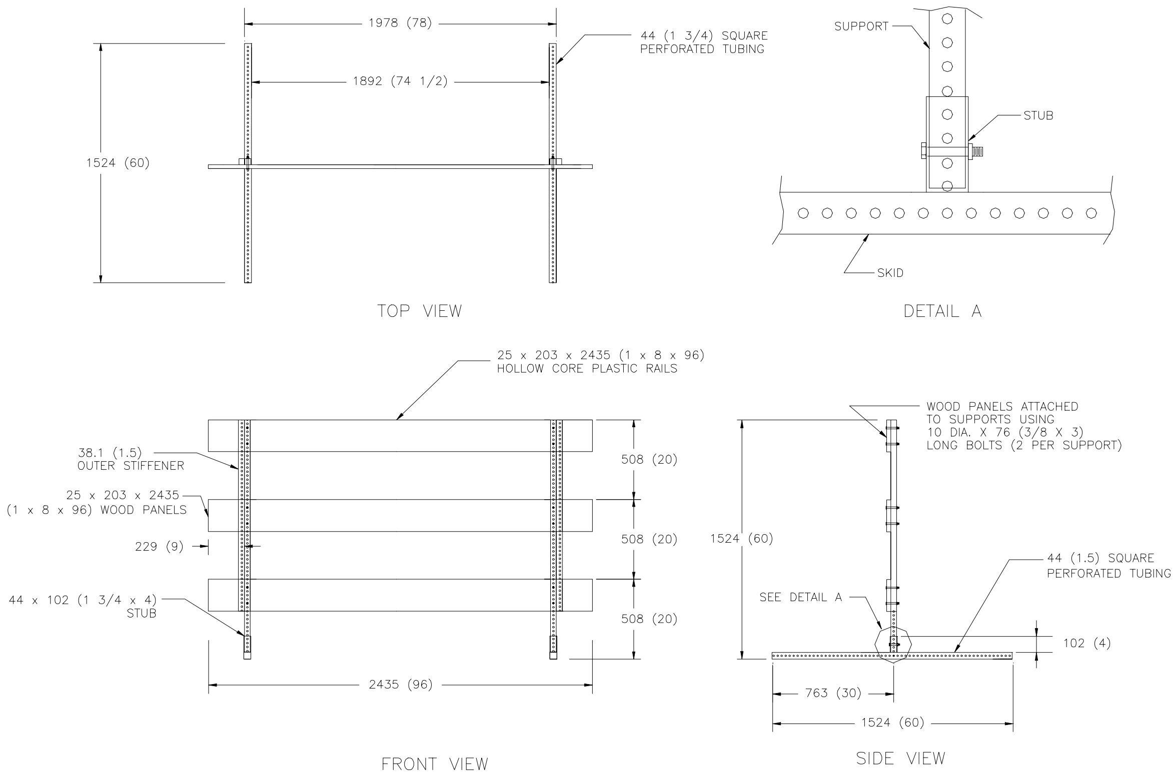


Figure 7. Type III Perforated Steel Tube Barricade for Test 417928-14.

Type III Barricade with Hollow Profile Plastic Supports (Test No. 417928-16)

The purpose of this test was to evaluate the performance of a previously tested Type III barricade with hollow profile plastic supports when attached to a shorter base. The use of a shorter base would permit easier transportation and more cost effective fabrication. Researchers conducted the test to investigate the possibility that shorter skids could rotate during impact and become entangled in the undercarriage of the vehicle. Such behavior could potentially cause vehicle instability or intrusion of the occupant compartment through the floor pan. It should be noted that additional ballast may be required with the shorter skids to provide a resistance to overturn comparable to that provided by the longer skids. Furthermore, the barricade supports were inserted between two 90 mm × 90 mm (4 inch × 4 inch) wood spacer blocks and were not bolted to the skids. Provided impact performance criteria are met, this detail would reduce the time required to transport and erect the barricade. In addition, the barricade could be easily disassembled and laid flat on the roadside rather that being tipped over or turned out of view after its use is not longer needed.

Figure 8 shows details of the Type III barricade with hollow profile plastic supports used in this test. The barricade consisted of two 102 mm × 102 mm × 1520 mm (4 inch × 4 inch × 60 inch) long hollow core plastic supports with 51 mm × 102 mm (2 inch × 4 inch) wood stiffeners 1200 mm (47 inch) long. The 25 mm x 185 mm (1 inch × 7.25 inch) wood horizontal rails were attached to the vertical supports with 8 mm (5/16 inch) diameter bolts. The vertical supports were inserted into but not bolted to wood skids, which consisted of two pairs of 51 mm × 152 mm (2 inch × 6 inch) wood 917 mm (36 inch) long with 90 mm × 90 mm × 140 mm (4 inch × 4 inch × 5.5 inch) wood spacers. Height to the top of the barricade was 1520 mm (60 inch).

TEMPORARY SIGN SUPPORTS

The testing of temporary sign supports under this project is intended to provide TxDOT additional crashworthy alternatives for both long/intermediate and short term applications.

Long/Intermediate Term Portable Sign Supports

Single FRP Support in Dual-Purpose Base (417928-3)

A single fiberglass reinforced plastic support in a dual-purpose base was tested and details of the support are shown in Figure 9. The single vertical support was a 76 mm (3 inch) diameter fiberglass reinforced plastic pipe 3050 mm (120 inch) long. A 914 mm × 914 mm × 13 mm (36 inch × 36 inch × ½ inch) plywood sign panel was attached to the support with two 10 mm (3/8 inch) diameter through bolts. The support was inserted into a wood dual-purpose base. The base consisted of two 51 mm × 152 mm (2 inch × 6 inch) boards with 51 mm x 152 mm (2 inch × 6 inch) outriggers 1524 mm (60 inch) long. Height to the bottom of the sign panel was 2134 mm (84 inch), and to the top of the panel it was 3355 mm (132 inch).

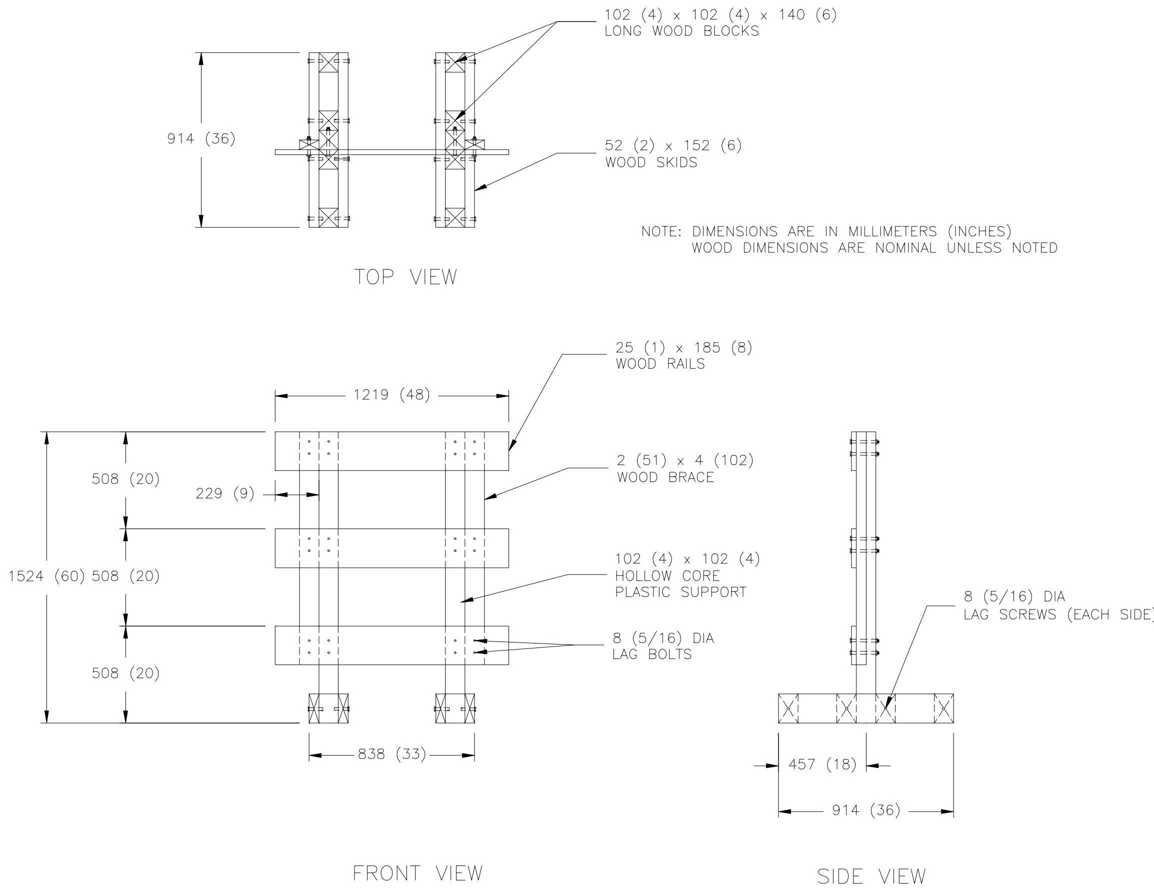


Figure 8. Type III Barricade with Hollow Profile Plastic Supports as Used in Test 417928-16.

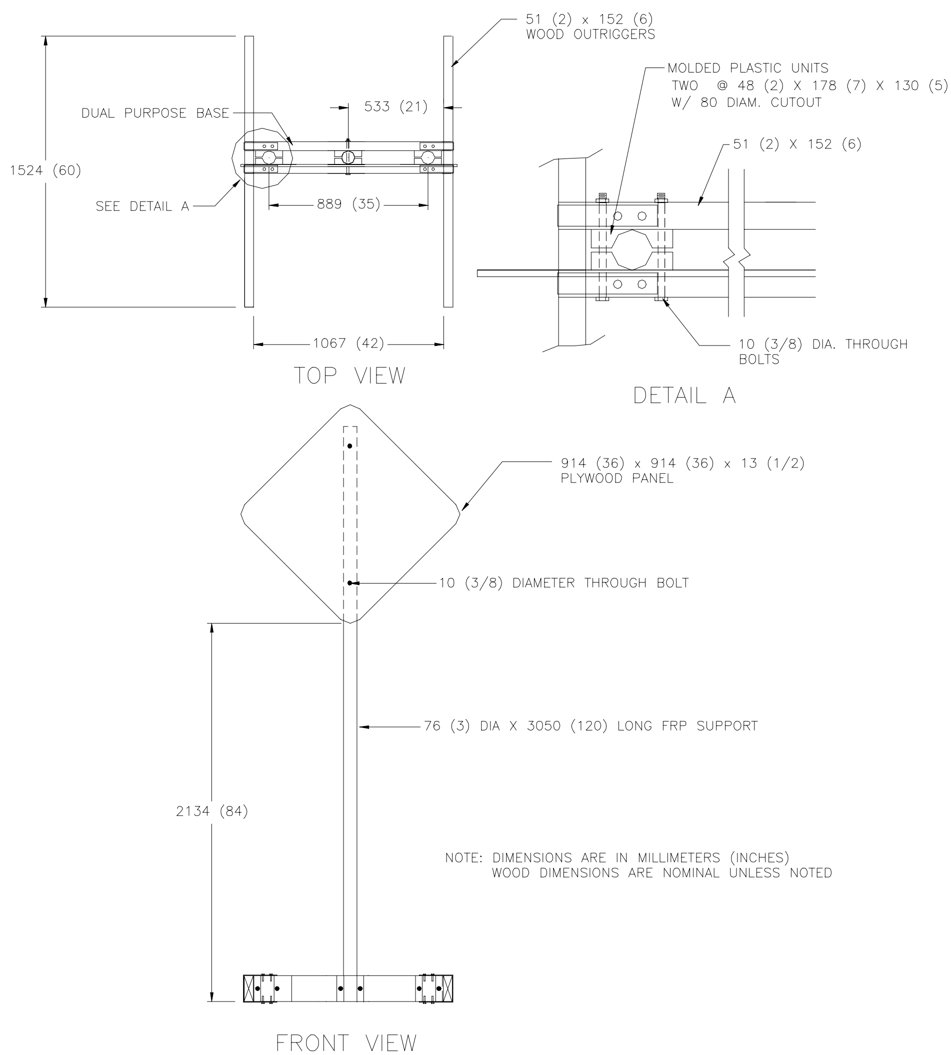


Figure 9. Single FRP Support in Dual-Purpose Base as Used in Test 417928-3.

Wood Sign Support in H-Leg Base (2.1 m [7-ft] mounting height) (417928-10)

Figure 10 shows details of the single wood sign support in H-leg base. A single 102 mm × 102 mm (4 inch × 4 inch) wood vertical support 3048 mm (120 inch) long was used in the barricade. A 76 mm × 76 mm × 13 mm (3 inch × 3 inch × ½ inch) plywood sign panel was attached to the support using two 10 mm (3/8 inch) diameter through bolts. The vertical support was inserted into the H-leg base, which consisted of a pair of 51 mm × 152 mm × 1605 mm (2 inch × 6 inch × 63 inch) long skids. A 51 mm × 152 mm × 610 mm (2 inch × 6 inch × 24 inch) long outrigger was attached at each end of the skid forming the "H." Height to the bottom of the sign panel was 2134 mm (84 inch).

Dual Perforated Steel Tube Skid Mounted Sign Support (417928-11)

A dual perforated steel tube skid mounted sign support was tested, and Figure 11 shows the details of the barricade. Two 38 mm (1.5 inch) square perforated tubes 3073 mm (121 inch) long telescoped into and bolted to a 44 mm (1.75 inch) square perforated tube stub. The stub was welded to 44 mm (1.75 inch) square perforated tubes 1520 mm (60 inch) long. A cross brace of 44 mm (1.75 inch) square perforated tubing 625 mm (24.5 inch) long was attached to the vertical supports at a height of 205 mm (8 inch). Height to the bottom of the sign panel was 2140 mm (84 inch).

Long/Intermediate Term Ground Mounted Sign Supports

Dual FRP Sign Support (Test No. 417928-4&5)

A dual ground mounted FRP sign support was used in these two tests, and Figure 12 shows details of the support. Two 76 mm (3 inch) Outside Diameter (OD) × 4270 mm (168 in) long fiberglass reinforced plastic pipes spaced 1065 mm (42 in) apart were embedded in *NCHRP Report 350* standard soil at a depth of 914 mm (36 in). A 1220 mm × 2438 mm × 13 mm (48 in × 96 inch × ½ inch) plywood sign panel was attached to the supports with four each support 10 mm (3/8 inch) diameter through bolts. Height to the bottom of the sign panel was 2135 mm (84 inch) and to the top of the sign panel it was 3350 mm (132 inch).

Short Term Portable Sign Supports

Roll-up Sign in Dual-Purpose Base (Test No. 417928-1)

A roll-up vinyl sign attached to a fiberglass reinforced plastic support in a dual-purpose base was tested, and details of the barricade are shown in Figure 13. The roll-up sign with nylon/fiber stays was attached with steel bands to a 76 mm (3 inch) OD FRP pipe 1524 mm (60 inch) long. The support was inserted in molded plastic inserts in a dual-purpose base which consisted of a pair of 51 mm x 152 mm (2 in x 6 in) boards 1040 mm (41 in) long with 51 mm x

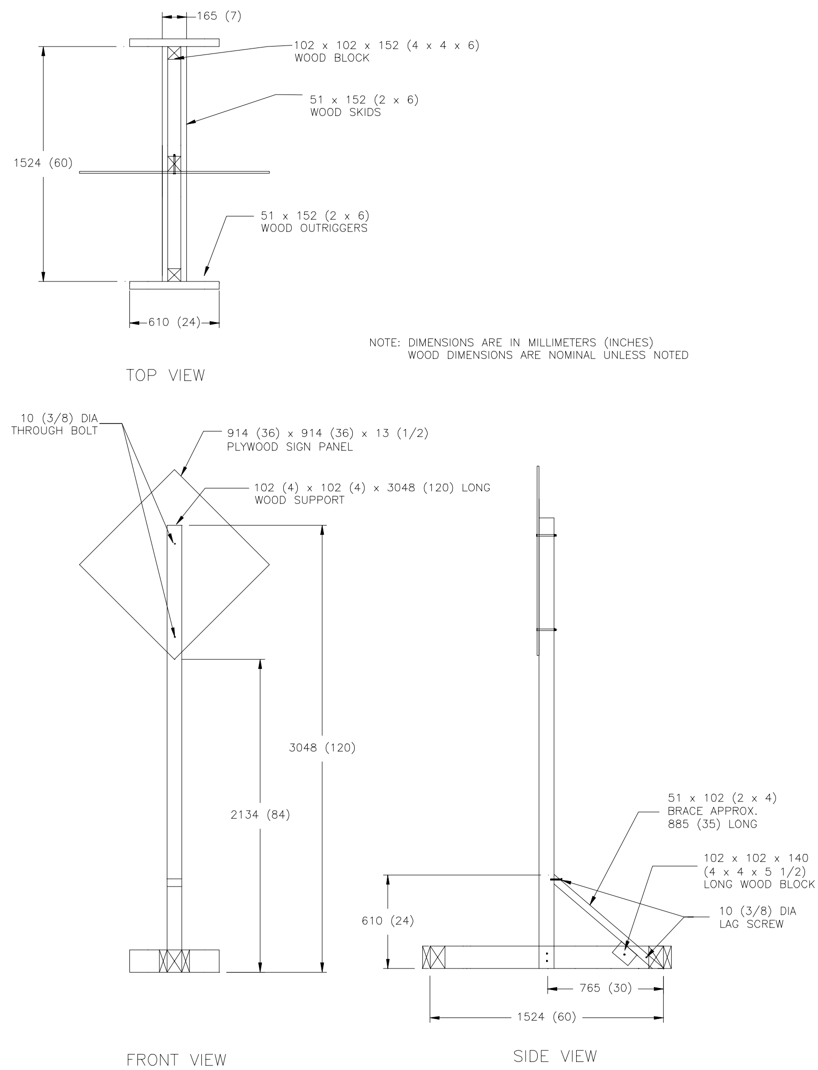


Figure 10. Wood Sign Support in H-Leg Base (2.1 m [7 ft] mounting height) for Test 417928-10.

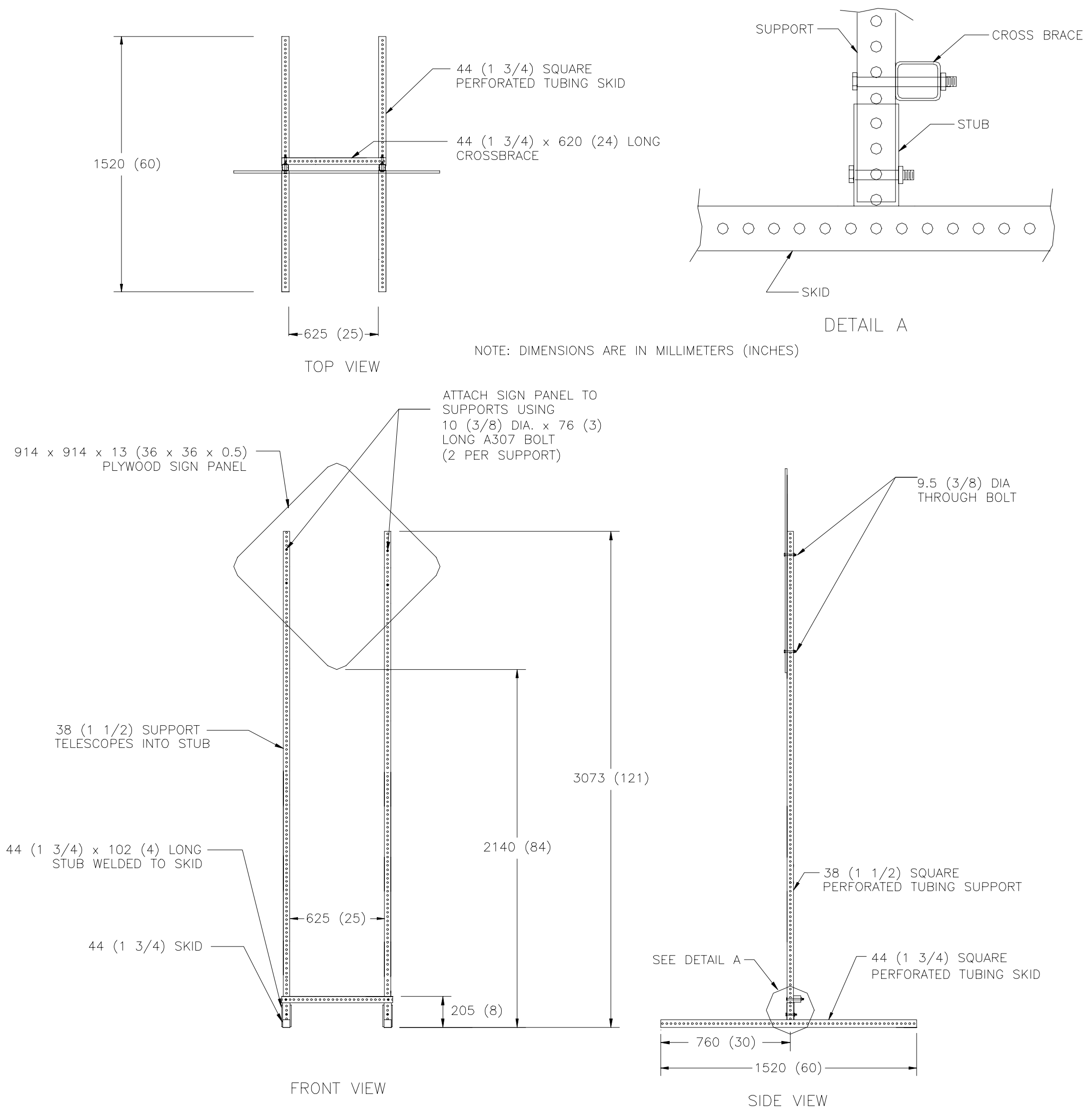


Figure 11. Dual Perforated Steel Tube Skid Mounted Sign Support as Used in Test 417928-11.

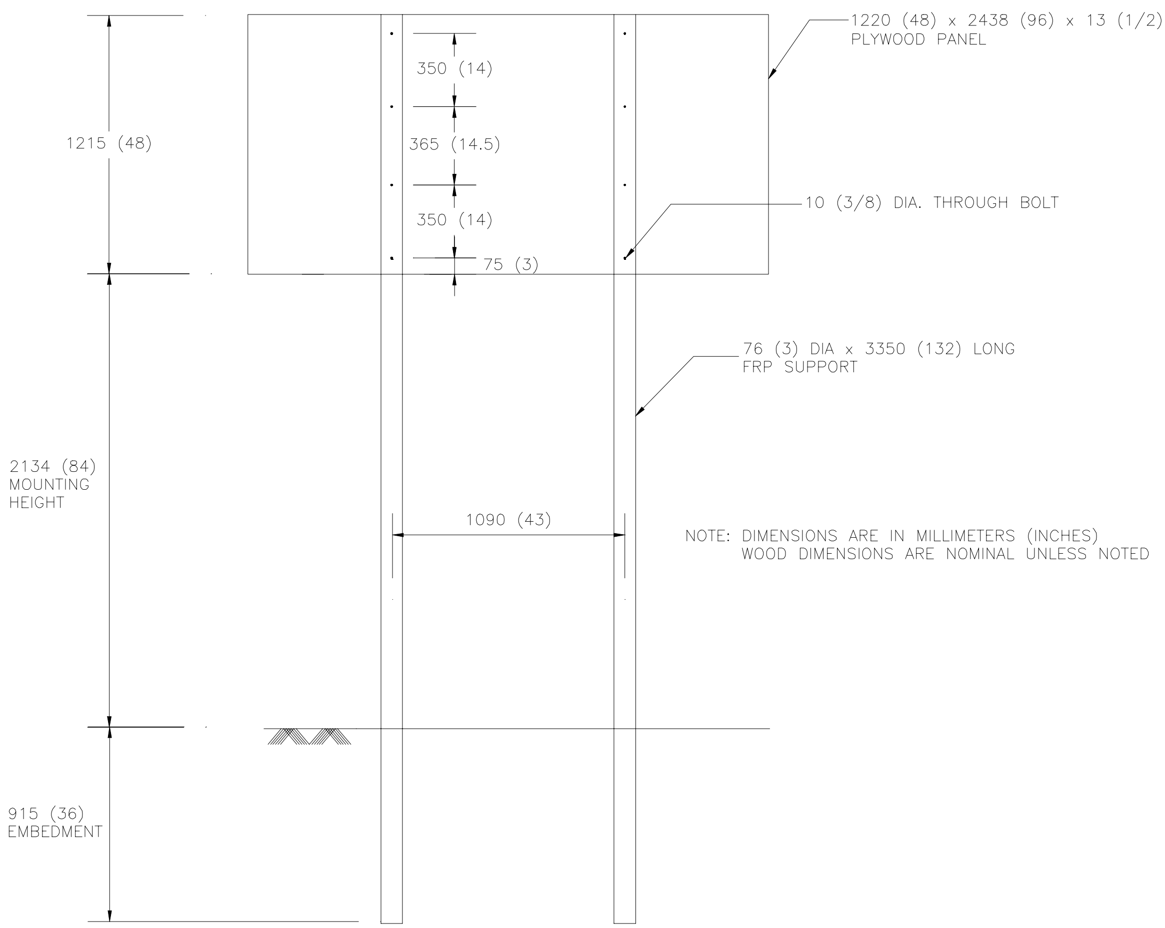


Figure 12. Dual FRP Sign Support for Tests 417928-4 and 417928-5.

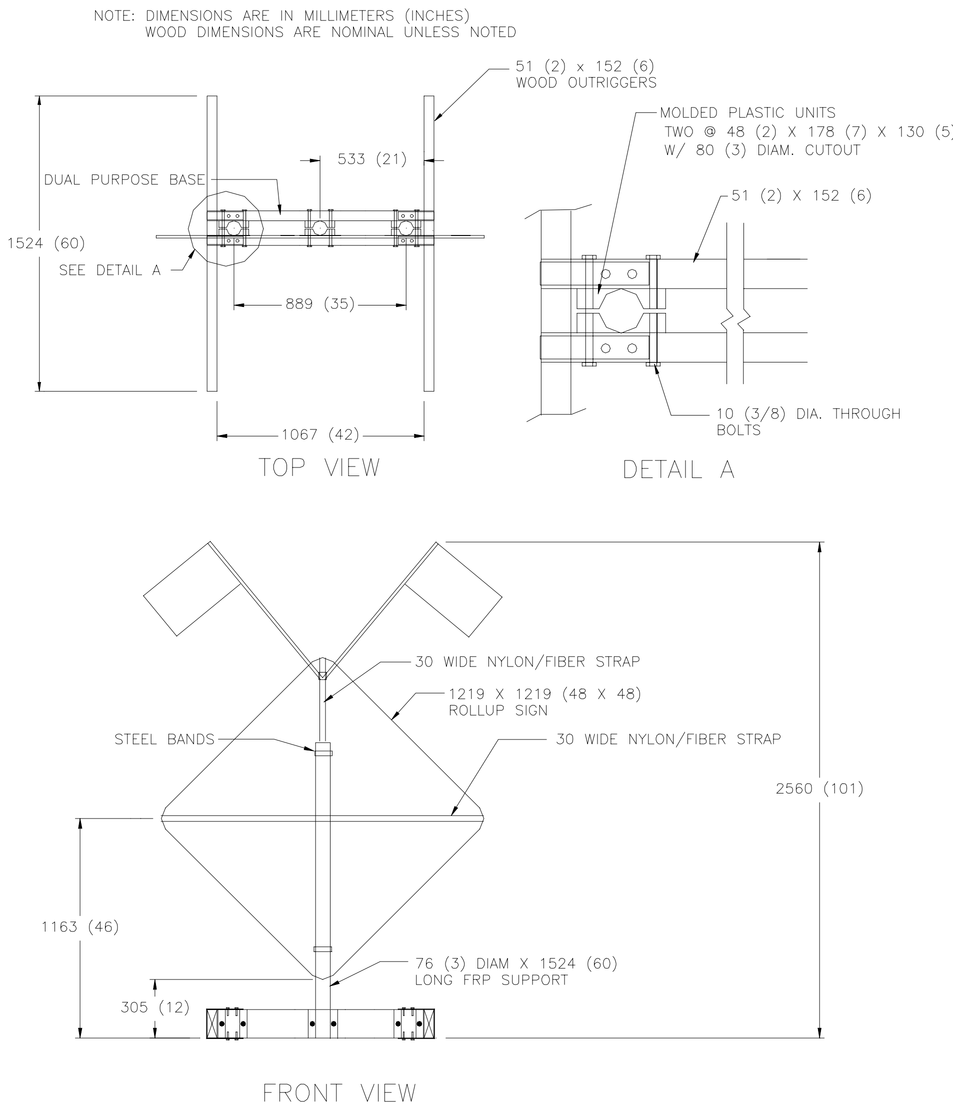


Figure 13. Roll-up Sign in Dual-Purpose Base as Used in Test 417928-1.

152 mm (2 inch x 6 inch) outriggers 1524 mm (60 inch) long on each end. Height to the bottom of the sign was 305 mm (12 inch).

PVC Easel Support (Test No. 417929-2)

Figure 14 shows details of the Poly Vinyl Chloride (PVC) easel support. Three 38 mm (1.5 inch) OD schedule 40 PVC pipes were bolted together to form an easel (two in front and one to the rear) to support a 1220 mm × 1220 mm (48 inch × 48 inch) sign panel. Each PVC pipe fit into an elbow, then a PVC pipe stub, and the PVC pipe was inserted into a rubber base. Each base was 450 mm × 375 mm × 51 mm (17 inch × 15 inch × 2 inch) and weighed 16 kg (35 lb). Height to the bottom of the sign panel was 340 mm (13 inch), and from the top of the support to the ground it was 2135 mm (84 inch).

Wood Sign Support in H-Leg Base (0.9 m × 0.9 m [3 ft × 3 ft] plywood panel - 0.3 m [1 ft] mounting height) (Test No. 417928-12)

A wood sign support in an H-leg base was tested, and Figure 15 gives details of the barricade. A 102 mm × 102 mm × 1524 mm (4 inch × 4 inch × 60 inch) long wood support with a 914 mm × 914 mm × 13 mm (36 inch × 36 inch × ½ inch) plywood sign panel attached with two 10 mm (3/8 inch) diameter through bolts was inserted into an H-leg base. The base consisted of a pair of wood skids 51 mm × 152 mm × 910 mm (2 inch × 6 inch × 36 inch) with 90 mm × 90 mm × 140 mm (3.5 inch × 3.5 inch × 4 inch) wood spacers and a 51 mm × 152 mm × 605 mm (2 inch × 6 inch × 24 inch) outrigger on each end. Height to the bottom of the sign was 308 mm (12 inch).

Hollow Profile Plastic Sign Support in H-Leg Base (0.9 m × 0.9 m [3 ft × 3 ft] plywood panel - 0.3 m [1 ft] mounting height) (Test No. 417928-13)

A hollow profile plastic sign support in an H-leg base was tested, and Figure 16 gives details of the barricade. A 102 mm × 102 mm × 1520 mm (4 inch × 4 inch × 60 inch) long hollow core plastic support with a 914 mm × 914 mm × 13 mm (36 inch × 36 inch × ½ inch) plywood sign panel attached with two 10 mm (3/8 inch) diameter through bolts was inserted into an H-leg base. The base consisted of a pair of wood skids 51 mm × 152 mm × 915 mm (2 inch × 6 inch × 36 inch) with 90 mm × 90 mm × 140 mm (3.5 inch × 3.5 inch × 4 inch) wood spacers and a 51 mm × 152 mm × 605 mm (2 inch × 6 inch × 24 inch) outrigger on each end. Height to the bottom of the sign was 305 mm (12 inch).

Hollow Profile Plastic Sign Support in H-leg Base (0.9 m × 0.9 m [3 ft × 3 ft] plywood panel - 0.6 [2 ft] mounting height) (Test No. 417929-1)

A second hollow profile plastic sign support in an H-leg base was tested, and Figure 17 gives details of the barricade. A 102 mm × 102 mm × 1520 mm (4 inch × 4 inch × 60 inch) long

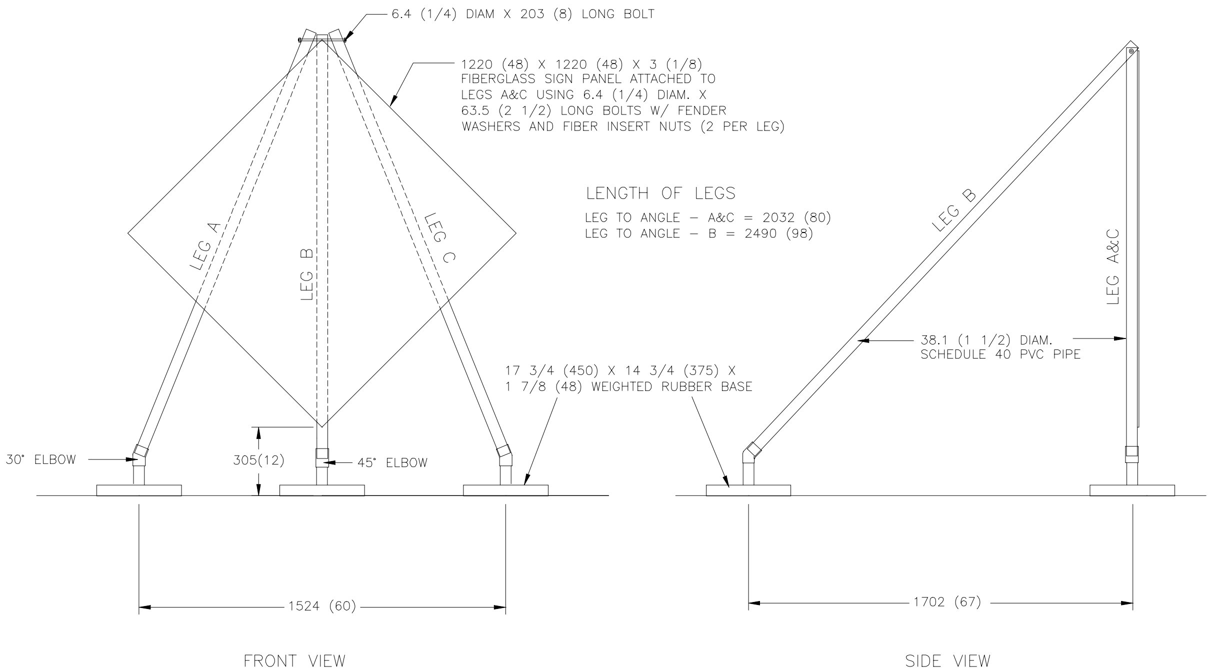


Figure 14. PVC Easel Support for Test 417929-2.

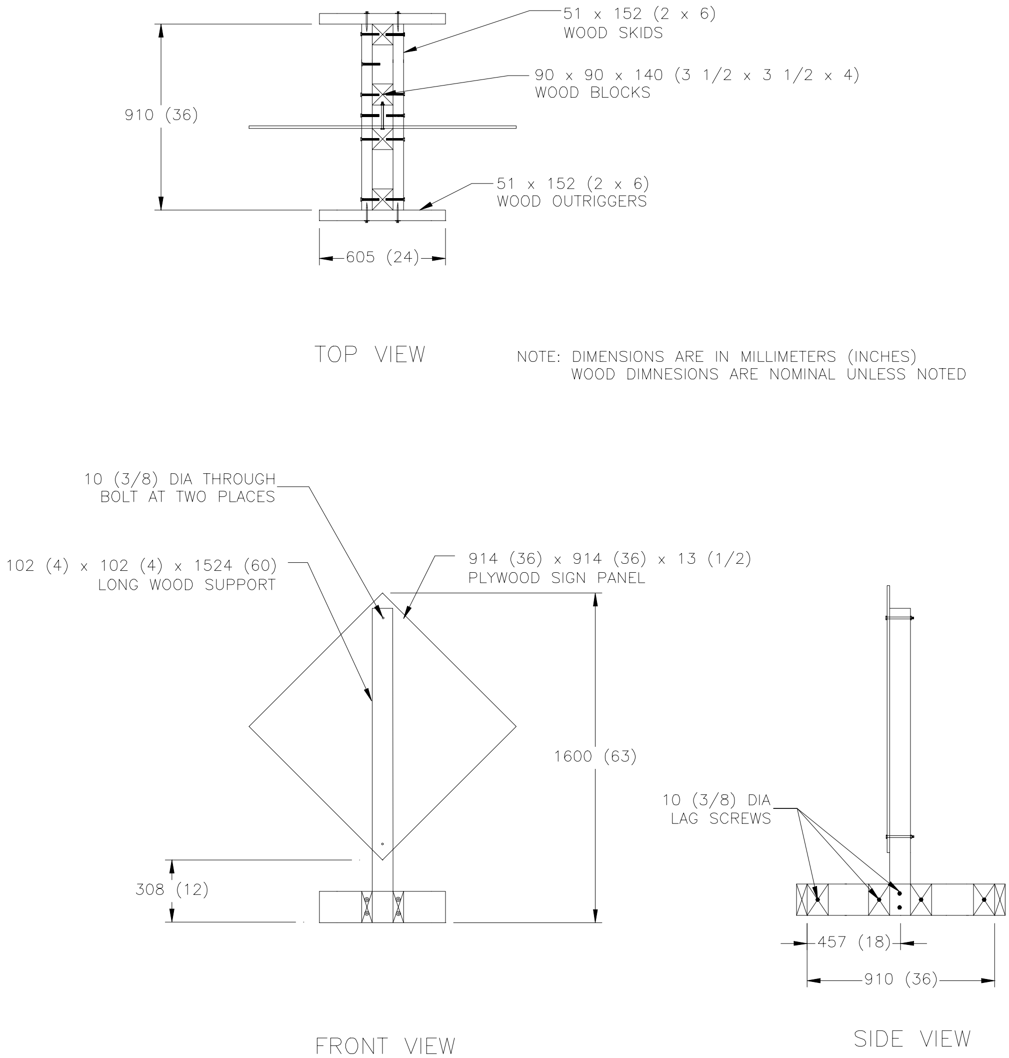


Figure 15. Wood Sign Support in H-Leg Base (0.9 m × 0.9 m [3 ft × 3 ft] panel - 0.3 m [1 ft] mounting height) for Test 417928-12.

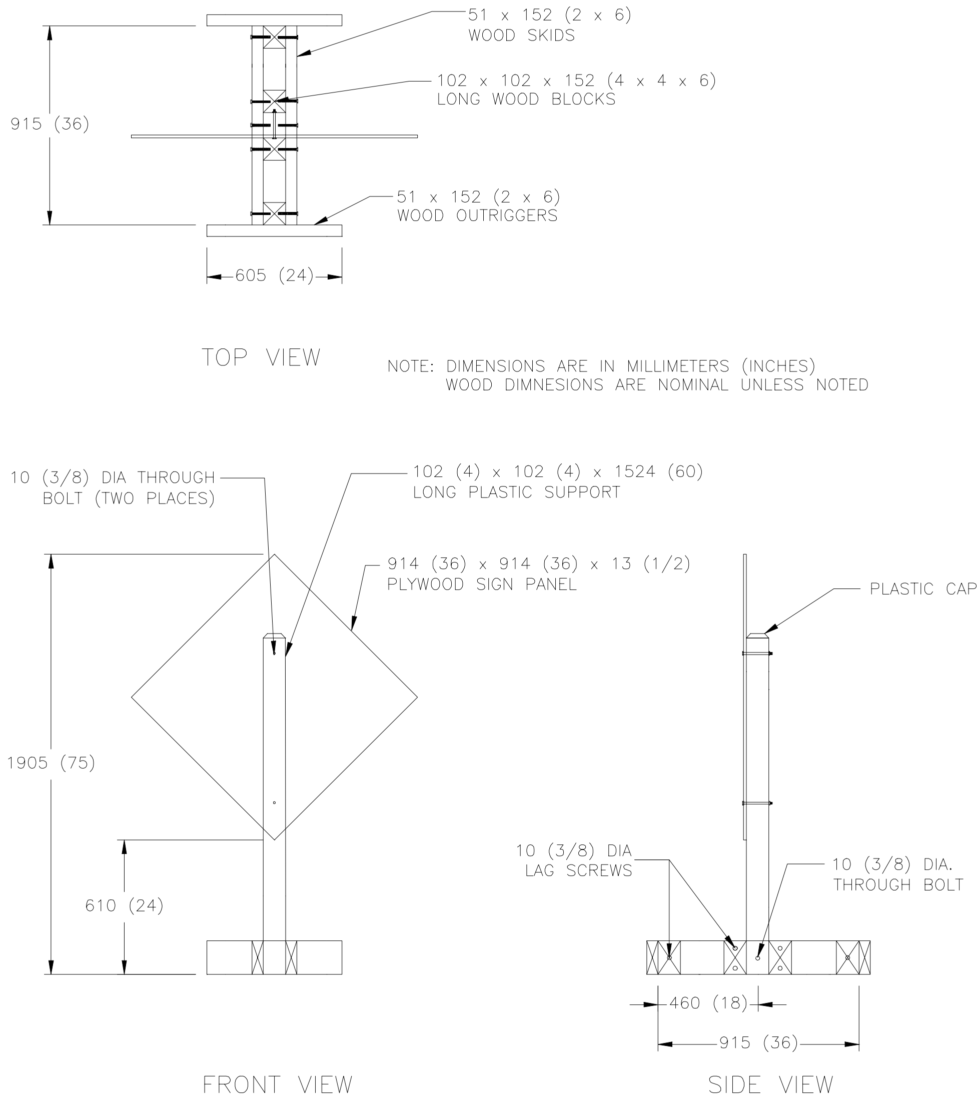


Figure 16. Hollow Profile Plastic Sign Support in H-Leg Base (0.9 m × 0.9 m [3 ft × 3 ft] panel - 0.3 [1 ft] mounting height) as Used in Test 417928-13.

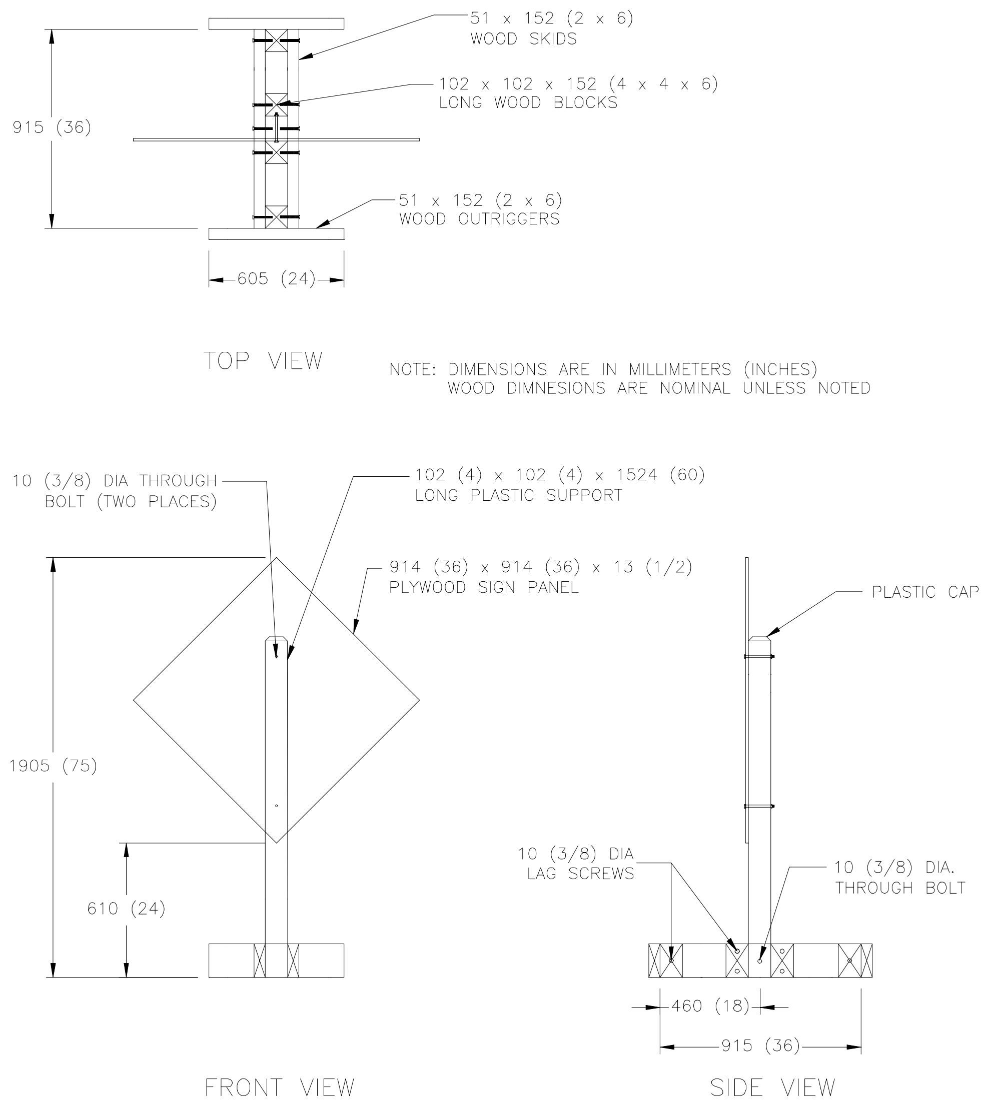


Figure 17. Hollow Profile Plastic Sign Support in H-Leg Support (0.9 m × 0.9 m [3 ft × 3 ft] panel - 0.6 m [2 ft] mounting height) Installation for Test 417929-1.

hollow core plastic support with a 914 mm × 914 mm × 13 mm (36 inch × 36 inch × ½ inch) plywood sign panel attached with two 10 mm (3/8 inch) diameter through bolts was inserted into an H-leg base. The base consisted of a pair of wood skids 51 mm × 152 mm × 915 mm (2 inch × 6 inch × 36 inch) with 90 mm × 90 mm × 140 mm (3.5 inch × 3.5 inch × 4 inch) wood spacers and a 51 mm × 152 mm × 605 mm (2 inch × 6 inch × 24 inch) outrigger on each end. Height to the bottom of the sign was 615 mm (24 inch).

Hollow Profile Plastic Sign Support in H-Leg Base (1.2 m × 1.2 m [4 ft x 4 ft] plywood panel - 0.6 m [2 ft] mounting height) (Test No. 417928-15)

The hollow profile plastic sign support in an H-leg base was tested with a larger panel, and details of the barricade are given in Figure 18. A 102 mm × 102 mm × 1520 mm (4 inch × 4 inch × 60 inch) long hollow core plastic support with a 1220 mm x 1220 mm x 13 mm (48 inch x 48 inch x ½ inch) plywood sign panel attached with two 10 mm (3/8 inch) diameter through bolts was inserted into an H-leg base. The base consisted of a pair of wood skids 51 mm × 152 mm × 915 mm (2 inch × 6 inch × 36 inch) with 90 mm x 90 mm x 140 mm (3.5 inch × 3.5 inch × 4 inch) wood spacers and a 51 mm × 152 mm × 605 mm (2 inch × 6 inch × 24 inch) outrigger on each end. Height to the bottom of the sign was 610 mm (24 inch).

Hollow Profile Plastic Sign Support in H-Leg Base (1.2 m × 1.2 m [4 ft × 4 ft] panel - 0.9 m [3 ft] mounting height) (Test No. 417928-18)

The hollow profile plastic sign support in an H-leg base was tested with a larger panel and higher mounting height. Details of the barricade are given in Figure 19. A 102 mm × 102 mm × 1520 mm (4 inch × 4 inch × 60 inch) long hollow core plastic support with a 1220 mm x 1220 mm × 13 mm (48 inch × 48 inch × ½ inch) plywood sign panel attached with two 10 mm (3/8 inch) diameter through bolts was inserted into an H-leg base. The base consisted of a pair of wood skids 51 mm × 152 mm × 915 mm (2 inch × 6 inch × 36 inch) with 90 mm × 90 mm × 140 mm (3.5 inch × 3.5 inch × 4 inch) wood spacers and a 51 mm × 152 mm × 605 mm (2 inch × 6 inch × 24 inch) outrigger on each end. Height to the bottom of the sign was 914 mm (36 inch).

Hollow Profile Plastic Sign Support in T-Leg Base (1.2 m × 1.2 m [4 ft × 4 ft] fiberglass panel - 0.6 m [2 ft] mounting height) (Test No. 417929-11)

The hollow profile plastic sign support in a T-leg base was tested with a fiberglass panel and details of the barricade are given in Figure 20. A 82 mm × 82 mm × 1530 mm (3.25 inch × 3.25 inch × 60 inch) long 10 mm (3/8 inch) thick hollow core plastic support with a 1220 mm × 1220 mm × 5 mm (48 inch × 48 inch × 3/16 inch) fiberglass sign panel attached with two 10 mm (3/8 inch) diameter through bolts and metal pipe clamps was inserted into a T-leg base. The base consisted of a pair of wood skids 51 mm × 152 mm × 1220 mm (2 inch × 6 inch × 48 inch) with 85 mm × 85 mm × 182 mm (3.5 inch × 3.5 inch × 7 inch) wood spacers and a 14 mm × 140 mm × 912 mm (½ inch × 5.5 inch × 36 inch) outrigger on one end. Height to the bottom of the sign was 610 mm (24 inch).

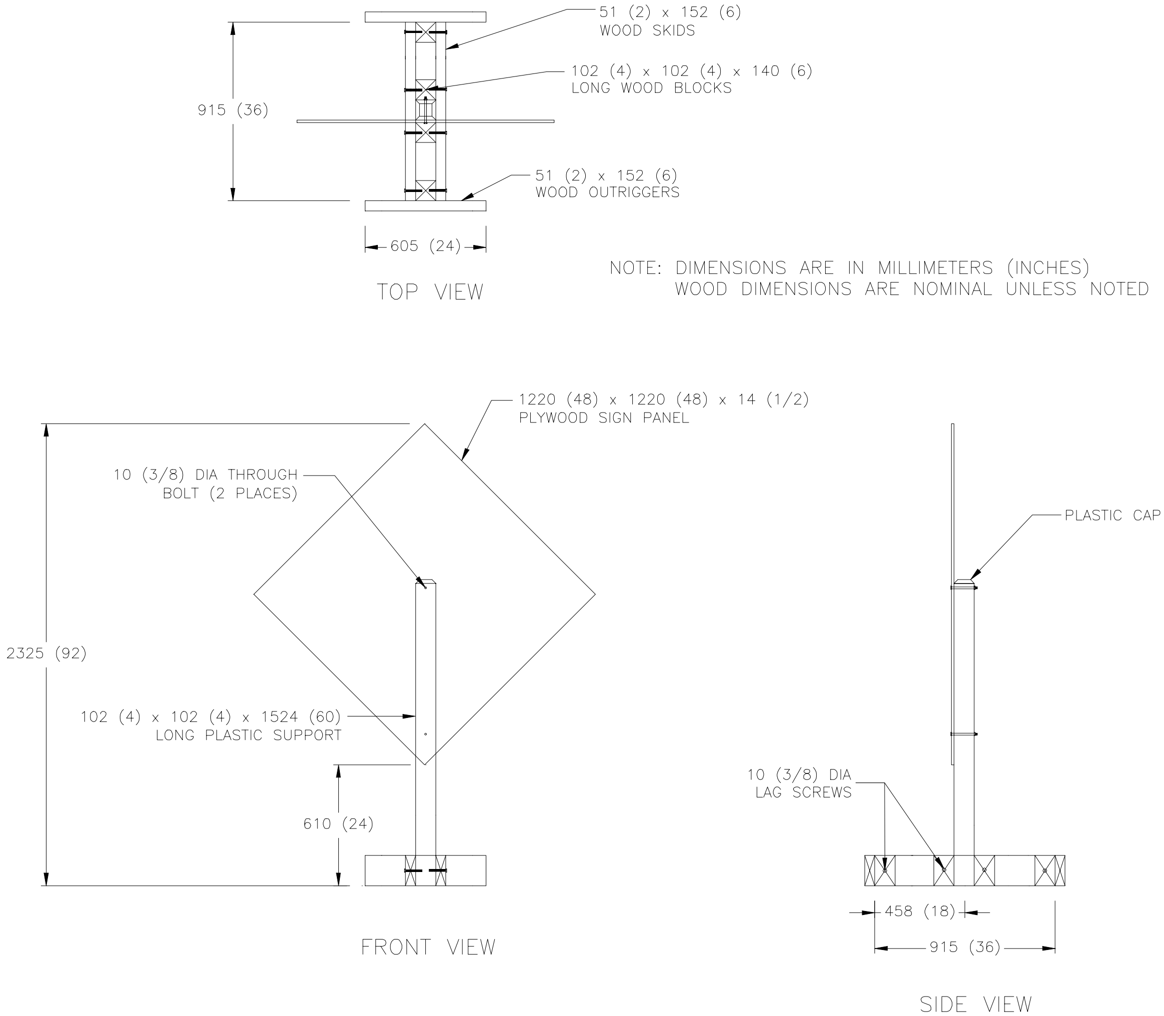


Figure 18. Hollow Profile Plastic Sign Support in H-Leg Base (1.2 m × 1.2 m [4 ft × 4 ft] panel - 0.6 m [2 ft] mounting height) as Used in Test 417928-15.

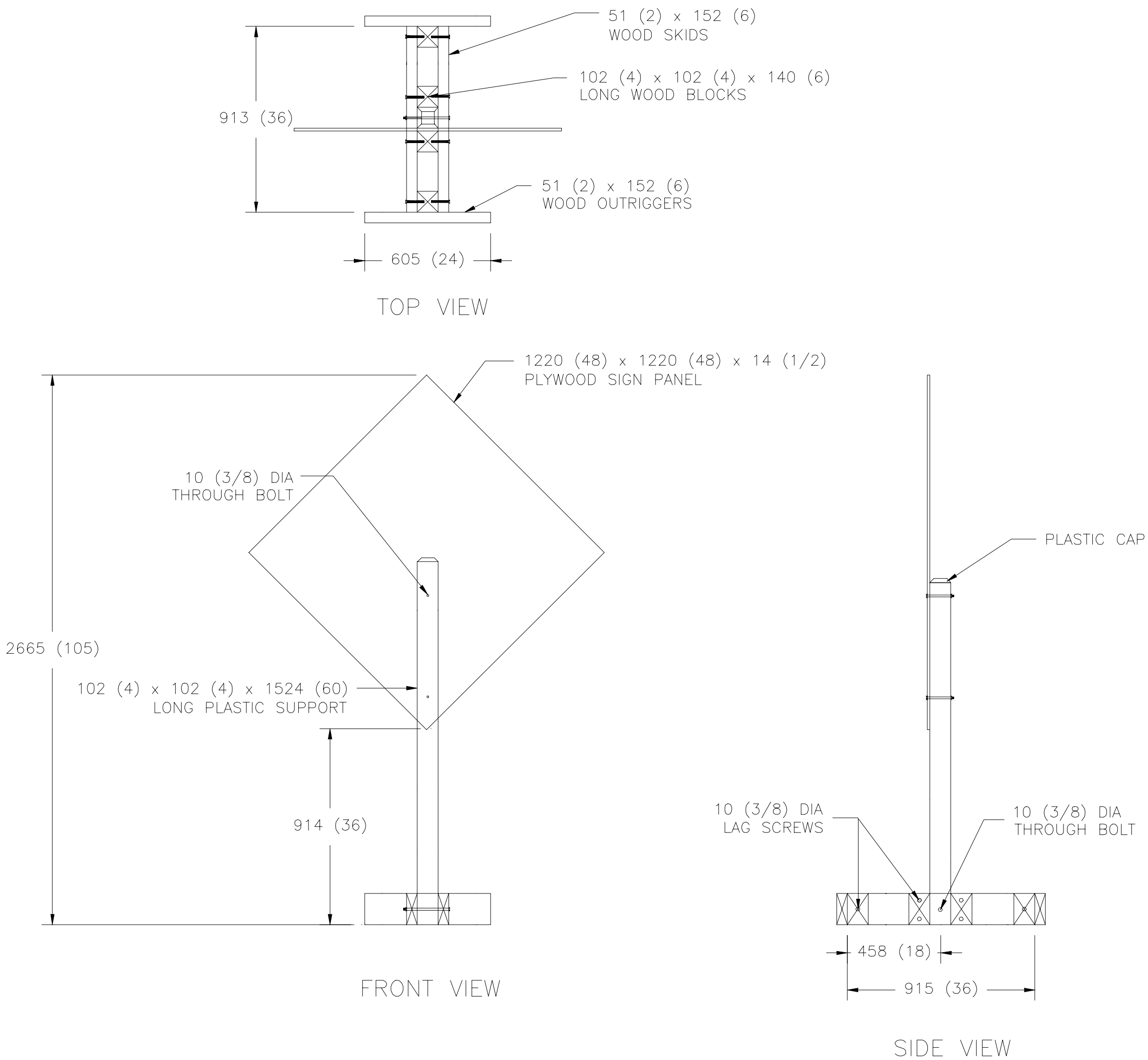


Figure 19. Hollow Profile Plastic Sign Support in H-Leg Base (1.2 m × 1.2 m [4 ft × 4 ft] panel - 0.9 m [3 ft] mounting height) Installation for Test 417928-18.

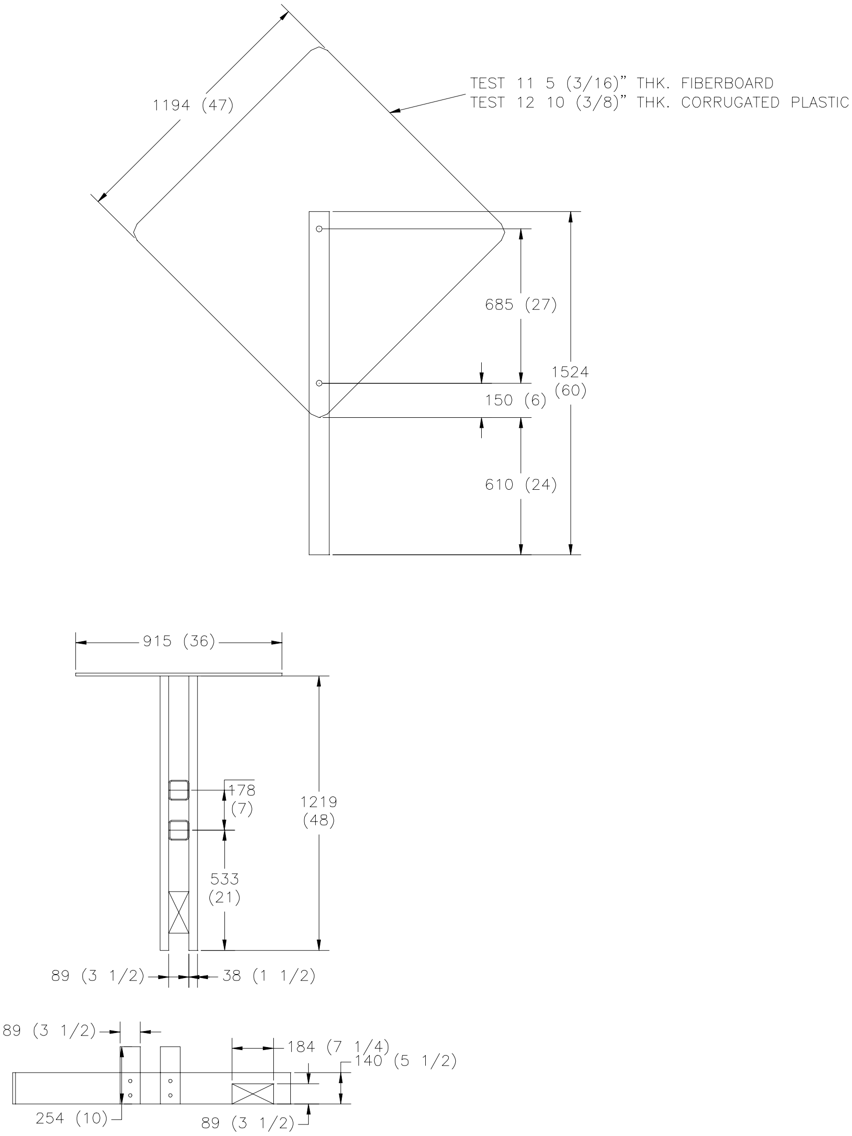


Figure 20. Hollow Profile Plastic Sign Support in T-Leg Base (1.2 m × 1.2 m [4 ft × 4 ft] fiberglass panel - 0.6 m [2 ft] mounting height) Installation for Test 417929-11.

Hollow Profile Plastic Sign Support in T-Leg Base (1.2 m × 1.2 m [4 ft × 4 ft] corrugated plastic panel - 0.6 m [2 ft] mounting height) (Test No. 417929-12)

The hollow profile plastic sign support in a T-leg base was tested with a corrugated plastic panel, and details of the barricade are given in Figure 21. A 82 mm × 82 mm × 1530 mm (3.25 inch × 3.25 inch × 60 inch) long 10 mm (3/8 inch) thick hollow core plastic support with a 1220 mm × 1220 mm × 5 mm (48 inch × 48 inch × 3/16 inch) corrugated plastic sign panel attached with two 10 mm (3/8 inch) diameter through bolts and metal pipe clamps was inserted into a T-leg base. The base consisted of a pair of wood skids 51 mm × 152 mm × 1220 mm (2 inch × 6 inch × 48 inch) with 85 mm × 85 mm × 182 mm (3.5 inch × 3.5 inch × 7 inch) wood spacers and a 14 mm × 140 mm × 912 mm (½ inch × 5.5 inch × 36 inch) outrigger on one end. Height to the bottom of the sign was 610 mm (24 inch).

Chevron/Object Marker Supports

Dual Chevron Support (Test No. 417929-3)

A dual chevron support was tested, and Figure 22 shows the details of the support. One support consisted of a 2.7 N·m (2 lb/ft) U-channel post with a 610 mm x 914 mm (24 inch × 36 inch) sign panel mounted at 1220 mm (48 inch) to the bottom of the sign panel. The second support consisted of a Poz-Loc thin wall tube with two (one on the front and one on the back side as if it was facing opposing traffic) 610 mm × 914 mm (24 inch × 36 inch) sign panels mounted at 1220 mm (48 inch) to the bottom of the sign panels. The supports were spaced 610 mm (24 inch) apart and anchored in *NCHRP Report 350* standard soil.

Temporary Mailbox Support

Mailbox on Plastic Drum (Test No. 417929-10)

A TrafFix Device Inc., HDPE model 2 Safety Lights plastic drum with a size 1 mailbox attached at the top was tested and is shown in Figure 23.

CRASH TEST CONDITIONS

According to *NCHRP Report 350*, two crash tests are required for evaluation of work zone traffic control devices, *NCHRP Report 350* test designations 3-70 and 3-71. The tests involve an 820-kg (1806 lb) passenger car impacting the device at a nominal speed of 35 km/h (21.7 mi/h) and 100 km/h (62.2 mi/h) for test level 3 (TL-3) conditions. The tests are intended to evaluate vehicular stability, test article trajectory, and occupant risk factors. Except for test 417928-4 (at 35 km/h) (21.7 mi/h), only *NCHRP Report 350* test designation 3-71 (100 km/h

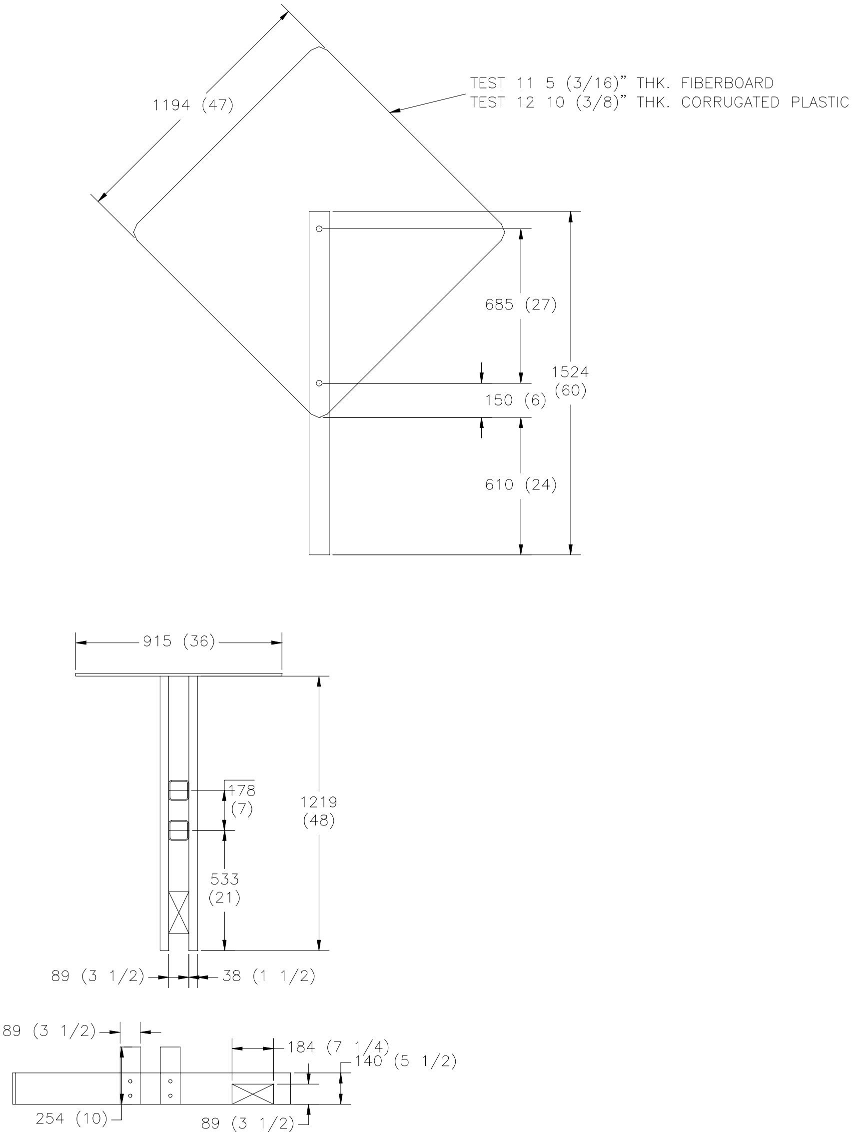


Figure 21. Hollow Profile Plastic Sign Support in T-Leg Base (1.2 m × 1.2 m [4 ft × 4 ft] corrugated plastic panel - 0.6 m [2 ft] mounting height) Installation for Test 417929-12.

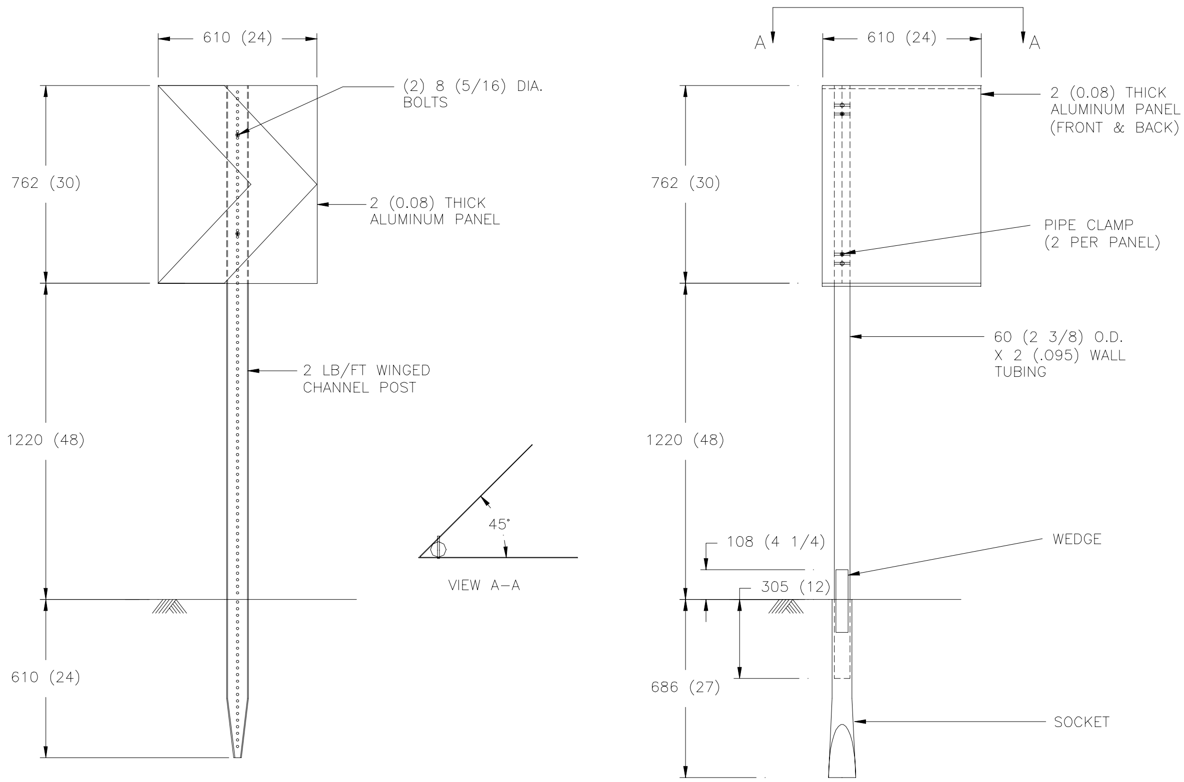


Figure 22. Dual Chevron Support Installation as Used in Test 417929-3.

Figure 23. Mailbox on Plastic Drum as Used in Test 417929-10.

test) (62.2 mi/h) was performed on the work zone traffic control devices. A 50th percentile male anthropomorphic dummy was placed in the driver's position and restrained with standard equipment lap and shoulder belts, thus increasing the test weight of the vehicle to 896 kg (1974 lb). The traffic control devices were placed on soil to simulate conditions that might be encountered on the roadside in actual applications.

It should be noted that all crash tests performed under this study were head-on impacts (0 degrees) with the centerline of the vehicle aligned with the centerline of the traffic control device. After testing was underway, FHWA issued a memo which stated the following:

> *Some work zone traffic control devices are normally used in a series to channelize traffic. There is the potential that singly some of these devices may have little effect on an impacting vehicle but, when struck in multiples, may cause vehicle instability or occupant compartment intrusion ... when testing devices that are typically installed in series, it is recommended that crash tests include two of these devices placed in a row aligned with the path of the test vehicle. For a 100-km/h test, the devices should be placed 6 meters apart, and the second device should be either turned 90 degrees relative to the first or laid on the ground, whichever is judged the "worst case" orientation for the device in question.*

Since some of the test matrix had been performed with only one device at 0 degrees, researchers felt that the test configuration should remain the same throughout this project.

The crash test and data analysis procedures were in accordance with guidelines presented in *NCHRP Report 350*. Appendix A presents brief descriptions of these procedures.

EVALUATION CRITERIA

The crash tests performed were evaluated in accordance with *NCHRP Report 350*. As stated in *NCHRP Report 350*, "Safety performance of a highway appurtenance cannot be measured directly but can be judged on the basis of three factors: structural adequacy, occupant risk, and vehicle trajectory after collision." Accordingly, researchers used the following safety evaluation criteria from Table 5.1 of *NCHRP Report 350* to evaluate the crash tests reported herein:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

H. *Occupant impact velocities should satisfy the following:*

Longitudinal Occupant Impact Velocity - m/s	
Preferred	*Maximum*
3	*5*

I. *Occupant ridedown accelerations should satisfy the following:*

Longitudinal and Lateral Occupant Ridedown Accelerations - g's	
Preferred	*Maximum*
15	*20*

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

N. *Vehicle trajectory behind the test article is acceptable.*

Researchers evaluated tests 417928-4 and 5 according to all the above criteria. The remaining crash tests performed under this study were evaluated in accordance with the above-mentioned criteria, with the exception of Criteria H and I on occupant risk factors, i.e., occupant impact velocity and ridedown acceleration. Previous full-scale crash tests have shown that the acceleration levels experienced by the vehicle during impact with traffic control devices weighing less than 45 kg (99.2 lb) were extremely low and not of any significance. Thus, the test vehicles were not instrumented, and the occupant risk factors were not calculated for this study.

In addition, the 1994 AASHTO Specification states:

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].[7]

III. CRASH TEST RESULTS

TYPE I BARRICADES

Type I Plastic A-Frame Barricade–
Test No. 417928-6 (*NCHRP Report 350* Test No. 3-71)

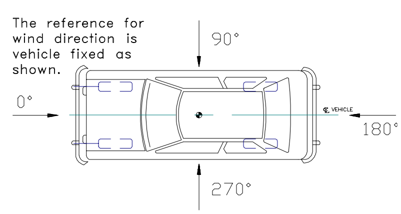
A Type I plastic fixed A-frame barricade with 1.1 m (3.6 ft) height, manufactured by Fender Enterprises, shown previously in Figure 1 and in Figure 24, was evaluated in this crash test. As shown in Figure 25, the 1067 mm (42 inch) rail height placed the rail at the bottom of the windshield of the test vehicle. The lower horizontal cross member of each A-frame of the barricade was ballasted with two 7.6 kg (16.8 lb) sandbags, as shown in Figure 25.

Test Vehicle

A 1994 Geo Metro, shown in Figures 25 and 26, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 385 mm (15.2 inch), and it was 520 mm (20.5 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 216. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the morning of July 6, 1998. A total of 35 mm (1.4 inch) of rain was recorded eight days prior to the test but would not affect the test as the barricade was installed on the ground surface. No other rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust and ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 3 km/h (2 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 34 °C (93 °F); relative humidity: 62 percent.



Test Description

The vehicle impacted the barricade head-on at a speed of 98.3 km/h (61.1 mi/h). At 0.054 s, the barricade moved, and the panel of the barricade contacted the bottom of the windshield. By 0.059 s, the panel traveled up the windshield, and by 0.072 s, the panel slightly

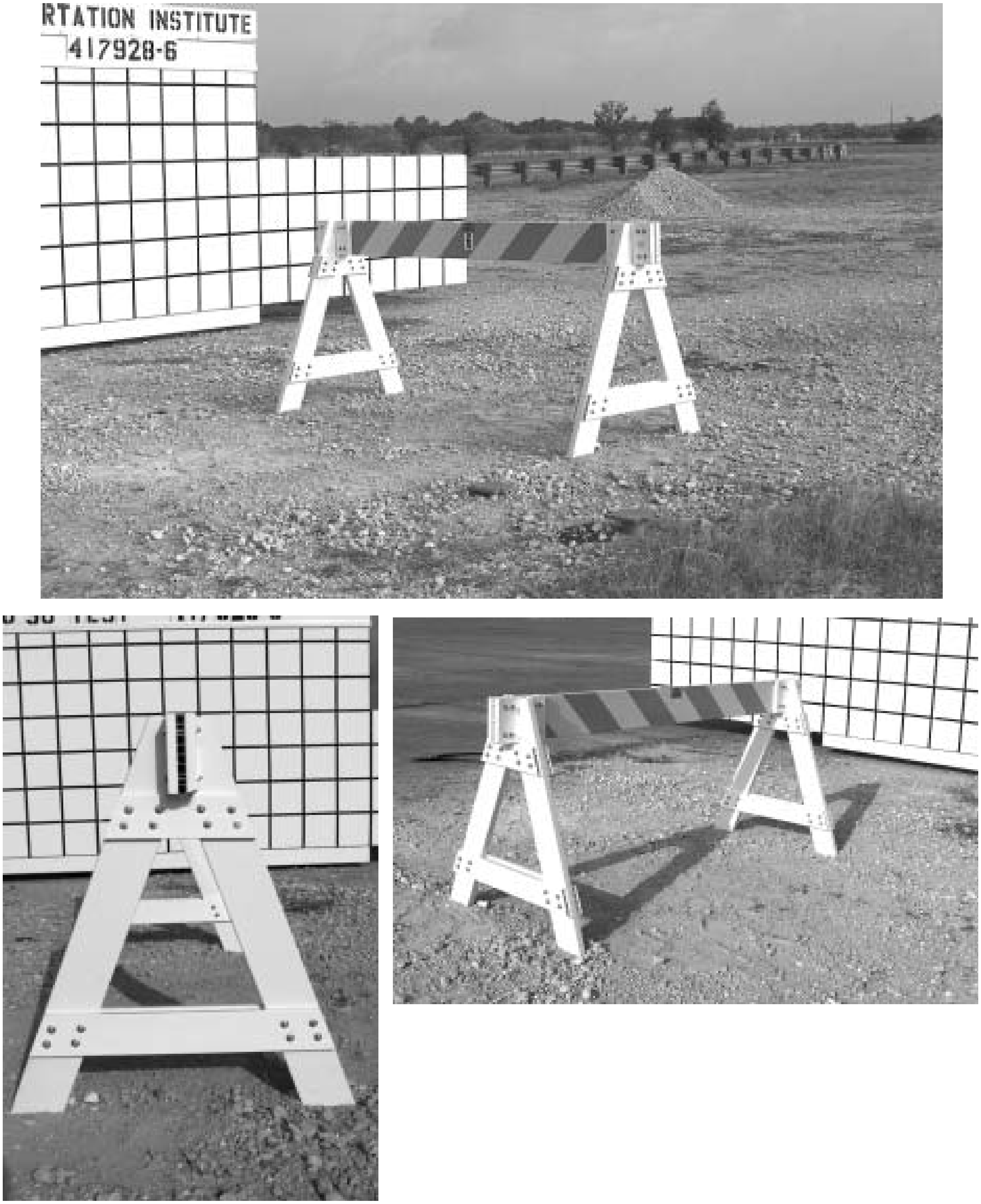


Figure 24. Installation before Test 417928-6.

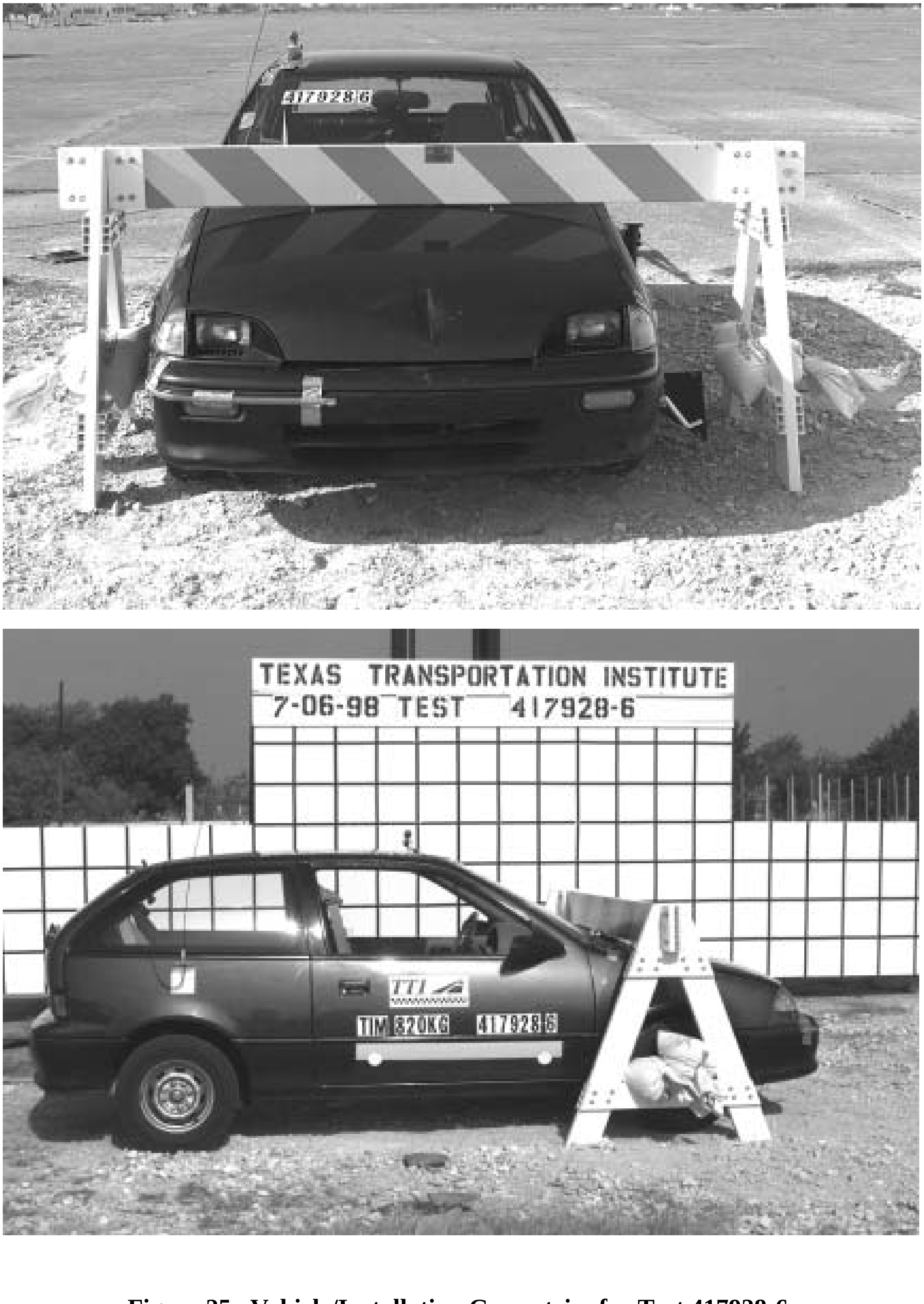


Figure 25. Vehicle/Installation Geometrics for Test 417928-6.

Figure 26. Vehicle before Test 417928-6.

pulled out of the left and right legs of the barricade. The panel completely separated from the right leg and left leg at 0.089 s and 0.094 s, respectively. At 0.099 s, the panel lost contact with the vehicle, and at 0.121 s, the vehicle's antenna on the right side contacted a barricade leg. As the vehicle lost contact with the A-Frame, at 0.171 s, the vehicle was traveling at 98.1 km/h (61.0 mi/h). Brakes on the vehicle were applied as the vehicle exited the test site, and the vehicle came to rest 75.0 m (246.1 ft) down from the impact point. Sequential photographs of the test can be found in Appendix C, Figure 226.

Damage to Test Installation

The barricade separated into three pieces, as shown in Figures 27 and 28. The debris extended 21.0 m (69.0 ft) down, 0.3 m (1.0 ft) to the left, and 1.8 m (5.9 ft) to the right of the impact point.

Vehicle Damage

The vehicle received damage to the front, as shown in Figure 29. The windshield was shattered on the passenger side from contact with the panel. However, the hollow profile PVC panel did not have sufficient mass to cause penetration into the occupant compartment of the vehicle. The interior of the vehicle is shown in Figure 30.

Assessment of Test Results

A summary of the test results is shown in Figure 31. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The Type I plastic fixed A-frame barricade, manufactured by Fender Enterprises, met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of,*

Figure 27. After Impact Trajectory for Test 417928-6.

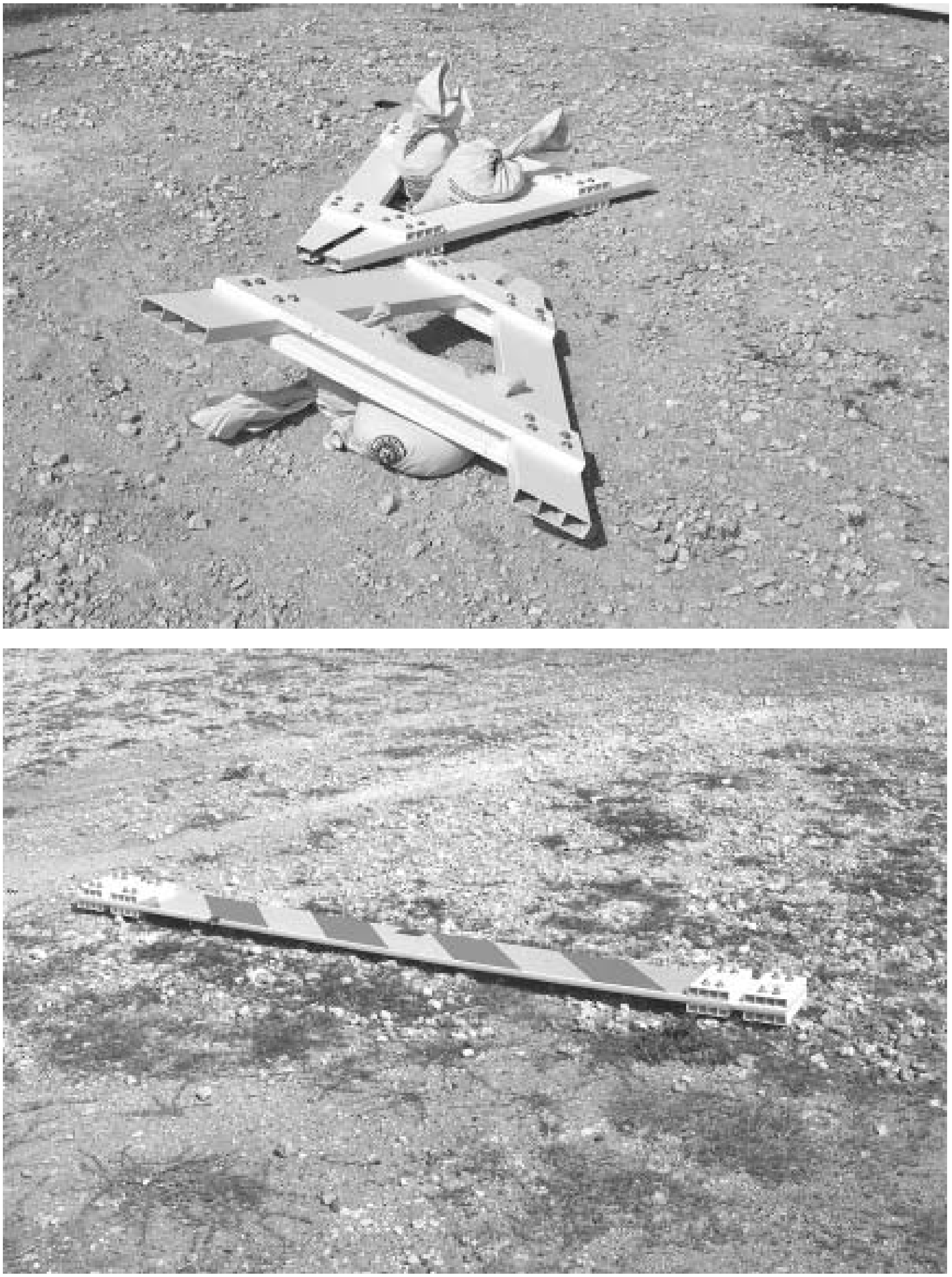


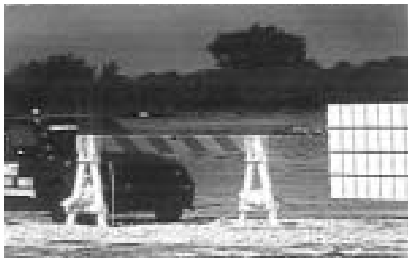
Figure 28. Installation after Test 417928-6.

Figure 29. Vehicle after Test 417928-6.

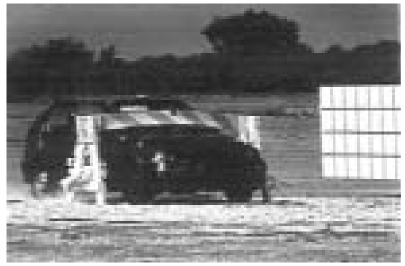
Before test

After test

Figure 30. Interior of Vehicle for Test 417928-6.



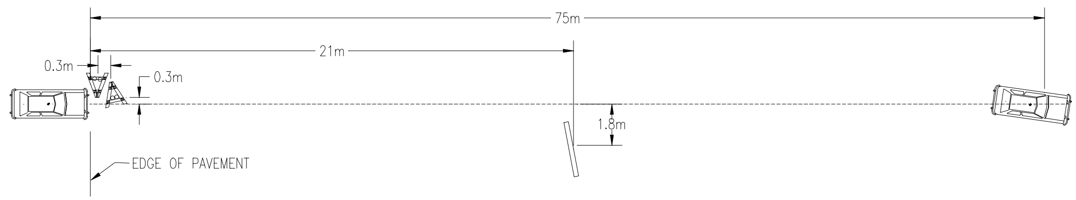
0.000 s

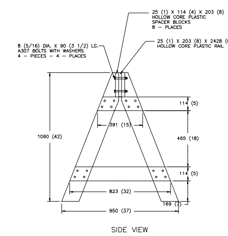


0.066 s

0.090 s

0.151 s





General Information

Test Agency	Texas Transportation Institute
Test No.	417928-6
Date	07/06/98

Test Article

Type	Traffic Control Device
Name	Type I Plastic A-frame
Installation Length (m)	2.4 (8.0 ft)
Material or Key Elements	All Hollow Plastic A-frame Barricade

Soil Type and Condition ...... Standard Soil, Dry

Test Vehicle

Type	Production
Designation	820C
Model	1994 Geo Metro
Mass (kg) Curb	798 (1760 lb)
Test Inertial	820 (1806 lb)
Dummy	76 (168 lb)
Gross Static	896 (1974 lb)

Impact Conditions

Speed (km/h)	98.3 (61.1 mi/h)
Angle (deg)	0

Exit Conditions

Speed (km/h)	98.1 (61.0 mi/h)
Angle (deg)	0

Test Article Debris Pattern (m)

Longitudinal	21.0 (69.0 ft)
Lateral	1.8 (5.9 ft)

Vehicle Damage

Exterior	
VDS	12FC1
CDC	12FCEW1
Maximum Exterior Vehicle Crush (mm)	nil
Interior	
OCDI	FS0000000
Max. Occ. Compart. Deformation (mm)	0

Figure 31. Summary of Results for Test 417928-6, *NCHRP Report 350* Test 3-71.

or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.

The plastic barricade shattered the base of the windshield, but it did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 0.06 m/s (2.0 ft/s).

Conclusion

The Type I plastic A-frame barricade performed acceptably for *NCHRP Report 350* test designation 3-71.

**Type I Perforated Steel Tube Skid Mount Barricade –
Test No. 417928-7 (*NCHRP Report 350* Test No. 3-71)**

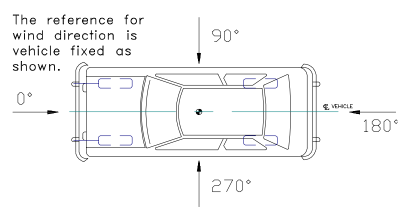
A Type I perforated steel tube barricade with a 20 mm × 185 mm × 1220 mm (0.8 inch × 7 inch × 48 inch) wooden panel, shown previously in Figure 2 and in Figure 32, was evaluated in this crash test. The height to the top of the barricade was 930 mm (36.6 inch). The skids of the barricade were ballasted with four 7.6 kg (16.8 lb) sandbags.

Test Vehicle

A 1993 Geo Metro, shown in Figures 33 and 34, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 395 mm (15.6 inch), and it was 525 mm (20.7 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 217. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the morning of July 6, 1998. A total of 35 mm (1.4 inch) of rain was recorded eight days prior to the test but would not affect the test as the barricade was installed on the ground surface. No other rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 3 km/h (2 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 34 °C (93 °F); relative humidity: 62 percent.



Test Description

The vehicle impacted the barricade head-on at a speed of 98.7 km/h (61.3 mi/h). At 0.024 s, the vehicle contacted the barricade panel, and at 0.027 s, the panel moved. The barricade began to slide with the vehicle at 0.029 s. The left side of the panel contacted the ground at 0.105 s, and at 0.144 s, the right tire of the vehicle rode onto the support frame forcing the top portion of the barricade toward the ground. At 0.159 s, the right side of the panel contacted the ground, and at 0.176 s the right front tire rode over the wooden panel. The vehicle was traveling at 90.0 km/h (56.0 mi/h) with the barricade still in contact with the vehicle as the vehicle exited the test site.

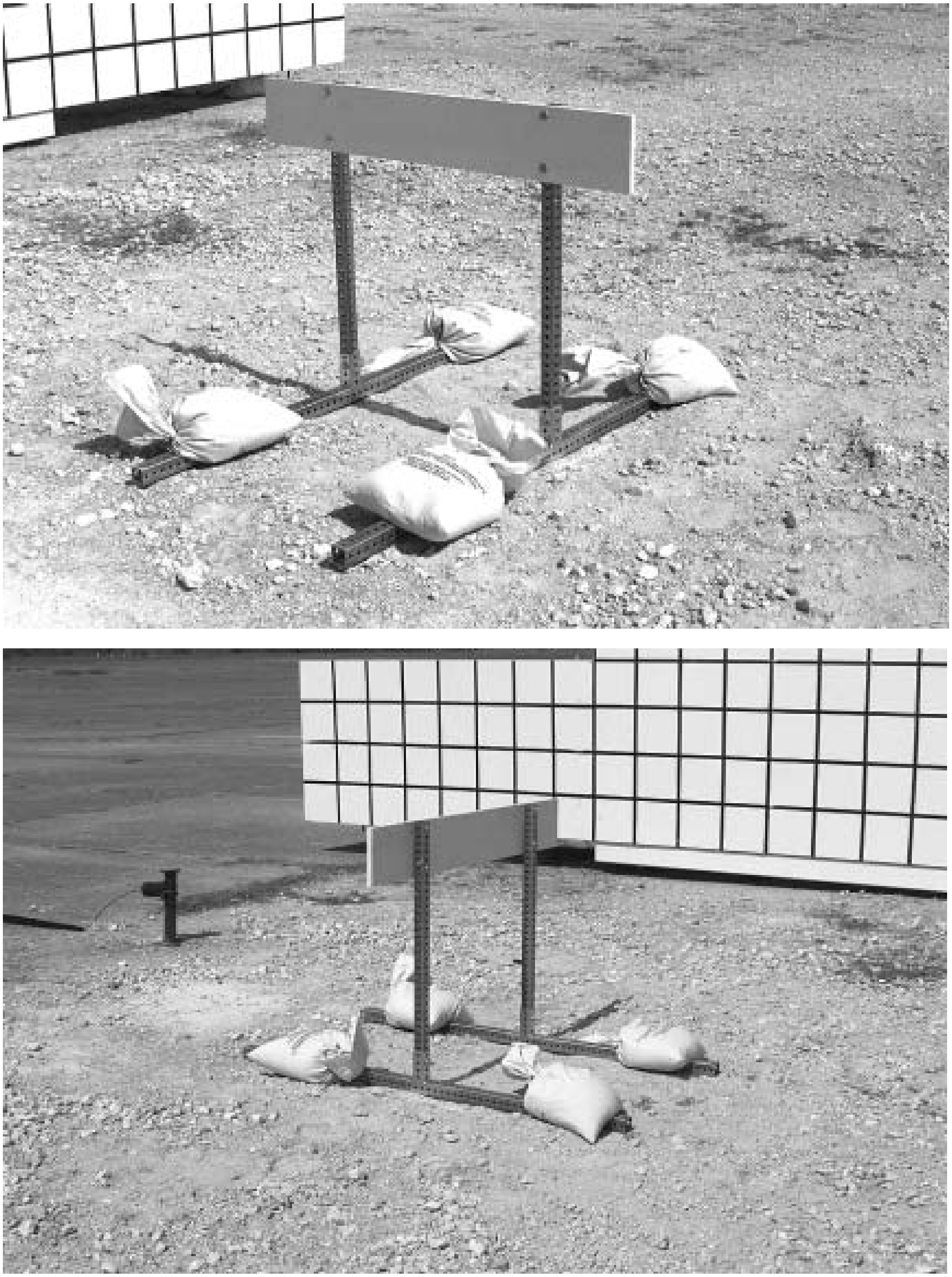


Figure 32. Installation before Test 417928-7.

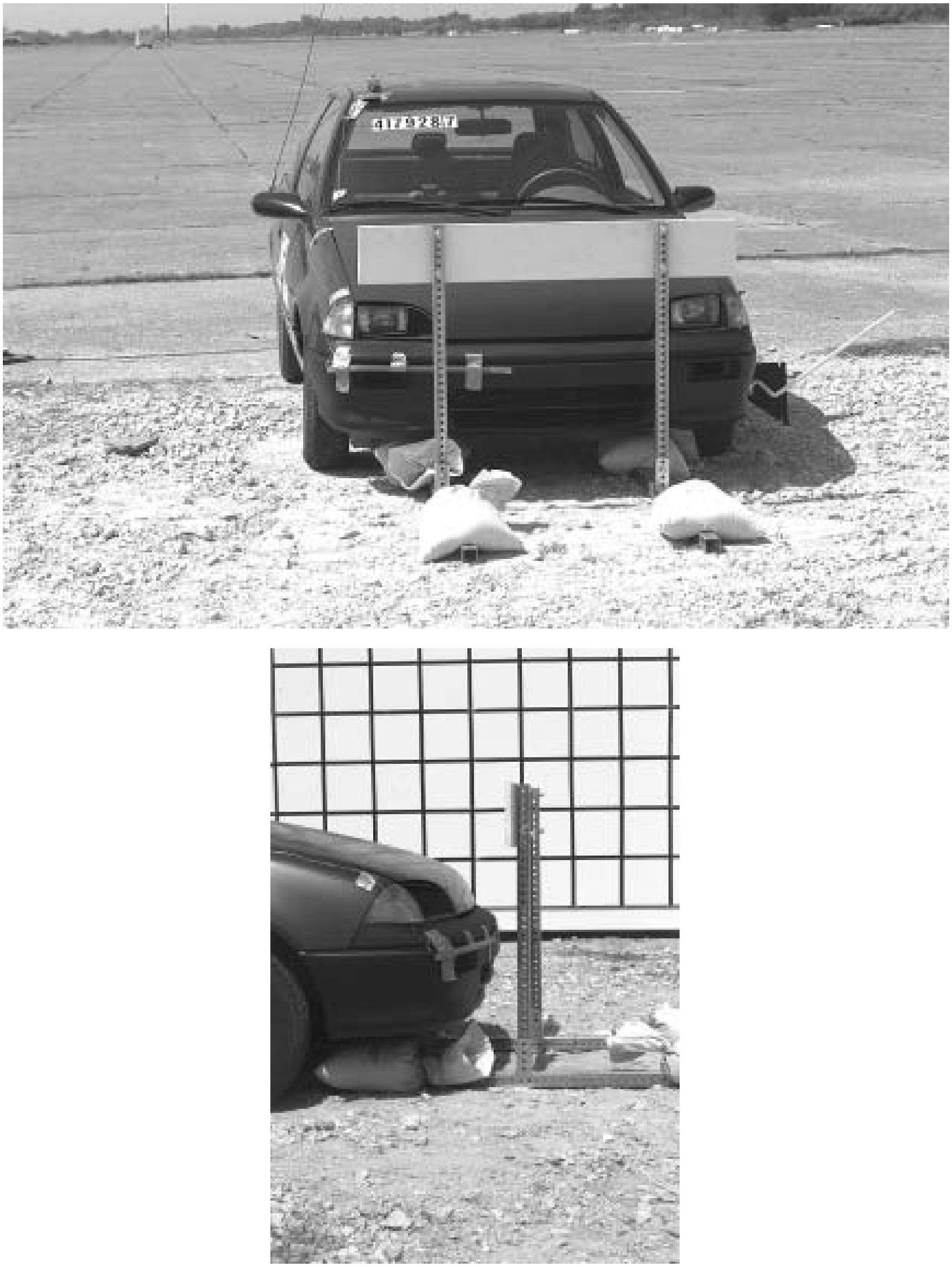


Figure 33. Vehicle/Installation Geometrics for Test 417928-7.

Figure 34. Vehicle before Test 417928-7.

Brakes on the vehicle were applied as it exited the test site, and the vehicle came to rest 97.5 m (320.0 ft) down and 1.8 m (5.9 ft) to the right of the impact point. Sequential photographs of the test can be found in Appendix C, Figure 227.

Damage to Test Installation

The barricade separated into multiple pieces, as shown in Figures 35 and 36. The debris extended 26.7 m (87.6 ft) down, 3.8 m (12.5 ft) to the left, and 6.1 m (20.0 ft) to the right of the impact point.

Vehicle Damage

The 914 mm (36 inch) rail height permitted the vehicle to ride down the barricade without any windshield damage. The only damage the vehicle received was a small dent in the hood and bumper, as shown in Figure 37. The interior of the vehicle is shown in Figure 38.

Assessment of Test Results

A summary of the test results is shown in Figure 39. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The Type I perforated steel tube barricade with wooden panel, separated from the base and thereby met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

Figure 35. After Impact Trajectory for Test 417928-7.

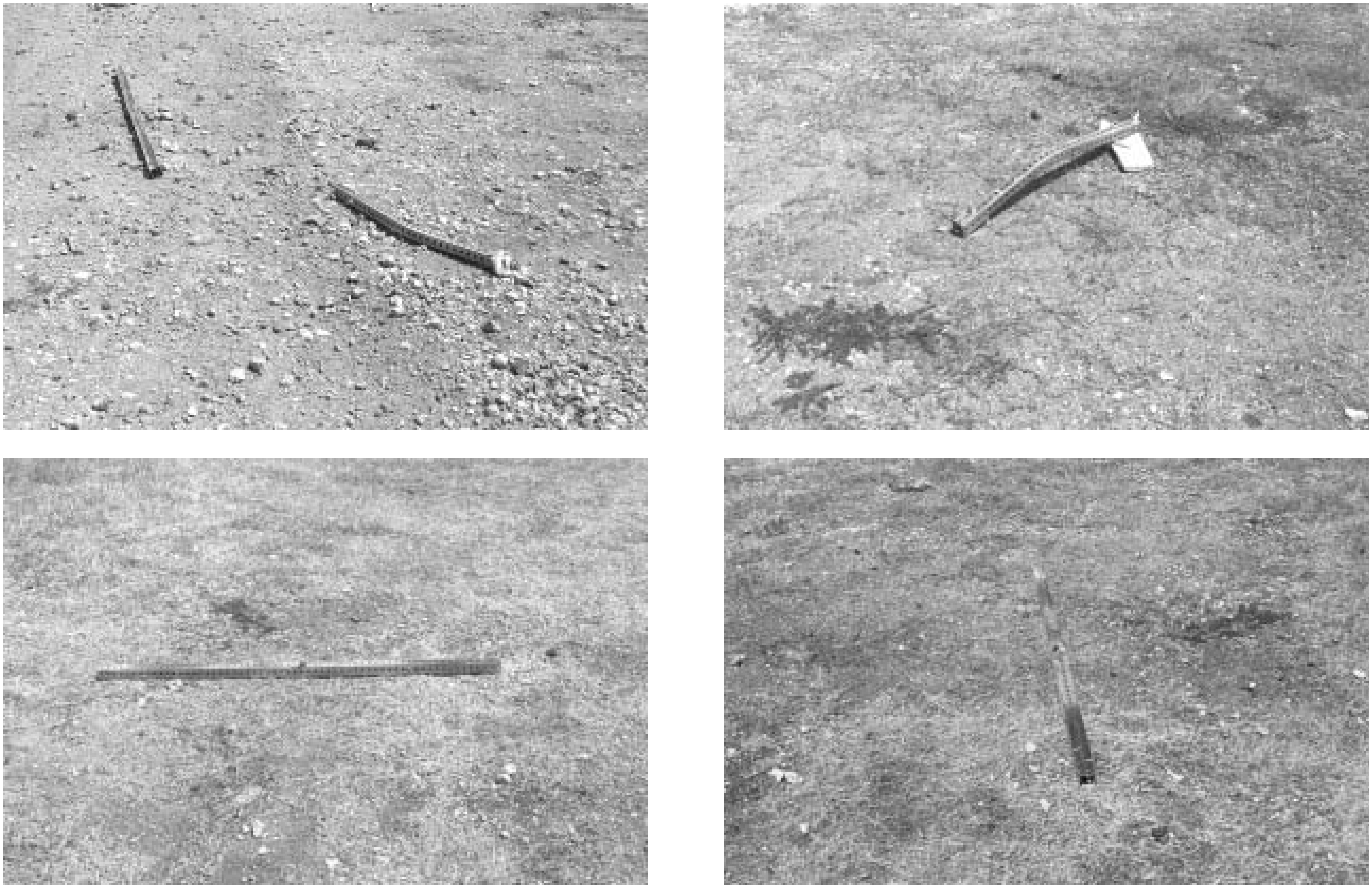


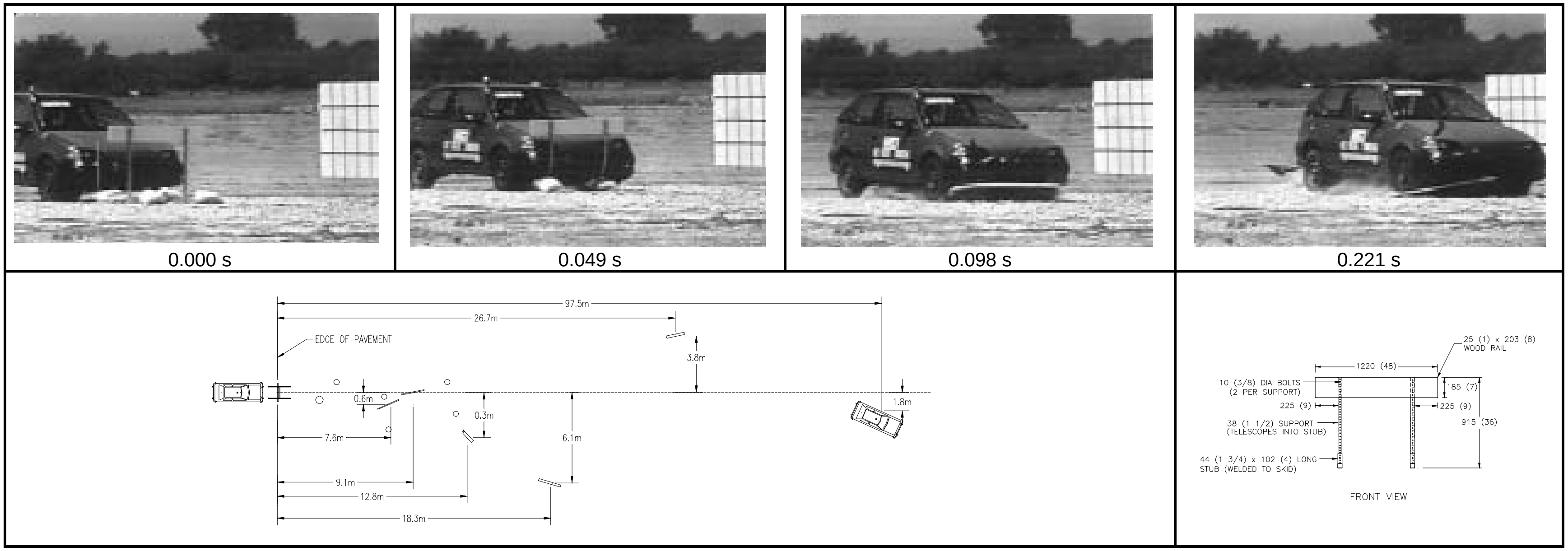
Figure 36. Installation after Test 417928-7.

Figure 37. Vehicle after Test 417928-7.

Before test

After test

Figure 38. Interior of Vehicle for Test 417928-7.



General Information

Test Agency	Texas Transportation Institute
Test No.	417928-7
Date	07/06/98

Test Article

Type	Traffic Control Device
Name	Type I Perforated Steel Tube Skid Mount Barricade
Installation Length (m)	1.2 (4.0 ft)
Material or Key Elements	Steel frame with 20 x 185 x 1220 mm (0.8x7x48 inch) Wooden Panel

Soil Type and Condition . . . . . . Standard Soil, Dry

Test Vehicle

Type	Production
Designation	820C
Model	1993 Geo Metro
Mass (kg) Curb	779 (1717 lb)
Test Inertial	820 (1806 lb)
Dummy	76 (168 lb)
Gross Static	896 (1974 lb)

Impact Conditions

Speed (km/h)	98.7 (61.3 mi/h)
Angle (deg)	0

Exit Conditions

Speed (km/h)	90.0 (56.0 mi/h)
Angle (deg)	0

Test Article Debris Pattern (m)

Longitudinal	26.7 (87.6 ft)
Lateral	6.1 (20.0 ft)

Vehicle Damage

Exterior	
VDS	12FL1
CDC	12FLEN1
Maximum Exterior Vehicle Crush (mm)	nil
Interior	
OCDI	FS0000000
Max. Occ. Compart. Deformation (mm)	0

Figure 39. Summary of Results for Test 417928-7, *NCHRP Report 350* Test 3-71.

The steel barricade did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 2.4 m/s (8.0 ft/s).

Conclusion

The Type I perforated steel tube skid mount barricade performed acceptably for *NCHRP Report 350* test designation 3-71.

Type I Hollow Profile Plastic Skid Mount Barricade –
Test No. 417928-8 (*NCHRP Report 350* Test No. 3-71)

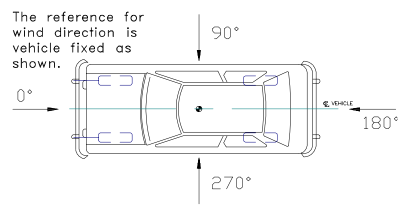
A Type I hollow core plastic barricade with a 20 mm × 185 mm x 1220 mm (0.8 inch × 7 inch × 48 inch) wooden panel and skids, shown previously in Figure 3 and in Figure 40, was evaluated in this crash test. The height to the top of the barricade was 910 mm (35.8 inch). The base of the barricade was ballasted with four 7.6 kg (16.8 lb) sandbags.

Test Vehicle

A 1993 Geo Metro, shown in Figures 41 and 42, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 395 mm (15.6 inch), and it was 525 mm (20.7 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 217. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the afternoon of July 6, 1998. A total of 35 mm (1.4 inch) of rain was recorded eight days prior to the test but would not affect the test as the barricade was installed on the ground surface. No other rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 3 km/h (2 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 34 °C (93 °F); relative humidity: 62 percent.



Test Description

The vehicle impacted the barricade head-on at a speed of 99.4 km/h (61.8 mi/h). Shortly after impact, the bottom of the bumper contacted the sandbags. At 0.015 s, the vehicle contacted the barricade panel, and at 0.017 s, the barricade moved. By 0.020 s, the barricade began to slide with the vehicle, and by 0.027 s, the top of the barricade panel contacted the hood of the vehicle. At 0.032 s, the barricade legs contacted the ground, and at 0.066 s, the left side of the panel contacted the ground. By 0.076 s, the right side of the panel contacted the ground, and at 0.191 s,

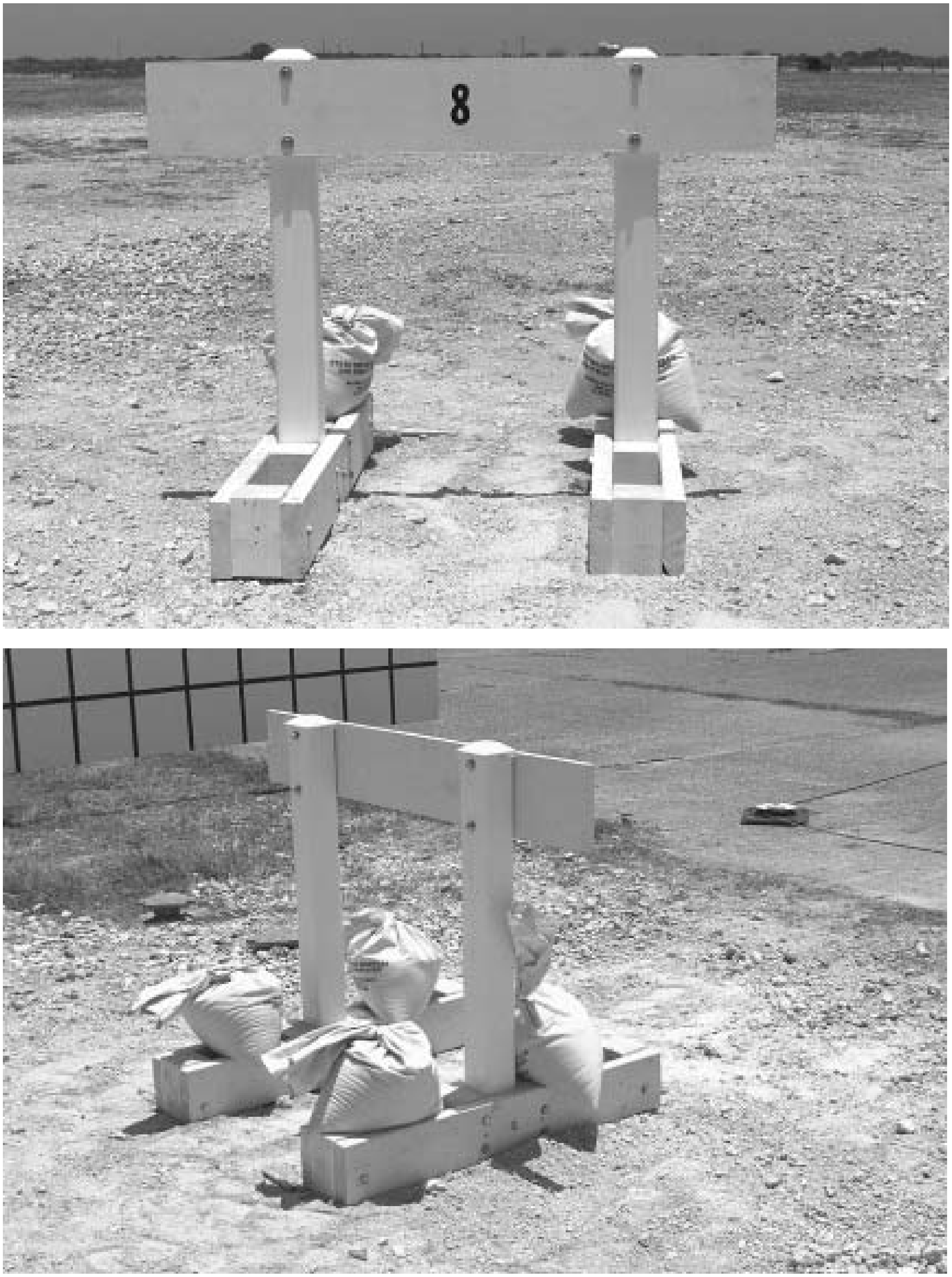


Figure 40. Installation before Test 417928-8.

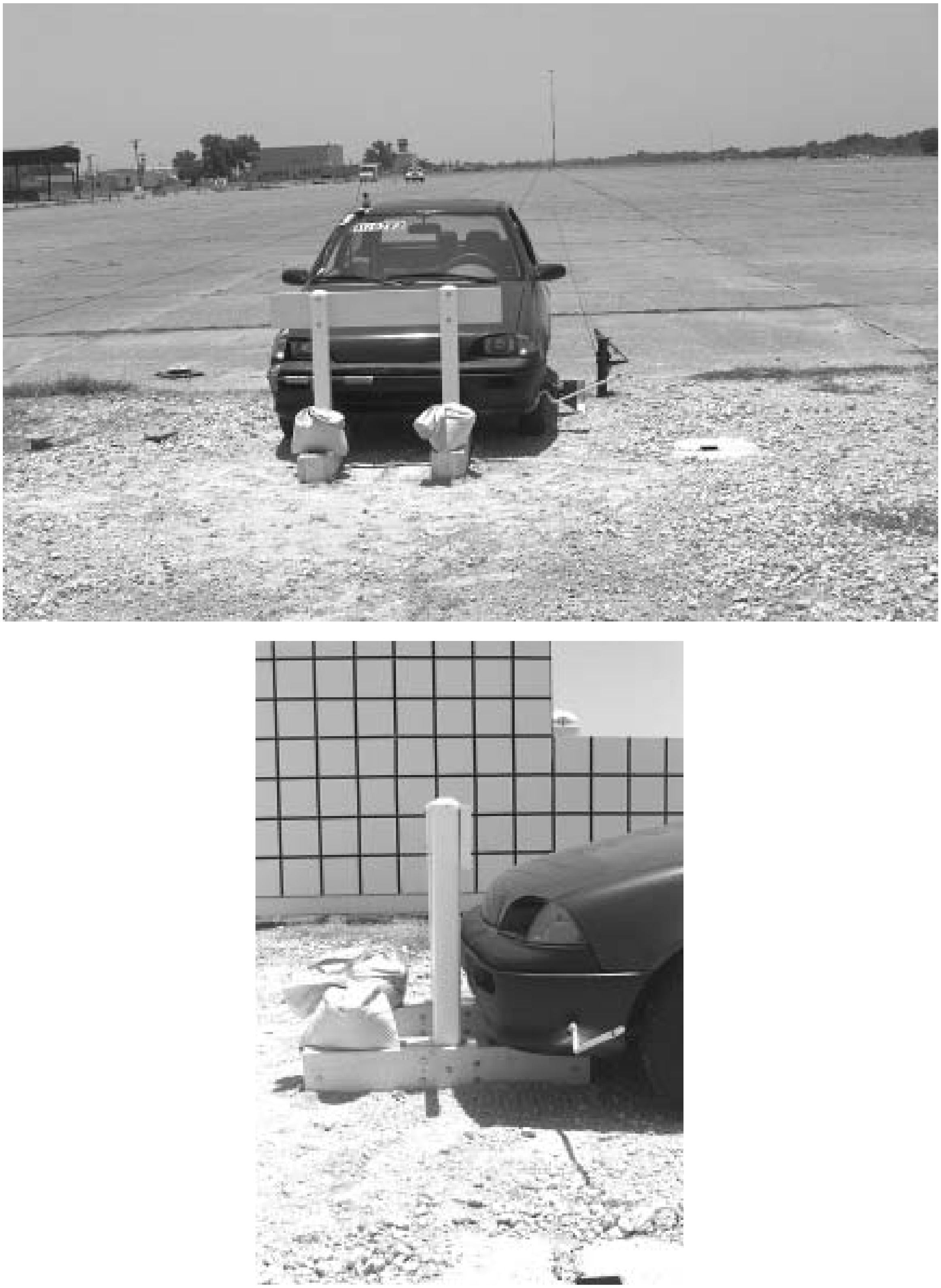


Figure 41. Vehicle/Installation Geometrics for Test 417928-8.

Figure 42. Vehicle before Test 417928-8.

the vehicle was traveling at 88.8 km/h (55.2 mi/h) with the barricade still in contact with the vehicle, as the vehicle exited the test site. Brakes on the vehicle were applied as it exited the test site and the vehicle came to rest 79.2 m (259.8 ft) down from impact. Sequential photographs of the test can be found in Appendix C, Figure 228.

Damage to Test Installation

The barricade separated into multiple pieces, as shown in Figures 43 and 44. The debris extended 26.7 m (87.6 ft) down, 6.1 m (20.0 ft) to the left, and 1.2 m (4.0 ft) to the right of impact point.

Vehicle Damage

As with the perforated steel tube design, the vehicle was able to ride down the 914 mm (36 in) tall barricade without any windshield contact. The minor damage sustained by the vehicle is shown in Figure 45. There was a dent across the hood (not measurable), small dents in the bumper, and the radiator support was deformed. Figure 46 shows the interior of the vehicle

Assessment of Test Results

Figure 47 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The Type I hollow core plastic barricade with wooden panel and skids separated from the base and thereby met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

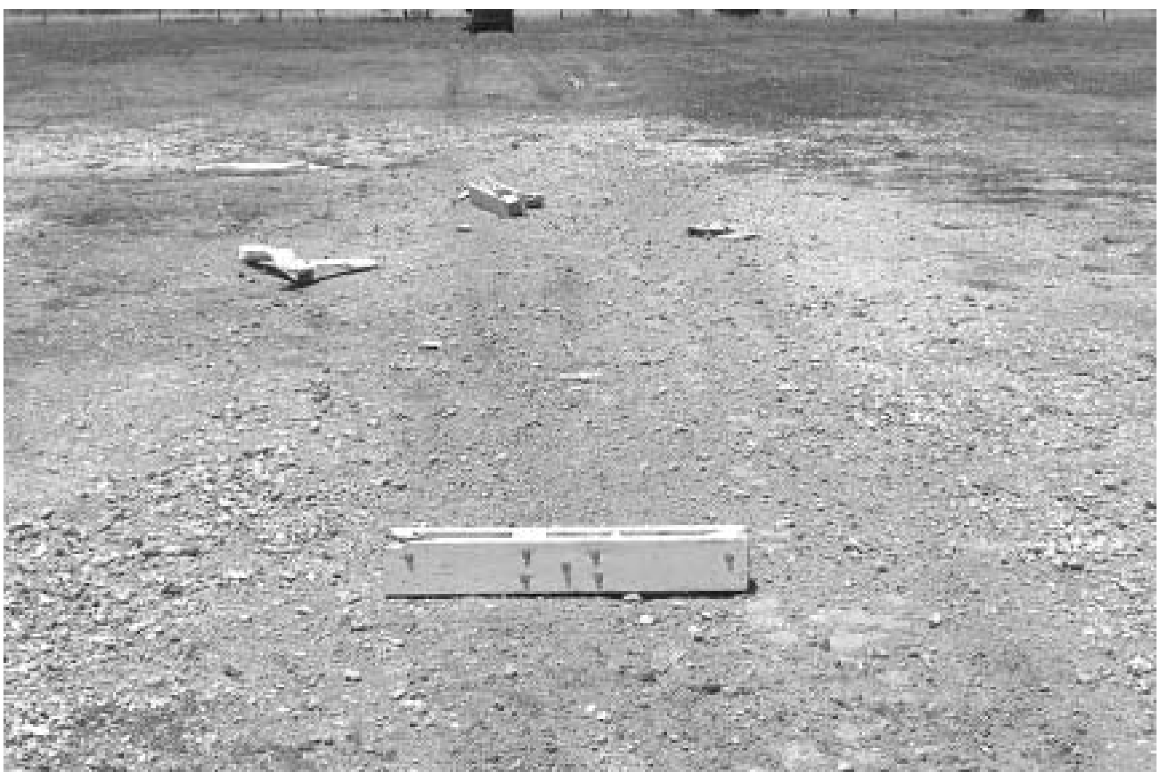


Figure 43. After Impact Trajectory for Test 417928-8.

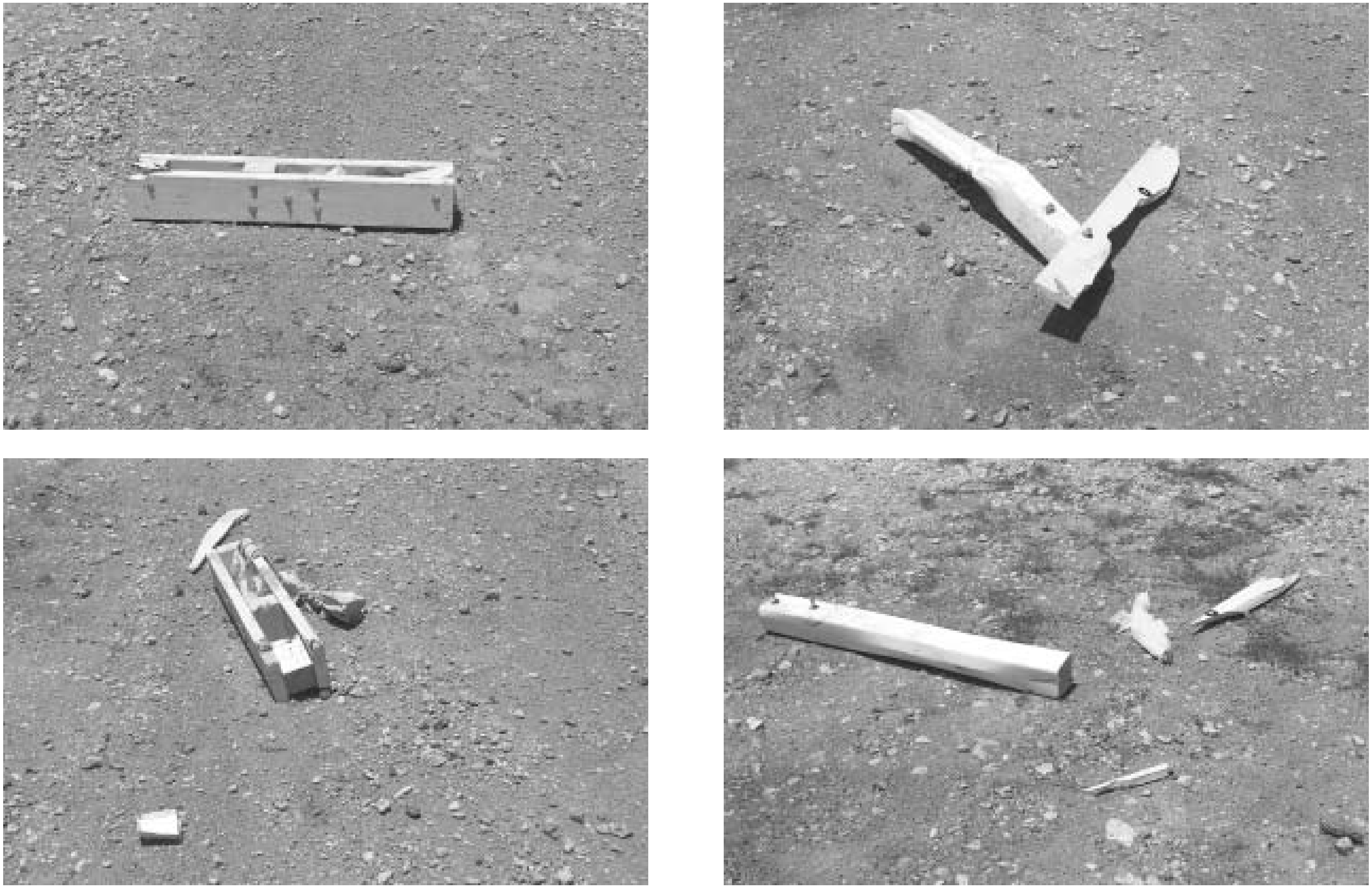


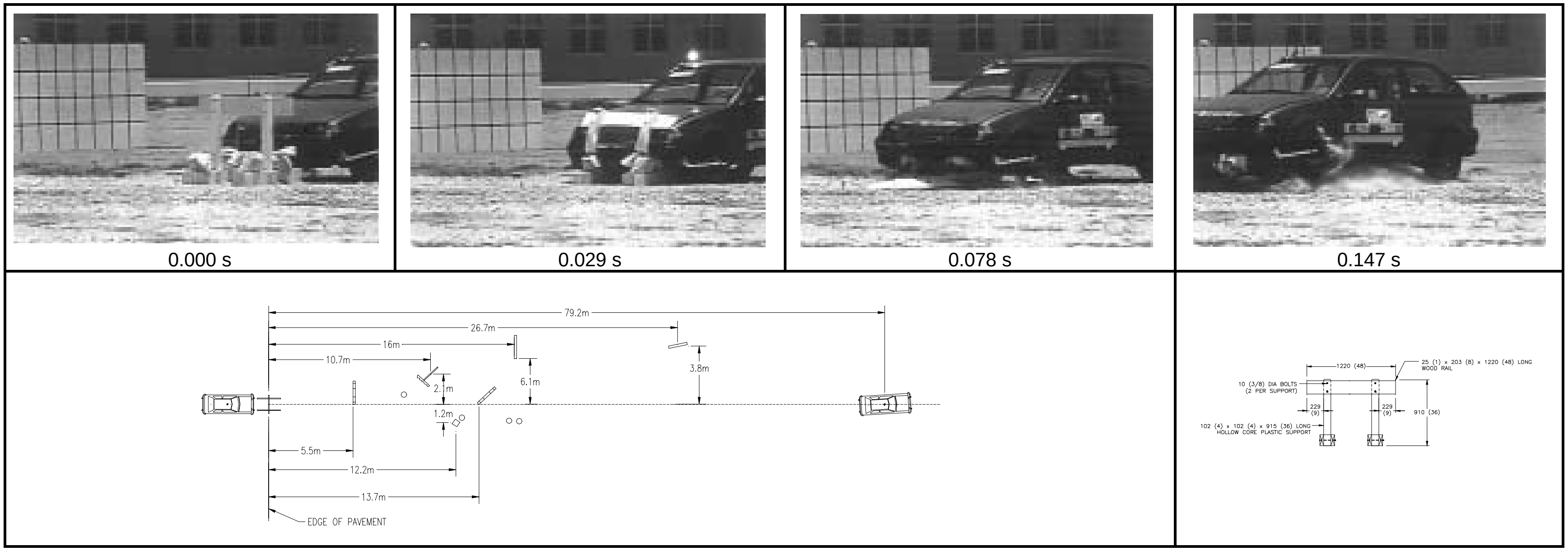
Figure 44. Installation after Test 417928-8.

Figure 45. Vehicle after Test 417928-8.

Before test

After test

Figure 46. Interior of Vehicle for Test 417928-8.



General Information
- Test Agency . . . . Texas Transportation Institute
- Test No. 471928-8
- Date 07/06/98

Test Article
- Type . . . . Traffic Control Device
- Name . . . . Type I Hollow Profile Plastic Skid Mount Barricade
- Installation Length (m) . . . . . . 1.2 (4.0 ft)
- Material or Key Elements . . . . Wooden Base w/ Plastic Support Post w/ 20x185x1220 mm (0.8x7x48 inch) Wooden Panel

Soil Type and Condition . . . . . . Standard Soil, Dry

Test Vehicle
- Type . . . . Production
- Designation 820C
- Model . . . . 1993 Geo Metro
- Mass (kg) Curb . . . . 779 (1717 lb)
  - Test Inertial . . . . 820 (1806 lb)
  - Dummy . . . . 76 (168 lb)
  - Gross Static . . . . 896 (1974 lb)

Impact Conditions
- Speed (km/h) . . . . 99.4 (61.8 mi/h)
- Angle (deg) 0

Exit Conditions
- Speed (km/h) . . . . 88.8 (55.2 mi/h)
- Angle (deg) 0

Test Article Debris Pattern (m)
- Longitudinal . . . . 26.7 (87.6 ft)
- Lateral . . . . 6.1 (20.0 ft)

Vehicle Damage
- Exterior
  - VDS 12FD1
  - CDC 12FDEW1
- Maximum Exterior
  - Vehicle Crush (mm) . . . . . . nil
- Interior
  - OCDI FS0000000
- Max. Occ. Compart.
  - Deformation (mm) 0

Figure 47. Summary of Results for Test 417928-8, *NCHRP Report 350* Test 3-71.

The plastic barricade did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 2.9 m/s (9.5 ft/s).

Conclusion

The Type I hollow profile plastic skid mount barricade performed acceptably for *NCHRP Report 350* test designation 3-71.

Type I Hollow Profile Plastic Folding A-Frame –
Test No. 417928-9 (*NCHRP Report 350* Test No. 3-71)

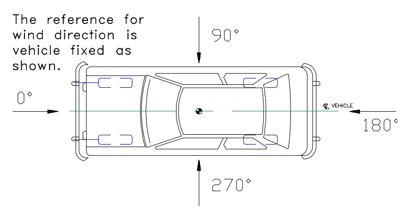
A Type I hollow core plastic folding A-frame barricade with wooden panels, shown previously in Figure 4 and in Figure 48, was evaluated in this crash test. The height to the top of the barricade was 991 mm (39 inch). The base of the barricade was ballasted with two 7.6 kg (16.8 lb) sandbags.

Test Vehicle

A 1994 Geo Metro, shown in Figures 49 and 50, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 385 mm (15.2 inch), and it was 520 mm (20.5 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 216. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the afternoon of July 6, 1998. A total of 35 mm (1.4 inch) of rain was recorded eight days prior to the test but would not affect the test as the barricade was installed on the ground surface. No other rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 3 km/h (2 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 34 °C (93 °F); relative humidity: 62 percent.



Test Description

The vehicle impacted the barricade head-on at a speed of 100.7 km/h (62.6 mi/h). Shortly after impact, the bumper of the vehicle contacted the sandbags, and at 0.007 s, the bumper of the vehicle contacted the barricade. At 0.009 s, the barricade moved, and at 0.014 s, the front legs of the barricade deformed. By 0.026 s, the upper portion of the barricade panel contacted the hood of the vehicle, and by 0.029 s, the rear legs of the barricade deformed. At 0.073 s, the panel lost contact with the hood of the vehicle, and at 0.112 s, the left side of the panel contacted the

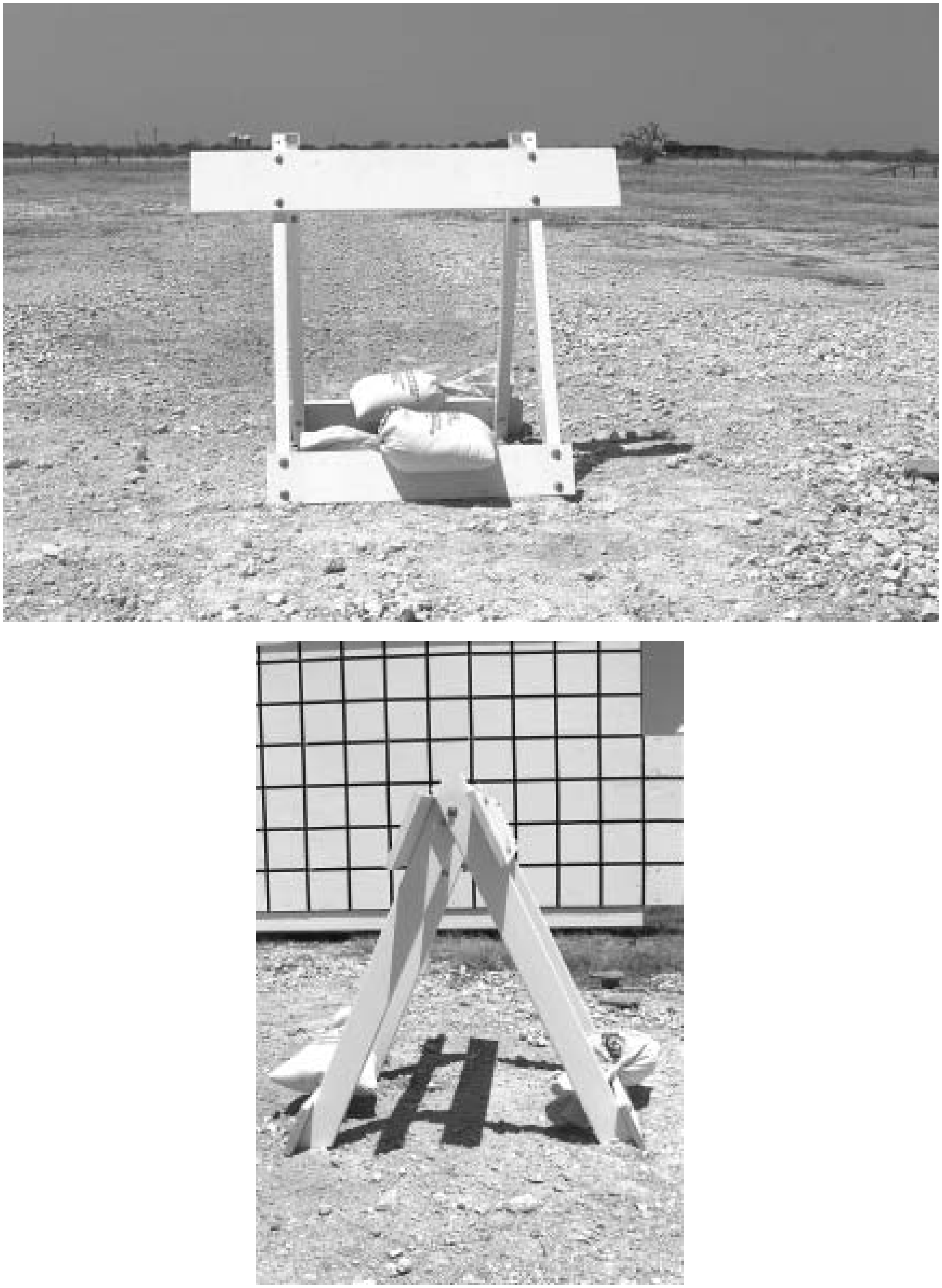


Figure 48. Installation before Test 417928-9.

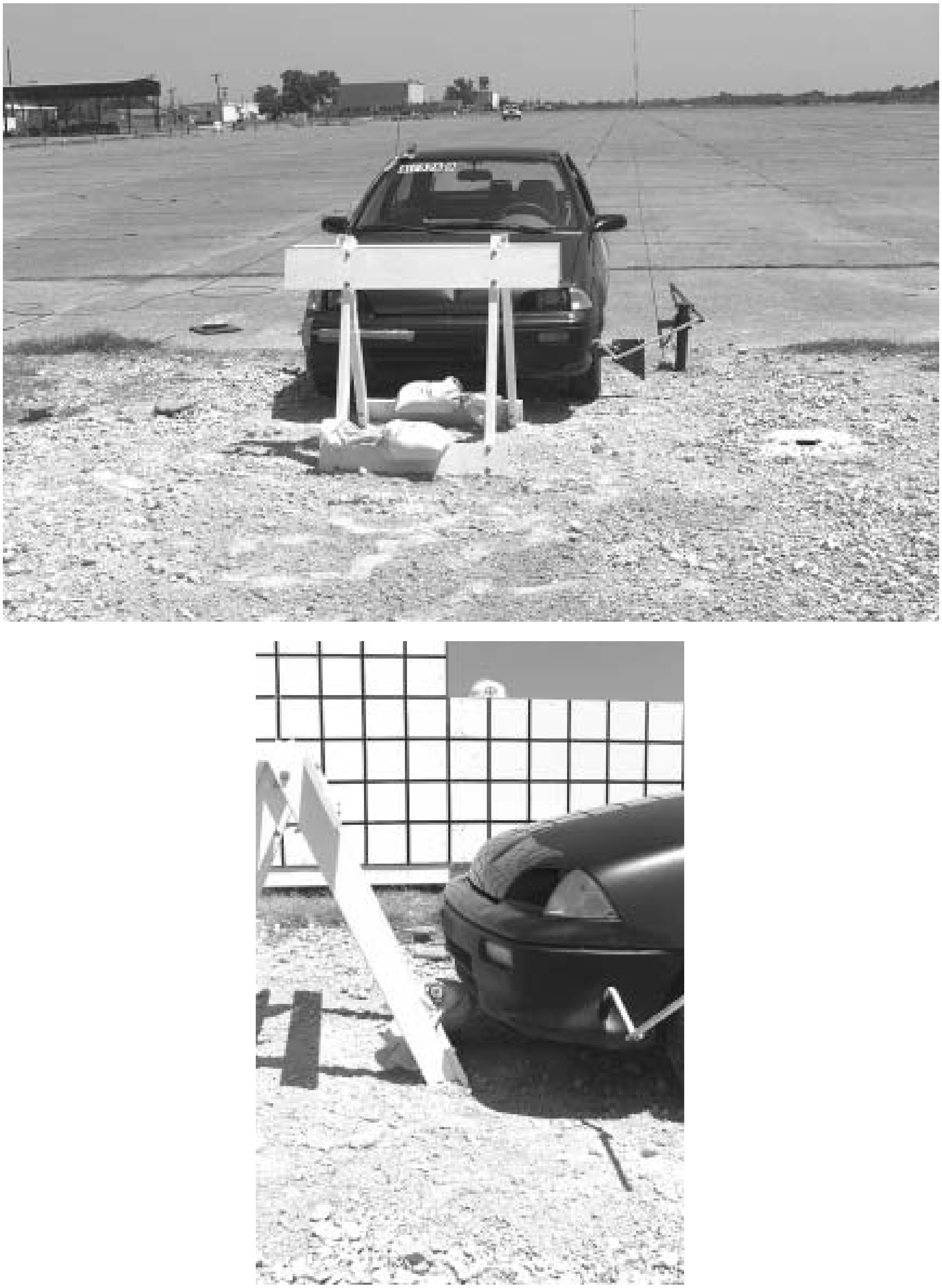


Figure 49. Vehicle/Installation Geometrics for Test 417928-9.

Figure 50. Vehicle before Test 417928-9.

ground. The vehicle was traveling at 94.0 km/h (58.4 mi/h) with the barricade still in contact with the vehicle as it exited the test site at 0.154 s. Brakes on the vehicle were applied as it exited the test site, and the vehicle came to rest 93.9 m (308.1 ft) down from impact. Sequential photographs of the test can be found in Appendix C, Figure 229.

Damage to Test Installation

The folding barricade separated into multiple pieces, as shown in Figures 51 and 52. The debris extended 82.3 m (264.0 ft) down and 1.8 m (5.9 ft) to the right of the impact point.

Vehicle Damage

The vehicle rode down the 914 mm (36 inch) tall folding A-frame barricade without any windshield contact. Figure 53 shows the damage sustained. There was a dent across the hood (not measurable) and small dents in the bumper. The interior of the vehicle is shown in Figure 54.

Assessment of Test Results

Figure 55 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The Type I hollow core plastic folding A-frame barricade with wood panels met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

Figure 51. After Impact Trajectory for Test 417928-9.

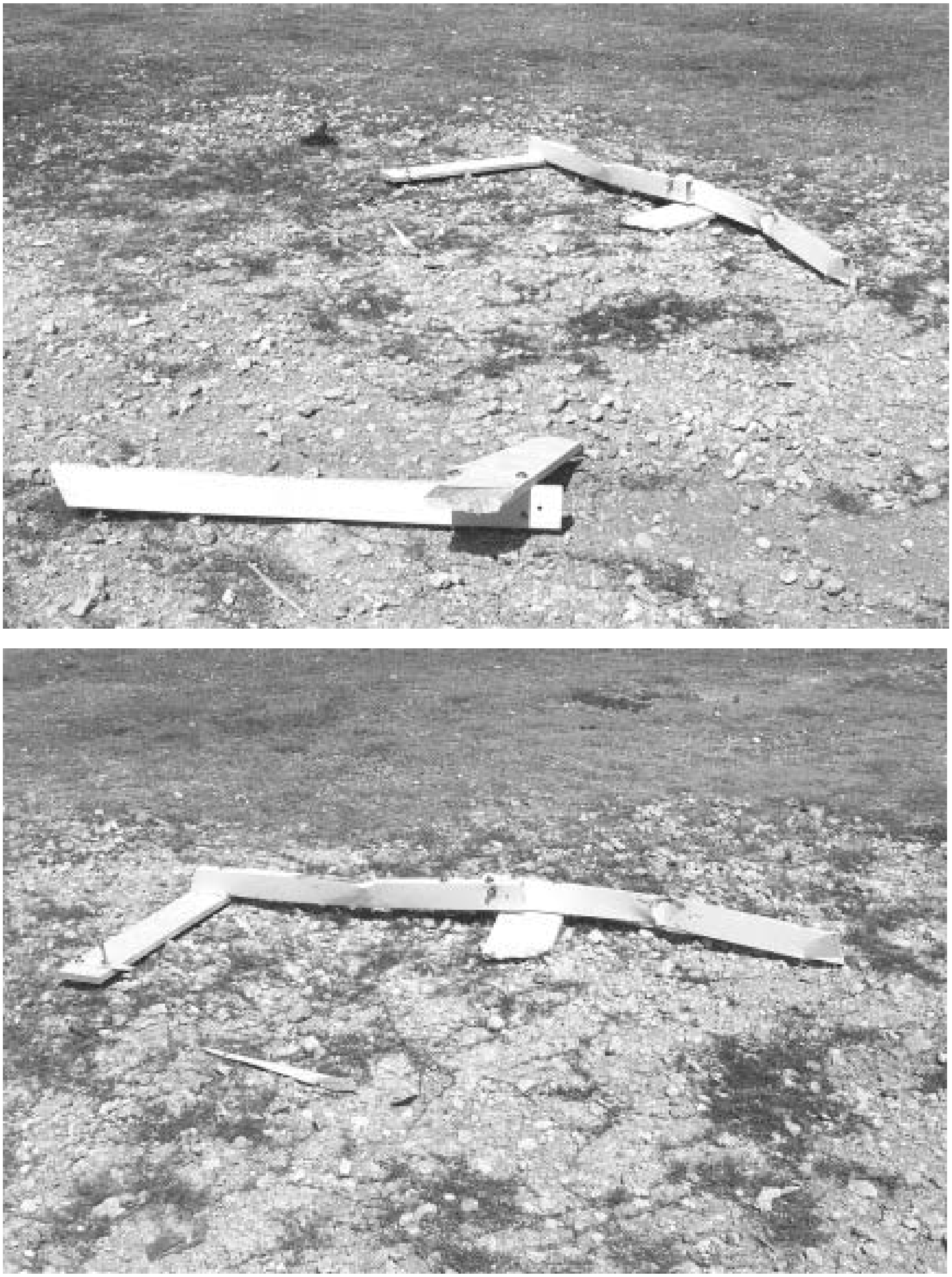


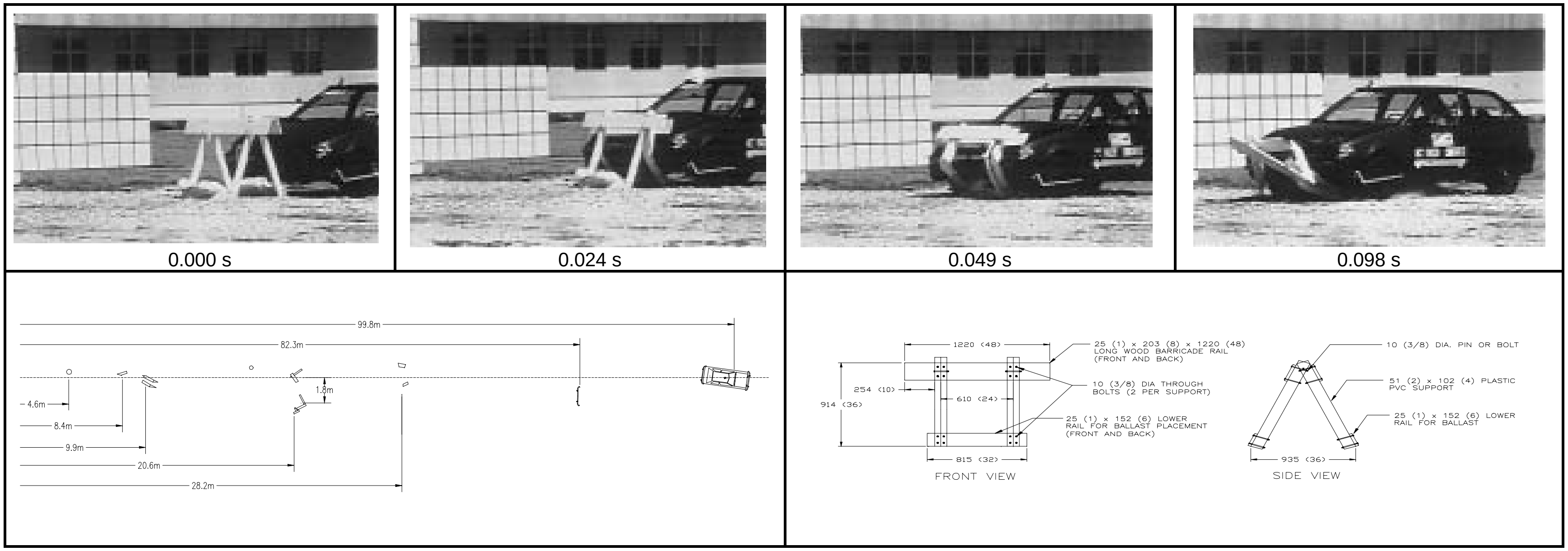
Figure 52. Installation after Test 417928-9.

Figure 53. Vehicle after Test 417928-9.

Before test

After test

Figure 54. Interior of Vehicle for Test 417928-9.



General Information
- Test Agency . . . . Texas Transportation Institute
- Test No. 417928-9
- Date 07/06/98

Test Article
- Type . . . . Traffic Control Device
- Name . . . . Type I Hollow Profile Plastic Folding A-Frame Barricade
- Installation Length (m) . . . . . . 1.2 (4.0 ft)
- Material or Key Elements . . . . Hollow Core PVC Legs with Upper Wooden Rails

Soil Type and Condition . . . . . . Standard Soil, Dry

Test Vehicle
- Type . . . . Production
- Designation 820C
- Model . . . . 1994 Geo Metro
- Mass (kg) Curb . . . . 798 (1759 lb)
  - Test Inertial . . . . . . 820 (1806 lb)
  - Dummy . . . . 76 (168 lb)
  - Gross Static . . . . . . 896 (1974 lb)

Impact Conditions
- Speed (km/h) . . . . 100.7 (62.6 mi/h)
- Angle (deg) 0

Exit Conditions
- Speed (km/h) . . . . 94.0 (58.4 mi/h)
- Angle (deg) 0

Test Article Debris Pattern (m)
- Longitudinal . . . . 82.3 (264 ft)
- Lateral . . . . 1.8 (5.9 ft)

Vehicle Damage
- Exterior
  - VDS 12FD1
  - CDC 12FDEW1
- Maximum Exterior
  - Vehicle Crush (mm) . . . . . . nil
- Interior
  - OCDI FS0000000
- Max. Occ. Compart.
  - Deformation (mm) 0

Figure 55. Summary of Results for Test 417928-9, *NCHRP Report 350* Test 3-71.

The plastic barricade did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

Vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 1.9 m/s (6.2 ft/s).

<u>Conclusion</u>

The Type I hollow profile plastic folding A-frame performed acceptably for *NCHRP Report 350* test designation 3-71.

Type I Wood Fixed A-Frame Barricade –
Test No. 417928-17 (*NCHRP Report 350* Test No. 3-71)

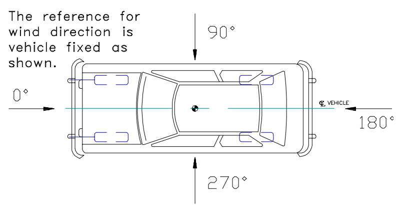
A wooden fixed A-frame barricade, shown previously in Figure 5 and in Figure 56, was evaluated in this crash test. The height to the top of the barricade was 925 mm (36.4 inch). The lower horizontal cross member was ballasted with a 7.6 kg (16.8 lb) sandbag.

Test Vehicle

A 1993 Geo Metro, shown in Figures 57 and 58, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 380 mm (15.0 inch), and it was 525 mm (20.7 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 218. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the morning of July 23, 1998. A total of 20 mm (0.8 inch) of rain was recorded nine days prior to the test but would not affect the test as the barricade was installed on the ground surface. No other rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 3 km/h (2 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 35 °C (95 °F); relative humidity: 58 percent.



Test Description

The vehicle impacted the barricade head-on at a speed of 100.0 km/h (62.1 mi/h). At 0.011 s, the barricade moved; at 0.222 s, the vehicle exited the test site with the barricade. After exiting the test site, the barricade separated into several pieces. Brakes on the vehicle were applied as the vehicle exited the test site, and the vehicle came to rest 96.8 m (317.6 ft) down from impact, with the test article scattered along its path. Sequential photographs of the test can be found in Appendix C, Figure 230.

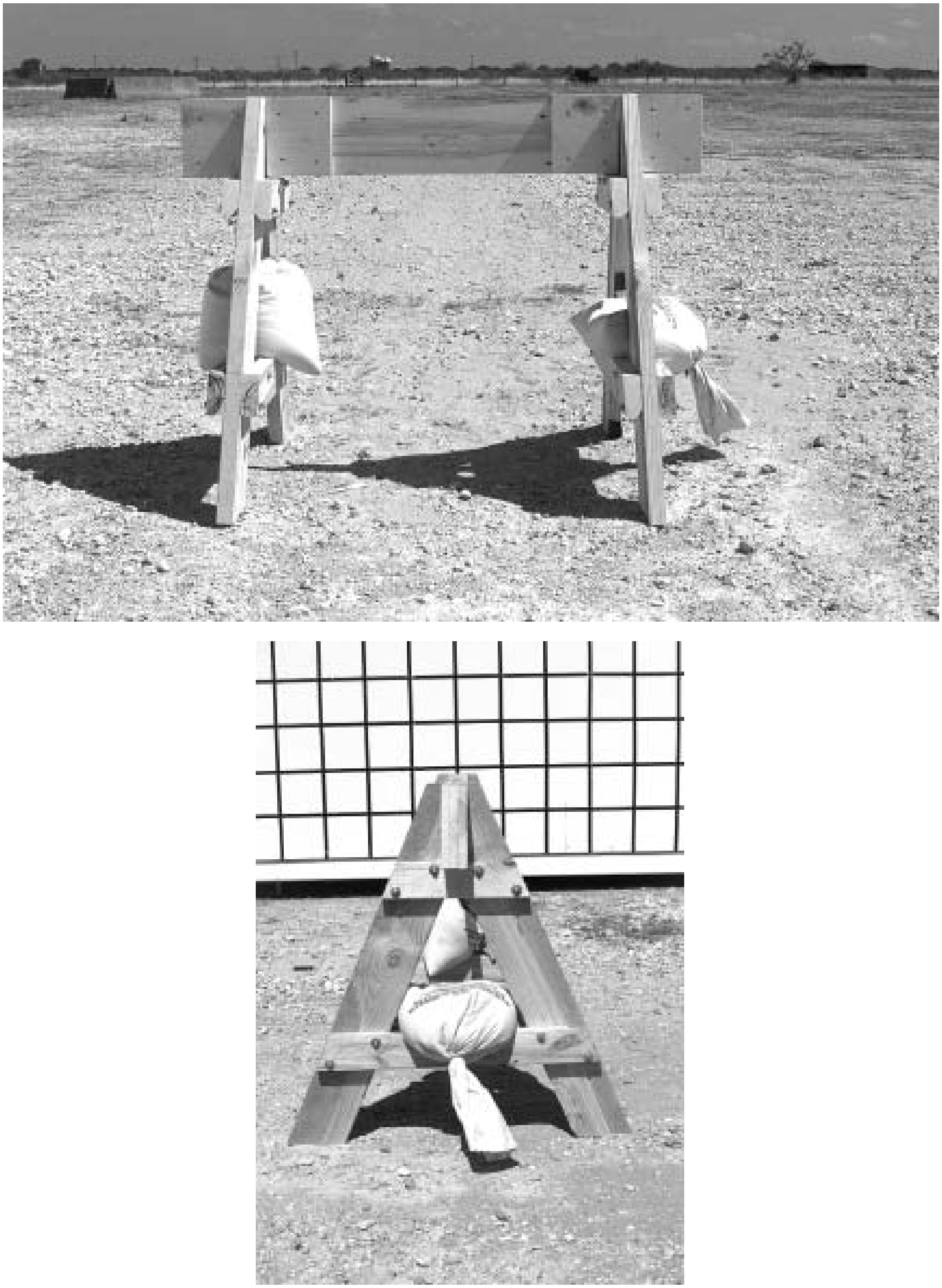


Figure 56. Installation before Test 417928-17.

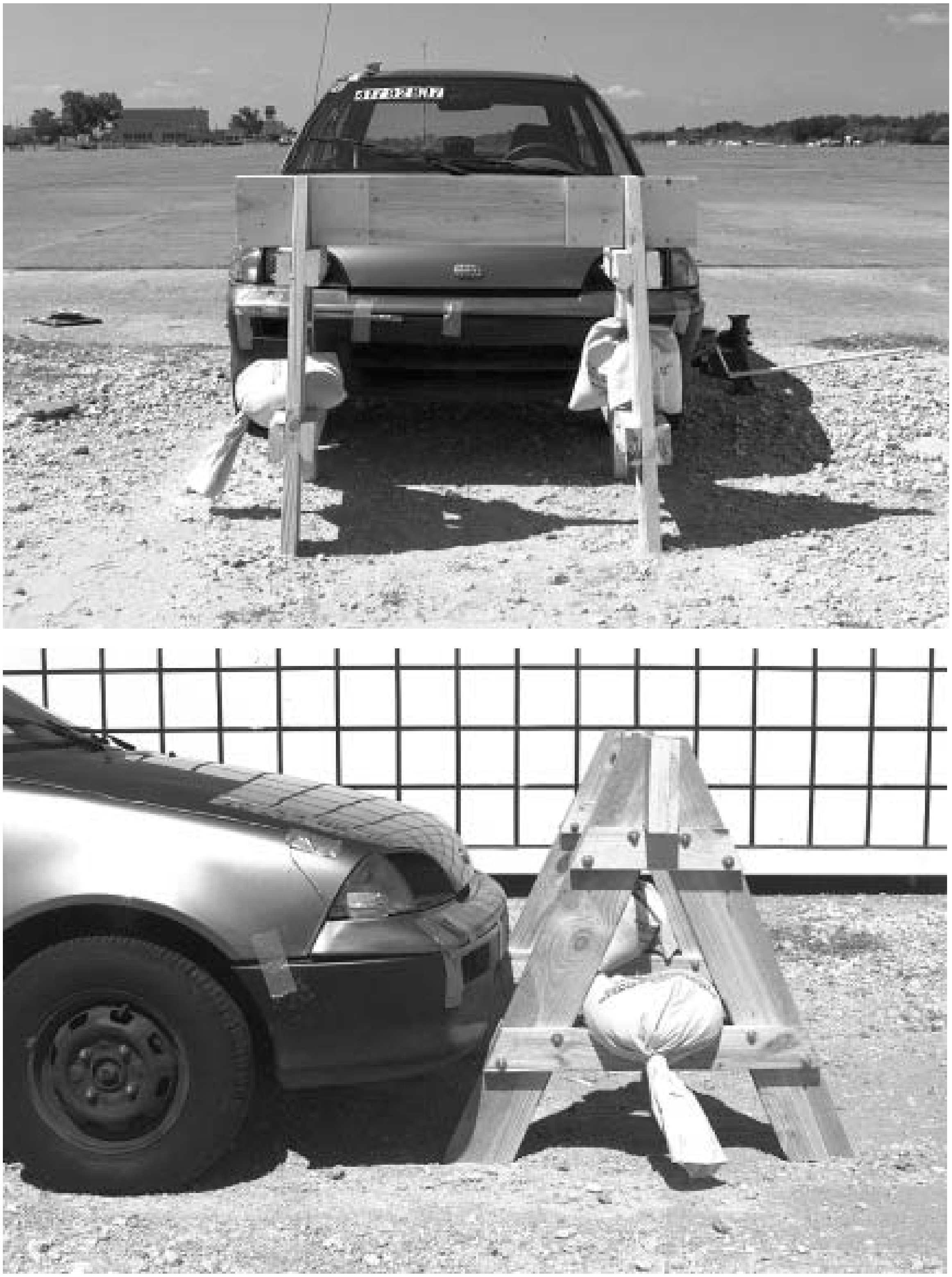


Figure 57. Vehicle/Installation Geometrics for Test 417928-17.

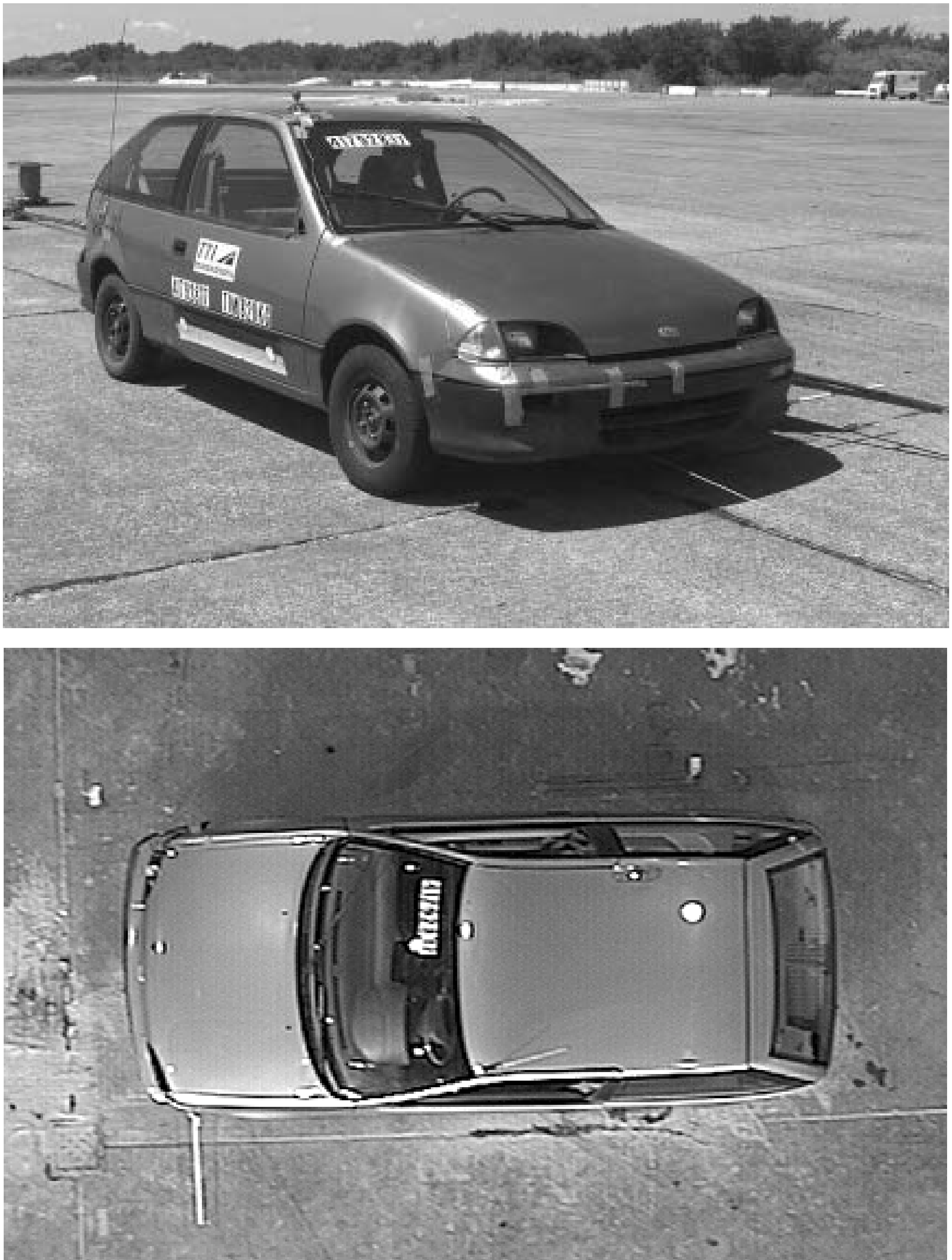


Figure 58. Vehicle before Test 417928-17.

Damage to Test Installation

The A-frame barricade separated into a few pieces, as shown in Figures 59 and 60. The debris extended 61.7 m (202.4 ft) down, 4.6 m (15.1 ft) to the right, and 4.0 m (13.1 ft) to the left of the impact point.

Vehicle Damage

There was no windshield contact during the test. The front bumper and radiator supports received minimal damage, as shown in Figure 61. Figure 62 shows the interior of the vehicle.

Assessment of Test Results

Figure 63 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The wooden fixed A-frame barricade met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

  The barricade traveled with the vehicle but did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred.

Figure 59. After Impact Trajectory for Test 417928-17.

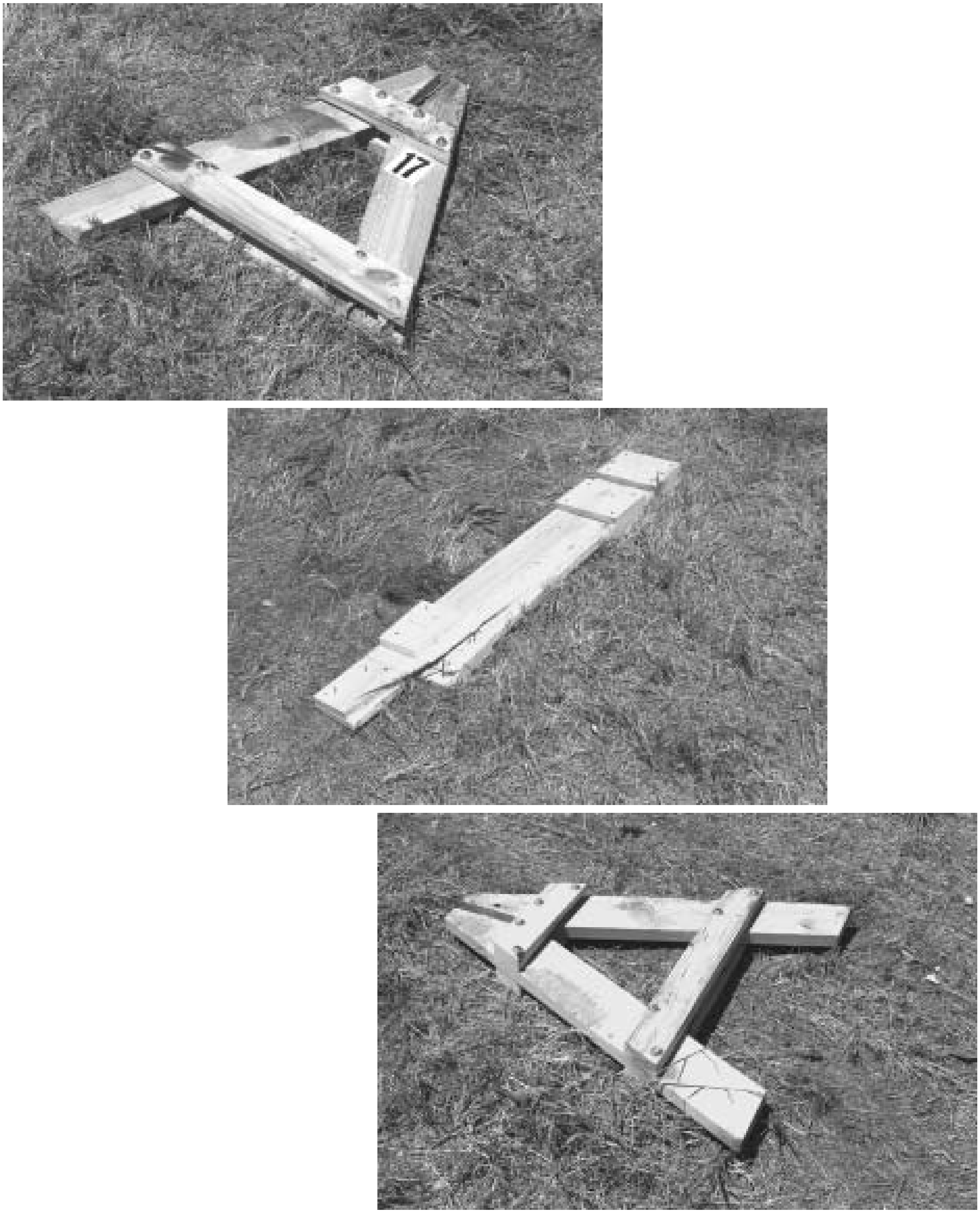


Figure 60. Installation after Test 417928-17.

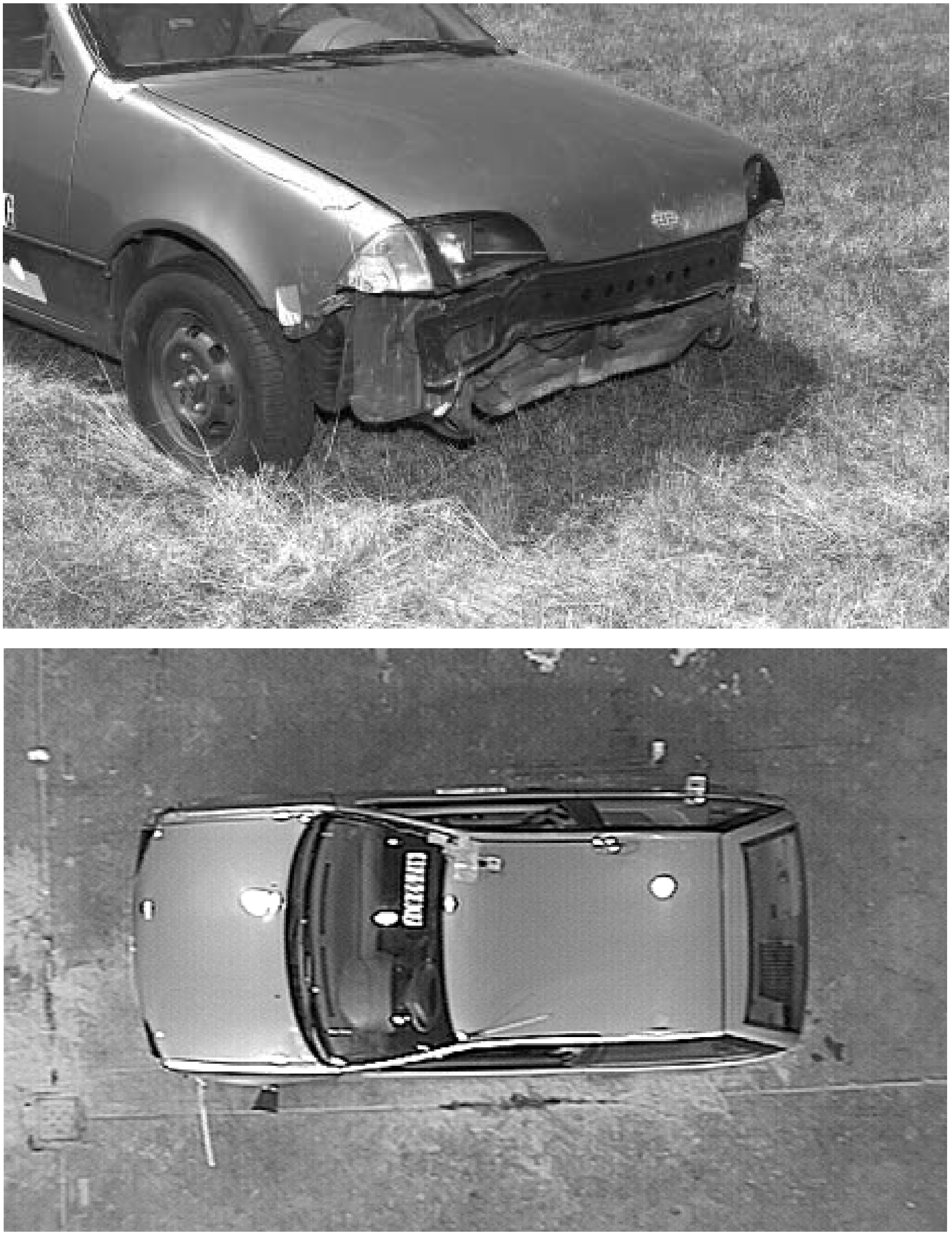
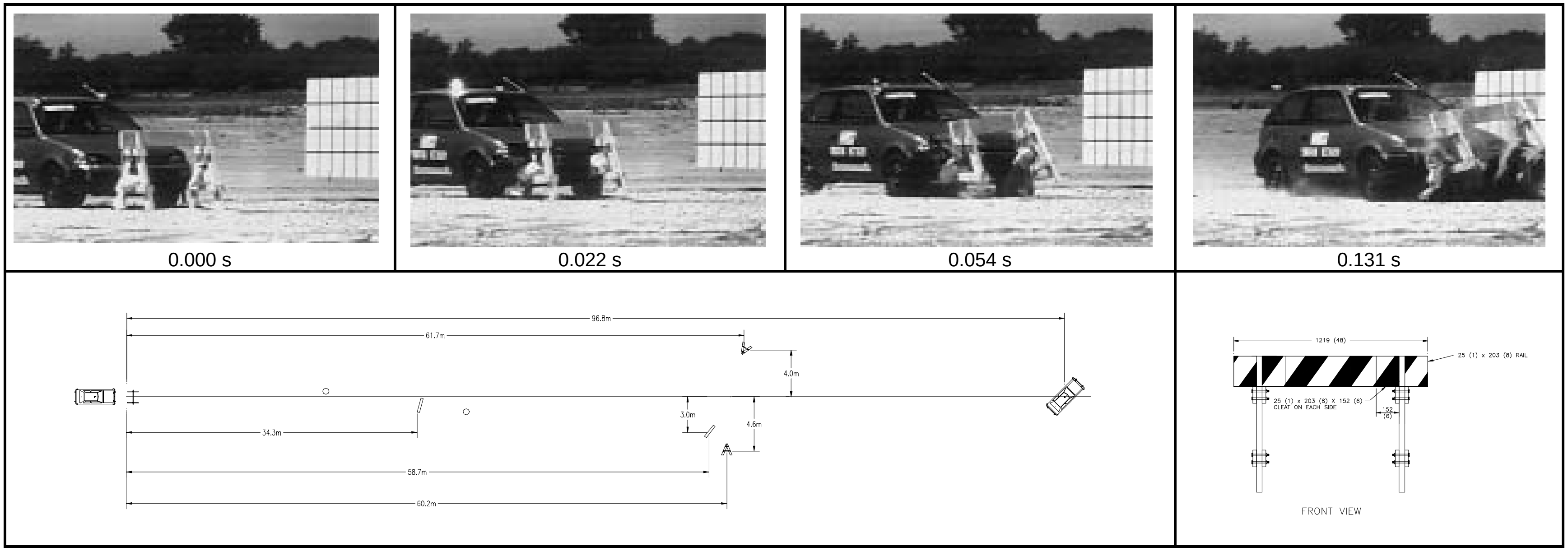


Figure 61. Vehicle after Test 417928-17.

Before test

After test

Figure 62. Interior of Vehicle for Test 417928-17.



General Information

Test Agency	Texas Transportation Institute
Test No.	417928-17
Date	07/23/98

Test Article

Type	Traffic Control Device
Name	Type I Wood Fixed A-Frame Barricade
Installation Length (m)	1.2 (4.0 ft)
Material or Key Elements	All Wooden A-Frame Barricade

Soil Type and Condition ...... Standard Soil, Dry

Test Vehicle

Type	Production
Designation	820C
Model	1993 Geo Metro
Mass (kg) Curb	753 (1660 lb)
Test Inertial	820 (1806 lb)
Dummy	76 (168 lb)
Gross Static	896 (1974 lb)

Impact Conditions

Speed (km/h)	100.0 (62.1 mi/h)
Angle (deg)	0

Exit Conditions

Speed (km/h)	N/A
Angle (deg)	0

Test Article Debris Pattern (m)

Longitudinal	61.7 (202.4 ft)
Lateral	4.6 (15.1 ft)

Vehicle Damage

Exterior	
VDS	12FD1
CDC	12FDEW1
Maximum Exterior Vehicle Crush (mm)	nil
Interior	
OCDI	FS0000000
Max. Occ. Compart. Deformation (mm)	0

Figure 63. Summary of Results for Test 417928-17, *NCHRP Report 350* Test 3-71.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 0.6 m/s (2.0 ft/s).

<u>Conclusion</u>

The Type I wood fixed A-frame barricade met the specifications for *NCHRP Report 350* test designation 3-71.

TYPE III BARRICADES

Type III Barricade with FRP Supports in Dual-Purpose Base – Test No. 417928-2 (*NCHRP Report 350* Test No. 3-71)

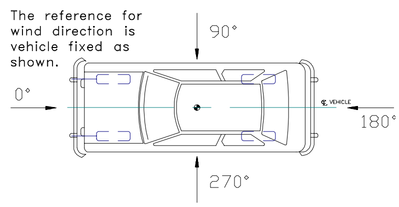
A Type III barricade with plastic panels and FRP sign supports in a dual-purpose base, shown previously in Figure 6 and in Figure 64, was evaluated in this crash test. The height to the top of the barricade was 1.5 m (5.0 ft). The base of the barricade was ballasted with eight 7.6 kg (16.8 lb) sandbags.

Test Vehicle

A 1993 Geo Metro, shown in Figures 65 and 66, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 395 mm (15.6 inch), and it was 525 mm (20.7 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 217. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the morning of June 23, 1998. No rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 2 km/h (1 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 32 °C (90 °F); relative humidity: 62 percent.



Test Description

The vehicle impacted the barricade head-on at a speed of 101.4 km/h (63.0 mi/h). At 0.019 s, the bumper of the vehicle contacted the barricade, and at 0.022 s, the barricade posts moved. By 0.027 s, the barricade deformed around the front bumper of the vehicle, and by 0.032 s, the sign posts pulled out of the dual-purpose base. The sign posts separated completely from the dual-purpose base at 0.040 s. At 0.051 s, the center panel on the barricade contacted the center of the vehicle’s hood, and at 0.071 s, the top of the barricade contacted the bottom of the

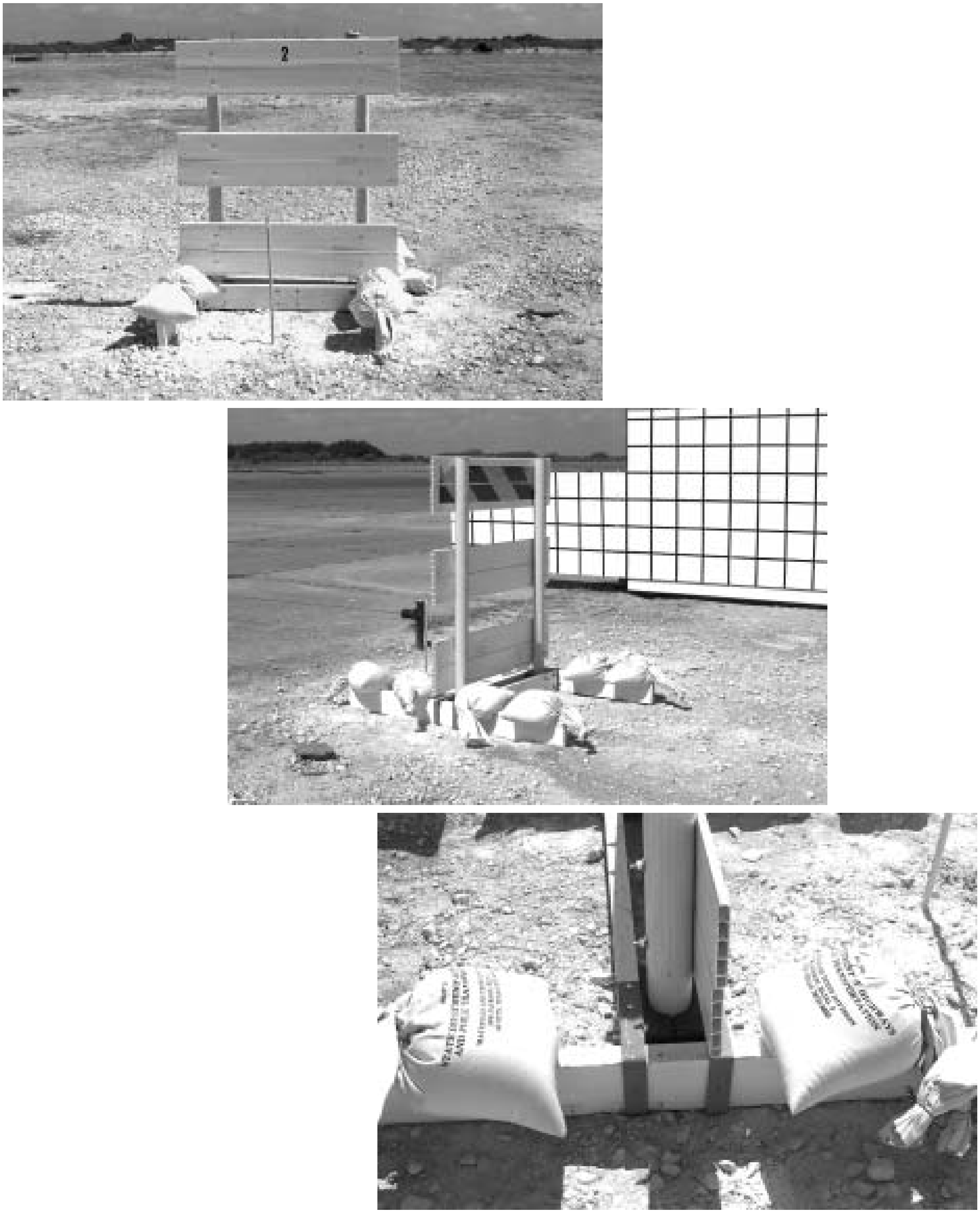


Figure 64. Installation before Test 417928-2.

Figure 65. Vehicle/Installation Geometrics for Test 417928-2.

Figure 66. Vehicle before Test 417928-2.

windshield near the wiper blades and moved upward on the windshield before loss of contact. The upper panel and posts bounced off the vehicle at 0.141 s. At 0.280 s, the vehicle was traveling at 86.3 km/h (53.6 mi/h) while the pieces were still in contact with the vehicle as it exited the test site. Brakes on the vehicle were applied as it exited the test site, and the vehicle came to rest 100.0 m (328.1 ft) downstream and 0.9 m (3.0 ft) to the right of the impact point. Sequential photographs of the test can be found in Appendix C, Figure 231.

Damage to Test Installation

The upper supports and the base of the barricade shattered into multiple pieces, as shown in Figures 67 and 68. The debris extended 93.6 m (307.1 ft) down, 1.5 m (5.0 ft) to the left, and 7.6 m (25.0 ft) to the right of the impact point.

Vehicle Damage

Damage sustained by the front of the vehicle is shown in Figure 69. The vehicle received minor scrapes to the hood, the windshield, and the left rear wheel rim. The interior of the vehicle is shown in Figure 70.

Assessment of Test Results

Figure 71 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  TheFRP sign support pulled out of the dual-purpose base and thereby met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

Figure 67. After Impact Trajectory for Test 417928-2.

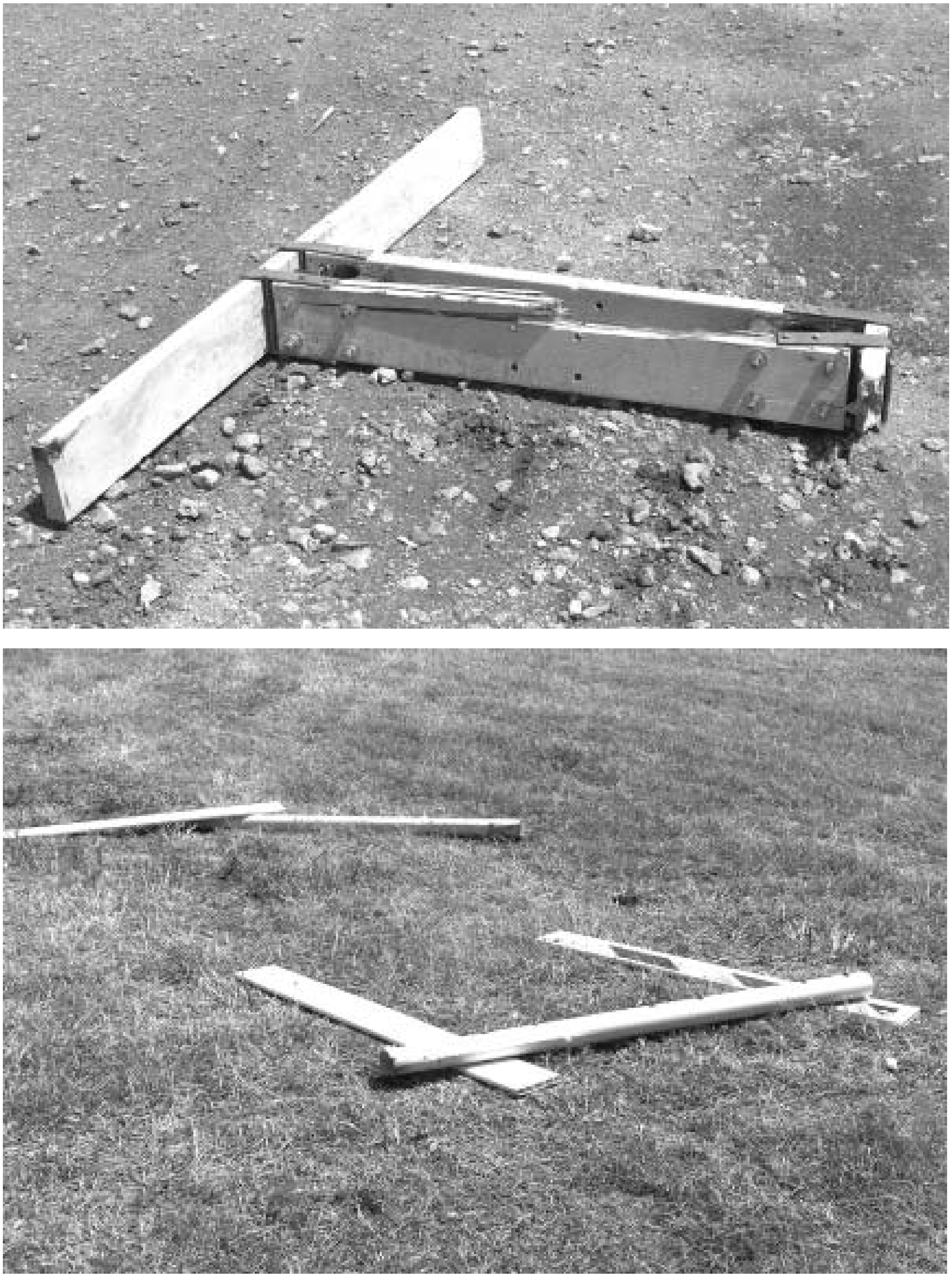


Figure 68. Installation after Test 417928-2.

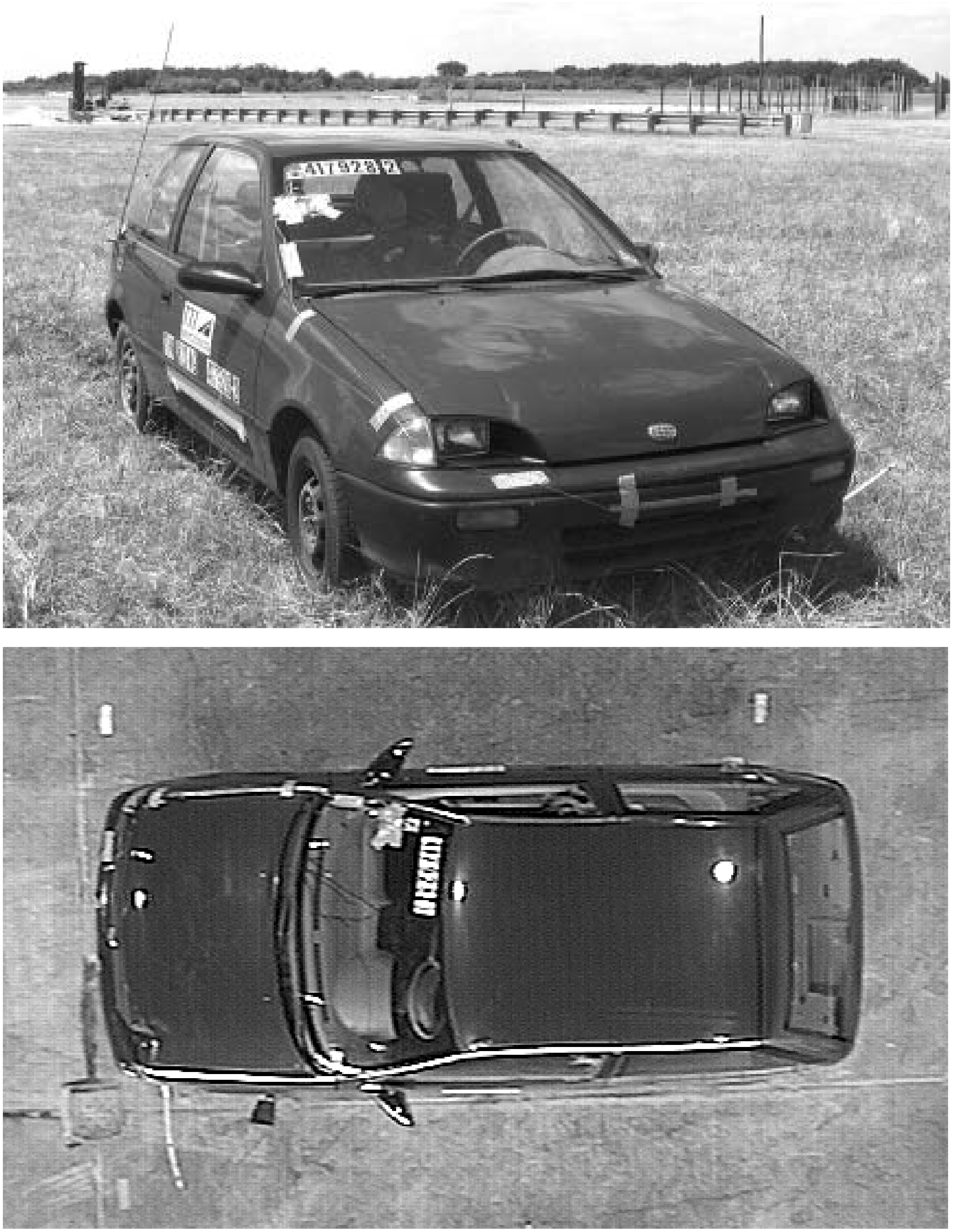


Figure 69. Vehicle after Test 417928-2.

Before test

After test

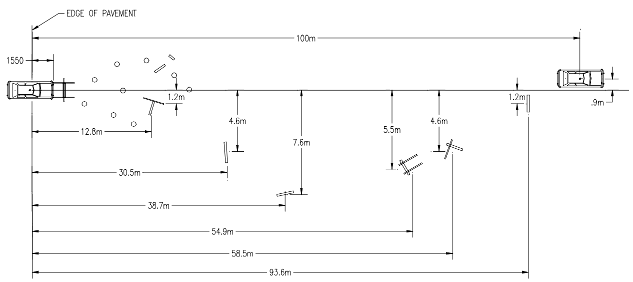
Figure 70. Interior of Vehicle for Test 417928-2.

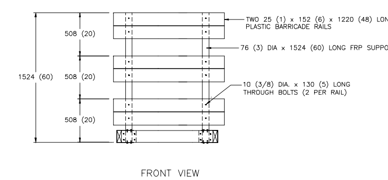
0.000 s

0.049 s

0.097 s

0.219 s





General Information
- Test Agency . . . . Texas Transportation Institute
- Test No. 417928-2
- Date 06/23/98

Test Article
- Type . . . . Traffic Control Device
- Name . . . . Type III Barricade with FRP Supports in Dual-Purpose Base
- Installation Length (m) . . . . . . 1.1 (3.6 ft)
- Material or Key Elements . . . . Plastic Panels, Single FRP Post in Dual Purpose Base

Soil Type and Condition . . . . . . Standard Soil, Dry

Test Vehicle
- Type . . . . Production
- Designation 820C
- Model . . . . 1993 Geo Metro
- Mass (kg) Curb . . . . 779 (1717 lb)
  - Test Inertial . . . . . . 820 (1806 lb)
  - Dummy . . . . 76 (168 lb)
  - Gross Static . . . . . . 896 (1974 lb)

Impact Conditions
- Speed (km/h) . . . . 101.4 (63.0 mi/h)
- Angle (deg) 0

Exit Conditions
- Speed (km/h) . . . . 86.3 (53.6 mi/h)
- Angle (deg) 0

Test Article Debris Pattern (m)
- Longitudinal . . . . 93.6 (307.1 ft)
- Lateral . . . . 7.6 (25.0 ft)

Vehicle Damage
- Exterior
  - VDS 12FD1
  - CDC 12FDEW1
- Maximum Exterior
  - Vehicle Crush (mm) . . . . . . nil
- Interior
  - OCDI FS0000000
- Max. Occ. Compart.
  - Deformation (mm) 0

Figure 71. Summary of Results for Test 417928-2, *NCHRP Report 350* Test 3-71.

The top of the barricade cracked the windshield at the edge near the hood, but it did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 4.2 m/s (13.8 ft/s).

Conclusion

The Type III Barricade with FRP supports in dual-purpose base met the specifications for *NCHRP Report 350* test designation 3-71.

Type III Perforated Steel Tube Barricade –
Test No. 417928-14 (*NCHRP Report 350* Test No. 3-71)

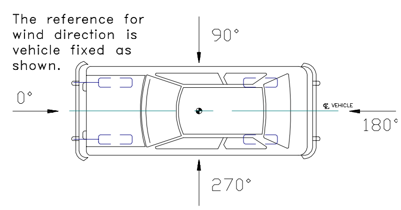
A Type III steel perforated tube barricade with plastic panels, shown previously in Figure 7 and in Figure 72, was evaluated in this crash test. The height to the top of the barricade was 1.5 m (5.0 ft). The base of the barricade was ballasted with eight 7.6 kg (16.8 lb) sandbags.

Test Vehicle

A 1993 Geo Metro, shown in Figures 73 and 74, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 380 mm (15.0 inch), and it was 525 mm (20.7 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 218. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the morning of July 10, 1998. A total of 26 mm (1.0 inch) of rain was recorded 10 days prior to the test but would not affect the test as the barricade was installed on the ground surface. No other rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 5 km/h (3 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 34 °C (93 °F); relative humidity: 58 percent.



Test Description

The vehicle impacted the barricade head-on at a speed of 97.8 km/h (60.8 mi/h). At 0.012 s, the bottom of the bumper contacted the sandbags, and at 0.029 s, the bumper of the vehicle contacted the lower barricade panel. By 0.039 s, the barricade moved and the steel base began to travel with the vehicle. By 0.044 s, the lower panel at the right side of the steel frame sheared away at the bolts, and by 0.052 s, the lower panel completely separated from the right side of the frame. The center panel contacted the vehicle at the lower portion of the windshield and the upper part of the hood of the vehicle, and the center panel traveled up the windshield.

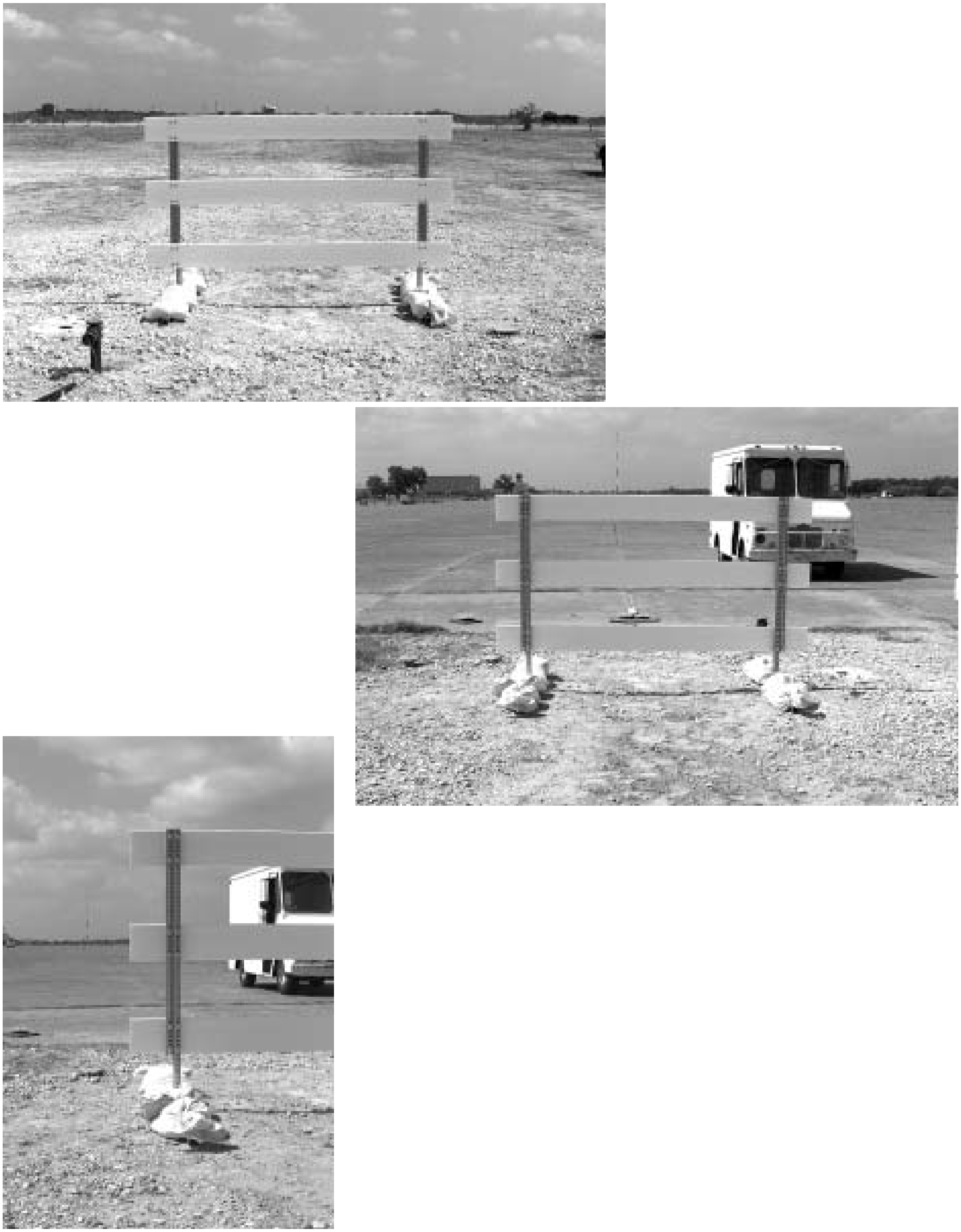


Figure 72. Installation before Test 417928-14.

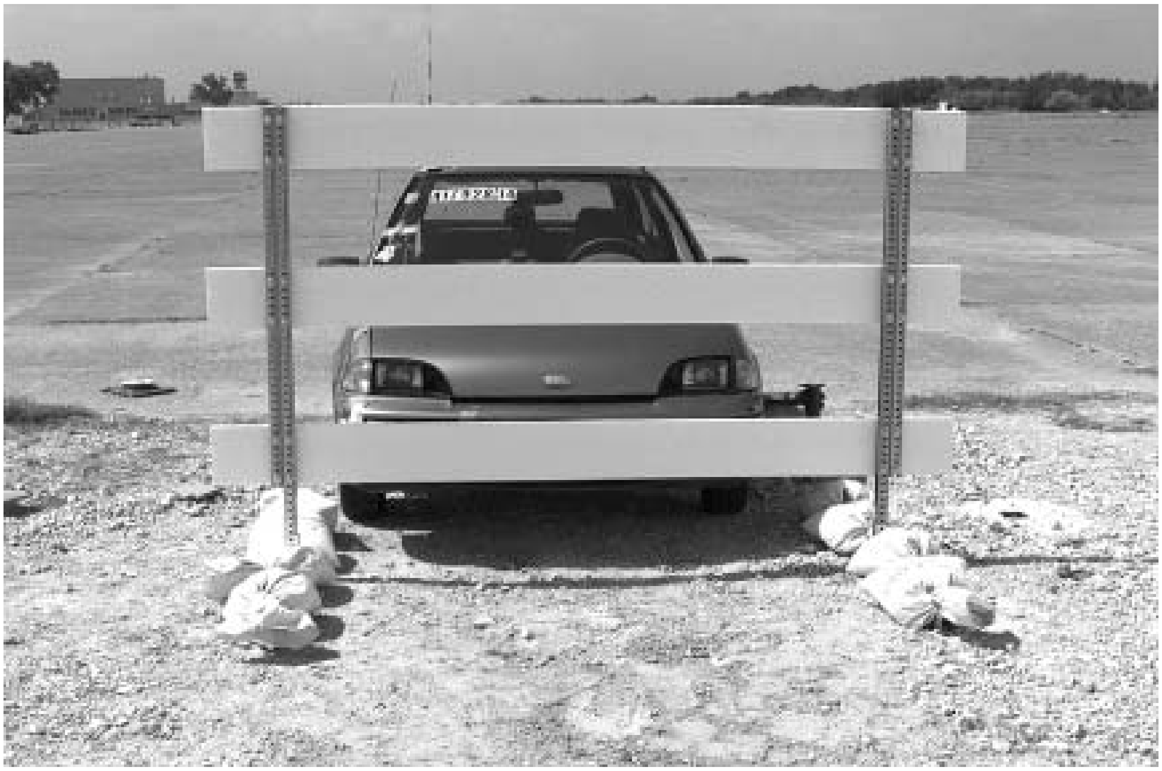


Figure 73. Vehicle/Installation Geometrics for Test 417928-14.

Figure 74. Vehicle before Test 417928-14.

The barricade lost contact with the ground surface at 0.085 s. At 0.086 s, the windshield shattered in the lower corners, and at 0.276 s, the vehicle lost contact with the center barricade panel. At 0.346 s, the vehicle was traveling at 94.2 km/h (58.5 mi/h) as the barricade lost contact with the vehicle. Brakes on the vehicle were applied as the vehicle exited the test site, and the vehicle came to rest 102.9 m (337.6 ft) down and 4.6 m (15.1 ft) to the left of the impact point. Sequential photographs of the test can be found in Appendix C, Figure 232.

Damage to Test Installation

The barricade remained in one piece, as shown in Figures 75 and 76. The debris extended 20.6 m (67.6 ft) down, and 3.0 m (9.8 ft) to the left of the impact point.

Vehicle Damage

The vehicle received damage to the front, as shown in Figure 77. The vehicle received minor scrapes to the roof and a dent in the front bumper. The left rear tire was deflated, and the windshield was shattered on the passenger's side. A dent on the right lower front fender was measured at 120 mm × 30 mm (4.7 inch ×1.2 inch). The interior of the vehicle is shown in Figure 78.

Assessment of Test Results

Figure 79 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The Type III steel perforated tube barricade with plastic panels met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

Figure 75. After Impact Trajectory for Test 417928-14.

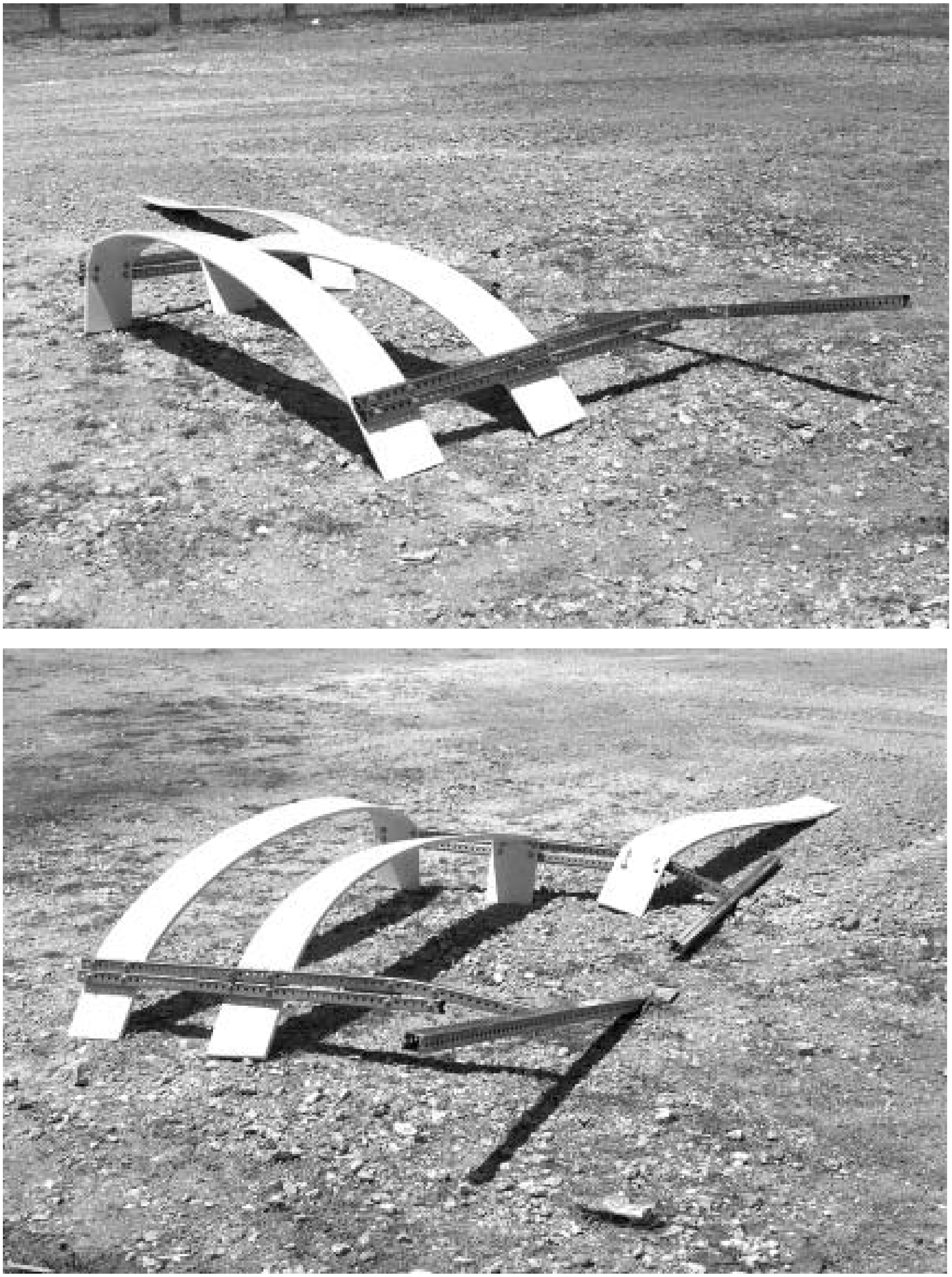


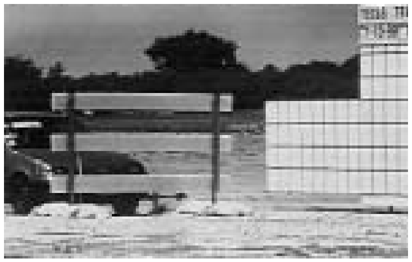
Figure 76. Installation after Test 417928-14.

Figure 77. Vehicle after Test 417928-14.

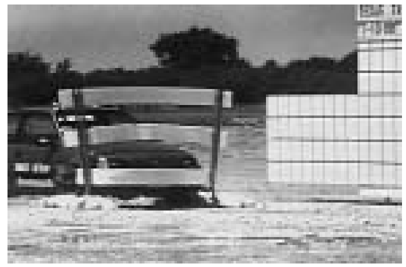
Before test

After test

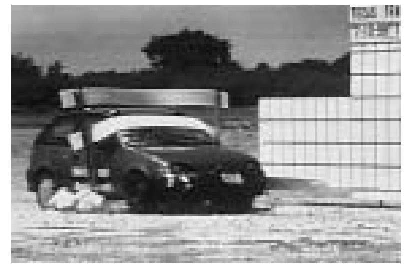
Figure 78. Interior of Vehicle for Test 417928-14.



0.000 s

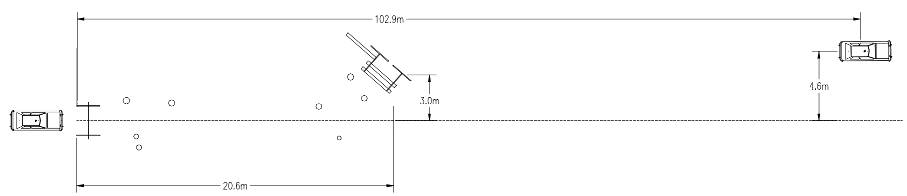


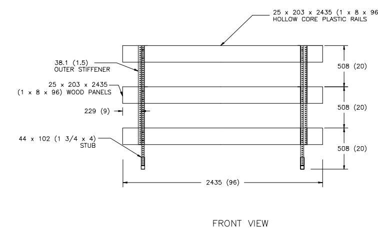
0.044 s



0.110 s

0.195 s





General Information

Test Agency	Texas Transportation Institute
Test No.	417928-14
Date	07/10/98

Test Article

Type	Traffic Control Device
Name	Type III Perforated Steel Tube Barricade
Installation Length (m)	2.4 (8.0 ft)
Material or Key Elements	Steel Perforated Tube Supports w/ Hollow Core Plastic Rails

Soil Type and Condition . . . . . . Standard Soil, Dry

Test Vehicle

Type		Production
Designation		820C
Model		1993 Geo Metro
Mass (kg)	Curb	753 (1660 lb)
	Test Inertial	820 (1806 lb)
	Dummy	76 (168 lb)
	Gross Static	896 (1974 lb)

Impact Conditions

Speed (km/h)	97.8 (60.8 mi/h)
Angle (deg)	0

Exit Conditions

Speed (km/h)	94.2 (58.5 mi/h)
Angle (deg)	0

Test Article Debris Pattern (m)

Longitudinal	20.6 (67.6 ft)
Lateral	3.0 (9.8 ft)

Vehicle Damage

Exterior	
VDS	12FD1
CDC	12FDEW1
Maximum Exterior Vehicle Crush (mm)	nil
Interior	
OCDI	FS0000000
Max. Occ. Compart. Deformation (mm)	0

Figure 79. Summary of Results for Test 417928-14, *NCHRP Report 350* Test 3-71.

The center plastic panel of the steel barricade shattered the bottom of the windshield, but it did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

The steel supports for the panels broke off the side mirrors from the vehicle, but none of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 1.0 m/s (3.3 ft/s).

Conclusion

The Type III perforated steel tube barricade performed acceptably for *NCHRP Report 350* test designation 3-71.

Type III Barricade with Hollow Profile Plastic Supports –
Test No. 417928-16 (*NCHRP Report 350* Test No. 3-71)

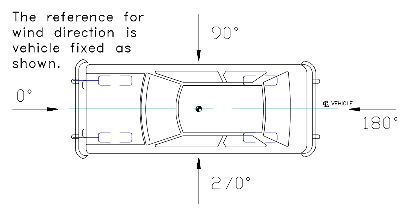
A Type III hollow core plastic support not bolted to skids, shown previously in Figure 8 and in Figure 80, was evaluated in this crash test. The height to the top of the barricade was 1.5 m (5.0 ft). The base of the barricade was ballasted with four 7.6 kg (16.8 lb) sandbags.

Test Vehicle

A 1994 Geo Metro, shown in Figures 81 and 82, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 395 mm (15.6 inch), and it was 535 mm (21.1 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 219. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the morning of July 23, 1998. A total of 20 mm (0.8 inch) of rain was recorded nine days prior to the test but would not affect the test as the barricade was installed on the ground surface. No other rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 3 km/h (2 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 35 °C (95 °F); relative humidity: 58 percent.



Test Description

The vehicle impacted the barricade head-on at a speed of 97.2 km/h (60.4 mi/h). At 0.005 s, the bumper of the vehicle contacted the sandbags, and at 0.015 s, the vehicle’s bumper contacted the barricade’s lower panel. By 0.017 s, the barricade moved, and by 0.022 s, the lower panel split. At 0.024 s, the legs pulled out of the base, and at 0.039 s, the legs were completely separated from the base. Between 0.041 s and 0.065 s, the barricade pivoted around the front of the vehicle. At 0.067 s, the upper panel of the barricade impacted the upper hood of the vehicle and cracked the windshield, and at 0.132 s, the barricade lost contact with the vehicle. At

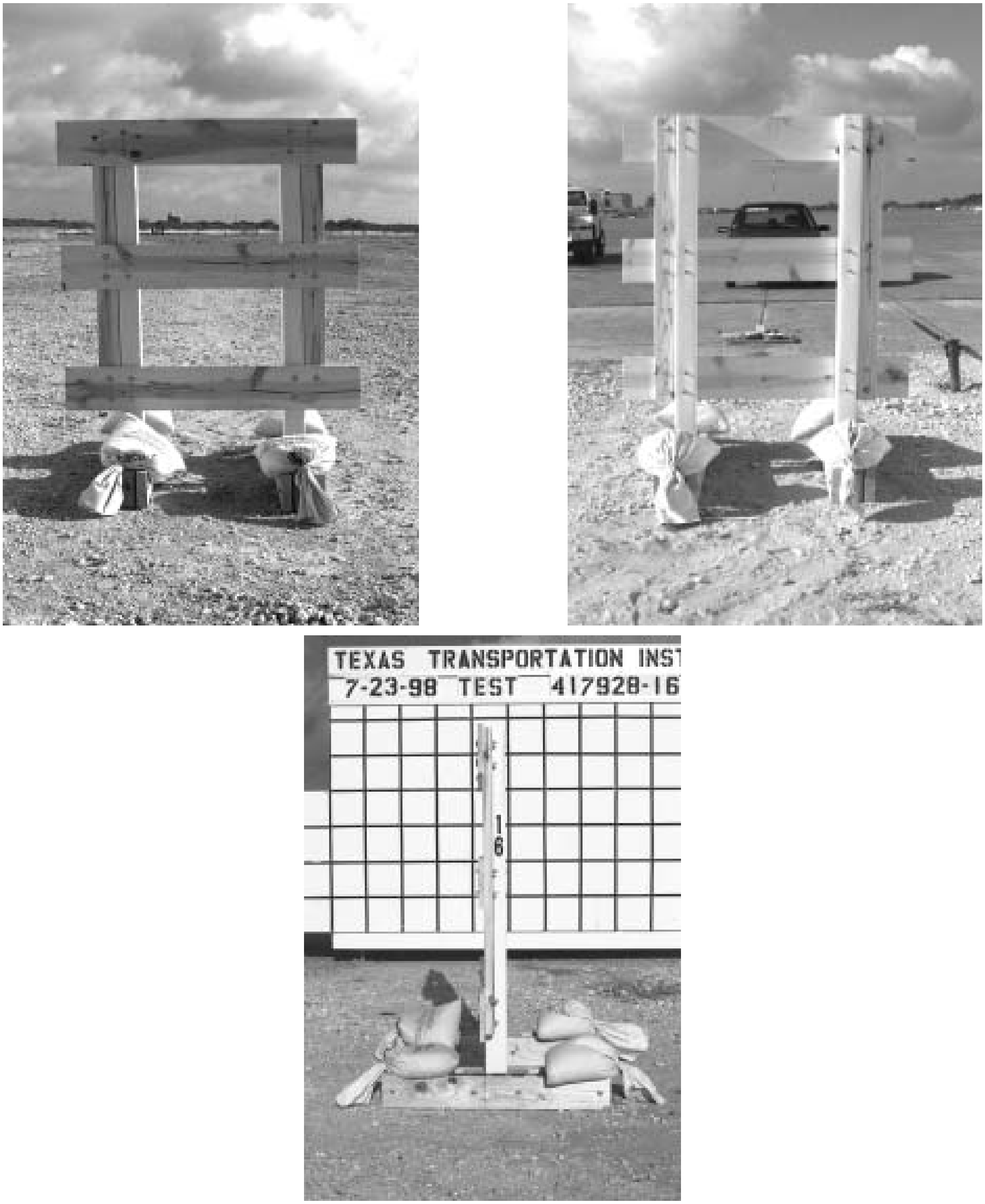


Figure 80. Installation before Test 417928-16.

Figure 81. Vehicle/Installation Geometrics for Test 417928-16.

Figure 82. Vehicle before Test 417928-16.

0.193 s, the vehicle was traveling at 92.2 km/h (57.3 mi/h) as the barricade lost contact with the vehicle. Brakes on the vehicle were applied as it exited the test site, and the vehicle came to rest 59.9 m (196.5 ft) down and 2.3 m (7.5 ft) to the left of the impact point. Sequential photographs of the test can be found in Appendix C, Figure 233.

Damage to Test Installation

The barricade remained in one piece, as shown in Figures 83 and 84. The base came to rest 1.5 m (4.9 ft) from impact while the bottom rail of the barricade was located at 44.9 m (147.3 ft). The upper portion of the barricade was located at 57.9 m (190.0 ft) downstream and 3.1 m (10.2 ft) to the left of impact.

Vehicle Damage

The vehicle received damage to the bumper, hood, and grill, as shown in Figure 85. The windshield was shattered on the passenger's side, and the radiator support was deformed. The interior of the vehicle is shown in Figure 86.

Assessment of Test Results

Figure 87 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The Type III barricade with hollow core plastic supports met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

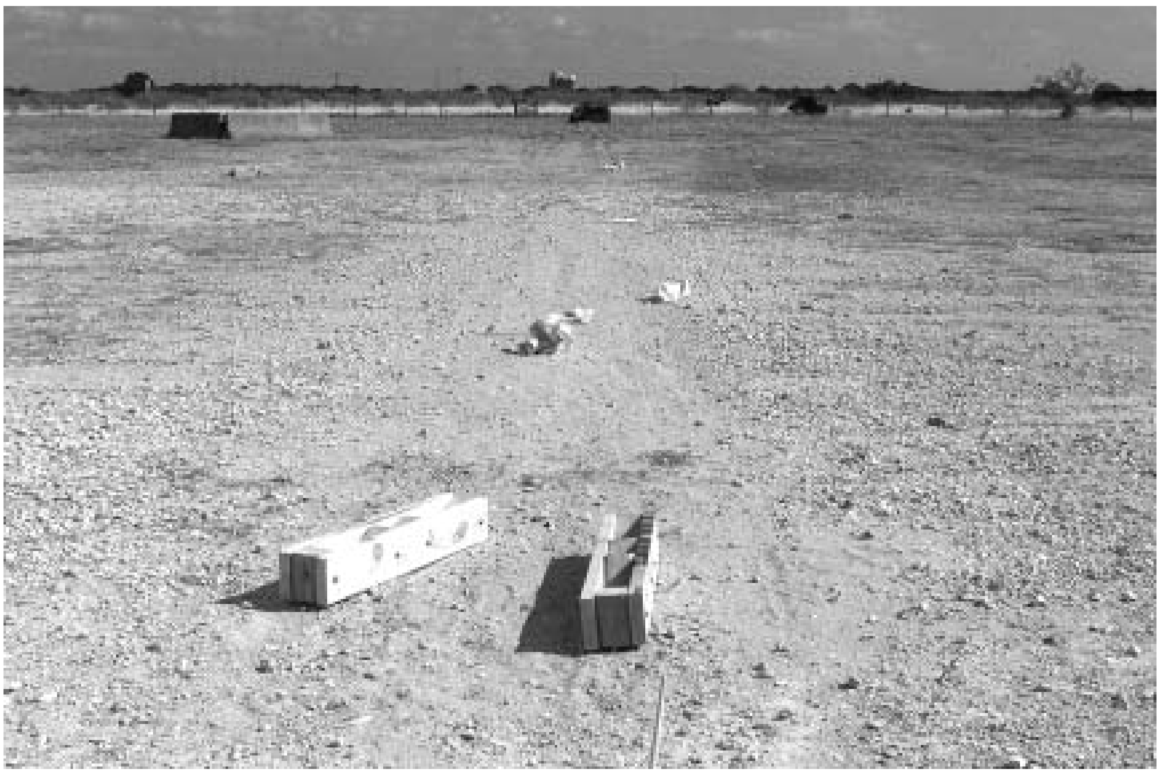


Figure 83. After Impact Trajectory for Test 417928-16.

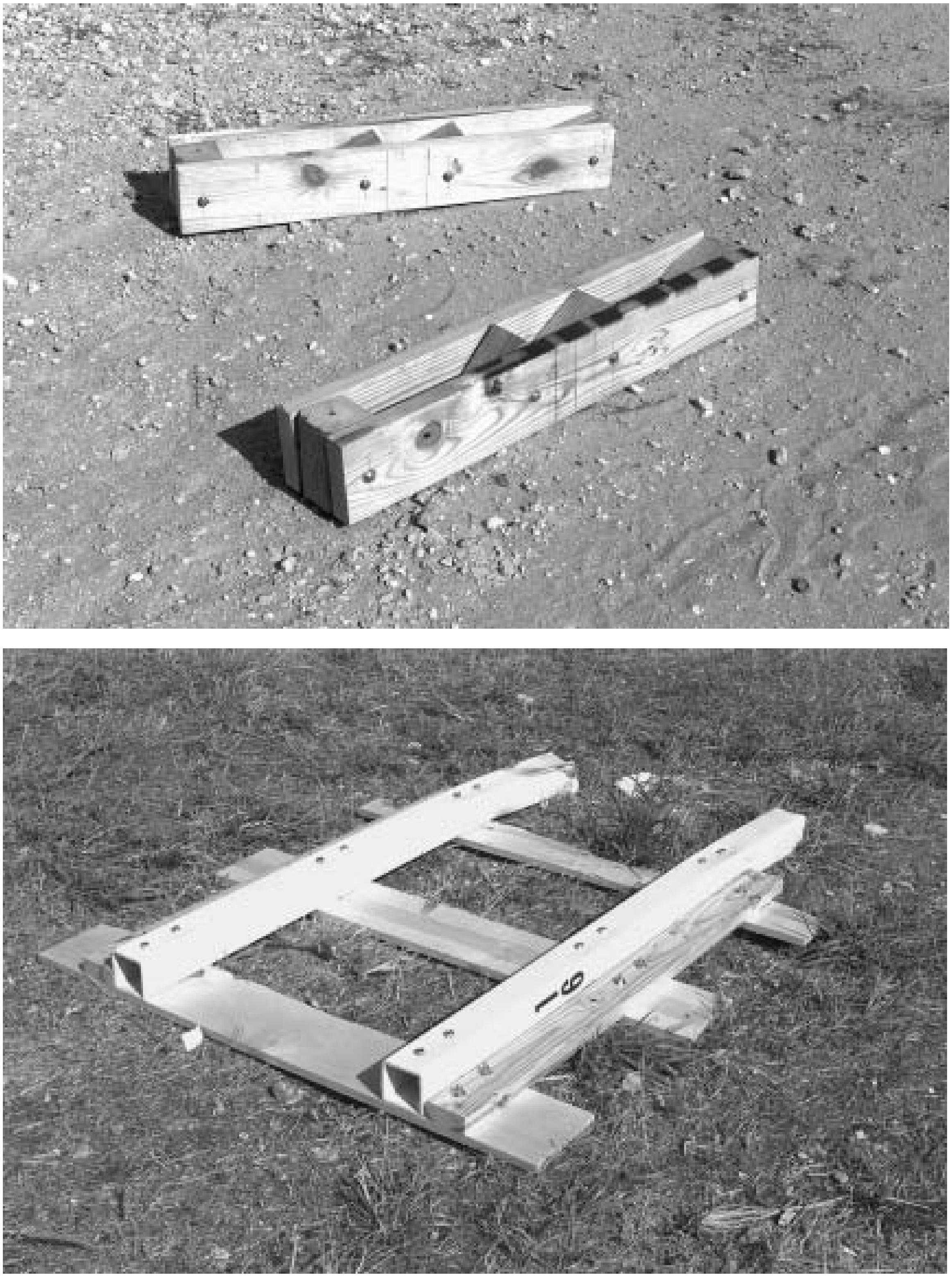


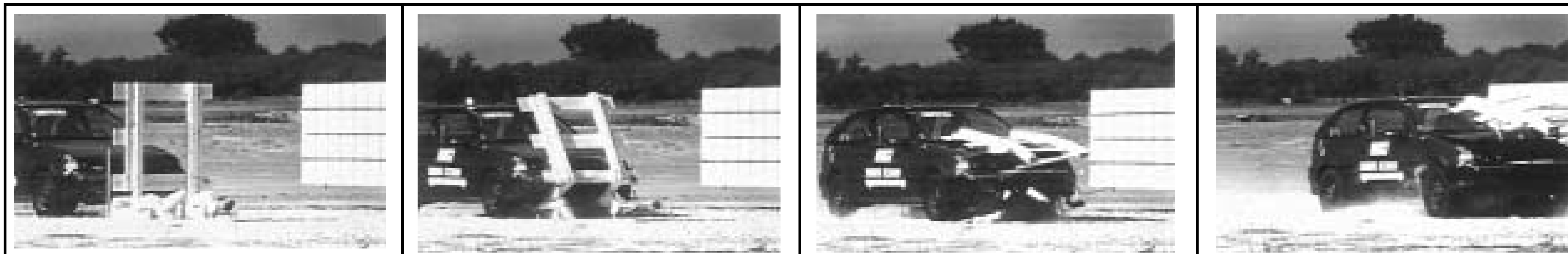
Figure 84. Installation after Test 417928-16.

Figure 85. Vehicle after Test 417928-16.

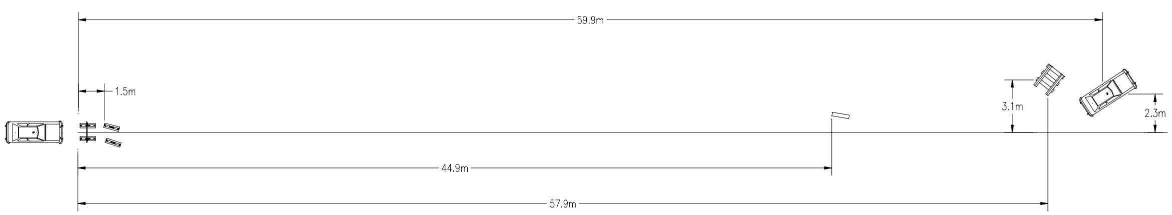
Before test

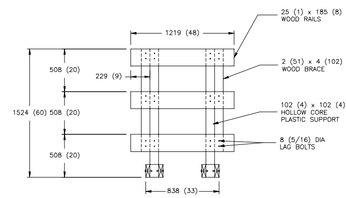
After test

Figure 86. Interior of Vehicle for Test 417928-16.



0.000 s — 0.037 s — 0.085 s — 0.171 s





FRONT VIEW

General Information

Test Agency	Texas Transportation Institute
Test No.	417928-16
Date	07/23/98

Test Article

Type	Traffic Control Device
Name	Type III Barricade w/ Hollow Profile Plastic Supports
Installation Length (m)	1.2 (4.0 ft)
Material or Key Elements	Wooden Base w/Plastic Post w/ Wood Rails and Braces

Soil Type and Condition ...... Standard Soil, Dry

Test Vehicle

Type	Production
Designation	820C
Model	1994 Geo Metro
Mass (kg) Curb	796 (1755 lb)
Test Inertial	820 (1806 lb)
Dummy	76 (168 lb)
Gross Static	896 (1974 lb)

Impact Conditions

Speed (km/h)	97.2 (60.4 mi/h)
Angle (deg)	0

Exit Conditions

Speed (km/h)	92.2 (57.3 mi/h)
Angle (deg)	0

Test Article Debris Pattern (m)

Longitudinal	57.9 (190.0 ft)
Lateral	3.1 (10.2 ft)

Vehicle Damage

Exterior	
VDS	12FR1
CDC	12FREW1
Maximum Exterior Vehicle Crush (mm)	nil
Interior	
OCDI	FS0000000
Max. Occ. Compart. Deformation (mm)	0

Figure 87. Summary of Results for Test 417928-16, *NCHRP Report 350* Test 3-71.

The barricade contacted the hood and cracked the base of the windshield, but it did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

The steel supports for the panels broke off the side mirrors from the vehicle, but none of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 1.4 m/s (4.6 ft/s).

Conclusion

The Type III Barricade with hollow profile plastic supports performed acceptably for *NCHRP Report 350* test designation 3-71.

TEMPORARY SIGN SUPPORTS: LONG/INTERMEDIATE TERM PORTABLE SIGN SUPPORTS

Single FRP Support in Dual-Purpose Base – Test No. 417928-3 (*NCHRP Report 350* Test No. 3-71)

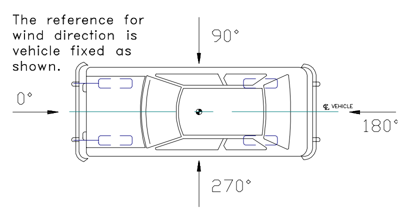
A single FRP support with a 914 mm × 914 mm×13 mm (36 inch × 36 inch × 0.5 inch) plywood sign panel mounted at 2.1 m (7 ft) above ground in a dual-purpose base, shown previously in Figure 9 and in Figure 88, was evaluated in this crash test. The base of the sign support was ballasted with eight 7.6 kg (16.8 lb) sandbags.

Test Vehicle

A 1993 Geo Metro, shown in Figures 89 and 90, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 395 mm (15.6 inch), and it was 525 mm (20.7 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 217. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the afternoon of June 23, 1998. No rainfall occurred for the10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 2 km/h (1 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 32 °C (90 °F); relative humidity: 62 percent.



Test Description

The vehicle impacted the sign support head-on at a speed of 100.1 km/h (62.2 mi/h). At 0.019 s, the sign post moved, and at 0.020 s, the post pulled out of the dual-purpose base. By 0.037 s, the post was completely separated from the base, and by 0.051 s, the sign post bounced off the bumper and lost contact with the vehicle. The sign and post were parallel to the ground at

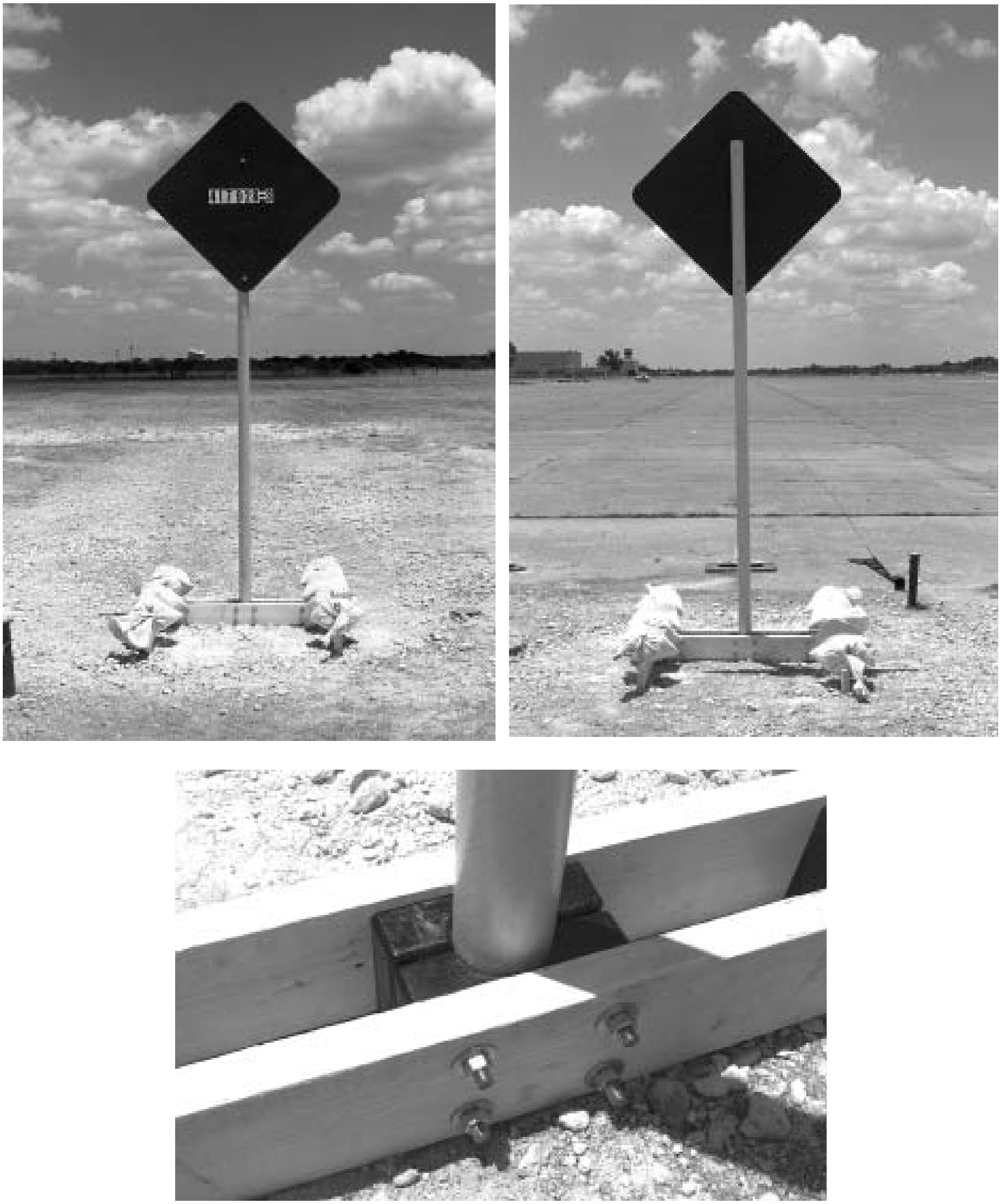


Figure 88. Installation before Test 417928-3.

Figure 89. Vehicle/Installation Geometrics for Test 417928-3.

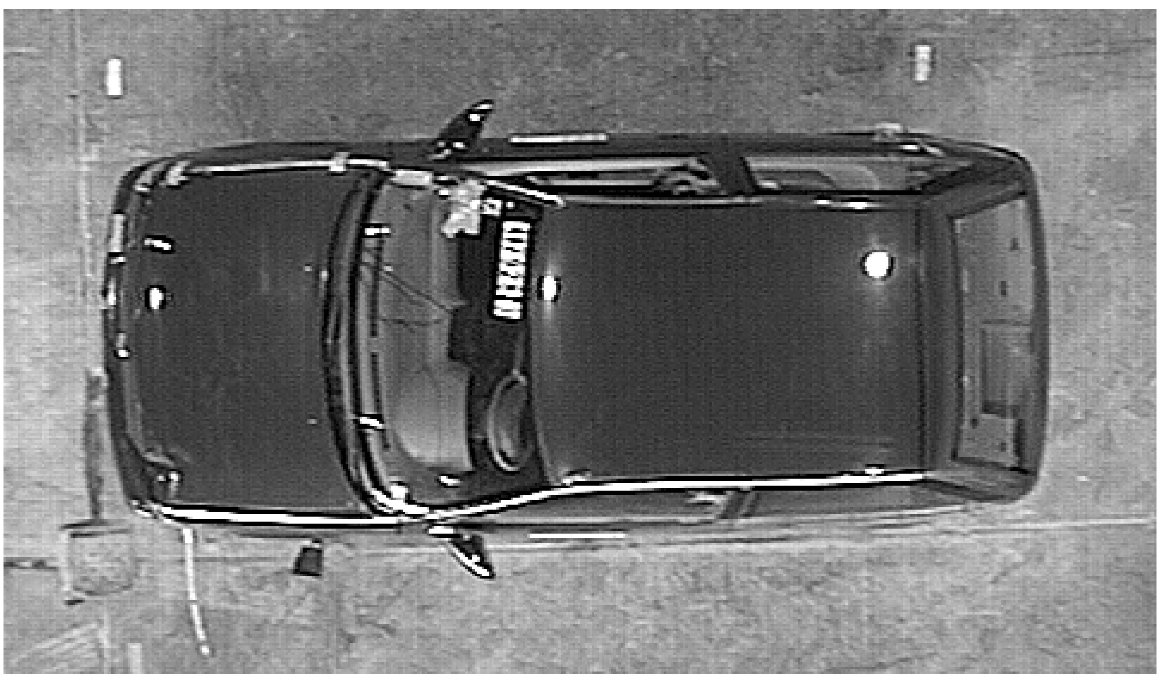


Figure 90. Vehicle before Test 417928-3.

0.129 s. At 0.171 s, the sign panel lightly contacted the upper portion of the rear window of the vehicle's hatch back, the sign panel rode down the rear window until 0.202 s. The sign panel lost contact with the lower portion of the rear window at 0.205 s. At 0.244 s, the vehicle was traveling at 88.0 km/h (54.7 mi/h) as it lost contact with the sign support. Brakes on the vehicle were applied as it exited the test site, and the vehicle came to rest 127.7 m (419.0 ft) downstream and 6.4 m (21.0 ft) to the left of the impact point. Sequential photographs of the test can be found in Appendix C, Figure 234.

Damage to Test Installation

All of the debris remained near the impact point, as shown in Figures 91 and 92. The sign and base were located 7.3 m (24.0 ft) downstream from the impact point.

Vehicle Damage

The vehicle received minor scrapes on the front bumper and hood, as shown in Figure 93. The interior of the vehicle is shown in Figure 94.

Assessment of Test Results

Figure 95 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The single fiber reinforced plastic sign support pulled out of the dual-purpose base and thereby met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

Figure 91. After Impact Trajectory for Test 417928-3.

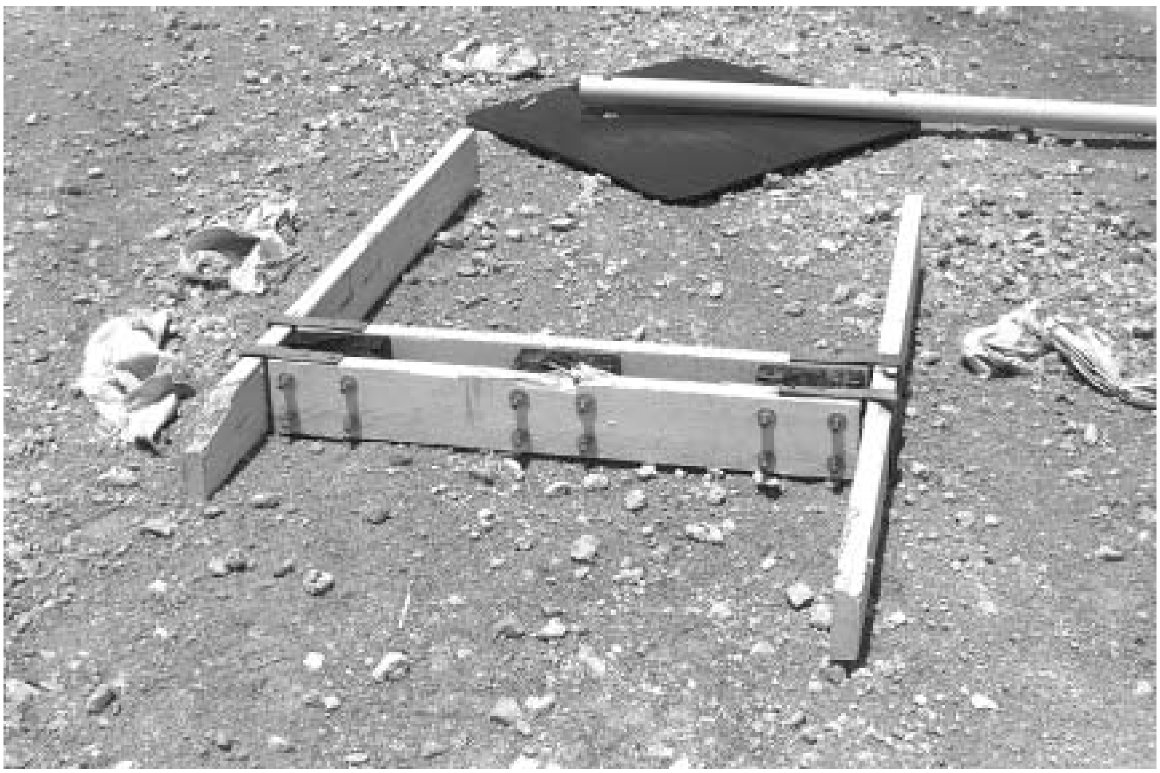


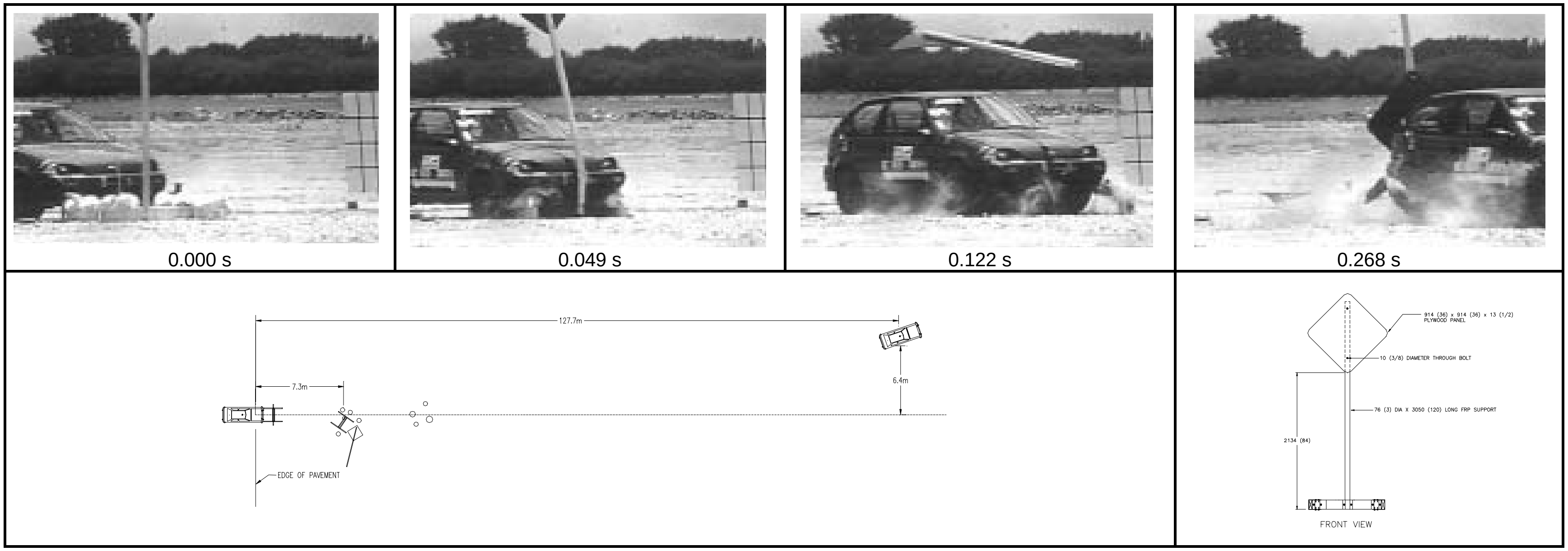
Figure 92. Installation after Test 417928-3.

Figure 93. Vehicle after Test 417928-3.

Before test

After test

Figure 94. Interior of Vehicle for Test 417928-3.



General Information

Test Agency	Texas Transportation Institute
Test No.	417928-3
Date	06/23/98

Test Article

Type	Traffic Control Device
Name	Single FRP Support in Dual-Purpose Base
Installation Length (m)	1.1 (3.6 ft)
Material or Key Elements	Single FRP Post, Dual Purpose Base, w/ 914x914x13 mm (36x36x0.5 inch) Plywood Panel

Soil Type and Condition ...... Standard Soil, Dry

Test Vehicle

Type	Production
Designation	820C
Model	1993 Geo Metro
Mass (kg) Curb	779 (1717 lb)
Test Inertial	820 (1806 lb)
Dummy	76 (168 lb)
Gross Static	896 (1974 lb)

Impact Conditions

Speed (km/h)	100.1 (62.2 mi/h)
Angle (deg)	0

Exit Conditions

Speed (km/h)	88.0 (54.7 mi/h)
Angle (deg)	0

Test Article Debris Pattern (m)

Longitudinal	127.7 (419.0 ft)
Lateral	0.9 (3.0 ft)

Vehicle Damage

Exterior	
VDS	12FC1
CDC	12FCEN1
Maximum Exterior Vehicle Crush (mm)	nil
Interior	
OCDI	FS0000000
Max. Occ. Compart. Deformation (mm)	0

Figure 95. Summary of Results for Test 417928-3, *NCHRP Report 350* Test 3-71.

The sign support did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 3.4 m/s (11.2 ft/s).

Conclusion

The single FRP support in dual-purpose base performed acceptably during *NCHRP Report 350* test designation 3-71.

Wood Sign Support in H-Leg Base (2.1 m [7.0 ft] mounting height) –
Test No. 417928-10 (*NCHRP Report 350* Test No. 3-71)

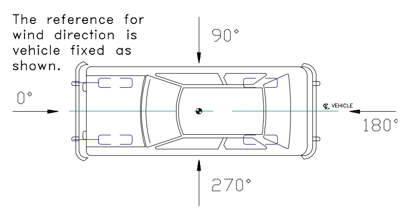
A single wood H-leg base sign support with a 76 mm ×76 mm × 13 mm (3 inch × 3 inch × 0.5 inch) plywood sign panel mounted at a height of 2.1 m (7.0 ft) above the ground, shown previously in Figure 10 and in Figure 96, was evaluated in this crash test. The base of the sign support was ballasted with six 7.6 kg (16.8 lb) sandbags.

Test Vehicle

A 1994 Geo Metro, shown in Figures 97 and 98, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 385 mm (15.2 inch), and it was 520 mm (20.5 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 216. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the morning of July 8, 1998. A total of 35 mm (1.4 inch) of rain was recorded eight days prior to the test but would not affect the test as the barricade was installed on the ground surface. No other rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 3 km/h (2 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 34 °C (93 °F); relative humidity: 61 percent.



Test Description

The vehicle impacted the sign support head-on at a speed of 100.2 km/h (62.3 mi/h). At 0.026 s, the bumper of the vehicle contacted the wooden post, and at 0.031 s, the hood of the vehicle deformed as it contacted the post. By 0.044 s, the post fractured, and by 0.155 s, the entire sign rotated up and over the vehicle. The vehicle was traveling at 84.2 km/h (52.3 mi/h) with the sign support still in contact with vehicle as the vehicle exited the test site. Brakes on the vehicle were applied as it exited the test site, and the vehicle came to rest 83.1 m (272.6 ft) down

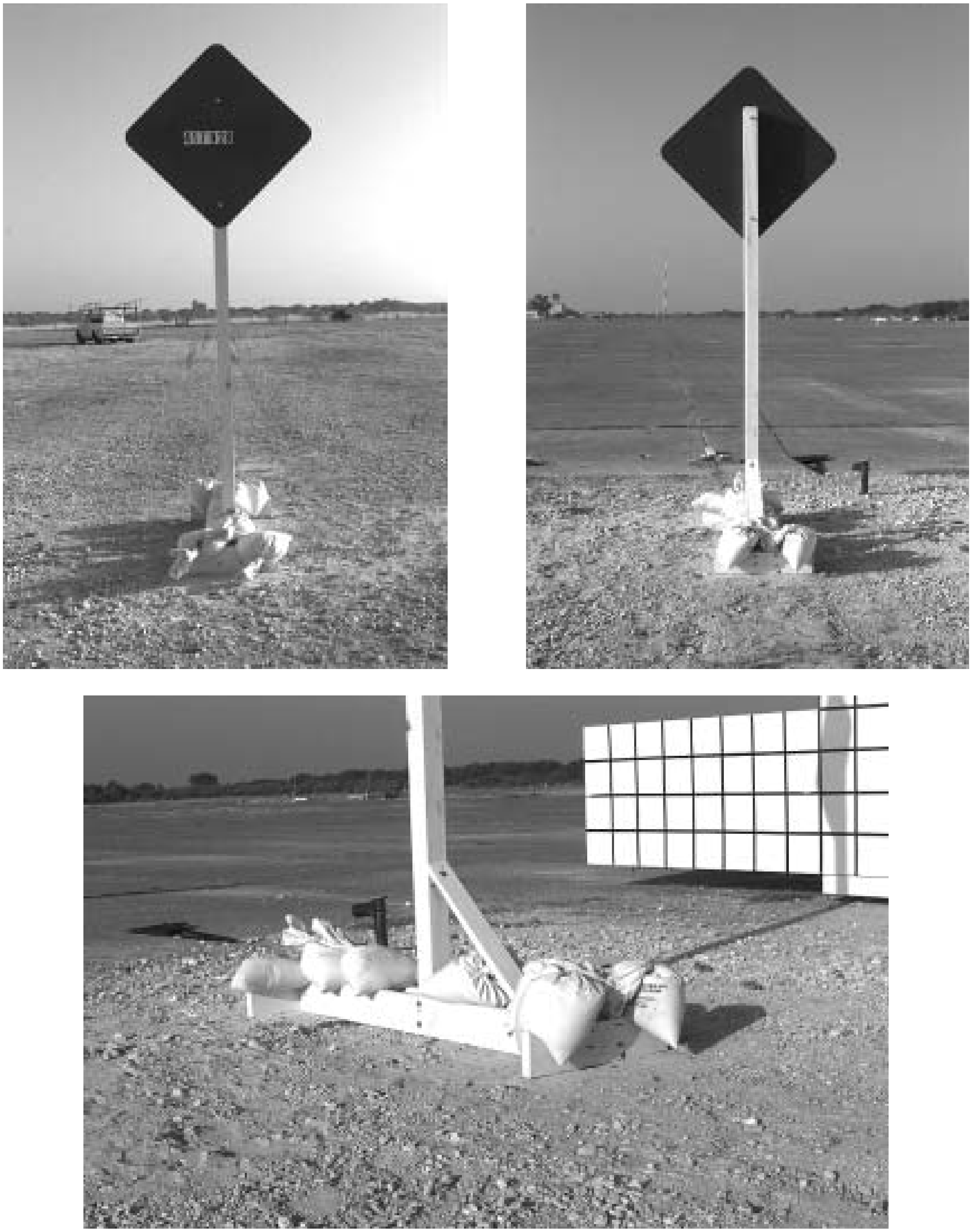


Figure 96. Installation before Test 417928-10.

Figure 97. Vehicle/Installation Geometrics for Test 417928-10.

Figure 98. Vehicle before Test 417928-10.

and 8.4 m (27.6 ft) to the left of the impact point. Sequential photographs of the test can be found in Appendix C, Figure 235.

Damage to Test Installation

The sign support separated into multiple pieces, as shown in Figures 99 and 100. The upper portion and a portion of the base came to rest within 5.3 m (17.4 ft) from impact, while the rest of the debris extended 19.8 m (65.0 ft) further down, 0.8 m (2.6 ft) to the left, and 0.9 m (3.0 ft) to the right of impact point.

Vehicle Damage

The hood and grill received damage, as shown in Figure 101. Maximum exterior crush to the center of the front bumper was 330 mm (13 inch). The fan, radiator, and radiator support were also damaged. The interior of the vehicle is shown in Figure 102.

Assessment of Test Results

Figure 103 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The single H-leg base with plywood sign panel met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

  The sign support did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred.

Figure 99. After Impact Trajectory for Test 417928-10.

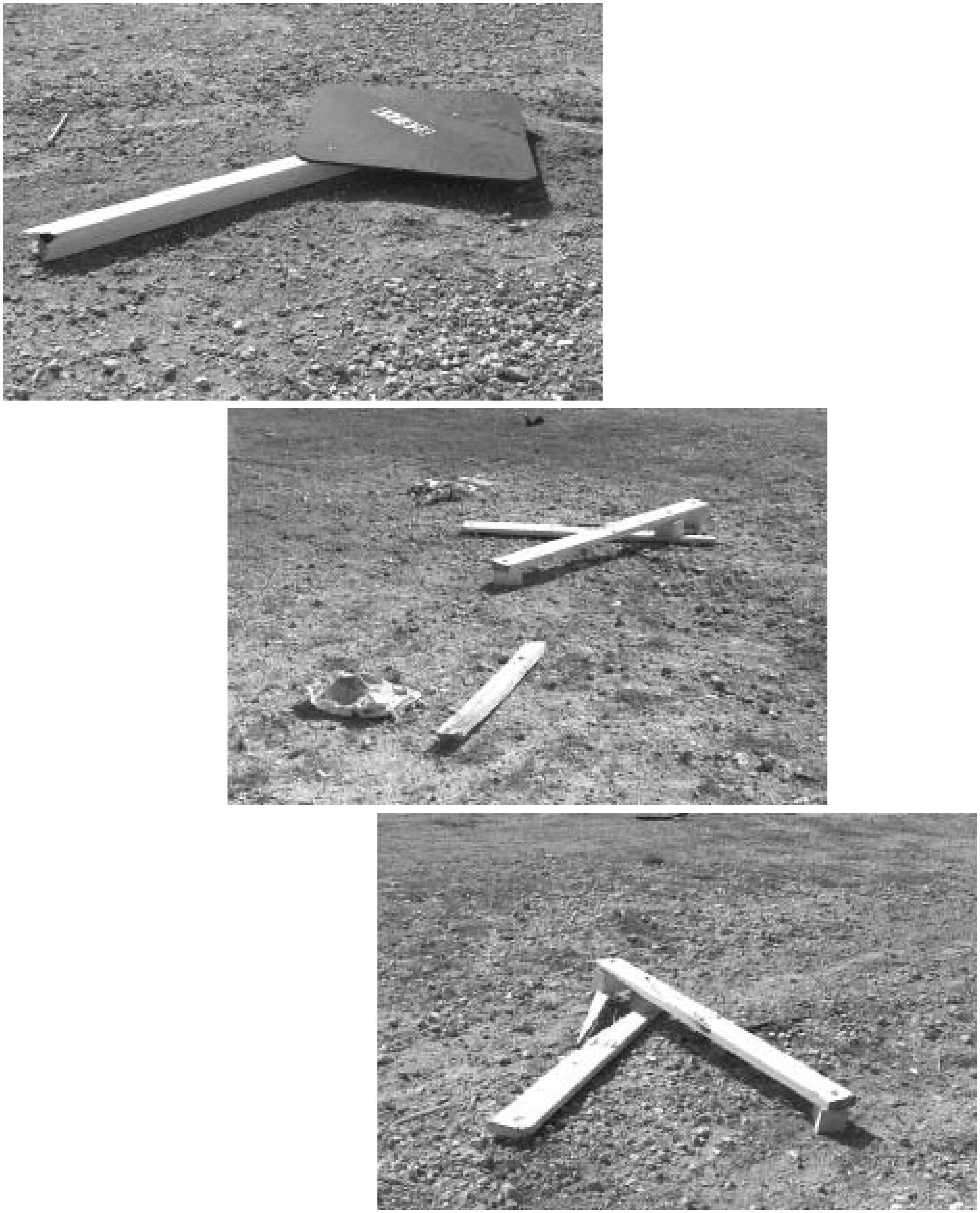


Figure 100. Installation after Test 417928-10.

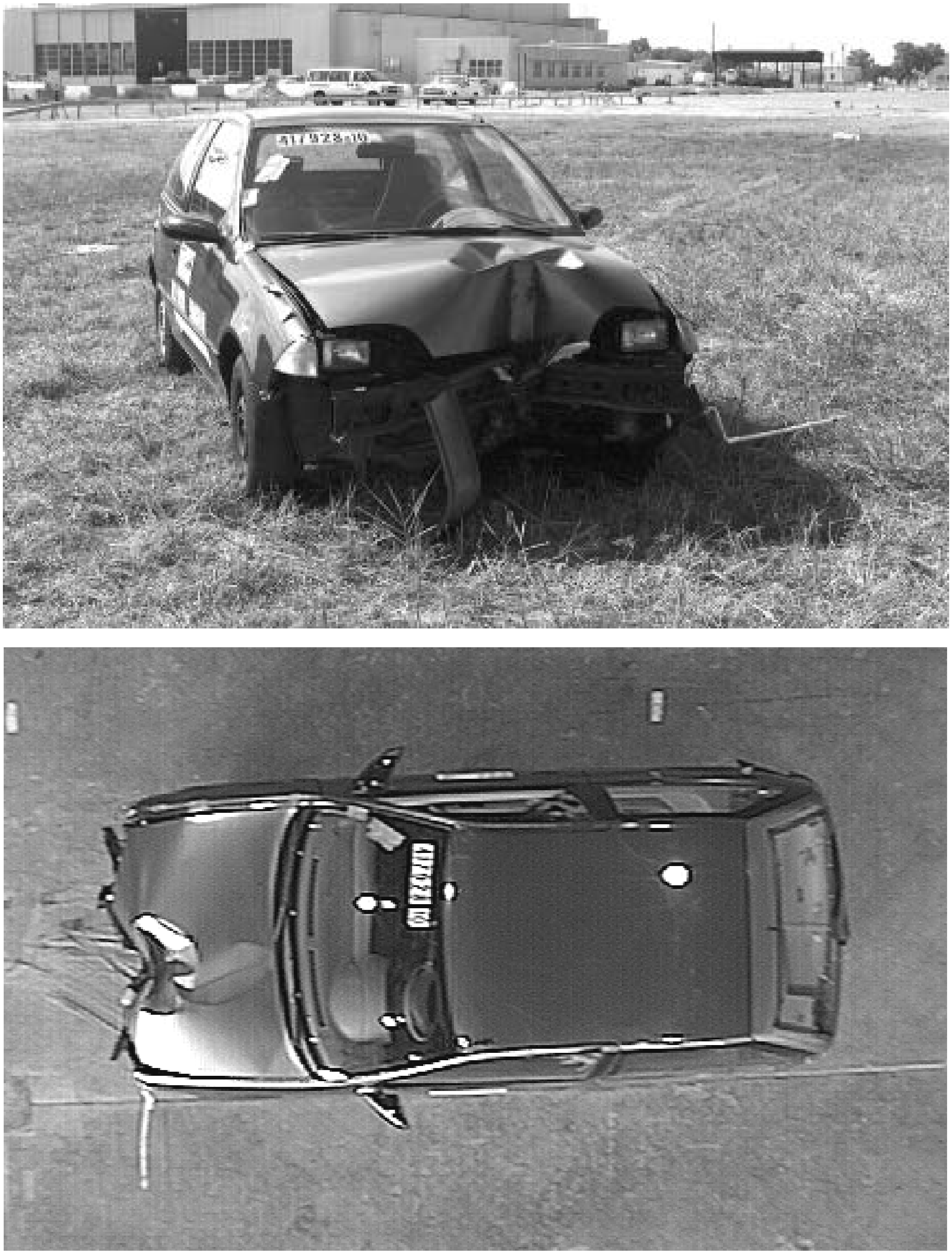
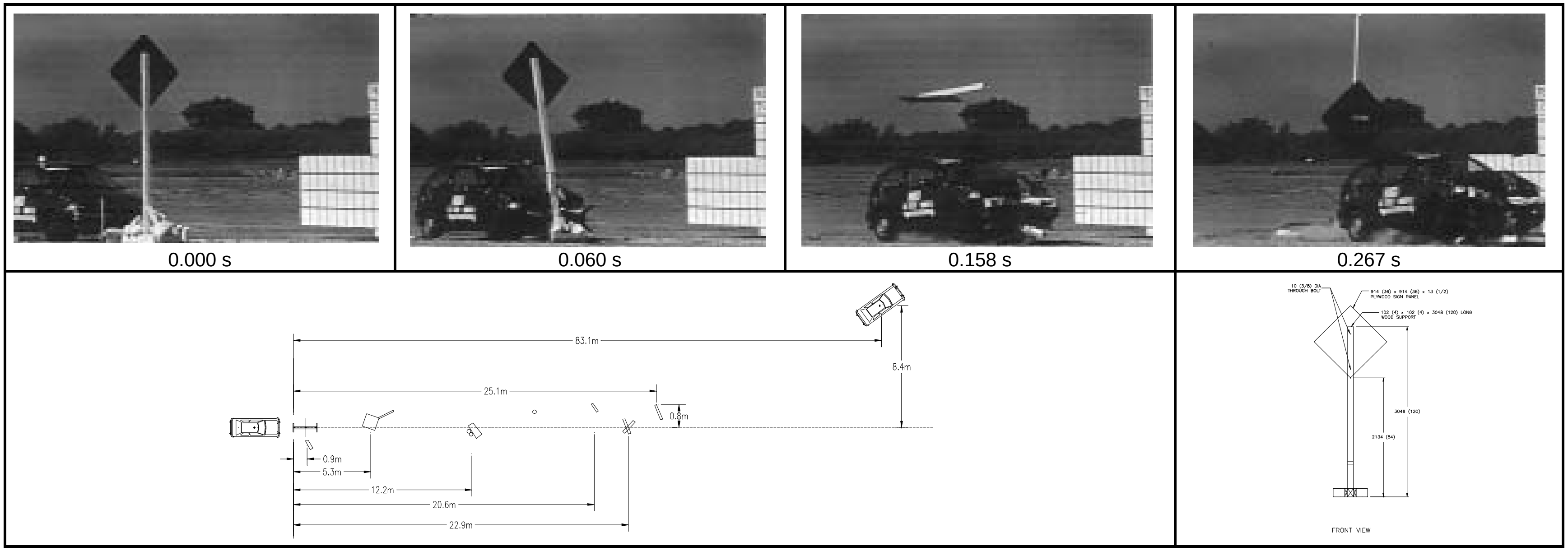


Figure 101. Vehicle after Test 417928-10.

Before test

After test

Figure 102. Interior of Vehicle for Test 417928-10.



General Information

Test Agency	Texas Transportation Institute
Test No.	417928-10
Date	07/08/98

Test Article

Type	Traffic Control Device
Name	Wood Sign Support in H-Leg Base
Installation Length (m)	0.6
Material or Key Elements	Wooden H-Leg Base with 76x76x13 mm (3x3x0.5 inch) Plywood Panel

Soil Type and Condition . . . . . . Standard Soil, Dry

Test Vehicle

Type	Production
Designation	820C
Model	1994 Geo Metro
Mass (kg) Curb	798 (1759 lb)
Test Inertial	820 (1806 lb)
Dummy	76 (168 lb)
Gross Static	896 (1974 lb)

Impact Conditions

Speed (km/h)	100.2 (62.3 mi/h)
Angle (deg)	0

Exit Conditions

Speed (km/h)	84.2 (52.3 mi/h)
Angle (deg)	0

Test Article Debris Pattern (m)

Longitudinal	25.1 (82.3 ft)
Lateral	0.9 (3.0 ft)

Vehicle Damage

Exterior	
VDS	12FC2
CDC	12FCEN2
Maximum Exterior Vehicle Crush (mm)	330 (13 in)
Interior	
OCDI	FS0000000
Max. Occ. Compart. Deformation (mm)	0

Figure 103. Summary of Results for Test 417928-10, *NCHRP Report 350* Test 3-71.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 4.4 m/s (14.4 ft/s).

Conclusion

The wood sign support in H-leg base (2.1 m [7.0 ft] mounting height) performed acceptably during *NCHRP Report 350* test designation 3-71.

Dual Perforated Steel Tube Skid Mounted Sign Support –
Test No. 417928-11 (*NCHRP Report 350* Test No. 3-71)

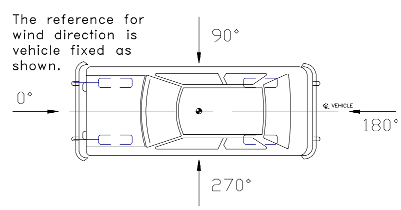
A dual perforated steel tube skid mounted sign support with a 914 mm × 914 mm × 13 mm (36 inch × 36 inch × 0.5 inch) plywood sign panel mounted at a height of 2.1 m (7.0 ft) above the ground, shown previously in Figure 11 and in Figure 104, was evaluated in this crash test. The base of the sign support was ballasted with eight 7.6 kg (16.8 lb) sandbags.

Test Vehicle

A 1993 Geo Metro, shown in Figures 105 and 106, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 370 mm (14.6 inch), and it was 510 mm (20.0 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 220. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the morning of July 8, 1998. A total of 35 mm (1.4 inch) of rain was recorded eight days prior to the test but would not affect the test as the barricade was installed on the ground surface. No other rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 3 km/h (2 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 34 °C (93 °F); relative humidity: 61 percent.



Test Description

The vehicle impacted the sign support head-on at a speed of 93.8 km/h (58.3 mi/h). The vehicle contacted the steel posts at 0.007 s, and at 0.014 s, the hood of the vehicle deformed. By 0.044 s, the left steel post fractured at the steel base, and by 0.092 s, the sign panel contacted the roof of the vehicle. The windshield shattered at 0.097 s. The vehicle was traveling at 83.2 km/h (51.7 mi/h) with the barricade still in contact with vehicle as it exited the test site. Brakes on the vehicle were applied as it exited the test site, and the vehicle came to rest 66.3 m (217.5 ft) from the impact point. Sequential photographs of the test can be found in Appendix C, Figure 236.

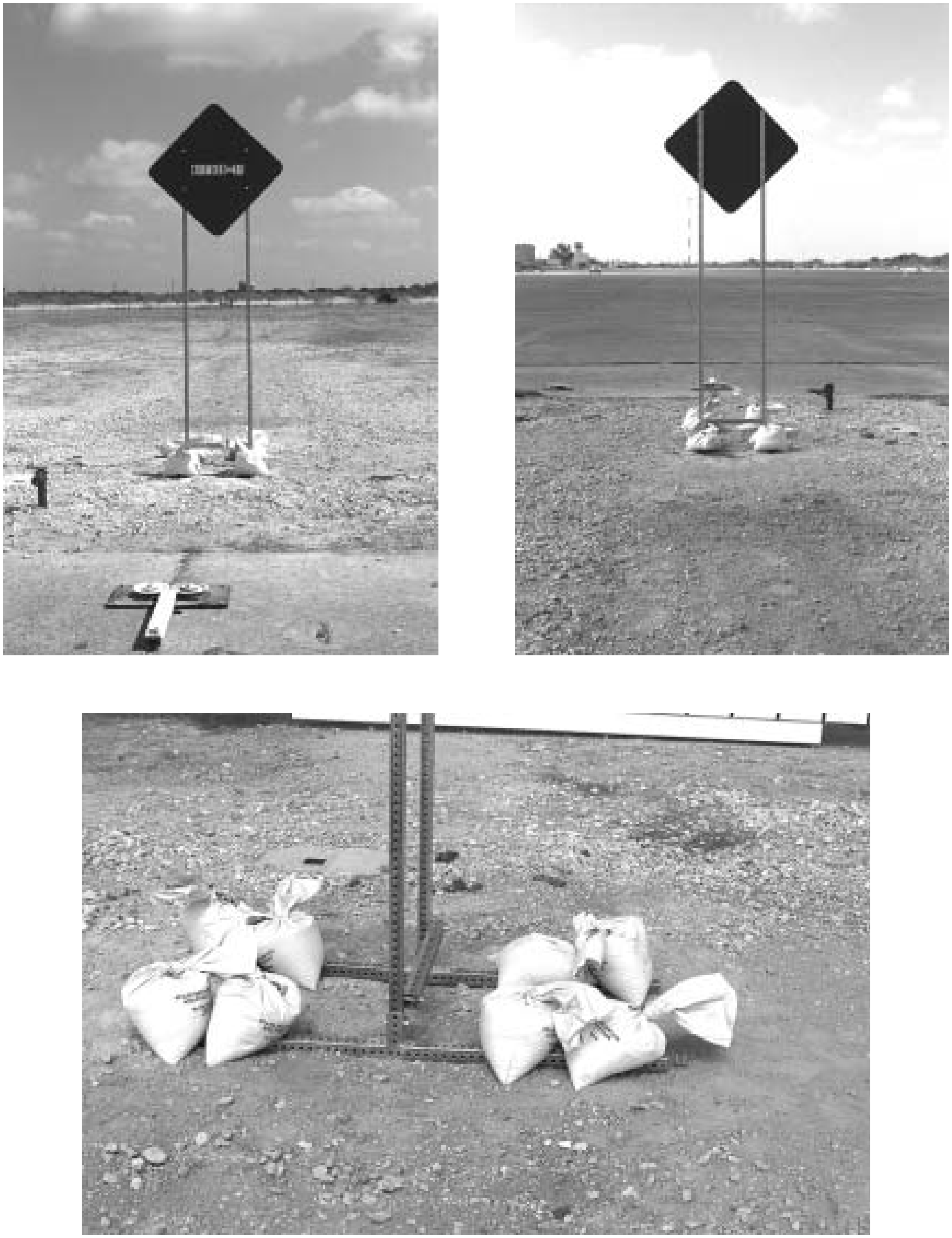


Figure 104. Installation before Test 417928-11.

Figure 105. Vehicle/Installation Geometrics for Test 417928-11.

Figure 106. Vehicle before Test 417928-11.

Damage to Test Installation

The upper portion of the barricade and left steel post remained in one piece and came to rest 59.4 m (194.9 ft) down and 3.8 m (12.5 ft) to the right of impact. The right steel post rode along with the vehicle, as shown in Figures 107 and 108. The bases and braces separated from the upright and were scattered along the path of the vehicle.

Vehicle Damage

As shown in Figure 109, the vehicle received major damage. The bumper, roof, hood, and grill were dented (not measurable), and the windshield was shattered on the driver's side. The radiator support was also deformed. Maximum deformation into the occupant compartment was 99 mm (3.9 inch) (11 percent reduction of space) measured between the roof of the vehicle and floor pan at the transmission tunnel. The interior of the vehicle is shown in Figure 110. Occupant compartment measurements are shown in Appendix B, Table 3.

Assessment of Test Results

A summary of the test results is shown in Figure 111. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The dual perforated steel tube skid mounted sign support with plywood sign panel met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

  The steel sign support penetrated the occupant compartment in the windshield area and deformed the roof. Maximum deformation into the

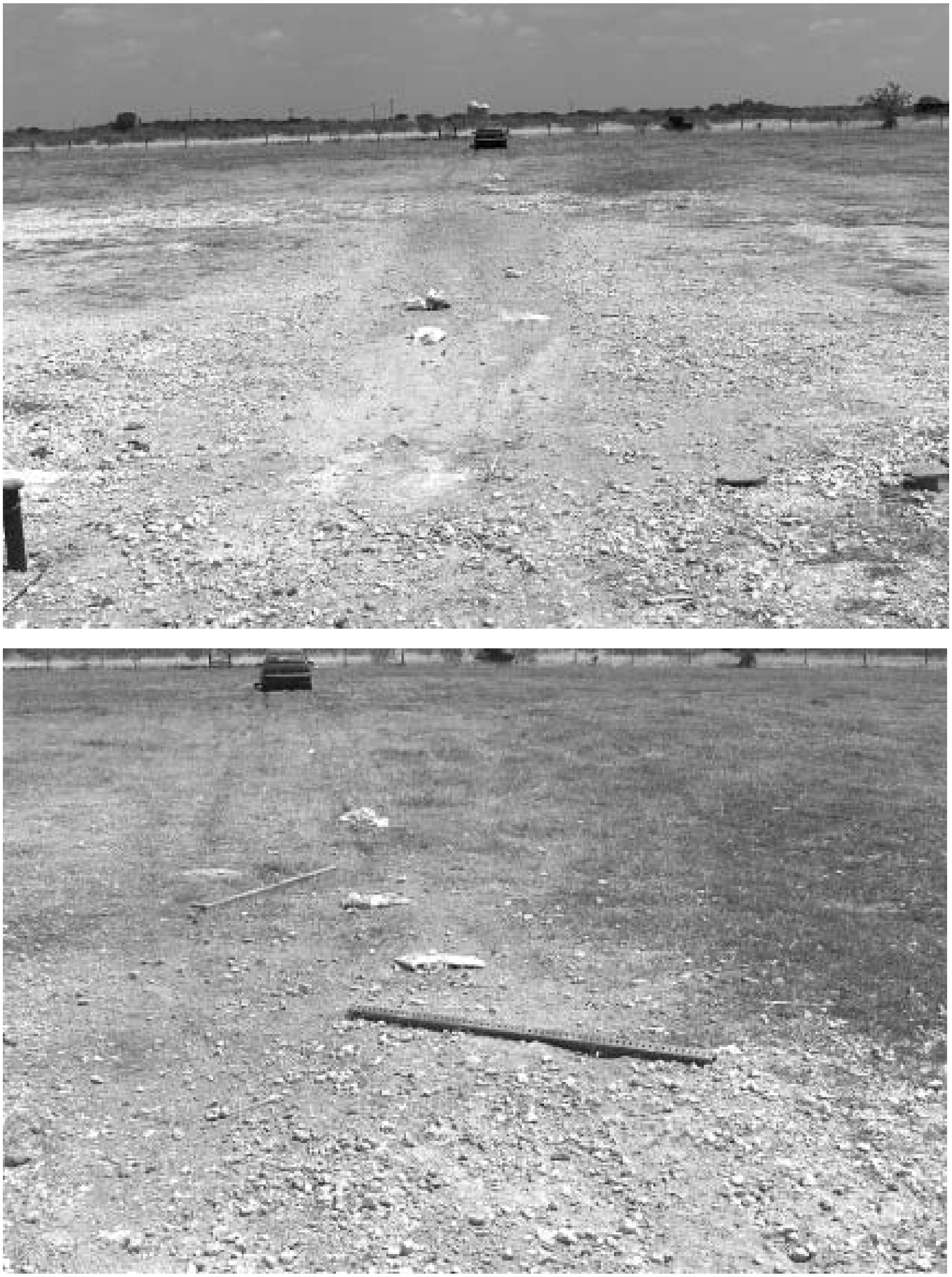
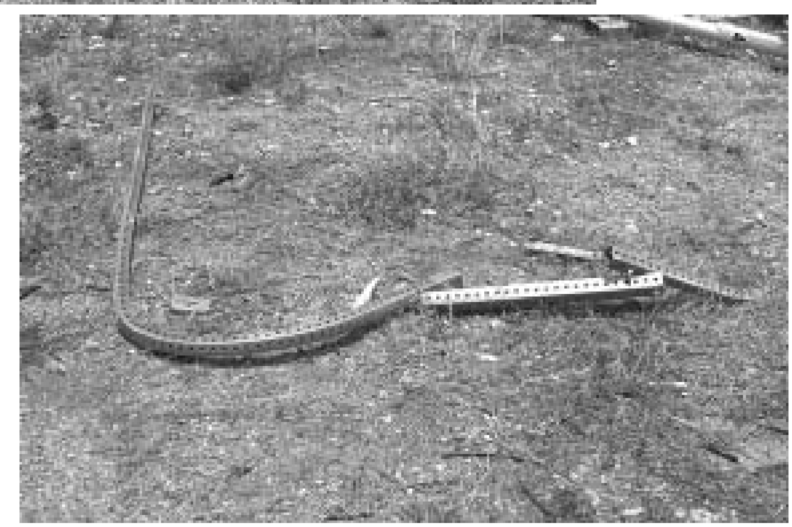


Figure 107. After Impact Trajectory for Test 417928-11.



After removing from under vehicle

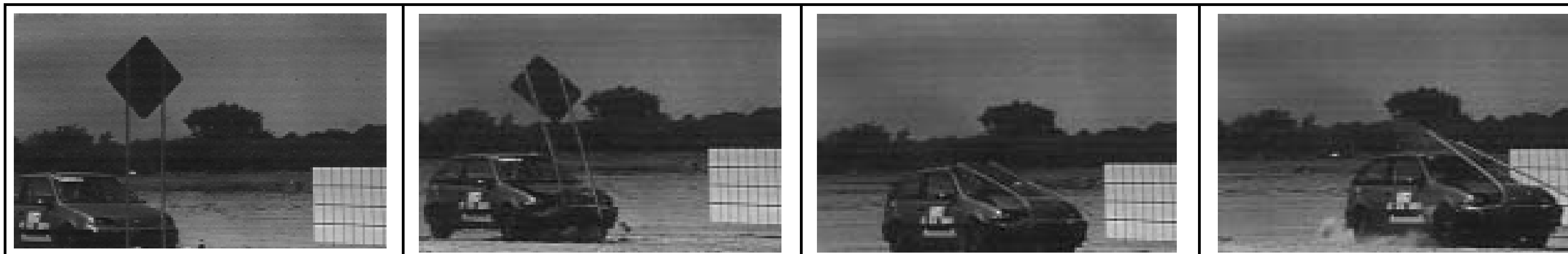
Figure 108. Installation after Test 417928-11.

Figure 109. Vehicle after Test 417928-11.

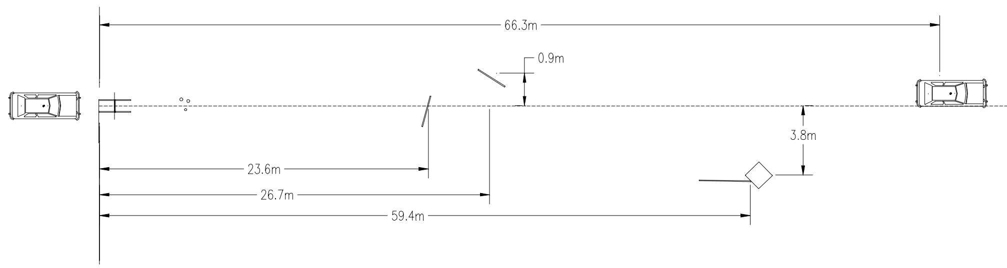
Before test

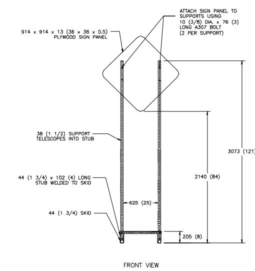
After test

Figure 110. Interior of Vehicle for Test 417928-11.



0.000 s	0.048 s	0.134 s	0.207 s





General Information
- Test Agency . . . . Texas Transportation Institute
- Test No. 417928-11
- Date 07/08/98

Test Article
- Type . . . . Traffic Control Device
- Name . . . . Dual Perforated Steel Tube Skid Mounted Sign Support
- Installation Length (m) . . . . . . 0.6 (2.0 ft)
- Material or Key Elements . . . . Steel Support 2.1 m (7.0 ft) Tall w/ 914x914x13 mm (36x36x0.5 inch) Plywood Panel

Soil Type and Condition . . . . . . Standard Soil, Dry

Test Vehicle
- Type . . . . Production
- Designation 820C
- Model . . . . 1993 Geo Metro
- Mass (kg) Curb . . . . 725 (1598 lb)
  - Test Inertial . . . . 820 (1806 lb)
  - Dummy . . . . 76 (168 lb)
  - Gross Static . . . . 896 (1974 lb)

Impact Conditions
- Speed (km/h) . . . . 93.8 (58.3 mi/h)
- Angle (deg) 0

Exit Conditions
- Speed (km/h) . . . . 83.2 (51.7 mi/h)
- Angle (deg) 0

Test Article Debris Pattern (m)
- Longitudinal . . . . 59.4 (194.9 ft)
- Lateral . . . . 3.8 (12.5 ft)

Vehicle Damage
- Exterior
  - VDS 12FD3
  - CDC 12FDEW3
- Maximum Exterior
  - Vehicle Crush (mm) . . . . . . nil
- Interior
  - OCDI FS0200000
- Max. Occ. Compart.
  - Deformation (mm) . . . . 99 (3.9 inch)

Figure 111. Summary of Results for Test 417928-11, *NCHRP Report 350* Test 3-71.

occupant compartment was 99 mm (3.9 inch) (11 percent reduction of space) in the floor pan near the transmission tunnel.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

The detached elements or vehicle damage would not block the driver's vision but might cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 2.9 m/s (9.5 ft/s).

Conclusion

The dual perforated steel tube skid mounted sign support failed to meet criterion D and, thus, does not meet *NCHRP Report 350* guidelines. The steel support posts penetrated the occupant compartment through the windshield and caused significant deformation to the roof of the vehicle.

TEMPORARY SIGN SUPPORTS:
LONG/INTERMEDIATE TERM GROUND MOUNTED SIGN SUPPORTS

Dual FRP Sign Support
Test No. 417928-4 (*NCHRP Report 350* Test No. 3-60)

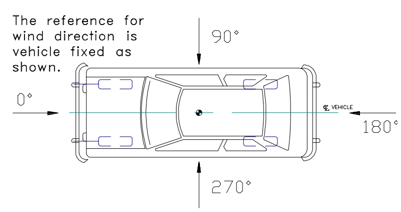
A ground-mounted dual FRP sign support with a 1220 mm × 2438 mm ×13 mm (48 inch × 96 inch × 0.5 inch) plywood sign panel mounted at 2.1 m (7 ft) above ground, shown previously in Figure 12 and in Figure 112, was evaluated in this crash test.

Test Vehicle

A 1993 Geo Metro, shown in Figures 113 and 114, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 395 mm (15.6 inch), and it was 525 mm (20.7 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 217. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the morning of June 25, 1998. No rainfall occurred for the 10 days prior to the test. Moisture content of the *NCHRP Report 350* standard soil, on which the traffic control devices were installed, was 4.9 percent, and the soil was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 3 km/h (2 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 29 °C (85 °F); relative humidity: 61 percent.



Test Description

The vehicle impacted the sign support head-on at a speed of 34.1 km/h (21.2 mi/h). At 0.019 s after impact, the sign posts deformed around the front bumper of the vehicle. At 0.202 s, the plywood sign panel contacted the hood of the vehicle. The cover on the front right of the bumper of the vehicle separated from the vehicle at 0.061 s. The vehicle was traveling at 16.5 km/h (10.3 mi/h) with the sign panel still in contact, as the vehicle exited the test site. The brakes on the vehicle were applied at 4.5 s, and the vehicle came to rest 8.2 m (27.0 ft)

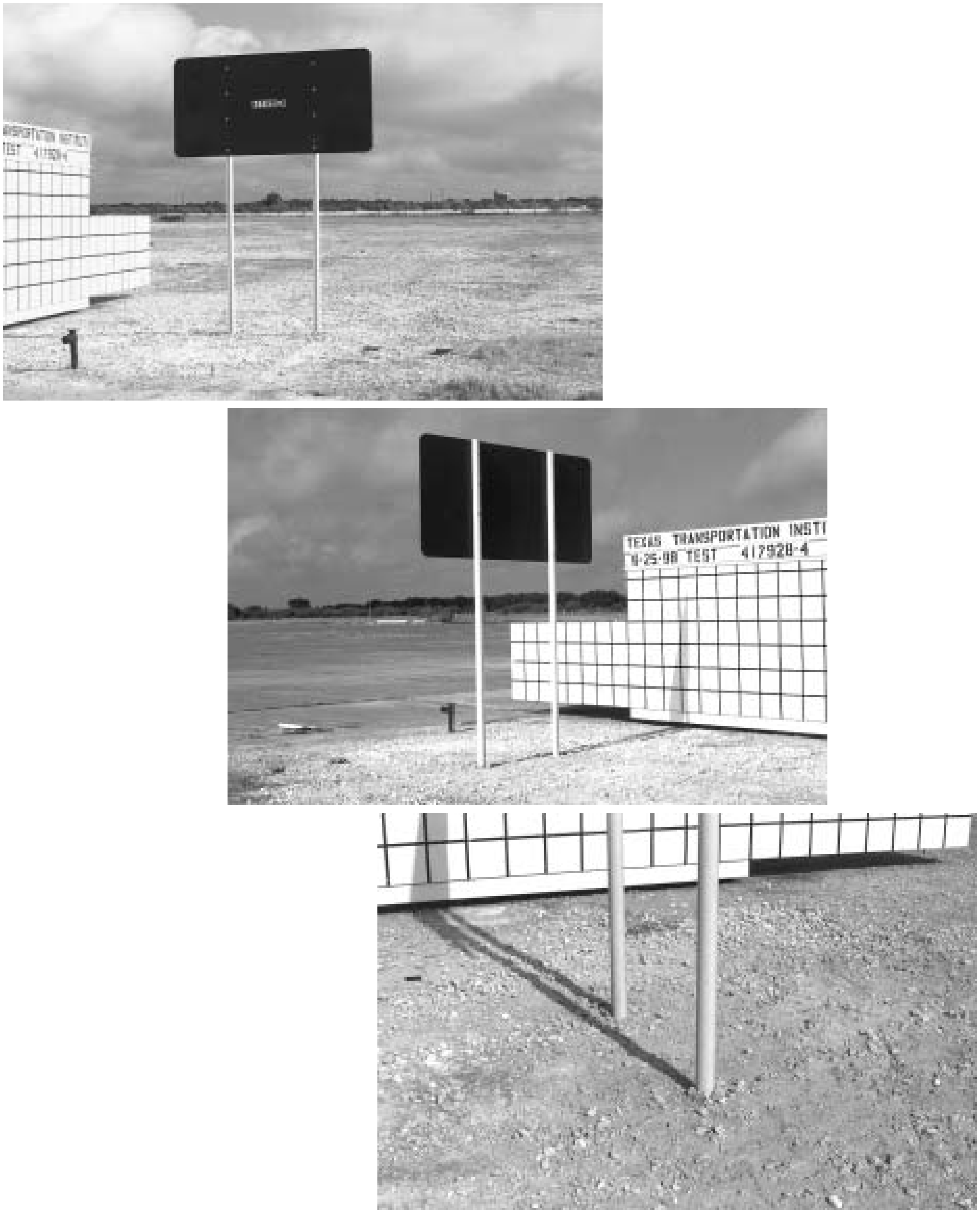


Figure 112. Installation before Test 417928-4.

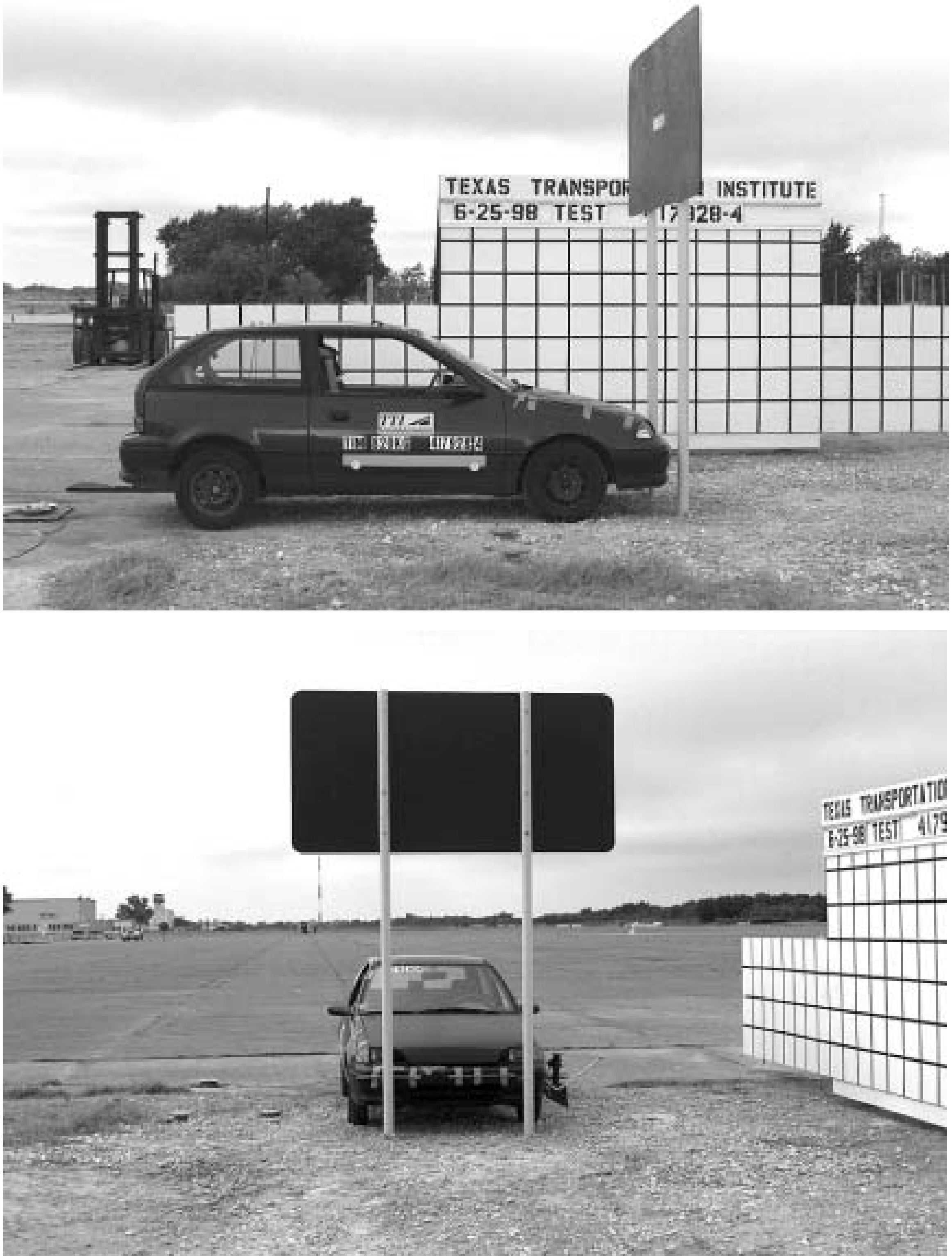


Figure 113. Vehicle/Installation Geometrics for Test 417928-4.

Figure 114. Vehicle before Test 417928-4.

down from the impact point. Sequential photographs of the test can be found in Appendix C, Figure 237.

Damage to Test Installation

The sign support and panel remained at their original location and were lying flat against the ground, as shown in Figures 115 and 116.

Vehicle Damage

The vehicle received damage to the front, as shown in Figure 117. The hood received two scrapes, and there was minor damage to the bumper cover. The windshield of the vehicle was shattered on the driver's side from contact with the sign panel. The interior of the vehicle is shown in Figure 118.

Assessment of Test Results

Figure 119 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The ground-mounted dual fiber reinforced plastic sign support met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

  The sign panel shattered the windshield, but it did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred.

Figure 115. After Impact Trajectory for Test 417928-4.

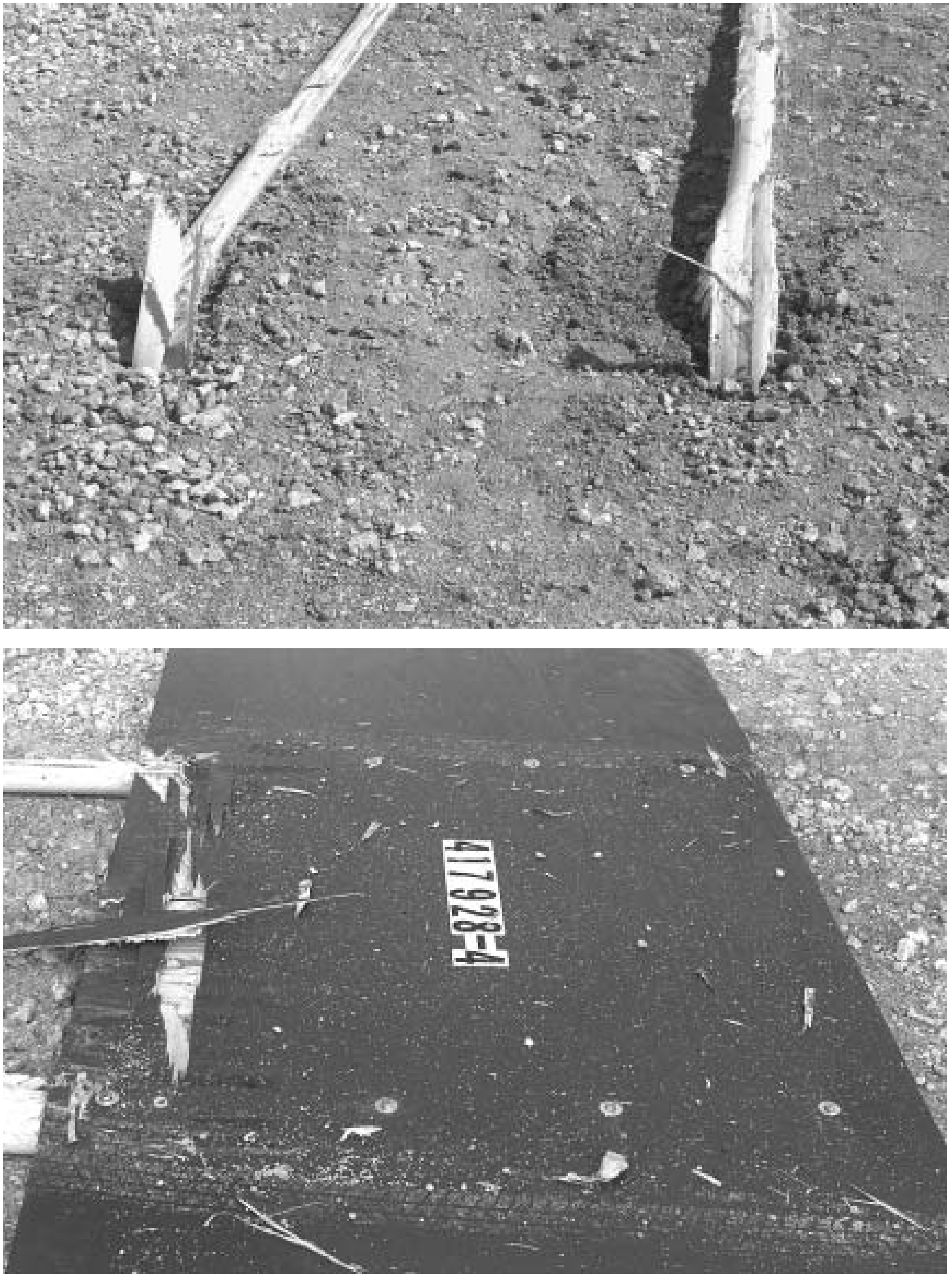


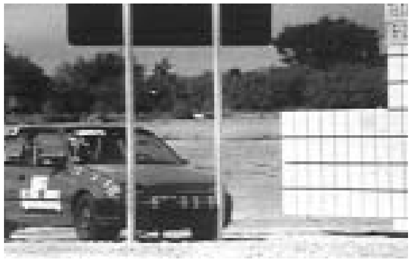
Figure 116. Installation after Test 417928-4.

Figure 117. Vehicle after Test 417928-4.

Before test

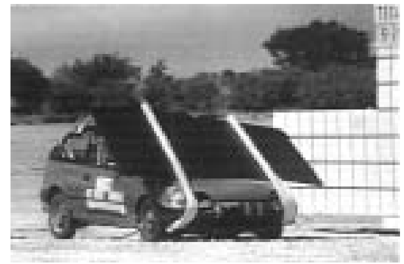
After test

Figure 118. Interior of Vehicle for Test 417928-4.



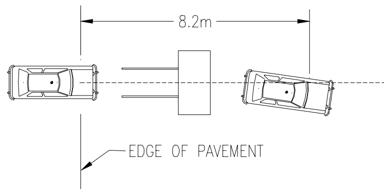
0.000 s

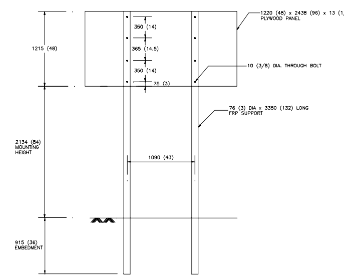
0.073 s



0.195 s

0.439 s





General Information
- Test Agency . . . . Texas Transportation Institute
- Test No. 417928-4
- Date 06/25/98

Test Article
- Type . . . . Traffic Control Device
- Name . . . . Dual FRP Sign Support
- Installation Length (m) 1.1
- Material or Key Elements . . . . Dual FRP Posts 2.1 m (7 ft) Tall w/ 1220x2438x13 mm (48x96x0.5 inch) Plywood Panel

Soil Type and Condition . . . . . . Standard Soil, Dry

Test Vehicle
- Type . . . . Production
- Designation 820C
- Model . . . . 1993 Geo Metro
- Mass (kg) Curb . . . . 779 (1717 lb)
  - Test Inertial . . . . . 820 (1806 lb)
  - Dummy . . . . 76 (168 lb)
  - Gross Static . . . . . 896 (1974 lb)

Impact Conditions
- Speed (km/h) . . . . 34.1 (21.2 mi/h)
- Angle (deg) 0

Exit Conditions
- Speed (km/h) . . . . 16.5 (10.3 mi/h)
- Angle (deg) 0

Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction . . . . 4.7 (15.4 ft/s)
  - y-direction . . . . 0.1 (0.3 ft/s)
- THIV (km/h) . . . . 16.9 (10.5 mi/h)
- Ridedown Accelerations (g's)
  - x-direction . . . . -2.3
  - y-direction 0.7
- PHD (g's) 2.4
- ASI 0.23
- Max. 0.050-s Average (g's)
  - x-direction . . . . -2.5
  - y-direction 0.4
  - z-direction 1.0

Test Article Debris Pattern (m)
- Longitudinal . . . . nil
- Lateral . . . . nil

Vehicle Damage
- Exterior
  - VDS 12FD1
  - CDC 12FDEW1
- Maximum Exterior
  - Vehicle Crush (mm) . . . . . . nil
- Interior
  - OCDI FS0000000
- Max. Occ. Compart.
  - Deformation (mm) 0

Post-Impact Behavior
(during 1.0 s after impact)
- Max. Yaw Angle (deg) 14
- Max. Pitch Angle (deg) . . . . . . -6
- Max. Roll Angle (deg) . . . . -2

Figure 119. Summary of Results for Test 417928-4, *NCHRP Report 350* Test 3-60.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

H. *Occupant impact velocities should satisfy the following:*

Longitudinal Occupant Impact Velocity - m/s	
Preferred	*Maximum*
3	*5*

I. *Occupant ridedown accelerations should satisfy the following:*

Longitudinal and Lateral Occupant Ridedown Accelerations - g's	
Preferred	*Maximum*
15	*20*

For criteria H and I, data from the accelerometer located at the vehicle center-of-gravity were digitized for evaluation of occupant risk and were computed as follows. In the longitudinal direction, the occupant impact velocity was 4.7 m/s (15.4 ft/s) at 0.292 s; the highest 0.010-s occupant ridedown acceleration was -2.3 g's from 0.295 to 0.305 s, and the maximum 0.050-s average acceleration -2.5 g's between 0.214 and 0.264 s. In the lateral direction, the occupant impact velocity was 0.1 m/s (0.3 ft/s) at 0.292 s; the highest 0.010-s occupant ridedown acceleration was 0.7 g's from 0.301 to 0.311 s, and the maximum 0.050-s average acceleration 0.4 m/s (1.3 ft/s) between 0.496 and 0.546 s. Vehicle angular displacements and vehicular accelerations versus time traces are presented in Appendix D, Figures 251 through 254.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

  Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

  Maximum change in velocity for this test was 4.9 m/s (16.1 ft/s).

Conclusion

The dual post, ground mounted FRP sign support system met *NCHRP Report 350* evaluation criteria for the low speed test, test designation 3-60.

Dual FRP Sign Support –
Test No. 417928-5 (*NCHRP Report 350* Test No. 3-61)

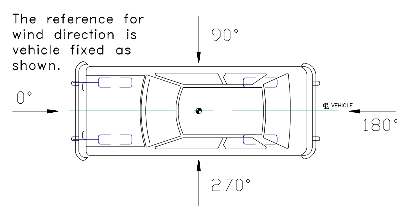
A ground-mounted dual FRP sign support with a 1220 mm × 2438 mm × 13 mm (48 inch × 96 inch ×0.5 inch) plywood sign panel mounted at 2.1 m (7 ft) above the ground, shown previously in Figure 12 and in Figure 120, was evaluated in this crash test.

Test Vehicle

A 1994 Geo Metro, shown in Figures 121 and 122, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 395 mm (15.6 inch), and it was 525 mm (20.7 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 217. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the afternoon of June 25, 1998. No rainfall occurred for the 10 days prior to the test. Moisture content of the *NCHRP Report 350* standard soil, on which the traffic control devices were installed, was 4.7 percent, and the soil was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 3 km/h (2 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 38 °C (101 °F); relative humidity: 61 percent.



Test Description

The vehicle impacted the sign support head-on at a speed of 98.6 km/h (61.3 mi/h). At 0.007 s, the sign posts deformed around the front of the bumper, and at 0.034 s, the sign posts were pulled out of the ground. By 0.112 s, the plywood sign panel contacted the roof of the vehicle, and by 0.142 s, the plywood sign panel was parallel above the vehicle. The vehicle was traveling at 97.4 km/h (60.5 mi/h) with the sign panel still in contact, as the vehicle exited the test site. The brakes on the vehicle were applied at 1.6 s, and the vehicle came to rest 29.9 m (98.1 ft) down and 0.6 m (2.0 ft) to the right of the impact point. Sequential photographs of the test can be found in Appendix C, Figure 238.

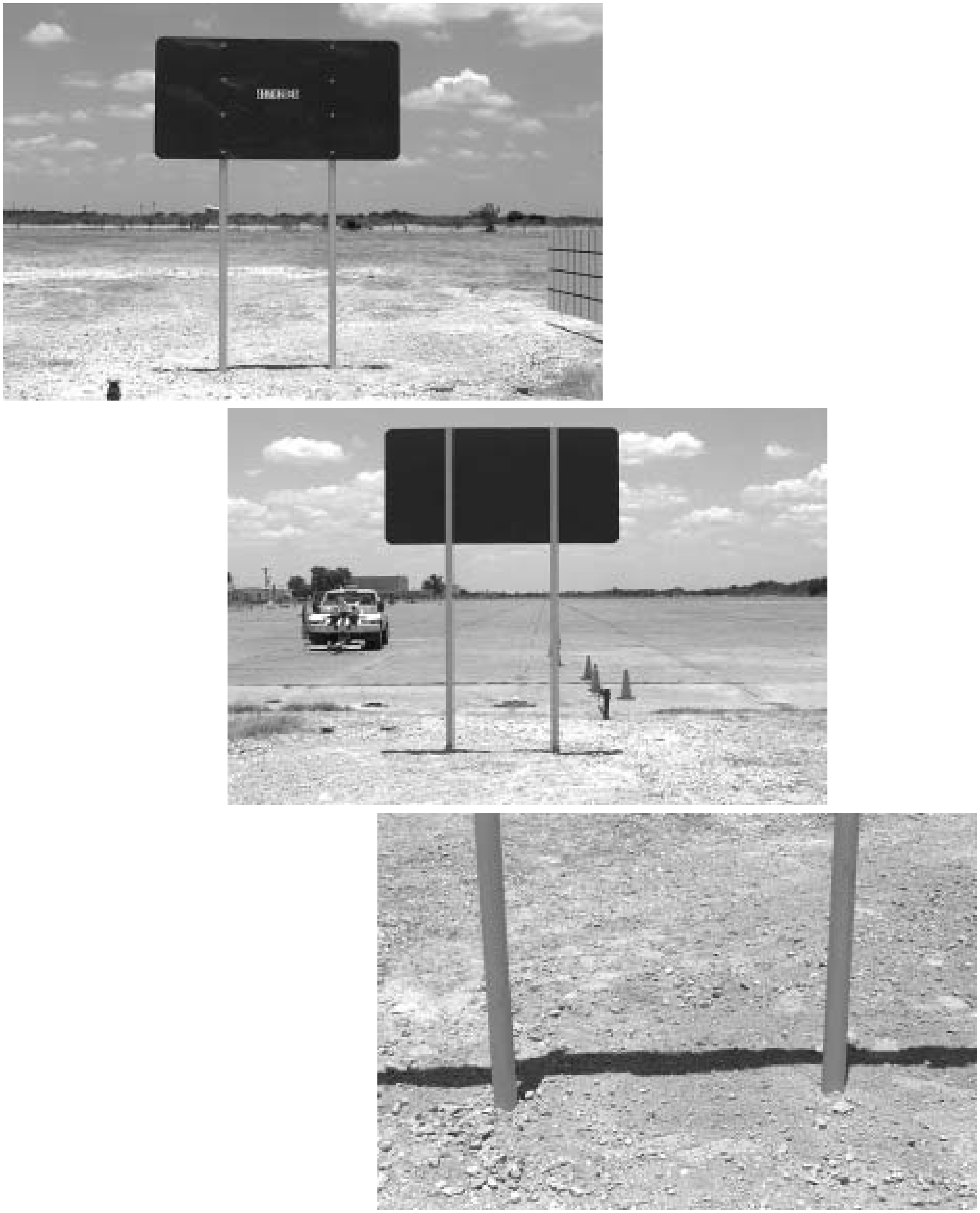


Figure 120. Installation before Test 417928-5.

Figure 121. Vehicle/Installation Geometrics for Test 417928-5.

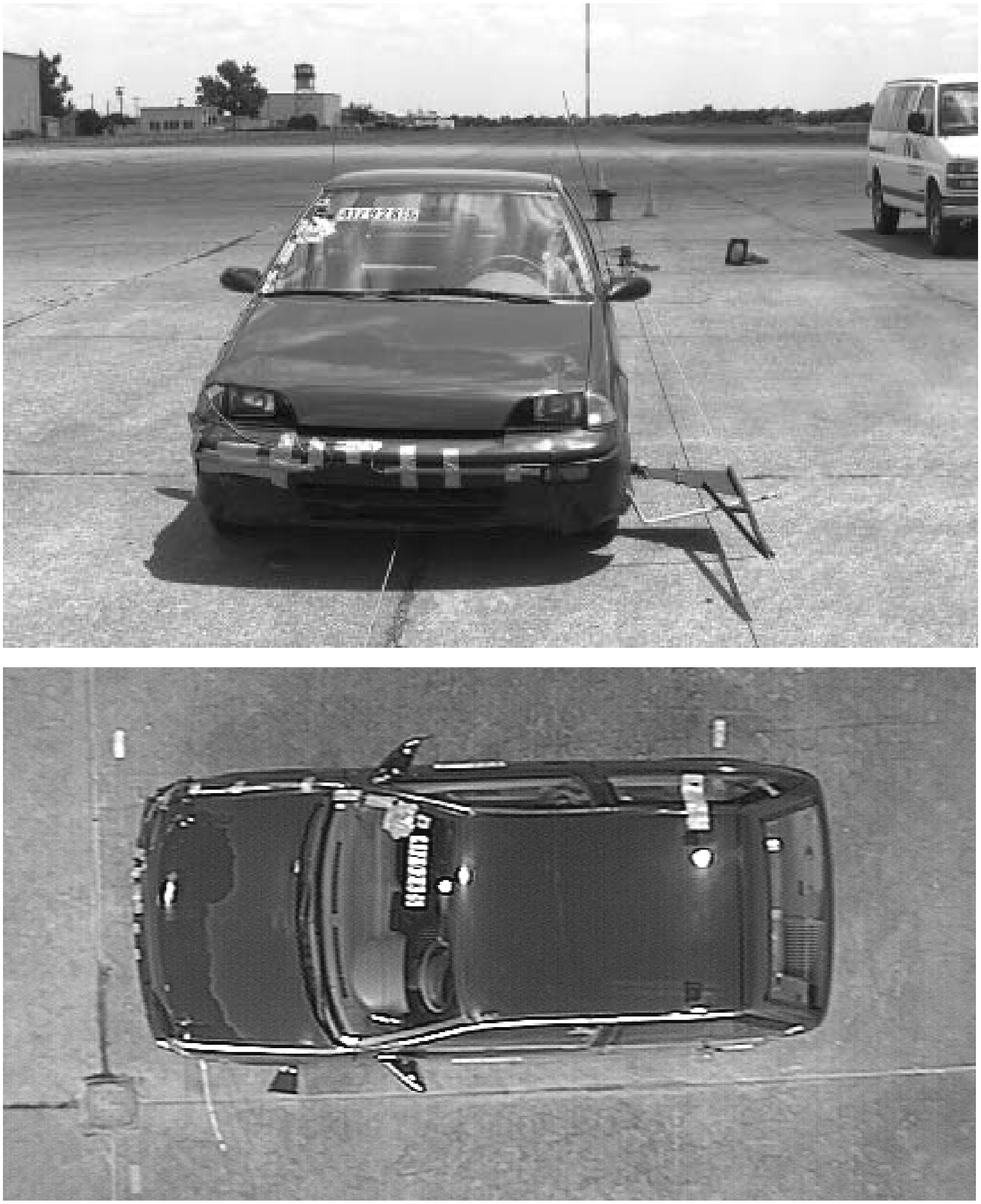


Figure 122. Vehicle before Test 417928-5.

Damage to Test Installation

The sign panel separated into two pieces, as shown in Figures 123 and 124. The two pieces of the sign and the posts came to rest 25.0 m (82.0 ft) from impact and 0.9 m (3.0 ft) to the right of impact.

Vehicle Damage

The vehicle received damage to the front, as shown in Figure 125. The vehicle received minor scrapes on the roof, dents in the bumper (not measurable), and shattered the windshield near the driver's side from contact with the sign panel. The interior of the vehicle is shown in Figure 126.

Assessment of Test Results

Figure 127 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The ground-mounted dual fiber reinforced plastic sign support pulled out of the ground and thereby met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

  The sign panel contacted the roof and cracked the windshield, but it did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred.

Figure 123. After Impact Trajectory for Test 417928-5.

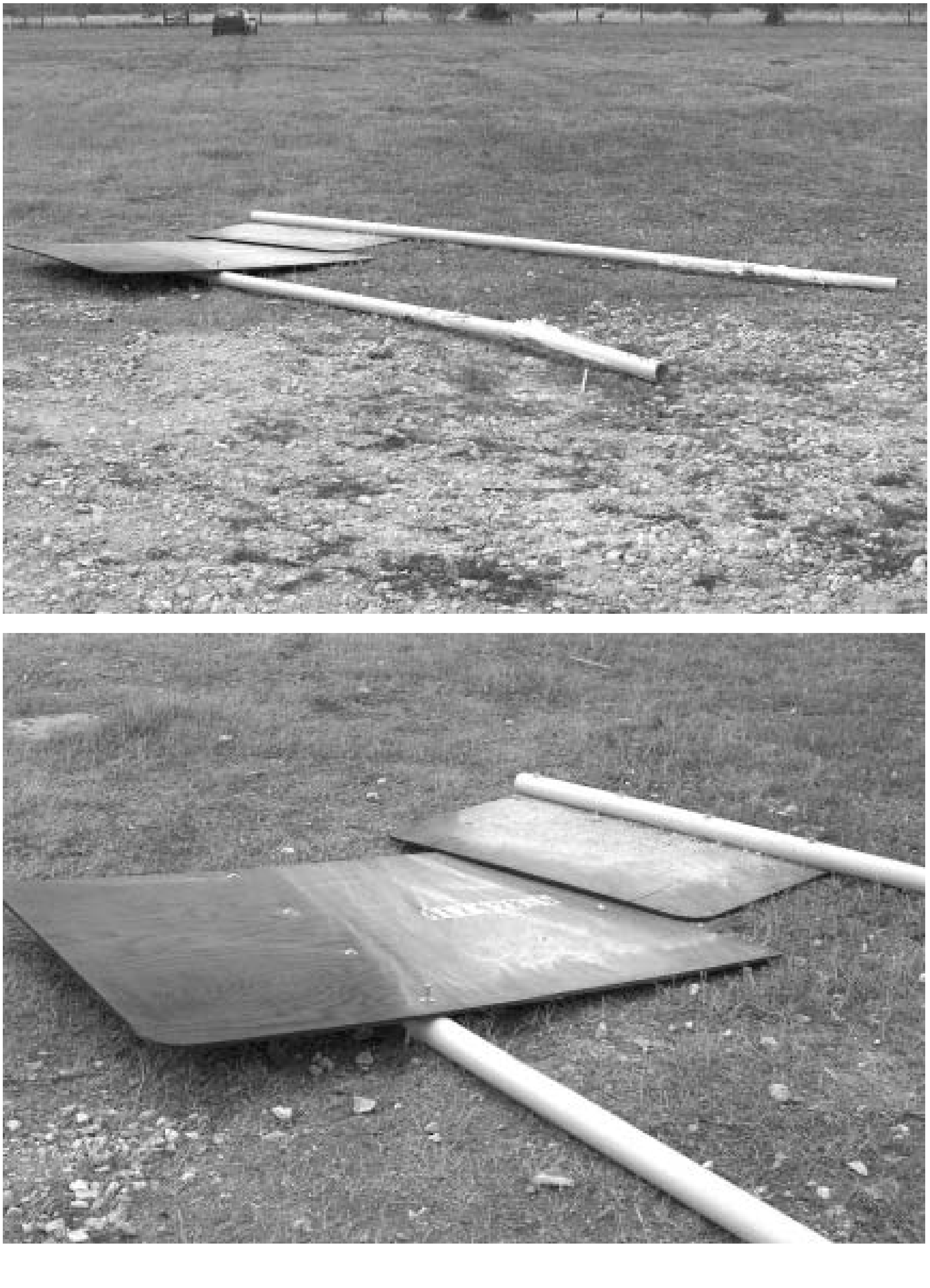


Figure 124. Installation after Test 417928-5.

Figure 125. Vehicle after Test 417928-5.

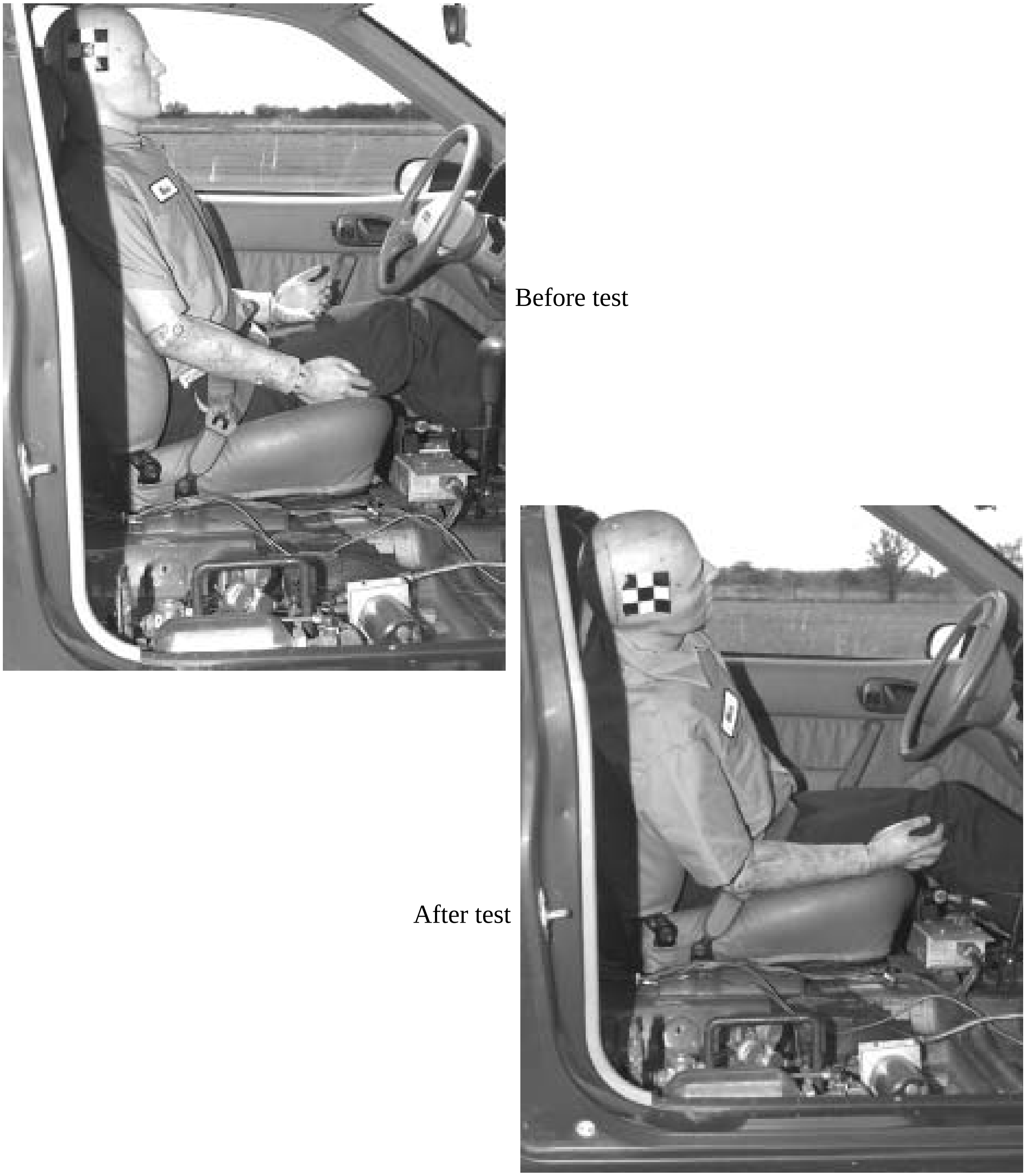
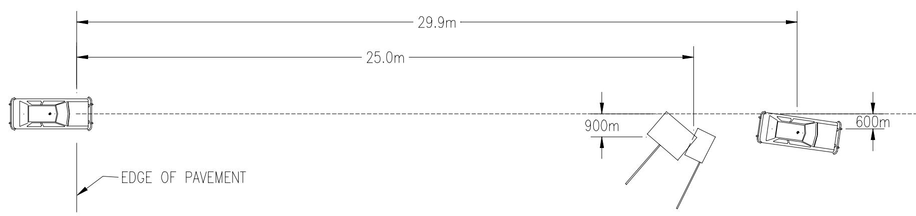
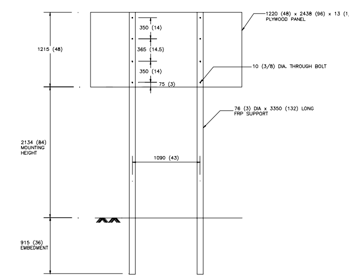


Figure 126. Interior of Vehicle for Test 417928-5.





General Information

Test Agency	Texas Transportation Institute
Test No.	417928-5
Date	06/25/98

Test Article

Type	Traffic Control Device
Name	Dual FRP Sign Support
Installation Length (m)	1.1 (3.6 ft)
Material or Key Elements	Dual FRP Posts, 2.1 m (7 ft) Tall w/ 1220x2438x13 mm (48x96x0.5 inch) Plywood Panel
Soil Type and Condition	Standard Soil, Dry

Test Vehicle

Type	Production
Designation	820C
Model	1993 Geo Metro
Mass (kg) Curb	779 (1717 lb)
Test Inertial	820 (1806 lb)
Dummy	76 (168 lb)
Gross Static	896 (1974 lb)

Impact Conditions

Speed (km/h)	98.6 (61.3 mi/h)
Angle (deg)	0

Exit Conditions

Speed (km/h)	97.4 (60.5 mi/h)
Angle (deg)	0

Occupant Risk Values

Impact Velocity (m/s)	
x-direction	1.1 (3.6 ft/s)
y-direction	No contact
THIV (km/h)	No contact
Ridedown Accelerations (g's)	
x-direction	0.5
y-direction	No contact
PHD (g's)	No contact
ASI	0.14
Max. 0.050-s Average (g's)	
x-direction	-1.5
y-direction	0.3
z-direction	-1.1

Test Article Debris Pattern (m)

Longitudinal	25.0 (82.0 ft)
Lateral	0.9 (3.0 ft)

Vehicle Damage

Exterior	
VDS	12FD1
CDC	12FDEW1
Maximum Exterior Vehicle Crush (mm)	nil
Interior	
OCDI	FS0000000
Max. Occ. Compart. Deformation (mm)	0

Post-Impact Behavior
(during 1.0 s after impact)

Max. Yaw Angle (deg)	2
Max. Pitch Angle (deg)	4
Max. Roll Angle (deg)	-1

Figure 127. Summary of Results for Test 417928-5, *NCHRP Report 350* Test 3-61.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

H. *Occupant impact velocities should satisfy the following:*

Longitudinal Occupant Impact Velocity - m/s	
Preferred	*Maximum*
3	*5*

I. *Occupant ridedown accelerations should satisfy the following:*

Longitudinal and Lateral Occupant Ridedown Accelerations - g's	
Preferred	*Maximum*
15	*20*

For criteria H and I, data from the accelerometer located at the vehicle center-of-gravity were digitized for evaluation of occupant risk and were computed as follows. In the longitudinal direction, the occupant impact velocity was 1.1 m/s (3.6 ft) at 0.549 s; the highest 0.010-s occupant ridedown acceleration was 0.5 g's from 0.796 to 0.806 s, and the maximum 0.050-s average acceleration -1.5 g's between 0 and 0.050 s. In the lateral direction, there was no contact. Vehicle angular displacements and vehicular accelerations versus time traces are presented in Appendix D, Figures 255 through 258.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

  Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

  Maximum change in velocity for this test was 0.3 m/s (1.0 ft/s).

Conclusion

The dual post, ground mounted FRP sign support system met *NCHRP Report 350* evaluation criteria for the high speed tests, test designation 3-61.

TEMPORARY SIGN SUPPORTS:
SHORT TERM PORTABLE SIGN SUPPORTS

Roll-up Sign in Dual-Purpose Base –
Test No. 417928-1 (*NCHRP Report 350* Test No. 3-71)

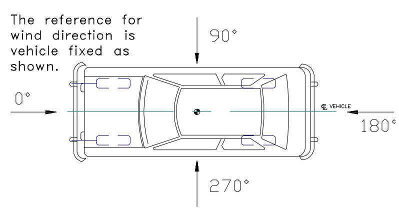
A roll-up vinyl sign on a single FRP sign support with a dual-purpose base, shown previously in Figure 13 and in Figure 128, was evaluated in this crash test. The bottom of the sign panel measured 305 mm (12.0 inch) above ground. The base of the sign support was ballasted with eight 7.6 kg (16.8 lb) sandbags.

Test Vehicle

A 1994 Geo Metro, shown in Figures 129 and 130, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 385 mm (15.2 inch), and it was 520 mm (20.5 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 216. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the morning of June 23, 1998. No rainfall occurred for the10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 2 km/h (1 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 32 °C (90 °F); relative humidity: 62 percent.



Test Description

The vehicle impacted the sign support head-on at a speed of 97.6 km/h (60.6 mi/h). At 0.019 s, the sign moved near bumper height of the vehicle, and at 0.029 s, the plastic sign post pulled out of the dual-purpose base. By 0.037 s, the post was completely separated from the base, and by 0.079 s, the top of the vinyl sign with the fiberglass stays contacted the center upper section of the windshield near the roof, shattering the windshield. The top of the plastic sign post contacted the bottom edge of the windshield and the upper section of the hood of the car at

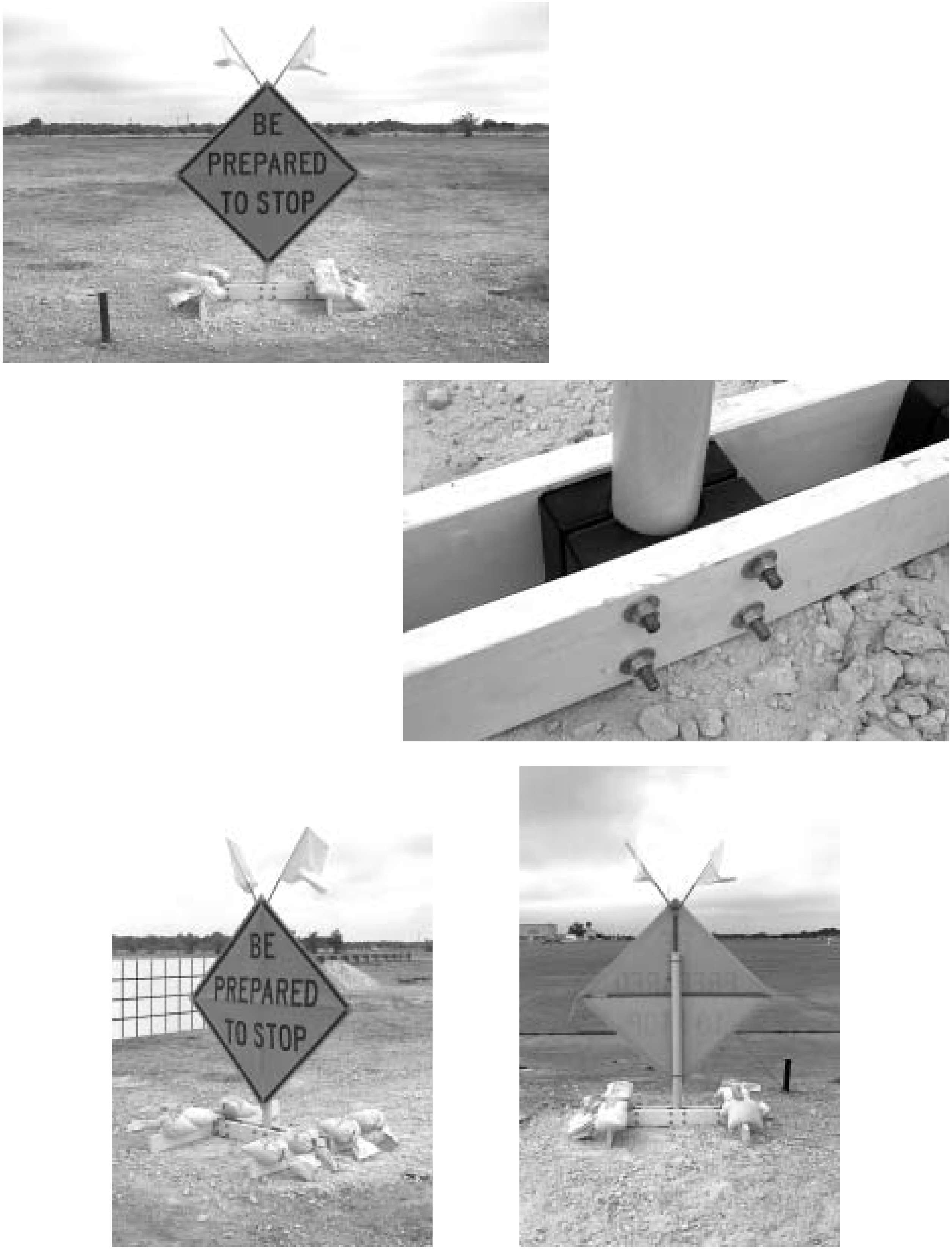


Figure 128. Installation before Test 417928-1.

Figure 129. Vehicle/Installation Geometrics for Test 417928-1.

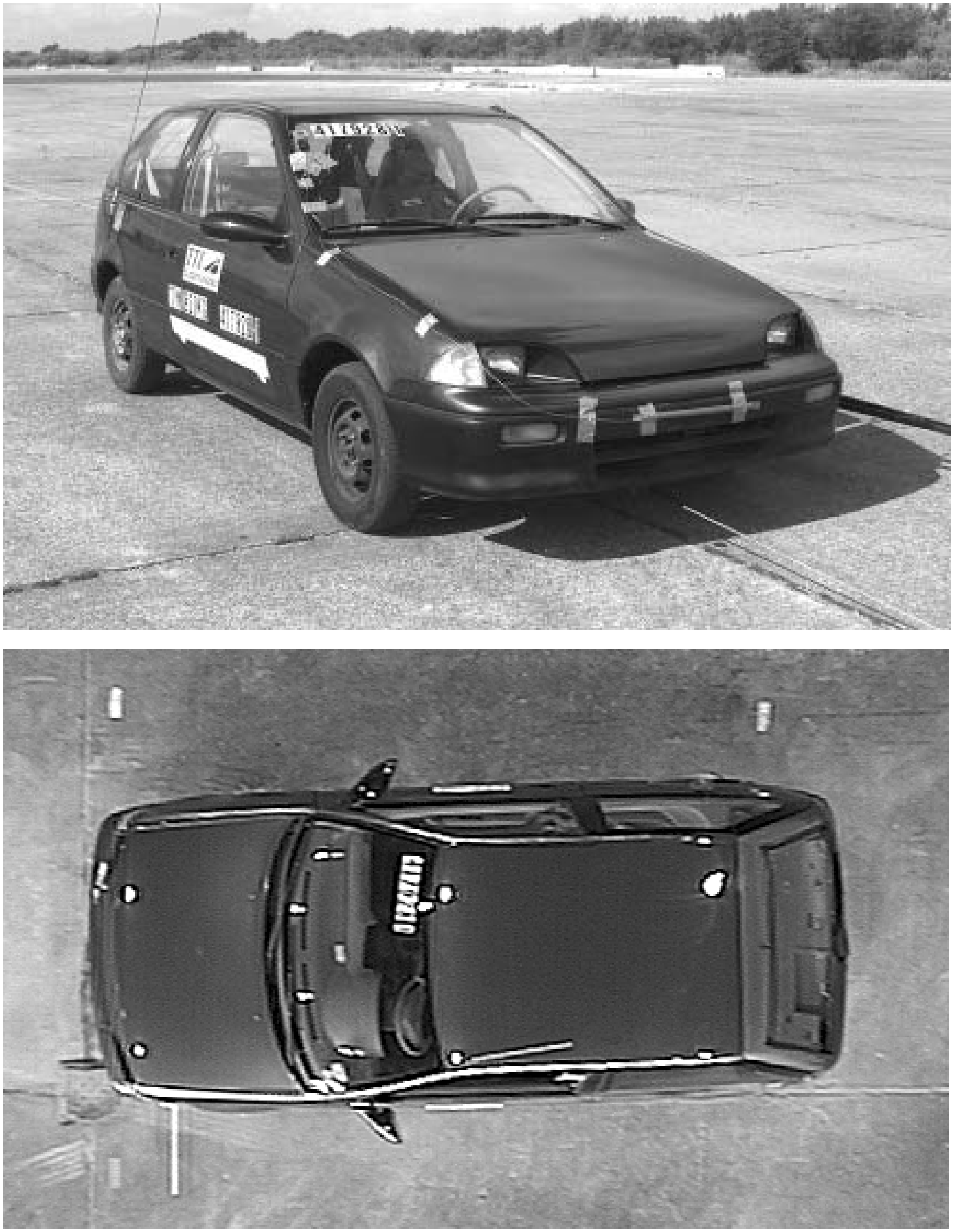


Figure 130. Vehicle before Test 417928-1.

0.084 s. At 0.092 s, the plastic sign post lost contact with the vehicle, and at 0.144 s, the fiberglass stays lost contact with the vehicle. The vehicle lost contact with the dual-purpose base at 0.221 s. At 0.304 s, the vehicle was traveling at 89.7 km/h (55.7 mi/h) as it lost contact with the barricade. Brakes on the vehicle were applied as it exited the test site, and the vehicle came to rest 87.5 m (287.1 ft) down and 2.7 m (8.9 ft) to the left of the impact point. Sequential photographs of the test can be found in Appendix C, Figure 239.

Damage to Test Installation

The roll-up vinyl sign panel and the upper tube separated from the dual-purpose base, as shown in Figures 131 and 132. The roll-up vinyl sign panel came to rest 25.3 m (83.0 ft) from impact and 1.8 m (5.9 ft) to the left of impact, while the support post came to rest 35.7 m (117.1 ft) further down and 4.6 m (15.1 ft) to the left of impact. The base was located 3.0 m (9.8 ft) downstream from impact.

Vehicle Damage

The vehicle received damage to the front as shown in Figure 133. The hood was deformed 30 mm × 190 mm × 5 mm (1.2 inch × 7.5 inch × 0.2 inch) deep, and the left rear rim of the tire was damaged. The windshield was shattered by the FRP post near the roof edge at the center. The interior of the vehicle is shown in Figure 134.

Assessment of Test Results

Figure 135 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The single FRP sign support pulled out of the dual-purpose base and thereby met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

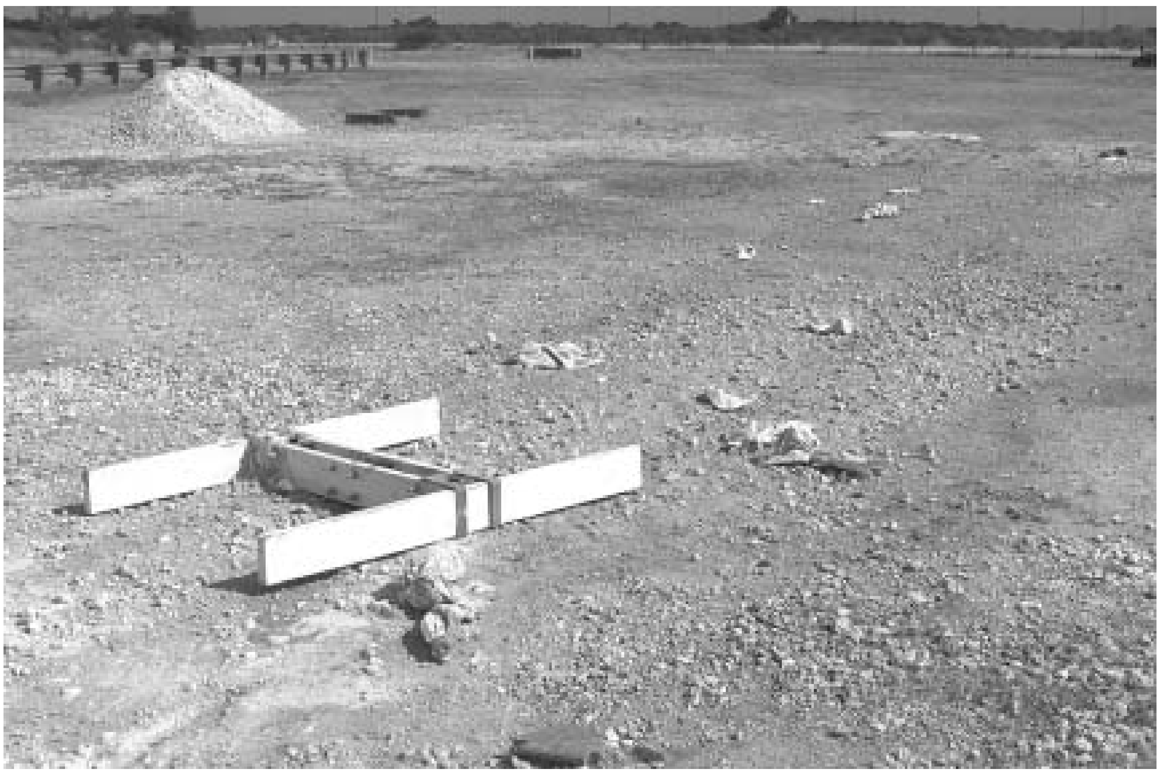


Figure 131. After Impact Trajectory for Test 417928-1.

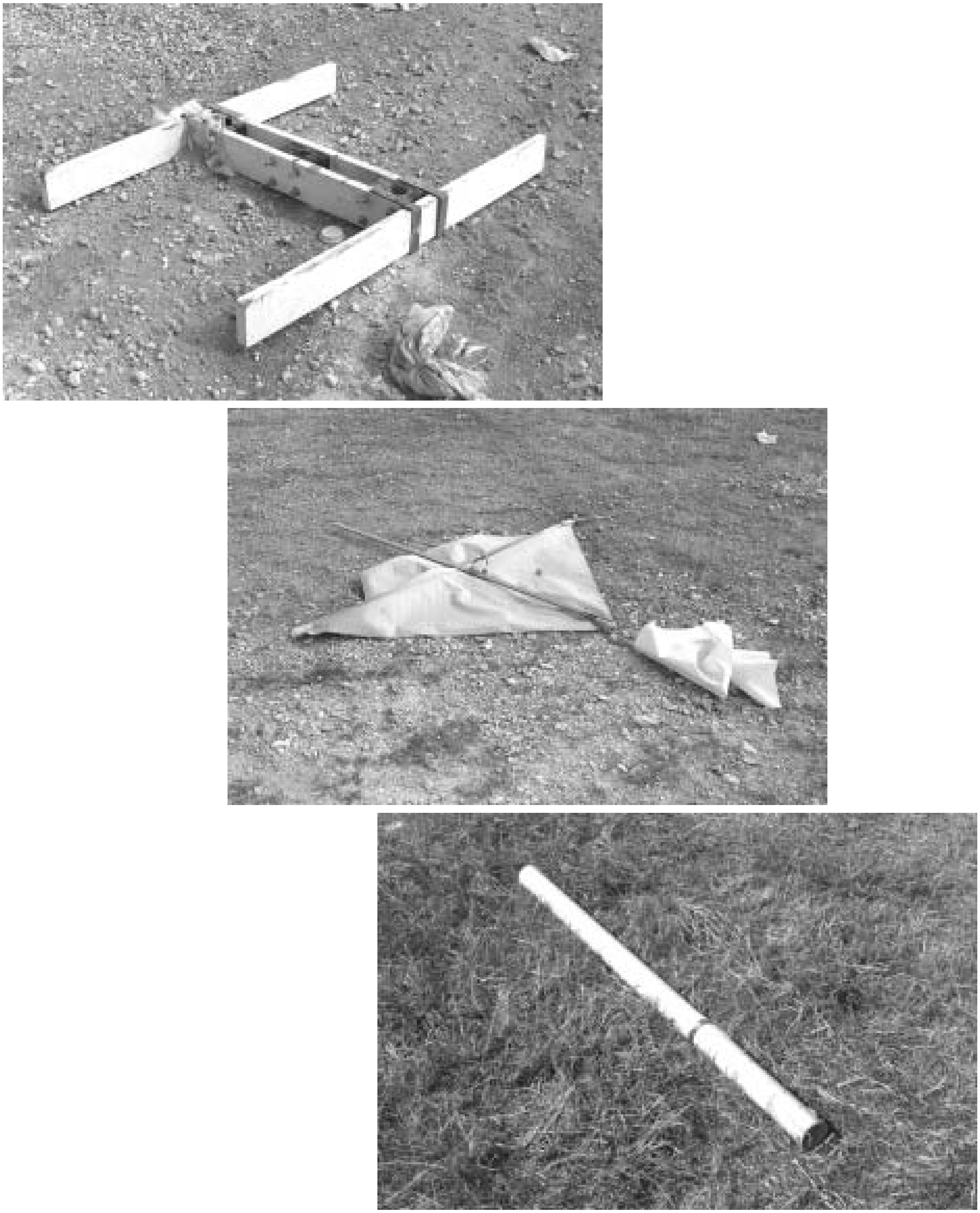


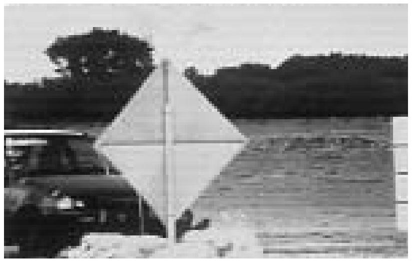
Figure 132. Installation after Test 417928-1.

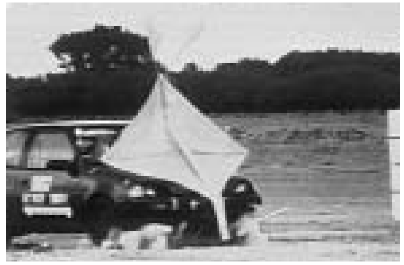
Figure 133. Vehicle after Test 417928-1.

Before test

After test

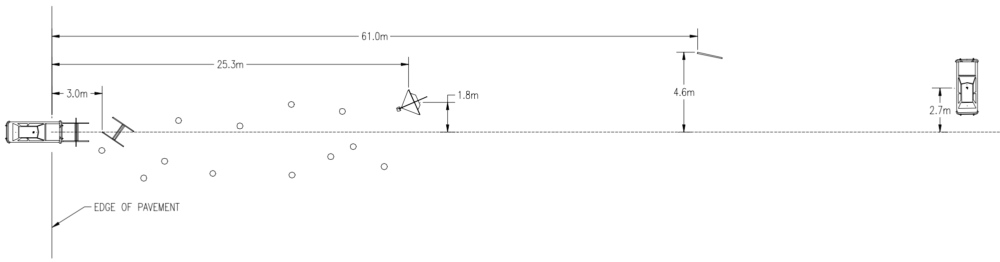
Figure 134. Interior of Vehicle for Test 417928-1.

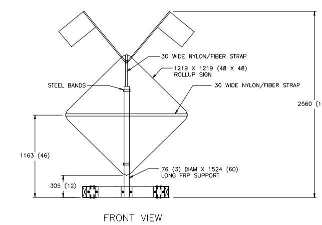

0.000 s


0.049 s


0.099 s


0.222 s





General Information
- Test Agency . . . . Texas Transportation Institute
- Test No. 417928-1
- Date 06/23/98

Test Article
- Type . . . . Traffic Control Device
- Name . . . . Roll-up Sign in Dual-Purpose Base
- Installation Length (m) . . . . . . 1.1 (3.6 ft)
- Material or Key Elements . . . . Roll-up Sign, Single FRP Post in Dual Purpose Base

Soil Type and Condition . . . . . . Standard Soil, Dry

Test Vehicle
- Type . . . . Production
- Designation 820C
- Model . . . . 1994 Geo Metro
- Mass (kg) Curb . . . . 798 (1759 lb)
  - Test Inertial . . . . 820 (1806 lb)
  - Dummy . . . . 76 (168 lb)
  - Gross Static . . . . 896 (1974 lb)

Impact Conditions
- Speed (km/h) . . . . 97.6 (60.6 mi/h)
- Angle (deg) 0

Exit Conditions
- Speed (km/h) . . . . 89.7 (55.7 mi/h)
- Angle (deg) 0

Test Article Debris Pattern (m)
- Longitudinal . . . . 61.0 (200.1 ft)
- Lateral . . . . 4.6 (15.1 ft)

Vehicle Damage
- Exterior
  - VDS 12FD1
  - CDC 12FDEW1
- Maximum Exterior
  - Vehicle Crush (mm) . . . . . . nil
- Interior
  - OCDI FS0000000
- Max. Occ. Compart.
  - Deformation (mm) 0

Figure 135. Summary of Results for Test 417928-1, *NCHRP Report 350* Test 3-71.

The fiberglass stay shattered the windshield which deformed inward slightly, but it did not penetrate the occupant compartment, nor did it present undue hazard to others in the area. Minimal deformation (windshield) of the occupant compartment occurred.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 2.22 m/s (7.3 ft/s).

Conclusion

The FRP sign support with roll-up sign panel was judged to be marginally acceptable. The contact of the sign with the windshield caused shattering and slight inward deformation of the windshield.

PVC Easel Support –
Test No. 417929-2 (*NCHRP Report 350* Test No. 3-71)

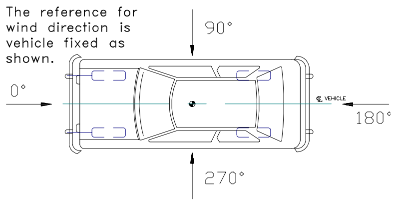
A PVC portable easel sign support with a 1720 mm × 1715 mm (67.7 inch × 67.5 inch) fiberglass sign panel mounted at 0.3 m (1.0 ft) above the ground, shown previously in Figure 14 and in Figure 136, was evaluated in this crash test. The weight of the barricade was 13 kg (28.7 lb).

Test Vehicle

A 1994 Geo Metro, shown in Figures 137 and 138, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 385 mm (15.2 inch), and it was 470 mm (18.5 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 221. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the afternoon of November 3, 1998. A total of 41 mm (1.6 inch) of rain was recorded nine days prior to the test but would not affect the test as the barricade was installed on the ground surface. No other rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 13 km/h (8 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 16 °C (61 °F); relative humidity: 72 percent.



Test Description

The vehicle impacted the barricade head-on at a speed of 100.7 km/h (62.6 mi/h). Shortly after impact, the front legs of the sign moved. By 0.007 s, the front legs broke away, and by 0.010 s, the legs had completely separated from the rubber base. At 0.019 s, the front tires rode up on the base, and at 0.022 s, the outside of the front tires of the vehicle lightly contacted the remaining tubing in the base. The rubber base allowed the PVC tubing to bend outward allowing the front tires to pass through the installation. The rear PVC support tubing pulled out of the base at 0.029 s, and by 0.046 s the rear PVC pulled out of the base. At 0.058 s, the rear PVC tube front contacted the front bumper and hood, and at 0.063 s the rear PVC shattered at the joint. By

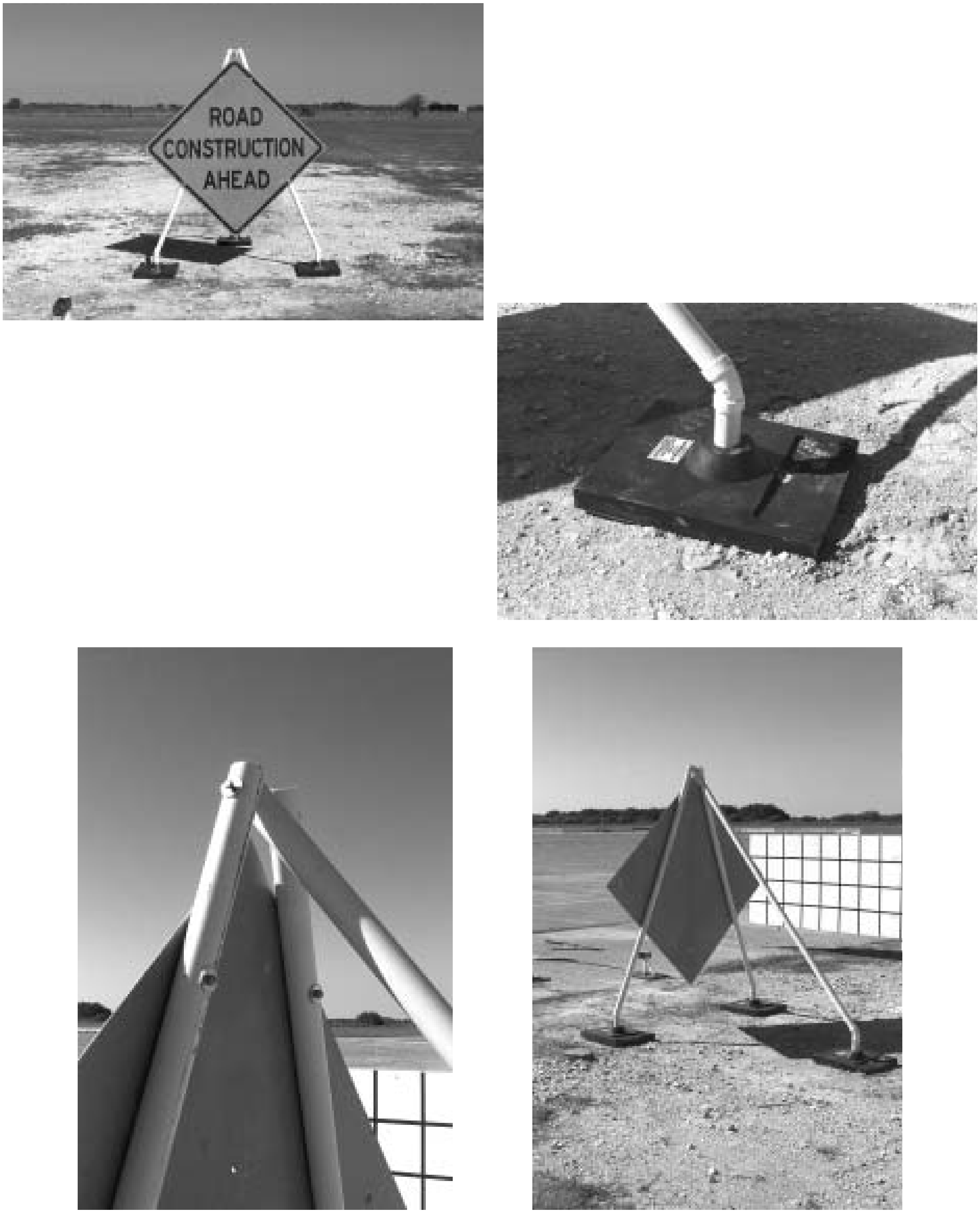


Figure 136. Installation before Test 417929-2.

Figure 137. Vehicle/Installation Geometrics for Test 417929-2.

Figure 138. Vehicle before Test 417929-2.

0.079 s, the sign panel lightly contacted the top of the roof above the windshield and fell, and by 0.102 s, the rear tires contacted the front bases. At 0.114 s, the remaining PVC tubing on the right side support base shattered from contact with the right rear tire. At 0.121 s, the sign panel and PVC legs lost contact with the vehicle. At 0.133 s, the vehicle was traveling at 98.7 km/h (61.3 mi/h) as the vehicle lost contact with the first two support bases, while the vehicle did not contact the third support base. Brakes on the vehicle were applied as it exited the test site. The vehicle came to rest 115.1 m (377.6 ft) downstream of impact. Sequential photographs of the test can be found in Appendix C, Figure 240.

Damage to Test Installation

The upright portion of the barricade remained in one piece and came to rest 9.1 m (30.0 ft) from impact as shown, in Figures 139 and 140. The PVC tube broke off from the front two rubber bases; the base on the left had a stub that measured 128 mm (5.0 inch), and the one on the right measured 45 mm (1.8 inch), while the rear fitting was totally extracted from the base.

Vehicle Damage

The front of the vehicle received damage, as shown in Figure 141. There was a small dent in the hood (not measurable) and scuff marks on the hood and roof of the vehicle. The interior of the vehicle is shown in Figure 142.

Assessment of Test Results

Figure 143 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The PVC portable sign support, supplied by Young Contractor's Inc., with a 1720 mm × 1715 mm (67.7 inch ×67.5 inch) fiberglass sign panel met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of,*

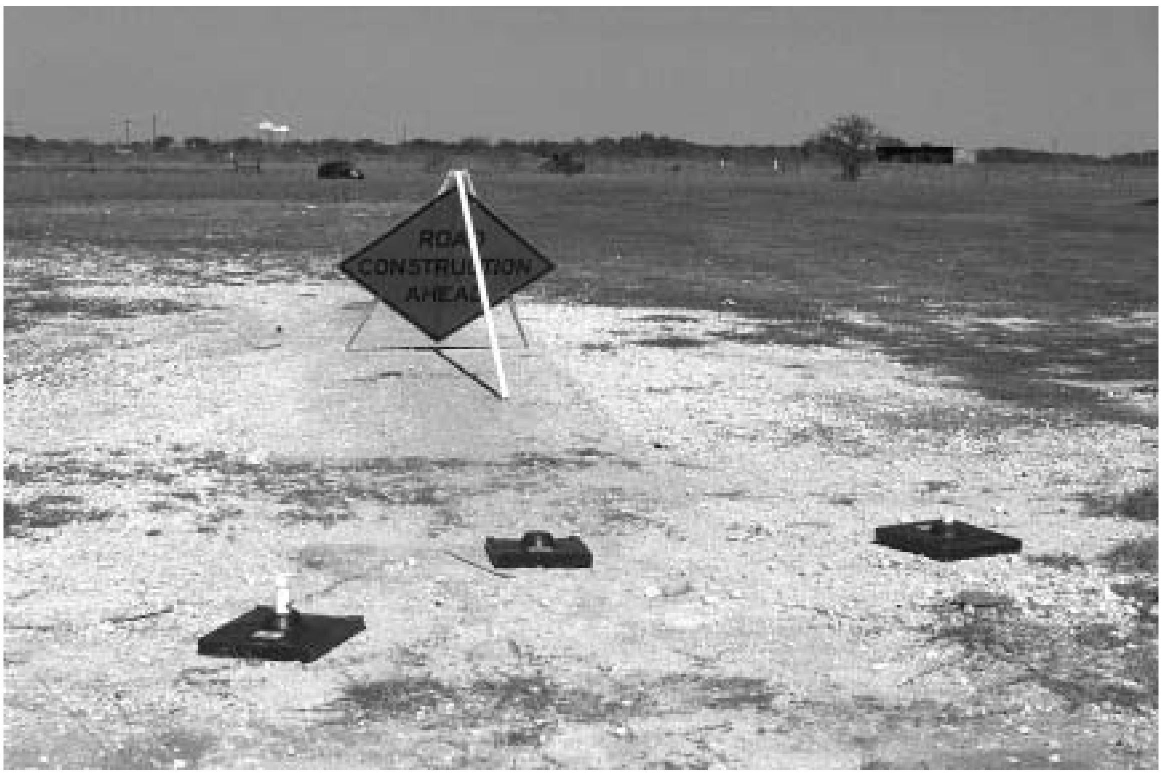


Figure 139. After Impact Trajectory for Test 417929-2.

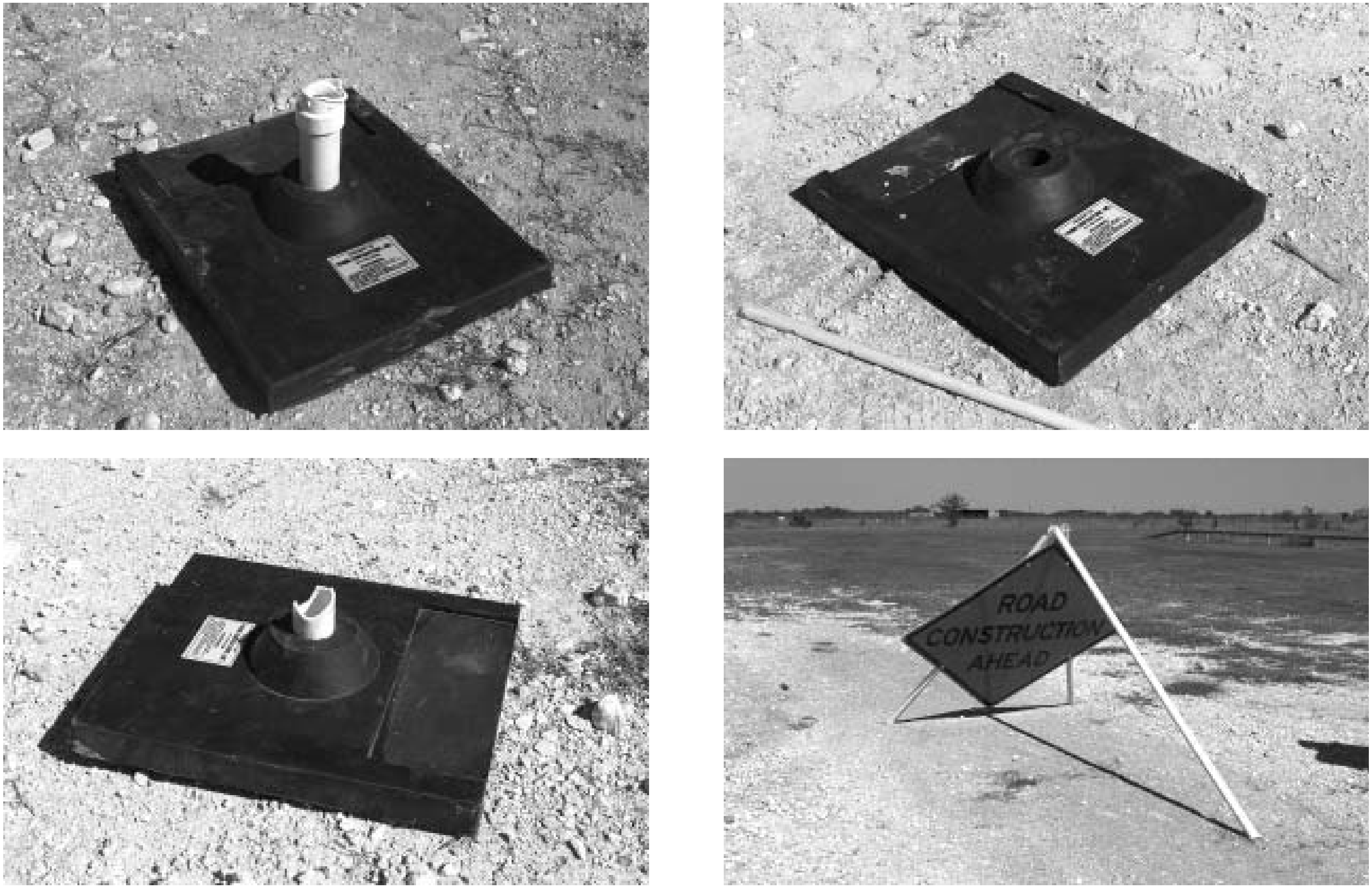


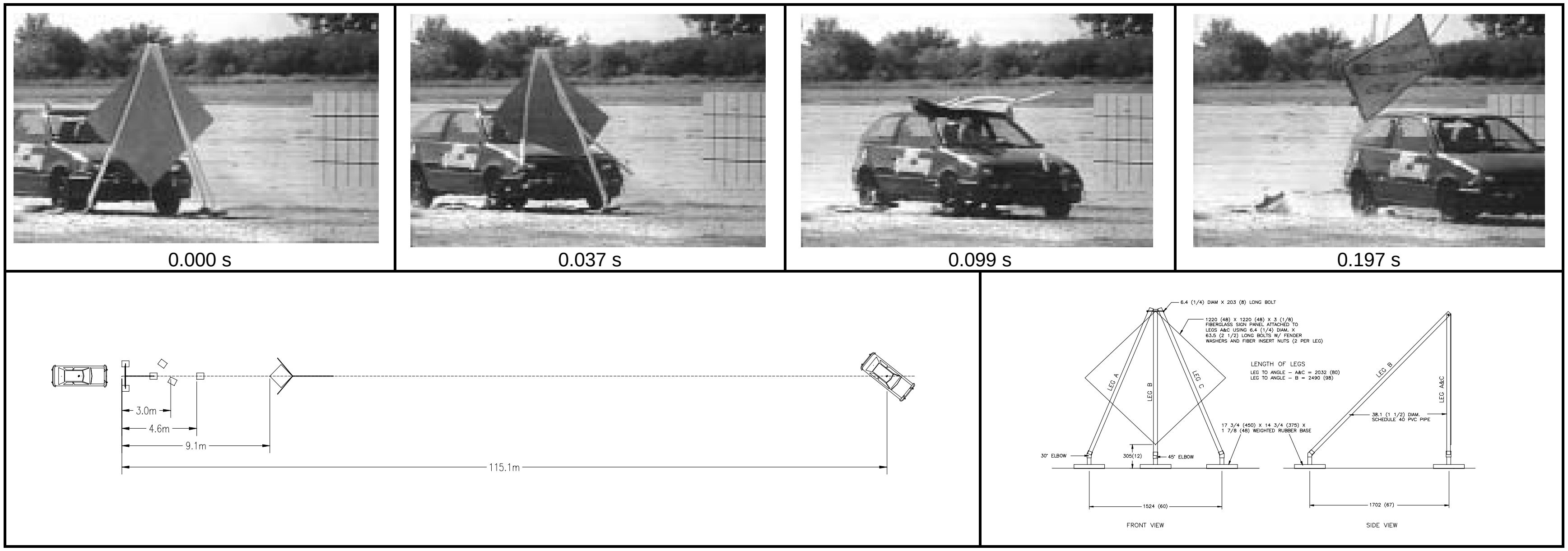
Figure 140. Installation after Test 417929-2.

Figure 141. Vehicle after Test 417929-2.

Before test

After test

Figure 142. Interior of Vehicle for Test 417929-2.



General Information

Test Agency	Texas Transportation Institute
Test No.	417929-2
Date	11/3/98

Test Article

Type	Traffic Control Device
Name	PVC Easel Support
Installation Length (m)	1.9 (6.2 ft)
Material or Key Elements	Rubber Base w/ PVC Post w/ 1720x1715 mm (67.7x67.5 inch) Sign Panel

Soil Type and Condition .... Standard Soil, Dry

Test Vehicle

Type	Production
Designation	820C
Model	1994 Geo Metro
Mass (kg)	
Curb	769 (1695 lb)
Test Inertial	820 (1806 lb)
Dummy	75 (165 lb)
Gross Static	895 (1973 lb)

Impact Conditions

Speed (km/h)	100.7 (62.6 mi/h)
Angle (deg)	0

Exit Conditions

Speed (km/h)	98.7 (61.3 mi/h)
Angle (deg)	0

Test Article Debris Pattern (m)

Longitudinal	9.1 (30.0 ft)
Lateral	0

Vehicle Damage

Exterior	
VDS	12FC1
CDC	12FCEN1
Maximum Exterior Vehicle Crush (mm)	nil
Interior	
OCDI	FS0000000
Max. Occ. Compart. Deformation (mm)	0

Figure 143. Summary of Results for Test 417929-2, *NCHRP Report 350* Test 3-71.

or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.

The sign support did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

None of the detached elements or vehicle damage would block the driver's vision nor cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 0.6 m/s (2.0 ft/s).

Conclusion

The PVC easel sign stand with FRP sign panel met all *NCHRP Report 350* evaluation criteria for test designation 3-71 when impacted in a 0-degree, head-on configuration.

Wood Sign Support in H-Leg Base –
Test No. 417928-12 (*NCHRP Report 350* Test No. 3-71)

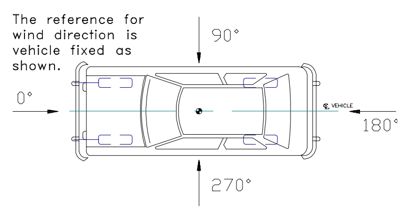
A single wooden H-leg sign support with a 914 mm × 914 mm ×13 mm (36 inch × 36 inch × 0.5 inch) plywood sign panel mounted at 0.3 m (1.0 ft) above the ground, shown previously in Figure 15 and in Figure 144, was evaluated in this crash test. The base of the sign support was ballasted with two 7.6 kg (16.8 lb) sandbags.

Test Vehicle

A 1993 Geo Metro, shown in Figures 145 and 146, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 370 mm (14.6 inch), and it was 510 mm (20.0 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 222. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the afternoon of July 8, 1998. A total of 35 mm (1.4 inch) of rain was recorded eight days prior to the test but would not affect the test as the barricade was installed on the ground surface. No other rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed ,was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 3 km/h (2 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 34 °C (93 °F); relative humidity: 61 percent.



Test Description

The vehicle impacted the sign support head-on at a speed of 101.7 km/h (63.2 mi/h). At 0.004 s, the bumper contacted the sandbags, and at 0.014 s, the bumper of the vehicle contacted the sign support. The sign panel separated from the post at 0.017 s, and at 0.019 s, the sign post fractured. The sign panel and post completely separated from the base at 0.029 s and 0.034 s, respectively. At 0.044 s, the sign panel contacted the hood of the vehicle, and at 0.051 s, the sign post contacted the vehicle. By 0.054 s, the windshield shattered by contact from the sign post,

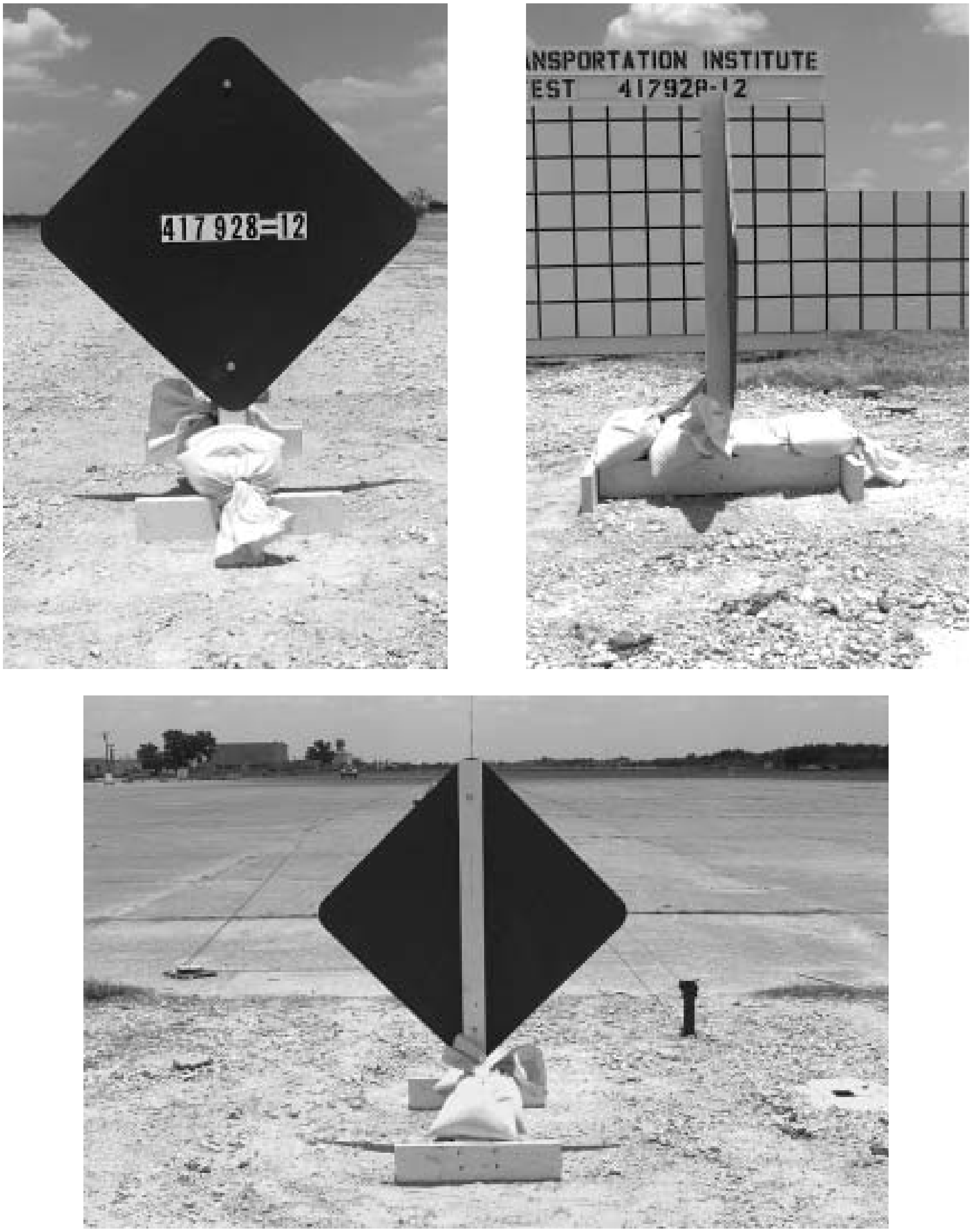


Figure 144. Installation before Test 417928-12.

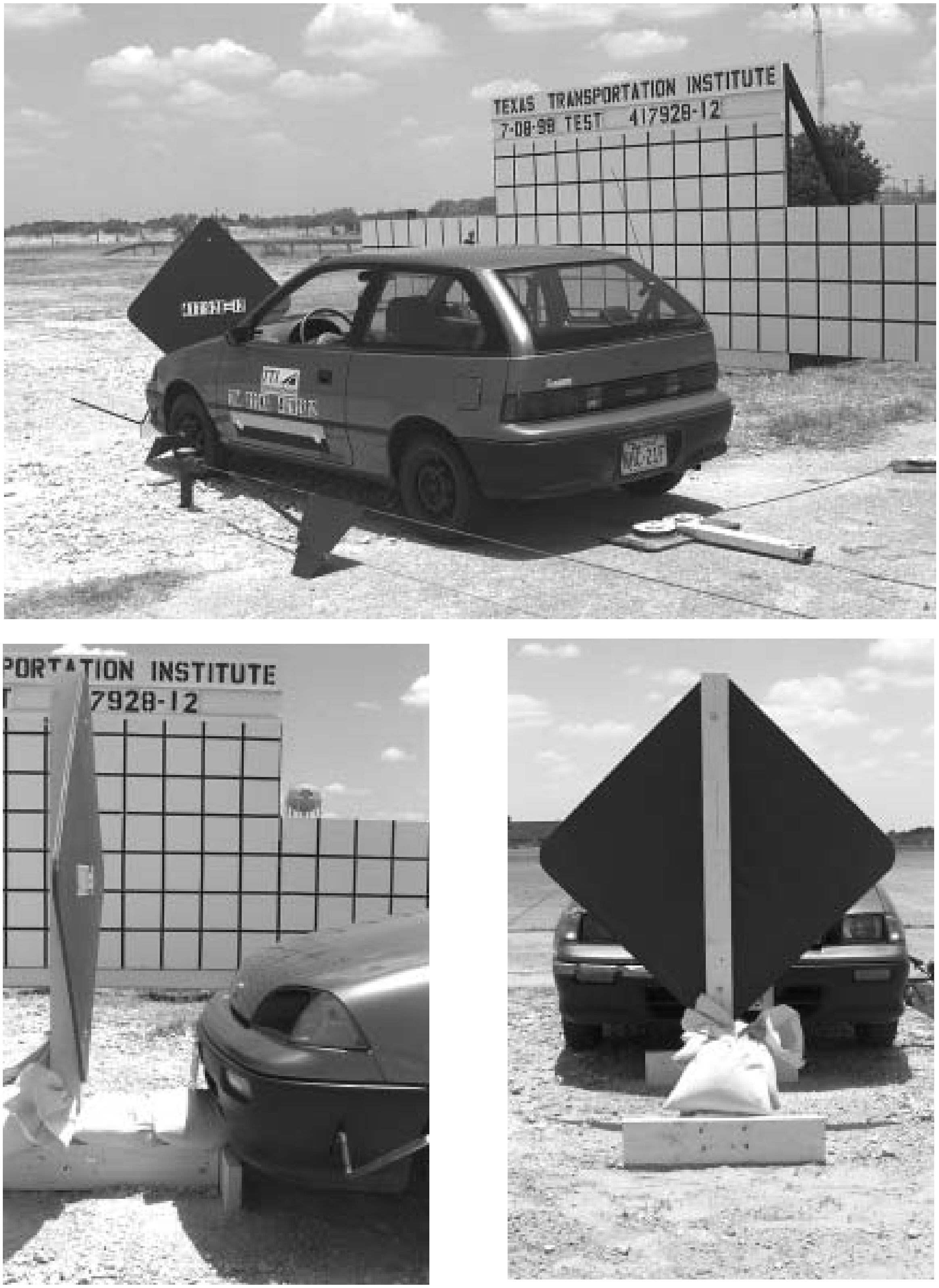


Figure 145. Vehicle/Installation Geometrics for Test 417928-12.

Figure 146. Vehicle before Test 417928-12.

and by 0.171 s, the entire sign rotated up and over the vehicle. The vehicle was traveling at 91.7 km/h (57.0 mi/h) with the sign support still in contact with vehicle as the vehicle exited the test site. Brakes on the vehicle were applied as the vehicle exited the test site, and the vehicle came to rest 90.7 m (297.6 ft) down and slightly tilted to the left of the impact point. Sequential photographs of the test can be found in Appendix C, Figure 241.

Damage to Test Installation

The sign support separated into multiple pieces, as shown in Figures 147 and 148. The debris extended 44.2 m (145.0 ft) down, 6.1 m (20.0 ft) to the left, and 1.9 m (6.2 ft) to the right of the impact point.

Vehicle Damage

The windshield of the vehicle shattered from the impact of the post, as shown in Figure 149. The hood, bumper, and radiator support were also damaged. The interior of the vehicle is shown in Figure 150.

Assessment of Test Results

Figure 151 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The single wooden H-leg sign support with a 914 mm × 914 mm ×13 mm (36 inch ×36 inch ×0.5 inch) plywood sign panel mounted met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

Figure 147. After Impact Trajectory for Test 417928-12.

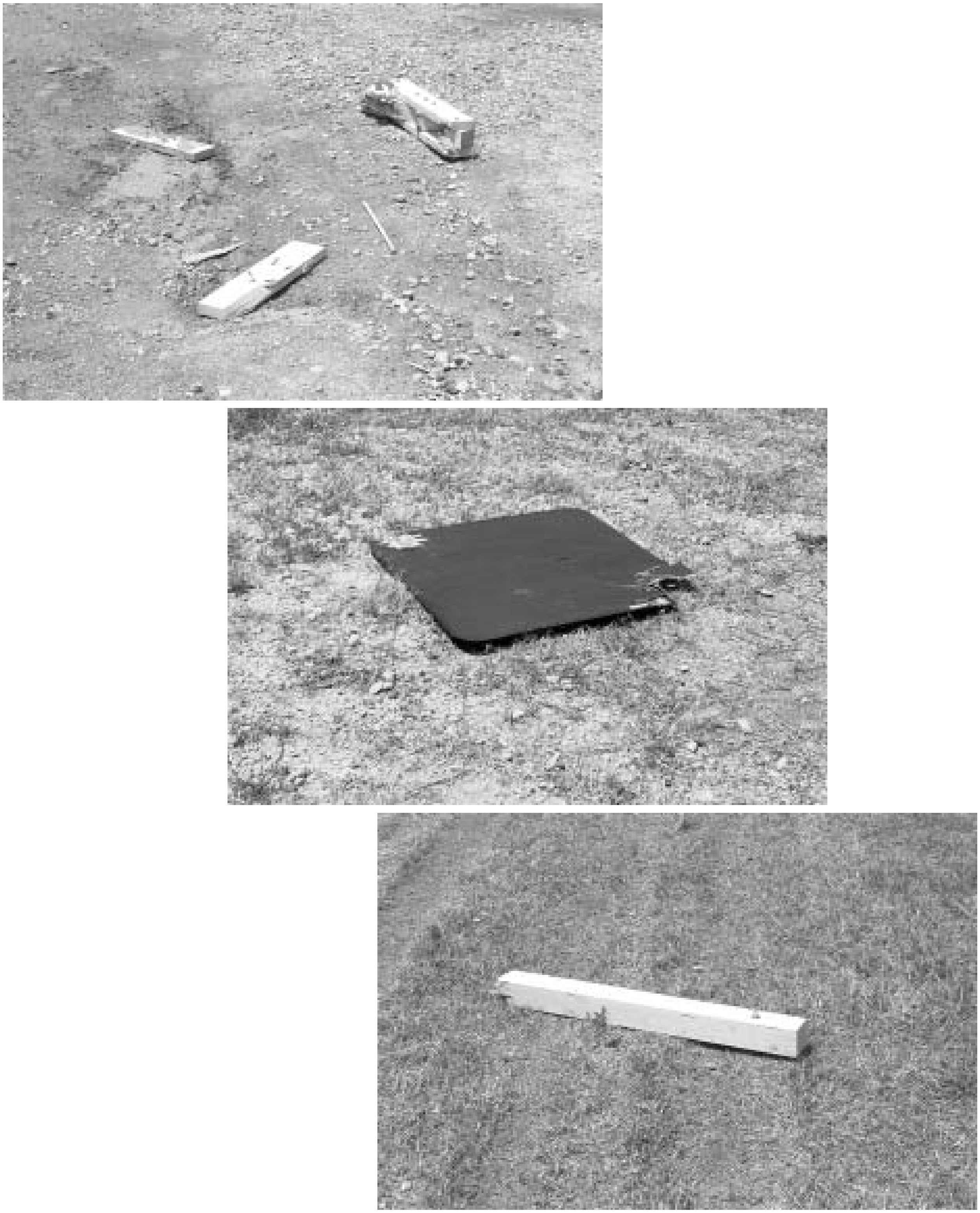


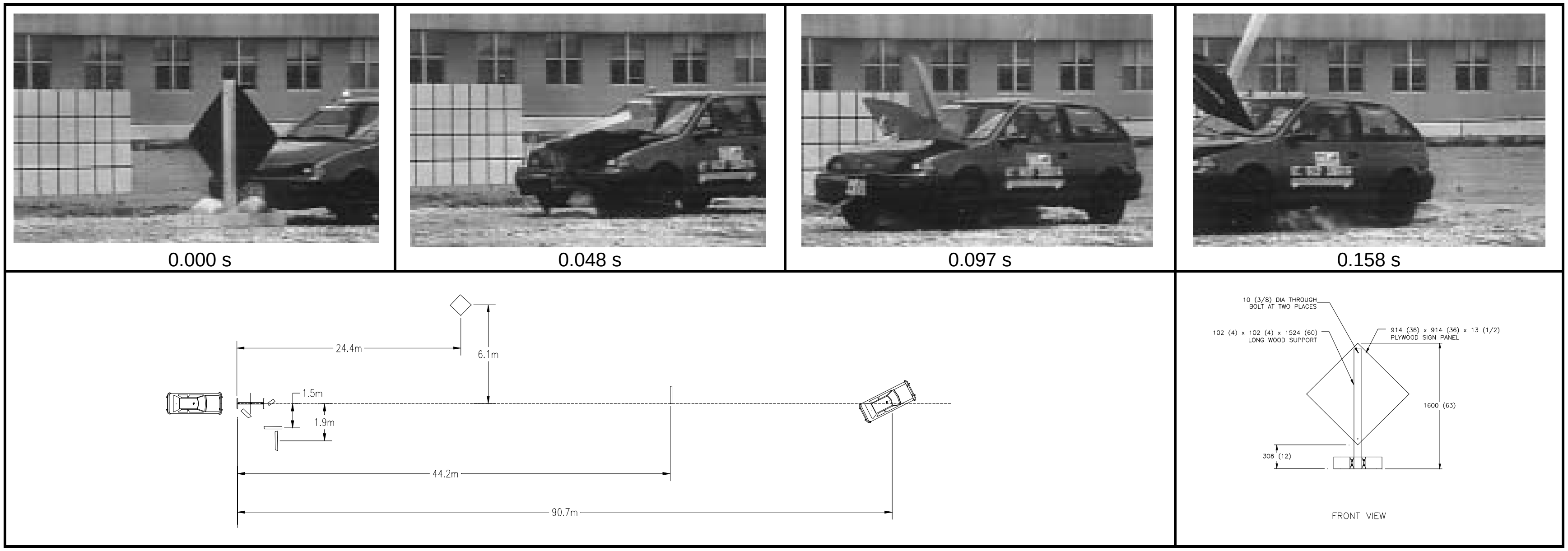
Figure 148. Installation after Test 417928-12.

Figure 149. Vehicle after Test 417928-12.

Before test

After test

Figure 150. Interior of Vehicle for Test 417928-12.



General Information

Test Agency	Texas Transportation Institute
Test No.	417928-12
Date	07/08/98

Test Article

Type	Traffic Control Device
Name	Wood Sign Support in H-Leg Base
Installation Length (m)	0.6
Material or Key Elements	Single H-Leg Wooden Support w/ 914x914x13 mm (36x36x0.5 inch) Plywood Sign

Soil Type and Condition ...... Standard Soil, Dry

Test Vehicle

Type		Production
Designation		820C
Model		1993 Geo Metro
Mass (kg)	Curb	734 (1618 lb)
	Test Inertial	820 (1806 lb)
	Dummy	76 (168 lb)
	Gross Static	896 (1974 lb)

Impact Conditions

Speed (km/h)	101.7 (63.2 mi/h)
Angle (deg)	0

Exit Conditions

Speed (km/h)	91.7 (57.0 mi/h)
Angle (deg)	0

Test Article Debris Pattern (m)

Longitudinal	44.2 (145.0 ft)
Lateral	6.1 (20.0 ft)

Vehicle Damage

Exterior	
VDS	12FD2
CDC	12FDEW2
Maximum Exterior Vehicle Crush (mm)	nil
Interior	
OCDI	FS0000000
Max. Occ. Compart. Deformation (mm)	0

Figure 151. Summary of Results for Test 417928-12, *NCHRP Report 350* Test 3-71.

The sign support penetrated the occupant compartment and deformed the roof.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

The vehicle damage would not block the driver's vision but may cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 2.8 m/s (9.2 ft/s).

Conclusion

The temporary wooden sign support with 914 mm × 914 mm (36 inch × 36 inch) plywood sign panel failed to meet *NCHRP Report 350* evaluation criterion D, and is thus considered to be unacceptable.

Hollow Profile Plastic Sign Support in H-Leg Base (0.9 m × 0.9 m [3 ft × 3 ft] plywood panel - 0.3 m [1 ft] mounting height) – Test No. 417928-13 (*NCHRP Report 350* Test No. 3-71)

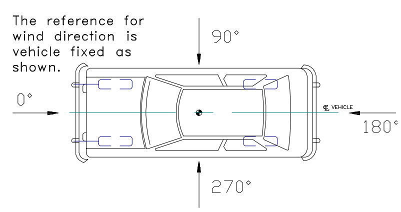
A single wooden H-leg base with a hollow core plastic sign support with a 915 mm × 915 mm × 13 mm (36 inch × 36 inch × 0.5 inch) plywood sign panel mounted 0.3 m (1.0 ft) above the ground, shown previously in Figure 16 and in Figure 152, was evaluated in this crash test. The base of the sign support was ballasted with two 7.6 kg (16.8 lb) sandbags.

Test Vehicle

A 1994 Geo Metro, shown in Figures 153 and 154, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 395 mm (15.6 inch), and it was 535 mm (21.1 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 219. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the morning of July 10, 1998. A total of 26 mm (1.0 inch) of rain was recorded 10 days prior to the test but would not affect the test as the barricade was installed on the ground surface. No other rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 5 km/h (3 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 34 °C (93 °F); relative humidity: 58 percent.



Test Description

The vehicle impacted the sign support head-on at a speed of 97.1 km/h (60.3 mi/h). At 0.007 s, the bottom of the bumper contacted the sandbags, and at 0.017 s, the vehicle's bumper contacted the plastic post and sign panel. By 0.019 s, the sign support moved, and by 0.022 s, the bumper of the vehicle contacted the post at the lower base connection. The top of the sign panel separated from the post at 0.032 s, and the sign panel contacted the hood of the vehicle at 0.044 s. The plastic post lost contact with the bumper at 0.068 s, while the lower section of the plastic post was under the vehicle. The sign panel lost contact with the hood of the vehicle and traveled with the vehicle parallel with the hood at 0.105 s. The plastic post lost contact with the

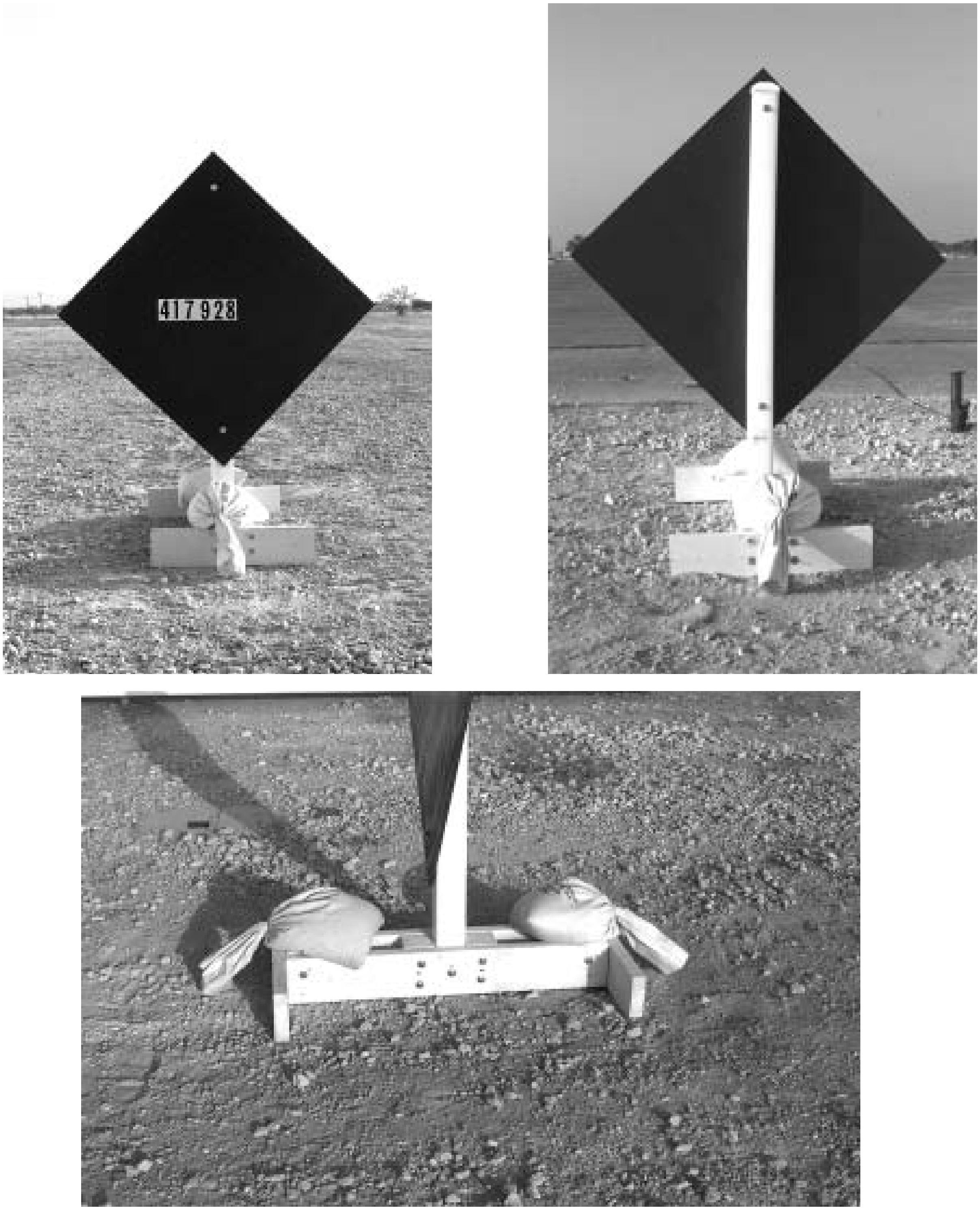


Figure 152. Installation before Test 417928-13.

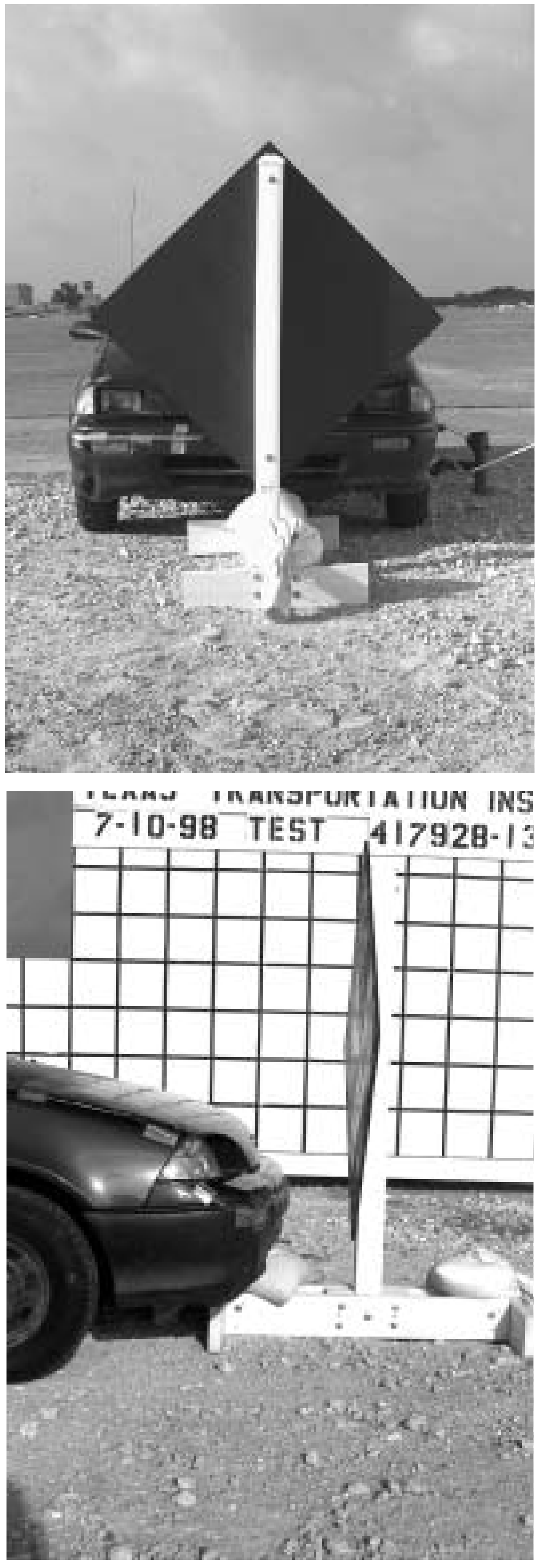


Figure 153. Vehicle/Installation Geometrics for Test 417928-13.

Figure 154. Vehicle before Test 417928-13.

vehicle and fell to the ground underneath the front vehicle bumper at 0.149 s. The vehicle was traveling at 92.4 km/h (57.4 mi/h) with the sign support still in contact, as the vehicle exited the test site. Brakes on the vehicle were applied as it exited the test site, and the vehicle came to rest 88.4 m (290.0 ft) from the impact point. Sequential photographs of the test can be found in Appendix C, Figure 242.

Damage to Test Installation

The sign support separated into several pieces, as shown in Figures 155 and 156. A large portion of the base stayed at the impact point, and the sign panel and plastic post were further downstream. The debris extended 32.7 m (107.3 ft) down and 2.3 m (7.5 ft) to the left of the impact point.

Vehicle Damage

The vehicle received damage to the hood and bumper, as shown in Figure 157. The windshield was shattered, and the radiator support was damaged. The interior of the vehicle is shown in Figure 158.

Assessment of Test Results

Figure 159 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The single wooden H-leg base with a hollow profile plastic sign support with a 915 mm × 915 mm ×13 mm (36 inch × 36 inch ×0.5 inch) plywood sign panel met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

Figure 155. After Impact Trajectory for Test 417928-13.

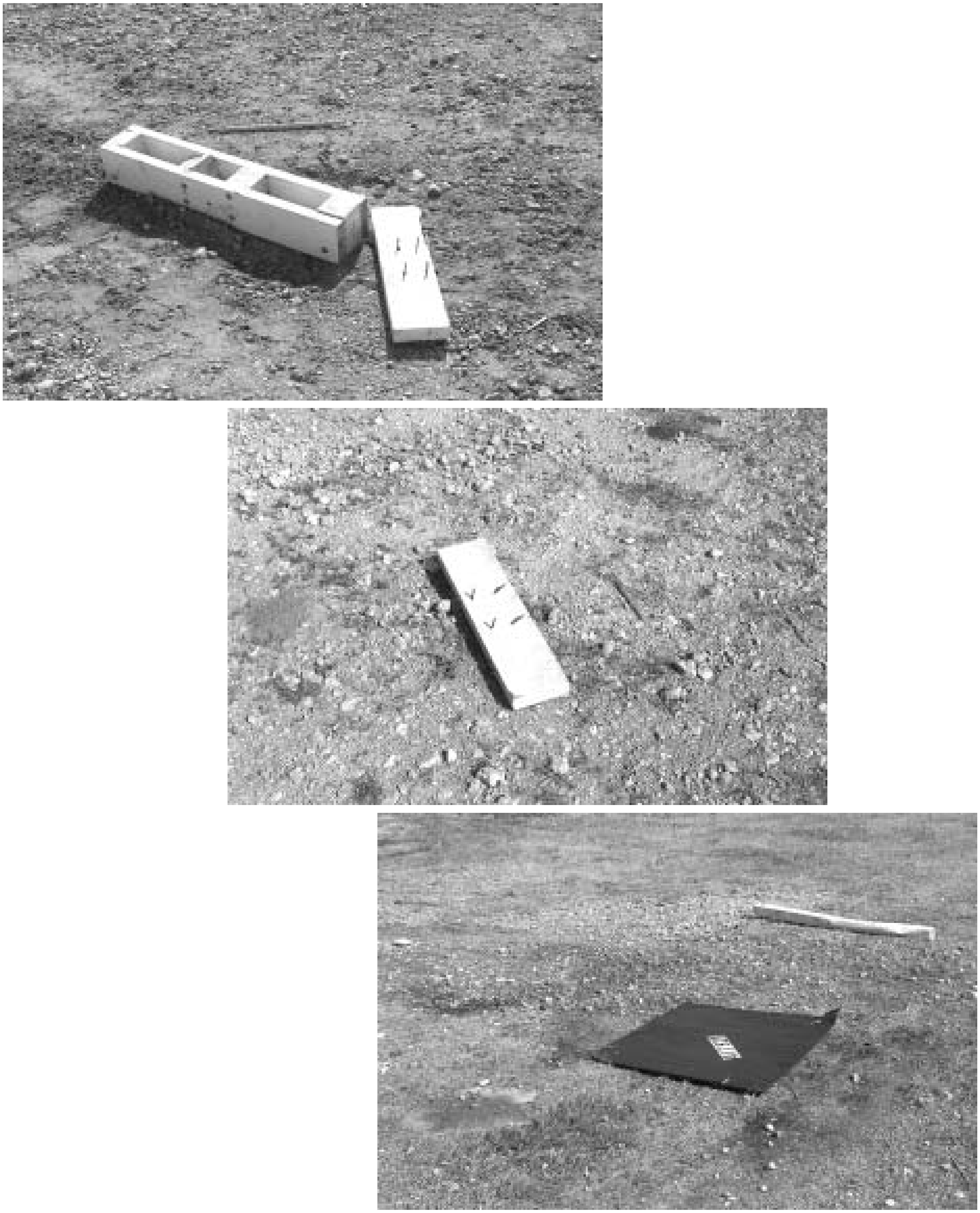


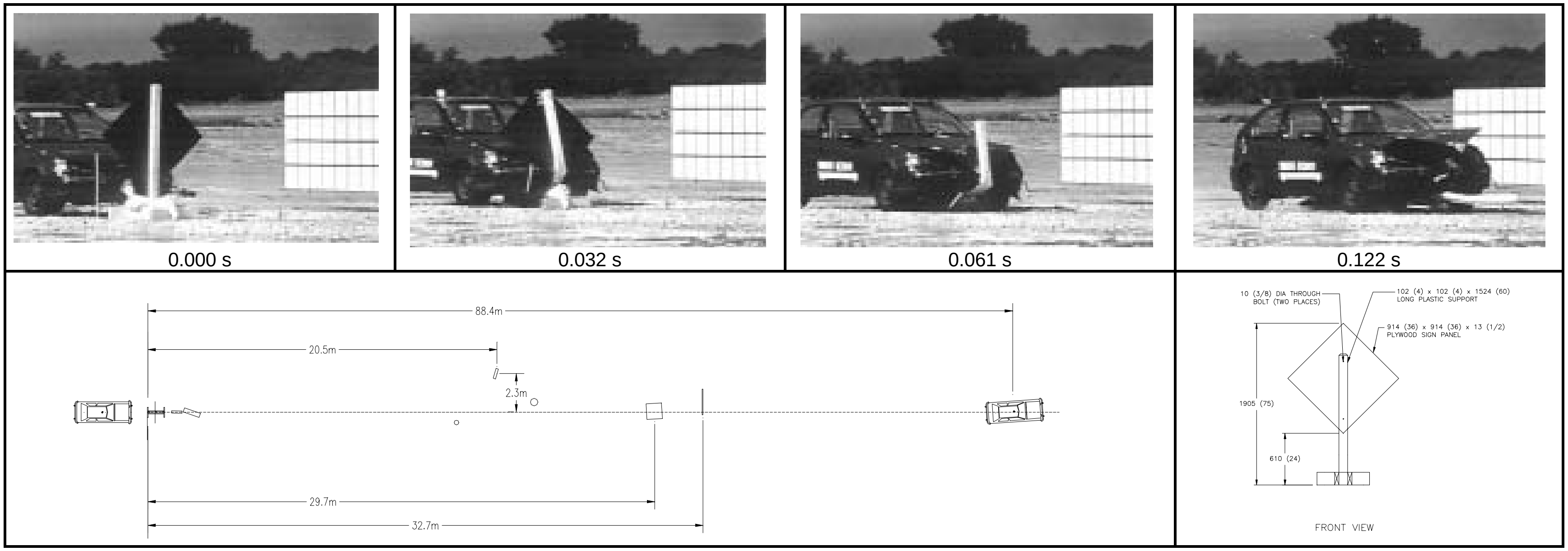
Figure 156. Installation after Test 417928-13.

Figure 157. Vehicle after Test 417928-13.

Before test

After test

Figure 158. Interior of Vehicle for Test 417928-13.



General Information
- Test Agency . . . . Texas Transportation Institute
- Test No. 417928-13
- Date 07/10/98

Test Article
- Type . . . . Traffic Control Device
- Name . . . . Hollow Profile Plastic Sign Support in H-Leg Base
- Installation Length (m) . . . . . . 0.6 (2.0 ft)
- Material or Key Elements . . . . Wooden Base w/Plastic Post w/ 914x914x13 mm (36x36x0.5 inch) Plywood Sign

Soil Type and Condition . . . . . . Standard Soil, Dry

Test Vehicle
- Type . . . . Production
- Designation 820C
- Model . . . . 1994 Geo Metro
- Mass (kg) Curb . . . . 796 (1755 lb)
  - Test Inertial . . . . 820 (1806 lb)
  - Dummy . . . . 76 (168 lb)
  - Gross Static . . . . 896 (1974 lb)

Impact Conditions
- Speed (km/h) . . . . 97.1 (60.3 mi/h)
- Angle (deg) 0

Exit Conditions
- Speed (km/h) . . . . 92.4 (57.4 mi/h)
- Angle (deg) 0

Test Article Debris Pattern (m)
- Longitudinal . . . . 32.7 (107.3 ft)
- Lateral . . . . 2.3 (7.5 ft)

Vehicle Damage
- Exterior
  - VDS 12FC1
  - CDC 12FCEN1
- Maximum Exterior
  - Vehicle Crush (mm) . . . . . . nil
- Interior
  - OCDI FS0000000
- Max. Occ. Compart.
  - Deformation (mm) 0

Figure 159. Summary of Results for Test 417928-13, *NCHRP Report 350* Test 3-71.

The hollow profile plastic sign support with wooden sign panel contacted the hood of the vehicle and cracked the base of the windshield, but did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 1.3 m/s (4.3 ft/s).

Conclusion

The hollow profile plastic sign support in H-leg base (with 0.9 m × 0.9 m [3 ft × 3 ft] plywood panel and 0.3 m [1 ft] mounting height) met the *NCHRP Report 350* evaluation criteria for test designation 3-71.

Hollow Profile Plastic Sign Support in H-Leg Support (0.9 m × 0.9 m [3 ft × 3 ft] plywood panel - 0.6 m [2 ft] mounting height) – Test No. 417929-1
(*NCHRP Report 350* Test No. 3-71)

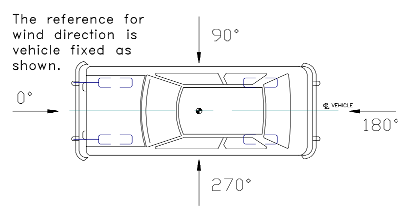
A single wooden H-leg barricade with a 1220 mm ×1220 mm ×13 mm (48 inch × 48 inch × 0.5 inch) plywood sign panel mounted at 1.5 m (5.0 ft) above the ground, shown previously in Figure 17 and in Figure 160, was evaluated in this crash test. The base of the barricade was ballasted with four 7.6 kg (16.8 lb) sandbags.

Test Vehicle

A 1994 Geo Metro, shown in Figures 161 and 162, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 895 kg (1973 lb). The height to the lower edge of the vehicle bumper was 380 mm (14.9 inch), and it was 465 mm (18.3 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 223. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the morning of November 3, 1998. A total of 41 mm (1.6 inch) of rain was recorded two days prior to the test but would not affect the test as the barricade was installed on the ground surface. No other rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 13 km/h (8 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 16 °C (61 °F); relative humidity: 72 percent.



Test Description

The vehicle impacted the barricade head-on at a speed of 101.2 km/h (62.9 mi/h). At 0.015 s, the hollow core plastic post moved, and at 0.022 s, the base moved. By 0.051 s, the post pulled from the base, and by 0.053 s, the top of the sign panel contacted the center of the lower section of the windshield, which then shattered. At 0.119 s, the bottom of the post was visible at the base, and at 0.160 s, the sign panel and post lost contact with the vehicle. At 0.246 s, the vehicle was traveling at 93.1 km/h (57.8 mi/h) as it lost contact with the barricade base pieces.

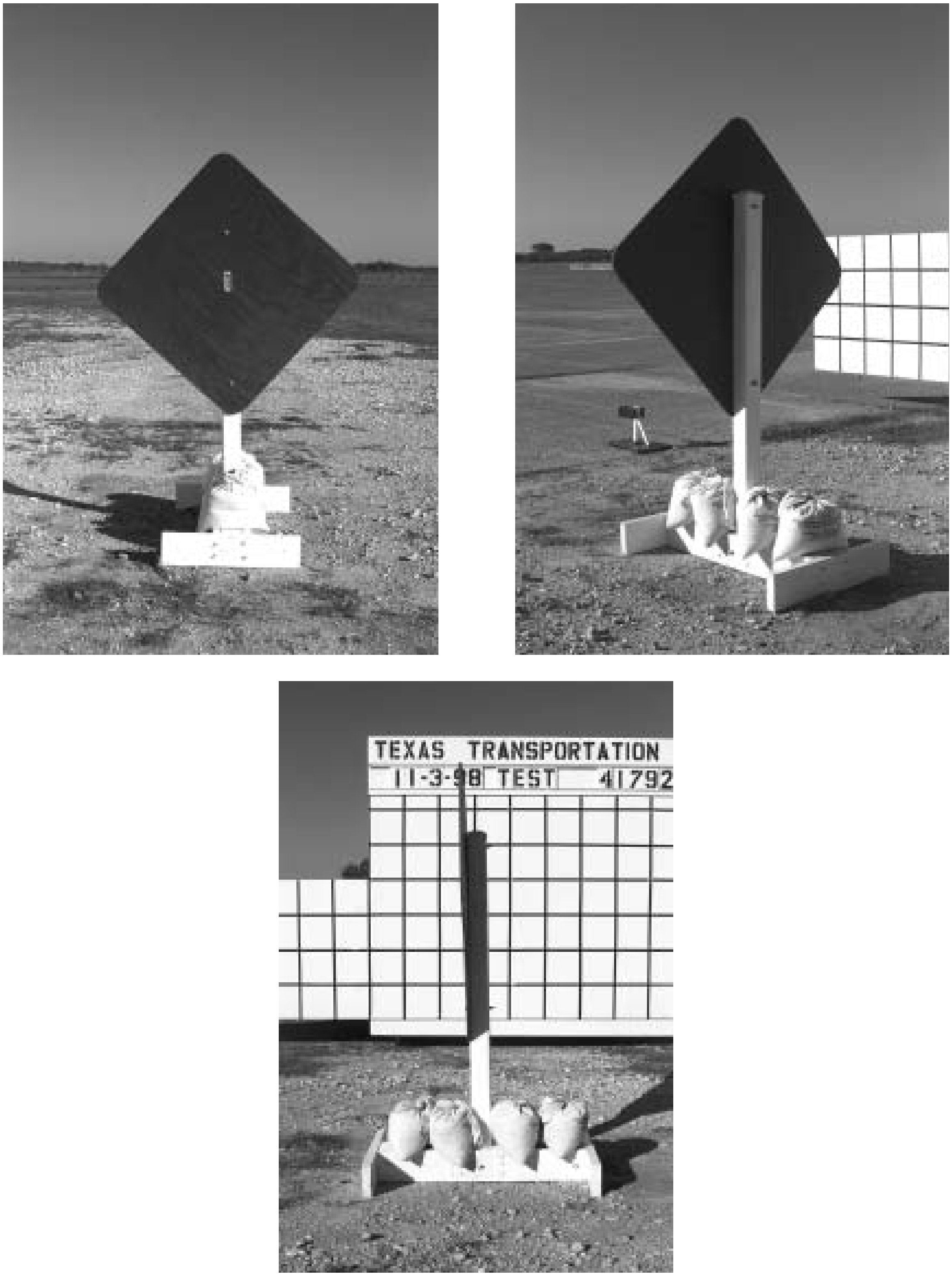


Figure 160. Installation before Test 417929-1.

Figure 161. Vehicle/Installation Geometrics for Test 417929-1.

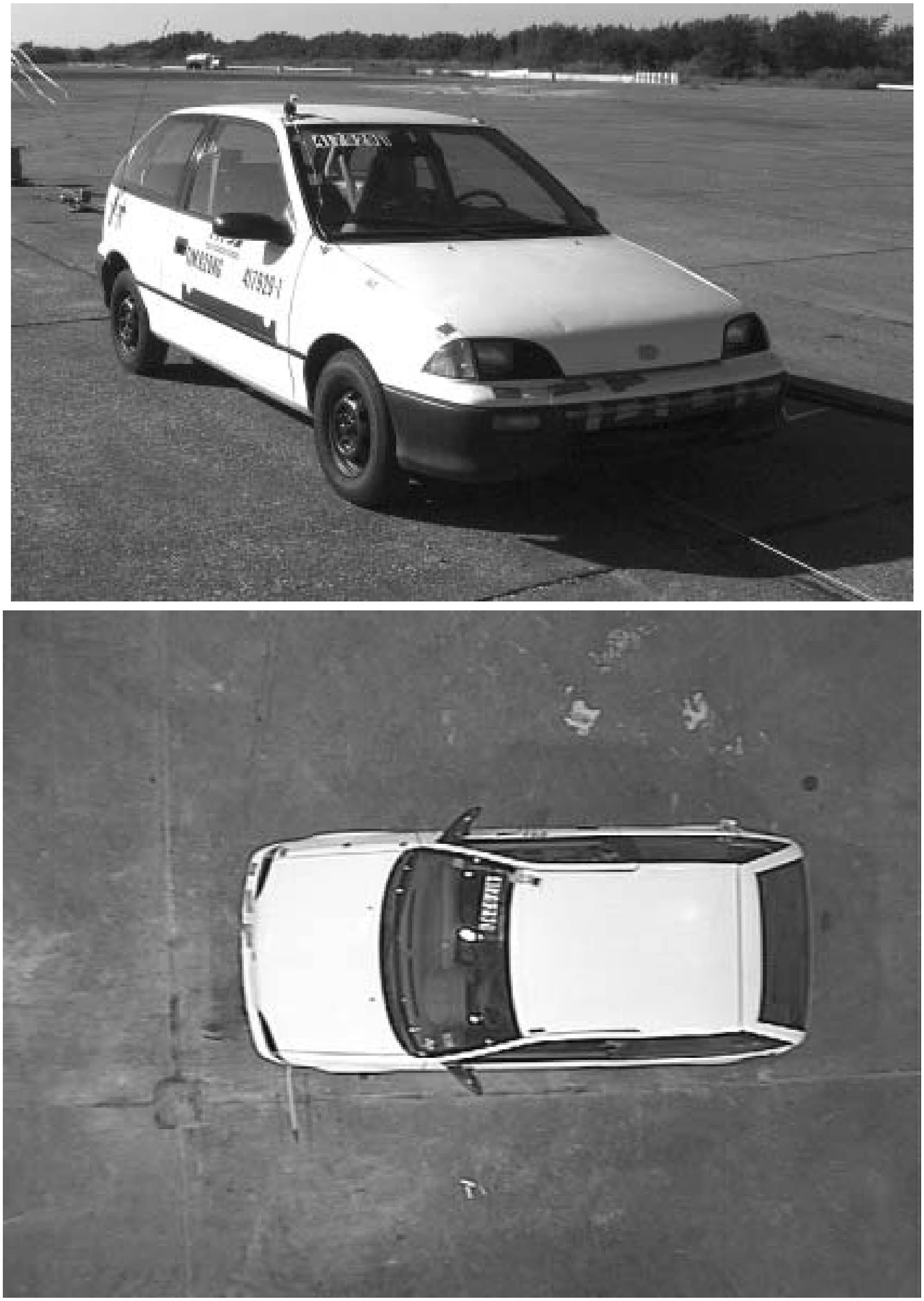


Figure 162. Vehicle before Test 417929-1.

Brakes on the vehicle were applied as it exited the test site, and the vehicle came to rest 102.1 m (335.0 ft) down and slightly yawed to the right of the impact point. Sequential photographs of the test can be found in Appendix C, Figure 243.

Damage to Test Installation

The barricade separated into a few pieces as shown in Figures 163 and 164. An end piece of the base came to rest 6.9 m (22.6 ft) from impact and 1.5 m (5.0 ft) to the right, while the rest of the debris extended 25.9 m (85.0 ft) further down, 3.1 m (10.2 ft) further to the right, and 9.1 m (30.0 ft) to the left of the impact point.

Vehicle Damage

The front of the vehicle received damage, as shown in Figure 165. The windshield was shattered. Maximum exterior crush to the center front of the hood was 25 mm (1 inch). The fan, radiator, and radiator support were also damaged. Exterior vehicle crush measurements are shown in Appendix B, Table 2. The interior of the vehicle is shown in Figure 166.

Assessment of Test Results

Figure 167 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The single wooden H-leg barricade with a 1220 mm × 1220 mm × 13 mm (48 inch ×48 inch ×0.5 inch) plywood sign panel met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

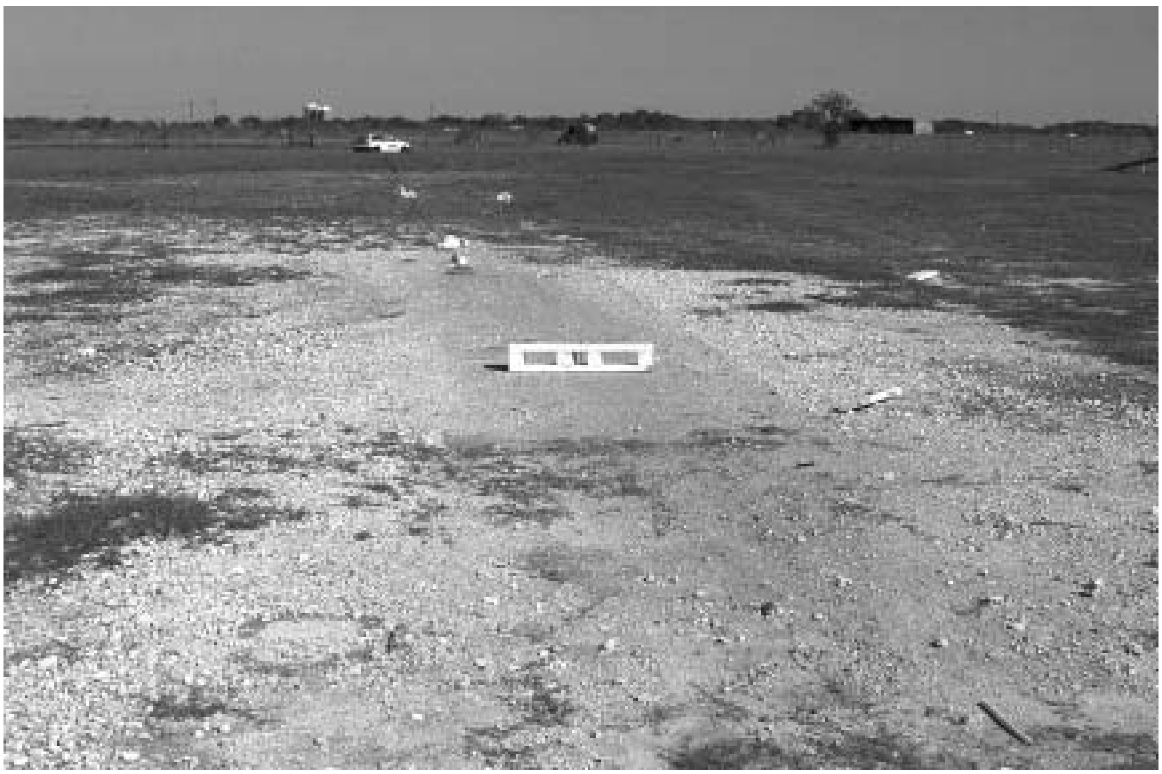


Figure 163. After Impact Trajectory for Test 417929-1.

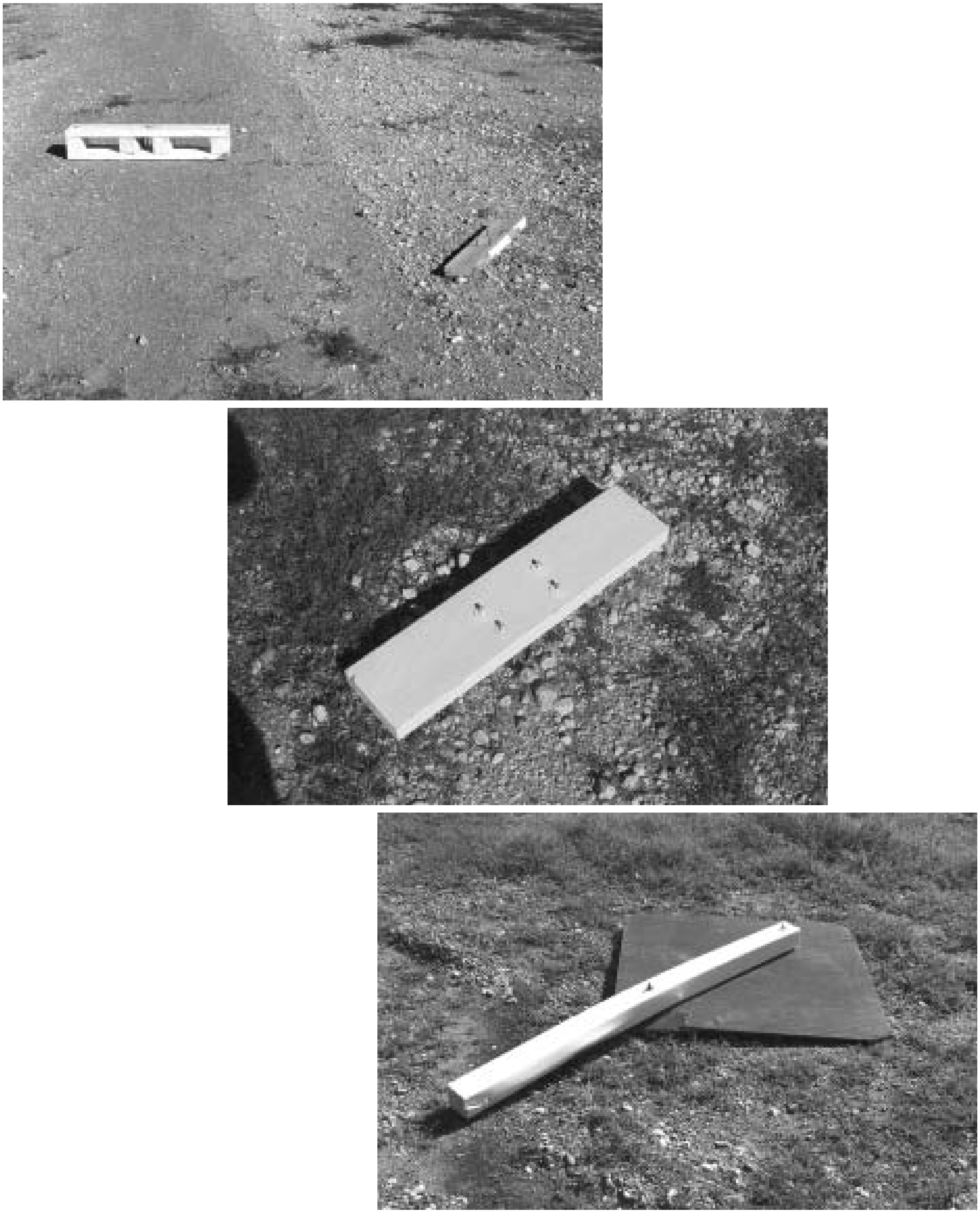


Figure 164. Installation after Test 417929-1.

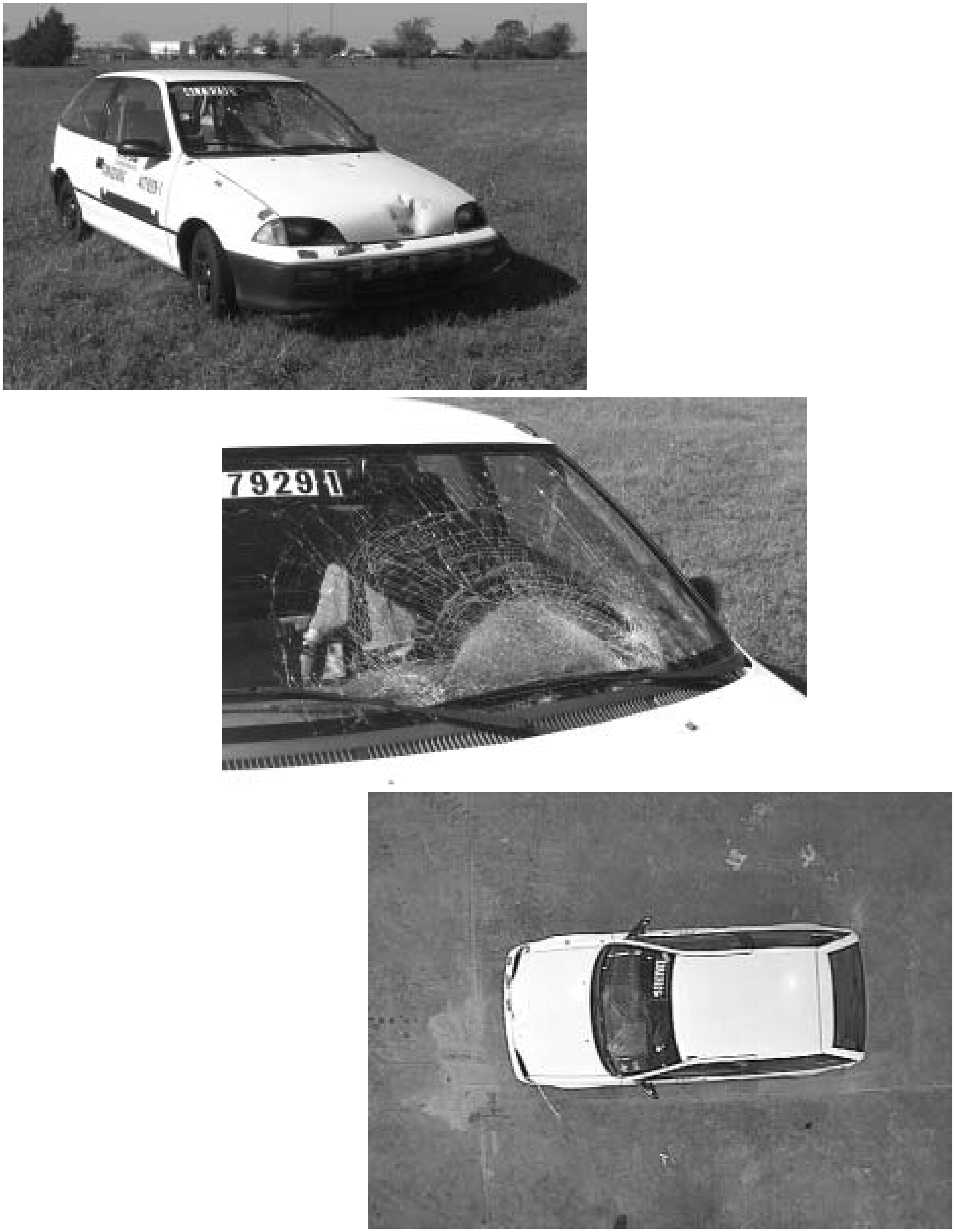


Figure 165. Vehicle after Test 417929-1.

Before test

After test

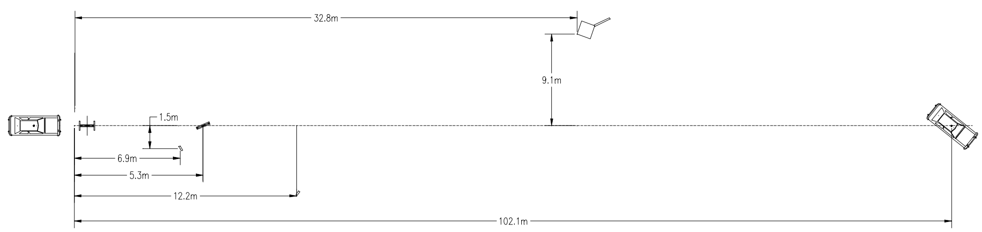
Figure 166. Interior of Vehicle for Test 417929-1.

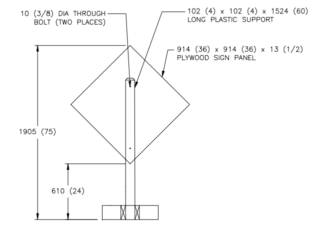
0.000 s

0.049 s

0.111 s

0.197 s





General Information

Test Agency	Texas Transportation Institute
Test No.	417929-1
Date	11/3/98

Test Article

Type	Traffic Control Device
Name	Hollow Profile Plastic Sign Support in H-Leg Base
Installation Length (m)	0.6 (2.0 ft)
Material or Key Elements	Wooden Base w/Plastic Post w/ 1220x1220x13 mm (48x48x0.5 inch) Plywood Sign

Soil Type and Condition .... Standard Soil, Dry

Test Vehicle

Type	Production
Designation	820C
Model	1994 Geo Metro
Mass (kg)	
Curb	770 (1698 lb)
Test Inertial	820 (1806 lb)
Dummy	75 (165 lb)
Gross Static	895 (1973 lb)

Impact Conditions

Speed (km/h)	101.2 (62.9 mi/h)
Angle (deg)	0

Exit Conditions

Speed (km/h)	93.1 (57.8 mi/h)
Angle (deg)	0

Test Article Debris Pattern (m)

Longitudinal	32.8 (107.6 ft)
Lateral	9.1 (30.0 ft)

Vehicle Damage

Exterior	
VDS	12FC1
CDC	12FCEN1
Maximum Exterior Vehicle Crush (mm)	25 (1.0 in)
Interior	
OCDI	FS0000000
Max. Occ. Compart. Deformation (mm)	0

Figure 167. Summary of Results for Test 417929-1, *NCHRP Report 350* Test 3-71.

The sign support penetrated the occupant compartment and shattered the windshield. No deformation or intrusion of the occupant compartment occurred.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

The resulting windshield damage could potentially block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 2.3 m/s (7.5 ft/s).

<u>Conclusion</u>

The temporary sign support with 914 mm × 914 mm (36 inch × 36 inch) plywood sign mounted at 610 mm (24 inch) marginally met *NCHRP Report 350* criteria. The windshield was shattered and deflected inward 25 mm (1 inch), but there were no holes, penetration, or separation of the windshield from the frame. Although the cracking was extensive, the driver should still be able to see through the damage to bring the vehicle to a safe, controlled stop.

Hollow Profile Plastic Sign Support in H-Leg Base (1.2 m × 1.2 m [4 ft × 4 ft] panel - 0.6 m [2 ft] mounting height) – Test No. 417928-15 (*NCHRP Report 350* Test No. 3-71)

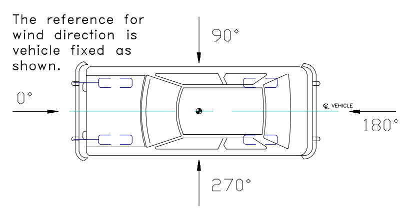
A hollow profile plastic sign support in H-leg base with 1220 mm × 1200 mm ×14 mm (48 inch × 48 inch × 0.5 inch) plywood sign panel mounted at 0.6 m (2.0 ft) above ground, shown previously in Figure 18 and in Figure 168, was evaluated in this crash test. The base of the sign support was ballasted with four 7.6 kg (16.8 lb) sandbags.

Test Vehicle

A 1994 Geo Metro, shown in Figures 169 and 170, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 395 mm (15.6 inch), and it was 535 mm (21.1 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 219. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the afternoon of July 10, 1998. A total of 26 mm (1.0 inch) of rain was recorded eight days prior to the test but would not affect the test as the barricade was installed on the ground surface. No other rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 5 km/h (3 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 34 °C (93 °F); relative humidity: 58 percent.



Test Description

The vehicle impacted the sign support head-on at a speed of 101.3 km/h (63.0 mi/h). Shortly after impact, the bumper of the vehicle contacted the sandbags. The vehicle's bumper contacted the hollow plastic post at 0.017 s. The post and base moved at 0.020 s and 0.022 s, respectively. At 0.051 s, the post pulled out of the wooden base, and at 0.068 s, the upper portion of the sign panel contacted the top of the windshield and pushed inward. By 0.078 s, the plastic post lost contact with the bumper of the vehicle, and by 0.093 s, the sign panel contacted the top section of the hood of the vehicle. The sign panel lost contact with the vehicle's hood at

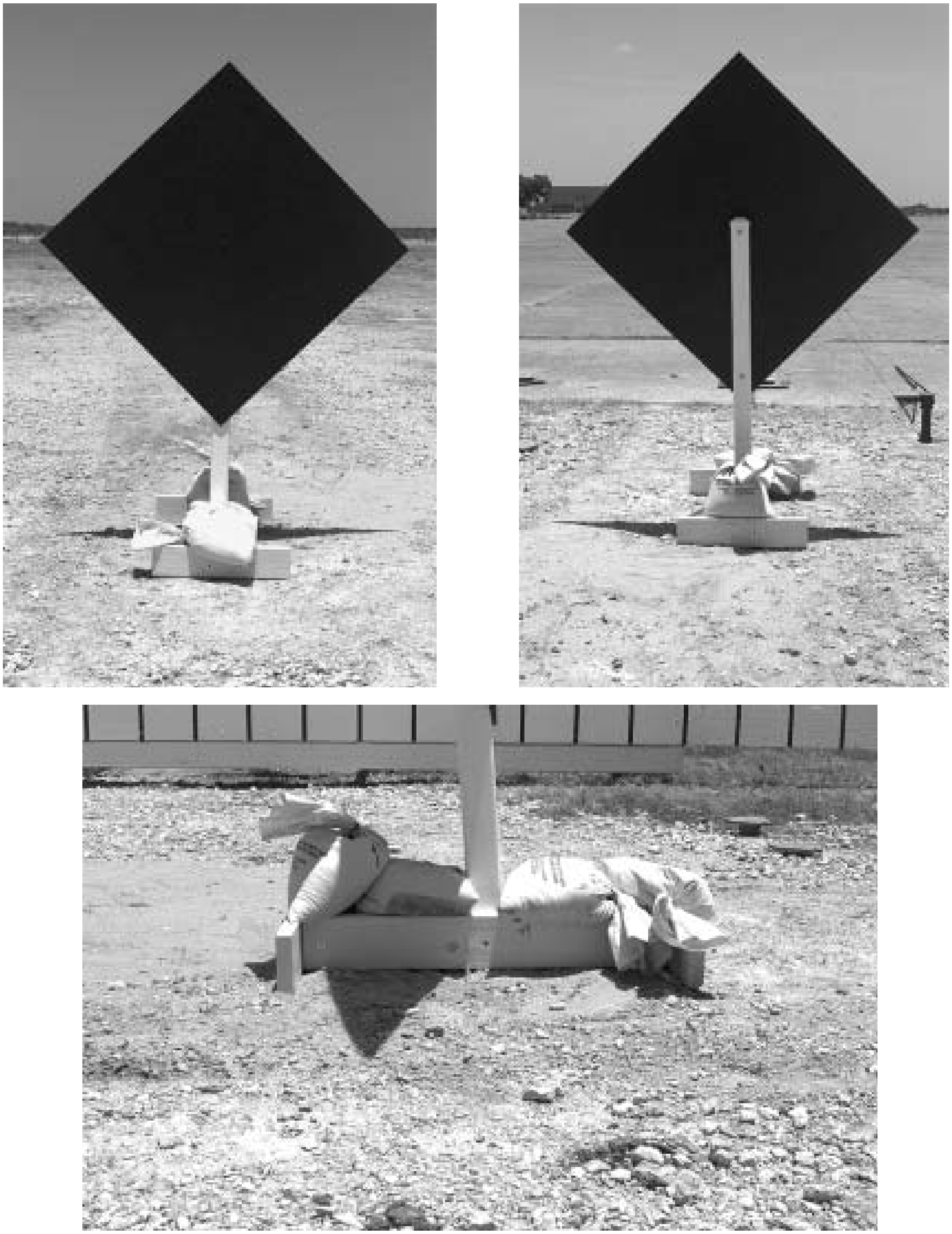


Figure 168. Installation before Test 417928-15.

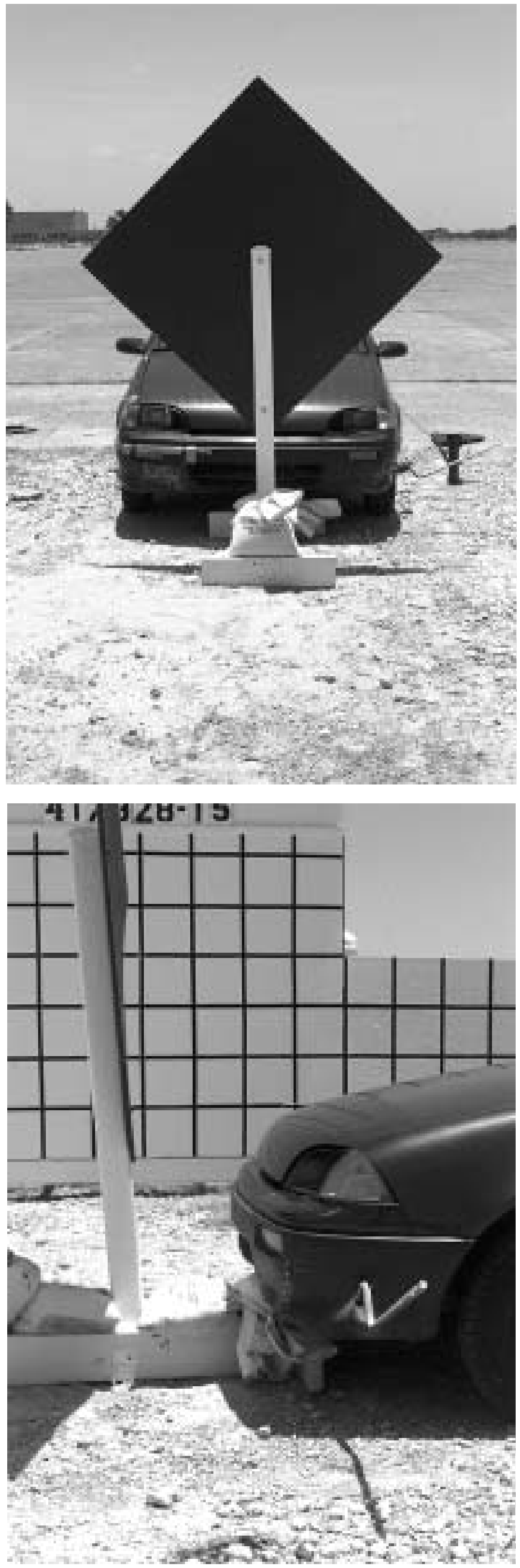


Figure 169. Vehicle/Installation Geometrics for Test 417928-15.

Figure 170. Vehicle before Test 417928-15.

0.119 s, and at 0.195 s the vehicle rode over the wooden base. The sign panel lost contact with the vehicle at 0.227 s. The vehicle was traveling at 92.5 km/h (57.5 mi/h) as the barricade panels lost contact with the vehicle. Brakes on the vehicle were applied as it exited the test site, and the vehicle came to rest 90.7 m (297.6 ft) down and 1.5 m (4.9 ft) to the left of the impact point. Sequential photographs of the test can be found in Appendix C, Figure 244.

Damage to Test Installation

The sign support separated into several pieces, as shown in Figures 171 and 172. The base came to rest 3.0 m (9.8 ft) from impact while the sign panel and plastic post were located 41.9 m (137.5 ft) down and 8.4 m (27.6 ft) to the right of impact.

Vehicle Damage

The vehicle received damage to the front, as shown in Figure 173. The hood and bumper received dents (not measurable), and the windshield was shattered from the impact of the sign panel. The interior of the vehicle is shown in Figure 174.

Assessment of Test Results

Figure 175 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The single wooden H-leg sign support with a 1220 mm × 1200 mm × 14 mm (48 inch × 48 inch ×0.5 inch) plywood sign panel met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of,or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

Figure 171. After Impact Trajectory for Test 417928-15.

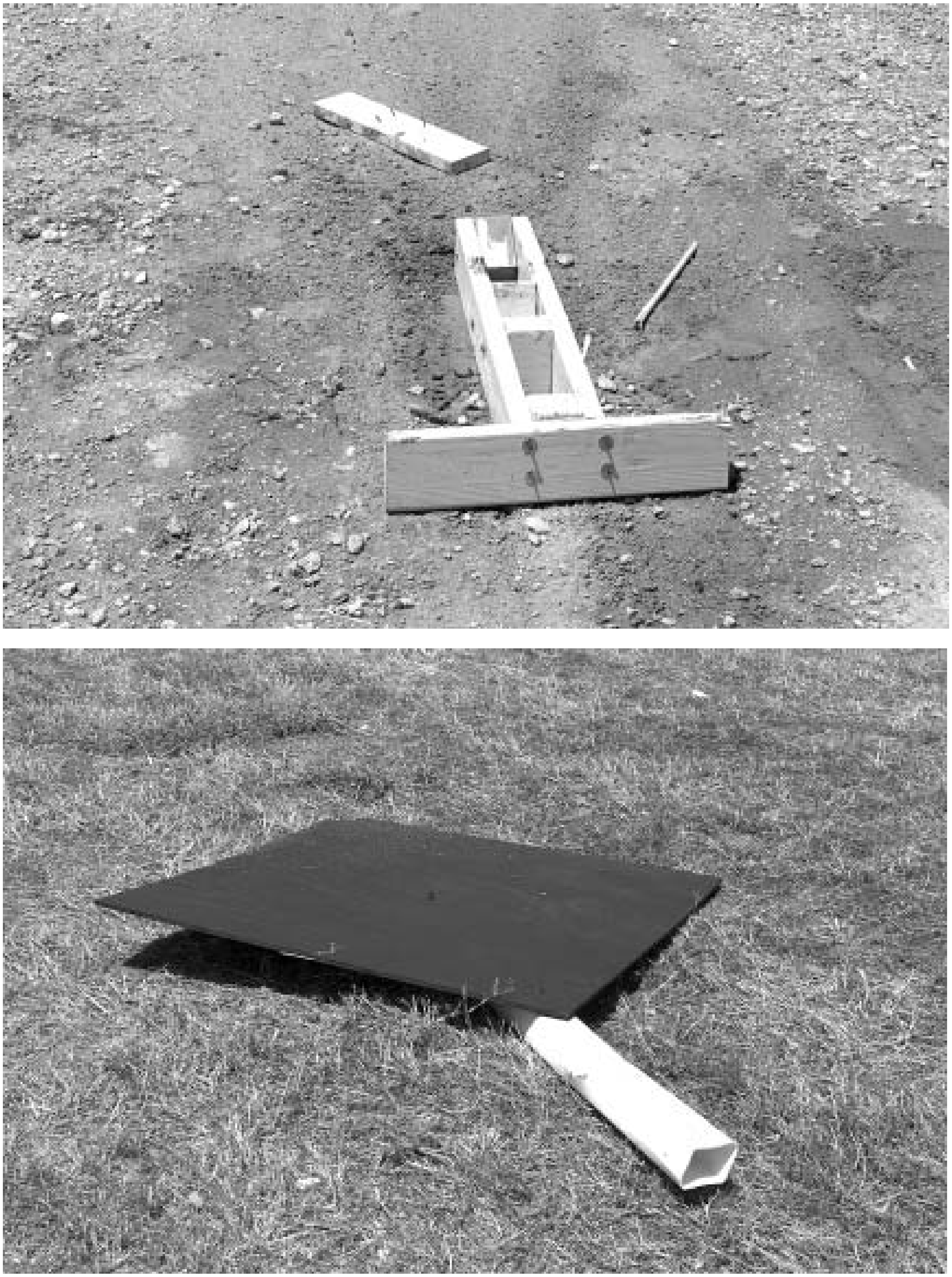


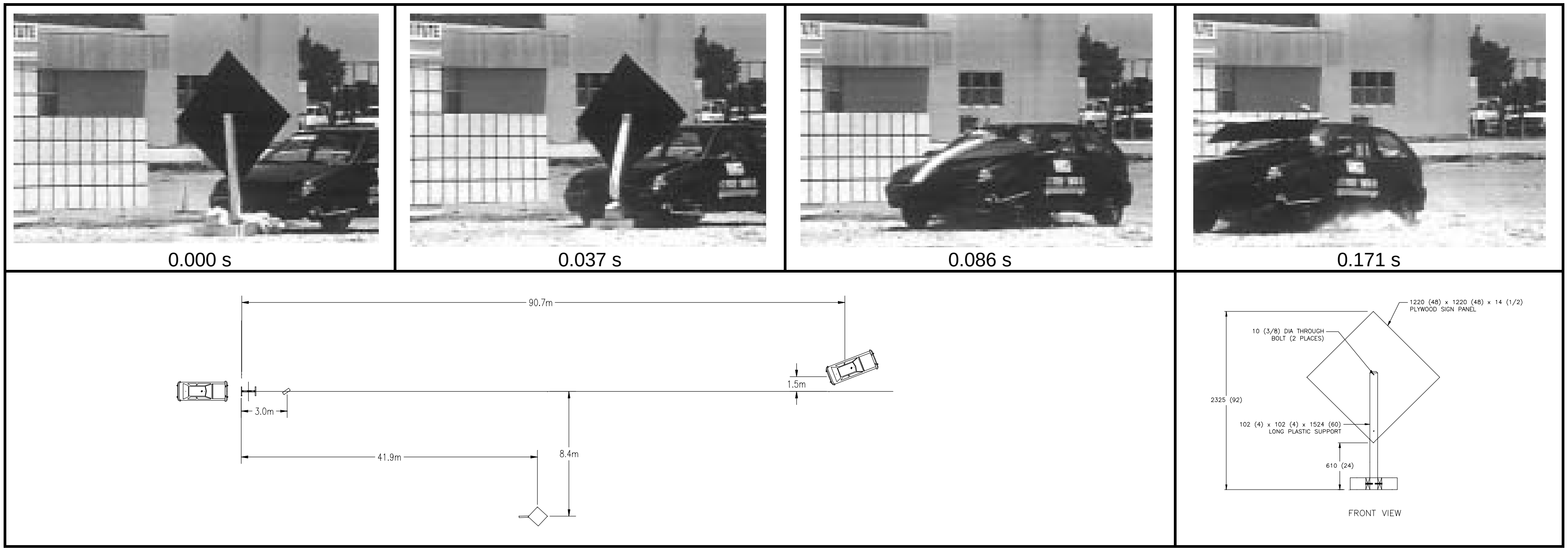
Figure 172. Installation after Test 417928-15.

Figure 173. Vehicle after Test 417928-15.

Before test

After test

Figure 174. Interior of Vehicle for Test 417928-15.



General Information

Test Agency	Texas Transportation Institute
Test No.	417928-15
Date	07/10/98

Test Article

Type	Traffic Control Device
Name	Hollow Profile Plastic Sign Support in H-Leg Base
Installation Length (m)	0.6 (2.0 ft)
Material or Key Elements	Wooden Base w/ Hollow Plastic Post w/ 1220x1220x14 mm (48x48x0.5 inch) Wooden Sign Panel

Soil Type and Condition . . . . . . Standard Soil, Dry

Test Vehicle

Type		Production
Designation		820C
Model		1994 Geo Metro
Mass (kg)	Curb	796 (1755 lb)
	Test Inertial	820 (1806 lb)
	Dummy	76 (168 lb)
	Gross Static	896 (1974 lb)

Impact Conditions

Speed (km/h)	101.3 (63.0 mi/h)
Angle (deg)	0

Exit Conditions

Speed (km/h)	92.5 (57.5 mi/h)
Angle (deg)	0

Test Article Debris Pattern (m)

Longitudinal	41.9 (137.5 ft)
Lateral	8.4 (27.6 ft)

Vehicle Damage

Exterior	
VDS	12FD4
CDC	12FDEW4
Maximum Exterior Vehicle Crush (mm)	nil
Interior	
OCDI	FS0000000
Max. Occ. Compart. Deformation (mm)	0

Figure 175. Summary of Results for Test 417928-15, *NCHRP Report 350* Test 3-71.

The sign support penetrated the occupant compartment, shattering and deforming the roof. Deformation of the occupant compartment occurred.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

The detached elements would block the driver's vision and cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 2.4 m/s (7.9 ft/s).

Conclusion

The temporary hollow profile plastic sign support with a 1219 mm × 1219 mm (4 ft × 4 ft) plywood sign panel mounted at 0.6 m (2 ft) failed to meet criterion D and E of *NCHRP Report 350* and was therefore judged to be unacceptable. The sign panel impacted the windshield causing separation of the windshield from the frame and penetration of the occupant compartment. The extent of the damage to the windshield would likely obstruct the driver's vision, preventing the driver from safely controlling the vehicle.

Hollow Profile Plastic Sign Support in H-Leg Base (1.2 m × 1.2 m [4 ft × 4 ft] panel - 0.9 m [3 ft] mounting height) – Test No. 417928-18 (*NCHRP Report 350* Test No. 3-71)

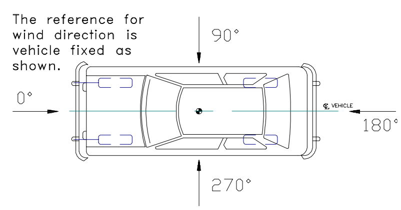
A single hollow profile plastic sign support with wooden H-leg base with a 1220 mm × 1220 mm × 13 mm (48 inch × 48 inch ×0.5 inch) plywood sign panel mounted at 0.9 m (3.0 ft) above the ground, shown previously in Figure 19 and in Figure 176, was evaluated in this crash test. The base of the barricade was ballasted with four 7.6 kg (16.8 lb) sandbags.

Test Vehicle

A 1993 Geo Metro, shown in Figures 177 and 178, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 380 mm (15.0 inch), and it was 525 mm (20.7 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 218. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the afternoon of July 23, 1998. A total of 20 mm (0.8 inch) of rain was recorded nine days prior to the test but would not affect the test as the barricade was installed on the ground surface. No other rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 3 km/h (2 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 35 °C (95 °F); relative humidity: 58 percent.



Test Description

The vehicle impacted the barricade head-on at a speed of 100.9 km/h (62.7 mi/h). At 0.015 s, the bumper of the vehicle contacted the plastic sign post, and at 0.017 s, the post moved. By 0.022 s the base moved, and by 0.050 s the post pulled completely out of the base. The post lost contact with the bumper of the vehicle but remained in contact with the front of the hood at 0.078 s. At 0.081 s, the sign panel contacted the upper windshield and roof of the vehicle. By 0.083 s, the roof of the vehicle deformed from contact with the sign panel, and by 0.085 s, the post lost contact with the vehicle. At 0.087 s, the windshield shattered and was pushed

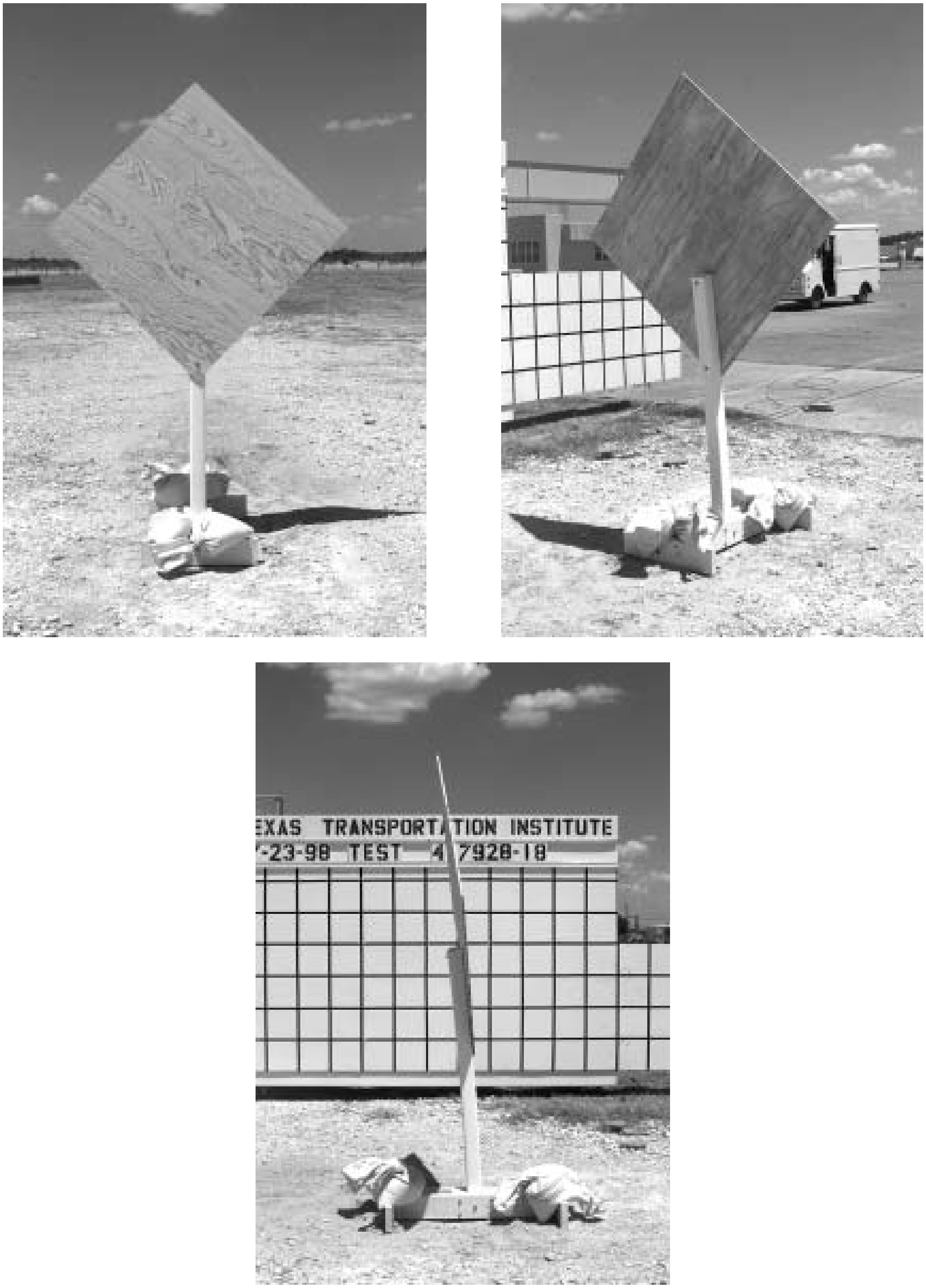


Figure 176. Installation before Test 417928-18.

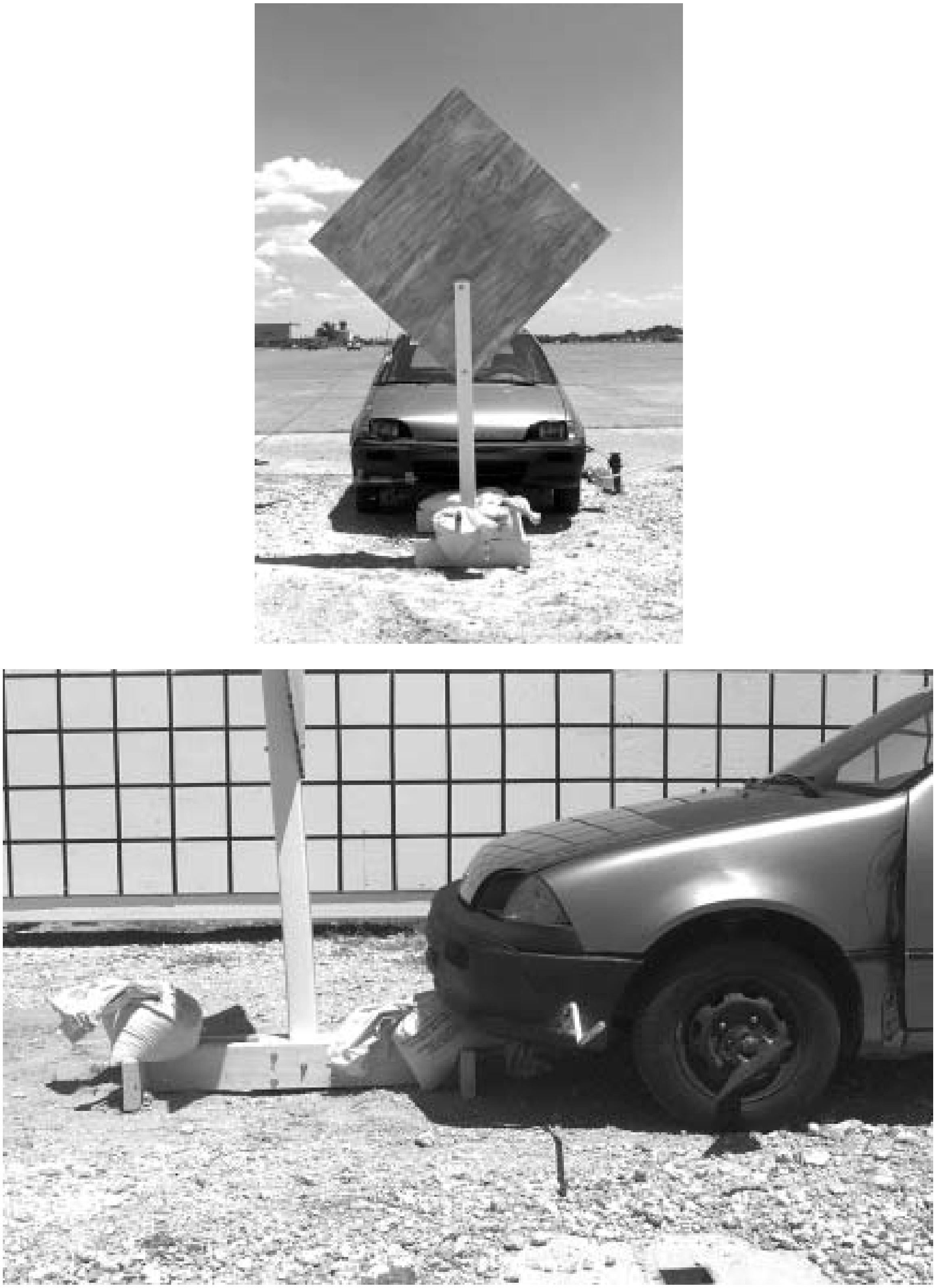


Figure 177. Vehicle/Installation Geometrics for Test 417928-18.

Figure 178. Vehicle before Test 417928-18.

inward. The sign panel lost contact with the roof of the vehicle at 0.205 s. At 0.207 s, the vehicle was traveling at 93.1 km/h (57.8 mi/h) as the barricade was still in contact with vehicle. The vehicle lost contact with the wooden base at 0.208 s. Brakes on the vehicle were applied as it exited the test site, and the vehicle came to rest 84.6 m (277.6 ft) from the impact point. Sequential photographs of the test can be found in Appendix C, Figure 245.

Damage to Test Installation

The sign support separated into multiple pieces as shown in Figures 179 and 180. The debris extended 70.9 m (232.6 ft) down, 1.9 m (6.2 ft) to the left, and 1.9 m (6.2 ft) to the right of the impact point.

Vehicle Damage

The windshield of the vehicle shattered and pushed inward from the impact of the wooden sign panel, as shown in Figure 181. The roof and hood were also damaged. Maximum deformation into the occupant compartment was 61 mm (2.4 inch) (7 percent reduction in space) in the floor pan area. The interior of the vehicle is shown in Figure 182. Occupant compartment measurements are shown in Appendix B, Table 4.

Assessment of Test Results

Figure 183 shows a summary of the test result. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The single hollow core plastic sign support with wooden H-leg base with a 1220 mm × 1220 mm × 14 mm (48 inch × 48 inch ×0.5 inch) plywood sign panel met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

Figure 179. After Impact Trajectory for Test 417928-18.

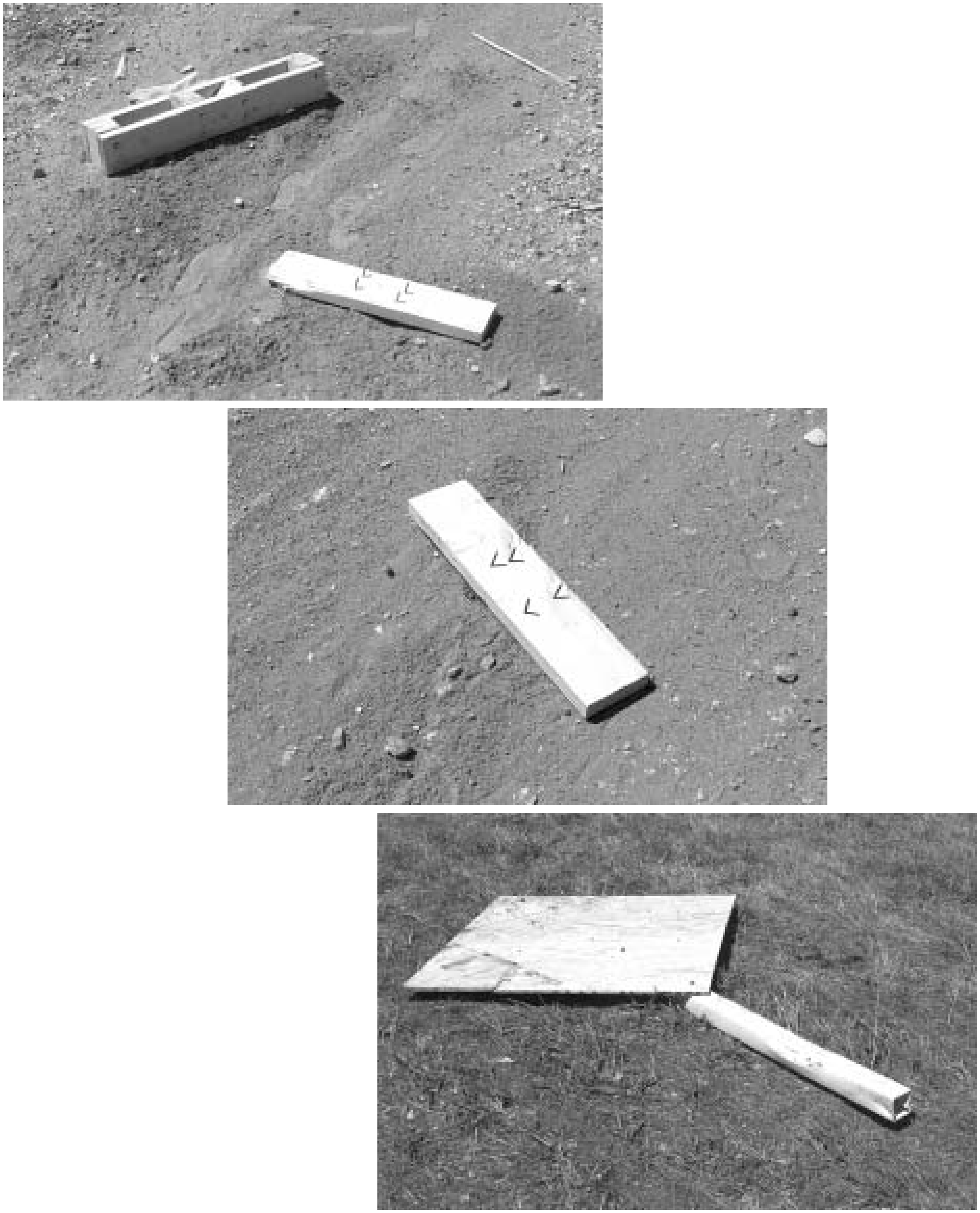


Figure 180. Installation after Test 417928-18.

Figure 181. Vehicle after Test 417928-18.

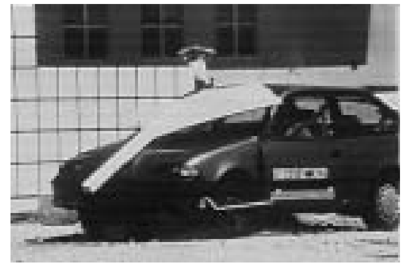
Before test

After test

Figure 182. Interior of Vehicle for Test 417928-18.

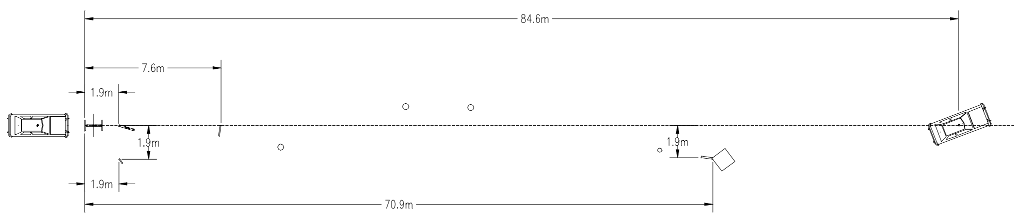
0.000 s

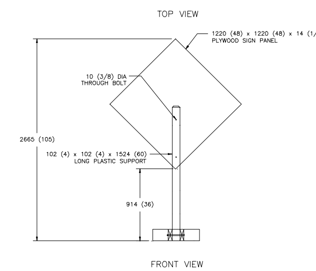
0.034 s



0.085 s

0.171 s





General Information

Test Agency	Texas Transportation Institute
Test No.	417928-18
Date	07/23/98

Test Article

Type	Traffic Control Device
Name	Hollow Profile Plastic Sign Support in H-Leg Base
Installation Length (m)	0.6 (2.0 ft)
Material or Key Elements	Wooden Base w/ Hollow Plastic Post w/ 1220x1220x13 mm (48x48x0.5 inch) Plywood Sign

Soil Type and Condition . . . . . . Standard Soil, Dry

Test Vehicle

Type	Production
Designation	820C
Model	1993 Geo Metro
Mass (kg) Curb	753 (1660 lb)
Test Inertial	820 (1806 lb)
Dummy	76 (168 lb)
Gross Static	896 (1974 lb)

Impact Conditions

Speed (km/h)	100.9 (62.7 mi/h)
Angle (deg)	0

Exit Conditions

Speed (km/h)	93.1 (57.8 mi/h)
Angle (deg)	0

Test Article Debris Pattern (m)

Longitudinal	70.9 (232.6 ft)
Lateral	1.9 (6.2 ft)

Vehicle Damage

Exterior	
VDS	12FD1
CDC	12FDEW1
Maximum Exterior Vehicle Crush (mm)	nil
Interior	
OCDI	FS0100000
Max. Occ. Compart. Deformation (mm)	61 (2.4 in)

Figure 183. Summary of Results for Test 417928-18, *NCHRP Report 350* Test 3-71.

The sign support penetrated the occupant compartment, shattered the windshield and deformed the roof. Maximum deformation into the occupant compartment was 61 mm (2.4 inch) (7 percent reduction in space) in the floor pan area.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

The detached elements and vehicle damage could block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 2.2 m/s (7.2 ft/s).

Conclusion

The temporary hollow profile plastic sign support with a 1219 mm × 1219 mm (4 ft × 4 ft) plywood sign panel mounted at 0.9 m (3 ft) failed to meet criterion D and E of *NCHRP Report 350* and is therefore judged to be unacceptable. The sign panel penetrated the occupant compartment, shattered the windshield, and deformed the roof. The extent of the damage to the windshield would likely obstruct the driver's view, preventing the driver from safely controlling the vehicle.

Hollow Profile Plastic Sign Support in T-Leg Base (1.2 m × 1.2 m [4 ft × 4 ft] fiberglass panel - 0.6 m [2 ft] mounting height) – Test No. 417929-11 (*NCHRP Report 350* Test No. 3-71)

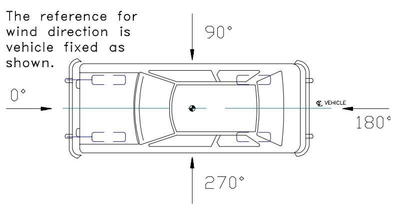
A single hollow profile plastic sign support in wooden T-leg barricade with a 1220 mm × 1220 mm × 5 mm (48 inch × 48 inch × 0.2 inch) fiber board sign panel mounted at 0.6 m (2.0 ft) above the ground, shown previously in Figure 20 and in Figure 184, was evaluated in this crash test. The base of the barricade was ballasted with four 7.6 kg (16.8 lb) sandbags.

Test Vehicle

A 1994 Geo Metro, shown in Figures 185 and 186, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 385 mm (15.2 inch), and it was 475 mm (18.7 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 224. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the morning of August 30, 1999. No rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust and ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 2 km/h (1 mi/h); wind direction: 90 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 36 °C (97 °F); relative humidity: 23 percent.



Test Description

The vehicle impacted the barricade head-on at a speed of 97.3 km/h (60.5 mi/h). At 0.028 s, the sign post was pulled out of the wooden base, and at 0.036 s, the bracket located at the top of the sign support slid off of the post. By 0.066 s, the post bounced off the front of the vehicle, and by 0.068 s, the bracket at the bottom of the sign support slid off of the post. The sign panel contacted the upper windshield, which shattered at 0.076 s, and at 0.128 s the sign panel lost contact with the vehicle. As the vehicle lost contact with the support, at 0.240 s, the vehicle was traveling at 91.8 km/h (57.0 mi/h). Brakes on the vehicle were applied as the vehicle exited the test site, and the vehicle came to rest 94.5 m (310.0 ft) down from the impact point. Sequential photographs of the test can be found in Appendix C, Figure 246.

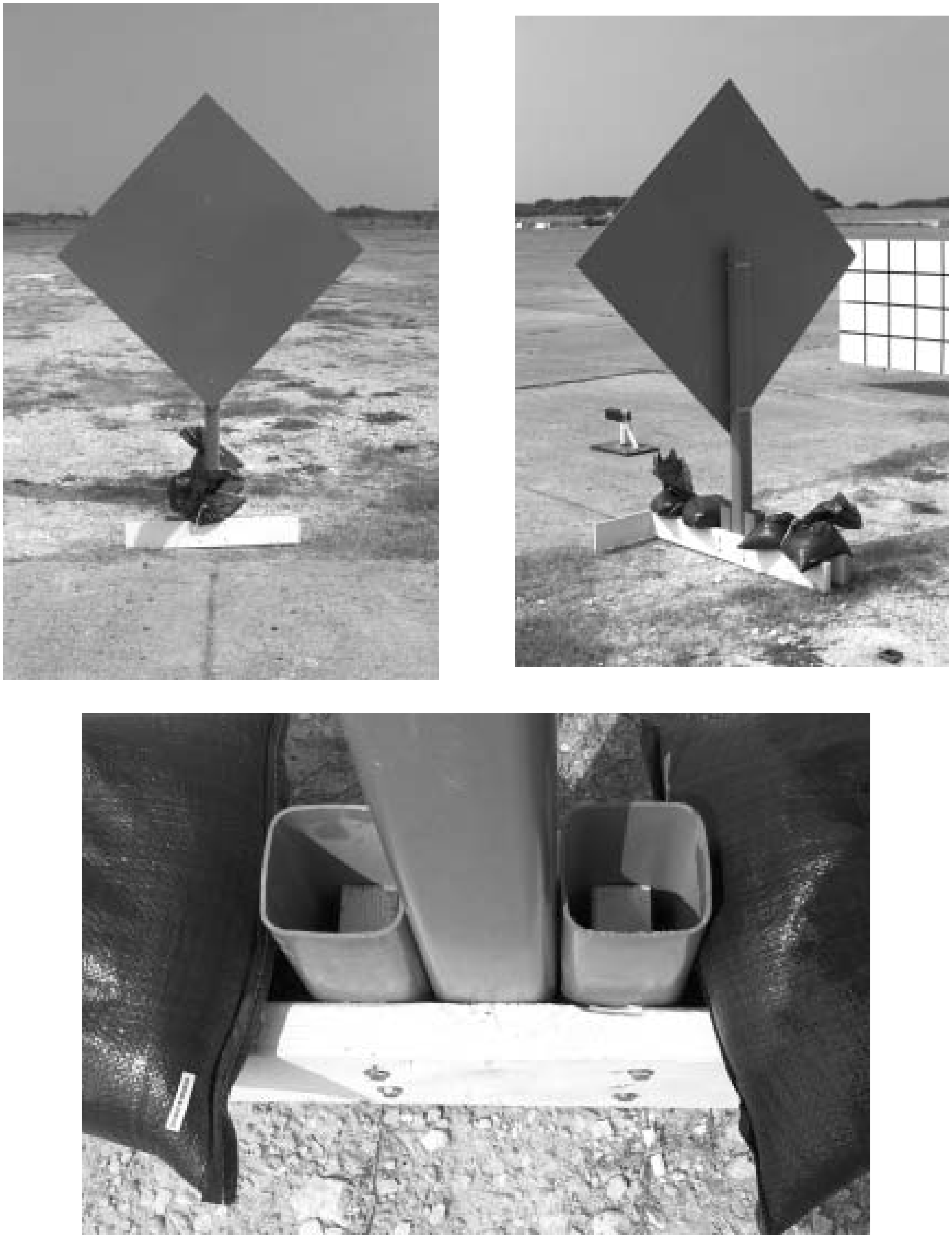


Figure 184. Installation before Test 417929-11.

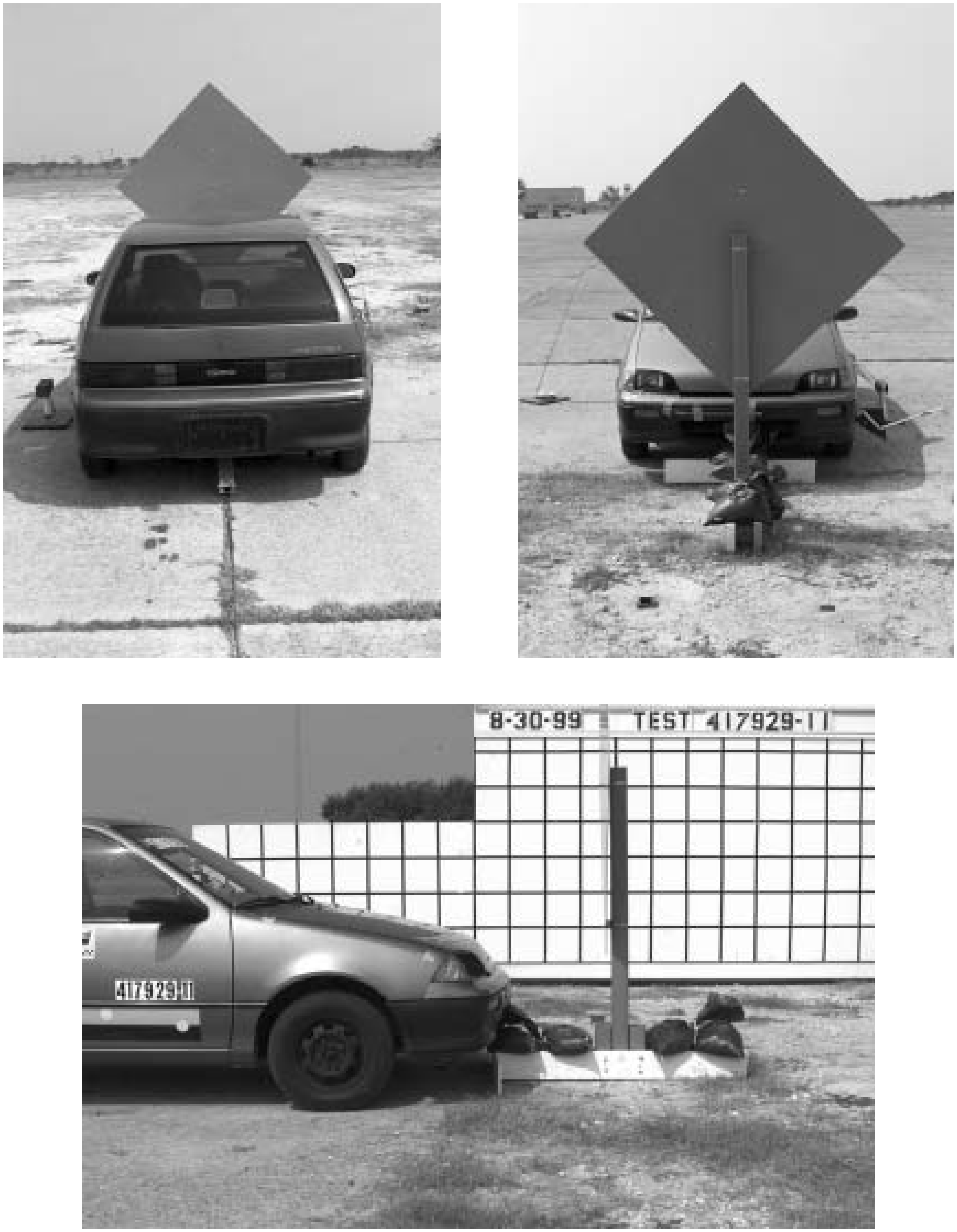


Figure 185. Vehicle/Installation Geometrics for Test 417929-11.

Figure 186. Vehicle before Test 417929-11.

Damage to Test Installation

The barricade separated into multiple pieces, as shown in Figures 187 and 188. The base of the unit moved 3.0 m (9.8 ft) from impact, and the remaining debris extended 40.4 m (132.5 ft) down from the impact point.

Vehicle Damage

The vehicle received damage to the hood, as shown in Figure 189. The windshield shattered and at the center of the roof, there was a dent that measured 60 mm × 120 mm × 10 mm (2 inch × 5 inch × 0.4 inch). There were also scrapes under the body of the vehicle. Deformation of the occupant compartment of 10 mm (0.4 inch) occurred in the windshield area. The interior of the vehicle is shown in Figure 190.

Assessment of Test Results

Figure 191 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The single hollow profile plastic sign support in wooden T-leg base with a 1220 mm × 1220 mm × 5 mm (48 inch × 48 inch ×0.2 inch) fiber board sign panel met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

  The windshield shattered, and glass was sprayed on the dash of the vehicle. At the center of the roof line, there was a dent that measured 60 mm × 120 mm × 10 mm (2 inch × 5 inch × 0.4 inch) from the fiber board sign panel. Although the sign panel did not penetrate, it demonstrated potential for penetrating the occupant compartment.

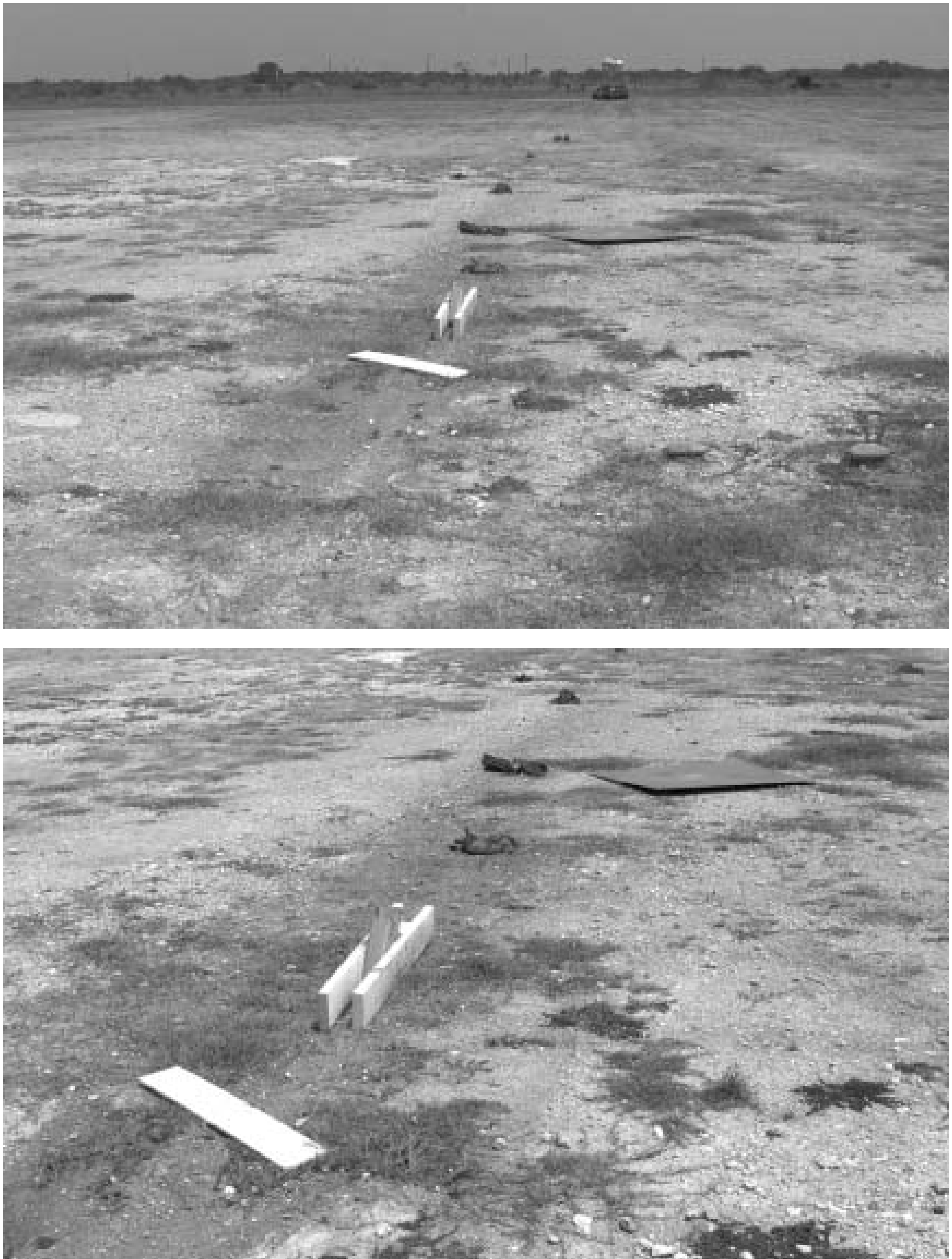


Figure 187. After Impact Trajectory for Test 417929-11.

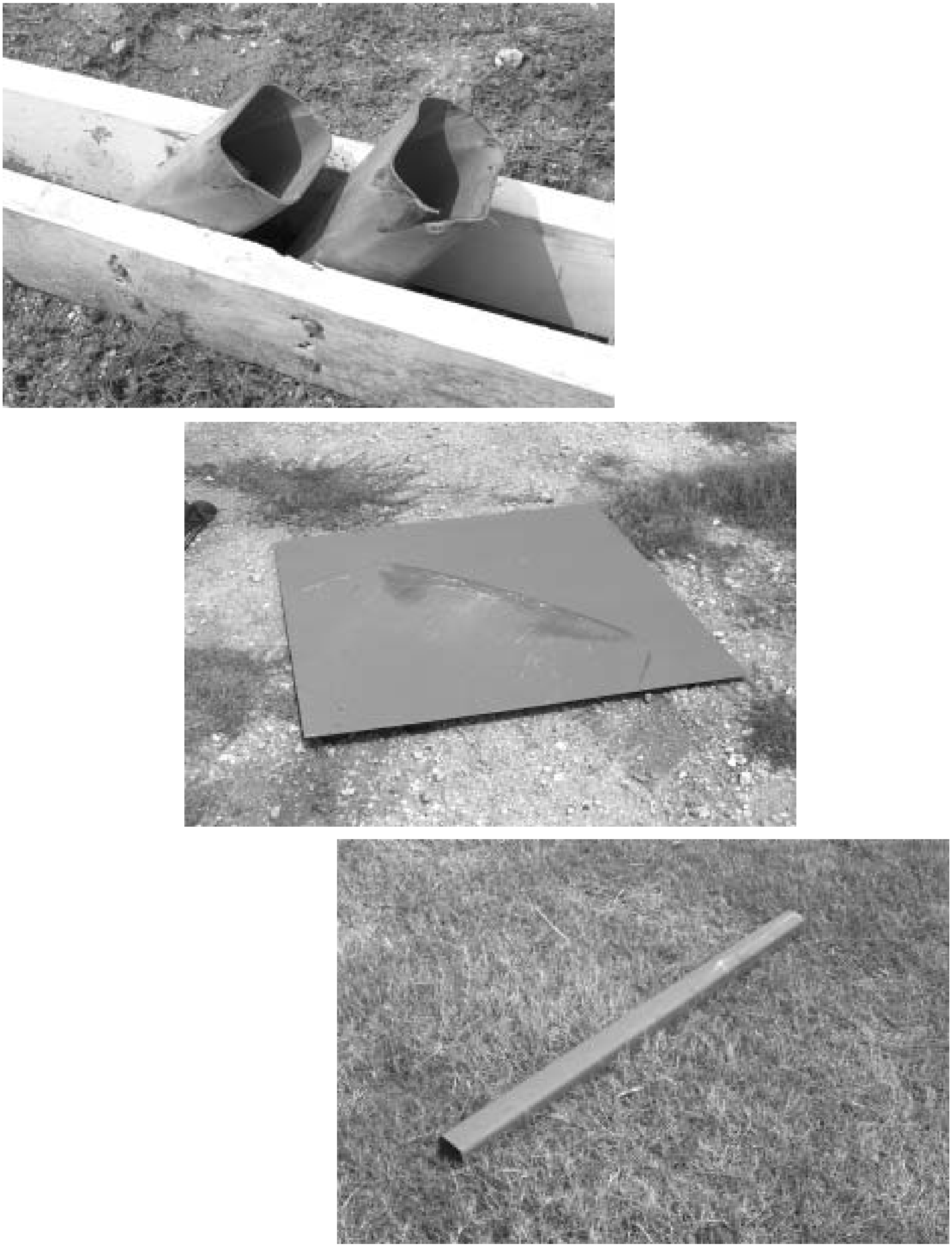


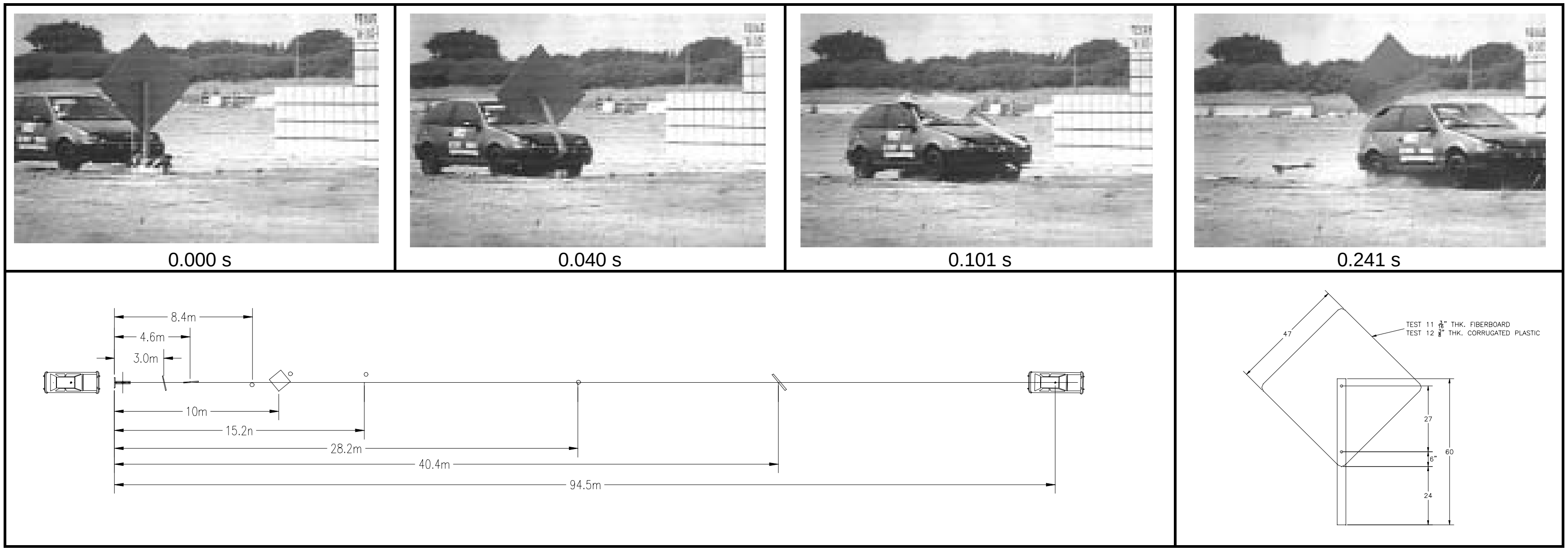
Figure 188. Installation after Test 417929-11.

Figure 189. Vehicle after Test 417929-11.

Before test

After test

Figure 190. Interior of Vehicle for Test 417929-11.



General Information
- Test Agency . . . . Texas Transportation Institute
- Test No. 417929-11
- Date 08/30/99

Test Article
- Type . . . . Traffic Control Device
- Name or Manufacturer . . . . . . Hollow core plastic sign support
- Installation Length (m) . . . . . . 0.6 (2.0 ft)
- Material or Key Elements . . . . Single wooden H-leg barricade with a 1220x1220x5 mm (48x48x0.2 inch) fiber board sign panel

Soil Type and Condition . . . . . . Standard Soil, dry

Test Vehicle
- Type . . . . Production
- Designation 820C
- Model . . . . 1994 Geo Metro
- Mass (kg) Curb . . . . 766 (1689 lb)
  - Test Inertial . . . . 820 (1806 lb)
  - Dummy . . . . 76 (168 lb)
  - Gross Static . . . . 896 (1974 lb)

Impact Conditions
- Speed (km/h) . . . . 97.3 (60.5 mi/h)
- Angle (deg) 0

Exit Conditions
- Speed (km/h) . . . . 91.8 (57.0 mi/h)
- Angle (deg) 0

Test Article Debris Pattern (m)
- Longitudinal . . . . 40.4 (132.5 ft)
- Lateral . . . . N/A

Vehicle Damage
- Exterior
  - VDS 12FC3
  - CDC 12FCEW2
- Maximum Exterior
  - Vehicle Crush (mm) . . . . . . nil
- Interior
  - OCDI FS0000000
- Max. Occ. Compart.
  - Deformation (mm) 0

Figure 191. Summary of Results for Test 417929-11, *NCHRP Report 350* Test 3-71.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

The windshield was shattered and deformed inward; however, visibility was not obstructed.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 1.5 m/s (4.9 ft/s).

Conclusion

The temporary hollow profile plastic sign support with a 1219 mm × 1219 mm (4 ft × 4 ft) FRP sign panel mounted at 0.6 m (2 ft) failed to meet criterion D of *NCHRP Report 350* and was therefore judged unacceptable. The sign panel shattered and caved in the windshield, deforming it inward more than 50 mm (2 inch), thereby demonstrating potential for penetrating the occupant compartment.

Hollow Profile Plastic Sign Support in T-Leg Base (1.2 m × 1.2 m [4 ft × 4 ft] corrugated plastic panel - 0.6 m [2 ft] mounting height) – Test No. 417929-12 (*NCHRP Report 350* Test No. 3-71)

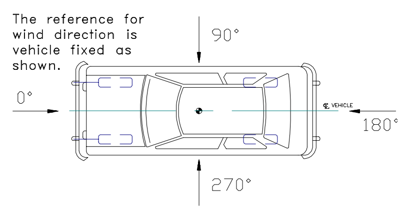
A single hollow profile plastic sign support in wooden T-leg base with a 1220 mm × 1220 mm × 11 mm (48 inch × 48 inch × 0.4 inch) corrugated plastic sign panel mounted at 0.6 m (2.0 ft) above the ground, shown previously in Figure 21 and in Figure 192, was evaluated in this crash test. The base of the barricade was ballasted with four 7.6 kg (16.8 lb) sandbags.

Test Vehicle

A 1994 Geo Metro, shown in Figures 193 and 194, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 370 mm (14.6 inch), and it was 455 mm (17.9 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 225. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the morning of August 30, 1999. No rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust and ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 5 km/h (3 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 36 °C (97 °F); relative humidity: 18 percent.



Test Description

The vehicle impacted the barricade head-on at a speed of 99.3 km/h (61.7 mi/h). At 0.020 s, the post moved, and at 0.032 s, the sign post was pulled out of the wooden base, and the bottom sign support bracket broke. By 0.036 s, the top sign support bracket broke, and by 0.038 s, the vehicle contacted the bottom of the sign panel. The post bounced off the front of the vehicle at 0.070 s, and at 0.072 s, the sign panel contacted the windshield. The top of the sign panel contacted the roof at 0.082 s. As the vehicle lost contact with the installation, at 0.297 s, the vehicle was traveling at 94.1 km/h (58.5 mi/h). Brakes on the vehicle were applied as the vehicle exited the test site, and the vehicle came to rest 109.7 m (359.9 ft) down from the impact point. Sequential photographs of the test can be found in Appendix C, Figure 247.

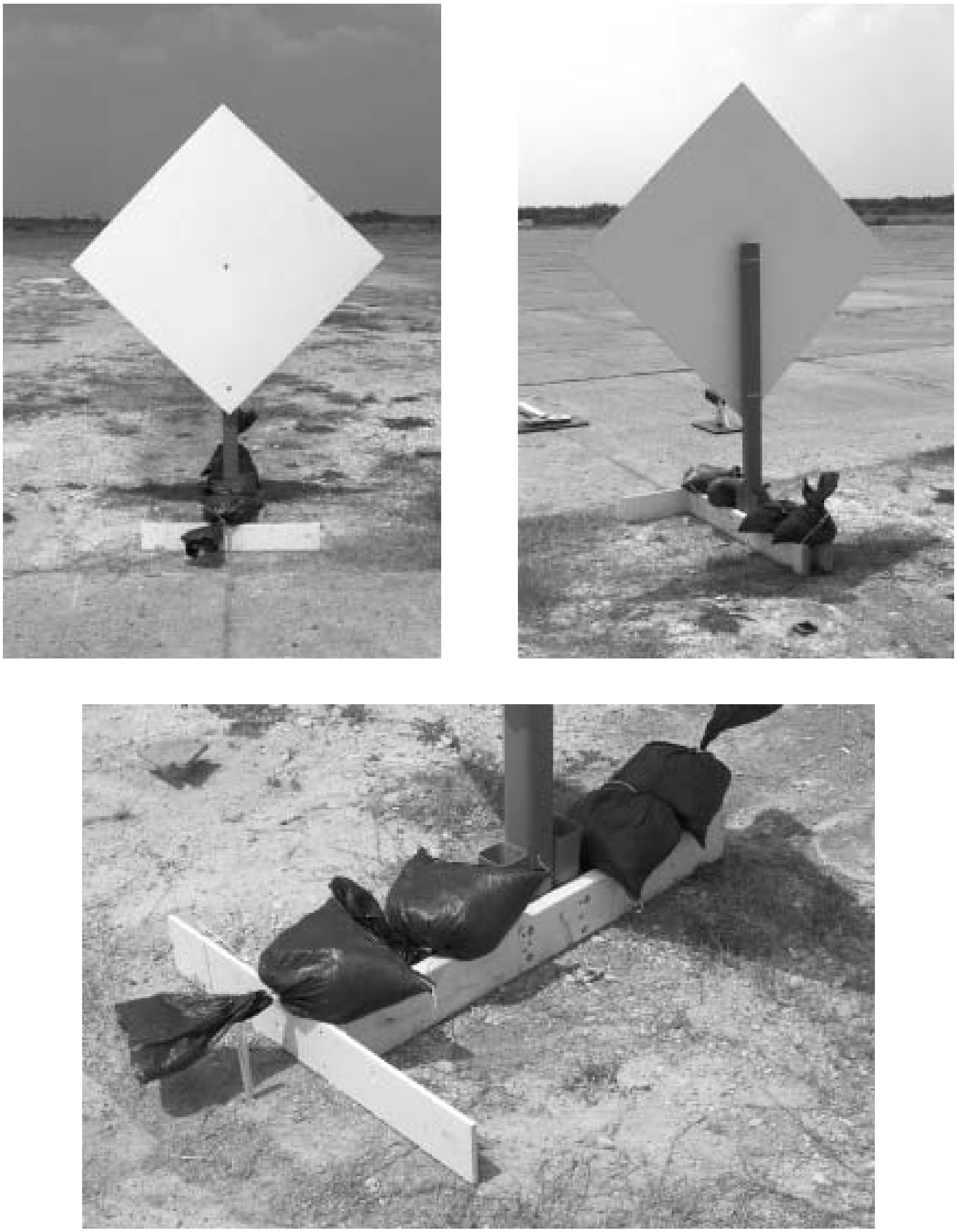


Figure 192. Installation before Test 417929-12.

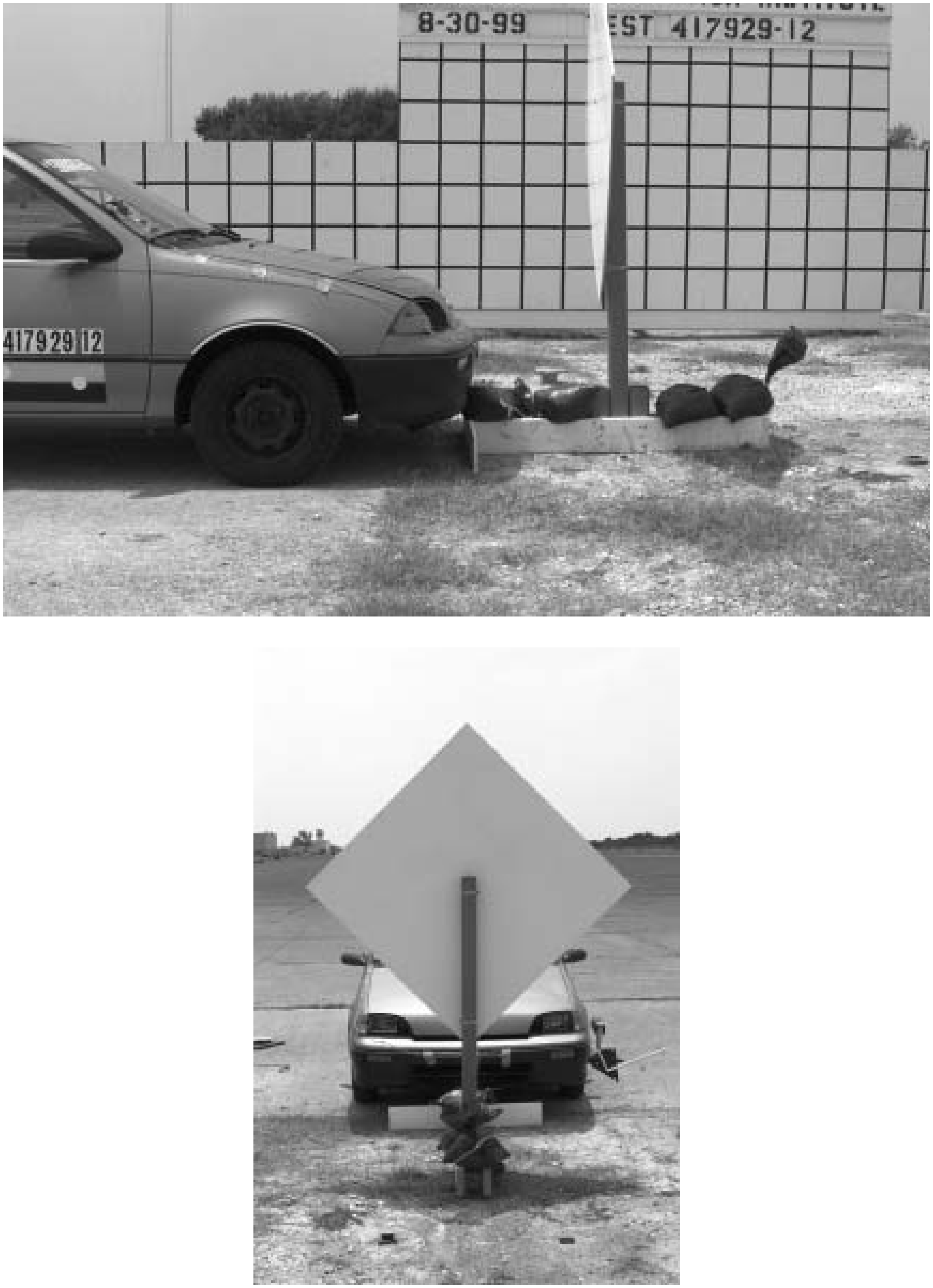


Figure 193. Vehicle/Installation Geometrics for Test 417929-12.

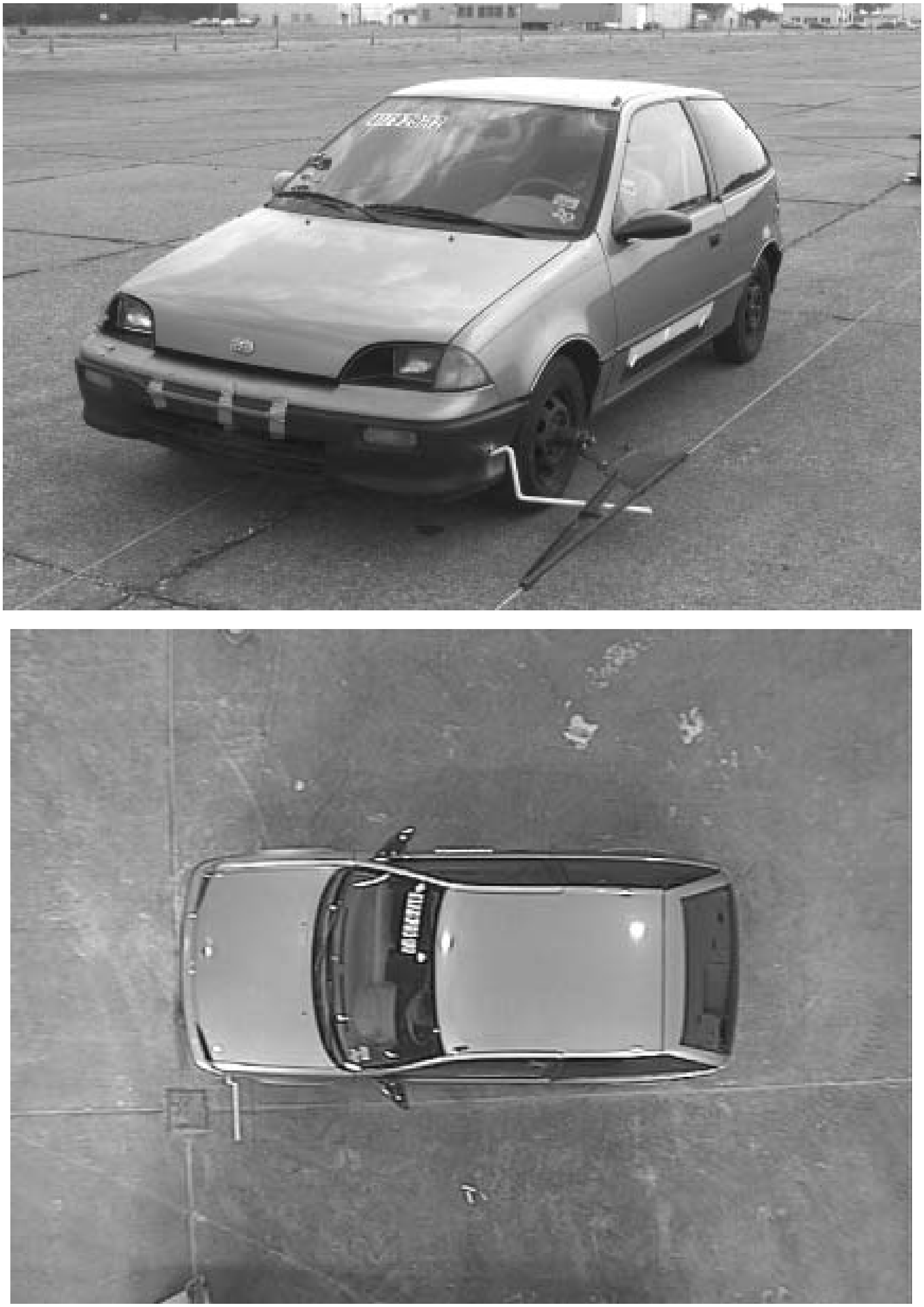


Figure 194. Vehicle before Test 417929-12.

Damage to Test Installation

The barricade separated into multiple pieces, as shown in Figures 195 and 196. The base of the unit moved 0.76 m (2.5 ft) from impact, and the remaining debris extended 38.9 m (127.6 ft) down and 7.6 m (25.0 ft) to the left of the impact point.

Vehicle Damage

The vehicle received damage, as shown in Figure 197. The hood, roof, and radiator support were damaged. The windshield was cracked at the top in the center. There were scrapes under the body, and the fuel tank was dented. No deformation or intrusion of the occupant compartment occurred. The interior of the vehicle is shown in Figure 198.

Assessment of Test Results

Figure 199 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The single hollow profile sign support in a wooden T-leg base with a 1220 mm × 1220 mm × 11 mm (48 inch × 48 inch × 0.4 inch) corrugated plastic sign panel met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

  The support cracked the windshield at the roof line in the center, but it did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred.

Figure 195. After Impact Trajectory for Test 417929-12.

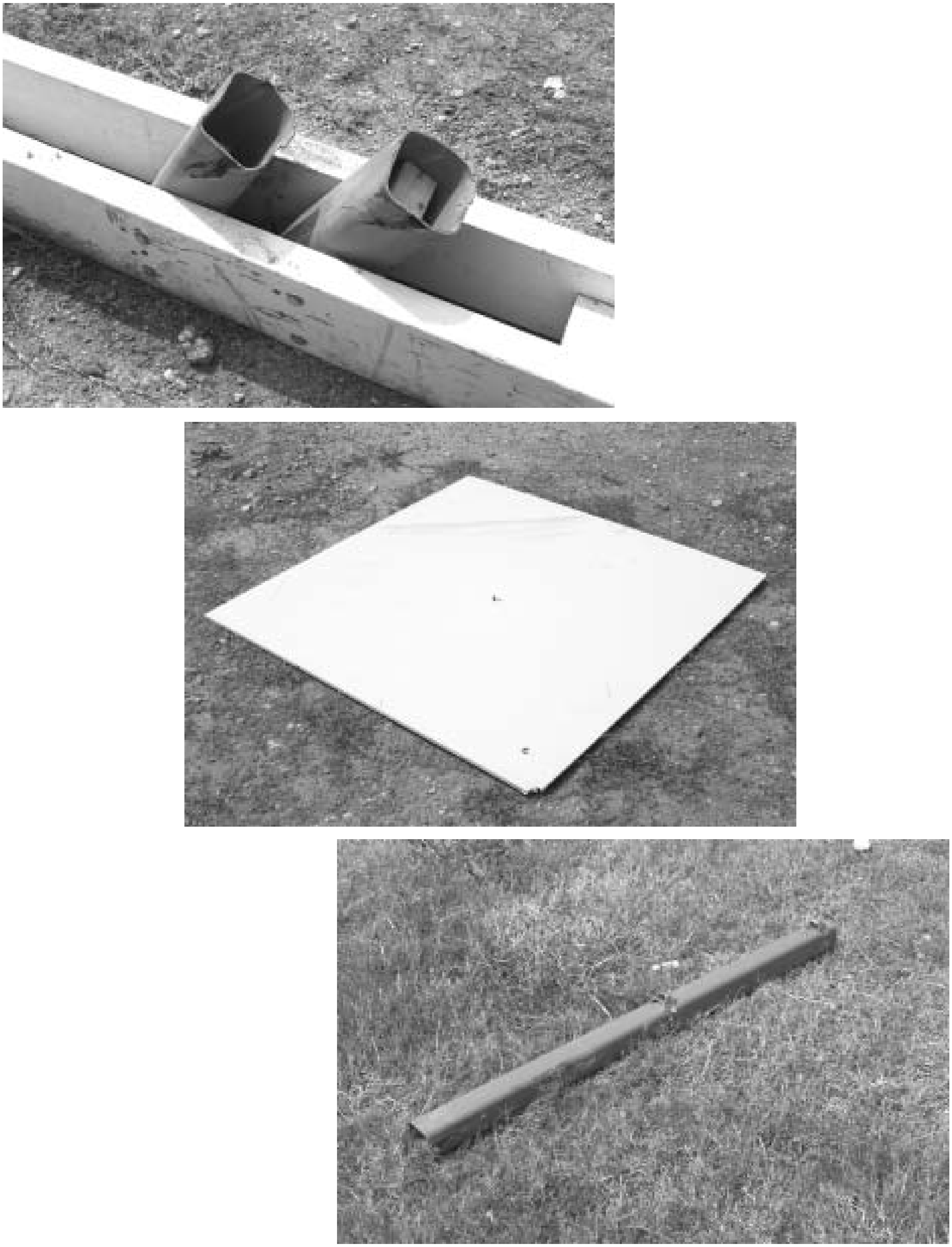


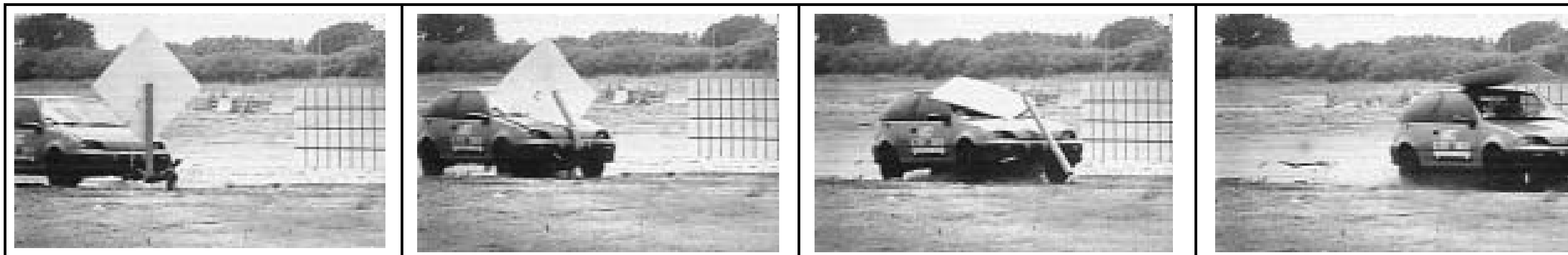
Figure 196. Installation after Test 417929-12.

Figure 197. Vehicle after Test 417929-12.

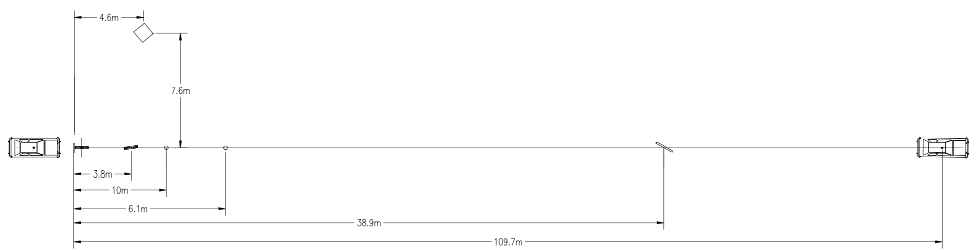
Before test

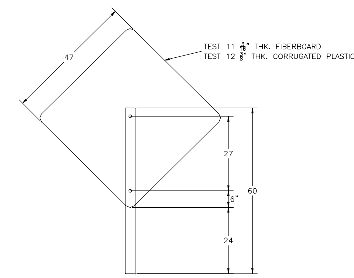
After test

Figure 198. Interior of Vehicle for Test 417929-12.



0.000 s | 0.049 s | 0.123 s | 0.247 s





General Information

Test Agency	Texas Transportation Institute
Test No.	417929-12
Date	08/30/99

Test Article

Type	Traffic Control Device
Name or Manufacturer	Hollow core plastic sign support
Installation Length (m)	0.6 (2.0 ft)
Material or Key Elements	Single wooden H-leg barricade with a 1220x1220x11 mm (48x48x0.4 inch) corrugated plastic sign panel

Soil Type and Condition . . . . . . Standard Soil, dry

Test Vehicle

Type	Production
Designation	820C
Model	1994 Geo Metro
Mass (kg) Curb	767 (1691 lb)
Test Inertial	820 (1806 lb)
Dummy	76 (168 lb)
Gross Static	896 (1974 lb)

Impact Conditions

Speed (km/h)	99.3 (61.7 mi/h)
Angle (deg)	0

Exit Conditions

Speed (km/h)	94.1 (58.5 mi/h)
Angle (deg)	0

Test Article Debris Pattern (m)

Longitudinal	38.9 (127.6 ft)
Lateral	7.6 (24.9 ft)

Vehicle Damage

Exterior	
VDS	12FC1
CDC	12FCEW1
Maximum Exterior Vehicle Crush (mm)	nil
Interior	
OCDI	FS0000000
Max. Occ. Compart. Deformation (mm)	0

Figure 199. Summary of Results for Test 417929-12, *NCHRP Report 350* Test 3-71.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 1.4 m/s (4.6 ft/s).

Conclusion

The temporary hollow profile plastic sign support with a 1219 mm × 1219 mm (4 ft × 4 ft) corrugated plastic sign panel mounted at 610 mm (24 inch) performed acceptably and met all *NCHRP Report 350* evaluation criteria for test designation 3-71 for a frontal, head-on impact.

TEMPORARY SIGN SUPPORTS:
CHEVRON/OBJECT MARKER SUPPORTS

Dual Chevron Support –
Test No. 417929-3 (*NCHRP Report 350* Test No. 3-71)

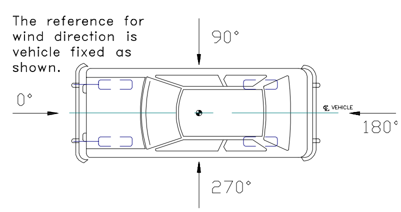
A dual chevron installation with panels at 1.2 m (4.0 ft) mounting height, shown previously in Figure 22 and in Figure 200, was evaluated in this crash test. One installation had a single panel through-bolted to a U-channel post, and the other installation had two panels (one on the front and one on the rear side as if facing the opposing traffic) attached to a Pozi-Loc thin wall tube using the standard mounting brackets.

Test Vehicle

A 1994 Geo Metro, shown in Figures 201 and 202, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 385 mm (15.2 inch), and it was 470 mm (18.5 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 221. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

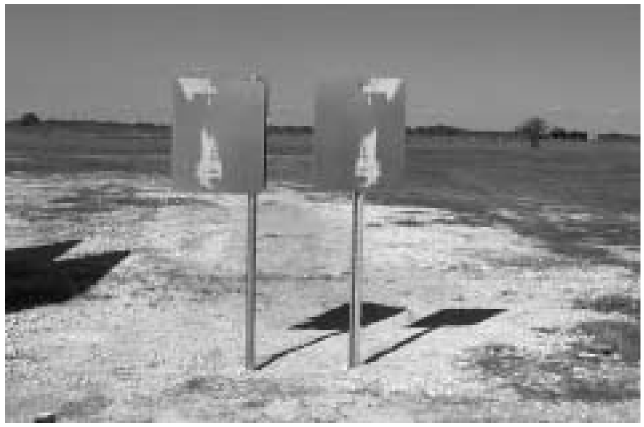
Soil and Weather Conditions

The test was performed the afternoon of November 3, 1998. A total of 41 mm (1.6 inch) of rain was recorded nine days prior to the test but would not affect the test as the barricade was installed on the ground surface. No other rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust to ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 13 km/h (8 mi/h); wind direction: 0 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 16 °C (61 °F); relative humidity: 72 percent.



Test Description

The vehicle impacted the sign supports head-on at a speed of 99.8 km/h (62.0 mi/h). Shortly after impact, both sign posts moved. At 0.005 s, the U-channel post split at bumper height, and at 0.007 s, the U-channel post fractured at the bumper. By 0.010 s, the tube post



Sign A

Sign A

Sign B

Figure 200. Installation before Test 417929-3.

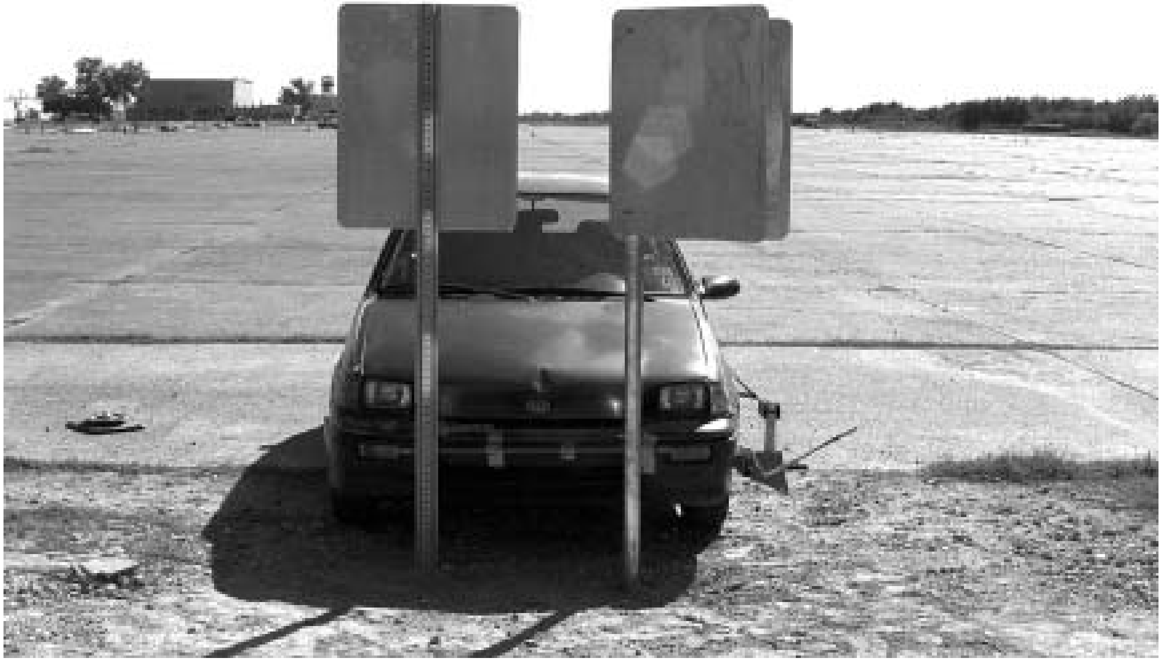


Figure 201. Vehicle/Installation Geometrics for Test 417929-3.

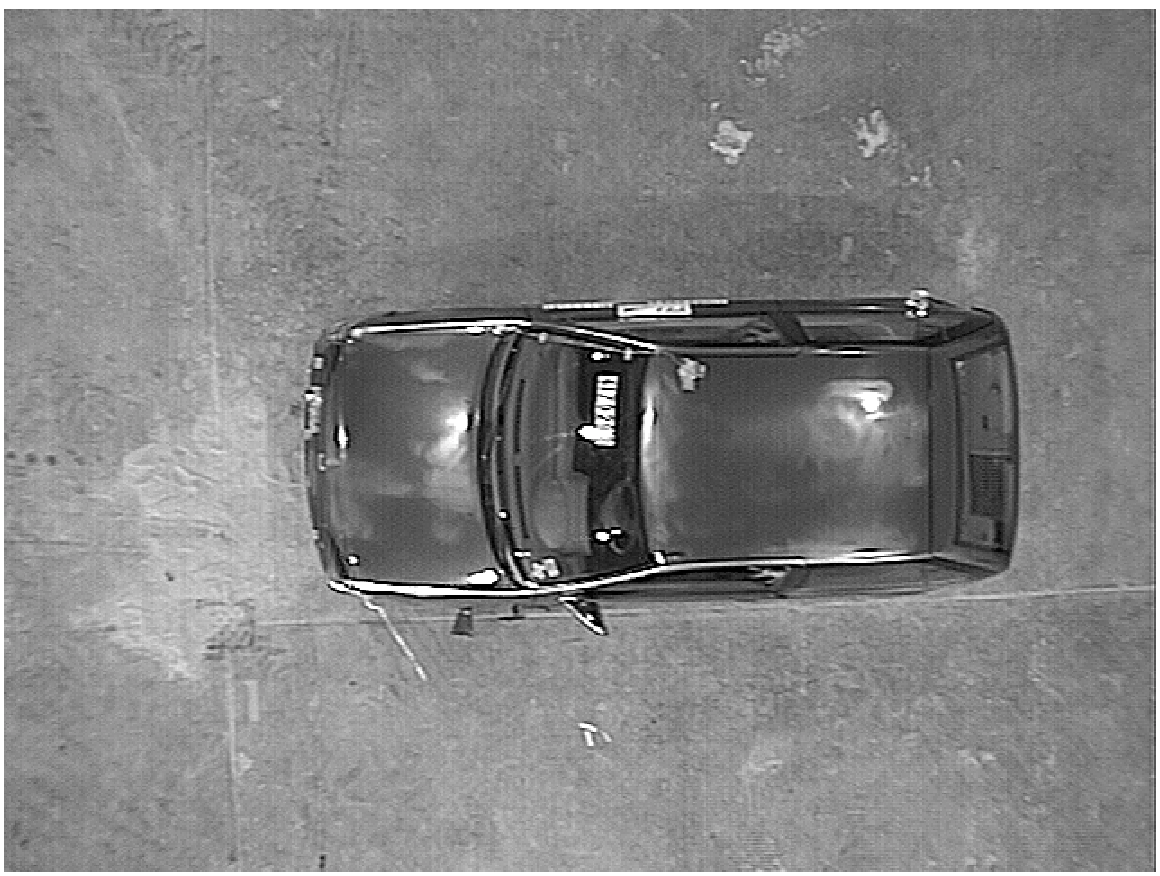


Figure 202. Vehicle before Test 417929-3.

deformed at bumper height and the base, and the post pulled out of the ground. By 0.029 s, the tube post pulled out of the ground. At 0.051 s, the tube post sign contacted the driver's side of the windshield and the door frame, and at 0.058 s, the U-channel sign contacted the roof at the windshield. By 0.064 s, the windshield shattered, and by 0.080 s, the tube post rear sign contacted the left side of the windshield at the frame of the vehicle. The U-channel sign lost contact with the vehicle at 0.102 s. At 0.255 s, the vehicle was traveling at 95.0 km/h (59.0 mi/h) as the vehicle exited the test site with the tube post sign. Brakes on the vehicle were applied as it exited the test site, and the vehicle came to rest 97.5 m (319.9 ft) downstream from impact. Sequential photographs of the test can be found in Appendix C, Figures 248 and 249.

Damage to Test Installation

The sign supports separated into multiple pieces, as shown in Figures 203 and 204. The U-channel post came to rest 28.2 m (92.5 ft) from impact and 0.76 m (2.5 ft) to the right of impact. One of the panels from the tube post sign came to rest 21.3 m (70.0 ft) down and 8.4 m (27.6 ft) to the left of impact, and the other sign panel came to rest 35.1 m (115.2 ft) down and 3.0 m (9.8 ft) to the left of impact. The tube post was 48.0 m (157.5 ft) downstream and 3.0 m (9.8 ft) to the left of impact.

Vehicle Damage

The front of the vehicle received damage, as shown in Figure 205. The hood and bumper of the vehicle were dented. The left door post was dented from contact with the sign. The windshield was shattered. Maximum deformation into the occupant compartment was 75 mm (3.0 inch) (8 percent reduction in space) to the roof of the vehicle. A cut, 110 mm (4.3 inch) in length, was in the deformed section of the roof. The interior of the vehicle is shown in Figure 206. Exterior vehicle crush and occupant compartment measurements are shown in Appendix B, Tables 5 and 6.

Assessment of Test Results

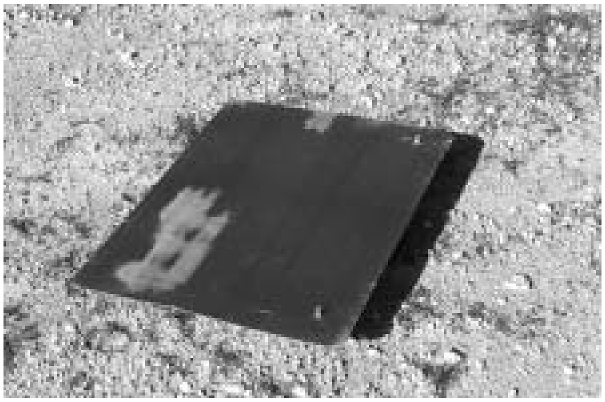
Figure 207 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

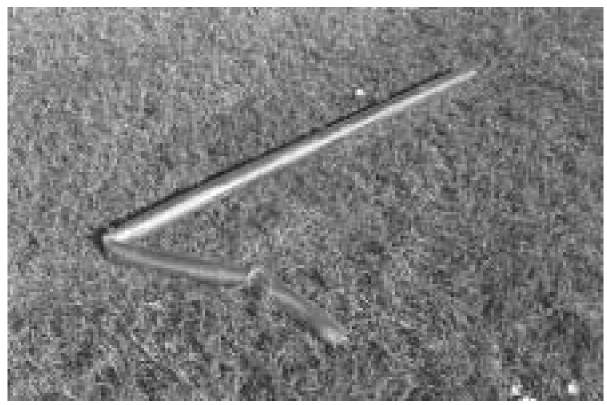
  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The thin-wall tube and the U-channel supports met the requirements for structural adequacy by yielding to the vehicle.

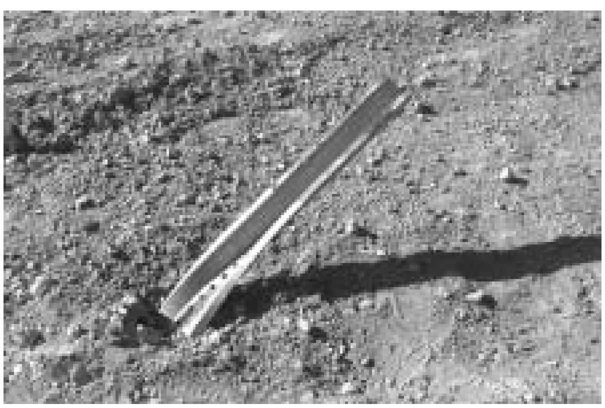
Figure 203. After Impact Trajectory for Test 417929-3.

Sign A

Sign A

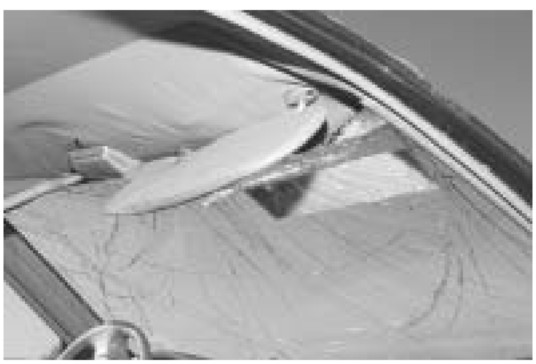
 

Sign B

Figure 204. Installation after Test 417929-3.

Figure 205. Vehicle after Test 417929-3.

Before test



After test

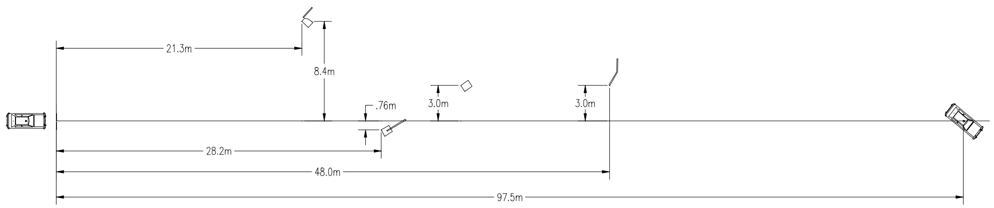
Figure 206. Interior of Vehicle for Test 417929-3.

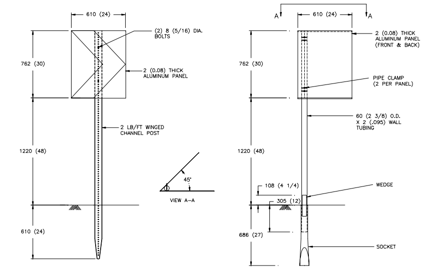

0.000 s


0.037 s


0.099 s


0.198 s





General Information
- Test Agency . . . . Texas Transportation Institute
- Test No. 417929-3
- Date 11/3/98

Test Article-Sign A
- Type . . . . Traffic Control Device
- Name . . . . Dual Chevron Support
- Installation Length (m) . . . . . 0.6 (2.0 ft)
- Material or Key Elements . . . 1.2 m (4.0 ft) tall steel support with 764x610 mm (30x24 inch) dual metal sign panels

Test Article-Sign B
- Type . . . . Traffic Control Device
- Name . . . . Dual Chevron Support
- Installation Length (m) . . . . . 0.6 (2.0 ft)
- Material or Key Elements . . . 1.2 m (4.0 ft) Tall U-Channel Post with 763x610 mm (30x24 inch) Single Metal Sign Panel

Soil Type and Condition . . . . Standard Soil, Dry

Test Vehicle
- Type . . . . Production
- Designation 820C
- Model . . . . 1994 Geo Metro

Mass (kg)
- Curb . . . . 769 (1695 lb)
- Test Inertial . . . . 820 (1806 lb)
- Dummy . . . . 75 (165 lb)
- Gross Static . . . . 895 (1973 lb)

Impact Conditions-Sign A
- Speed (km/h) . . . . 99.8 (62.0 mi/h)
- Angle (deg) 0

Exit Conditions
- Speed (km/h) . . . . 95.0 (59.0 mi/h)
- Angle (deg) 0

Impact Conditions-Sign B
- Speed (km/h) . . . . 99.8 (62.0 mi/h)
- Angle (deg) 0

Exit Conditions
- Speed (km/h) . . . . 95.0 (59.0 mi/h)
- Angle (deg) 0

Test Article Debris Pattern-Sign A (m)
- Longitudinal . . . . 48.0 (157.5 ft)
- Lateral . . . . 8.4 (27.6 ft)

Test Article Debris Pattern-Sign B (m)
- Longitudinal . . . . 28.2 (92.5 ft)
- Lateral . . . . 0.8 (2.5 ft)

Vehicle Damage-Sign A
- Exterior
  - VDS 12FL1
  - CDC 12FLEN1
- Maximum Exterior
  - Vehicle Crush (mm) . . . nil
- Interior
  - OCDI FS0000000
- Max. Occ. Compart.
  - Deformation (mm) 0

Vehicle Damage-Sign B
- Exterior
  - VDS 12FR1
  - CDC 12FREW1
- Maximum Exterior
  - Vehicle Crush (mm) . . . nil
- Interior
  - OCDI FS0100000
- Max. Occ. Compart.
  - Deformation (mm) . . . . 75 (3.0 inch)

Figure 207. Summary of Results for Test 417929-3, *NCHRP Report 350* Test 3-71.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

The U-channel sign support contacted the windshield and cut the roof but did not intrude into the occupant compartment. Maximum deformation into the occupant compartment was 75 mm (3.0 inch) (8 percent reduction in space) to the roof of the vehicle, with a 110 mm (4.3 inch) cut. The thin-wall tube sign support contacted the windshield frame at the A-pillar and cracked the windshield slightly. The thin-wall support did not cause deformation or intrusion into the occupant compartment

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph

[32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 1.3 m/s (4.3 ft/s).

Conclusion

The U-channel chevron support did not meet criterion D of *NCHRP Report 350* and therefore was judged unacceptable. The U-channel contacted the windshield and cut the roof just behind the windshield frame, thereby showing potential for penetrating the occupant compartment. The thin-wall chevron support contacted the windshield, which cracked only slightly. The thin-wall chevron support performed acceptably according to the guidelines of *NCHRP Report 350*.

TEMPORARY SIGN SUPPORTS:
TEMPORARY MAILBOX SUPPORT

Mailbox on Plastic Drum –
Test No. 417929-10 (*NCHRP Report 350* Test No. 3-71)

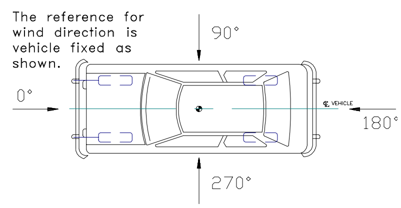
A mailbox on a plastic drum with 835 mm (33 inch) height, manufactured by Traffix Device, Inc., shown previously in Figure 23 and in Figure 208, was evaluated in this crash test.

Test Vehicle

A 1994 Geo Metro, shown in Figures 209 and 210, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1806 lb), and its gross static weight was 896 kg (1974 lb). The height to the lower edge of the vehicle bumper was 385 mm (15.2 inch), and it was 475 mm (18.7 inch) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in Appendix B, Figure 224. The vehicle was directed into the installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

Soil and Weather Conditions

The test was performed the morning of August 30, 1999. No rainfall occurred for the 10 days prior to the test. The *NCHRP Report 350* standard soil, on which the traffic control devices were placed, was moistened slightly just prior to the test to settle the dust and ensure an unimpaired view for the high-speed cameras. Weather conditions at the time of testing were as follows: wind speed: 3 km/h (2 mi/h); wind direction: 80 degrees with respect to the vehicle (vehicle was traveling in a northerly direction); temperature: 33 °C (91 °F); relative humidity: 36 percent.



Test Description

The vehicle impacted the mailbox support head-on at a speed of 91.3 km/h (56.7 mi/h). Shortly after impact, the mailbox moved, and the drum lost contact with the ground. At 0.040 s, the mailbox contacted the hood of the vehicle, and at 0.054 s, the drum lost contact with the bumper of the vehicle. The drum lost contact with the front of the vehicle at 0.058 s, and at 0.078 s, the mailbox lost contact with the hood of the vehicle. As the vehicle lost contact with the installation, at 0.094 s, the vehicle was traveling at 90.3 km/h (56.1 mi/h). Brakes on the vehicle were applied as the vehicle exited the test site, and the vehicle came to rest 91.4 m (300.0 ft) down from the impact point. Sequential photographs of the test can be found in Appendix C, Figure 250.

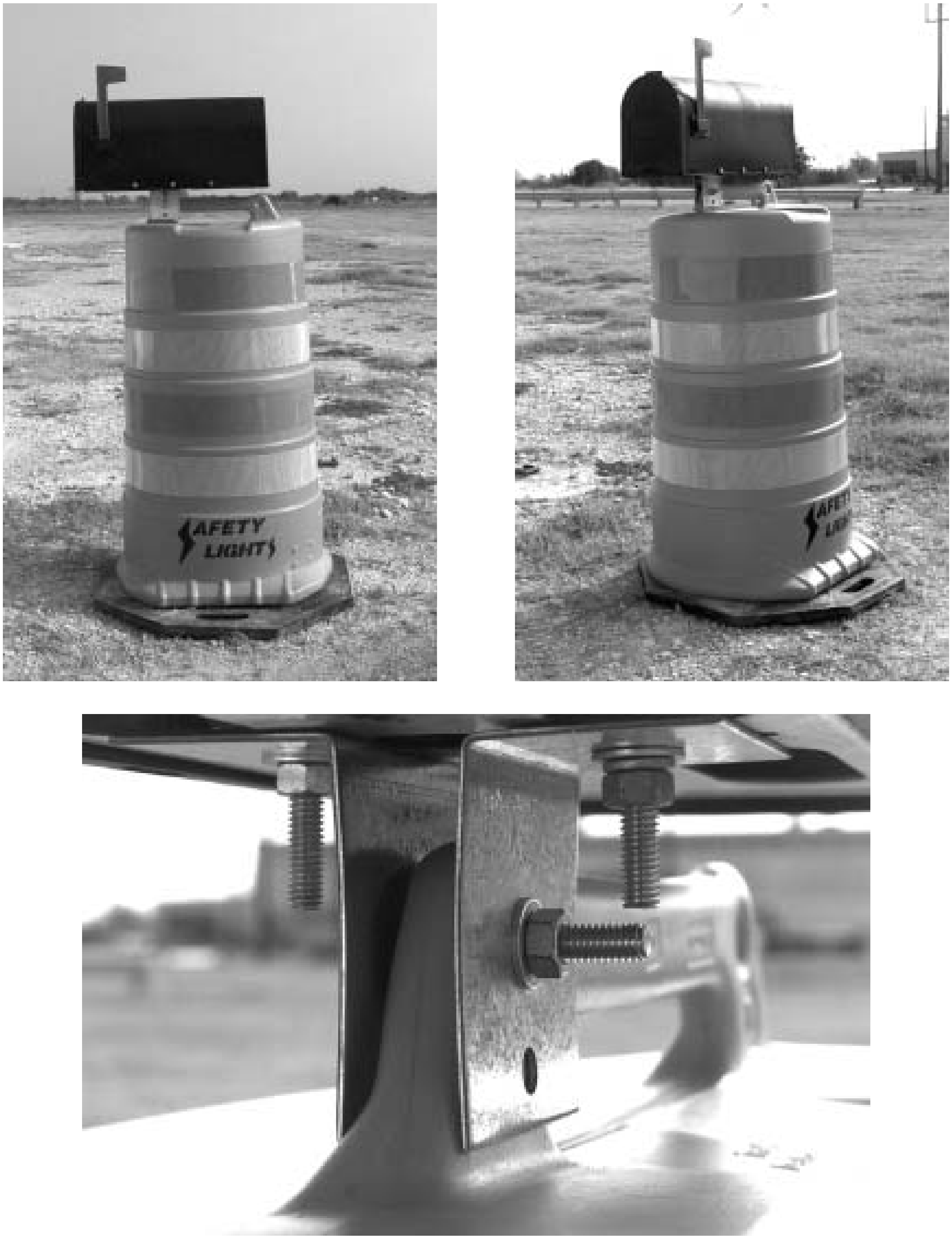


Figure 208. Installation before Test 417929-10.

Figure 209. Vehicle/Installation Geometrics for Test 417929-10.

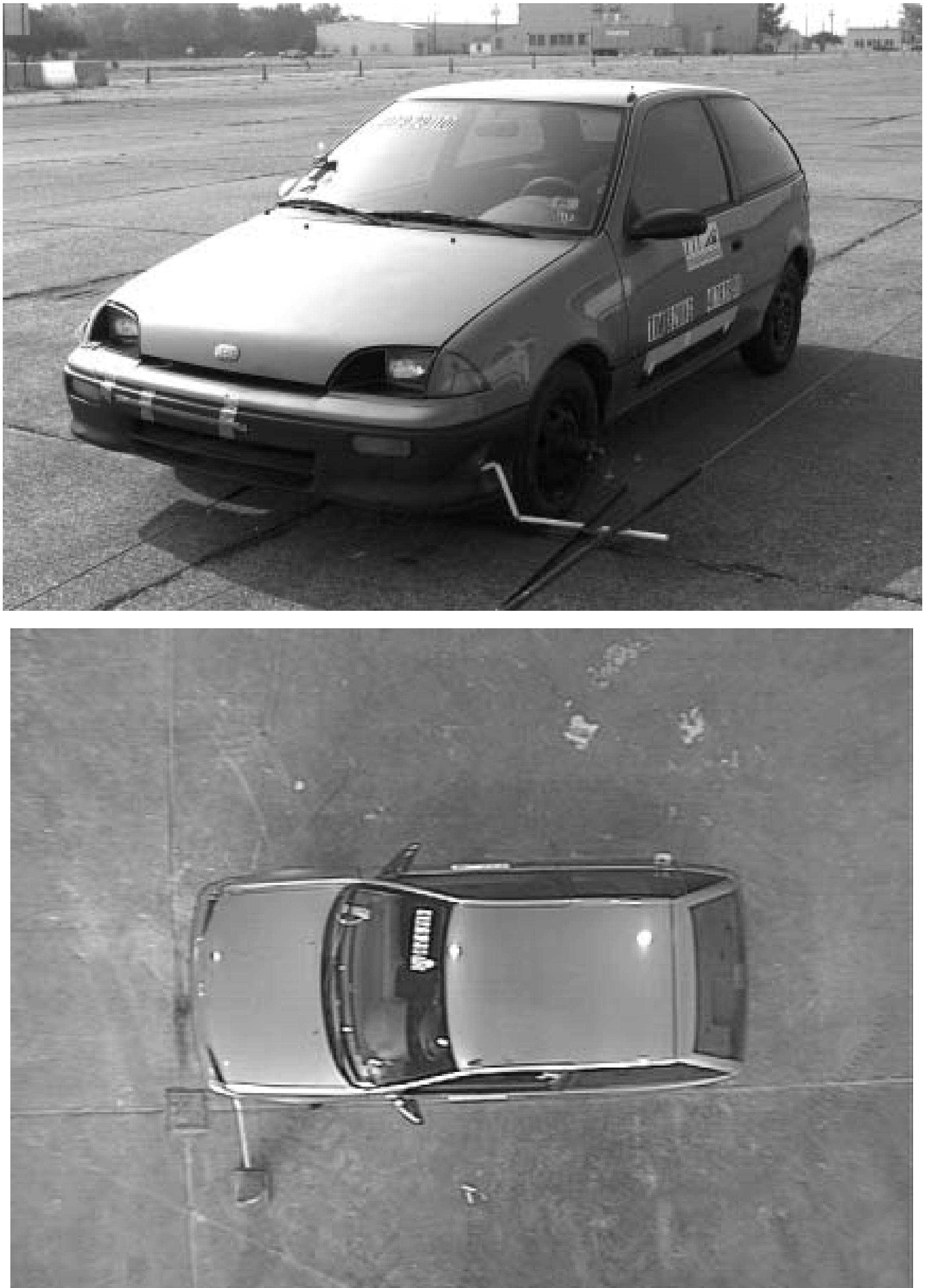


Figure 210. Vehicle before Test 417929-10.

Damage to Test Installation

The drum remained in one piece, as shown in Figures 211 and 212. The base of the unit moved 19 mm (0.8 inch), and debris extended 28.2 m (92.5 ft) down and 4.6 m (15.1 ft) to the left of the impact point.

Vehicle Damage

The vehicle received minor damage to the hood as shown in Figure 213. No deformation or intrusion of the occupant compartment occurred. The interior of the vehicle is shown in Figure 214.

Assessment of Test Results

Figure 215 shows a summary of the test results. As stated previously, the following *NCHRP Report 350* safety evaluation criteria were used to evaluate this crash test:

- **Structural Adequacy**

  B. *The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.*

  The mailbox on plastic drum met the requirements for structural adequacy by yielding to the vehicle.

- **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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.*

  The mailbox on plastic drum did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred.

Figure 211. After Impact Trajectory for Test 417929-10.

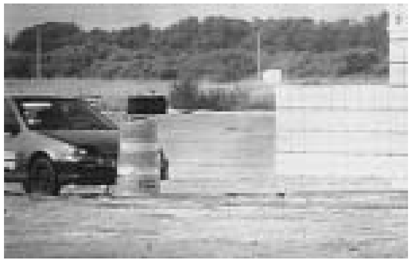
Figure 212. Installation after Test 417929-10.

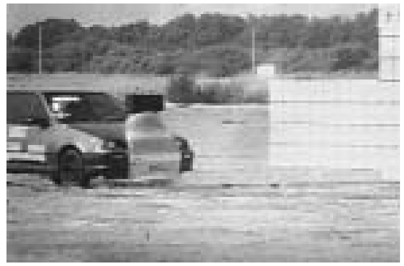
Figure 213. Vehicle after Test 417929-10.

Before test

After test

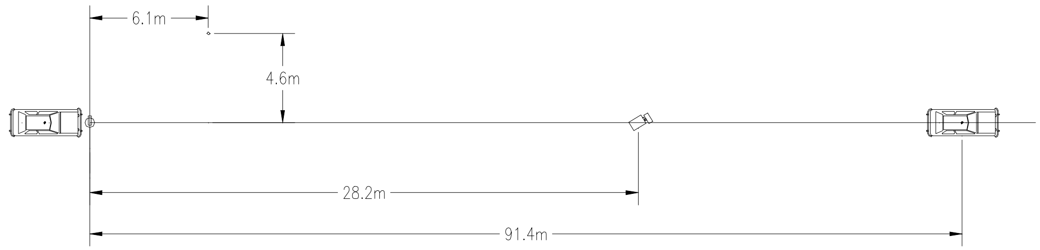
Figure 214. Interior of Vehicle for Test 417929-10.

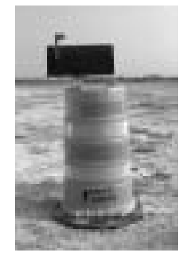

0.000 s


0.025 s


0.087 s


0.198 s





General Information

Test Agency	Texas Transportation Institute
Test No.	417929-10
Date	08/30/99

Test Article

Type	Traffic Control Device
Name or Manufacturer	Mailbox on plastic drum
Installation Length (m)	1.1 (3.6 ft)
Material or Key Elements	Plastic drum with mailbox installed on top

Soil Type and Condition . . . . . . Standard Soil, dry

Test Vehicle

Type	Production
Designation	820C
Model	1994 Geo Metro
Mass (kg) Curb	766 (1689 lb)
Test Inertial	820 (1806 lb)
Dummy	76 (168 lb)
Gross Static	896 (1974 lb)

Impact Conditions

Speed (km/h)	91.1 (56.6 mi/h)
Angle (deg)	0

Exit Conditions

Speed (km/h)	90.3 (56.1 mi/h)
Angle (deg)	0

Test Article Debris Pattern (m)

Longitudinal	28.2 (92.5 ft)
Lateral	4.6 (15.1 ft)

Vehicle Damage

Exterior	
VDS	12FC1
CDC	12FCEW1
Maximum Exterior Vehicle Crush (mm)	nil
Interior	
OCDI	FS0000000
Max. Occ. Compart. Deformation (mm)	0

Figure 215. Summary of Results for Test 417929-10, *NCHRP Report 350* Test 3-71.

E. *Detached elements, fragments, or other debris from the test article, or vehicular damage should not block the driver's vision or otherwise cause the driver to lose control of the vehicle.*

None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle.

F. *The vehicle should remain upright during and after collision although moderate roll, pitching, and yawing are acceptable.*

The vehicle remained upright during and after the collision period.

- **Vehicle Trajectory**

K. *After collision, it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.*

The vehicle did not intrude into adjacent traffic lanes.

N. *Vehicle trajectory behind the test article is acceptable.*

The vehicle trajectory behind the test article is acceptable.

- **1994 AASHTO Specification**

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800-pound [816.5 kg] vehicle, or its equivalent, striking a breakaway support at speeds of 20 mph to 60 mph [32 kmph to 97 kmph] does not exceed 16 fps [4.87 mps], but preferably does not exceed 10 fps [3.05 mps].

Maximum change in velocity for this test was 0.2 m/s (0.7 ft/s).

Conclusion

The temporary mailbox support performed acceptably according to the guidelines specified in *NCHRP Report 350*.

IV. SUMMARY OF FINDINGS, CONCLUSIONS AND IMPLEMENTATION RECOMMENDATIONS

SUMMARY OF FINDINGS

Type I Barricades

Type I Plastic A-frame Barricade (Test No. 417928-6)

The Type I plastic fixed A-frame barricade, manufactured by Fender Enterprises, met the requirements for structural adequacy by yielding to the vehicle. The plastic barricade shattered the base of the windshield, but it did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred. None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision period. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 0.06 m/s (2.0 ft/s). The Type I plastic A-frame barricade performed acceptably for a 0-degree impact according to *NCHRP Report 350*.

Type I Perforated Steel Tube Skid Mount Barricade (Test No. 417928-7)

The Type I perforated steel tube barricade with wooden panel separated from the base and thereby met the requirements for structural adequacy by yielding to the vehicle. The steel barricade did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred. None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 2.4 m/s (8.0 ft/s). The Type I perforated steel tube skid mount barricade performed acceptably for a 0-degree impact according to *NCHRP Report 350*.

Type I Hollow Profile Plastic Skid Mount Barricade (Test No. 417928-8)

The Type I hollow core plastic barricade with wooden panel and skids separated from the base and thereby met the requirements for structural adequacy by yielding to the vehicle. The plastic barricade did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred. None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 2.9 m/s (9.5 ft/s). The Type I hollow profile plastic skid mount barricade performed acceptably for a 0-degree impact according to *NCHRP Report 350*.

<u>Type I Hollow Profile Plastic Folding A-Frame (Test No. 417928-9)</u>

The Type I hollow core plastic folding A-frame barricade with wood panels met the requirements for structural adequacy by yielding to the vehicle. The plastic barricade did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred. None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 1.9 m/s (6.2 ft/s). The Type I hollow profile plastic folding A-frame performed acceptably for a 0-degree impact according to *NCHRP Report 350*.

<u>Type I Wood Fixed A-Frame Barricade (Test No. 417928-17)</u>

The wooden fixed A-frame barricade met the requirements for structural adequacy by yielding to the vehicle. The barricade traveled with the vehicle, but it did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred. None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 0.6 m/s (2.0 ft/s). The Type I wood fixed A-frame barricade performed acceptably for a 0-degree impact according to *NCHRP Report 350*.

Type III Barricades

<u>Type III Barricade with FRP Supports in Dual-Purpose Base (Test No. 417928-2)</u>

The fiber reinforced plastic sign support pulled out of the dual-purpose base and thereby met the requirements for structural adequacy by yielding to the vehicle. The top of the barricade cracked the windshield at the edge near the hood, but it did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred. None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 4.2 m/s (13.8 ft/s). The Type III barricade with FRP supports in dual-purpose base performed acceptably for a 0-degree impact according to *NCHRP Report 350*.

Type III Perforated Steel Tube Barricade (Test No. 417928-14)

The Type III steel perforated tube barricade with plastic panels met the requirements for structural adequacy by yielding to the vehicle. The center plastic panel of the steel barricade shattered the bottom of the windshield, but it did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred. The steel supports for the panels broke off the side mirrors from the vehicle, but none of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 1.0 m/s (3.3 ft/s). The Type III perforated steel tube barricade performed acceptably for a 0-degree impact according to *NCHRP Report 350*.

Type III Barricade with Hollow Profile Plastic Supports (Test No. 417928-16)

The Type III barricade with hollow core plastic supports met the requirements for structural adequacy by yielding to the vehicle. The barricade contacted the hood and cracked the base of the windshield, but it did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred. The steel supports for the panels broke off the side mirrors from the vehicle, but none of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 1.4 m/s (4.6 ft/s). The Type III barricade with hollow profile plastic supports performed acceptably for a 0-degree impact according to *NCHRP Report 350*.

Temporary Sign Supports

Long/Intermediate Term Portable Sign Supports

Single FRP Support in Dual-Purpose Base (Test No. 417928-3)

The single fiber reinforced plastic sign support pulled out of the dual-purpose base and thereby met the requirements for structural adequacy by yielding to the vehicle. The sign support did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred. None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 3.4 m/s (11.2 ft/s). The single FRP supports in dual-purpose base performed acceptably for a 0-degree impact according to *NCHRP Report 350*.

Wood Sign Support in H-Leg Base (2.1 m [7 ft] mounting height) (Test No. 417928-10)

The single H-leg base with plywood sign panel met the requirements for structural adequacy by yielding to the vehicle. The sign support did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred. None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 4.4 m/s (14.4 ft/s). The wood sign support in h-leg base performed acceptably for a 0-degree impact according to *NCHRP Report 350*.

Dual Perforated Steel Tube Skid Mounted Sign Support (Test No. 417928-11)

The dual perforated steel tube skid mounted sign support with plywood sign panel met the requirements for structural adequacy by yielding to the vehicle. The steel sign support penetrated the occupant compartment in the windshield area and deformed the roof. Maximum deformation into the occupant compartment was 99 mm (3.9 inch) (11 percent reduction of space) in the floor pan near the transmission tunnel. The detached elements or vehicle damage would not block the driver's vision but might cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 2.9 m/s (9.5 ft/s). The dual perforated steel tube skid mounted support did not perform acceptably for a 0-degree impact according to *NCHRP Report 350*.

Long/Intermediate Term Ground-Mounted Sign Supports

Dual FRP Sign Support (Test Nos. 417928-4&5)

In the low speed test (Test No. 417928-4), the ground-mounted dual fiber reinforced plastic sign support met the requirements for structural adequacy by yielding to the vehicle. The sign panel shattered the windshield, but it did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred. None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision period. Longitudinal occupant impact velocity was 4.7 m/s (15.4 ft/s), and the highest 0.010-s longitudinal occupant ridedown acceleration was -2.3 g's. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 4.9 m/s (16.1 ft/s).

The ground-mounted dual fiber reinforced plastic sign support pulled out of ground and thereby met the requirements for structural adequacy by yielding to the vehicle during the high speed test (Test No. 417928-5). The sign panel contacted the roof and cracked the windshield, but it did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred. None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision period. Longitudinal occupant impact velocity was 1.1 m/s (3.6 ft), and the highest 0.010-s longitudinal occupant ridedown acceleration was 0.5 g's. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 0.3 m/s (1.0 ft/s). The dual, ground-mounted FRP sign support performed acceptably for both the low-speed and high-speed tests.

Short Term Portable Sign Supports

Roll-up Sign in Dual-Purpose Base (Test No. 417928-1)

The single fiber reinforced plastic sign support pulled out of the dual-purpose base and thereby met the requirements for structural adequacy by yielding to the vehicle. The fiberglass stay shattered the windshield, which deformed inward, but it did not penetrate the occupant compartment, nor did it present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred. None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 2.22 m/s (7.3 ft/s). The roll-up sign in dual-purpose base was considered a marginal pass.

PVC Easel Support (Test No. 417929-2)

The PVC portable sign support, supplied by Young Contractor's Inc., with a 1720 mm × 1715 mm (67.7 inch × 67.5 inch) fiberglass sign panel met the requirements for structural adequacy by yielding to the vehicle. The sign support did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred. None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 0.6 m/s (2.0 ft/s). The PVC easel support performed acceptably for a 0-degree impact according to criteria of *NCHRP Report 350*.

Wood Sign Support in H-Leg Base (0.9 m × 0.9 m [3 ft × 3 ft] panel - 0.3 m [1-ft] mounting height) (Test No. 417928-12)

The single wooden H-leg sign support with a 914 mm × 914 mm × 13 mm (36 inch × 36 inch × 0.5 inch) plywood sign panel mounted met the requirements for structural adequacy by yielding to the vehicle. The sign support penetrated the occupant compartment and deformed the roof. The vehicle damage would not block the driver's vision but may cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 2.8 m/s (9.2 ft/s). The wood sign support in H-leg base with 914 mm × 914 mm (36 inch × 36 inch) plywood panel mounted at 305 mm (12 inch) did not perform acceptably for a 0-degree impact according to *NCHRP Report 350*.

Hollow Profile Plastic Sign Support in H-Leg Base (0.9 m × 0.9 m [3 ft × 3 ft] panel - 0.30 m [1-ft] mounting height) (Test No. 417928-13)

The hollow profile plastic sign support in H-leg base with a 915 mm × 915 mm × 13 mm (36 inch × 36 inch × 0.5 inch) plywood sign panel met the requirements for structural adequacy by yielding to the vehicle. The hollow core plastic sign support with wooden sign panel contacted the hood of the vehicle and cracked the base of the windshield, but it did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred. None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 1.3 m/s (4.3 ft/s). The support performed acceptably for a 0-degree impact.

Hollow Profile Plastic Sign Support in H-Leg Base (0.9 m × 0.9 m [3 ft × 3 ft] panel - 0.6 m [2-ft] mounting height) (Test No. 417929-1)

The hollow profile plastic sign support in wooden H-leg base with a 1220 mm × 1220 mm × 13 mm (48 inch × 48 inch × 0.5 inch) plywood sign panel met the requirements for structural adequacy by yielding to the vehicle. The sign support penetrated the occupant compartment and shattered the windshield. No deformation of the occupant compartment occurred. The detached elements or vehicle damage could block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 2.3 m/s (7.5 ft/s). The support did not perform acceptably.

Hollow Profile Plastic Sign Support in H-Leg Base (1.2 m × 1.2 m [4 ft × 4 ft] panel - 0.6 m [2-ft] mounting height) (Test No. 417928-15)

The hollow profile plastic sign support in wooden H-leg base with a 1220 mm × 1200 mm × 14 mm (48 inch × 48 inch × 0.5 inch) plywood sign panel met the requirements for structural adequacy by yielding to the vehicle. The sign support penetrated the occupant compartment, shattering and deforming the roof. Deformation of the occupant compartment occurred. The detached elements would block the driver's vision and cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 2.4 m/s (7.9 ft/s). The support did not perform acceptably.

Hollow Profile Plastic Sign Support in H-Leg Base (1.2 m × 1.2 m [4 ft × 4 ft] panel- 0.9 m [3-ft] mounting height) (Test No. 417928-18)

The hollow profile plastic sign support in wooden H-leg base with a 1220 mm × 1220 mm × 14 mm (48 inch × 48 inch × 0.5 inch) plywood sign panel met the requirements for structural adequacy by yielding to the vehicle. The sign support penetrated the occupant compartment, shattered the windshield, and deformed the roof. Maximum deformation into the occupant compartment was 61 mm (2.4 inch) (7 percent reduction in space) in the floor pan area. The detached elements and vehicle damage could block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 2.2 m/s (7.2 ft/s). The support did not perform acceptably.

Hollow Profile Plastic Sign Support in T-Leg Base (1.2 m × 1.2 m [4 ft × 4 ft] fiberglass panel - 0.6 m [2-ft] mounting height) (Test No. 417929-11)

The single wooden T-leg barricade with a 1220 mm × 1220 mm × 5 mm (48 inch × 48 inch × 0.2 inch) fiber board sign panel met the requirements for structural adequacy by yielding to the vehicle. The windshield shattered, and glass was sprayed on the dash of the vehicle. The roof line was deformed at the center of the vehicle. The roof deformation measured 60 mm × 120 mm × 10 mm (2 inch × 5 inch × 0.4 inch) and was caused by the fiber board sign panel. Although the sign panel did not penetrate the occupant compartment, it may have potential to penetrate the occupant compartment. None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 1.5 m/s (4.9 ft/s). The support did not perform acceptably.

Hollow Profile Plastic Sign Support in T-Leg Base (1.2 m × 1.2 m [4 ft × 4 ft] corrugated plastic panel - 0.6 m [2-ft] mounting height) – (Test No. 417929-12)

The single hollow profile sign support in wooden T-leg base with a 1220 mm × 1220 mm × 11 mm (48 inch × 48 inch × 0.4 inch) corrugated plastic sign panel met the requirements for structural adequacy by yielding to the vehicle. The support cracked the windshield at the roof line in the center, but it did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred. None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright during and after the collision. The vehicle did not intrude into adjacent traffic lanes and came to rest behind the test article. Maximum change in velocity for this test was 1.4 m/s (4.6 ft/s). The support performed acceptably for a 0-degree impact.

Chevron/Object Marker Supports

Dual Chevron Support (417929-3)

The dual chevron installation met the requirements for structural adequacy by yielding to the vehicle. The sign support did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. However, the single chevron on U-channel cut the roof of the vehicle, which showed potential for penetrating the occupant compartment. Maximum deformation into the occupant compartment was 75 mm (3.0 inch) (8 percent reduction in space) in the roof of the vehicle. None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright, did not intrude into adjacent traffic lanes, and came to rest behind the test article. Maximum change in velocity for this test was 1.3 m/s (4.3 ft/s). The U-channel chevron support did not perform acceptably. The thin-wall chevron support performed acceptably for a 0-degree impact.

Temporary Mailbox Support

Mailbox on Plastic Drum (417929-10)

The mailbox on plastic drum met the requirements for structural adequacy by yielding to the vehicle. The mailbox on plastic drum did not penetrate or show potential to penetrate the occupant compartment, or present undue hazard to others in the area. No deformation or intrusion of the occupant compartment occurred. None of the detached elements or vehicle damage would block the driver's vision or cause the driver to lose control of the vehicle. The vehicle remained upright, did not intrude into adjacent traffic lanes, and came to rest behind the test article. Maximum change in velocity for this test was 0.2 m/s (0.7 ft/s). The temporary mailbox support performed acceptably for a 0-degree impact.

CONCLUSIONS

Type I Barricades

All the Type I barricades tested passed *NCHRP Report 350* requirements, as shown in Table 1. The Type I plastic A-frame barricade (Fender Enterprises) mounted at 42-inch height shattered the base of the windshield but did not penetrate nor show potential for penetrating the occupant compartment. The vehicle rode over the Type I steel tube skid mount barricade, and the supports separated from the base causing minimal damage to the vehicle. The vehicle rode over the Type I hollow profile plastic skid mount barricade, and the supports separated from the base, which caused minimal damage to the vehicle. In the test on the Type I hollow profile plastic folding A-frame barricade, the vehicle rode over the barricade, and minimal damage occurred to the vehicle. The Type I Wood fixed A-frame barricade pushed forward in front of vehicle, and the vehicle bumper was torn off with otherwise minimal damage to the vehicle.

Type III Barricades

The Type III barricades tested performed acceptably according to *NCHRP Report 350,* as shown in Table 1. The supports pulled out of bases of the Type III barricades and in all cases caused minor cracking of the windshield. However, there was no penetration and no blockage of the driver's view.

Temporary Sign Supports

Long/Intermediate Term Portable Sign Supports

As shown in Table 1, the FRP sign support in dual-purpose base with plywood panel at 2.1 m (7 ft) and the wood sign support in H-leg base with plywood panel at 2.1 m (7 ft) both performed acceptably according to *NCHRP Report 350*. Both supports caused damage to the vehicle, but the damage was not significant. In the test on the dual perforated steel tube skid mounted sign support, the plywood sign blank and steel supports shattered, caved in the windshield, and deformed the roof. This system does not meet the *NCHRP Report 350* criteria.

Long/Intermediate Term Ground-Mounted Sign Supports

In the low speed test on the ground-mounted dual FRP sign support, the vehicle rode over FRP supports and sign blank, and the sign blank partially shattered the windshield as it was pulled down by the vehicle. The change in velocity was marginal. In the high speed test, the FRP supports pulled out of the ground, and the sign panel contacted the roof and cracked the windshield causing minimal damage. As shown in Table 1, the ground-mounted dual FRP sign support performed acceptably.

Short Term Portable Sign Supports

The PVC easel support and fiberglass sign panel and the hollow profile plastic sign support in H-leg base with 0.9 m × 0.9 m (3 ft × 3-ft) plywood panel at 0.3 m (1-ft) mounting height performed acceptably. The FRP support with the roll-up sign in dual-purpose base pulled out of base and the fiberglass stay shattered and partially caved in the windshield. This was considered a marginal pass. The hollow profile plastic support in H-leg base with 0.9 × 0.9 m (3 ft × 3 ft) plywood panel at 0.6 m (2 ft) mounting height was also considered a marginal pass. The wood sign support in H-leg base with 0.9 m × 0.9 m (3 ft × 3 ft) plywood panel at 0.3 m (1 ft) mounting height, the 1.2 m × 1.2 m (4 ft × 4 ft) plywood panel at 0.6 m (2 ft) mounting height, the 1.2 m × 1.2 m (4 ft × 4 ft) plywood panel at 0.9 m (3 ft) mounting height, and the hollow profile plastic support in T-leg base with a 1220 mm × 1220 mm × 5 mm (48 inch × 48 inch × 0.2 inch) fiberglass sign panel mounted at 0.6 m (2.0 ft) all failed to perform acceptably, due to penetration or significant deformation of the windshield. The hollow profile plastic support in T-leg base with a 1220 mm × 1220 mm × 5 mm (48 inch × 48 inch × 0.2 inch) with corrugated plastic sign mounted at 0.6 m (2.0 ft) and the hollow profile plastic H-leg base with 914 mm × 914 mm (36 inch × 36 inch) plywood panel at 305 mm (12 inch) mounting height performed acceptably.

Chevron/Object Marker Supports

During the test with the dual chevron supports, the U-channel post fractured at the bumper, and the thin-wall tube post deformed at bumper height and pulled out of the ground. The thin-wall tube post sign contacted the driver's side of the windshield and the door frame, and slightly cracked the windshield. The U-channel sign contacted the roof at the windshield, which shattered, and cut the roof of the vehicle, thereby showing potential for penetration. The thin-wall dual chevron was judged to have performed acceptably; however the U-channel dual chevron support did not perform acceptably.

Temporary Mailbox Support

The mailbox on plastic drum met the requirements of *NCHRP Report 350*.

Table 1. Assessment of Barricade Testing on TxDOT Project 1792.

Test No.	Date	Description of Barricade	Results	Test Assessment	Device Modified	Device Approved	Added to CWZTCD List
Type I Barricades							
417928-6	07/06/98	Type I plastic A-frame barricade (Fender Enterprises) – 1067 mm (42 inch) height	Plastic barricade rail at 1067 mm (42 inch) height shattered base of windshield	Pass	No	Yes	Yes
417928-7	07/06/98	Type I steel tube skid mount barricade with wood panel	Vehicle rode over barricade; barricade supports separated from base; minimal damage	Pass	No	Yes	Yes
417928-8	07/06/98	Type I hollow profile plastic skid mount barricade with wood panel and skids	Vehicle rode over barricade; barricade supports separated from base; minimal damage	Pass	No	Yes	Yes
417928-9	07/06/98	Type I hollow profile plastic folding A-frame barricade with wood panels	Vehicle rode over barricade; minimal damage	Pass	No	Yes	Yes
417928-17	07/23/98	Type I wood fixed A-frame barricade with 50.8 × 152.4 mm (2 × 6 inch) legs and 25.4 × 203.2 mm (1 × 8 inch) panel	Barricade pushed forward in front of vehicle; bumper torn off; minimal damage	Pass	No	Yes	Yes
Type III Barricades							
417928-2	06/23/98	Type III barricade with FRP supports in dual-purpose base	FRP supports pulled out of base; top of barricade cracked windshield at intersection with hood	Pass	No	Yes	Yes
417928-14	07/10/98	Type III perforated steel tube barricade with plastic panels 2.44 m (8 ft wide – centered impact)	Vehicle rode under barricade; middle plastic panel shattered bottom of windshield; steel supports broke off side mirrors of vehicle	Pass	No	Yes	Yes
417928-16	07/23/98	Type III barricade with hollow profile plastic supports not bolted to skids	Supports separated from base; barricade unit contacted hood and cracked base of windshield	Pass	No	Unknown	Unknown

Table 1. Assessment of Barricade Testing on TxDOT Project 1792 (continued).

Test No.	Date	Description of Barricade	Results	Test Assessment	Device Modified	Device Approved	Added to CWZTCD List
Temporary Sign Supports: Long/Intermediate Term Portable Sign Supports							
417928-3	06/23/98	Single FRP sign support in dual-purpose base with plywood panel at 2.1 m (7 ft)	Impact extended existing crack in windshield; minimal damage	Pass	No	Yes	Yes
417928-10	07/08/98	Wood sign support in H-leg base with plywood panel at 2.1 m (7 ft)	Vehicle fractured support; support and sign panel rotated over vehicle; significant damage to front bumper and hood	Pass	No	Yes	Yes
417928-11	07/08/98	Dual perforated steel tube skid mounted sign support	Plywood sign blank and steel supports shattered and caved in windshield and deformed roof	Fail	No	No	No
Temporary Sign Supports: Long/Intermediate Term Ground Mounted Sign Supports							
417928-4	06/25/98	Ground mounted dual FRP sign support (low speed)	Vehicle rode over FRP supports and sign blank; sign blank partially shattered windshield as it was pulled down by vehicle	Pass	No	Yes	Yes
417928-5	06/25/98	Ground mounted dual FRP sign support (high speed)	FRP supports pulled out of ground; sign panel contacted roof and cracked windshield; minimal damage	Pass	No	Yes	Yes
Temporary Sign Supports: Short Term Portable Sign Supports							
417928-1	06/23/98	Roll-up sign in dual-purpose base	FRP support pulled out of base; fiberglass stay shattered and partially caved in windshield	Marginal Pass	No	Yes	Yes
417929-2	11/03/98	PVC easel support and fiberglass sign panel	The support separated upon impact, lightly contacted the roof; minimal damage	Pass	No	Yes	Yes
417928-12	07/08/98	Wood sign support in H-leg base with 0.9 m × 0.9 m (3 ft × 3 ft) plywood panel at 0.3 m (1 ft) mounting height	Wood support fractured and penetrated windshield	Fail	Yes (retested in Test 417928-13)	No	No

Table 1. Assessment of Barricade Testing on TxDOT Project 1792 (continued).

Test No.	Date	Description of Barricade	Results	Test Assessment	Device Modified	Device Approved	Added to CWZTCD List
417928-13	07/10/98	Hollow profile plastic sign support in H-leg base with 0.9 m × 0.9 m (3 × 3 ft) plywood panel at 0.3 m (1 ft) mounting height	Plastic support separated from base; sign panel contacted hood and cracked base of windshield	Pass	No	Yes	Yes
417929-1	11/03/98	Hollow profile plastic support in H-leg base with 0.9 m × 0.9 m (3 ft × 3 ft) plywood panel at 0.61 m (2 ft) mounting height	The sign support penetrated the occupant compartment and shattered the windshield.	Fail	No	No	No
417928-15	07/10/98	Hollow profile plastic sign support in H-leg base with 1.2 m × 1.2 m (4 ft × 4 ft) plywood panel at 0.6 m (2 ft) mounting height	Support separated from base; wood sign panel shattered and penetrated windshield	Fail	Yes (retested in Tests 417929-11 & 12 with alternate sign substrates)	No	No
417928-18	07/23/98	Hollow profile plastic sign support in H-leg base with 1.2 m × 1.2 m (4 ft × 4 ft) plywood panel at 0.9 m (3 ft) mounting height – sign support not bolted to skids	Support separated from base; wood sign panel shattered and caved in windshield and deformed roof	Fail	No	No	No
417929-11	8/30/99	Single wooden T-leg barricade with a 1220 × 1220 × 5 mm (48 × 48 × 0.2 inch) fiber board sign panel mounted at 0.6 m (2.0 ft)	The windshield shattered, and glass was sprayed on the dash of the vehicle; at the center of the roof line of the vehicle, there was a dent that measured 60 × 120 × 10 mm (2 × 5 × 0.4 inch) from the fiber board sign panel. Although the sign panel did not penetrate, it may have potential to penetrate the occupant compartment.	Fail	Yes (retested in Test 417929-12 with alternate sign substrate)	No	No
417929-12	8/30/99	A single hollow profile plastic sign support in wooden T-leg base with a 1220 × 1220 × 11 mm (48 × 48 × 0.4 inch) corrugated plastic sign panel mounted at 0.6 m (2.0 ft)	Plastic support separated from base; sign panel contacted hood and cracked the windshield at the center roof line.	Pass	No	Yes	Yes

Table 1. Assessment of Barricade Testing on TxDOT Project 1792 (continued).

Test No.	Date	Description of Barricade	Results	Test Assessment	Device Modified	Device Approved	Added to CWZTCD List
Temporary Sign Supports: Chevron/Object Marker Supports							
417929-3	11/03/98	Thin-Wall Tube Dual Chevron Sign Support	The thin-wall tube post deformed at bumper height and pulled out of the ground. The tube post sign contacted the driver's side of the windshield near the door frame, and the windshield cracked slightly.	Pass	No	No	No
417929-3	11/03/98	U-Channel Dual Chevron Sign Support	The U-channel post fractured at the bumper and then contacted the roof at the windshield, which shattered. The U-channel also cut a hole in the roof just behind the windshield frame.	Fail	No	No	No
Temporary Sign Supports: Temporary Mailbox Support							
417929-10	8/30/99	Mailbox on Plastic Drum	Performed acceptably	Pass	No	Yes	Yes

IMPLEMENTATION RECOMMENDATIONS

Under this project, researchers evaluated the safety performance of selected work zone traffic control devices through full-scale crash testing in accordance with *NCHRP Report 350* guidelines. Devices found to be in compliance with *NCHRP Report 350* guidelines are considered suitable for implementation. Devices that failed to meet the required evaluation criteria of *NCHRP Report 350* were either modified and retested, or abandoned in favor of new designs with improved impact performance that satisfy the same functional requirements as the failed devices. During the design process, the researchers received input from TxDOT personnel, contractors, and manufacturers to help ensure that the design improvements resulted in devices that are functional, durable, and cost effective and meet the needs of the department.

Researchers conducted a total of 24 crash tests on work zone traffic control devices including various Type I and Type III barricades, short-term portable sign supports, intermediate/long-term portable and ground-mounted sign supports, Chevron supports, and a temporary mailbox support. The performance of 18 of these tests were considered satisfactory while eight were judged to be unacceptable. Drawings and descriptions for each of the acceptable, crashworthy designs were provided to personnel in the Traffic Operations Division to assist with their review, approval, and implementation through TxDOT's Compliant Work Zone Traffic Control Device (CWZTCD) list. A summary of the testing, approval, and implementation status for each device is provided in the following table.

It should be noted that as work zone activities are completed, portable work zone traffic control devices are sometimes rotated out of view or laid down on the roadside until they can be removed from the work site. During these periods, the devices may be subjected to atypical impacts that may or may not be more critical than the more conventional head-on impact. For this reason, the Federal Highway Administration (FHWA) currently requires that work zone devices be impacted in both a 0-degree and 90-degree configuration. The performance of these two configurations may be evaluated by a single test in which the devices are placed in series 6 m (20 ft) apart from one another.

This study was initiated prior to these requirements and, hence, all crash tests performed under this study were head-on (0-degree) impacts with the centerline of the vehicle aligned with the centerline of the work zone device. The performance of these devices when impacted in a 90-degree configuration is therefore unknown. However, previous end-on (90-degree) tests of Type III barricades [2,3] indicate that the end-on configuration should not be a critical concern for the Type I and Type III barricades evaluated under this project. The performance of short-term portable sign supports on the other hand, may degrade when impacted in an end-on configuration. This should be considered when implementing the devices evaluated under this study.

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APPENDIX A. CRASH TEST PROCEDURES AND DATA ANALYSIS

The crash test and data analysis procedures were in accordance with guidelines presented in *NCHRP Report 350*. Brief descriptions of these procedures are presented as follows.

ELECTRONIC INSTRUMENTATION AND DATA PROCESSING

Previous full-scale crash tests have shown that the acceleration levels experienced by the vehicle during impact with traffic controls devices weighing less than 45 kg (99 lb) were extremely low and of little significance; therefore, with the exception of tests 417928-4 and 5, the vehicles were not instrumented. This kept the cost of crash testing down, allowing more tests to be performed under the available budget.

In tests 417928-4 and 5, each of the test vehicles was instrumented with three solid-state angular rate transducers to measure roll, pitch, and yaw rates; a triaxial accelerometer near the vehicle center-of-gravity to measure longitudinal, lateral, and vertical acceleration levels; and a back-up biaxial accelerometer in the rear of the vehicle to measure longitudinal and lateral acceleration levels. These accelerometers were ENDEVCO Model 2262CA, piezoresistive accelerometers with a ±100 g range.

The accelerometers are strain gage type with a linear millivolt output proportional to acceleration. Rate of turn transducers are solid state, gas flow units designed for high g service. Signal conditioners and amplifiers in the test vehicle increase the low level signals to a ±2.5 volt maximum level. The signal conditioners also provide the capability of an R-Cal or shunt calibration for the accelerometers and a precision voltage calibration for the rate transducers. The electronic signals from the accelerometers and rate transducers are transmitted to a base station by means of a 15 channel, constant bandwidth, Inter-Range Instrumentation Group (I.R.I.G.), FM/FM telemetry link for recording on magnetic tape and for display on a real-time strip chart. Calibration signals, from the test vehicle, are recorded minutes before the test and also immediately afterwards. A crystal controlled time reference signal is simultaneously recorded with the data. Wooden dowels actuate pressure-sensitive switches on the bumper of the impacting vehicle just prior to impact to indicate the elapsed time over a known distance to provide a measurement of impact velocity. The initial contact also produces an ‘event’ mark on the data record to establish the exact instant of contact with the installation.

The multiplex of data channels, transmitted on one radio frequency, is received at the data acquisition station and demultiplexed onto separate tracks of a 28 track, (I.R.I.G.) tape recorder. After the test, the data are played back from the tape machine, filtered with Society of Automotive Engineers (SAE J211) filters, and digitized using a microcomputer, at 2000 samples per second per channel, for analysis and evaluation of impact performance.

All accelerometers are calibrated annually according to SAE J211 *4.6.1* by means of an ENDEVCO 2901, precision primary vibration standard. This device along with its support instruments is returned to the factory annually for a National Institute of Standards Technology (NIST) traceable calibration. The subsystems of each data channel are also evaluated annually, using instruments with current NIST traceability, and the results are factored into the accuracy of the total data channel, per SAE J211. Calibrations and evaluations will be made any time data is suspect.

The digitized data were then processed using two computer programs: DIGITIZE and PLOTANGLE. Brief descriptions on the functions of these two computer programs are provided as follows.

The DIGITIZE program uses digitized data from vehicle-mounted linear accelerometers to compute occupant/compartment impact velocities, time of occupant/compartment impact after vehicle impact, and the highest 10-ms average ridedown acceleration. The DIGITIZE program also calculates a vehicle impact velocity and the change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 50-ms intervals in each of the three directions are computed. For reporting purposes, the data from the vehicle-mounted accelerometers were then filtered with a 60 Hz digital filter, and acceleration versus time curves for the longitudinal, lateral, and vertical directions were plotted using a commercially available software package (Excel).

The PLOTANGLE program used the digitized data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.0002-s intervals and then instructed a plotter to draw a reproducible plot: yaw, pitch, and roll versus time. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation of the vehicle-fixed coordinate system being that which existed at initial impact.

ANTHROPOMORPHIC DUMMY INSTRUMENTATION

An Alderson Research Laboratories Hybrid II, 50th percentile male anthropomorphic dummy, restrained with lap and shoulder belts, was placed in the driver’s position of the 820C vehicle. The dummy was uninstrumented.

PHOTOGRAPHIC INSTRUMENTATION AND DATA PROCESSING

Photographic coverage of the test included two high-speed cameras: one placed behind the installation at an angle and a second placed to have a field of view perpenducular to and aligned with the test article. A flash bulb activated by pressure-sensitive tape switches was positioned on the impacting vehicle to indicate the instant of contact with the installation and was visible from each camera. The films from these high-speed cameras were analyzed on a computer-linked Motion Analyzer to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A BetaCam, a VHS-format video camera and recorder, and still cameras were used to record and document conditions of the test vehicle and installation before and after the test.

TEST VEHICLE PROPULSION AND GUIDANCE

The test vehicle was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. An additional steel cable was connected to the test vehicle, passed around a pulley near the impact point, through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. A 2-to-1 speed ratio between the test and tow vehicle existed with this system. Just prior to impact with the installation, the test vehicle was released to be free-wheeling and unrestrained. The vehicle remained free-wheeling, i.e., no steering or braking inputs, until the vehicle cleared the immediate area of the test site, at which time brakes on the vehicle were activated to bring it to a safe and controlled stop.

APPENDIX B. TEST VEHICLE PROPERTIES AND INFORMATION

DATE: 6/23/98 TEST NO.: 417928-1-6-9-10 VIN NO.: 2C1MR2462R6716837

YEAR: 1994 MAKE: GEO MODEL: METRO

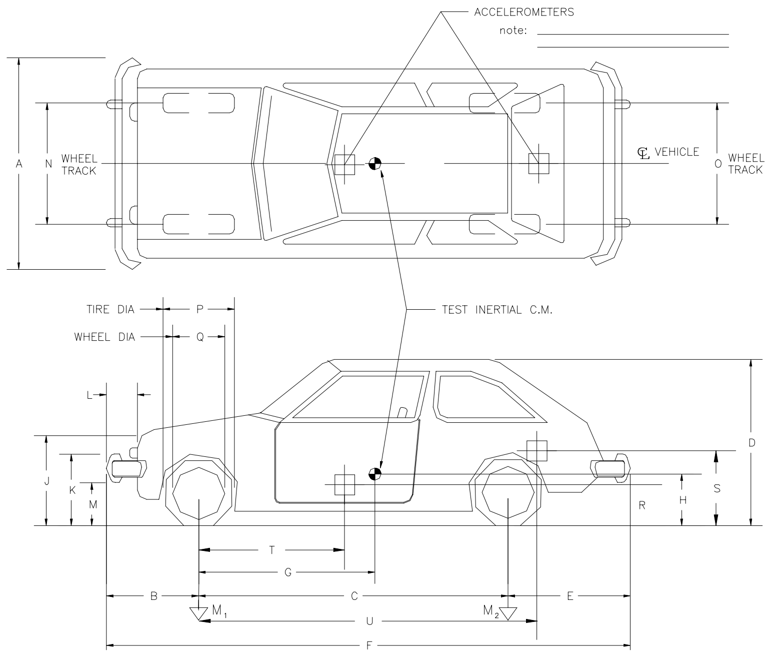
TIRE INFLATION PRESSURE: ______ ODOMETER: 111879 TIRE SIZE: 155R12

1st Use: X 2nd or More Use: ____ Minor Damage Charged to Project: ______

MASS DISTRIBUTION (kg) LF 248 RF 245 LR 165 RR 162

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:

DENT IN LT REAR PANEL



ENGINE TYPE: 3 CYL

ENGINE CID: 1.0 L

TRANSMISSION TYPE:

__ AUTO

X MANUAL

OPTIONAL EQUIPMENT:

DUMMY DATA:

TYPE: 50th percentile male

MASS: 76 kg

SEAT POSITION: Driver

GEOMETRY – (mm)

A	430	E	640	J	635	N	1355	R	
B	700	F	3610	K	520	O	1330	S	
C	2270	G	905.2	L	85	P	530	T	
D	1345	H		M	385	Q	335	U	

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	501	493	528
M_2	297	327	368
M_T	798	820	896

Figure 216. Vehicle Properties for Test 4-17928-1, 6, 9, and 10.

DATE: 6/23/98 TEST NO.: 417928-2 to 5 -7 - 8 VIN NO.: 2C1MR2464P6779418

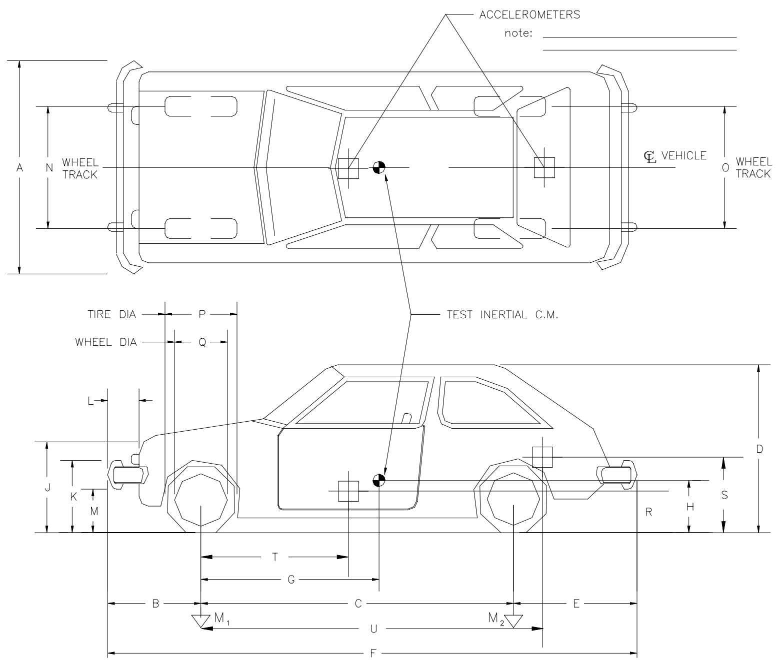
YEAR: 1993 MAKE: GEO MODEL: METRO

TIRE INFLATION PRESSURE: ________ ODOMETER: 78433 TIRE SIZE: 155R12

1st Use: X 2nd or More Use: ____ Minor Damage Charged to Project: ________

MASS DISTRIBUTION (kg) LF 250 RF 245 LR 162 RR 163

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



ENGINE TYPE: 3 CYL

ENGINE CID: 1.0 L

TRANSMISSION TYPE:

X AUTO

__ MANUAL

OPTIONAL EQUIPMENT:

DUMMY DATA:

TYPE: 50th percentile male

MASS: 76 kg

SEAT POSITION: Driver

GEOMETRY – (mm)

A	1420	E	650	J	680	N	1340	R	
B	680	F	3605	K	525	O	1320	S	
C	2275	G	901.7	L	95	P	550	T	
D	1360	H		M	395	Q	335	U	

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	487	495	530
M_2	292	325	366
M_T	779	820	896

Figure 217. Vehicle Properties for Test 4-17928-2 through 5, 7, and 8.

DATE: 7-10-98 TEST NO.: 417928-14, 17 -18 VIN NO.: 2C1MR2460P6728675

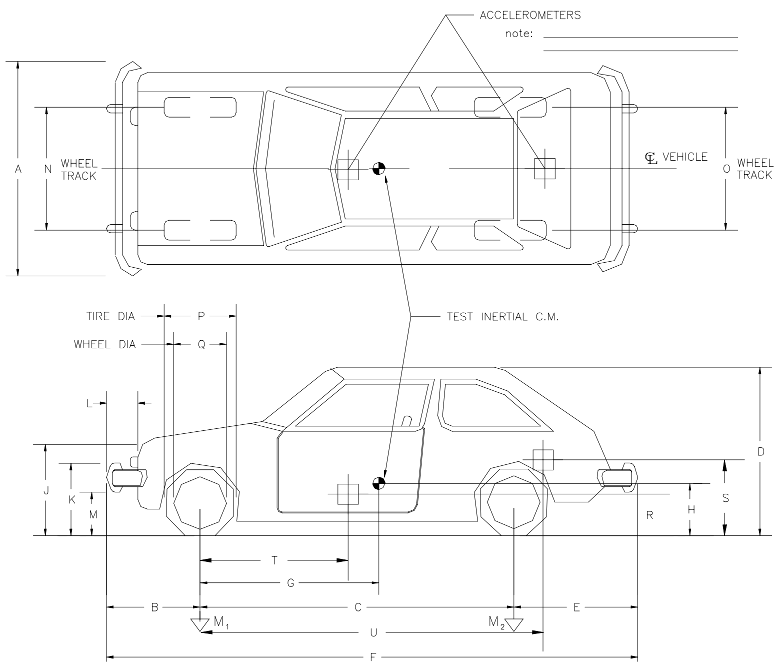
YEAR: 1993 MAKE: GEO MODEL: METRO

TIRE INFLATION PRESSURE: ________ ODOMETER: 108624 TIRE SIZE: 155R12

1st Use: X 2nd or More Use: ____ Minor Damage Charged to Project: ________

MASS DISTRIBUTION (kg) LF 240 RF 222 LR 183 RR 175

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



ENGINE TYPE: 3 CYL

ENGINE CID: 1.0 L

TRANSMISSION TYPE:

X AUTO

__ MANUAL

OPTIONAL EQUIPMENT:

DUMMY DATA:

TYPE: 50th percentile male

MASS: 76 kg

SEAT POSITION: Driver

GEOMETRY - (mm)

A	1420	E	660	J	675	N	1360	R	
B	720	F	3645	K	525	O	1350	S	
C	2265	G		L	95	P	520	T	
D	1320	H		M	380	Q	330	U	

MASS - (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	462	462	498
M_2	291	358	398
M_T	753	820	896

Figure 218. Vehicle Properties for Test 4-17928-14, 17, and 18.

DATE: 7-10-98 TEST NO.: 417928-13, 15-16 VIN NO.: 2C1MR2467R6761269

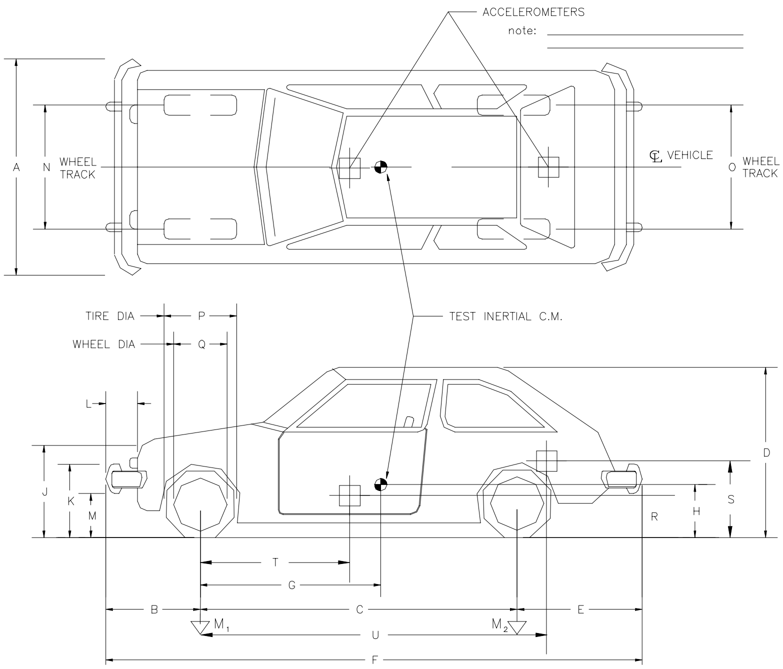
YEAR: 1994 MAKE: GEO MODEL: METRO

TIRE INFLATION PRESSURE: ODOMETER: 70538 TIRE SIZE: 155R12

1st Use: X 2nd or More Use: Minor Damage Charged to Project:

MASS DISTRIBUTION (kg) LF 251 RF 227 LR 174 RR 168

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



ENGINE TYPE: 3 CYL

ENGINE CID: 1.0 L

TRANSMISSION TYPE:

X AUTO

__ MANUAL

OPTIONAL EQUIPMENT:

DUMMY DATA:

TYPE: 50th percentile male

MASS: 76 kg

SEAT POSITION: Driver

GEOMETRY – (mm)

A	1430	E	690	J	670	N	1360	R	
B	730	F	3690	K	535	O	1345	S	
C	2270	G		L	90	P	540	T	
D	1350	H		M	395	Q	330	U	

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	484	478	513
M_2	282	342	383
M_T	796	820	896

Figure 219. Vehicle Properties for Test 4-17928-13, 15, and 16.

DATE: 7-08-98 TEST NO.: 417928-11 VIN NO.: 2C1MR2460P6709172

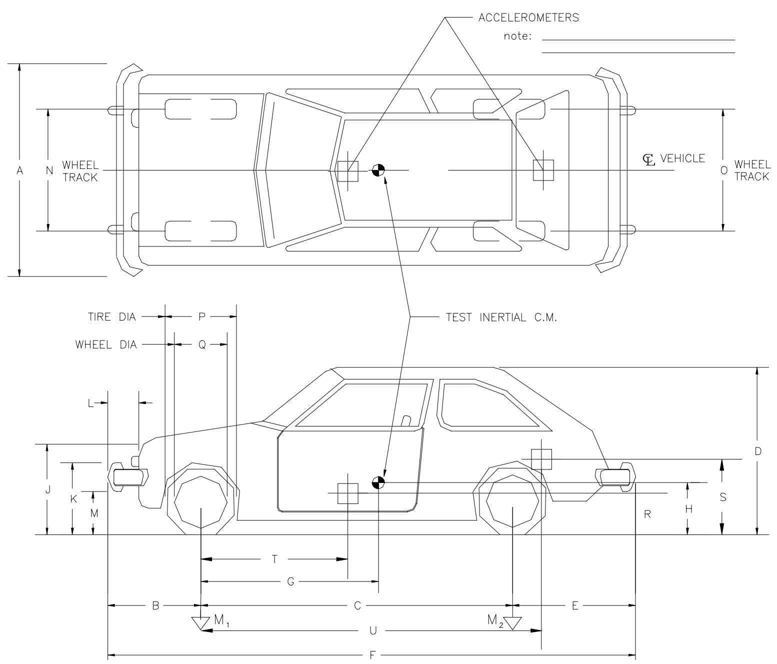
YEAR: 1993 MAKE: GEO MODEL: METRO

TIRE INFLATION PRESSURE: ______ ODOMETER: 93488 TIRE SIZE: 155R12

1st Use: X 2nd or More Use: ____ Minor Damage Charged to Project: ______

MASS DISTRIBUTION (kg) LF 239 RF 237 LR 175 RR 169

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



ENGINE TYPE: 3 CYL

ENGINE CID: 1.0 L

TRANSMISSION TYPE:

__ AUTO

X MANUAL

OPTIONAL EQUIPMENT:

DUMMY DATA:

TYPE: 50th percentile male

MASS: 76 kg

SEAT POSITION: Driver

GEOMETRY - (mm)

A	1420	E	730	J	660	N	1360	R	
B	730	F	3725	K	510	O	1350	S	
C	2265	G		L	95	P	525	T	
D	1335	H		M	370	Q	330	U	

MASS - (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	431	476	510
M_2	294	344	386
M_T	725	820	896

Figure 220. Vehicle Properties for Test 4-17928-11.

DATE: 11-3-98 TEST NO.: 417929-2&3 VIN NO.: 2C1MR2464R6755994

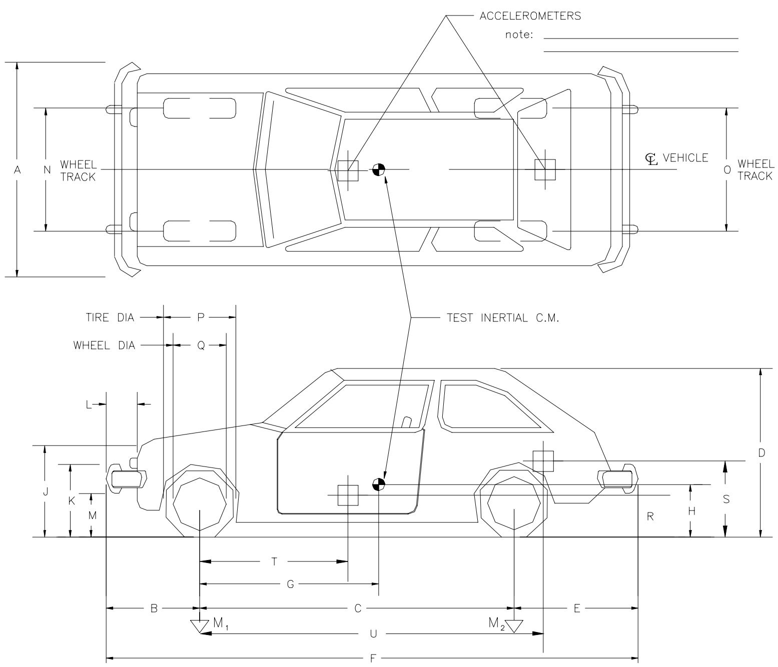
YEAR: 1994 MAKE: GEO MODEL: METRO

TIRE INFLATION PRESSURE: ________ ODOMETER: 86742 TIRE SIZE: 155R12

1st Use: X 2nd or More Use: ____ Minor Damage Charged to Project: ________

MASS DISTRIBUTION (kg) LF 260 RF 240 LR 163 RR 157

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



ENGINE TYPE: 3 CYL.

ENGINE CID: 1.0L

TRANSMISSION TYPE:

X AUTO

__ MANUAL

OPTIONAL EQUIPMENT:

DUMMY DATA:

TYPE: 50th percentile male

MASS: 76 kg

SEAT POSITION: Driver

GEOMETRY – (mm)

A	1430	E	660	J	675	N	1370	R	
B	730	F	3655	K	470	O	1340	S	
C	2265	G		L	95	P	540	T	
D	1345	H		M	385	Q	335	U	

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	480	500	534
M_2	289	320	361
M_T	769	820	895

Figure 221. Vehicle Properties for Test 417929-2 and 3.

DATE: 7-08-98 TEST NO.: 417928-12 VIN NO.: 2C1MR2464R6769040

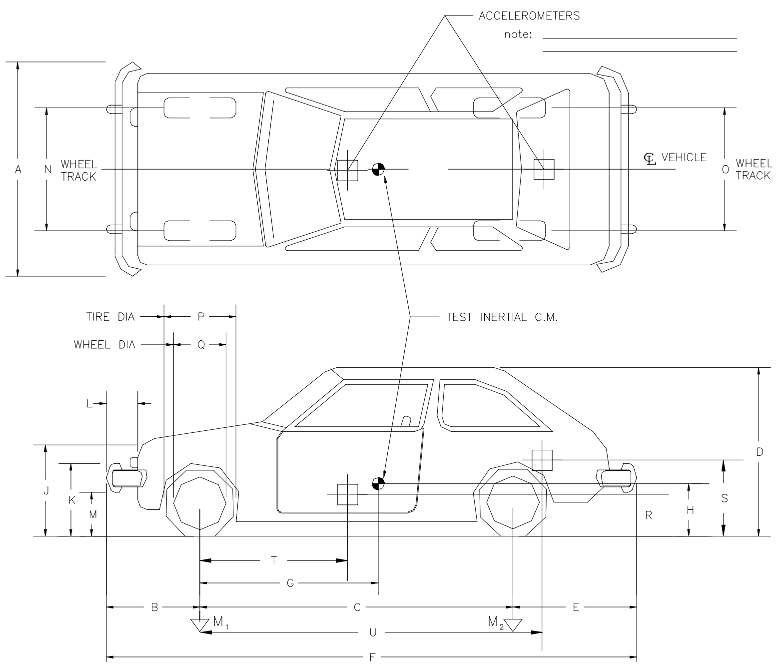
YEAR: 1993 MAKE: GEO MODEL: METRO

TIRE INFLATION PRESSURE: ________ ODOMETER: 145333 TIRE SIZE: 155R12

1st Use: X 2nd or More Use: ____ Minor Damage Charged to Project: ________

MASS DISTRIBUTION (kg) LF 243 RF 240 LR 169 RR 168

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



ENGINE TYPE: 3 CYL

ENGINE CID: 1.0 L

TRANSMISSION TYPE:

__ AUTO

X MANUAL

OPTIONAL EQUIPMENT:

DUMMY DATA:

TYPE: 50th percentile male

MASS: 76 kg

SEAT POSITION: Driver

GEOMETRY – (mm)

A	1420	E	730	J	660	N	1365	R	
B	740	F	3730	K	510	O	1355	S	
C	2260	G		L	95	P	525	T	
D	1330	H		M	370	Q	330	U	

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	429	483	525
M_2	305	337	371
M_T	734	820	896

Figure 222. Vehicle Properties for Test 4-17928-12.

DATE: 11-3-98 TEST NO.: 417929-1 VIN NO.: 2C1MR2462R6784863

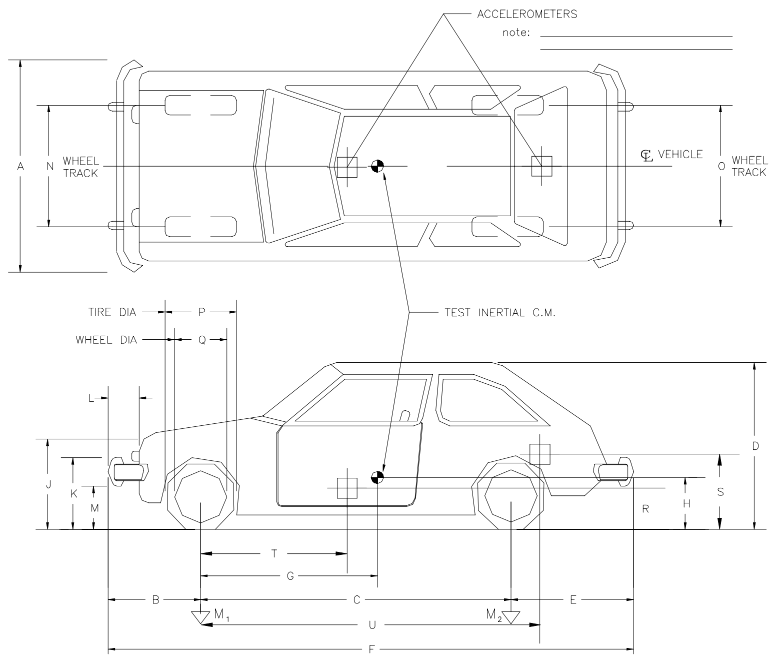
YEAR: 1994 MAKE: GEO MODEL: METRO

TIRE INFLATION PRESSURE: ______ ODOMETER: 71819 TIRE SIZE: 155R12

1st Use: X 2nd or More Use: ____ Minor Damage Charged to Project: ______

MASS DISTRIBUTION (kg) LF 259 RF 235 LR 168 RR 158

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



ENGINE TYPE: 3 CYL.

ENGINE CID: 1.0L

TRANSMISSION TYPE:

X AUTO

__ MANUAL

OPTIONAL EQUIPMENT:

DUMMY DATA:

TYPE: 50th percentile male

MASS: 76 kg

SEAT POSITION: Driver

GEOMETRY – (mm)

A	1450	E	640	J	665	N	1375	R	
B	750	F	3655	K	465	O	1345	S	
C	2265	G	900.5	L	95	P	540	T	
D	1340	H		M	380	Q	335	U	

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	480	494	529
M_2	290	326	366
M_T	770	820	895

Figure 223. Vehicle Properties for Test 4-17929-1.

DATE: 8/30/99 TEST NO.: 417929-10 & 11 VIN NO.: 2C1MR2463R6721805

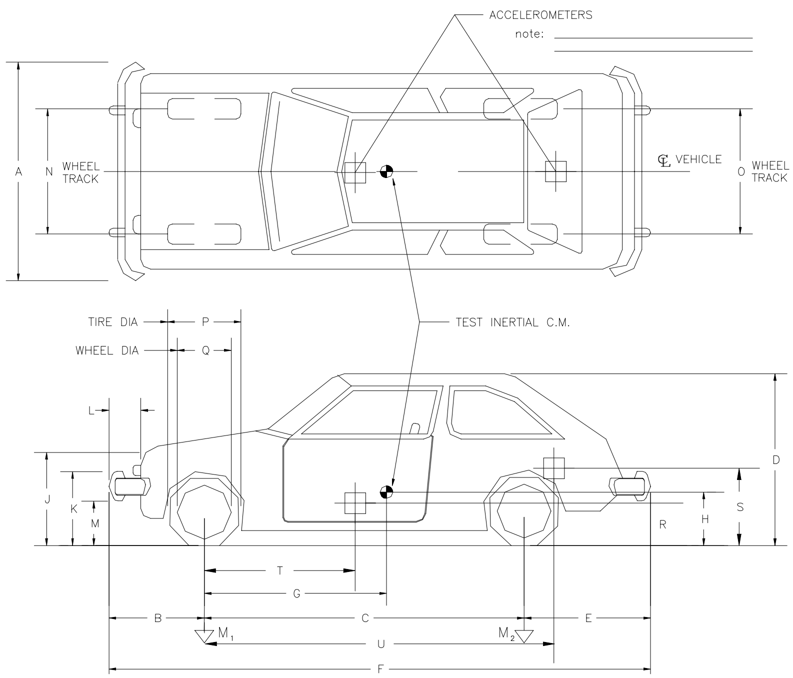
YEAR: 1994 MAKE: GEO MODEL: METRO

TIRE INFLATION PRESSURE: ODOMETER: 093756 TIRE SIZE: 155R12

1st Use: 2nd or More Use: Minor Damage Charged to Project:

MASS DISTRIBUTION (kg) LF 247 RF 232 LR 178 RR 163

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



ENGINE TYPE: 3 CYL.

ENGINE CID: 1.0L

TRANSMISSION TYPE:

X AUTO

__ MANUAL

OPTIONAL EQUIPMENT:

DUMMY DATA:

TYPE: 50th percentile male

MASS: 76 kg

SEAT POSITION: Driver

GEOMETRY – (mm)

A 1480	E 615	J 710	N 1360	R N/A
B 750	F 3635	K 475	O 1340	S N/A
C 2270	G 943.99	L 90	P 530	T N/A
D 1340	H	M 385	Q 330	U N/A

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	467	479	514
M_2	299	341	382
M_T	766	820	896

Figure 224. Vehicle Properties for Test 417929-10 and 11.

DATE: 8/30/99 TEST NO.: 417929-12 VIN NO.: 2C1MR2460R6767110

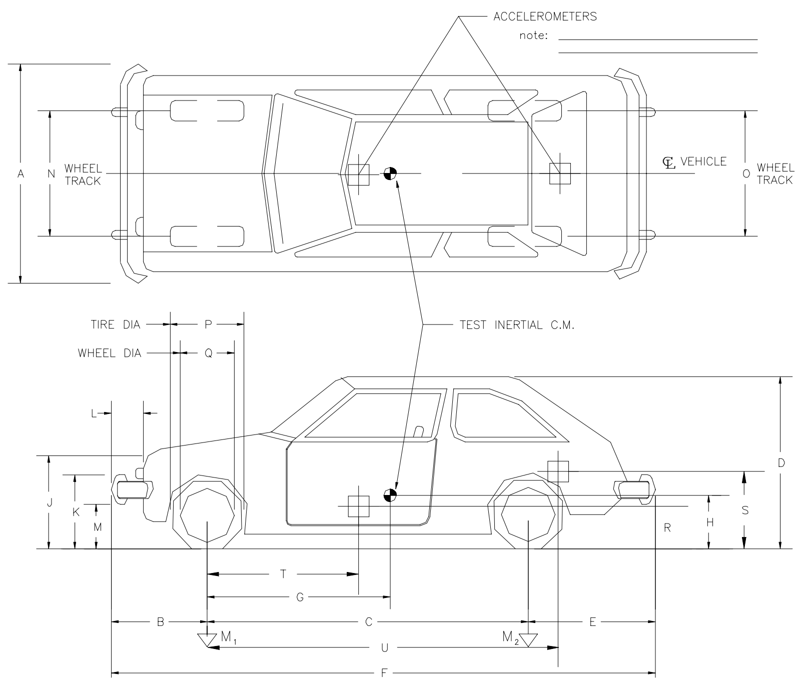
YEAR: 1994 MAKE: GEO MODEL: METRO

TIRE INFLATION PRESSURE: ______ ODOMETER: 112815 TIRE SIZE: 155R12

1st Use: X 2nd or More Use: ____ Minor Damage Charged to Project: ______

MASS DISTRIBUTION (kg) LF 250 RF 235 LR 178 RR 157

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:



ENGINE TYPE: 3 CYL.

ENGINE CID: 1.0L

TRANSMISSION TYPE:

X AUTO

__ MANUAL

OPTIONAL EQUIPMENT:

DUMMY DATA:

TYPE: 50th percentile male

MASS: 76 kg

SEAT POSITION: Driver

GEOMETRY – (mm)

A	1480	E	615	J	680	N	1360	R	N/A
B	750	F	3635	K	455	O	1340	S	N/A
C	2270	G	927.38	L	95	P	530	T	N/A
D	1320	H		M	370	Q	330	U	N/A

MASS – (kg)	CURB	TEST INERTIAL	GROSS STATIC
M_1	483	485	522
M_2	284	335	374
M_T	767	820	896

Figure 225. Vehicle Properties for Test 417929-12.

Table 2. Exterior Crush Measurements for Test 417929-1.

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width ________ Corner shift: A1 ________ A2 ________ End shift at frame (CDC) (check one) < 4 inches ________ ≥ 4 inches ________	Bowing: B1 ____ X1 ____ B2 ____ X2 ____ Bowing constant $\frac{X1 + X2}{2}$ = ______

Note: Measure C1 to C6 from Driver to Passenger side in Front or Rear impacts–
Rear to Front in Side impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width ** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
1	Front of hood	230	25	280	0	20	10	0	--	--	-90

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

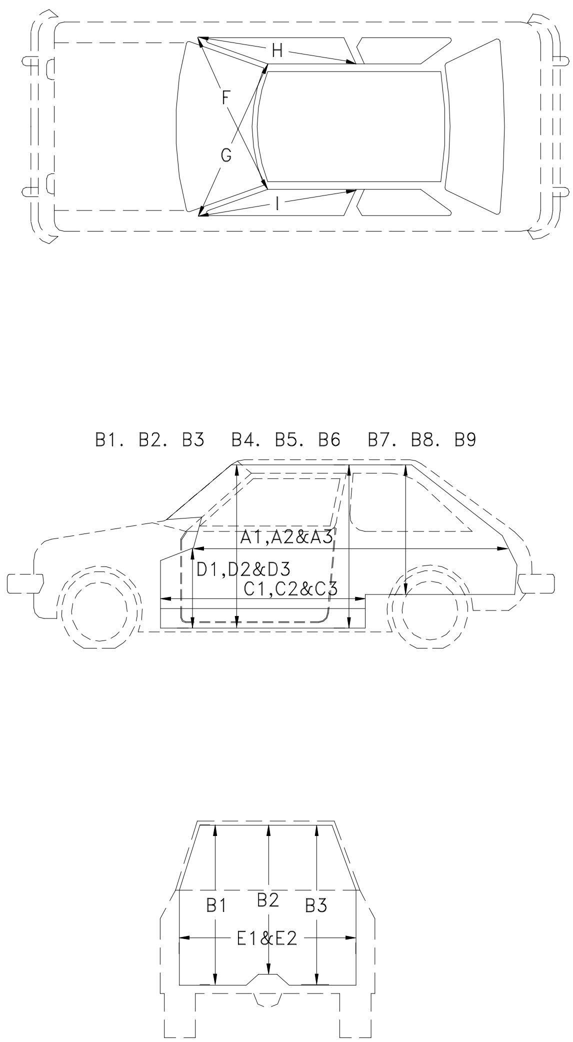
***Measure and document on the vehicle diagram the location of the maximum crush.

Note: Use as many lines/columns as necessary to describe each damage profile.

Table 3. Occupant Compartment Measurements for Test 417928-11.

Small Car

Occupant Compartment Deformation

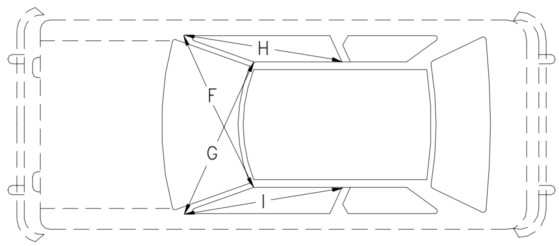


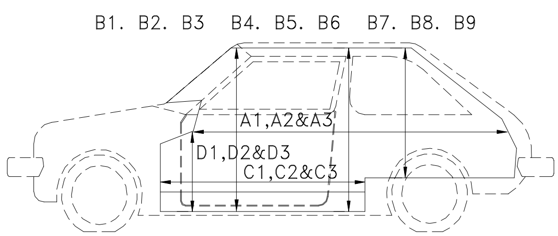
	BEFORE	AFTER
A1	1504	1504
A2	2070	2070
A3	1514	1514
B1	977	948
B2	926	827
B3	976	941
B4	964	964
B5	860	860
B6	957	957
B7	----	----
B8	----	----
B9	----	----
C1	703	703
C2	707	707
C3	570	570
D1	295	295
D2	84	84
D3	290	290
E1	1230	1230
E2	1234	1234
F	1215	1215
G	1215	1215
H	900	900
I	900	900

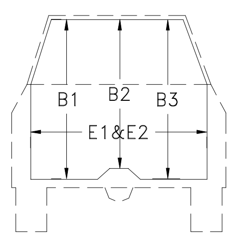
Table 4. Occupant Compartment Measurements for Test 417928-18.

Small Car

Occupant Compartment Deformation







	BEFORE	AFTER
A1	1509	1509
A2	2065	2065
A3	1511	1511
B1	980	973
B2	911	850
B3	990	972
B4	956	956
B5	852	852
B6	961	961
B7	----	----
B8	----	----
B9	----	----
C1	565	565
C2	706	706
C3	570	570
D1	290	290
D2	105	105
D3	290	290
E1	1226	1226
E2	1231	1231
F	1215	1215
G	1215	1215
H	900	900
I	900	900

Table 5. Exterior Crush Measurements for Test 417929-3.

VEHICLE CRUSH MEASUREMENT SHEET[1]

Complete When Applicable	
End Damage	Side Damage
Undeformed end width ________ Corner shift: A1 ________ A2 ________ End shift at frame (CDC) (check one) < 4 inches ________ ≥ 4 inches ________	Bowing: B1 ____ X1 ____ B2 ____ X2 ____ Bowing constant $\frac{X1 + X2}{2} =$ ______

Note: Measure C1 to C6 from Driver to Passenger side in Front or Rear impacts– Rear to Front in Side impacts.

Specific Impact Number	Plane* of C-Measurements	Direct Damage Width ** (CDC)	Direct Damage Max*** Crush	Field L**	C_1	C_2	C_3	C_4	C_5	C_6	±D
Most of damage on left side of roof.											

[1]Table taken from National Accident Sampling System (NASS).

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

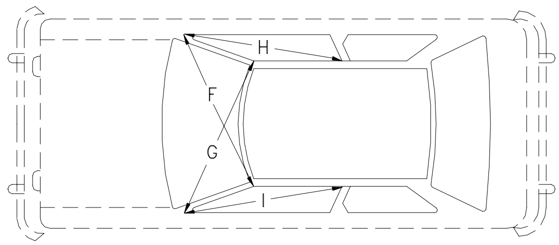
***Measure and document on the vehicle diagram the location of the maximum crush.

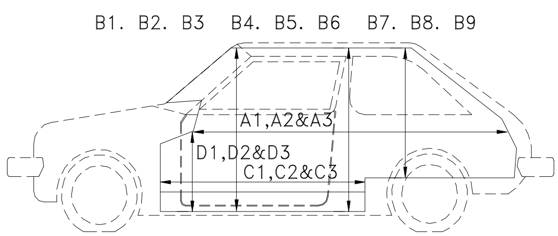
Note: Use as many lines/columns as necessary to describe each damage profile.

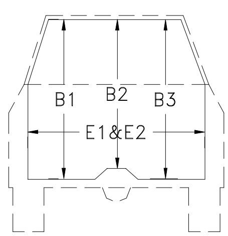
Table 6. Occupant Compartment Measurements for Test 417929-3.

Small Car

Occupant Compartment Deformation







	BEFORE	AFTER
A1	1510	1510
A2	2065	2065
A3	510	510
B1	965	965
B2	911	860
B3	980	905
B4	960	960
B5	865	865
B6	965	965
B7	773	773
B8	785	785
B9	790	790
C1	704	704
C2	692	692
C3	736	736
D1	290	295
D2	165	165
D3	285	285
E1	1230	1230
E2	1240	1240
F	1210	1210
G	1210	1210
H	900	900
I	900	900

APPENDIX C. SEQUENTIAL PHOTOGRAPHS

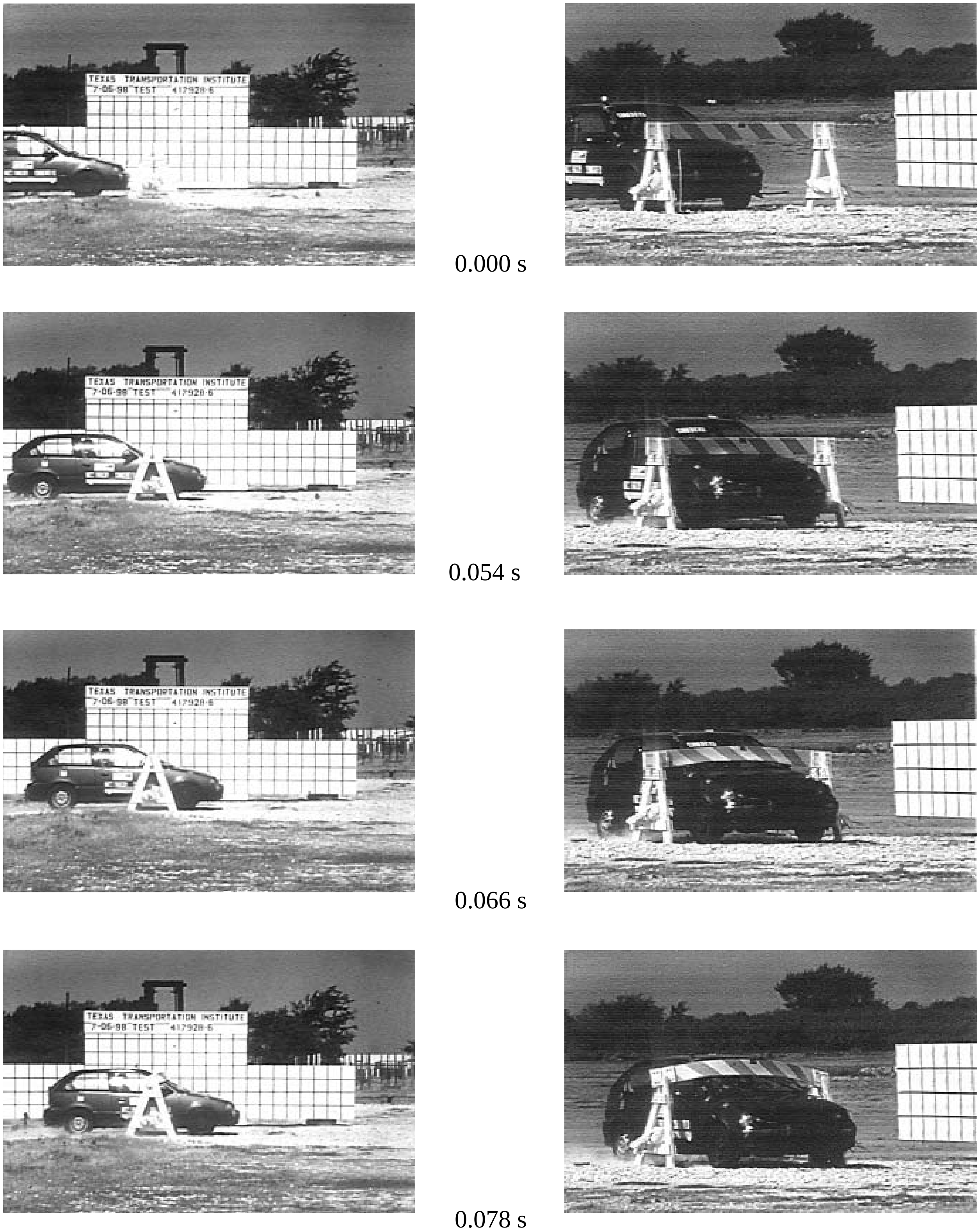
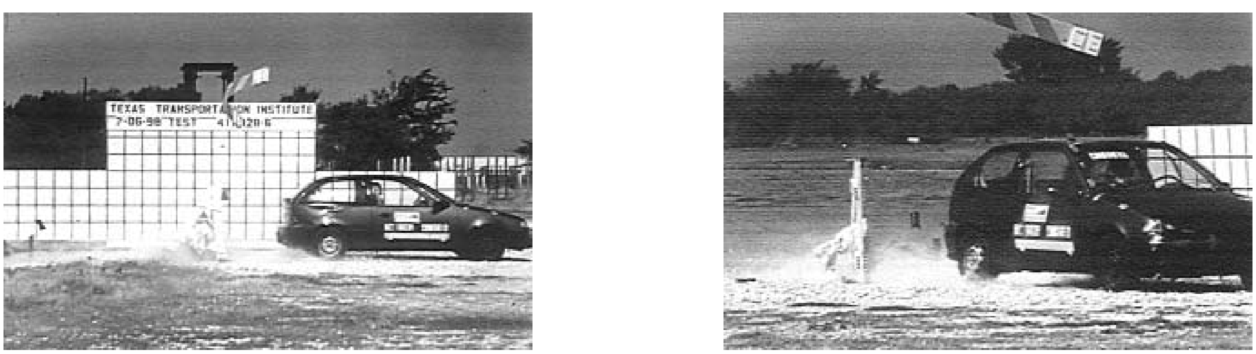


Figure 226. Sequential Photographs for Test 417928-6 (Perpendicular and Oblique Views).

0.090 s

0.115 s

0.151 s



0.200 s

Figure 226. Sequential Photographs for Test 417928-6 (Perpendicular and Oblique Views) (continued).

0.000 s

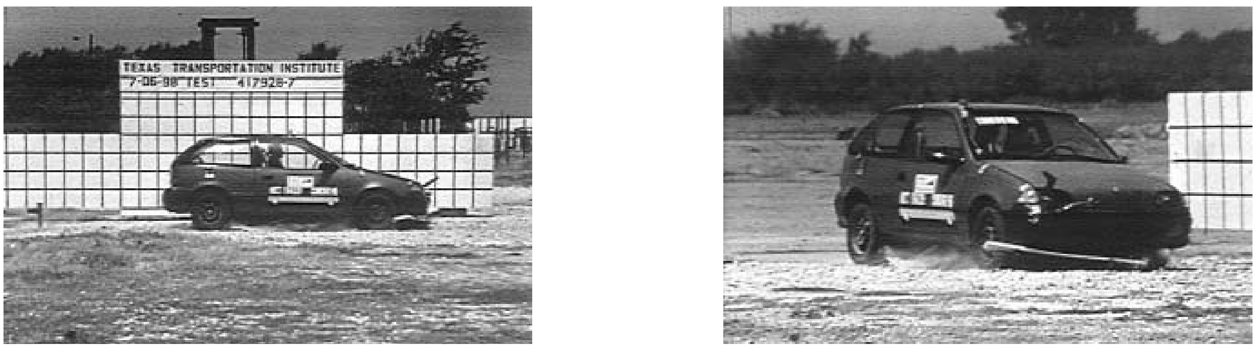
0.024 s

0.049 s

0.074 s

Figure 227. Sequential Photographs for Test 417928-7 (Perpendicular and Oblique Views).

0.098 s

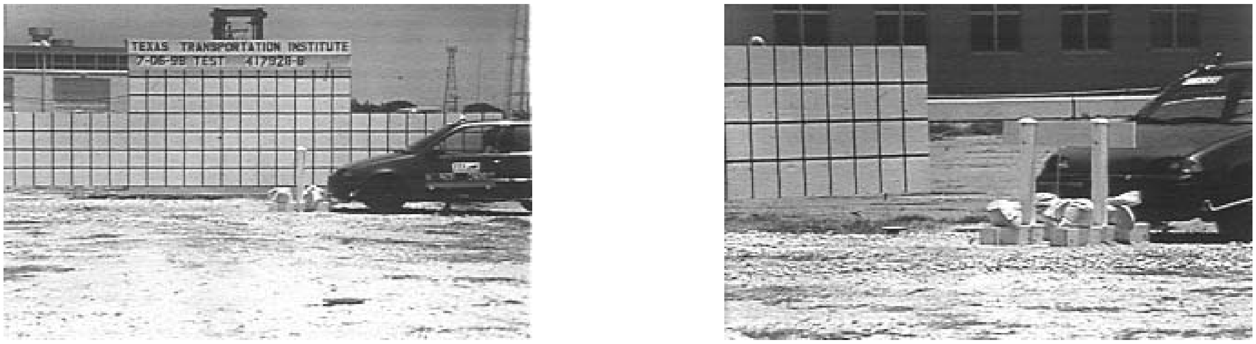


0.135 s

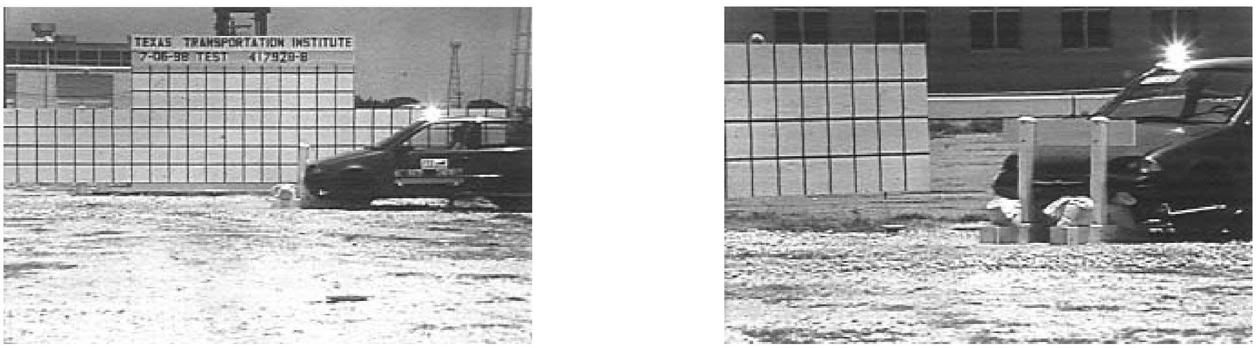
0.172 s

0.221 s

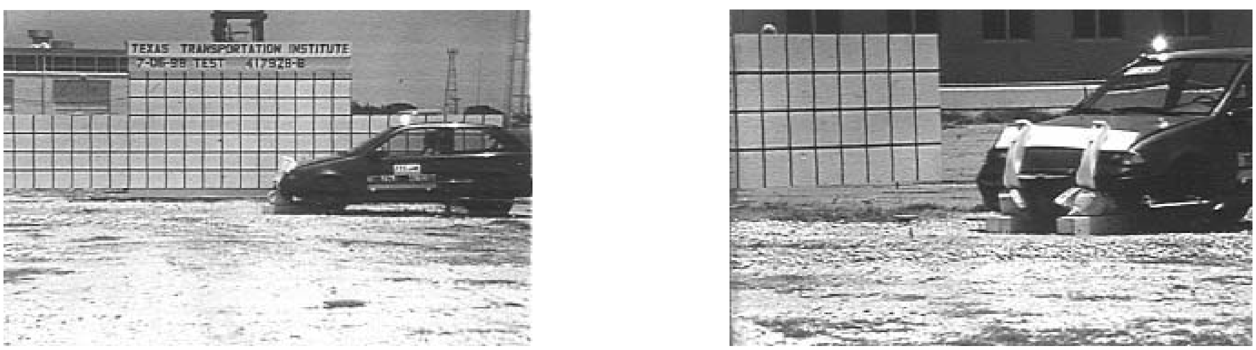
Figure 227. Sequential Photographs for Test 417928-7 (Perpendicular and Oblique Views) (continued).



0.000 s



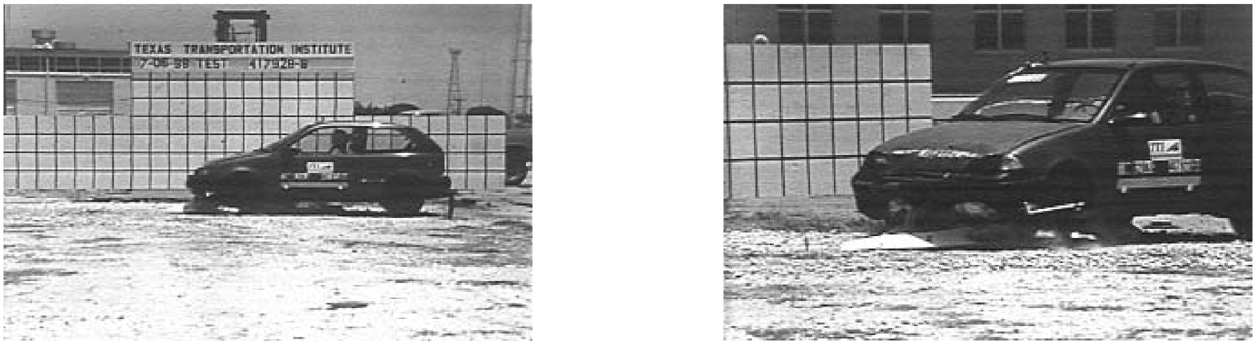
0.017 s



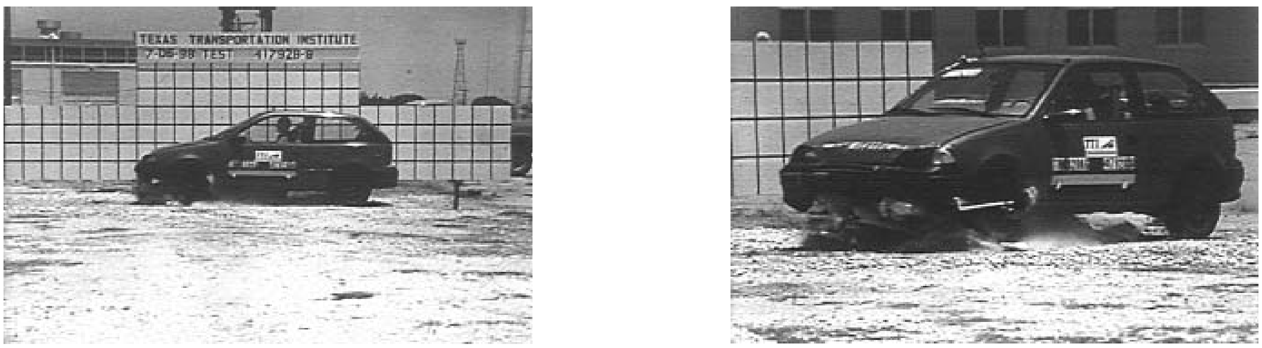
0.029 s

0.054 s

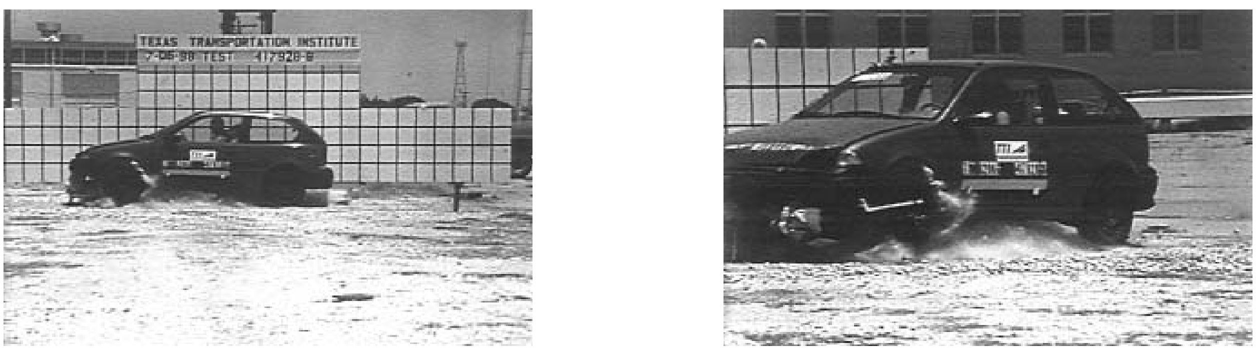
Figure 228. Sequential Photographs for Test 417928-8 (Perpendicular and Oblique Views).



0.078 s



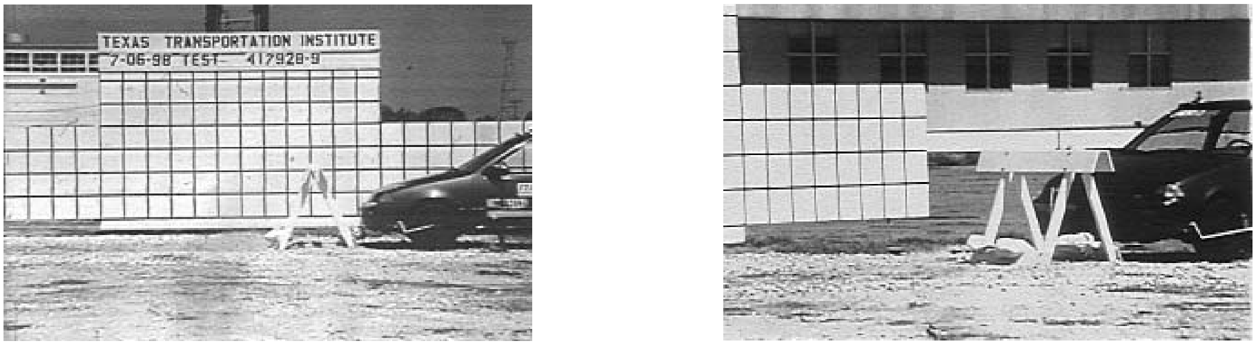
0.110 s



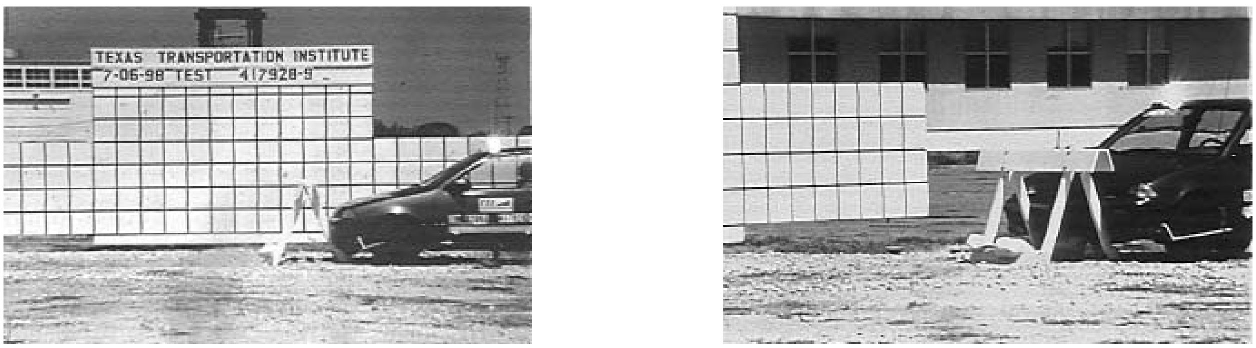
0.147 s

0.196 s

Figure 228. Sequential Photographs for Test 417928-8 (Perpendicular and Oblique Views) (continued).



0.000 s

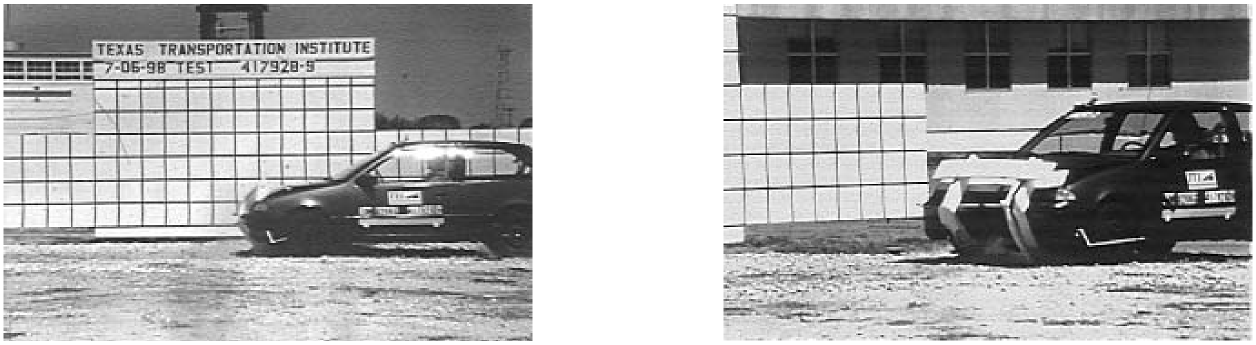


0.012 s

0.024 s

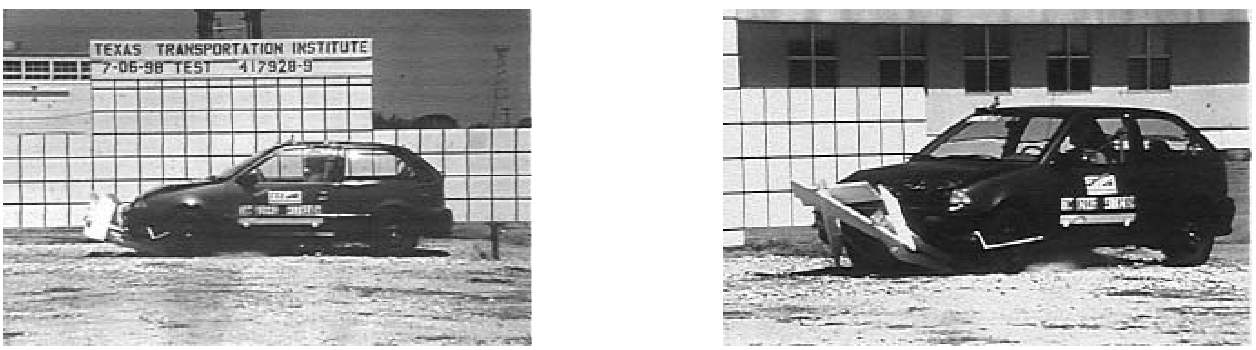
0.037 s

Figure 229. Sequential Photographs for Test 417928-9 (Perpendicular and Oblique Views).

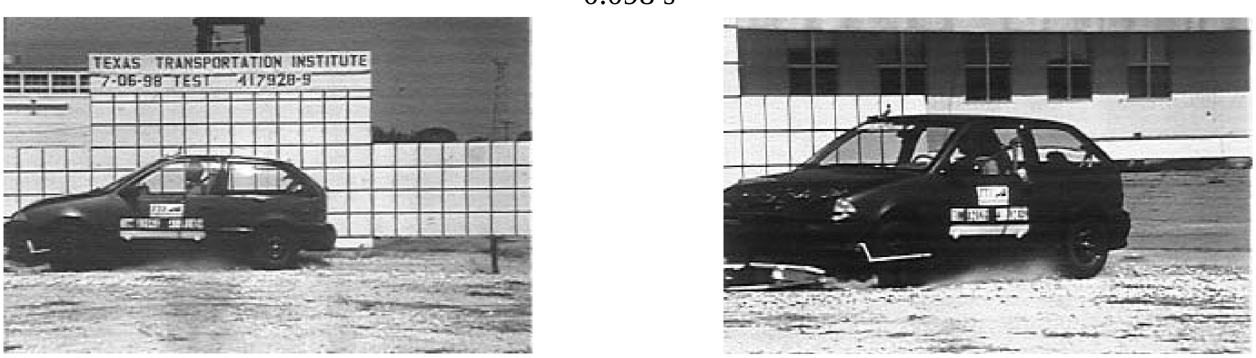


0.049 s

0.073 s



0.098 s



0.147 s

Figure 229. Sequential Photographs for Test 417928-9 (Perpendicular and Oblique Views) (continued).

0.000 s

0.011 s

0.022 s

0.033 s

0.054 s

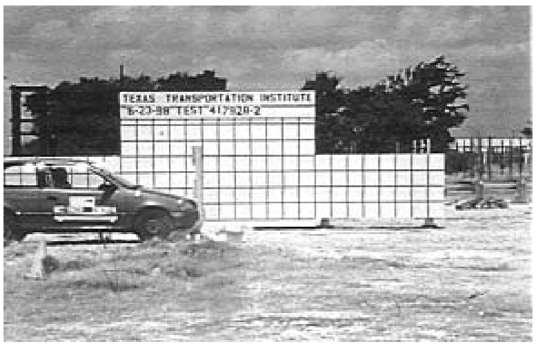
0.087 s

0.131 s

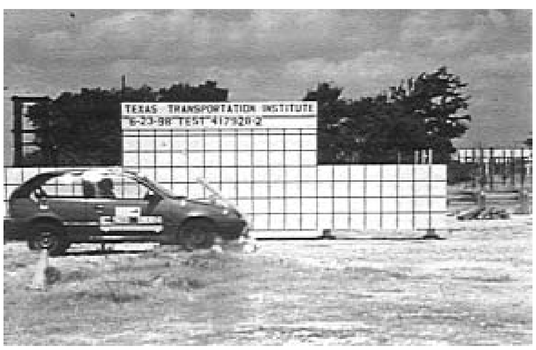
0.196 s

Figure 230. Sequential Photographs for Test 417928-17 (Oblique View).

0.000 s



0.024 s

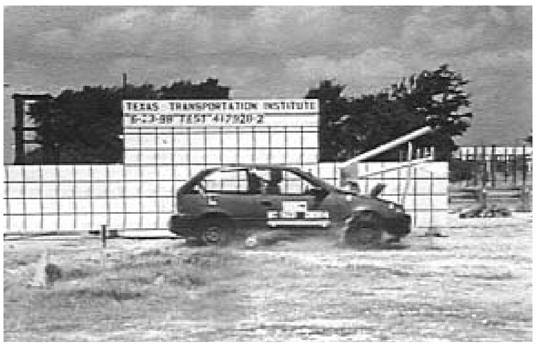


0.049 s

0.073 s

Figure 231. Sequential Photographs for Test 417928-2 (Perpendicular and Oblique Views).

0.097 s



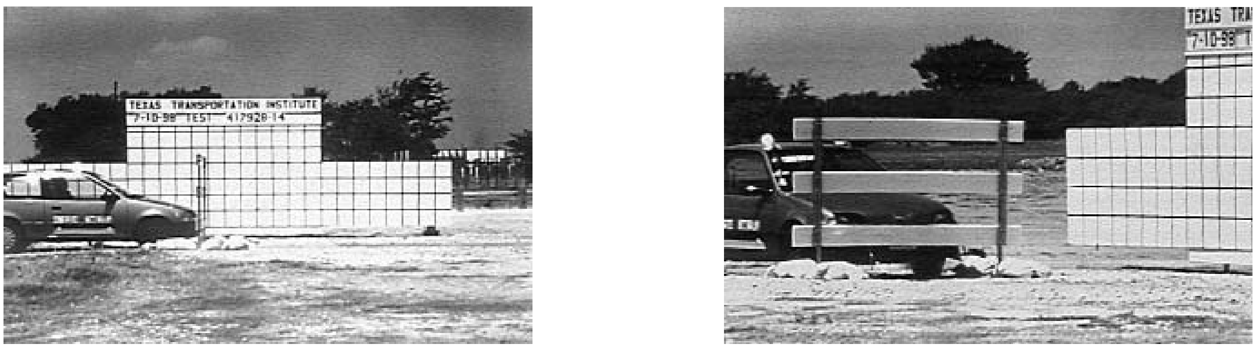
0.146 s

0.219 s

0.293 s

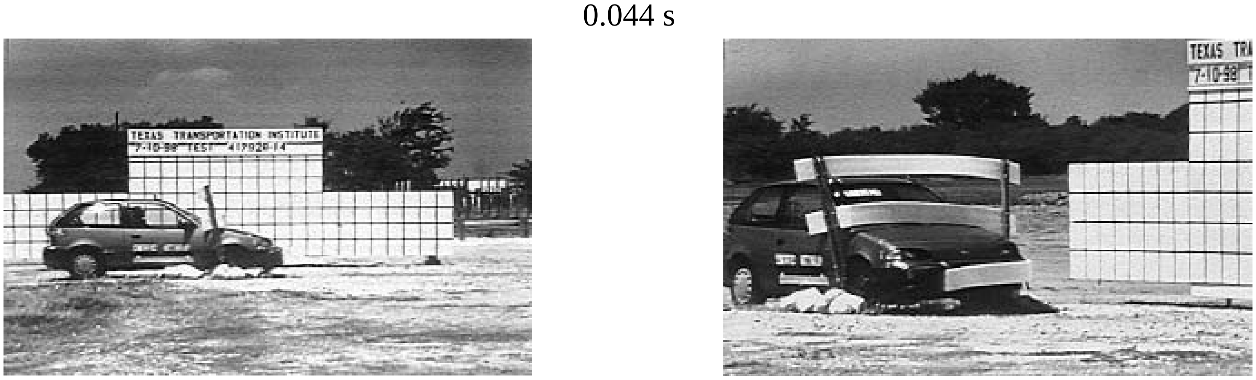
Figure 231. Sequential Photographs for Test 417928-2 (Perpendicular and Oblique Views) (continued).

0.000 s



0.029 s

0.044 s



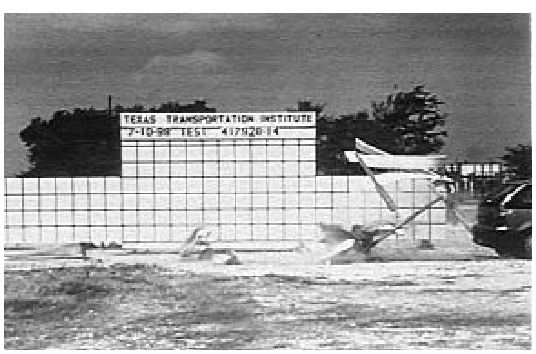
0.073 s

Figure 232. Sequential Photographs for Test 417928-14 (Perpendicular and Oblique Views).

0.110 s

0.146 s

0.195 s



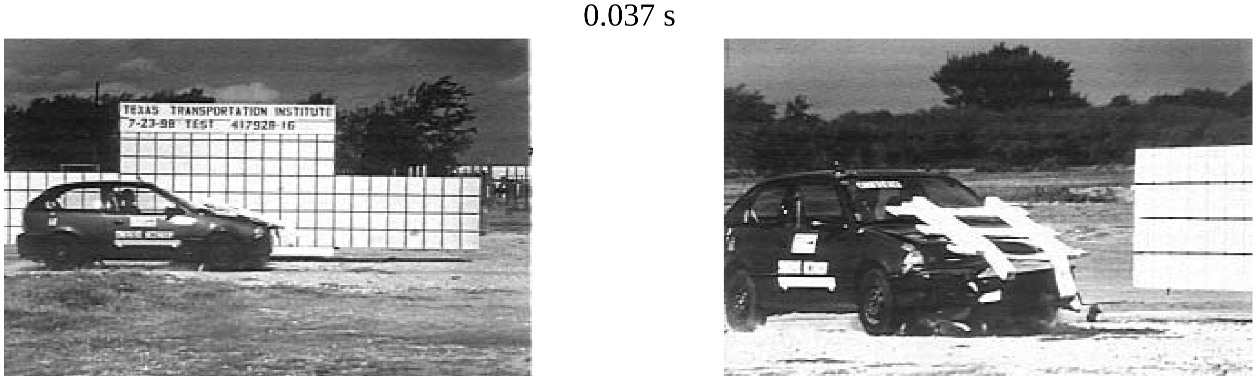
0.341 s

Figure 232. Sequential Photographs for Test 417928-14 (Perpendicular and Oblique Views) (continued).

0.000 s

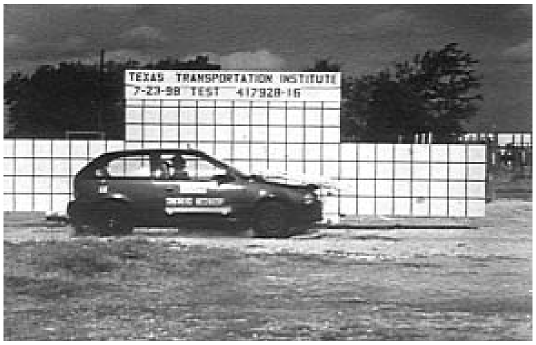
0.017 s

0.037 s

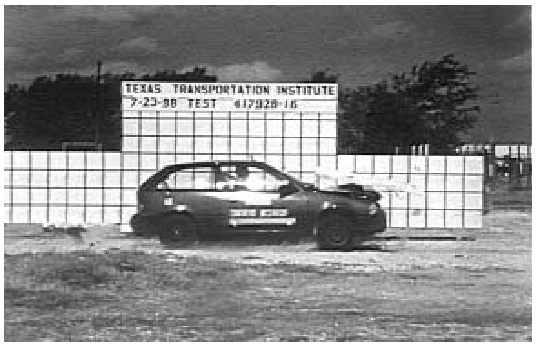


0.061 s

Figure 233. Sequential Photographs for Test 417928-16 (Perpendicular and Oblique Views).



0.085 s



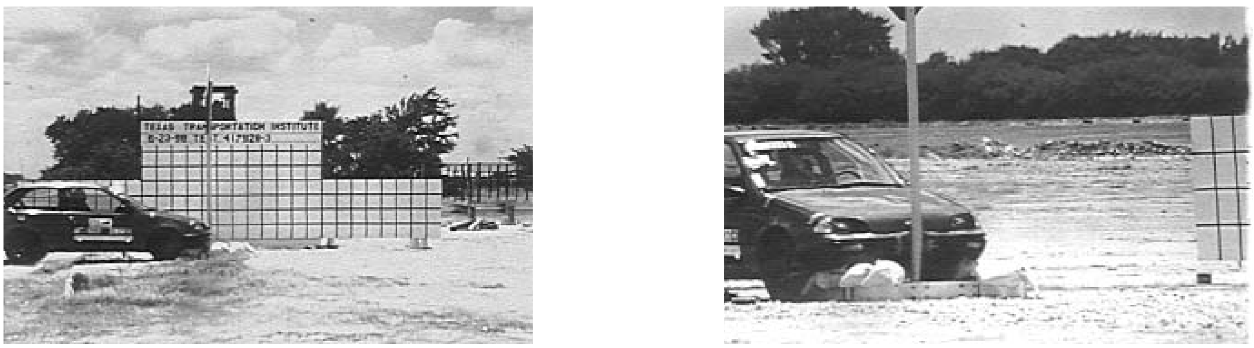
0.122 s

0.171 s

0.219 s

Figure 233. Sequential Photographs for Test 417928-16 (Perpendicular and Oblique Views) (continued).

0.000 s

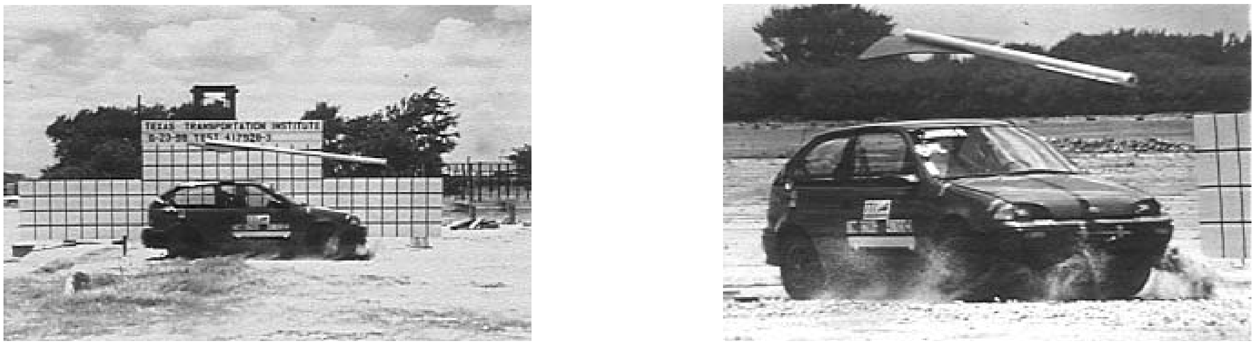


0.024 s

0.049 s

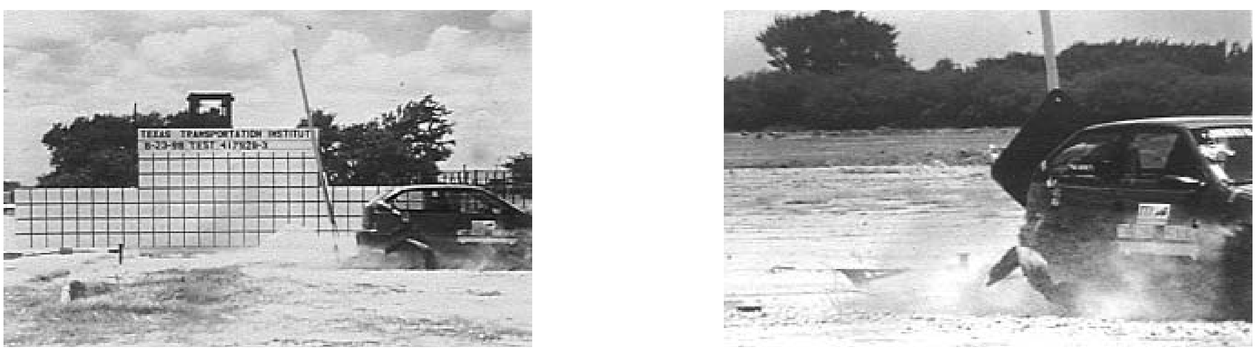
0.073 s

Figure 234. Sequential Photographs for Test 417928-3 (Perpendicular and Oblique Views).



0.122 s

0.183 s



0.268 s

0.366 s

Figure 234. Sequential Photographs for Test 417928-3
(Perpendicular and Oblique Views) (continued).

0.000 s

0.036 s

0.060 s

0.097 s

Figure 235. Sequential Photographs for Test 417928-10 (Perpendicular and Oblique Views).

0.158 s

0.206 s

0.267 s

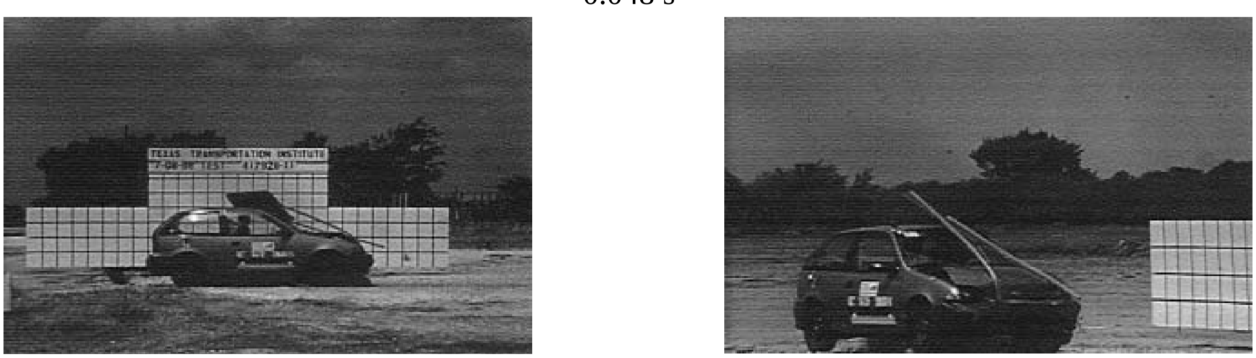
0.365 s

Figure 235. Sequential Photographs for Test 417928-10 (Perpendicular and Oblique Views) (continued).

0.000 s

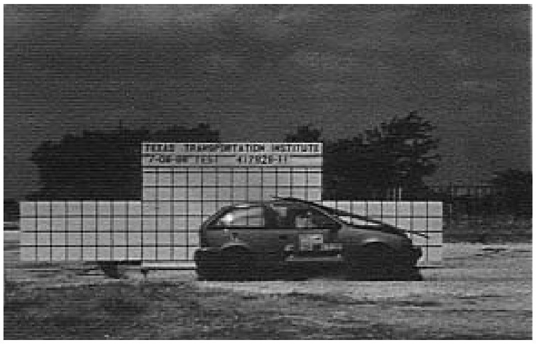
0.024 s

0.048 s

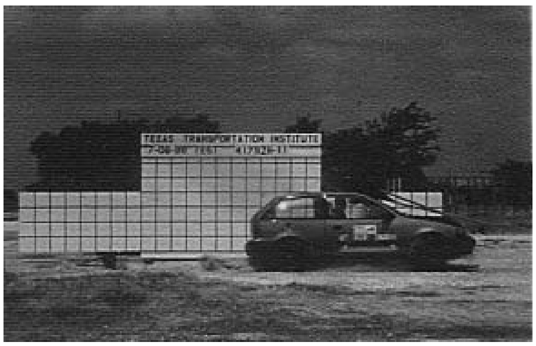


0.097 s

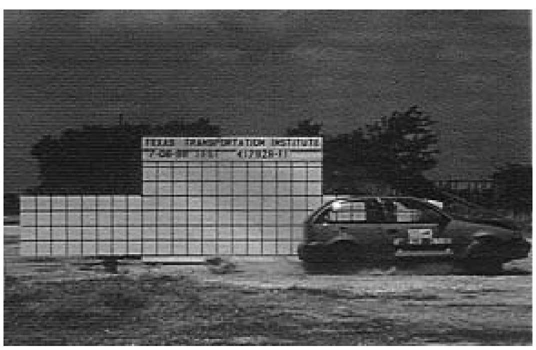
Figure 236. Sequential Photographs for Test 417928-11 (Perpendicular and Oblique Views).



0.134 s



0.170 s



0.207 s

0.244 s

Figure 236. Sequential Photographs for Test 417928-11 (Perpendicular and Oblique Views) (continued).

0.000 s

0.024 s

0.073 s

0.122 s

Figure 237. Sequential Photographs for Test 417928-4 (Perpendicular and Oblique Views).

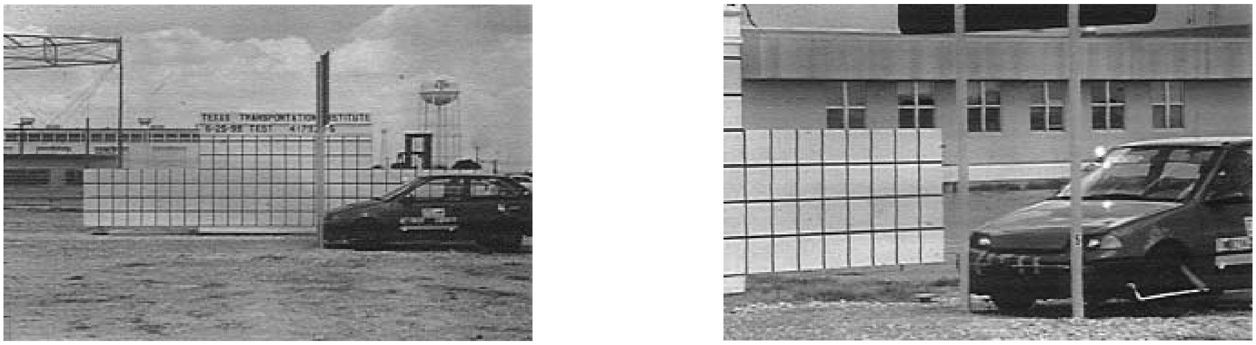
0.195 s

0.292 s

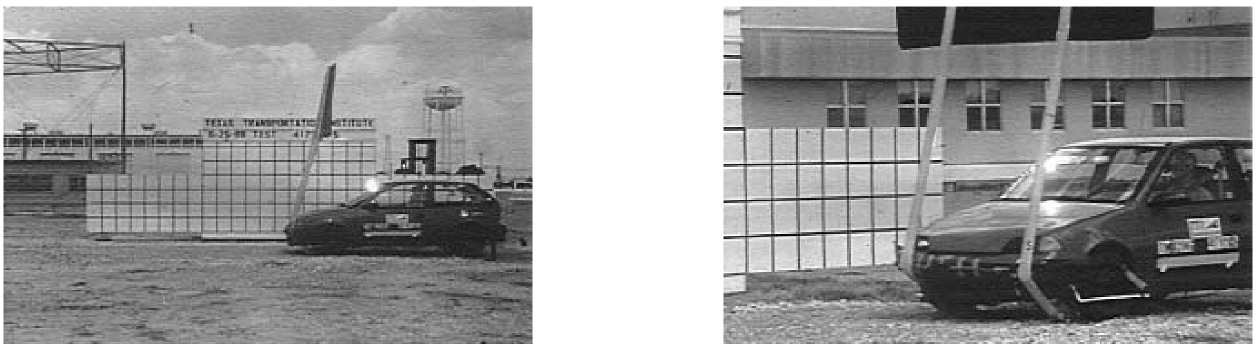
0.439 s

0.976 s

Figure 237. Sequential Photographs for Test 417928-4 (Perpendicular and Oblique Views) (continued).

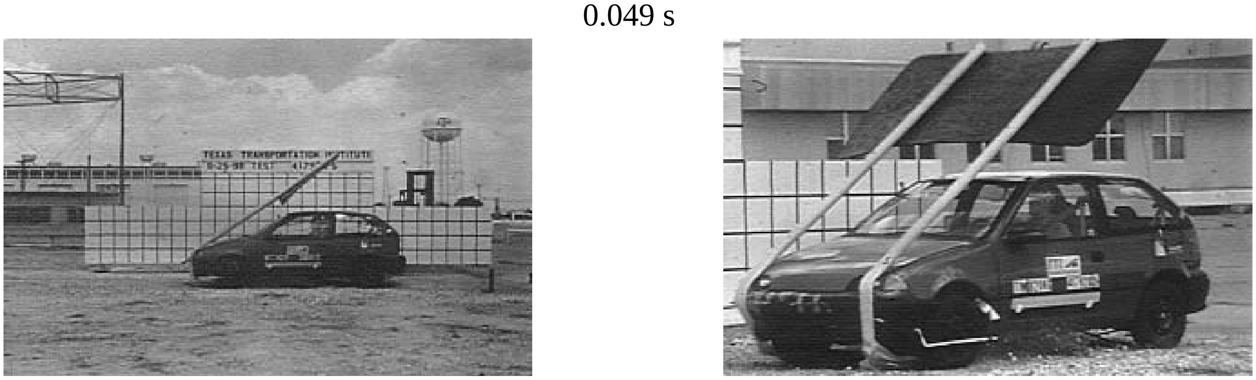


0.000 s



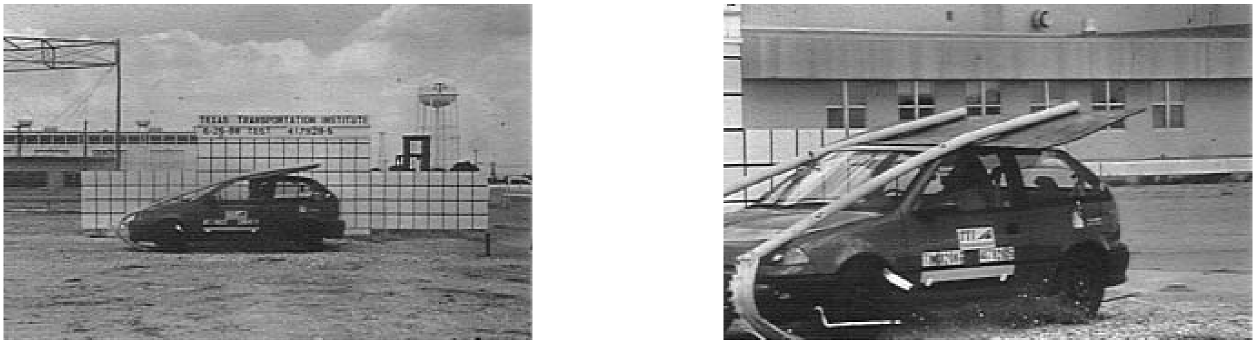
0.024 s

0.049 s



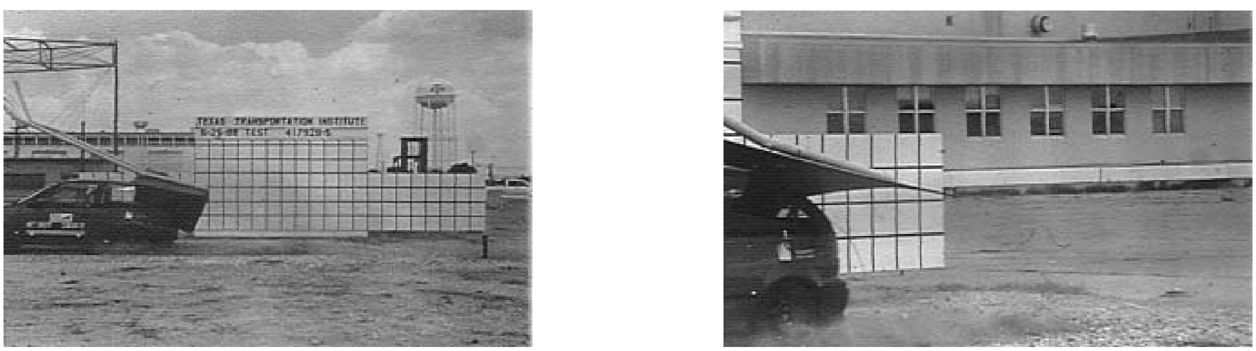
0.085 s

Figure 238. Sequential Photographs for Test 417928-5 (Perpendicular and Oblique Views).

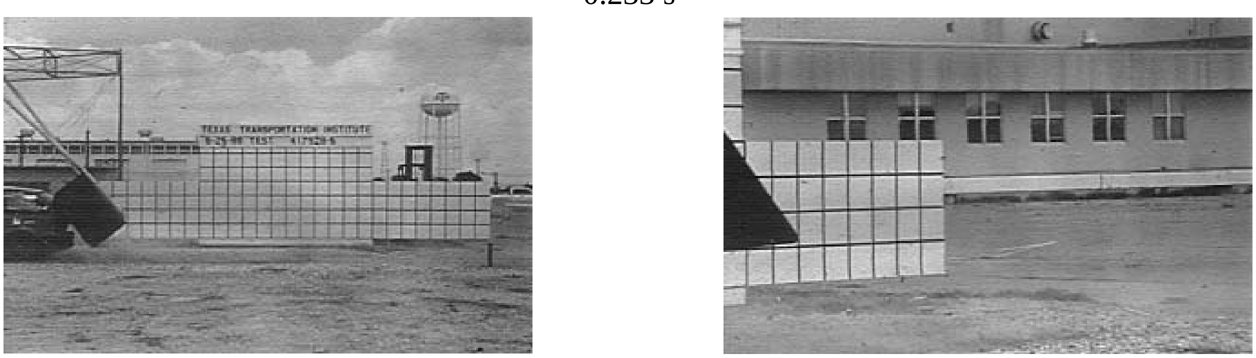


0.122 s

0.183 s

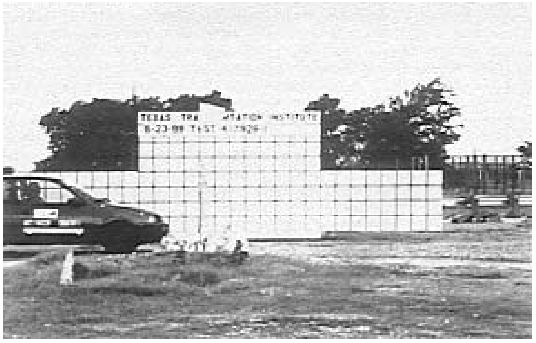
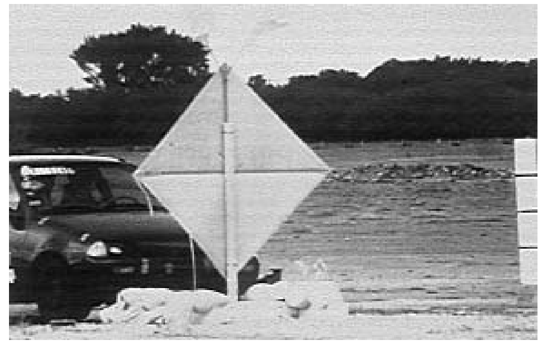


0.233 s

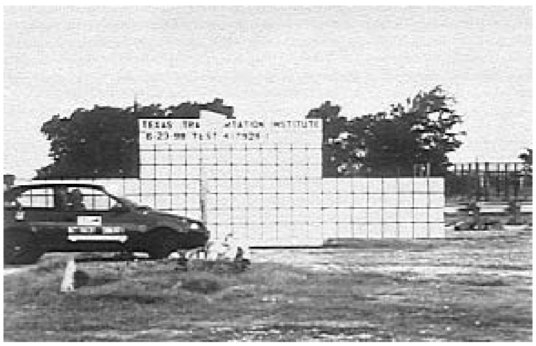
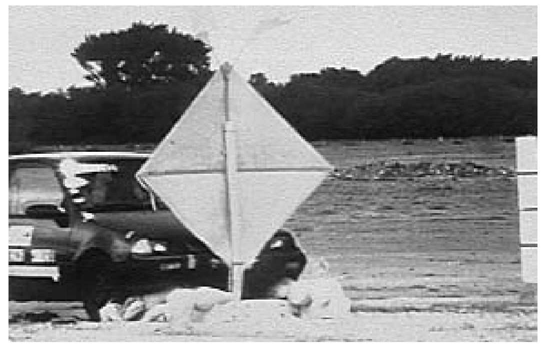


0.306 s

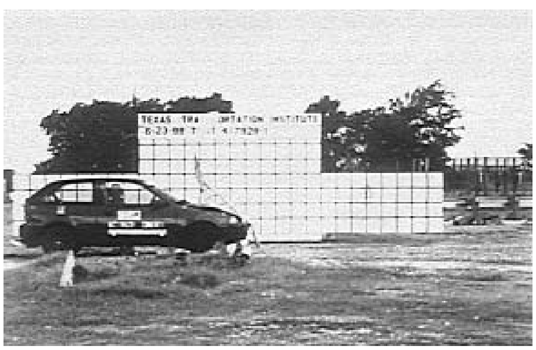
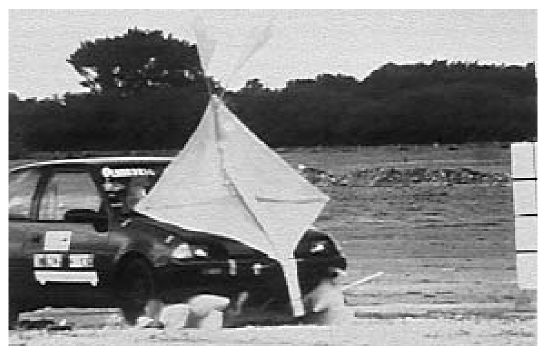
Figure 238. Sequential Photographs for Test 417928-5 (Perpendicular and Oblique Views) (continued).

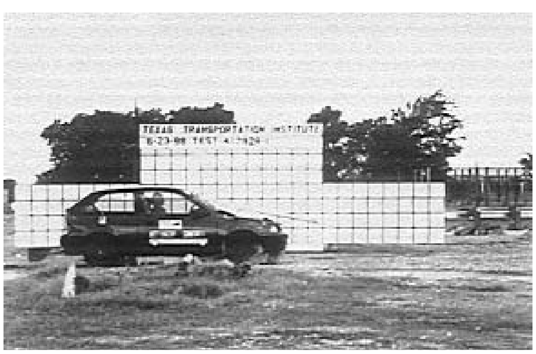
0.000 s

0.025 s

0.049 s




0.074 s

Figure 239. Sequential Photographs for Test 417928-1 (Perpendicular and Oblique Views).

0.099 s

0.148 s

0.222 s

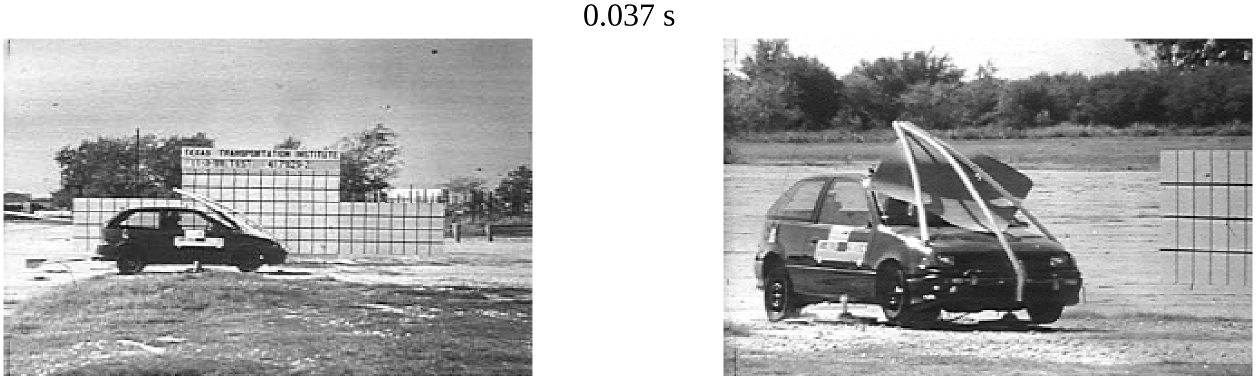
0.297 s

Figure 239. Sequential Photographs for Test 417928-1 (Perpendicular and Oblique Views) (continued).

0.000 s

0.012 s

0.037 s



0.062 s

Figure 240. Sequential Photographs for Test 417929-2 (Perpendicular and Oblique Views).

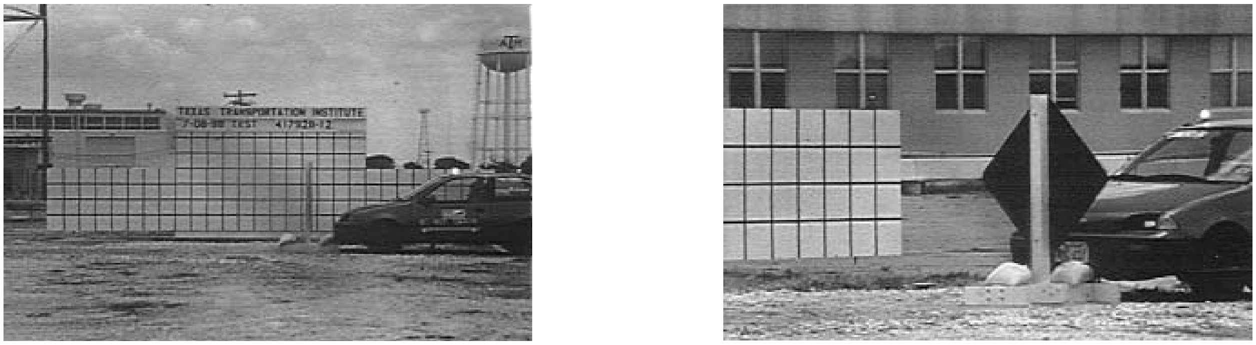
0.099 s

0.136 s

0.197 s

0.271 s

Figure 240. Sequential Photographs for Test 417929-2 (Perpendicular and Oblique Views) (continued).



0.000 s

0.024 s

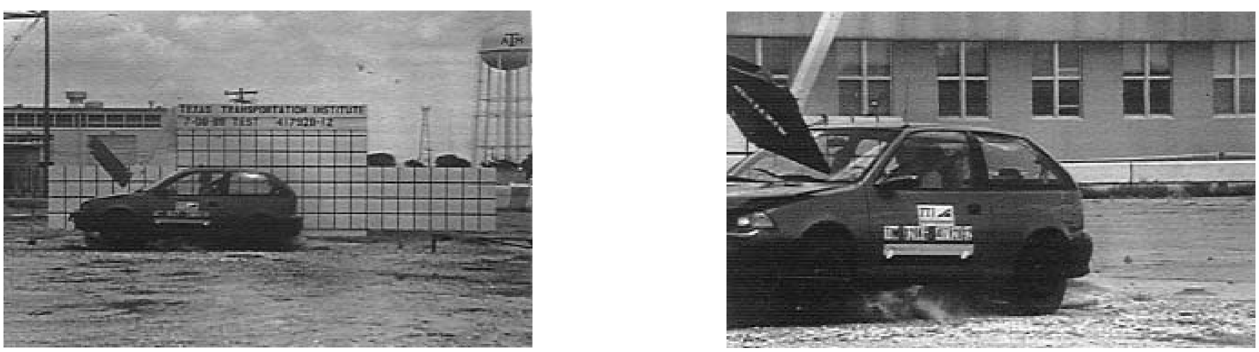
0.048 s

0.073 s

Figure 241. Sequential Photographs for Test 417928-12 (Perpendicular and Oblique Views).

0.097 s

0.134 s



0.158 s

0.195 s

Figure 241. Sequential Photographs for Test 417928-12 (Perpendicular and Oblique Views) (continued).

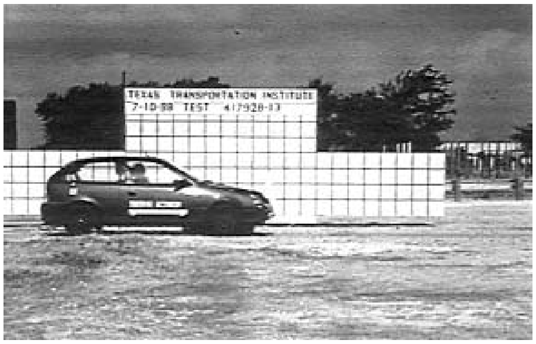
0.000 s

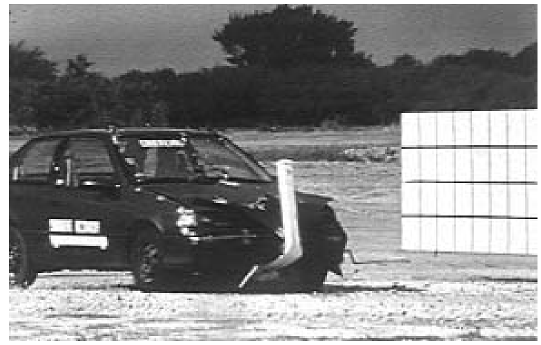
0.019 s

0.032 s

0.044 s

Figure 242. Sequential Photographs for Test 417928-13 (Perpendicular and Oblique Views).

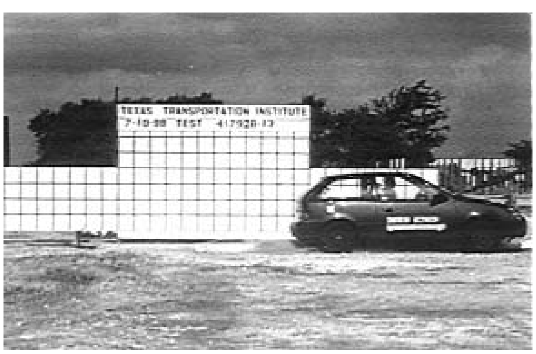




0.061 s

0.085 s

0.122 s



0.220 s

Figure 242. Sequential Photographs for Test 417928-13 (Perpendicular and Oblique Views) (continued).

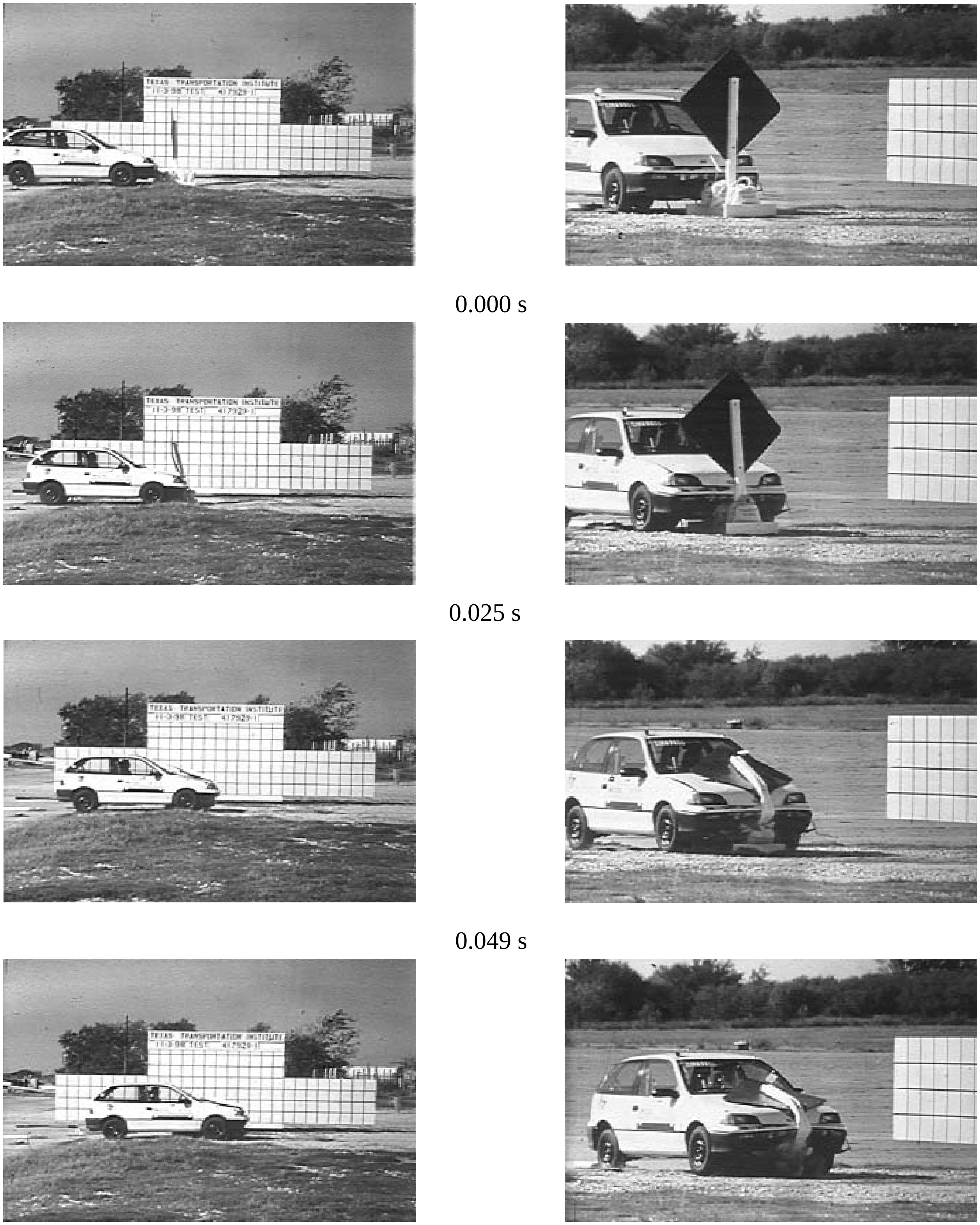
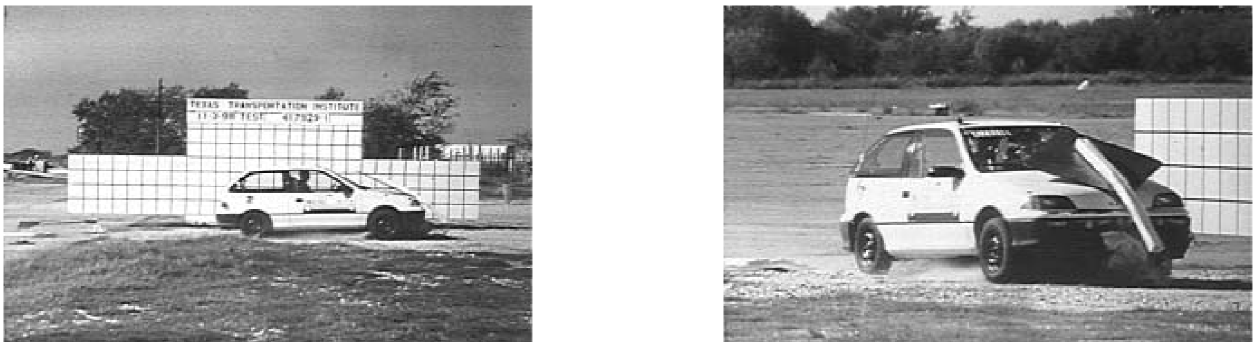


Figure 243. Sequential Photographs for Test 417929-1 (Perpendicular and Oblique Views).

0.111 s

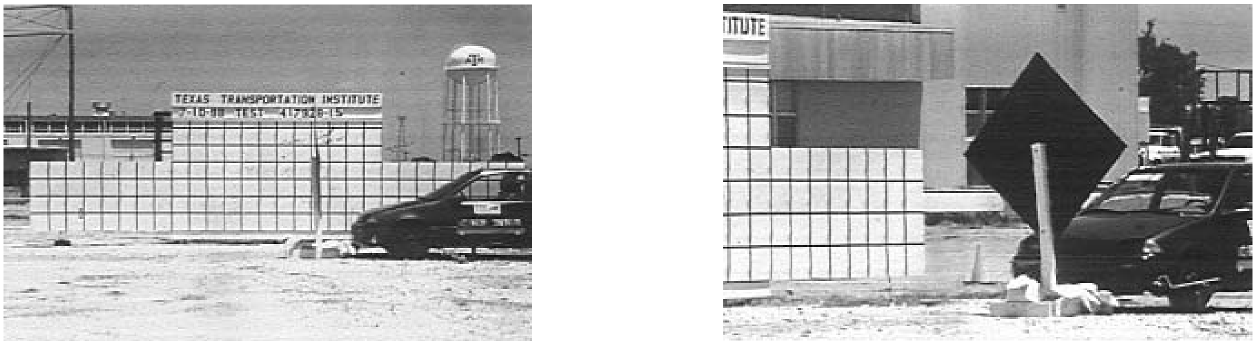


0.148 s

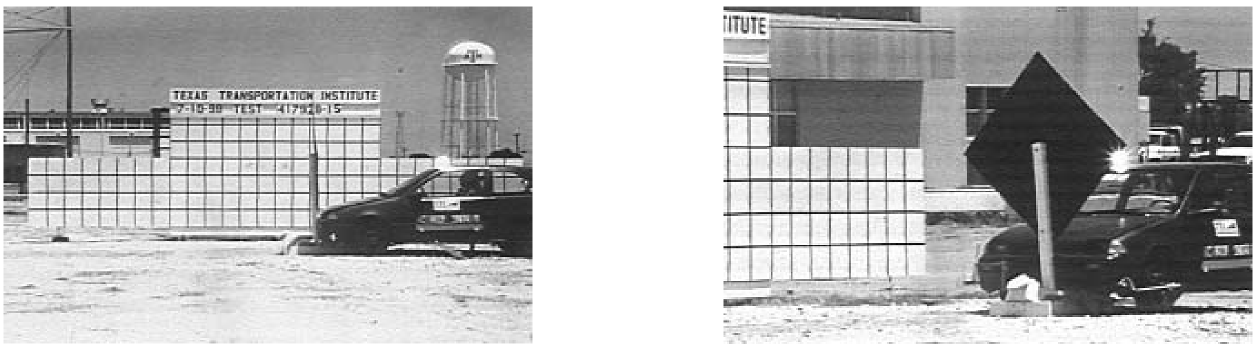
0.197 s

0.246 s

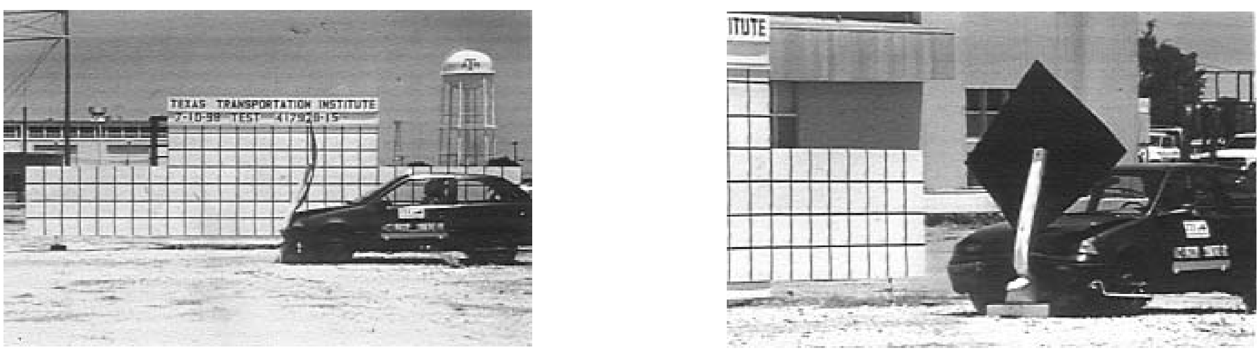
Figure 243. Sequential Photographs for Test 417929-1 (Perpendicular and Oblique Views) (continued).



0.000 s



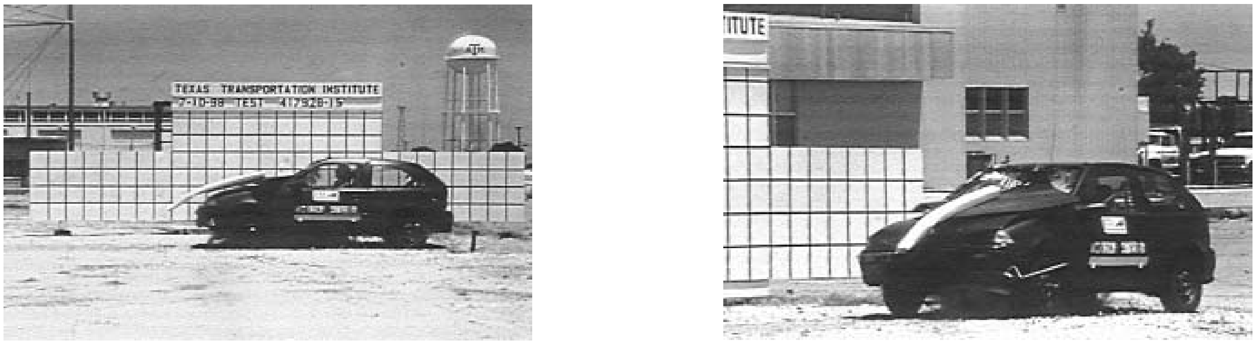
0.019 s



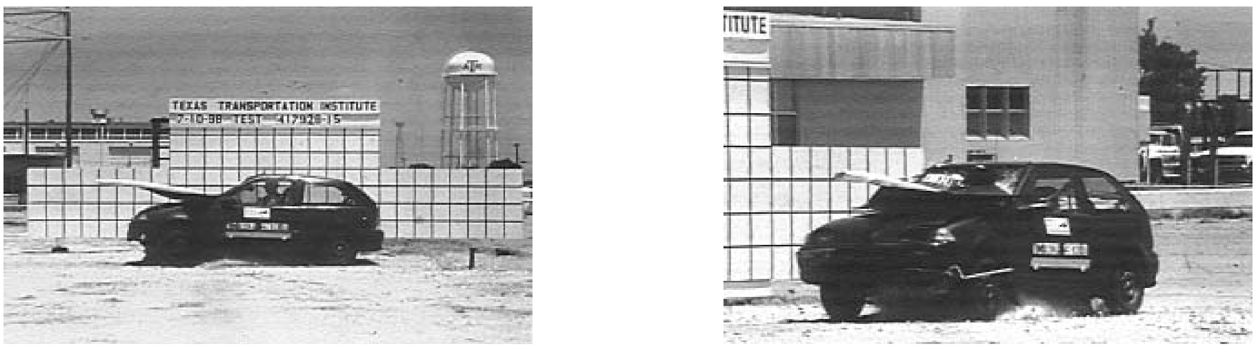
0.037 s

0.061 s

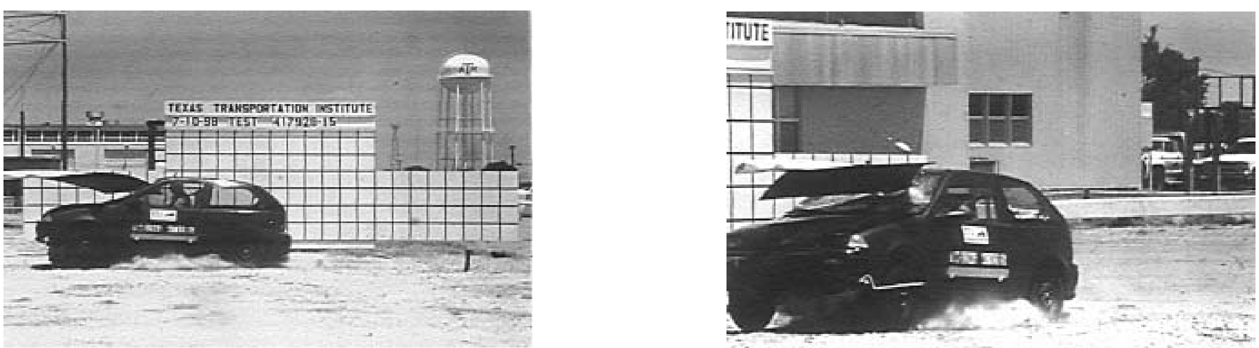
Figure 244. Sequential Photographs for Test 417928-15 (Perpendicular and Oblique Views).



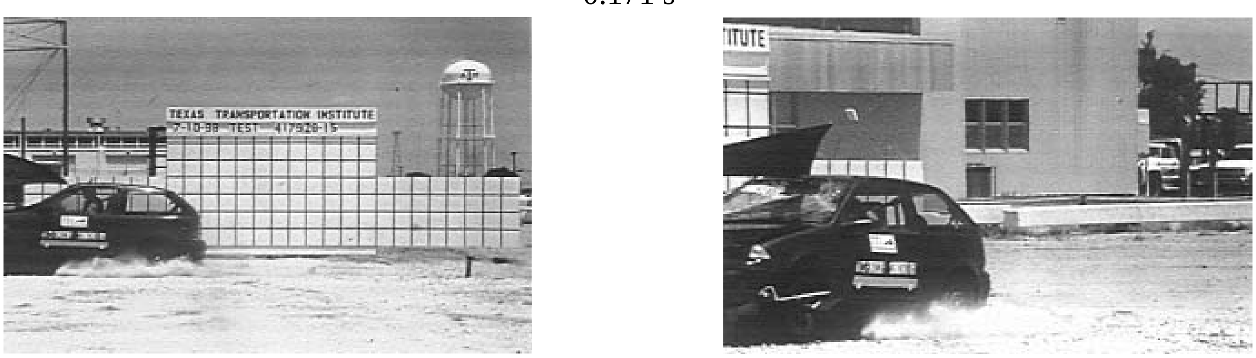
0.086 s



0.122 s



0.171 s



0.220 s

Figure 244. Sequential Photographs for Test 417928-15 (Perpendicular and Oblique Views) (continued).

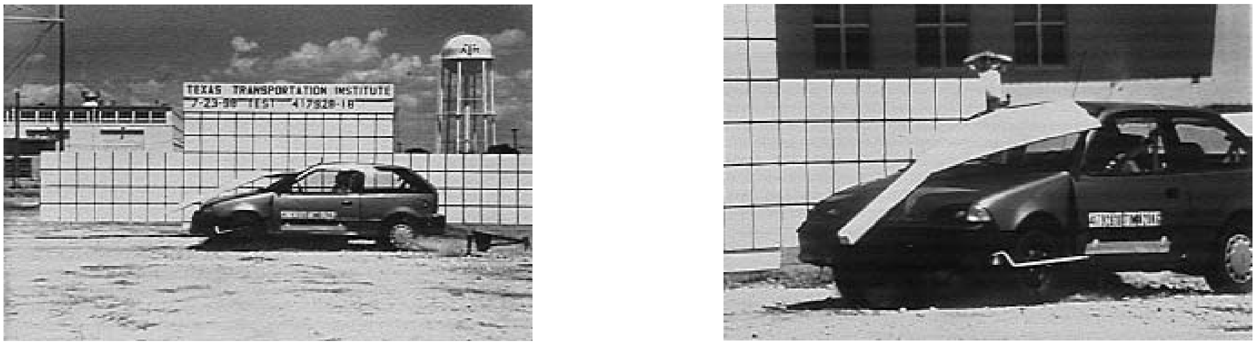
0.000 s

0.017 s

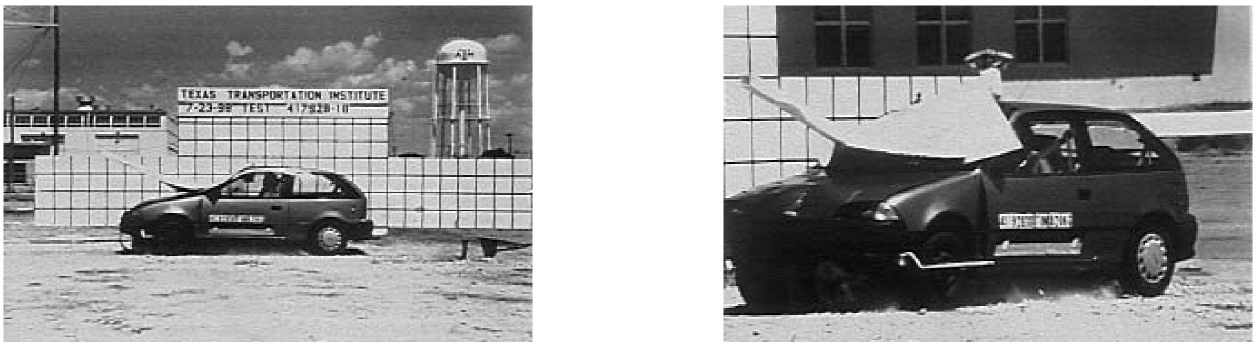
0.034 s

0.061 s

Figure 245. Sequential Photographs for Test 417928-18 (Perpendicular and Oblique Views).



0.085 s

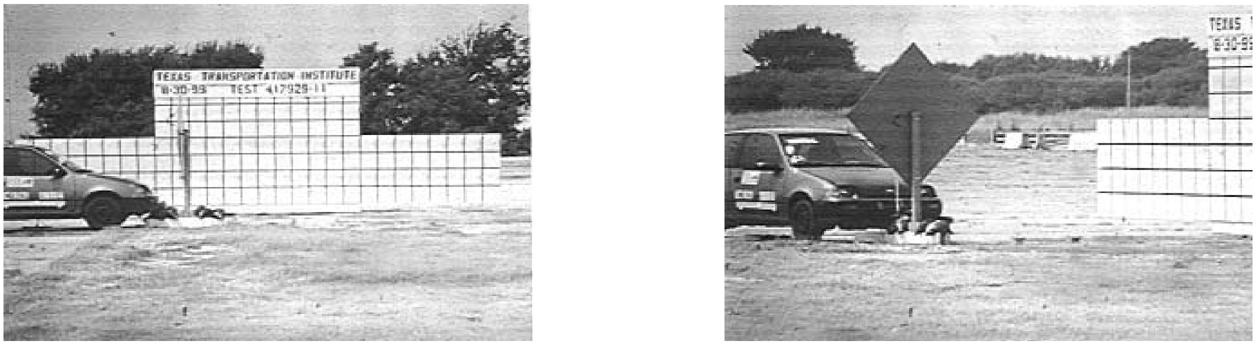


0.122 s

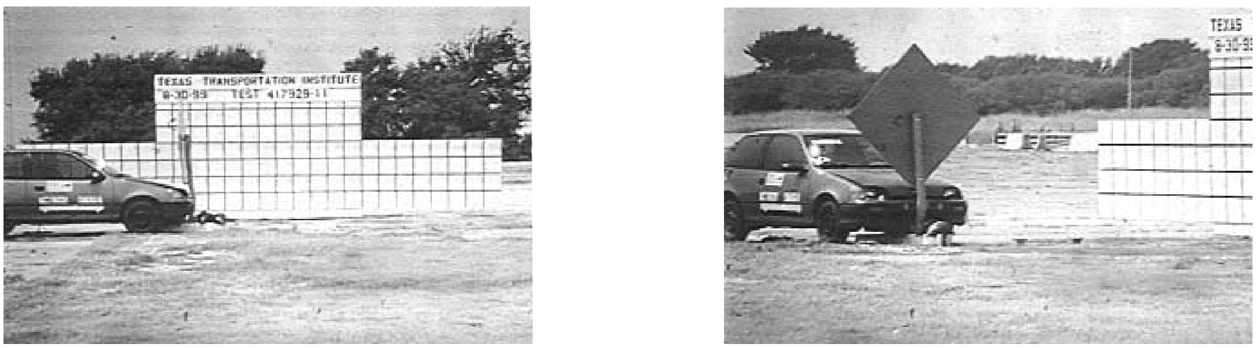
0.171 s

0.220 s

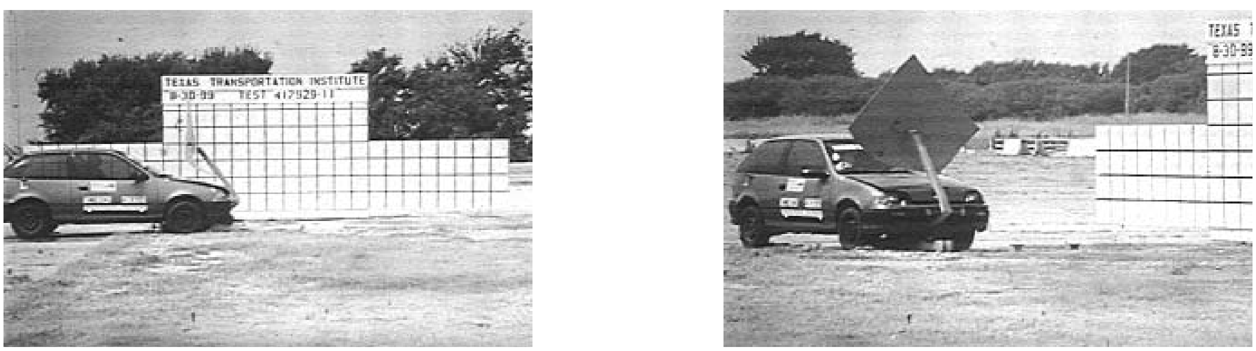
Figure 245. Sequential Photographs for Test 417928-18 (Perpendicular and Oblique Views) (continued).



0.000 s



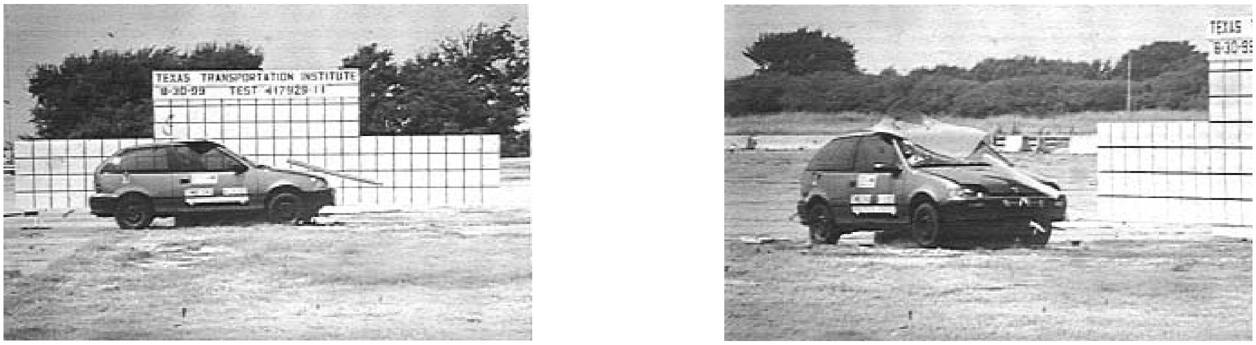
0.020 s



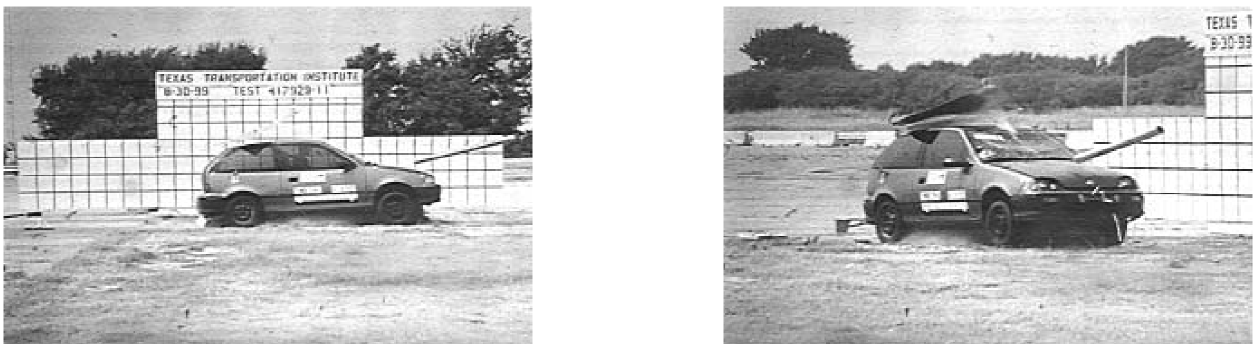
0.040 s

0.070 s

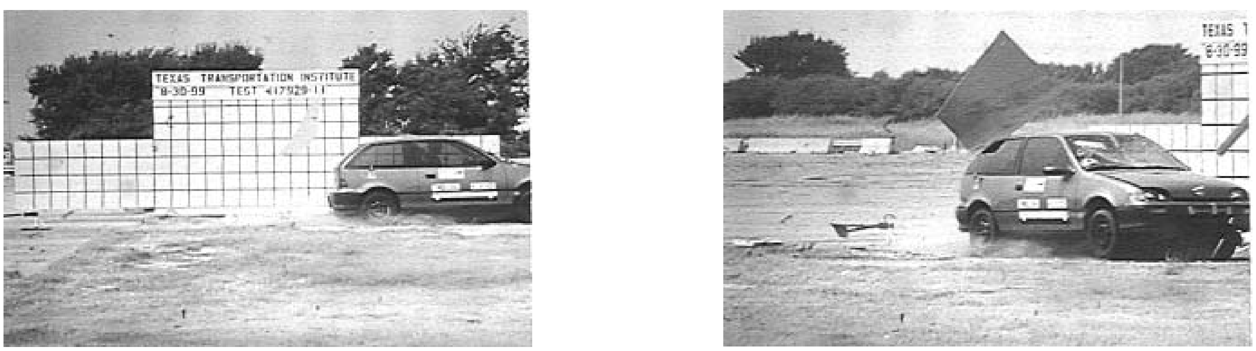
Figure 246. Sequential Photographs for Test 417929-11 (Perpendicular and Oblique Views).



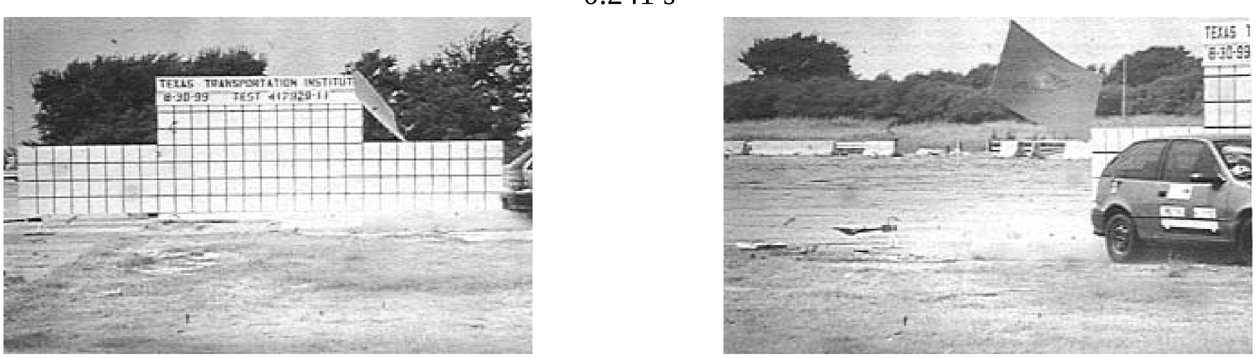
0.101 s



0.161 s



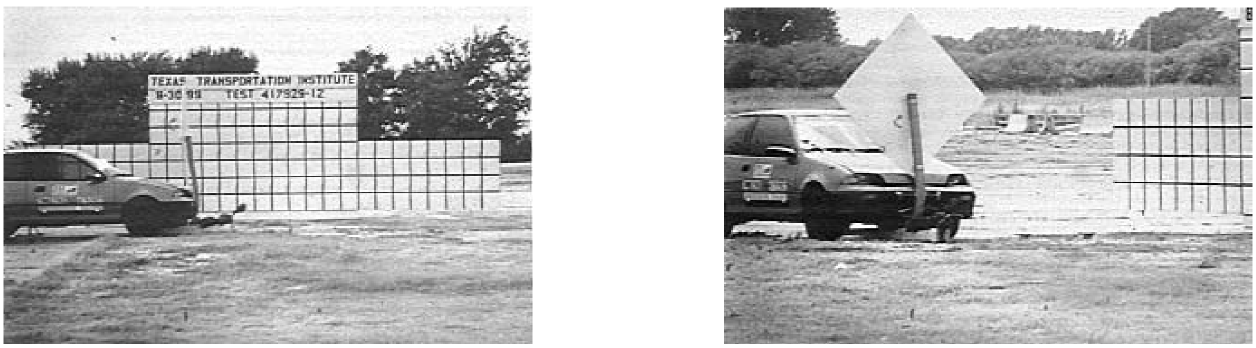
0.241 s



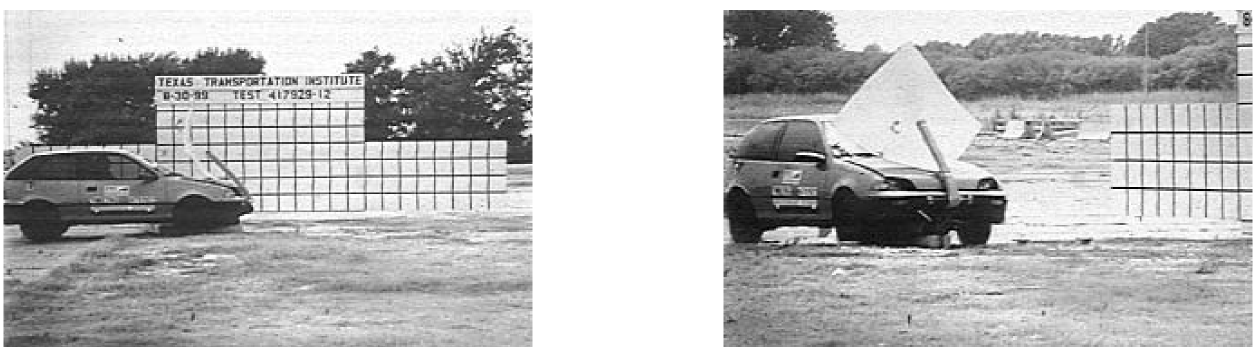
0.342 s

Figure 246. Sequential Photographs for Test 417929-11 (Perpendicular and Oblique Views) (continued).

0.000 s



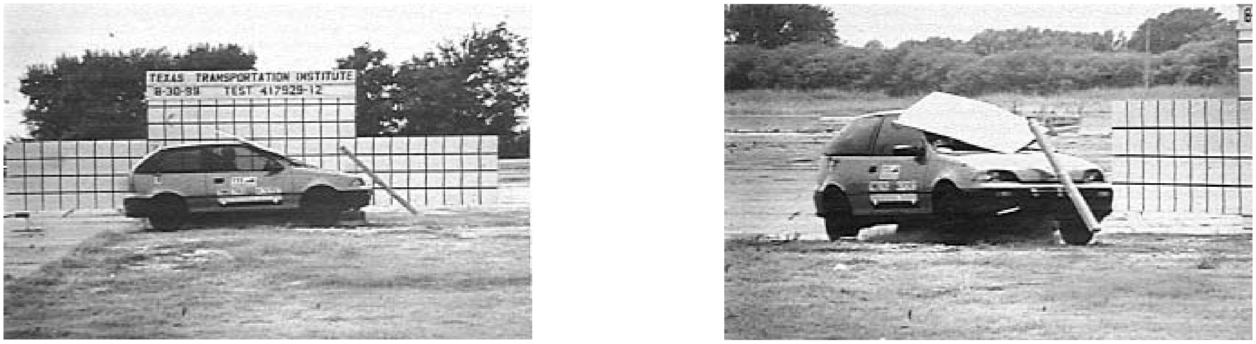
0.025 s



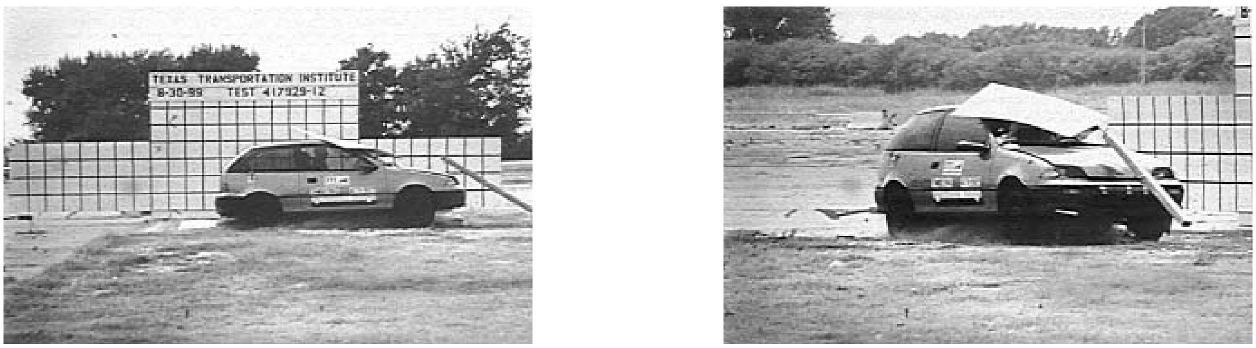
0.049 s

0.086 s

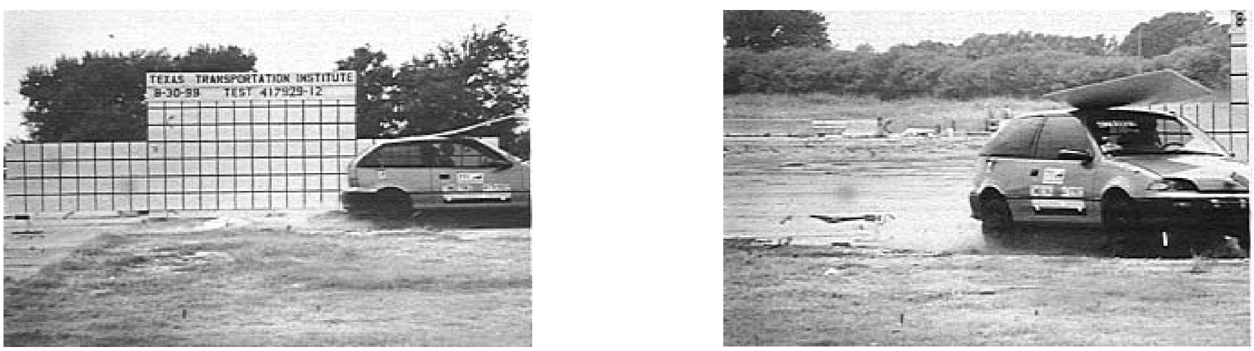
Figure 247. Sequential Photographs for Test 417929-12 (Perpendicular and Oblique Views).



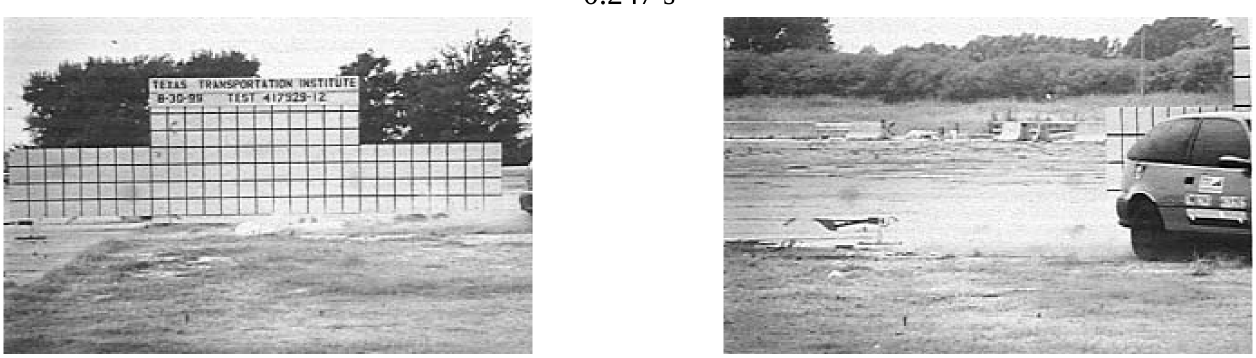
0.123 s



0.173 s



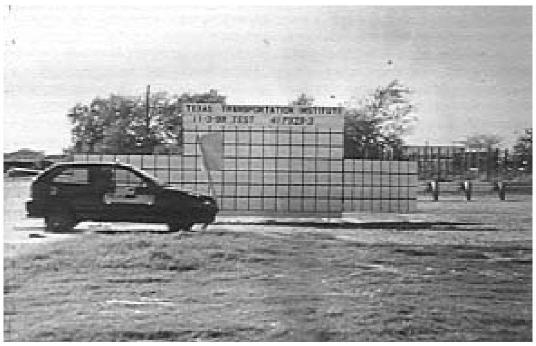
0.247 s



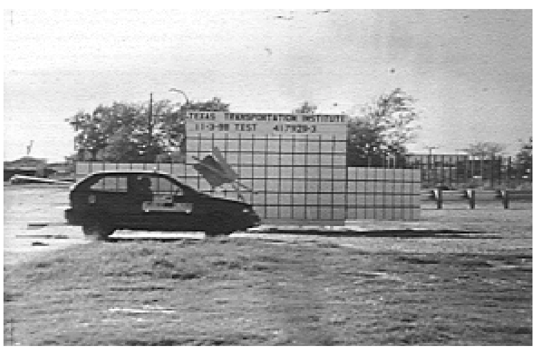
0.346 s

Figure 247. Sequential Photographs for Test 417929-12 (Perpendicular and Oblique Views) (continued).

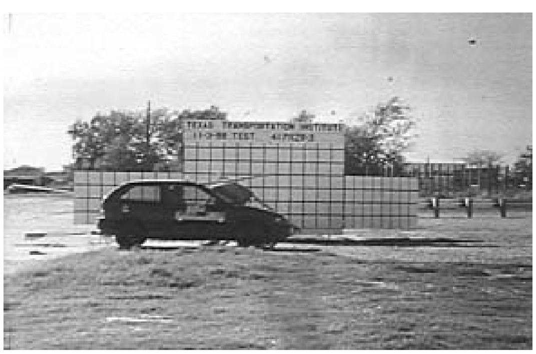
0.000 s



0.012 s

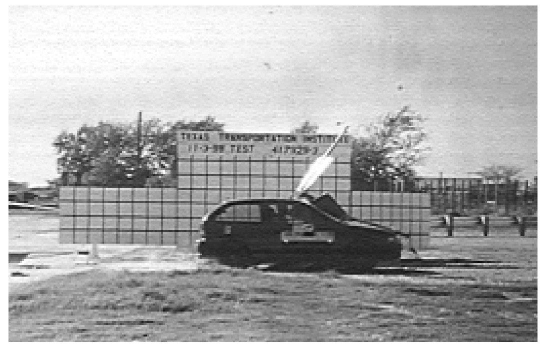


0.037 s



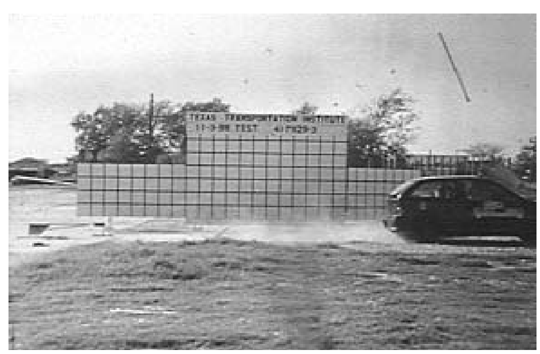
0.062 s

0.099 s



0.136 s

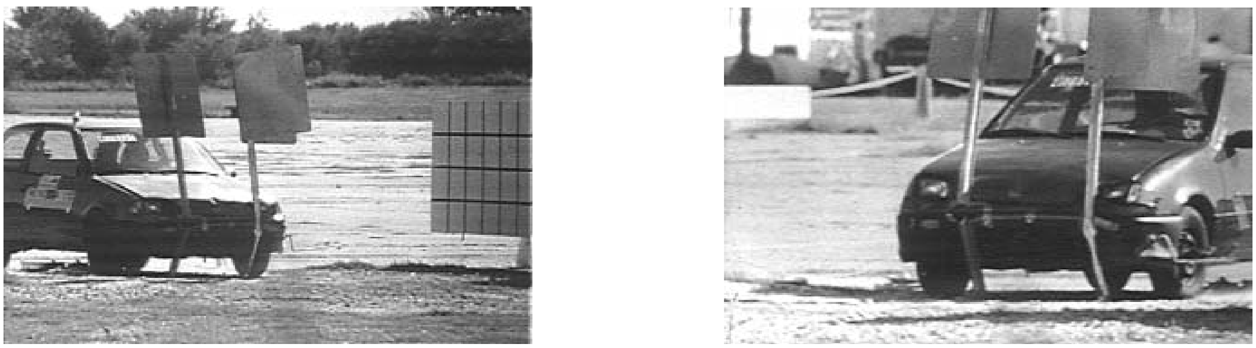
0.198 s



0.272 s

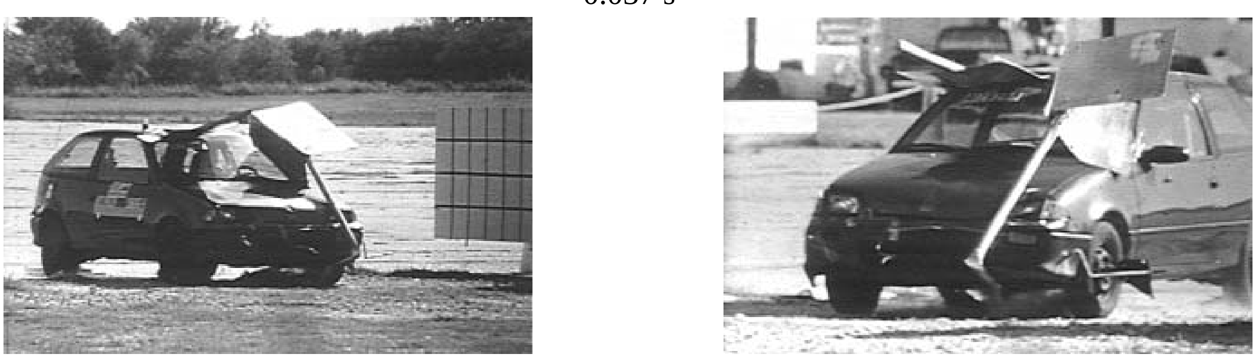
Figure 248. Sequential Photographs for Test 417929-3 (Perpendicular View).

0.000 s



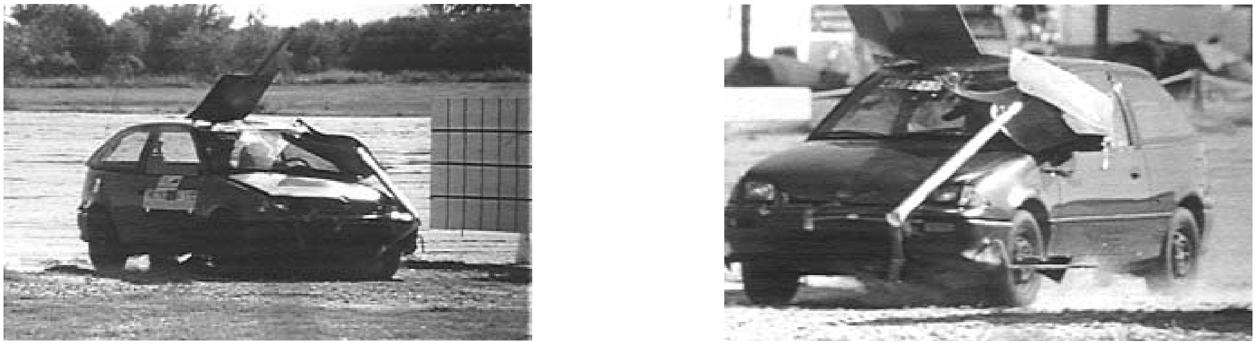
0.012 s

0.037 s



0.062 s

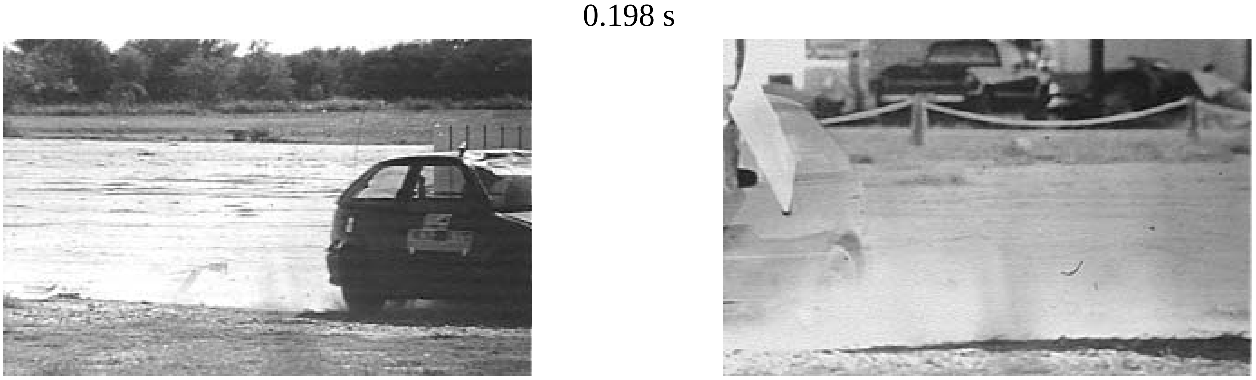
Figure 249. Sequential Photographs for Test 417929-3 (Oblique Views).



0.099 s

0.136 s

0.198 s



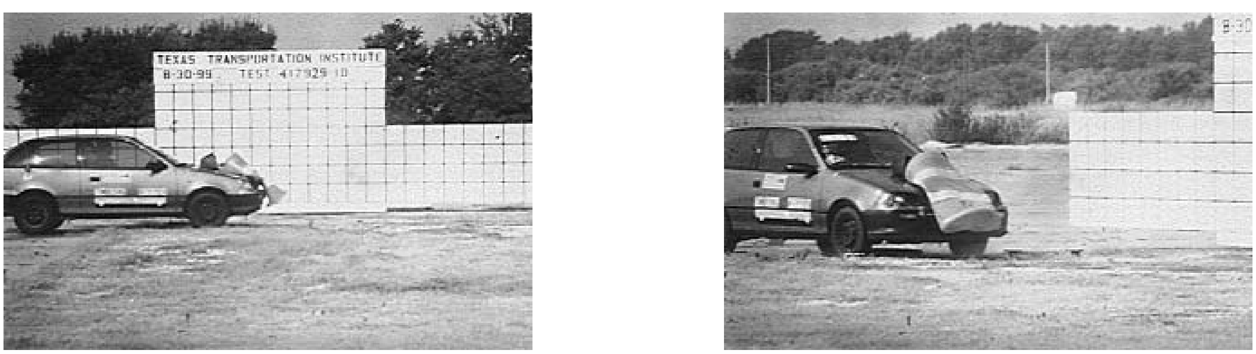
0.272 s

Figure 249. Sequential Photographs for Test 417929-3 (Oblique Views) (continued).

0.000 s

0.012 s

0.025 s



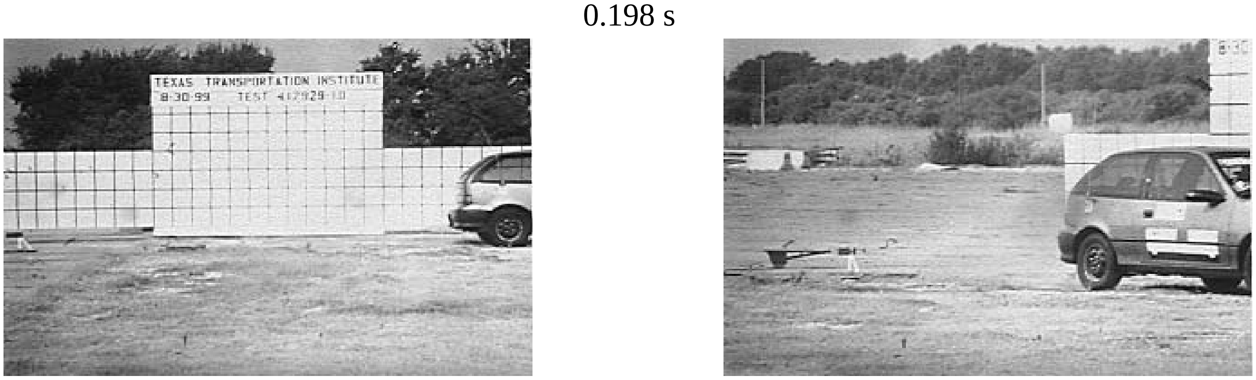
0.050 s

Figure 250. Sequential Photographs for Test 417929-10 (Perpendicular and Oblique Views).

0.087 s

0.124 s

0.198 s



0.297 s

Figure 250. Sequential Photographs for Test 417929-10 (Perpendicular and Oblique Views) (continued).

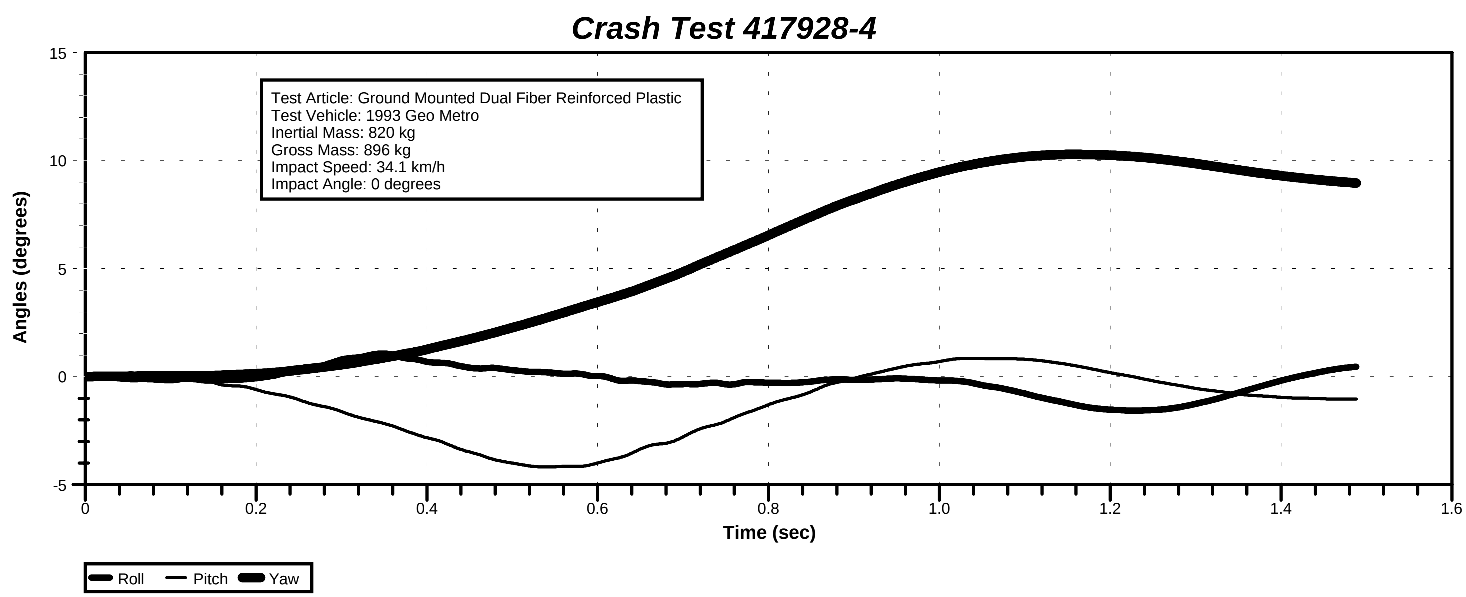


Figure 251. Vehicular Angular Displacements for Test 417928-4.

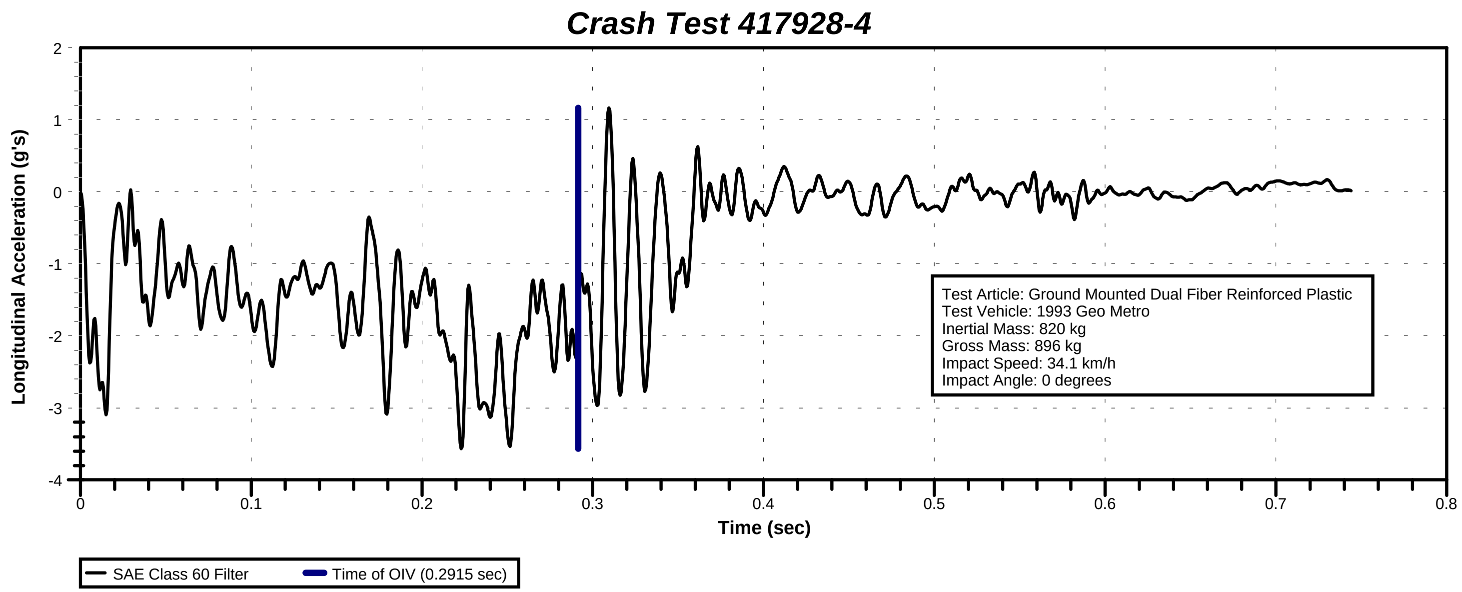


Figure 252. Vehicle Longitudinal Accelerometer Trace for Test 417928-4.

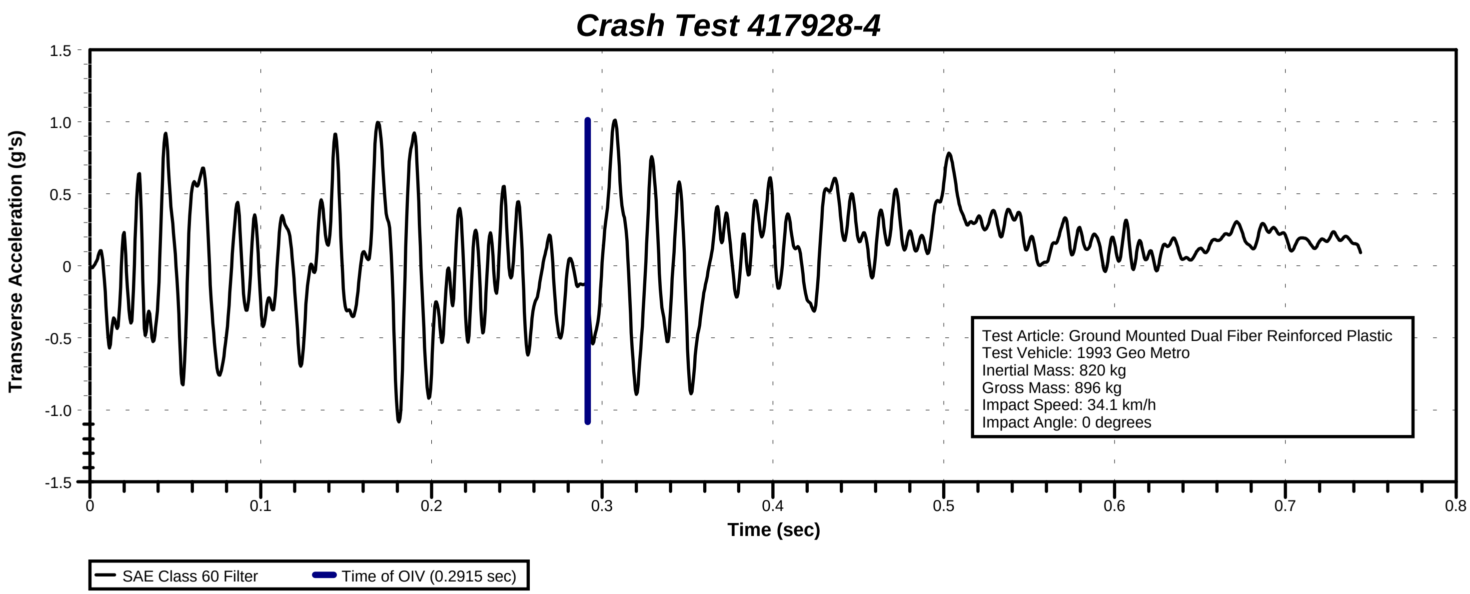


Figure 253. Vehicle Lateral Accelerometer Trace for Test 417928-4.

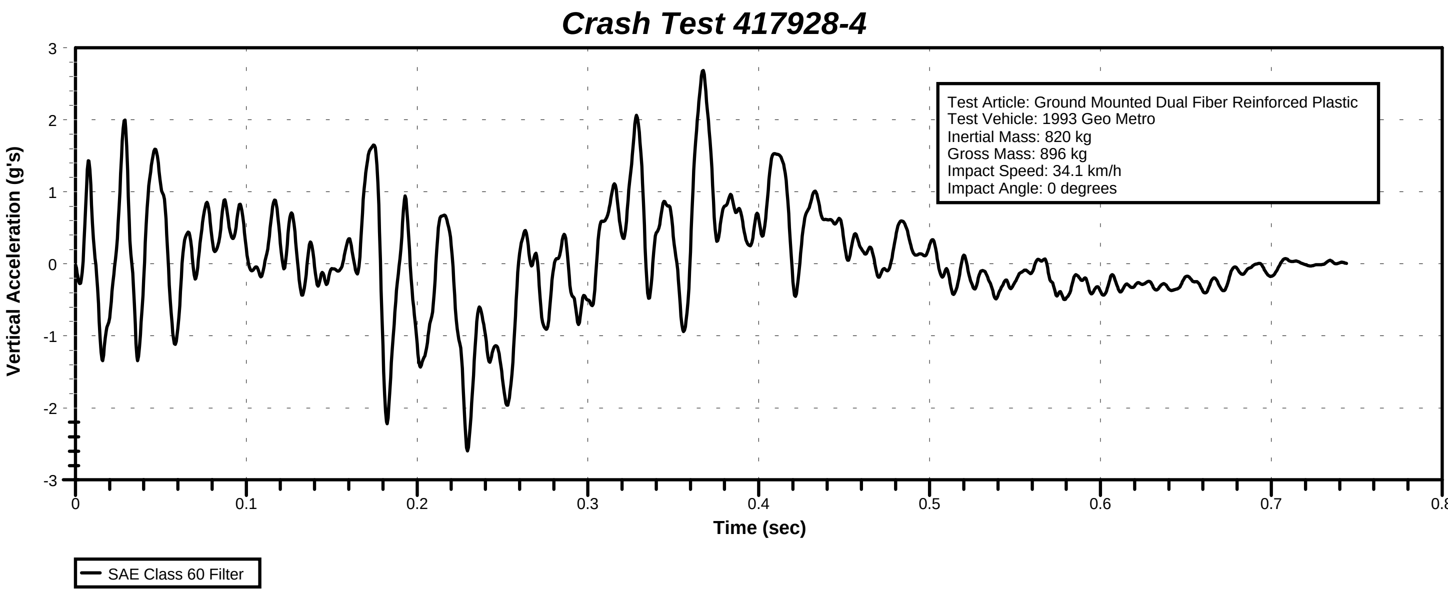


Figure 254. Vehicle Vertical Accelerometer Trace for Test 417928-4.

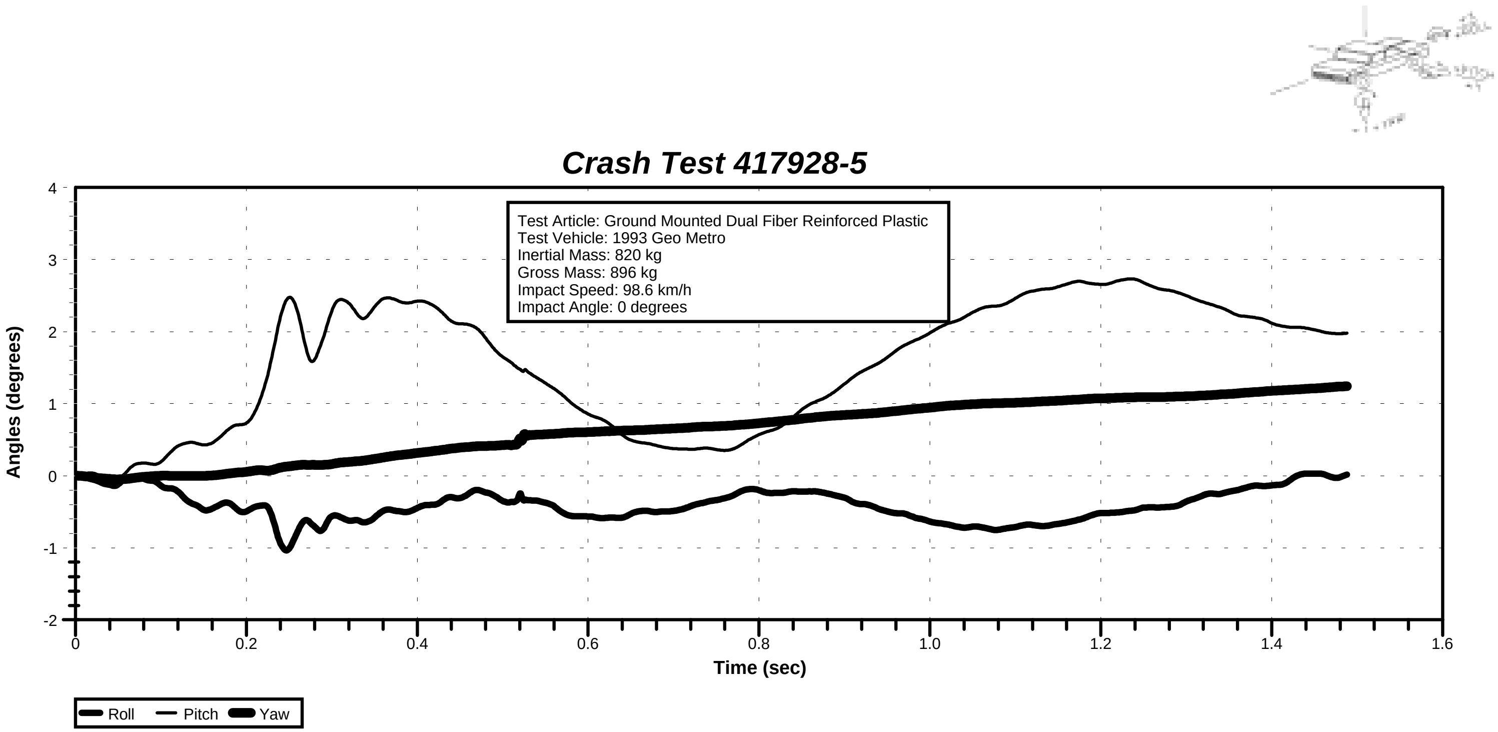


Figure 255. Vehicular Angular Displacements for Test 417928-5.

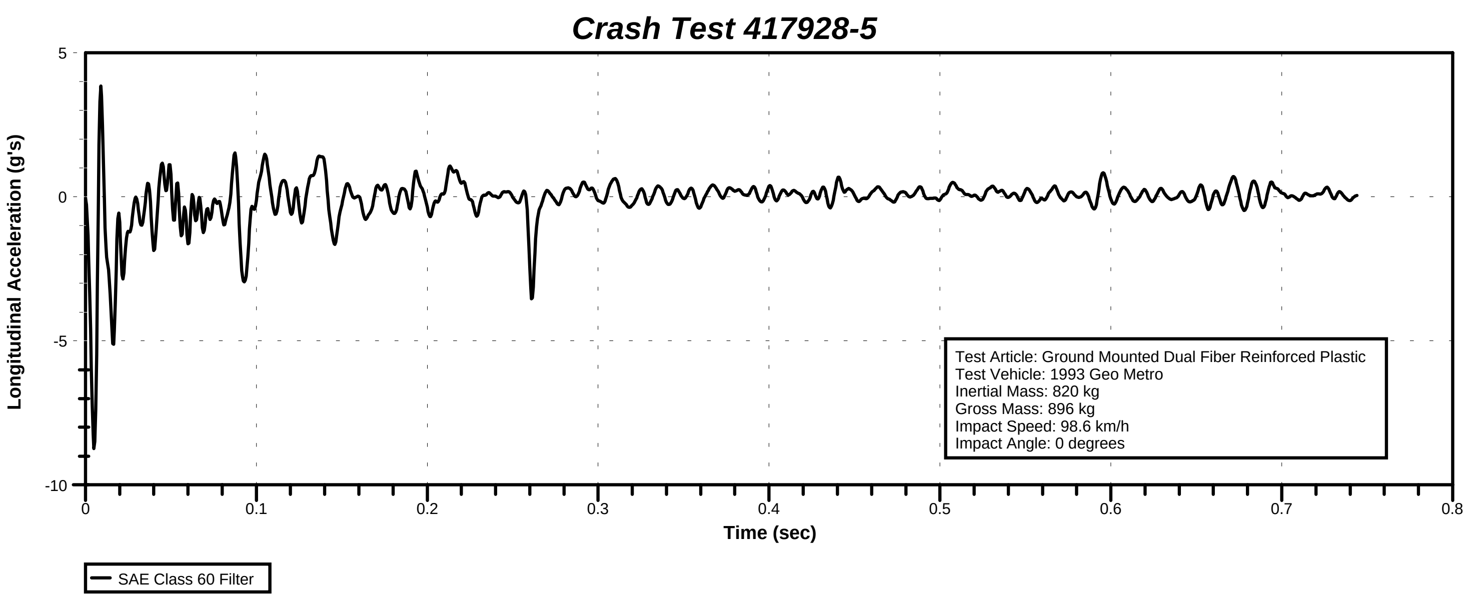


Figure 256. Vehicle Longitudinal Accelerometer Trace for Test 417928-5.

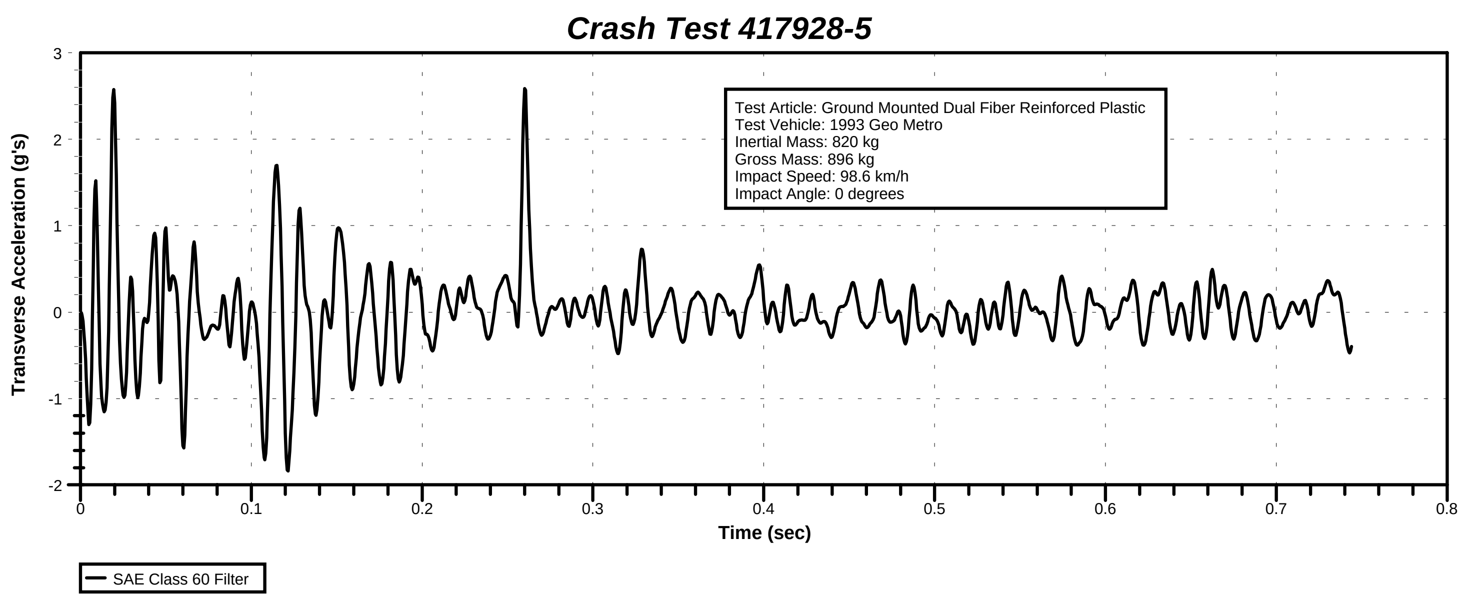


Figure 257. Vehicle Lateral Accelerometer Trace for Test 417928-5.

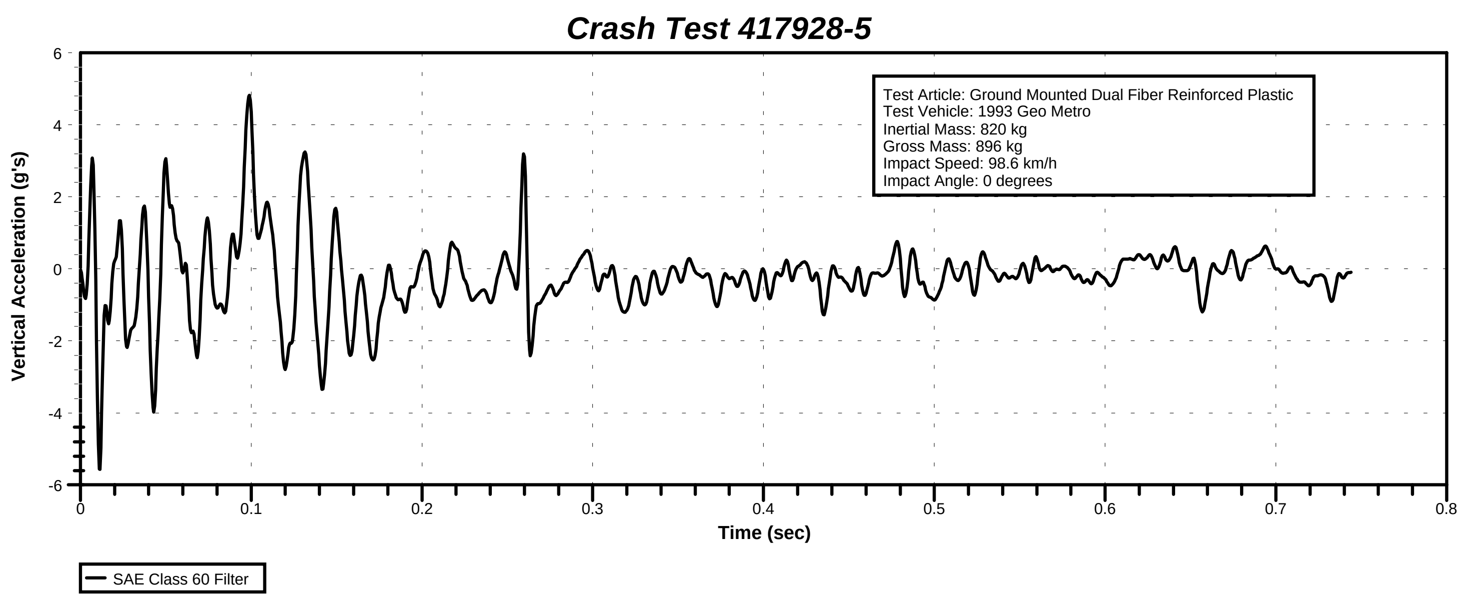


Figure 258. Vehicle Vertical Accelerometer Trace for Test 417928-5.