

1. Report No. TX-97/3910-S		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle EVALUATION OF WORK ZONE BARRICADES				5. Report Date November 1997	
				6. Performing Organization Code	
7. Author(s) King K. Mak, Roger P. Bligh, and Wanda L. Menges				8. Performing Organization Report No. Research Report 3910-S	
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135				10. Work Unit No.	
				11. Contract or Grant No. Study No. 7-3910	
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Transfer Office P. O. Box 5080 Austin, Texas 78763-5080				13. Type of Report and Period Covered Project Summary: October 1996 - August 1997	
				14. Sponsoring Agency Code	
15. Supplementary Notes Research performed in cooperation with the Texas Department of Transportation. Research Study Title: Design, Evaluate, and Test Work Zone Sign Supports and Barricades					
16. Abstract  <p>Safety of work zones is a major area of 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. Little is known about the impact performance of many work zone traffic control devices.</p> <p>The objective of the study was to design, evaluate, and test additional work zone sign supports and barricades that would perform satisfactorily when impacted by errant vehicles.</p> <p>Researchers conducted a total of 12 crash tests on various work zone traffic control devices, including Type III barricades, Type I barricade, portable sign support, ground-mounted Type III barricade, skid-mounted sign support, and three vertical panel supports. Results of the crash tests are presented in this report together with conclusions and recommendations.</p>					
17. Key Words Barricades, Temporary Sign Supports, Impact Performance, Work Zone Safety			18. Distribution Statement No restriction. 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) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 156	22. Price



# **EVALUATION OF WORK ZONE BARRICADES**

by

King K. Mak  
Research Engineer  
Texas Transportation Institute

Roger P. Bligh  
Assistant Research Engineer  
Texas Transportation Institute

and

Wanda L. Menges  
Associate Research Specialist  
Texas Transportation Institute

Research Report 3910-S  
Research Study Number 7-3910  
Research Study Title: Design, Evaluate, and Test  
Work Zone Sign Supports and Barricades

Sponsored by the  
Texas Department of Transportation

November 1997

TEXAS TRANSPORTATION INSTITUTE  
The Texas A&M University System  
College Station, Texas 77843-3135



## **IMPLEMENTATION RECOMMENDATIONS**

Results of the research are applicable for immediate implementation by the Traffic Division to complete the revision of current Barricade and Construction Standard Sheets, including the following findings and recommendations.

### **Type III Barricades**

- The attachment of warning lights to Type III barricades is not recommended.
- The use of vertical braces for the horizontal rail elements of Type III barricades fabricated from either hollow core plastic or steel perforated tubing is recommended for field implementation. However, the size for the center vertical brace should be as small as practical.
- The modified connection design of welding a short stub to the skid and inserting and bolting the vertical supports to the stubs for steel perforated tubing Type III barricades is recommended for field implementation.
- The two proprietary prototype barricades with fiberglass vertical supports are recommended for field applications. However, since these are prototype units, the final designs for these fiberglass Type III barricades should be evaluated to make sure the production units would perform similarly to the prototype units.

### **Wooden Type I Barricades**

- The field implementation of a wooden Type I barricade, with or without sign panel, is not recommended under test level 3 conditions.

### **Spring-loaded Portable Sign Supports**

- A higher mounting height of 610 mm is considered acceptable for spring-loaded portable sign supports with fabric/plastic sign panels.

### **Ground-mounted Type III Barricades**

- The ground-mounted Type III barricade design using thin-wall steel tubing is recommended for field implementation.

### **Skid-mounted Sign Supports**

- The skid-mounted sign support was found to perform satisfactorily in both head-on and end-on configurations and is recommended for field implementation.

## **Vertical Panels**

- The three support types: 51 mm × 102 mm wooden post, 12.7 mm × 12.7 mm × 6.4 mm steel angle, and 38 mm × 51 mm plastic C-channel, are considered acceptable for use with vertical panels.

## **DISCLAIMER**

The contents of this report reflect the views of the authors who are solely responsible for the facts and accuracy of the data, and the opinions, findings and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation. In addition, the above assumes no liability for its contents or use thereof. The engineer in charge of the project was King K. Mak, P.E. # 51502.

It is the policy of the Texas Transportation Institute (TTI) and Texas A&M University not to endorse any specific manufacturers, trademarks, or products. However, identifying the specific barricades and temporary sign supports tested in the study is necessary in the report. It should, therefore, be noted that the mention of specific manufacturers, trademarks, and products in the report does not constitute endorsement of such manufacturers, trademarks, or products by TTI or Texas A&M University.

## **ACKNOWLEDGMENT**

This study was sponsored by the Texas Department of Transportation (TxDOT). Mr. Lewis Rhodes was the Project Director for TxDOT, and his guidance and support are deeply appreciated. Other personnel from TxDOT and Mr. Bob Musselman of the Federal Highway Administration (FHWA) also provided information and direction on the study, and their assistance is gratefully acknowledged.



# TABLE OF CONTENTS

	<u>Page</u>
LIST OF FIGURES .....	xi
LIST OF TABLES .....	xiv
SUMMARY .....	xv
I. INTRODUCTION .....	1
1.1 BACKGROUND .....	1
1.2 STUDY OBJECTIVE AND SCOPE .....	1
II. STUDY APPROACH .....	3
2.1 WORK ZONE CONTROL DEVICES TESTED .....	3
2.2 CRASH TEST MATRIX .....	15
2.3 CRASH TEST AND DATA ANALYSIS PROCEDURES .....	18
2.3.1 Electronic Instrumentation and Data Processing .....	18
2.3.2 Anthropomorphic Dummy Instrumentation .....	18
2.3.3 Photographic Instrumentation and Data Processing .....	18
2.3.4 Test Vehicle Propulsion and Guidance .....	19
2.3.5 Evaluation Criteria .....	19
III. CRASH TEST RESULTS .....	25
3.1 TYPE III BARRICADES .....	25
3.1.1 Test No. 439107-1 .....	25
3.1.2 Test No. 439107-2 .....	32
3.1.3 Test No. 439107-3 .....	39
3.1.4 Test No. 439107-5 .....	39
3.1.5 Test No. 439107-12 .....	48
3.2 TYPE I BARRICADE (TEST NO. 439107-4) .....	59
3.3 PORTABLE SIGN SUPPORT (TEST NO. 439107-6) .....	59
3.4 GROUND-MOUNTED TYPE III BARRICADE .....	67
3.4.1 Test No. 439107-7 .....	67
3.4.2 Test No. 439107-8 .....	76
3.4.3 Test No. 439107-9 .....	76
3.5 SKID-MOUNTED SIGN SUPPORT (TEST NO. 439107-10) .....	87
3.6 VERTICAL PANEL (TEST NO. 439107-11) .....	94
IV. SUMMARY OF FINDINGS AND RECOMMENDATIONS .....	105
4.1 TYPE III BARRICADE .....	105
4.2 WOODEN TYPE I BARRICADE .....	105
4.3 SPRING-LOADED PORTABLE SIGN SUPPORT .....	105
4.4 GROUND-MOUNTED TYPE III BARRICADE .....	105

**TABLE OF CONTENTS (continued)**

4.5 SKID-MOUNTED SIGN SUPPORT ..... 106  
4.6 VERTICAL PANELS ..... 106  
REFERENCES ..... 107  
APPENDIX A.  
DIMENSIONS AND PROPERTIES OF TEST VEHICLES ..... 109  
APPENDIX B.  
SEQUENTIAL PHOTOGRAPHS ..... 115

## LIST OF FIGURES

<u>Figure No.</u>		<u>Page</u>
1	Type III Hollow Core Plastic Barricade as Used in Test 439107-1. . . . .	4
2	Type III Steel Perforated Tubing Barricade (3.7 m) as Used in Test 439107-2. . .	5
3	Type III Steel Perforated Tubing Barricade (1.2 m) as Used in Test 439107-3. . .	7
4	Hycom Fiberglass Type III Barricade (Test 439107-5). . . . .	8
5	Price Fiberglass Type III Barricade (Test 439107-12). . . . .	9
6	Type I Wooden A-frame Barricade (Test 439107-4). . . . .	11
7	Spring-loaded Portable Sign Support (Test 439107-6). . . . .	12
8	Ground-mounted Type III Barricade (Test 439107-7). . . . .	13
9	Side-by-Side Barricade Installation for Tests 439107-8 and 439107-9. . . . .	14
10	Skid-mounted Sign Support (Test 439107-10) . . . . .	16
11	Vertical Panel Assembly (Test 439107-11). . . . .	17
12	Vehicle/Installation Geometrics for Test 439107-1. . . . .	26
13	Vehicle Before Test 439107-1. . . . .	27
14	After Impact Trajectory for Test 439107-1. . . . .	28
15	Installation After Test 439107-1. . . . .	29
16	Vehicle after test 439107-1. . . . .	30
17	Summary of Results for Test 439107-1. . . . .	31
18	Vehicle/Installation Geometrics for Test 439107-2 . . . . .	33
19	Vehicle Before Test 439107-2. . . . .	34
20	After Impact Trajectory for Test 439107-2. . . . .	35
21	Installation After Test 439107-2. . . . .	36
22	Vehicle After Test 439107-2. . . . .	37
23	Summary of Results for Test 439107-2. . . . .	38
24	Vehicle/Installation Geometrics for Test 439107-3. . . . .	40
25	Vehicle Before Test 439107-3. . . . .	41
26	After Impact Trajectory for Test 439107-3. . . . .	42
27	Installation After Test 439107-3. . . . .	43
28	Vehicle After Test 439107-3. . . . .	44
29	Summary of Results for Test 439107-3. . . . .	45
30	Vehicle/Installation Geometrics for Test 439107-5 . . . . .	46
31	Vehicle Before Test 439107-5. . . . .	47
32	After Impact Trajectory for Test 439107-5. . . . .	49
33	Installation After Test 439107-5. . . . .	50
34	Vehicle After Test 439107-5. . . . .	51
35	Summary of Results for Test 439107-5. . . . .	52
36	Vehicle/Installation Geometrics for Test 439107-12. . . . .	53
37	Vehicle Before Test 439107-12. . . . .	54
38	After Impact Trajectory for Test 439107-12. . . . .	55
39	Installation After Test 439107-12. . . . .	56
40	Vehicle After Test 439107-12. . . . .	57
41	Summary of Results for Test 439107-12. . . . .	58

## LIST OF FIGURES (continued)

<u>Figure No.</u>		<u>Page</u>
42	Vehicle/Installation Geometrics for Test 439107-4. . . . .	60
43	Vehicle Before Test 439107-4. . . . .	61
44	Installation After Test 439107-4. . . . .	62
45	Vehicle After Test 439107-4 . . . . .	63
46	Summary of Results for Test 439107-4. . . . .	64
47	Vehicle/Installation Geometrics for Test 439107-6. . . . .	65
48	Vehicle Before Test 439107-6. . . . .	66
49	After Impact Trajectory for Test 439107-6. . . . .	68
50	Installation After Test 439107-6. . . . .	69
51	Vehicle After Test 439107-6. . . . .	70
52	Summary of Results for Test 439107-6. . . . .	71
53	Vehicle/Installation Geometrics for Test 439107-7 . . . . .	72
54	Vehicle Before Test 439107-7. . . . .	73
55	After Impact Trajectory for Test 439107-7 . . . . .	74
56	Installation After Test 439107-7. . . . .	75
57	Vehicle After Test 439107-7. . . . .	77
58	Summary of Results for Test 439107-7. . . . .	78
59	Vehicle/Installation Geometrics for Test 439107-8 . . . . .	79
60	Vehicle Before Test 439107-8. . . . .	80
61	After Impact Trajectory for Test 439107-8. . . . .	81
62	Installation After Test 439107-8. . . . .	82
63	Vehicle After Test 439107-8. . . . .	83
64	Summary of Results for Test 439107-8. . . . .	84
65	Vehicle/Installation Geometrics for Test 439107-9. . . . .	85
66	Vehicle Before Test 439107-9. . . . .	86
67	After Impact Trajectory for Test 439107-9. . . . .	88
68	Installation After Test 439107-9. . . . .	89
69	Vehicle After Test 439107-9 . . . . .	90
70	Summary of Results for Test 439107-9 . . . . .	91
71	Vehicle/Installation Geometrics for Test 439107-10. . . . .	92
72	Vehicle Before Test 439107-10. . . . .	93
73	After Impact Trajectory for Test 439107-10 . . . . .	95
74	Installation After Test 439107-10. . . . .	96
75	Vehicle After Test 439107-10. . . . .	97
76	Summary of Results for Test 439107-10. . . . .	98
77	Vehicle/Installation Geometrics for Test 439107-11. . . . .	99
78	After Impact Trajectory for Test 439107-11. . . . .	100
79	Installation After Test 439107-11 . . . . .	101
80	Vehicle After Test 439107-11. . . . .	103
81	Summary of Results for Test 439107-11. . . . .	104
82	Vehicle Properties for Test 439107-1, 8, and 9. . . . .	110

## LIST OF FIGURES (continued)

<u>Figure No.</u>		<u>Page</u>
83	Vehicle Properties for Test 439107-2 Through 7. . . . .	111
84	Vehicle Properties for Test 439107-11 and 12. . . . .	112
85	Vehicle Properties for Test 439107-10. . . . .	113
86	Sequential Photographs for Test 439107-1 (Perpendicular and Oblique Views). . . . .	116
87	Sequential Photographs for Test 439107-2 (Perpendicular and Oblique Views). . . . .	118
88	Sequential Photographs for Test 439107-3 (Perpendicular and Oblique Views). . . . .	120
89	Sequential Photographs for Test 439107-5 (Perpendicular and Oblique Views). . . . .	122
90	Sequential Photographs for Test 439107-12 (Perpendicular and Oblique Views). . . . .	124
91	Sequential Photographs for Test 439107-4 (Perpendicular and Oblique Views) . . . . .	126
92	Sequential Photographs for Test 439107-6 (Perpendicular and Oblique Views). . . . .	128
93	Sequential Photographs for Test 439107-7 (Perpendicular and Oblique Views). . . . .	130
94	Sequential Photographs for Test 439107-8 (Perpendicular and Oblique Views). . . . .	132
95	Sequential Photographs for Test 439107-9 (Perpendicular and Oblique Views). . . . .	134
96	Sequential Photographs for Test 439107-10 (Perpendicular and Oblique Views). . . . .	136
97	Sequential Photographs for Test 439107-11 (Perpendicular and Oblique Views). . . . .	138

## LIST OF TABLES

<u>Table No.</u>		<u>Page</u>
1	Crash Test Matrix .....	21

## SUMMARY

Safety of work zones is a major area of 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. Little is known about the impact performance of many work zone traffic control devices. The Texas Department of Transportation (TxDOT) has previously sponsored other studies at the Texas Transportation Institute (TTI) to assess the impact performance of various traffic control devices. However, there is a need for additional design, evaluation, and testing of work zone sign supports and barricades to complete the revision of the standard sheets for construction projects.

The objective of the study was to design, evaluate, and test additional work zone sign supports and barricades that would perform satisfactorily when impacted by errant vehicles.

The scope of the study included: (1) evaluation and testing of a barricade design for direct burial of supports; (2) designing and testing a barricade design using square tubing uprights welded to skids; (3) designing and testing a barricade design using additional vertical members to stabilize and provide a more rigid design when lightweight plastics are used for the horizontal rails; (4) determination of tolerances for mounting height of temporary and portable sign supports; (5) evaluation and testing of new designs for barricades and sign supports that are available on the open market; and (6) evaluation and testing of warning light attachments to barricades and sign supports.





# I. INTRODUCTION

## 1.1 BACKGROUND

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 themselves.

Little is known about the impact performance of many work zone traffic control devices. The Texas Department of Transportation (TxDOT) has, in recent years, sponsored a number of studies at the Texas Transportation Institute (TTI) to assess the impact performance of various work zone traffic control devices, including plastic drums and sign substrates, temporary sign supports, and barricades.<sup>(1-4)</sup> Results from these studies are being incorporated by the department into the standard sheets for construction projects. However, additional design, evaluation, and testing of work zone sign supports and barricades are needed to complete the revision of the standard sheets.

A literature search was conducted in previous studies using computerized data bases, including the Transportation Research Information System (TRIS). Pertinent publications identified in the literature search were obtained through the library or contacts with the respective organizations and authors.<sup>(5-9)</sup> Of particular interest are studies by the Federal Highway Administration (FHWA) and the New York Department of Transportation (NYDOT). A number of work zone traffic control devices were crash tested and evaluated in these studies. The literature provided some useful information, but there remained unanswered questions regarding the performance of work zone traffic control devices specified in the TxDOT standards which are somewhat different from those crash tested. Also, the previous crash tests were not conducted or evaluated in accordance with current guidelines set forth in National Cooperative Highway Research Program (NCHRP) Report 350.<sup>(10)</sup>

## 1.2 STUDY OBJECTIVE AND SCOPE

The goal of this proposed study and previous studies 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 NCHRP Report 350. The specific objective of this proposed study is to design, evaluate, and test additional work zone sign supports and barricades that would perform satisfactorily when impacted by errant vehicles.

The scope of the study would include: (1) evaluate and test a barricade design for direct burial of supports; (2) design and test a barricade design using square tubing uprights welded to skids; (3) design and test a barricade design using additional vertical members to stabilize and

provide a more rigid design when lightweight plastics are used for the horizontal rails; (4) determine tolerances for mounting height of temporary and portable sign supports; (5) evaluate and test new designs for barricades and sign supports that are available on the open market; and (6) evaluate and test warning light attachment to barricades and sign supports.

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 crash test and data analysis procedures. Results of the crash tests are presented in Chapter III. A summary of findings, conclusions, and recommendations are presented in Chapter IV.

## II. STUDY APPROACH

### 2.1 WORK ZONE CONTROL DEVICES TESTED

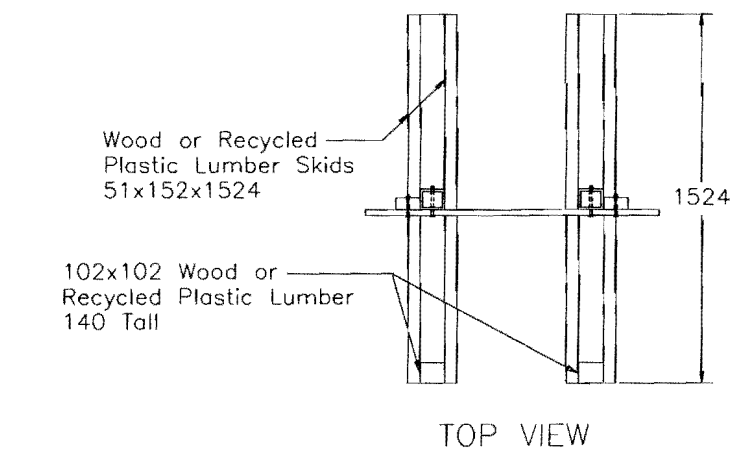
Researchers conducted a total of 12 crash tests on various work zone traffic control devices under this study. The traffic control devices were either constructed by the project staff or purchased commercially, and they were in accordance with the specifications outlined in “Barricade and Construction Standards” sheets dated April 1992. The various work zone traffic control devices crash tested and evaluated in this study are as follows:

- Type III Barricades.

1. Hollow core plastic. The barricade consisted of 102 mm × 102 mm × 1524 mm long hollow core plastic vertical supports with a recycled plastic lumber skid base and wooden 25 mm × 203 mm horizontal rail elements. Two wooden 51 mm × 102 mm × 1168 mm long intermediate vertical braces were attached to the horizontal rail elements with 10-mm diameter bolts, one on the outside of each vertical support. The overall barricade length was 1.2 m. A warning light was attached to the vertical brace with a 51 mm × 102 mm metal bracket. A schematic of this barricade is shown as Figure 1.

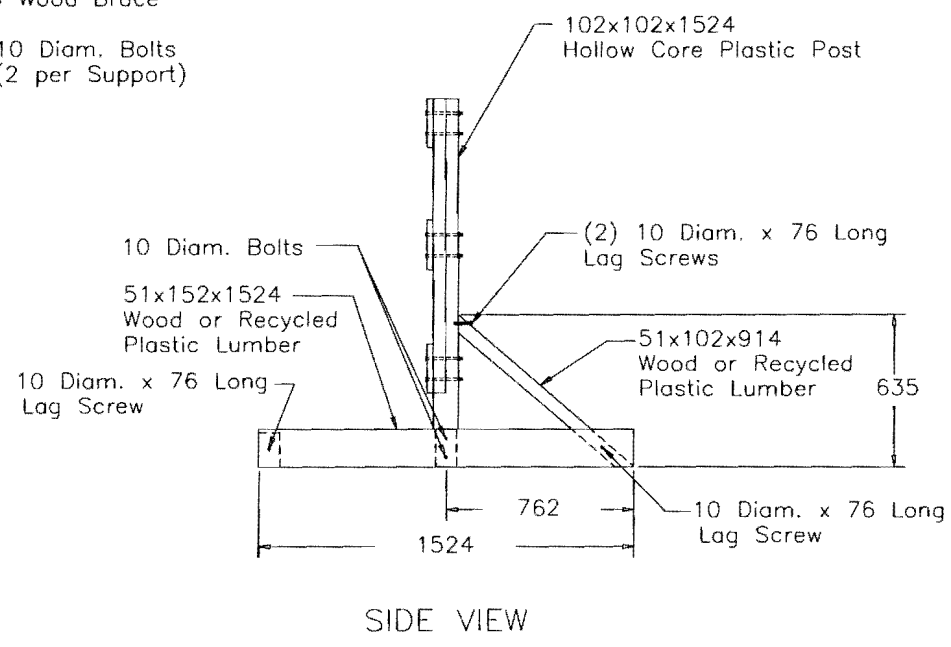
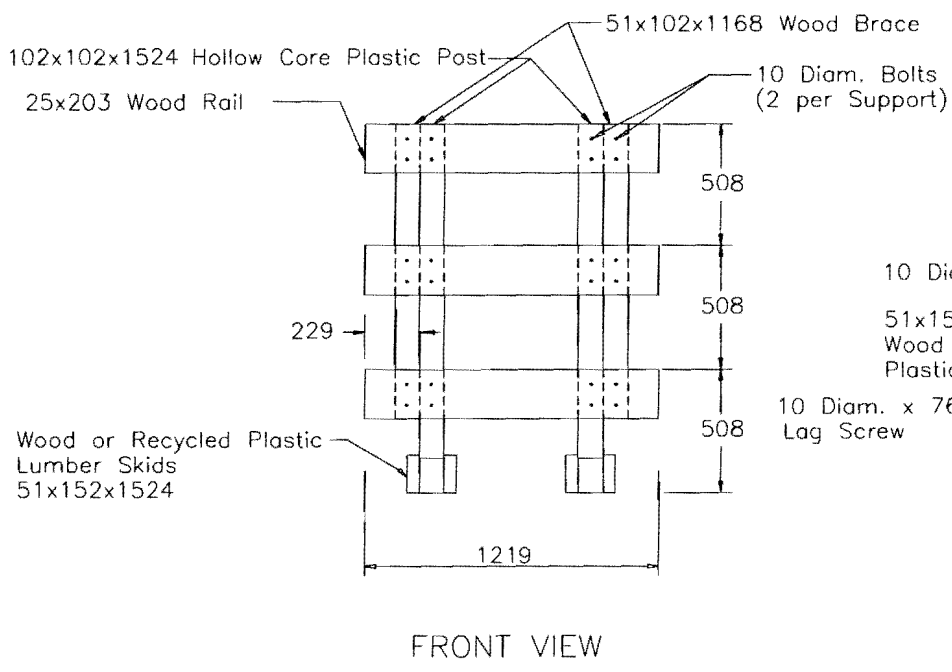
The hollow core plastic Type III barricade was previously crash tested and found to perform satisfactorily.<sup>(1)</sup> The purpose of this crash test was to evaluate the effect on the impact performance of the barricade when additional vertical braces are attached to the horizontal rails to provide a more stabilized and rigid design. A secondary purpose was to evaluate the effect on the impact performance of the barricade when a warning light is attached to the barricade.

2. Steel perforated tubing. The barricade consisted of: 38 mm square perforated tubing vertical supports which were inserted into and bolted to 45 mm square × 102 mm long perforated tubing stubs welded to 45 mm square perforated tubing skids, and wooden 25 mm × 203 mm horizontal rail elements. Two barricades of this design were tested:
  - a) A barricade with overall length of 3.7 m. Three wooden 51 mm × 102 mm × 1219 mm long intermediate vertical braces were attached to the horizontal rail elements with 10-mm diameter, 76 mm long bolts, one on the outside of each vertical support and one centered between the vertical supports. A warning light was attached to an outside brace with a 51 mm × 102 mm metal bracket. A schematic of this barricade is shown in Figure 2.
  - b) A barricade with overall length of 1.2 m. Two wooden 51 mm × 102 mm × 1219 mm long intermediate vertical braces were attached to the

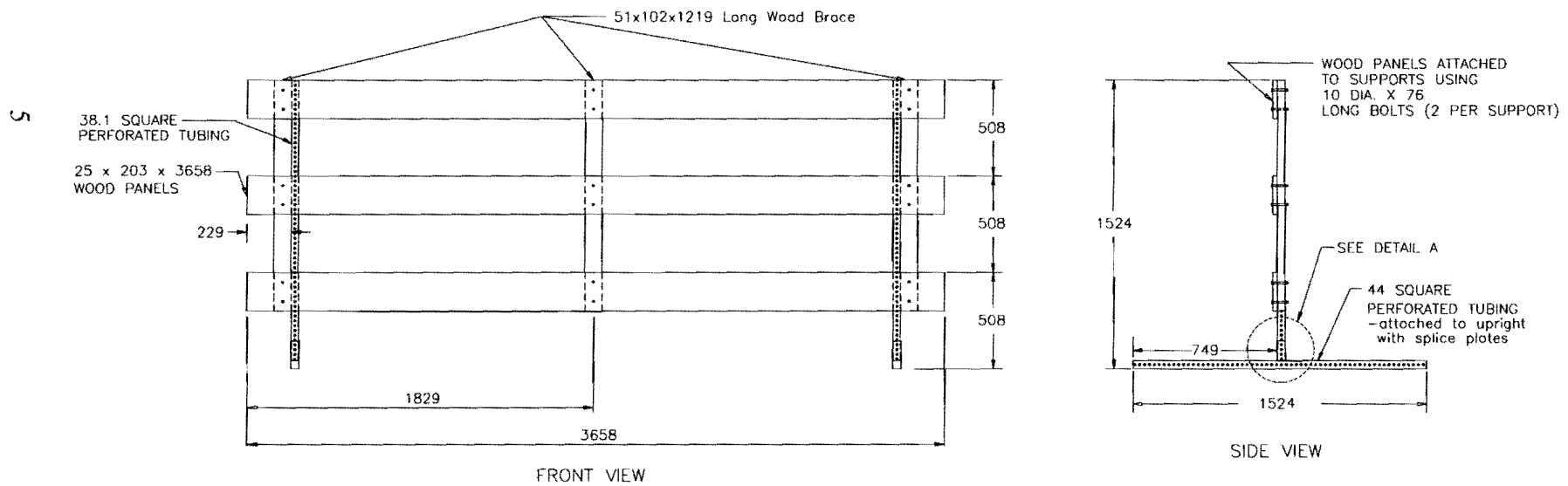
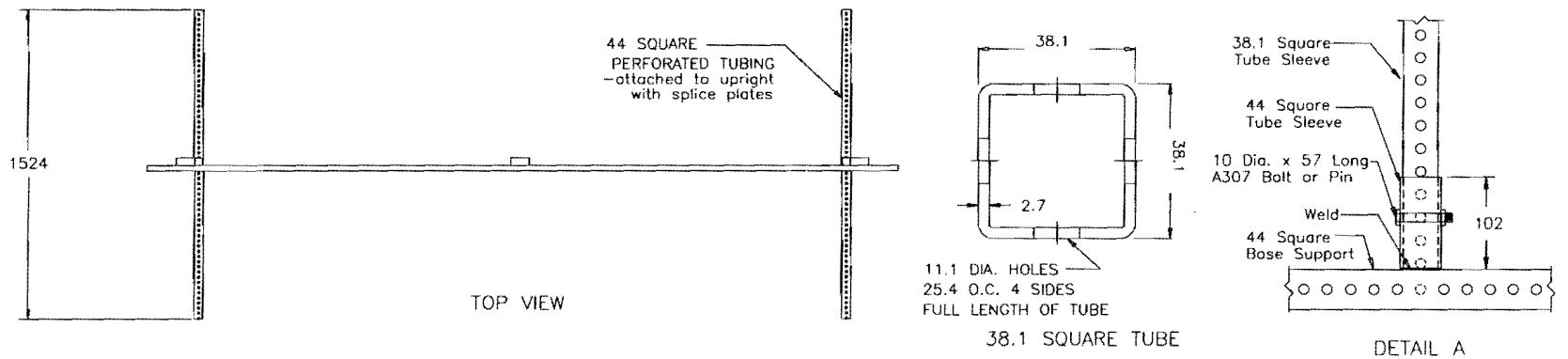


BARRICADE DETAILS

All lumber sizes are nominal dimensions



**Figure 1. Type III Hollow Core Plastic Barricade as Used in Test 439107-1.**



TYPE III BARRICADE  
PERFORATED STEEL TUBING WITH WOOD PANELS

Figure 2. Type III Steel Perforated Tubing Barricade (3.7 m) as Used in Test 439107-2.

horizontal rail elements with 10-mm diameter, 76 mm long bolts, one on the outside of each vertical support. The center vertical brace was not needed due to the shorter barricade length. No warning light was attached to this barricade. A schematic of this barricade is shown in Figure 3.

The steel perforated tubing Type III barricade was previously crash tested and found to perform satisfactorily.<sup>(1)</sup> The vertical supports were bolted to the skid with connection plates in those tests. From an operational standpoint, modifying the connection detail by welding a short (102 mm long) stub of the tubing to the skid may be desirable so the vertical supports could be inserted into it and bolted to the stub. The primary purpose of these crash tests was to evaluate the effect of this design modification to the impact performance of the barricade.

A secondary purpose of these crash tests was to evaluate the effect on impact performance of the barricade when additional vertical braces are attached to the horizontal rails to provide a more stabilized and rigid design. The longer (3.7 m) barricade allowed the vehicle to impact only the horizontal rail elements and the center vertical brace and not the vertical supports. The shorter (1.2 m) barricade allowed the vertical supports, the horizontal rails, and the vertical braces to be impacted simultaneously.

Another purpose of these crash tests was to evaluate the effect on the impact performance of the barricade when a warning light is attached to the barricade.

3. Fiberglass. Two proprietary prototype fiberglass barricades were crash tested, one manufactured by HyCom, Inc. and the other by Price Barricades. The purpose of these crash tests was to evaluate the impact performance of Type III barricades fabricated with fiberglass vertical supports.
  - a) A schematic of the HyCom fiberglass Type III barricade is shown in Figure 4. The barricade consisted of two 76-mm diameter fiberglass vertical supports, with a lumber skid base. Each of the three horizontal rail elements consisted of two 25 mm × 152 mm hollow core plastic boards placed one on top of the other for a total width of 304 mm. The overall barricade length was 1.2 m. No warning light was attached to this barricade.
  - b) A schematic of the Price fiberglass Type III barricade is shown in Figure 5. The barricade consisted of two 89 mm × 32 mm × 6.4 mm fiberglass U-channel vertical supports, with a fiberglass skid base. The three horizontal rail elements consisted of 203 mm × 1219 mm × 6.4 mm thick fiberboard attached to 89 mm × 32 mm × 6.4 mm fiberglass U-channels which were bolted to the vertical supports with 10-mm diameter carriage bolts and wooden inserts. The overall barricade length was 1.2 m. No warning light was attached to this barricade.

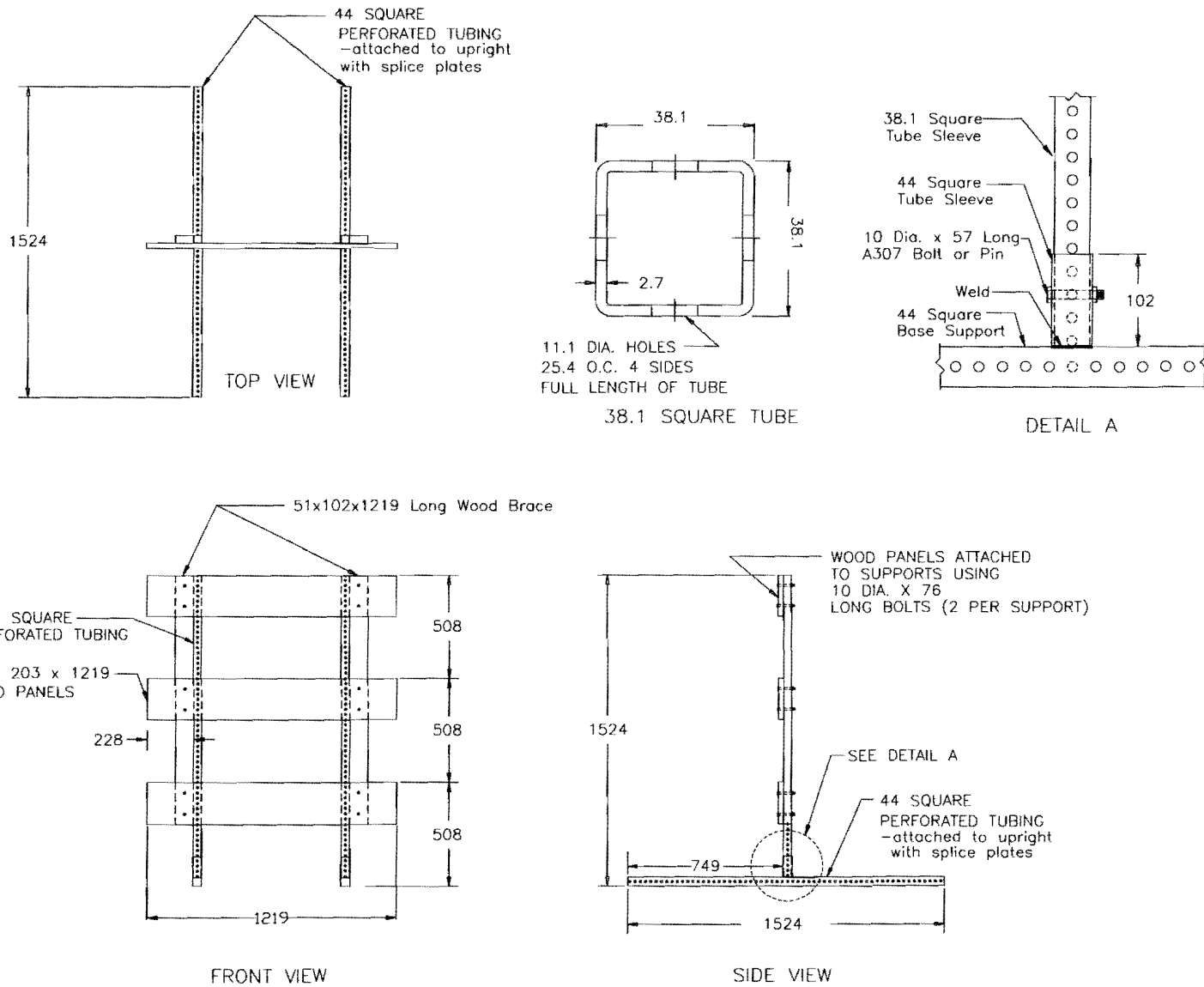
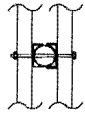


Figure 3. Type III Steel Perforated Tubing Barricade (1.2 m) as Used in Test 439107-3.



Section A-A

8

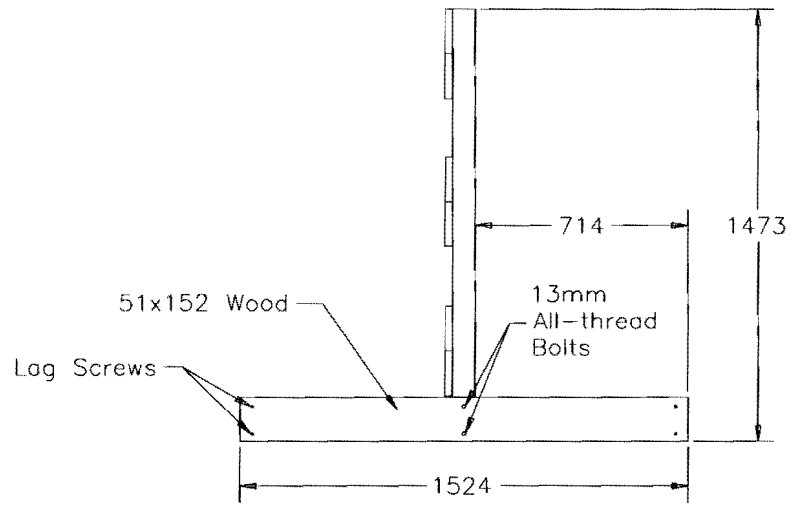
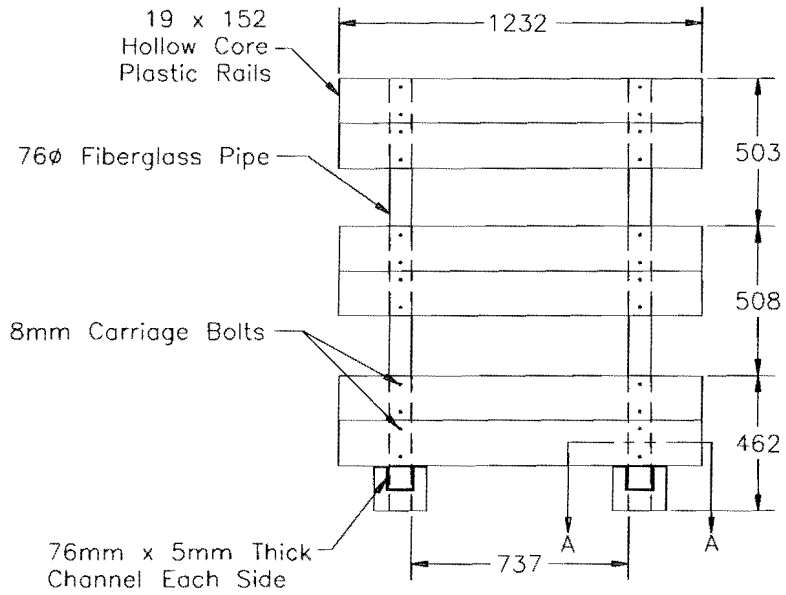
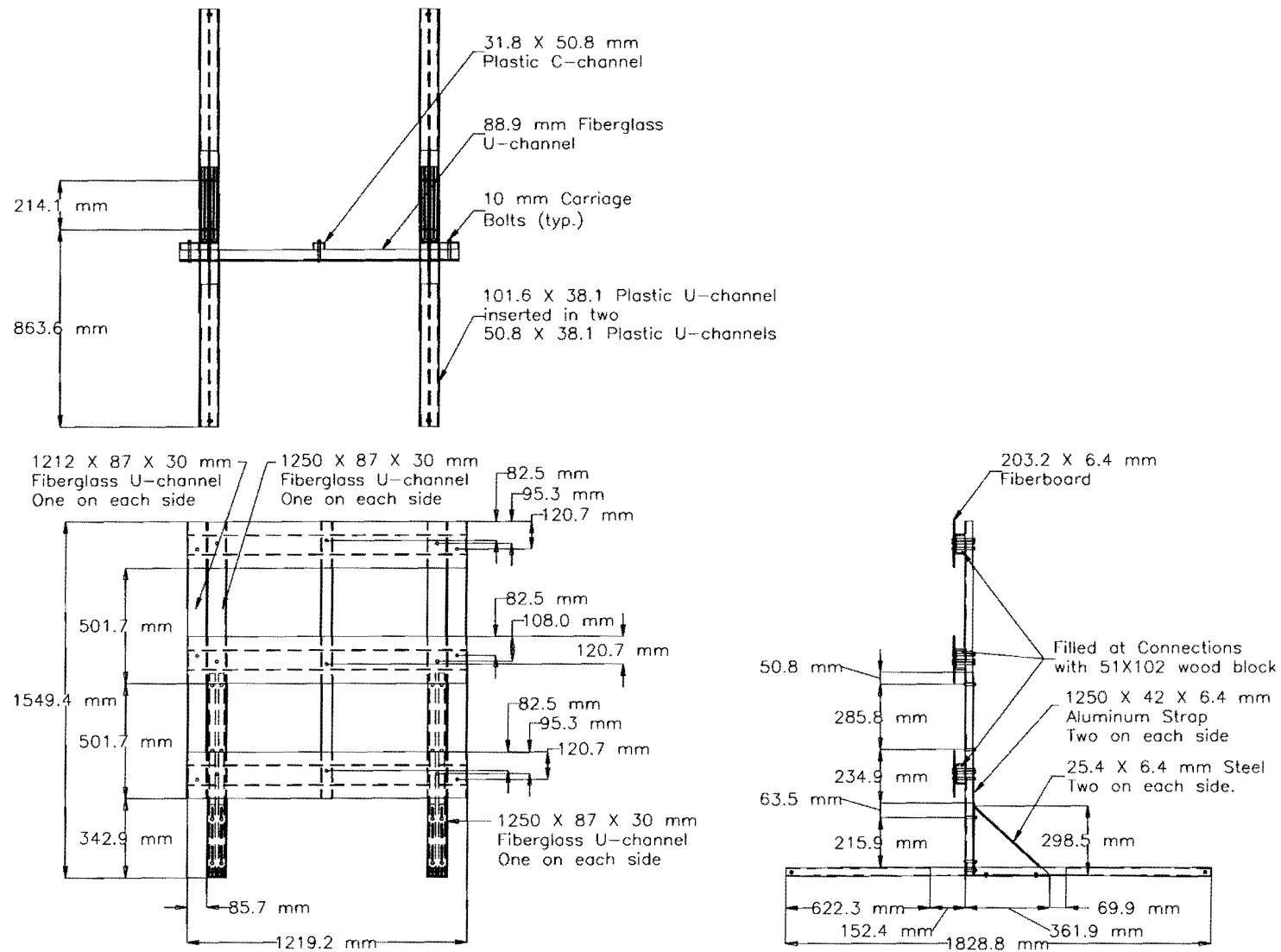


Figure 4. Hycom Fiberglass Type III Barricade (Test 439107-5).





**Figure 5. Price Fiberglass Type III Barricade (Test 439107-12).**

- Type I barricade/sign support. The Type I wooden A-frame barricade was of a foldout design, details of which is shown in Figure 6. A 1.2 m × 1.2 m × 13 mm thick plywood sign panel, with a mounting height of 305 mm from the bottom of the sign panel to the ground, was attached to the barricade. No warning light was attached to the barricade.

The attachment of sign panels to Type III barricades was found to be undesirable in previous crash tests and not recommended for field implementation.<sup>(1)</sup> However, wooden Type I barricades are also sometimes used as a temporary and portable sign support. The purpose of this crash test was to evaluate the impact performance of a wooden Type I barricade for use as a temporary and portable sign support.

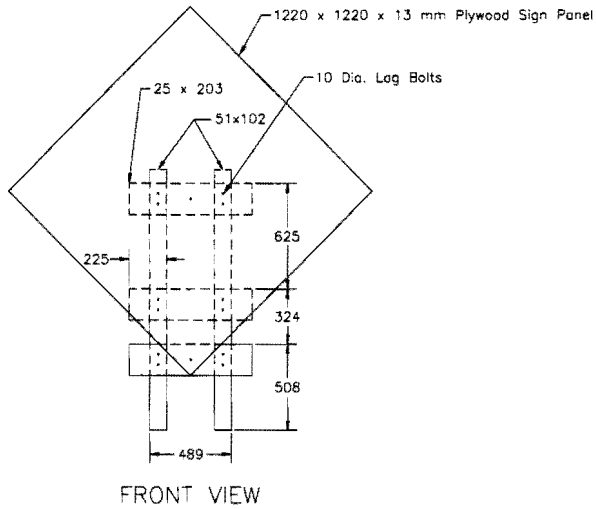
- Spring-loaded portable sign support. The spring-loaded portable sign support was manufactured by Traffix, Inc. and is available commercially. A 1.2 m × 1.2 m plastic/fabric sign panel was mounted to the support at an extended mounting height of 610 mm from the bottom of the sign panel to the ground. No warning light was attached. A schematic showing details of the spring-loaded portable sign support is shown in Figure 7.

A spring-loaded portable sign support with a fabric/plastic sign panel was previously crash tested and found to perform satisfactorily.<sup>(1)</sup> Portable sign supports are sometimes placed off the paved surface, and the sign panel might be obscured due to vegetation or roadside slope, thus necessitating a higher mounting height. The purpose of this crash test was to evaluate the effect of higher sign panel mounting heights on the impact performance of the portable sign support.

- Ground-mounted Type III barricade. There are instances in actual field applications where Type III barricades are used for traffic control on a more long-term or permanent basis, such as at ends of roads or at road closings. For such applications, a ground-mounted barricade would serve better than a skid-mounted barricade. A ground-mounted Type III barricade design was developed for this application. The purpose of these crash tests was to evaluate the impact performance of the ground-mounted Type III barricade design.

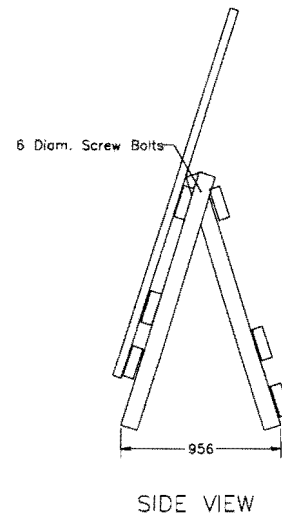
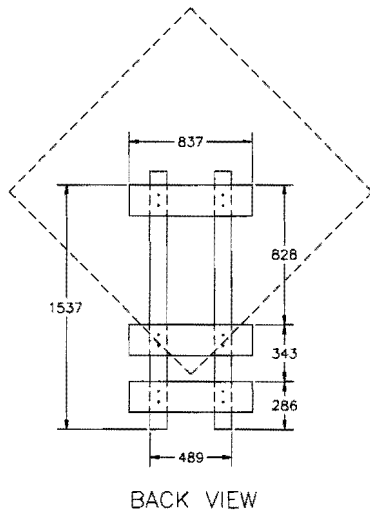
The ground-mounted Type III barricade consisted of thin-wall steel tube vertical supports installed inside ground sockets and secured with wedges. The three 16 mm × 203 mm horizontal rail elements were ripped from plywood sheets. Three wooden 51 mm × 102 mm intermediate vertical braces were attached to the horizontal rail elements, one on the outside of each vertical support and one centered between the vertical supports. A warning light was not attached. The overall barricade length was 2.4 m. A schematic showing details of the barricade is shown in Figure 8.

For the end-on test, a single barricade was used. For the two head-on tests, two 2.4 m long barricades erected side by side with a 305 mm gap between them were installed, as shown in Figure 9. The test vehicle was centered between the two barricades such that it would impact two supports (one from each barricade) simultaneously. No warning light was attached to any of these barricades.

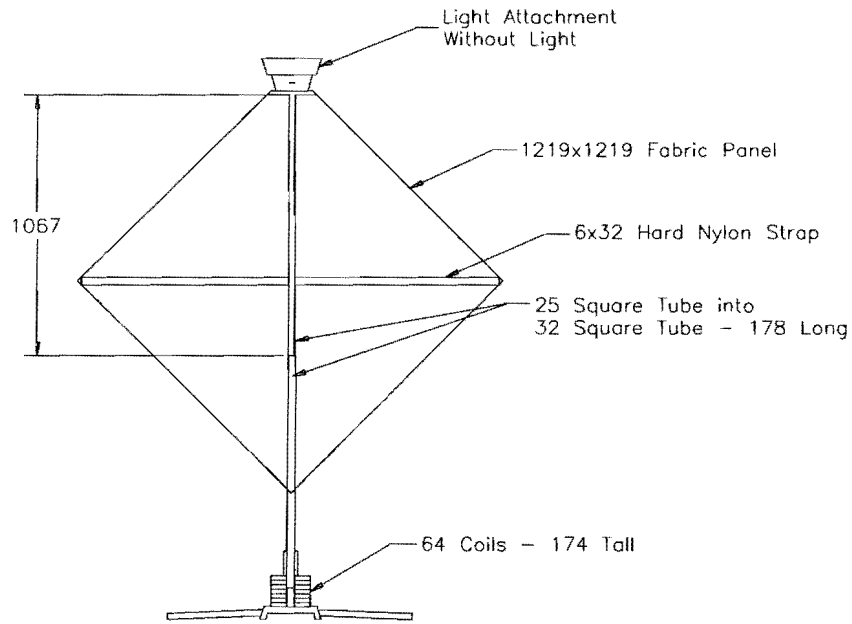


### A-FRAME BARRICADE

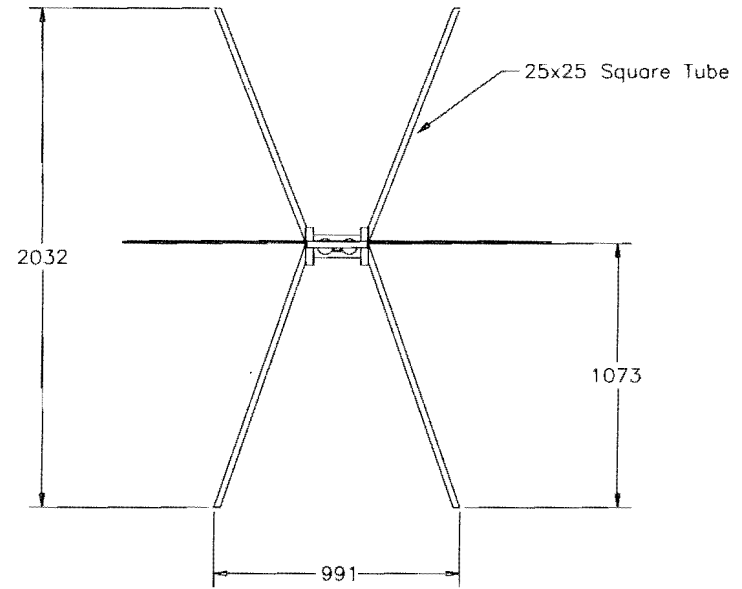
1220x1220x13 Plywood Sign Panel Attached to Front With 10 dia Through Bolts



**Figure 6. Type I Wooden A-frame Barricade (Test 439107-4).**

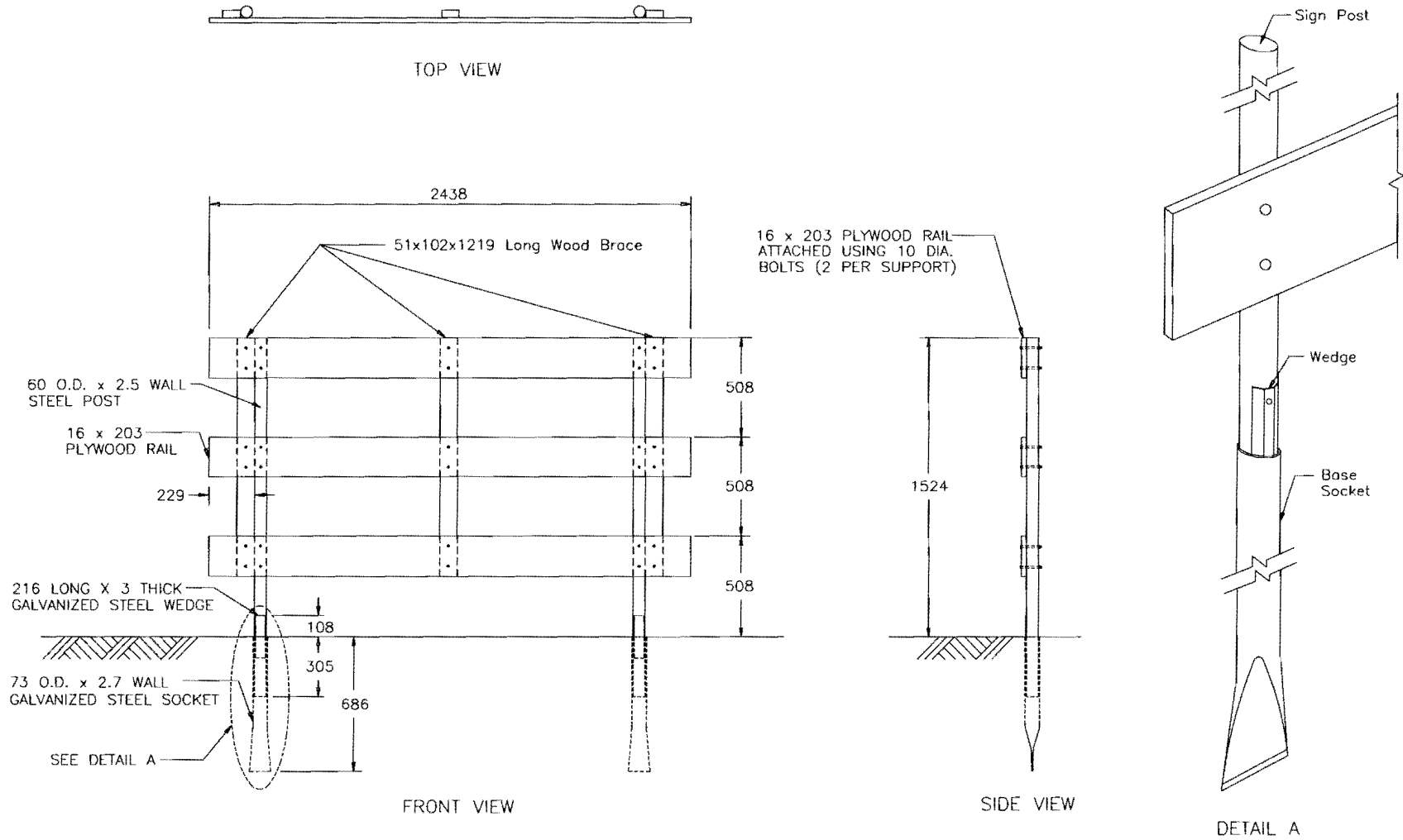


BACK VIEW



TOP VIEW

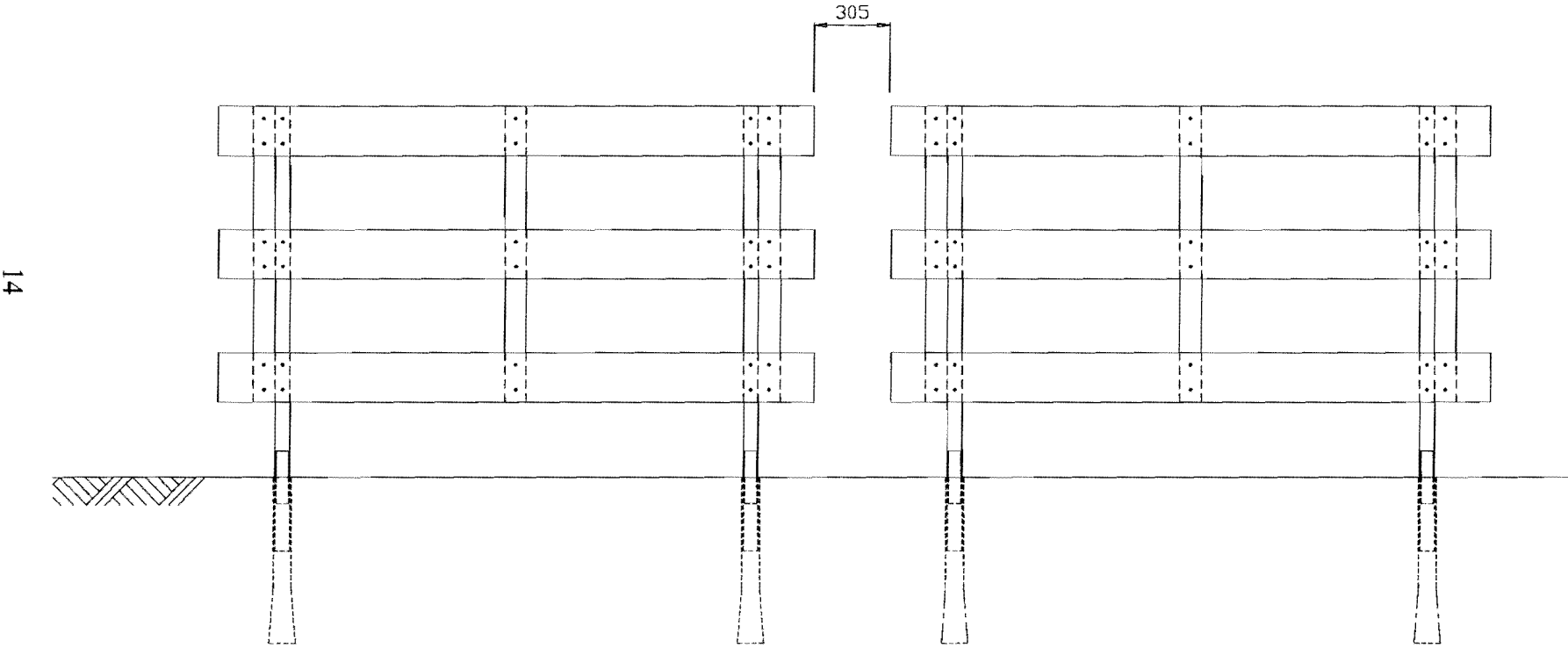
**Figure 7. Spring-loaded Portable Sign Support (Test 439107-6).**



TYPE III GROUND MOUNT BARRICADE WITH POS-LOC SUPPORT

**Figure 8. Ground-mounted Type III Barricade (Test 439107-7).**

See Figure 8 for construction details



**Figure 9. Side-by-Side Barricade Installation for Tests 439107-8 and 439107-9.**

- Skid-mounted sign support. The skid-mounted sign support consisted of two 90 mm × 90 mm × 3353 mm long wooden vertical supports spaced 852 mm center to center with a wooden skid base. A 1219 mm × 1219 mm × 12.7 mm thick plywood sign panel was attached to the vertical supports with 10-mm diameter bolts and mounted at a height of 2134 mm from the bottom of the sign panel to the ground. No warning light was attached to the sign support. A schematic showing details of the sign support is shown in Figure 10.

A skid-mounted sign support was previously crash tested and found to perform satisfactorily when impacted in a head-on configuration.<sup>(1)</sup> There are instances in actual field applications where the sign support may be exposed to impacts in the end-on configuration. The purpose of this crash test was to evaluate the impact performance of the skid-mounted sign support when impacted in an end-on configuration to make sure that the sign support would not pose any undue hazard to errant vehicles.

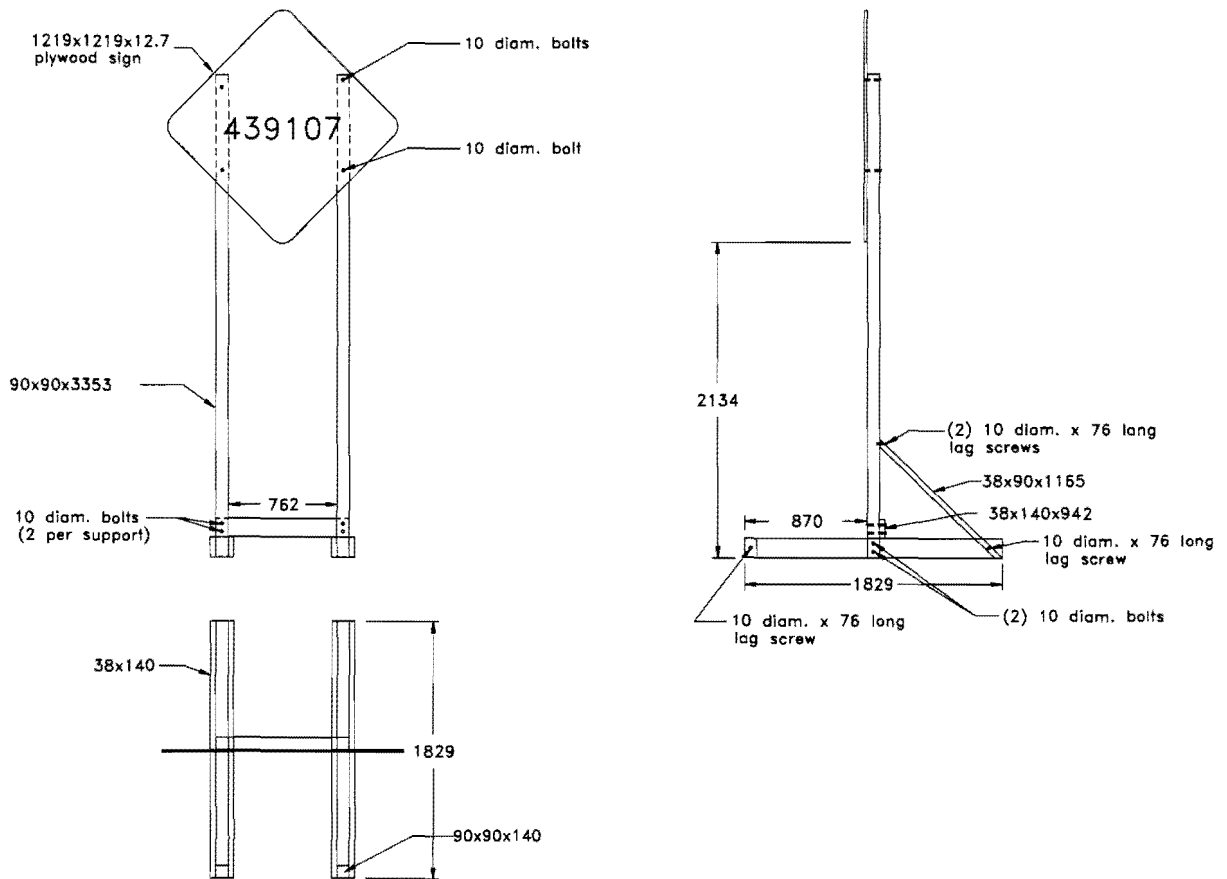
- Vertical panels. Three different support types for vertical panels were evaluated: 51 mm × 102 mm wooden post, 38.1 mm × 38.1 mm × 7.9 mm thick steel angle, and 38 mm × 51 mm plastic C-channel. All three supports were 1524 mm long with 610 mm embedded in soil. The vertical panels were fabricated from 12.7 mm thick plywood with the dimensions of 305 mm × 203 mm and attached to the supports with 10-mm diameter carriage bolts. The three vertical panel assemblies were installed in line, spaced 2464 mm apart so they could be evaluated in a single crash test. A schematic showing details of the vertical panel assemblies is shown in Figure 11.

The purpose of this crash test was to evaluate the impact performance of the various support types for use with vertical panels.

## 2.2 CRASH TEST MATRIX

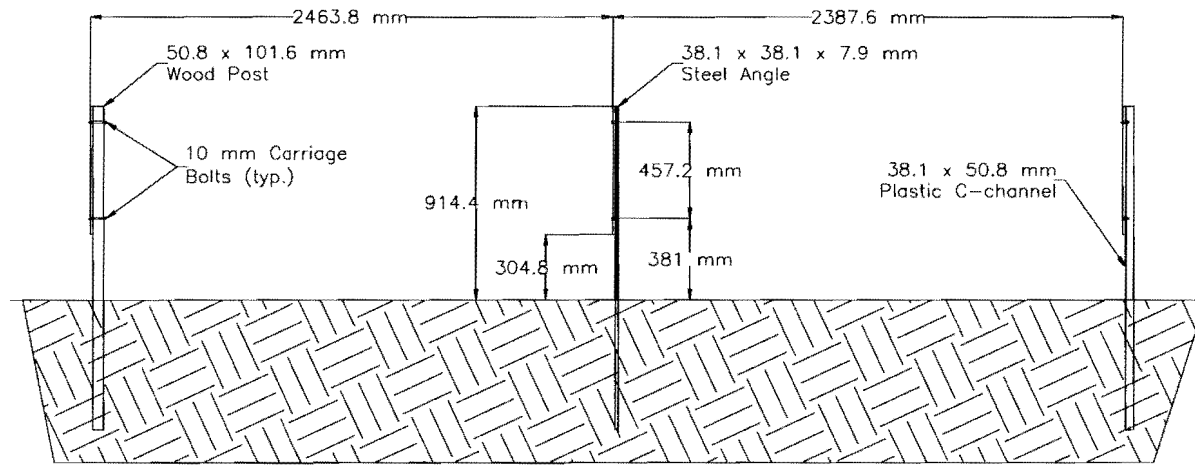
As mentioned previously, researchers conducted a total of 12 crash tests on the various barricade, work zone sign support, and vertical panel designs. All tests were conducted with an 820-kg passenger car. Table 1 summarizes the test articles and the test conditions for these 12 crash tests.

According to NCHRP Report 350, only one crash test is required for evaluation of work zone traffic control devices, NCHRP test designation 3-71. The test involves an 820-kg passenger car impacting the device at a nominal speed of 100 km/h for test level 3 (TL-3) conditions. The test is intended to evaluate vehicular stability, test article trajectory, and occupant risk factors. 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. All but one crash test (test no. 439107-8) were conducted under the test conditions specified for test designation 3-71 at a nominal impact speed of 100 km/h. Test no. 439107-8 was a low-speed test of 35 km/h for the dual ground-mounted barricades to ensure that the supports



**Figure 10. Skid-mounted Sign Support (Test 439107-10).**



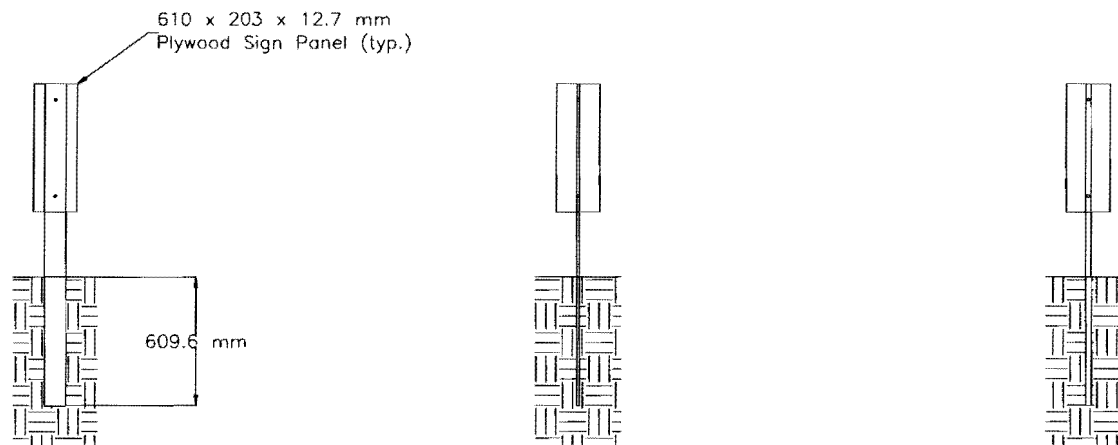


Side View

Marker 1

Marker 2

Marker 3



Front View

Figure 11. Vertical Panel Assembly (Test 439107-11).

would perform satisfactorily. This test corresponded to test designation 3-70 under NCHRP Report 350, which is an optional test.

Also, all crash tests were head-on impacts with the centerline of the vehicle aligned with the centerline of the traffic control device, except for two end-on tests, one on a ground-mounted Type III barricade in test no. 439107-7 and the other on a skid-mounted sign support. In the end-on tests, the centerline of the vehicle was aligned with the vertical support of the barricade. The traffic control devices were placed on concrete pavement for tests 439107-4, 5, and 6. The remaining devices were tested on soil to simulate conditions that might be encountered on the roadside in actual applications.

## **2.3 CRASH TEST AND DATA ANALYSIS PROCEDURES**

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.

### **2.3.1 Electronic Instrumentation and Data Processing**

Previous full-scale crash tests have shown that the acceleration levels experienced by the vehicle were extremely low and of little significance; therefore, the vehicles were not instrumented. This kept the cost of the crash testing down, allowing more tests to be performed under the available budget.

### **2.3.2 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.

### **2.3.3 Photographic Instrumentation and Data Processing**

Photographic coverage of the test included two high-speed cameras: one placed perpendicular to the vehicle path in line with the traffic control device, and one placed behind the traffic control device at an angle to the path of the vehicle and the traffic control device. 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 traffic control device before and after the test.

### 2.3.4 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 freewheeling and unrestrained. The vehicle remained freewheeling, 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.

### 2.3.5 Evaluation Criteria

The crash tests performed were evaluated in accordance with the criteria presented in 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, the following safety evaluation criteria from table 5.1 of NCHRP Report 350 were used to evaluate the crash test reported herein:

- **Structural Adequacy**

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

- **Occupant Risk**

- 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.

- H. Occupant impact velocities should satisfy the following:

Longitudinal Occupant Impact Velocity - m/s

<u>Preferred</u>	<u>Maximum</u>
3	5

- I. Occupant ridedown accelerations should satisfy the following:

Longitudinal and Lateral Occupant Ridedown Accelerations - g's

<u>Preferred</u>	<u>Maximum</u>
15	20

Note that previous crash tests with traffic control devices have shown that the occupant impact velocities and occupant ridedown accelerations are extremely low and not of any significance.

- **Vehicle Trajectory**

N. Vehicle trajectory behind the test article is acceptable.

All crash tests were evaluated in accordance with the criteria described above, 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 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. Results of the crash tests are presented in Chapter III. Appendix A provides detailed dimensions and information on the test vehicles. Appendix B provides sequential photographs of crash tests.

**Table 1. Crash Test Matrix.**

Test No.	Test Article	Impact Speed (km/h)	Point of Impact
439107-1	Hollow core plastic Type III barricade. Recycled plastic base. Wooden horizontal rail elements with two wooden vertical braces. Overall length of barricade 1.2 m. Warning light attached to vertical brace. Barricade placed on wet soil. Head-on impact.	100	Centered on barricade
439107-2	Steel perforated tubing Type III barricade. Wooden horizontal rail elements with three wooden vertical braces. Overall length of barricade 3.7 m. Warning light attached to vertical brace. Barricade placed on wet soil. Head-on impact.	100	Centered on barricade
439107-3	Perforated tubing Type III barricade. Wooden horizontal rail elements with two wooden vertical braces. Overall length of barricade 1.2 m. No warning light attached. Barricade placed on wet soil. Head-on impact.	100	Centered on barricade
439107-4	Wooden A-frame Type I barricade/sign support. 1.2 m × 1.2 m plywood sign panel attached at a mounting height of 305 mm. Overall length = 1.2 m. No warning light attached. Barricade placed on pavement. Head-on impact.	100	Centered on barricade
439107-5	HyCom Type III barricade with circular fiberglass vertical support and hollow core plastic horizontal rails. Barricade placed on pavement. No warning light attached. Head-on impact.	100	Centered on barricade
439107-6	Spring-loaded portable sign support with fabric sign panel at 610 mm mounting height. Sign support placed on pavement. No warning light attached. Head-on impact.	100	Centered on sign support

**Table 1. Crash Test Matrix (continued).**

Test No.	Test Article	Impact Speed (km/h)	Point of Impact
439107-7	Ground-mounted Type III barricade with thin-wall steel tube vertical supports and 16 mm × 203 mm plywood rail elements. Wooden 51 mm × 102 mm intermediate vertical braces on outside of each vertical support and centered between vertical supports. Thin wall tube supports installed inside ground sockets and secured with wedge. Overall barricade length 2.4 m. No warning light attached. Dry soil. End-on (90 deg) impact.	100	Centered on support
439107-8	Two 2.4 m long ground-mounted Type III barricades erected side by side with 305 mm gap between them. Construction of barricade is identical to that described under Test no. 439107-7. No warning light attached. Dry soil. Head-on impact.	35	Centered between two barricades such that one support from each barricade would be impacted simultaneously
439107-9	Two 2.4 m long ground-mounted Type III barricades erected side by side with 305 mm gap between them. Construction of barricade is identical to that described under Test no. 439107-7. No warning light attached. Dry soil. Head-on impact.	100	Centered between two barricades such that one support from each barricade would be impacted simultaneously
439107-10	Skid-mounted sign support with 1219 mm × 1219 mm plywood sign panel mounted at a height of 2134 mm from the bottom of the sign panel to the ground. Placed on dry soil. End-on (90 deg.) test.	100	Centered on support

**Table 1. Crash Test Matrix (continued).**

Test No.	Test Article	Impact Speed (km/h)	Point of Impact
439107-11	Three vertical panels mounted on three different support types: 51 mm × 102 mm wooden post, 12.7 mm × 12.7 mm × 6.4 mm steel angle, and 38 mm × 51 mm plastic C-channel, spaced 2.5 m apart. Support length 1.5 m with 610 mm embedded in dry soil. No warning light attached. Head-on impact.	100	Centered on vertical panel
439107-12	Price fiberglass Type III barricade. Fiberboard horizontal rail elements. Overall length of barricade 1.2 m. No warning light attached. Barricade placed on dry soil. Head-on impact.	100	Centered on barricade





### **III. CRASH TEST RESULTS**

A total of 12 crash tests were conducted under this study. This chapter presents brief descriptions of the tests and results for each of the 12 tests. Note that the presentation of the results is organized by the type of traffic control device and by crash test number within each type.

#### **3.1 TYPE III BARRICADES**

##### **3.1.1 Test No. 439107-1**

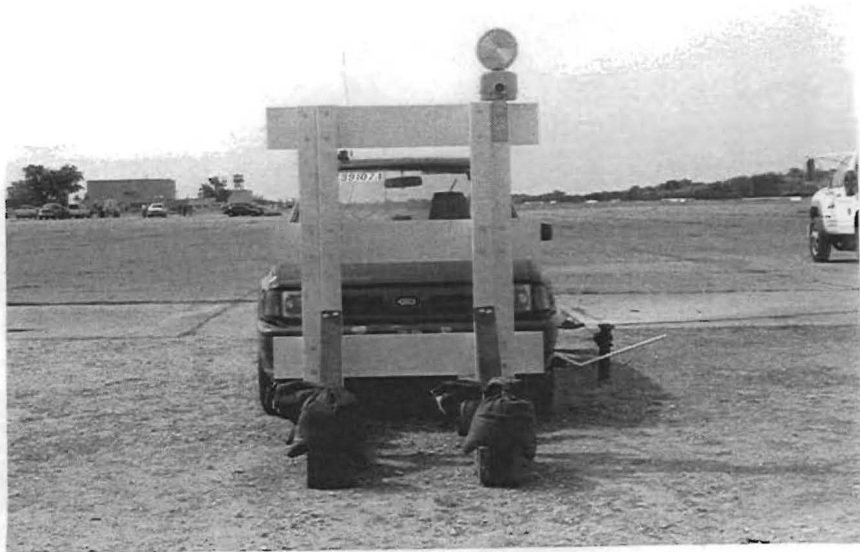
A hollow core plastic Type III barricade, a schematic of which was shown previously in Figure 1, was evaluated in this crash test. The overall length of the barricade was 1.2 m. A warning light was attached to the top of a vertical brace. The barricade was placed on wet soil. The test vehicle was a 1990 Ford Festiva, shown in Figures 12 and 13. Dimensions and information on the vehicle are given in Appendix A, Figure 82.

The vehicle impacted the barricade head-on with the centerline of the vehicle aligned with the centerline of the barricade at a speed of 99.5 km/h. At 0.042 s after impact, the rear brace on the right side of the barricade separated at the upper attachment to the upright. At 0.045 s, the rear brace on the left side separated at the upper attachment to the upright, and the left upright fractured just above the center horizontal panel. The upright made contact with the hood at 0.048 s, and the left upright fractured between the lower and center horizontal panels at 0.050 s. The warning light contacted the windshield at 0.072 s. The vehicle was traveling at 83.6 km/h as it lost contact with the warning light. Brakes on the vehicle were applied as the vehicle exited the test site, and the vehicle came to rest 51.6 m downstream and 2.8 m to the right of the impact point. Sequential photographs of the test can be found in Appendix B, Figure 86.

The upright portion of the barricade remained in one piece and rode along with the vehicle as shown in Figures 14 and 15. The bases and braces separated from the upright and were scattered along the path of the vehicle. The debris scatter extended 4.9 m on both sides of the centerline of the path of the vehicle and 52.8 m downstream of impact.

The vehicle received minor superficial damage as shown in Figure 16. The bumper, hood, and grill were dented and scraped, and the headlights were broken. The windshield was shattered on the driver's side from contact with the warning light.

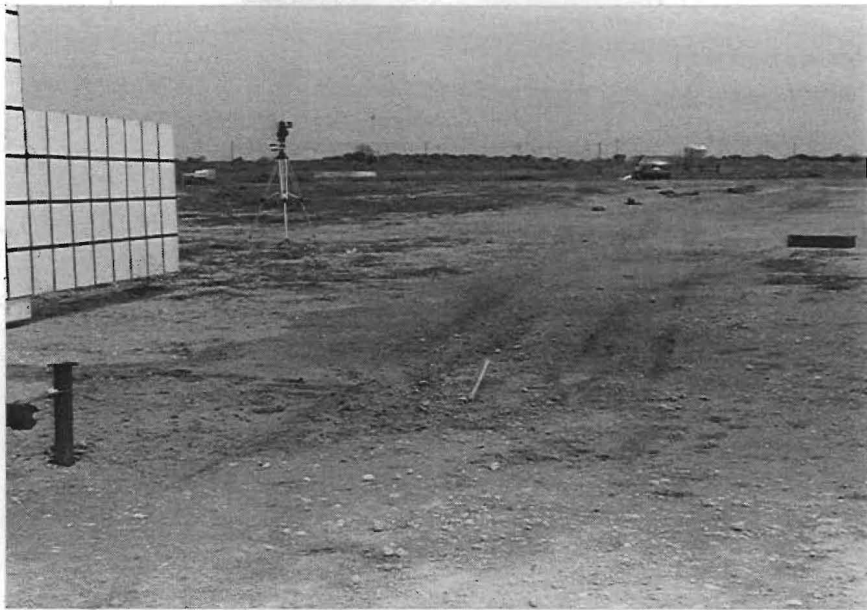
A summary of the test results is shown in Figure 17. This test is judged to be unsatisfactory due to shattering of the windshield by the warning light attachment. Thus, it is recommended that warning lights should not be used with barricades. However, it is the opinion of the project staff that the barricade would have performed satisfactorily, meeting all evaluation criteria set forth in NCHRP Report 350, if there were no warning light attached to the barricade.



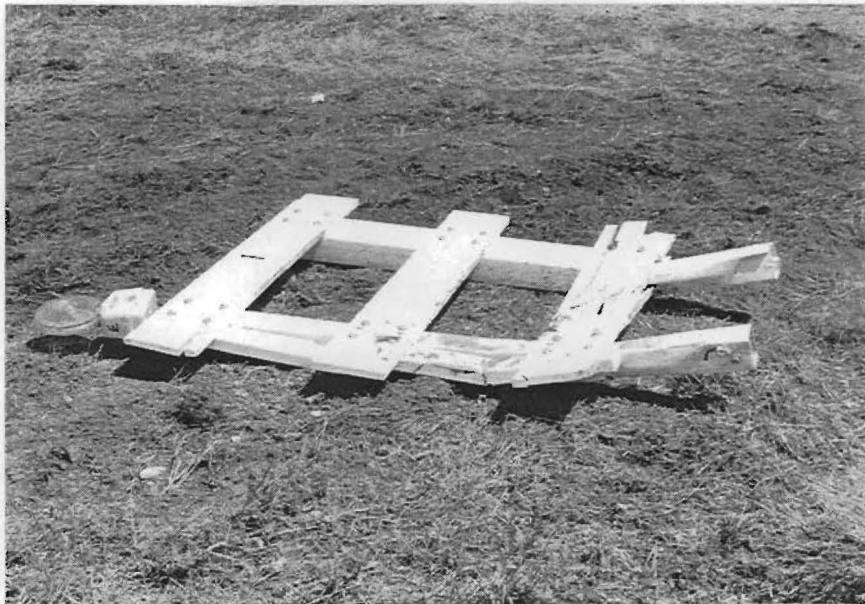
**Figure 12. Vehicle/Installation Geometrics for Test 439107-1.**



**Figure 13. Vehicle Before Test 439107-1.**



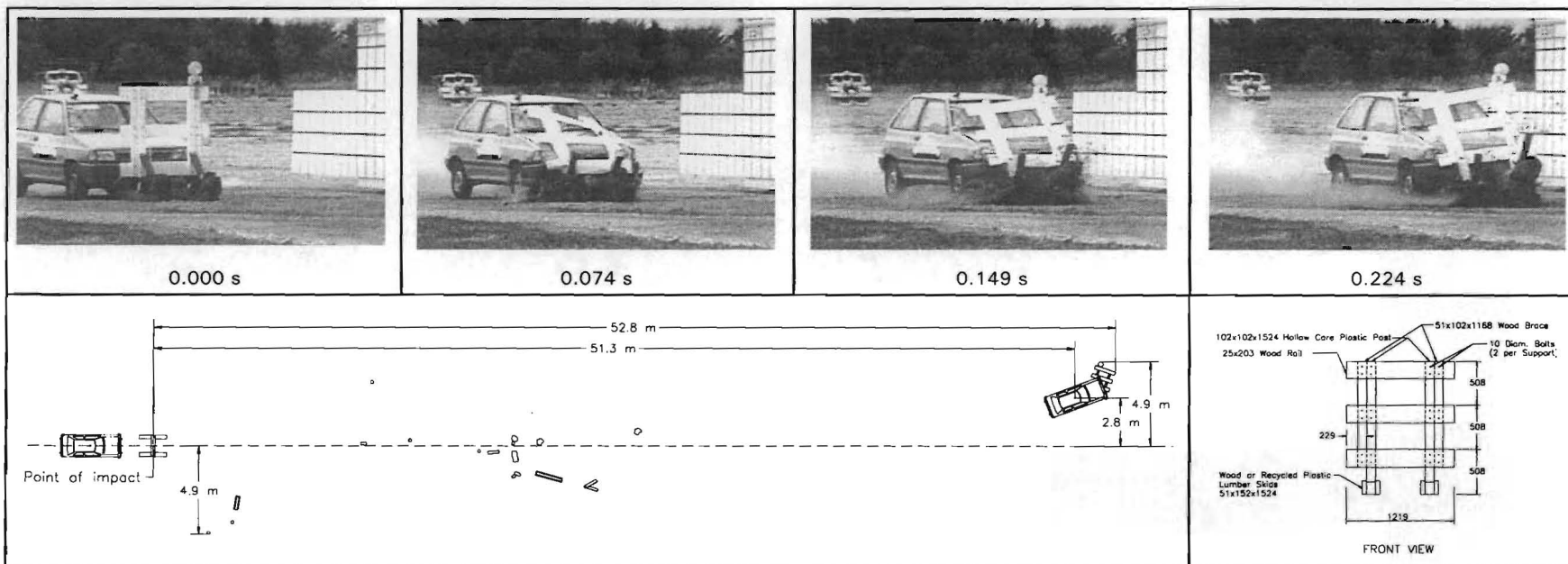
**Figure 14. After Impact Trajectory for Test 439107-1.**



**Figure 15. Installation After Test 439107-1.**



**Figure 16. Vehicle after test 439107-1.**



31

**General Information**

Test Agency . . . . . Texas Transportation Institute  
 Test No. . . . . 439107-1  
 Date . . . . . 04/09/97

**Test Article**

Type . . . . . Traffic Control Device  
 Name . . . . . Type III Barricade  
 Installation Length (m) . . . . . 1.22  
 Size and/or dimension  
 and material of key . . . . . Hollow core plastic supports  
 elements . . . . . w/recycled plastic lumber base  
 Soil Type and Condition . . . . . Standard soil, wet

**Test Vehicle**

Type . . . . . Production  
 Designation . . . . . 820C  
 Model . . . . . 1990 Ford Festiva  
 Mass (kg) Curb . . . . . 834  
 Test Inertial . . . . . 820  
 Dummy . . . . . 76  
 Gross Static . . . . . 896

**Impact Conditions**

Speed (km/h) . . . . . 99.48  
 Angle (deg) . . . . . 0

**Exit Conditions**

Speed (km/h) . . . . . 83.56  
 Angle (deg) . . . . . 0

**Occupant Risk Values**

Impact Velocity (m/s)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 Ridedown Accelerations (g's)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 Max. 0.050-s Average (g's)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 z-direction . . . . . N/A

**Debris Pattern Spread (m)**

Longitudinal . . . . . 52.8  
 Lateral . . . . . 4.9

**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. Roll Angle (deg) . . . . . N/A  
 Max. Pitch Angle (deg) . . . . . N/A  
 Max. Yaw Angle (deg) . . . . . N/A

**Figure 17. Summary of Results for Test 439107-1.**

In other words, the addition of the vertical braces for the horizontal rails did not appear to adversely effect the impact performance of the hollow core plastic barricade. Therefore, the use of vertical braces is considered acceptable.

### 3.1.2 Test No. 439107-2

A steel perforated tubing Type III barricade, a schematic of which was shown previously in Figure 2, was evaluated in this crash test. The overall length of the barricade was 3.7 m. A warning light was attached to the top of a vertical brace. The barricade was placed on wet soil. The test vehicle was a 1991 Ford Festiva, shown in Figures 18 and 19. Dimensions and information on the vehicle are given in Appendix A, Figure 83.

The vehicle impacted the barricade head-on at a speed of 98.04 km/h. At 0.011 s after impact, the lower and center horizontal panels fractured near the center vertical support. The center vertical support fractured near the center at 0.015 s, and a section of the center support contacted the windshield at 0.072 s. By 0.103 s, the barricade had shattered into multiple pieces. The vehicle was traveling at 94.52 km/h as it lost contact with the barricade. Brakes on the vehicle were applied as the vehicle exited the test site, and the vehicle came to rest 71.6 m down and 5.9 m to the right of the impact point. Sequential photographs can be found in Appendix B, Figure 87.

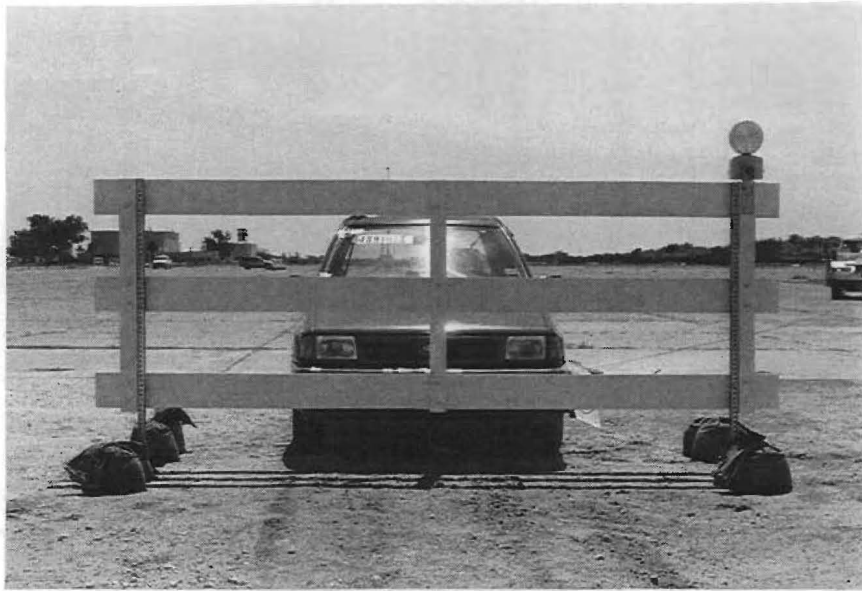
The barricade shattered into several pieces as shown in Figures 20 and 21. The left vertical support was pulled inward 5 mm at the lower panel, and the base was bowed downward 5 mm. The right vertical support was pulled inward 8 mm at the lower panel and deformed back 7 mm. The right base was not deformed. The debris scatter extended 1.8 m to the left side, 4.9 m to the right side, and 12.2 m downstream of the impact point.

As shown in Figure 22, the vehicle received minor damage. The hood was dented (not measurable), and the windshield was shattered near the roof edge at the center.

A summary of the test results is shown in Figure 23. This test is judged to be marginal. While the windshield was shattered near the roof edge at the center, there was no deformation or intrusion into the occupant compartment. The potential for such deformation or intrusion is judged to be minimal due to the large contact area between the separated section of the barricade and the windshield. Thus, the use of vertical braces for the horizontal rail elements is still considered acceptable. However, it is recommended that a smaller vertical brace be used at the center, e.g., a 25 mm × 102 mm instead of the 52 mm × 102 mm used in the test, to reduce the potential for any deformation or intrusion into the occupant compartment.

The modification to the connection design between the vertical supports and the skids, i.e., welding a stub to the skid and inserting and bolting the vertical supports to the stubs, does not appear to have any apparent effect on the impact performance of the barricade under this set of impact conditions.

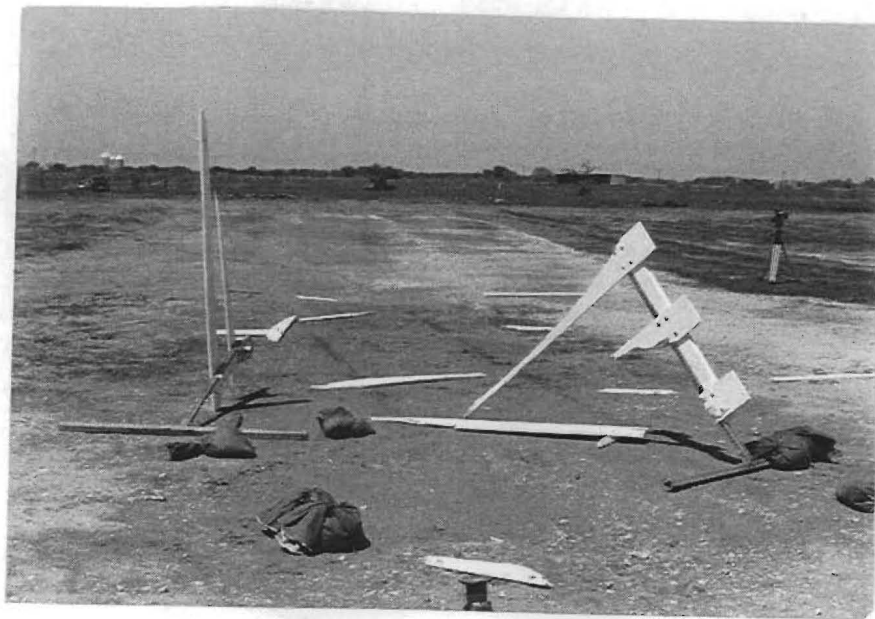
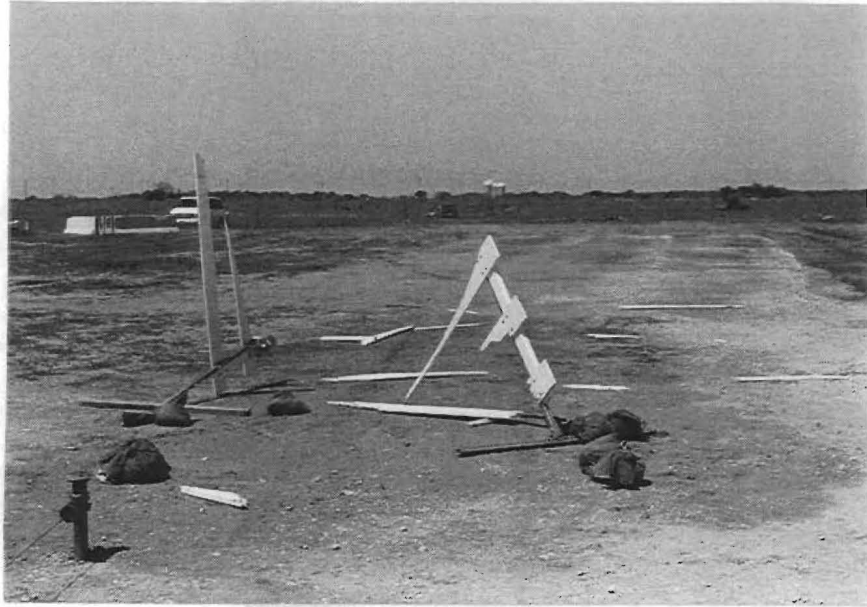




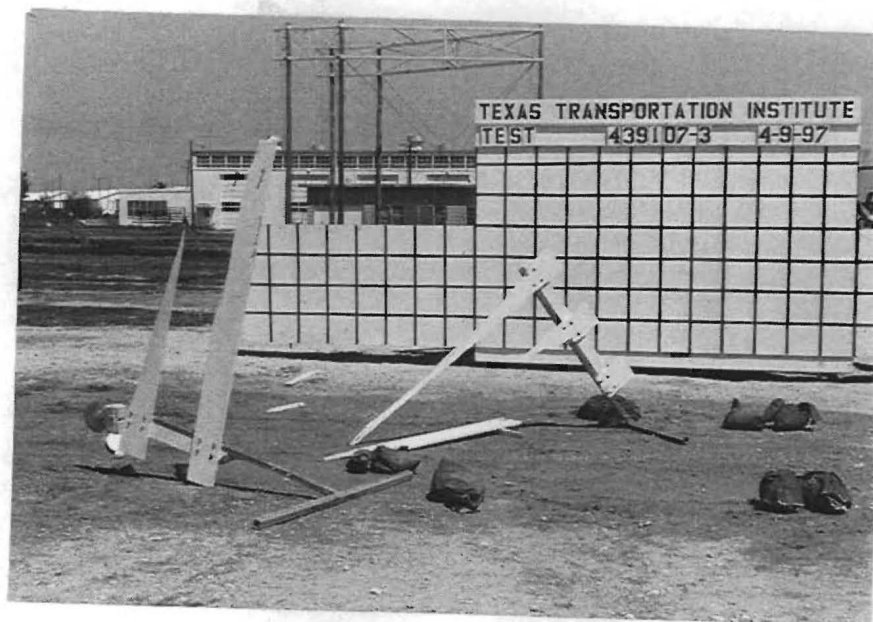
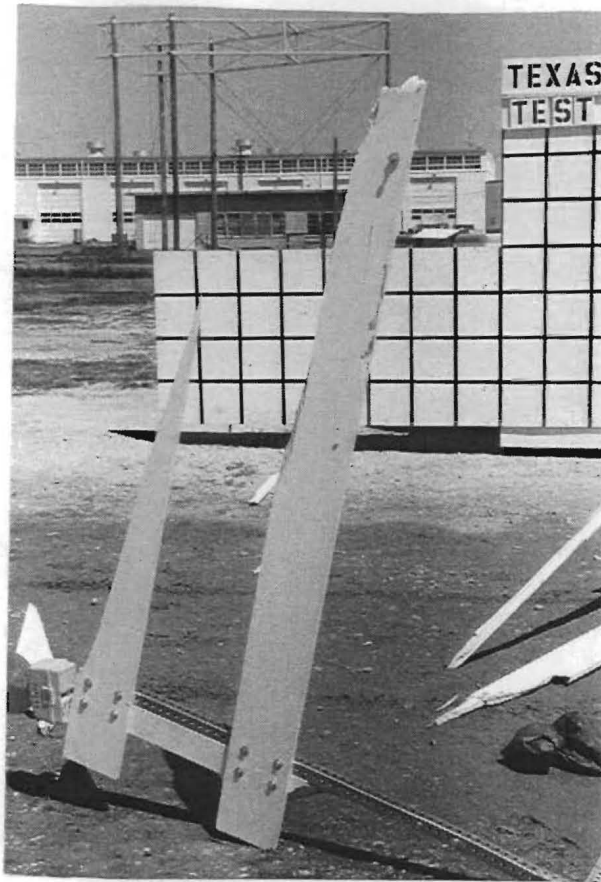
**Figure 18. Vehicle/Installation Geometrics for Test 439107-2.**



**Figure 19. Vehicle Before Test 439107-2.**



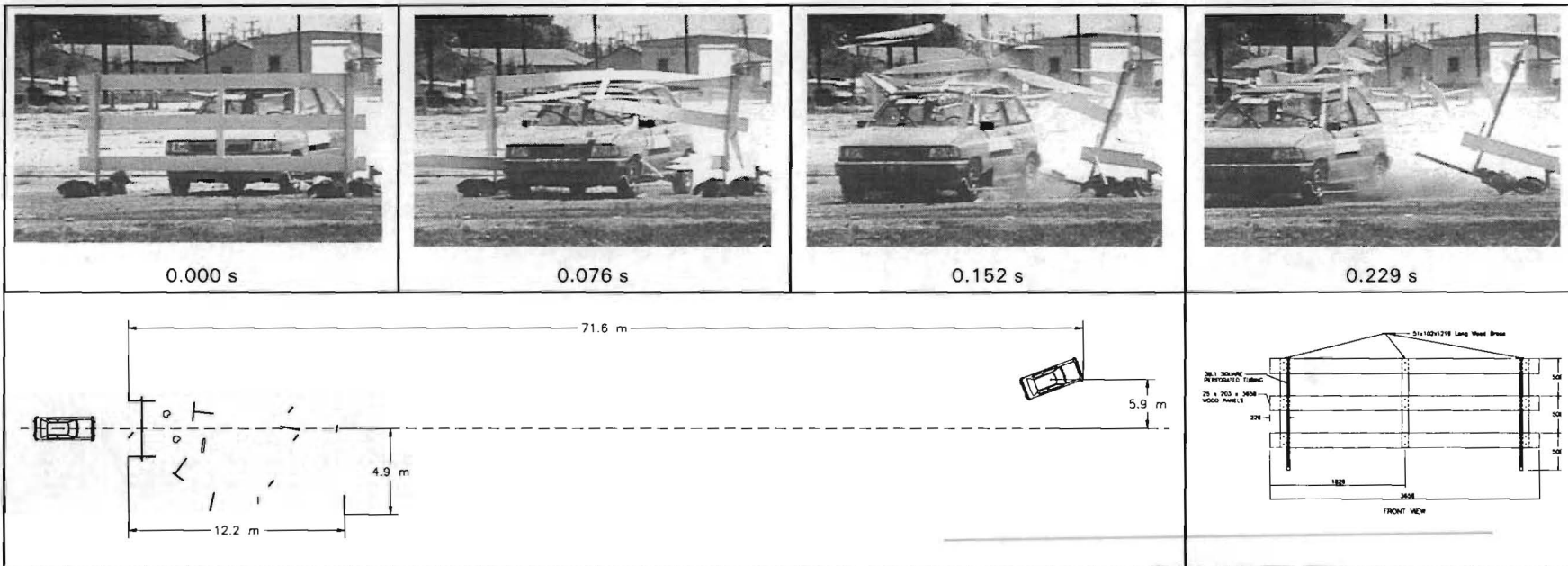
**Figure 20. After Impact Trajectory for Test 439107-2.**



**Figure 21. Installation After Test 439107-2.**



**Figure 22. Vehicle After Test 439107-2.**



38

**General Information**

Test Agency . . . . . Texas Transportation Institute  
 Test No. . . . . 439107-2  
 Date . . . . . 04/09/97

**Test Article**

Type . . . . . Traffic Control Device  
 Name . . . . . Type III Barricade  
 Installation Length (m) . . . . . 3.66  
 Size and/or dimension  
 and material of key . . . . . 44 mm square perforated steel  
 elements . . . . . support w/wood element  
 Soil Type and Condition . . . . . Standard soil, wet

**Test Vehicle**

Type . . . . . Production  
 Designation . . . . . 820C  
 Model . . . . . 1991 Ford Festiva  
 Mass (kg) Curb . . . . . 838  
 Test Inertial . . . . . 820  
 Dummy . . . . . 76  
 Gross Static . . . . . 896

**Impact Conditions**

Speed (km/h) . . . . . 98.04  
 Angle (deg) . . . . . 0

**Exit Conditions**

Speed (km/h) . . . . . 94.52  
 Angle (deg) . . . . . 0

**Occupant Risk Values**

Impact Velocity (m/s)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 Ridedown Accelerations (g's)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 Max. 0.050-s Average (g's)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 z-direction . . . . . N/A

**Debris Pattern Spread (m)**

Longitudinal . . . . . 12.2  
 Lateral . . . . . 4.9

**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. Roll Angle (deg) . . . . . N/A  
 Max. Pitch Angle (deg) . . . . . N/A  
 Max. Yaw Angle (deg) . . . . . N/A

**Figure 23. Summary of Results for Test 439107-2.**

### **3.1.3 Test No. 439107-3**

A steel perforated tubing Type III barricade, a schematic of which was shown previously in Figure 3, was evaluated in this crash test. The overall length of the barricade was 1.2 m. A warning light was not attached to the barricade due to the unsatisfactory performance displayed in test no. 439107-1 in which the warning light assembly impacted and shattered the windshield. The barricade was placed on wet soil. The test vehicle was a 1991 Ford Festiva, shown in Figures 24 and 25. Dimensions and information on the vehicle are given in Appendix A, Figure 83.

The vehicle impacted the barricade head-on at a speed of 98.05 km/h. At 0.022 s, the lower horizontal panel fractured, and at 0.026 s, the support post began to bend. The support post fractured at the bend at 0.030 s, and the center horizontal panel contacted the hood of the vehicle at 0.039 s. The vehicle was traveling at 89.99 km/h as it lost contact with the barricade. Brakes on the vehicle were applied as the vehicle exited the test site. The vehicle came to rest 50.3 m down and 5.7 m to the right of impact point. Sequential photographs of the test can be found in Appendix B, Figure 88.

The barricade separated into several pieces as shown in Figures 26 and 27. Both supports were torn at the rear side where the lower horizontal panel connected, on the left support at the lower bolt and on the right support at the upper bolt. The left base was bowed upward at the center 8 mm and the right base 3 mm. The debris scatter extended 6.9 m to the left, 5.0 m to the right, and 47.2 m down from impact.

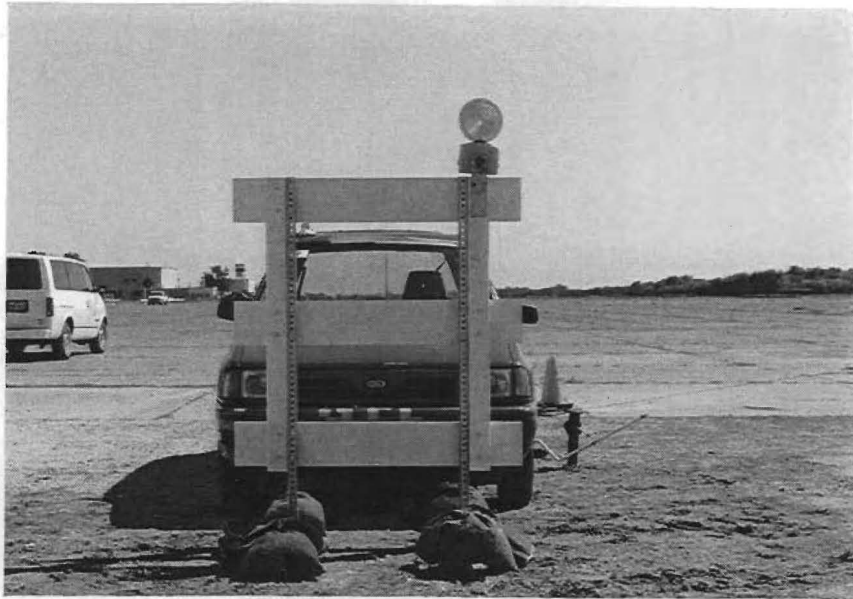
The vehicle received minor damage, as shown in Figure 28. The bumper and grill were dented and scraped, and the headlights were broken.

A summary of the test results is shown in Figure 29. This test is judged to be successful, meeting all evaluation criteria set forth in NCHRP Report 350. It may be concluded from this crash test that the impact performance of the steel perforated tubing Type III barricade is not adversely affected by: (a) the modification to the connection design between the vertical supports and the skids, i.e., welding a stub to the skid and inserting and bolting the vertical supports to the stubs; and (b) the addition of vertical braces to the horizontal rail elements on the outside of the vertical supports.

### **3.1.4 Test No. 439107-5**

A fiberglass Type III barricade manufactured by HyCom, Inc. was evaluated in this crash test. A schematic of this barricade was shown previously in Figure 4. The overall length of the barricade was 1.2 m. A warning light was not attached to the barricade. The barricade was placed on pavement. A 1991 Ford Festiva, shown in Figures 30 and 31, was used in the crash test. Dimensions and information on the vehicle are given in Appendix A, Figure 83.

The vehicle impacted the barricade head-on at a speed of 97.63 km/h. At 0.043 s after impact, the barricade contacted the hood. The barricade then rode along with the vehicle and, at



The warning light was removed prior to the test.

**Figure 24. Vehicle/Installation Geometrics for Test 439107-3.**



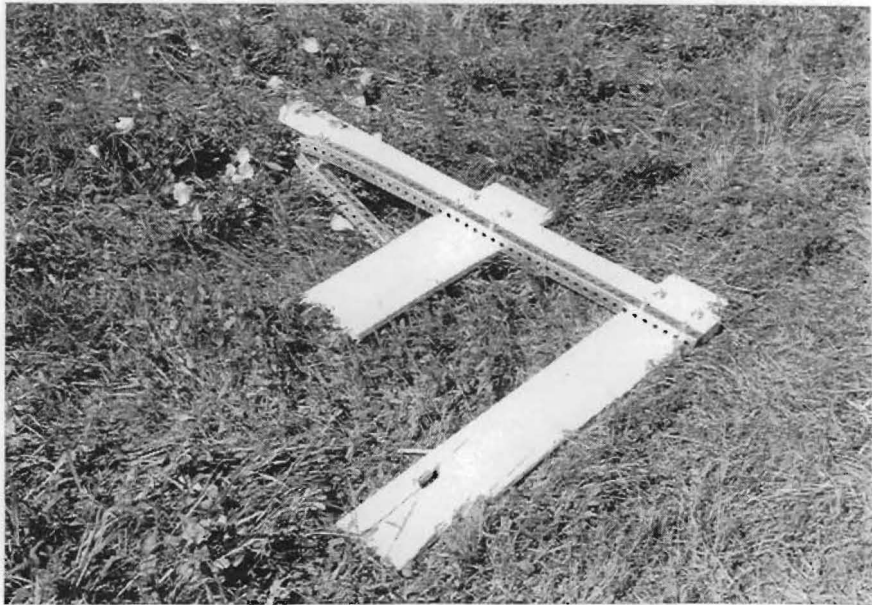
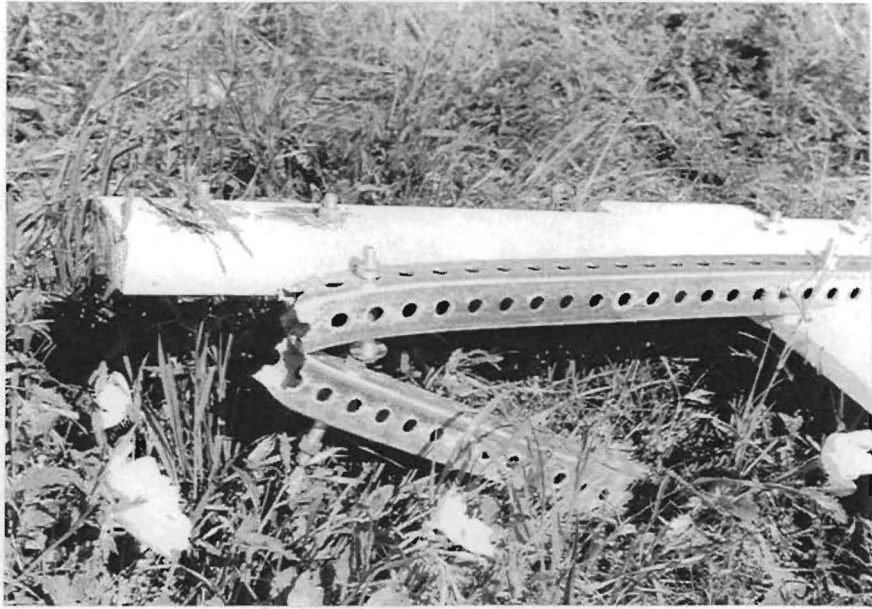


The warning light was removed prior to the test.

**Figure 25. Vehicle Before Test 439107-3.**



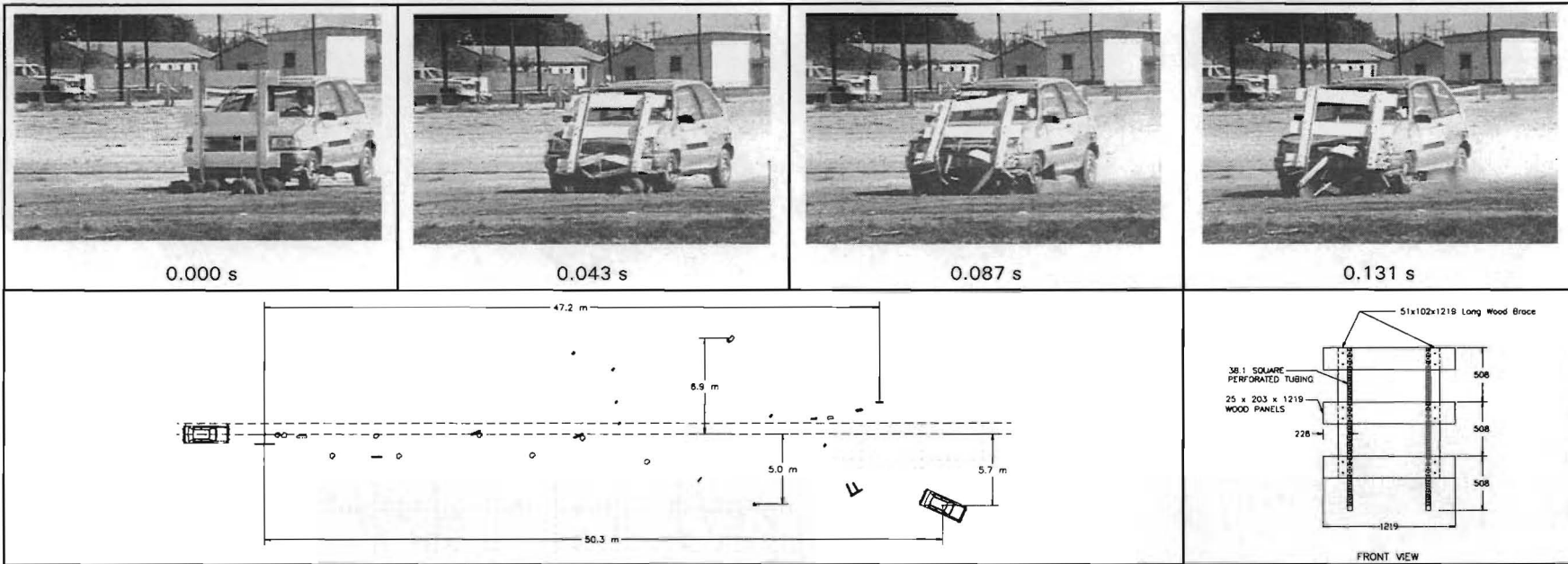
**Figure 26. After Impact Trajectory for Test 439107-3.**



**Figure 27. Installation After Test 439107-3.**



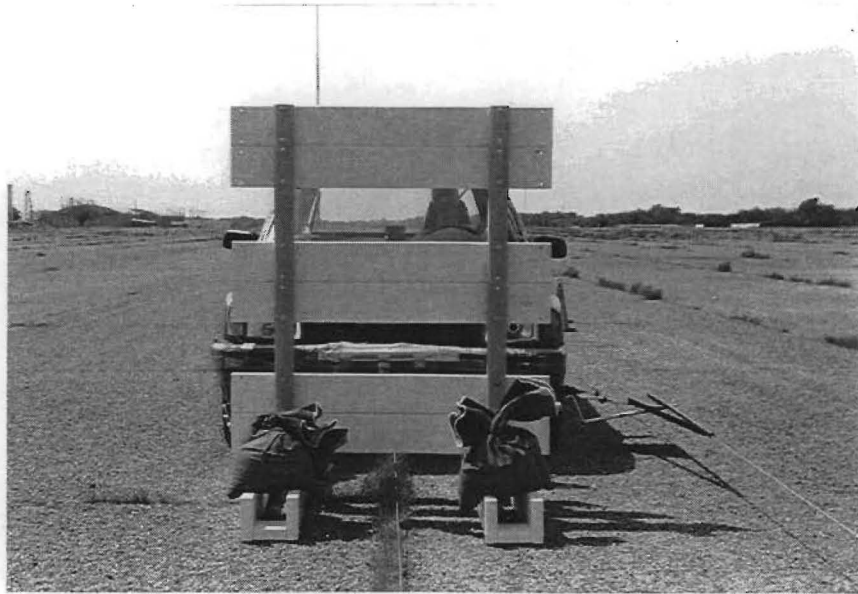
**Figure 28. Vehicle After Test 439107-3.**



45

<b>General Information</b>		<b>Impact Conditions</b>		<b>Debris Pattern Spread (m)</b>	
Test Agency	Texas Transportation Institute	Speed (km/h)	98.05	Longitudinal	47.2
Test No.	439107-3	Angle (deg)	0	Lateral	6.9
Date	04/09/97				
<b>Test Article</b>		<b>Exit Conditions</b>		<b>Vehicle Damage</b>	
Type	Traffic Control Device	Speed (km/h)	89.99	Exterior	
Name	Type III Barricade	Angle (deg)	0	VDS	12FD1
Installation Length (m)	1.22			CDC	12FDEW1
Size and/or dimension		<b>Occupant Risk Values</b>		Maximum Exterior	
and material of key	44 mm square perforated steel	Impact Velocity (m/s)		Vehicle Crush (mm)	nil
elements	support w/wood element	x-direction	N/A	Interior	
Soil Type and Condition	Standard soil, wet	y-direction	N/A	OCDI	FS0000000
Test Vehicle		Ridedown Accelerations (g's)		Max. Occ. Compart.	
Type	Production	x-direction	N/A	Deformation (mm)	0
Designation	820C	y-direction	N/A	<b>Post-Impact Behavior</b>	
Model	1991 Ford Festiva	Max. 0.050-s Average (g's)		(during 1.0 s after impact)	
Mass (kg) Curb	838	x-direction	N/A	Max. Roll Angle (deg)	N/A
Test Inertial	820	y-direction	N/A	Max. Pitch Angle (deg)	N/A
Dummy	76	z-direction	N/A	Max. Yaw Angle (deg)	N/A
Gross Static	896				

Figure 29. Summary of Results for Test 439107-3.



**Figure 30. Vehicle/Installation Geometrics for Test 439107-5.**



**Figure 31. Vehicle Before Test 439107-5.**

0.235 s, the vehicle was traveling at 84.65 km/h. Brakes on the vehicle were applied as it exited the test site. The vehicle subsequently came to rest 90.6 m down from the impact point. Sequential photographs of the test can be found in Appendix B, Figure 89.

The barricade separated from the bases, and the upper portion rode along with the vehicle as shown in Figures 32 and 33. The debris remained along the path of the vehicle with the upper portion at 95.1 m down from point of initial impact.

The vehicle received minor scrapes and dents as shown in Figure 34. Only the bumper and hood were damaged.

A summary of the test results is shown in Figure 35. This test with the HyCom fiberglass Type III barricade is judged to be successful, meeting all evaluation criteria set forth in NCHRP Report 350.

### **3.1.5 Test No. 439107-12**

A fiberglass Type III barricade manufactured by Price Barricades was evaluated in this crash test. A schematic of this barricade was shown previously in Figure 5. The overall length of the barricade was 1.2 m. A warning light was not attached to the barricade. The barricade was placed on dry soil. A 1990 Ford Festiva, shown in Figures 36 and 37, was used in the crash test. Dimensions and information on the vehicle are given in Appendix A, Figure 84.

The vehicle impacted the barricade at a speed of 100.5 km/h. By 0.002 s after impact, the barricade showed movement and started to deform at bumper height. The barricade wrapped around the front of the vehicle, the top of the barricade, then impacted the rear of the hood near the windshield. At 0.041 s, the barricade lost contact with the hood. As the vehicle exited the test site, its speed was 88.5 km/h. The vehicle subsequently came to rest 109.7 m down and 6.4 m to the left of the impact point. Sequential photographs of the test can be found in Appendix B, Figure 90.

The barricade separated into just a few pieces, as shown in Figures 38 and 39. The bases were 6.4 m down and 0.6 m to the right of impact point. The upper portion of the barricade was 22.3 m down and 2.6 m to the left of impact.

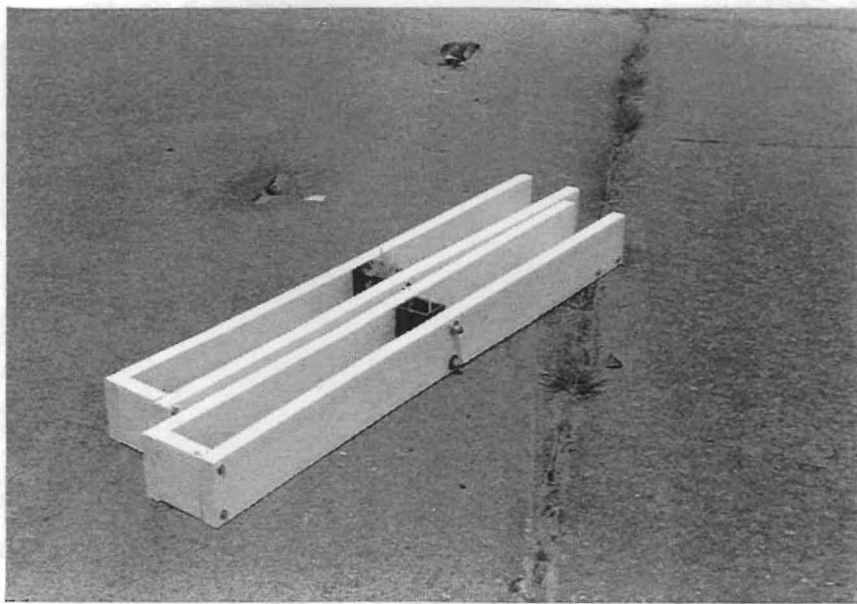
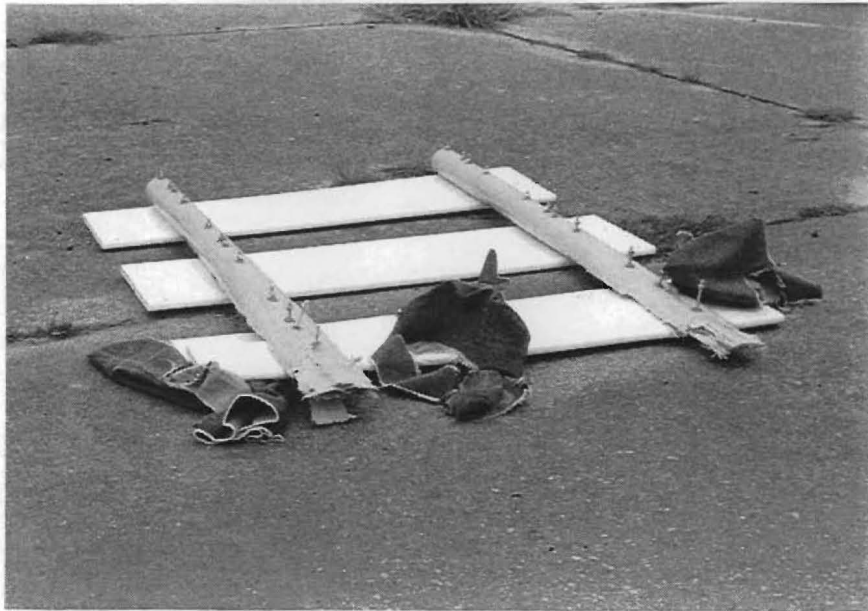
The only damage the vehicle received was a dent in the hood and a broken headlight, as shown in Figure 40.

A summary of the test results is shown in Figure 41. This test with the Price fiberglass Type III barricade is judged to be successful, meeting all evaluation criteria set forth in NCHRP Report 350.





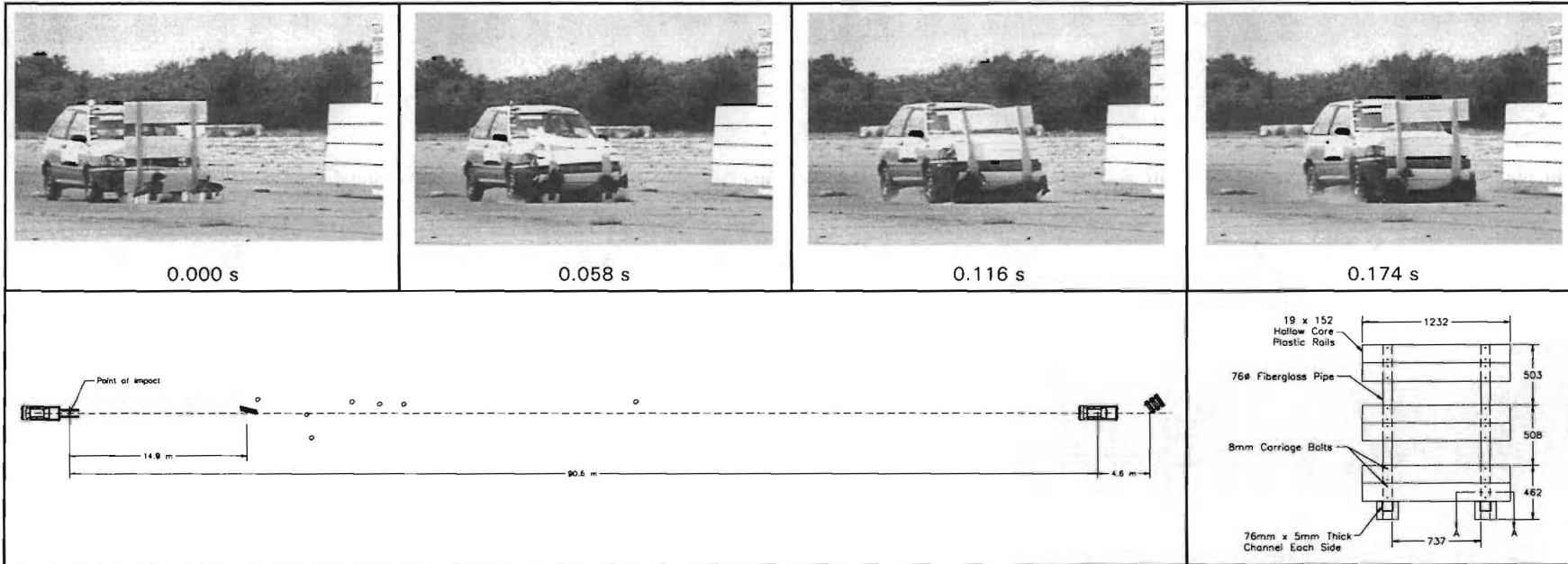
**Figure 32. After Impact Trajectory for Test 439107-5.**



**Figure 33. Installation After Test 439107-5.**



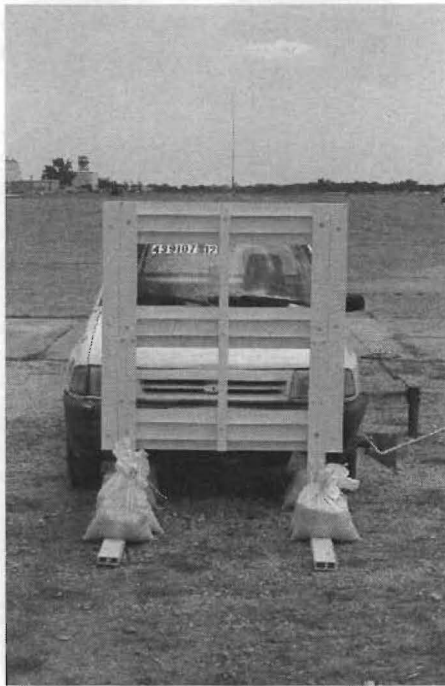
**Figure 34. Vehicle After Test 439107-5.**



52

<b>General Information</b>		<b>Impact Conditions</b>	<b>Debris Pattern Spread (m)</b>
Test Agency . . . . .	Texas Transportation Institute	Speed (km/h) . . . . .	97.63
Test No. . . . .	439107-5	Angle (deg) . . . . .	0
Date . . . . .	04/10/97		
<b>Test Article</b>		<b>Exit Conditions</b>	<b>Vehicle Damage</b>
Type . . . . .	Traffic Control Device	Speed (km/h) . . . . .	84.65
Name . . . . .	Type III Barricade	Angle (deg) . . . . .	0
Installation Length (m) . . . . .	1.23		
Size and/or dimension and material of key elements . . . . .	Fiberglass support with wood base	<b>Occupant Risk Values</b>	
Soil Type and Condition . . . . .	Concrete Pavement, dry	Impact Velocity (m/s)	
<b>Test Vehicle</b>		x-direction . . . . .	N/A
Type . . . . .	Production	y-direction . . . . .	N/A
Designation . . . . .	820C	Ridedown Accelerations (g's)	
Model . . . . .	1991 Ford Festiva	x-direction . . . . .	N/A
Mass (kg) Curb . . . . .	838	y-direction . . . . .	N/A
Test Inertial . . . . .	820	Max. 0.050-s Average (g's)	
Dummy . . . . .	76	x-direction . . . . .	N/A
Gross Static . . . . .	896	y-direction . . . . .	N/A
		z-direction . . . . .	N/A
			<b>Post-Impact Behavior</b>
			(during 1.0 s after impact)
			Max. Roll Angle (deg) . . . . .
			N/A
			Max. Pitch Angle (deg) . . . . .
			N/A
			Max. Yaw Angle (deg) . . . . .
			N/A

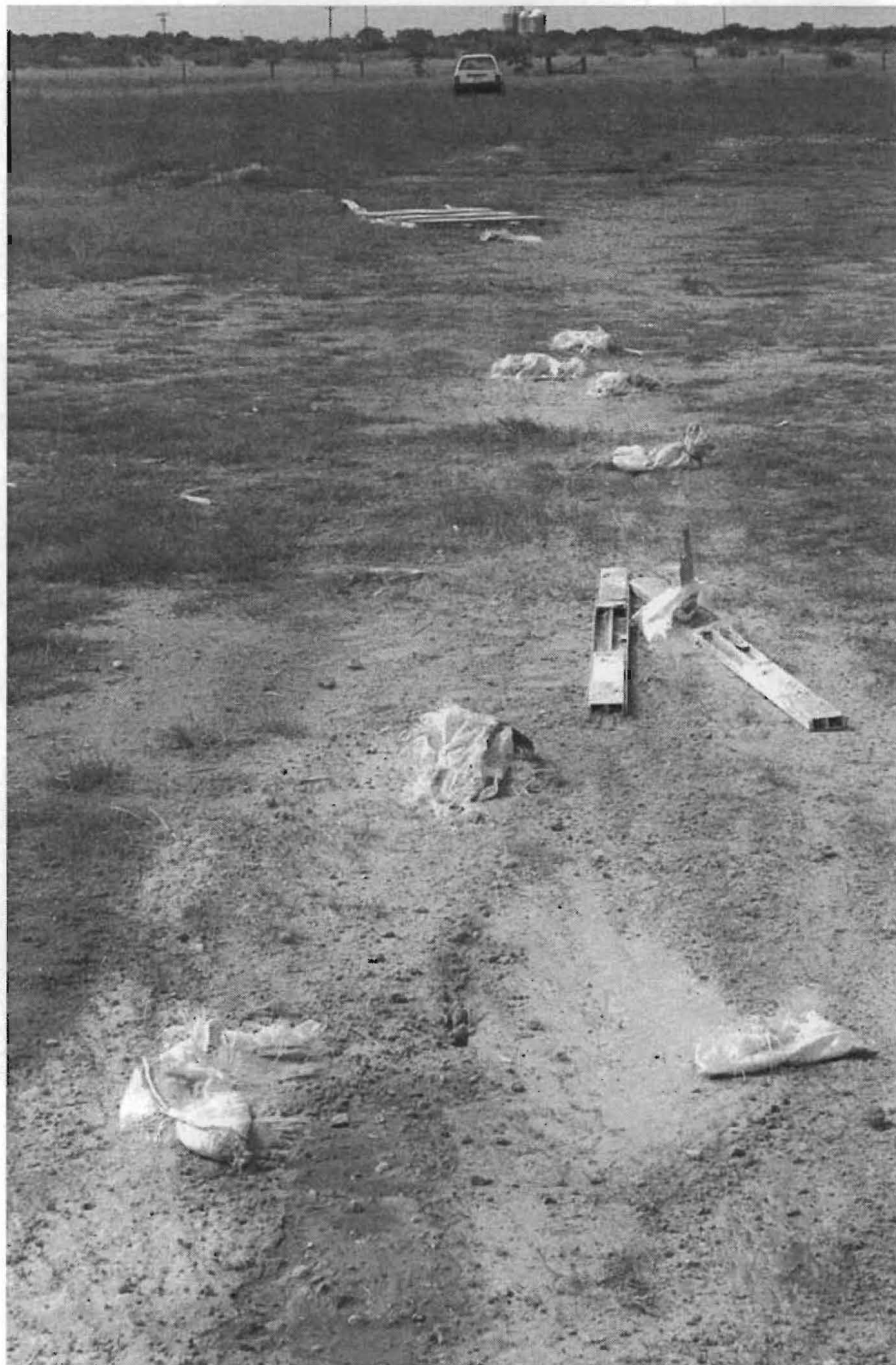
Figure 35. Summary of Results for Test 439107-5.



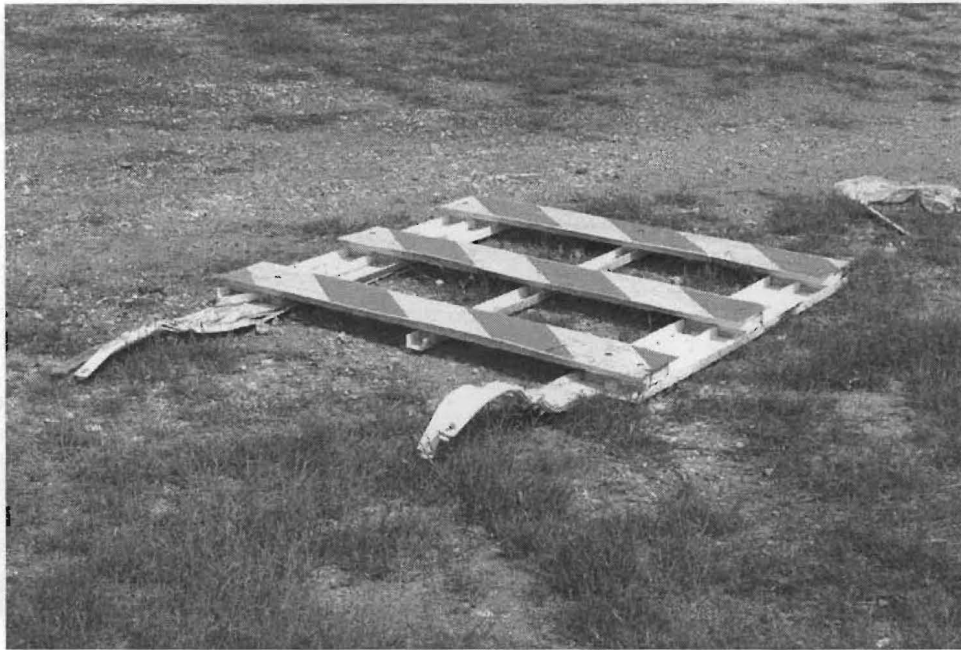
**Figure 36. Vehicle/Installation Geometrics for Test 439107-12.**



**Figure 37. Vehicle Before Test 439107-12.**



**Figure 38. After Impact Trajectory for Test 439107-12.**

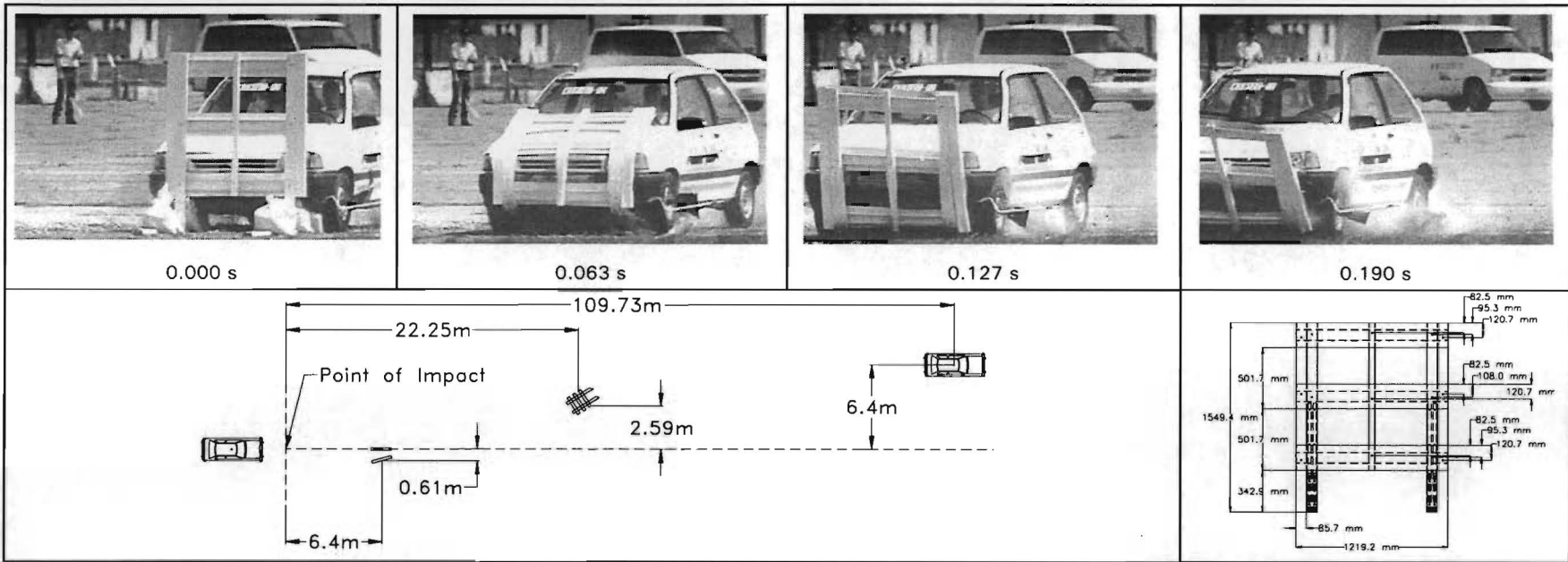


**Figure 39. Installation After Test 439107-12.**





**Figure 40. Vehicle After Test 439107-12.**



58

**General Information**

Test Agency . . . . . Texas Transportation Institute  
 Test No. . . . . 439107-12  
 Date . . . . . 06/03/97

**Test Article**

Type . . . . . Traffic Control Device  
 Name . . . . . Type III Barricade  
 Installation Length (m) . . . . . 1.22  
 Size and/or dimension  
 and material of key . . . . . Recycled plastic U-channel  
 elements . . . . . with fiberglass panels

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

**Test Vehicle**

Type . . . . . Production  
 Designation . . . . . 820C  
 Model . . . . . 1990 Ford Festiva  
 Mass (kg) Curb . . . . . 828  
 Test Inertial . . . . . 820  
 Dummy . . . . . 76  
 Gross Static . . . . . 896

**Impact Conditions**

Speed (km/h) . . . . . 100.50  
 Angle (deg) . . . . . 0

**Exit Conditions**

Speed (km/h) . . . . . 88.46  
 Angle (deg) . . . . . 0

**Occupant Risk Values**

Impact Velocity (m/s)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 Ridedown Accelerations (g's)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 Max. 0.050-s Average (g's)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 z-direction . . . . . N/A

**Debris Pattern Spread (m)**

Longitudinal . . . . . 22.3  
 Lateral . . . . . 2.6

**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. Roll Angle (deg) . . . . . N/A  
 Max. Pitch Angle (deg) . . . . . N/A  
 Max. Yaw Angle (deg) . . . . . N/A

**Figure 41. Summary of Results for Test 439107-12.**

### **3.2 TYPE I BARRICADE (TEST NO. 439107-4)**

A wooden Type I with a plywood sign panel was evaluated in this crash test. A schematic of this barricade was shown previously in Figure 6. The overall length of the barricade was 837 mm. A warning light was not attached to the barricade. The barricade was placed on pavement. A 1991 Ford Festiva, shown in Figures 42 and 43, was used in the crash test. Dimensions and information on the vehicle are given in Appendix A, Figure 83.

The vehicle impacted the barricade head-on at a speed of 98.12 km/h. At 0.005 s after impact, the right front support of the A-frame fractured at bumper height. The barricade folded up with the front and rear supports impacting each other at 0.023 s, causing three of the four supports to fracture. At 0.052 s, the top of the A-frame contacted and shattered the windshield. By 0.077 s, the barricade was parallel with the ground, just over the hood, and then rotated up and over the vehicle. As the vehicle lost contact with the A-frame, the vehicle was traveling at 92.79 km/h. Brakes on the vehicle were applied as the vehicle exited the test site, and subsequently came to rest 89.0 m down and 4.6 m to the left of impact point. Sequential photographs of the test can be found in Appendix B, Figure 91.

The A-frame barricade separated into multiple pieces, as shown in Figure 44. The debris extended 7.3 m to the right, 17.7 m to the left, and 68.6 m down from impact.

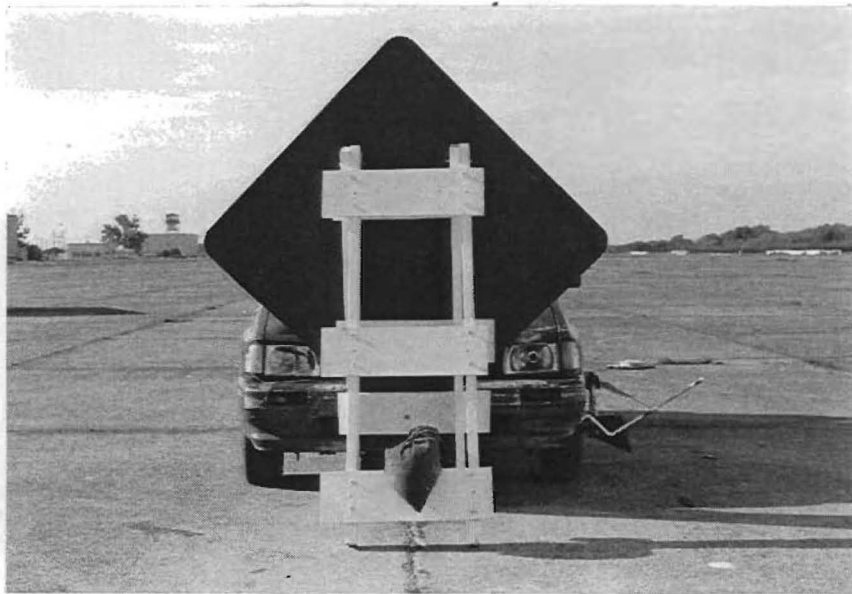
The windshield of the vehicle was shattered and pushed inward, as shown in Figure 45. The bumper was dented and scraped.

A summary of the test results is shown in Figure 46. The test is judged to be unsatisfactory due to the shattering of the windshield and partial intrusion into the occupant compartment. It is anticipated that similar unsatisfactory performance would result even if the plywood sign panel is replaced with a lightweight fabric/plastic sign panel. Thus, the field implementation of wooden Type I barricade, with or without sign panel, is not recommended under test level 3 conditions.

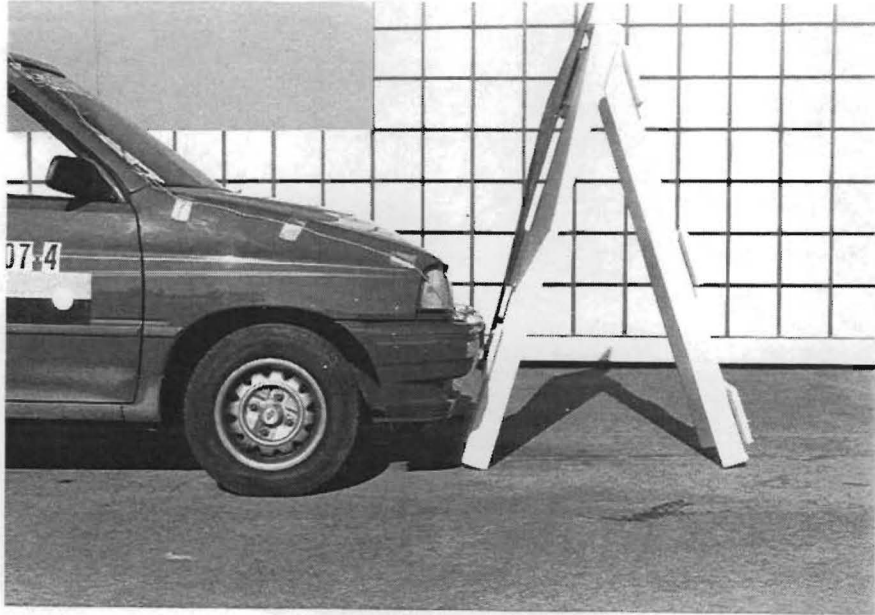
### **3.3 PORTABLE SIGN SUPPORT (TEST NO. 439107-6)**

A spring-loaded portable sign support with a fabric/plastic sign panel mounted at a height of 610 mm was evaluated in this crash test. A schematic of this portable sign support was shown previously in Figure 7. A warning light was not attached to the sign support. The sign support was placed on pavement for this test. A 1991 Ford Festiva, shown in Figures 47 and 48, was used in the crash test. Dimensions and information on the vehicle are given in Appendix A, Figure 92.

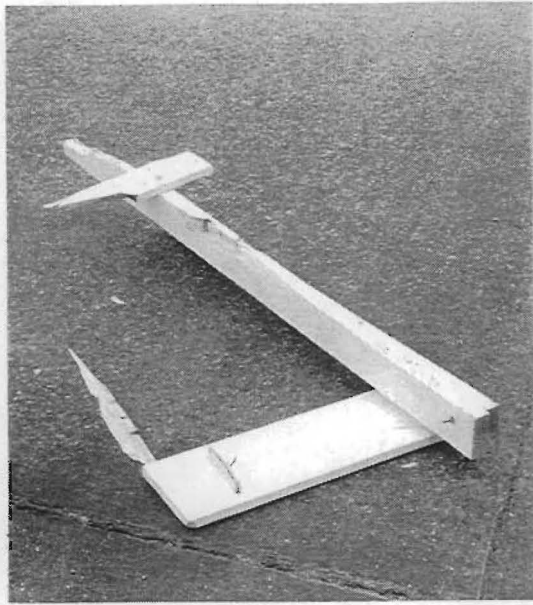
The vehicle impacted the spring-loaded portable sign support head-on at a speed of 99.09 km/h. At 0.047 s after impact, the support deformed at bumper height, and the upper and lower tubes pulled apart at 0.051 s. The fabric/plastic sign panel separated from the lower tube at 0.062 s. At 0.066 s, the fabric/plastic sign panel and the upper tube support contacted the windshield. At 0.094 s, the lower tube of the support deformed and contacted the ground.



**Figure 42. Vehicle/Installation Geometrics for Test 439107-4.**



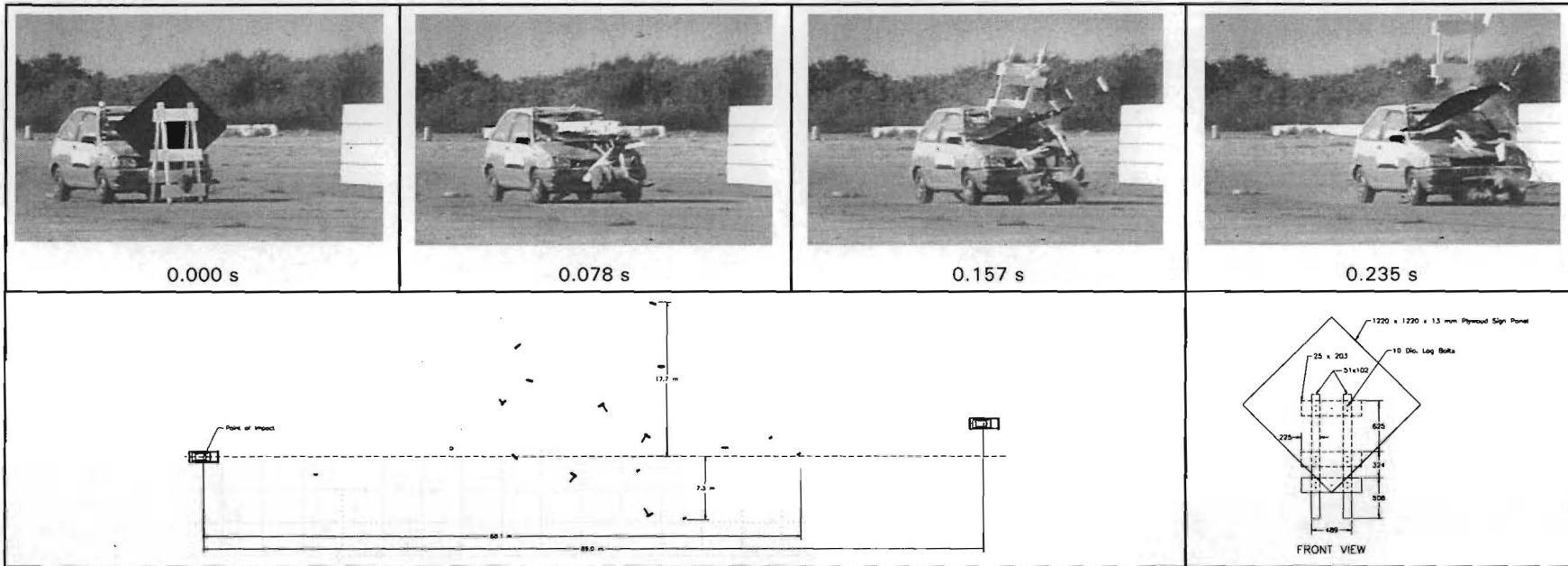
**Figure 43. Vehicle Before Test 439107-4.**



**Figure 44. Installation After Test 439107-4.**



**Figure 45. Vehicle After Test 439107-4.**

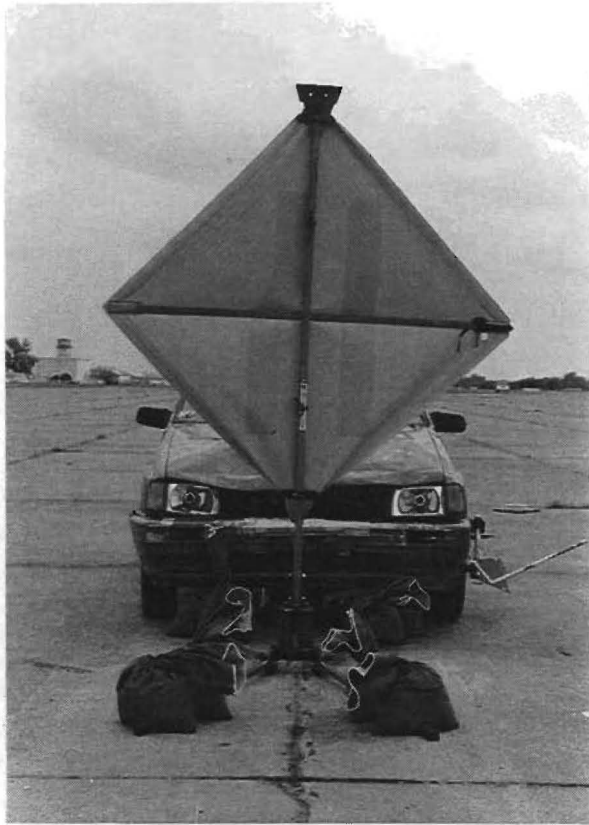


64

<b>General Information</b>		<b>Impact Conditions</b>		<b>Debris Pattern Spread (m)</b>	
Test Agency	Texas Transportation Institute	Speed (km/h)	98.12	Longitudinal	68.1
Test No.	439107-4	Angle (deg)	0	Lateral	17.7
Date	04/10/97				
<b>Test Article</b>		<b>Exit Conditions</b>		<b>Vehicle Damage</b>	
Type	Traffic Control Device	Speed (km/h)	92.79	Exterior	
Name	Type I wooden A-frame	Angle (deg)	0	VDS	12FD1
Installation Length (m)	0.84			CDC	12FDEW1
Size and/or dimension		<b>Occupant Risk Values</b>		Maximum Exterior	
and material of key	Wooden A-frame with	Impact Velocity (m/s)		Vehicle Crush (mm)	nil
elements	1.2x1.2 m plywood sign panel	x-direction	N/A	Interior	
Soil Type and Condition	Concrete Pavement, dry	y-direction	N/A	OCDI	FS0000000
Test Vehicle		Ridedown Accelerations (g's)		Max. Occ. Compart.	
Type	Production	x-direction	N/A	Deformation (mm)	0
Designation	820C	y-direction	N/A	<b>Post-Impact Behavior</b>	
Model	1991 Ford Festiva	Max. 0.050-s Average (g's)		(during 1.0 s after impact)	
Mass (kg) Curb	838	x-direction	N/A	Max. Roll Angle (deg)	N/A
Test Inertial	820	y-direction	N/A	Max. Pitch Angle (deg)	N/A
Dummy	76	z-direction	N/A	Max. Yaw Angle (deg)	N/A
Gross Static	896				

Figure 46. Summary of Results for Test 439107-4.





**Figure 47. Vehicle/Installation Geometrics for Test 439107-6.**



**Figure 48. Vehicle Before Test 439107-6.**

The fabric/plastic sign panel moved up over the windshield; the upper tube support contacted the roof, and then flew off the vehicle at 0.196 s. The vehicle was traveling at 92.35 km/h at this time. The base rode along with the vehicle and came to rest under the vehicle 93.9 m down from impact. Sequential photographs of the test can be found in Appendix B, Figure 92.

The fabric/plastic sign panel and the upper tube separated from the spring-loaded sign support, as shown in Figures 49 and 50. The fabric/plastic sign panel and the upper tube support came to rest 31.2 m down and 10.6 m to the left of impact point. The base and lower tube support stayed with the vehicle.

The vehicle received damage to the front and the roof, as shown in Figure 51. The bumper, grill, and hood received scrapes. The roof was cut and dented.

A summary of the test results is shown in Figure 52. The test is judged to be successful, meeting all evaluation criteria set forth in NCHRP Report 350. The use of portable spring-loaded sign supports at the higher mounting height of 610 mm is, therefore, considered acceptable.

### **3.4 GROUND-MOUNTED TYPE III BARRICADE**

Three crash tests were conducted on the ground-mounted Type III barricade design. The first test (test no. 439107-7) involved a single ground-mounted Type III barricade impacted in an end-on (90 deg.) configuration, a schematic of which was shown previously as Figure 8. The other two crash tests (test nos. 439107-8 and 9) involved dual ground-mounted Type III barricades erected side by side with a gap of 305 mm between them so the test vehicle would impact one support from each barricade simultaneously, a schematic of which was shown previously in Figure 9.

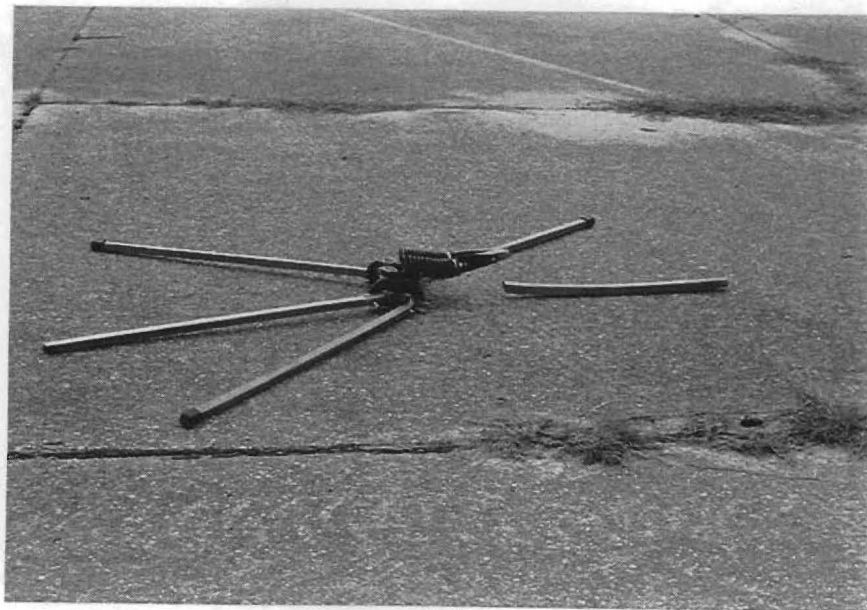
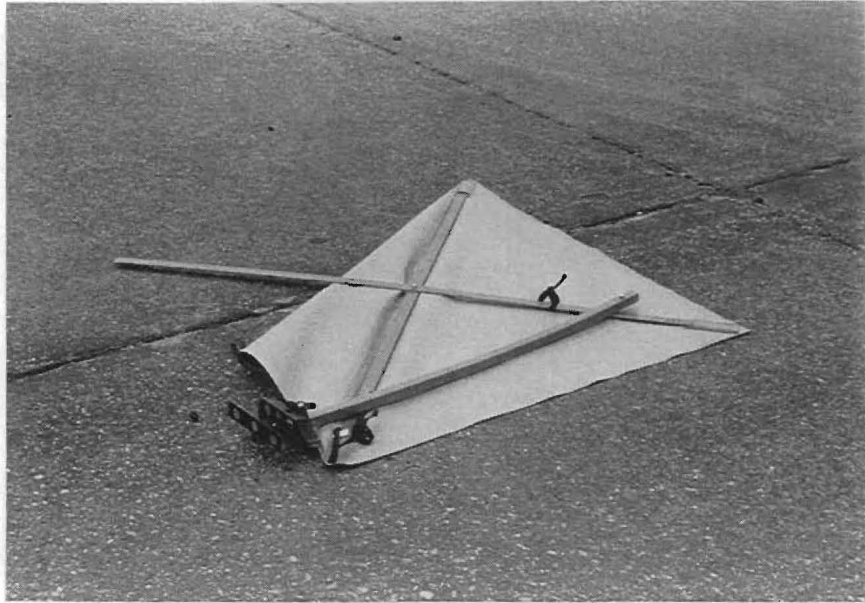
#### **3.4.1 Test No. 439107-7**

A 1991 Ford Festiva, shown in Figures 53 and 54, was used in this test. Dimensions and information on the vehicle are given in Appendix A, Figure 83. The barricade was placed on dry soil. The vehicle impacted the barricade end-on at a speed of 98.95 km/h. At 0.014 s after impact, the vehicle contacted the first upright support, and at 0.024 s, the horizontal panels began to separate. The vehicle contacted the second upright support at 0.092 s. As the vehicle exited the test site, it was traveling at a speed of 86.59 km/h. The brakes on the vehicle were applied, and the vehicle came to rest 68.9 m down and 4.3 m to the left of the impact point.

The barricade separated into several pieces, as shown in Figures 55 and 56. The debris extended 42.1 m down, 8.5 m to the left, and 7.0 m to the right of the impact point. Sequential photographs of the test can be found in Appendix B, Figure 93.



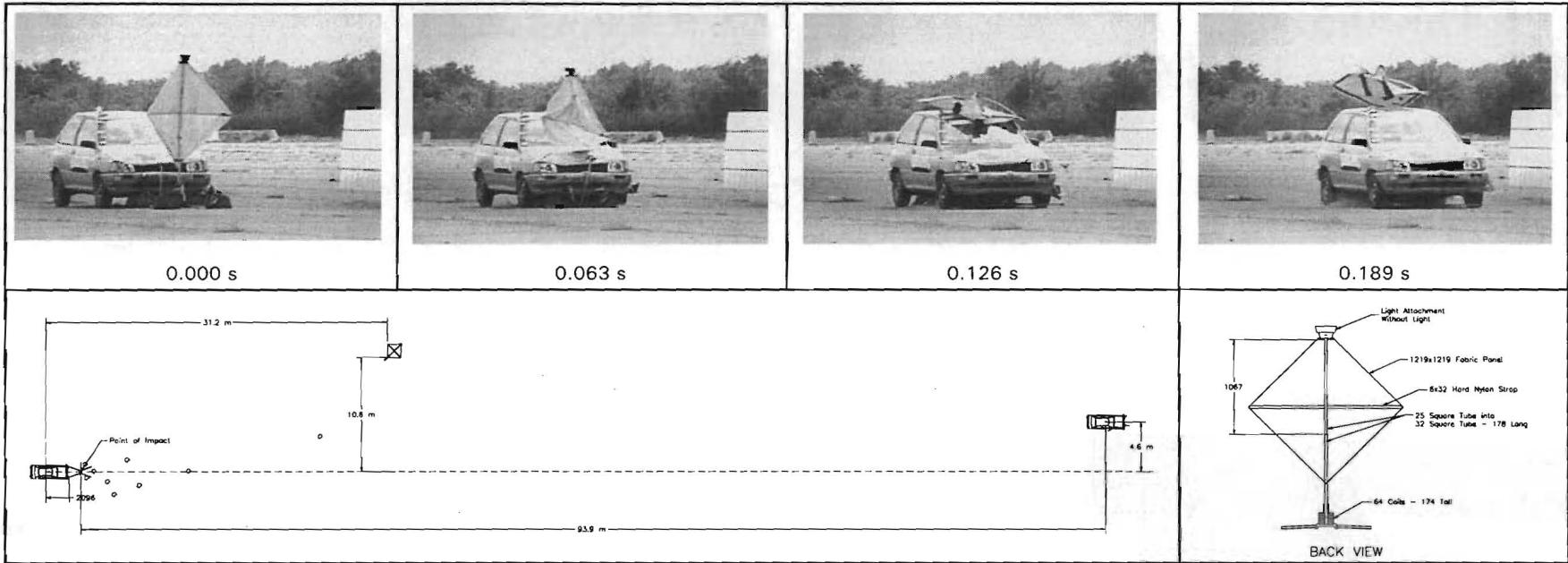
**Figure 49. After Impact Trajectory for Test 439107-6.**



**Figure 50. Installation After Test 439107-6.**



**Figure 51. Vehicle After Test 439107-6.**



71

**General Information**

Test Agency . . . . . Texas Transportation Institute  
 Test No. . . . . 439107-6  
 Date . . . . . 04/10/97

**Test Article**

Type . . . . . Traffic Control Device  
 Name . . . . . Spring-loaded Portable Sign  
 Installation Length (m) . . . . . 2.03  
 Size and/or dimension and material of key elements . . . . . 25x25 mm square tube support with fabric sign panel  
 Soil Type and Condition . . . . . Concrete Pavement, dry

**Test Vehicle**

Type . . . . . Production  
 Designation . . . . . 820C  
 Model . . . . . 1991 Ford Festiva  
 Mass (kg) Curb . . . . . 838  
 Test Inertial . . . . . 820  
 Dummy . . . . . 76  
 Gross Static . . . . . 896

**Impact Conditions**

Speed (km/h) . . . . . 99.09  
 Angle (deg) . . . . . 0

**Exit Conditions**

Speed (km/h) . . . . . 92.35  
 Angle (deg) . . . . . 0

**Occupant Risk Values**

Impact Velocity (m/s)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 Ridedown Accelerations (g's)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 Max. 0.050-s Average (g's)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 z-direction . . . . . N/A

**Debris Pattern Spread (m)**

Longitudinal . . . . . 93.9  
 Lateral . . . . . 10.6

**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. Roll Angle (deg) . . . . . N/A  
 Max. Pitch Angle (deg) . . . . . N/A  
 Max. Yaw Angle (deg) . . . . . N/A

**Figure 52. Summary of Results for Test 439107-6.**



**Figure 53. Vehicle/Installation Geometrics for Test 439107-7.**





**Figure 54. Vehicle Before Test 439107-7.**



**Figure 55. After Impact Trajectory for Test 439107-7.**



**Figure 56. Installation After Test 439107-7.**

The vehicle received moderate damage to the center front as shown in Figure 57. The front bumper, grill, and hood were dented a maximum of 51 mm. The hood received a tear, and the windshield was shattered in the lower right corner.

A summary of the test results is shown in Figure 58. This test is judged to be successful, meeting all evaluation criteria set forth in NCHRP Report 350. This test indicates that impact with the ground-mounted Type III barricade in an end-on configuration does not pose undue hazard to errant vehicles.

### **3.4.2 Test No. 439107-8**

A 1990 Ford Festiva, shown in Figures 59 and 60, was used in this test. Dimensions and information on the vehicle are given in Appendix A, Figure 82. The barricade was placed on dry soil. The vehicle impacted one support of both barricades simultaneously at a speed of 35.37 km/h. At 0.004 s after impact, the inner supports began to deform, and at 0.016 s, the lower horizontal panels began to fracture apart. The outer supports began to rotate at 0.020 s, and the upper panels began to fracture at the outer supports at 0.072 s. By 0.100 s, the barricade separated into multiple pieces. The vehicle was traveling at a speed of 21.07 km/h as it lost contact with the barricades. The brakes were then applied, and the vehicle subsequently came to rest 18.9 m down and 3.6 m to the left of the impact point.

Most of the debris remained at the impact point, as shown in Figures 61 and 62. The outer supports of the barricade remained upright, and the two supports impacted by the vehicle laid over on the ground. One small fragment of the support was 4.3 m down and 1.8 m to the left of the impact point. Sequential photographs of the test can be found in Appendix B, Figure 94.

The vehicle received minor dents and scrapes to the bumper and hood, as shown in Figure 63.

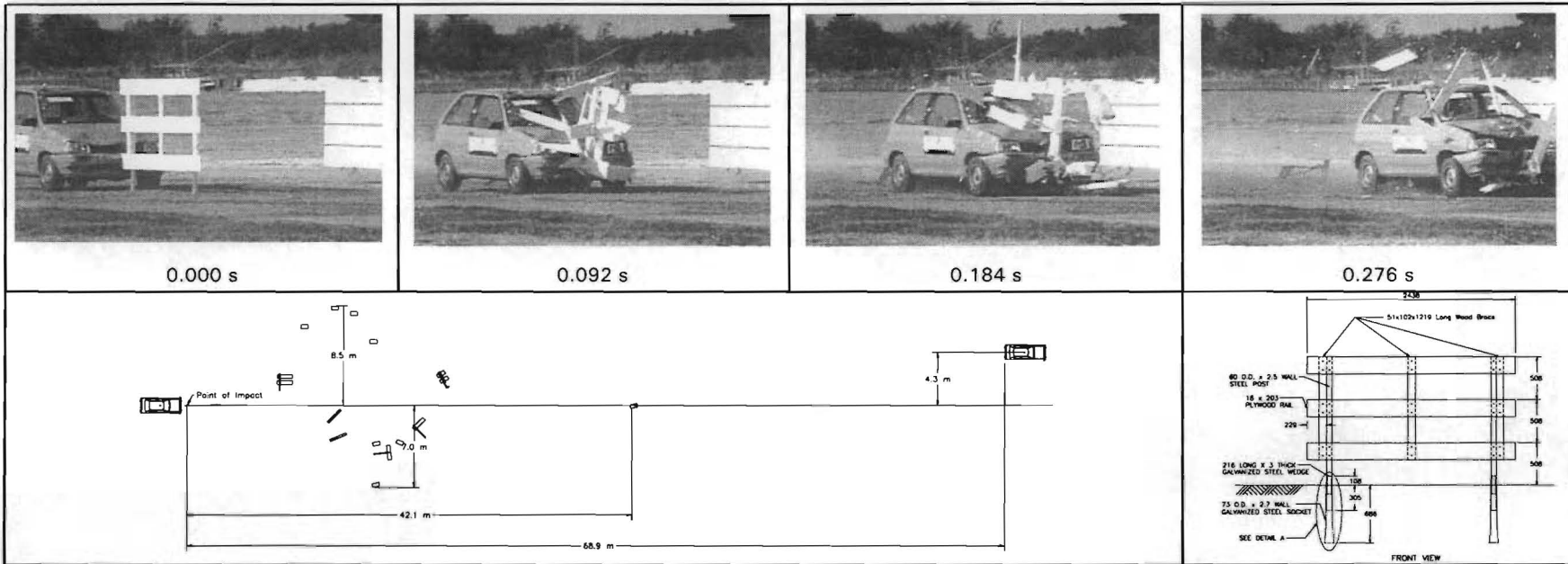
A summary of the test results is shown in Figure 64. This test is judged to be successful, meeting all evaluation criteria set forth in NCHRP Report 350. The ground-mounted vertical supports functioned as designed under low-speed impact conditions.

### **3.4.3 Test No. 439107-9**

The 1990 Ford Festiva used in the previous test (test no. 439107-8) was also used in this test, as shown in Figures 65 and 66. The barricade was placed on dry soil. The vehicle impacted both barricades simultaneously at a speed of 99.04 km/h. At 0.004 s after impact, the two impacted supports began to deform, and at 0.008 s, the lower horizontal panels began to fracture. The impacted support of the right barricade began to fracture at bumper height at 0.012 s, and the impacted support on the left barricade developed a tear at bumper height at 0.016 s. By 0.020 s, the barricades separated into several pieces, and at 0.040 s, the impacted support on the left barricade fractured near ground level. The vehicle was traveling at 88.80



**Figure 57. Vehicle After Test 439107-7.**



78

**General Information**

Test Agency . . . . . Texas Transportation Institute  
 Test No. . . . . 439107-7  
 Date . . . . . 04/17/97

**Test Article**

Type . . . . . Traffic Control Device  
 Name . . . . . Ground-mounted Type III Barricade  
 Installation Length (m) . . . . . 2.44  
 Size and/or dimension  
 and material of key . . . . . 51x102 mm wooden support  
 elements . . . . . with 16x102 mm elements  
 Soil Type and Condition . . . . . Standard soil, dry

**Test Vehicle**

Type . . . . . Production  
 Designation . . . . . 820C  
 Model . . . . . 1991 Ford Festiva  
 Mass (kg) Curb . . . . . 838  
 Test Inertial . . . . . 820  
 Dummy . . . . . 76  
 Gross Static . . . . . 896

**Impact Conditions**

Speed (km/h) . . . . . 98.95  
 Angle (deg) . . . . . 0

**Exit Conditions**

Speed (km/h) . . . . . 86.59  
 Angle (deg) . . . . . 0

**Occupant Risk Values**

Impact Velocity (m/s)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 Ridedown Accelerations (g's)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 Max. 0.050-s Average (g's)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 z-direction . . . . . N/A

**Debris Pattern Spread (m)**

Longitudinal . . . . . 42.1  
 Lateral . . . . . 8.5

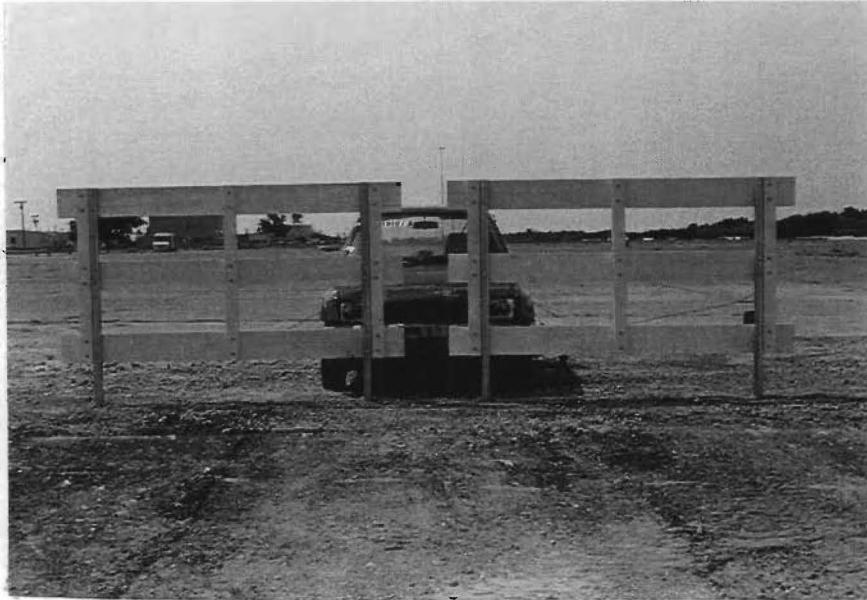
**Vehicle Damage**

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. Roll Angle (deg) . . . . . N/A  
 Max. Pitch Angle (deg) . . . . . N/A  
 Max. Yaw Angle (deg) . . . . . N/A

**Figure 58. Summary of Results for Test 439107-7.**

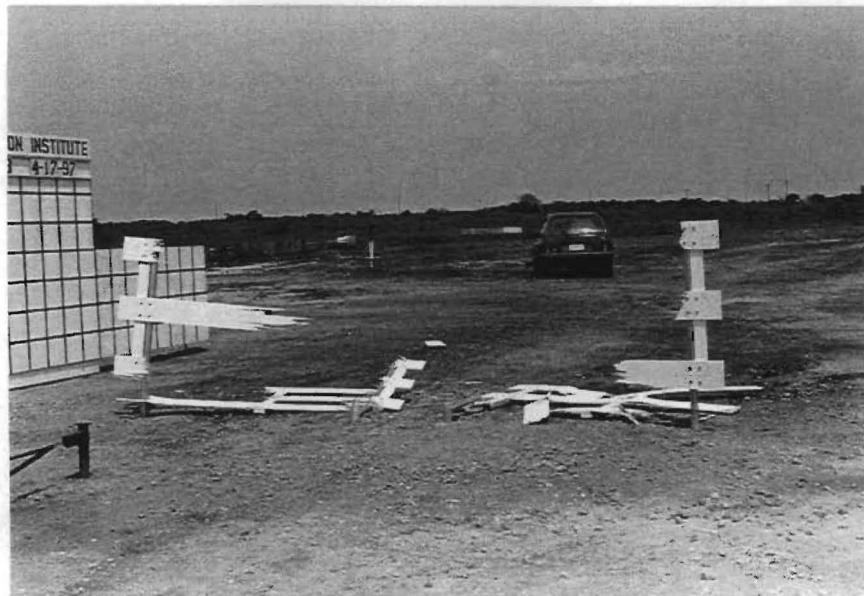
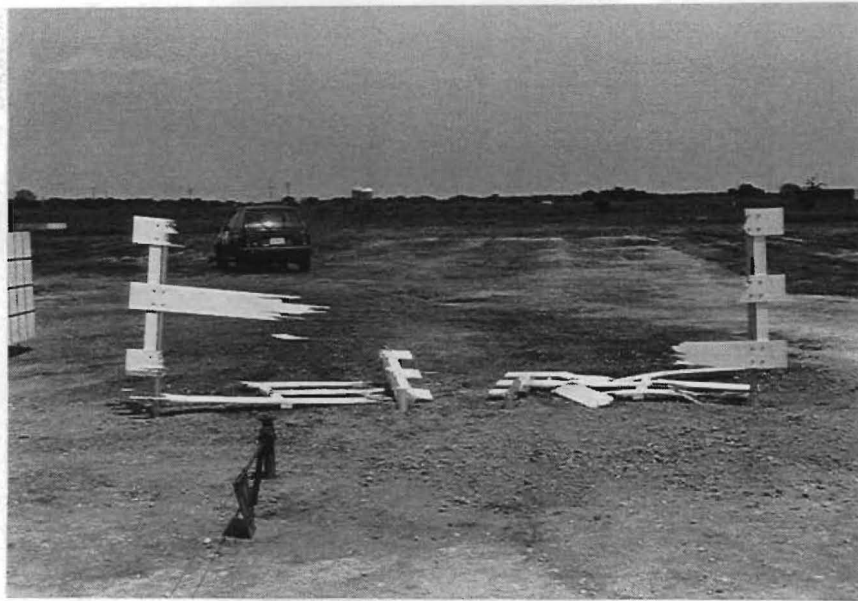


**Figure 59. Vehicle/Installation Geometrics for Test 439107-8.**

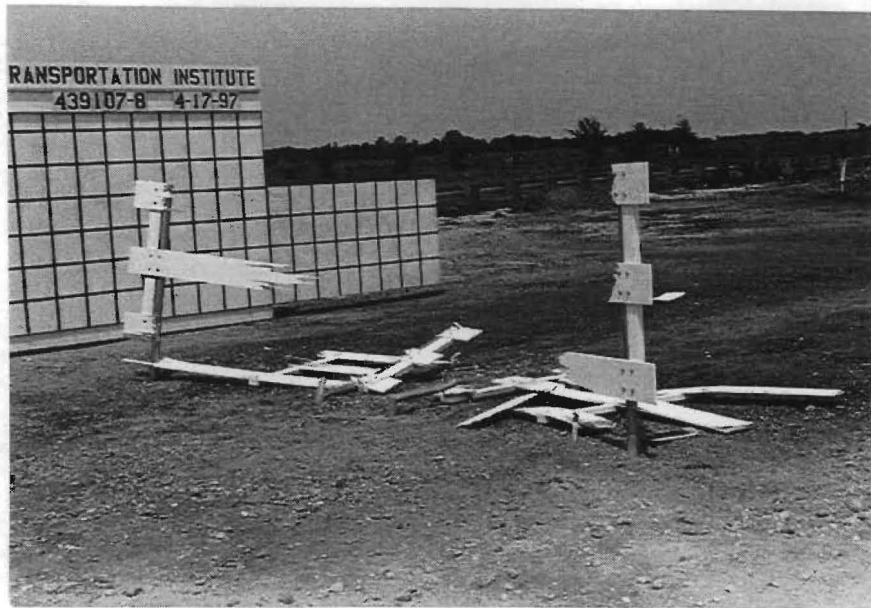
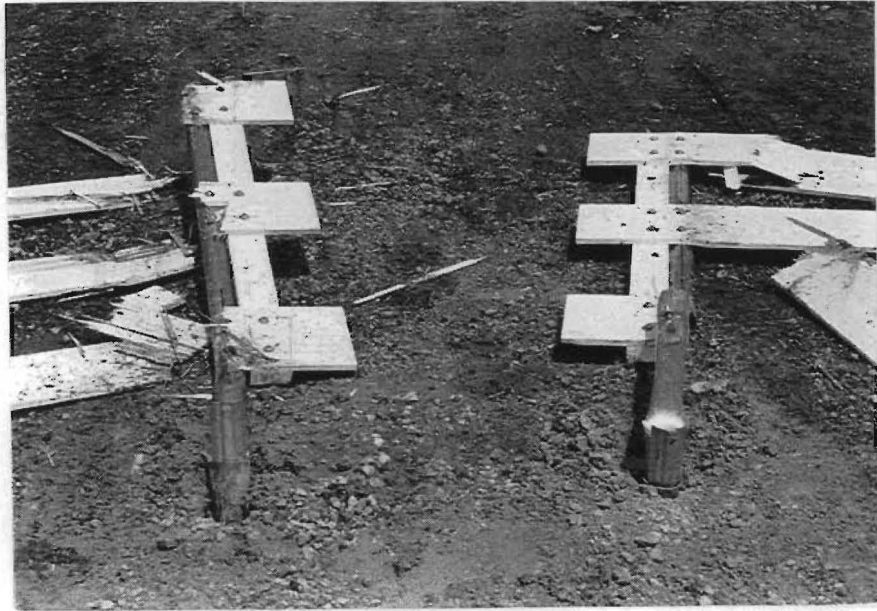


**Figure 60. Vehicle Before Test 439107-8.**





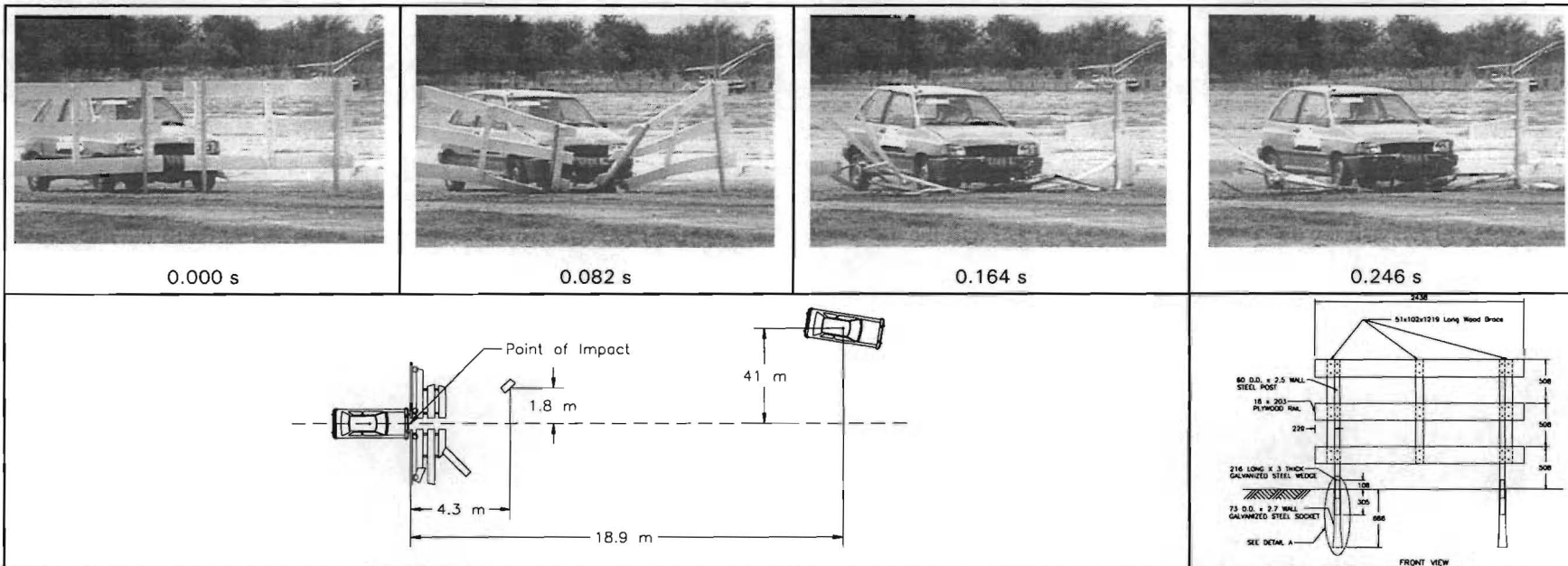
**Figure 61. After Impact Trajectory for Test 439107-8.**



**Figure 62. Installation After Test 439107-8.**



**Figure 63. Vehicle After Test 439107-8.**



84

**General Information**

Test Agency . . . . . Texas Transportation Institute  
 Test No. . . . . 439107-8  
 Date . . . . . 04/17/97

**Test Article**

Type . . . . . Traffic Control Device  
 Name . . . . . Dual Ground-mounted Type III  
 Installation Length (m) . . . . 5.18 (2.44 each w/0.3 m gap)  
 Size and/or dimension  
 and material of key  
 elements . . . . . 2 each 51x102 mm wooden  
 support w/16x102 mm elements

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

**Test Vehicle**

Type . . . . . Production  
 Designation . . . . . 820C  
 Model . . . . . 1990 Ford Festiva  
 Mass (kg) Curb . . . . . 834  
 Test Inertial . . . . . 820  
 Dummy . . . . . 76  
 Gross Static . . . . . 896

**Impact Conditions**

Speed (km/h) . . . . . 35.37  
 Angle (deg) . . . . . 0

**Exit Conditions**

Speed (km/h) . . . . . 21.07  
 Angle (deg) . . . . . 0

**Occupant Risk Values**

Impact Velocity (m/s)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 Ridedown Accelerations (g's)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 Max. 0.050-s Average (g's)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 z-direction . . . . . N/A

**Debris Pattern Spread (m)**

Longitudinal . . . . . 4.3  
 Lateral . . . . . 1.8

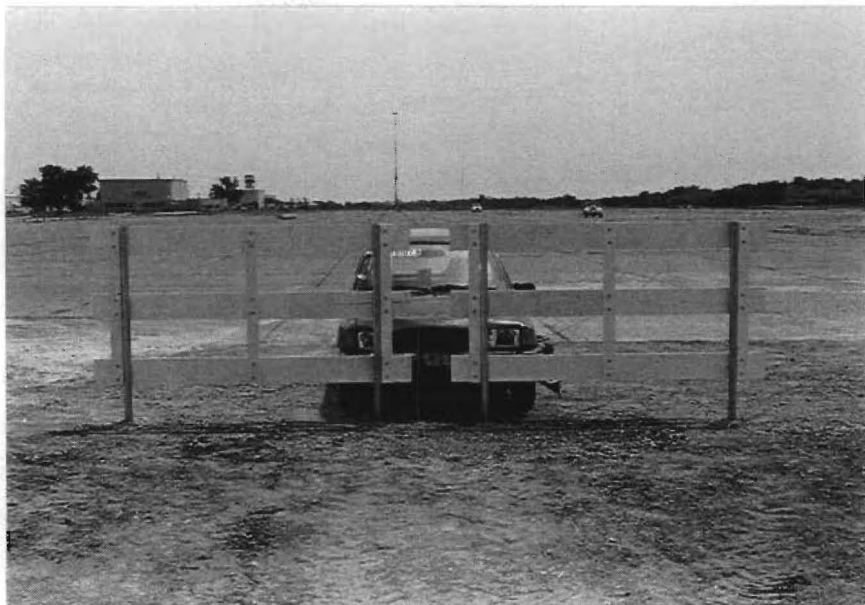
**Vehicle Damage**

Exterior  
 VDS . . . . . 12FD1  
 CDC . . . . . 12FDEW1  
 Maximum Exterior  
 Vehicle Crush (mm) . . . . nil  
 Interior  
 OCDI . . . . . FS000000  
 Max. Occ. Compart.  
 Deformation (mm) . . . . 0

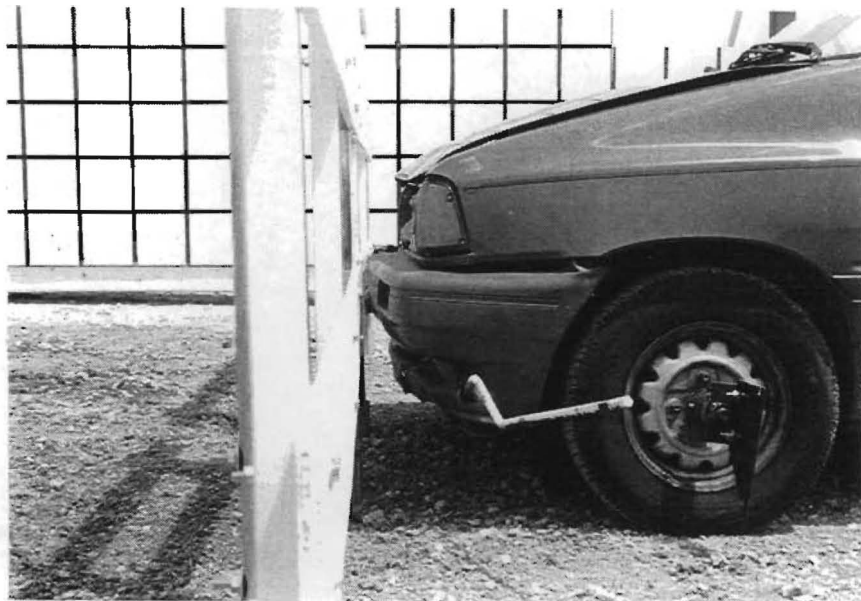
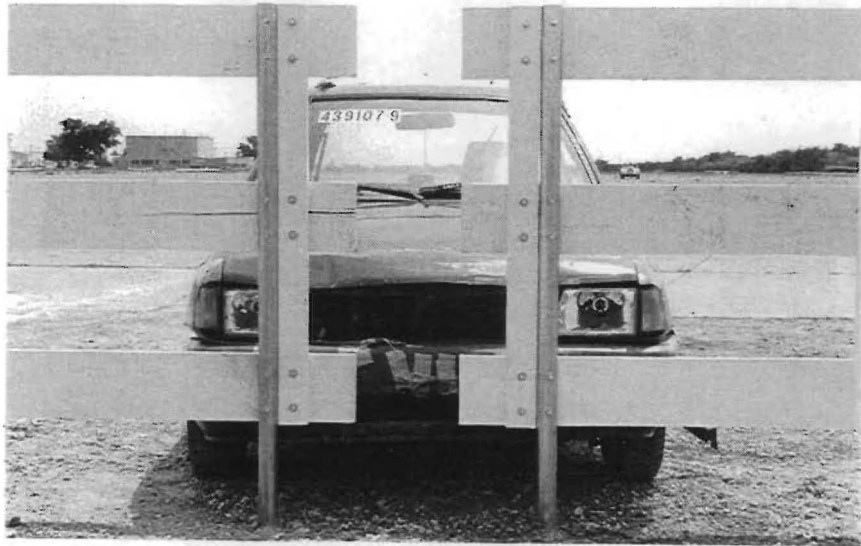
**Post-Impact Behavior**

(during 1.0 s after impact)  
 Max. Roll Angle (deg) . . . . N/A  
 Max. Pitch Angle (deg) . . . . N/A  
 Max. Yaw Angle (deg) . . . . N/A

**Figure 64. Summary of Results for Test 439107-8.**



**Figure 65. Vehicle/Installation Geometrics for Test 439107-9.**



**Figure 66. Vehicle Before Test 439107-9.**

km/h as it lost contact with the barricades. Brakes were applied on the vehicle as it left the test site, and the vehicle yawed and rotated to the left due to uneven braking forces. The vehicle subsequently came to rest 73.8 m down and 22.9 m to the left of the impact point.

About half of each barricade on the non-impact sides remained upright and in one piece, as shown in Figures 67 and 68. The impacted support of the right barricade fractured at bumper height, and the impacted support on the left barricade fractured near ground level. The remaining fragments were scattered 45.7 m down, 9.1 m to the right, and 5.4 m to the left of the impact point. Sequential photographs of the test can be found in Appendix B, Figure 95.

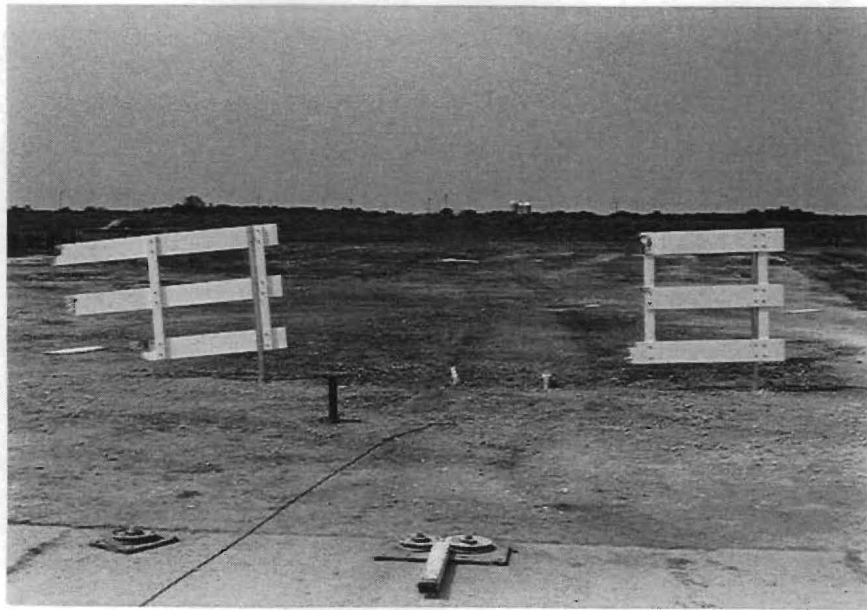
The vehicle's hood and bumper received most of the damage, as shown in Figure 69. The left strut was also damaged, and there was a scratch on the passenger side door and door glass.

A summary of the test results is shown in Figure 70. This test is judged to be successful, meeting all evaluation criteria set forth in NCHRP Report 350. The ground-mounted Type III barricade design performed satisfactorily in both the low-speed (test no. 439107-8) and high-speed (test no. 439107-9) head-on tests, as well as the end-on test (test no. 439107-7) and is, therefore, recommended for field implementation.

### **3.5 SKID-MOUNTED SIGN SUPPORT (TEST NO. 439107-10)**

A skid-mounted sign support with a 1219 mm × 1219 mm × 12.7 mm plywood sign panel mounted at a height of 2134 mm was evaluated in this crash test. A schematic of this skid-mounted sign support was shown previously in Figure 10. A warning light was not attached to the sign support. The sign support was placed on soil for this test. A 1992 Ford Festiva, shown in Figures 71 and 72, was used in the crash test. Dimensions and information on the vehicle are given in Appendix A, Figure 85.

The vehicle impacted the sign support end-on at a speed of 99.23 km/h. Shortly after impact, the vertical support on the impact side showed movement. At 0.005 s, the vertical support and the support brace on the non-impact side also started movement. The base for the vertical support on the impact side started to move at 0.008 s. At the same time, the support brace on the non-impact side broke away, causing pieces of wood from the vertical support to break away. At 0.026 s, the base of the vertical support on the impact side rolled over on its side and separated into pieces. The impact-side vertical support contacted the non-impact side vertical support at 0.032 s. The base of the vertical support on the non-impact side then rolled over and separated into pieces. Both supports contacted the vehicle with the support on the impact side, contacting the vehicle's roof just above the windshield. At 0.145 s, the support from the impact side was lying on the vehicle's roof. By 0.186 s, the sign panel and the vertical support from the impact side rotated off the back of the vehicle. The vehicle's speed at exit was 84.78 km/h. Asymmetrical brake actuation on the vehicle as it left the test site caused the vehicle to yaw and rotate to the left. The vehicle subsequently came to rest 88.7 m down and 27.4 m to the left of the impact point. Sequential photographs of the test can be found in Appendix B, Figure 96.



**Figure 67. After Impact Trajectory for Test 439107-9.**

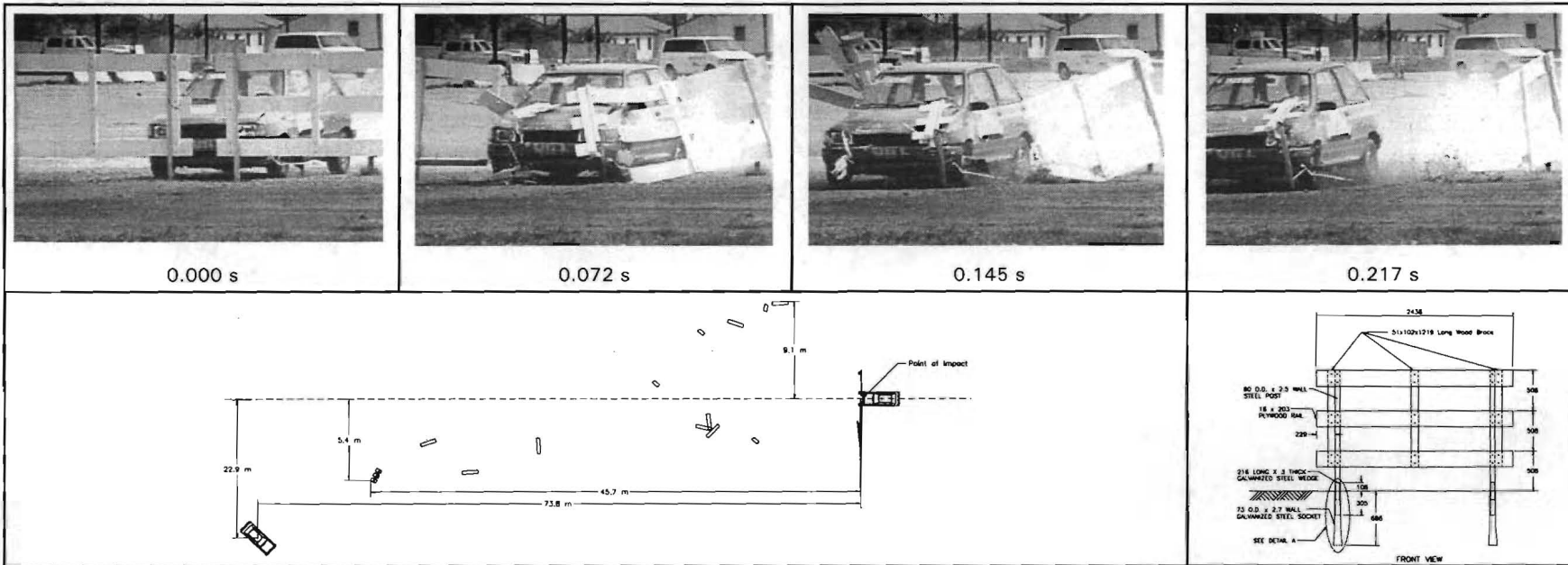




**Figure 68. Installation After Test 439107-9.**



**Figure 69. Vehicle After Test 439107-9.**



16

**General Information**

Test Agency . . . . . Texas Transportation Institute  
 Test No. . . . . 439107-9  
 Date . . . . . 04/17/97

**Test Article**

Type . . . . . Traffic Control Device  
 Name . . . . . Dual Ground-mounted Type III  
 Installation Length (m) . . . . . 5.18 (2.44 each w/0.3 m gap)  
 Size and/or dimension and material of key elements . . . . . 2 each 51x102 mm wooden support w/16x102 mm elements  
 Soil Type and Condition . . . . . Standard soil, dry

**Test Vehicle**

Type . . . . . Production  
 Designation . . . . . 820C  
 Model . . . . . 1990 Ford Festiva  
 Mass (kg) Curb . . . . . 834  
 Test Inertial . . . . . 820  
 Dummy . . . . . 76  
 Gross Static . . . . . 896

**Impact Conditions**

Speed (km/h) . . . . . 99.04  
 Angle (deg) . . . . . 0

**Exit Conditions**

Speed (km/h) . . . . . 88.80  
 Angle (deg) . . . . . 0

**Occupant Risk Values**

Impact Velocity (m/s)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 Ridedown Accelerations (g's)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 Max. 0.050-s Average (g's)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 z-direction . . . . . N/A

**Debris Pattern Spread (m)**

Longitudinal . . . . . 45.7  
 Lateral . . . . . 9.1

**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. Roll Angle (deg) . . . . . N/A  
 Max. Pitch Angle (deg) . . . . . N/A  
 Max. Yaw Angle (deg) . . . . . N/A

**Figure 70. Summary of Results for Test 439107-9.**



**Figure 71. Vehicle/Installation Geometrics for Test 439107-10.**



**Figure 72. Vehicle Before Test 439107-10.**

The barricade separated into several pieces, as shown in Figures 73 and 74. The debris extended 33.8 m down and 1.8 m to either side of the impact point.

The bumper and hood were damaged, and the roof was dented, as shown in Figure 75. The motor support was also bent. Maximum exterior crush to the center of the front bumper was 55 mm. Maximum occupant compartment deformation was 35 mm in the roof area over the left rear passenger position.

A summary of the test results is shown in Figure 76. This test is judged to be successful, meeting all evaluation criteria set forth in NCHRP Report 350. There was some minor occupant compartment deformation in the roof area over the left rear passenger position, but it was not considered to pose any potential hazard to the vehicle occupants. It may, therefore, be concluded that the skid-mounted sign support does not pose any undue hazard to errant motorists when impacted in the end-on configuration.

### **3.6 VERTICAL PANEL (TEST NO. 439107-11)**

Three different support types for use with vertical panels were evaluated in this crash test. A schematic showing the test installation and the support types was shown previously in Figure 11. The vertical panels were installed in soil for this test. A 1990 Ford Festiva, shown in Figure 77, was used in the crash test. Dimensions and information on the vehicle are given in Appendix A, Figure 84.

The vehicle impacted the first vertical panel mounted on a wooden post at a speed of 99.52 km/h. At 0.007 s, the support for the first vertical panel was fractured by the vehicle's bumper. The lower portion of the fractured support contacted the ground, followed by the upper section of the support and the attached panel contacting the vehicle. At 0.083 s, the separated upper portion of the support and attached panel from the first vertical panel assembly rotated around and impacted the top of the second vertical panel assembly. Sequential photographs of the test can be found in Appendix B, Figure 97.

The vehicle then impacted the second vertical panel mounted on steel angle, which started to deform at bumper height. By 0.122 s, the second vertical panel contacted the ground, and some pieces of the panel started to break free.

The vehicle impacted the third vertical panel mounted on a plastic C-channel at 0.184 s, while traveling at a speed of 95.68 km/h. The panel began to fracture at bumper height, and by 0.213 s, the sign panel contacted the ground. As the vehicle exited from the test installation, its speed was 92.4 km/h. The brakes were then applied, and the vehicle subsequently came to rest 53.0 m down and 0.8 m to the left of the impact point.

The wooden support for the first vertical panel assembly broke off at ground level, and the steel angle and the supports for the remaining two vertical panel assemblies were bent over, as shown in Figures 78 and 79. The panel from the first vertical panel assembly came to

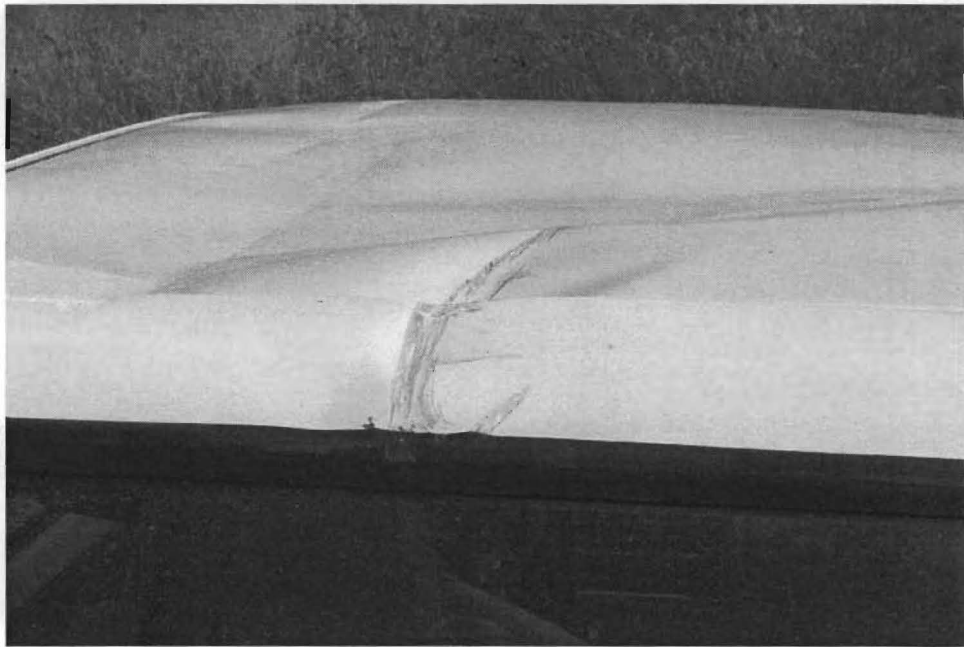


**Figure 73. After Impact Trajectory for Test 439107-10.**

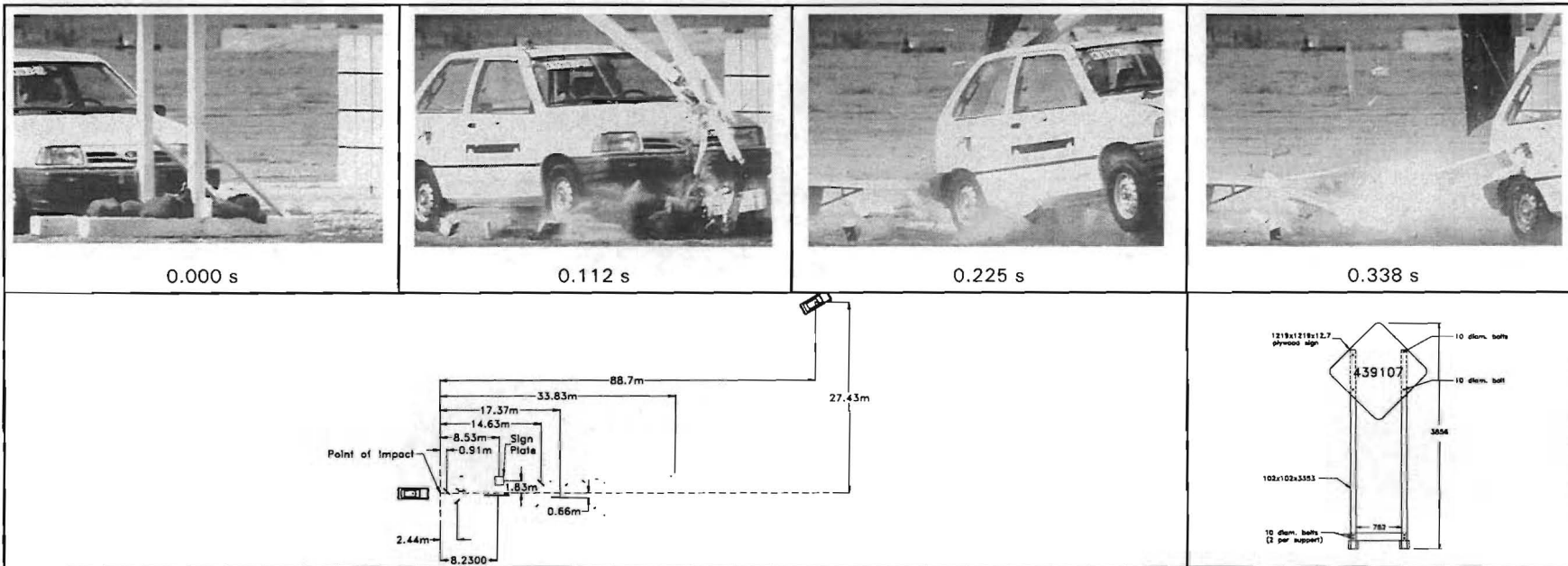


**Figure 74. Installation After Test 439107-10.**





**Figure 75. Vehicle After Test 439107-10.**



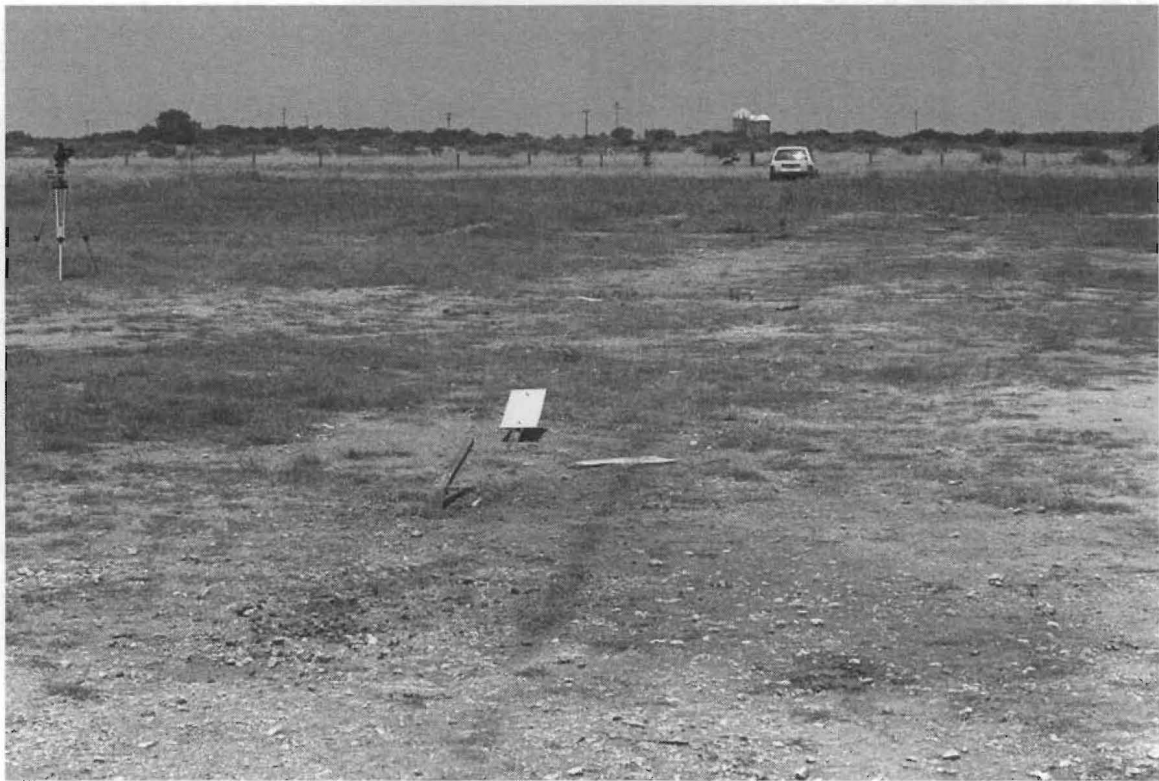
86

<p><b>General Information</b></p> <p>Test Agency . . . . . Texas Transportation Institute</p> <p>Test No. . . . . 439107-10</p> <p>Date . . . . . 06/03/97</p> <p><b>Test Article</b></p> <p>Type . . . . . Traffic Control Device</p> <p>Name . . . . . Skid-mounted barricade</p> <p>Installation Length (m) . . . . . 1.02</p> <p>Size and/or dimension and material of key elements . . . . . 102x102x3353 m tall wooden support w/1219x1219x13 sign</p> <p>Soil Type and Condition . . . . . Standard soil, dry</p> <p><b>Test Vehicle</b></p> <p>Type . . . . . Production</p> <p>Designation . . . . . 820C</p> <p>Model . . . . . 1992 Ford Festiva</p> <p>Mass (kg) Curb . . . . . 805</p> <p>    Test Inertial . . . . . 820</p> <p>    Dummy . . . . . 76</p> <p>    Gross Static . . . . . 896</p>	<p><b>Impact Conditions</b></p> <p>Speed (km/h) . . . . . 99.23</p> <p>Angle (deg) . . . . . 0</p> <p><b>Exit Conditions</b></p> <p>Speed (km/h) . . . . . 84.79</p> <p>Angle (deg) . . . . . 0</p> <p><b>Occupant Risk Values</b></p> <p>Impact Velocity (m/s)</p> <p>    x-direction . . . . . N/A</p> <p>    y-direction . . . . . N/A</p> <p>Ridedown Accelerations (g's)</p> <p>    x-direction . . . . . N/A</p> <p>    y-direction . . . . . N/A</p> <p>Max. 0.050-s Average (g's)</p> <p>    x-direction . . . . . N/A</p> <p>    y-direction . . . . . N/A</p> <p>    z-direction . . . . . N/A</p>	<p><b>Debris Pattern Spread (m)</b></p> <p>Longitudinal . . . . . 33.8</p> <p>Lateral . . . . . 1.8</p> <p><b>Vehicle Damage</b></p> <p>Exterior</p> <p>    VDS . . . . . 12FD2</p> <p>    CDC . . . . . 12FDEW2</p> <p>Maximum Exterior</p> <p>    Vehicle Crush (mm) . . . . . 55</p> <p>Interior</p> <p>    OCDI . . . . . LR0100000</p> <p>Max. Occ. Compart. Deformation (mm) . . . . . 35</p> <p><b>Post-Impact Behavior</b> (during 1.0 s after impact)</p> <p>Max. Roll Angle (deg) . . . . . N/A</p> <p>Max. Pitch Angle (deg) . . . . . N/A</p> <p>Max. Yaw Angle (deg) . . . . . N/A</p>
--	--	---

**Figure 76. Summary of Results for Test 439107-10.**



**Figure 77. Vehicle/Installation Geometrics for Test 439107-11.**



**Figure 78. After Impact Trajectory for Test 439107-11.**

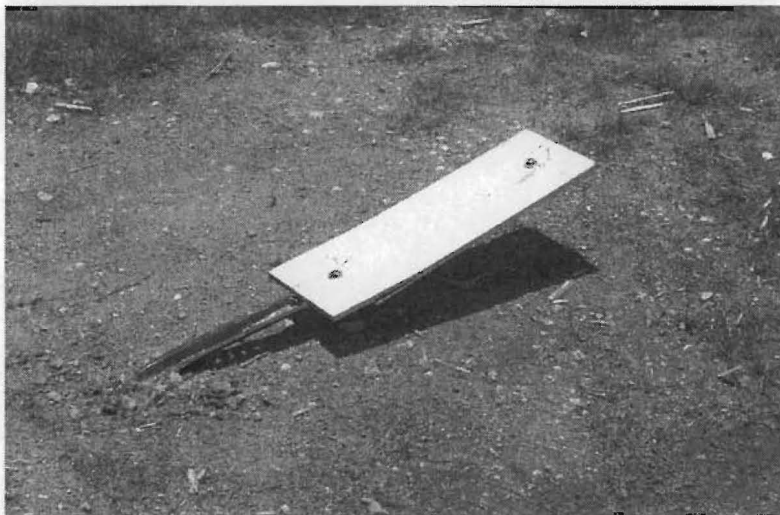


Figure 79. Installation After Test 439107-11.

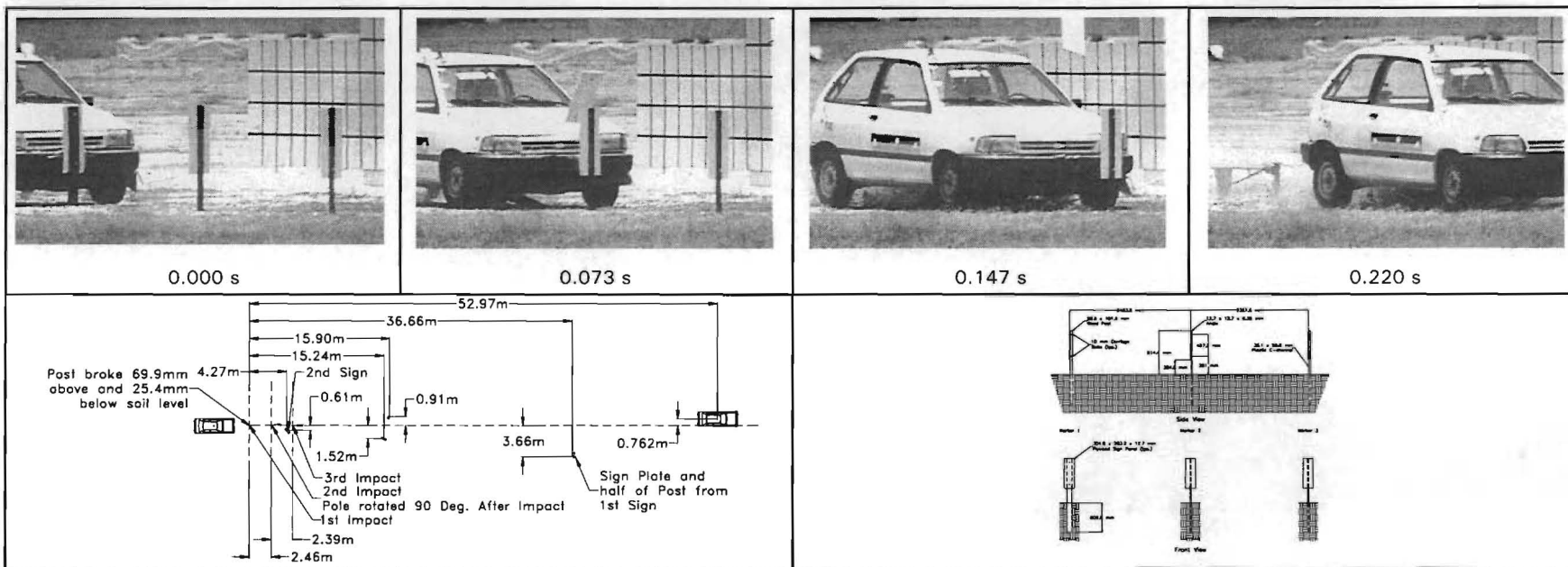
rest 36.7 m down and 3.7 m to the right of impact with pieces of the support 15.2 and 15.9 m down from impact. The panel for the second vertical panel assembly came to rest 1.8 m from its original position. The third vertical panel assembly was pushed back but remained intact.

The front bumper of the vehicle received minor scrapes only, as shown in Figure 80.

A summary of the test results is shown in Figure 81. This test is judged to be successful, meeting all evaluation criteria set forth in NCHRP Report 350. The test results indicate that all three support types for vertical panels performed satisfactorily and are acceptable for field implementation.



**Figure 80. Vehicle After Test 439107-11.**



104

**General Information**

Test Agency . . . . . Texas Transportation Institute  
 Test No. . . . . 439107-11  
 Date . . . . . 06/03/97

**Test Article**

Type . . . . . Traffic Control Device  
 Name . . . . . Delineators  
 Installation Height (m) . . . . . 0.91  
 Size and/or dimension and material of key elements . . . . .  
 Soil Type and Condition . . . . . Standard soil, dry

**Test Vehicle**

Type . . . . . Production  
 Designation . . . . . 820C  
 Model . . . . . 1990 Ford Festiva  
 Mass (kg) Curb . . . . . 828  
 Test Inertial . . . . . 820  
 Dummy . . . . . 76  
 Gross Static . . . . . 896

**Impact Conditions**

Speed (km/h) . . . . . 99.52  
 Angle (deg) . . . . . 0

**Exit Conditions**

Speed (km/h) . . . . . 92.50  
 Angle (deg) . . . . . 0

**Occupant Risk Values**

Impact Velocity (m/s)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 Ridedown Accelerations (g's)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 Max. 0.050-s Average (g's)  
 x-direction . . . . . N/A  
 y-direction . . . . . N/A  
 z-direction . . . . . N/A

**Debris Pattern Spread (m)**

Longitudinal . . . . . 36.7  
 Lateral . . . . . 1.5

**Vehicle Damage**

Exterior  
 VDS . . . . . 12FC1  
 CDC . . . . . 12FCEW1  
 Maximum Exterior  
 Vehicle Crush (mm) . . . . . nil  
 Interior  
 OCDI . . . . . FS000000  
 Max. Occ. Compart.  
 Deformation (mm) . . . . . 0

**Post-Impact Behavior**

(during 1.0 s after impact)  
 Max. Roll Angle (deg) . . . . . N/A  
 Max. Pitch Angle (deg) . . . . . N/A  
 Max. Yaw Angle (deg) . . . . . N/A

**Figure 81. Summary of Results for Test 439107-11.**



## **IV. SUMMARY OF FINDINGS AND RECOMMENDATIONS**

### **4.1 TYPE III BARRICADE**

- The attachment of warning lights to Type III barricades poses a potential hazard to the impacting vehicles and is, therefore, not recommended.
- The use of vertical braces for the horizontal rail elements to provide a more stabilized and rigid design does not adversely effect the impact performance of Type III barricades, fabricated from either hollow core plastic or steel perforated tubing, and is, therefore, recommended for field implementation. However, the size for the center vertical brace, when used with longer barricades, should be as small as practical, e.g., 25 mm × 102 mm, to minimize the potential hazard to the impacting vehicles.
- The modified connection design between the vertical supports and the skid, i.e., welding a short stub to the skid and inserting and bolting the vertical supports to the stubs, performed satisfactorily in crash tests and is, therefore, recommended for field implementation.
- The two proprietary prototype barricades with fiberglass vertical supports performed satisfactorily in crash tests and are, therefore, recommended for use in field applications. However, if the final designs for these fiberglass Type III barricades differ significantly from these prototype units, additional evaluation may be required.

### **4.2 WOODEN TYPE I BARRICADE**

- The field implementation of a wooden Type I barricade, with or without sign panel, is not recommended under test level 3 conditions.

### **4.3 SPRING-LOADED PORTABLE SIGN SUPPORT**

- A spring-loaded portable sign support with a fabric/plastic sign panel mounted at a height of 610 mm from the bottom of the sign panel to the ground performed satisfactorily in the crash test. The higher mounting height is, therefore, considered acceptable.

### **4.4 GROUND-MOUNTED TYPE III BARRICADE**

- A ground-mounted Type III barricade design using thin-wall steel tubing was developed and successfully crash tested in both head-on and end-on configurations.

The ground-mounted Type III barricade design is, therefore, recommended for field implementation.

#### **4.5 SKID-MOUNTED SIGN SUPPORT**

- A skid-mounted sign support with plywood sign panel was successfully crash tested in the end-on configuration. The skid-mounted sign support was found to perform satisfactorily in the head-on configuration in a previous crash test. The skid-mounted sign support is, therefore, recommended for field implementation.

#### **4.6 VERTICAL PANELS**

- Three candidate support types for vertical panels: 51 mm × 102 mm wooden post, 12.7 mm × 12.7 mm × 6.4 mm steel angle, and 38 mm × 51 mm plastic C-channel, were crash tested and found to perform satisfactorily. Any of these support types would be acceptable for use with vertical panels.

## REFERENCES

1. Mak, K. K., Bligh, Roger P., and Menges, W. L., "Evaluation of Work Zone Barricades and Temporary Sign Supports," Research Report 5388-1F, Texas Transportation Institute, Texas A&M University, College Station, Texas, February 1996.
2. Mak, K. K., and Campise, W. L., "Testing and Evaluation of Work Zone Traffic Control Devices," Research Report 1938-1F, Texas Transportation Institute, Texas A&M University, College Station, Texas, November 1991.
3. Mak, K. K., and Campise W. L., "Testing and Evaluation of Traffic Control Devices Used in Work Zones," Research Report 1917-1F, Texas Transportation Institute, Texas A&M University, College Station, Texas, September 1990.
4. Mak, K. K., and Campise, W. L., "Testing and Evaluation of Traffic Control Devices for Use in Work Zones," Final Report, Project 9850B, Texas Transportation Institute, Texas A&M University, College Station, Texas, January 1990.
5. Miller, A. S., "Breakaway Barricades," Public Roads, Vol. 40, No. 1, 1976.
6. Carlson, L. E., and Hoffman, A. G., "Safety Assessment of Several Traffic Channelizing Devices, Volume II - Research Results," Report No. FHWA/RD-83/024, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., March 1983.
7. Bryden, J. E., "Crash Tests of Work Zone Traffic Control Devices," Research Report 147, Engineering Research and Development Bureau, New York Department of Transportation, Albany, New York, February 1990.
8. Bryden, J. E., "Crash Tests of Work Zone Traffic Control Devices," Transportation Research Record 1254, Transportation Research Board, Washington, D.C., 1990.
9. Davis, T. D., "Signs on Breakaway Barricades - Wind and Crash Tests," Transportation Research Record 1258, Transportation Research Board, Washington, D.C., 1990
10. Ross, H. E., Jr., Sickling, D. L., Zimmer, R. A., and Michie, J. D., "Recommended Procedures for the Safety Performance Evaluation of Highway Features," NCHRP Report 350, Transportation Research Board, Washington, D.C., 1993.



**APPENDIX A.  
DIMENSIONS AND PROPERTIES OF TEST VEHICLES**

This appendix provides details on the dimensions and information on the vehicles used for the crash tests performed under this study.

DATE: 04/9&17/97 TEST NO.: 439107-1 - 8 - 9 VIN NO.: KNJPT06H1L6134324  
 YEAR: 1990 MAKE: Ford MODEL: Festivo  
 TIRE INFLATION PRESSURE: \_\_\_\_\_ ODOMETER: 66753 TIRE SIZE: 155 R12 765

MASS DISTRIBUTION (kg) LF 279 RF 267 LR 136 RR 138

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:  
 \_\_\_\_\_  
 \_\_\_\_\_

ENGINE TYPE: 4 cylinder  
 ENGINE CID: \_\_\_\_\_  
 TRANSMISSION TYPE:  
    AUTO  
    MANUAL  
 OPTIONAL EQUIPMENT:  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

DUMMY DATA:  
 TYPE: 50th perc. male  
 MASS: 76 kg  
 SEAT POSITION: Driver

GEOMETRY - (mm)

A	<u>1520</u>	E	<u>530</u>	J	<u>765</u>	N	<u>1400</u>	R	_____
B	<u>600</u>	F	<u>3420</u>	K	<u>530</u>	O	<u>1410</u>	S	_____
C	<u>2290</u>	G	_____	L	<u>104</u>	P	<u>530</u>	T	_____
D	<u>1430</u>	H	_____	M	<u>380</u>	Q	<u>330</u>	U	_____

MASS - (kg)	CURB	TEST INERTIAL	GROSS STATIC
M <sub>1</sub>	<u>533</u>	<u>546</u>	<u>557</u>
M <sub>2</sub>	<u>301</u>	<u>274</u>	<u>339</u>
M <sub>T</sub>	<u>834</u>	<u>820</u>	<u>896</u>

c:\reports\439107\veh1&2&9.dwg

Figure 82. Vehicle Properties for Test 439107-1, 8, and 9.

DATE: 04/9-10&17/97 TEST NO.: 439107-2 thru 7 VIN NO.: KNJPT06H3M6121012  
 YEAR: 1991 MAKE: Ford MODEL: Festiva  
 TIRE INFLATION PRESSURE: \_\_\_\_\_ ODOMETER: 135897 TIRE SIZE: 155 R12

MASS DISTRIBUTION (kg) LF 256 RF 266 LR 147 RR 151

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:  
 \_\_\_\_\_  
 \_\_\_\_\_

ACCELEROMETERS  
note: \_\_\_\_\_

ENGINE TYPE: 4 cylinder  
 ENGINE CID: 1.3 L  
 TRANSMISSION TYPE:  
 \_\_\_\_\_ AUTO  
 MANUAL  
 OPTIONAL EQUIPMENT:  
 \_\_\_\_\_  
 \_\_\_\_\_  
 DUMMY DATA:  
 TYPE: 50th perc. male  
 MASS: 76 kg  
 SEAT POSITION: Driver

GEOMETRY - (mm)

A	<u>1500</u>	E	<u>550</u>	J	<u>750</u>	N	<u>1400</u>	R	_____
B	<u>650</u>	F	<u>3500</u>	K	<u>540</u>	O	<u>1385</u>	S	_____
C	<u>2300</u>	G	_____	L	<u>120</u>	P	<u>535</u>	T	_____
D	<u>1460</u>	H	_____	M	<u>380</u>	Q	<u>330</u>	U	_____

MASS - (kg)	CURB	TEST INERTIAL	GROSS STATIC
M <sub>1</sub>	<u>541</u>	<u>522</u>	<u>557</u>
M <sub>2</sub>	<u>297</u>	<u>298</u>	<u>339</u>
M <sub>T</sub>	<u>838</u>	<u>820</u>	<u>896</u>

L:\reports\439107\ver2-7.dwg

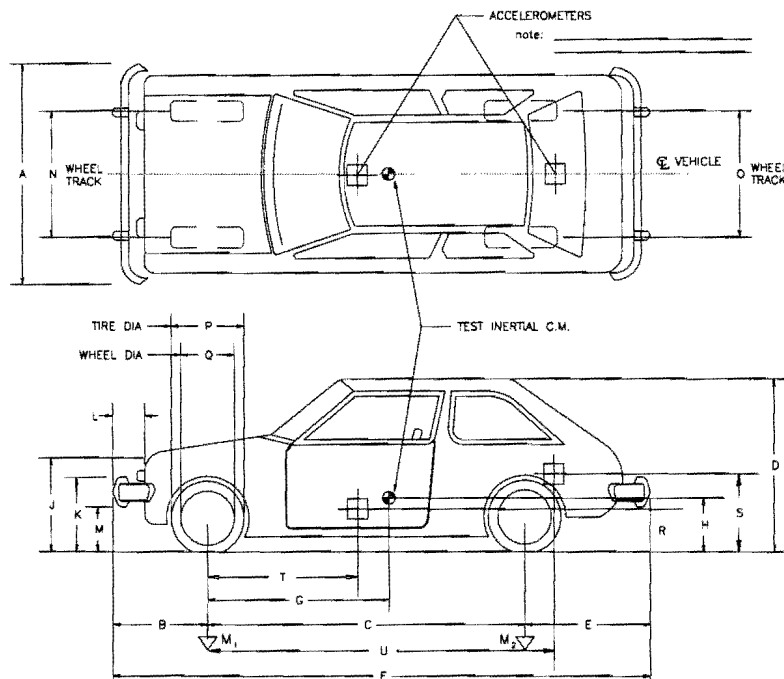
Figure 83. Vehicle Properties for Test 439107-2 Through 7.

DATE: 06/03/97 TEST NO.: 439107-11&12 VIN NO.: KNJPT06H6L6151331 MAKE: FORD  
 MODEL: FESTIVA YEAR: 1990 ODOMETER: 100730 TIRE SIZE: 155 R12  
 TIRE INFLATION PRESSURE: \_\_\_\_\_

1st Use: \_\_\_\_\_ 2nd or More Use:  Minor Damage Charged to Project: \_\_\_\_\_

MASS DISTRIBUTION (kg) LF 269 RF 251 LR 169 RR 131

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:  
 \_\_\_\_\_  
 \_\_\_\_\_



ENGINE TYPE: 4 CYL.

ENGINE CID: 1.3 L

TRANSMISSION TYPE:

AUTO

MANUAL

OPTIONAL EQUIPMENT:  
 \_\_\_\_\_  
 \_\_\_\_\_

DUMMY DATA:

TYPE: 50th perc. male

MASS: 75 kg

SEAT POSITION: driver

GEOMETRY - (mm)

A	<u>520</u>	E	<u>540</u>	J	<u>770</u>	N	<u>1380</u>	R	<u>-</u>
B	<u>640</u>	F	<u>3480</u>	K	<u>560</u>	O	<u>1395</u>	S	<u>-</u>
C	<u>2300</u>	G	<u>841.5</u>	L	<u>125</u>	P	<u>540</u>	T	<u>-</u>
D	<u>1440</u>	H	<u>-</u>	M	<u>410</u>	Q	<u>330</u>	U	<u>-</u>

MASS - (kg)	CURB	TEST INERTIAL	GROSS STATIC
M <sub>1</sub>	<u>539</u>	<u>520</u>	<u>561</u>
M <sub>2</sub>	<u>289</u>	<u>300</u>	<u>334</u>
M <sub>T</sub>	<u>828</u>	<u>820</u>	<u>895</u>

t:\reports\439107\veh11&12.dwg

Figure 84. Vehicle Properties for Test 439107-11 and 12.



DATE: 06/03/97 TEST NO.: 439107-10 VIN NO.: KWJPT05HXP6113527 MAKE: FORD  
 MODEL: FESTIVA YEAR: 1992 ODOMETER: 106094 TIRE SIZE: 155 R12  
 TIRE INFLATION PRESSURE: \_\_\_\_\_

1st Use:  2nd or More Use: \_\_\_\_\_ Minor Damage Charged to Project: \_\_\_\_\_

MASS DISTRIBUTION (kg) LF 258 RF 259 LR 156 RR 147

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:  
 \_\_\_\_\_  
 \_\_\_\_\_

ACCELEROMETERS  
note: \_\_\_\_\_

ENGINE TYPE: 4 CYL.  
 ENGINE CID: 1.3 L  
 TRANSMISSION TYPE:  
 AUTO  
 MANUAL

OPTIONAL EQUIPMENT:  
 \_\_\_\_\_  
 \_\_\_\_\_

DUMMY DATA:  
 TYPE: 50th perc. male  
 MASS: 76 kg  
 SEAT POSITION: driver

GEOMETRY - (mm)

A	<u>1500</u>	E	<u>550</u>	J	<u>760</u>	N	<u>1400</u>	R	<u>-</u>
B	<u>650</u>	F	<u>3500</u>	K	<u>550</u>	O	<u>1385</u>	S	<u>-</u>
C	<u>2300</u>	G	<u>850</u>	L	<u>120</u>	P	<u>535</u>	T	<u>-</u>
D	<u>1460</u>	H	<u>-</u>	M	<u>380</u>	Q	<u>330</u>	U	<u>-</u>

MASS - (kg)	CURB	TEST INERTIAL	GROSS STATIC
M <sub>1</sub>	<u>510</u>	<u>517</u>	<u>555</u>
M <sub>2</sub>	<u>295</u>	<u>303</u>	<u>341</u>
M <sub>T</sub>	<u>805</u>	<u>820</u>	<u>896</u>

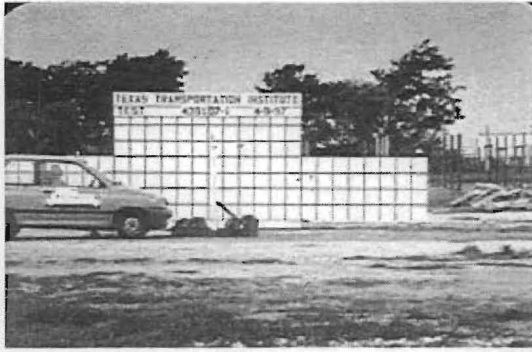
f:\reports\439107\veh10.dwg

Figure 85. Vehicle Properties for Test 439107-10.

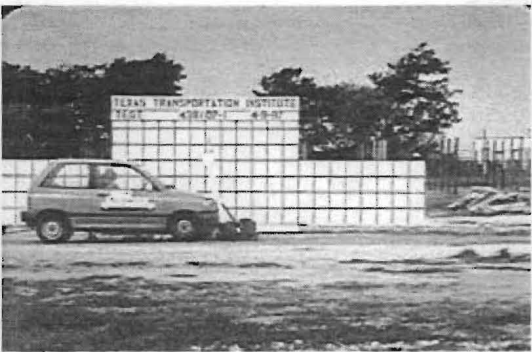


## **APPENDIX B. SEQUENTIAL PHOTOGRAPHS**

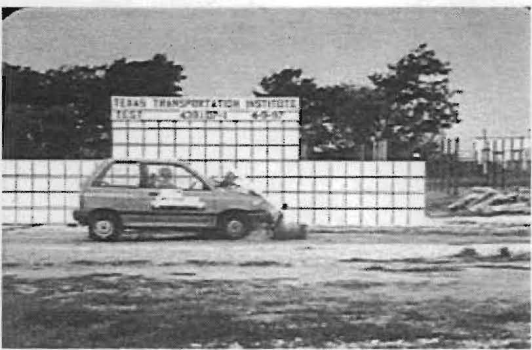
This appendix contains photographs taken from high speed film during the test sequence of the crash tests performed under this study.



0.000 s



0.037 s



0.074 s



0.112 s



**Figure 86. Sequential Photographs for Test 439107-1  
(Perpendicular and Oblique Views).**



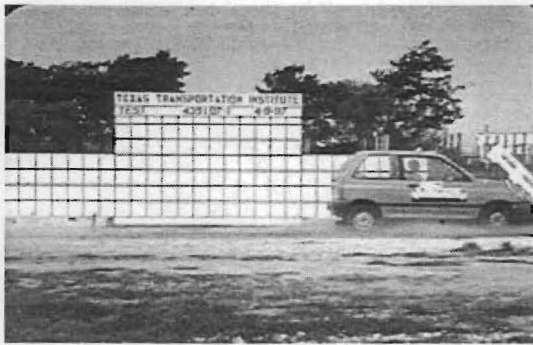
0.149 s



0.186 s



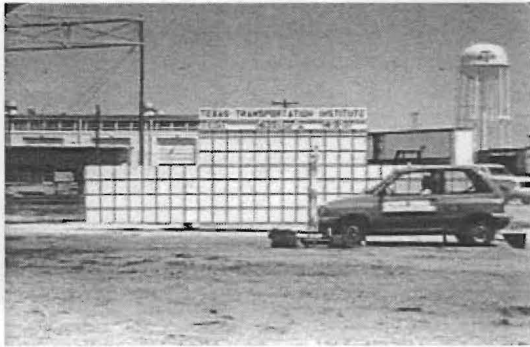
0.224 s



0.261 s



**Figure 86. Sequential Photographs for Test 439107-1 (Perpendicular and Oblique Views) (continued).**



0.000 s



0.038 s



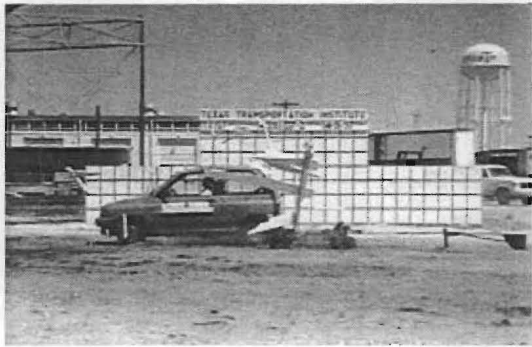
0.076 s



0.114 s



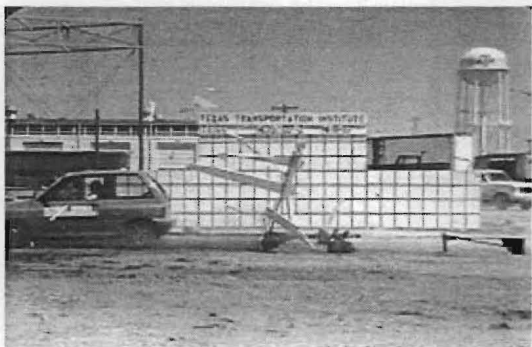
**Figure 87. Sequential Photographs for Test 439107-2  
(Perpendicular and Oblique Views).**



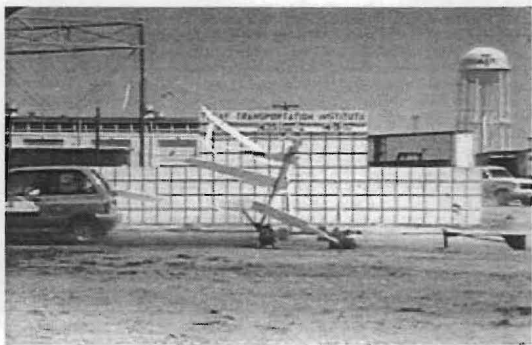
0.152 s



0.190 s



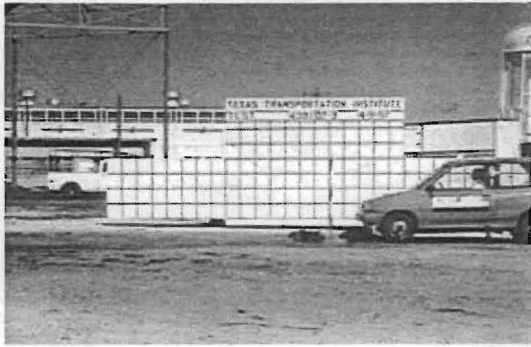
0.229 s



0.267 s



**Figure 87. Sequential Photographs for Test 439107-2  
(Perpendicular and Oblique Views) (continued).**



0.000 s



0.021 s



0.043 s



0.065 s



**Figure 88. Sequential Photographs for Test 439107-3  
(Perpendicular and Oblique Views).**





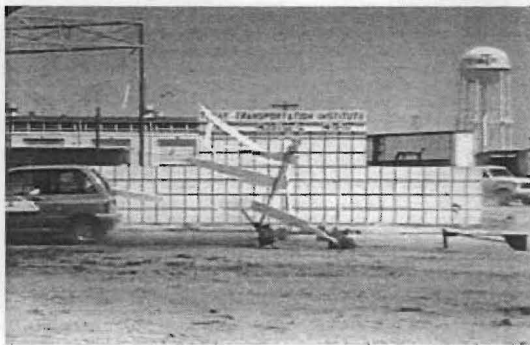
0.087 s



0.106 s



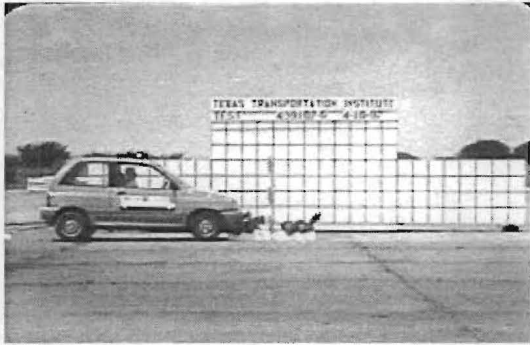
0.131 s



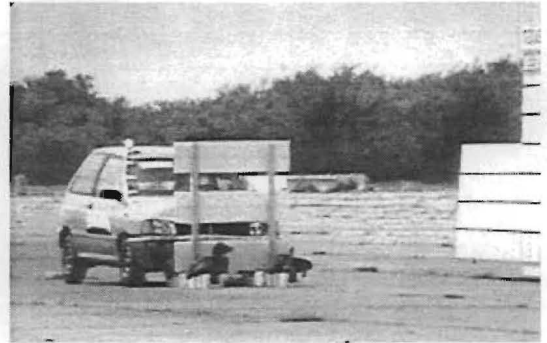
0.153 s



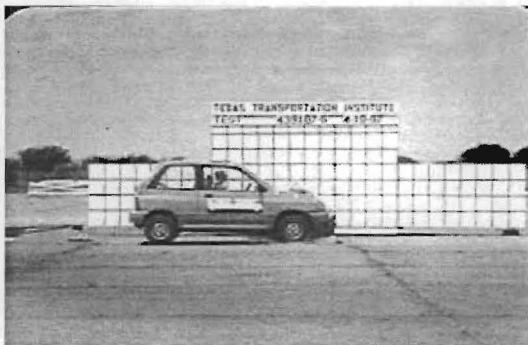
**Figure 88. Sequential Photographs for Test 439107-3  
(Perpendicular and Oblique Views) (continued).**



0.000 s



0.029 s



0.058 s



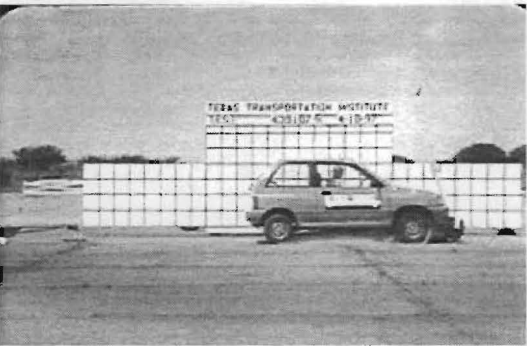
0.087 s



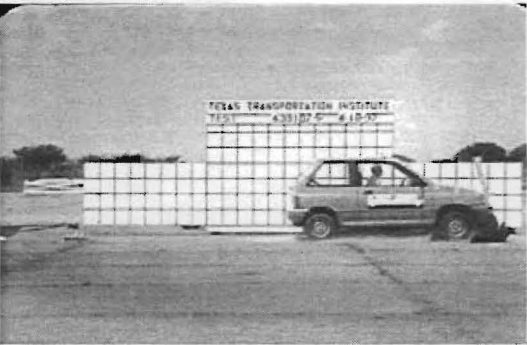
**Figure 89. Sequential Photographs for Test 439107-5 (Perpendicular and Oblique Views).**



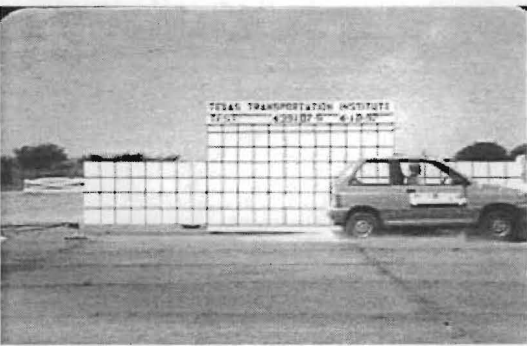
0.116 s



0.145 s



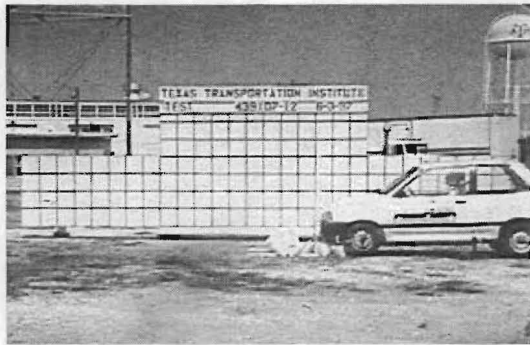
0.174 s



0.203 s



**Figure 89. Sequential Photographs for Test 439107-5  
(Perpendicular and Oblique Views) (continued).**



0.000 s



0.031 s



0.063 s



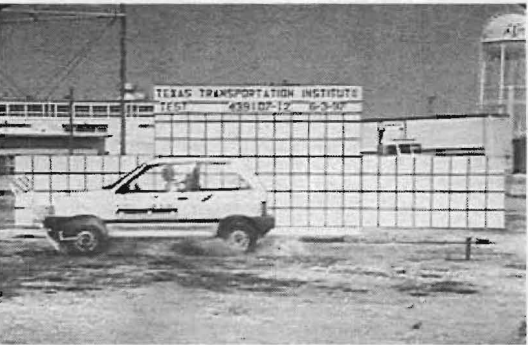
0.095 s



**Figure 90. Sequential Photographs for Test 439107-12  
(Perpendicular and Oblique Views).**



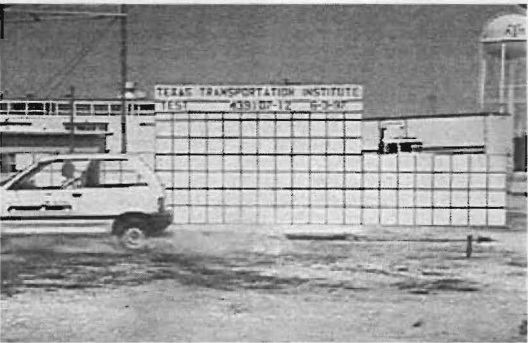
0.127 s



0.159 s



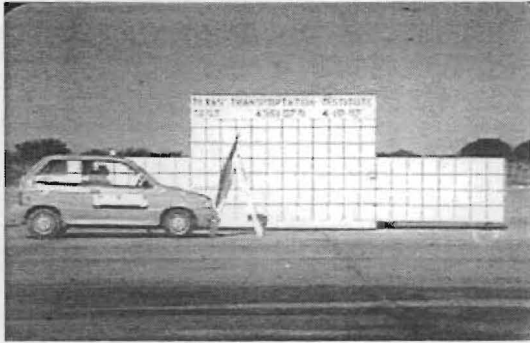
0.190 s



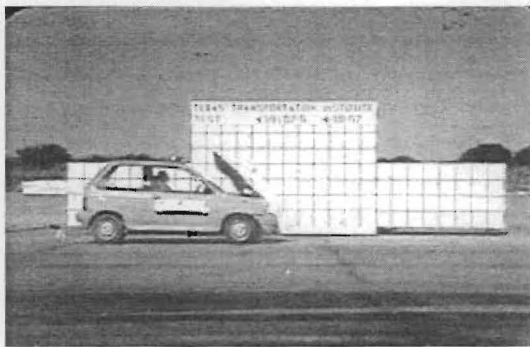
0.222 s



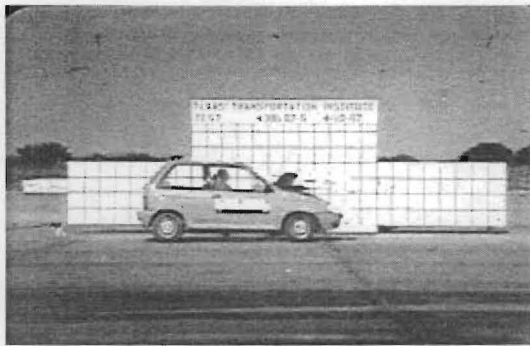
**Figure 90. Sequential Photographs for Test 439107-12 (Perpendicular and Oblique Views) (continued).**



0.000 s



0.039 s



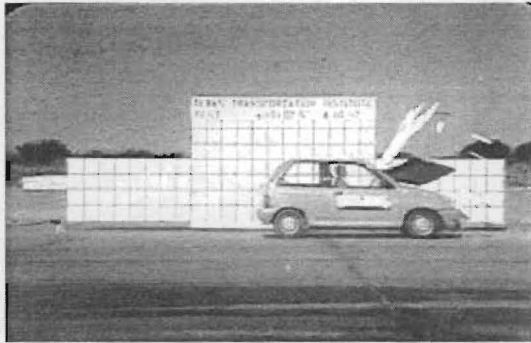
0.078 s



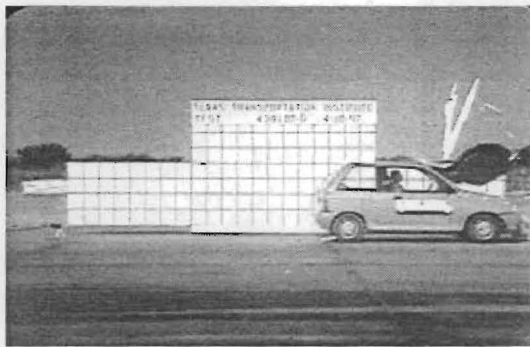
0.117 s



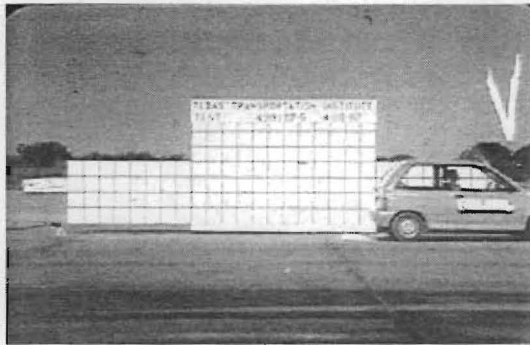
**Figure 91. Sequential Photographs for Test 439107-4  
(Perpendicular and Oblique Views).**



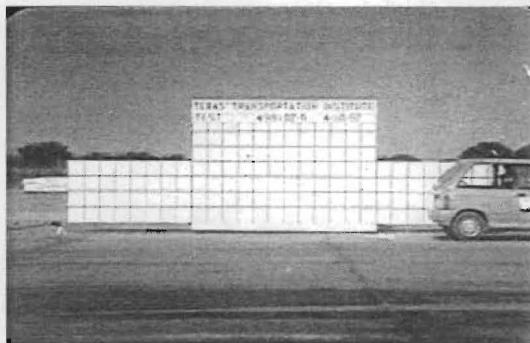
0.157 s



0.196 s



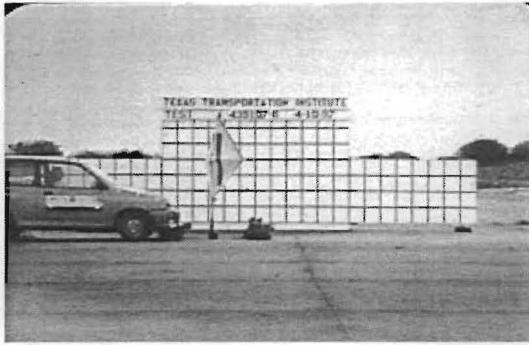
0.235 s



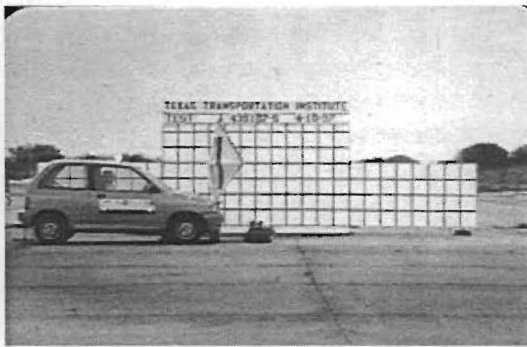
0.274 s



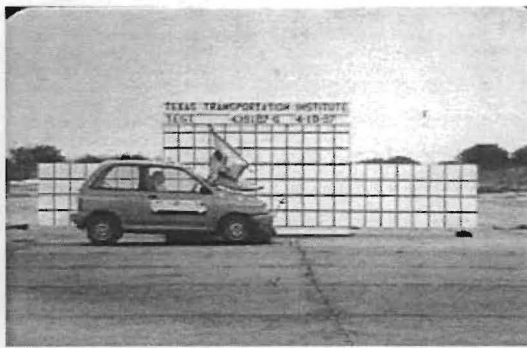
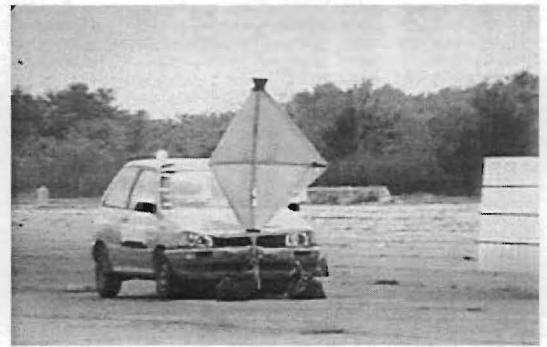
**Figure 91. Sequential Photographs for Test 439107-4  
(Perpendicular and Oblique Views) (continued).**



0.000 s



0.031 s



0.063 s



0.087 s



**Figure 92. Sequential Photographs for Test 439107-6  
(Perpendicular and Oblique Views).**





0.126 s



0.157 s



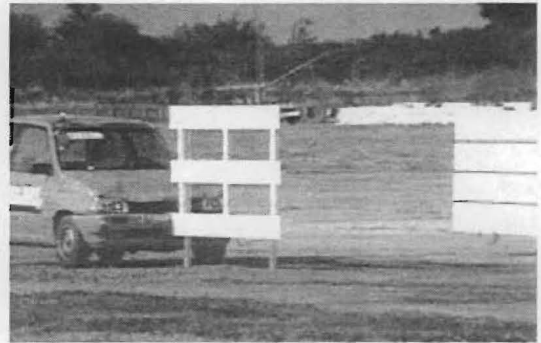
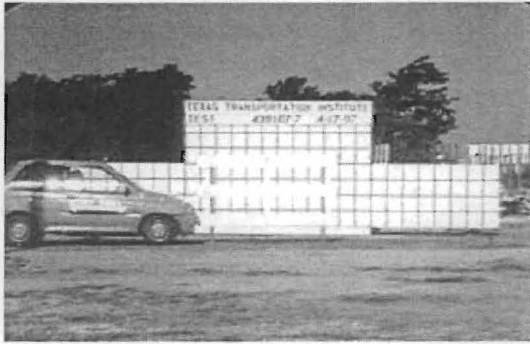
0.189 s



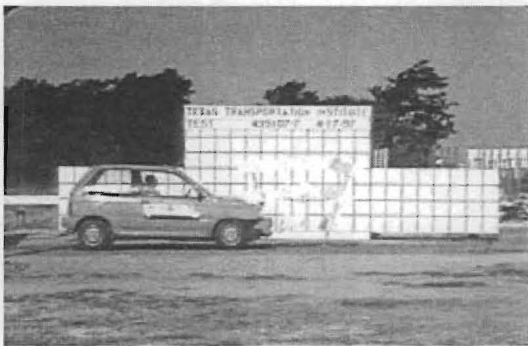
0.221 s



**Figure 92. Sequential Photographs for Test 439107-6 (Perpendicular and Oblique Views) (continued).**



0.000 s



0.046 s

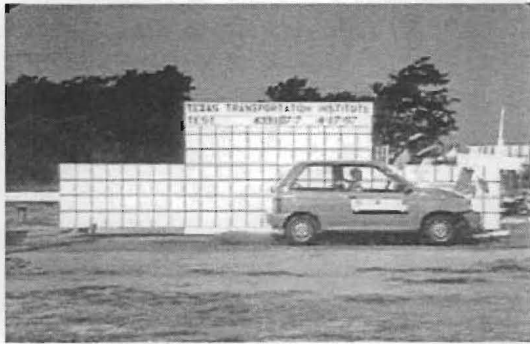


0.092 s



0.138 s

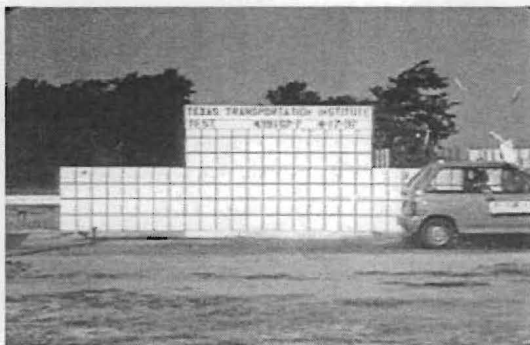
**Figure 93. Sequential Photographs for Test 439107-7 (Perpendicular and Oblique Views).**



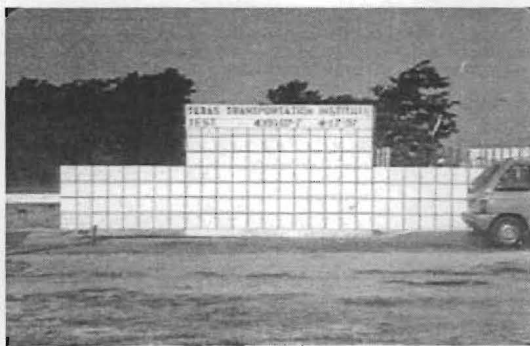
0.184 s



0.230 s



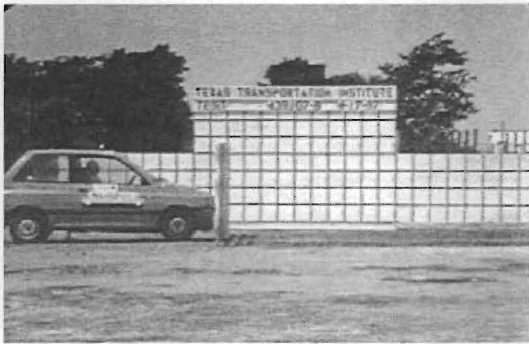
0.276 s



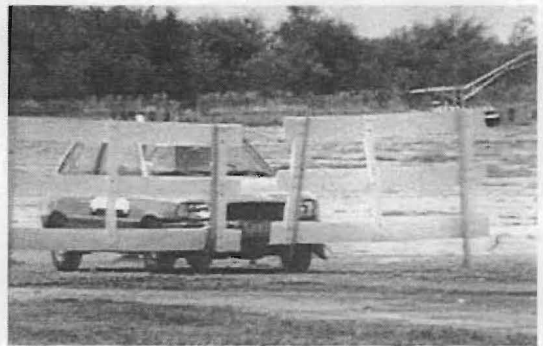
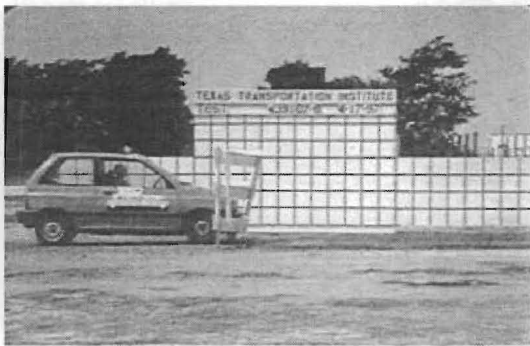
0.322 s



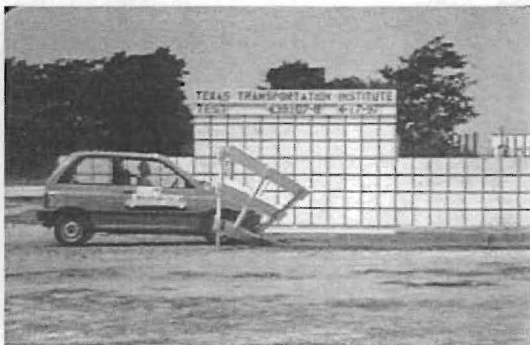
**Figure 93. Sequential Photographs for Test 439107-7 (Perpendicular and Oblique Views) (continued).**



0.000 s



0.041 s



0.082 s



0.123 s

**Figure 94. Sequential Photographs for Test 439107-8 (Perpendicular and Oblique Views).**



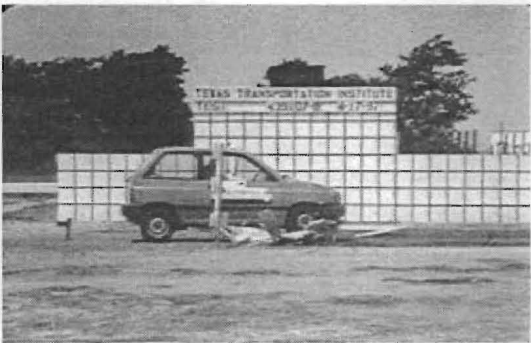
0.164 s



0.205 s



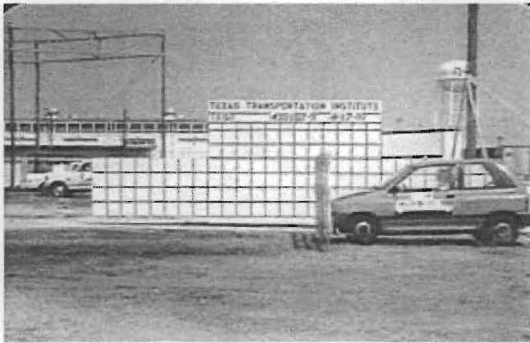
0.246 s



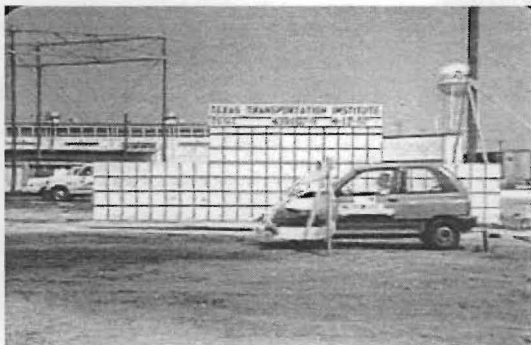
0.287 s



**Figure 94. Sequential Photographs for Test 439107-8  
(Perpendicular and Oblique Views) (continued).**



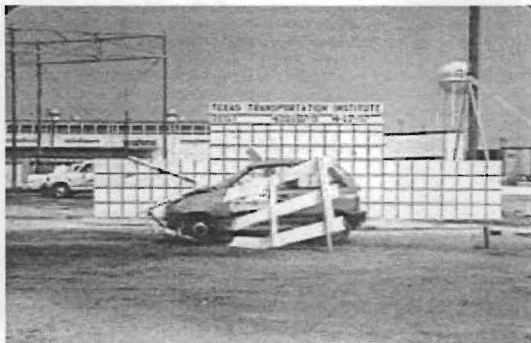
0.000 s



0.036 s



0.072 s



0.108 s



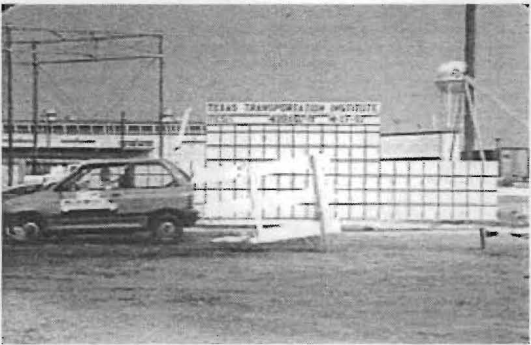
**Figure 95. Sequential Photographs for Test 439107-9  
(Perpendicular and Oblique Views).**



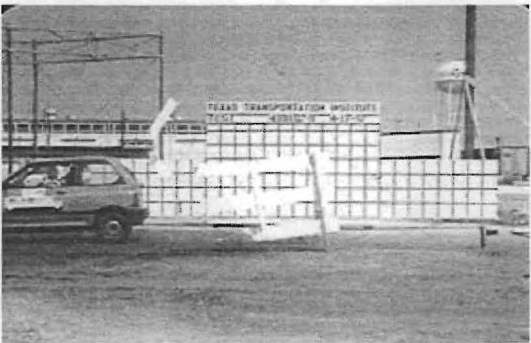
0.145 s



0.181 s



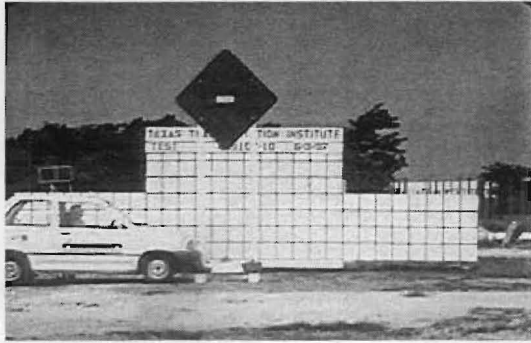
0.217 s



0.254 s



**Figure 95. Sequential Photographs for Test 439107-9  
(Perpendicular and Oblique Views) (continued).**



0.000 s



0.056 s



0.112 s

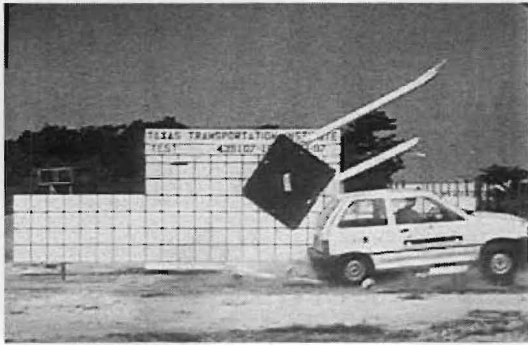


0.169 s

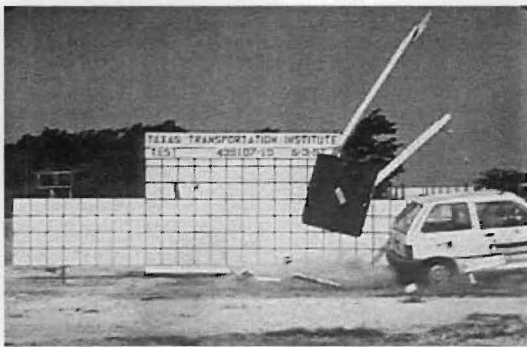


**Figure 96. Sequential Photographs for Test 439107-10 (Perpendicular and Oblique Views).**

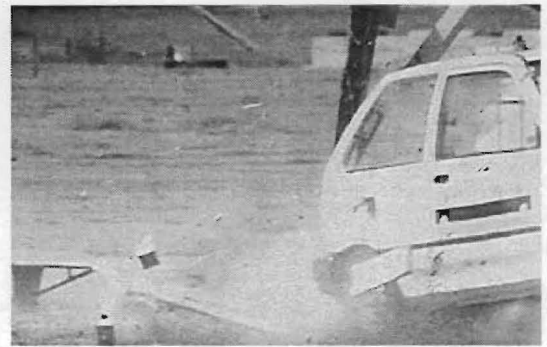




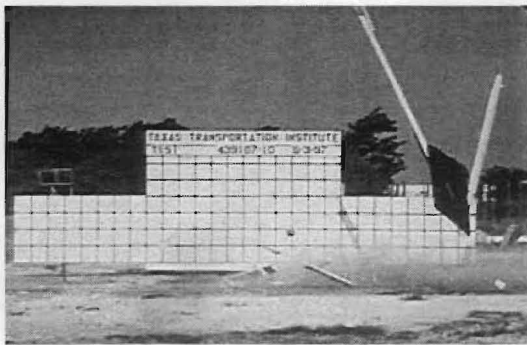
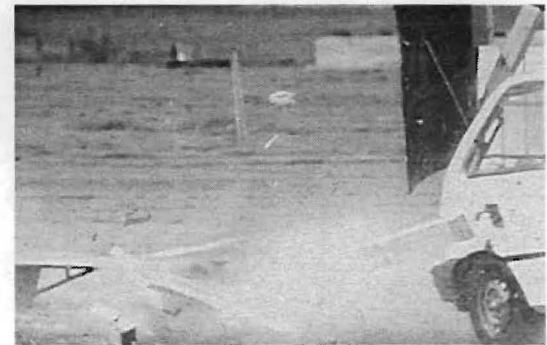
0.225 s



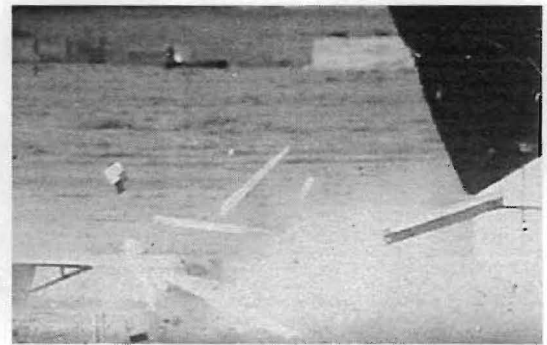
0.281 s



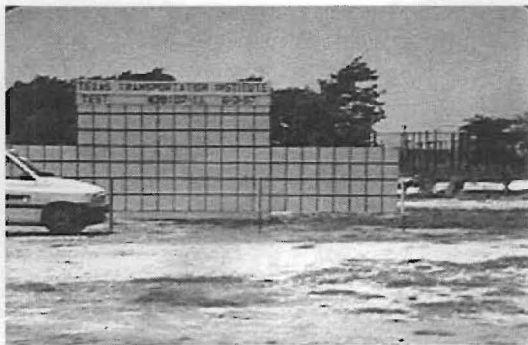
0.338 s



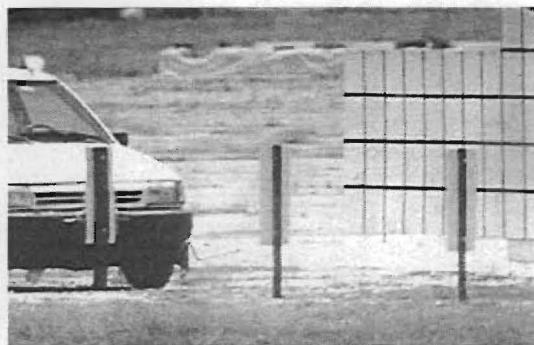
0.394 s



**Figure 96. Sequential Photographs for Test 439107-10 (Perpendicular and Oblique Views) (continued).**



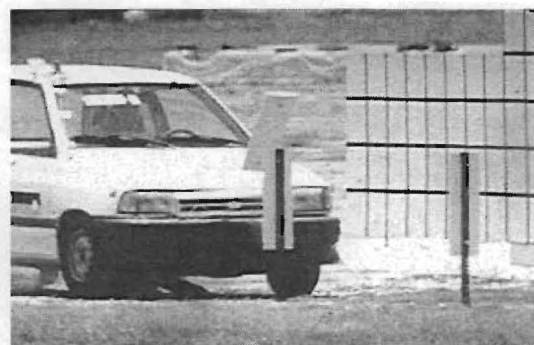
0.000 s



0.036 s



0.073 s



0.110 s



**Figure 97. Sequential Photographs for Test 439107-11  
(Perpendicular and Oblique Views).**



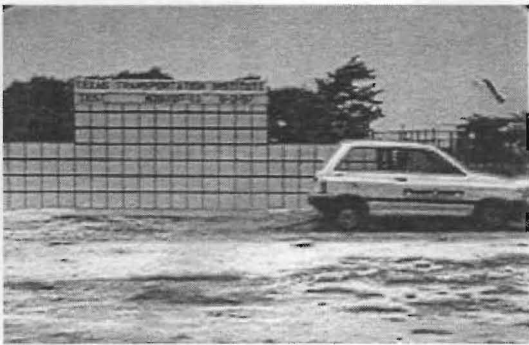
0.147 s



0.183 s



0.220 s



0.257 s



**Figure 97. Sequential Photographs for Test 439107-11 (Perpendicular and Oblique Views) (continued).**