ARIZONA DEPARTMENT OF TRANSPORTATION

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SMALL SIGN SUPPORT ANALYSIS

Phase I
Crash Test Program

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16. Abstract

This report describes a series of full-scale vehicular crash tests conducted to evaluate the impact performance of small sign supports used by the Arizona Department of Transportation (ADOT). The tests were conducted and evaluated in accordance with the recommendations of NCHRP Report 230 and the 1985 AASHTO "Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals."

Based on the test program, it was concluded that the following systems are in compliance with recommended safety performance standards: (1) one P1 post; (2) one 3 lb/ft U-post; (3) one 4 lb/ft U-post; (4) two 3 lb/ft U-posts; and (5) a slipbase design having two S4 x 7.7 posts with a hinge at the midheight of the sign panel. It was concluded that the following systems are not in compliance with recommended safety performance standards: (1) two or more P2 posts within a 7 ft spacing; (2) three or more 3 lb/ft U-posts within a 7 ft spacing; and (3) two or more 4 lb/ft U-posts within a 7 ft spacing.

This is one of three reports prepared in the subject project. The other two are:

Small Sign Support Analysis:
Phase II - Static, Pendulum and Full-Scale Crash Test Programs (two volumes)
Phase III - Benefit/Cost Analysis

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As usual, Don Cangelose and his associates did an excellent job in setting up and conducting the crash tests. Thanks also go to Sylvia Velasco and Patsy Astle for their help in preparing the report.

PREFACE

Arizona Department of Transportation (ADOT) Project HPR-PL-1(31), Item 202, "Small Sign Support Analysis", was initiated by the Texas Transportation Institute (TTI) October 1, 1984. Originally, the project consisted of 18 full-scale vehicular crash tests to evaluate ADOT small sign supports. Upon completion of one-half of the tests it became evident that additional tests would be needed. The project was modified May 31, 1985 to increase the number of tests to 23. Also, the modification included a benefit/cost (B/C) study to develop guidelines for upgrading existing ADOT small sign supports and for selection of new small sign supports. The project was again modified in August, 1986 to develop an improved small sign support system. The B/C study was also modified to include results of the improved support system.

A description of the 23 crash tests and results therefrom are presented herein.

A description of the study in which an improved sign support system was developed is presented in a report entitled "Small Sign Support Analysis: Phase II - Development of New Small Sign Support," (two volumes).

A description of the B/C study and results therefrom are presented in a report entitled "Small Sign Support Analysis: Phase III - Benefit/Cost Analysis."

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METRIC CONVERSION FACTORS

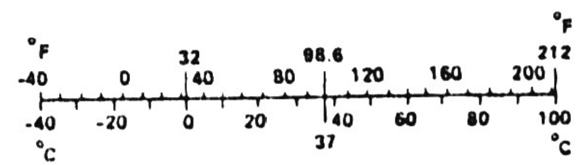
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



I. INTRODUCTION

This report describes a series of full-scale vehicular crash tests conducted to evaluate the impact performance of small sign supports used by the Arizona Department of Transportation (ADOT). The tests were conducted and evaluated in accordance with the recommendations of NCHRP Report 230 (1)* and AASHTO specifications (2).

Test articles, including sign posts, sign blanks, and fasteners, were supplied by ADOT. Installation of the test articles, testing, data acquisition, and data reduction were performed by Texas Transportation Institute (TTI) personnel at the Texas A&M Research and Extension Center.

High-speed film, still photos and slides, and video were used in documenting each test. ADOT has been provided a copy of all film, slides, and video of each test.

A summary of the test program is given in the main text. Details of each test are given in the appendix. Also given in the appendix are results of laboratory tests, conducted by a materials lab, to ascertain the physical and chemical properties of the various sign posts, a description of the soil at the test site, and data acquisition systems.

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*Underscored numbers in parentheses are references listed at the end of the report.

II. SUMMARY AND EVALUATION OF TEST RESULTS

Presented in this chapter is a summary of the impact performance criteria for roadside signs and results of the 23 crash tests. Complete details and photographs of each test are presented in the appendices.

II-A. Impact Performance Criteria

The sign supports were tested and evaluated in accordance with the guidelines of NCHRP Report 230 (1) and AASHTO specifications (2). A summary of the guidelines is presented here. Interested parties should refer to references 1 and 2 for complete details and a commentary on development of the criteria.

Shown in Table 1 are crash test conditions for various safety features per reference 1. Note that tests 60-63 pertain to roadside sign supports. Tests 60 and 61 are identical to tests 62 and 63, respectively, except the latter two tests are with an 1800 lb auto instead of a 2250 lb auto. While an agency may choose to use either car, the Federal Highway Administration (FHWA) urges use of the smaller car. Further, the soon-to-be-released revisions to the current AASHTO Specifications (2) will require that sign supports meet the 1800 lb car criteria. The 1800 lb car was used in the present study.

Shown in Table 2 are criteria used to evaluate crash tests of the various safety features per reference 1. Three basic factors are used: structural adequacy, occupant risk, and vehicle trajectory. Note that items B, D, E, F, H, and J pertain to sign testing. Further, note that item F, within "occupant risk", involves "acceptance factors" F_1, F_2, F_3, and F_4. Recommended values for these factors as shown in Table 3 were adopted for the present study. For sign testing, the two factors of importance are F_1 and F_3 since the signs are impacted head-on, with the vehicle in a "tracking" mode. Thus, with F_1 equaling 2.67 and F_3 equaling 1.33, the recommended limit on "occupant impact velocity" is 15 ft/sec and the recommended limit on "occupant ridedown acceleration" is 15 g's (1 g = 32.2 ft/sec^2).

According to AASHTO (2), "Satisfactory dynamic performance is indicated when the maximum change in momentum for a standard 2250 lb vehicle, or its equivalent, striking a breakaway support at speeds from 20 mph to 60 mph does not exceed 1100 lb-sec, but desirably does not exceed 750 lb-sec."

TABLE 1. CRASH TEST CONDITIONS FOR MINIMUM MATRIX (1)

Appurtenance	Test Designation	Vehicle Type[d]	Impact Speed (mph)	Impact Angle[e] (deg)	Target Impact Severity[f] (ft-kips)	Impact Point[g]	Evaluation Criteria[h]
Longitudinal Barrier[a] Length-of-Need	10	4500S	60	25[i]	$97^{-9,+17}$	For post and beam systems, midway between posts in span contianing railing splice	A,D,E,H,I
	11	2250S	60	15[i]	$18^{-2,+3}$	For post and beam systems, vehicle should contact railing splice	A,D,E,F,(G),H,I
	12	1800S	60	15[i]	$14^{-2,+2}$	For post and beam system, vehicle should contact railing splice	A,D,E,F,(G),H,I
Transition	30	4500S	(/)	25[i]	$97^{-9,+17}$	15 ft upstream from second system	A,D,E,H,I
Terminal	40	4500S	60	25[i]	$97^{-9,+17}$	At beginning of lenth-of-need	A,D,E,H,I
	41	4500S	60	0[i]	$541^{-53,+94}$	Center nose of device	C,D,E,F,(G),H,J
	42	2250S	60	15[i]	$18^{-2,+3}$	Midway between nose and lenth-of-need	C,D,E,F,(G),H,I,J
	43	2250S	60[o]	0[i]	$270^{-26,+47}$	Offset 1.25 ft from center nose of device	C,D,E,F,(G),H,J
	44	1800S	60	15[i]	$14^{-2,+2}$	Midway between nose and length-of-need	C,D,E,F,(G),H,I,J
	45	1800S	60[o]	0[i]	$216^{-21,+37}$	Offset 1.25 ft from center nose of device	C,D,E,F,(G),H,J
Crash Cushion[b]	50	4500S	60	0[j]	$541^{-53,+94}$	Center nose of device	C,D,E,F,(G),H,J
	51	2250S	60[o]	0[j]	$270^{-26,+47}$	Center nose of device	C,D,E,F,(G),H,J
	52	1800S	60[o]	0[j]	$216^{-21,+37}$	Center nose of device	C,D,E,F,(G),H,J
	53[l]	4500S	60	20[j]	$63^{-6,+11}$	Alongside, midlength	C,D,E,H,I,J
	54	4500S	60	10-15[j]	$541^{-53,+94}$	0-3 ft offset from center of nose of device	C,D,E,F,(G),H,J
Breakaway or Yielding Support[c]	60	2250S	20	[k]	$30^{-4,+4}$	Center of bumper[m,n]	B,D,E, F,(G),H,J
	61	2250S	60	[k]	$270^{-26,+47}$	At quarter point of bumper[n]	B,D,E,F,(G),H,J
	62	1800S	20	[k]	$24^{-3,+3}$	Center of bumper[m,n]	B,D,E,F,(G),H,J
	63	1800S	60	[k]	$216^{-21,+37}$	At quarter point of bumper[n]	B,D,E,F,(G),H,J

(a) Includes guardrail, bridgerail, median and construction barriers.
(b) Includes devices such as water cells, sand containers, steel drums, etc.
(c) Includes sign, luminaire, and signal box supports.
(d) See Table 2 for description.
(e) + 2 degrees
(f) $IS = 1/2\ m\ (v \sin \theta)^2$ where m is vehicle test inertial mass, slugs; v is impact speed, fps; and θ is impact angle for redirectional impacts or 90 deg for frontal impacts, deg.
(g) Point on appurtenance where initial vehicle contact is made.
(h) See Table 6 for performance evaluation factors; ( ) denotes supplementary status.
(i) From centerline of highway.
(j) From line of symmetry of device.
(k) Test article shall be oriented with respect to the vehicle approach path to a position that will theoretically produce the maximum vehicle velocity change; the orientation shall be consistent with reasonably expected traffic situations.
(l) See Commentary, Chapter 4 Test Conditions for devices which are not intended to redirect vehicle when impacted on the side of the device.
(m) For base bending devices, the impact point should be at the quarter point of the bumper.
(n) For multiple supports, align vehicle so that the maximum number of supports are contacted assuming the vehicle departs from the highway with an angle from 0 to 30 deg.
(o) For devices that produce fairly constant or slowly varying vehicle accelerations; an additional test at 20 mph (32 kph) is recommended for staged devices, those devices that produce a sequence of individual vehicle deceleration pulses (i.e. "lumpy" device) and/or those devices comprised of massive components that are displaced during dynamic performance (see commentary).

TABLE 2. SAFETY EVALUATION GUIDELINES (1)

Evaluation Factors		Evaluation Criteria	Applicable to Minimum Matrix Test Conditions (see Table 3)
Structural Adequacy	A.	Test article shall smoothly redirect the vehicle; the vehicle shall not penetrate or go over the installation although controlled lateral deflection of the test article is acceptable.	10, 11, 12, 30, 40
	B.	The test article shall readily activate in a predictable manner by breaking away or yielding.	60, 61, 62, 63
	C.	Acceptable test article performance may be by redirection, controlled penetration, or controlled stopping of the vehicle	41, 42, 43, 44, 45, 50, 51, 52, 53, 54
	D.	Detached elements, fragments or other debris from the test article shall not penetrate or show potential for penetrating the passenger compartment or present undue hazard to other traffic.	All
Occupant Risk	E.	The vehicle shall remain upright during and after collision although moderate roll, pitching and yawing are acceptable. Integrity of the passenger compartment must be maintained with essentially no deformation or intrusion.	All
	F.	Impact velocity of hypothetical front seat passenger against vehicle interior, calculated from vehicle accelerations and 24 in. (0.61m) forward and 12 in. (0.30m) lateral displacements, shall be less than: Occupant Impact Velocity-fps Longitudinal: $40/F_1$; Lateral: $30/F_2$ and vehicle highest 10 ms average accelerations subsequent to instant of hypothetical passenger impact should be less than: Occupant Ridedown Accelerations—g's Longitudinal: $20/F_3$; Lateral: $20/F_4$ where F_1, F_2, F_3, and F_4 are appropriate acceptance factors (see Table 8, Chapter 4 for suggested values).	11, 12, 41, 42, 43, 44, 45, 50, 51, 52, 54, 60, 61, 62, 63
	G.	(Supplementary) Anthropometric dummy responses should be less than those specified by FMVSS 208, i.e., resultant chest acceleration of 60g, Head Injury Criteria of 1000, and femur force of 2250 lb (10 kN) and by FMVSS 214, i.e., resultant chest acceleration of 60 g, Head Injury Criteria of 1000 and occupant lateral impact velocity of 30 fps (9.1 m/s).	11, 12, 41, 42, 43, 44, 45, 50, 51, 52, 54, 60, 61, 62, 63
Vehicle Trajectory	H.	After collision, the vehicle trajectory and final stopping position shall intrude a minimum distance, if at all, into adjacent traffic lanes.	All
	I.	In test where the vehicle is judged to be redirected into or stopped while in adjacent traffic lanes, vehicle speed change during test article collision should be less than 15 mph and the exit angle from the test article should be less than 60 percent of test impact angle, both measured at time of vehicle loss of contact with test device.	10, 11, 12, 30, 40, 42, 44, 53
	J.	Vehicle trajectory behind the test article is acceptable.	41, 42, 43, 44, 45, 50, 51, 53, 54, 60, 61, 62, 63

TABLE 3. RECOMMENDED OCCUPANT RISK VALUES (1)

Impact Direction[aa] and Appurtenance Type	Occupant/Compartment Impact Velocity[b]— (fps)			Occupant Ridedown Acceleration— (g's)		
	Flail Space Recommendation		TRC	Flail Space Recommendation		TRC
	$(\Delta V)_{Limit}/F$[c]	$(\Delta V)_{Design}$	191	$(a)_{Limit}/F$[c]	$(a)_{Design}$	191[e]
Longitudinal (X) Direction						
Breakaway/Yielding Supports						
• Signs and luminaire	40/2.67	15	11-16[f]	20/1.33	15	
• Timber Utility Poles	40/1.33	30	—	20/1.33	15	
Vehicle Deceleration Devices						
• Crash cushions and barrier terminals	40/1.33	30	32-39[d]	20/1.33	15	
Redirectional Barriers						
• Longitudinal, transitions and crash cushion side impacts	40/1.33	30	25-36[d]	20/1.33	15	
Lateral (Y) Direction						
Redirectional Barriers						
• Longitudinal, transitions and crash cushion side impacts	30/1.50	20	14-18[d]	20/1.33	15	

Notes:

(aa) With respect to vehicle axis.

(b) Occupant to windshield, dash or door impact velocity with occupant propelled by vehicle deceleration pulse through 2-ft forward or 1 ft lateral flail space; multiply fps by 0.305 to convert to m/s.

(c) F is acceptance factor to be established by highway agency.

(d) Values calculated from TRC 191 criteria assuming that the highest 50-ms acceleration limits of TRC 191 are constant for the duration of the event and shown here for reference.

(e) Flail space accelerations are highest 10 ms averages beginning with occupant impact to completion of pulse; TRC 191 accelerations are less severe, highest 50 ms averages or those averaged over vehicle stopping distance. These values are not comparable.

(f) From TRC 191.

As used in the Specification, "breakaway supports" is a generic term meant to include all types of sign supports whether the release mechanism is a slip plane, plastic hinges, fracture elements, or a combination of these. The Specification states that "Breakaway structures should also be designed to prevent the structure or its parts from penetrating the vehicle occupant compartment." The Specification also alludes to the unacceptability of vehicle rollover following impact with the test article.

Use of small cars has increased since the Specification was written (1975). Hence, the current guidelines (1) recommend that an 1800 lb vehicle be used to evaluate small signs. Nonetheless, the intent of the Specification was to limit a vehicle's velocity change during impact to values implicit in the "change in momentum" limits. The implied vehicle velocity change limits are 15.7 ft/sec (10.7 mph) for the 1100 lb-sec momentum change and 10.7 ft/sec (7.3 mph) for the 750 lb-sec momentum change. For an 1800 lb vehicle, the corresponding momentum change limits would be 878 lb-sec (for 15.7 ft/sec) and 598 lb-sec (for 10.7 ft/sec).

It should be noted that the NCHRP 230 (1) "occupant/compartment impact velocity" limiting value of 15 ft/sec approximates the upper vehicle velocity change limit of 15.7 ft/sec in the Specification. For most sign impacts, the vehicle's change in velocity will approximately equal the occupant/compartment impact velocity if the latter is computed according to the NCHRP 230 guidelines.

II-B. Test Results

Shown in Table 4 is a summary of the 23 crash tests. Reference should be made to Appendix A for a description of the test vehicles, design and installation details of the test articles, and a description of the details of each test.

Four parameters were used to quantify the test results, namely, occupant impact velocity, occupant ridedown acceleration, change in vehicle momentum, and change in vehicle velocity. Methods used to calculate these parameters are discussed in A-3 of Appendix A.

For some tests, "no contact" is listed under "occupant impact velocity" and "occupant ridedown acceleration". This means that an occupant, idealized as a free missile, did not travel a flail space distance of 2 ft during the "impulse period". In such cases, one can assume the occupant impact velocity

TABLE 4. SUMMARY OF TESTS

TEST NO.	TEST ARTICLE	NO. OF POSTS HIT	VEHICLE IMPACT VELOCITY (mph)	TEST RESULTS: OCCUPANT IMPACT VELOCITY (ft/sec)	OCCUPANT RIDEDOWN ACCELERATION (G's)	CHANGE IN VEHICLE MOMENTUM (lb-sec)	CHANGE IN VEHICLE VELOCITY (ft/sec)	ADHERENCE TO EVALUATION GUIDELINES[a] — STRUCTURAL ADEQUACY: B. PROPER ACTIVATION?	D. PENETRATION OF PASSENGER COMPARTMENT?	OCCUPANT RISK: E. VEHICLE STABLE?	F. ACCEPTABLE IMPACT VELOCITY?	F. ACCEPTABLE RIDEDOWN ACCELERATION?	VEHICLE TRAJECTORY: H. TRAJECTORY ACCEPTABLE?
1	Two S4x7.7 with Slipbase, Hinge at Midheight of Panel	1 of 2	19.6	No Contact[b]	No Contact[b]	282	5.0	Yes	No	Yes	Yes	Yes	Yes
2	Same as Test 1	1 of 2	59.3	No Contact[b]	No Contact[b]	174	3.1	Yes	No	Yes	Yes	Yes	Yes
3	One Square Steel Tube (Unistrut) ADOT P1 Post Design	1 of 1	20.0	No Contact[b]	No Contact[b]	193	3.5	Yes	No	Yes	Yes	Yes	Yes
4	Same as Test 2	1 of 1	56.8	No Contact[b]	No Contact[b]	468	8.5	Yes	No[c]	Yes[d]	Yes	Yes	Yes
5	Three Square Steel Tubes (Unistrut) ADOT P2 Post Design	2 of 3	19.7	21.0	0.9	1150	20.7	Yes	No	Yes	No	Yes	Yes
6	Same as Test 5	3 of 3	59.3	24.9	3.3	1459	26.3	Yes	No[c]	Yes	No	Yes	Yes
7	One 3 lb/ft, High Carbon, Billet Steel U-Post (100 ksi)	1 of 1	60.5	No Contact[b]	No Contact[b]	169	3.1	Yes	No	Yes	Yes	Yes	Yes
8	Same as Test 7	1 of 1	19.9	No Contact[b]	No Contact[b]	339	6.0	Yes	No	Yes	Yes	Yes	Yes
9	Three 3 lb/ft, High Carbon, Billet Steel U-Posts (100 ksi)	3 of 3	59.3	No Contact	No Contact	990	10.6	Yes	No	Yes	Yes	Yes	Yes
10	Same as Test 9	3 of 3	19.4	19.3	1.6	1336	[illegible]	Yes	No	Yes	No	Yes	Yes
11	Two 4 lb/ft, High Carbon, Billet Steel U-Posts (80 ksi)	2 of 2	20.2	14.2	1.6	653	12.5	Yes	Partially[b]	Yes	Yes	Yes	Yes
12	Same as Test 11	2 of 2	60.9	10.1	0.5	589	10.3	Yes	No	Yes	Yes	Yes	Yes
13	One 4 lb/ft, High Carbon, Billet Steel U-Post (100 ksi)	1 of 1	61.3	No Contact	No Contact	352	6.3	Yes	No	Yes[d]	Yes	Yes	Yes
14	Three 3 lb/ft, Rail Steel U-Posts (Short Lap Splice)	3 of 3	20.3	26.9	1.6	1541	27.6	Yes	No	Yes	No	Yes	Yes
15	Same as Test 14	3 of 3	62.0	31.2	4.6	1927	34.5	Yes	Partially[b]	Yes	No	Yes	Yes
16	Three 3 lb/ft, High Carbon, Billet Steel U-Posts (80 ksi) (Long Lap Splice)	3 of 3	20.0	22.4	3.6	1534	27.9	Yes	No	Yes	No	Yes	Yes
17	Same as Test 16	3 of 3	62.0	12.8	2.0	1058	18.9	Yes	No	Yes	Yes	Yes	Yes
18	Same as Test 16 Except Short Lap Splice	3 of 3	19.5	22.5	1.3	1394	24.9	Yes	No	Yes	No	Yes	Yes
19	Two Square Steel Tubes (Unistrut) ADOT P2 Design (40 in. Post Spacing)	2 of 2	18.9	14.1	2.5	825	14.7	Yes	No	Yes	Yes	Yes	Yes
20	Same as Test 19	2 of 2	57.5	17.4	1.7	1006	17.9	Yes	No[c]	Yes	No	Yes	Yes
21	Same as Test 16 Except Short Lap Splice	3 of 3	61.5	19.0	1.9	1235	22.4	Yes	Partially[b]	Yes	No	Yes	Yes
22	Two 3 lb/ft, High Carbon, Billet Steel U-Posts	2 of 2	20.0	10.1	1.9	534	9.4	Yes	No	Yes	Yes	Yes	Yes
23	Same as Test 22	2 of 2	62.8	11.8	0.8	666	11.7	Yes	No	Yes	Yes	Yes	Yes

[a] Recommended limits are as follows:
Occupant impact velocity - 15 ft/sec
Occupant ridedown acceleration - 15 g's
See Tables 2 and 3 for more details
[b] See discussion in text
[c] Sign panel hit and broke windshield but did not penetrate passenger compartment
[d] Vehicle rollover not attributed to test article (see discussion in text).

will equal the vehicle's change in velocity, as given in Table 4. Further commentary on this matter is given in Section A-3 of Appendix A.

Each test was evaluated according to the criteria of Table 2. Following is a discussion of the results, categorized according to the type of sign support.

II-B-1. Slipbase Sign Support (Tests 1 and 2)

Details of this design are given in Section A-2-1 of Appendix A. It differs from the conventional slipbase sign support system in that the hinge is placed at the midheight of the sign panel rather than just below the sign panel. The purpose of this modification is to minimize improper hinge activation during strong winds or during snow removal operations (when snow is blown against a sign by snow blowers). The system met all safety criteria in both tests.

II-B-2. Square Steel Tube, Single Post (Tests 3 and 4)

Details of the design are given in Section A-2-2 of Appendix A. The system is considered to have met all safety criteria in both tests. However, in test 4 the panel separated from the post at impact, then struck and broke the windshield. Although it did not penetrate the windshield, the potential for doing so exists in such instances.

From Figure A-44 of Appendix A, it can be seen that the washer on the lower bolt cupped and pulled through the plywood panel. The 0.065 inch thick flat washer had an outside diameter of 1.25 inches. This problem could be remedied by increasing the washer's thickness, by increasing its yield strength, or by using additional bolts to attach the panel to the post. Further analysis and testing would be required to determine the best solution.

As noted in Table 4, the vehicle in test 4 rolled subsequent to impact with the test article. However, analysis of the test film showed that the rollover was not attributable to the impact. Rather it was due to vehicle yawing that resulted from unsymmetrical braking, leading to tire rutting and the tripping of the vehicle. While the rollover cannot be attributed to the impact, it does point out the relative instability of the 1800 lb vehicle. As shown, rollover of this vehicle can occur on relatively flat, traversable, grassy sod, quite similar to actual roadside conditions.

II-B-3. Square Steel Tube, Multiple Posts (Tests 5, 6, 19, and 20)

Details of the design evaluated in tests 5, 6, 19, and 20 are given in Section A-2-3 of Appendix A. Two of the three posts were impacted in test 5, and all three posts were hit in test 6. Neither test met the occupant risk criteria of reference 1 or the vehicle's velocity change criteria of reference 2. Also, in test 6, as the sign panel rotated down, it struck and partially penetrated the windshield.

Tests 19 and 20 involved a two-support system. Test 19 met all safety criteria, while test 20 did not. In test 20, the occupant risk criteria and the vehicle's velocity change criteria were not met. Also, in test 20, as the panel rotated down it struck and partially penetrated the windshield. The strength of the fasteners was increased to Grade 5 in tests 19 and 20 to determine if this would reduce the windshield impact problem seen in test 6. The fasteners in tests 5 and 6 were Grade 1 in strength. A close examination of the film of tests 6 and 20 shows that the panel remained attached to the posts in test 20 up to the time of windshield impact, while the posts detached from the panel prior to that time in test 6. However, the end result was essentially the same in that the windshield was partially penetrated in both cases.

II-B-4. Steel U-Post, Single Support (Tests 7, 8, and 13)

Details of this design are shown in Section A-2-4 of Appendix A. Tests 7 and 8 involved a 3 lb/ft post and test 13 involved a 4 lb/ft post. The posts were from billet steel having a minimum yield strength of approximately 100 ksi. All safety criteria were met in each test. It is noted that the vehicle rollover that occurred in test 13 was not attributed to the test article (see discussion at end of Section II-B-2).

II-B-5. Steel U-Post, Multiple Supports (Tests 9, 10, 11, 12, 14, 15, 16, 17, 18, 21, 22, and 23)

Details of the system tested are given in Section A-2-5 of Appendix A. Table 5 summarizes the basic details and differences of each of the various systems.

A review of the results shows that the systems in tests 9 and 10, 14 and 15, 16 and 17, and 18 and 21 did not satisfy either the occupant impact velocity criteria nor the change in the vehicle's velocity criteria. Also, in test 15, the panel detached from the posts, hit and broke the windshield, and dented the roof above the front passenger area. A similar event happened

TABLE 5. MULTIPLE U-POST SIGN SUPPORT DETAILS

TEST NO.	NO. OF POSTS	POST SIZE (lb/ft)	POST TYPE	MINIMUM YIELD STRENGTH (ksi)	SPLICE LENGTH (ft)	GRADE OF BOLTS[a]	WASHER SIZE (in.)	PANEL SIZE (ft)
9 & 10	3	3	Billet	100	1.0	1	3/8	5 x 6
11 & 12	2	4	Billet	80	1.0	5	1 1/4	5 x 6
14 & 15	3	3	Rail	60	1.0	5	1 1/4	5 x 6
16 & 17	3	3	Billet	80	3.0	5	1 1/4	5 x 8
18 & 21	3	3	Billet	80	1.0	5	1 1/4	5 x 8
22 & 23	2	3	Billet	80	2.0	5	1 1/4	4 x 7

[a]S.A.E. Grades

in test 21, although the panel remained attached to the posts up to and during impact with the windshield and roof.

With one exception, the systems in tests 11 and 12 and tests 22 and 23 satisfied all safety criteria. Test 11 did not meet evaluation criteria "D" of NCHRP Report 230 (1). In this test, a broken post stub penetrated approximately 3 inches into the floor of the test vehicle. In all probability, such a penetration would not pose a significant hazard to an occupant. However, the potential may exist for these stubs to rupture the gas tank in a similar impact with an attendant fire risk.

A review and comparison of the multiple U-post tests indicates that the number of posts in an installation is more significant in terms of impact performance than any other variable investigated. With the exception of the partial penetration noted in test 11, both of the two-post systems passed, and all of the three-post systems failed. Other observations were:

(1) While neither system passed, a comparison of the system in tests 14 and 15 with the system in tests 18 and 21 indicates the 80 ksi billet steel post had a better impact performance than the rail steel post.

(2) A comparison of tests 16 and 17 with tests 18 and 21 indicates that the splice length had negligible effect on impact performance.

(3) A comparison of test 9 with test 21 (see Figures A-76 and A-138) shows the 100 ksi post (test 9) performed much better for 60 mph impacts than did the 80 ksi post (test 21). It is interesting that there are no appreciable differences in the impact properties of the posts in test 9 with those in test 21 (see Table B-2 of Appendix B). At 20 mph both systems performed similarly (tests 10 and 18).

(4) There was a tendency for the 0.065 inch thick, 1.25 inch diameter, flat washer to cup and pull through the plywood sign panels. This could be remedied by a thicker washer, a higher strength washer, additional post-to-panel fasteners, or a combination of these. Further analysis and testing is needed to determine the best solution.

(5) The effect of a higher strength post-to-panel fastener and larger washer on impact performance could not be conclusively determined from the limited test results. However, it is the researchers' opinion that in most instances, impact performance of a small sign support system will be enhanced if the panel remains attached to the post(s) during the vehicle/sign impact phase.

III. CONCLUSIONS

A series of full-scale vehicular crash tests were conducted to evaluate the impact performance of small sign supports used by ADOT. The tests were conducted and evaluated in accordance with the recommendations of NCHRP Report No. 230 and the 1985 AASHTO "Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals." Based on the test results, some support systems were found to be in compliance with the recommended safety standards and some were not.

A. Systems in compliance

(1) A slipbase design having two S4 x 7.7 posts with a hinge at the midheight of the sign panel. Sign details are given in Figure A-2.

(2) The ADOT P1 Single Post Design as described in Figure A-4. It is a square steel tube, telescoping post design.

(3) A single 3 lb/ft billet steel U-post (100 ksi) as described in Figure A-9.

(4) A two-post system with 3 lb/ft billet steel U-posts (80 ksi) as described in Figure A-21.

B. Systems not in compliance

(1) The ADOT P2 multiple post design as described in Figure A-6, for both two- and three-post systems. The system is composed of square steel telescoping tubes.

(2) A two-post system with 4 lb/ft billet steel U-posts (80 ksi) as described in Figure A-14. This system was considered unacceptable since there was partial penetration of the occupant compartment by the fractured posts (see discussion in Section II-B-5).

(3) A three-post system with 3 lb/ft billet steel U-posts (100 ksi) as described in Figure A-12.

(4) A three-post system with 3 lb/ft rail steel U-posts (60 ksi) as described in Figure A-16.

(5) A three-post system with 3 lb/ft billet steel U-post (80 ksi) as described in Figure A-19.

(6) A three-post system with 3 lb/ft billet steel U-post (80 ksi) as described in Figure A-16.

Other conclusions and observations made as a result of the test program were as follows:

C. There was a tendency for the 0.065 inch thick, 1.25 inch diameter, flat washer to cup and pull through the plywood sign panels. This could be remedied by a thicker washer, a higher strength washer, additional post-to-panel fasteners, or a combination of these. Further analysis and testing is needed to determine the best solution. (Note: This problem was investigated in Phase II of the study. See the Phase II report for suggested solutions.)

D. The effect of a higher strength post-to-panel fastener and larger washer on impact performance could not be conclusively determined from the limited test results. However, it is the researchers' opinion that in most instances, impact performance of a small sign support system will be enhanced if the panel remains attached to the post(s) during the vehicle/sign impact phase.

E. The number of supports in a U-post system is more significant than any other factor investigated. Both of the two-post systems passed the safety criteria (with one exception as noted in Section II-B-5), and all three-post systems failed.

F. The 80 ksi billet steel U-post had a better impact performance than the rail steel U-post.

G. The 100 ksi billet steel U-post had a better impact performance at 60 mph than did the 80 ksi billet steel U-post.

H. The splice length in the U-post designs tested had a negligible effect on impact performance.

I. The 1800 lb Honda Civic test vehicle rolled over in two different tests. The rollover was not attributed to impact with the test article. Rather, rollover occurred as a consequence of unsymmetrical braking that caused the vehicle to yaw, allowing the tires to plow into the grassy sod, which tripped the vehicle. While the rollover was not attributed to the impact, it underlines the relative instability of an 1800 lb vehicle. As demonstrated, rollover of this vehicle can occur on relatively flat, traversable, grassy sod.

APPENDIX A. TEST DETAILS

A. TEST DETAILS

This appendix contains a description of the test vehicle, design details of the test article, and installation details for each of the 23 tests. Also presented are results from accelerometer measurements and photographs of before, during, and after scenes of each test. Appendix B contains physical and chemical properties of the sign supports. Appendix C contains a description of the properties of the soil at the test site. Appendix D contains a description of the data acquisition systems.

A-1. Test Vehicles

The test vehicles consisted of 1979-80 Honda Civics weighing approximately 1,800 lb. A 50th percentile male dummy weighing approximately 170 lb was placed in the driver position in each test vehicle in an unrestrained condition. The dummy was not instrumented. Design differences between the 1979 and 1980 models were very minor. Figure A-1 contains typical dimensions of the 1979-80 Hondas used in the crash tests. Photos of each test car are given in Section A-3 of Appendix A.

Damage to the vehicle after each test is given in subsequent sections of this appendix. In some cases the same vehicle was used in two tests. This was done only when the initial test caused minor damage to the vehicle.

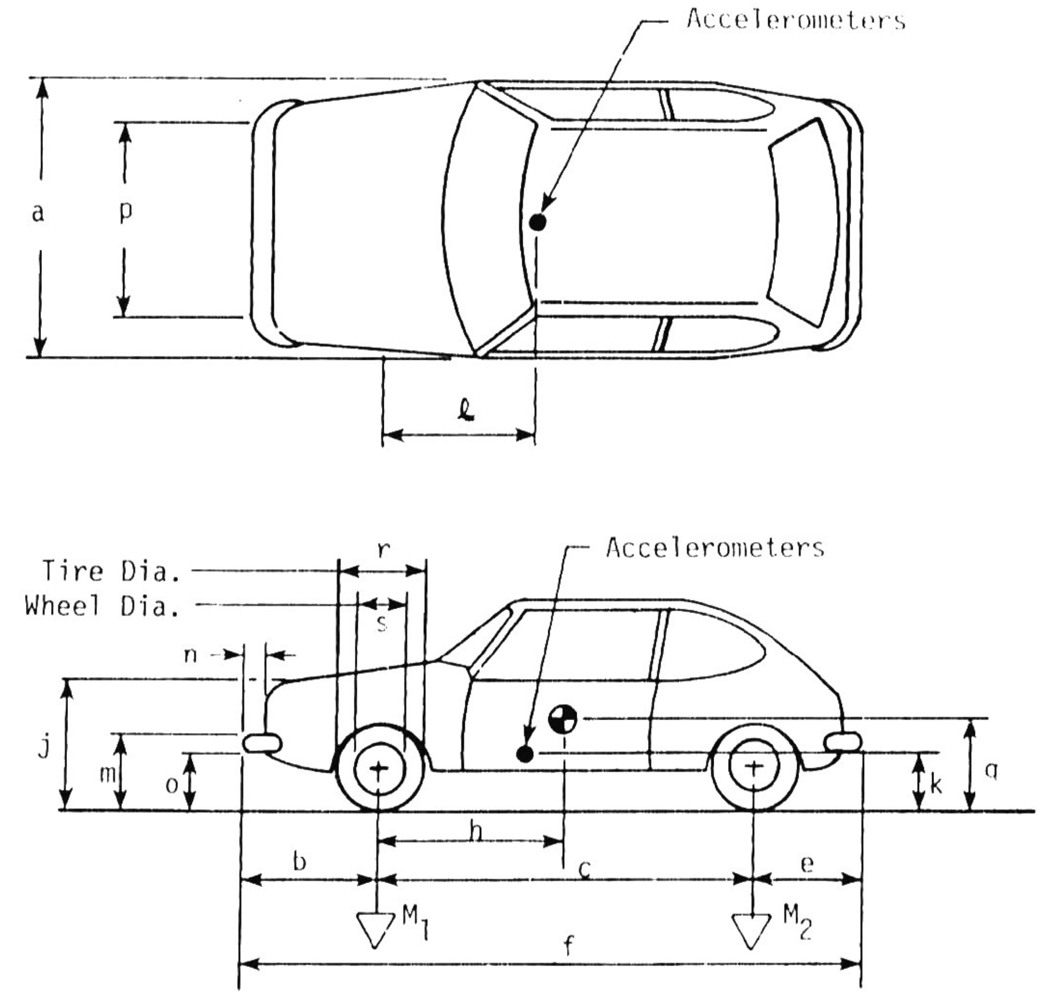
A-2. Design and Installation Details of Test Articles

This section describes the as-tested sign support systems. All of the supports were placed in soil per NCHRP 230 (1) recommendations. Properties of the soil are given in Appendix C.

A-2-1. Slipbase Sign Support (Tests 1 and 2)

Shown in Figure A-2 (3 sheets) are details of the system evaluated in tests 1 and 2. Photos of the installation for test 1 are given in Figure A-3 (2 sheets).

An 8 ft wide by 5 ft high extruded aluminum panel was mounted on the two S4 x 7.7 posts, with the lower edge of the panel approximately 7 ft above ground. The posts were spaced 5 ft apart. Note that the hinge was placed at the midheight of the panel as shown on the first sheet of Figure A-2, not as shown on the second sheet. It should also be noted that the hinge details differed from those shown on the second sheet. For the installations tested,



4-wheel weight for c.g. det. ℓf 572 rf 506 ℓr 353 rr 369

Vehicle Geometry - inches

a	59 3/8	b	29 1/4
c	86	d*	51 9/16
e	27 1/4	f	140 1/4
g	18.6	h	34.5
i	----	j	30 3/4
k	13 1/2	ℓ	34.0
m	19 9/14	n	6 7/8
o	15 5/8	p	51 3/8
r	22	s	13 1/2

FIGURE A-1. TEST VEHICLE PROPERTIES

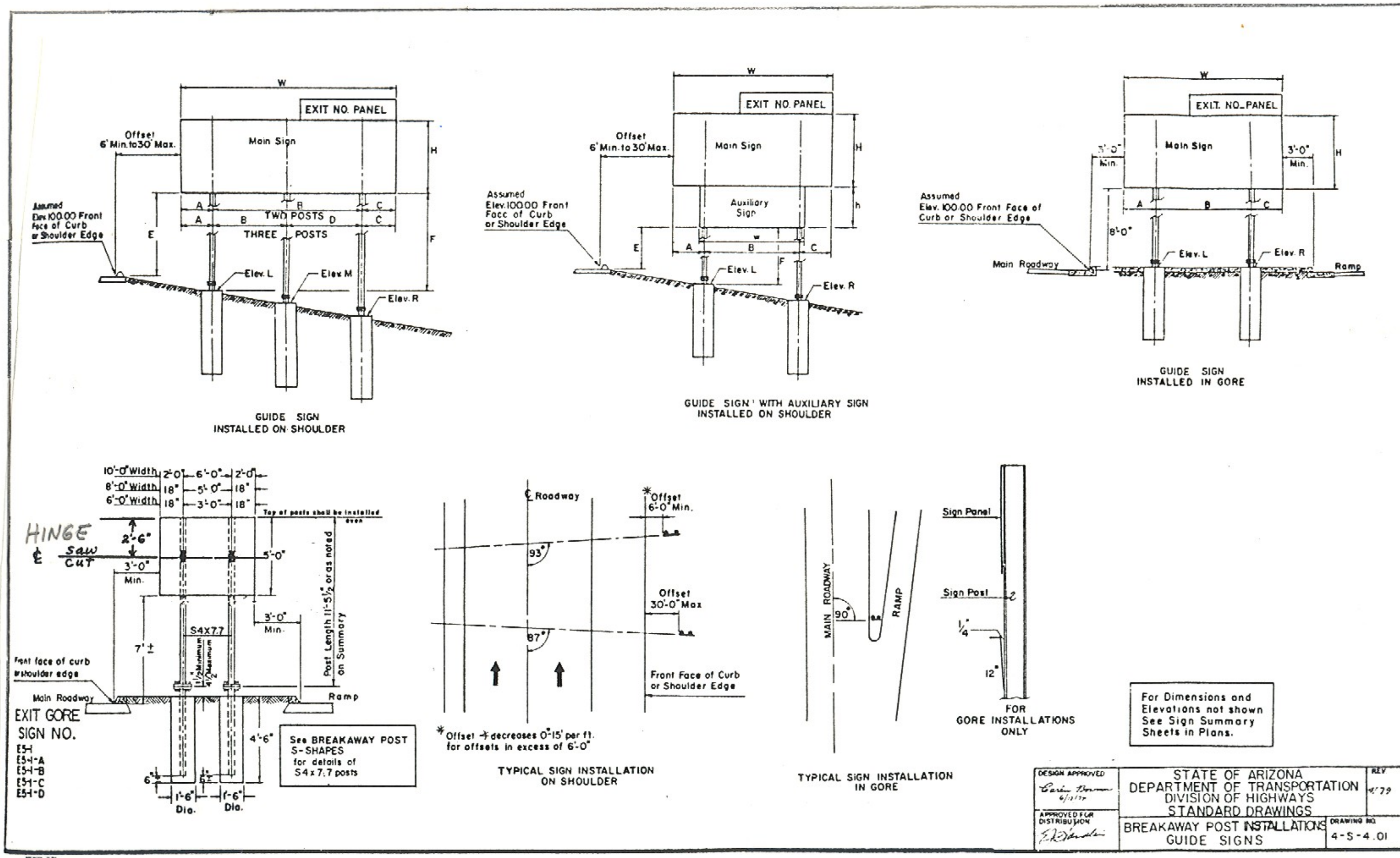


FIGURE A-2. SLIPBASE DESIGN, TESTS 1 AND 2

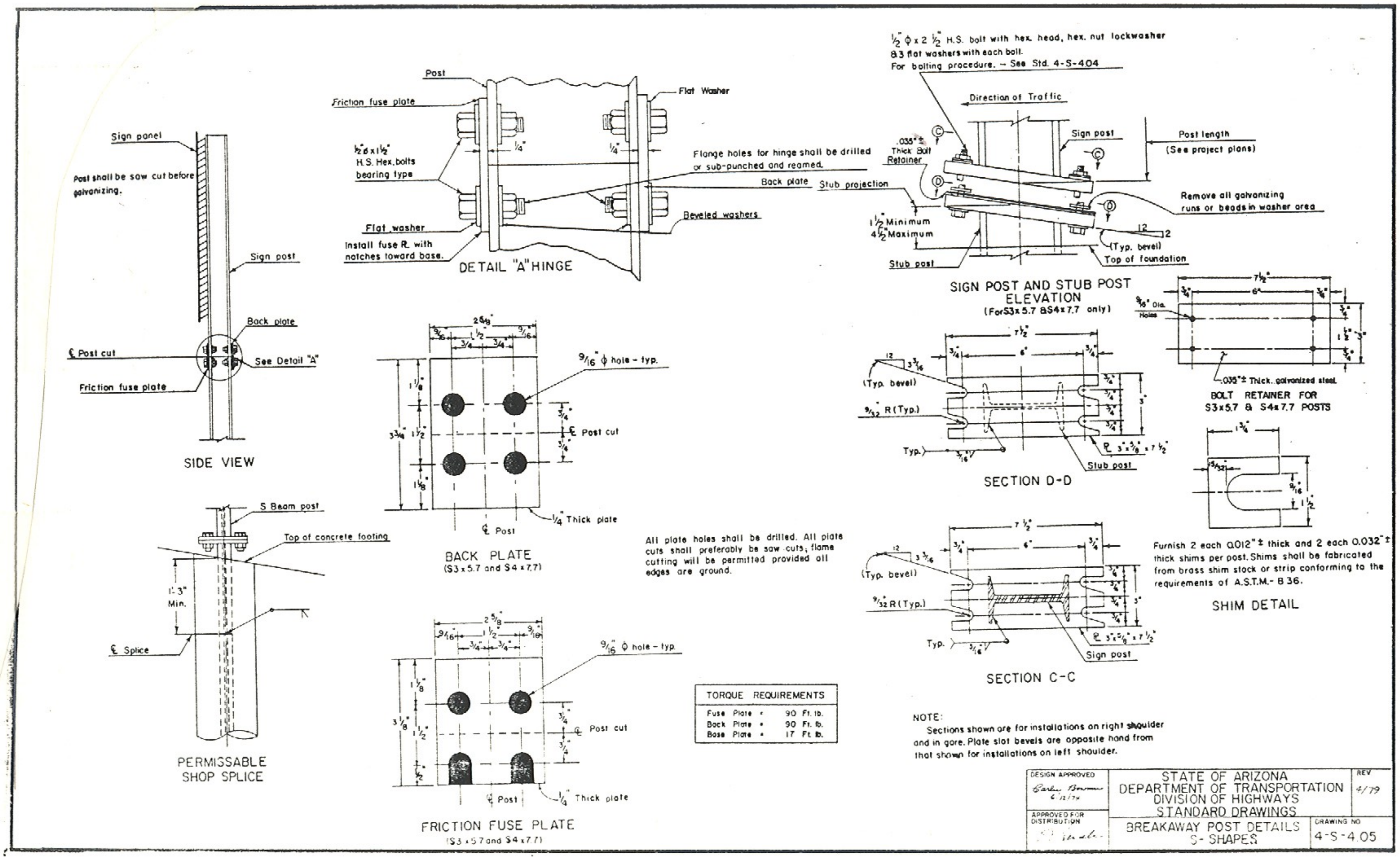


FIGURE A-2. SLIPBASE DESIGN, TESTS 1 AND 2 (continued)

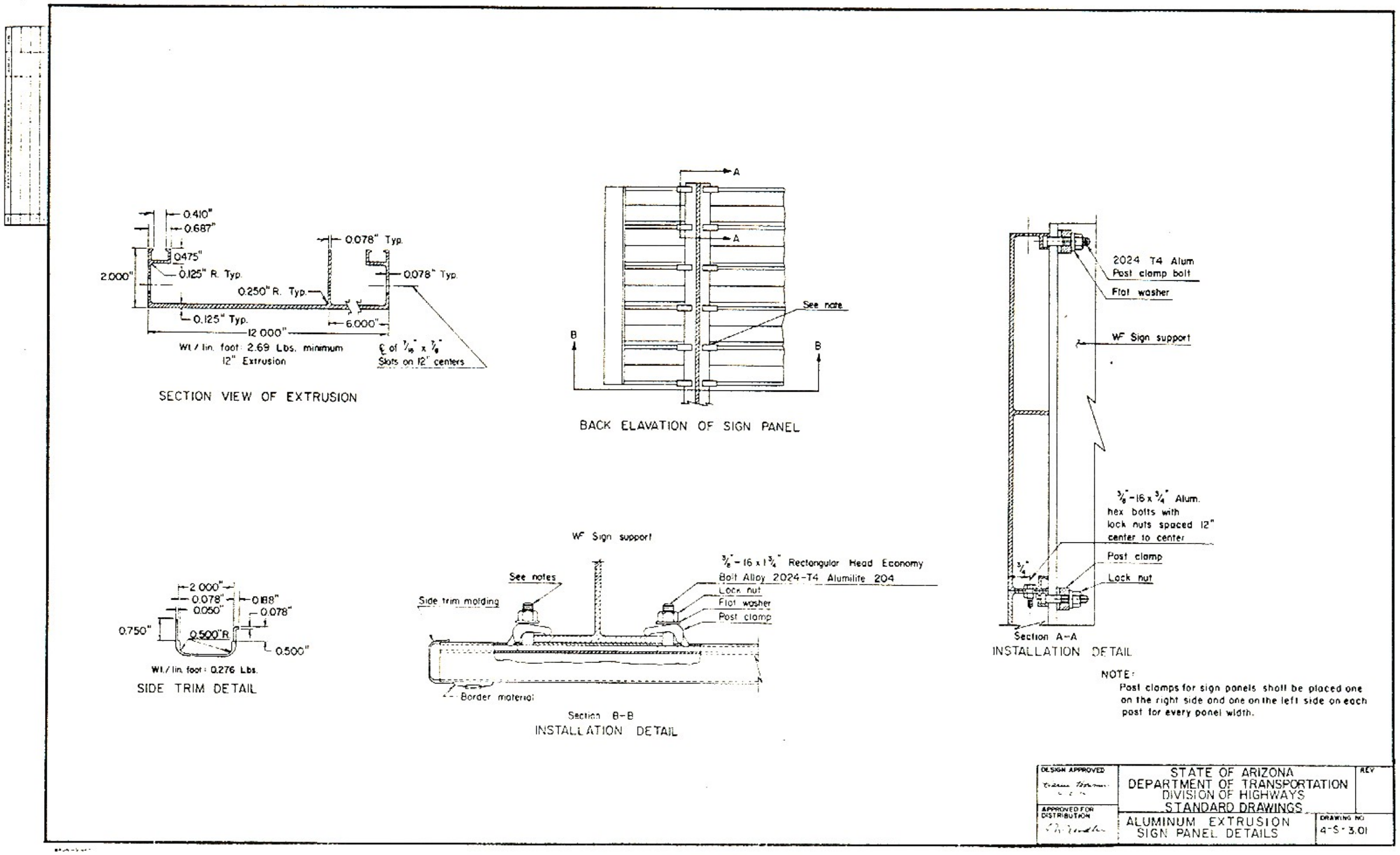


FIGURE A-2. SLIPBASE DESIGN, TESTS 1 AND 2 (concluded)

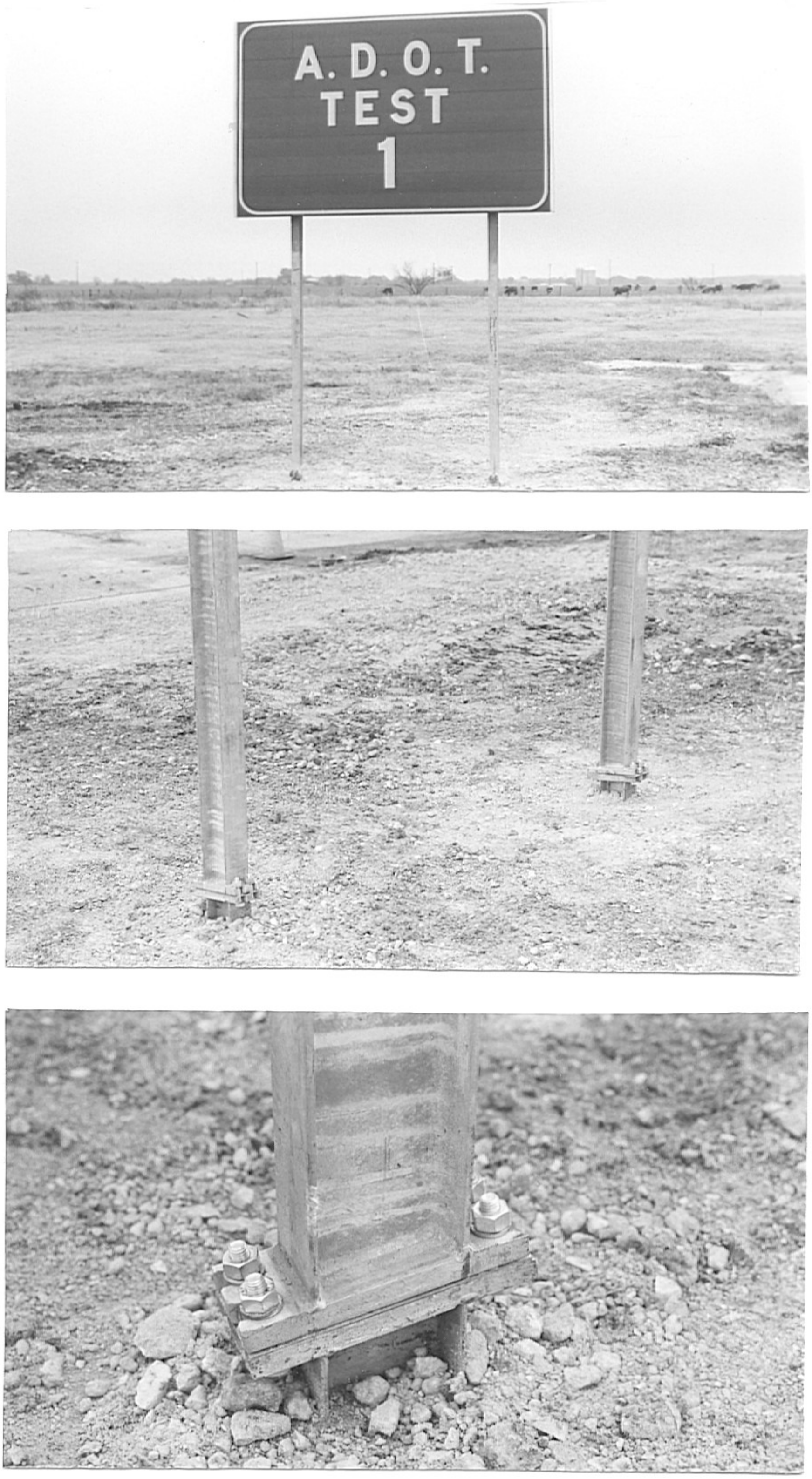


FIGURE A-3. SIGN INSTALLATION, TEST 1
(SAME AS TEST 2)

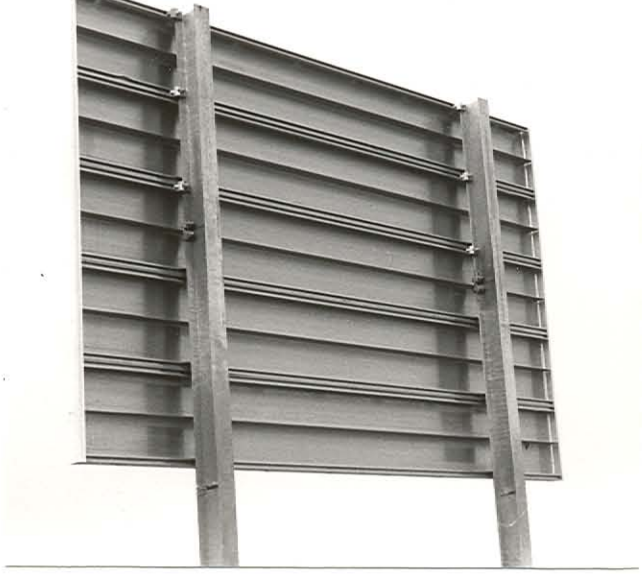


FIGURE A-3. (CONCLUDED)

the sign post was not cut completely into as shown. The flange adjacent to the sign panel and the web was cut but the back flange was not cut. The "friction fuse plate" was installed as shown but there was no need for the "back plate".

The panel was attached to the sign posts with six post clamps and lock nuts, per post, all of which were above the hinge. Details of the post clamps are given on the third sheet of Figure A-2.

A-2-2. Square Steel Tube, Single Post (Tests 3 and 4)

Shown in Figure A-4 are details of the system evaluated in tests 3 and 4. Photos of the installation for test 3 are shown in Figure A-5.

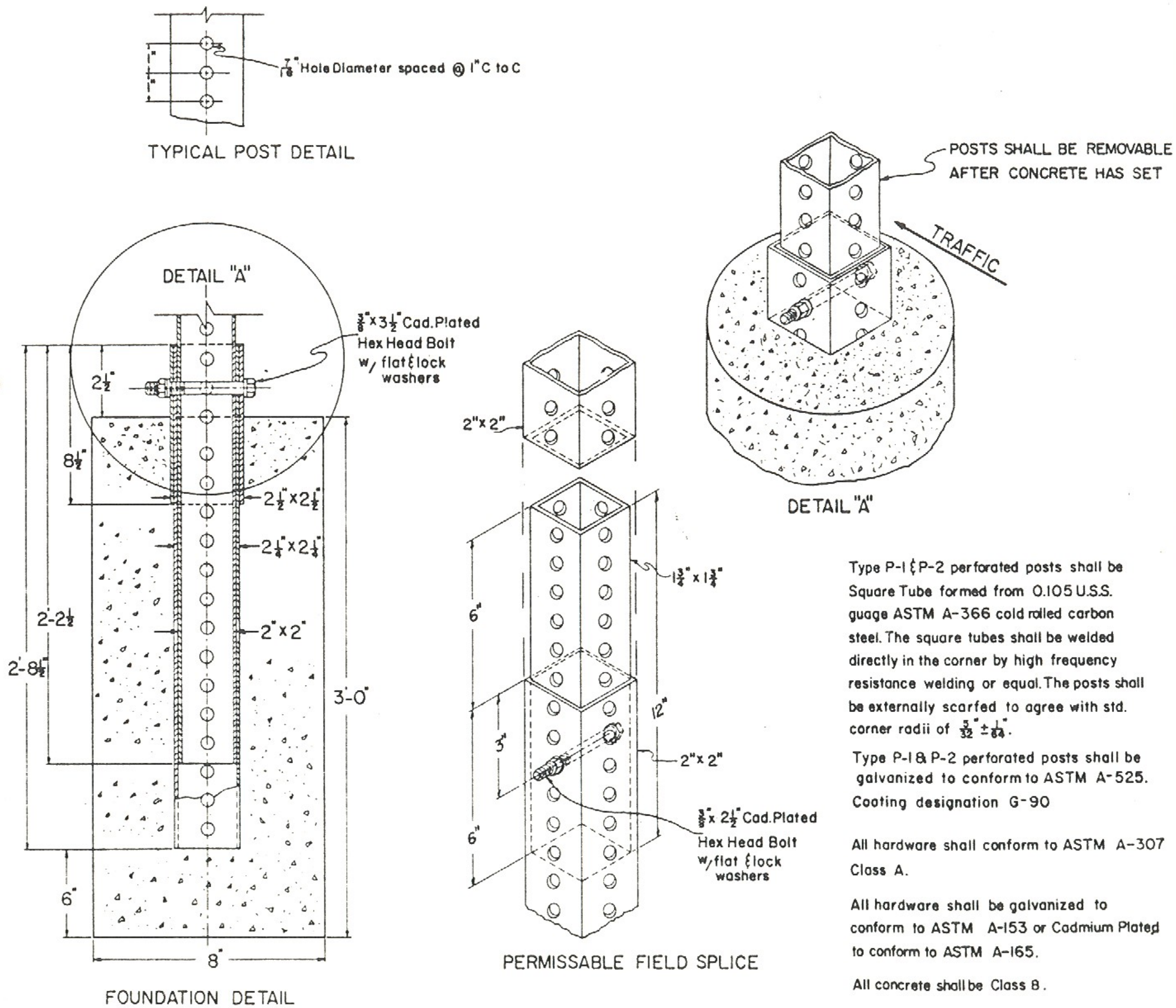
A 2 ft wide by 2 1/2 ft high by 5/8 inch thick plywood (MDO) panel was mounted on the 2 inch square sign post, with the lower edge of the panel approximately 5 ft above ground. Two fasteners were used to attach the panel to the post. Attachment hardware was as shown on the second sheet of Figure A-6.

A-2-3. Square Steel Tube, Multiple Posts (Tests 5, 6, 19, and 20)

Shown in Figure A-6 (2 sheets) are details of the system evaluated in tests 5, 6, 19, and 20. Photos of the installation for test 5 are shown in Figure A-7. Photos of the installation for tests 19 are shown in Figure A-8.

In tests 5 and 6, a 6 ft wide by 5 ft high by 5/8 inch thick plywood (MDO) panel was mounted on three 1 3/4 inch square sign posts, with the lower edge of the panel approximately 5 ft above ground. Post spacing was 21 inches rather than the 25 inches called for the in the plans (first sheet, Figure A-6). The smaller spacing was used so that the test vehicle would strike all three posts (vehicle width was approximately 51 inches). Three fasteners were used to attach the panel to each of the three posts. Attachment hardware was as shown on the second sheet of Figure A-6. Hardware specifications are given in the notes of Figure A-4. It is noted that a bolt for this specification is equivalent to an SAE Grade 1 bolt.

In tests 19 and 20, a 6 ft wide by 4 ft high by 5/8 inch thick plywood (MDO) panel was mounted on two 1 3/4 inch square sign posts, with the lower edge of the panel approximately 5 ft above ground. Post spacing was 40 inches rather than the 43 inches called for in the plans (first sheet, Figure A-6). The smaller spacing was requested by ADOT. Two fasteners were used to attach the panel to each post. Attachment hardware was as shown on the second sheet of Figure A-6. In tests 19 and 20, the bolts were SAE Grade 5 and the nuts were Grade 8.



Type P-1 & P-2 perforated posts shall be Square Tube formed from 0.105 U.S.S. guage ASTM A-366 cold rolled carbon steel. The square tubes shall be welded directly in the corner by high frequency resistance welding or equal. The posts shall be externally scarfed to agree with std. corner radii of $\frac{5}{32}" \pm \frac{1}{64}"$.

Type P-1 & P-2 perforated posts shall be galvanized to conform to ASTM A-525. Coating designation G-90

All hardware shall conform to ASTM A-307 Class A.

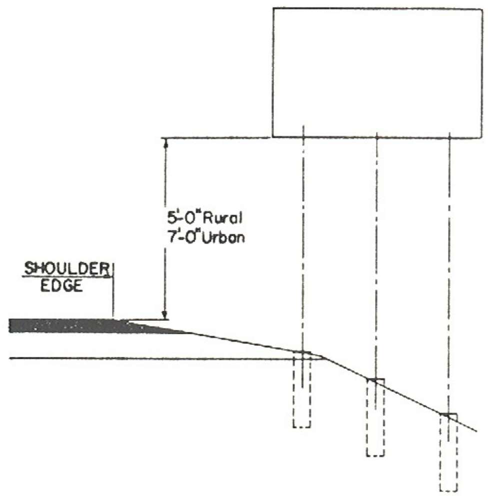
All hardware shall be galvanized to conform to ASTM A-153 or Cadmium Plated to conform to ASTM A-165.

All concrete shall be Class B.

DESIGN APPROVED Carlie Bowman 6/12/74	STATE OF ARIZONA DEPARTMENT OF TRANSPORTATION DIVISION OF HIGHWAYS STANDARD DRAWINGS		REV. 11/4/74 1/83
APPROVED FOR DISTRIBUTION [signature]	FOUNDATION DETAIL FOR P-1 PERFORATED POST (SINGLE)	DRAWING NO. 4-S-4.16	

FIGURE A-4. SQUARE STEEL TUBE, SINGLE POST, TESTS 3 AND 4

FIGURE A-5. SIGN INSTALLATION, TEST 3
(SAME AS TEST 4)



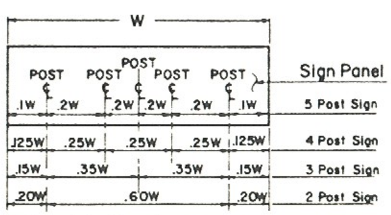
TYPICAL INSTALLATION
for Guide Signs.

NUMBER of POSTS PER SIGN (TELESCOPED)

Sign Height	Sign Width 4'	5'	6'	7'	8'	9'	10'	11'	12'
4'	*		2	2	3	3	3	4	4
5'		2	2	3	3	4	4	5	5
6'	2	2	3	4	4	5	5		
7'	2	3	4	4	4	5			
8'	3	3	4						

USE BREAKAWAY POSTS

* See Drawing No. 4-S-4.16

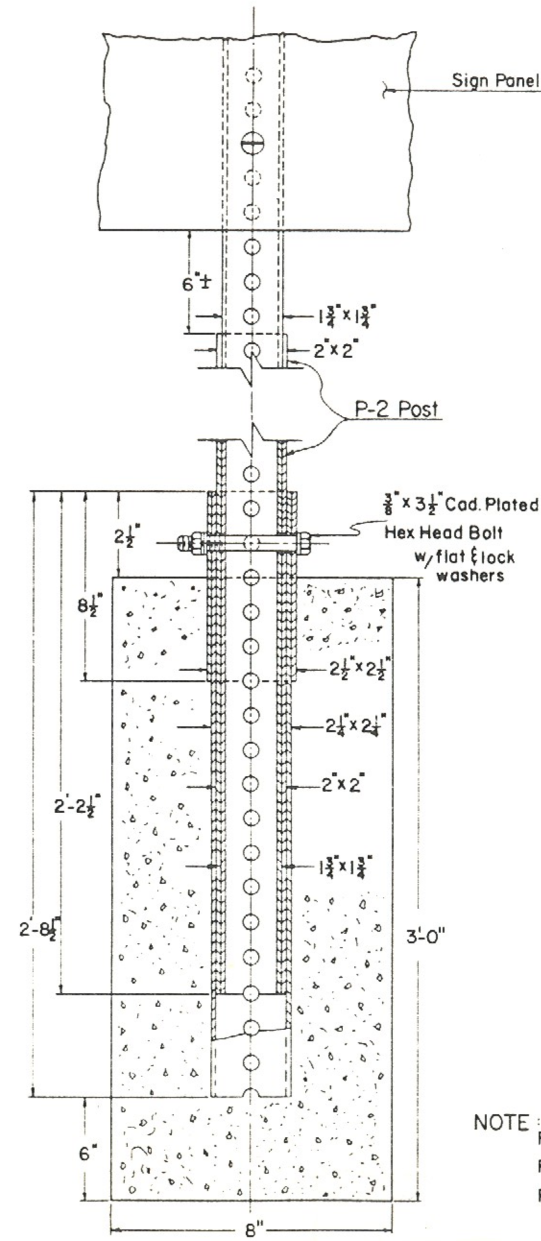


SIGN POST LOCATIONS

SIGN WIDTH

	4'	5'	6'	7'	8'	9'	10'	11'	12'
.10 W						.9'	1.0'	1.1'	1.2'
.125W			.75'	.875'	1.0'	1.125'	1.25'	1.375'	1.5'
.15W	.6'	.75'	.90'	1.05'	1.2'	1.35'	1.5'		
.20W	.8'	1.0'	1.2'	1.4'					
.25W			1.5'	1.75'	2.0'	2.25'	2.5'	2.75'	3.5'
.35W	1.4'	1.75'	2.1'	2.45'	2.8'	3.15'	3.5'		
.60W	2.4'	3.0'	3.6'	4.2'					

POST SPACING CHART



FOUNDATION DETAIL
P-2 POST

NOTE: For permissible field splice see Foundation Detail for P-1 Perforated Post (Single)

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APPROVED FOR DISTRIBUTION	FOUNDATION DETAIL FOR P2 PERFORATED POST (TELESCOPING)	DRAWING NO. 4-S-4.17

FIGURE A-6. SQUARE STEEL TUBE, MULTIPLE POSTS, TESTS 5, 6, 19, AND 20

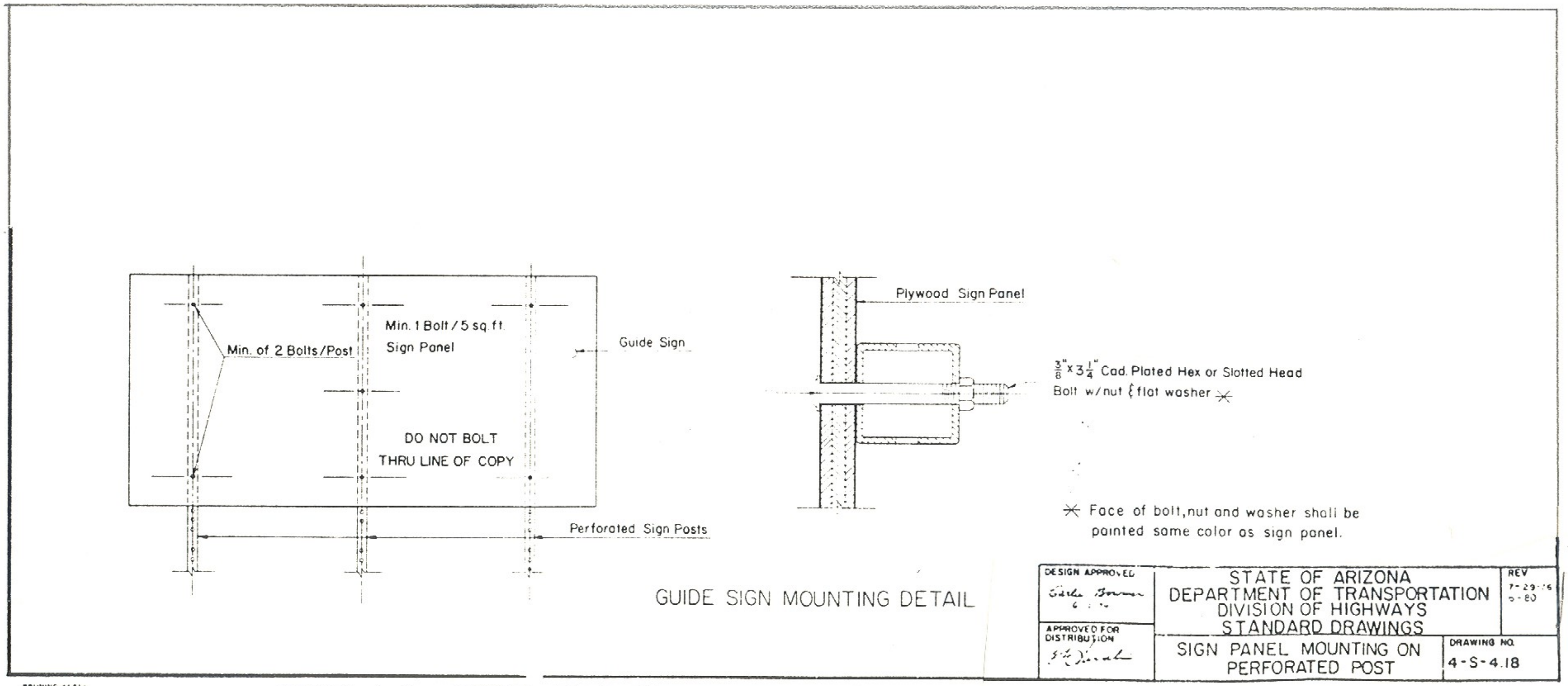


FIGURE A-6. SQUARE STEEL TUBE, MULTIPLE POSTS, TESTS 5, 6, 19, AND 20 (concluded)

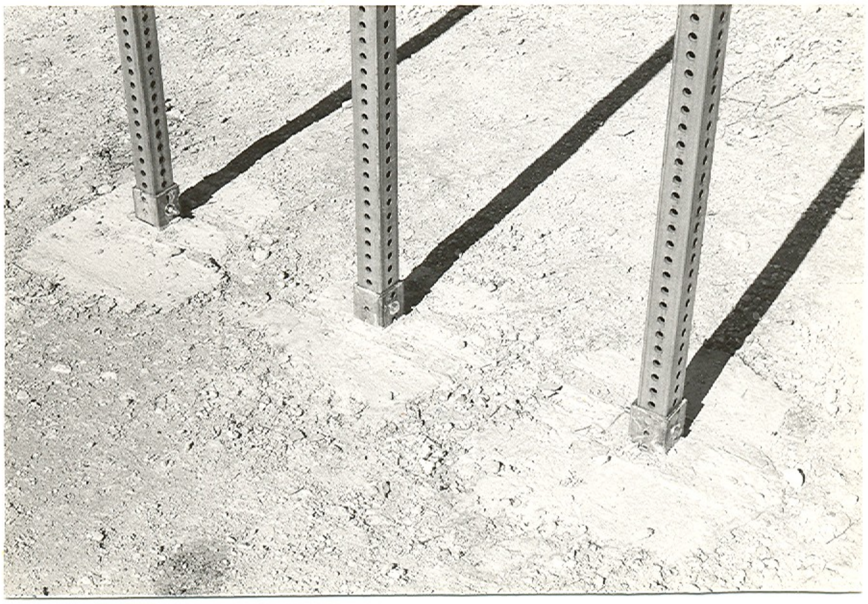


FIGURE A-7. SIGN INSTALLATION, TEST 5
(SAME AS TEST 6)

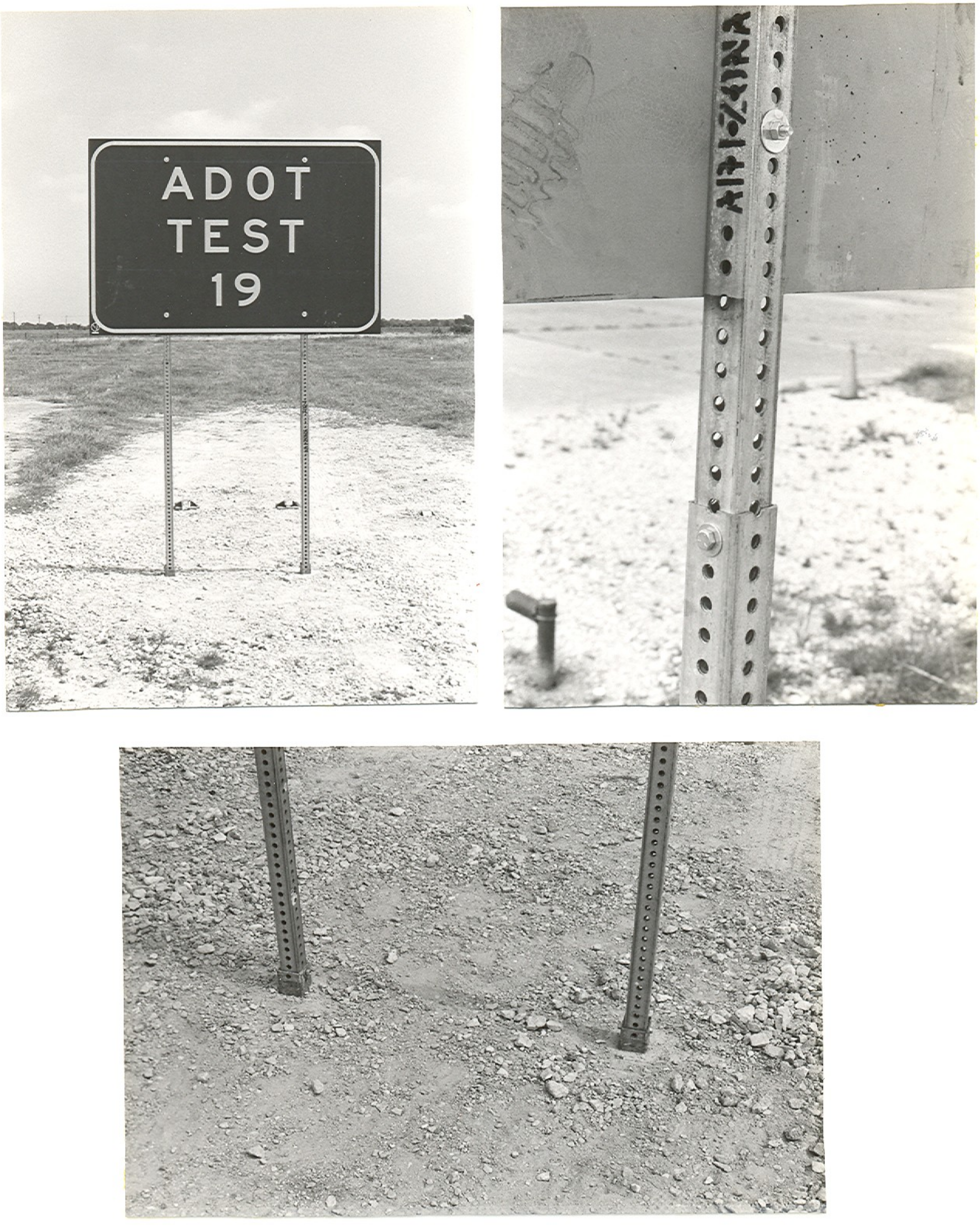


FIGURE A-8. SIGN INSTALLATION, TEST 19
(SAME AS TEST 20)

A-2-4. Steel U-Post, Single Support (Tests 7, 8, and 13)

Shown in Figure A-9 are details of the system evaluated in tests 7, 8, and 13. Photos of the installation for test 7 are shown in Figure A-10. Photos of the installation for test 13 are shown in Figure A-11.

Sign panel size and mounting details were as shown on Figure A-9. The lower 7 ft-6 inch post section was driven in the soil to the depth shown. A 3 lb/ft, high carbon, billet steel post was used in tests 7 and 8 and a 4 lb/ft, high carbon, billet steel post was used in test 13.

A-2-5. Steel U-Post, Multiple Supports (Tests 9, 10, 11, 12, 14, 15, 16, 17, 18, 21, 22, and 23)

The system evaluated in tests 9 and 10 is shown in Figure A-12. Photos of the installation for test 9 are shown in Figure A-13. All posts were 3 lb/ft, high carbon, billet steel.

Details of the system evaluated in tests 11 and 12 are shown in Figure A-14. Photos of the installation for test 11 are shown in Figure A-15. The posts were 4 lb/ft, high carbon, billet steel.

The system evaluated in tests 14, 15, 18, and 21 is shown in Figure A-16. Photos of the installation for tests 14 and 18 are shown in Figures A-17 and A-18, respectively. Posts in tests 14 and 15 were 3 lb/ft rail steel. Posts in tests 18 and 21 were 3 lb/ft, high carbon, billet steel.

Details of the system evaluated in tests 16 and 17 are shown in Figure A-19. Photos of the installation for test 16 are shown in Figure A-20. The posts were 3 lb/ft, high carbon, billet steel.

The system evaluated in tests 22 and 23 is shown in Figure A-21. Photos of the installation for test 22 are shown in Figure A-22. Posts were 3 lb/ft, high carbon, billet steel.

A-3. Test Results

Presented in this section is a description of the test results on a test-by-test basis. Reference should be made to Chapter II for a summary of the results in terms of current evaluation criteria.

Data acquisition and data reduction procedures were in accordance with recognized guidelines (1). Test results consist of data derived from an accelerometer attached to the vehicle, photos of the impact phase, and photos of the damage to the sign installation and the vehicle. Details of data acquisition systems are given in Appendix D.

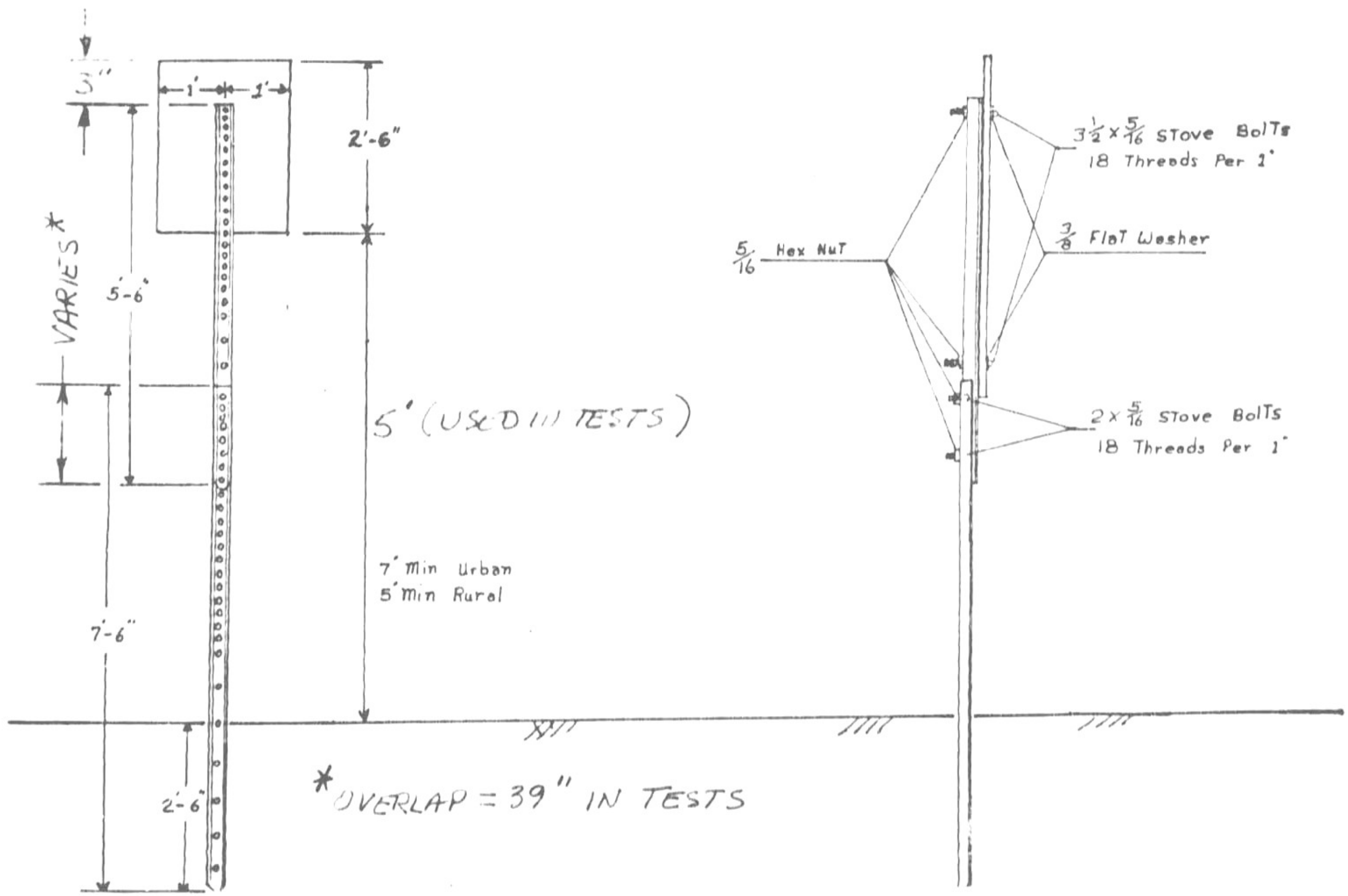


FIGURE A-9. STEEL U-POST, SINGLE SUPPORT, TESTS 7, 8, AND 13

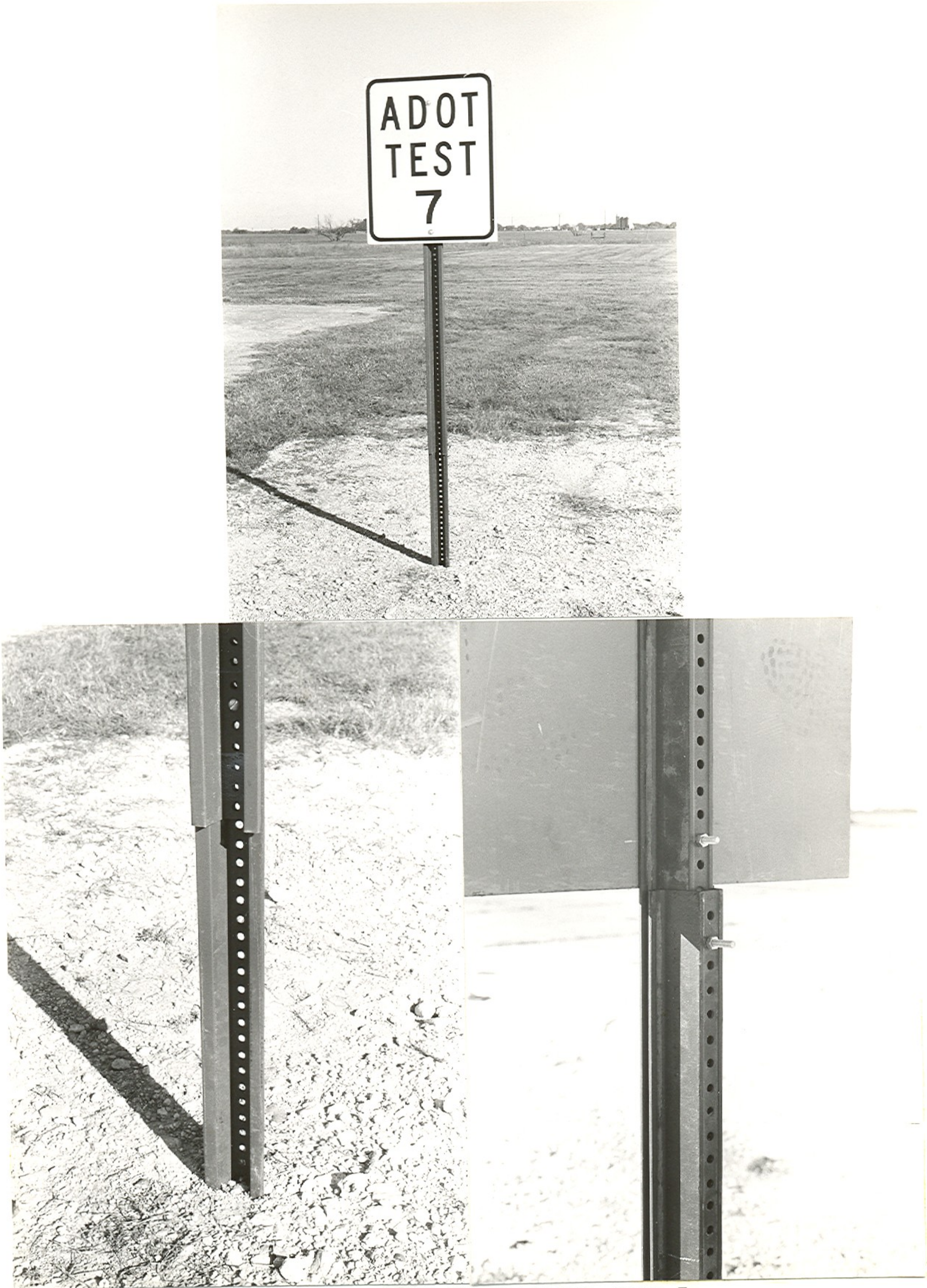


FIGURE A-10. SIGN INSTALLATION, TEST 7
(SAME AS TEST 8)

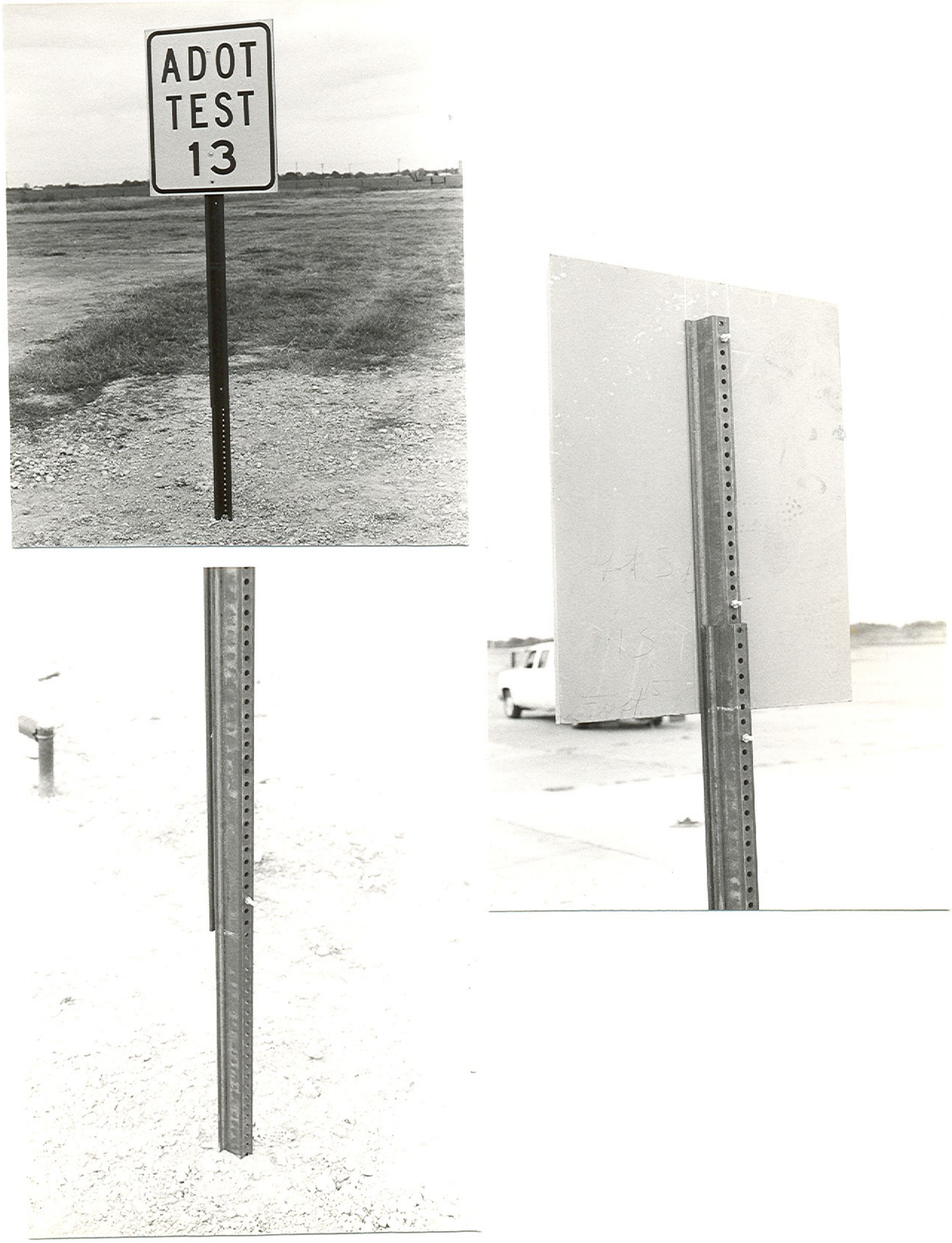


FIGURE A-11. SIGN INSTALLATION, TEST 13

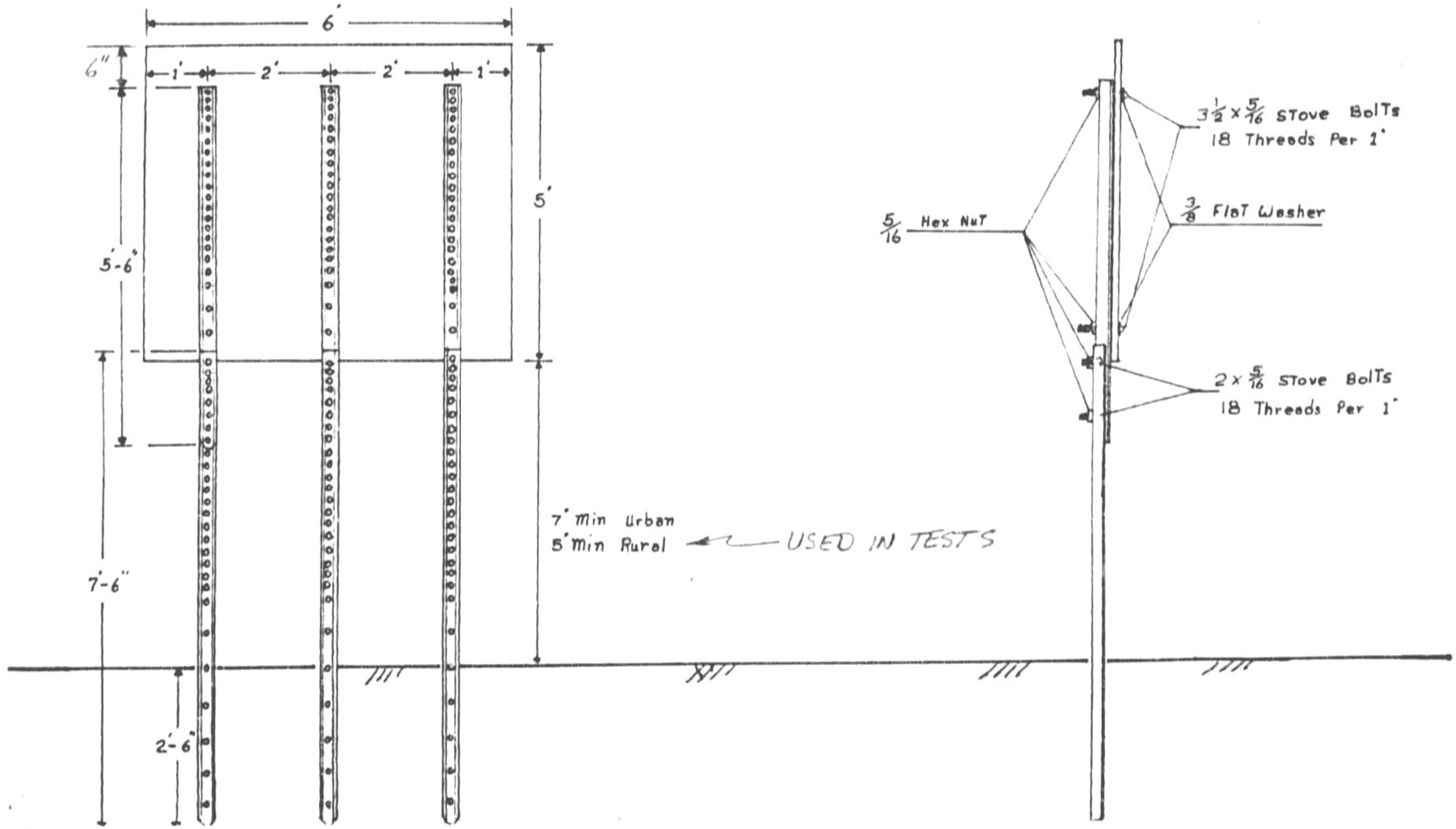


FIGURE A-12. STEEL U-POST, THREE SUPPORTS, TESTS 9 AND 10

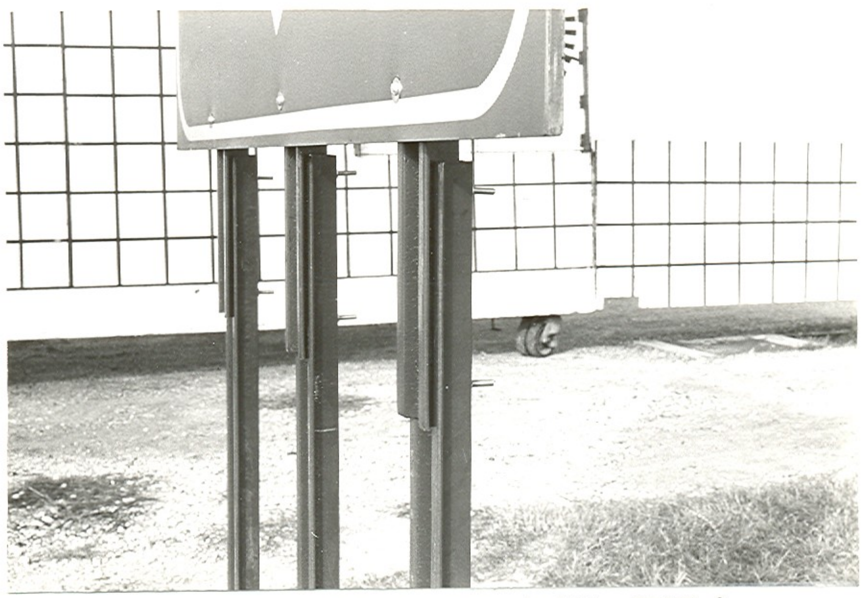


FIGURE A-13. SIGN INSTALLATION, TEST 9
(SAME AS TEST 10)

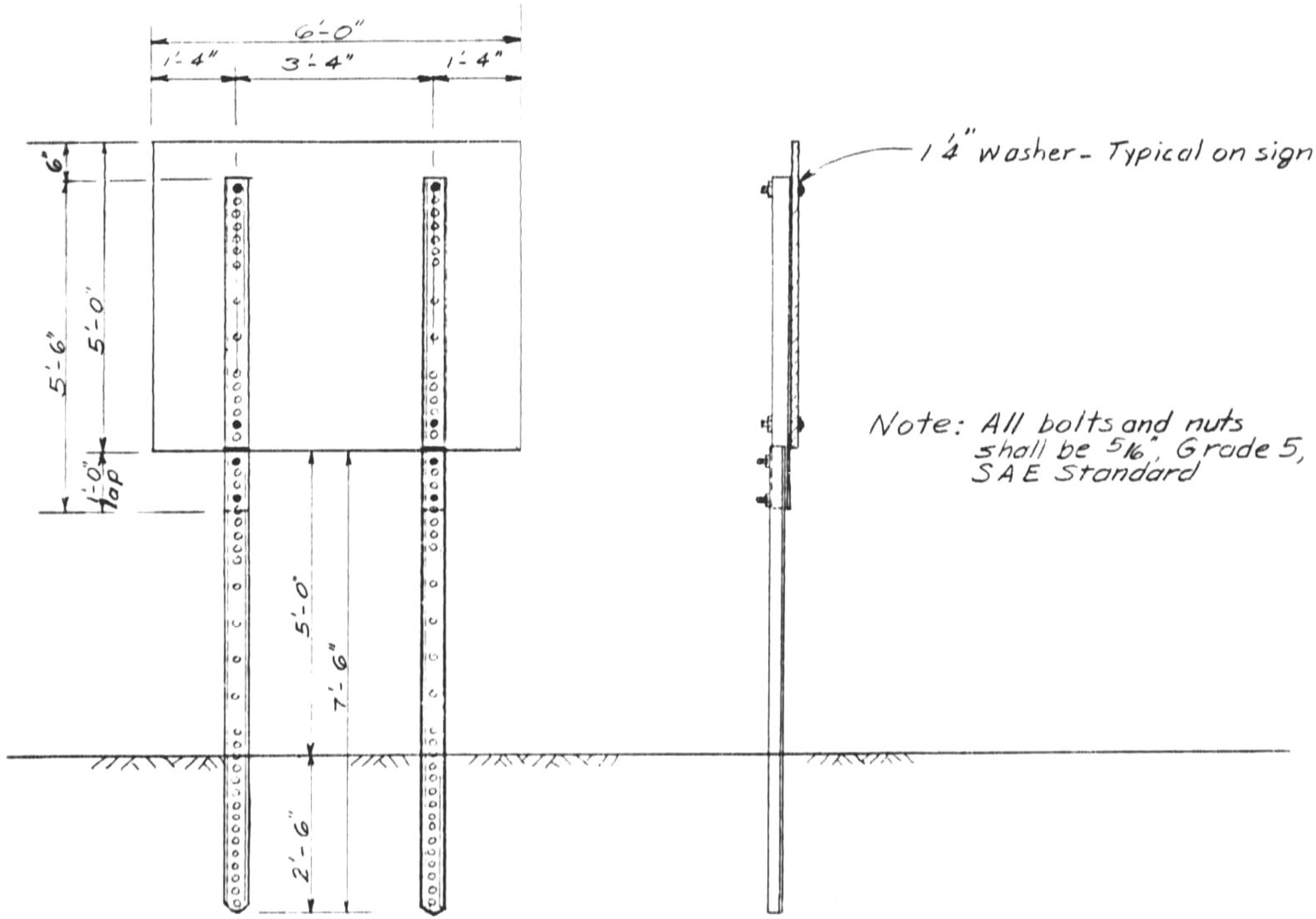


FIGURE A-14. STEEL U-POST, TWO SUPPORTS, TESTS 11 AND 12

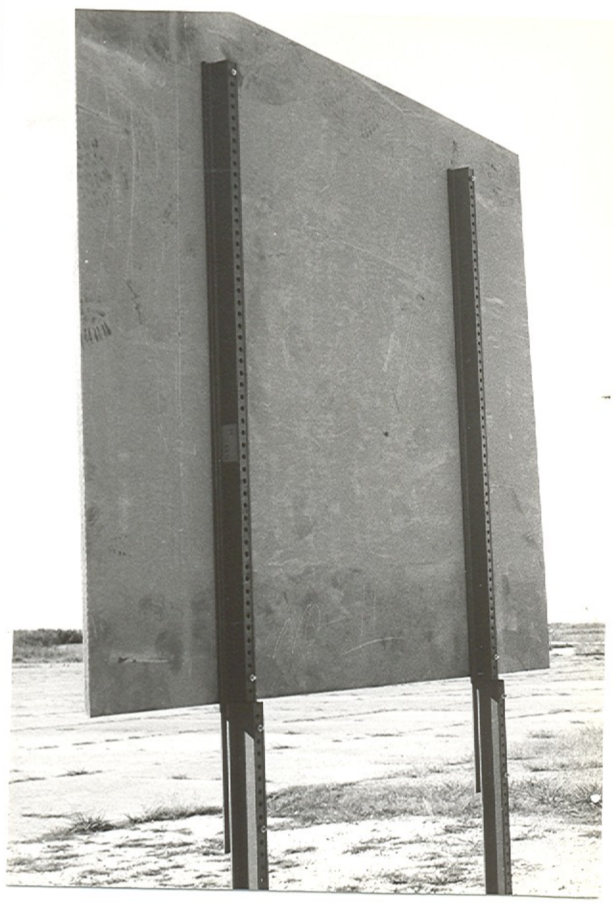


FIGURE A-15. SIGN INSTALLATION, TEST 11
(SAME AS TEST 12)

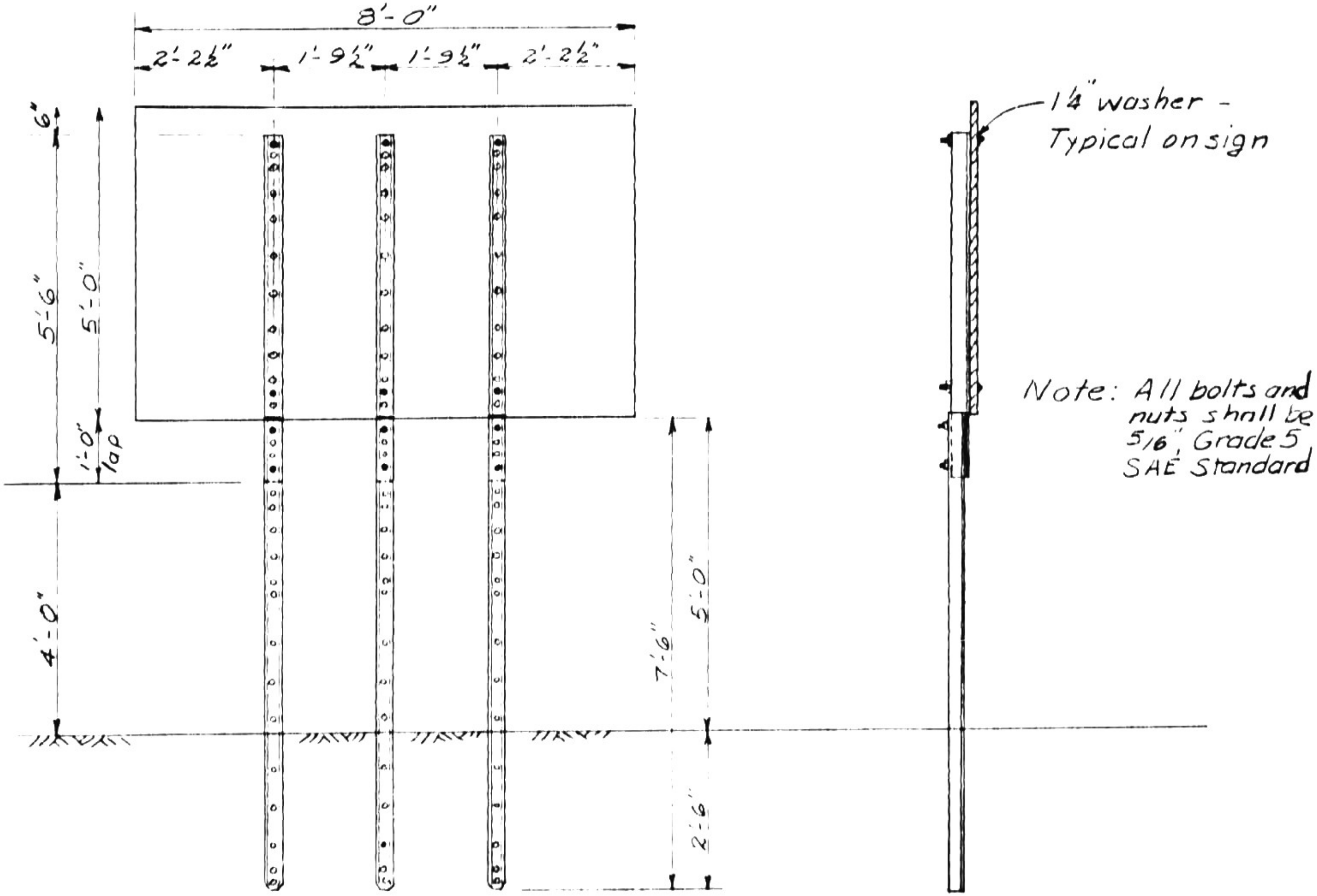


FIGURE A-16. STEEL U-POST, THREE SUPPORTS, TESTS 14, 15, 18, AND 21

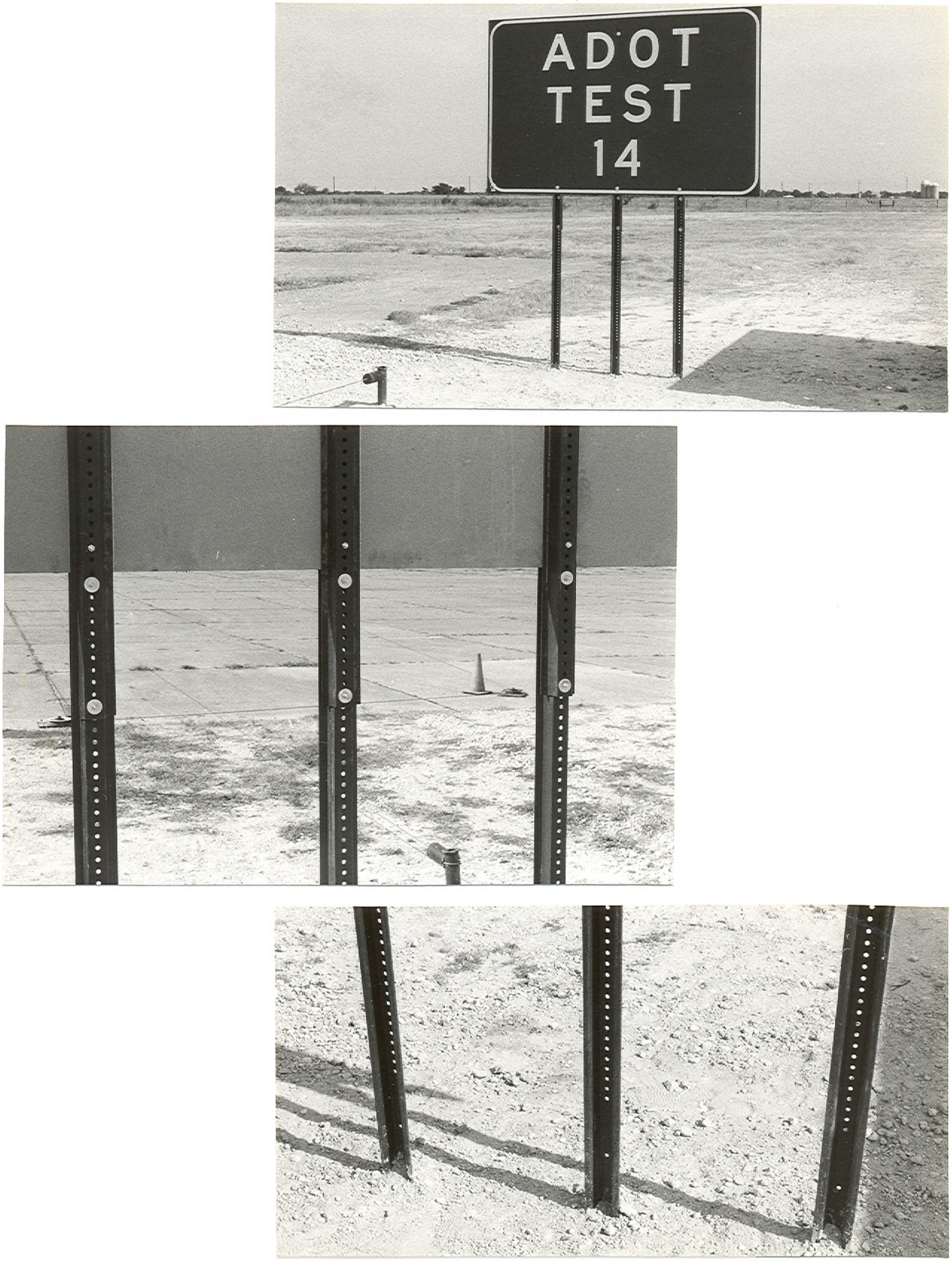


FIGURE A-17. SIGN INSTALLATION, TEST 14
(SAME AS TEST 15)

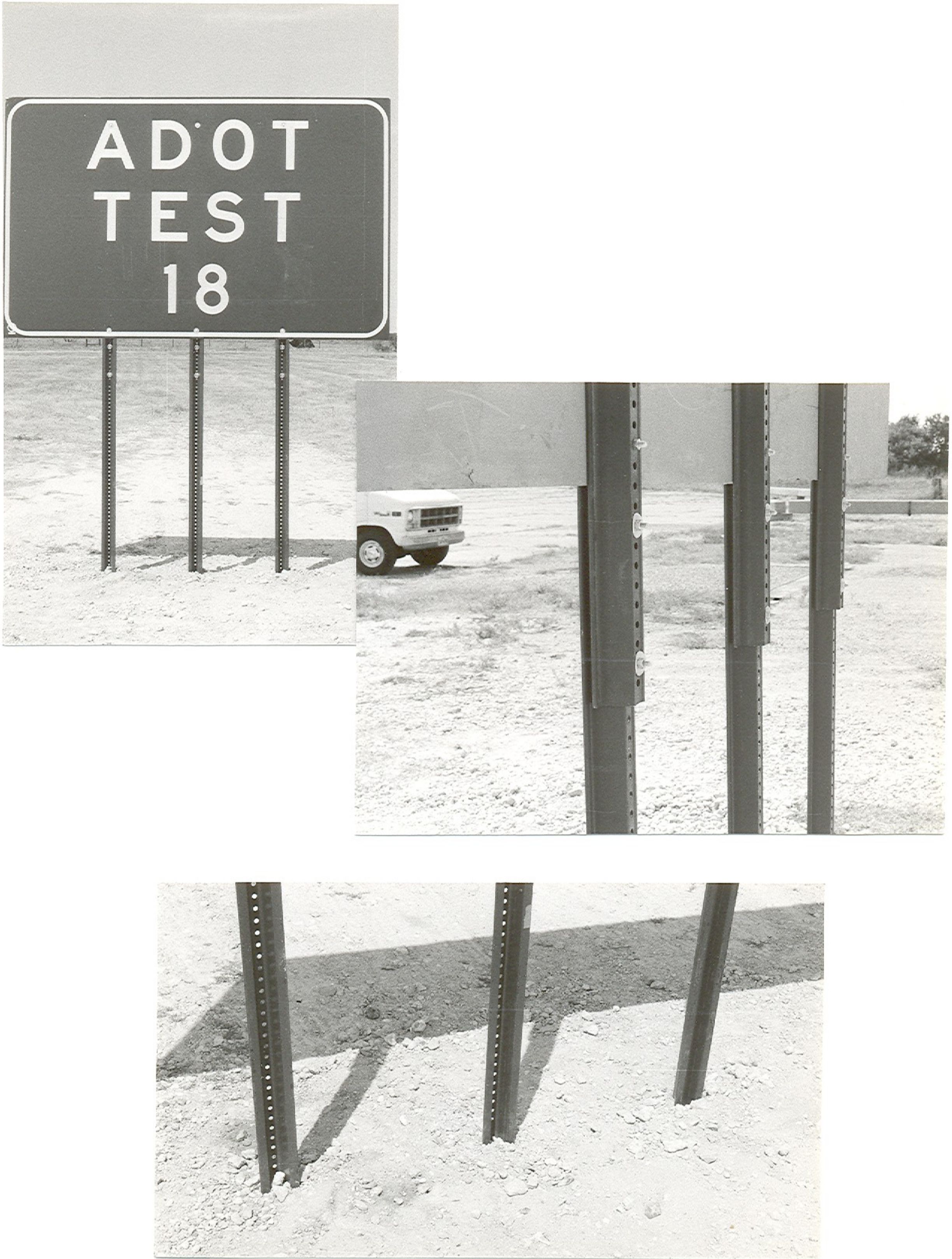


FIGURE A-18. SIGN INSTALLATION, TEST 18
(SAME AS TEST 21)

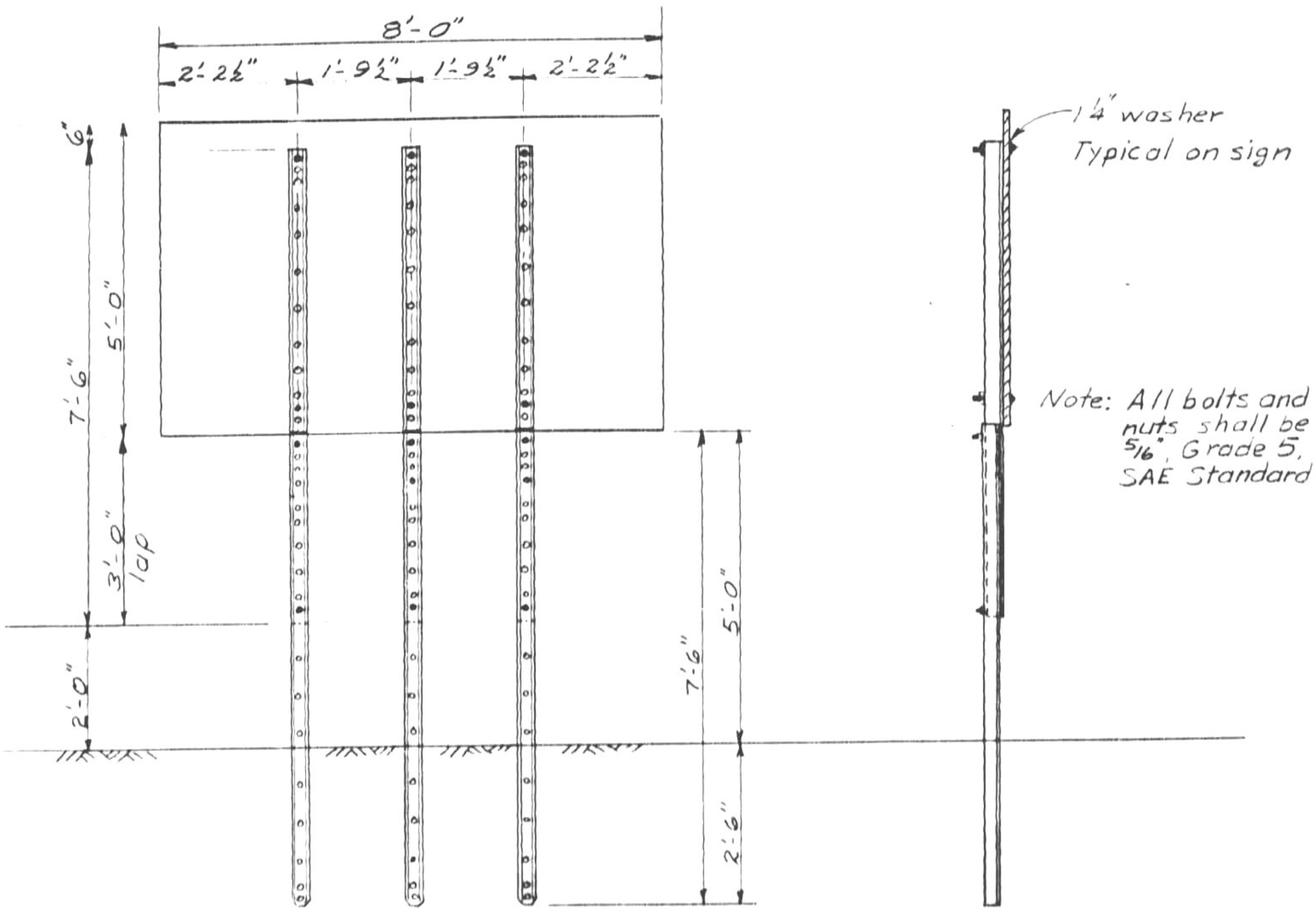


FIGURE A-19. STEEL U-POST, THREE SUPPORTS, TESTS 16 AND 17

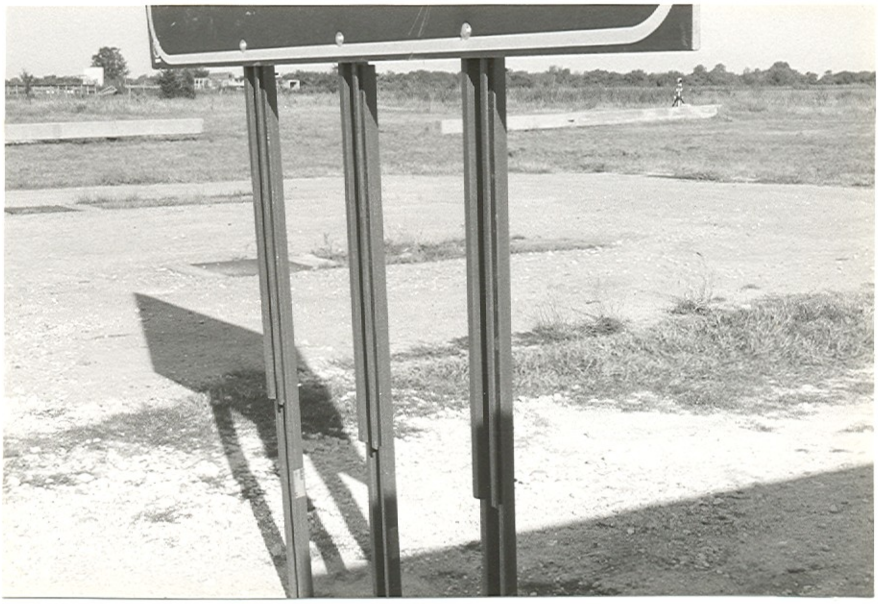


FIGURE A-20. SIGN INSTALLATION, TEST 16
(SAME AS TEST 17)

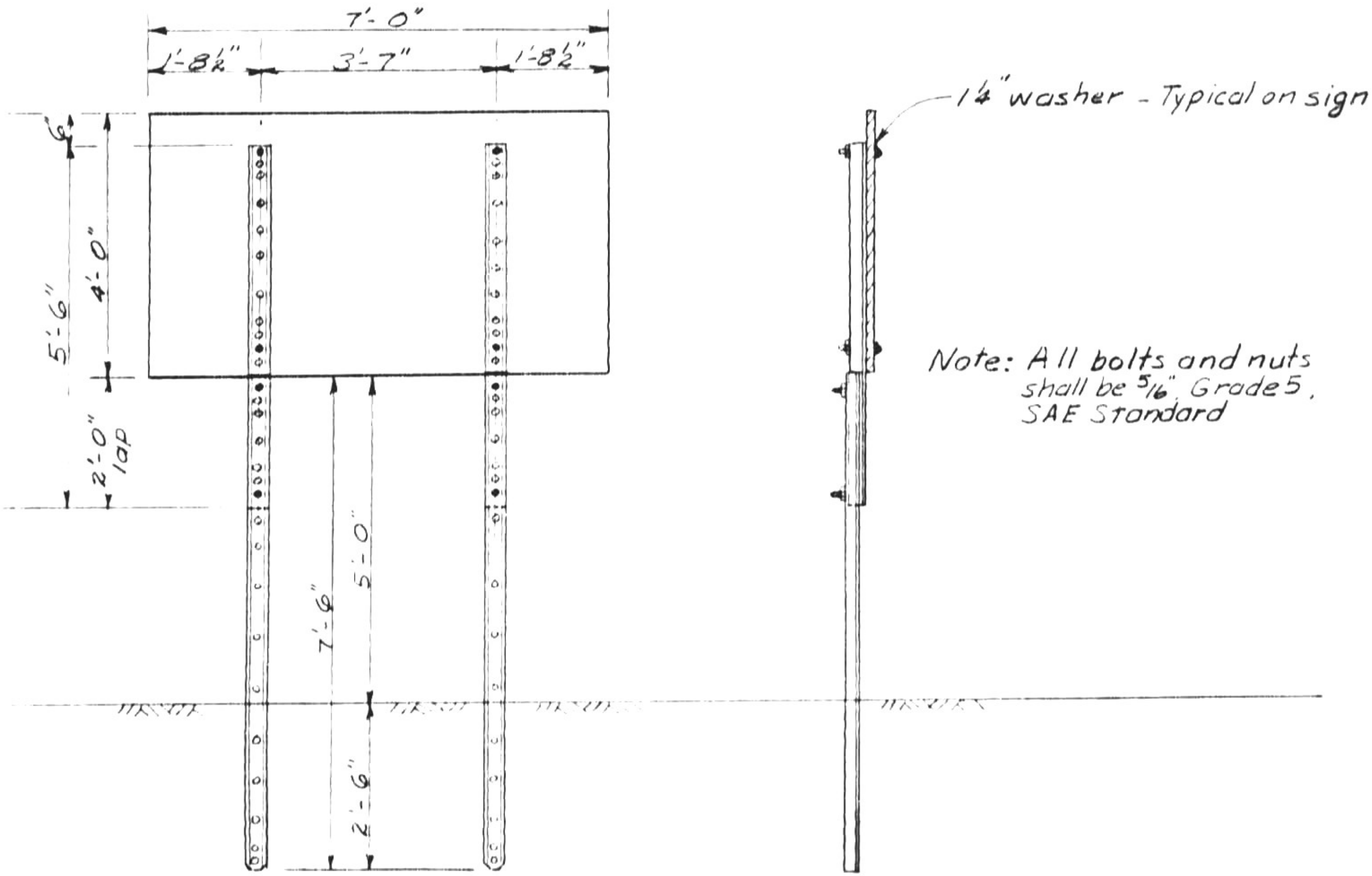


FIGURE A-21. STEEL U-POST, TWO SUPPORTS, TESTS 22 AND 23

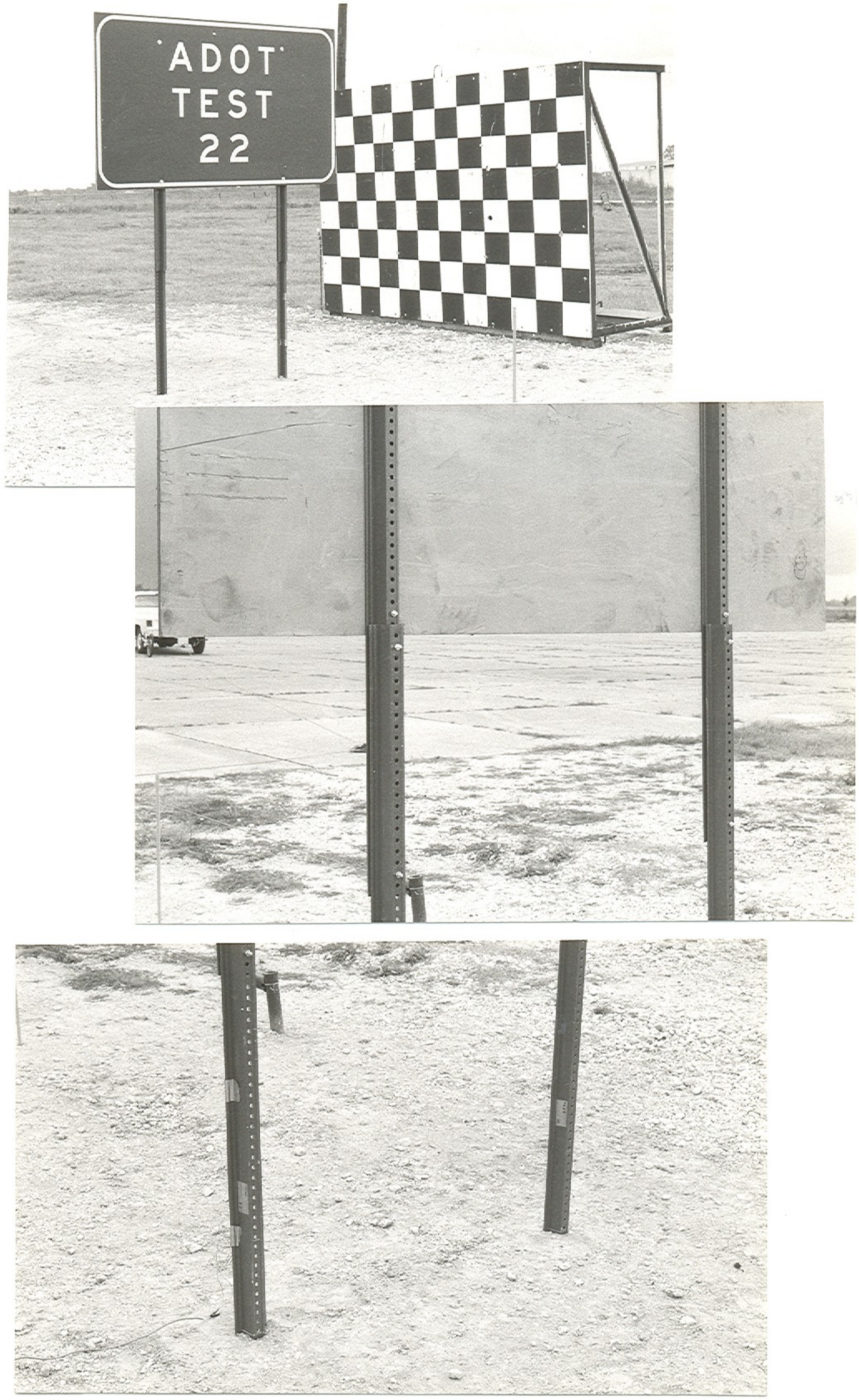


FIGURE A-22. SIGN INSTALLATION, TEST 22
(SAME AS TEST 23)

Vehicle acceleration data were analyzed to obtain three parameters: (1) change in the vehicle's velocity (and hence change in the vehicle's momentum), (2) occupant impact velocity, and (3) occupant ridedown acceleration. Following is a discussion of the procedures used in the analysis.

Change in the vehicle's momentum was obtained by first integrating the vehicle's deceleration over a given time interval, which gives the change in the vehicle's velocity during the interval. Change in velocity is then multiplied by the vehicle's mass to obtain the change in momentum. Since change in momentum is time dependent, a time duration must be specified for its computation. Guidelines for determining this duration, presented in reference 3, are as follows:

> For yielding supports (such as base-bending signs) change in vehicle momentum to be used in the acceptance criteria of this section shall be computed on the basis of time integration of the vehicle deceleration signal over a "duration of event". This duration shall be defined as the lesser of the following: (1) time between incipient contact and loss of contact between the vehicle and the yielding support, or (2) the time for a free missile to travel a distance of 24 in. starting from rest with the same magnitude of vehicle deceleration.

Free missile travel is explicitly determined from measured accelerometer data. "Time between incipient contact and loss of contact between the vehicle and the yielding support" is not so explicit. High-speed film would seem to be the logical means with which this time duration could be determined. However, it is often difficult to ascertain the time that "loss of contact" occurs with precision. In a low-speed impact, the vehicle may bend the post down and travel over it. "Apparent contact" can occur over a relatively large time period, although there may be no appreciable contact forces. In a high-speed impact, the post may wrap around and remain with the vehicle after it has fractured or pulled from the ground. Again, "apparent contact" is still being made with no appreciable contact forces. Compounding the problem is the fact that filtered accelerometer output causes slight phase shifts in the filtered data.

To overcome these difficulties with computation of "contact time" for change in momentum calculations, a simple procedure was adopted in which only the accelerometer data were used. Contact time, or "impulse period" as used herein, was defined as the duration between initial contact and the time at which the deceleration essentially returned to and remained at zero. Obviously, deceleration does not remain at zero unless the vehicle reaches a constant velocity or comes to a stop. However, in most tests, contact was followed by a period where wind drag and rolling resistance were the only forces on the vehicle. These forces decelerate the vehicle at a level which is small in comparison with that caused by contact forces. Subsequent to that period, the brakes were applied.

Computation of occupant impact velocity and occupant ridedown acceleration is more direct. Vehicle deceleration is double integrated with respect to time to find the time, T_O, for a free missile ("occupant") to travel 2 ft relative to the vehicle, with the missile having a constant velocity equal to the vehicle's velocity at impact. Occupant impact velocity equals the vehicle's change in velocity at time T_O. Occupant ridedown acceleration is computed from the vehicle's deceleration and equals the highest average deceleration computed over any continuous 10 millisecond period after T_O.

In some tests the "occupant" will not travel 2 ft relative to the vehicle during the "impulse period". If so, the results presented herein indicate "no contact" for the occupant. For these cases, one may assume the occupant impact velocity equals the vehicle's change in velocity that occurs during the impulse period. In other words, once an occupant is moving relative to the vehicle at a velocity, V_O, he will eventually strike the vehicle's interior at V_O, provided the vehicle does not accelerate or decelerate.

Damage to the vehicle was assessed in terms of two nationally recognized rating scales. These were the Vehicle Damage Scale published by the Traffic Accident Data Project (TAD) (4) and the Collision Deformation Classification recommended by the Society of Automotive Engineers (SAE) (5).

All tests were conducted with the vehicle impacting the sign installation in a head-on, tracking orientation. From the time of impact to the time of rest, the vehicle was in a free-steering mode (no steer input). In each test, the brakes were applied once the vehicle cleared the test area.

A-3-1. Test 1

A 1980 Honda Civic was directed into the sign installation at 19.6 mph. Test inertia mass of the test vehicle was 1,820 lb and its gross static mass was 1,985 lb. Impact point was 15 in. to the left of the vehicle centerline. Relative positions of the test vehicle and sign installation are shown in Figure A-23.

Approximately 0.020 sec after impact the breakaway base on the right support began to slip. At 0.035 sec the right support began to kick up and by 0.067 sec the support lost contact with the vehicle. At about 0.261 sec the vehicle regained contact with the support and at 0.348 sec the hinge activated. As the vehicle continued forward it lost contact with the support at 0.498 sec and subsequently came to rest 72 ft behind and 18 ft to the left of the impact point. The sign installation remained standing with the right support bent back about 4 ft as shown in Figure A-24.

Photographs of the sign installation after the test are shown in Figures A-24 and A-25. Damage to the vehicle was minimal as shown in Figure A-26. The left front quarter was deformed and was crushed 1.0 in. at bumper height. Sequential photographs of the test are shown in Figure A-27.

A summary of test results is provided in Figure A-28. Change in the vehicle's velocity during the impulse period was 3.4 mph and change in momentum was 282 lb-sec. There was no occupant contact during the impulse period.

FIGURE A-23. RELATIVE POSITIONS OF SIGN INSTALLATION AND TEST VEHICLE FOR TEST 1.

FIGURE A-24. SIGN INSTALLATION AFTER TEST 1.

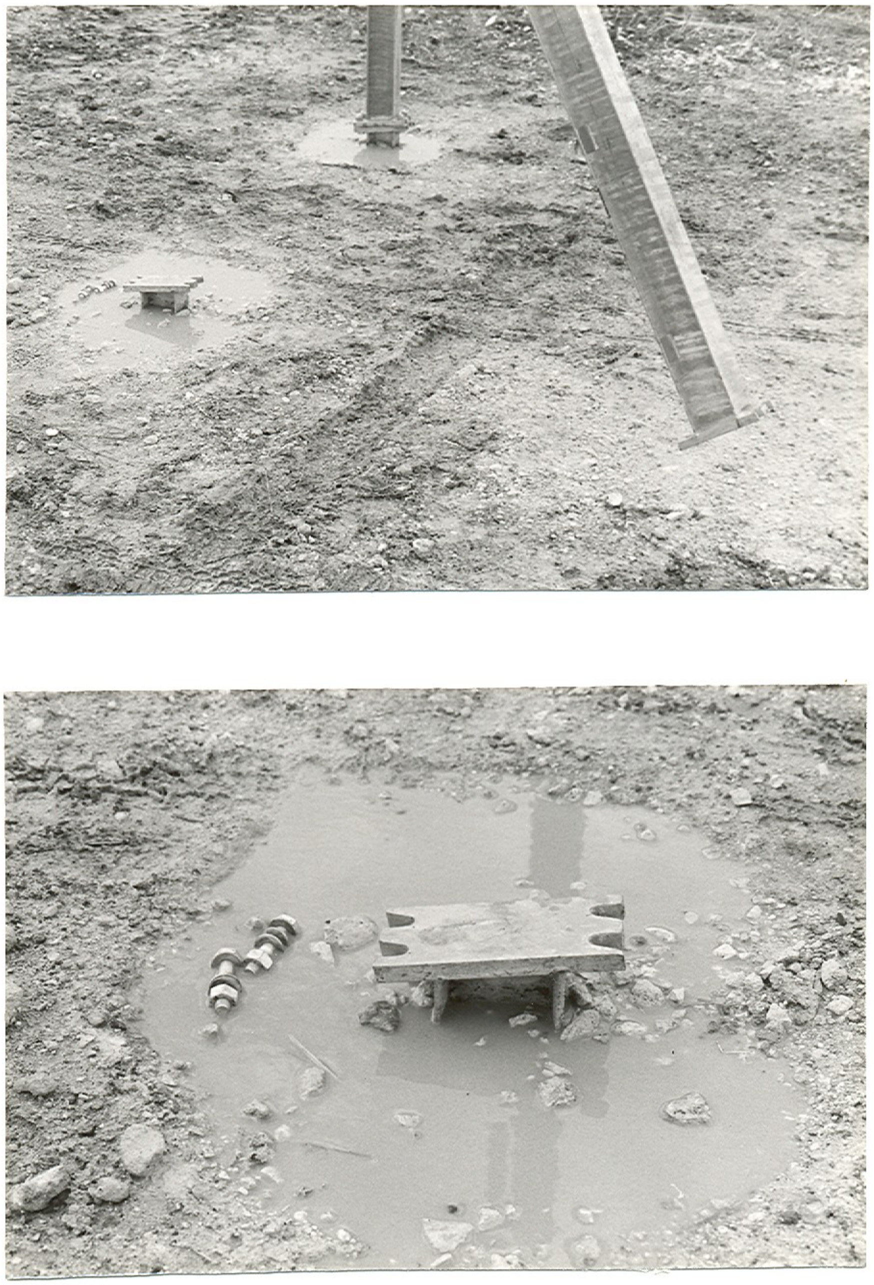
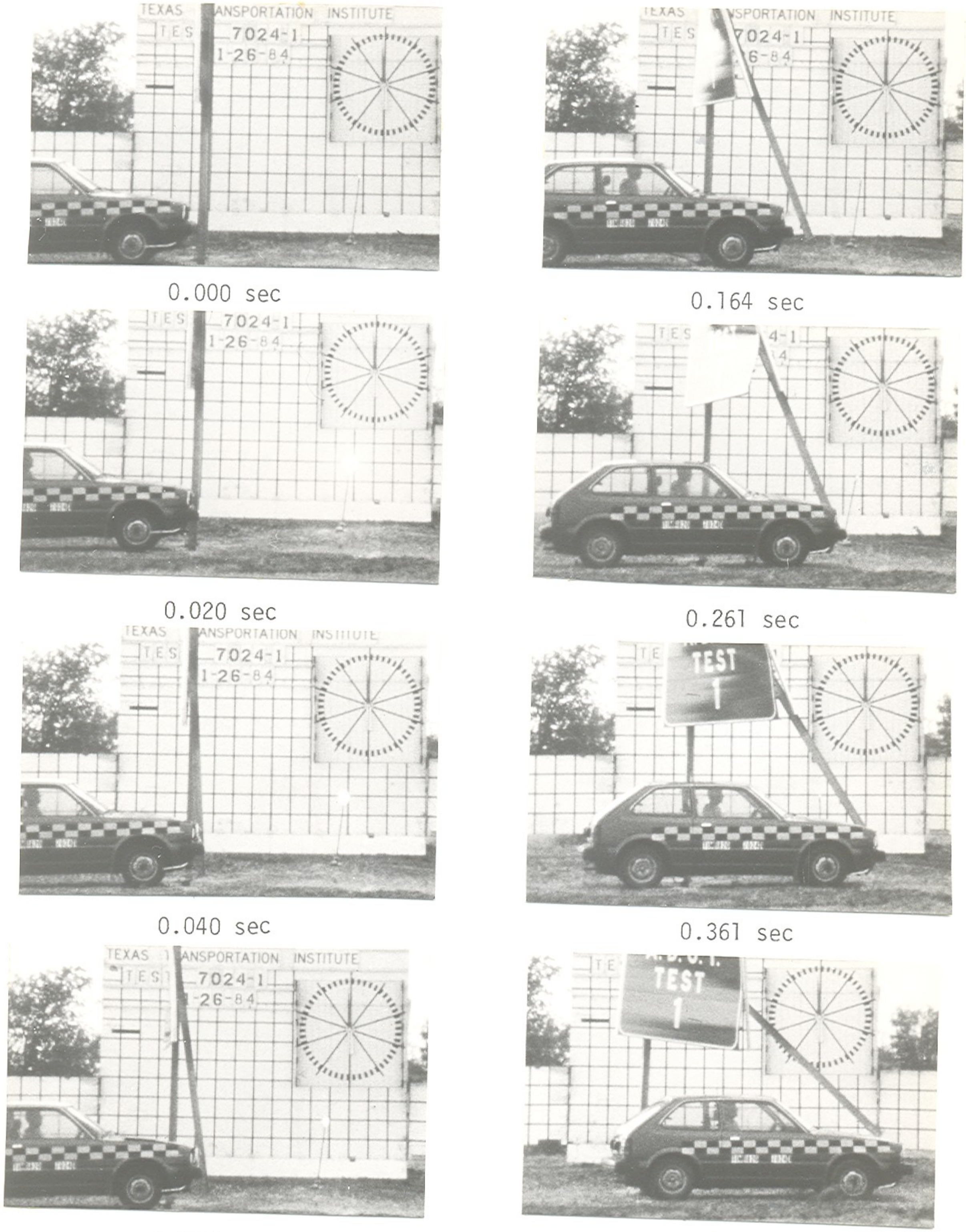


FIGURE A-25. BREAKAWAY BASE AFTER TEST 1.

FIGURE A-26. TEST VEHICLE BEFORE AND AFTER TEST 1.



0.000 sec

0.164 sec

0.020 sec

0.261 sec

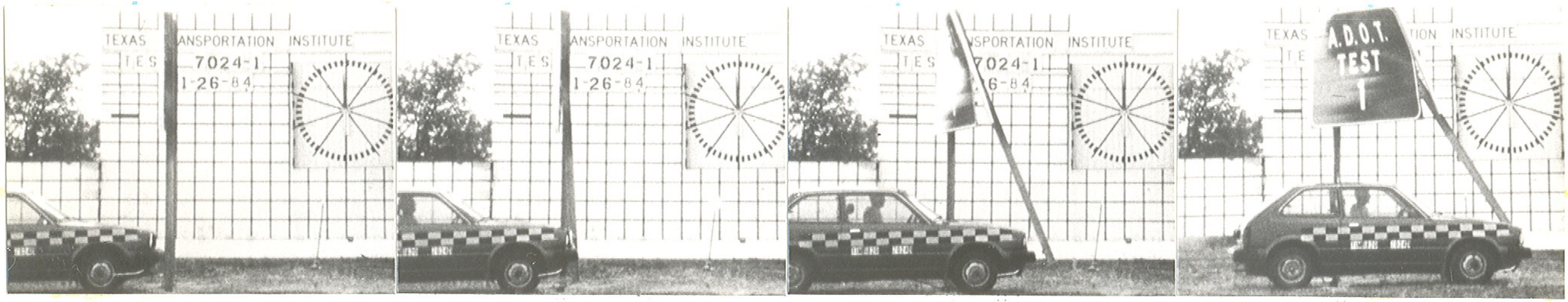
0.040 sec

0.361 sec

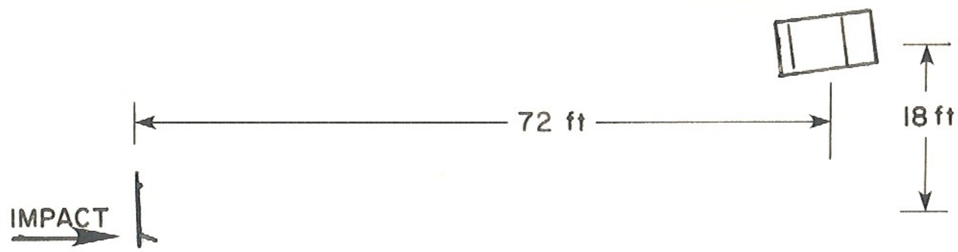
0.067 sec

0.498 sec

FIGURE A-27. SEQUENTIAL PHOTOGRAPHS FOR TEST 1.



0.000 sec | 0.040 sec | 0.164 sec | 0.361 sec



Test No.	7024-1
Date	11/26/84
Test Article	Multi-leg Sign support of S4x7.7 posts
Vehicle.	1980 Honda Civic
Vehicle Weight	
Test Inertia	1,820 lb (826 kg)
Gross Static	1,985 lb (901 kg)
Vehicle Damage Classification	
TAD.	12FL1
SAE.	12FLEN1

Impact Speed.	19.6 mph (31.5 kph)
Change in Velocity.	3.4 mph (5.5 kph)
Change in Momentum	282 lb-sec
Occupant Impact Velocity	
Longitudinal.	No Contact
Lateral	No Contact
Occupant Ridedown Accelerations	
Longitudinal.	N/A
Lateral	N/A
Maximum Vehicle Crush	
Bumper Height	1.0 in. (2.5 cm)
Hood Height	None

FIGURE A-28. SUMMARY OF RESULTS FOR TEST 1.

A-3-2. Test 2

A 1980 Honda Civic, pictured in Figure A-29, was directed into the sign installation at 59.3 mph. Test inertia mass of the test vehicle was 1,820 lb and its gross static mass was 1,985 lb. Impact point was 15 in. to the right of the vehicle centerline. Relative positions of the test vehicle and sign installation are shown in Figure A-30.

Approximately 0.005 sec after impact the breakaway base of the left support began to slip and by 0.025 sec the upper hinge activated. At 0.052 sec the support lost contact with the front of the vehicle and continued moving upward. After the vehicle exited the test area, the clamps attaching the sign panel to the left support began to release and at 1.160 sec the sign panel fell from the right support. The vehicle came to a relatively safe, stable stop approximately 240 ft behind and 24 ft to the left of the impact point.

Photographs of the sign after the test are shown in Figures A-31 and A-32. The vehicle received minimal damage as shown in Figure A-33. The right front quarter received 2.0 in. crush at bumper height and 2.0 in. at hood height. Sequential photographs of the test are shown in Figure A-34.

A summary of test results is provided in Figure A-35. Change in the vehicle's velocity during the impulse period was 2.1 mph and change in momentum was 174 lb-sec. There was no occupant impact during the impulse period.

FIGURE A-29. TEST VEHICLE BEFORE TEST 2.

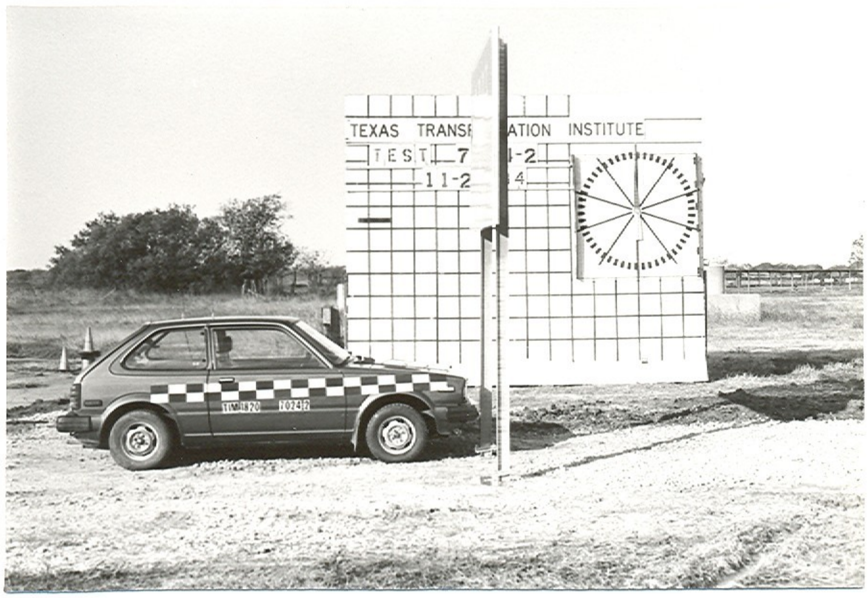
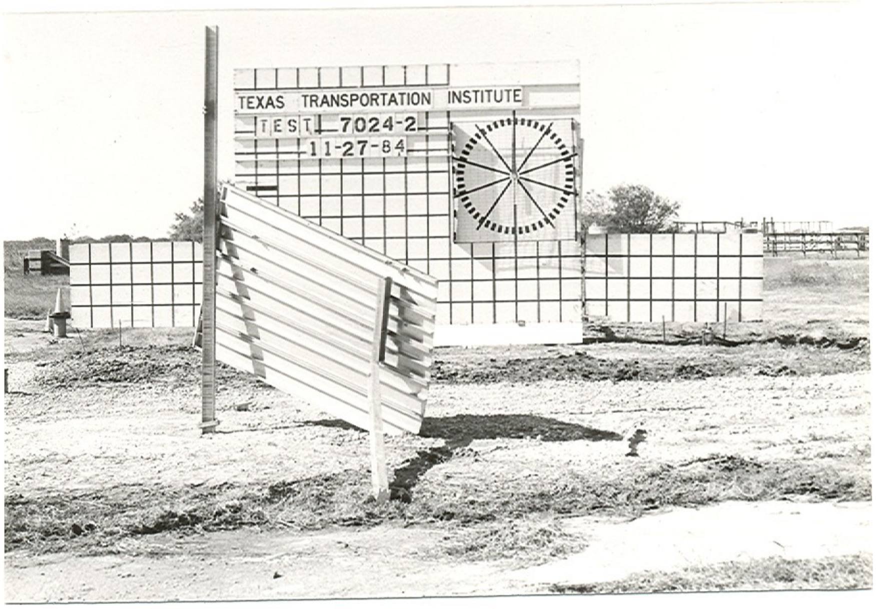


FIGURE A-30. RELATIVE POSITIONS OF SIGN INSTALLATION AND TEST VEHICLE FOR TEST 2.



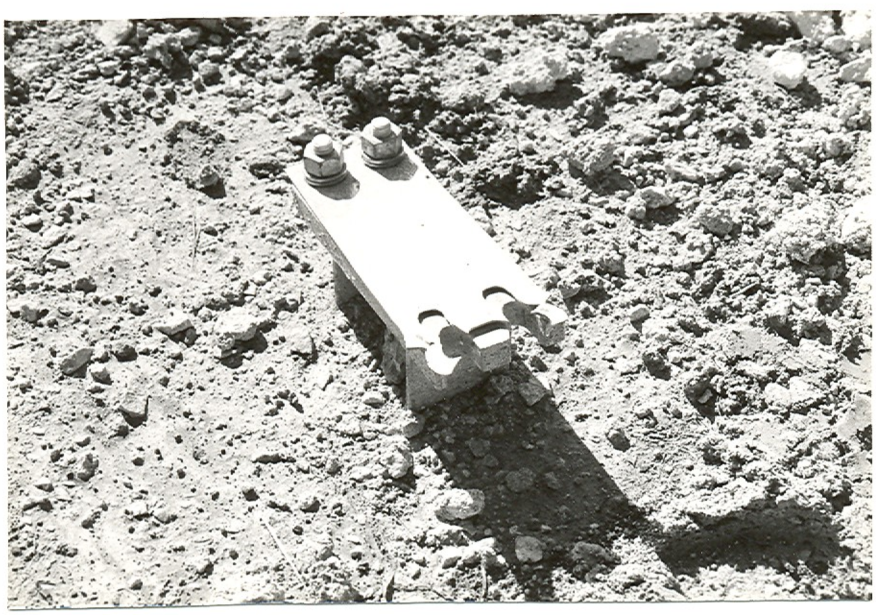
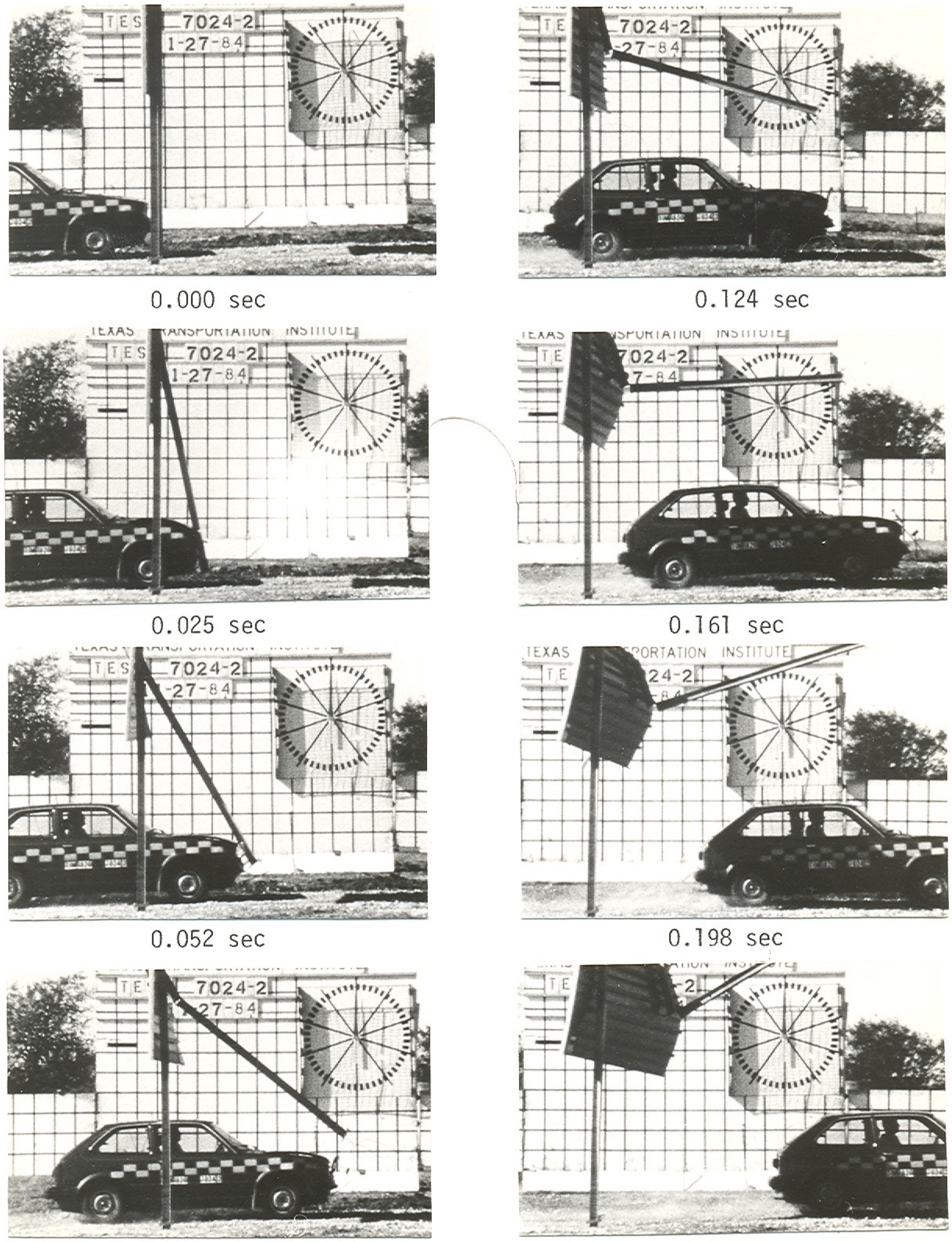


FIGURE A-31. BREAKAWAY BASE AFTER TEST 2.

FIGURE A-32. HINGE AFTER TEST 2.

FIGURE A-33. TEST VEHICLE AFTER TEST 2.



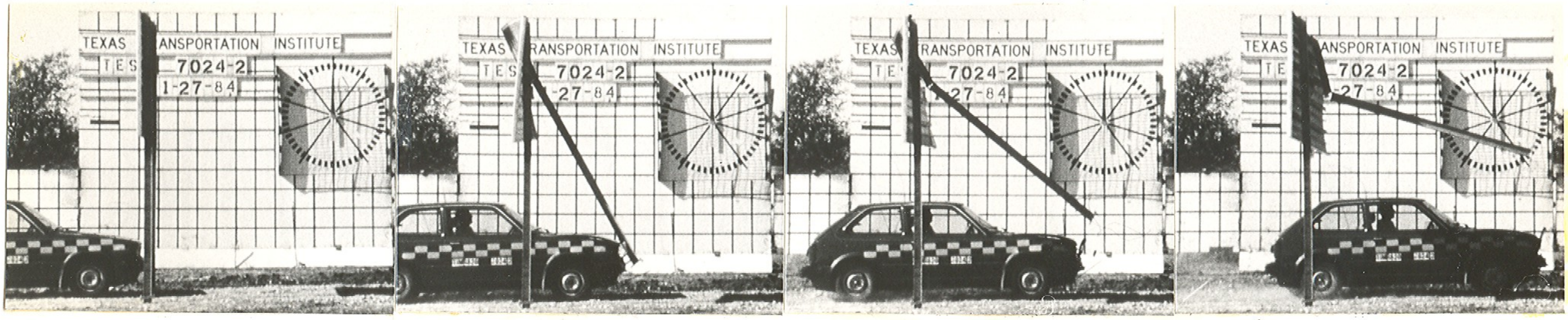
0.000 sec | 0.124 sec

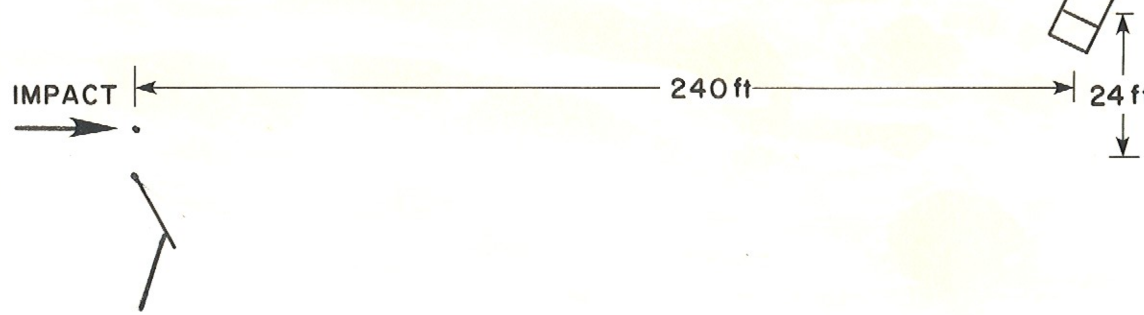
0.025 sec | 0.161 sec

0.052 sec | 0.198 sec

0.087 sec | 0.235 sec

FIGURE A-34. SEQUENTIAL PHOTOGRAPHS FOR TEST 2.





Test No. 7024-2
Date 11/8/84
Test Article . . . . Multi-leg Sign Support of S4x7.7 post
Vehicle. . . . . 1980 Honda Civic
Vehicle Weight
  Test Inertia . . . . 1,820 lb (826 kg)
  Gross Static . . . . 1,985 lb (901 kg)
Vehicle Damage Classification
  TAD. 12FR1
  SAE. 12FREN2

Impact Speed. . . . . 59.3 mph (95.4 kph)
Change in Velocity. . . . . . 2.1 mph (3.4 kph)
Change in Momentum . . . . . 174 lb-sec
Occupant Impact Velocity
  Longitudinal. . . . . No Contact
  Lateral . . . . No Contact
Occupant Ridedown Accelerations
  Longitudinal. . . . . N/A
  Lateral . . . . N/A
Maximum Vehicle Crush
  Bumper Height . . . . 2.0 in. (5.1 cm)
  Hood Height . . . . 2.0 in. (5.1 cm)

FIGURE A-35. SUMMARY OF RESULTS FOR TEST 2.

A-3-3. Test 3

The 1979 Honda Civic, shown in Figure A-36, was directed into the sign at 20.0 mph. The test inertia mass of the vehicle was 1,770 lb and its gross static mass was 1,939 lb. Impact was such that the vehicle bumper contacted the support 15 in. to the right of the vehicle centerline.

Approximately 0.025 sec after impact the support fractured at bumper height. The vehicle lost contact with the sign installation at 0.110 sec. Sequential photographs of the test are shown in Figure A-37. The support was fractured (but not completely separated) at the base and 16 in. above the ground as shown in Figure A-38. As shown in Figure A-39 the vehicle sustained minor scrapes to the bumper.

Results of the test are summarized in Figure A-40. Change in the vehicle's velocity was 2.4 mph and change in momentum was 193 lb-sec. There was no occupant impact during the impulse period.

FIGURE A-36. VEHICLE BEFORE TEST 3.

0.000 sec

0.018 sec

0.035 sec

0.053 sec

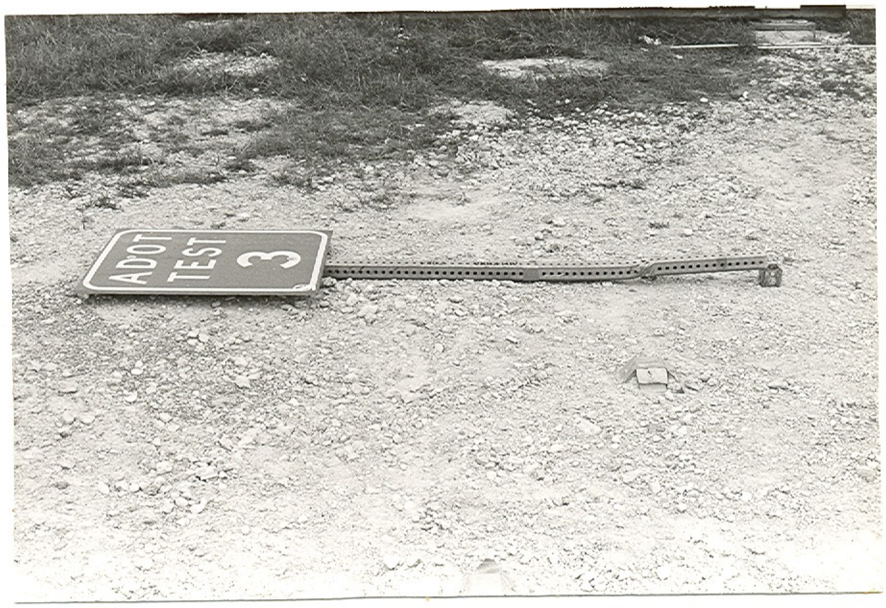
0.070 sec

0.088 sec

0.110 sec

0.135 sec

FIGURE A-37. SEQUENTIAL PHOTOGRAPHS FOR TEST 3.



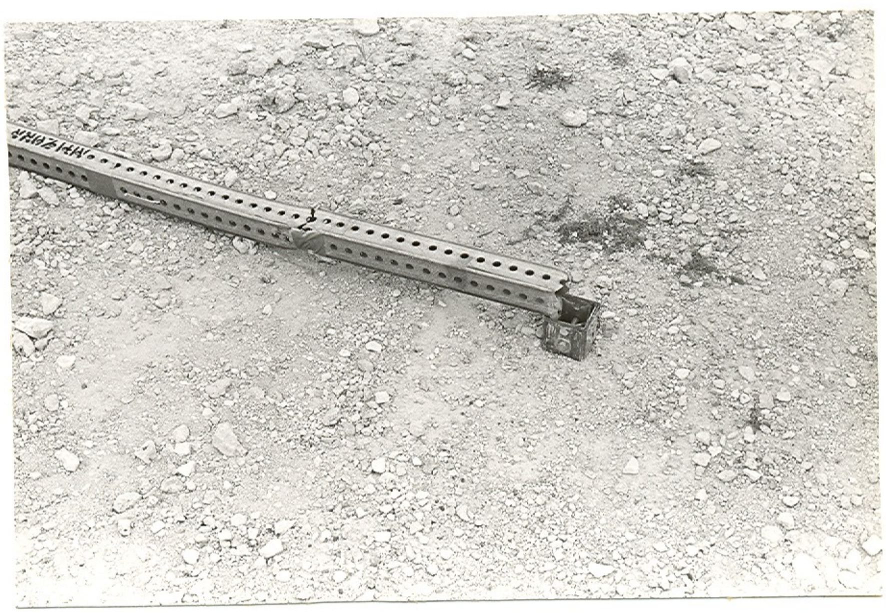
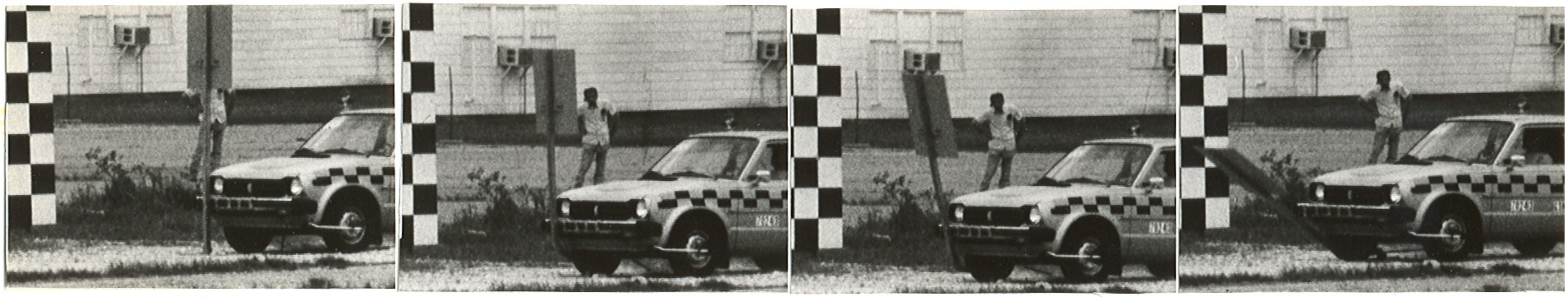


FIGURE A-38. TEST INSTALLATION AFTER TEST 3.

FIGURE A-39. VEHICLE AFTER TEST 3.



0.000 sec | 0.035 sec | 0.070 sec | 0.110 sec

Test No.	7024-3
Date	5/28/85
Test Article	Sign installation
Support.	Square-tube (Unistrut) P1 post
Vehicle.	1979 Honda Civic
Vehicle Weight	
Test Inertia	1,770 lb (804 kg)
Gross Static	1,939 lb (880 kg)
Vehicle Damage Classification	
TAD.	12FR0
SAE.	12FRLN1

Impact Speed.	20.0 mph (32.2 kph)
Change in Velocity. . . .	2.4 mph (3.9 kph)
Change in Momentum. . . .	193 lb-sec
Occupant Impact Velocity	
Longitudinal.	None
Lateral	None
Occupant Ridedown Accelerations	
Longitudinal.	N/A
Lateral	N/A
Maximum Vehicle Crush	
Bumper Height	0.0 in. (0.0 cm)
Hood Height	0.0 in. (0.0 cm)

FIGURE A-40. SUMMARY OF RESULTS FOR TEST 3.

A-3-4. Test 4

The 1979 Honda Civic, shown in Figure A-41, was directed toward the sign at 56.8 mph. The test inertia mass of the vehicle was 1,770 lb and its gross static mass was 1,939 lb. Impact was such that the vehicle bumper contacted the support 15 in. to the left of vehicle centerline.

Approximately 0.010 sec after impact the sign panel split at the lower bolt connection and at 0.013 sec the support began to fracture at bumper height. At 0.035 sec the bottom of the sign panel hit the hood and shortly thereafter (0.043 sec) broke away from the support. The top of the sign panel then hit the windshield at 0.050 sec. Loss of contact occurred at 0.148 sec. As the vehicle left the test site the brakes were applied. The brakes locked up and the vehicle yawed in counterclockwise rotation. The wheels dug into the soft soil causing the vehicle to roll one and three-quarter revolutions. The vehicle subsequently came to rest on its right side. Sequential photographs of the test are shown in Figure A-42.

The support broke away at the base and was deformed as shown in Figures A-43 and A-44. The vehicle sustained a maximum crush of 3.0 in. at bumper height and the hood was scraped and dented. The windshield was cracked but not penetrated when the sign panel hit it. All other damage was due to post-test rollover. Photos of the vehicle after the test are shown in Figure A-45.

Results of this test are summarized in Figure A-46. Change in the vehicle's velocity was 5.8 mph and change in momentum was 468 lb-sec. There was no occupant impact during the impulse period.

The vehicle remained upright and stable throughout the impact phase and up to the time of brake application. Rollover of the vehicle was considered to be totally due to unsymmetrical brake application in combination with soft soil and not induced by impact with the sign.

FIGURE A-41. TEST VEHICLE BEFORE TEST 4.

0.000 sec

0.025 sec

0.050 sec

0.075 sec

0.100 sec

0.126 sec

0.151 sec

0.176 sec

FIGURE A-42. SEQUENTIAL PHOTOGRAPHS FOR TEST 4.

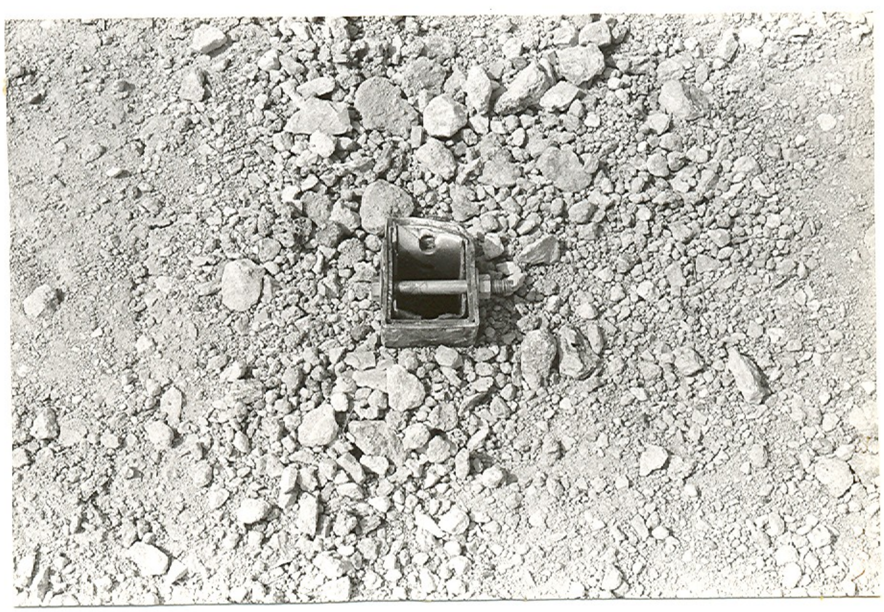
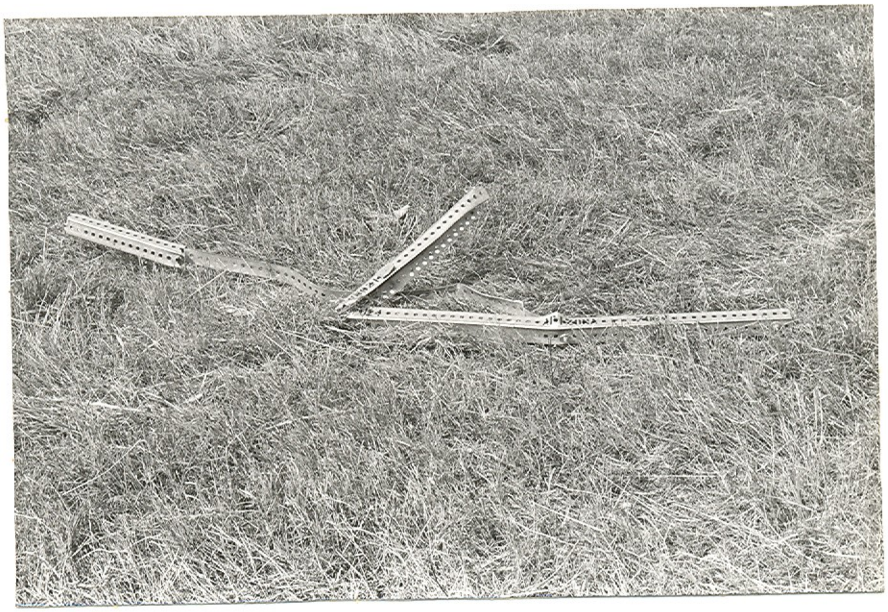


FIGURE A-43. TEST SITE AFTER TEST 4.



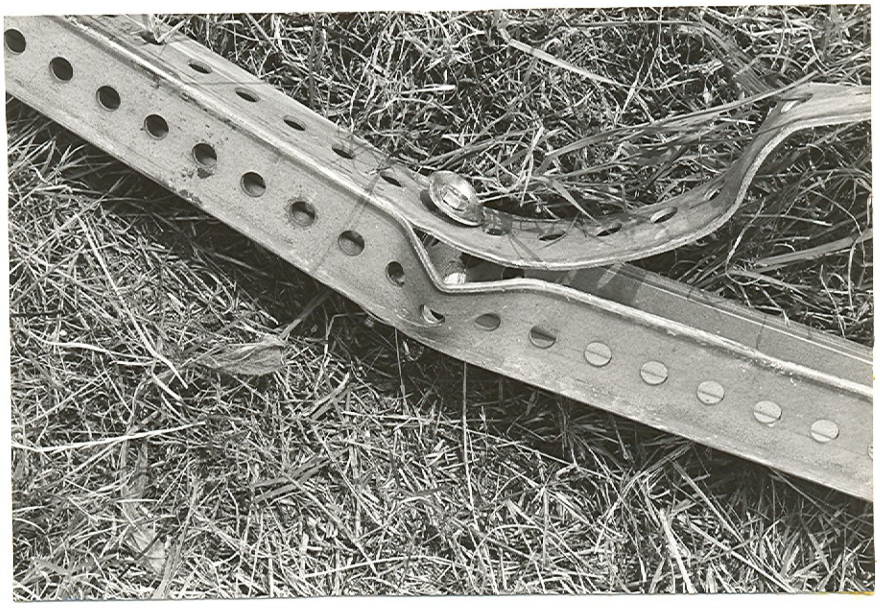


FIGURE A-44. SIGN POST AFTER TEST TEST 4.

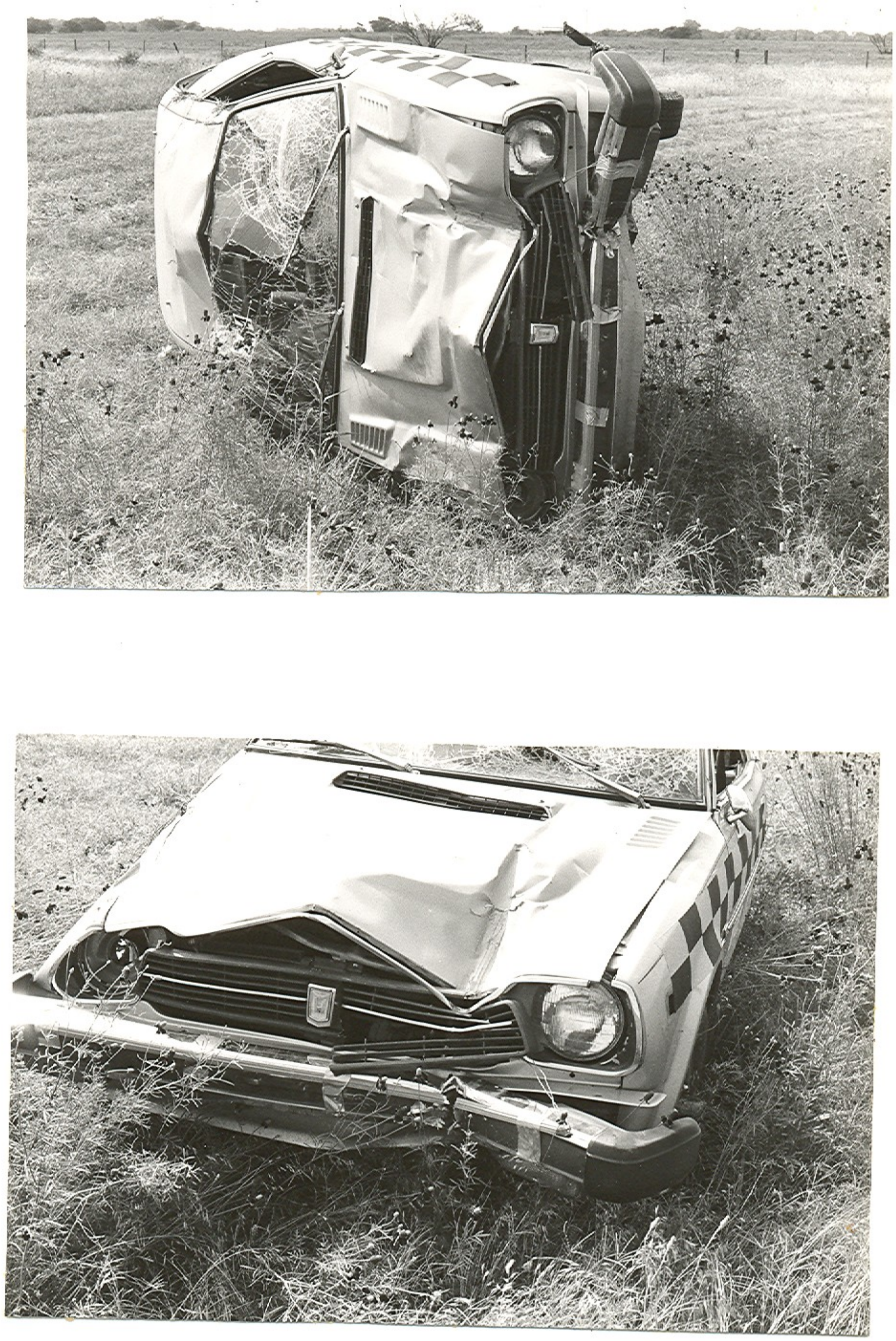


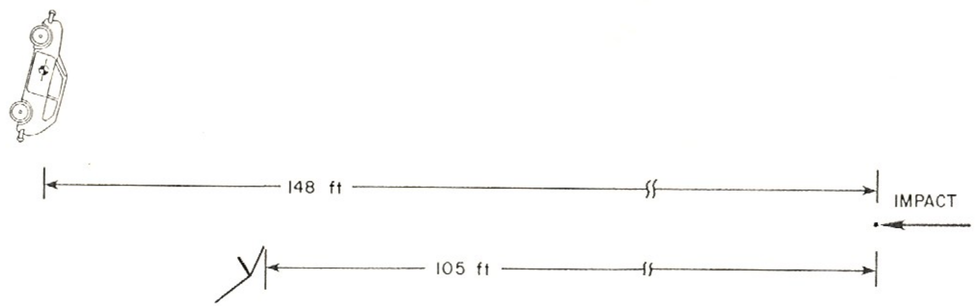
FIGURE A-45. VEHICLE AFTER TEST 4.

0.000 sec

0.050 sec

0.100 sec

0.151 sec



Test No.	7024-4
Date	5/28/85
Test Article	Sign installation
Support.	Square tube (Unistrut) P1 post
Vehicle.	1979 Honda Civic
Vehicle Weight	
Test Inertia	1,770 lb (804 kg)
Gross Static	1,939 lb (880 kg)
Vehicle Damage Classification	
TAD.	12FR2
SAE.	12FRLN1

Impact Speed.	56.8 mph (91.4 kph)
Change in Velocity.	5.8 mph (9.3 kph)
Change in Momentum.	468 lb-sec
Occupant Impact Velocity	
Longitudinal.	None
Lateral	None
Occupant Ridedown Accelerations	
Longitudinal.	N/A
Lateral	N/A
Maximum Vehicle Crush	
Bumper Height.	3.0 in. (7.6 cm)

FIGURE A-46. SUMMARY OF RESULTS FOR TEST 4.

A-3-5. Test 5

A 1980 Honda Civic, shown in Figure A-47, was directed into the sign installation at 19.7 mph. Test inertia mass of the test vehicle was 1,790 lb and its gross static mass was 1,952 lb. The test was designed so that the vehicle would impact all three supports. Relative positions of the test vehicle and sign installation are shown in Figure A-48.

Due to a malfunction in the cable release mechanism of the guidance system just moments before impact, the vehicle shifted to the left and impacted the center and left supports only. Approximately 0.027 sec after impact the center and left supports were bending. At 0.037 sec the dummy was moving forward and to the right and by 0.090 sec the dummy's head hit the mirror. As the vehicle moved forward it began to ride up the supports. At 0.144 sec the dummy's head hit the dash and at 0.269 sec the back of the dummy's head hit the windshield. Shortly thereafter the connections on the sign panel began to fail and at 0.488 sec the sign panel released from the right support, fell on the hood of the test vehicle, and bounced away. Subsequently, the vehicle came to rest over the left and center supports as shown in Figures A-49 and A-50. The sign came to rest approximately 10 ft from the front of the vehicle. As shown in Figure A-49, the left and center supports were bent back at the base. The right support was scratched and bent back slightly.

The front of the vehicle was deformed as shown in Figure A-50. The right front quarter received 4.0 in. crush at bumper height. The center was crushed 2.0 in. at bumper height. The windshield was slightly cracked just below the mirror. Sequential photographs of the test are shown in Figure A-51.

Test results are shown in Figure A-52. Change in the vehicle's velocity during the impulse period was 14.1 mph and change in momentum was 1,150 lb-sec. Occupant impact velocity in the longitudinal direction was 21.0 fps and the highest 0.010-second occupant ridedown acceleration was 0.9 g.

FIGURE A-47. TEST VEHICLE BEFORE TEST 5.

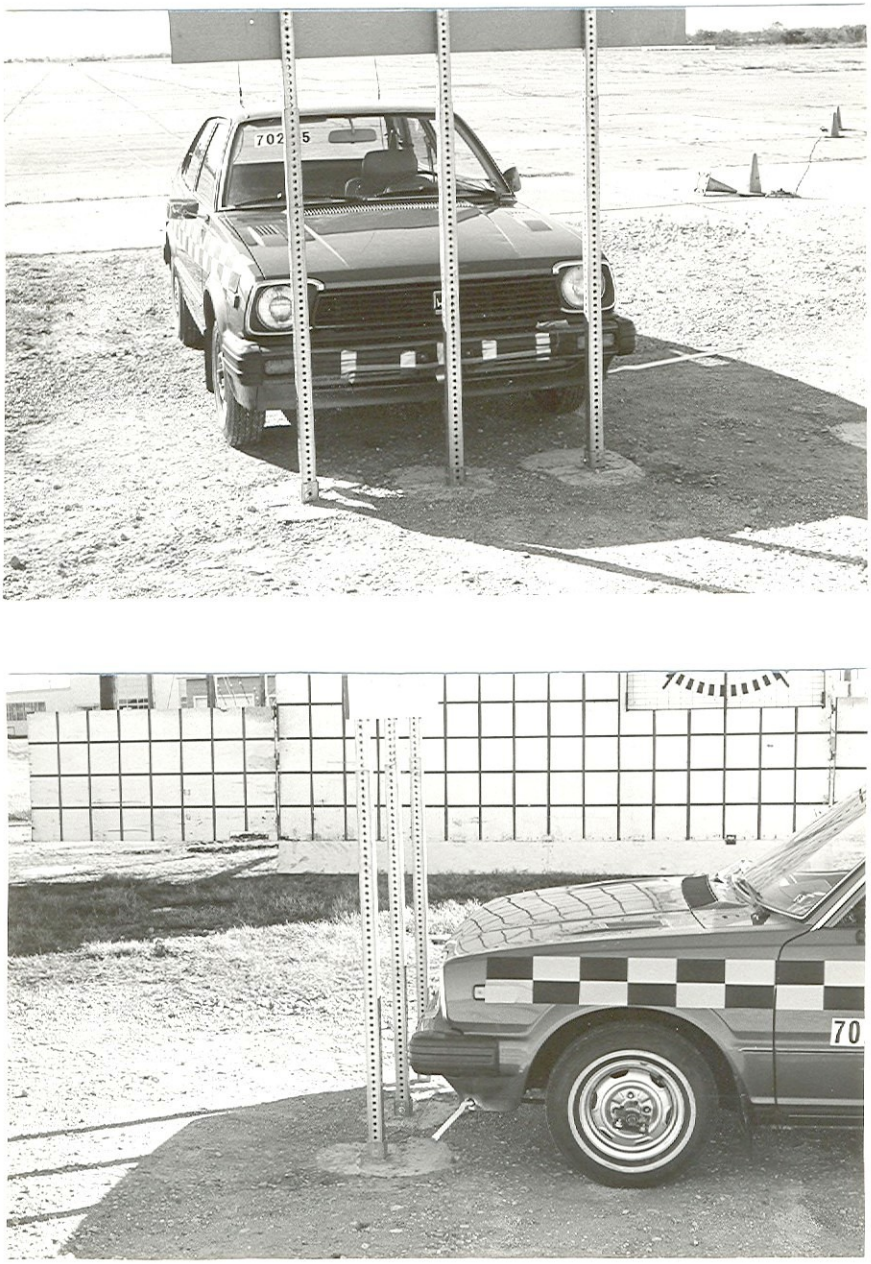
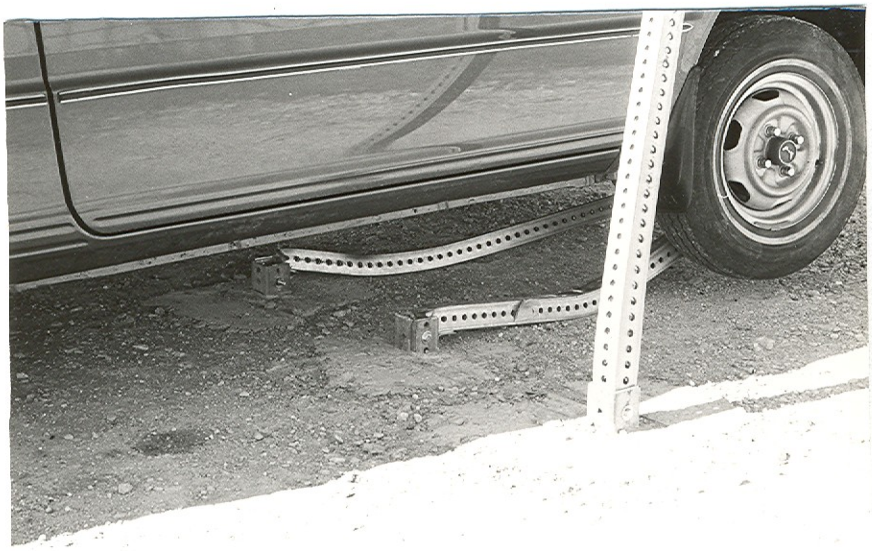


FIGURE A-48. RELATIVE POSITIONS OF THE TEST VEHICLE AND SIGN INSTALLATION FOR TEST 5.



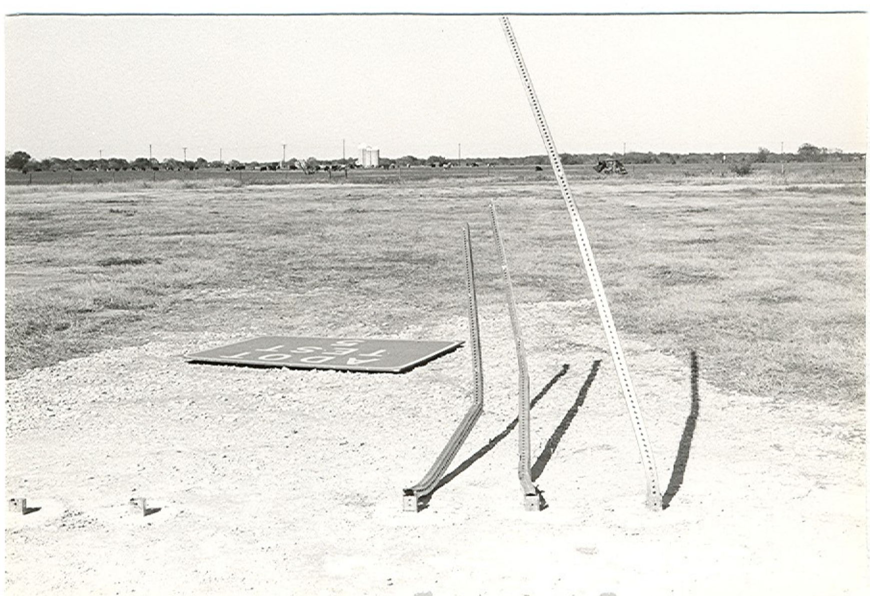
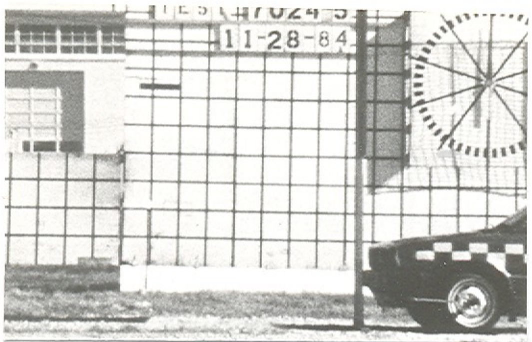
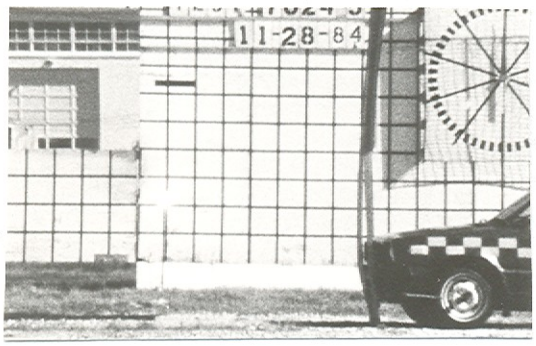


FIGURE A-49. SIGN INSTALLATION AFTER TEST 5.

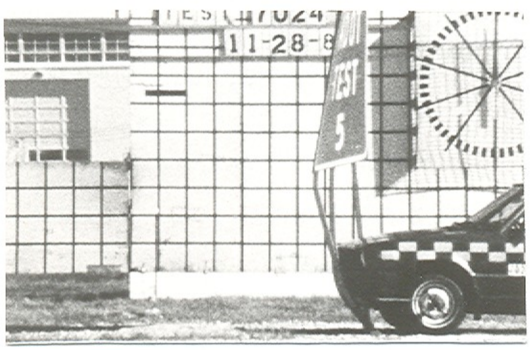
FIGURE A-50. TEST VEHICLE AFTER TEST 5.



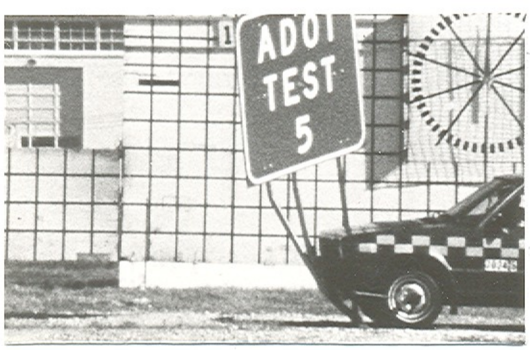
0.000 sec



0.025 sec



0.062 sec



0.100 sec

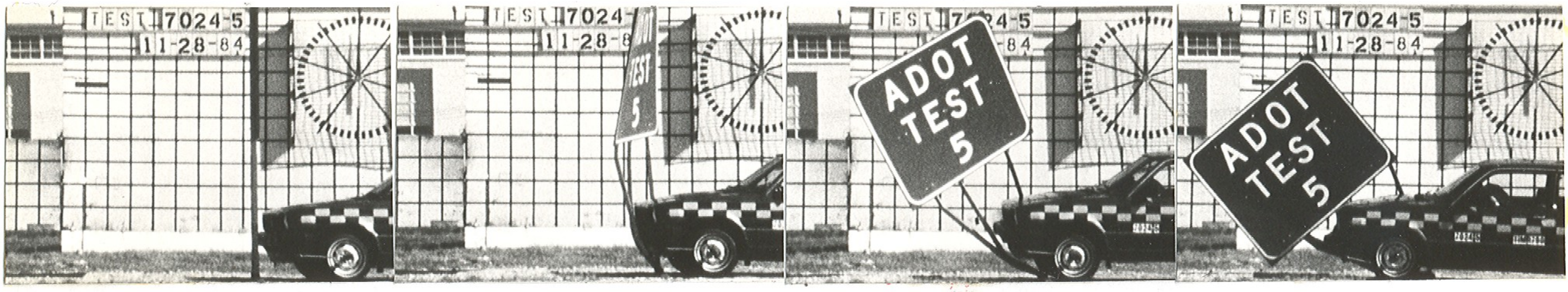
0.162 sec

0.274 sec

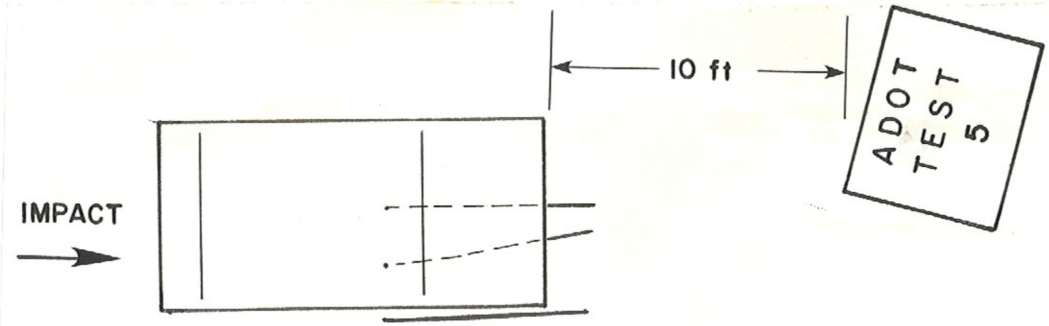
0.386 sec

0.500 sec

FIGURE A-51. SEQUENTIAL PHOTOGRAPHS FOR TEST 5.



0.000 sec   0.062 sec   0.162 sec   0.500 sec



Test No.	7024-5
Date	11/9/84
Test Article	Multi-leg Sign Installation w/Square Tube (Unistrut)P2 posts
Vehicle.	1979 Honda Civic
Vehicle Weight	
Test Inertia	1,790 lb (813 kg)
Gross Static	1,952 lb (886 kg)
Vehicle Damage Classification	
TAD.	12FD1
SAE.	12FDEW1

Impact Speed.	19.7 mph (31.7 kph)
Change in Velocity*	14.1 mph (22.7 kph)
Change in Momentum*	1,150 lb-sec
Occupant Impact Velocity	
Longitudinal.	21.0 fps (6.4 m/s)
Lateral	No Contact
Occupant Ridedown Accelerations	
Longitudinal.	0.9 g
Lateral	N/A
Maximum Vehicle Crush	
Bumper Height	4.0 in. (10.2 cm)
Hood Height	Nominal

*Impulse period computed from 0.000 to 0.250 sec

FIGURE A-52. SUMMARY OF RESULTS FOR TEST 5.

A-3-6. Test 6

A 1980 Honda Civic, pictured in Figure A-53, was directed into the sign installation at 59.3 mph. Test inertia mass of the test vehicle was 1,790 lb and its gross static mass was 1,952 lb. The test was designed so that the vehicle would impact all three supports. Relative positions of the test vehicle and sign installation are shown in Figure A-54.

Almost immediately after impact (0.002 sec), the supports began bending. At 0.022 sec the supports began to fracture and, as the vehicle continued forward, the supports deformed around the front of the vehicle. At 0.072 sec the sign panel hit the windshield knocking it loose from the upper molding. At 0.090 sec the dummy's head came through the opening between the windshield and the roof of the vehicle and by 0.162 sec the dummy's head was completely out of the vehicle. The vehicle exited the test area carrying the sign panel and parts of the supports. The vehicle came to rest approximately 156 ft behind and 18 ft to the right of the impact point.

As shown in Figure A-55, the left and right supports were bent back at the base. The center support broke at the base and was carried 90 ft with the vehicle. It was deformed and torn as shown in Figure A-56. The sign panel and fragments of the supports were scattered along the exit path of the vehicle.

The front of the vehicle was deformed and the windshield was broken as shown in Figure A-57. The right front quarter received 4.0 in. crush at bumper height. The center was crushed 1.0 in. at bumper height and 1.5 in. at hood height. Sequential photographs of the test are shown in Figure A-58.

Test results are shown in Figure A-59. Change in vehicle's velocity during the impulse period was 17.9 mph and change in momentum was 1,459 lb-sec. Occupant impact velocity was 24.9 fps in the longitudinal direction. The highest 0.010-second occupant ridedown acceleration was 3.3 g.

(cracks in windshield from Test 5)

FIGURE A-53. TEST VEHICLE BEFORE TEST 6.

FIGURE A-54. RELATIVE POSITIONS OF TEST VEHICLE AND SIGN INSTALLATION FOR TEST 6.

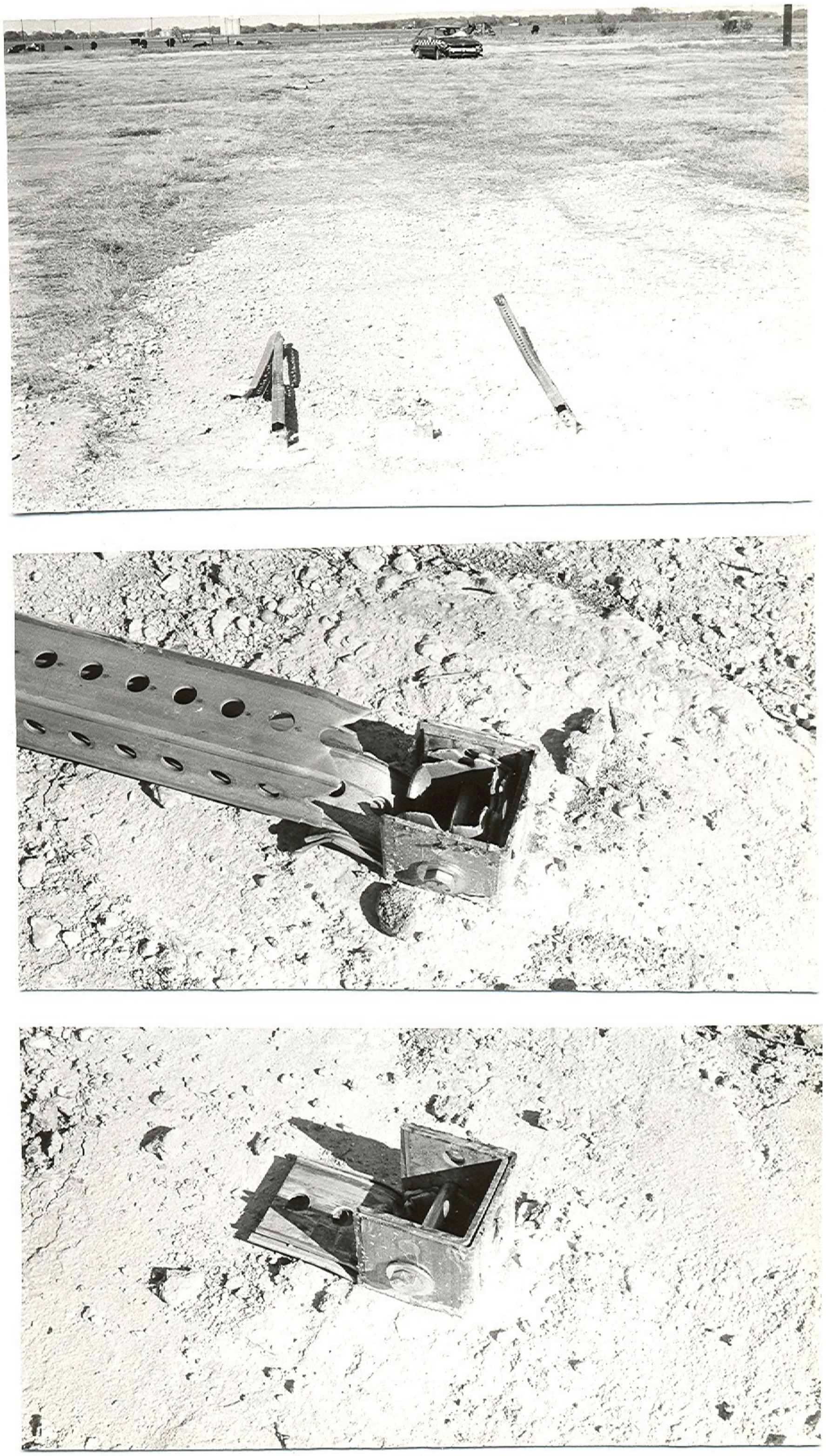
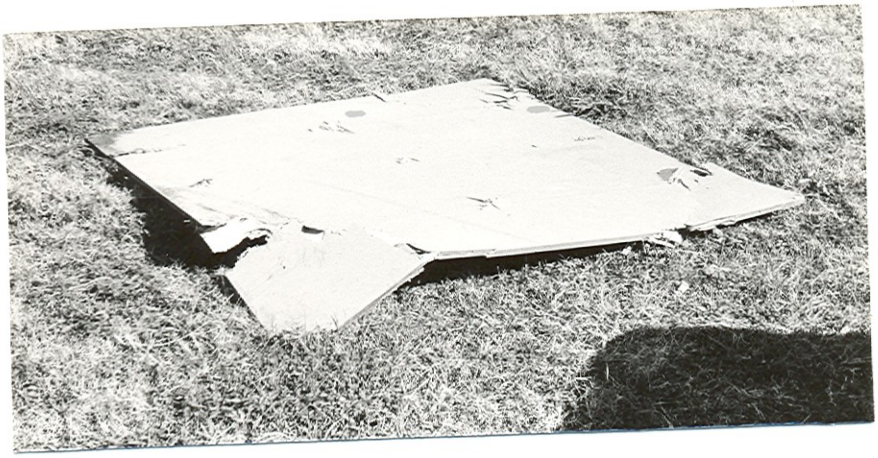
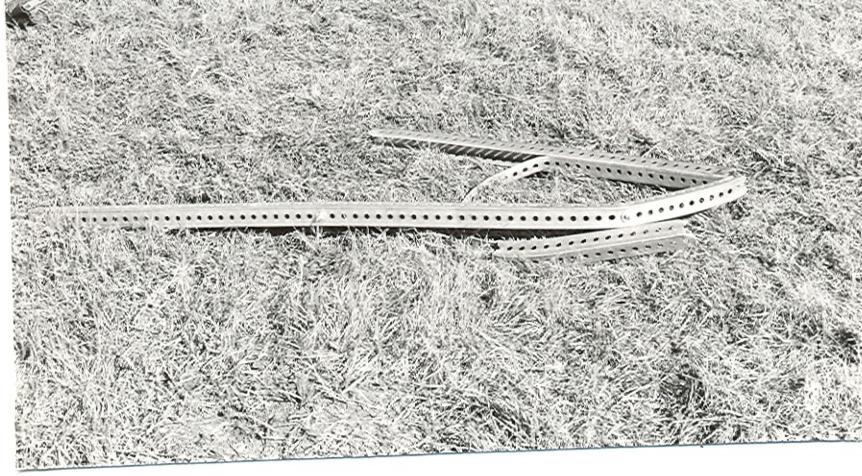


FIGURE A-55. SIGN INSTALLATION AFTER TEST 6.
(BASE)

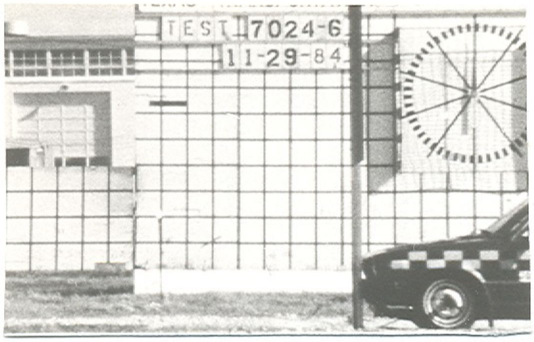




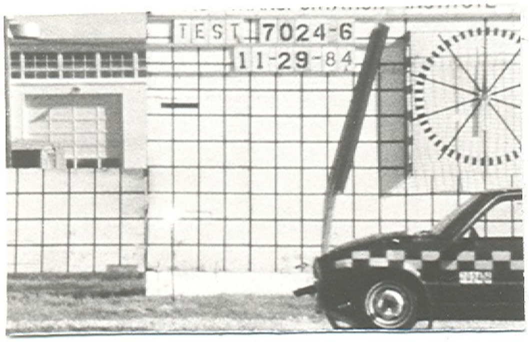
Center Support

FIGURE A-56. SIGN INSTALLATION AFTER TEST 6.
(SUPPORTS AND SIGN PANEL)

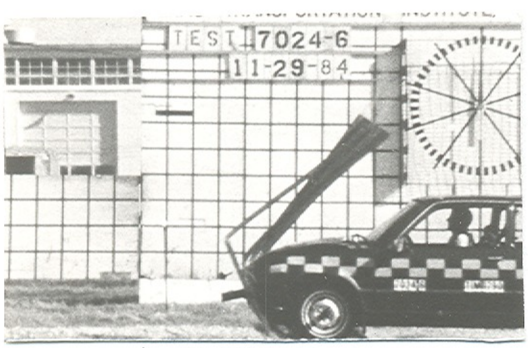
FIGURE A-57. TEST VEHICLE AFTER TEST 6.



0.000 sec

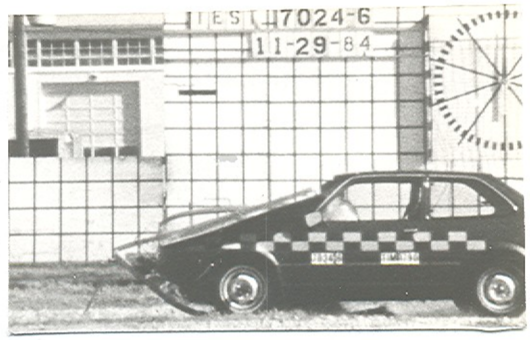


0.025 sec

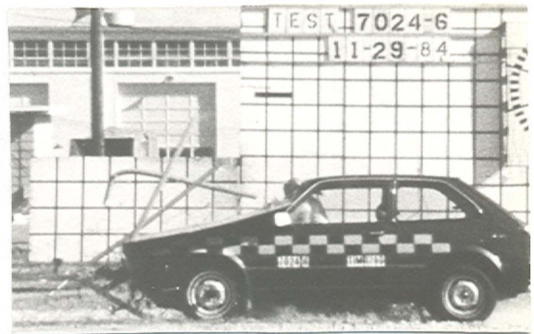


0.050 sec

0.075 sec

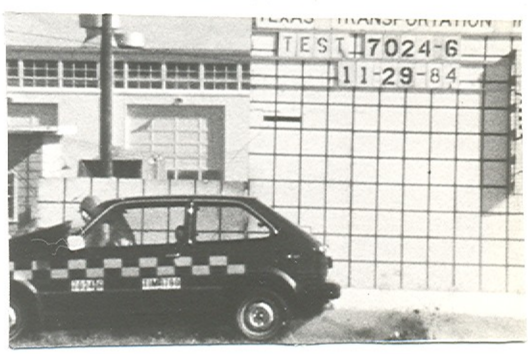


0.100 sec



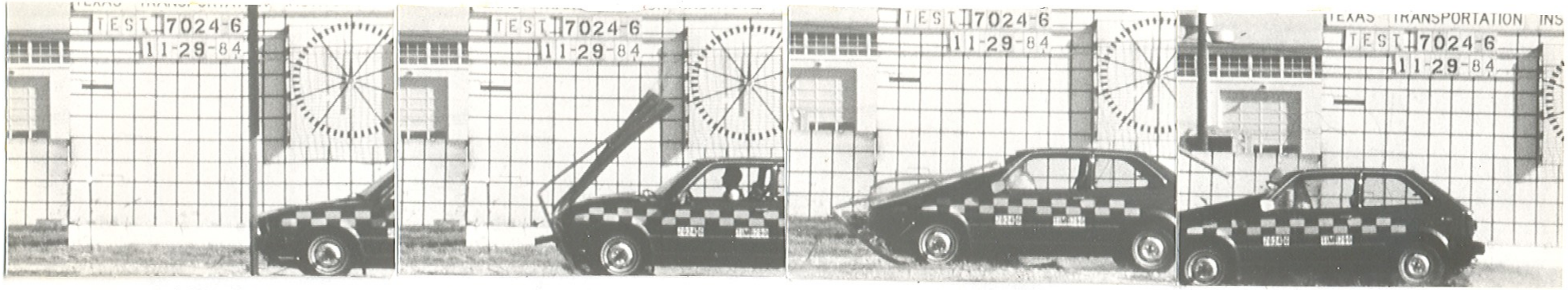
0.149 sec

0.199 sec

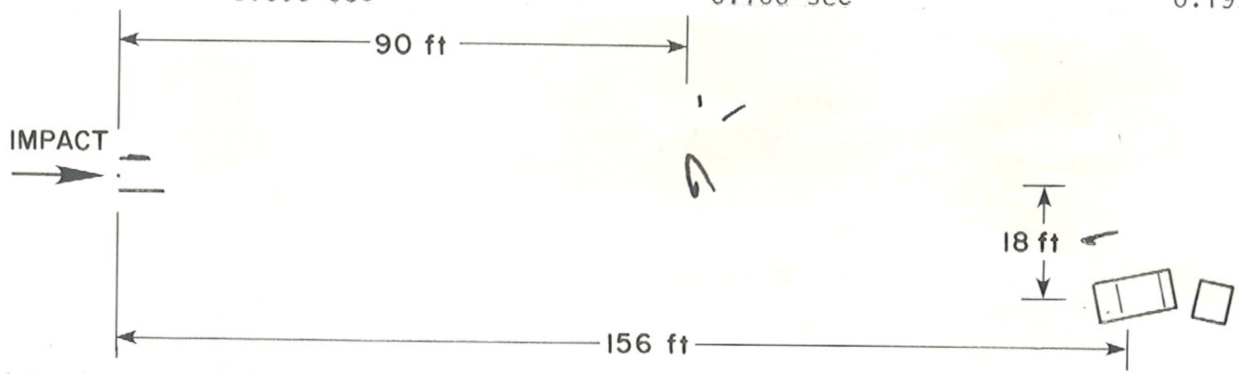


0.249 sec

FIGURE A-58. SEQUENTIAL PHOTOGRAPHS FOR TEST 6.



0.000 sec 0.050 sec 0.100 sec 0.199 sec



Test No.	7024-6	Impact Speed	59.3 mph (95.4 kph)
Date	11/29/84	Change in Velocity*	17.9 mph (28.8 kph)
Test Article	Multi-leg Sign Installation w/Square Tube (Unistrut) P2 Posts	Change in Momentum*	1,459 lb-sec
		Occupant Impact Velocity	
		Longitudinal	24.9 fps (7.6 m/s)
		Lateral	No Contact
Vehicle	1980 Honda Civic	Occupant Ridedown Accelerations	
Vehicle Weight		Longitudinal	3.3 g
Test Inertia	1,790 lb (813 kg)	Lateral	N/A
Gross Static	1,952 lb (886 kg)	Maximum Vehicle Crush	
Vehicle Damage Classification		Bumper Height	4.0 in. (10.2 cm)
TAD	12FD3	Hood Height	1.5 in. (3.8 cm)
SAE	12FDEW1		

*Impulse period computed over 0.000 to 0.300 sec

FIGURE A-59. SUMMARY OF RESULTS FOR TEST 6.