SD94-10-F

SD Department of Transportation
Office of Research

Crash Testing of Standard South Dakota Road Closure Gates

Study SD94-10
Final Report

Prepared by:
Midwest Roadside Safety Facility (MwRSF)
Center for Infrastructure Research
Civil Engineering Department
University of Nebraska-Lincoln
1901 Y Street, Building C
Lincoln, Nebraska 68588-0601
(402)472-6864

January 1995

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
SD94-10-F		

4. Title and Subtitle	5. Report Date
Crash Testing of Standard South Dakota Road Closure Gates	January 27, 1995
	6. Performing Organization Code
7. Author(s) Holloway, J.C., Rosson, B.T., and Faller, R.K.	8. Performing Organization Report No. TRP-03-44-94
9. Performing Organization Name and Address Midwest Roadside Safety Facility (MwRSF) Civil Engineering Department University of Nebraska - Lincoln 1901 Y St., Bldg C Lincoln, Nebraska 68588-0601	10. Work Unit No. 11. Contract or Grant No. Project SPR-3 (017)
12. Sponsoring Agency Name and Address South Dakota Department of Transportation Office of Research 700 East Broadway Avenue Pierre, SD 57501-2586	13. Type of Report and Period Covered Final Report: October 1994 to January 1995 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Two full-scale vehicle crash tests were performed on South Dakota's Standard Road Closure Gate. Test SDG-1 was conducted with a 1986 Chevrolet Sprint weighing 794 kg (1751 lbs) at an impact speed of 37.1 km/h (23.1 mph) and an angle of 0 degrees. The center line of the vehicle impacted the upstream end and center line of the gate. Test SDG-2 was conducted with the same vehicle at an impact speed of 95.5 km/h (59.4 mph) and an angle of 0 degrees. The quarter point of the vehicle impacted the upstream end and center line of the gate.

The tests were conducted and reported in accordance with the requirements specified in the *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, National Cooperative Research Program (NCHRP) Report No. 350 and the American Association of State Highway and Transportation Officials (AASHTO), 1985 *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*. The safety performance evaluation of the road closure gate was determined to be acceptable according to these criteria for support structures.

17. Keyword	18. Distribution Statement
Road Closure Gates, Breakaway Supports, Frangible Couplers, Access Control, Highway Safety, Crash Tests, Compliance Tests	No restrictions. This document is available to the public from the sponsoring agency.

19. Security Classification (of this report)	Security Classification (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	66	

DISCLAIMER

ACKNOWLEDGEMENTS

This work was performed under the supervision of the SD94-10 Technical Panel:

Paul Orth . . . . Office of Research
Norm Humphrey . . . . . . Operations Support
Bob Griffith . . . . Roadway Design
Dean Hoelscher . . . . Roadway Design
Jon Becker . . . . Office of Research
Lubin Quinones . . . . FHWA

Nebraska Department of Roads (NDOR):

Leona Kolbet, Research Coordinator

Center for Infrastructure Research (CIR):

Maher Tadros, Ph.D., Professor and Director of Center for Infrastructure Research

Engineering Research Center (ERC):

Samy Elias, Ph.D., Professor and Associate Dean for Engineering Research Centers

Midwest Roadside Safety Facility (MwRSF):

Dean Sicking, Ph.D., Director
Brian Pfeifer, Research Associate Engineer
Kenneth Krenk, Field Operations Manager
Graduate and Undergraduate Assistants

South Dakota Department of Transportation (SDDOT):

Mike Young, Operations Support
Steve Ulvestad, Operations Support
David Huft, Office of Research
Roland Stanger, FHWA

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

1 INTRODUCTION

1.1 Problem Statement

The South Dakota Department of Transportation (SDDOT) currently uses road closure gates for access control at several interchanges. These road closure gates have been installed for the purpose of preventing motorists from accessing and traveling on the state trunk highway system during severe weather conditions and hazardous roadway situations. When not in use, the road closure gates are oriented in a stowed or open position parallel to and along the side of the roadway. When in use, the road closure gates are placed in a closed position with the gate projecting across the roadway, perpendicular to the direction of travel.

Recently, there have been safety concerns regarding the use of these access control devices. The Federal Highway Administration (South Dakota Division Office) has requested that these access control devices be evaluated in order to determine if they are crash worthy when impacted by an errant vehicle.

1.2 Objective

The objective of this research study was to evaluate the safety performance of the SDDOT road closure gates according to the evaluation criteria set forth in the National Cooperative Highway Research Program Report No. 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features* (1) and the American Association of State Highway and Transportation Officials (AASHTO), *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals,*(2).

1.3 Scope

The research objective was achieved by performing a literature search on the crash testing of existing road closure gates and a design review of the current road closure gate assembly. Compliance testing was then conducted using an 820 kg (1,808 lb) mini-compact impacting at speeds of 35 km/h (21.7 mph) and 100 km/h (62.1 mph) and an angle of 0 degrees (NCHRP 350 Test Nos. 3-60 and 3-61). The low-speed test rather than the high-speed test was performed first in order to minimize vehicle damage and repair costs. Finally, the test results were analyzed, evaluated, documented, and conclusions were formed regarding the safety and use of the SDDOT standard road closure gates.

The full-scale vehicle crash tests were conducted on the road closure gates in the stowed position rather than the closed position because it was determined that it would result in the most severe impact condition. This was reasonable, since the vehicle would be required to break both the gate support post and the hold back post. In addition, the entire mass of the gate assembly would be impacted and concentrated on the front of the vehicle. SDDOT reasoned that vehicle impacts into road closure gates in the closed position rather than the stowed position would not be as likely to occur due to the significant increase in delineation and subsequent lower driving speeds.

1.4 Background

A preliminary investigation has revealed that very little research has been performed on the testing and evaluation of road closure gates. One research project, conducted by the Texas Transportation Institute (TTI) (3), evaluated a single-arm road closure gate using a luminaire pole as the support post. The luminaire pole was attached to the ground using a 4-bolt slipbase breakaway device. Originally, the road closure gate did not meet the safety performance criteria found in NCHRP Report No. 350. Following a redesign, the road closure gate successfully met the NCHRP Report No. 350 evaluation criteria.

Another related research project, conducted at the Federal Outdoor Impact Laboratory (FOIL) (4), consisted of full-scale bogie crash tests on 16.2-m (53-ft) high, breakaway aluminum luminaire supports weighing 237 kg (523 lbs). The breakaway mechanism consisted of PrecisionForm breakaway couplers (Type PFI 200-1). Both low and high speed tests were conducted, and the results showed that the tests were acceptable according to the evaluation criteria. The criteria included vehicle change in velocity (ΔV), theoretical occupant impact velocity, and the stub height requirements of less than 10.2 cm (4 in.). These breakaway couplers were approved for use on Federal-Aid highway projects when the luminaire combinations weigh less than 363 kg (800 lbs).

2 TEST CONDITIONS

2.1 Test Facility

The Midwest Roadside Safety Facility's outdoor test site is located at the Lincoln Air-Park on the NW end of the Lincoln Municipal Airport. The test facility is approximately 8 km (5 mi) NW of the University of Nebraska-Lincoln. The site is surrounded and protected by an 2.4-m (8-ft) high chain-link security fence.

2.2 Vehicle Tow and Guidance System

A reverse cable tow system with a 1:2 mechanical advantage was used to propel the test vehicle. The distance traveled and the speed of the tow vehicle are one-half that of the test vehicle. The test vehicle was released from the tow cable before impact with the bridge rail. A fifth wheel, built by the Nucleus Corporation, was used in conjunction with a digital speedometer to increase the accuracy of the test vehicle impact speed.

A vehicle guidance system developed by Hinch (6) was used to steer the test vehicle. The guide-flag, attached to the front-left wheel and the guide cable, was sheared off before impact. The 0.95-cm (3/8-in.) diameter guide cable was tensioned to approximately 13.3 kN (3,000 lbs), and supported laterally and vertically every 30.5 m (100 ft) by hinged stanchions. The vehicle guidance cable was approximately 91.4-m (300-ft) and 243.8-m (800-ft) long for the low and high-speed tests, respectively.

2.3 Test Installation Design Details

The test installation was a mainline road closure gate. This gate is most often located on a major State Highway or Interstate as opposed to the ramp closure gate which is located at the on ramps. Ramp road closure gates have a shorter overall length. Typical locations of these gates are shown in Figure 1. The test installation consisted of several components such as the gate, gate post, breakaway support, hold back hardware, and gate attachments. Each of these components are described in the following sub-sections.

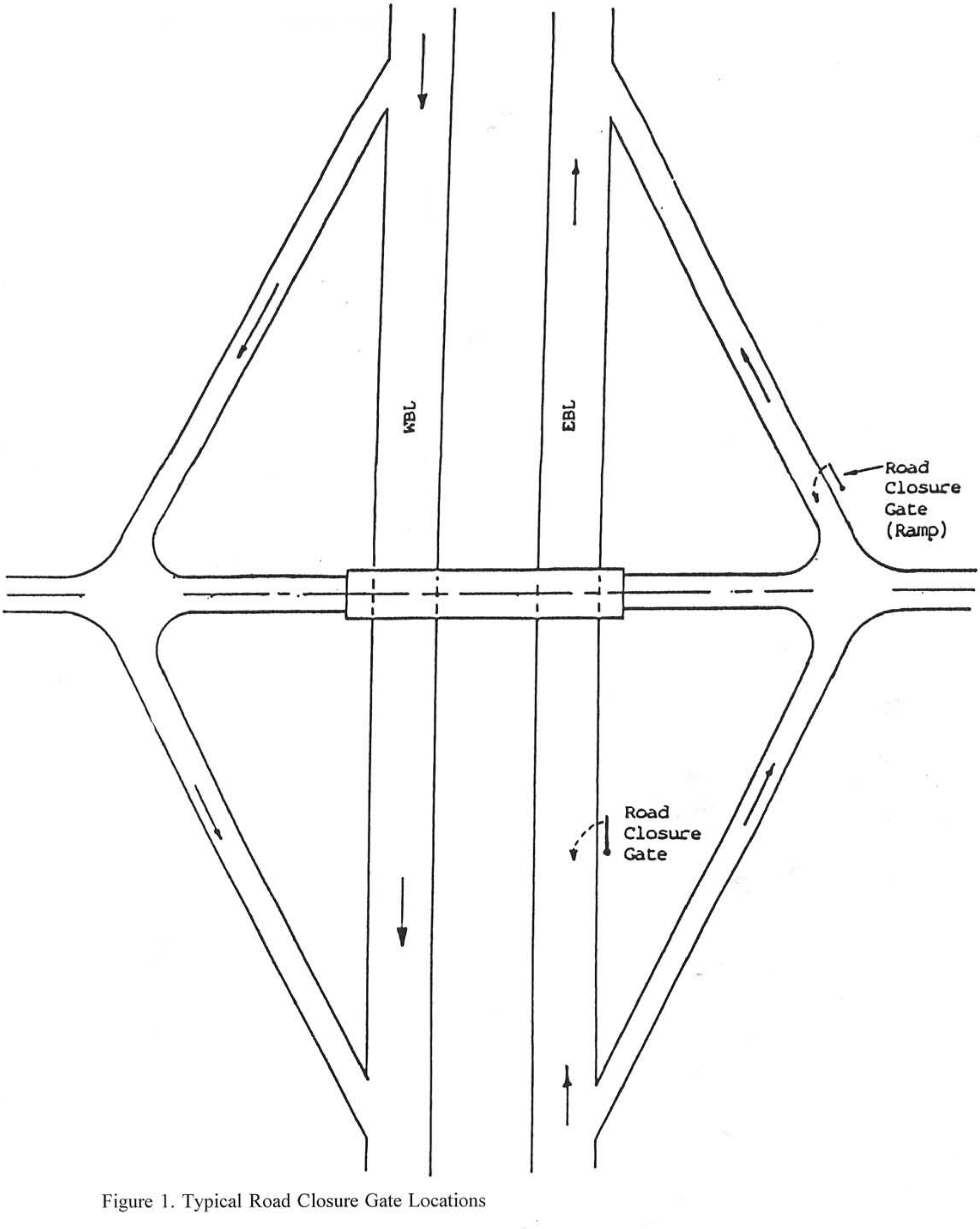


Figure 1. Typical Road Closure Gate Locations

2.3.1 Gate

The gate detail is shown in Figure 2. Photographs of the installation are shown in Figure 3. A layout of the gate in the stowed or open position is shown in Figure 4. The gate was 8.5-m (28-ft) long and 76.2-cm (30-in.) tall and was constructed of 5.1-cm (2-in.) square aluminum tubing with a minimum wall thickness of 3.2 mm (0.125 in.), welded at all the joints. The tubing layout consisted of three longitudinal members and seven vertical members. The total weight of the gate was 68 kg (150 lbs) including attachments (i.e., signs, object markers, warning lights, stands, and cables).

2.3.2 Gate Post

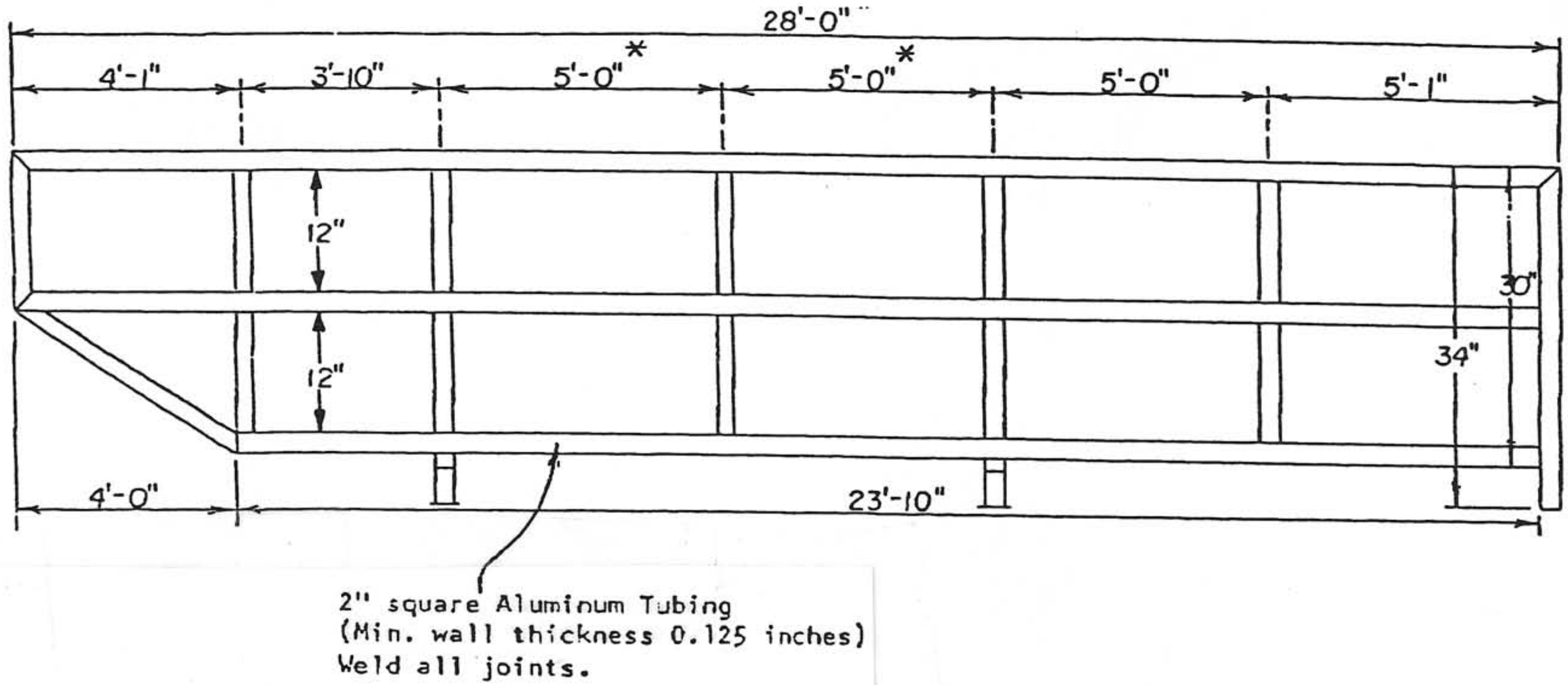
The gate was supported by the gate post, around which the gate was allowed to pivot or rotate. Details on the gate post are shown in Figure 5. The post consisted of a standard weight, 12.7-cm (5-in.) diameter ASTM A36 steel pipe. The gate post, including the base plate weighed approximately 34 kg (75 lbs). The post was 1.2-m (4-ft) long with no taper and was capped on the top end. Photographs of the gate post and base plate are shown in Figure 6. An ASTM A36 steel base plate, measuring 30.5-cm (12-in.) square x 1.9-cm (3/4-in.) thick, was welded to the base of the steel post, as shown in Figure 7.

The gate was attached to the gate post with three 1.9-cm (3/4-in.) diameter bent threaded rods as shown on the hinge detail in Figure 5. The hinge was formed by inserting each bent threaded rod into a 1.9-cm (3/4-in.) diameter pipe section which was welded to the gate post. This connection allowed the gate to be opened and closed freely and was also used for leveling the gate by tightening/loosening each of the threaded bars. In addition, the gate was supported and leveled on the level grade with two stands. The details for the stands are shown in Figure 8. The stands were located at the third and fifth vertical gate tubes downstream of the gate post, as shown in Figure 2.

2.3.3 Breakaway Support

The gate post was attached to the concrete using breakaway support couplings. commonly referred to as frangible couplers, as shown in Figure 7. The frangible couplers were Pole-Safe breakaway support couplings (Model No. 201), manufactured by Transpo Industries, Inc. The frangible couplers conformed

GATE DETAIL



* Delete 10' section for Ramp Gate

Figure 2. Road Closure Gate Detail

Figure 3. Road Closure Gate

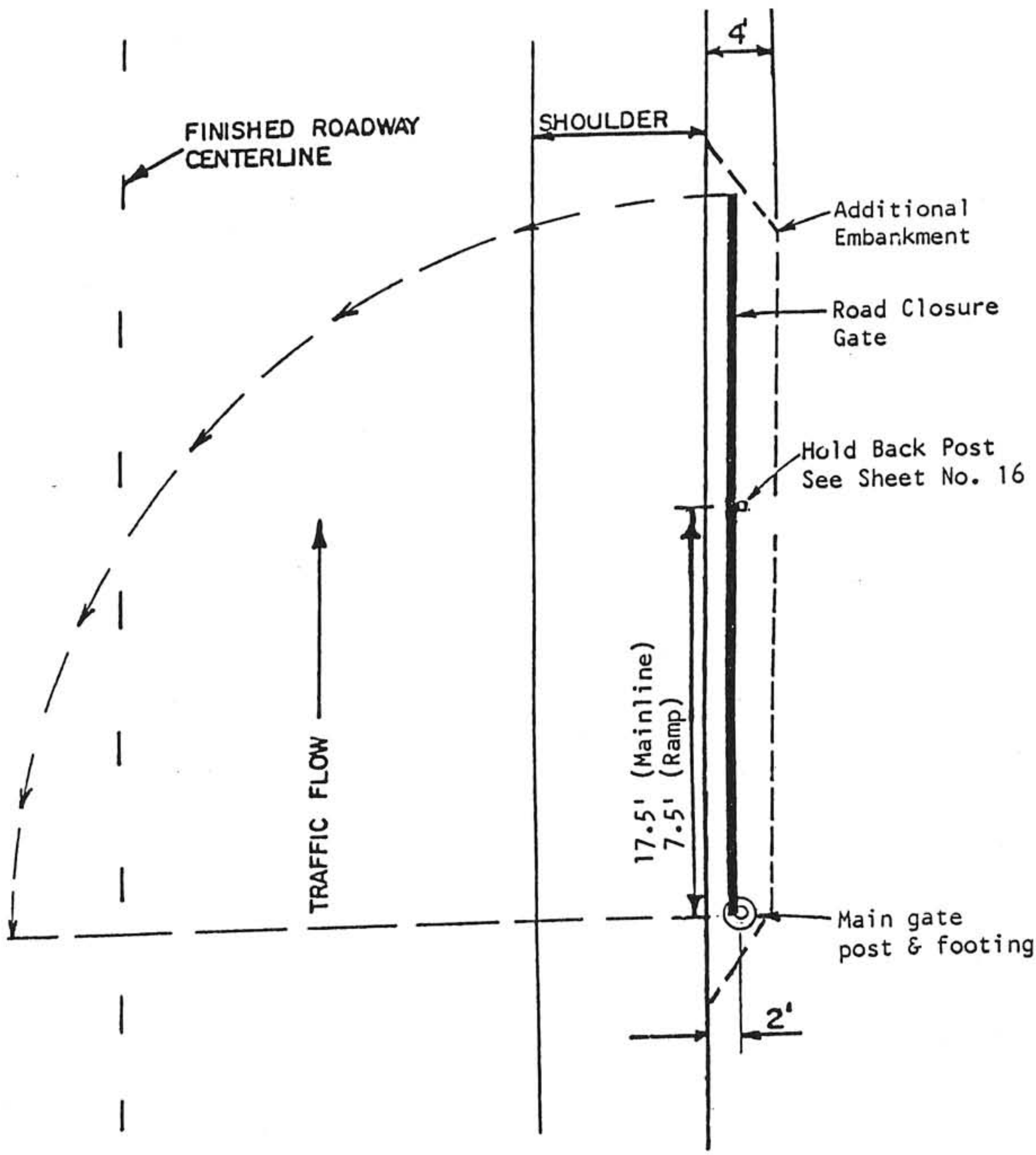


Figure 4. Plan View of Gate

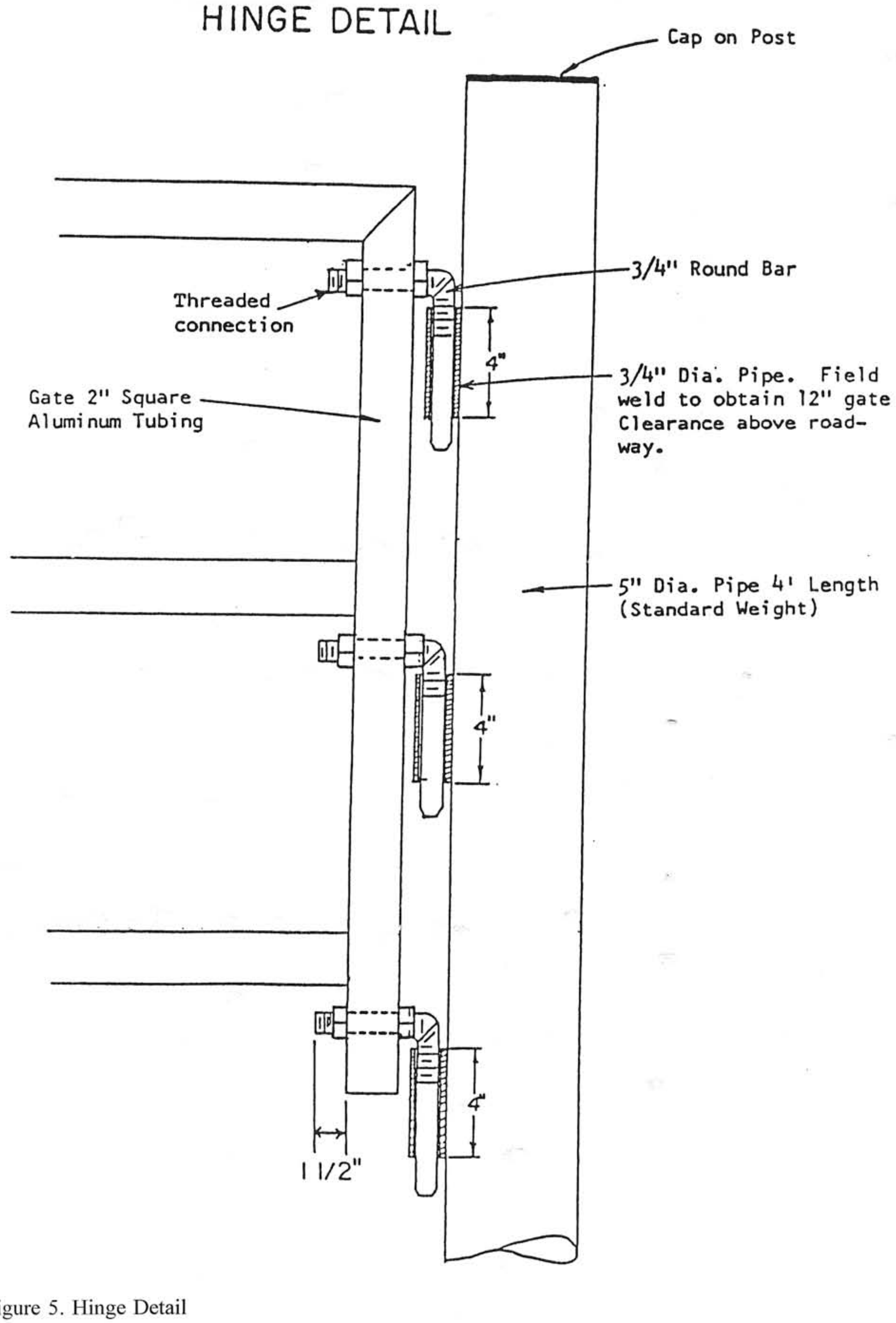


Figure 5. Hinge Detail

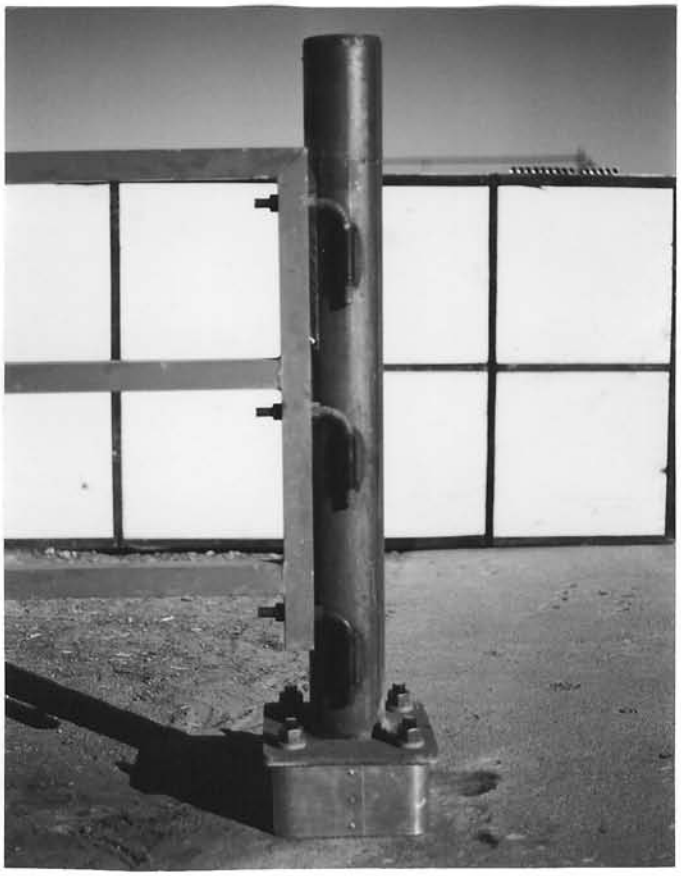


Figure 6. Gate Post and Base Plate

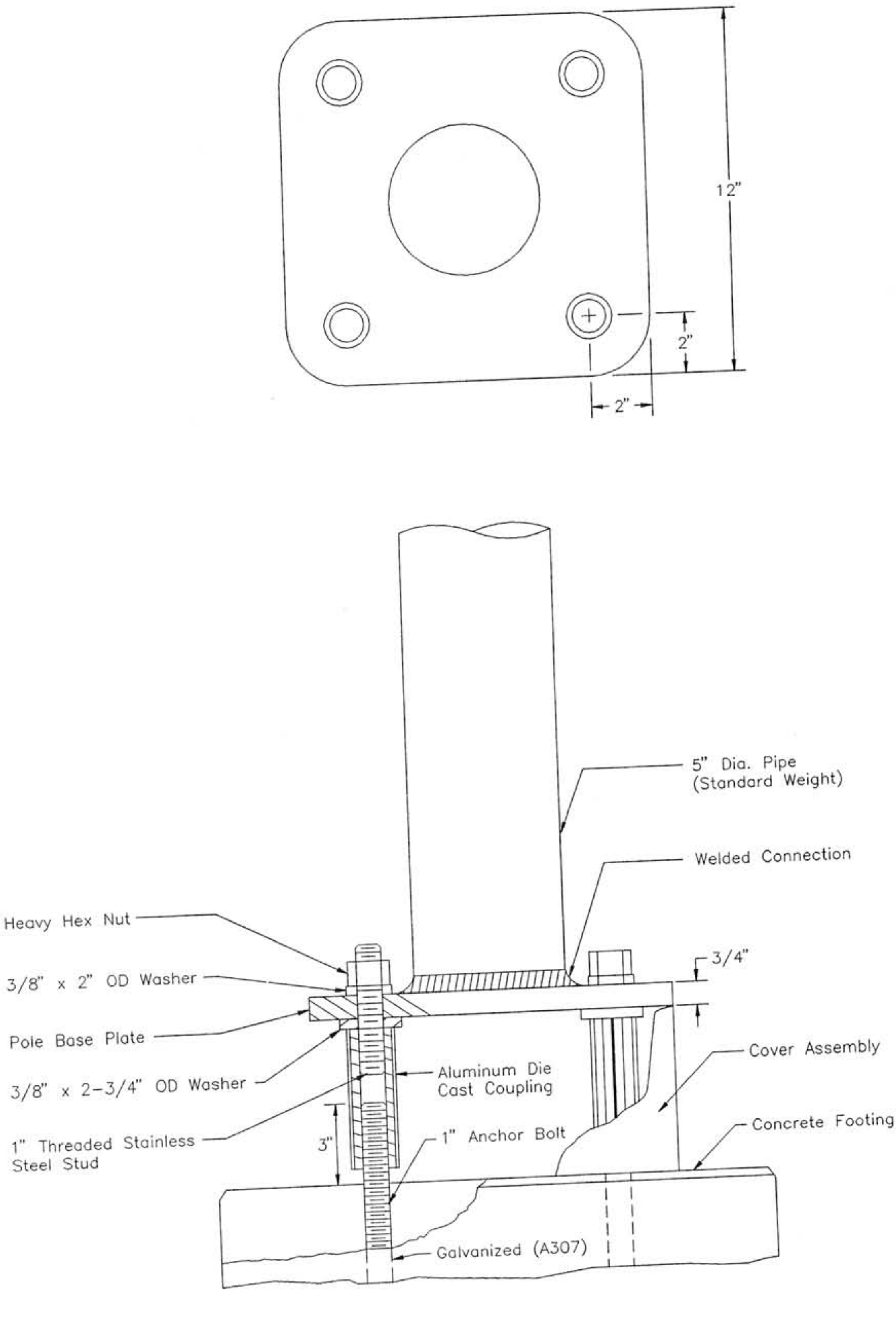


Figure 7. Breakaway Support Detail

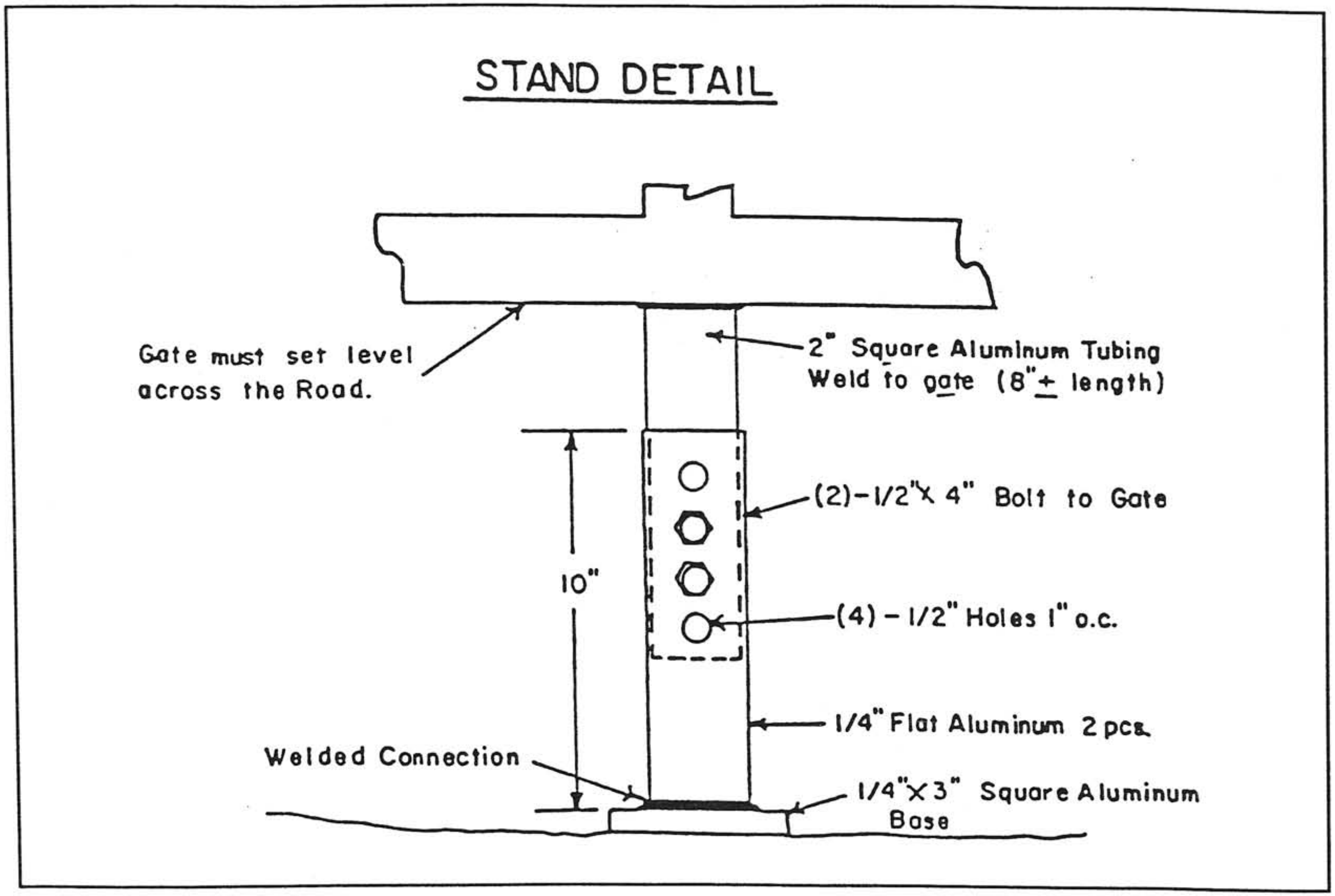


Figure 8. Stand Detail

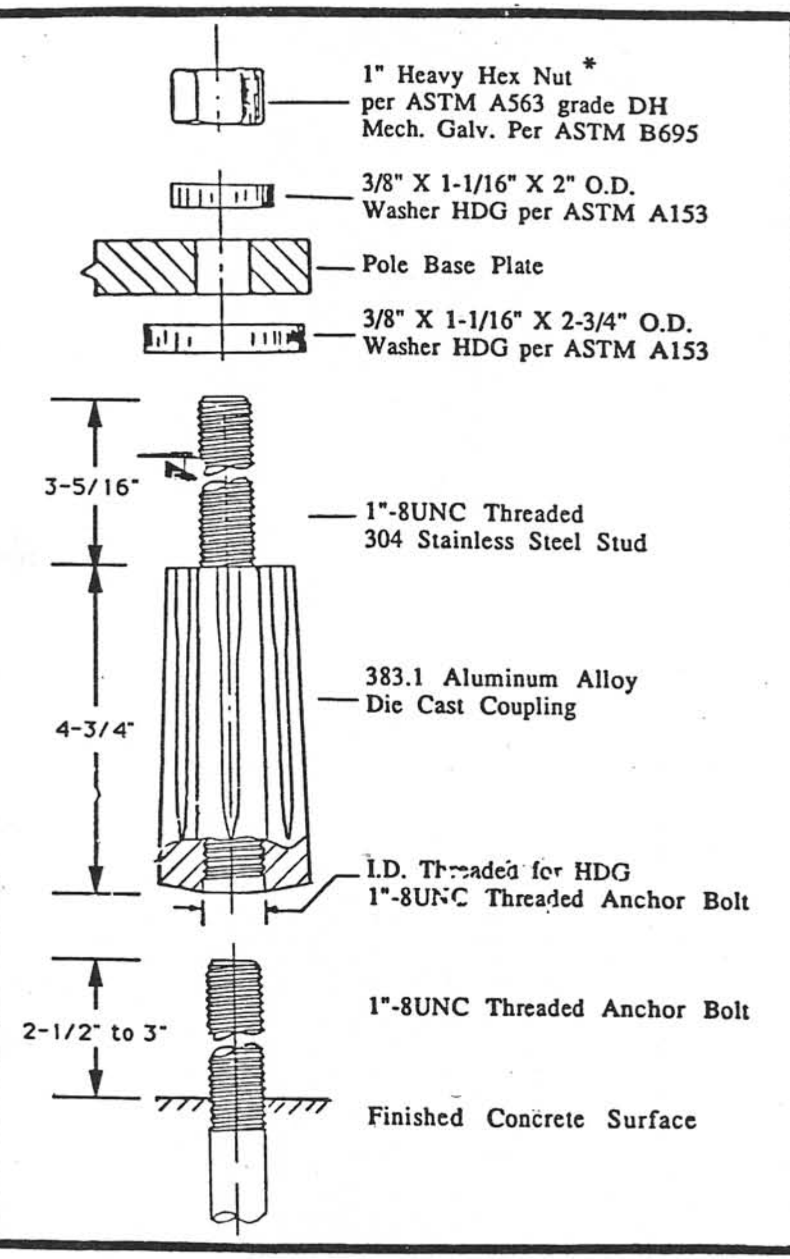
to the AASHTO 1985 standards for breakaway luminaire poles and were approved by the Federal Highway Administration (FHWA) for use on Federal-Aid projects. Specifications for the frangible couplers are shown in Figure 9.

The frangible couplers were attached to 2.54-cm (1-in.) diameter x 38.1-cm (15-in.) long ASTM A307 galvanized threaded rods embedded 30.5 cm (12 in.) into the existing 61-cm (24-in.) thick concrete apron. Each rod was set with a structural epoxy adhesive that conformed to ASTM C-881 and AASHTO M-235 specifications (Sikudar 32, Hi-Mod) (5). The total length of the rods were 38.1 cm (15 in.), providing a 7.6-cm (3-in.) stub height above the concrete surface. The thread depth of each frangible couplers was 7.0 cm (2 3/4 in.). This provided a 6.4-cm (1/4-in.) gap between the concrete and the bottom of the frangible coupler, which was used for leveling the post base plate. The overall length of the coupler was approximately 20.3 cm (8 in.).

Four 2.54-cm (1-in.) diameter 8UNC threaded 304 stainless steel studs, extending from the top of the frangible couplers, were used to attach the gate post base plate to the tops of the four frangible couplers. After placing the gate post onto the frangible couplers, the washers were installed and the heavy hex nuts were hand tightened. The post was then plumbed and squared, and the installation of the gate post was completed by tightening the heavy hex nut to the specified torque of 117.5 Nm (175 ft-lbs). Photographs of the installed frangible couplers are shown in Figure 10. The frangible couplers were covered with a sheet metal cover assembly, attached with 1.27-cm (1/2-in.) diameter sheet metal screws.

2.3.4 Hold Back Hardware

The gate was held back in the stowed position using a hold back post, as shown in Figure 11. The 10.2-cm (4-in.) square x 1.8-m (6-ft) long, wooden hold back post measured 8.9-cm (3½-in.) square actual size. The hold back post was placed in a 10.2-cm (4-in.) square x 1.5-m (5-ft) long x 0.48-cm (3/16-in.) thick galvanized, steel tube. The top of the tube extended 5.1 cm (2 in.) above the ground line, as shown in Figure 11. The post was held in the foundation tube with two 1.27-cm (1/2-in.) diameter x 5.1-cm (2-in.) long lag bolts. The gate was fastened to the hold back post with a steel strap and padlock assembly.



SPECIFICATION

Breakaway Support Couplings (longitudinally grooved) conforms to AASHTO 1985 standards for breakaway supports for light poles and are approved by FHWA for use on Federal Aid projects.

Tensile strength	24.0 kips min.
Restrained shear	3.6 kips min., 6.5 kips max.
Nut torque	175 ± 25 ft. lbs.

*Torque control nut should not be used in highly corrosive environment.

Coupling coating	*External surface:* Phosphate per Mil. Std. TTC-490 method 3 type 2, prime using cathodic epoxy electrocoat and fusion bond black nylon #11, 7-15 mil *Internal Threads:* Dry Film Lubricant per Mil-L-23398
Anchor Bolt	1"-8 UNC HDG per ASTM 153, 2-1/2" - 3" above foundation. (Supplied by others.)
Installation note:	Coupling is installed 1/8" min. to 3/8" max. off the anchor foundationand and provides for leveling. (See installation instructions).

INTENDED USE

The breakaway support coupling is used with base plate equipped poles installed in locations exposed to vehicular collisions, on 1" diameter HDG anchor bolts.

BREAKAWAY SUPPORT COUPLINGS FOR LIGHT POLES
FOR USE WITH 1" DIAMETER HDG ANCHOR BOLT
Model No. 201

pole-safe® BY TRANSPO® INDUSTRIES, INC.

Figure 9. Breakaway Support Couplings Specifications

Figure 10. Installed Breakaway Couplings

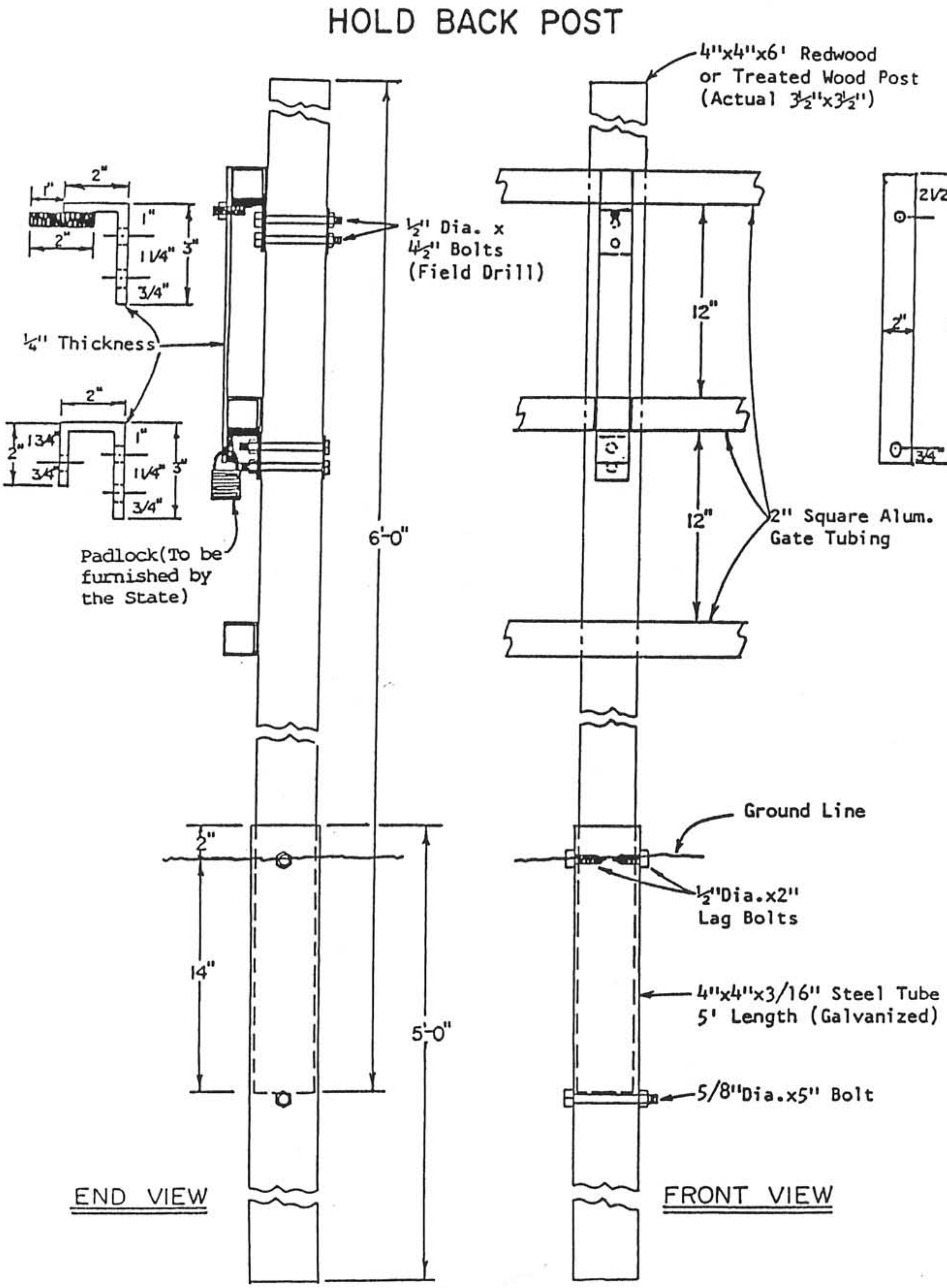


Figure 11. Hold Back Post Detail

2.3.5 Gate Attachments

Details of the sign and Type 1 object markers used during testing are shown in Figure 12. Three object markers were attached to the second through fourth vertical supports on the gate while the sign was attached to the last two vertical supports. Although not typically used in the stowed position, two Type "B" flashing warning lights with battery packs were attached to the top horizontal aluminum tube on each side of the sign.

In addition to the object markers, sign, and warning lights, two cables were attached to the gate. The 0.95-cm (3/8-in.) diameter galvanized aircraft cables were stored on the gate while in the stowed position. During testing, the cables were wrapped around the second vertical support and each end was hooked at the bottom of the fifth vertical support. The cable hooks and pinned connections are shown on the cable detail in Figure 13(a). The orientation of the cables in the closed gate position are shown in Figure 13(b).

2.4 Test Vehicle

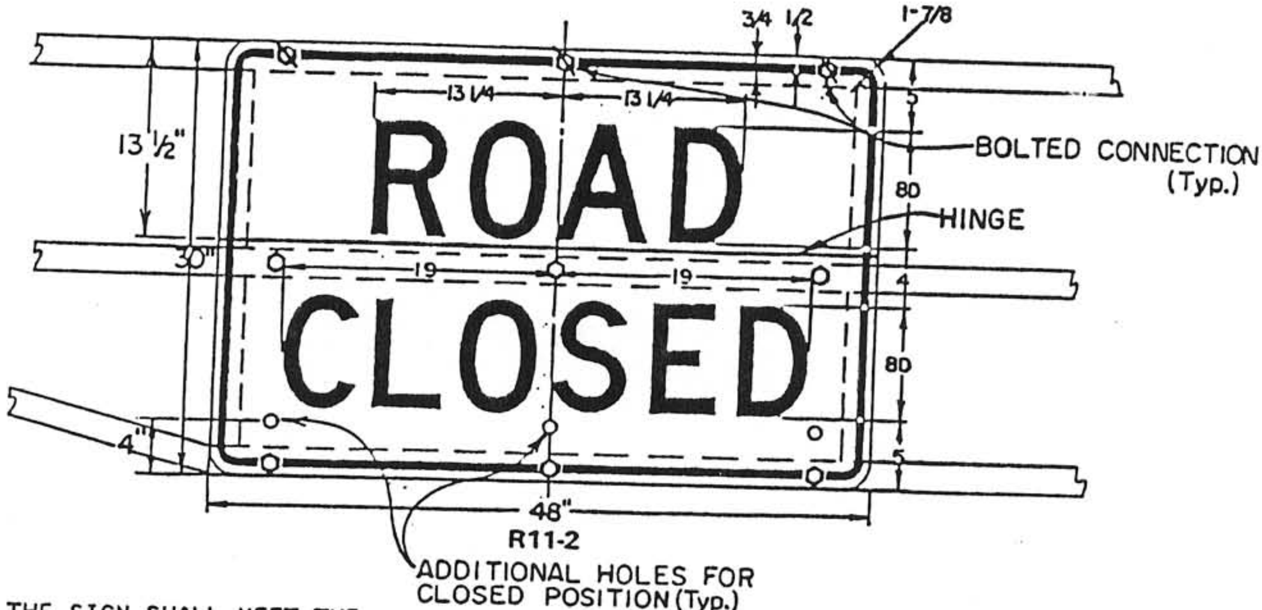
A 794-kg (1751-lb) 1986 Chevrolet Sprint, shown in Figure 14, was used as a test vehicle in both tests SDG-1 and SDG-2. Dimensions and axle weights of the test vehicle are shown in Figure 15. Black and white-checkered targets were placed on the vehicle for high-speed film analysis, as shown in Figure 16. Two targets were located on the center of gravity, one on the driver's side and one on the passenger side of the test vehicle. Additional targets were located for reference so that they could be viewed from all cameras. The front wheels of the test vehicle were aligned for camber, caster, and toe-in values of zero so that the vehicle would track properly along the guide cable. Two 5B flash bulbs, fired by a pressure tape switch on the front bumper, were mounted on the roof of the vehicle to establish the time of impact on the high-speed film.

2.5 Data Acquisition Systems

Vehicle reactions during the full-scale testing program were monitored with SVHS video, high-speed photography, accelerometers, rate gyro, and tape pressure switches. Each of these data acquisition

Use nut on back side of sign and wing nut on front side along the top of ROAD CLOSED sign.

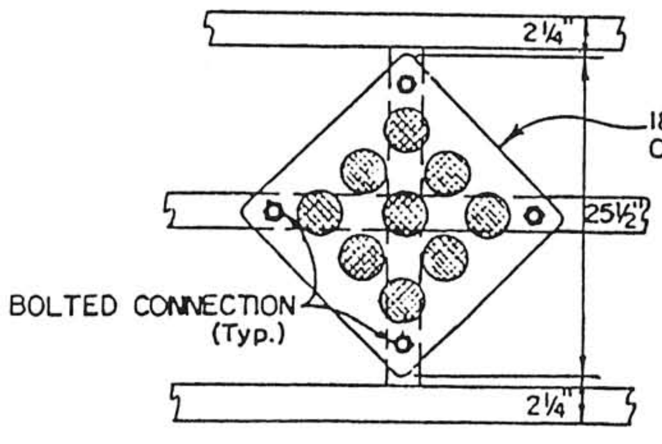
SIGN DETAILS



Furnish necessary bolts.

THE SIGN SHALL MEET THE REQUIREMENTS OF AN R11-2 SIGN. (MUTCD). IT MUST BE REFLECTORIZED.

TYPICAL TYPE 1 OBJECT MARKERS



Nine yellow 3" reflectors, mounted symmetrically on a yellow reflective diamond panel

Use plastic washers on face of sign & object marker.

Figure 12. Sign and Object Marker Detail

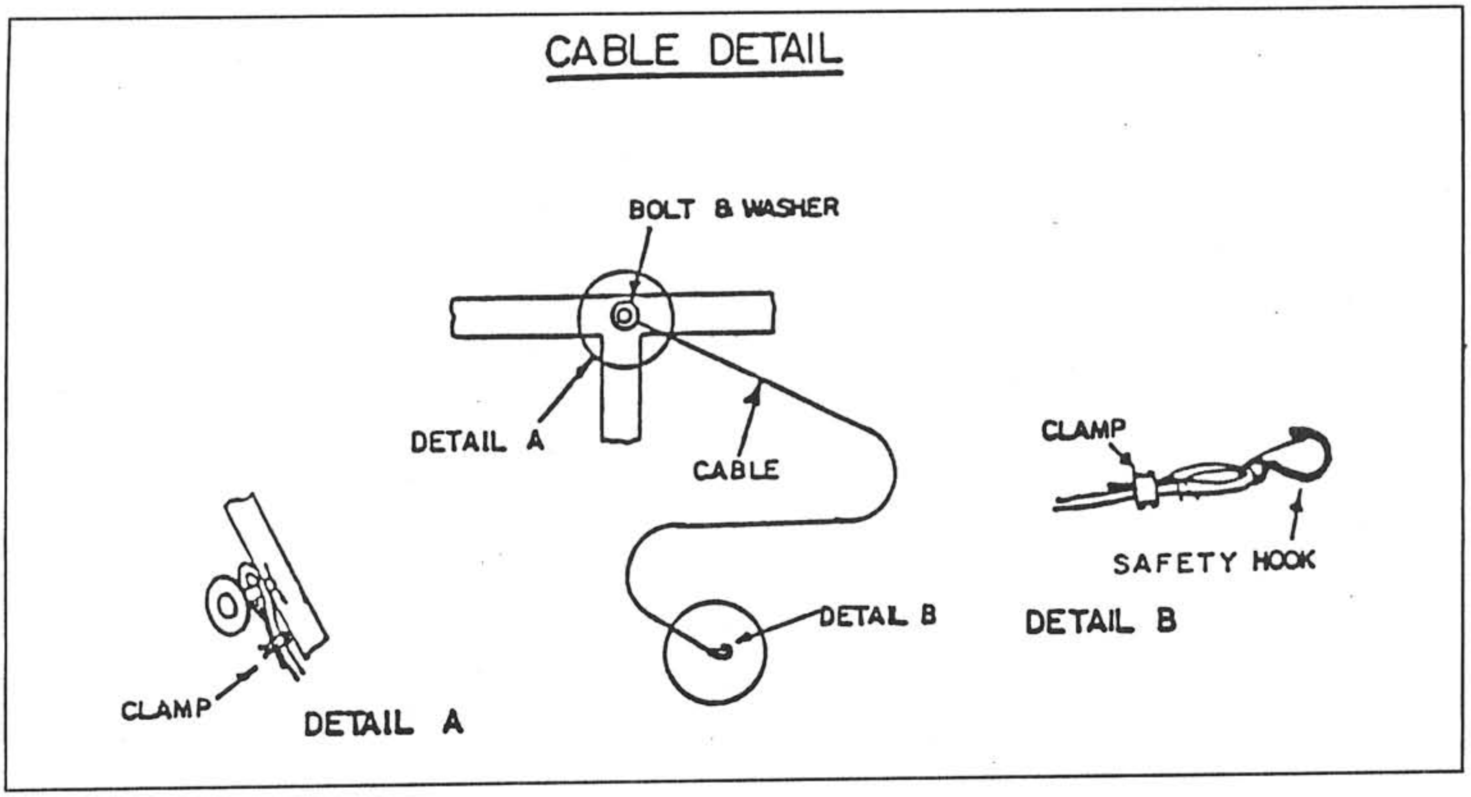


Figure 13(a). Cable Details

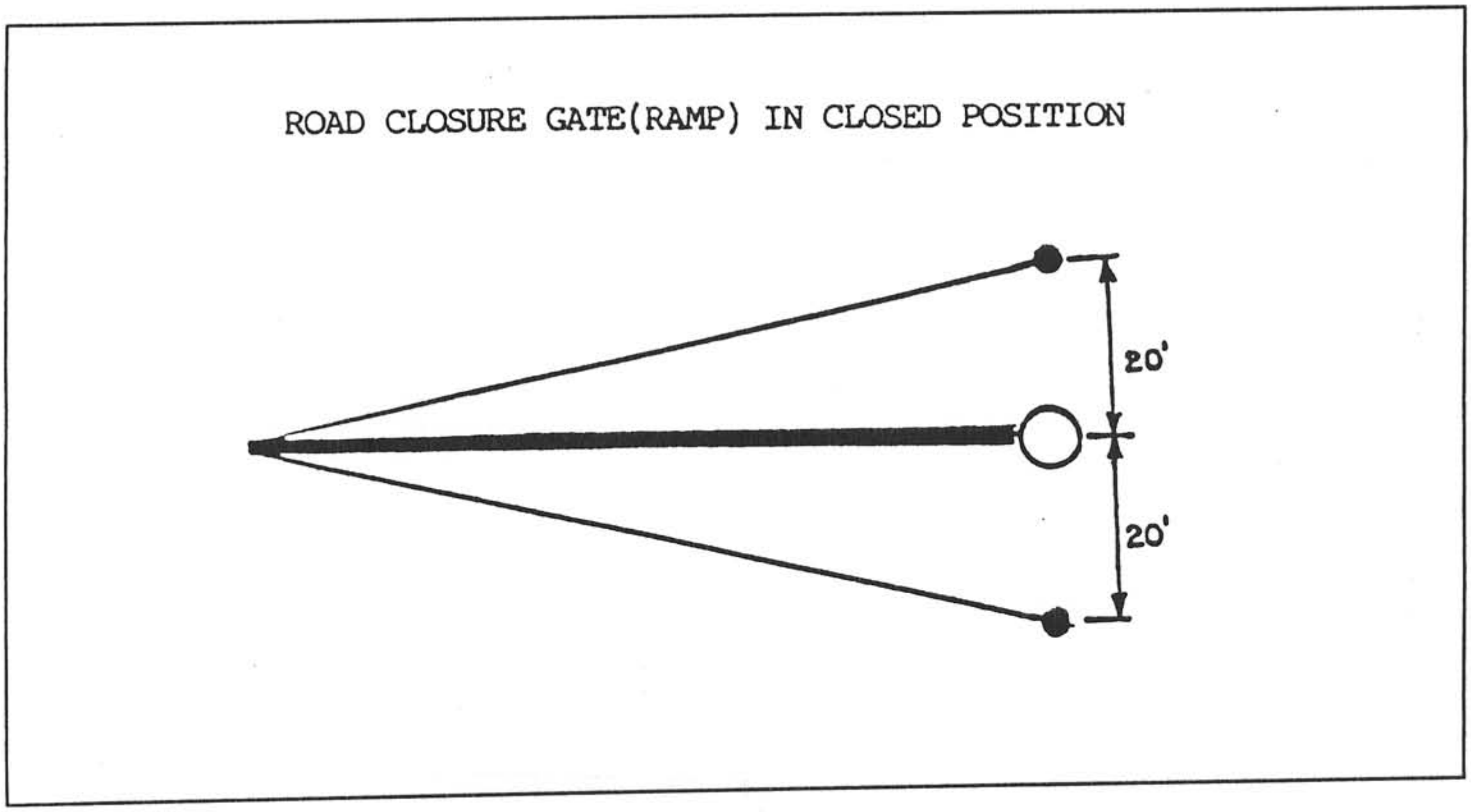


Figure13(b) Cable Orientation in Closed Position

Figure 14. Test Vehicle, SDG-1,2

Make: Chevrolet

Test No.: SDG-1,2

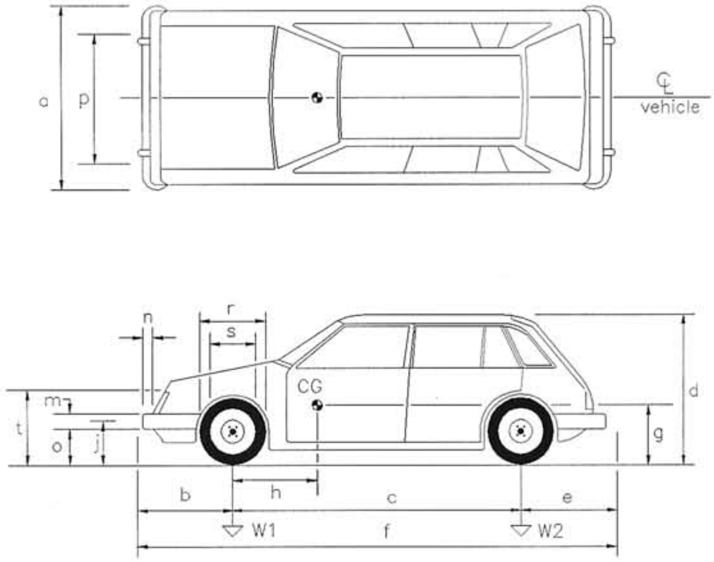
Model: Sprint

Tire Size: 145/R12

Year: 1986

VIN: JG1MR6857GK814924

Damage prior to test: None



Vehicle Geometry
cm (in.)

a	141/(55.5)	b	95.6/(27)
c	234/(92.5)	d	132/(52)
e	63.5/(25)	f	367/(144.5)
g	55.9/(22)	h	88.9/(35)
j	40.6/(16)	m	45.7/(18)
n	8.3/(3.25)	o	34.9/(13.75)
p	134.6/(53)	r	54.6/(21.5)
s	33/(13)	t	68.6/(27)

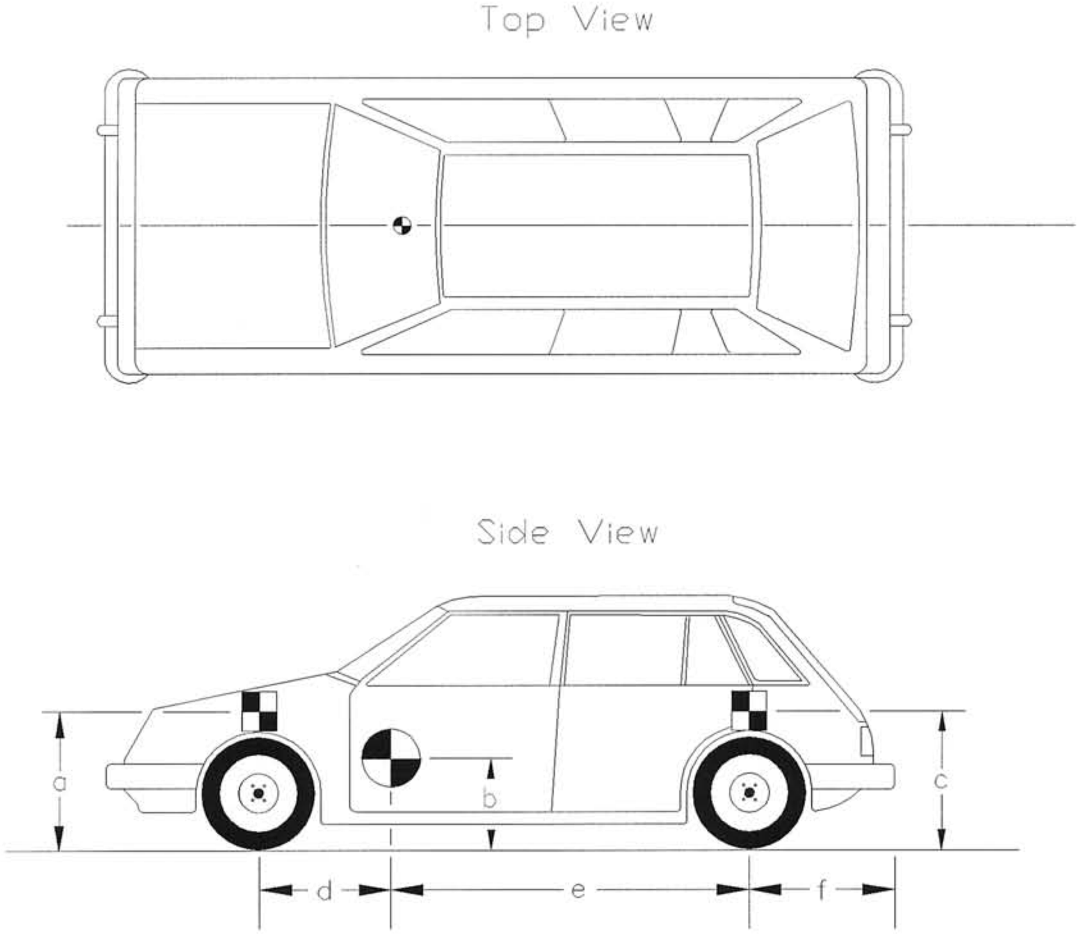
Engine Size: 3cyl. 1.0L

Transmission: man. 5-speed

Mass (kg/lbs)	Curb [1]	Test Inertial [2]	Gross Static [3]
W1	367/(810)	469/(1033)	469/(1033)
W2	277/(610)	326/(718)	326/(718)
Wtotal	644/(1420)	794/(1751)	794/(1751)

[1] Curb – mass of test vehicle in its standard manufactured condition.
[2] Test Inertial – mass of test vehicle and all items including ballast and test equipment.
[3] Gross Static – total of test inertial and dummy masses.

Figure 15. Test Vehicle Dimensions and Weights, SDG-1,2



TARGET GEOMETRY
cm (in.)

a 71.1 (28.0)	c 68.6 (27.0)	e 147.3 (58.0)
b 55.9 (22.0)	d 88.9 (35.0)	f 63.5 (25.0)

Figure 16. Test Vehicle Target Dimensions, SDG-1,2

systems are described in the following subsections.

2.5.1 High-Speed Photography

Three high-speed 16-mm cameras, with operating speeds of approximately 500 frames/sec, were used to film the crash tests. The camera locations are shown in Figure 17. Two Red Lake Model 51 LoCam high-speed cameras were used to provide perpendicular views of the tests. One with a wide-angle 12.5-mm lens and the other with a 12- to 75-mm zoom lens. The third high-speed camera was a Red Lake Model 50 Locam with a 76-mm lens located parallel to the installation and downstream of the gate. In addition to the high-speed cameras, three other cameras were used for documentary footage. These three cameras were a 16-mm Bolex (64 fr/sec), a SVHS video camera, and 35-mm camera with a high-speed shutter

A 1.2-m (4-ft) high by 7.3-m (24-ft) long backboard with a 0.6-m (2-ft) grid was located 2.4 m (94 in.) behind the road closure gate. The grid was used to provide a visible reference system which could be used in the analysis of the perpendicular high-speed film. Targets, measuring 10.2-cm (4-in.) square, were also strategically placed on the gate and the steel post in order to monitor hardware displacements using the high-speed film. The film was analyzed using a Vanguard Motion Analyzer. Actual camera speed and camera divergence factors were considered in the analysis of the high-speed film.

2.5.2. Accelerometers and Rate Gyro

Two triaxial piezoresistive accelerometer systems with a range of ±200 G's (Endevco Model 7264) were used to measure vehicle accelerations. A Humphrey 3-axis rate transducer with a range of 250 deg/sec in each of the three directions (roll, pitch, and yaw) was used to measure the rotational rates. Since vehicle rotations become coupled in the presence of high rotation rates, an uncoupling procedure of the measured angular velocities was conducted. The accelerometers and rate gyro were rigidly attached to a metal block mounted near the vehicle's center of gravity.

Signals were transmitted and received via telemetry and stored to a Honeywell 101 Analog Tape Recorder. The signals were then conditioned by an onboard Series 300 Multiplexed FM Data System built

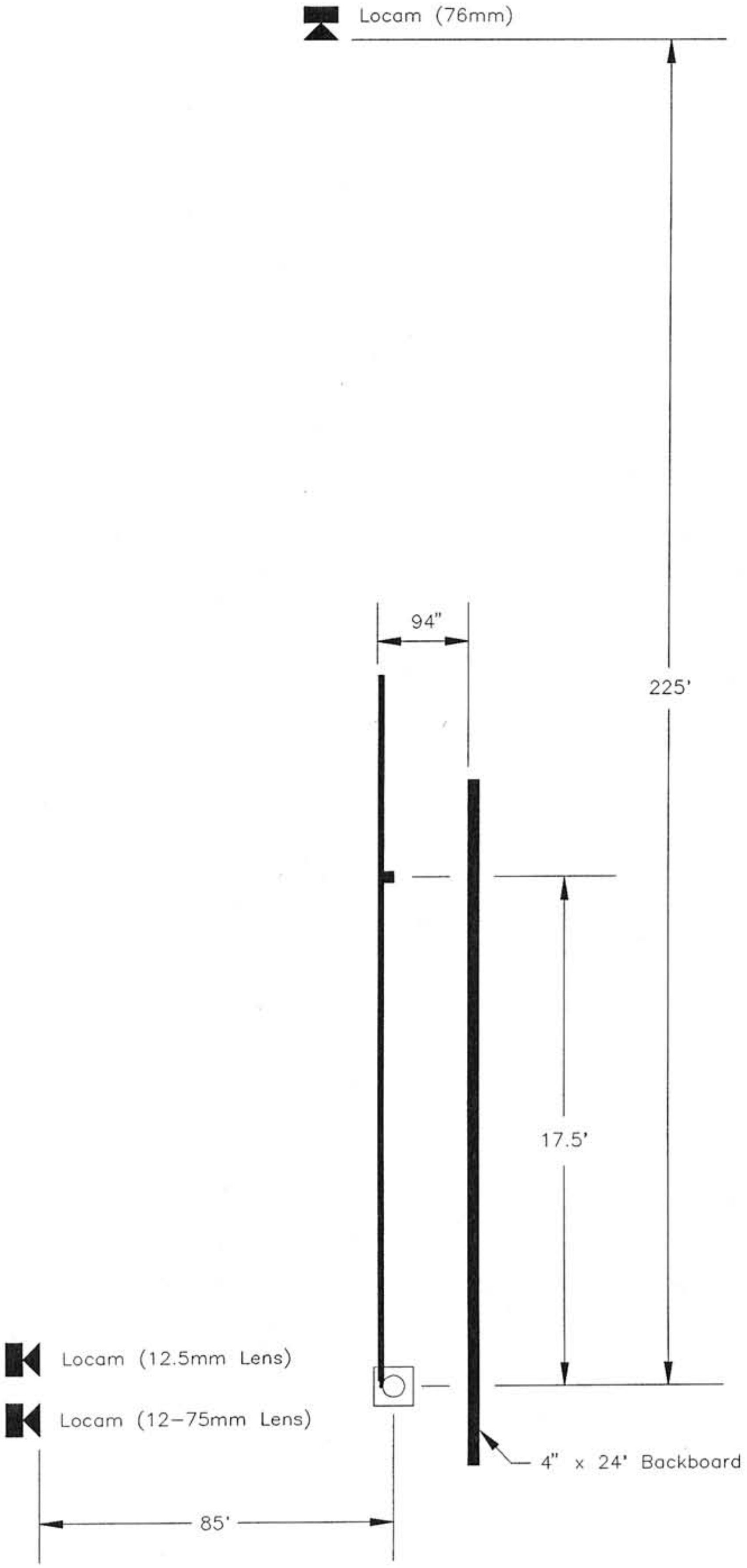


Figure 17. Layout of High-Speed Cameras, SDG-1,2

by Metraplex Corporation. "Enhanced Graphics Acquisition and Analysis" (EGAA) (7) software was used to digitize the data and store the data for analysis with "Data Analysis and Display Software" (DaDiSP) (8).

An Environmental Data Recorder (EDR-3), developed by Instrumented Sensor Technology (IST) of Okemos, Michigan was also used to record the accelerations during the full-scale tests at a sample rate of 3200 Hz. This self-contained unit consists of a triaxial accelerometer system, triggering upon impact and storing the data on board. The EDR-3 was configured with 256 Kb of RAM memory and a 1,120 Hz filter. Computer software, "DynaMax 1 (DM-1)" software was then used to download the EDR-3 unit and filter the data with an 180 Hz low-pass filter.

2.5.3 Pressure Tape Switches

Five pressure tape switches, spaced at 1.52-m (5-ft) intervals, were used to determine the speed of the vehicle before and after impact. Each tape switch fired a strobe light and sent an electronic timing mark to the data acquisition system as the left front tire of the test vehicle passed over it. Test vehicle speeds were determined from recorded electronic timing mark data. Strobe lights and high speed film analysis were used only as a backup in the event that vehicle speeds were not able to be determined from the electronic data.

3 PERFORMANCE EVALUATION CRITERIA

The safety performance evaluation was conducted according to the guidelines presented in NCHRP 350 (1) and the 1985 AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals* (2). These guidelines, shown in Tables 1 and 2, require two compliance tests in order to evaluate the performance of a breakaway support. These two compliance tests are test level 3 tests (Tests 60 and 61). Descriptions of these tests are as follows:

1) Test 3-60: An 820-kg (1808-lb) vehicle impacting the support structure head-on at a nominal impact speed of 35 km/h (21.7 mph) with the center of the front bumper aligned with the center of the installation. The objective of this test is to investigate the breakaway or fracture mechanism of the support.

2) Test 3-61: An 820-kg (1808-lb) vehicle impacting the support structure head-on at a nominal impact speed of 100 km/h (62.1 mph) with the quarter point of the front bumper aligned with the center of the installation. The objective of this test is to investigate the trajectories of both the test installation and the test vehicle.

The vehicle damage was assessed by the traffic accident scale (TAD) (9) and the vehicle damage index (VDI) (10).

TABLE 1. NCHRP Report 350 Safety Evaluation Guidelines.

Evaluation Factors	Evaluation Criteria	
Structural Adequacy	B.	The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.
Occupant Risk	D.	Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.
	F.	The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable.
	H.	Longitudinal occupant impact velocity should satisfy the following limits: Preferred: 3 m/s (9.8 fps) Maximum: 5 m/s (16.4 fps)
	I.	Occupant ridedown accelerations should satisfy the following longitudinal and lateral limits: Preferred: 15 G's Maximum: 20 G's
Vehicle Trajectory	K.	After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.
	N.	Vehicle trajectory behind the test article is acceptable.

TABLE 2. AASHTO 1985 Safety Evaluation Guidelines.

Evaluation Factors	Evaluation Criteria
Vehicle Change in Speed (ΔV)	Satisfactory dynamic performance is indicated when the maximum change in velocity of the vehicle, striking a breakaway support at speeds from 20 mph to 60 mph (32 km/h to 97 km/h does not exceed 15 fps (4.57 m/s), but preferably does not exceed 10 fps (3.05 m/s)