TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.
FHWA/TX-84/34+262-1

2. Government Accession No.

3. Recipient's Catalog No.

4. Title and Subtitle
Design and Tests of a Precast Concrete Barrier for Work Zones

5. Report Date
July 1983

6. Performing Organization Code

7. Author(s)
Hayes E. Ross, Jr., and Dean L. Sicking

8. Performing Organization Report No.
Research Report 262-1

9. Performing Organization Name and Address
Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843

10. Work Unit No.

11. Contract or Grant No.
Study No. 2-18-79-262

12. Sponsoring Agency Name and Address
Texas State Department of Highways and Public Transportation
11th and Brazos Streets
Austin, Texas 78701

13. Type of Report and Period Covered
Interim - September 1978 - July 1983

14. Sponsoring Agency Code

15. Supplementary Notes
Research performed in cooperation with SDHPT, DOT, and FHWA.
Research Study Title: Safety Devices for Highway Work Zones

16. Abstract

A portable precast concrete traffic barrier has been designed which utilizes 15 ft (4.6 m) barrier segments. The barrier should be much more portable than barriers currently in use in Texas which employ 30 ft (9.1 m) segments. Barrier segments are attached with two C5 x 9 steel splice channels and four 1-1/8 in. (2.86 cm) steel bolts. This joint construction provides significant joint moment capacity without significantly complicating barrier installation.

The barrier was successfully crash tested with a 4500 lb (2045 kg) vehicle impacting at 25 degrees and 60 mph (96.6 km/h). The test vehicle was smoothly redirected, and vehicle accelerations were within nationally accepted guidelines. No barrier segments were damaged during testing, and only a few splice channels required repair or replacement. Portable barriers currently in use on Texas highways were damaged more severely when tested under identical conditions.

17. Key Words
Traffic Barrier, Concrete, Precast, Work Zone, Construction, Crash Test

18. Distribution Statement
No restrictions. This document is available to the public through the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	61	

Form DOT F 1700.7 (8-69)

DESIGN AND TESTS OF A PRECAST CONCRETE BARRIER FOR WORK ZONES

by

Hayes E. Ross, Jr.
Research Engineer

and

Dean L. Sicking
Engineering Research Associate

Research Report 262-1
on
Research Study No. 2-18-79-262
Safety Devices for Highway Work Zones

Sponsored by

Texas State Department of Highways and Public Transportation

in cooperation with

The U. S. Department of Transportation
Federal Highway Administration

July 1983

Texas Transportation Institute
Texas A&M University
College Station, Texas

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Texas State Department of Highways and Public Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

KEY WORDS

Traffic Barrier, Concrete, Precast, Work Zone, Construction, Crash Test

ACKNOWLEDGMENTS

This research study was conducted under a cooperative program between the Texas Transportation Institute, the Texas State Department of Highways and Public Transportation, and the Federal Highway Administration.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF TABLES

INTRODUCTION

Although for many years considerable emphasis has been placed on safety along completed portions of the highway system, only recently has concern been shown for the hazards that exist on highways under construction or repair. During expansion or repair of an existing highway, construction equipment and workers are usually operating very close to the travelway. This situation can be hazardous for both motorists and workmen. Often a positive barrier is warranted to prevent errant vehicles from entering the work zone.

Ideally, a positive barrier should be capable of safely redirecting vehicles impacting at speeds up to 60 mph (96.6 km/h) and angles up to 25 degrees. Lateral deflections of the barrier resulting from impacts should be small to protect workers standing behind the barrier. Finally, the barrier should be relatively portable since it may be moved within a work zone several times during a single construction project.

Many state highway departments have used segmented precast concrete barriers in construction zones. The segment lengths and connection details of these barriers vary greatly from state to state. Some of the designs currently in use are summarized in Figures 1 and 2. Some of these barriers have performed well when struck by errant vehicles, while others have shown serious deficiencies. The Texas State Department of Highways and Public Transportation has had good success with segment lengths of 30 ft (9.1 m) and a dowel bar connection as shown in Figure 1 (1). Precast concrete barriers weigh as much as 500 lb/ft (745 kg/m) and therefore 30 ft (9.1 m) segments are not very portable. Segment lengths from 12 to 20 ft (3.7 to 6.1 m) would be much more portable than the current 30 ft (9.1 m) length

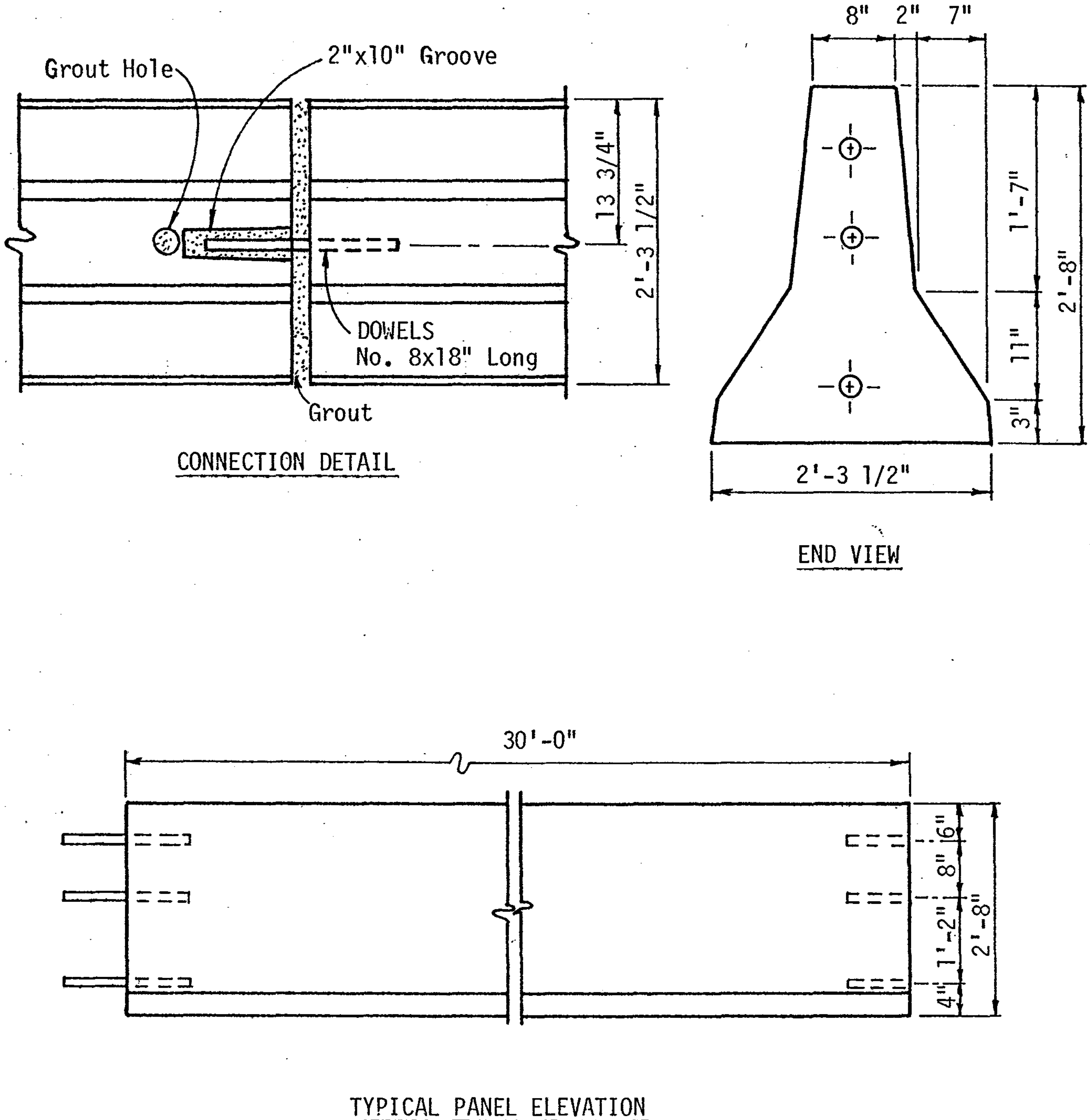


FIGURE 1. TEXAS PORTABLE CONCRETE BARRIER, DOWEL BAR CONNECTION.

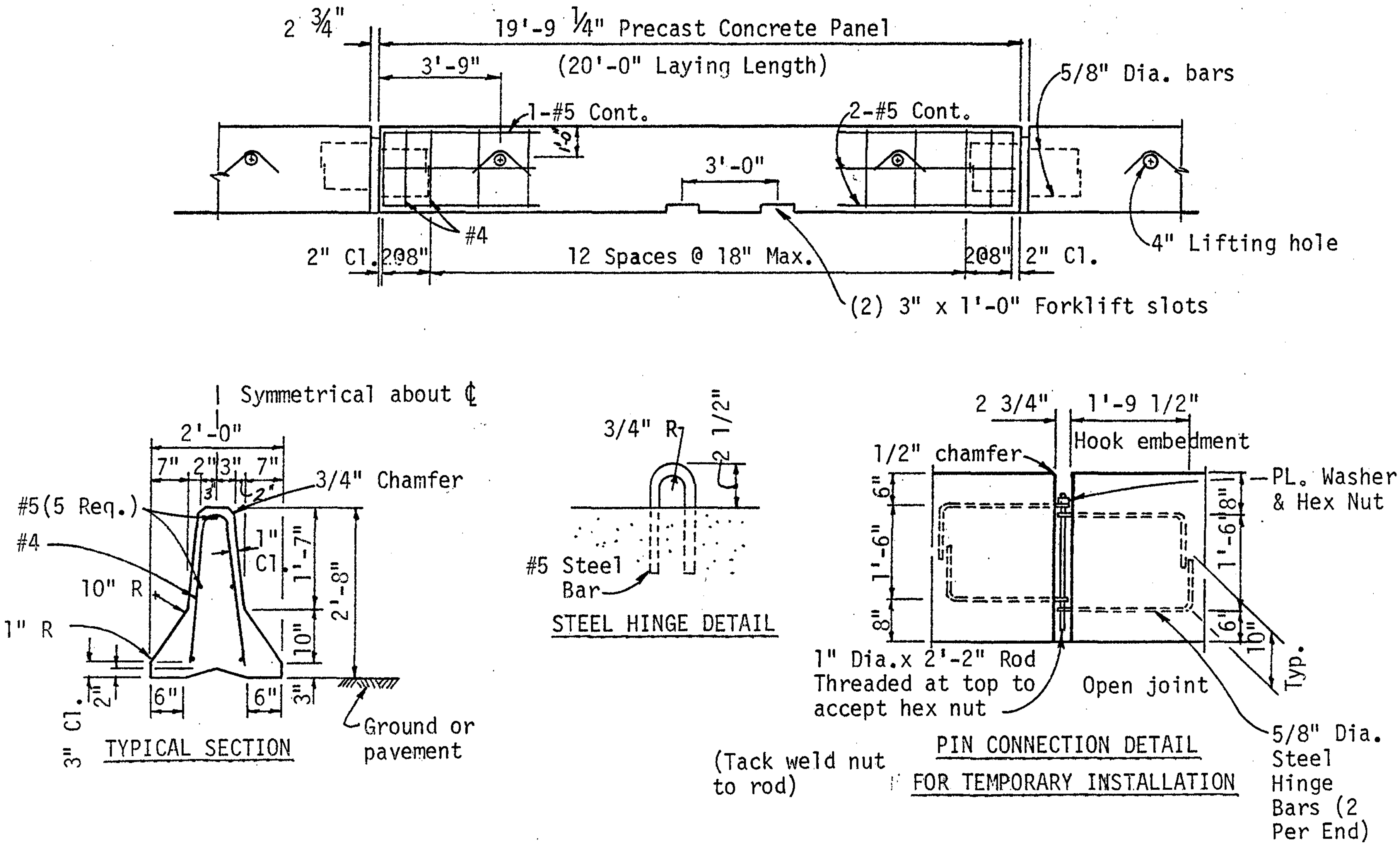


FIGURE 2. A TYPICAL CONCRETE BARRIER, PIN JOINT CONNECTION.

used in Texas. A review of the literature revealed that tests of 12 and 20 ft (3.7 and 6.1 m) pin-jointed precast segments had been only partially successful (2,3). Tests indicate that at a high speed, high angle impact a vehicle will likely override the barrier and/or roll over subsequent to impact.

This study was therefore undertaken to develop a portable precast concrete barrier which would a) safely redirect vehicles impacting at a speed of 60 mph (96.6 km/h) and an angle of 25 degrees; b) deflect only a short distance during high-speed and high-angle impacts; and c) be relatively portable.

RESEARCH APPROACH

Tests have shown that if a segmented concrete barrier remains intact during impact, the barrier's capacity for safely redirecting an errant vehicle will be determined by the amount of rotation and lateral movement of the segments. Segment rotation and movement is dependent on segment-to-segment joint properties (torque and moment capacity and slack), barrier segment length, barrier mass, and friction between barrier and the surface on which it rests. The relationship between these properties and the dynamic response of a barrier must be understood if an optimum design for a portable concrete traffic barrier (PCTB) is to be developed.

Contributions of each of these parameters to the behavior of a PCTB cannot be fully determined through full-scale crash testing due to the inordinate expense of such a program. Therefore a barrier simulation program developed by TTI to model a PCTB (4) was employed to study these parameters. This simulation is a two-dimensional program that computes the lateral movement and yaw of the barrier segments for a given lateral impulse. It does not predict vehicle response and as such vehicle/barrier interaction is not considered. However, vehicle behavior can be inferred from previous tests of segmented concrete barriers (2,3) in which barrier movement was known. A series of computer runs were made to evaluate the effects of barrier length, joint moment capacity, joint slack, and roadway friction on lateral barrier deflections by varying each parameter independently. The impulse applied to the barrier in each of these runs was obtained from full-scale test measurements (5), specifically, force-time measurements for a 60 mph, 25 degree impact. Since this analysis was designed to model barrier response to the most vigorous test that the barrier would be expected to withstand, all simulations modeled impact with a 4500 lb (2043 kg) vehicle traveling at 60 mph (96.6 km/h) at an angle of 25 degrees. For all simulations, the impact point was located approximately at the third point of the system.

A sensitivity analysis was initially conducted to determine the length of barrier system required to eliminate significant end point movement and the location of the critical impact point with respect to a barrier segment. Significant end point movement was arbitrarily defined as 2 in. (5.08 cm) of displacement. This analysis was conducted with no joint moment capacity and a coefficient of friction of 0.7 between barrier and roadway surface.

The results of the initial analysis are summarized in Table 1. Barriers with segment lengths equal to or greater than 20 ft (6.1 m) require approximately 120 ft (36.6 m) of barrier to eliminate significant end point movement. However, those barriers with shorter segment lengths require approximately 180 ft (54.9 m). Also shown in this table is that impacts at the center of a joint cause larger deflections for all segment lengths except the 30 ft (9.1 m) segments.

Joint Moment Capacity

The effects of joint moment capacity, Mu, on maximum barrier deflections were examined by combining each segment length under investigation with five joint moment capacities ranging from 0 to 100 kip-ft (0 to 1356 kN-m). The joint slack, ϕ_s, was assumed to be 3 degrees and the elastic limit, ϕ_e, was 5 degrees. No failure limit was established. The coefficient of friction between the barrier and the roadway surface was assumed to be 0.7.

Results of these simulations are given in Table 2 and Figures 3 and 4. As shown in these figures, the effects of increased joint moment capacity on

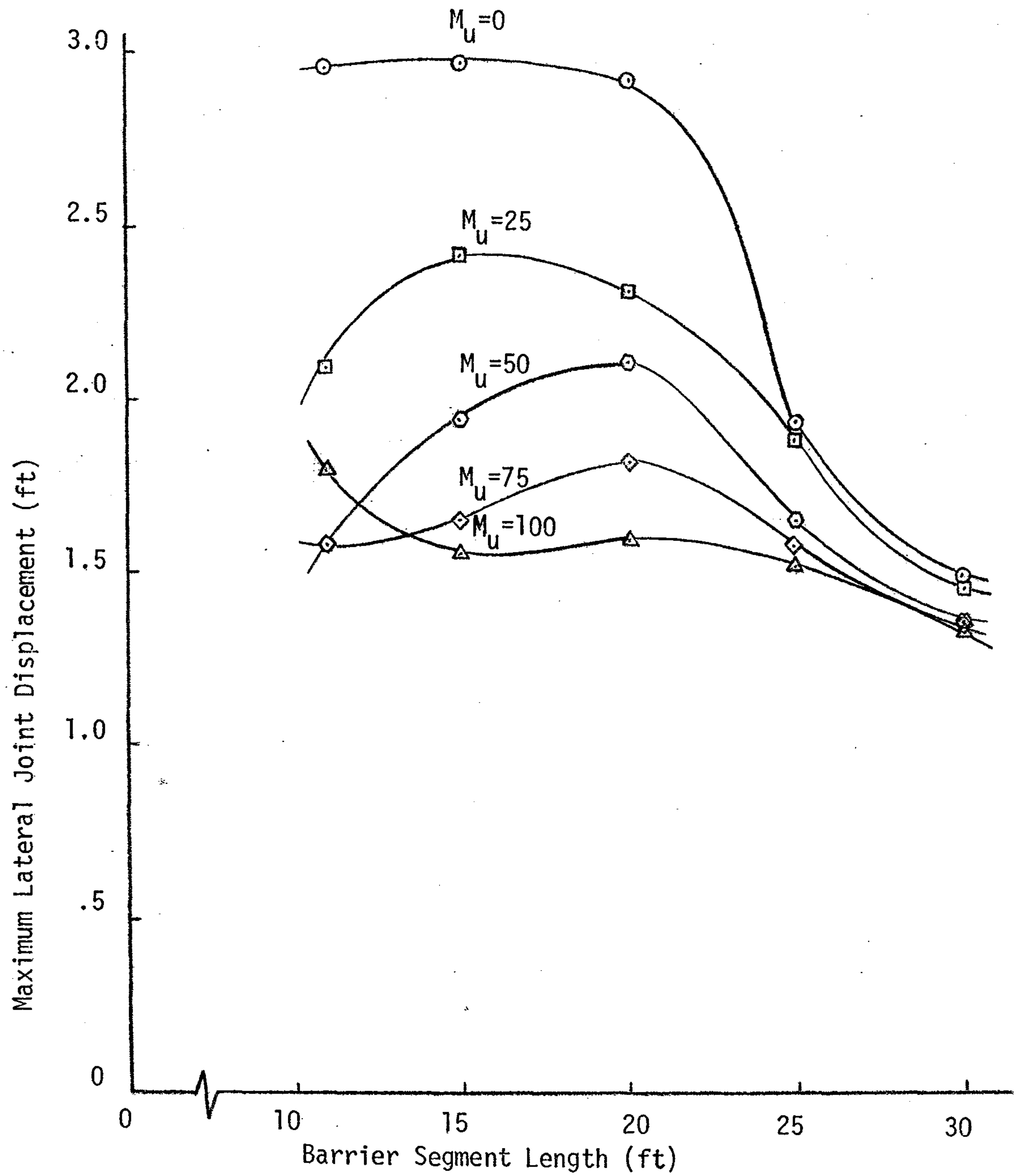
TABLE 1. LENGTH OF NEED AND CRITICAL IMPACT POINT STUDY RESULTS

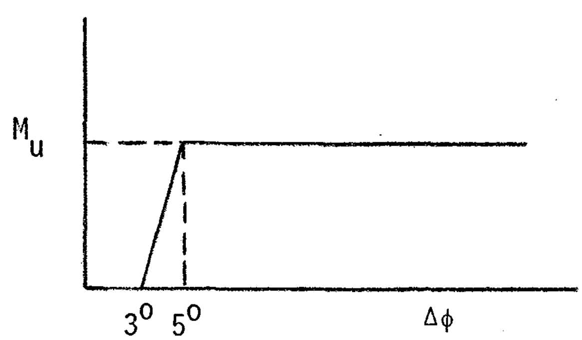
Segment Length (ft)(m)	No. of Segments	Impact Point	Max. Defl. in. (cm)	End Point Displacement X_1 in. (cm)	Y_1 in. (cm)	X_2 in. (cm)	Y_2 in. (cm)
12 (3.66)	8	JT	34 (86)	2.3 (5.8)	-0.1 (-0.3)	-4.8 (-12.2)	0.0 (0.0)
12 (3.66)	10	JT	33 (84)	2.0 (5.1)	0.2 (0.5)	-4.0 (-10.2)	0.0 (0.0)
12 (3.66)	12	JT	31 (79)	1.8 (4.6)	1.2 (3.0)	-3.2 (-8.1)	0.0 (0.0)
12 (3.66)	12	CTR	39 (99)	3.7 (9.4)	0.2 (0.5)	-3.2 (-8.1)	0.0 (0.0)
12 (3.66)	15	CTR	35 (89)	2.3 (5.8)	0.7 (1.8)	-2.9 (-7.4)	0.0 (0.0)
15 (4.57)	8	CTR	43 (109)	4.7 (11.9)	-0.5 (-1.3)	-3.7 (-9.4)	0.0 (0.0)
15 (4.57)	8	JT	26 (66)	1.3 (3.3)	-0.2 (-0.5)	-2.2 (-5.6)	0.0 (0.0)
15 (4.57)	10	CTR	39 (99)	3.6 (9.1)	0.1 (0.2)	-3.7 (-9.4)	0.0 (0.0)
15 (4.57)	12	CTR	35 (89)	2.9 (7.4)	0.5 (1.3)	-2.9 (-7.4)	0.0 (0.0)
20 (6.10)	5	CTR	34 (86)	1.3 (3.3)	0.0 (0.0)	4.3 (10.9)	2.8 (7.11)
20 (6.10)	6	CTR	32 (81)	2.5 (6.4)	0.0 (0.0)	0.2 (0.5)	-0.1 (-0.3)
20 (6.10)	6	JT	24 (61)	1.0 (2.5)	0.2 (0.5)	1.2 (3.0)	0.2 (0.5)
25 (7.62)	5	CTR	22 (56)	0.1 (0.3)	0.2 (0.5)	-1.8 (-4.6)	2.4 (6.1)
25 (7.62)	5	JT	21 (53)	0.2 (0.5)	-0.2 (-0.5)	-1.2 (-3.0)	-1.7 (-4.3)
30 (9.14)	3	CTR	18 (46)	0.1 (0.3)	-1.0 (-2.5)	1.7 (4.3)	-13.3 (-33.8)
30 (9.14)	4	CTR	14 (36)	0.2 (0.5)	-1.2 (-3.0)	-0.4 (-1.0)	1.7 (4.3)
30 (9.14)	4	JT	17 (43)	0.5 (1.3)	2.0 (5.1)	0.4 (1.0)	-0.6 (-1.5)

TABLE 2. CONNECTION MOMENT-SEGMENT LENGTH-DEFLECTION STUDY

$\phi_s = 3^o \quad \phi_e = 5^o$

Barrier Segment Length ft (m)	Connection Moment k-ft (kN-m)	Maximum Displacement in. (cm)
12 (3.66)	0 (0)	35.01 (88.93)
	25 (33.9)	25.21 (64.03)
	30 (40.7)	23.92 (60.76)
	50 (67.8)	19.80 (50.29)
	75 (102)	19.76 (50.19)
	100 (136)	21.67 (55.04)
15 (4.57)	0 (0)	35.31 (89.69)
	25 (33.9)	29.06 (73.81)
	30 (40.7)	27.93 (70.94)
	50 (67.8)	22.73 (57.73)
	75 (102)	19.98 (50.75)
	100 (136)	18.76 (47.65)
20 (6.10)	0 (0)	33.80 (85.85)
	25 (33.9)	28.01 (71.15)
	30 (40.7)	26.94 (68.43)
	50 (67.8)	26.70 (67.82)
	75 (102)	21.87 (55.55)
	100 (136)	19.07 (48.44)
25 (7.62)	0 (0)	22.32 (56.69)
	25 (33.9)	21.37 (54.28)
	30 (40.7)	21.17 (53.77)
	50 (67.8)	19.89 (50.52)
	75 (102)	18.82 (47.80)
	100 (136)	18.34 (46.58)
30 (9.14)	0 (0)	17.74 (45.06)
	25 (33.9)	16.87 (42.85)
	30 (40.7)	16.80 (42.67)
	50 (67.8)	16.55 (42.04)
	75 (102)	16.25 (41.28)
	100 (136)	15.98 (40.59)





Friction Coefficient =0.7

FIG. 3. Lateral Joint Displacement versus Segment Length, Variable Connection Moment.

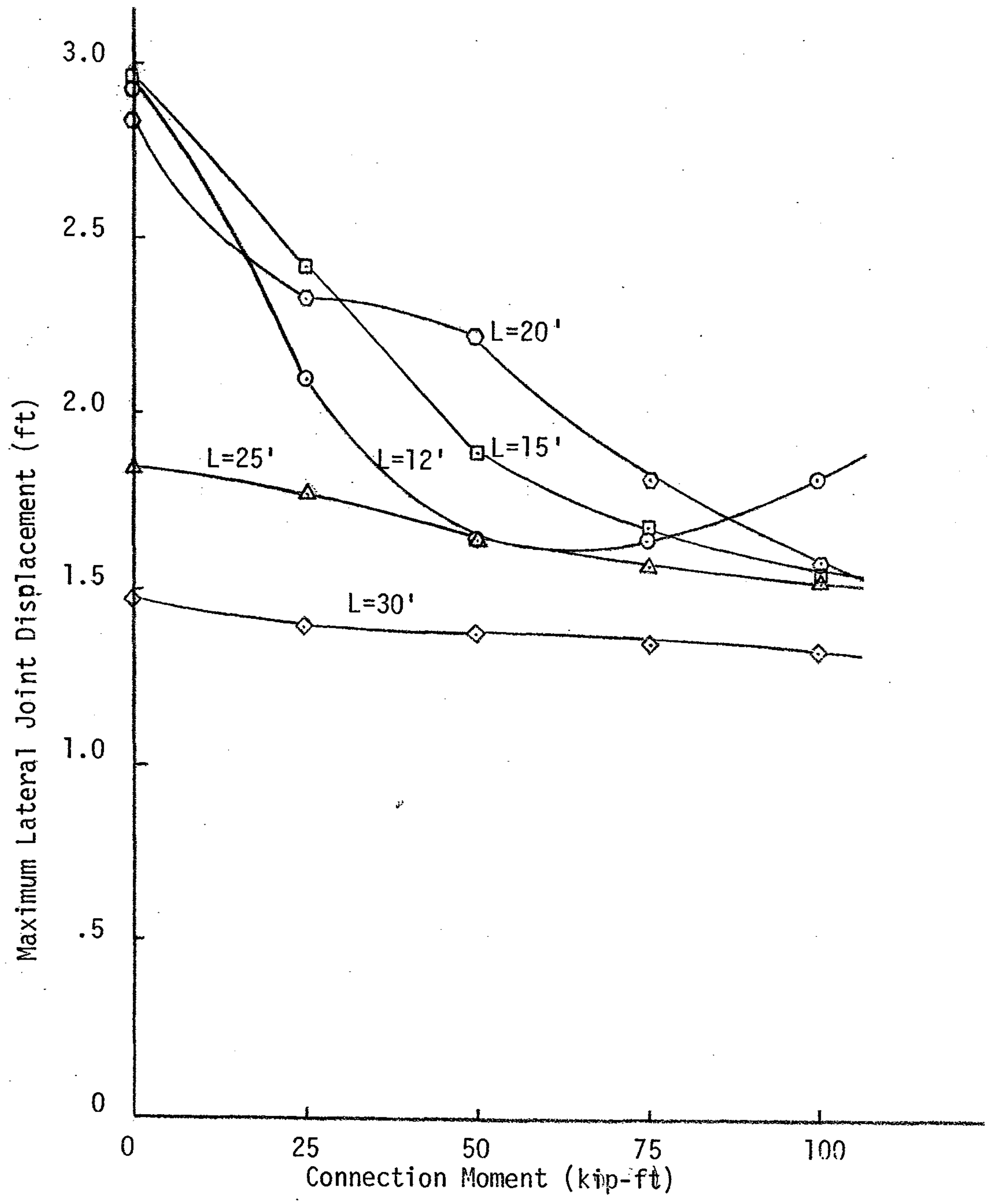


FIG. 4. Lateral Joint Displacement versus Connection Moment, Variable Segment Length.

barrier deflections decrease as the barrier segment lengths increase. This can be understood if the relative joint rotations due to a barrier deflection of 1 ft (0.30 m) are examined for several segment lengths. The relative joint rotations of 12 ft, 20 ft, and 30 ft (3.7 m, 6.1 m, and 9.14 m) segments subjected to 1 ft (0.30 m) lateral displacement are 9.5, 5.7, and 3.8 degrees, respectively. Since joint rotations are larger for short segments, more energy is absorbed in the barrier joints and a larger portion of the energy absorbed is dissipated in plastic deformation of the joint than for long segments.

Although the 12 ft (3.6 m), 15 ft (4.6 m), and 20 ft (6.1 m) segment lengths with no joint moment capacity were deflected approximately the same distance, the 12 ft length deflected less for moderate moment capacities than did the two intermediate segment lengths. The 15 ft (4.6 m) and 20 ft (6.1 m) segment lengths were deflected less than the 12 ft (3.6 m) length for barriers with large joint moment capacities. The results of this phase of the study have shown that a) moderate joint moment capacity will effectively reduce deflections of short barrier segments; b) intermediate segment lengths require large joint moment capacities to insure similarly reduced deflections; and c) deflections of long barrier segments are not reduced significantly by large joint moment capacities.

Joint Connection Slack

The effects of connection slack on maximum barrier deflection were investigated by varying connection, ϕ_S, slack from 1 to 8 degrees for each of the five barrier lengths. The ultimate moment was held constant at 100 kip-ft (136 kN-m), and the elastic limit was 2 degrees larger than the slack rotational limit. The coefficient of friction between the barrier and the roadway was 0.7.

Results of the simulations are given in Table 3 and are plotted in Figure 5. The curves in Figure 5 show a general increase in deflection as the connection slack grows. However, for segment lengths of 20 ft (0.61 m) and less there is no significant increase in barrier deflections below a joint slack of 5 degrees.

Roadway Friction

The effects of surface friction on maximum barrier displacement were examined for barrier lengths of 20 ft (0.61 m) and less. Segment lengths in excess of 20 ft (0.61 m) were not considered portable enough to warrant further study, since the shorter segments had been shown to be capable of redirecting vehicles without deflecting excessively. For this investigation the coefficient of friction was varied from 0.4 to 0.6. A joint moment capacity of 150 kip-ft (2.03 kn-m), a slack rotation of 1 degree, and an elastic limit of 3 degrees were used in all tests.

Results of these simulations are shown in Table 4 and Figure 6. As expected, an increase in friction reduced maximum barrier deflections.

TABLE 3. CONNECTION SLACK-SEGMENT LENGTH-DEFLECTION STUDY

$Mu = 100$ k-ft $\quad \phi_e = \phi_s + 2^o$

Length ft (m)	Slack (deg)	Lateral Displacement ft (m)
12 (3.66)	1	1.59 (0.48)
	2	1.70 (0.52)
	3	1.76 (0.54)
	5	1.45 (0.44)
	8	1.71 (0.52)
15 (4.57)	1	1.45 (0.44)
	2	1.50 (0.46)
	3	1.56 (0.48)
	5	1.65 (0.50)
	8	1.99 (0.61)
20 (6.10)	1	1.37 (0.42)
	2	1.53 (0.47)
	3	1.59 (0.48)
	5	1.92 (0.59)
	8	2.34 (0.71)
25 (7.62)	1	1.13 (0.34)
	2	1.34 (0.41)
	3	1.53 (0.47)
	5	1.75 (0.53)
	8	1.86 (0.57)
30 (9.14)	1	1.06 (0.32)
	2	1.22 (0.37)
	3	1.33 (0.41)
	5	1.43 (0.44)
	8	1.43 (0.44)

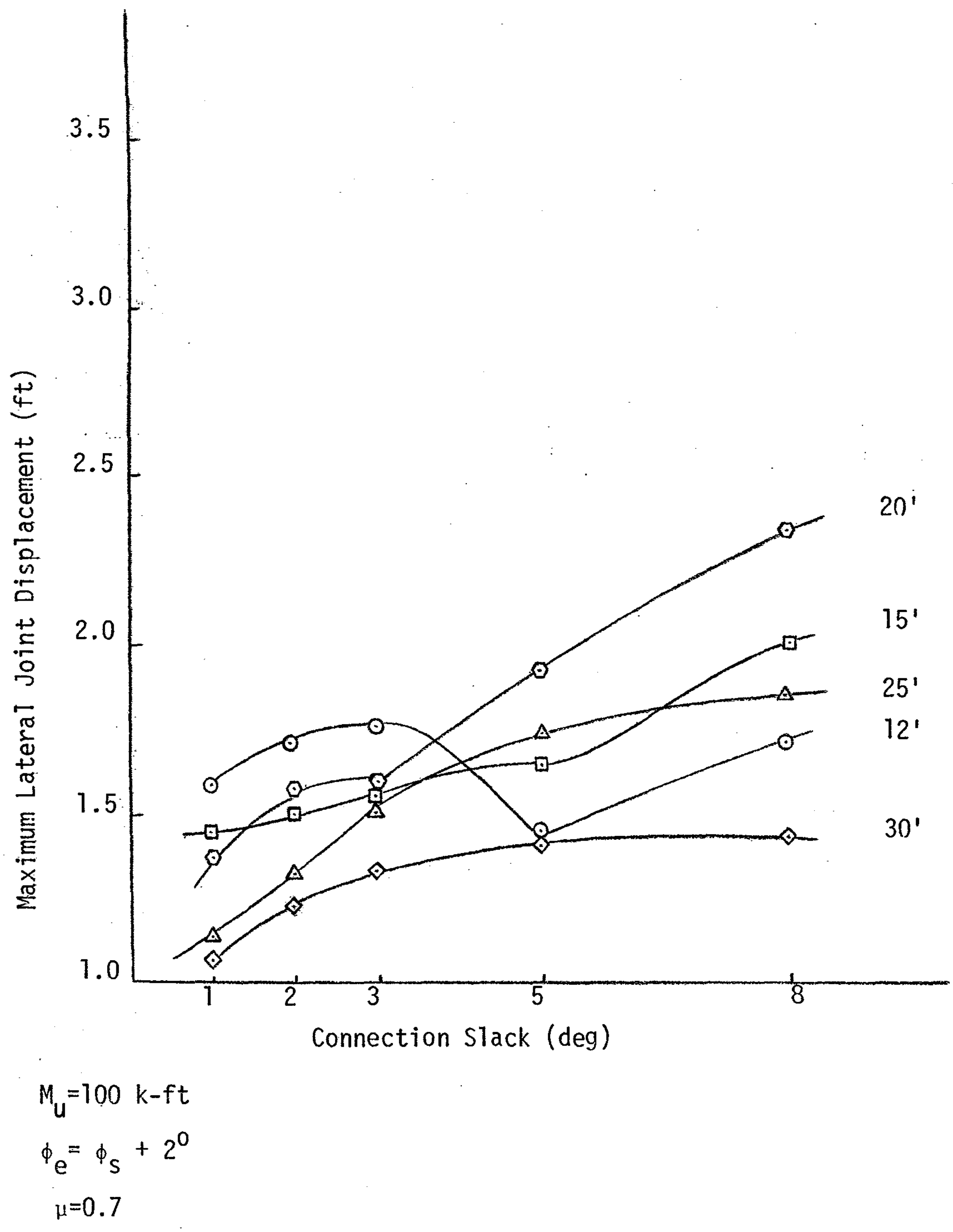


FIG. 5. Lateral Joint Displacement versus Connection Slack, Variable Segment Length.

TABLE 4. Friction Variation Study Results

$\phi_s = 1^o \quad \phi_e = 3^o \quad M_u = 150$ k-ft

LENGTH (ft)	FRICTION COEFFICIENT (μ)	LATERAL DEFLECTION (ft)
12	0.4	1.68
	0.5	1.61
	0.6	1.50
15	0.4	1.68
	0.5	1.60
	0.6	1.52
20	0.4	1.35
	0.5	1.26
	0.6	1.20

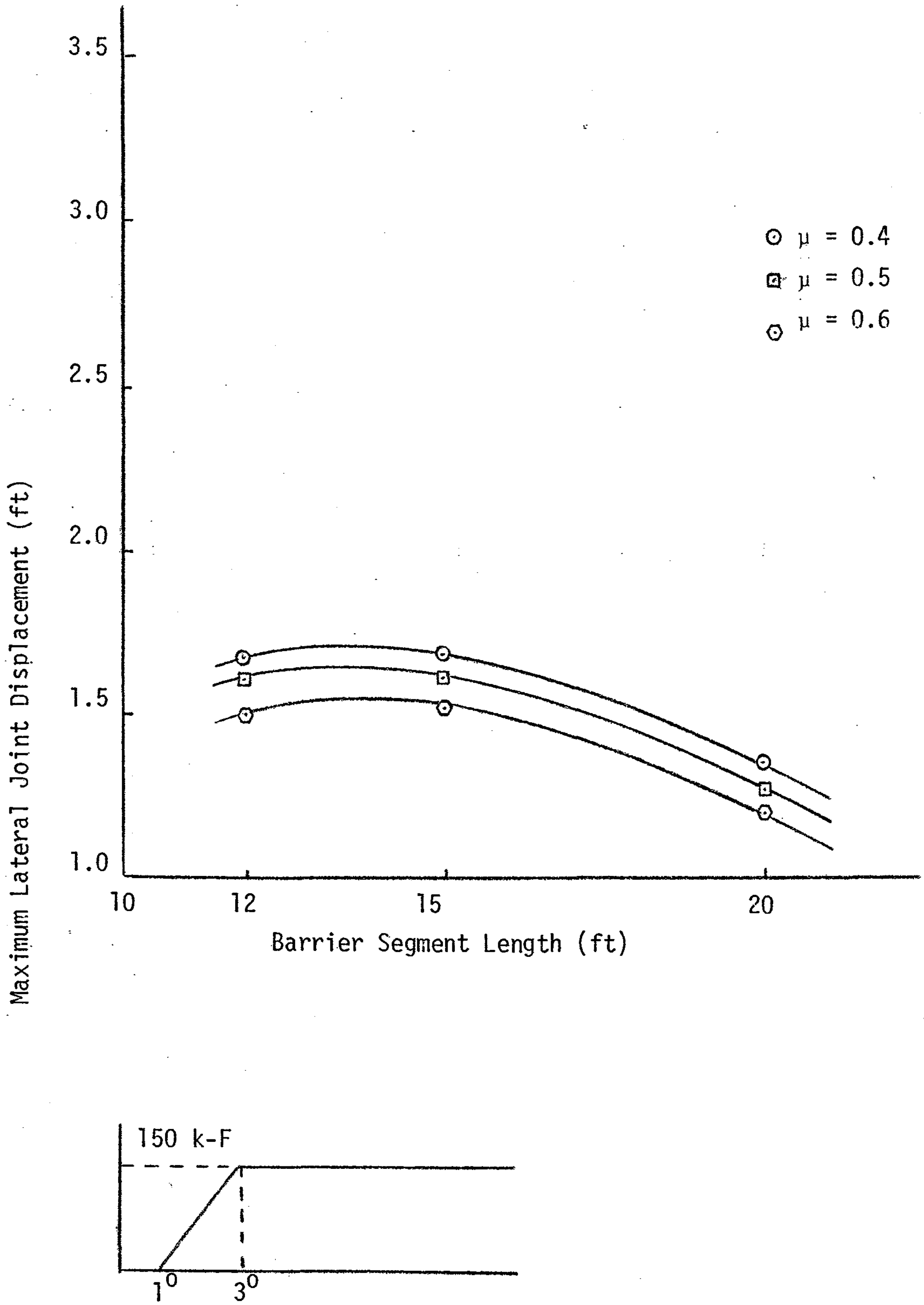


FIG. 6. Lateral Joint Displacement versus Segment Length, Variable Friction.

PORTABLE CONCRETE TRAFFIC BARRIER DESIGN

The previous analysis had shown that a PCTB with short barrier segments could withstand severe impacts without deflecting excessively if the barrier joints had sufficient moment capacity, limited slack, and the ability to deform plastically. Therefore researchers concluded that an optimum design for a PCTB could be developed with barrier segment lengths beween 12 and 20 ft (3.7 m and 6.1 m) which would be more portable than those currently in use on Texas highways.

Three of the parameters investigated previously -- barrier segment length, joint moment capacity, and joint slack -- can be controlled by the barrier design. Roadway surface friction cannot be entirely controlled by the design of the barrier and as shown previously, short segment lengths can perform acceptably with low friction if the barrier is designed properly. Therefore a design for a PCTB was developed by estimating the optimum segment length, joint moment capacity, and slack.

The key to increasing portability of a segmented concrete traffic barrier is determining the optimum barrier segment length. Long segments are very heavy and must be moved by heavy equipment. However, very short segments require many joints for the same barrier length as one long barrier segment. Thus the optimum segment length is the longest segment that can be installed without great difficulty due to the weight of each segment. It was concluded that 15 ft (4.6 m) is an optimum length of a PCTB barrier segment since a 15 ft (4.6 m) segment could be moved with little more difficulty than a 12 ft (3.7 m) segment. Further, the state of Texas currently uses a 30 ft (9.1 m) segment, and two 15 ft (4.6 m) segments could be cast in existing forms.

Previous analysis has shown that a joint moment capacity of 100 kip-ft (136 kn-m) would be required to minimize deflections and that a joint slack of 3 degrees is acceptable if the joint was capable of 7 degrees rotation before lockup occurs. A joint was designed which utilizes two 1/2 in. x 5 in. (1.27 cm x 12.7 cm) steel splice plates for development of joint moment capacity. The assembly of this barrier joint requires that two segments be placed end to end with a small space between. Two splice plates and four 1-1/8 in. (2.86 cm) dia. bolts are then used to connect the segments as shown in Figure 7.

Barrier segments were designed to withstand impact forces and joint loads predicted by the computer analysis. Construction drawings of the barrier are shown in Figure 8. Special reinforcement was required near the end of the barrier segments due to large stresses which develop near each joint during impact. Bearing pads at the ends of each segment help reduce damage to the barrier when the joint rotates to lockup.

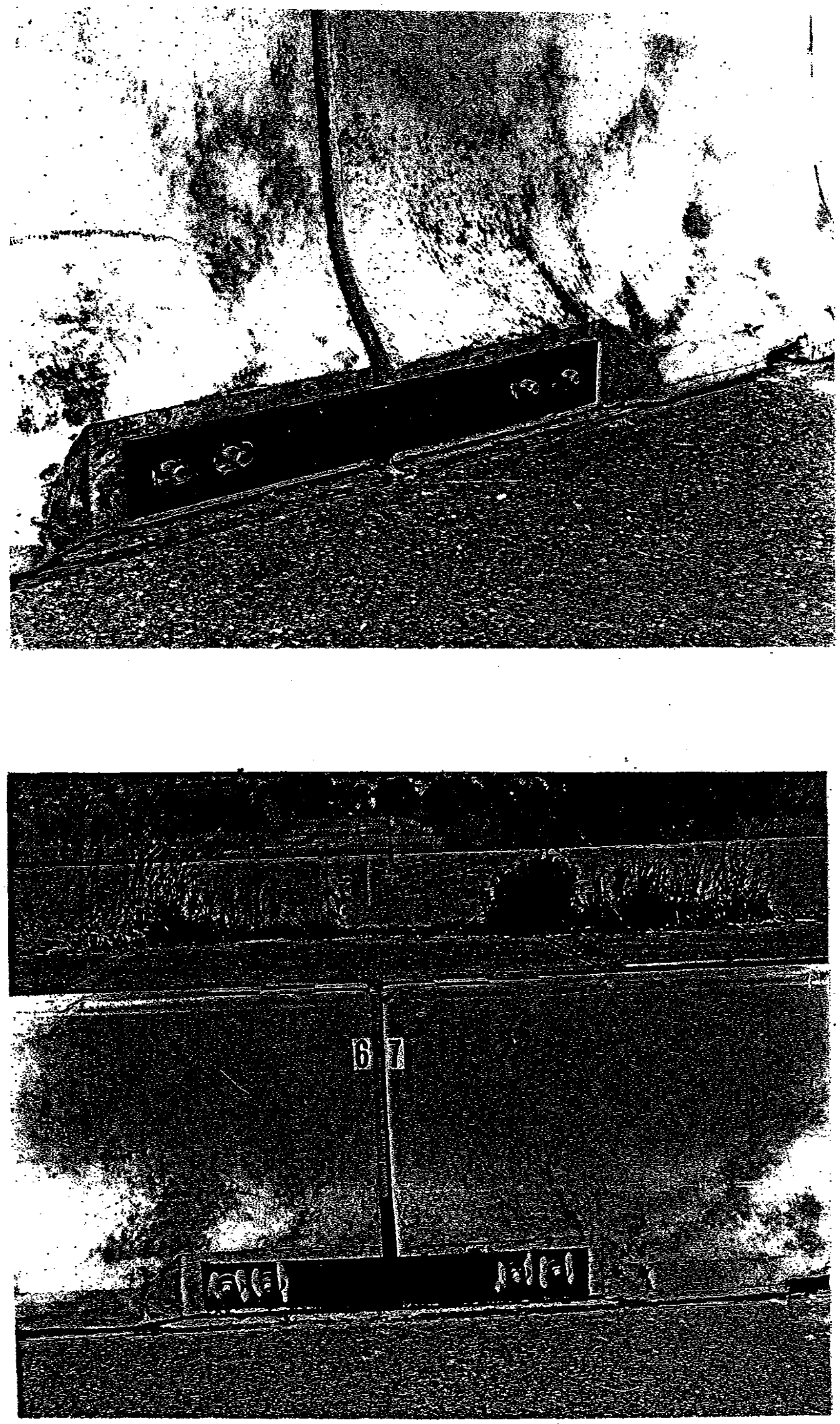
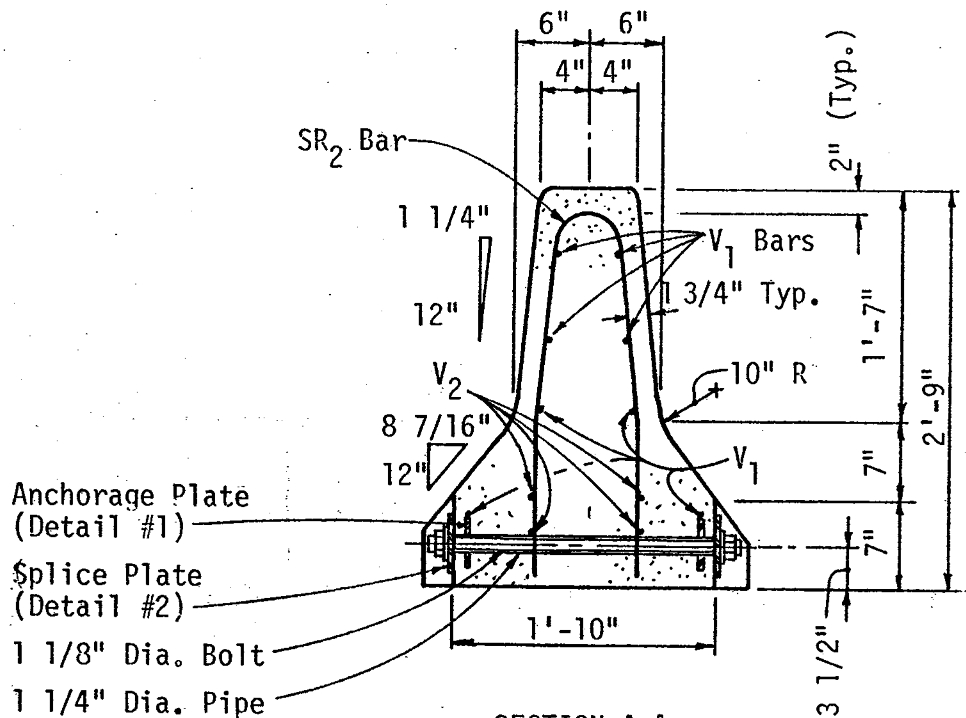
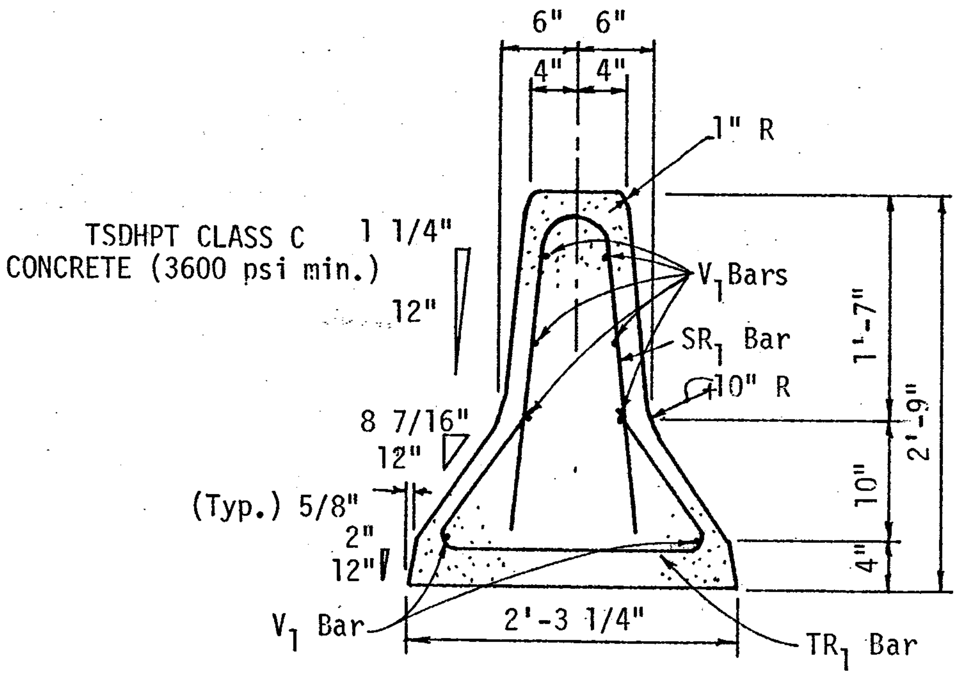


FIGURE 7. JOINT CONNECTION USING STEEL PLATE.

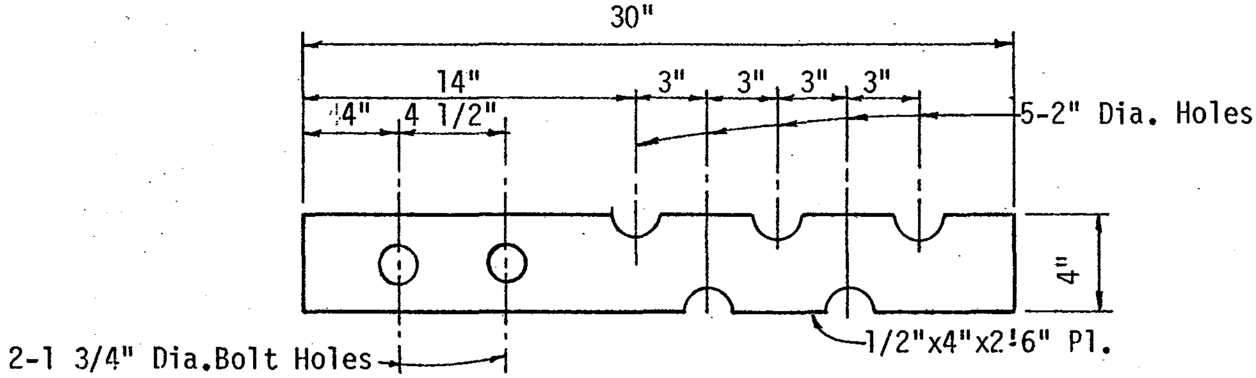


SECTION A-A

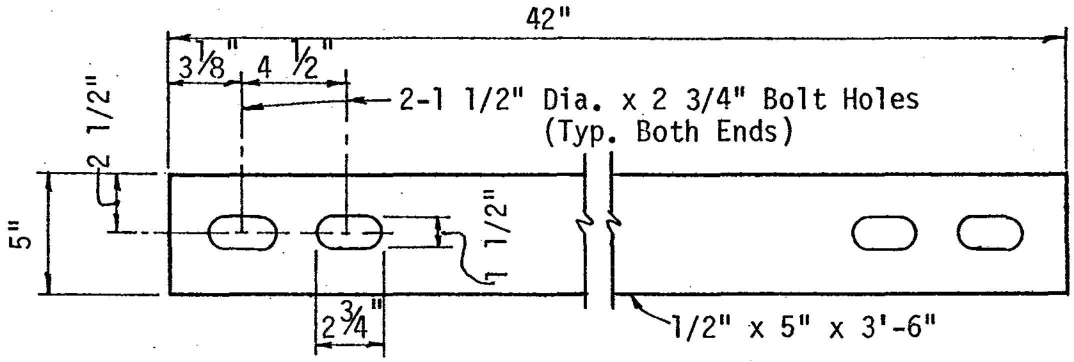


SECTION B-B

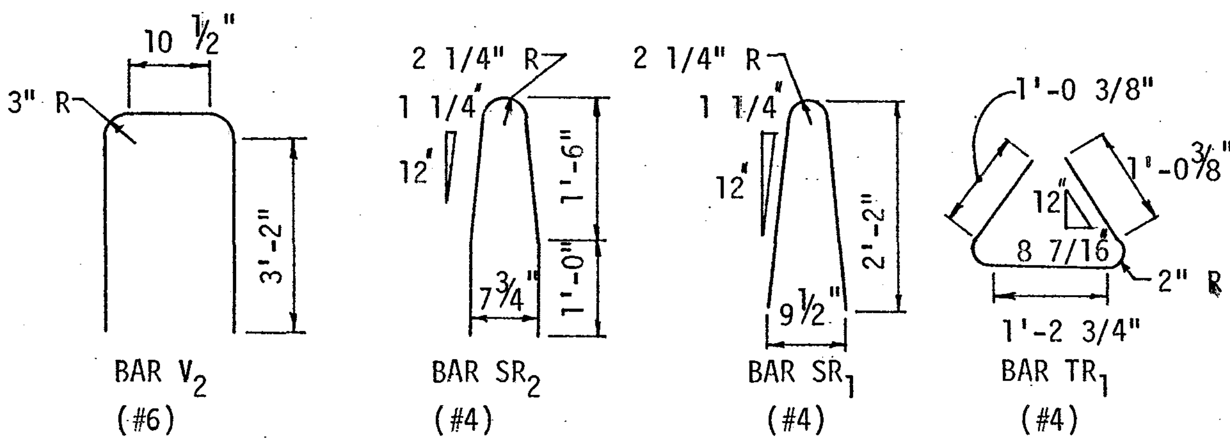
FIGURE 8. CONSTRUCTION DETAILS FOR PORTABLE CONCRETE BARRIER WITH LAP-SPLICE CONNECTIONS.



DETAIL #1



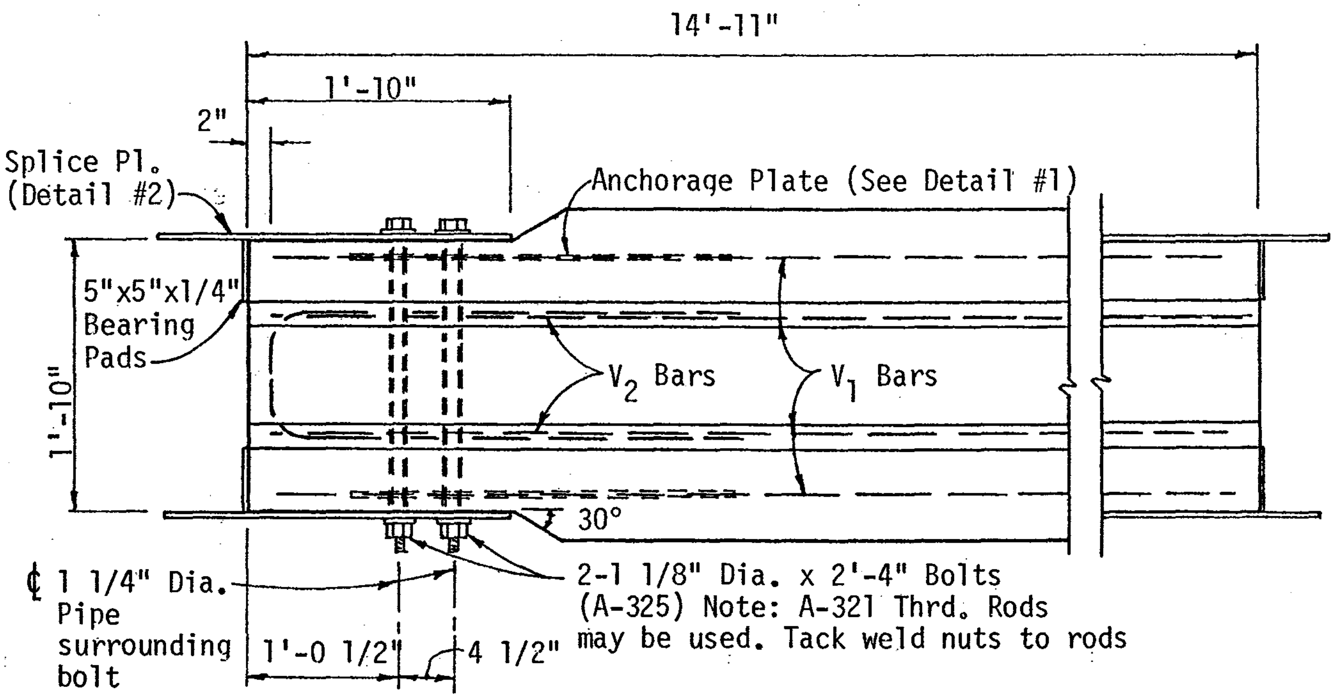
DETAIL # 2



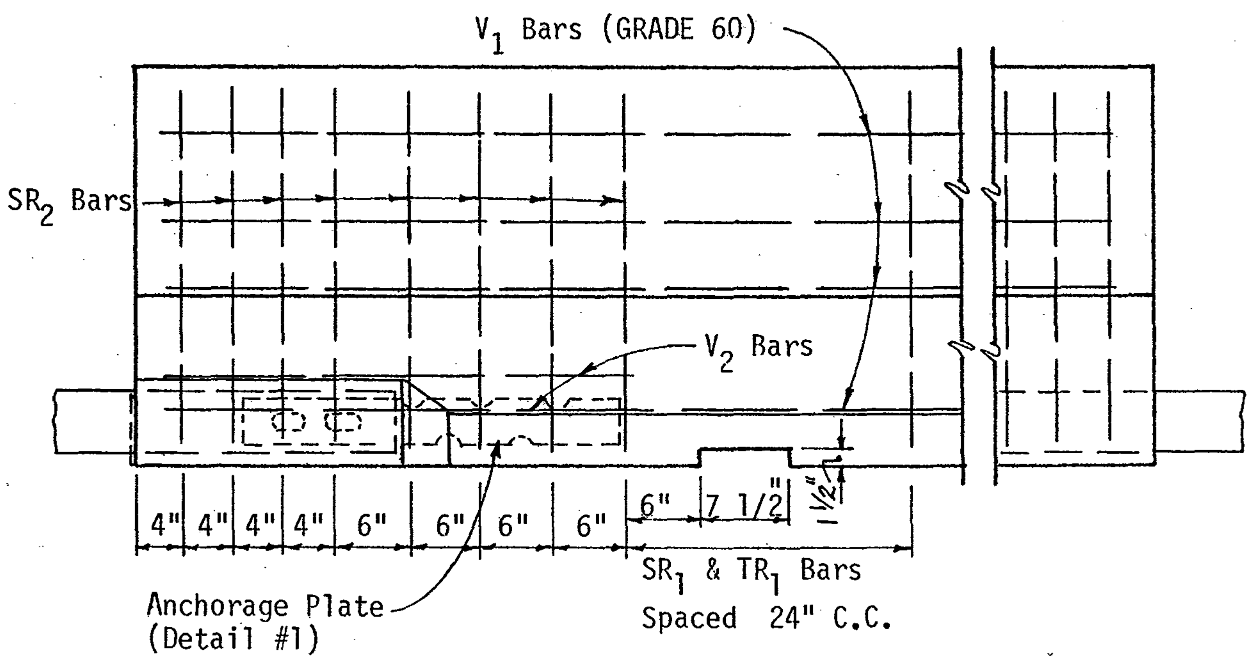
REINFORCING STEEL DETAILS (N.T.S.)

(GRADE 60 STEEL)

FIGURE 8. CONSTRUCTION DETAILS FOR PORTABLE CONCRETE BARRIER WITH LAP-SPLICE CONNECTIONS (continued).



PLAN VIEW
(Typ. Both Ends)



ELEVATION
(Typ. Both Ends)

FIGURE 8. CONSTRUCTION DETAILS FOR PORTABLE CONCRETE BARRIER WITH LAP-SPLICE CONNECTIONS (continued).

CRASH TESTS

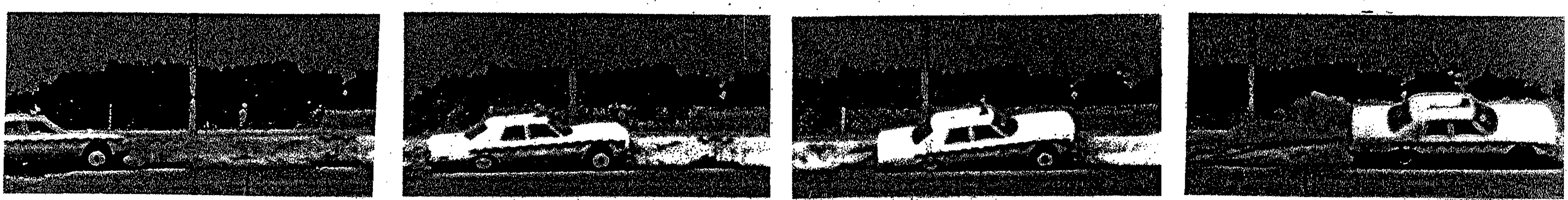
The cross-sectional geometry of the New Jersey concrete median barrier has been proven to effectively redirect subcompact vehicle and large vehicles at shallow impact angles (5). Therefore it was concluded that crash tests with small vehicles and shallow impact angles would only duplicate previous research. Two full-scale crash tests were conducted to evaluate the limits of performance of the portable precast concrete traffic barrier.

Sequential photographs selected from high-speed films of the tests are presented in Appendix A. Accelerometer traces and roll, pitch, and yaw rates are presented in Appendix B.

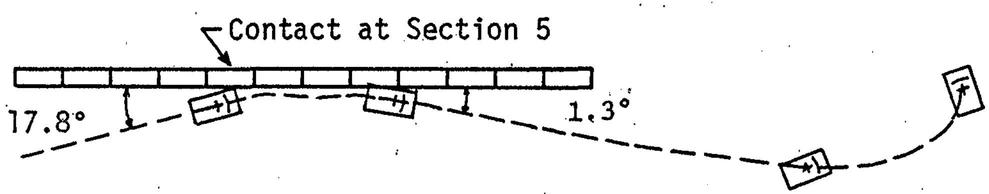
Test 1

The first crash test involved a 4500 lb (2043 kg) vehicle impacting the barrier at 60.9 mph (98.0 km/h) and 15 degrees. Figure 9 gives a summary of this test. Figure 10 shows the test vehicle and barrier prior to impact. The test vehicle was smoothly redirected and was not severely damaged as shown in Figure 11. All maximum 50 msec average accelerations were well below recommended limits (6). Vehicle trajectory after impact would not have been a hazard to other traffic.

The barrier was displaced only 0.9 ft and was not damaged significantly, as shown in Figure 12. Damage to the barrier installation was limited to superficial scarring of the concrete surface and major deformations in three splice plates. However, as shown in Figure 13, there was significant differential horizontal movement between barriers. At large impact angles, this differential movement could prove to be a snag point for impacting vehicles.



0.038 sec | 0.128 sec | 0.233 sec | 0.399 sec



Test No.	2262-1
Date	8/17/79
Drawing	
Barrier Type: NJ Precast w/8" Top and 27" bottom	
Installation Length-ft (m)	180 (54.9)
Barrier Segment Length-ft (m)	15 (4.6)
Joint Connection: Two 1/2" x 5" x 42" Slotted Steel Plates	
Barrier Deflection	
Max. Dynamic - ft (m)	1.02 (.31)
Max. Permanent - ft (m)	0.92 (.28)
Max. Roll Angle - deg	8.5

Vehicle	1975 Plymouth Fury
Vehicle Mass - lb (kg)	4500 (2043)
Impact Speed - mph (km/h)	60.9 (96.0)
Impact Angle - deg	17.8
Exit Speed mph (km/h)	52.1 (82.1)
Exit Angle - deg.	1.3
Vehicle Acceleration (max. 0.050 sec. avg.)	
Longitudinal - g's	3.9
Transverse - g's	4.9
Vertical - g's	5.6
Vehicle Damage Classification	
TAD	LFQ-4
SAE	11FLEWZ

FIGURE 9. SUMMARY OF TEST 1.

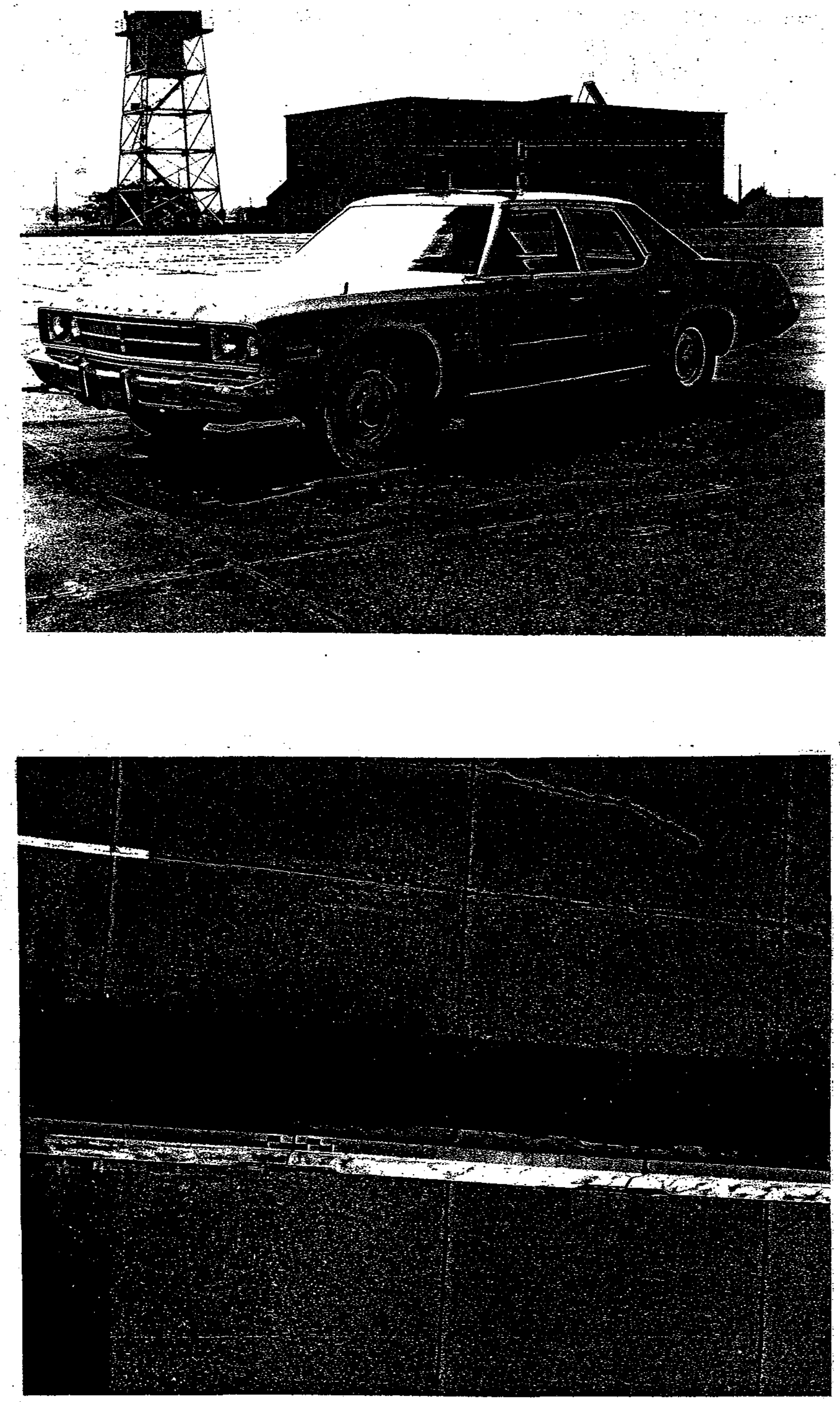


FIGURE 10. TEST VEHICLE AND BARRIER BEFORE TEST 1.

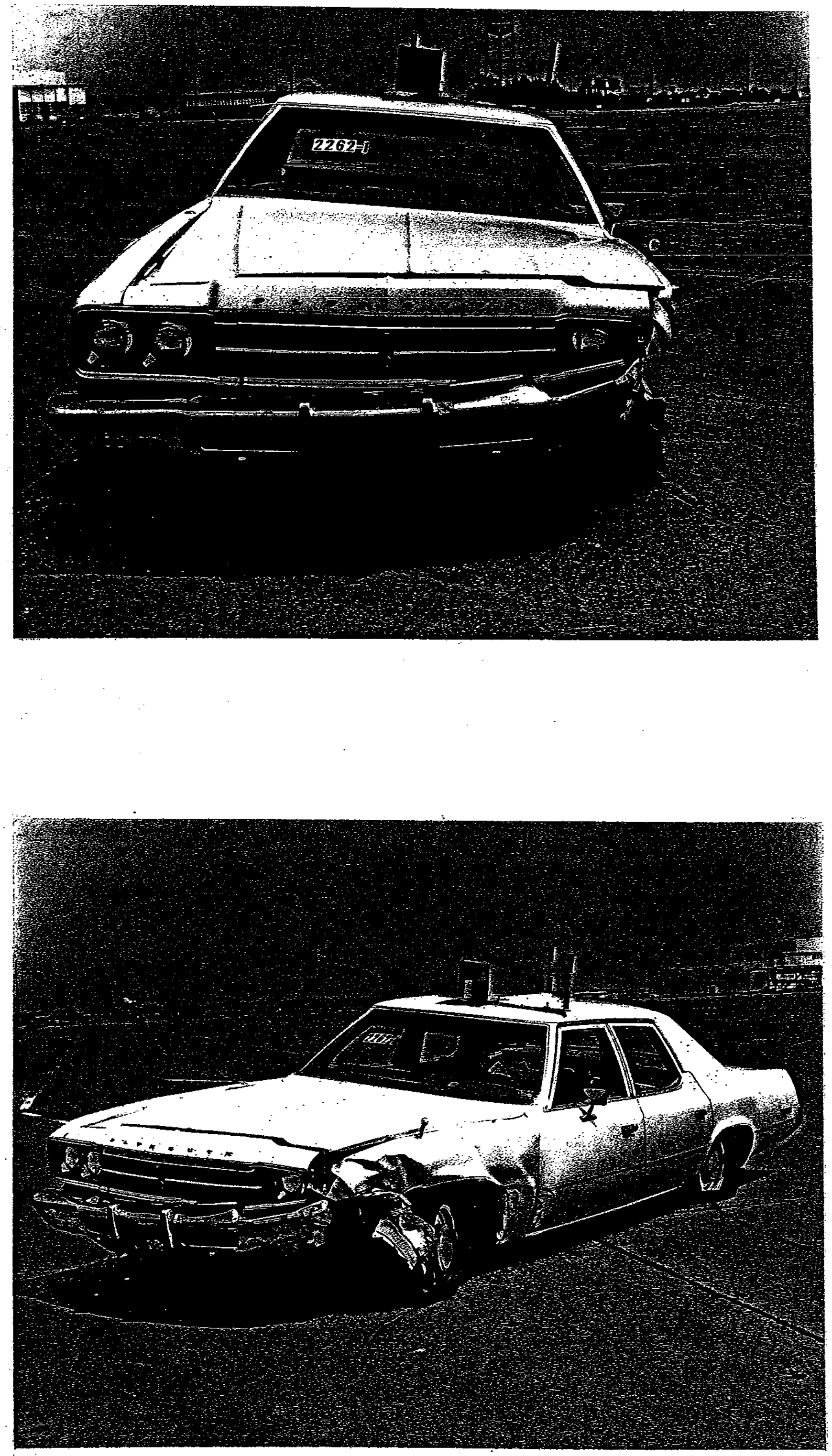
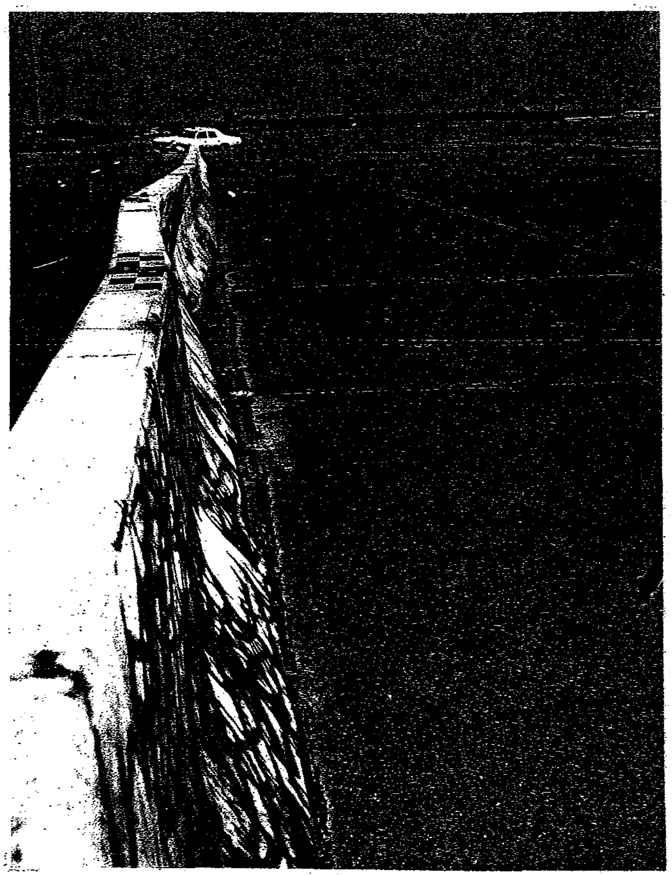


FIGURE 11. TEST VEHICLE AFTER TEST 1.



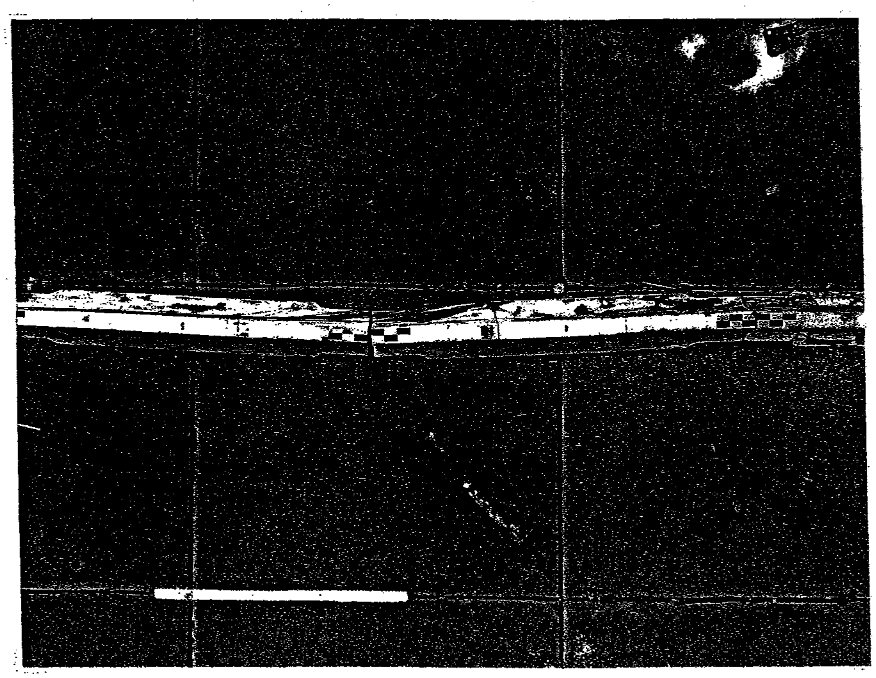


FIGURE 12. BARRIER AFTER TEST 1.

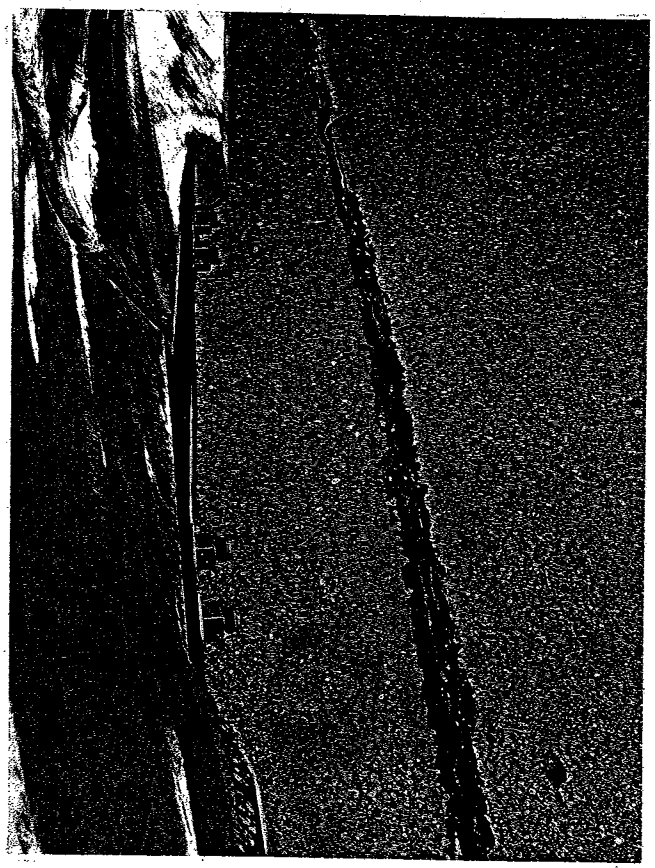


FIGURE 13. BARRIER JOINT AFTER TEST 1.

This test was considered very successful since the test vehicle was safely redirected and both barrier and vehicle were lightly damaged.

Test 2

After reviewing the results of test 1 it was concluded that the differential motion between barrier ends at a joint could be eliminated by increasing the shear capacity of the joint. This was accomplished by replacing the steel splice plates in each joint with C5 x 9 steel channels as shown in Figure 14. The second test was conducted with this design modification.

Test 2 involved a 4500 lb (2043 kg) vehicle impacting the barrier at a speed of 56 mph (88.2 km/h) and an angle of 25 degrees. This test is summarized in Figure 15. Figure 16 shows the test vehicle and barrier prior to impact. The test vehicle was again redirected smoothly, and as shown in Figure 17 was not badly damaged for a test of this severity. Maximum 50 msec average accelerations were 7.4 g's longitudinal, 7.7 g's transverse, and 4.3 g's vertical. These acceleration levels are not high for this type of test and are below maximum acceptable limits (6).

The maximum deflection of the barrier was only 1.3 ft (0.41 m). Damage to concrete barrier segments was again limited to surface scarring as shown in Figure 18. The channel splices were lightly damaged, and only six channels required replacement. There was no differential motion between barrier ends as shown in Figure 19.

This test was considered very successful due to the safe redirection of the test vehicle and the limited damage to the barrier.

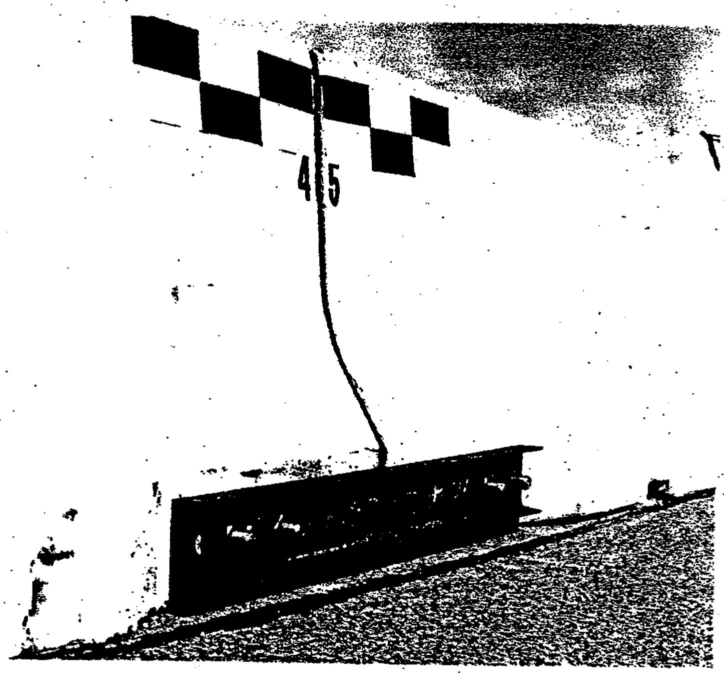
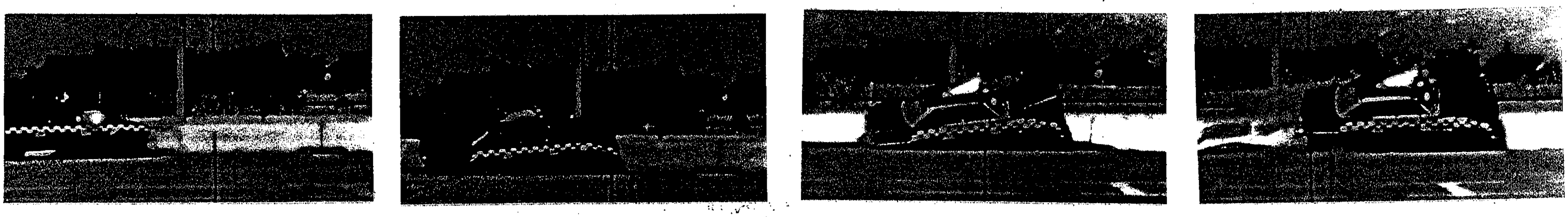
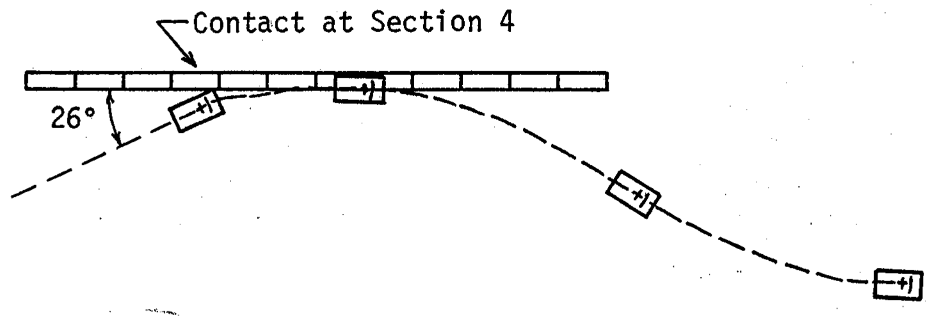


FIGURE 14. JOINT CONNECTION USING STEEL CHANNEL.



0.038 sec | 0.127 sec | 0.229 sec | 0.382 sec



Test No.	2262-2
Date	8/28/82
Drawing	
Barrier Type: NJ Precast w/8" top and 27" bottom	
Installation Length - ft (m)	180 (54.9)
Barrier Segment Length - ft (m)	15 (4.6)
Joint Connection: Two 42" C5 x 9 Steel Channels	
Barrier Deflection	
Max. Dynamic - ft (m)	1.94 (0.59)
Max. Permanent - ft (m)	1.33 (0.41)
Max. Roll Angle - deg	17.0

Vehicle	1974 Plymouth Fury
Vehicle Mass - lb (kg)	4510 (2048)
Vehicle Accelerations (max. 0.050 sec. avg.)	
Longitudinal - g's	7.4
Transverse - g's	7.7
Vertical - g's	4.3
Impact Speed - mph (km/h)	56.0 (88.2)
Impact Angle - deg	26.0
Exit Speed - mph (km/h)	N/A*
Exit Angle - deg	N/A*
Vehicle Damage Classification	
TAD	LFQ-5
SAE	10FLEW3

*Not available, vehicle did not exit barrier in field of view of overhead camera.

FIGURE 15. SUMMARY OF TEST 2.

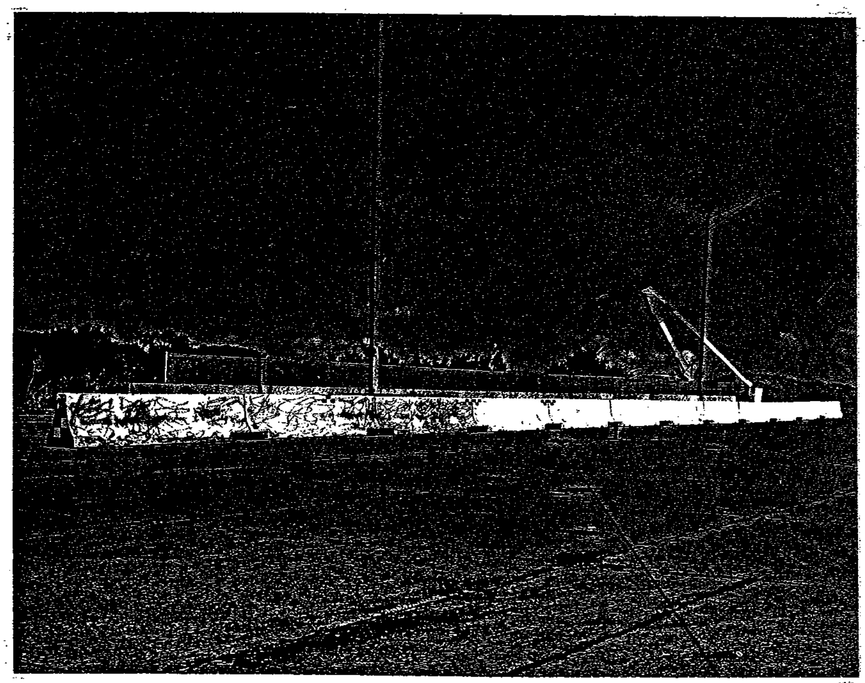


FIGURE 16. TEST VEHICLE AND BARRIER BEFORE TEST 2.

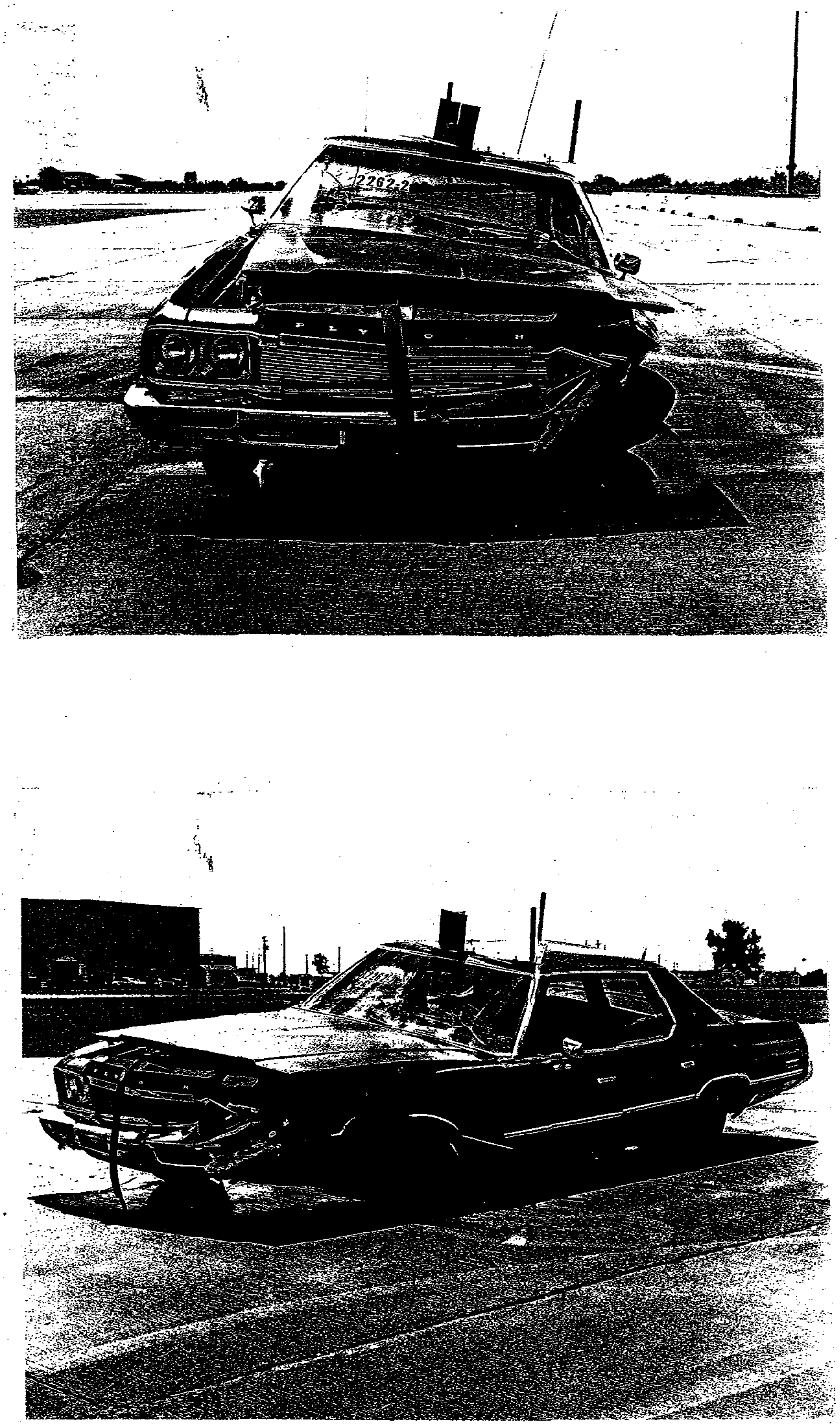


FIGURE 17. TEST VEHICLE AFTER TEST 2.

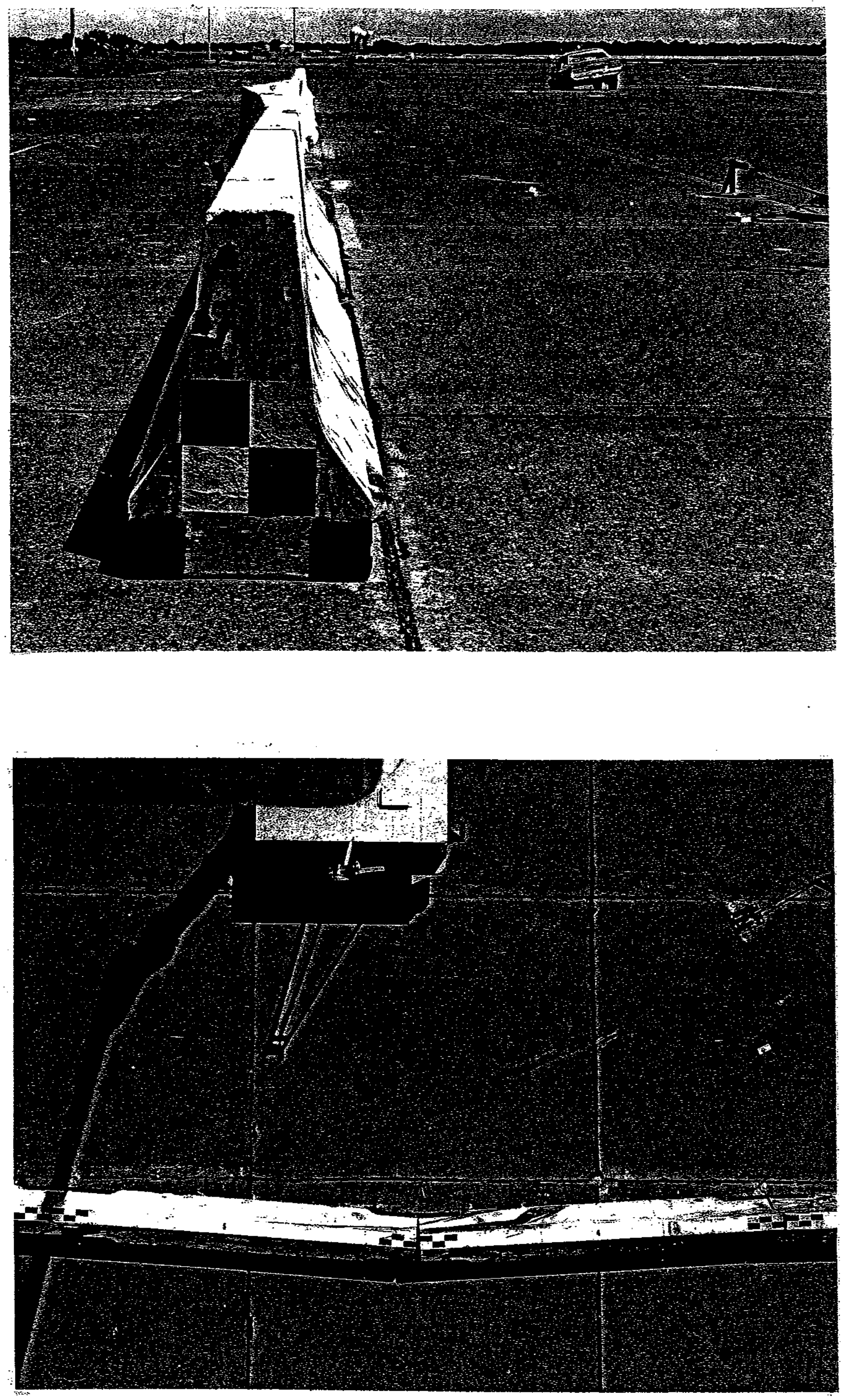


FIGURE 18. BARRIER AFTER TEST 2.

FIGURE 19. BARRIER JOINT AFTER TEST 2.

CONCLUSIONS

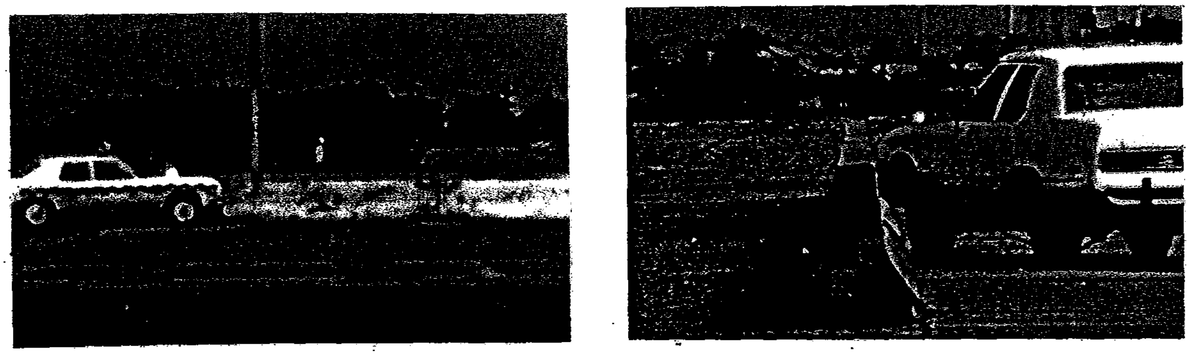
A precast concrete traffic barrier has been designed for work zones which utilizes 15 ft (4.6 m) barrier segments. The barrier should be much more portable than barriers currently in use in Texas which employ 30 ft (9.1 m) segments. Barrier segments are attached with two C5 x 9 steel splice channels and four 1-1/8 in. (2.86 cm) steel bolts. This joint construction provides significant joint moment capacity without significantly complicating barrier installation.

The barrier was successfully crash tested with a 4500 lb (2045 kg) vehicle impacting at 25 degrees and 60 mph (96.6 km/h). The test vehicle was smoothly redirected, and vehicle accelerations were within nationally accepted guidelines (6). No barrier segments were damaged during testing, and only a few splice channels required repair or replacement. Temporary barriers currently in use on Texas highways were damaged more severely when tested under identical conditions (1). Therefore the precast concrete traffic barrier described herein should be less costly to install and maintain than similar barriers currently in use in Texas.

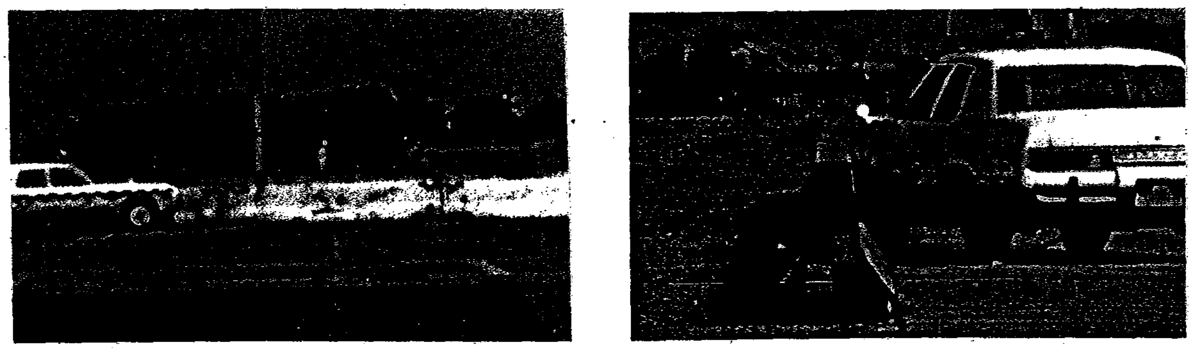
Although the barrier met impact performance standards for a permanent barrier, it probably should not be used as such. For severe impacts, the barrier can be expected to deflect 12 in. (30.5 cm) or more, and damage to splice channels will occur.

APPENDIX A.

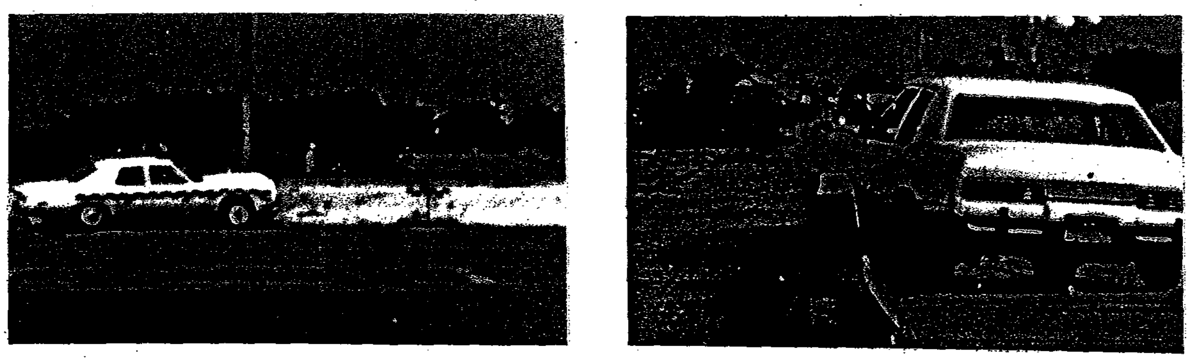
SEQUENTIAL PHOTOGRAPHS



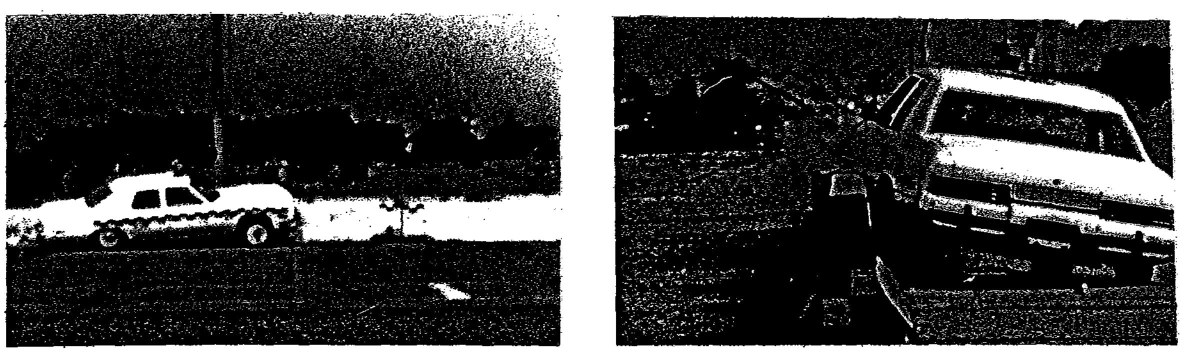
0.000 sec



0.039 sec

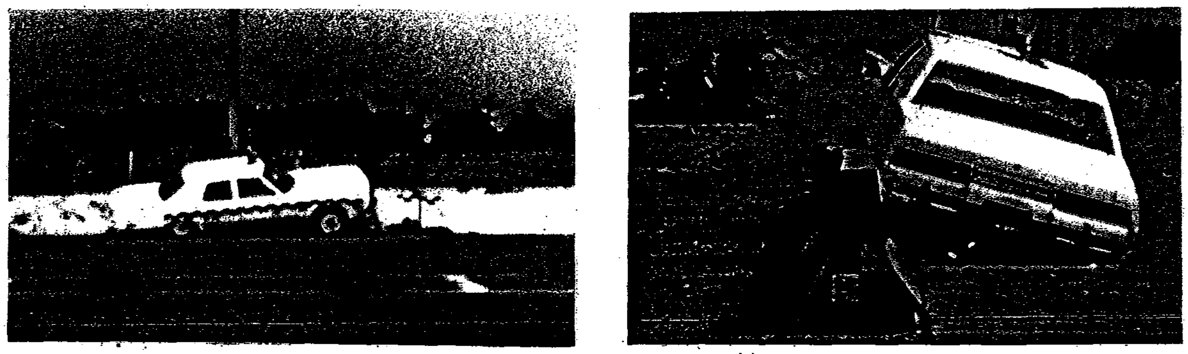


0.091 sec

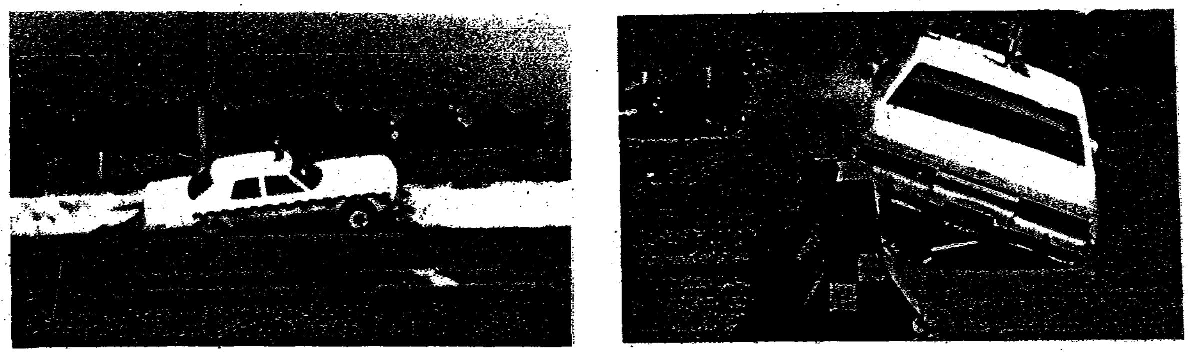


0.130 sec

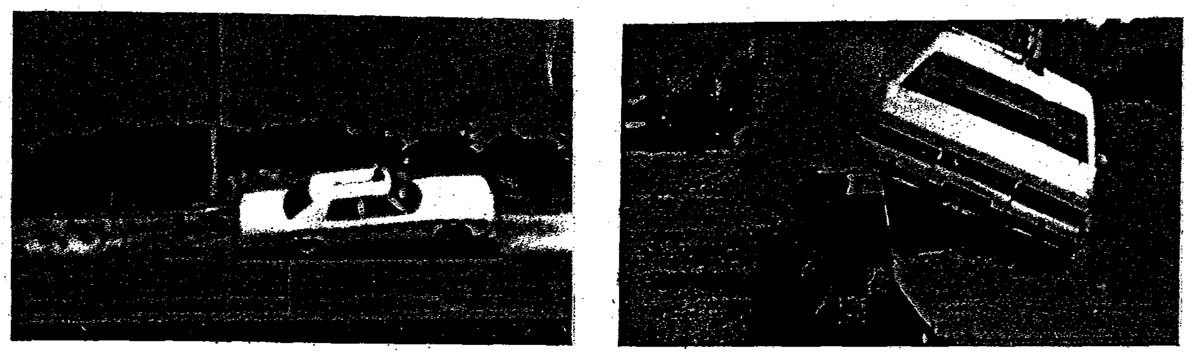
FIGURE 20. SEQUENTIAL PHOTOGRAPHS FOR TEST 1.



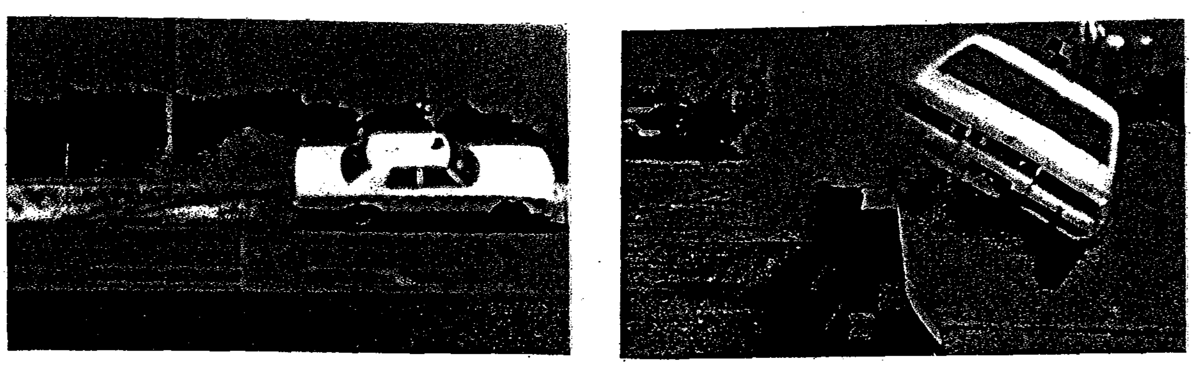
0.180 sec



0.232 sec

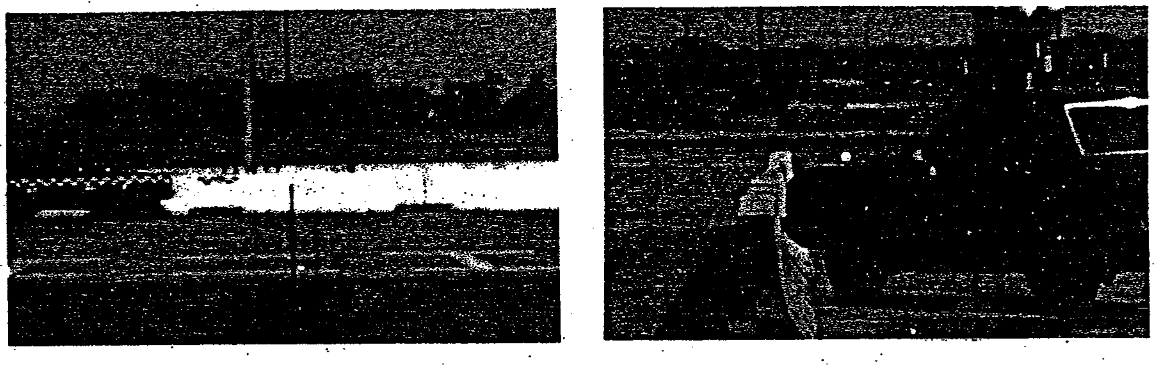


0.310 sec

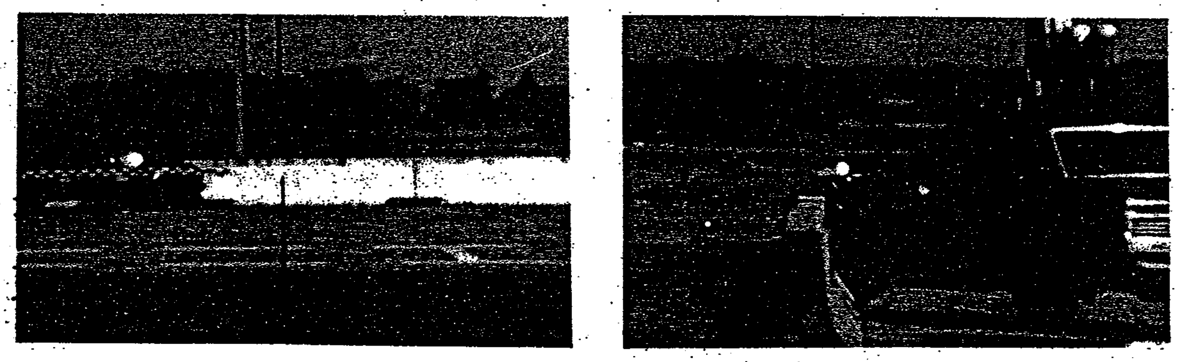


0.398 sec

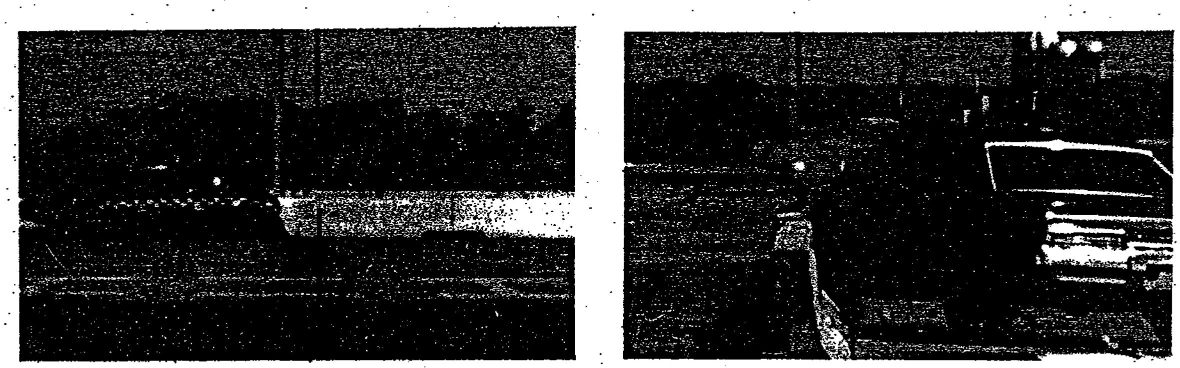
FIGURE 20. SEQUENTIAL PHOTOGRAPHS FOR TEST 1 (continued).



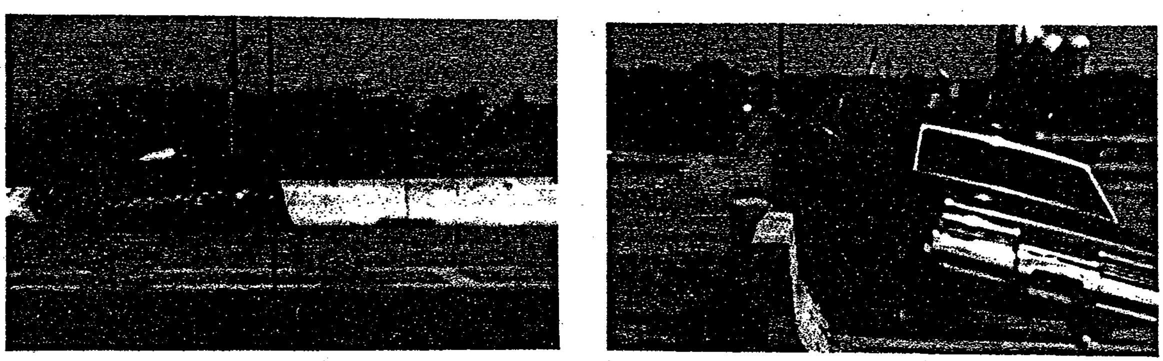
0.000 sec



0.038 sec

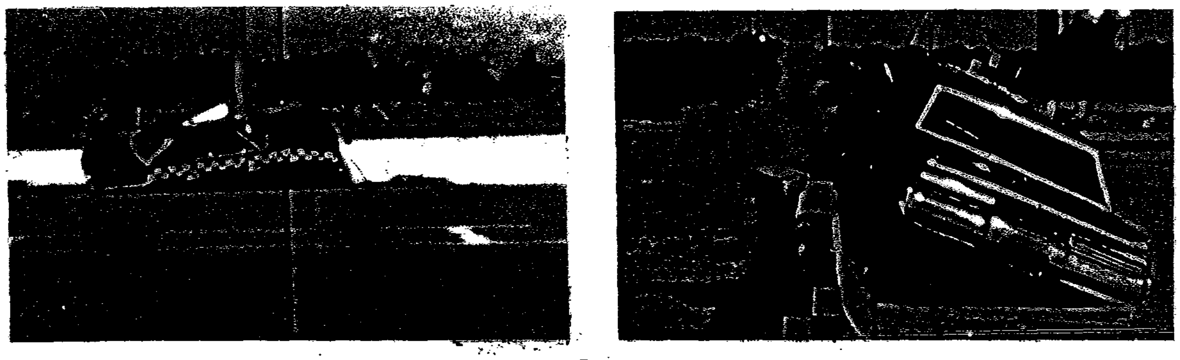


0.075 sec

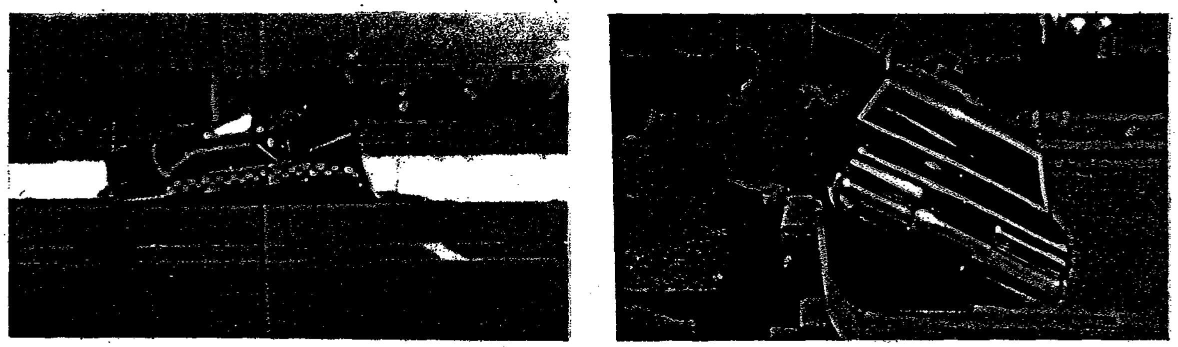


0.128 sec

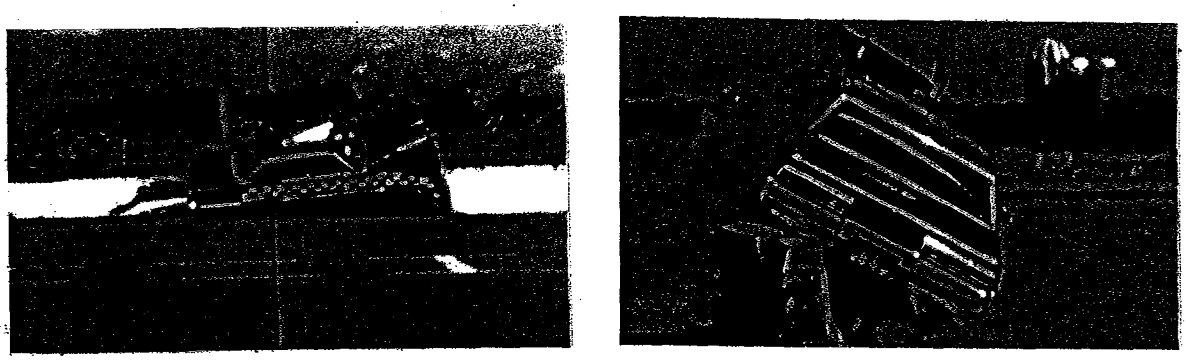
FIGURE 21. SEQUENTIAL PHOTOGRAPHS FOR TEST 2.



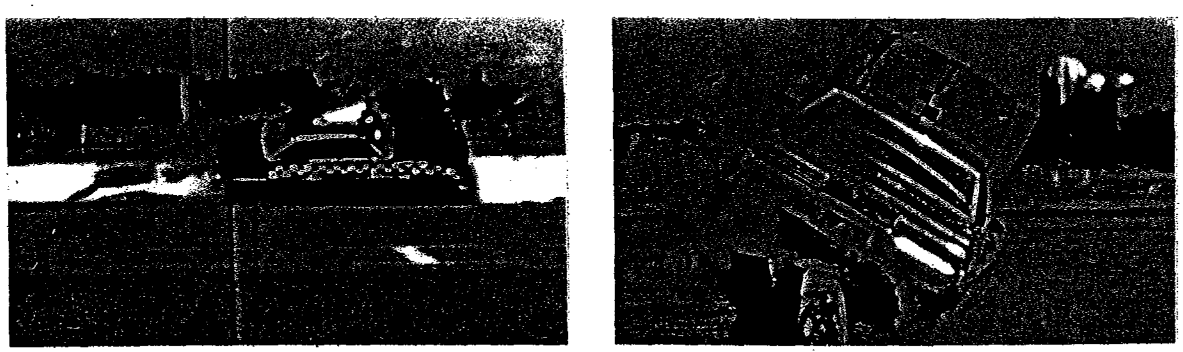
0.178 sec



0.228 sec



0.306 sec



0.382 sec

FIGURE 21. SEQUENTIAL PHOTOGRAPHS FOR TEST 2 (continued).

APPENDIX B.

ACCELEROMETER TRACES
AND
PLOTS OF ROLL, PITCH, AND YAW RATES

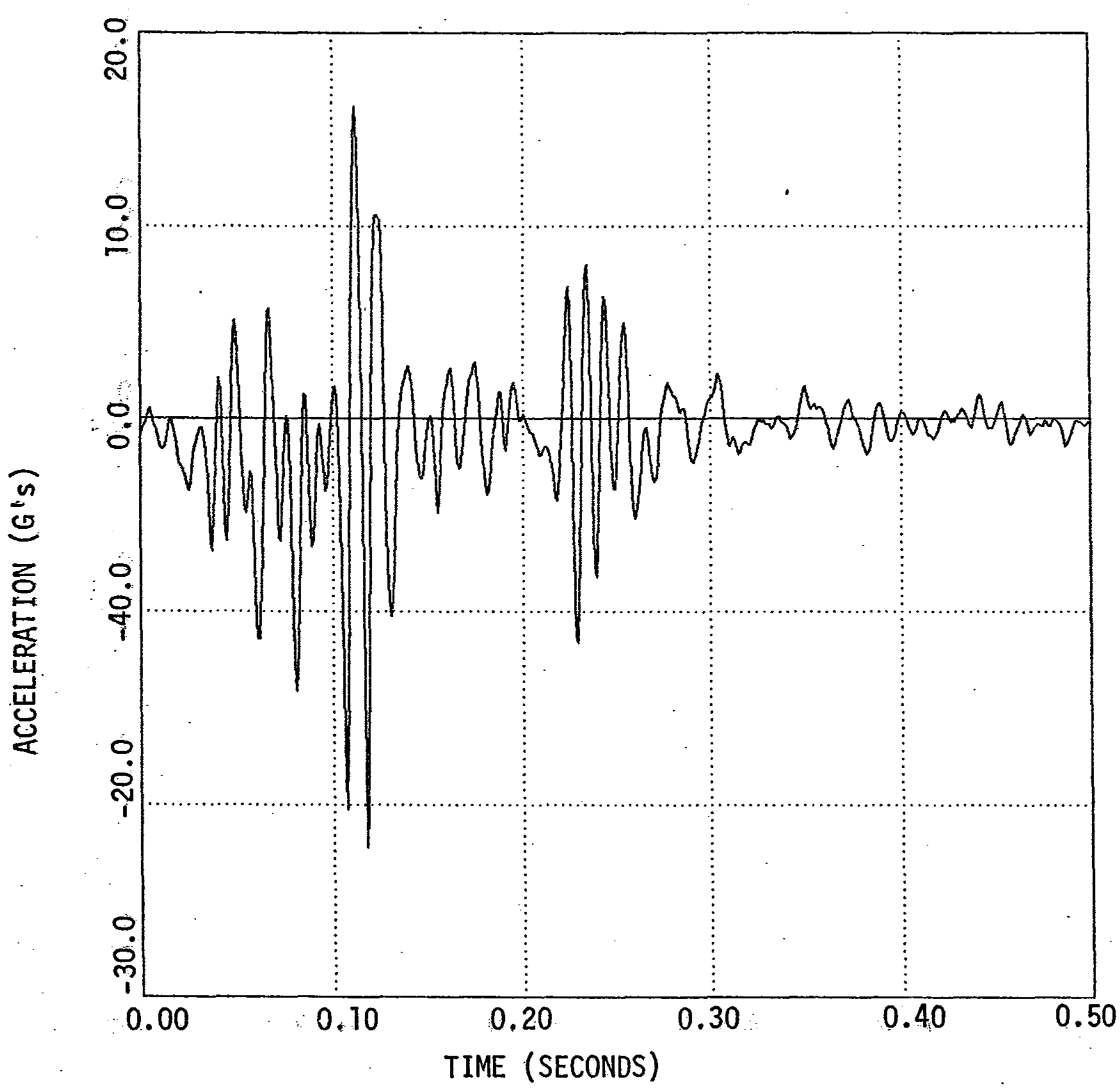


FIGURE 22. ACCELEROMETER TRACE FOR TEST 1 - LONGITUDINAL DIRECTION.

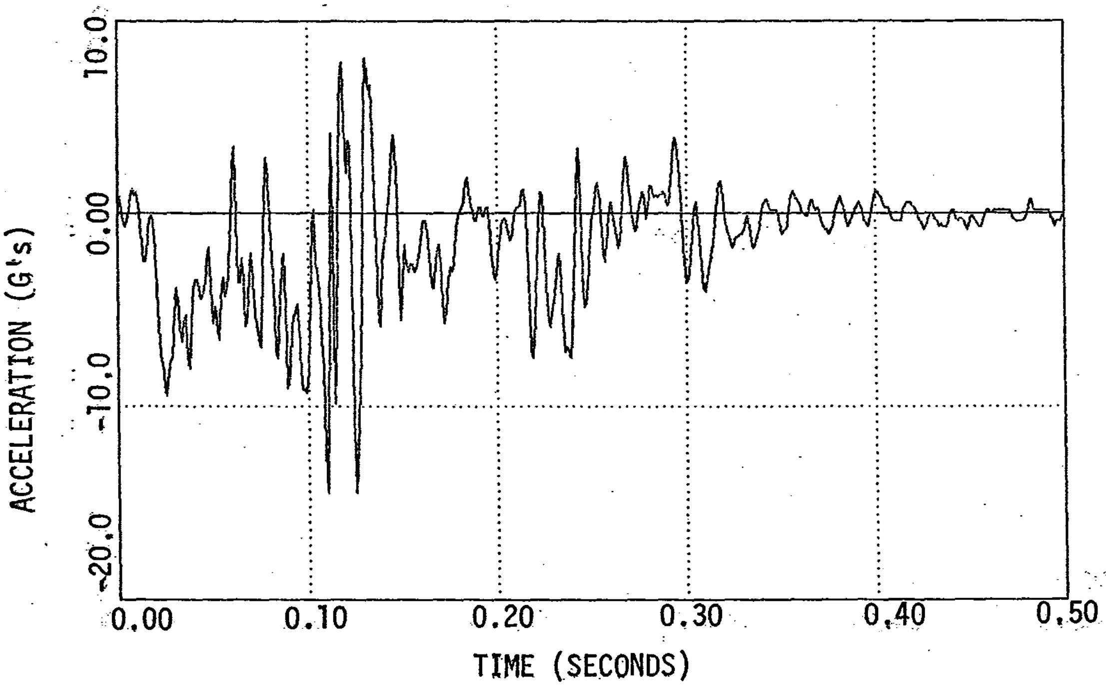


FIGURE 23. ACCELEROMETER TRACE FOR TEST 1 - LATERAL DIRECTION.

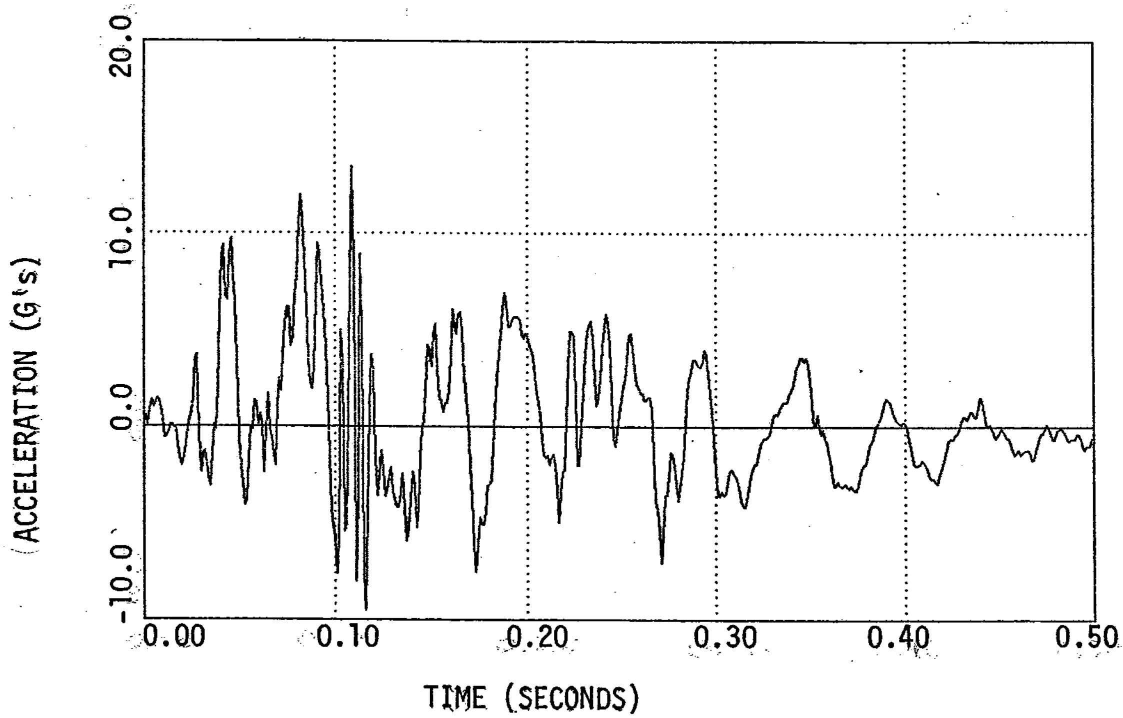


FIGURE 24. ACCELEROMETER TRACE FOR TEST 1 - VERTICAL DIRECTION.

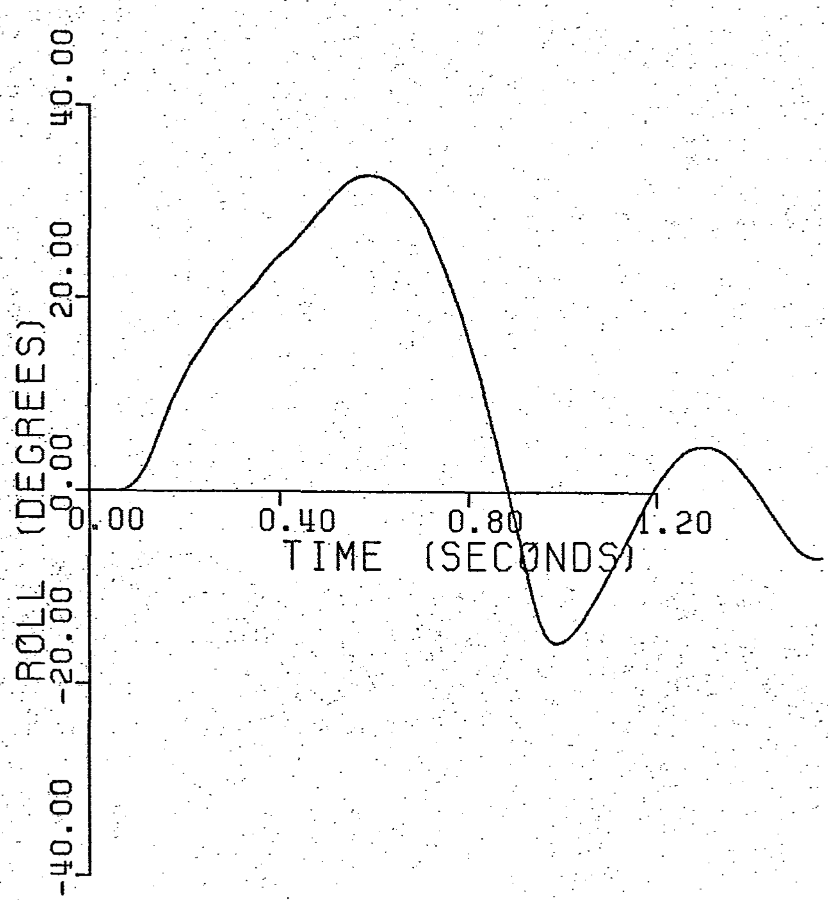


FIGURE 25. VEHICLE ROLL VERSUS TIME FOR TEST 1.

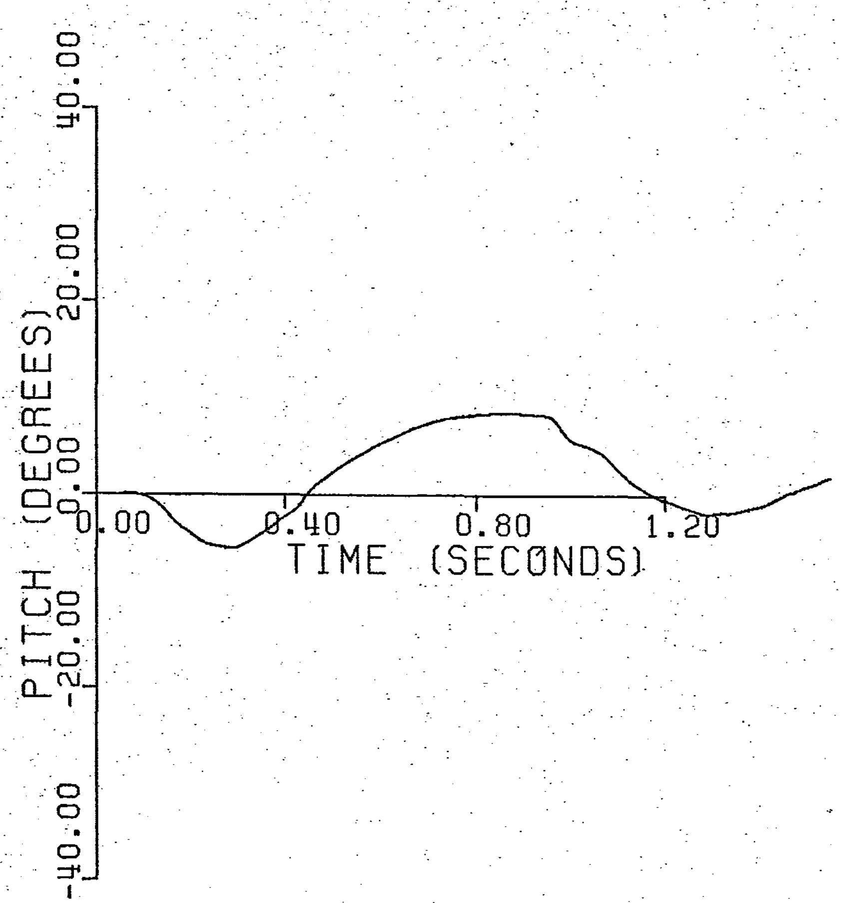


FIGURE 26. VEHICLE PITCH VERSUS TIME FOR TEST 1.

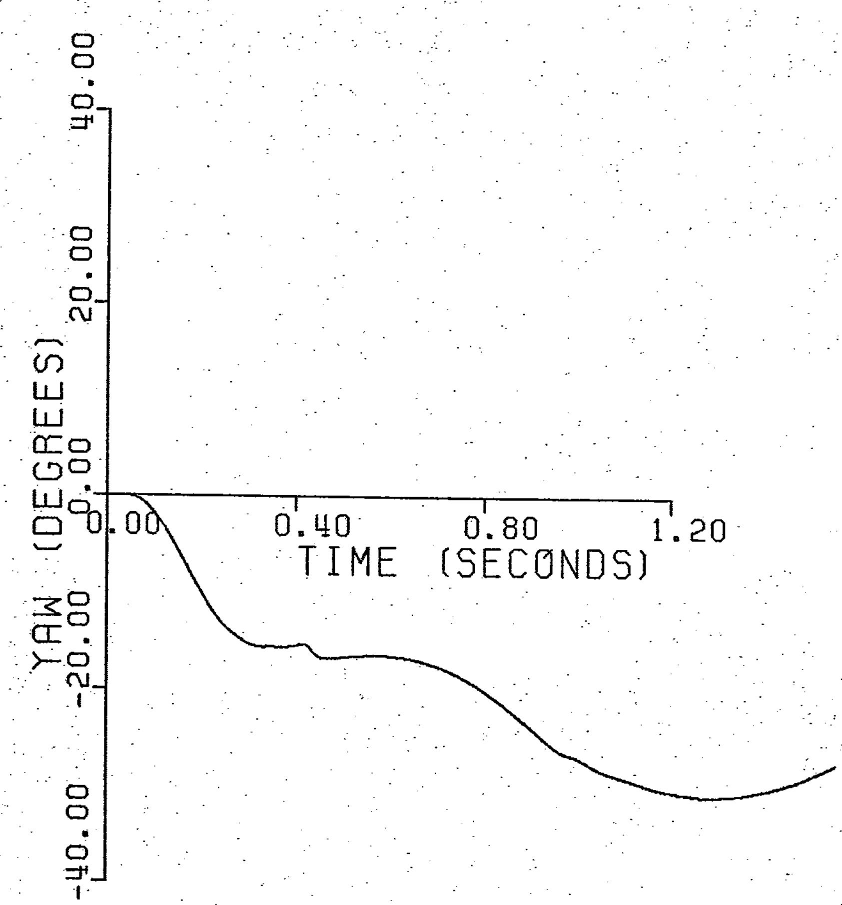


FIGURE 27. VEHICLE YAW VERSUS TIME FOR TEST 1.

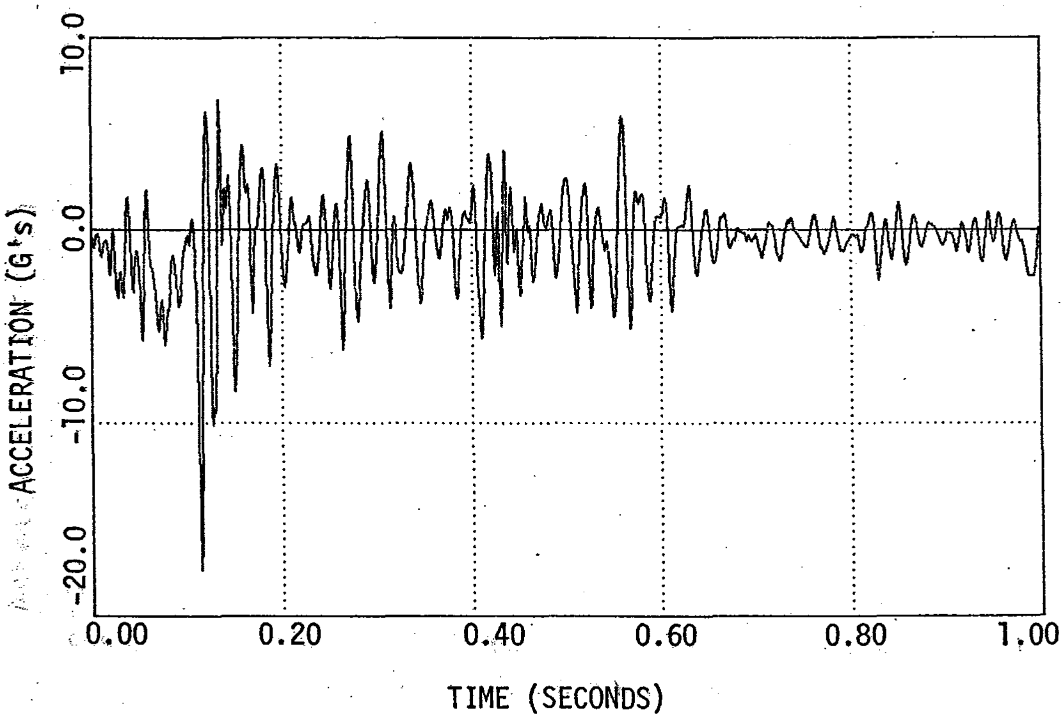


FIGURE 28. ACCELEROMETER TRACE FOR TEST 2 - LONGITUDINAL DIRECTION.

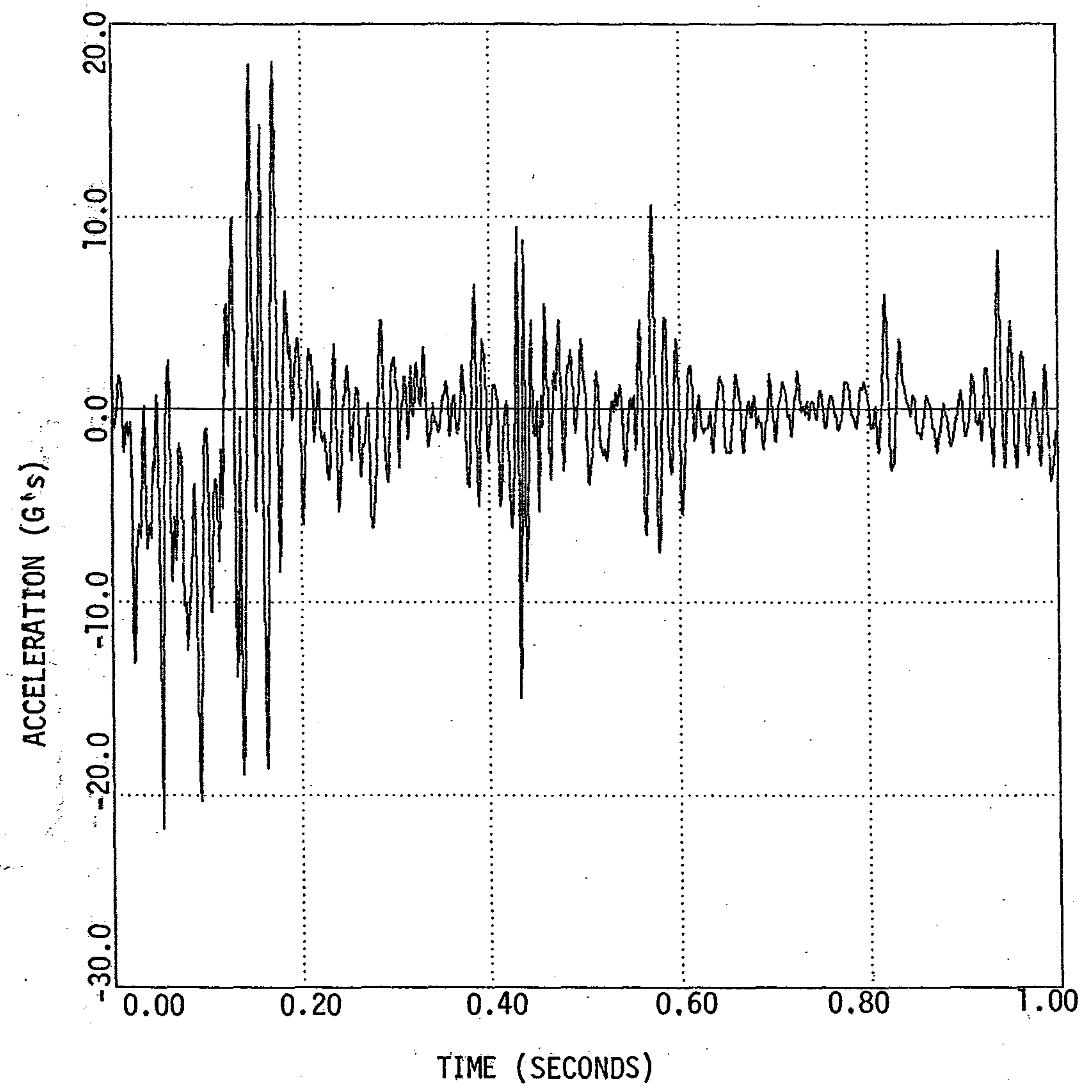


FIGURE 29. ACCELEROMETER TRACE FOR TEST 2 - LATERAL DIRECTION.

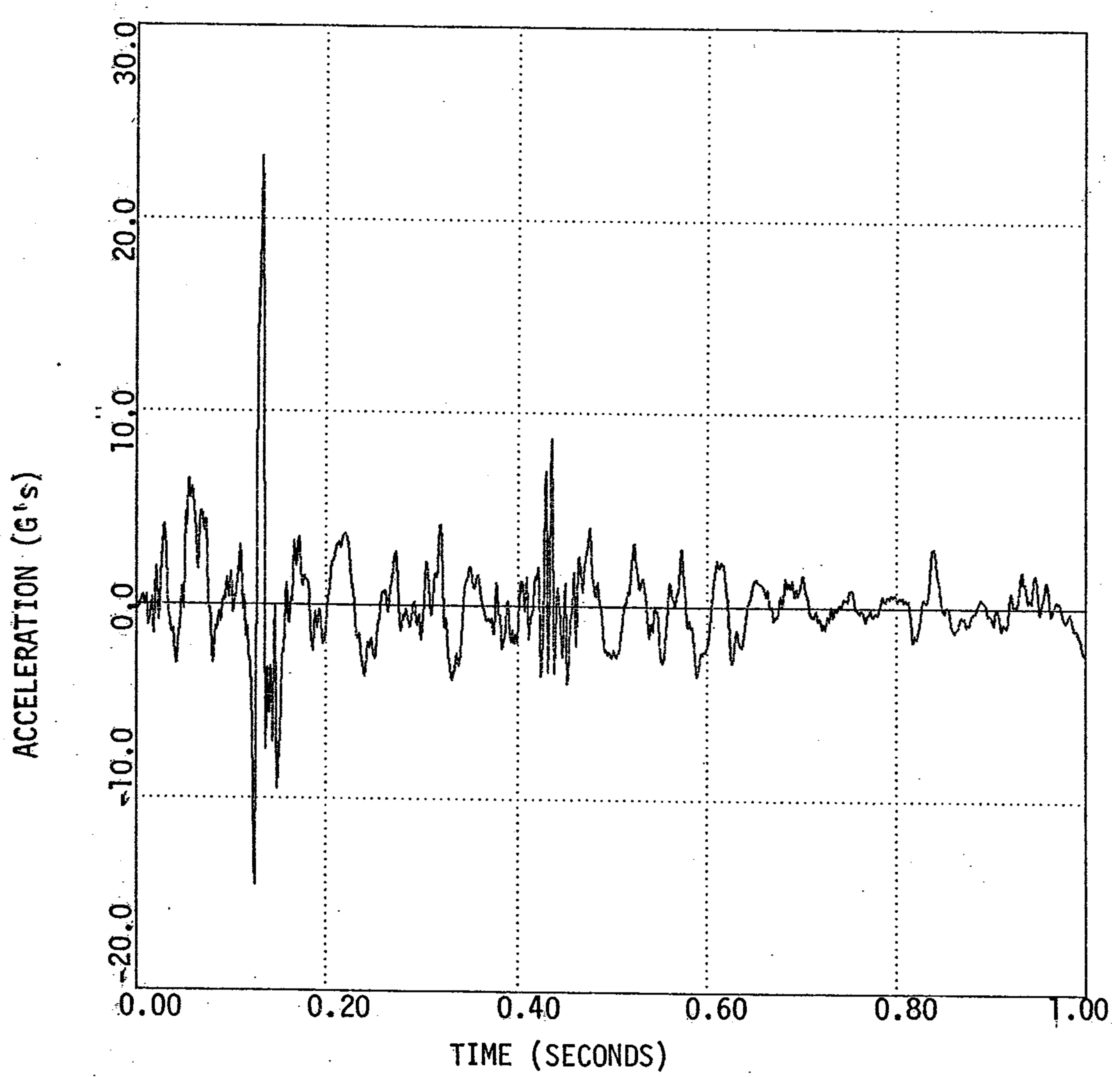


FIGURE 30. ACCELEROMETER TRACE FOR TEST 2 - VERTICAL DIRECTION.

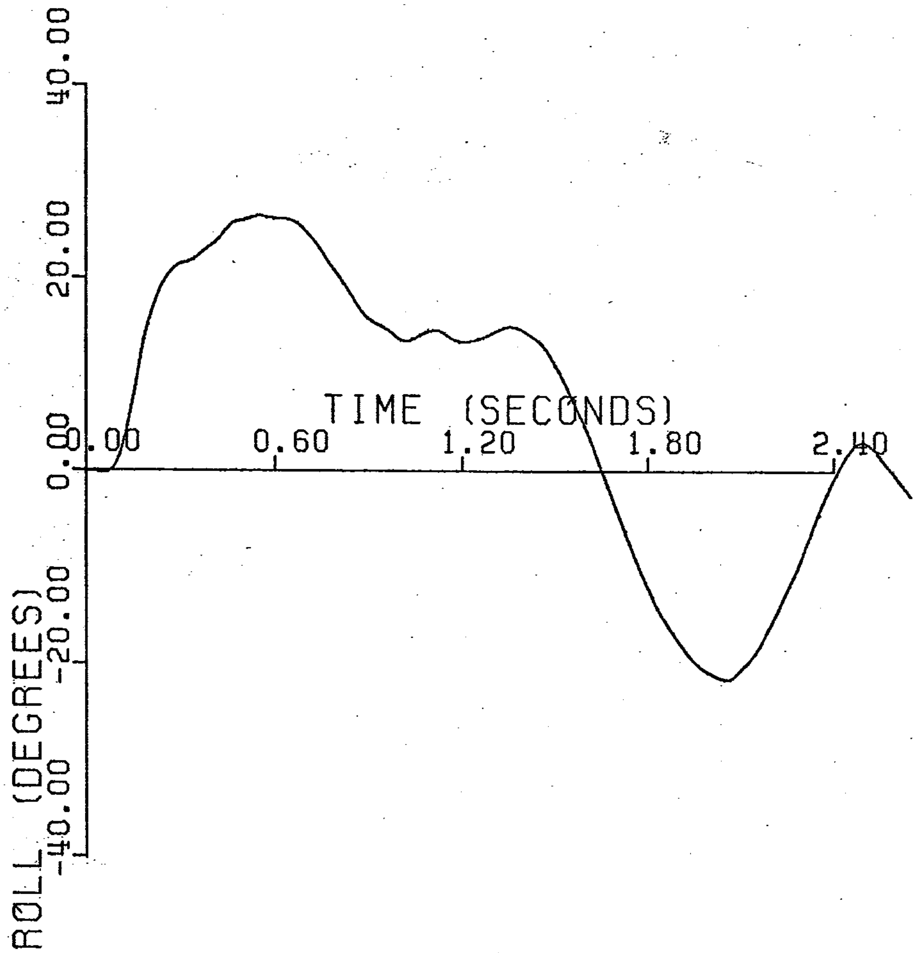


FIGURE 31. VEHICLE ROLL VERSUS TIME FOR TEST 2.

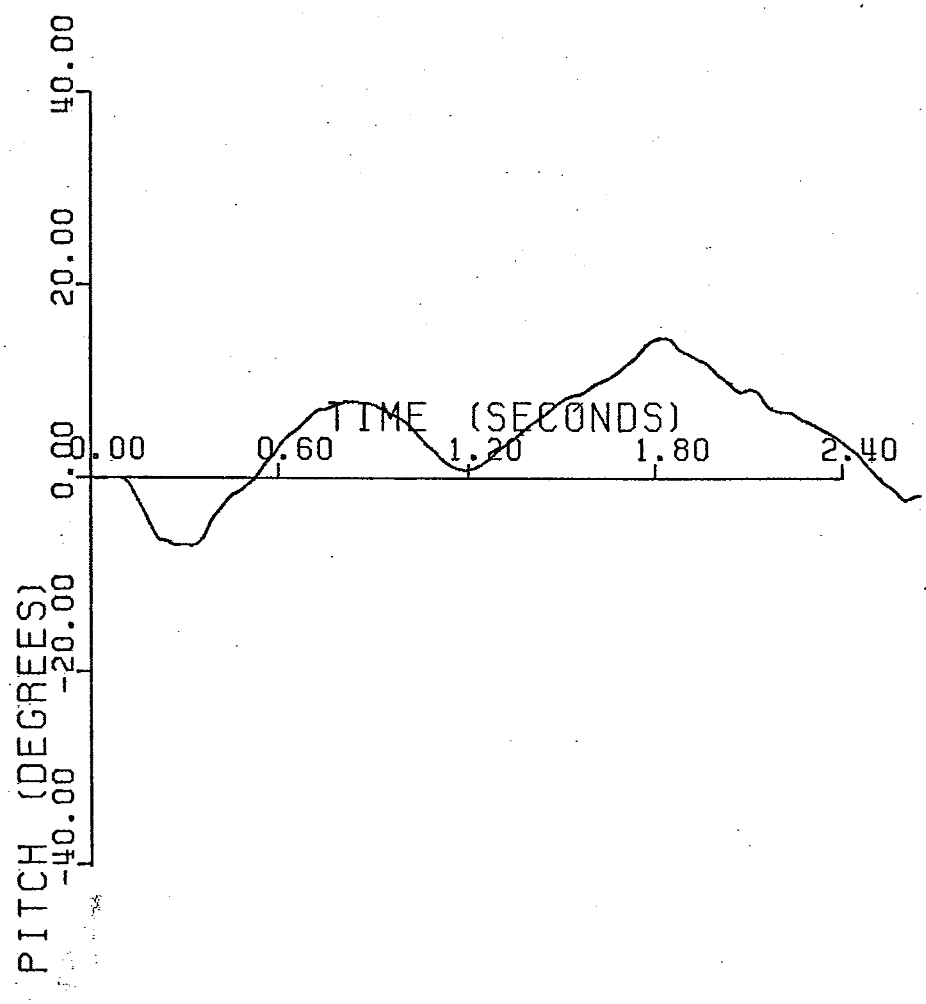


FIGURE 32. VEHICLE PITCH VERSUS TIME FOR TEST 2.

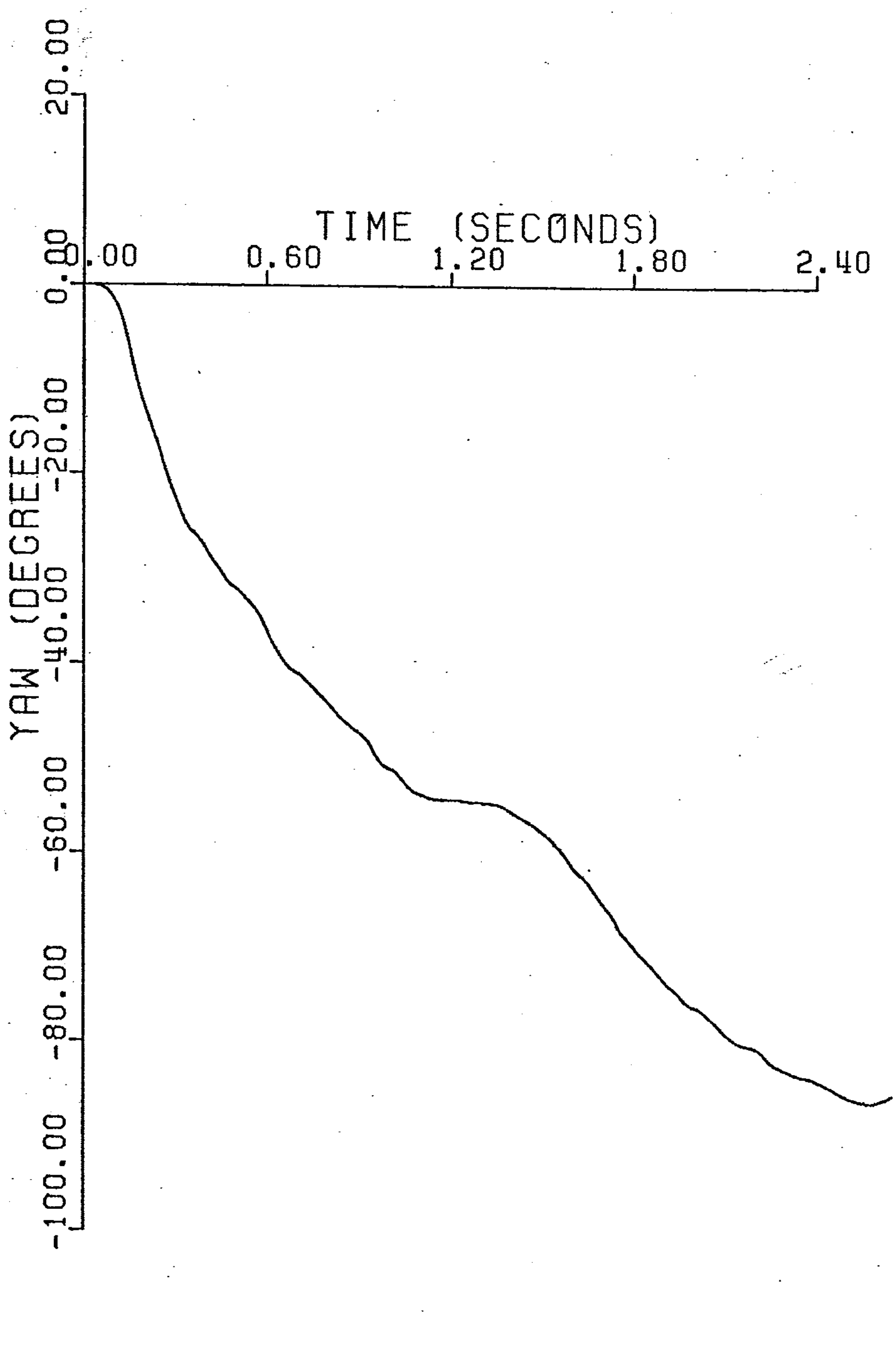


FIGURE 33. VEHICLE YAW VERSUS TIME FOR TEST 2.

REFERENCES

1. Hirsch, T. J. and Marquis, E. L., "Crash Test and Evaluation of a Precast Concrete Median Barrier," Report No. TTI-2-10-75-223-1, Texas Transportation Institute, Texas A&M University, Oct. 1975.

2. Parks, D. M., Stoughton, R. L., Stoker, J. R., and Nordlin, E. F., "Vehicular Crash Tests of Unanchored Safety-Shaped Precast Concrete Median Barriers with Pinned End Connections," Report No. CA-DOT-TL-6624-1-76-52, Office of Transportation, Calif. DOT, Sacramento, Ca., Aug. 1976.

3. Stoughton, R. L., Parks, D. M., Stoker, J. R., and Nordlin, E. F., "Vehicular Impact Tests of Precast Concrete Median Barriers with Corrugated Ends and Tensioned Cables," Report No. FHWA-CA-TL-78-13, Office of Transportation Laboratory, Calif. DOT, Sacramento, Ca., June 1978.

4. Walker, K. C., "Simulation, Design, and Testing of a Portable Concrete Median Barrier," Master of Science Thesis, Texas A&M University, Civil Engineering Department, December 1979.

5. Bronstad, M. E., Calcote, L. R., and Kimball, C. E. Jr., "Concrete Median Barrier Research - Research Report," Report No. FHWA-RD-77-4, Southwest Research Institute, Mar. 1976.

6. "Recommended Procedures for Vehicular Crash Testing of Highway Appurtenances," Transportation Research Circular No. 191, Transportation Research Board, Feb. 1978.