

TEXAS
TRANSPORTATION
INSTITUTE

TEXAS
HIGHWAY
DEPARTMENT

COOPERATIVE
RESEARCH

**IN-SERVICE EXPERIENCE ON
INSTALLATIONS OF TEXAS
MODULAR CRASH CUSHIONS**

in cooperation with the
Department of Transportation
Federal Highway Administration
Bureau of Public Roads

**RESEARCH REPORT 146-2
STUDY 2-8-68-146
ADAPTATION OF ATTENUATION SYSTEMS**



**IN-SERVICE EXPERIENCE ON INSTALLATIONS
OF TEXAS MODULAR CRASH CUSHIONS**

by

Monroe C. White

Engineering Research Associate

Don L. Ivey

Associate Research Engineer

and

T. J. Hirsch

Research Engineer

Research Report Number 146-2

Studies of Field Adaption of Impact

Attenuation Systems

Research Study Number 2-8-68-146

Sponsored by

The Texas Highway Department in Cooperation with

The U. S. Department of Transportation,

Federal Highway Administration,

Bureau of Public Roads

December 1969

TEXAS TRANSPORTATION INSTITUTE

Texas A&M University

College Station, Texas

ABSTRACT

From September 1961 through June 30, 1968, ninety-nine fatalities occurred on freeways in Houston, Texas. Concrete abutments and "T" mounts, located in the gore of diverging lanes, accounted for 27.3% of these fatalities. The Modular Crash Cushion, composed of 55-gallon steel barrels, was developed to decrease the severity of vehicle collisions with these gore obstacles. Three concrete abutment gore locations were the scene of eight fatal accidents reported during the period from September 1965 through October 1968. Modular Crash Cushions were installed at these three locations as well as at two other gore positions in late October 1968. Records show there have been thirteen accidents involving these installations through October 1969 with no serious injuries nor fatalities at any of these sites.

This report describes these Modular Crash Cushion installations and the experience gained from investigation of each accident which has occurred since their installation.

ACKNOWLEDGMENTS

This study was conducted under an interagency contract between the Texas Transportation Institute and the Texas Highway Department. It was sponsored jointly by the Texas Highway Department and the Bureau of Public Roads. Liaison was maintained through Mr. John Nixon and Mr. Paul Tutt, contact representatives for the Texas Highway Department in Austin.

The cooperation of Mr. Wiley E. Carmichael, Mr. George P. Munson, Jr., and Mr. John N. Lipscomb of the Texas Highway Department, District 12, Houston, is gratefully acknowledged. These gentlemen installed several of the crash cushions and supplied most of the accident details and photographs. Credit is also due Mr. Albert C. Kyser and Mr. William V. Ward of the Houston Urban Project, Texas Highway Department, for site selection and design of several of the crash cushions.

Our thanks go to Mr. A. Taragin, chief of the Planning Division, Office of Traffic Operations, Bureau of Public Roads, and Mr. R. T. Gregory of TTI for making the films and photos from the surveillance cameras available and especially for the use of the photo of the accident at Site No. 1 on October 12, 1969 (Figure 29).

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Bureau of Public Roads.

SUMMARY

From September 1961 through June 30, 1968, ninety-nine fatalities occurred on freeways in Houston, Texas. Concrete abutments and "T" mounts, located in the gore of diverging lanes, accounted for 27.3% of these fatalities. The Modular Crash Cushion, composed of 55-gallon steel barrels, was developed to decrease the severity of vehicle collisions with these gore obstacles. Three concrete abutment gore locations were the scene of eight fatal accidents reported during the period from September 1965 through October 1968. Modular Crash Cushions were installed at these three locations as well as at two other gore positions in late October 1968. Records show there have been thirteen accidents involving these installations through October 1969 with no serious injuries nor fatalities at any of these sites.

In-service experience with the Modular Crash Cushions at the five reported sites has indicated satisfactory performance. A good example was the most gratifying performance of the crash cushion during a head-on collision at an estimated speed of 70 mph. The vehicle came to a complete stop in approximately 17 ft. with an average deceleration of about 9.5 g's. Even though the driver and passenger were not wearing seat belts, their injuries were minor (the driver received a broken nose and the passenger a broken collarbone).

As a result of this study, the following general conclusions were drawn:

1. The Modular Crash Cushions have performed as designed; they have effectively reduced the collision severity, as indicated by the thirteen reported crashes, to the extent that no fatalities or serious injuries have occurred.
2. At existing elevated exit ramps the greatest portion of the total initial cost, site modification, can be greatly reduced on new freeway construction by designing elevated gores to accept the Modular Crash Cushion during initial construction.
3. Maintenance costs are minimal and repair costs are reasonable.
4. Appearance is unobtrusive.
5. This safety device has been readily accepted by the public, police, news media, and highway engineers.

IMPLEMENTATION STATEMENT

This report was developed from accident data received from Texas Highway Department engineers who have implemented and installed the Texas Modular Crash Cushion. No major deficiencies in the crash cushion system have been found to date. This report, concerning the favorable and satisfactory in-service performance of the Texas Modular Crash Cushion, is most reassuring and should expedite further implementation of this safety device.

TABLE OF CONTENTS

	Page
Introduction.....	1
Installations.....	2
Costs.....	2
Accidents.....	5
Conclusions.....	14
Selected References.....	14
Appendix.....	15

LIST OF FIGURES

Figure	Page
1 Site No. 1, IH 610 Northbound (West Loop) and US 59 Exit (Southwest Freeway).....	3
2 Site No. 2, IH 610 Southbound (West Loop) and US 59 (Southwest Freeway).....	3
3 Site No. 3, IH 610 Southbound (West Loop) and IH 10 (Katy Freeway).....	4
4 Site No. 4, US 59 Northbound (Eastex Freeway) and IH 10 (East Freeway).....	4
5 A Site in Dallas and Site No. 5 in Houston.....	5
6 Schematic View of Accident Sequence at Site No. 3 on December 12, 1968.....	6
7 Damage to Vehicles in Accident at Site No. 3 on December 12, 1968.....	6
8 Cushion Damage from Accident at Site No. 3 on December 12, 1968.....	7
9 Damage to Cushion from Accident at Site No. 1 on January 17, 1969.....	7
10 Schematic Sketch of Accident at Site No. 4 on February 15, 1969.....	7
11 Cushion Damage from Accident at Site No. 4 on February 15, 1969.....	8
12 Schematic Sketch of Accident at Site No. 4 on March 19, 1969.....	8
13 Vehicle Damage Sustained in Accident at Site No. 4 on March 19, 1969.....	8
14 Damage to Cushion at Site No. 4 from Accident on March 19, 1969.....	9
15 Schematic Sketch of Accident at Site No. 2 on June 17, 1969.....	9
16 Vehicle Damage from Accident at Site No. 2 on June 17, 1969.....	9
17 Cushion Damage from Accident at Site No. 2 on June 17, 1969.....	9
18 Schematic Sketch of Accident at Site No. 4 on June 22, 1969.....	10
19 Vehicle Damage from Accident at Site No. 4 on June 22, 1969.....	10
20 Cushion Damage from Accident at Site No. 4 on June 22, 1969.....	10
21 Schematic Sketch of Accident at Site No. 1 on September 4, 1969.....	10
22 Vehicle and Cushion Damage at Site No. 1 on September 4, 1969.....	11
23 Sequential Sketch of Accident at Site No. 5 on October 4, 1969.....	11
24 Vehicle Damage from Accident at Site No. 5 on October 4, 1969.....	11
25 Cushion Damage at Site Nos. 2 and 5 on October 12, 1969.....	12
26 Sequential Sketch of Accident at Site No. 1 on October 12, 1969.....	12
27 Vehicle Damage from Accident at Site No. 1 on October 12, 1969.....	12
28 Steering Wheel Damage from Accident at Site No. 1 on October 12, 1969.....	13
29 Photo Taken During Collision from Surveillance Camera at Site No. 1 on October 12, 1969.....	13
30 Cushion Damage from Accident at Site No. 1 on October 12, 1969.....	13
31 Cushion Damage from Accident at Site No. 2 on October 22, 1969.....	13
A1 Design Features of the Modular Crash Cushion at Site No. 1.....	15
A2 Design Features of the Modular Crash Cushion at Site No. 2.....	16
A3 Design Features of the Modular Crash Cushion at Site No. 3.....	17
A4 Design Features of the Modular Crash Cushion at Site No. 5.....	18

LIST OF TABLES

Table	Page
1 Freeway Fatalities in Houston, Texas.....	1
2 Tabulation of Fatalities at Gores on Interstate Highway 610.....	2
3 Summary of Collisions.....	6

In-Service Experience on Installations of Texas Modular Crash Cushions

Introduction

Statistics developed by the Texas Highway Department show that from September 1961 through June 30, 1968, ninety-nine fatalities occurred on freeways in Houston, Texas. A summary of these fatalities by location and type of accident is shown in Table 1. Of these 99 fatalities, 21 occurred at concrete abutments and six occurred at "T" mounts. These concrete abutments and "T" mounts, located in the gore of diverging lanes, thus account for 27.3% of the fatalities.

A list of fatal gore accidents at three concrete abutments located on IH 610 is given in Table 2. From September 1965 through October 1968, there were three vehicle collision fatalities at Site No. 1, IH 610 Northbound (West Loop) and US 59 exit (Southwest Freeway); one vehicle collision fatality at Site No. 2, IH 610 Southbound and US 59 exit; and four vehicle collision fatalities at Site No. 3, IH 610 and IH 10 exit (Katy Freeway).

Texas Highway Department engineers recognized the need to provide some sort of vehicle crash cushion at these and other points of high accident incidence. The Modular Crash Cushion was in a very early developmental stage at Texas Transportation Institute at this time and it was recognized as a possible device to decrease the severity of accidents at these sites. The Modular Crash Cushions, composed of 55-gallon steel

barrels, are positioned so that they provide a relatively soft, deformable "cushion" between an errant vehicle and a rigid obstacle. In late October 1968, Modular Crash Cushions were installed at Sites 1, 2, and 3 on IH 610 in Houston, Texas. In early 1969, two other Modular Crash Cushions were installed, one at US 59 Northbound (Eastex Freeway) and IH 10 Eastbound in Houston (Site No. 4), and one on IH 20 in Dallas, Texas. A typical installation at a concrete abutment is shown in Figure 1. In September 1969, a Modular Crash Cushion was installed around a "T" mount located in the gore of the Lyons Avenue exit of US 59, Northbound (Eastex Freeway) in Houston (Site No. 5).

Department of Public Safety and Texas Highway Department records show 13 accidents involving the five Houston crash cushion installations through October 1969. Since installation of the crash cushions, there have been no fatalities or serious injuries at any of these sites.

This report describes six installations, their cost and their performance. The five Houston sites form the basis of this report with the Dallas site added to give cost figures from another area of the State. The design of Modular Crash Cushions and the research conducted during the development stage is given in Research Report 146-1^{1*} and in Technical Memorandum 505-1.² Plans of four of the Modular Crash Cushions are presented in Figures A1 through A4 in the Appendix.

*Refer to corresponding numbers in Selected References.

TABLE 1. FREEWAY FATALITIES IN HOUSTON, TEXAS FROM SEPTEMBER 1961 THROUGH JUNE 1968

	US 59 SOUTH- WEST	US 59 EASTEX	IH 45 NORTH	IH 45 SOUTH	IH 10 EAST	IH 610 NORTH	IH 610 WEST	TOTAL
1. FIXED OBJECT:								
A. Light Standard	2			4		2		8
B. Concrete Abutment	6		2	2	3	1	7	21
C. "T" Mount in Gore, Includ. Protect.	2		1	2		1		6
D. Sign Post	1							1
E. Guardrail—Outside		1		2		3		7
F. Guardrail—Inside	1	1		1			1	4
2. CAR STALLED—HIT BY ANOTHER VEHICLE	3	1	4	6			2	16*
3. THROWN OR FELL OUT	3	3	1	1	1	4		12
4. PEDESTRIAN		6	2	1	1	2		12
5. WRONG-WAY COLLISION		1	3	3	1			8
6. ACROSS MEDIAN ACCIDENT						2		2
7. HIT RAIL—STRUCK BY ANOTHER VEHICLE		1						1
8. RAN OFF EMBANKMENT			1					1
TOTAL	18	14	14	22	6	15	10	99

*10 at night on unlighted freeways; 2 in daylight.

TABLE 2. TABULATION OF FATALITIES AT GORES ON INTERSTATE HIGHWAY 610

DATE	DAY	TIME	LOCATIONS*	AGE	NO. OF OCCUPANTS	CONTRIBUTING FACTORS
9-16-65	Thurs.	10:15 PM	1	39	Alone	Speed—Had been drinking
4- 1-67	Sat.	3:35 AM	3	33	Alone	Excessive speed
8-20-67	Sat.	3:55 AM	1	39	Alone	Speed—Had been drinking
11-28-67	Tues.	11:15 AM	3	29	Alone	Speed
4- 8-68	Mon.	12:25 AM	3	44	Alone	Car slid sideways into divider— Late decision as to exit
4- 8-68	Mon.	4:25 AM	1	52	Alone	Excessive speed
5-18-68	Sat.	4:00 AM	3	18	Alone	Excessive speed (70-100 mph)
10- 3-68	Thurs.	12:30 AM	2	23	Alone	Floodlight not on—no skid marks

*1—IH 610 Northbound at Southwest Fwy.

2—IH 610 Southbound at Southwest Fwy.

3—IH 610 Southbound at IH 10 (Katy exit).

NOTE: I 610-US 59 interchange opened 7-26-62. Lighted 8-15-67.

I 610-IH 10 interchange opened 10-27-63. Lighted 8-15-67.

Installations

Sites 1, 2, and 3, before and after installation of Modular Crash Cushions, are shown in Figures 1, 2, and 3. The "Before" photos of all three sites show the pock-marked curbs and parapet walls; the result of vehicle collisions. These photos, taken from a moving vehicle, show the motorists' view of these sites. The "After" photos show only a slight change of appearance resulting from the Modular Crash Cushion installation. When a Modular Crash Cushion is viewed from an automobile, it blends in with its surroundings to the extent that it is barely noticeable. The sheet aluminum cover gives it the appearance of a concrete wall. The "Elevated View"

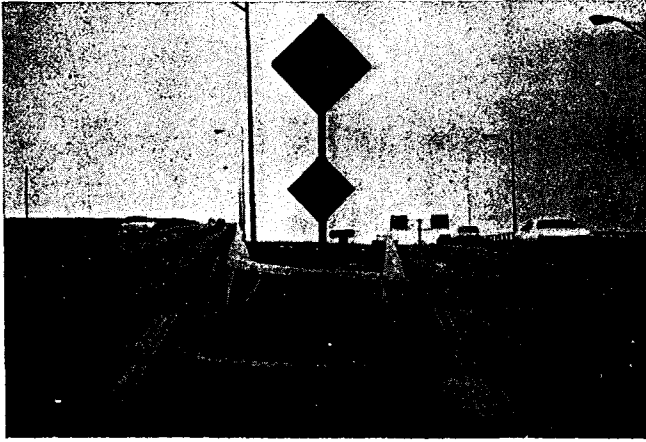
photos show how the Modular Crash Cushion configurations can be adapted to fit the site geometries. The vertical rods and pressure tubes surrounding the front of the Modular Crash Cushions are switches to trigger overhead cameras that will take movies of collision events. Figures A1, A2, A3, and A4 in the Appendix show pertinent design features of the Modular Crash Cushions as installed at Sites No. 1, 2, 3, and 5, respectively.

The crash cushion installations at Sites 4 and 5 are shown in Figures 4 and 5. Figure 5 also shows the Dallas installation.

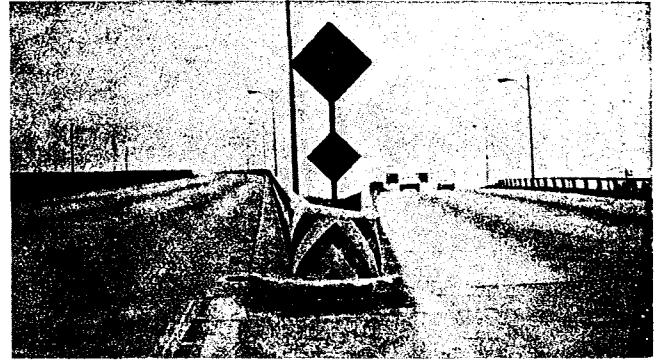
Costs

The Modular Crash Cushions at Sites 1, 2, and 3 cost a total of \$10,750 for fabrication, site modification, and installation. The installation on IH 20 in Dallas (see Figure 5) had a total cost of \$2,981 with \$2,581 for site modification and \$400 for fabrication and installation of the Modular Crash Cushion itself.³ Site No. 5 cost a total of \$1,200 with only minor site modification necessary. As shown by this current cost infor-

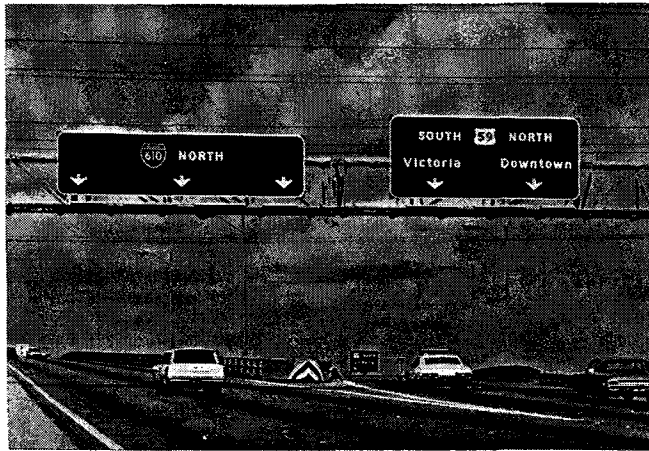
mation and by previous cost estimates, the cost of the crash cushion proper is extremely low (\$400 to \$600 per cushion). The greater portion of the cost on existing elevated exit ramps results from having to modify the gores to accept the cushion. On new freeway construction, the elevated gores can be designed to accept the crash cushion at very little added expense.



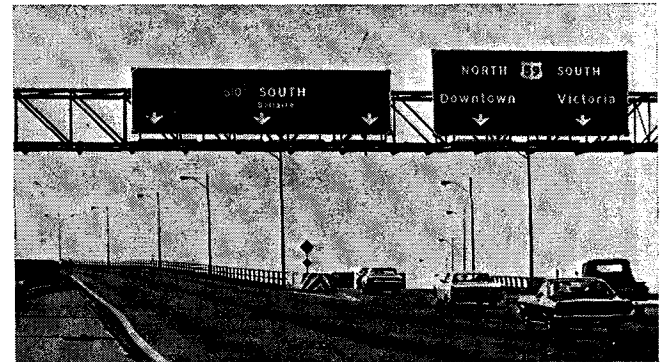
Before



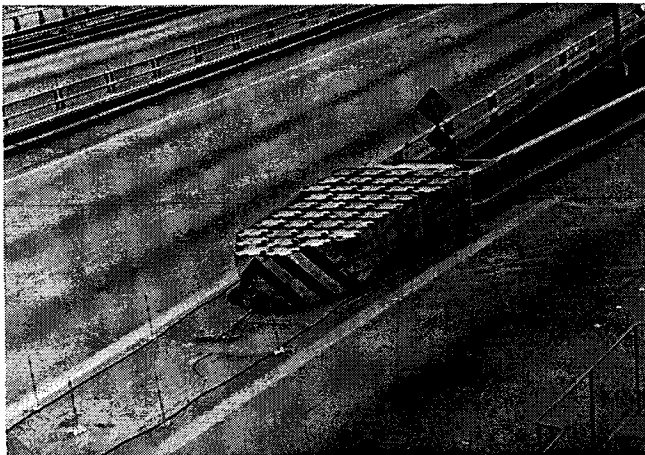
Before



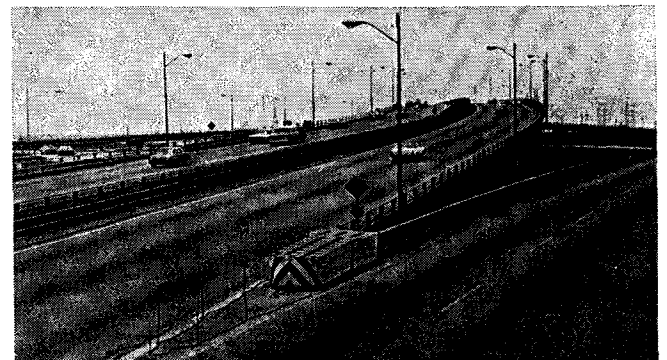
After



After



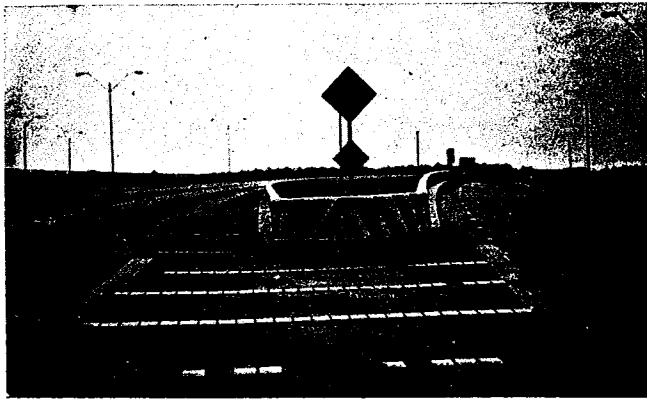
Elevated View



Elevated View

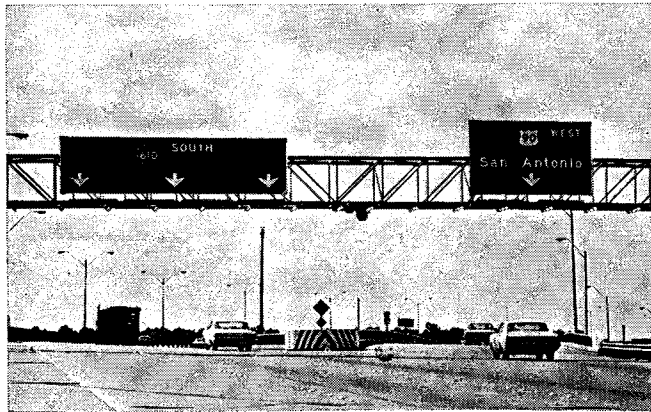
Figure 1. Site No. 1, IH 610 Northbound (West Loop) and US 59 Exit (Southwest Freeway).

Figure 2. Site No. 2, IH 610 Southbound (West Loop) and US 59 (Southwest Freeway).

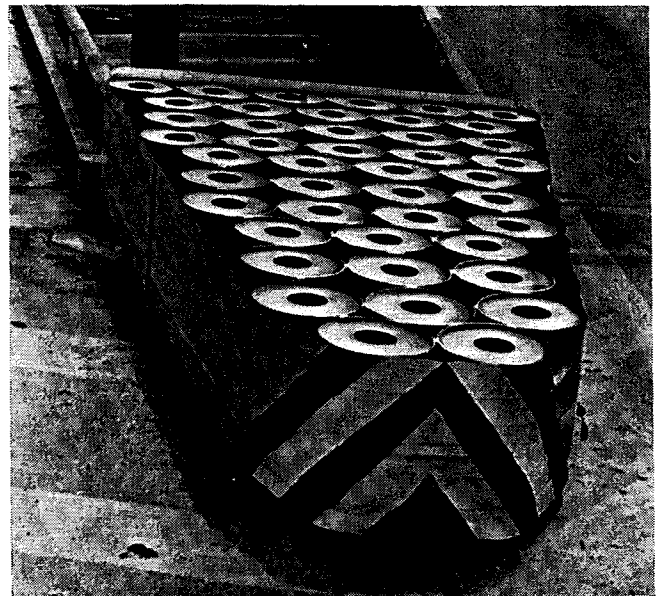


Before

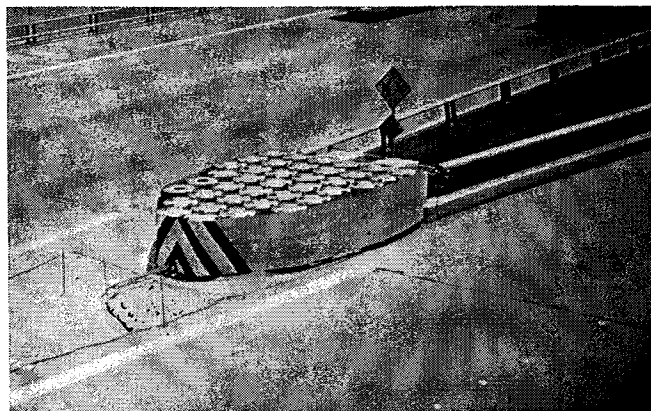
Before Photo Not Available



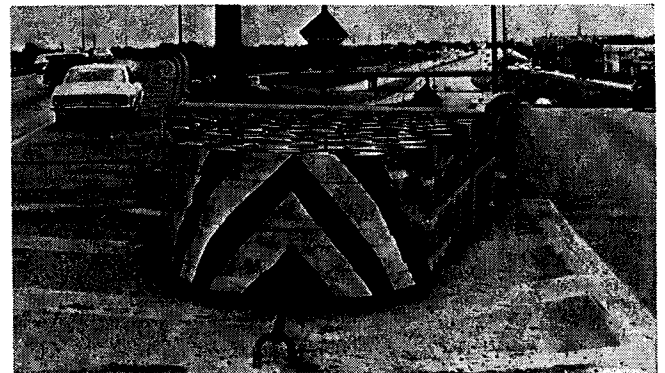
After



Elevated View



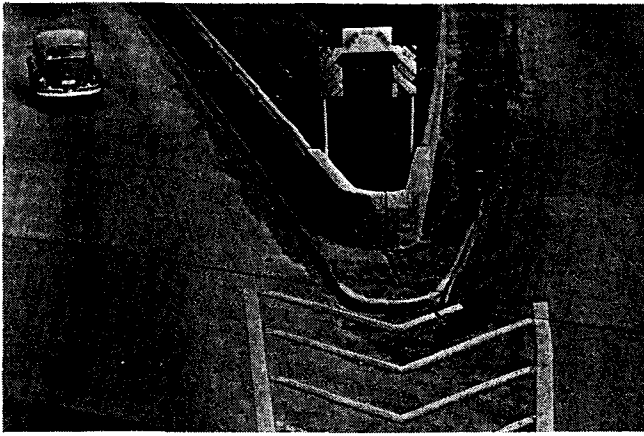
Elevated View



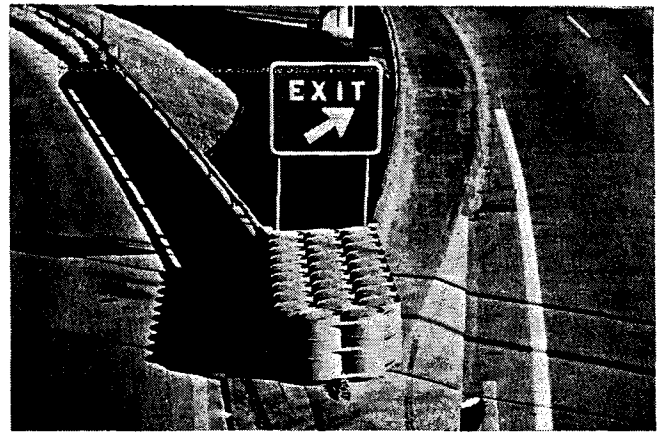
Front View

Figure 3. Site No. 3, IH 610 Southbound (West Loop Freeway) and IH 10 (Katy Freeway).

Figure 4. Site No. 4, US 59 (Eastex Freeway) and IH 10 (East Freeway).

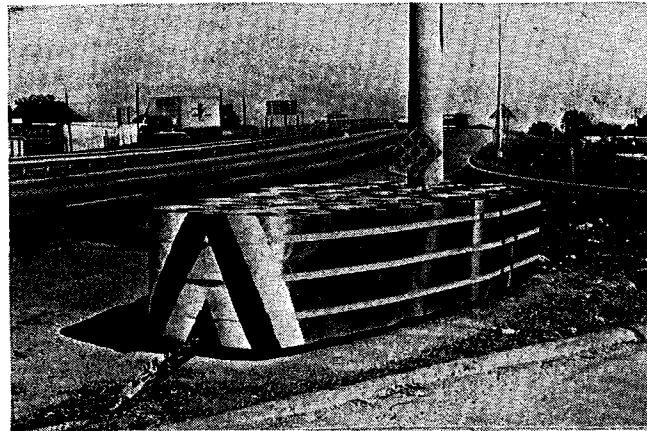


Before



After

Site on IH 20 in Dallas



Site No. 5, US 59 (Eastex Freeway) Northbound at Lyons Avenue Exit in Houston.

Figure 5. A Site in Dallas and Site No. 5 in Houston.

Accidents

Since installation of crash cushions at Sites 1 through 5, there have been thirteen collisions which are summarized by Table 3.

The first accident involving a Modular Crash Cushion occurred on December 12, 1968, 8:40 p.m., at Site No. 3. Figure 6 shows, in sketch form, how the accident occurred. Vehicle 1 was changing lanes to accommodate the IH 10 exit. During this maneuver, the right side of Vehicle 1 struck the left side of Vehicle 2. Both vehicles then simultaneously struck the Modular Crash Cushion head-on. Figure 7 shows the very minor damage to each of the vehicles involved in the collision. Figure 8 shows the extent of damage to the Modular Crash Cushion. Neither driver sustained injury, and both vehicles were driveable after the collision. The accident report indicates the weather was clear and pavement dry at the time of the accident.

The exact time of the second accident is not known since no official accident report was filed. On January 20, 1969, approximately 25 feet of straight skid marks were observed leading directly to the damaged crash cushion at Site No. 1. Figure 9 shows the damage to the left front barrel. The driver and vehicle remain unknown since the vehicle undoubtedly sustained very little damage and was driven from the scene of the accident.

The third accident occurred on February 15, 1969, 11:00 p.m., at Site No. 4, and as shown in Figure 10. The vehicle was traveling North on Eastex Freeway and while attempting to change lanes, struck the Modular Crash Cushion on the left-hand side of the right front of the vehicle. After crushing the first ten barrels on the left-hand side of the Modular Crash Cushion, the vehicle came to a stop. Photographs of

TABLE 3. SUMMARY OF COLLISIONS

NO.	DATE	DAY	TIME	SITE	SPEED*	AGE	SEX	OCCUPANTS	REMARKS
1	12-12-68	Thurs.	8:40 PM	3	45 45	28 46	F M	Driver Driver	Two vehicles—no injury
2	1-17-69	Fri.		1					Minor head-on by persons unknown
3	2-15-69	Sat.	11:00 PM	4	55	22	M	Driver	One vehicle—minor injury
4	3-19-69	Wed.	11:00 PM	4	55	39	M	Driver	One vehicle—minor injury
5	3-26-69	Wed.		4					Minor—by persons unknown
6	6-17-69	Tues.	11:45 AM	2	N. A.**	23 4 mo.	F F	Driver Passenger	One vehicle—no injury Minor injury
7	6-22-69	Sun.	4:45 AM	4	N. A.**	39	M	Driver	One vehicle—no injury
8	9- 4-69	Thurs.	2:15 AM	1	55	50	M	Driver	One vehicle—no injury
9	10- 4-69	Sat.		5				Driver	One vehicle—minor injury
10	10-12-69	Sun.		2					Minor head-on by persons unknown
11	10-12-69	Sun.		5					Minor head-on by persons unknown
12	10-12-69	Sun.	2:27 AM	1	70+	20	M	Driver	Broken nose and bruised ribs
						15	F	Passenger	Broken collarbone—70 mph, head-on
13	10-22-69	Wed.		2					Minor head-on by persons unknown

*Speed given is estimated speed in mph from police reports and is not necessarily impact speed.

**Not available on police report.

***Speed at impact estimated from energy absorbed by cushion and vehicle deformation.⁴

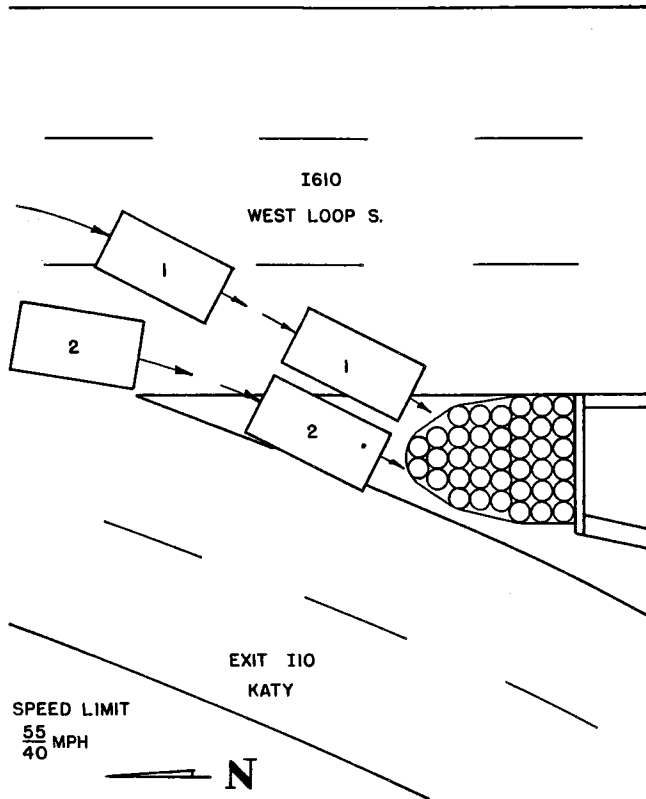
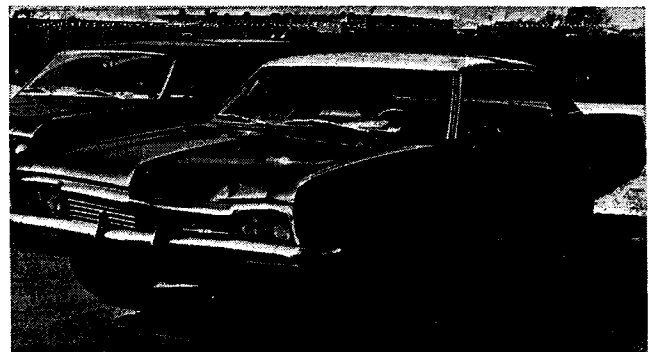


Figure 6. Schematic View of Accident Sequence at Site No. 3 on December 12, 1968.



Vehicle No. 1



Vehicle No. 2

Figure 7. Damage to Vehicles in Accident at Site No. 3 on December 12, 1968.



Figure 8. Cushion Damage from Accident at Site 3 on December 12, 1968.

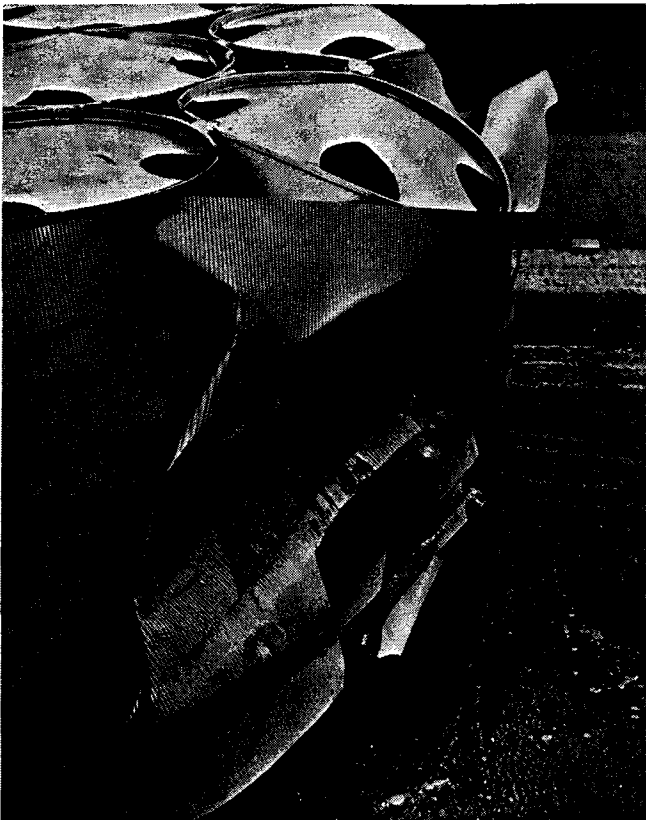


Figure 9. Damage to Cushion from Accident at Site 1 on January 17, 1969.

the vehicle are not available, but the investigating officer estimated \$700 damage to the right front of the vehicle. It was reported that the driver refused treatment for minor injuries and that he had been drinking. The officer's report stated that the weather was clear and the pavement dry at the time of the accident. Figure 11 shows the damage done to the Modular Crash Cushion.

On March 19, 1969 at 11:55 p.m., a collision occurred at Site No. 4. A vehicle traveling North on the

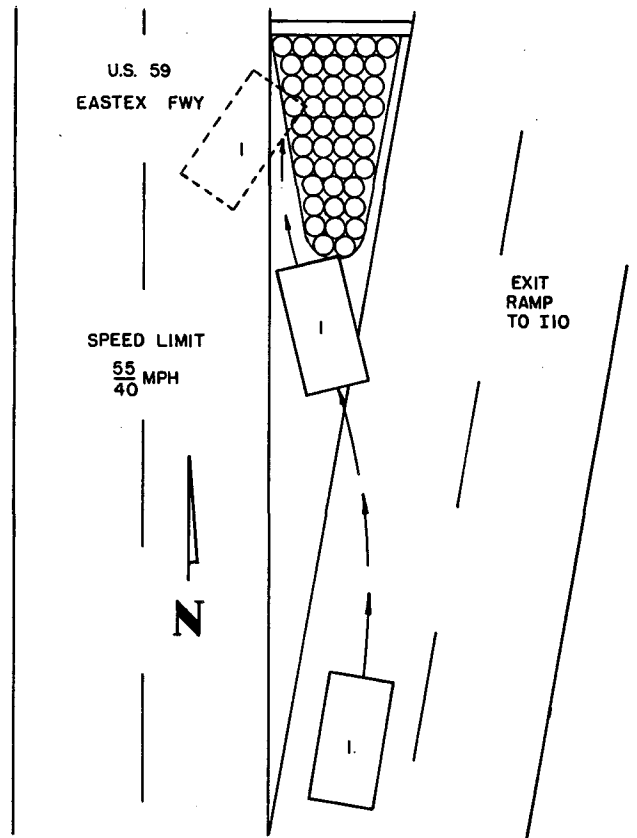


Figure 10. Schematic Sketch of Accident at Site No. 4 on February 15, 1969.

exit ramp from the Eastex Freeway to IH 10, struck the Modular Crash Cushion with the left side of the vehicle impacting the right side of the crash cushion. The sketch in Figure 12 shows the path of the vehicle, as it swerved from the crash cushion, moved across the exit ramp and struck the guardrail on the right side of the ramp. Photographs of the crash cushion damage are shown in Figure 14 while Figure 13 indicates damage sustained by the vehicle. The accident report states that the driver sustained minor injuries. The report also shows that the driver had been drinking, failed to keep a proper lookout, and was not wearing his seat belt when the accident occurred. The weather is reported to have been clear, and the road surface dry at the time of the accident.

On March 26, 1969, two rows of barrels were discovered to be damaged in the Modular Crash Cushion located at Site No. 4. Since there is no police report on this accident and no photographs are available, it may be surmised that the vehicle was still driveable and the driver left the scene without notifying authorities.

The sixth accident took place at Site No. 2 on June 17, 1969, at 11:45 a.m. As may be seen in the sketch in Figure 15, the driver of Vehicle No. 1 was forced to sideswipe the Modular Crash Cushion in order to avoid a collision with Vehicle No. 2 as Vehicle No. 2 changed lanes. Damage to Vehicle No. 1 is shown in Figure 16, and Figure 17 illustrates the damage to the crash cushion. The accident report indicates no injury to the

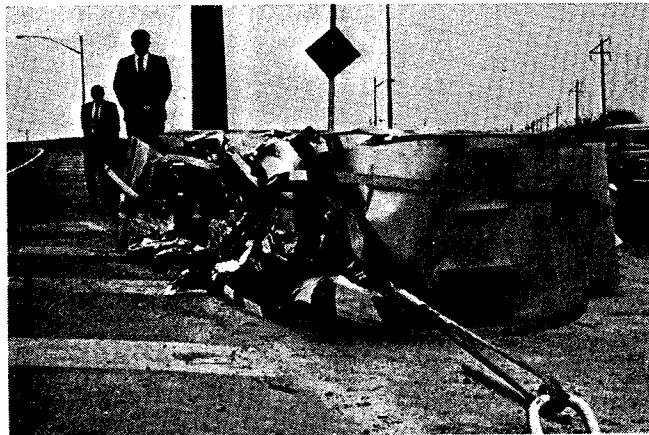
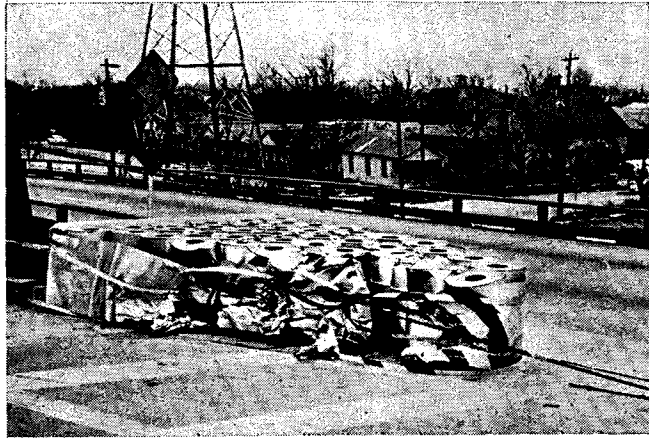


Figure 11. Cushion Damage from Accident at Site No. 4 on February 15, 1969.

driver of Vehicle No. 1 and minor injuries to a child passenger in this vehicle. The report also describes the weather as clear and the road surface as dry.

The next accident took place at Site No. 4 on June 22, 1969, at 4:45 a.m. The accident sequence, shown in Figure 18, illustrates the path of the colliding vehicle. Vehicle No. 2 cut in front of Vehicle No. 1 as Vehicle No. 2 changed lanes. The driver of Vehicle No. 1 reported hitting his brakes and skidding into the Modular Crash Cushion in a head-on attitude. Damages to Vehicle No. 1 are shown in the photograph in Figure 19, while damage to the crash cushion is shown in Figure 20. The accident report states that the weather was clear and road surface dry. There were no injuries in this accident.

On September 4, 1969, at 2:15 a.m., a vehicle side-swiped the cushion at Site No. 1. The right rear of the vehicle impacted the left front of the cushion as shown in Figure 21. Damage to the cushion and vehicle are shown in Figure 22. The accident report indicates the driver was exceeding the speed limit by approximately 5 mph, made his exit maneuver too late, struck the crash cushion, but sustained no injuries. Also, the weather was clear and the pavement dry.

The first accident at a cushion installed around a "T" mount occurred at Site No. 5 on October 4, 1969. The driver sustained minor injuries and the vehicle sus-

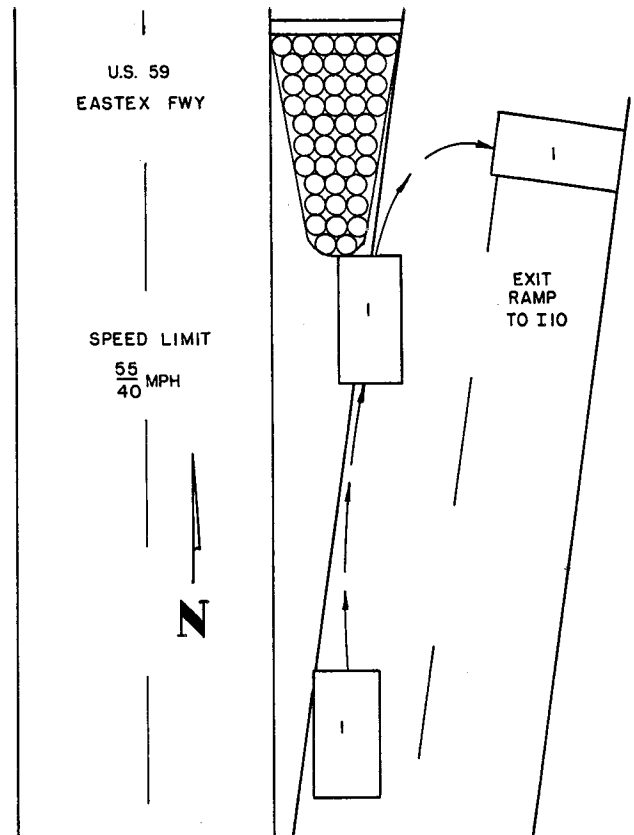


Figure 12. Schematic Sketch of Accident at Site No. 4 on March 19, 1969.

tained damages as shown in Figure 24. The accident sequence is sketched in Figure 23 as no photos of the cushion were available.

On October 12, 1969, three Modular Crash Cushions were impacted. The accidents on this date at Sites 2 and 5 were minor head-on collisions by persons unknown. Figure 25 shows the cushion damages at these



Figure 13. Vehicle Damage Sustained in Accident at Site No. 4 on March 19, 1969.

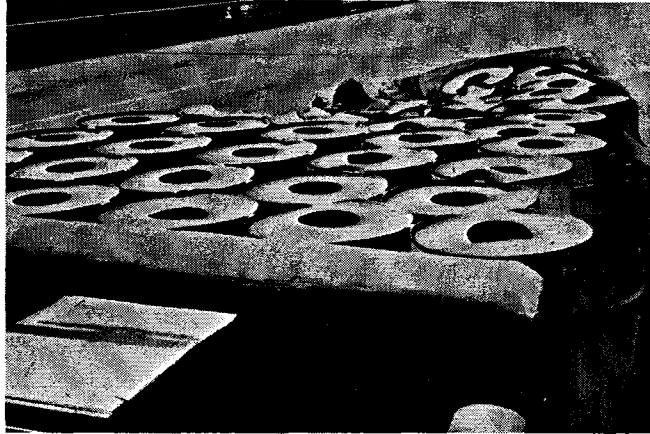
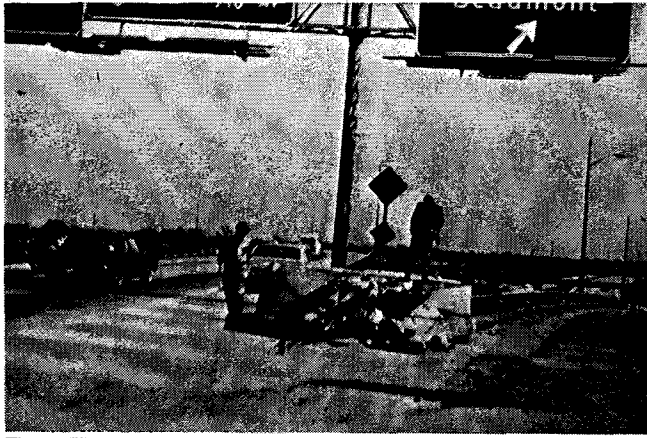


Figure 14. Damage to Cushion at Site No. 4 from Accident on March 19, 1969.

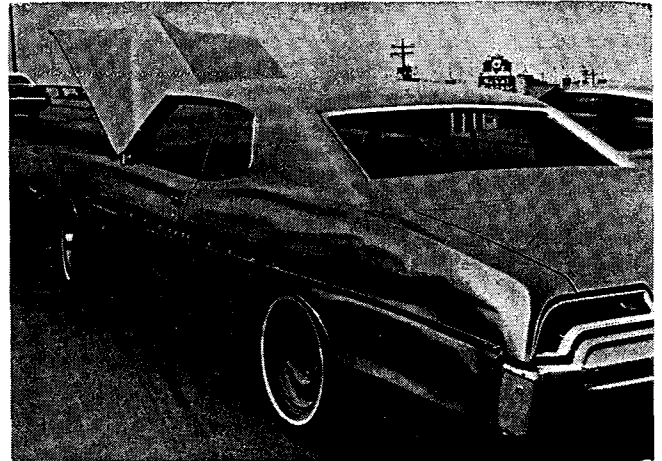


Figure 16. Vehicle Damage from Accident at Site No. 2 on June 17, 1969.

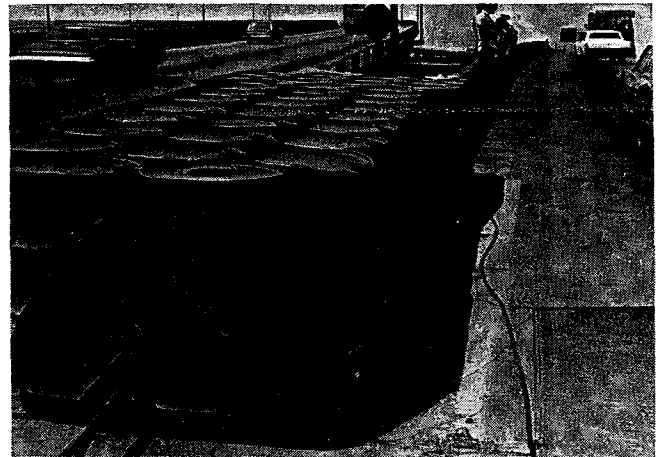


Figure 17. Cushion Damage from Accident at Site No. 2 on June 17, 1969.

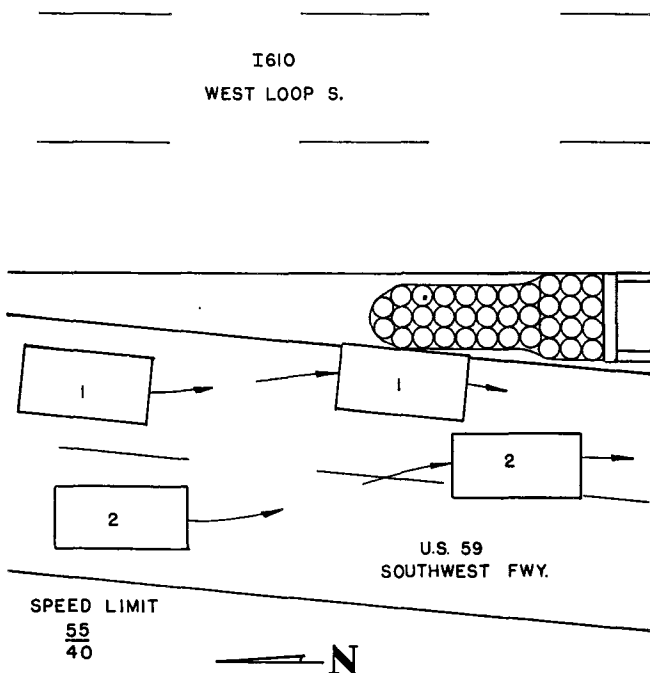


Figure 15. Schematic Sketch of Accident at Site No. 2 on June 17, 1969.

two sites. The accident at Site No. 1 on this date was a major head-on collision at an estimated impact speed of 70 mph. This estimated speed was based on the energy required to crush the 55-gallon drums. The vehicle came to a complete stop in approximately 17 ft.; consequently, the average deceleration of the vehicle was approximately 9.5 g's.

Even though neither the driver nor the passenger was wearing seat belts, their injuries were moderate. The driver received a broken nose and bruised ribs from impacting the steering wheel; Figure 28 shows the damaged steering wheel. The passenger received a broken collarbone.

Figure 26 shows the sequential sketch of the colliding vehicle's path, while Figure 27 shows several photos of the damage to the vehicle. Figure 29 is a still photo from the surveillance camera and was taken during impact. Figure 30 indicates the complete crushing of the cushion. The crush energy of the barrel system was entirely used up to stop the vehicle and the vehicle itself crushed about 12 to 13 inches. This crash

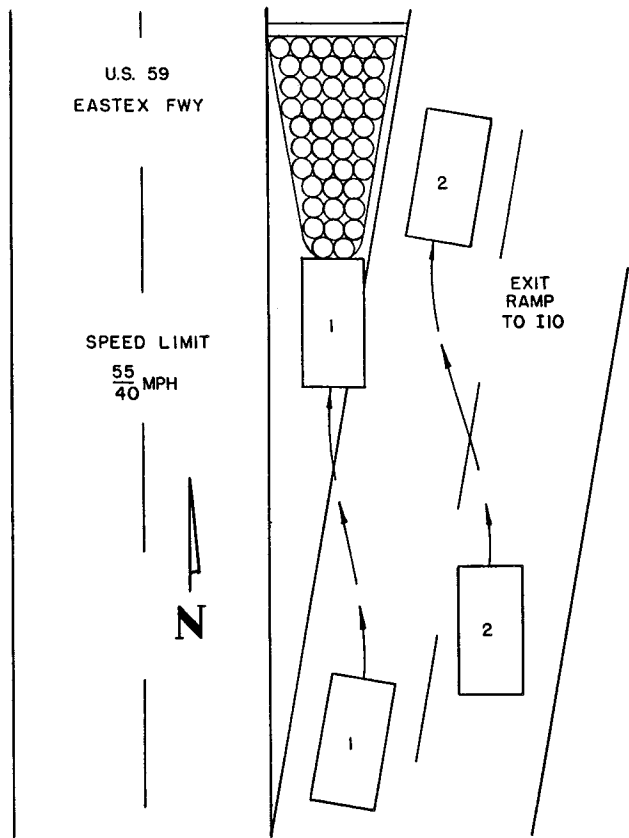


Figure 18. Schematic Sketch of Accident at Site No. 4 on June 22, 1969.

is indicative of the high upper limit of safe performance of the Modular Crash Cushion under head-on impact.

The thirteenth accident occurred at Site No. 2 on October 22, 1969. There was no information on the vehicle, but the cushion damage is shown in Figure 31 and indicates the collision was a minor head-on.



Figure 19. Vehicle Damage from Accident at Site No. 4 on June 22, 1969.

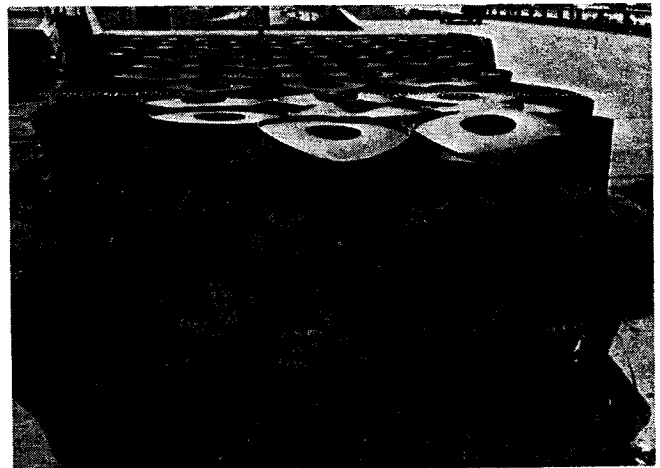


Figure 20. Cushion Damage from Accident at Site No. 4 on June 22, 1969.

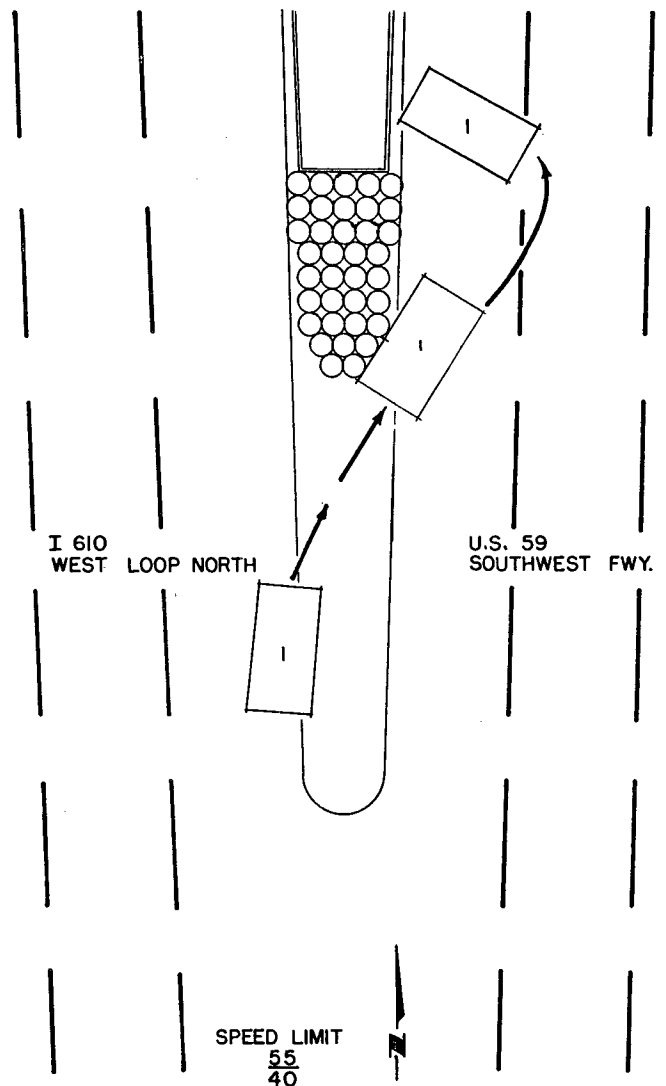
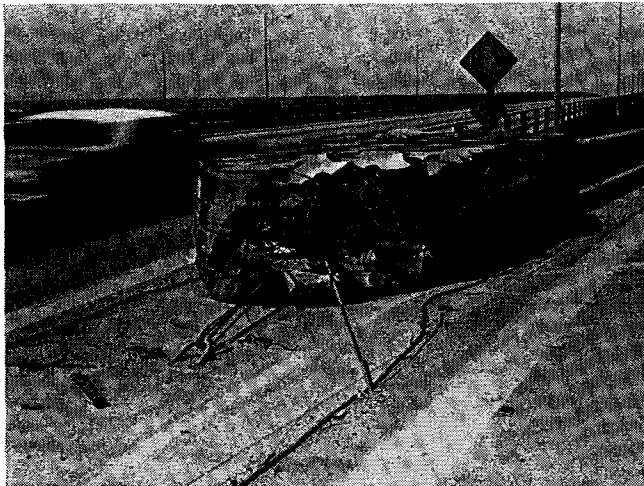


Figure 21. Schematic Sketch of Accident at Site No. 1 on September 4, 1969.



Vehicle Damage



Cushion Damage

Figure 22. Vehicle and Cushion Damage at Site No. 1 on September 4, 1969.

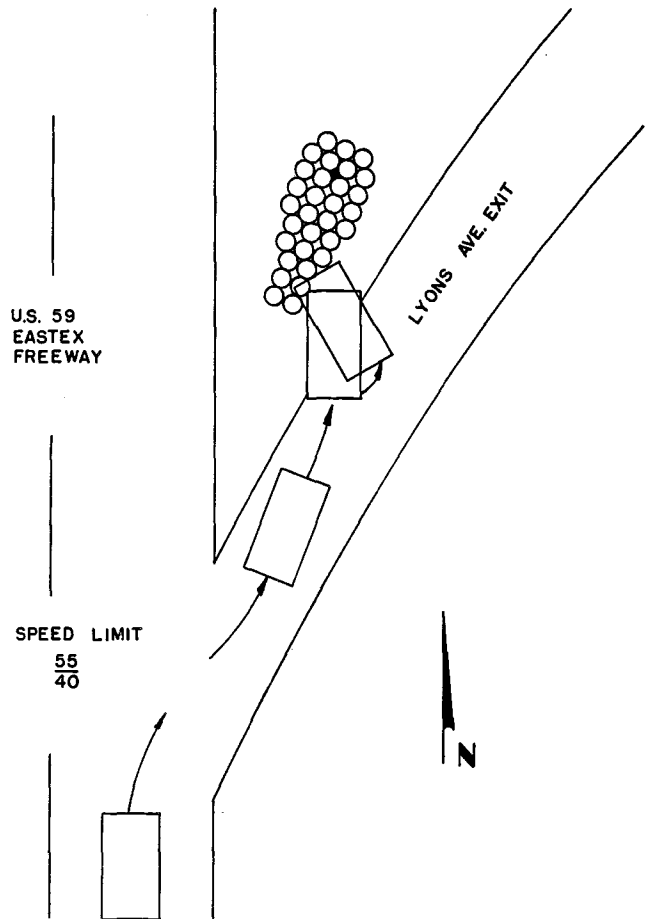
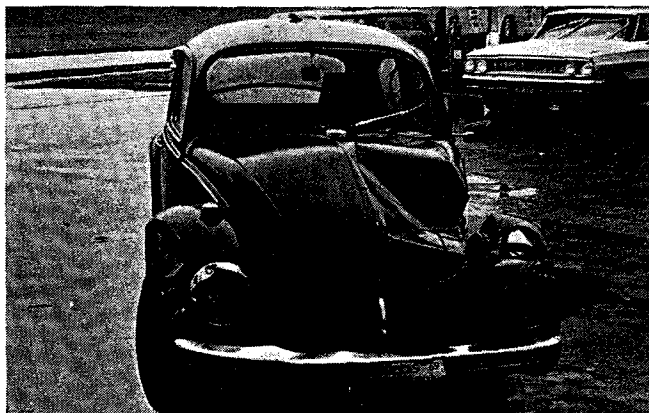
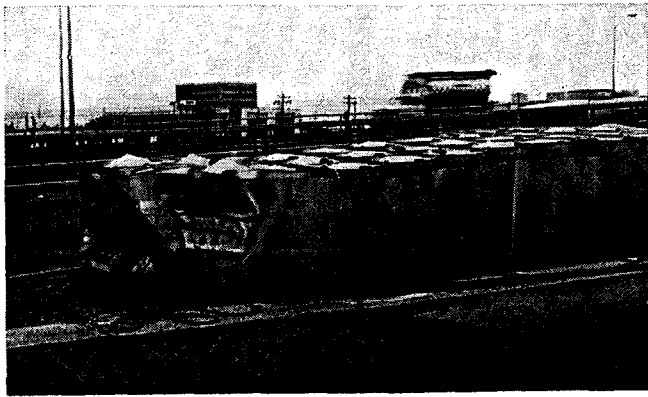


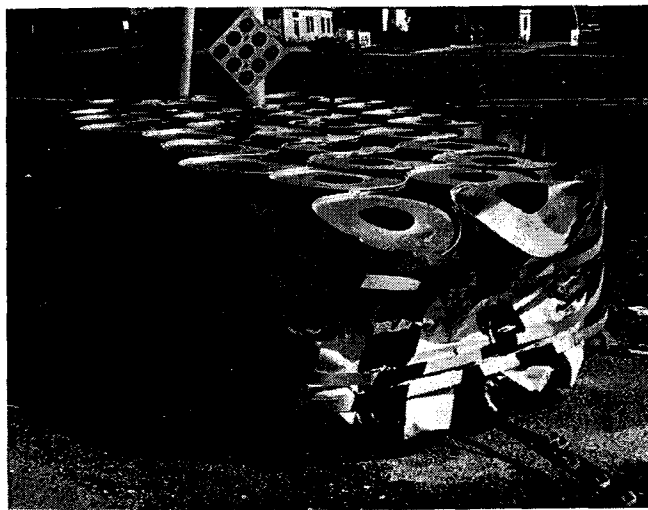
Figure 23. Sequential Sketch of Accident at Site No. 5 on October 4, 1969.



Figure 24. Vehicle Damage from Accident at Site No. 5 on October 4, 1969.



Cushion Damage at Site No. 2



Cushion Damage at Site No. 5

Figure 25. Cushion Damage at Site Nos. 2 and 5 on October 12, 1969.

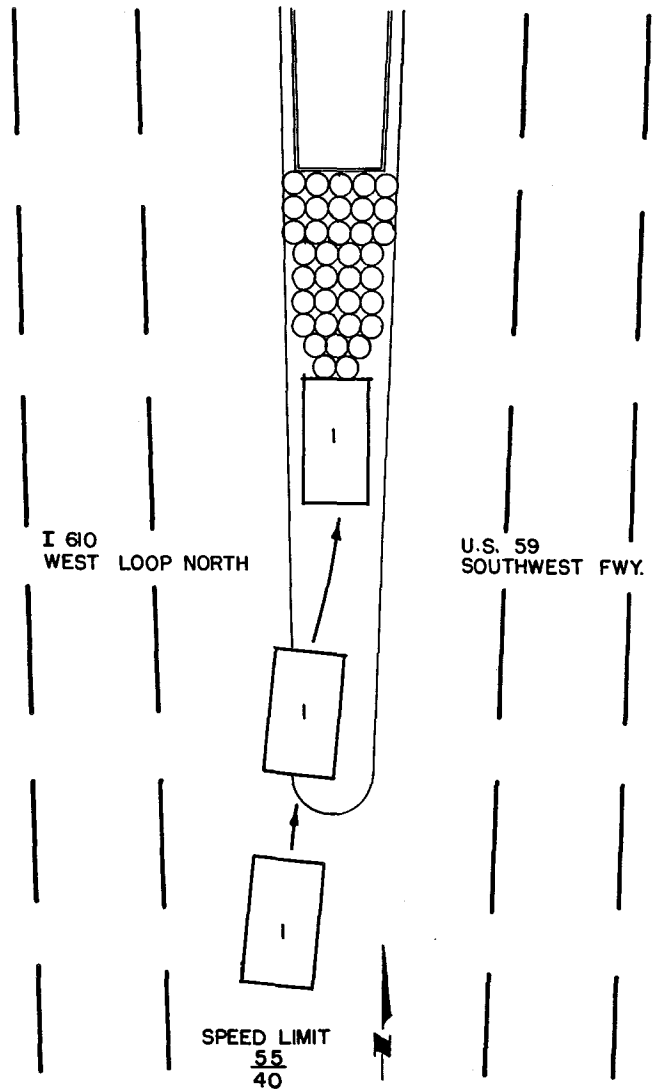


Figure 26. Sequential Sketch of Accident at Site No. 1 on October 12, 1969.

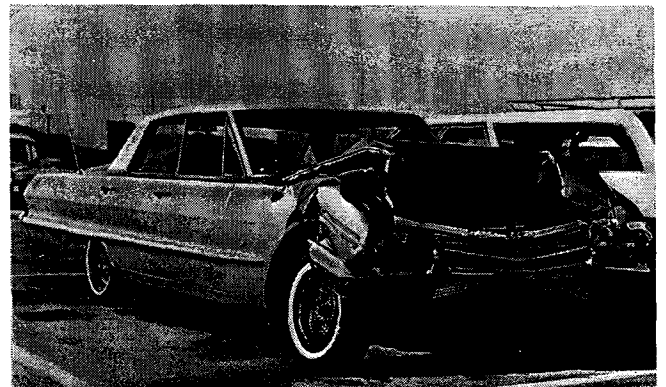
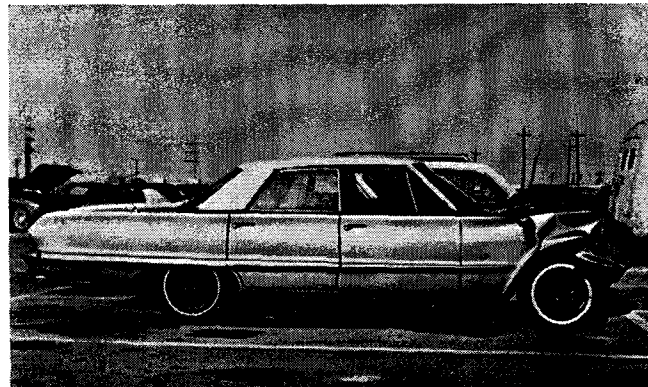


Figure 27. Vehicle Damage from Accident at Site No. 1 on October 12, 1969.

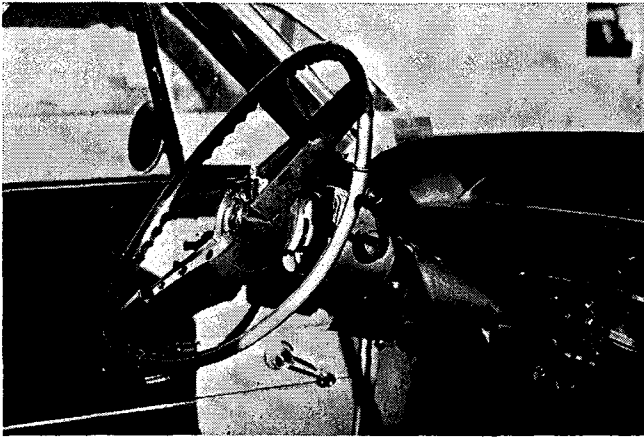


Figure 28. Steering Wheel Damage from Accident at Site No. 1 on October 12, 1969.

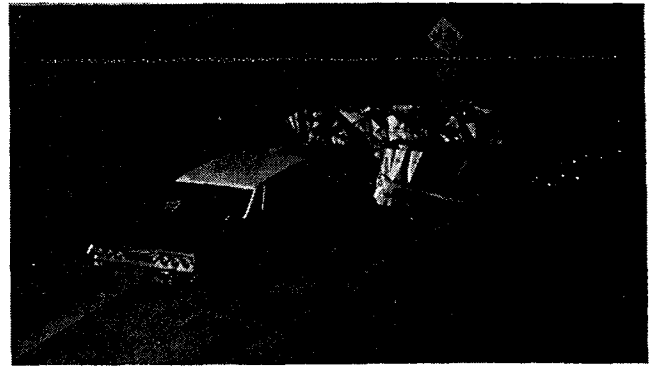


Figure 29. Photo Taken During Collision from Surveillance Camera at Site No. 1 on October 12, 1969.

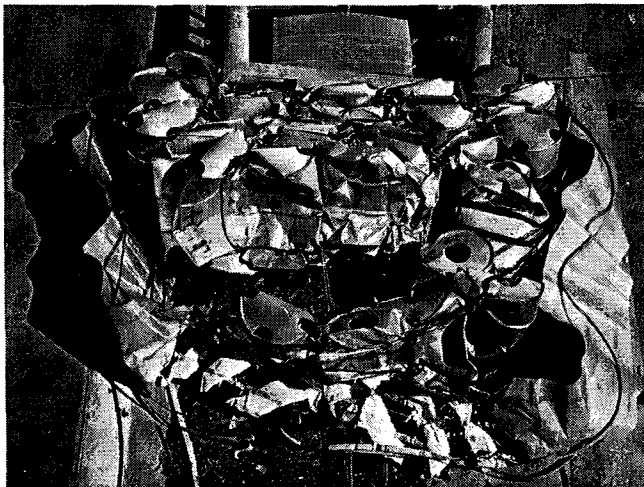
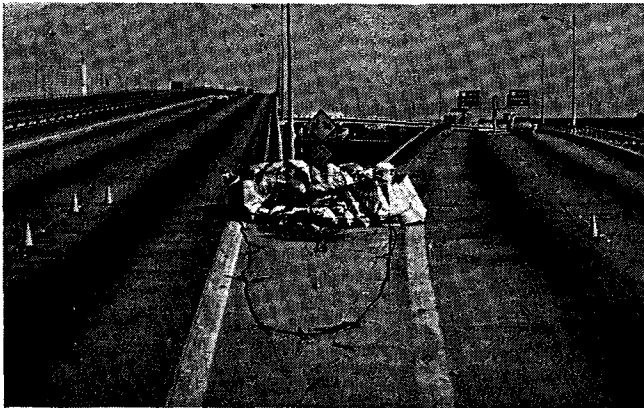


Figure 30. Cushion Damage from Accident at Site No. 1 on October 12, 1969.

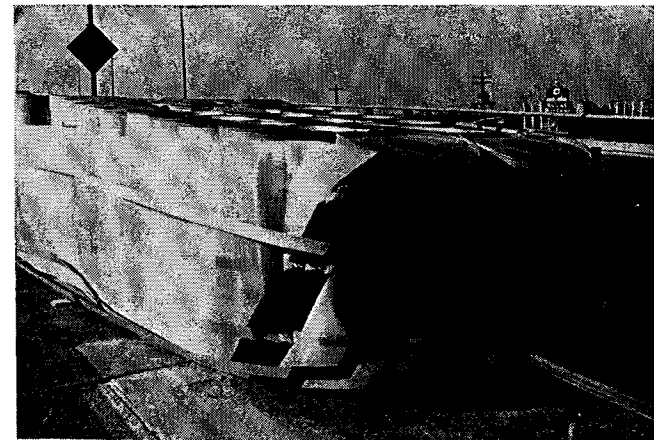
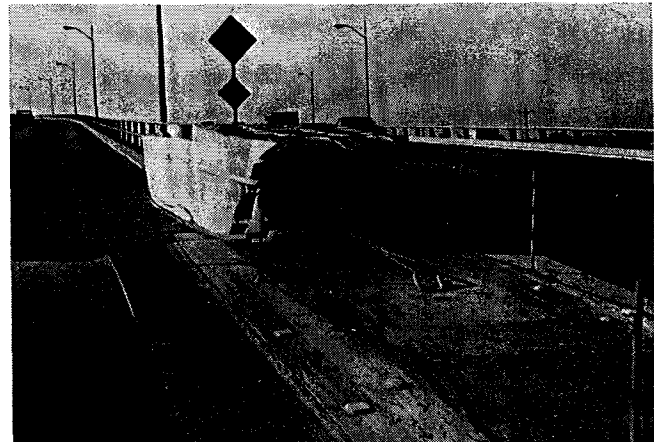


Figure 31. Cushion Damage from Accident at Site No. 2 on October 22, 1969.

Conclusions

In-service experience with the Modular Crash Cushions at the five reported sites has indicated satisfactory performance. A good example was the most gratifying performance of the crash cushion during a head-on collision at an estimated speed of 70 mph. The vehicle came to a complete stop in approximately 17 ft. with an average deceleration of about 9.5 g's. Even though the driver and passenger were not wearing seat belts, their injuries were minor (the driver received a broken nose and the passenger a broken collarbone).

As a result of this study, the following general conclusions were drawn:

1. The Modular Crash Cushions have performed as designed; they have effectively reduced the collision severity, as indicated by the thirteen reported crashes, to the extent that no fatalities or serious injuries have occurred.
2. At existing elevated exit ramps the greatest portion of the total initial cost, site modification, can be greatly reduced on new freeway construction by designing elevated gores to accept the Modular Crash Cushion during initial construction.
3. Maintenance costs are minimal and repair costs are reasonable.
4. Appearance is unobtrusive.

5. This safety device has been readily accepted by the public, police, news media, and highway engineers.

Selected References

1. Hirsch, T. J. and Ivey, D. L., "Vehicle Impact Attenuation by Modular Crash Cushion," Research Report 146-1, Texas Transportation Institute, Texas A&M University, June, 1969.
2. Hirsch, T. J., "Barrel Protective Barrier," Technical Memorandum 505-1, Texas Transportation Institute, Texas A&M Research Foundation, a progress memorandum on Contract No. CPR 11-5851, U. S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads, June 17, 1968.
3. Bowman, J. W., "Use of Steel Drums as an Impact Attenuator," Texas Division, U. S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads, December 17, 1968.
4. Hirsch, T. J., Ivey, D. L., and White, M. C., "The Modular Crash Cushion, Research Findings and Field Experience," Texas Transportation Institute, Texas A&M University, presented at Western Summer Meeting of the Highway Research Board, Salt Lake City, Utah, August, 1969.

Appendix

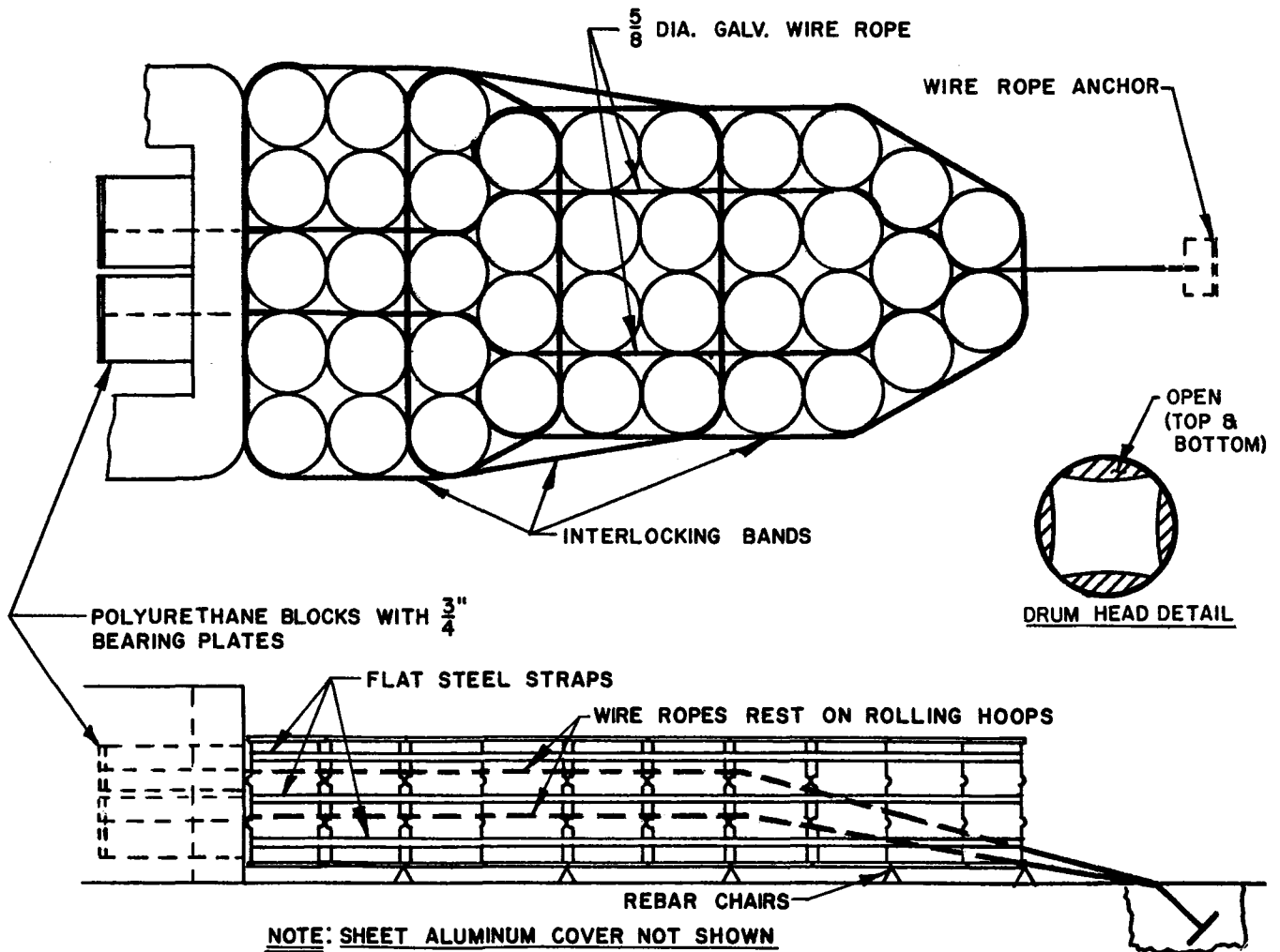
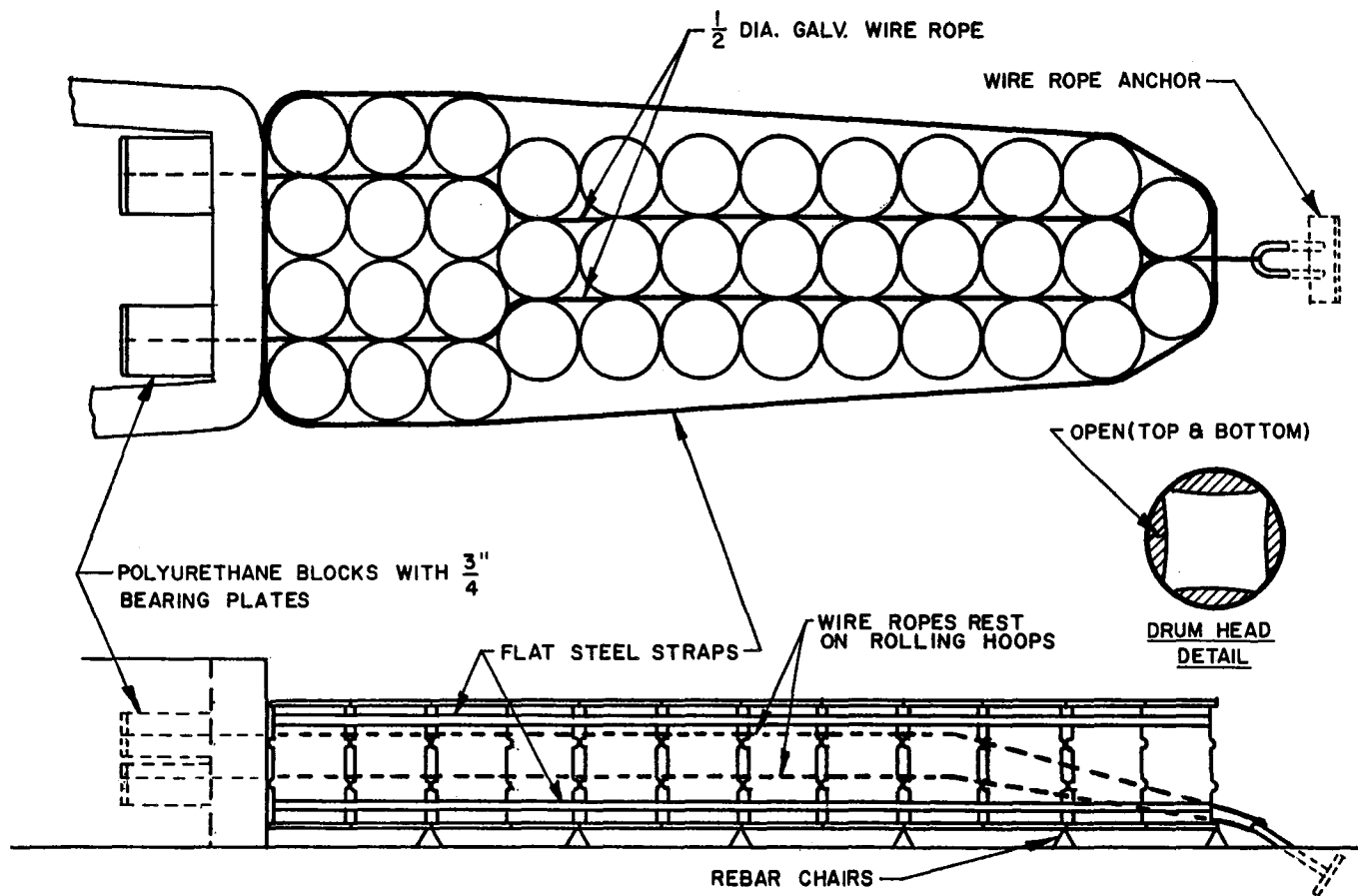
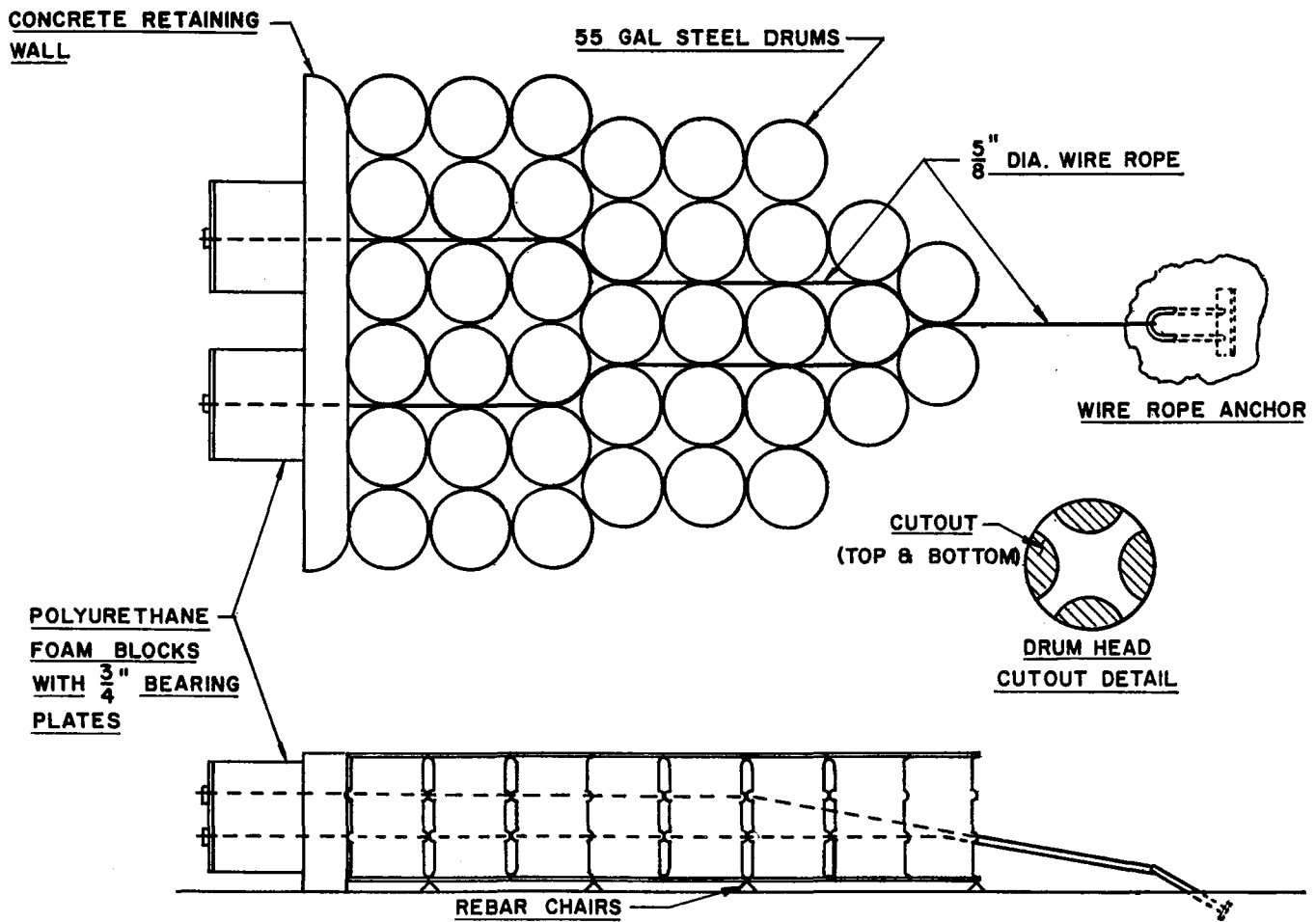


Figure A1. Design Features of the Modular Crash Cushion at Site No. 1.



NOTE: SHEET ALUMINUM COVER NOT SHOWN

Figure A2. Design Features of the Modular Crash Cushion at Site No. 2.



NOTE: SHEET ALUMINUM COVER NOT SHOWN

Figure A3. Design Features of the Modular Crash Cushion at Site No. 3.

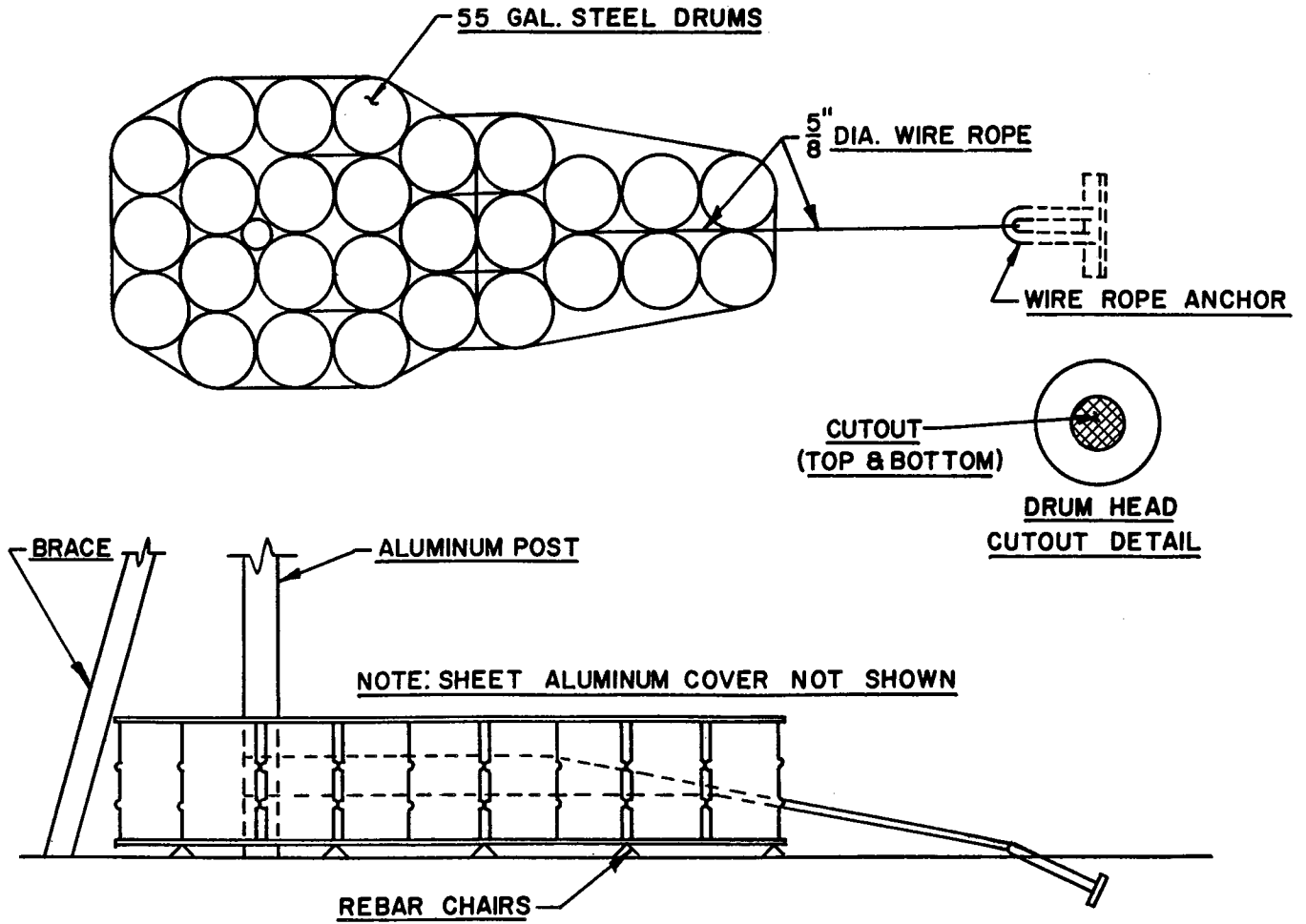


Figure A4. Design Features of the Modular Crash Cushion at Site No. 5.