VEHICLE CRASH TEST AND EVALUATION OF MEDIAN BARRIERS FOR TEXAS HIGHWAYS

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Full-scale tests were conducted to evaluate and compare the performance of three median barriers of different configuration and lateral stiffness: the semirigid metal beam guard fence, which consists of two back-to-back steel W-beam guardrails on breakaway steel posts; the relatively rigid E-3, which consists of two different sizes of strong elliptical steel rail members mounted on strong fabricated steel posts; and the rigid concrete median barrier with inclined faces. All three barriers satisfactorily restrained and redirected a standard-sized 4,000-lb passenger vehicle under the severe impact conditions of about 60 mph and 25 deg. However, severe snagging occurred on a post of the E-3 barrier as a result of the vehicle mounting the lower rail member. The semirigid fence barrier is the most economical with regard to initial construction costs and the safest concerning probability of injury to unrestrained occupants during test impact conditions. However, the barrier will cost the most to repair, and its use in narrow medians is not desirable because of the possibility of the vehicle displacing the barrier and knocking the light pole onto the roadway. The barrier would be satisfactory for use on rural roadways with wide shoulders and wide medians. The rigid medium barrier is the most economical when both initial construction costs and estimated repair costs are considered.

•ENGINEERS in Texas became concerned about the performance of certain median barriers being used or being considered for use on Texas highways. Consequently, three different types of median barriers were selected by the Texas Highway Department (THD) for full-scale vehicle crash testing in order to determine their performance under controlled impact conditions.

The three barriers selected by THD were the metal beam guard fence, which consists of two back-to-back steel W-beam guardrails on breakaway steel posts; the E-3, which consists of two different sizes of strong elliptical steel rail members mounted on strong fabricated steel posts; and the concrete median barrier with inclined faces.

Median barriers are effective in preventing head-on vehicle accidents. The three selected median barriers were subjected to severe impact conditions (1): a standard-sized passenger vehicle weighing about 4,000 lb impacting at a speed of 60 mph and an angle of 25 deg. Conducting the tests under similar impact conditions also provides a means of comparing the performance of the three barriers.

Most concrete median barriers are located in narrow medians in large urban areas, and many collisions occur at relatively shallow angles. Therefore, two additional tests were conducted on the concrete median barrier at impact angles of 7 and 15 deg.

One other objective of this study was to determine if a passenger vehicle would snag or dislodge a light pole mounted on the top of the concrete median barrier. One test was conducted under the impact conditions of 60 mph and 25 deg to investigate this problem.

DESCRIPTION OF MEDIAN BARRIERS

Metal Beam Guard Fence

The metal beam guard fence (MBGF) consists of two standard 12-gauge steel W-shaped rail members mounted back-to-back on each side of a 6 WF 8.5 support post (Fig. 1). The posts are spaced on 6-ft, 3-in. centers, and the height above the roadway to the top of the rail member is 27 in.

The $\frac{3}{8}$-in. fillet welds connecting the outer faces of the two post flanges and the base plate are designed to fracture in restraining and redirecting a standard-sized passenger vehicle under high impact speeds and moderate to large angles. Failure of the welded connections allows the two back-to-back rail members to displace several feet laterally, thereby reducing the vehicle decelerations and incidents of injury. Also, failure of the welds allows the posts to displace laterally with the rail member without pulling the rail member down, thereby preventing vehicle ramping.

E-3 Median Barrier

The E-3 median barrier consists of two strong elliptical-shaped steel rail members mounted on strong fabricated steel posts (Fig. 2). The height from the roadway to the top of the lower rail member is 14 in., and the height to the top of the upper rail member is 30 in. The posts are spaced on 10-ft centers.

The rail members are rolled from a round to an elliptical shape to increase the moment-carrying capacity under lateral loading. Also, the lower rail member is larger than the upper rail member because the larger portion of the lateral load is developed in the area of the wheel hub and structural frame of a passenger vehicle, whereas the upper rail member is subjected to primarily sheet metal crushing.

A post consists of two high-strength steel rectangular shapes that extend through the lower rail member. Fillet welds are used to connect the post to the two rail members and the high-strength steel base plate. The base plate is anchored by two $\frac{3}{4}$-in. A325 U-shaped bolts embedded in an 18-in. diameter concrete shaft.

The E-3 median barrier is considered to be a rigid barrier capable of undergoing only small displacements in redirecting a standard-sized passenger vehicle because of the relatively strong posts and rail members.

Concrete Median Barrier

The Texas concrete median barrier (CMB-70) is a massive concrete barrier with inclined plane surfaces (Fig. 3). The prototype CMB has a weight of about 507 lb/lin ft, a height of 32 in. above the roadway, a lower 10-in. high inclined surface of about 55 deg, an upper 18-in. high inclined surface of about 84 deg, a base width of 27 in., and a top width of 8 in.

As shown in Figure 3, the CMB was constructed in two longitudinally reinforced continuous length sections of 150 and 50 ft. The construction joint between the two sections offers no lateral restraint.

The light pole was mounted on top of the shorter 50-ft section. Three 18-in. diameter drilled concrete shafts were used to support the shorter CMB section. The Texas plans and specifications require that a drilled concrete shaft be used directly under each light pole to support a CMB section against possible overturning resulting from wind and vibratory forces on high light poles. The other two exterior drilled concrete shafts were used to prevent movement of the barrier during the full-scale test.

The longer 150-ft CMB section, on which three tests were conducted, contains no mechanical anchors to the roadway. The 1-in. layer of hot-mix asphalt at the base of the CMB provided some restraint to sliding during a vehicle collision.

VEHICLE TEST SETUP

Vehicle Control Apparatus

The test vehicles were guided along collision paths by a cable guidance system. In this system, a breakaway flange attached to the left front wheel hub follows a cable

Figure 1. Metal beam guard fence.

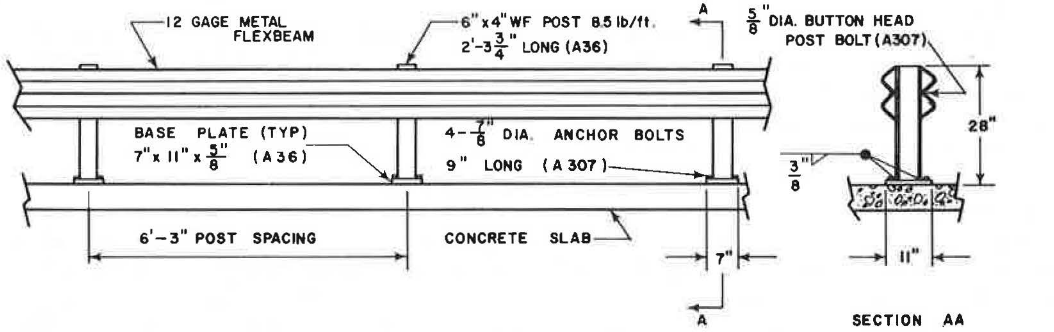
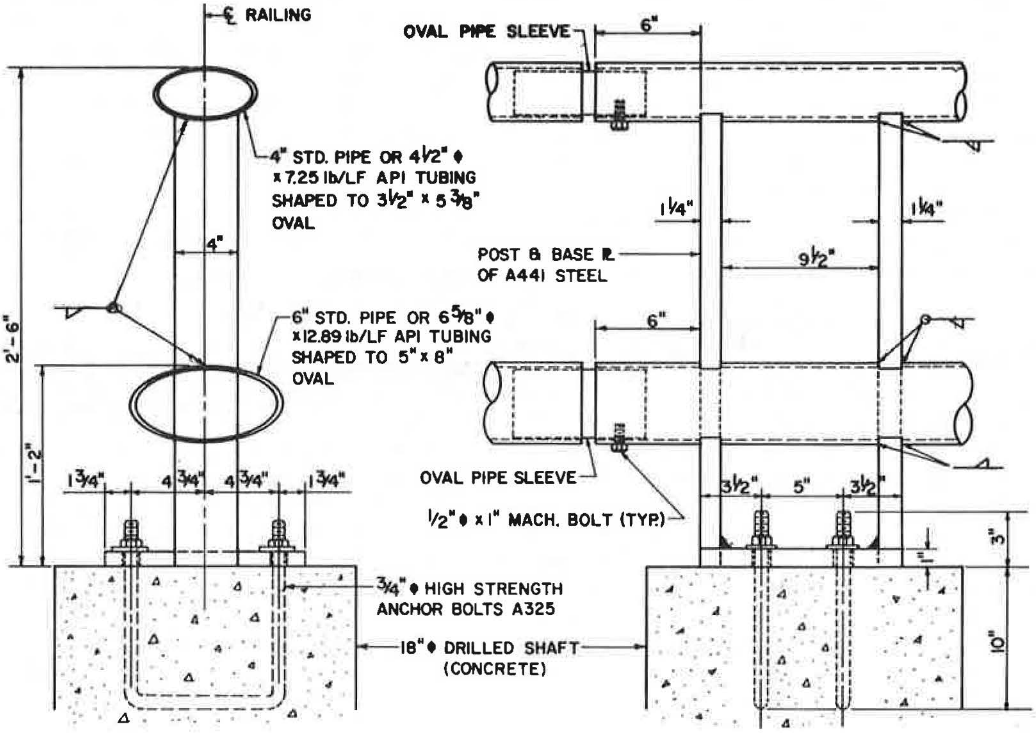


Figure 2. Texas E-3 barrier.



stretched along the path. Before impact, this device shears off and leaves the vehicle unguided.

The vehicles were brought to test speed by a cable attached through a pulley system to a reverse tow vehicle. The cable has an eye in the end that is looped around a pin welded to the front bumper of the test vehicle. As the test vehicle approaches the impact area, the pulley system exerts a downward force on the cable and causes it to disengage from the towing pin on the bumper.

Instrumentation

The barrier tests were recorded photographically using high-speed and documentary motion-picture cameras. The high-speed film (usually 500 frames per second) had accurate timing marks placed on the edge from which elapsed times were computed. Vehicle displacements were measured from the film using stadia boards on the vehicle and range poles on other targets. The position of the vehicle in the horizontal plane was determined by using two cameras and a triangulation technique.

The test vehicles had accelerometers mounted on the longitudinal frame members behind the front seat. One accelerometer was mounted transversely and one longitudinally on each frame member. During the tests on the E-3 and MBGF, the signals from the accelerometers were transmitted by a shielded cable to a nearby instrumentation mobile trailer. The data were recorded on magnetic tape.

The later tests on the CMB were conducted using a telemetry data acquisition system that transmitted the accelerometer data by radio signals to a ground station. The data were recorded on magnetic tape. The telemetry system eliminates the need for a physical connection to the test vehicle.

A 160-lb anthropometric dummy simulated a driver secured by a lap belt. A load cell attached to the belt measured the lap belt force. The accelerometer and lap belt data were passed through an 80-Hz low-pass active filter.

Data Reduction Techniques

The impact speed of the vehicle was determined from film obtained with a camera located perpendicular to the vehicle approach path, and the position of the vehicle was determined at the end of successive small time intervals throughout redirection.

The average lateral and longitudinal decelerations from the film data were calculated from impact to the time when the vehicle was parallel to the barrier. It is to be noted that these decelerations are perpendicular and parallel to the barrier, whereas the decelerations from the vehicle accelerometers are perpendicular and parallel to the longitudinal axis of the vehicle. The longitudinal and lateral decelerations from the film were calculated as given in Tables 1 and 2, which contain a summary of the E-3 and MBGF and CMB test results respectively.

Peak decelerations were read directly from the accelerometer traces, whereas the average decelerations from the traces were computed over the interval from impact to the point where significant accelerations had ceased.

DISCUSSION AND EVALUATION OF TESTS

A discussion and evaluation of the six full-scale tests conducted on the three median barriers follow.

MBGF Test

The MBGF test was conducted at an impact speed of 57.3 mph and an impact angle of 25 deg using a 1963 Plymouth weighing 3,460 lb with instrumentation and dummy. The point of impact was near a support post.

Sequential photographs of the vehicle collision and its redirection are shown in Figure 4. A summary of the test results from an analysis of the film data and accelerometer traces are given in Table 1.

A peak longitudinal deceleration of 12.8 g indicated that snagging on the posts was not severe. The change in heading speed of the vehicle during redirection was 25 mph, the

Figure 3. Texas CMB-70.

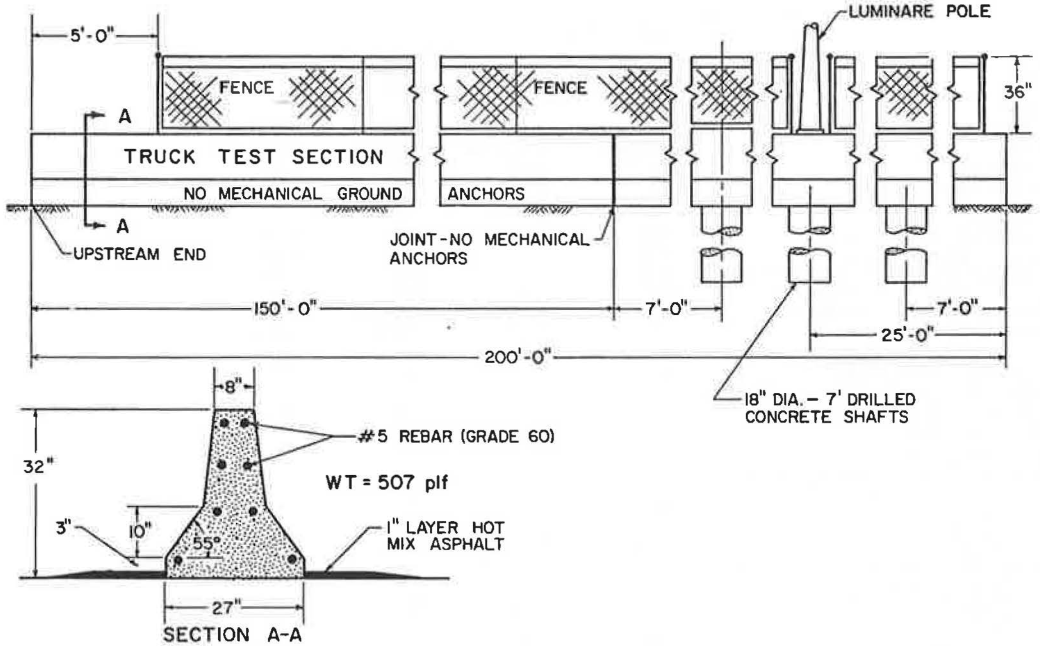


Table 1. Test data summary for E-3 and MBGF tests.

Item	Barrier Test	
	E3	MBGF
Vehicle		
Year	1963	1963
Make	Plymouth	Plymouth
Weight (lb)	3,610	3,640
Impact angle (deg)	25	25
Film data		
Initial impact speed (mph)	59.3	57.3
Speed at parallel (mph)	28.9	32.7
Longitudinal distance to parallel (ft)	20.7	17.5
Dynamic barrier displacement (ft)	0.7	1.5
Lateral distance to parallel (ft)	3.4	4.28
Time to parallel (sec)	0.394	0.270
Average longitudinal deceleration[a], parallel to barrier (g)	3.3	3.0
Average lateral deceleration[b], normal to barrier (g)	6.2	4.6
Departure angle (deg)	8.7	19.7
Accelerometer data		
Longitudinal deceleration, parallel to longitudinal axis of vehicle (g)		
Maximum	21.3	12.8
Average	4.1	3.0
Time (sec)	0.533	0.560
Transverse deceleration, normal to longitudinal axis of vehicle (g)		
Maximum	6.1	–
Average	0.4	–
Time (sec)	0.537	–

[a] $G_{long} = \frac{(V_I \cos\theta)^2 - V_P^2}{2g\,S_{long}}$.

[b] $G_{lat} = \frac{V_I^2 \sin^2\theta}{2g\,S_{lat}}$ where $S_{lat} = AL \sin\theta - B(1 - \cos\theta) + D$.

Table 2. Test data summary for CMB tests.

Item	Barrier Test CMB-1	CMB-2	CMB-3	CMB-4
Vehicle				
Year	1963	1964	1963	1963
Make	Plymouth	Chevrolet	Chevrolet	Chevrolet
Weight (lb)	4,000	4,230	4,210	4,210
Impact angle (deg)	25	25	7	15
Film data				
Initial impact speed (mph)	62.4	55.7	60.9	60.7
Speed at parallel (mph)	47.2	–	58.8	50.5
Longitudinal distance to parallel (ft)	15.3	–	17.6	23.0
Dynamic barrier deceleration (ft)	0.0	0.0	0.0	0.0
Lateral distance to parallel (ft)	2.9	2.9	0.85	1.74
Time to parallel (sec)	0.223	0.320	0.206	0.298
Average longitudinal deceleration[a], parallel to barrier (g)	2.0	–	0.4	1.3
Average lateral deceleration[b], normal to barrier (g)	8.0	6.4	2.2	4.7
Departure angle (deg)	7.3	6.0	6.5	11.5
Accelerometer data				
Longitudinal deceleration, parallel to longitudinal axis of vehicle (g)				
Maximum	8.7	10.3	8.4	7.8
Average	3.2	1.8	0.5	1.4
Time (sec)	0.184	0.271	0.325	0.244
Transverse deceleration, normal to longitudinal axis of vehicle (g)				
Maximum	16.1	13.3	29.2	14.0
Average	4.4	2.8	1.8	3.0
Time (sec)	0.254	0.280	0.282	0.264

[a]See Table 1 footnote. [b]See Table 1 footnote.

Figure 4. MBGF test.

t = 0.000 sec

t = 0.079 sec

t = 0.123 sec

t = 0.198 sec

t = 0.277 sec

t = 0.358 sec

t = 0.512 sec

t = 0.664 sec

departure angle from the barrier was 20 deg, and the maximum dynamic lateral displacement of the barrier was 1.5 ft.

The large departure angle was due to the side ramping effect resulting from the large displacements of the rail member. In any event, the large departure angle would probably not create a hazardous condition to other nearby traffic because the severely damaged wheel pulled the vehicle toward the barrier after redirection (Fig. 5).

The effectiveness of the breakaway fillet welded post connection in allowing the posts to displace laterally without pulling the rail member down, and thereby preventing any tendency of the vehicle to ramp, is evident in the photographs of the damaged barrier.

It can be seen in Figure 5 that the MBGF remained intact under the severe test conditions. Maintenance would essentially require the replacement of three posts and one 25-ft length section of the two back-to-back W-beam guardrails. It appears that the damaged barrier would, prior to repair, be functional under a possible second low-angle collision.

The damaged test vehicle is shown in Figure 6. The left front quarter was damaged, but the windshield remained intact and the passenger compartment area was not warped.

E-3 Test

The E-3 test was conducted at an impact speed of 59.3 mph and an impact angle of 25 deg using a standard-sized 1963 Plymouth weighing 3,610 lb with instrumentation and dummy. The point of impact was slightly upstream from the splice connections in the rail members and support post (Fig. 7).

Sequential photographs of the vehicle collision and its redirection are shown in Figures 8 and 9. Summary data are given in Table 1.

The longitudinal accelerometer traces on the right and left frame members of the vehicle indicated that a large amount of snagging occurred on a support post during the time interval of 100 to 160 msec after impact. The peak acceleration was 21.3 g. The tire marks and the motion of the vehicle (Fig. 9) show that the vehicle had climbed on the lower rail member. It appears that the snagging on a post could be greatly reduced by placing the lower rail member higher.

As indicated in Table 1, the change in heading speed of the vehicle during redirection was 30 mph, the departure angle from the barrier was 9 deg, and the maximum dynamic lateral displacement of the top rail member was 0.7 ft.

It can be seen in Figure 7 that the barrier remained intact and was not extensively damaged under the test conditions. Maintenance would require the replacement of one 10-ft long upper rail member and straightening of one support post. It appears that the damaged barrier would, prior to repair, be functional under a possible second collision.

The damaged test vehicle is shown in Figure 10. It can be seen that the left front quarter and wheel were severely damaged, the windshield was knocked out, and the passenger compartment area was warped.

CMB-1 Test

The first rigid concrete median barrier test, designated CMB-1, was conducted to determine if a standard-sized 4,000-lb vehicle would snag and knock down a light pole mounted on top of the barrier under the impact conditions of about 60 mph and 25 deg.

Sequential photographs of the vehicle collision and its redirection are shown in Figures 11 and 12. The contact point of the left front fender was approximately 9 ft upstream from the light pole. As the vehicle was redirected, it climbed to the top of the barrier and lightly scraped the light pole and fence.

The change in heading speed during redirection was 15 mph, the average lateral vehicle deceleration was 8.0 g, and the departure angle from the barrier was 7 deg (Table 2).

The damaged vehicle is shown in Figure 13. As can be seen, the front quarter and wheel were severely damaged, the door on the side of the driver was sprung open, and the windshield was cracked.

Figure 5. Damage to MBGF.

Figure 6. Vehicle damage after MBGF test.

Figure 7. Damage to E-3 barrier.

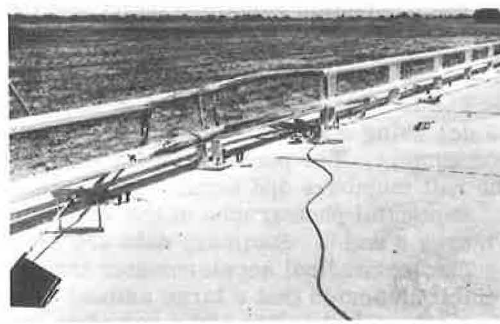


Figure 8. E-3 barrier test (rear view).

t = 0.000 sec

t = 0.063 sec

t = 0.116 sec

t = 0.213 sec

t = 0.309 sec

t = 0.382 sec

t = 0.441 sec

t = 0.567 sec

Figure 9. E-3 barrier test (side view).

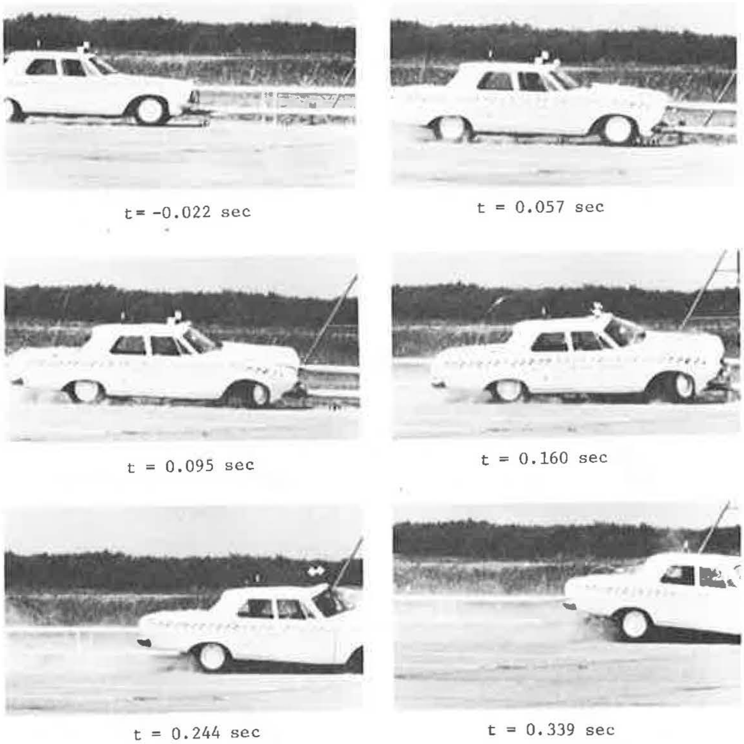
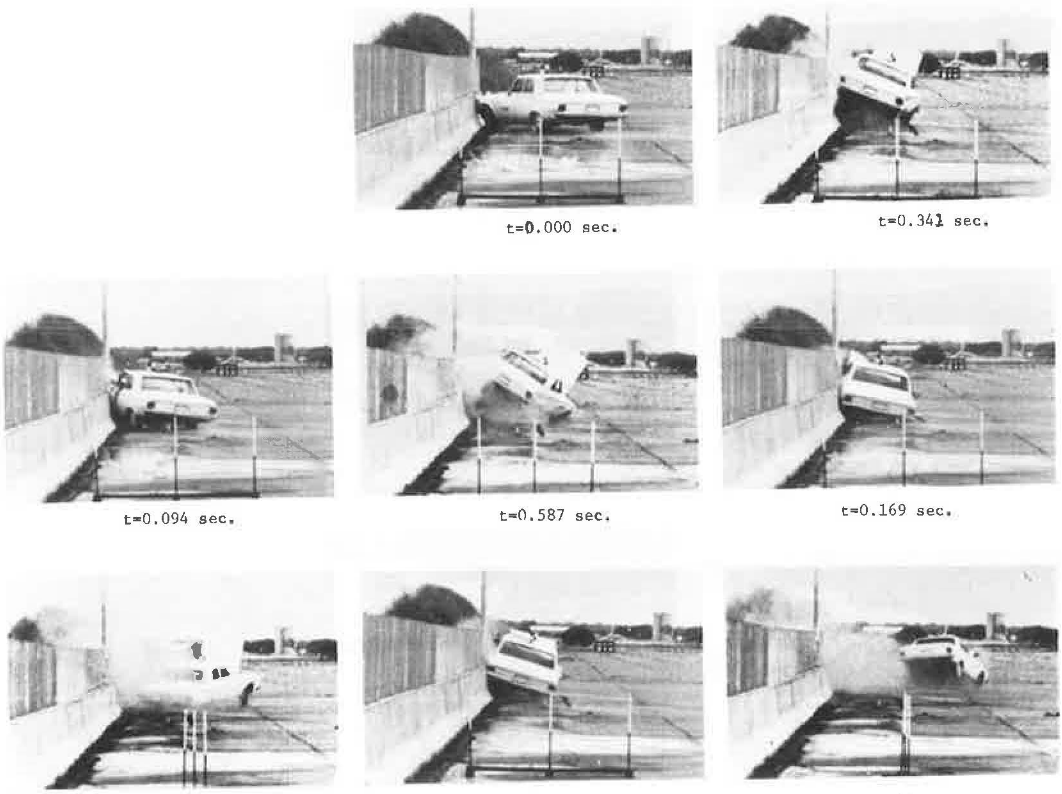


Figure 10. Vehicle damage after E-3 test.

Figure 11. CMB-1 test (rear view).

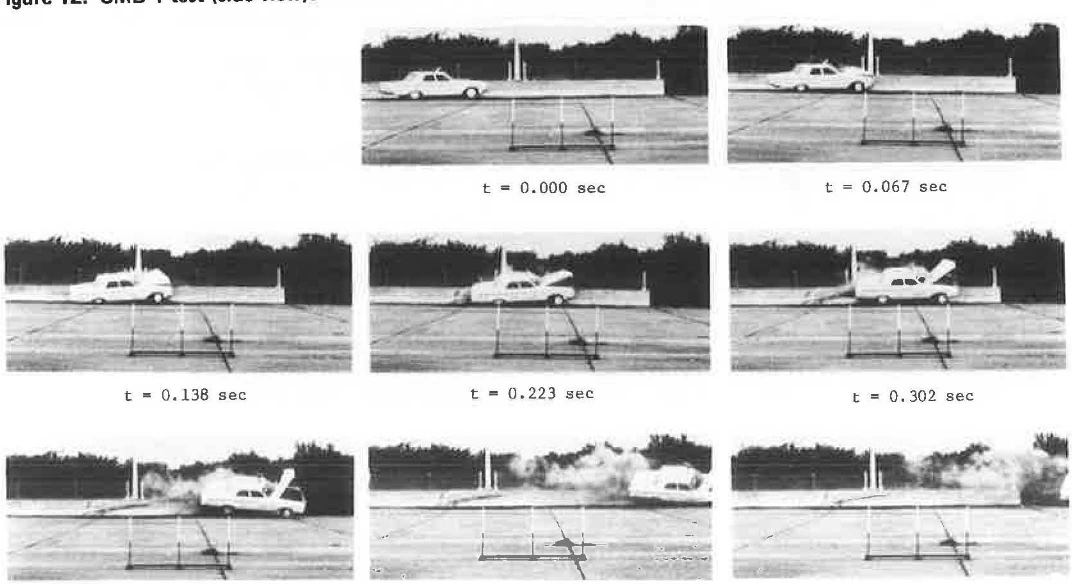


t=0.000 sec. t=0.341 sec.

t=0.094 sec. t=0.587 sec. t=0.169 sec.

t=0.954 sec. t=0.223 sec. t=1.396 sec.

Figure 12. CMB-1 test (side view).



t = 0.000 sec t = 0.067 sec

t = 0.138 sec t = 0.223 sec t = 0.302 sec

t = 0.456 sec t = 0.631 sec t = 0.742 sec

CMB-2 Test

The CMB-2 test was conducted to determine if the 150-ft unanchored section of the CMB, with continuous steel reinforcement, would slide or rotate or both in restraining and redirecting a standard-sized 4,000-lb passenger vehicle under the impact conditions of about 60 mph and 25 deg.

The vehicle-barrier interaction in the CMB-2 test was similar to that of the CMB-1 test. While the vehicle was being redirected, the left front fender was crushed, and the tire rode up to the top of the barrier. Sequential photographs of the vehicle collision and redirection are shown in Figure 14, and photographs of the minor barrier damage are shown in Figure 15.

Linear displacement voltage transducers (LDVT) placed on the barrier showed that the lateral and rotational displacements of the barrier were negligible. The LDVT placed 2 in. above the asphalt showed a maximum displacement of 0.03 in., whereas the LDVT placed near the top of the barrier showed a maximum displacement of 0.09 in.

The average lateral vehicle deceleration in this test of 6.4 g was smaller than that in the previous test because the impact speed was about 6 mph less. For all practical purposes, the departure angle of 6 deg in this test was the same as in the previous test (Table 2).

The damaged vehicle is shown in Figure 16. It can be seen that the 6-mph lower impact speed in this test also resulted in slightly less vehicle damage than that encountered in the CMB-1 test. For instance, the door was not sprung open in this test.

CMB-3 Test

Concrete median barriers with inclined faces are currently being used mostly on urban roadways having narrow medians and carrying high traffic volumes. The majority of the accidents under these conditions usually occur at shallow angles of 15 deg and less. This test, designated CMB-3, was therefore conducted to evaluate the performance of the barrier in redirecting a 4,000-lb passenger vehicle under representative in-service impact conditions of about 60 mph and 7 deg.

This test was again run on the 150-ft length section of the CMB that was not anchored to the roadway. Sequential photographs of the vehicle collision and redirection are shown in Figure 17. The vehicle quickly climbed up the lower face of the barrier and was redirected when the tire contacted the steeper upper face of the barrier. The maximum height of climb was approximately 18 in.

The departure angle was, for all practical purposes, the same as in the two previous 25-deg angle collisions. The change in the vehicle heading speed of 2 mph was much lower than in the 25-deg angle collision because the redirection of the vehicle occurred primarily as the result of an interaction between the vehicle tire and the barrier. Also, the average lateral vehicle decelerations of 2.2 g were very low in comparison to the previous tests (Table 2).

The damaged test vehicle is shown in Figure 18. The relatively minor damage consisted of bumper and sheet-metal crushing.

CMB-4 Test

The CMB-4 test was conducted to determine the performance of the barrier in redirecting a 4,000-lb passenger vehicle under somewhat of an upper bound on in-service collisions of 60 mph and 15 deg.

The 150-ft unanchored section of the CMB was again used. Sequential photographs of the vehicle collision and redirection are shown in Figure 19. The vehicle motion was similar to that in the two previous 25-deg tests in that the vehicle climbed all the way to the top of the barrier and caused minor damage to the barrier and fence.

For some unknown reason, the change in the vehicle heading speed of 11 mph was roughly double the speed of the CMB-1 test, which was run at a much larger impact angle and, hence, probably developed greater sheet-metal frictional forces. However, the greater change in heading speed could be the reason for the departure angle of 12 deg being roughly double the departure angles in previous test runs. In any event, it appears

Figure 13. Vehicle damage after CMB-1 test.

Figure 14. CMB-2 test.

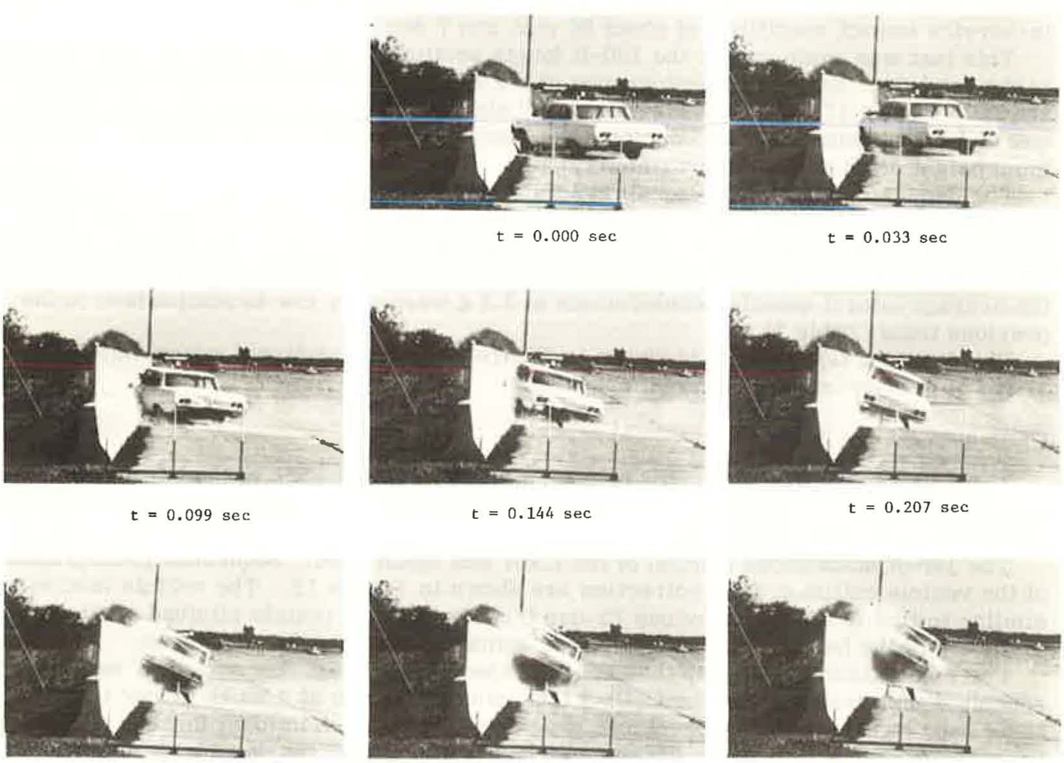


Figure 15. Damage to CMB-2.

Figure 16. Vehicle damage after CMB-2 test.

Figure 17. CMB-3 test.

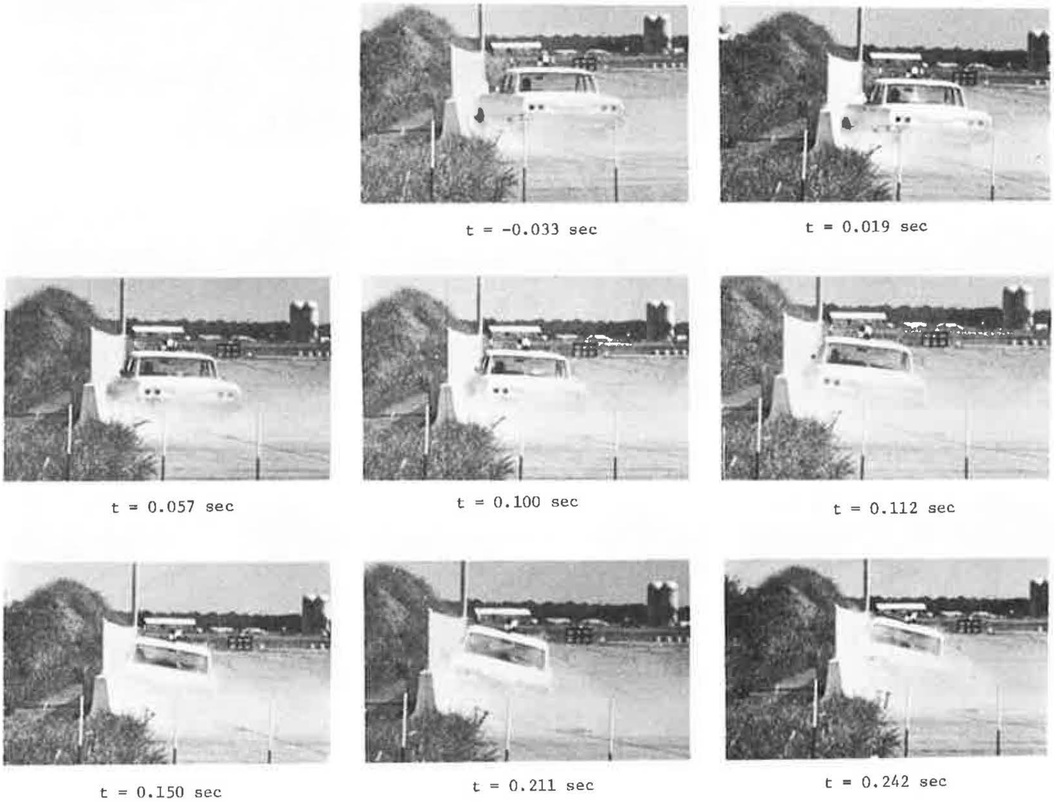
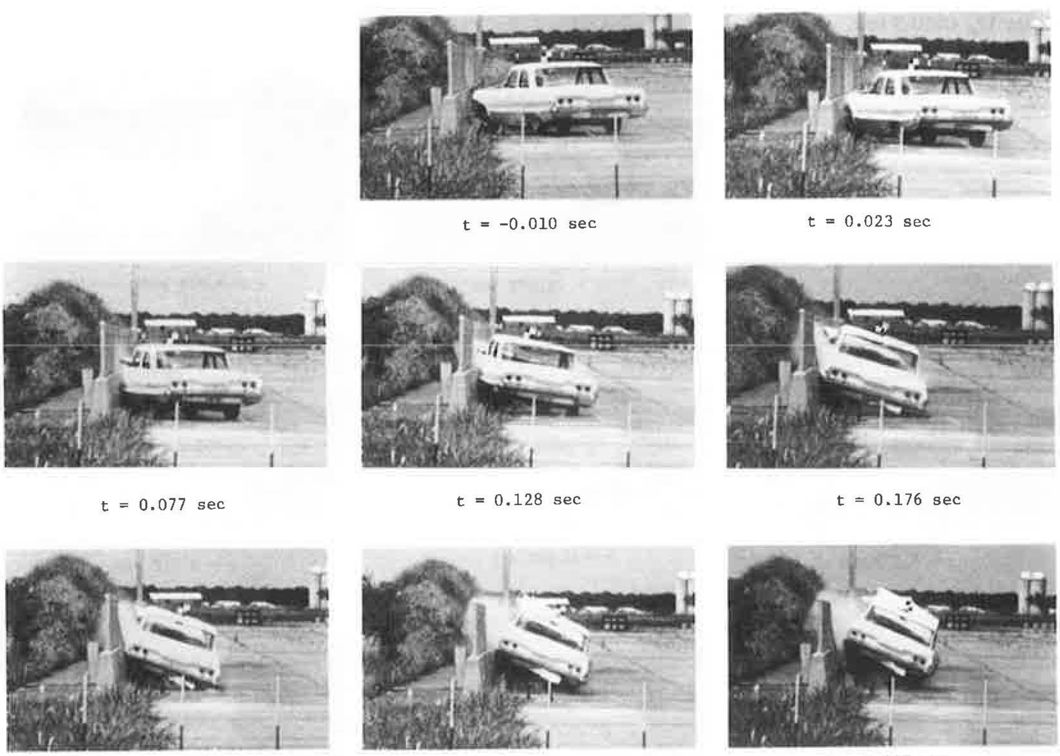


Figure 18. Vehicle damage after CMB-3 test.

Figure 19. CMB-4 test.



t = -0.010 sec

t = 0.023 sec

t = 0.077 sec

t = 0.128 sec

t = 0.176 sec

t = 0.199 sec

t = 0.273 sec

t = 0.327 sec

that this larger departure angle would most likely not create any hazardous situation to other nearby vehicles because the drag forces of the damaged front wheel pulled the vehicle back toward the barrier.

The damaged vehicle is shown in Figure 20. The damage to the vehicle in this test was slightly less than the damaged vehicles in the CMB-1 and CMB-2 tests that were run at larger impact angles.

INJURY PROBABILITY

Vehicle damage appears to be, at the present time, a good indicator of the probability of occupant injury. Michalski (2) recently established from a statistical analysis of accident information a relation among type of collision, vehicle damage, and percentage of vehicles in which injuries occurred to unrestrained occupants.

Predictions on the probability of injury for the three median barriers of different configuration and lateral stiffness are given in Table 3. These predictions were based on the average damage rating values of nine research engineers using the seven-point photographic scales developed by the National Safety Council (3).

The comparison of the three barriers during a 25-deg collision clearly illustrates the desirable effect of barrier displacements in enhancing safety; that is, the semirigid MBGF undergoing the largest displacement of 1.5 ft resulted in the lowest probability of injury. Also, the effects of snagging are reflected in the results given in Table 3 because the relatively rigid E-3 barrier undergoing a displacement of 0.7 ft resulted in the highest probability of injury.

A comparison of the safety aspects of the three median barriers cannot be reached in this study for the more representative in-service impact conditions of 15 deg and less because no tests were conducted on the E-3 and MBGF.

ESTIMATED CONSTRUCTION COSTS AND REPAIR COST

In order to properly evaluate the three selected barriers, it is important that one take into consideration initial construction costs and maintenance costs.

Initial construction costs for the three selected barriers are given in Table 4. The unit cost breakdowns were adjusted to agree with the total cost per linear foot figures obtained from the Texas Highway Department (5). As evident, the construction cost of $19.20/lin ft for the E-3 barrier is relatively high in comparison to the more efficient CMB with a cost of $13.40/lin ft and the MBGF with a cost of $11.75/lin ft.

The estimated maintenance repair costs for the three barriers after the comparable 4,000-lb automobile tests of 60 mph and 25 deg are given in Table 5. The initial construction costs for the E-3 and MBGF were increased by a factor of 1.5 for purposes of repair to a small section.

CONCLUSIONS

A summary of the comparative results made on the three Texas median barriers is given in Table 6. One could conclude from the results that the MBGF is the most economical barrier with regard to initial construction costs and that it is the safest with regard to probability of injury to unrestrained occupants during a crash under test conditions. However, the MBGF would cost the most to maintain, and its use in narrow medians is not desirable because of the possibility of the vehicle displacing the barrier a sufficient distance and knocking the light pole onto the roadway. It appears that the MBGF would probably be satisfactory for use on rural roadways with wide shoulders and wide medians.

One could further conclude that the CMB is the most economical when both initial construction costs and estimated maintenance costs are considered. The CMB with light poles would be very desirable for use on urban roadways with narrow medians and carrying high-speed and high-volume traffic. In addition, low maintenance reduces the amount of exposure time and, hence, increases safety to maintenance personnel.

It is important that one keep in mind that all three median barriers investigated in this study have performed adequately while in service. Also, other factors in addition

Figure 20. Vehicle damage after CMB-4 test.

Table 3. Injury probability.

Angle (deg)	Rigid CMB (percent)	Rigid E-3 (percent)	Semirigid MBGF (percent)
7	10	No test	No test
15	60	No test	No test
25	70	80 (snagging)	50

Table 4. Initial construction costs.

Barrier	Structural Component	Unit Cost Including Labor	Dollar Cost per Linear Foot
CMB-70	Steel forms (rental and labor)		4.00
	8-pcs No. 5 reinforcing steel	$0.30/ft	2.40
	Concrete (ready-mix)	$45/yd^3	5.50
	Site preparation, stabilize soil, 1 in. asphalt at base, contingencies		1.50
	Total		13.40
E-3	Top rail member (7.25 lb/ft)	$0.60/lb	4.35
	Bottom rail member (12.89 lb/ft)	$0.60/lb	7.75
	Fabricated posts (10 ft on centers)		4.25
	Drilled concrete shafts (18-in. diameter)		1.00
	Base plates and anchor bolts		1.00
	Contingencies		0.85
	Total		19.20
MBGF	2 to 12 gauge steel W-beams	$0.45/lb	6.00
	6 B 8.5 posts (6 ft, 3 in. on centers)	$0.45/lb	1.50
	Drilled concrete shafts (18-in. diameter)		1.80
	Base plates and anchor bolts		1.60
	Contingencies		0.85
	Total		11.75

Note: These costs do not include the costs of the fence and light poles because in roadway medians they would be common to all three barriers.

Table 5. Estimated maintenance costs.

Barrier	Required Maintenance	Dollar Cost per Linear Foot[a]	Total Cost[b] (dollars)
CMB-70	Occasional sandblasting to remove tire scrub marks		0
E-3	Replace one 10-ft long section upper rail Straighten one support post Paint touchup (galvanized)	19.20 (1.5)	290
MBGF	Replace one 25-ft long section of two back-to-back W-beam guardrails Replace three breakaway support posts	11.75 (1.5)	440

[a]The initial construction costs for the E-3 and MBGF barriers were increased by a factor of 1.5 for purposes of repair to a small section.
[b]Values rounded off to the nearest $10.

Table 6. Comparative summary of three barriers.

Basis for Comparison	CMB-70 (longitudinally reinforced concrete)	E-3 (tubular rails)	MBGF (back-to-back W-beams)
Initial construction cost[a] (dollar/ft)	13.40	19.20	11.75
Estimated maintenance after impact (dollars)	0	290	440
Predicted probability of injury (percent)	70	80	50
National Safety Council vehicle damage rating	5.8	6.1 (snagging)	5.2
Should barrier be used on narrow medians with light poles under test impact conditions	Yes (negligible barrier displacements)	Probably (small barrier displacements of 0.7 ft, lower rail raised to prevent snagging)	Probably not (barrier displacements of 1.5 ft may allow automobile to knock down light pole)
Appearance	Simple and smooth lines	Smooth and thin tubular rails	Adequate

Note: Data based on 4,000-lb automobile impacting at 65 mph and 25 deg.
[a]Cost does not include chain link fence (glare screen) or light poles.

to those presented here should be considered when selecting a barrier. For example, Hutchinson and Kennedy (6) present data that indicate that approximately 75 percent of vehicle collisions are at angles of 15 deg or less. At lower impact angles, the safety and maintenance aspects of all three median barriers would improve.

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The contents of this paper reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

REFERENCES

1. Highway Research Board Circular 482, Sept. 1962.
2. Michalski, C. S. Model Vehicle Damage Scale: A Performance Test. Traffic Safety, Vol. 12, No. 2, June 1968, pp. 34-39.
3. Vehicle Damage Scale for Traffic Accident Investigation. Traffic Accident Data Project, National Safety Council, TAD Bull. 1, 1968, 18 pp.
4. McFarland, W. F., and Walton, N. E. Economic and Accident Potential Analysis of Roadway Lighting Alternatives. Highway Research Record 377, 1971, pp. 92-102.
5. Texas Highway Department D-8 Interoffice Memorandum to Mr. John Nixon from R. S. Williamson, April 10, 1972.
6. Hutchinson, J. W., and Kennedy, T. W. Medians of Divided Highways—Frequency and Nature of Vehicle Encroachments. Eng. Exp. Sta., Univ. of Illinois, Bull. 487, 1966.