

CRASH TEST EVALUATION OF THRIE BEAM TRAFFIC BARRIERS

M. E. Bronstad and J. D. Michie, Southwest Research Institute;
J. G. Viner, Federal Highway Administration; and
W. E. Behm, Anderson Safeway Guard Rail Corporation

Since its general nationwide adoption, the standard W-beam or flex-beam has been widely used as a traffic barrier element; its performance has been proved in crash tests and field use. However, the mounting height of the W-beam has been shown to be critical in tests as well as field installations. Background information on the conception and development of a configuration known as the Thrie beam is presented in this paper along with findings of a crash test series (five tests) on this new barrier element. Basically, the Thrie beam can be described as a triple corrugated beam as compared to a double corrugated W-beam. It is $1\frac{1}{2}$ times the width of the W-beam, but the corrugation geometry and $3\frac{1}{4}$ -in. (83-mm) depth are similar. The crash test series was conducted on blocked-out steel post median barrier and guardrail systems. Test conditions included 4,500- to 2,200-lbm (2.0- to 1.0-Mg) vehicles with speeds ranging from 54 to 67 mph (87 to 108 km/h) and impact angles varying from 16 to 29 deg.

•THE NEED for a rail element deeper than the 12-gauge U. S. standard steel W-beam ($12\frac{1}{4}$ in. or 311 mm deep) was recognized by the Federal Highway Administration as a result of problems experienced with one particular guardrail system and crash test results of other traffic railing designs. This guardrail system, using the New York weak-post W-beam design, was originally installed with the top of the rail 27 in. (0.7 m) above the ground (1,2). Field experience with this design disclosed that a surprising percentage of vehicles were going over the installation during collision (2,3). After further examination of this problem, the mounting height of this system was increased to 33 in. (0.8 m) (3,4, Table 6). Tests conducted on this design showed problems with small cars contacting the posts at the 33-in. mounting height (5).

About this time, a test (T1-D) was conducted on a bridge rail that used two standard W sections overlapped (6). This 18-in. (0.5-m) deep rail is shown in Figure 1a after a 60-mph (97-km/h), 25-deg impact with a 3,600-lbm (1.6-Mg) vehicle (test T1-D), and the vehicle is shown in Figure 1b. The results of a similar test (T1-B) with a normal 12-gauge W section without the second overlapping section are shown in Figure 2. In this case, the 18-in. (0.5-m) deep overlapped W rails clearly reduced both vehicle damage and barrier damage (6). Thus, FHWA staff speculated that such an 18-in. deep section might help solve the problems noted in the G2 guardrail system.

Following the tests conducted on the Texas T-1 bridge rail, Walker and Warner (7) developed and tested a guardrail-bridge rail transition that used a lapped W-beam similar to that used in test T1-D. Energy-absorbing cartridges between the rail section and the posts were used, and the investigation concluded that, for the conditions examined, "overall acceleration loads and velocity changes are reduced while postcrash controllability is increased, as compared to the performance of G-4 guardrail systems." At this point it appeared that a new 18-in. deep section would be helpful in the guardrail-bridge rail design developed by Warner and Walker, and the following potential uses for such a shape were identified:

Figure 1. Barrier and vehicle damage after test T1-D.

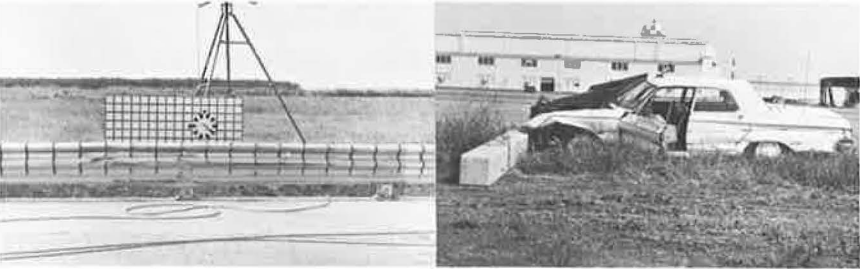
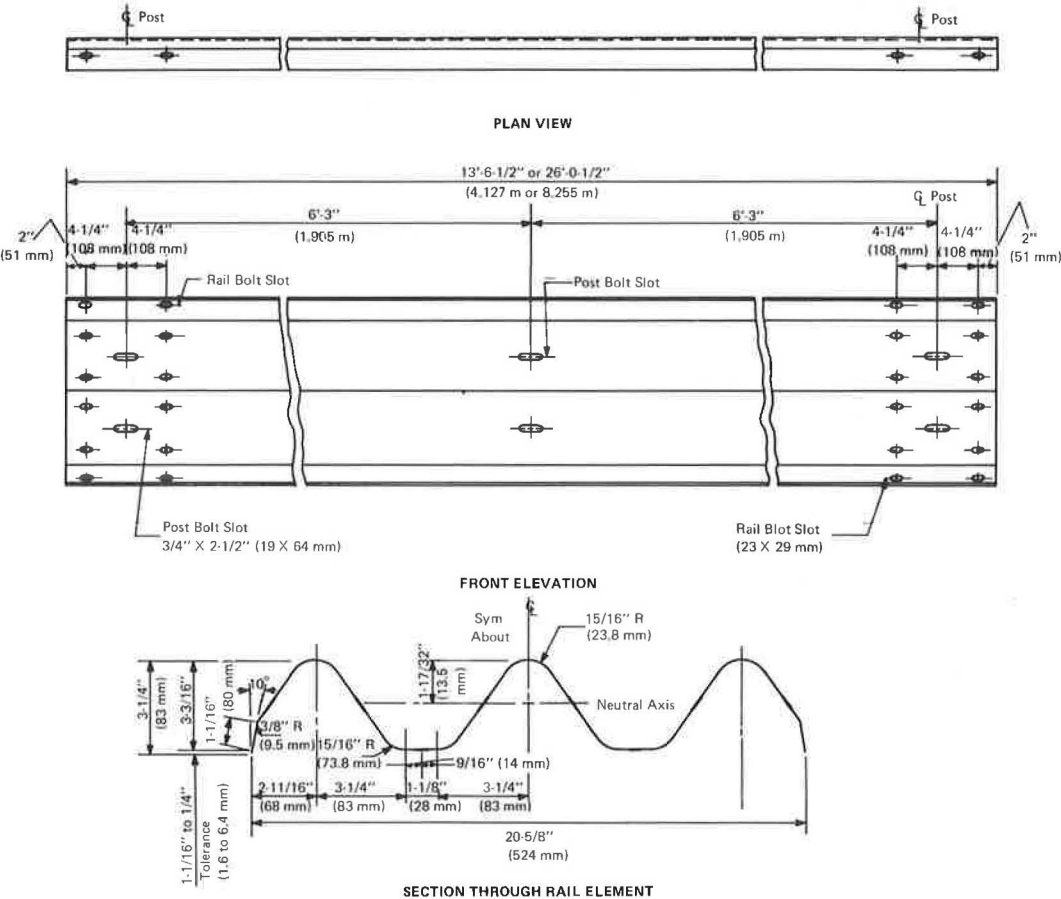


Figure 2. Barrier and vehicle damage after test T1-B.



Figure 3. Thrie beam geometry.



1. Weak-post guardrail designs with improved performance for vehicles ranging from subcompacts through standard-sized passenger cars,
2. Upgrading of the safety performance of existing bridge rail designs,
3. Guardrail-bridge rail transitions,
4. Elimination of the rub rail in the California blocked-out W-beam median barrier (MB4W) design, and
5. New guardrails, median barriers, bridge rails, and guardrail-bridge rail transitions capable of improved performance for both large vehicles (buses and trucks) and small subcompact automobiles.

Several guardrail suppliers were contacted to see whether it would be feasible to produce such a rail section. The Anderson Safeway Guard Rail Corporation produced such a shape, and, at the suggestion of the staff of FHWA, the elimination of the rub rail of the MB4W was selected as the first objective of the test program. The cost of such a design would be significantly less than that of the MB4W, possibly making it economical to retool to produce a new deep rail section. This would make the section available for development and use for all of the other applications listed. A drawing of the Thrie beam element as produced by Anderson Safeway is shown in Figure 3. Photographs in Figure 4 show the advantages of the Thrie beam over the current W-beam regarding vehicle bumper-barrier interface. [The vehicles are a 1969 Ford 2-ton (1814-kg) truck, a 1972 subcompact car, and a 1973 medium-sized car.]

CRASH TEST EVALUATION

The objective of this research was to evaluate by crash test Thrie beam barrier systems. A program consisting of five tests examined the dynamic performance of guardrail and median barrier installations composed of 12-gauge (2.8-mm thick) Thrie beam elements and W6 × 8.5-lb steel posts and blocks. The specific objectives and test conditions are discussed by test number.

Test AS-1

Early test results from the California Division of Highways (8) indicate that the maximum mounting height of the 12-in. (304-mm) wide flex-beam that could be used without a rub rail was 27 in. (0.69 m) for the strong-post systems; at higher mounting heights, impacting vehicles tend to wedge under the beam and snag on the posts. A 30-in. (0.76-m) high rail system with rub rail is used for the MB4W, whereas a 27-in. high rail with no rub rail is specified for guardrail (G4W). It is worth noting that California tests median barriers at 65 mph (105 km/h) instead of the standard 60 mph (97 km/h). Most states that specify the MB4W system use the C6 × 8.2 structural steel channel for the rub rail element; however, Michigan and others use a W-beam element.

The cost of the channel rub rail element is significant—as much as 25 percent more than the W-beam element. The function of the rub rail could also be served by increasing the depth of the W-beam. Accordingly, AS-1 test conditions (Fig. 5) were formulated to permit comparison of the Thrie beam installation with California test 103, which featured the standard W-beam mounted on 8 × 8 timber posts with a channel rub rail (8).

Test AS-2

There are still a number of guardrail installations that have a W-beam mounting height of 24 in. (0.6 m) or less. Work reported by California (8) included the following conclusions and observations:

1. A high incidence of vehicle vaulting with 24-in. (0.6-m) mounting height (blocked-out W-beam on 8 × 8 timber posts with 12½-ft or 3.81-m spacing),
2. Recommendation that all future beam barriers be designed with an overall height of at least 26 in. (0.66 m) above the ground, and
3. Less pocketing in tests with 6¾-ft (1.91-m) post spacing with 27-in. (0.69-m) mounting height than with 24-in. mounting height.

Figure 4. Bumper-beam interface.

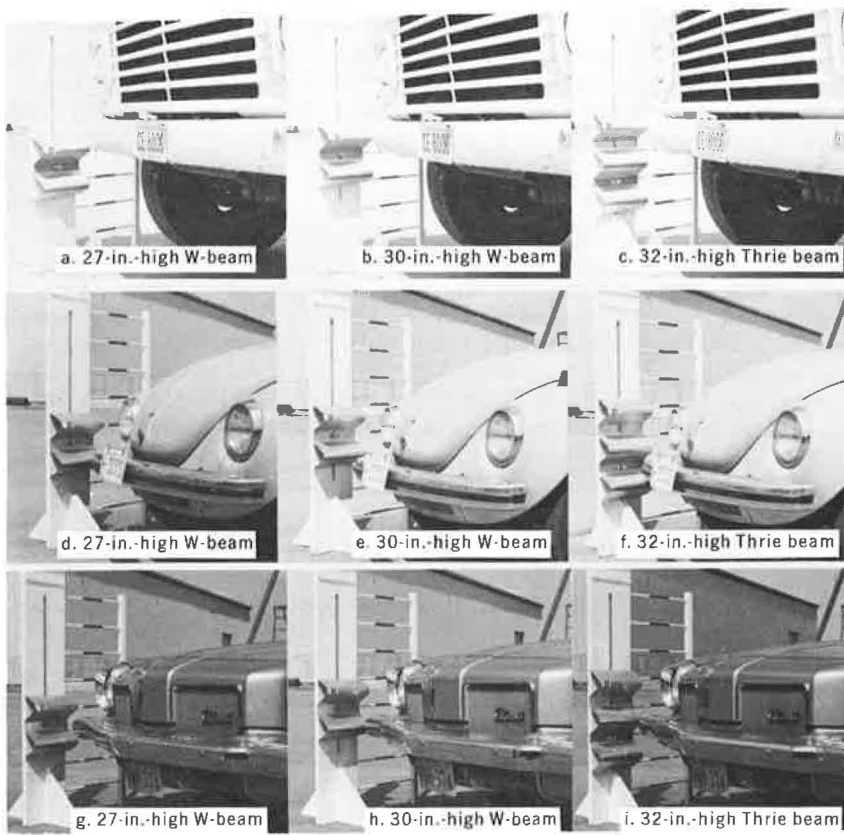


Figure 5. Installation for test AS-1.

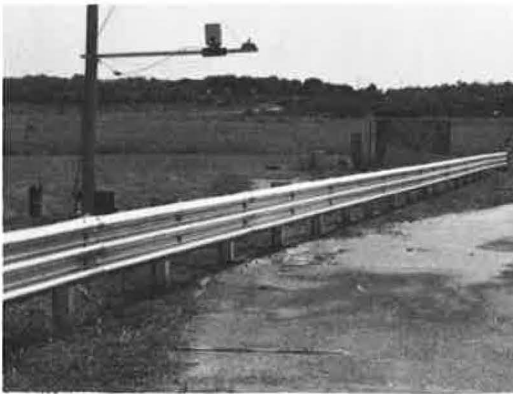


Figure 6. Installation for test AS-2.



The Thrie beam is proposed as a higher warranty barrier, affording better protection for a greater range of vehicles. Because 24-in. or less barriers warrant upgrading, it would be desirable to salvage as much of existing installations as possible in an upgrading program. Hence, test AS-2 was devised to evaluate performance of the 32-in. (0.8-m) Thrie beam system mounted on short posts (Fig. 6) as would occur with upgrading an existing installation by using the in-place posts. Of particular interest was the effect of the block-out projecting 6 in. (150 mm) or more above the top of the post.

Test AS-3

The standard test conditions originally outlined in HRB Circular 482 (9) characterized by a 4,000-lbm (1.8-Mg) vehicle and 60-mph (97-km/h), 25-deg impact are considered to constitute a strength test of the barrier; i.e., these conditions permit evaluation of the capacity of the barrier to restrain and redirect a vehicle impacting at these conditions. It is conjectured that impact angles of 15 deg or less represent the preponderance of actual impact angles. Test AS-3 was designed to evaluate dynamic performance of the 32-in. (0.8-m) Thrie beam median barrier system when impacted by a 2,000-lbm (0.9-Mg) subcompact car at 60 mph from an angle of 15 deg. The installation for test AS-3 is shown in Figure 7

Test AS-4

The purpose of the test was to evaluate the performance of a 32-in. high Thrie beam guardrail system when impacted at 60 mph and 15 deg by a 4,000-lbm (1.8-Mg) vehicle. The test installation for AS-4 is shown in Figure 8.

Test AS-5

The objective of this test was to evaluate the effectiveness of 14-in. (0.36-m) spacer used with 10-gauge (5.5-mm) Thrie beam in a guardrail installation. The M14 \times 17.2 spacer element was selected because of its compatible flange width with the standard W6 \times 8.5 post (Fig. 9). Standard crash test conditions were selected to evaluate performance of this increased spacer block depth; a goal of this test was to prevent wheel contact with posts.

TEST RESULTS

Results of the test series are given in Table 1 with a detailed description of each test.

Test AS-1

A 4,500-lbm (2.0-Mg) vehicle impacted the barrier downstream of post 10 (posts are numbered consecutively beginning upstream) with a speed of 66 mph (106 km/h) and an angle of 26.8 deg. The vehicle was redirected as shown in Figure 10; evidence of wheel contact with posts 12 and 13 was noted. Maximum dynamic deflection of 3.17 ft (0.97 m) occurred between posts 12 and 13.

Damage to the installation included two rail sections between posts 10 and 14, spacer blocks at posts 11 and 12, and post 12. Maximum permanent rail deflection of 22 in. (0.56 m) occurred between posts 12 and 13. Vehicle damage was severe at the left front corner as shown in Figure 11.

Test AS-2

The 4,000-lbm (1.8-Mg) vehicle impacted the barrier downstream of post 10 at a speed of 67.1 mph (106 km/h) and an angle of 28.7 deg. The vehicle was redirected at a large exit angle as shown in Figure 12. Vehicle stability appeared to be good until the vehicle left the pavement. As the vehicle dropped off the pavement, the damaged left wheel plowed into the rain-soaked ground causing complete vehicle rollover; there was evidence of some wheel snagging on post 13.

The barrier maximum dynamic deflection of 3.4 ft (1.04 m) occurred between posts 12 and 13.

Figure 7. Installation for test AS-3.



Figure 8. Installation for test AS-4.



Figure 9. Installation for test AS-5.



Table 1. Summary of Thrie beam tests.

Test	Beam Height (in.)	Post Embedment (in.)	Vehicle Weight (lbm)	Vehicle Speed (mph)	Impact Angle (deg)	Maximum Average Decelerations ^a (g)		Remarks
						Long.	Lat.	
AS-1	33	48	4,500	66.1	26.8	6.6	6.3	Median barrier test; vehicle redirection; no damage to passenger compartment
AS-2	32	42	4,000	67.1	28.7	5.9	7.4	Guardrail test; beam installed on short posts; vehicle redirected at large exit angle, relatively stable before crossing roadway where underside of vehicle plowed into ground causing vehicle upset
AS-3	32	48	2,200	54.1	16.8	2.0	5.3	Vehicle redirected with little damage to barrier or vehicle; vehicle was driveable after test
AS-4	32	48	4,500	59.1	15.9	2.9	4.1	Vehicle redirected with little damage to barrier or vehicle; left rear tire was split by off-site object; otherwise vehicle was driveable
AS-5	32	48	4,000	56.4	25.2	3.9	7.9	Vehicle redirected with no wheel-to-post contact.

Note: 1 in. = 25.4 mm; 1 lbm = 0.45 kg; 1 mph = 1.6 km/h.

^aHighest 50-msec average obtained from high-speed cine analysis.

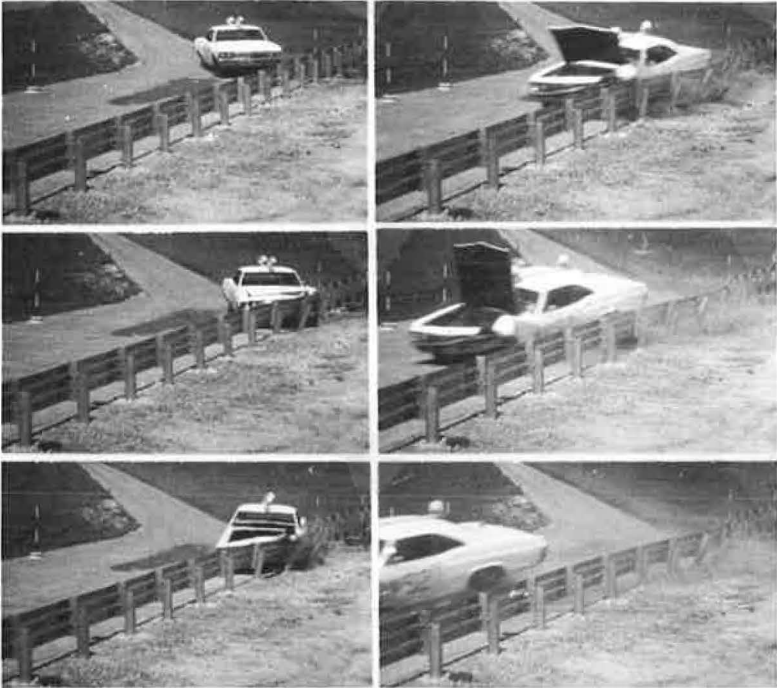
Figure 10. Test AS-1.



Figure 11. Beam and vehicle damage after test AS-1.



Figure 12. Test AS-2.



Damage to the barrier (Fig. 13) included two beam sections between posts 10 and 14. Although locally deformed near grade by the vehicle, post 12 was reusable. All posts and spacer blocks were judged to be reusable. There was no evidence of distress

Vehicle damage was severe because of the rollover; however, the passenger compartment was not deformed badly. Evidence of severe damage to the left corner of the vehicle (Fig. 13) is typical for strong-post guardrail systems under standard test conditions.

Test AS-3

A 2,200-lbm (1.0-Mg) vehicle impacted the barrier 0.1 ft (30 mm) upstream of post 9 at a speed of 54.1 mph (87 km/h) and an angle of 16.8 deg. The vehicle was smoothly redirected as shown in Figure 14. Barrier maximum dynamic deflection of less than 4 in. (100 mm) occurred between posts 9 and 10. No evidence of wheel contact with posts was noted.

Barrier damage as shown in Figure 15 was insignificant. The vehicle was driven from the test site with minimal front-end damage.

Test AS-4

The 4,500-lbm (2.0-Mg) vehicle impacted the barrier 0.1 ft upstream of post 9 at a speed of 59.1 mph (95 km/h) and an angle of 15.9 deg. The vehicle was redirected as shown in Figure 16. No evidence of wheel contact with posts was noted, and the vehicle was very stable throughout the impact. Maximum dynamic deflection of 7 in. (180 mm) occurred between posts 9 and 10. Damage to vehicle and barrier was very moderate (Fig. 17). The left rear vehicle tire was cut during the post impact trajectory; otherwise, the vehicle was driveable and was driven back to the impact zone.

Test AS-5

The 4,000-lbm (2.0-Mg) vehicle impacted the barrier 2.3 ft (0.7 m) downstream of post 9 at a speed of 56.4 mph (90.7 km/h) and an angle of 25.5 deg. The vehicle was redirected with no wheel-to-post contact (Fig. 18). Maximum dynamic deflection of 1.5 ft (0.56 m) occurred between posts 10 and 11. Damage to the barrier was limited to two rail sections inasmuch as most of the energy absorbed by the barrier was dissipated in beam flexure (plastic deformation) and translation of posts in soil (Fig. 19). No crushing or buckling of the 14-in. (0.35-m) spacers occurred. Damage to the vehicle was confined to the left front quarter; significant frame and suspension damage did not occur.

DISCUSSION OF RESULTS

The Thrie beam barrier systems tested in this program are proposed as a higher warranty system than the current W-beam systems. Because of the greater depth of this new element, the sensitivity of installation height is less than that of the standard 12-in. (305-mm) wide W-beam. In addition, the higher mounting height of the Thrie beam system will make it more compatible for impacts of vehicles with high centers of gravity.

Specifically, the findings of this program are as follows:

1. Use of the Thrie beam element eliminates the need for a rub rail in median barrier installations, thus effecting a substantial cost reduction. The capacity of the Thrie beam system to restrain a 4,500-lbm (2.0-Mg) vehicle impacting at 65 mph (105 km/h) and 25 deg on this system was demonstrated in test AS-1.
2. The Thrie beam can be mounted to existing posts of systems requiring upgrading. No structural problems developed in the details of this retrofit in test AS-2.
3. After impacts of both a 2,200-lbm (1.0-Mg) subcompact at 54 mph (87 km/h) and 17 deg with the Thrie beam median barrier design (test AS-3) and a 4,500-lbm (2.0-Mg) standard sedan impact at 59 mph (95 km/h) and 16 deg with the Thrie beam

Figure 13. Beam and vehicle damage after test AS-2.



Figure 14. Test AS-3.



Figure 15. Beam and vehicle damage after test AS-3.



Figure 16. Test AS-4.



Figure 17. Beam and vehicle damage after test AS-4.

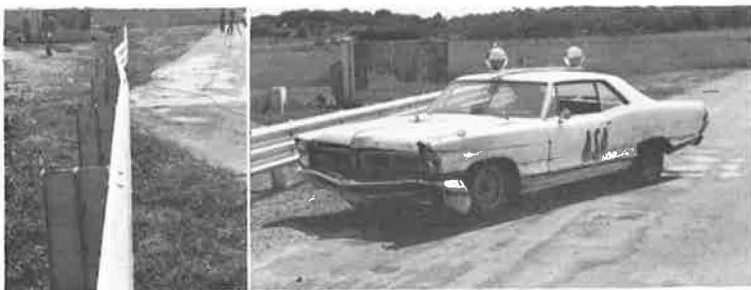


Figure 18. Test AS-5.

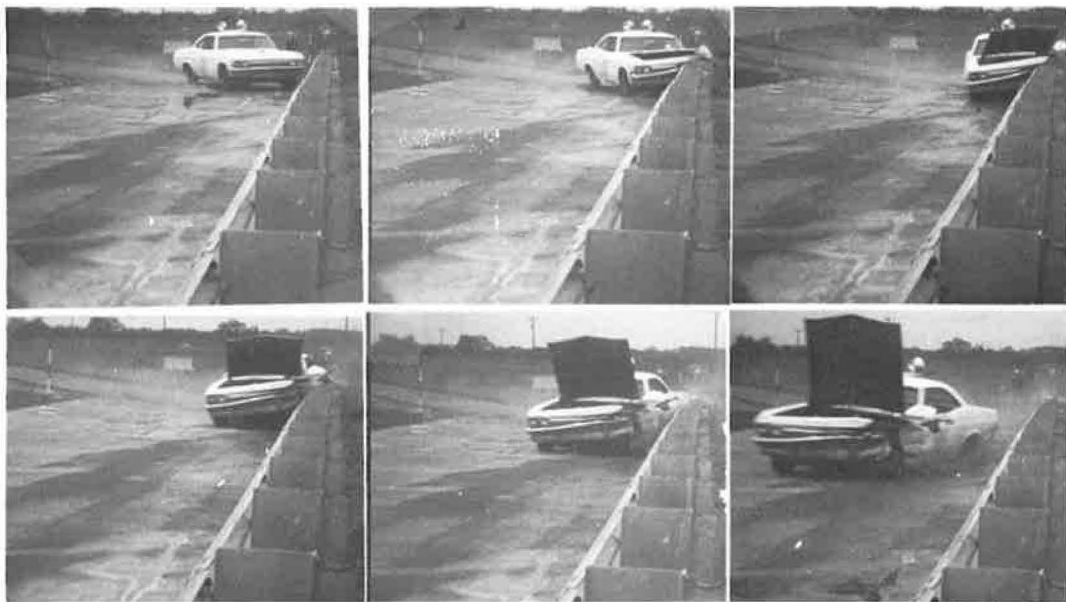


Figure 19. Beam and vehicle damage after test AS-5.



guardrail design (Test AS-4), the vehicles were driveable.

4. Use of 10-gauge (5.5-mm) Thrie beam element with 14-in. (356-mm) spacers prevented wheel contact with posts in test AS-5.

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The opinions, findings, and conclusions expressed in this paper are those of the authors and not necessarily those of the sponsor or other agencies with which the authors are affiliated.

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