

Crash Test Evaluation of Temporary Traffic Barriers

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In and around highway construction zones, delineation devices as well as barriers are used to control and restrict the flow of traffic. The need for positive containment barriers was recognized by the Federal Highway Administration. The Federal Highway Administration further recognized that the use of many temporary barrier devices was not based on documented performance. Accordingly, three temporary barriers were selected for crash test evaluation: (a) 250 x 250-mm (10 x 10-in) timber barrier, (b) W-beam-barrel barrier, and (c) type X curb. These barriers were subjected to controlled impacts with full-sized 2040-kg (4500-lb) automobiles impacting at angles from 7° to 16° at speeds from 56 km/h (35 mph) to 90 km/h (56 mph). Results indicate that the first and third barrier designs had minimal redirection-containment capacity, and performance was judged to be poor. The W-beam-barrel concept performed well during a 72-km/h (45-mph), 15° angle impact; however, the system was penetrated during a 93-km/h (57.6-mph), 16° angle impact.

In or around highway construction zones, delineation devices, barricades, and barriers are used to control and restrict the flow of traffic. The term barrier as used in this paper denotes a device with certain capacity to contain and redirect impacting vehicles. Barricade devices that have minimal strength requirements (e.g., environment) should be much less formidable or hazardous when impacted than a barrier. This distinction between a barrier and a barricade device should be clearly understood.

This paper is concerned with crash test evaluation of some currently used temporary barriers. These barriers were being used without knowledge of containment capacity, and the purpose of the tests was to ascertain performance limits of these selected devices.

BACKGROUND

There are many traffic barriers with known capacities for containment and redirection; however, these barriers are primarily used for permanent installations. There is a need for barriers that are portable to readily accommodate movement during the course of highway construction. Due to the unique requirements of portability, these barriers must accomplish their function without benefit of foundation restraint that is costly to either install or remove.

Three currently used temporary barriers were selected by the Federal Highway Administration (FHWA) for evaluation by crash test. The three barriers, as described in Figure 1, are (a) 250 x 250-mm (10 x 10 in) timber barrier, (b) W-beam-barrel barrier, and (c) type X curb.

All of these barriers are currently in use, although the timber barrier has been banned by FHWA from further applications (1).

TEST PROGRAM

The selected temporary barriers were known not to be of sufficient strength to meet the current barrier strength test requirements set by the National Cooperative Highway Research Program (NCHRP) (2). Since there are no criteria for temporary barriers, test conditions were selected based on what was believed to represent the upper limit of barrier performance. Full-

sized sedans weighing approximately 2000 kg (4500 lb) were selected for the evaluations.

The timber barrier was evaluated for both 7° and 15° angle impacts at speeds from 56 to 62 km/h (35 to 39 mph). The W-beam-barrel barrier was evaluated in three 15° angle tests at speeds of 56, 72, and 88 km/h (35, 45, and 55 mph). The type X curb was evaluated in a 15° angle test at 56 km/h (35 mph).

The crash tests in this program were performed with vehicles running under power with guidance provided by a guide channel that captivated the right wheels of the vehicle. Vehicle ignition and brakes were controlled through a tether line, which also carried the signals from strain gauge accelerometers located in the longitudinal and lateral (or transverse) directions of the vehicle. These transducers were mounted near the vehicle center of gravity (c.g.). Vehicle ignition was turned off just prior to impact. Brakes were not applied in any of these tests. Both high-speed and real-time cameras were used to document the impact events.

Data were derived from two primary sources: (a) micromotion analysis of high-speed film and (b) accelerometers. Data were taken from film using a Vanguard motion analyzer and then processed by the SwRI DATA IV motion analysis computer program.

Data from the strain gauge accelerometers were recorded at 1.5 m/s (60 in/s) on magnetic tape and replayed through SAE J211 class 60 specification filters; the signals were displayed on oscillograph charts.

RESULTS

Results of the test series are summarized in Table 1.

Test TB-1, Timber Barrier

Impact conditions for the vehicle were 61 km/h (38.0 mph) and a 7° angle. The vehicle's left front tire contacted the barrier approximately 13.1 m (43 ft) from the upstream end and immediately climbed up and over the base, as shown in Figure 2. After straddling the barrier, one of the steel strap splices released, allowing the barrier section to pivot and imparting redirection to the vehicle. The vehicle came to rest 1.2 m (4 ft) from the downstream end of the barrier, as shown in Figure 3. The vehicle sustained only minor damage; damage to the upper barrier rails downstream of the impact was total. The 250 x 250-mm (10 x 10-in) base sections were widely displaced, as shown in Figure 3.

Test TB-2, Timber Barrier

Vehicle impact conditions were 55.3 km/h (34.6 mph) and a 15° angle. The vehicle's left-front tire contacted the barrier 14.6 m (48 ft) from the upstream end. As shown in Figure 4, the vehicle vaulted over the base and with little redirection continued over and through the barrier. Two of the base sections were displaced, as shown in Figure 5. The vehicle came to rest with the rear end 6.1 m (20 ft) behind the barrier.

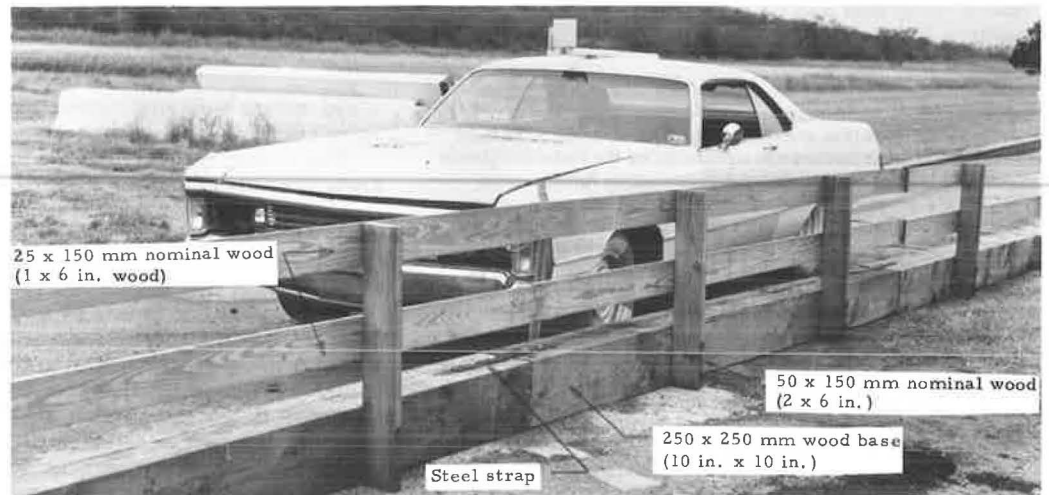
Vehicle damage resulted from spearing of the grill by one of the upper rail members. There was consider-

able damage to the vehicle front suspension, transmission, and rear-end (differential) assembly.

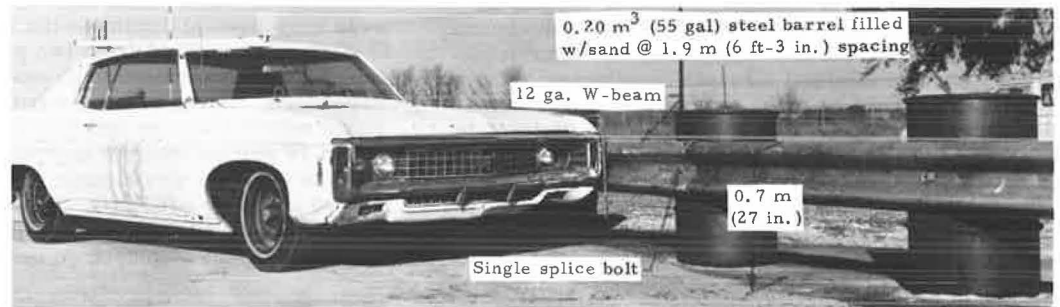
Test TB-3, W-Beam-Barrier

Vehicle impact conditions were 57 km/h (35.5 mph) and a 14.3° impact angle. As shown in Figure 6, the barrels

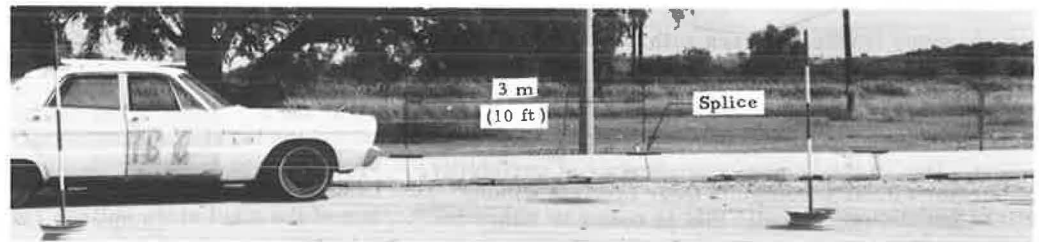
Figure 1. Temporary barrier test installations.



(a) Timber barrier
[Test installation length = 43.9 m (144 ft)]



(b) W-beam/barrel barrier
[Test installation length = 30.5 m (100 ft)]



(c) Type X concrete curb
[Test installation length = 30.5 m (100 ft)]

Table 1. Summary of crash test results.

Test	Barrier	Vehicle Weight (kg)	Impact Speed (km/h)	Impact Angle (degrees)	Maximum Average (50 m/s) Accelerations Obtained From High-Speed Cine		Barrier Maximum Lateral Displacement (m)	Remarks
					Longitudinal (g)	Lateral (g)		
TB-1	Timber	2040	61.0	6.9	-0.7	-1.6	4.6	Vehicle redirected, straddled barrier
TB-2	Timber	2040	55.3	15.5	-1.1	-2.4	4.0	Vehicle penetrated barrier
TB-3	W-beam/barrel	1954	57.3	14.3	-0.6	-1.9	1.2	Vehicle redirected
TB-4	W-beam/barrel	1954	73.1	14.6	-1.2	-2.7	1.8	Vehicle redirected
TB-5	W-beam/barrel	2008	92.7	15.8	-2.5	-2.2	10.1	Vehicle penetrated barrier
TB-6	Type X curb	1970	56.3	8.1	-2.1	-1.1	0.3	Vehicle mounted barrier, remained on top; abrupt deceleration caused by snagging on exposed splice plates

Note: 1 kg = 2.2 lb; 1 km/h = 0.6 mph; 1 m/s = 3.3 ft/s; 1 m = 3.3 ft.

in the impact area immediately tipped away from the vehicle as it was smoothly redirected. Barrels adjacent to the impact area subsequently began to tip, and similar to a domino effect, the barrels rotated over on their sides, as shown in Figures 6 and 7. Although there was wheel contact with three barrels, no abrupt decelerations were observed.

The vehicle sustained minor sheet metal damage; otherwise it was undamaged. Although the entire installation was displaced, as shown in Figure 7, it was easily

restored to an upright position for test TB-4.

Test TB-4, W-Beam-Barrel Barrier

Vehicle impact conditions were 73 km/h (45.4 mph) and a 14.6° angle. As shown in Figure 8, the vehicle impacted the installation 15.2 m (50 ft) from the upstream end, and barrels in the impact area immediately tipped away from the redirected vehicle. As in test TB-3, the barrels out of the impact area rotated sequentially until the entire installation was pushed over. Vehicle contact with six barrels was noted; however, no snagging or abrupt deceleration occurred.

The vehicle sustained minor sheet metal damage to left-front and rear fenders, as shown in Figure 9. In ad-

Figure 2. Test TB-1 sequential photographs.

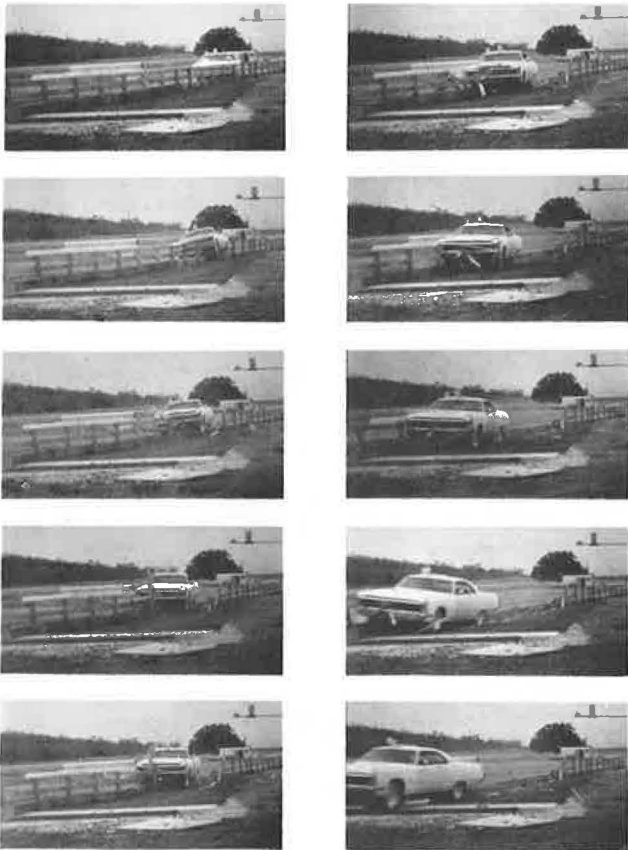


Figure 3. Test TB-1 vehicle and barrier damage.



Figure 4. Test TB-2 sequential photographs.

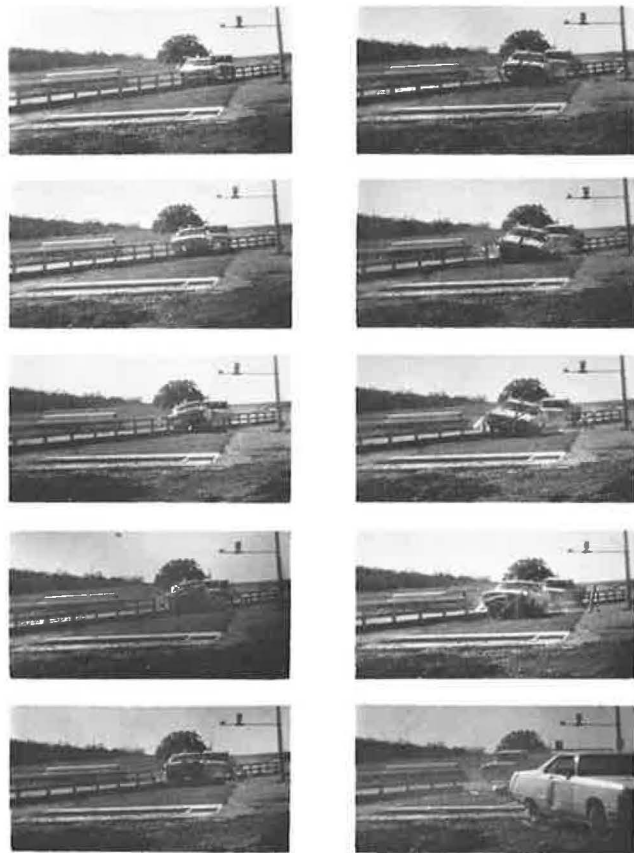


Figure 5. Test TB-2 vehicle and barrier damage.

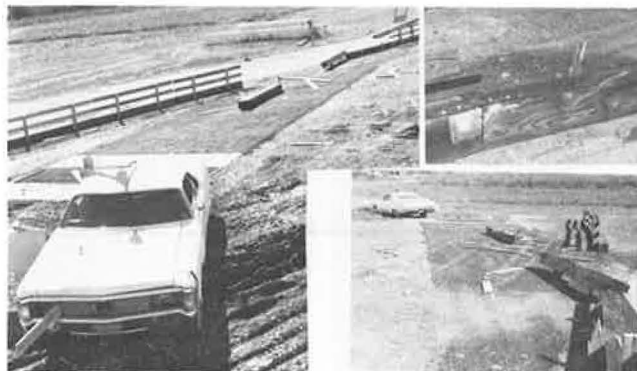


Figure 6. Test TB-3 sequential photographs.

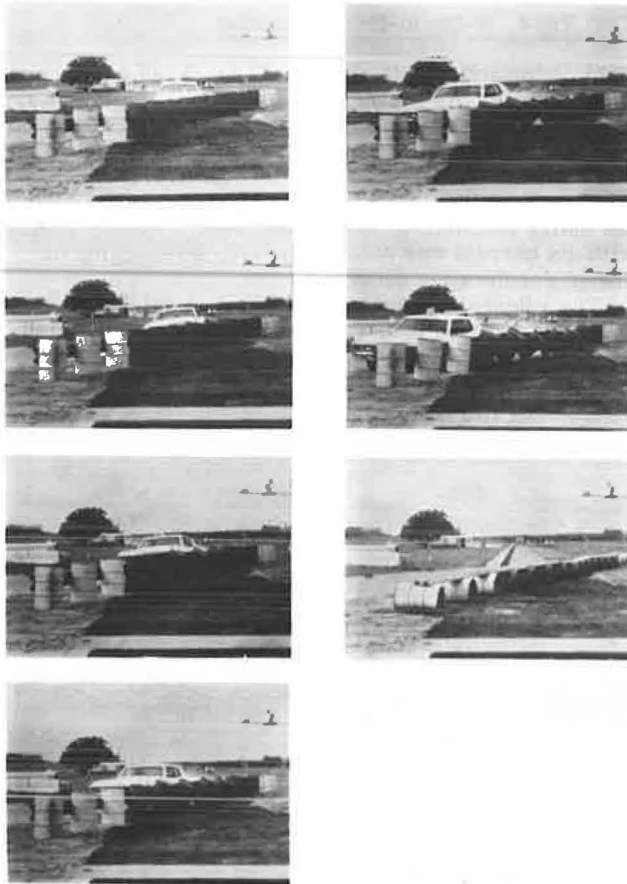


Figure 7. Test TB-3 vehicle and barrier damage.

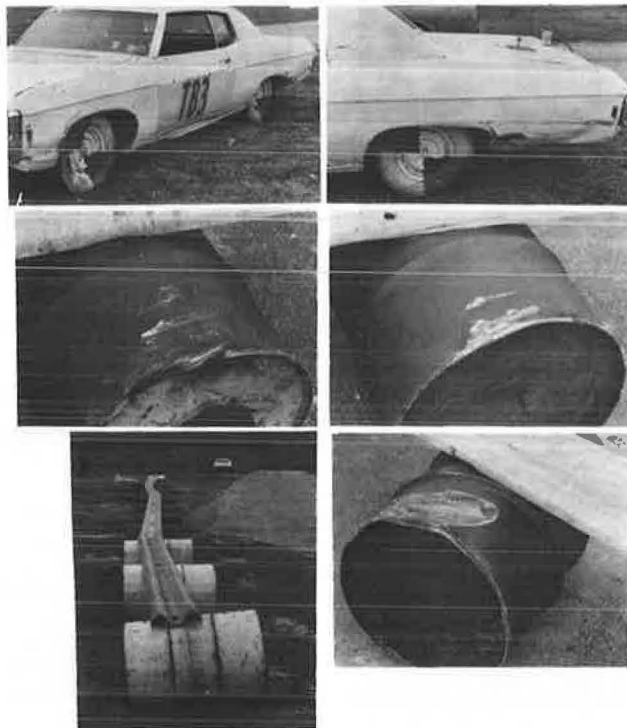


Figure 8. Test TB-4 sequential photographs.

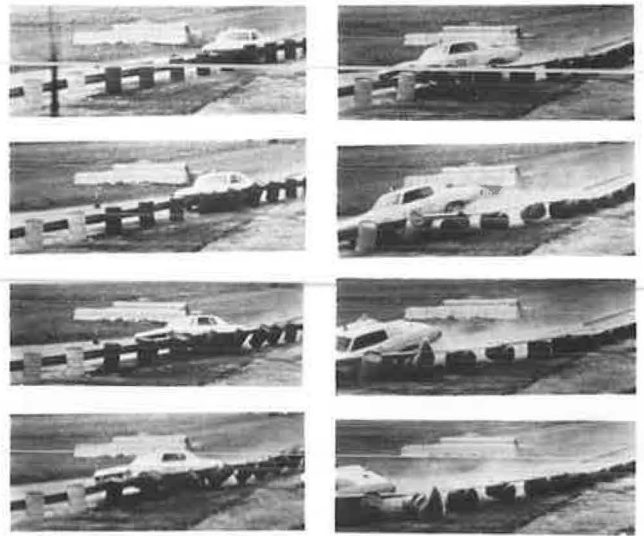
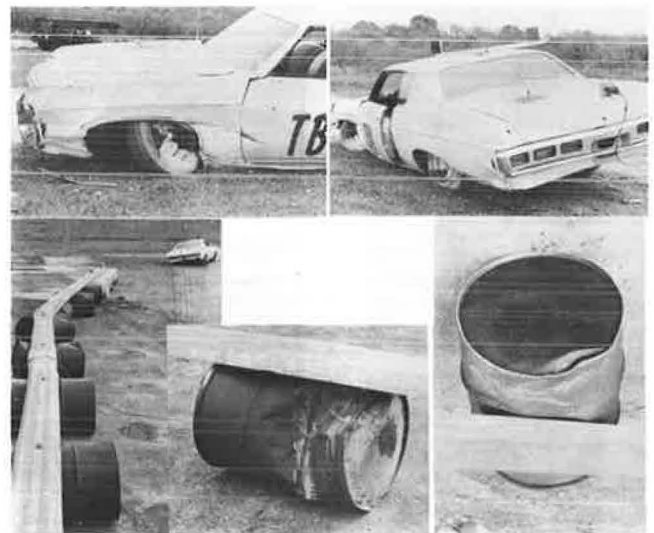


Figure 9. Test TB-4 vehicle and barrier damage.



dition, the lower ball joint at left-front wheel was separated and both left tires were punctured during impact. Damage to the installation was limited to three barrels, which were replaced prior to the next test.

Test TB-5, W-Beam-Barrel Barrier

Vehicle impact conditions were 92.7 km/h (57.6 mph) and a 15.8° impact angle. As seen in the sequential photograph of Figure 10, the vehicle pocketed slightly, and then, from an orientation approximately parallel to the barrier, vaulted over the barrier. As the W-beam splice connection failed, the vehicle climbed over the barrels in front. Although the vehicle was airborne and unstable, it did not roll over and came to rest as shown in Figure 11.

Considerable sheet metal and suspension damage was sustained by the vehicle's left-front quadrant. In addition, the rear transmission mount and differential housing attachments failed. Barrier damage was extensive, as shown in Figure 11.

Test TB-6, Type X Curb

Vehicle impact conditions were 56 km/h (35 mph) and an 8.1° angle. Initial impact was 9.8 m (32 ft) from the upstream end. As shown in Figure 12, the left wheels immediately climbed up the sloped curb face. The vehicle pitched (nose up) initially, and then as it straddled the barrier, the front underside snagged on one of the 25-mm

Figure 10. Test TB-5 sequential photographs.

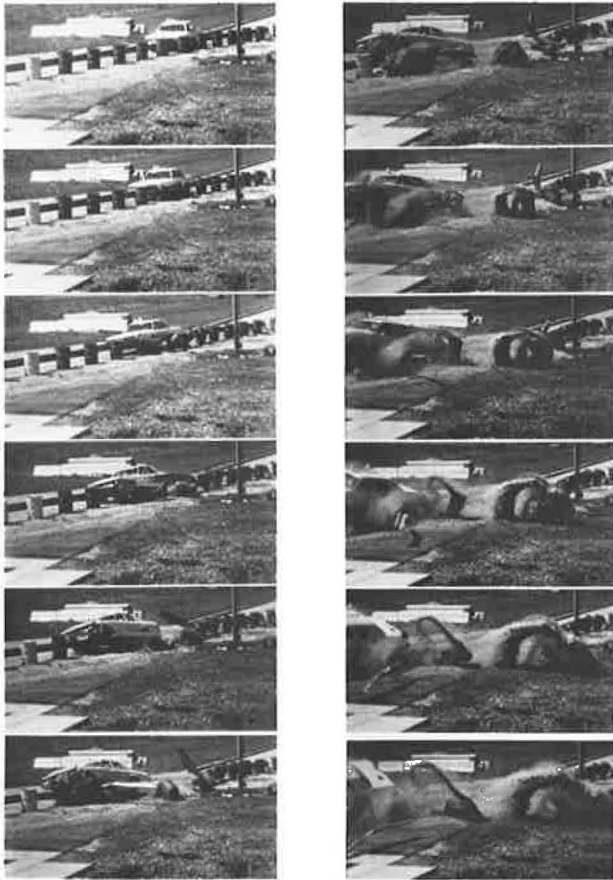


Figure 11. Test TB-5 vehicle and barrier damage.



Figure 12. Test TB-6 sequential photographs.

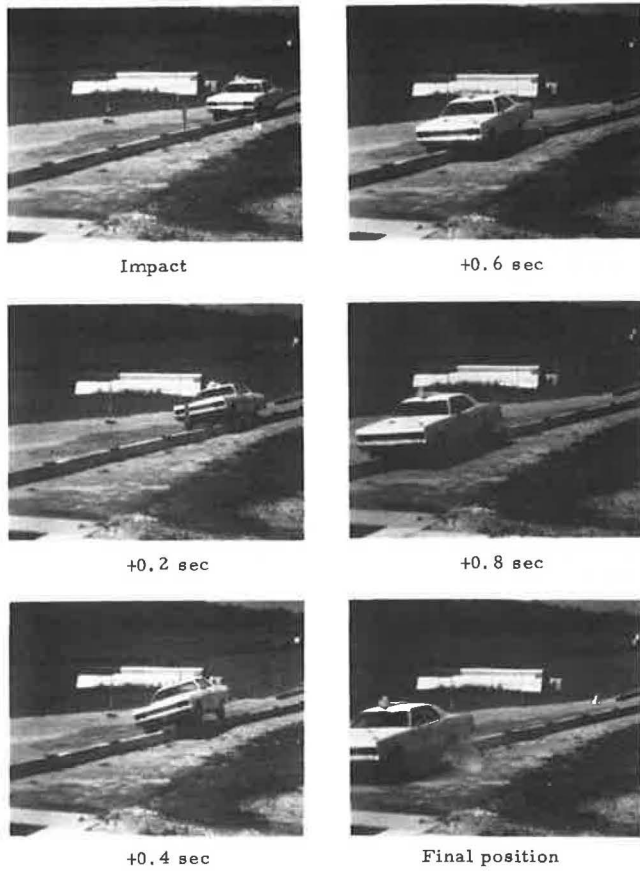


Figure 13. Test TB-6 vehicle and barrier damage.



(1-in) thick splice plates. Significant deceleration forces were then applied to the vehicle by this splice plate and the one immediately downstream. These forces were sufficient to prevent the vehicle from proceeding over the barrier; however, considerable damage to the vehicle's underside and three barrier sections was observed. Final position of the vehicle and the barrier damage are shown in Figure 13.

CONCLUSIONS

Based on the findings of these crash tests, the following conclusions can be made:

1. The 250 × 250-mm (10 × 10-in) timber barrier tested has minimal redirection capability. The upper rail members are not functional and exhibit a potential for spearing both vehicle and occupants. The lower 250 × 250-mm base is readily mounted by vehicles at nominal speeds and angles. Use of this barrier for containment and redirection is not recommended. The 250 × 250-mm base with upper railings removed could be used for very low speed operations, where speeds and impact angles are low and traffic consists of automobiles only.
2. The W-beam-barrel concept evaluated in this program is an effective containment barrier for impacts characterized by a 2040-kg (4500-lb) vehicle impacting at 73 km/h (45 mph) and an angle of 15°.
3. The type X curb is ineffective in redirecting vehicles. The curb is readily mounted and even at angles

of 8° it does not appear to be capable of redirecting a 2040-kg vehicle impacting at 56 km/h (35 mph). The fact that the test vehicle did not completely go over the test barrier is attributed to the deceleration force imparted to the vehicle by the splice plate snagging previously cited. This snagging is undesirable in that it causes severe damage to both vehicle and barrier segments. In addition it cannot be considered as a repeatable means of decelerating a vehicle due to the intermittent spacing of the splices.

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REFERENCES

1. News Release. Federal Highway Administration, FHWA 9-77, March 3, 1977.
2. M. E. Bronstad and J. D. Michie. Recommended Procedures of Vehicle Crash Testing of Highway Appurtenances. NCHRP, Rept. 153, 1974.

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Evaluation of Timber Barricades and Precast Concrete Traffic Barriers for Use in Highway Construction Areas

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This paper summarizes the results of a study of the performance of the timber barricade and a comparison of its characteristics and performance with those of the precast concrete traffic barrier. The study included (a) a traffic accident analysis of the construction zone on I-495 where the timber barricade was employed; (b) a comparison of the technical, operational, and economic feasibility of the timber barricade and the precast concrete traffic barrier; and (c) a review of the legal requirements for temporary barrier systems. The frequency of accident occurrence during construction on I-495 was approximately 119 percent higher than that before construction. Of the reported crashes during construction, 52.5 percent involved vehicle contact with the timber barricades. Of the vehicles involved in crashes with the barricades, 73.5 percent straddled or penetrated the barricades. Thus, on the I-495 site, the timber barricades were ineffective as positive barriers. From the technical, operational, and economic analyses, the precast concrete traffic barrier appeared to be superior to the timber barricade. Since the completion of this study, the Federal Highway Administration has banned the use of the timber barricade as a positive barrier on any federal or federal-aid project.

This paper summarizes the results of a study requested in August 1975 by the Virginia Department of Highways

and Transportation to evaluate the performance of the timber barricade employed to separate freeway traffic and construction activities in the widening of I-495 in northern Virginia (1). The department further requested that the characteristics and performance of the timber barricade be compared to those of the New Jersey-shaped precast concrete traffic barrier (PCTB) to determine whether the PCTB could be substituted for the timber barricade in future projects.

The evaluation covered three major areas: (a) accident analysis, (b) barricade and barrier feasibility, and (c) legal requirements for temporary barriers. Data for the first area were obtained on three widening projects on the Virginia portion of I-495 where the timber barricades were employed. I-495 is the beltway for Washington, D.C., and carries a traffic volume in the range of 80 000 to 100 000 vehicles/d. Two of the projects, 12.30 km (7.64 miles) and 10.73 km (6.67 miles) in length, included the addition of two lanes in each direction to an existing four-lane roadway. The third