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Portable Traffic Barrier for Work Zones

DEAN L. SICKING, HAYES E. ROSS, JR., D.L. IVEY, and T.J. HIRSCH

A portable, positive construction zone barrier is described. The barrier is suitable for use at sites where work will take as little as several hours. It is constructed from used cars and thrie-beam guardrail. Two full-scale vehicular crash tests of the portable barrier are described that demonstrate its adequacy in terms of impact performance. The barrier can be used in construction zones where conventional positive barriers have been impractical.

The number of injuries and fatalities among Texas highway construction and maintenance personnel has increased greatly during the past several years. In one Texas highway maintenance district traffic accidents have caused 39 injuries and 12 fatalities among highway construction and maintenance personnel during the past 2 years. Examination of these accidents has revealed that most of the injury- and fatality-producing accidents occurred at construction sites or routine maintenance sites where all blocked travel lanes were to be cleared at the end of each work period. Normal traffic control for this operation includes arrow boards and cones for traffic channelization. Often most of the cones are knocked down during the course of a single work period. After cones have been knocked down drivers may be confused and return to the blocked lane. Errant motorists also enter work zones as a result of collisions with other motorists or roadside objects.

Initial efforts to reduce the number of accidents in these work areas included increasing the number of law enforcement personnel, increasing efforts to replace cones that had been knocked down, reducing the length of the work zones, and conducting the work only during periods of light traffic. None of these alternatives proved effective, however, so an effort was made to develop a portable, positive barrier for use in certain critical work zones.

Conventional construction zone positive barriers include portable precast concrete barriers and W-beam on barrels. These barriers cannot be erected and removed quickly enough to allow their use in construction and maintenance zones where all blocked lanes are to be cleared at the end of each work period. Therefore, this research was undertaken to develop a truly portable positive work zone barrier that would be (a) portable enough for use in maintenance zones that are to be in place for only a few hours, (b) crashworthy for use in construction zones, and (c) relatively inexpensive to construct and maintain. The findings of a research study conducted in 1981 (1) are described in the following sections.

PORTABLE CONSTRUCTION ZONE BARRIER

A truly portable construction zone barrier can be brought to the work site and set up in a few minutes. Heavy machinery or specialized equipment should be unnecessary because these may not be available at the site. The barrier must be capable of redirecting an errant vehicle without deflecting it excessively and thereby endangering workers standing behind the barrier. Finally, the barrier should be relatively inexpensive to build and maintain.

Researchers examined many portable construction zone barrier concepts before concluding that the used car barrier was the most promising design considered. This barrier consists of a line of cars connected together with tow bars. The barrier is portable and can be driven to the work site. Special equipment is not required for its setup, and the barrier is relatively inexpensive when compared with other barriers considered.

The used car barrier is shown in Figure 1 and described in Figures 2 and 3. The vehicles used in

Figure 1. Used car barrier.

the barrier were 1973 and 1974 Plymouth Suburban station wagons. These vehicles have torsion bar front suspension, which allows the height of the front bumper to be adjusted easily for towing. Standard thrie-beam guardrail is attached to each of the vehicles, as shown in Figure 3. The thrie beam provides a continuous, smooth surface to prevent impacting vehicles from snagging on the used cars. A hinged thrie-beam gate prevents impacting vehicles from snagging on the joints between barrier vehicles. The gate hinges are attached to the front of a vehicle and the thrie-beam gate rests against the

Figure 2. Construction drawing of used car barrier.

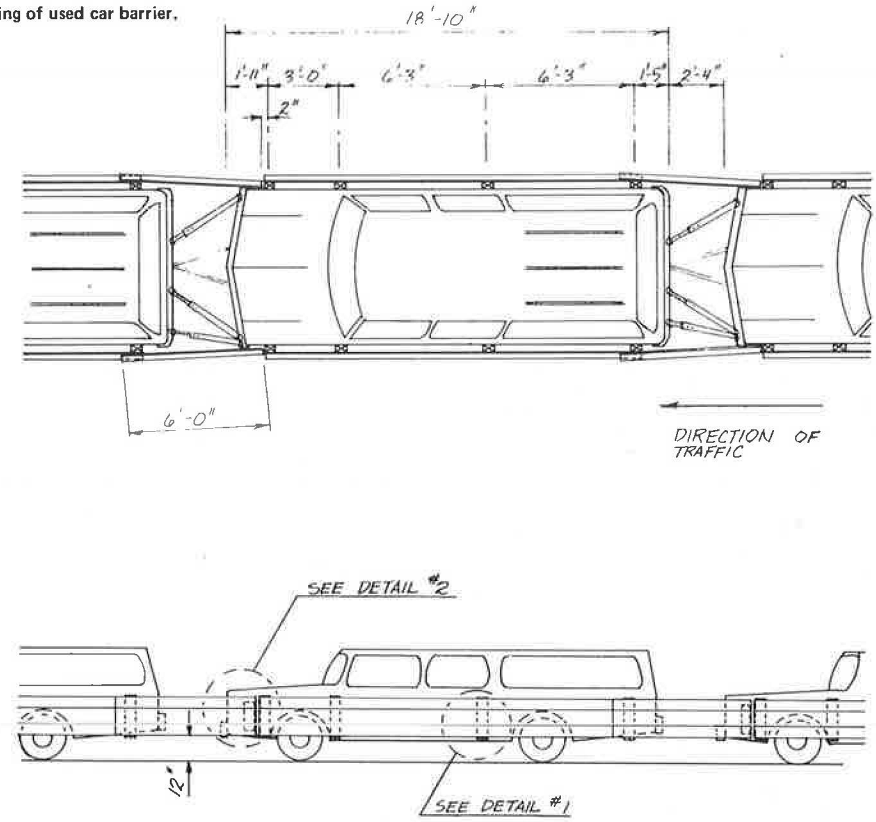
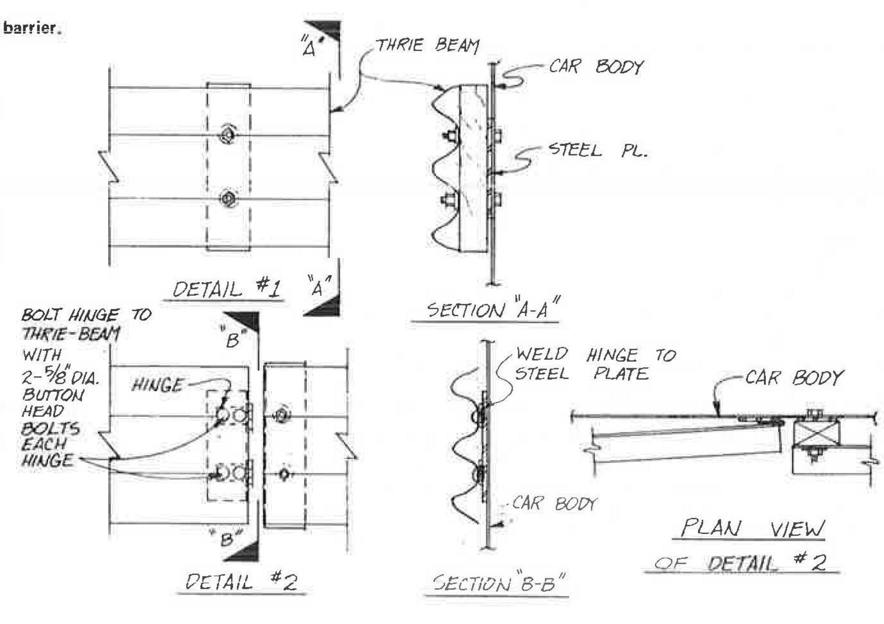


Figure 3. Details of thrie-beam attachment to barrier.



rear of the next vehicle. The gate is not attached to the rear of the next vehicle; therefore, the barrier can turn a corner. The thrie beam is blocked out 3.5 in. (8.9 cm) from the vehicles to reduce the possibility of wheel snag on the barrier and to allow the front wheels of the barrier vehicles to turn.

Three telescoping tube members (see Figures 4 and 5) were constructed from standard schedule 40 steel pipe and are used to develop moment and shear capacity between the barrier vehicles. The top photograph in Figure 4 is a left-side view. The bottom photograph is a right-side view. When the barrier is to be moved only one of the members must be removed from the joint and two steel pins must be removed from each of the other members. Telescoping members are designed to withstand an 18-kip (80.0-kN) axle load before yielding begins. The yield moment of the car-to-car joint is approximately 50 kips-ft (67.8 kN•m). The vehicle bumpers were reinforced to develop the yield strength of the telescoping tube members. Figure 6 shows front (top) and rear (bottom) views of reinforcement details. As shown in Figure 5, commercially available heavy-duty tow bars are employed to move the barrier. The tow bars remain in place when the barrier is put into service, thereby reducing setup time.

The used car barrier constructed at the Texas Transportation Institute (TTI) consisted of five

Figure 4. Barrier segment connection details.

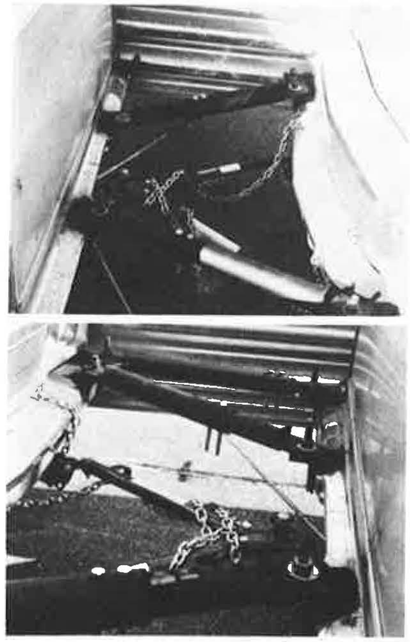
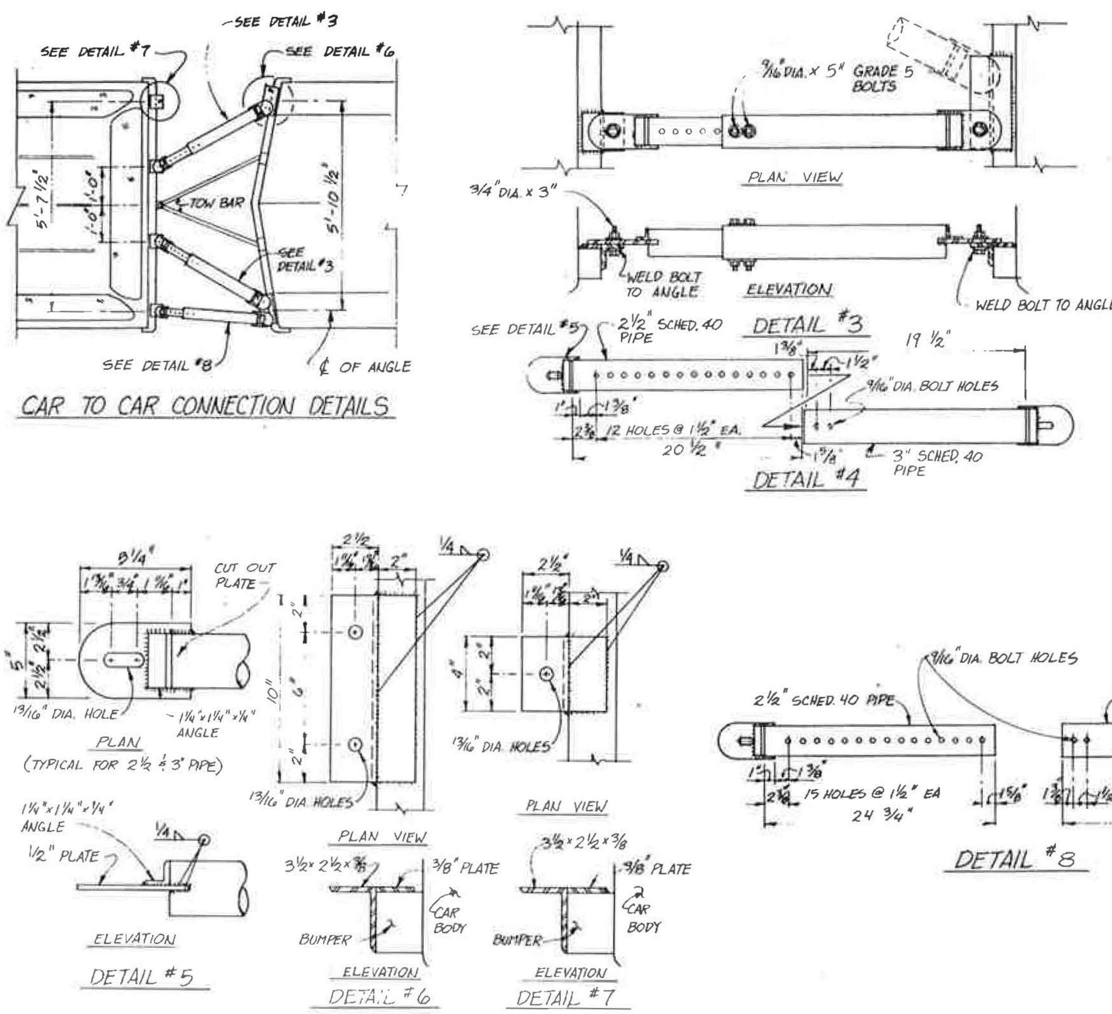


Figure 5. Details of barrier vehicle joints.



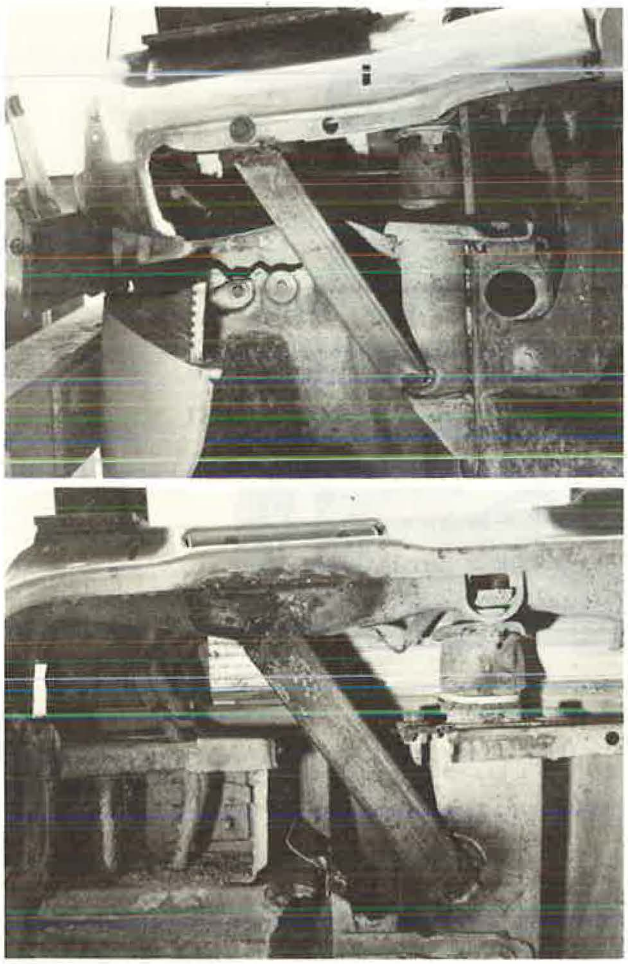


Figure 6. Bumper reinforcement details.

vehicles. The lead car was maintained in operational condition and was used to tow the barrier. Although the barrier could not be backed up, it was still maneuverable and had a turning radius approximately twice that of a conventional automobile. The time required to set up the barrier is short because only one telescoping member and four pins must be placed in each joint at setup time. The barrier was 92 in. (234 cm) wide and 100 ft (30.5 m) long and cost approximately $7,000. At a cost of $70/ft the barrier is inexpensive when compared with other alternatives.

IMPACT PERFORMANCE CRITERIA

Current test standards contained in NCHRP Report 230 (2) recommend that temporary barriers be designed for impact conditions equal to those for permanent barriers. However, the type of barrier discussed here (i.e., a highly portable, relatively short, longitudinal barrier system) is not addressed specifically in NCHRP Report 230. Preliminary analysis indicates that such a system would be difficult and impractical to design to meet permanent barrier standards. Selection of crash test conditions (vehicle size, impact speed, and impact angle) was therefore made jointly by TTI and Texas State Department of Highways and Public Transportation (TSDHPT) engineers. Factors considered in the subjective selection process included exposure time, traffic speeds in work zones, costs, and the state of the art for temporary barriers. As a result of this process the test conditions described in the following section were chosen.

ANALYSIS

The used car barrier should behave similarly to the portable precast concrete traffic barrier when it is impacted by an errant vehicle. Both barriers are a series of large rigid beams that have moment-resisting joints. The used car barrier was therefore analyzed with a computer program developed to model portable precast concrete barriers (3).

The algorithm used to examine impact with the barrier is a two-dimensional model designed to predict barrier deflections and the forces transmitted by the barrier joints. Therefore, only impacts with a large, 4,500-lb (2043-kg) vehicle were investigated because impacts with smaller vehicles would produce lower deflections and joint loadings. Predicted barrier deflections for the impact conditions investigated and barrier deflections for the crash tests conducted are given in Table 1. As given in the table, predicted barrier deflections compare well with test results. Further, the computer model predicted a barrier deflection of only 26 in. (66 cm) for an impact at 60 mph (96.6 km/h) and 25 degrees, which is a small deflection for a test of this severity. Therefore, the barrier is acceptable for use in place of conventional construction zone barriers.

TEST RESULTS

Two full-scale crash tests were conducted on the used car barrier (see Figure 7). The tests conducted were designed to evaluate the limits of the barrier's performance. Impact with small vehicles was not investigated because barrier performance is similar to that of the thrie-beam guardrail for small-vehicle and low-angle impacts. The impact point for both tests was upstream from the last joint between the barrier vehicles. This point of impact should cause maximum barrier deflection and give the greatest possibility of joint failure and vehicle snag on the barrier. The tests are summarized in Table 2.

Test 1

In the first test a 4,500-lb (2043-kg) vehicle impacted at 51.7 mph (83.2 km/h) and 7 degrees. The test vehicle was redirected smoothly and exhibited no tendency to become snagged on the barrier. As the data given in Table 2 indicate, all occupant

Table 1. Barrier deflections.

Impact Velocity (mph)	Impact Angle (degree)	Max. Barrier Deflection (in.) Predicted	Actual
50	7	0.5	2.0
50	15	10.0	7.2
60	15	15.0	–[a]
60	25	26.0	–[a]

[a]Crash test not conducted.

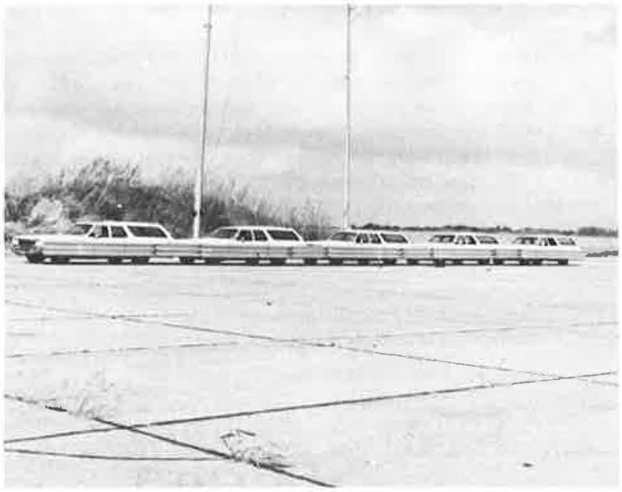


Figure 7. Used car barrier test configuration.

Figure 8. Test vehicle and barrier after test 1.

Table 2. Summary of crash tests.

Item	Test 1	Test 2
Impact speed (mph)	51.7	48.3
Impact angle (degrees)	7	15
Exit angle (degrees)	2	2
Barrier displacement (in.)	2	7.2
Occupant impact velocity (ft/sec)		
Longitudinal	10.9	12.1
Lateral	0	0
Occupant ridedown acceleration (g)		
Longitudinal	2.8	8.66
Lateral	0	0
Vehicle damage classification		
Traffic Accident Damage Scale	10RFQ1	10RFQ3
Vehicle Damage Index	10RFMW1	10RFMW3

Figure 9. Test vehicle after test 2.

risk values and the vehicle trajectory hazard were well below recommended values (3).

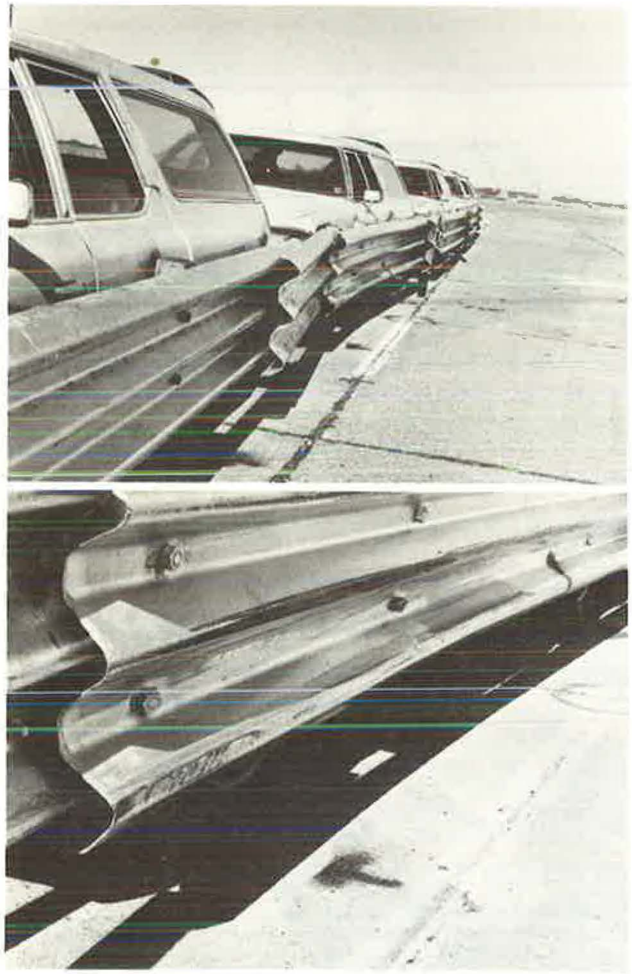
Figure 8 shows the test vehicle and barrier after test 7. As shown in this figure, damage to the test vehicle was limited to sheet metal deformations. The barrier sustained no visible damage and was driven from the test site. Barrier displacement was limited to 2 in. Test 1 was considered successful because damage to the test vehicle was light and damage to the barrier was negligible.

Test 2

In test 2 a 4,500-lb (2043-kg) vehicle impacted the barrier at 48.3 mph (77.7 km/h) and 15 degrees. The vehicle damage from test 1 was light, so the same vehicle was used in test 2. The test vehicle was redirected smoothly and, as the data given in Table 2 indicate, occupant risk values and the vehicle trajectory hazard were below recommended limits (3). Note that no lateral occupant impact occurred during the 3 sec for which accelerometer data were analyzed. Maximum barrier deflection was limited to 8.4 in.

The test vehicle (see Figure 9) was damaged only lightly. Barrier damage (see Figure 10) was limited to minor deformations in the thrie-beam rail and the barrier vehicle sheet metal. The barrier was driven from the test site, and no barrier repair was required. This test was also considered successful.

Figure 10. Used car barrier after test 2.



cm). Computer simulation of an impact at 60 mph (96.6 km/h) and 25 degrees with a 4,500-lb (2043-kg) vehicle predicted only 26 in. (66 cm) of barrier deflection.

The used car barrier was constructed for testing at a cost of approximately $70/ft of barrier. No barrier repairs were required subsequent to the two crash tests conducted; therefore, the barrier should be inexpensive both to construct and to maintain. The barrier can be placed on either a tangent or in a transition zone (see Figures 11 and 12). Figure 12 shows photographs of a barrier in use on Houston

Figure 11. Applications of used car barrier.

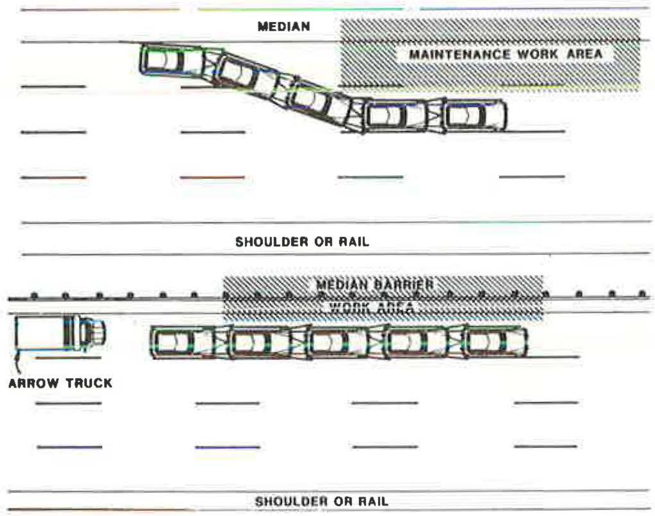
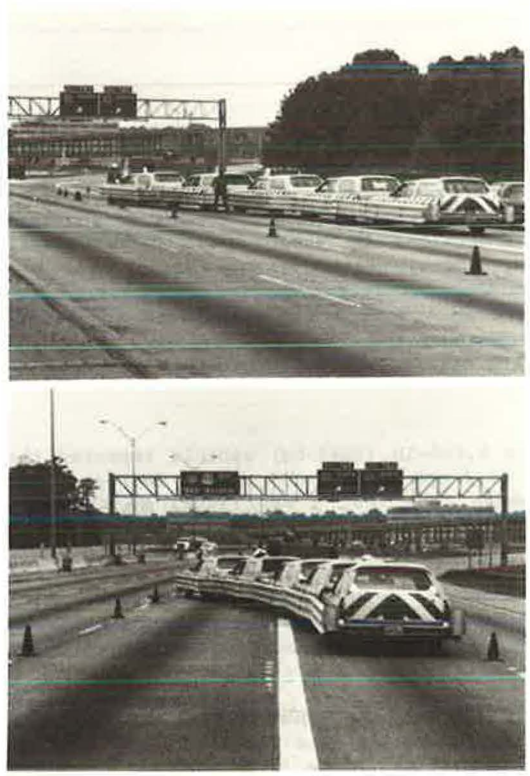


Figure 12. Used car barrier in use at maintenance site.



SUMMARY AND CONCLUSIONS

The number of injuries and fatalities among Texas highway construction and maintenance personnel has increased significantly in recent years. Investigation of the problem revealed that much of this increase resulted from accidents at short-duration construction and maintenance zones, and the only practical solution was to employ positive barriers at these sites. None of the construction zone barriers currently in use can be installed and removed quickly enough for use at short-duration construction sites. Therefore, a truly portable positive construction zone barrier has been developed that is (a) portable enough for use in maintenance zones that are to be in place for only a few hours, (b) crashworthy for use in construction zones, and (c) relatively inexpensive to construct and maintain.

The used car barrier consists of a line of used cars with thrie-beam guardrail attached to each side. Telescoping tube members provide moment capacity in the joints and hinged thrie-beam gates provide a smooth redirecting surface between barrier vehicles. The lead vehicle is maintained operational and can be used to tow the barrier.

The barrier was crash tested successfully with a 4,500-lb (2043-kg) vehicle at an impact speed of 48.3 mph (77.7 km/h) at an angle of 15 degrees. Barrier deflection for this test was 8.4 in. (21 freeways. The barrier was used at several test sites after the study was completed, and it has performed well according to TSDHPT engineers.

The used car barrier can be used to protect highway construction and maintenance personnel at work sites where conventional positive construction zone barriers are impractical. It can be set up and removed quickly enough to be used when maintenance is scheduled to take only a few hours. The used car barrier should therefore reduce injury and fatality rates among highway construction and maintenance personnel.

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Crash Tests of Portable Concrete Median Barrier for Maintenance Zones

JAN S. FORTUNIEWICZ, JAMES E. BRYDEN, AND RICHARD G. PHILLIPS

An 8-ft version of New York's standard 20-ft portable barrier was evaluated through full-scale crash tests. The 8-ft barrier is both shorter and more portable than the standard concrete median. It employs the basic New Jersey shape and New York's pin-connected joints but is not connected to the pavement. Four full-scale crash tests were performed with 2,250- and 4,500-lb sedans at about 60 mph and 15- or 25-degree angles. Test results were generally good in terms of vehicle accelerations and occupant-vehicle impact velocities. Lateral barrier movement was similar to that experienced with the 20-ft barrier sections. Vehicle reactions were somewhat violent, especially in the 25-degree impacts, which demonstrates the severity of high-angle impacts with rigid barriers. Smooth barrier surface textures appear to be important for minimizing vehicle roll angles. Performance of 8-ft barriers appears comparable to that of the 20-ft lengths now in use.

Research reported by New York State in 1980 (1) demonstrated that a portable concrete barrier with 20-ft sections is suitable for use on construction projects. A similar use of portable concrete median barrier (CMB) by state maintenance forces could improve safety in work zone situations for both state forces and the motoring public. Some drawbacks of the standard 20-ft CMB, as noted by the New York State Department of Transportation's (NYSDOT) Highway Maintenance Division, are its size, weight, and requirements for handling equipment. A standard 20-ft long section weighs about 8,000 lb and must be set in place by a crane. Maintenance forces often have only light equipment available to move and set barriers, and the amount of heavy equipment that would be required to move and set a 20-ft CMB is unavailable. The Highway Maintenance Division suggested 8-ft sections, weighing about 3,200 lb each, for full-scale crash tests to determine the performance on impact of the shorter barrier. Verification of adequate performance of the shorter sections of temporary CMB would permit their use in an anticipated major bridge rehabilitation program during the next decade and in other maintenance work zones where a positive temporary barrier is warranted.

METHODOLOGY AND DESCRIPTION OF BARRIER

Four full-scale tests were conducted to determine the performance of 8-ft sections of portable CMB with New York State's standard pinned connection (Figure 1). Evaluation parameters included vehicle redirection and impact severity, barrier damage, and barrier movement. Testing details were taken from Transportation Research Circular 191 (2). Data analysis and reporting procedures were subsequently revised to reflect the requirements specified in NCHRP Report 230 (3).

The test matrix was composed of longitudinal barrier length-of-need tests designated in NCHRP Report 230 as nos. 10 and 11. Two strength tests were performed--one with and one without added joint restraints--and impact severity tests were performed on both smooth- and rough-textured barriers. This test matrix was sufficient to determine if the shortened version of the portable CMB would perform satisfactorily and to find any drawbacks because of the smaller mass of each unit.

In all tests the barrier was the basic New Jersey shape as used for the current standard New York barrier (standard sheet 619-3R2), following reinforcement recommendations by Southwest Research Institute (4). Except for section length and minor adjustments in reinforcing detail, the revision was identical to New York's current standard. The barrier installation consisted of 20 sections of 8-ft barriers, placed in a straight line and anchored by three steel pins into the pavement at the first and last section. Joints were secured by connection keys. For one of the four tests, sections were pulled to remove any slack in the joints, and portland-cement mortar was packed into the bottom of the joint to restrain movement during impact. The test sections were placed on an asphalt pavement to simulate typical field installations. The 8-ft sections were delivered with a rough-brushed surface texture which the fabricator had applied to cover minor air voids. For the final test, two 20-ft barrier sec-