4. Five bridge-railing safety-improvement modifications (for categories II and III systems) have been developed and evaluated. These modifications are judged suitable for carefully monitored in-service use.

ACKNOWLEDGMENTS

The work reported here was conducted by the Division of Structural Research and Ocean Engineering, Southwest Research Institute, for the Federal Highway Administration. The opinions, findings, and conclusions expressed are ours and not necessarily those of the sponsor. Special appreciation is expressed to John G. Viner, James Wentworth, and Morton Oskard, for FHWA technical support of the program. From Southwest Research Institute, M. E. Bronstad is recognized for technical contributions, and Glenn Deel, who supervised the experimental investigations, and R. P. Guillot, B. M. Johnson and C. F. Berger, Jr., who assisted Deel, are acknowledged.

REFERENCES

1. R. M. Olson and others. Tentative Service Requirements for Bridge-Rail Systems. NCHRP, Rept. 86, 1970.
2. H. E. Hosea. Fatal Accidents on Completed Sections of the Interstate Highway System, 1968. Public Roads, Oct. 1969, pp. 217-224.
3. Highway Design and Operational Practices Related to Highway Safety. AASHO, 1967.
4. Freeway Fatal Accidents: 1965-1975. California Department of Transportation.
5. Standard Specifications for Highway Bridges. AASHO, 11th Ed., 1973.

Publication of this paper sponsored by Committee on Safety Appurtenances.

Evaluation of Concrete Safety Shapes by Crash Tests With Heavy Vehicles

E. O. Wiles, M. E. Bronstad, and C. E. Kimball, Southwest Research Institute, San Antonio

Three crash tests were made to evaluate concrete median barriers at speeds of approximately 70 and 90 km/h (45 and 55 mph) and angles of approximately 7 and 16° with an 18 000-kg (40 000-lb) intercity bus. The 61.0-m (200-ft) long installation was cast in place and reinforced with one number 4 bar placed 150 mm (6 in) below the barrier top. The freestanding barrier was restrained by a 25-mm (1-in) layer of asphalt placed at the installation bottom on the side opposite the impact. The results of the program include the following: The safety shape performed well at the lower angle impacts with no barrier distress or translation. The severe test [an impact speed of 85.1 km/h (52.9 mph) and an impact angle of 16°] showed that the concrete safety shape with minimum reinforcement and foundation restraint can redirect large vehicles at high impact speeds and angles. In the severe test, the rear-end impact during redirection was the principal cause of the extensive barrier damage and displacement.

The concrete safety shape is a widely used traffic barrier. Although it was originally used as a median barrier, it is also used on structures and roadway shoulders. This paper is taken from the report (4) of a study of safety shapes that was sponsored by 21 transportation agencies and administered by the Federal Highway Administration Office of Research. One part of this program was a crash-test evaluation that used an 18 000-kg (40 000-lb) intercity bus impacting a concrete median barrier (CMB) under various conditions.

BACKGROUND

In 1971, 36 states used concrete safety shapes to some extent (1). Of these 36 states, 19 specified the shape first used by New Jersey, which is denoted as MB5 by Michie and Bronstad (2).

In this program, a survey of 25 agencies provided information about CMB accident cases. The following observations were made:

1. The performances of various shapes are comparable except in the prevention of vehicle rollovers, for which the MB5 shape has a definite advantage.
2. A number 4 bar placed 152 mm (6 in) below the top of the barrier is the most common reinforcement used in CMB construction.
3. The CMB is effective in containing and redirecting large vehicles. Only two of the 49 heavy-vehicle accidents reported resulted in penetration of the barrier.
4. The barrier failures that occur are due primarily to heavy-vehicle impacts.

Full-scale, heavy-vehicle crash tests of the CMB have been extremely limited (3). In this program, a series of tests was used to evaluate the performance of a lightly reinforced MB5 barrier with minimal foundation restraint when impacted by an 18 000-kg (40 000-lb) intercity bus. The cast-in-place installation, as shown in Figure 1, was 61.0 m (200 ft) long and was reinforced with one number 4 bar placed 152 mm (6 in) below the barrier top. Restraint of the freestanding barrier was provided by a 25-mm (1-in) layer of asphalt, 1.2 m (4 ft) wide, on the bottom of the installation on the side opposite the impact.

TEST PROCEDURES

The crash tests were performed with a vehicle controlled by linear actuators attached to the steering linkage, and the linear actuators were remotely controlled through a hard line by the operator in the chase vehicle. The vehicle ignition and brakes were remotely controlled through a tether line that also carried the signals from strain-gauge accelerometers, which were mounted to the vehicle floor pan, 0.30 m (12 in) aft of the front axle

Figure 1. MB5 barrier.

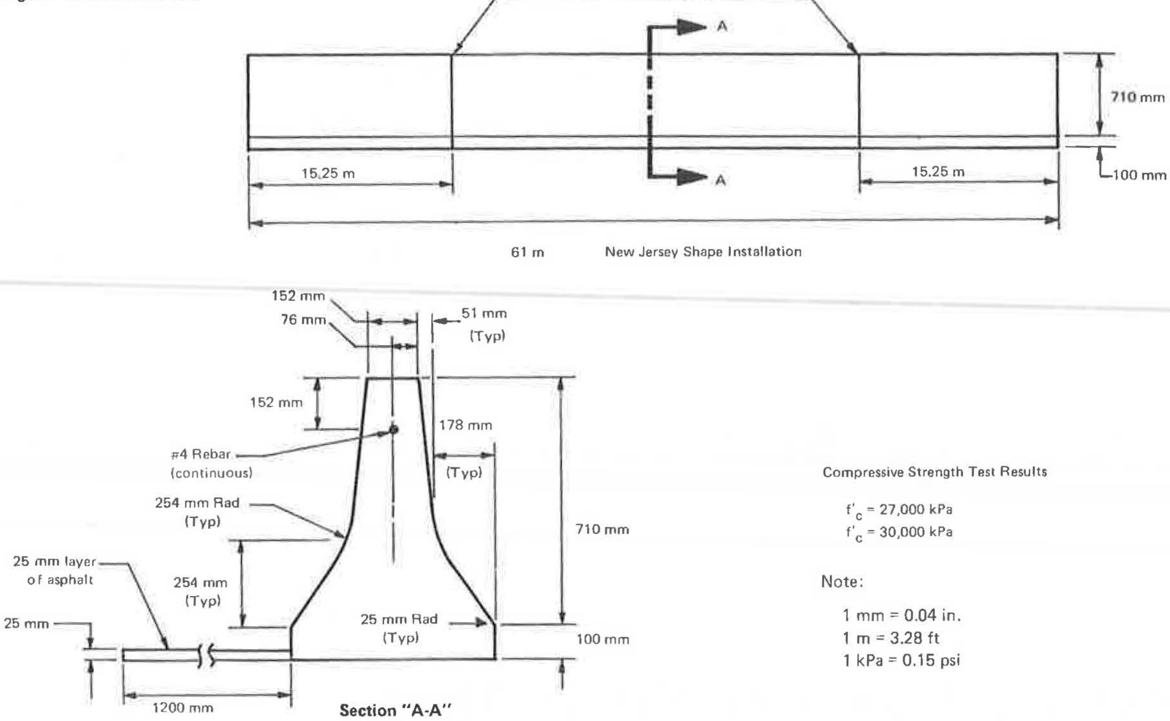
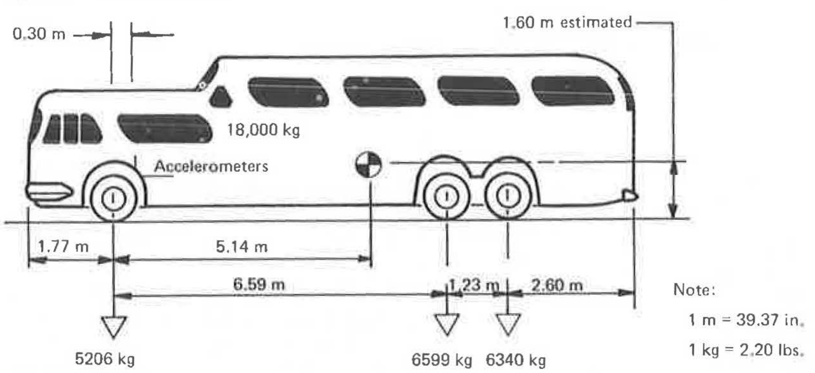


Figure 2. CMB test vehicle.



on the longitudinal centerline (Figure 2). The data were derived from two sources: micromotion analysis of high-speed film and accelerometers.

The data were taken from the film by using a motion analyzer and processed by the Southwest Research Institute Data IV motion-analysis computer program. The strain-gauge accelerometer data were recorded at 1.5 m/s (60 in/s) on magnetic tape and replayed through Society of Automotive Engineers J211 class 60 specification filters; the signals were recorded on oscillograph charts or directly processed by using analog-to-digital conversion.

TEST RESULTS

The results of the test series with an 18 000-km (40 000-lb), 1955-model bus are summarized below (1 km/h = 0.62 mph and 1 m = 3.3 ft).

Item Measured	Test CMB-21	CMB-22	CMB-23
Impact speed, km/h	67.1	83.0	85.1
Impact angle, °	11.5	6.6	16.0
Max roll angle toward barrier,°	8	9	24
Max 50-ms avg vehicle accelerations			
Longitudinal, *g*	-0.9	-0.9	-0.8
Lateral, *g*	-0.7	-0.8	-1.0
Maximum barrier translation, m	0	0	0.8

Further details of the test program have been given by Bronstad and others (4).

Test CMB-21

The impact conditions were a speed of 67.1 km/h (41.7 mph) and an angle of 11.5°. As shown in Figure 3, the vehicle impacted the barrier 12.4 m (40.8 ft) from the upstream end of the system and was smoothly redirected with a maximum roll angle of 8° toward the barrier and a total barrier-contact length of 7.9 m (25.9 ft). The maximum 50-ms average vehicle accelerations, which were obtained from high-speed film, were -0.9 *g* (longitudinal) and -0.7 *g* (lateral). The barrier damage (Figure 4) consisted of gouging and scraping of the concrete

Figure 3. Sequential photographs of tests CMB-21 and CMB-22.

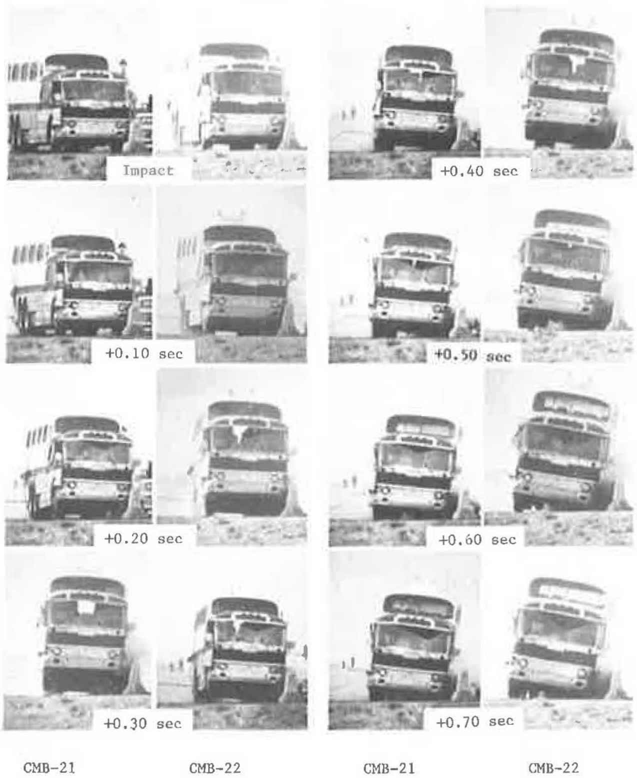


Figure 4. Damage after test CMB-21.

surface by contact with the rim; there was no translation of the barrier. The vehicle, which was drivable after the test, sustained minor front-bumper and sheet-metal damage, which caused some wheel-well intrusion on the left front corner.

Test CMB-22

The minor repairs necessary after test CMB-21 were made before this test. The impact conditions were a speed of 83.0 km/h (51.6 mph) and an angle of 6.6°. As shown in Figure 3, the vehicle impacted the barrier 23.5 m (77.1 ft) from the upstream end of the system and was smoothly redirected with a maximum roll angle

Figure 5. Damage after test CMB-22.

of 9° toward the barrier. The right front tire of the bus was airborne for approximately 0.3 s. The vehicle was redirected with a total barrier-contact length of 8.5 m (28.0 ft). The maximum 50-ms average vehicle accelerations, which were obtained from high-speed film, were -0.9 *g* (longitudinal) and -0.8 *g* (lateral). The damages to the barrier and the vehicle were similar to those in test CMB-21 (Figure 5). The vehicle was drivable after the test.

Test CMB-23

A leak in the oil system and the wheel-well damage were repaired before this test. The impact conditions were a speed of 85.1 km/h (52.9 mph) and an angle of 16°. As shown in Figure 6, the vehicle impacted the barrier 23.5 m (77.0 ft) from the upstream end of the system and was redirected with a maximum roll angle of 24° toward the barrier. The maximum 50-ms average vehicle accelerations, which were obtained from high-speed film, were -0.8 *g* (longitudinal) and -1.0 *g* (lateral). There was a local failure of the barrier and subsequent asphalt displacement because of the frontal contact; the resulting displacement was not measurable, but was estimated to be between 0 and 100 mm (0 and 4 in). The significant barrier and foundation failure was caused by the secondary impact. The maximum deflection of the barrier was 0.8 m (2.6 ft). The vehicle damage was extensive: There was major damage to the left front quadrant of the vehicle around the fender and the left side radiator and radiator door. These damages are shown in Figure 7.

DISCUSSION OF RESULTS

The following conclusions can be made from the results of the crash-test program.

1. The severe test (16°) illustrates that a standard MB5 barrier with minimum reinforcement and foundation

Figure 6. Sequential photographs of test CMB-23: front view and rear view.

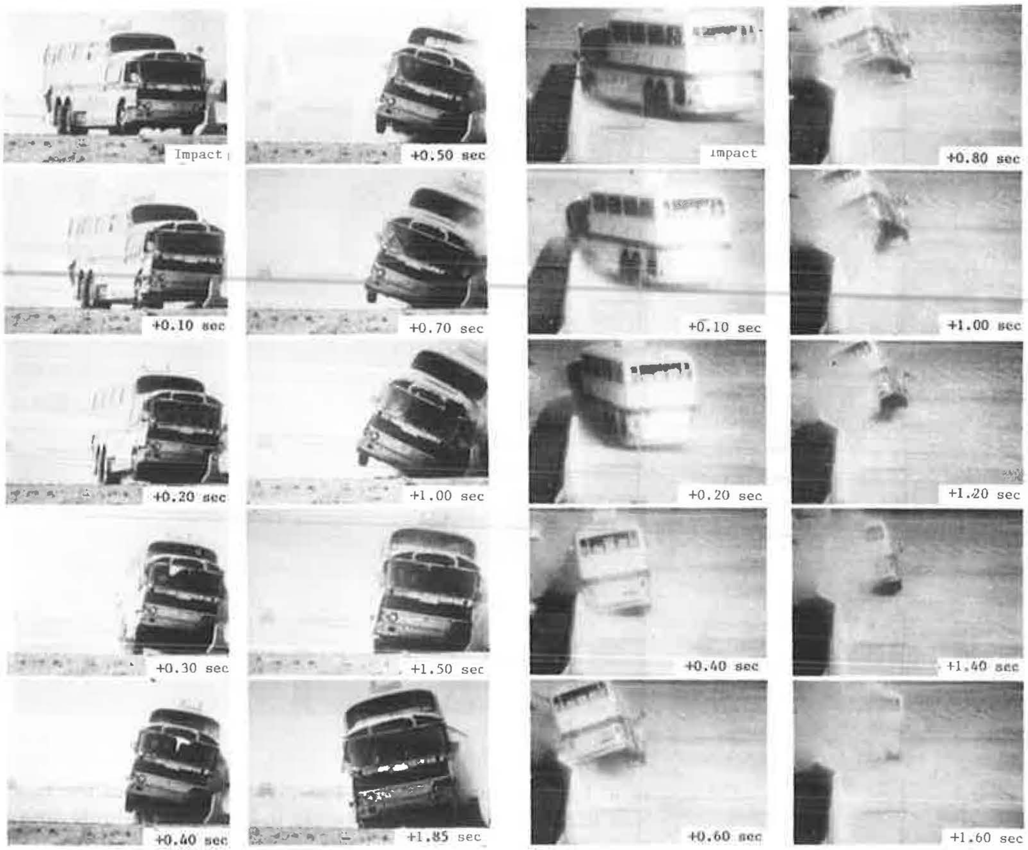
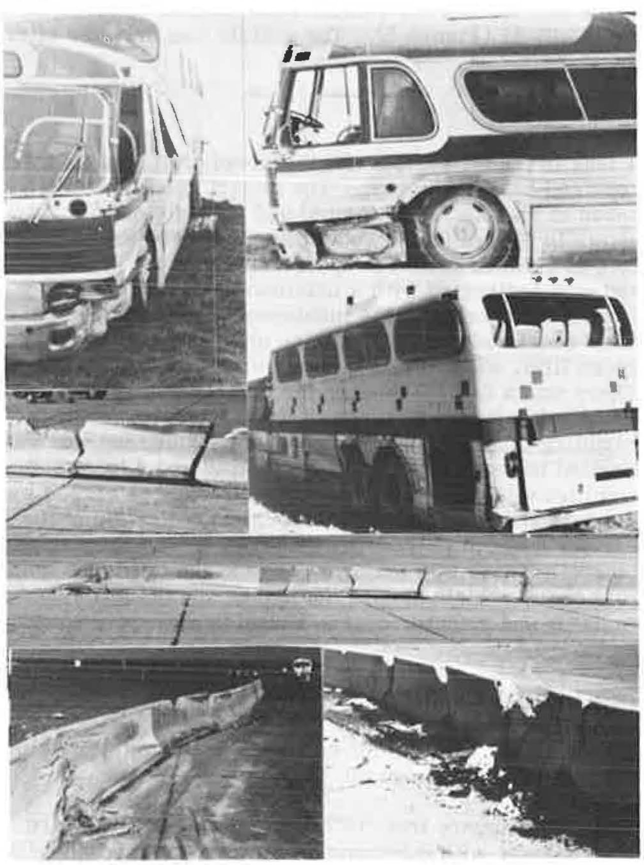


Figure 7. Damage after test CMB-23.



restraint can redirect large vehicles at high impact speeds and angles. Since the redirection of the bus occurred (i.e., the bus rotated through an angle larger than the impact angle) before the significant barrier damage and displacement, this redirection would have occurred regardless of the damage and deflection. The possibility of the bus rolling over the barrier cannot be completely dismissed, but is considered unlikely.

2. In the severe test (16°), the local fracture of the concrete occurred during the initial contact with the bus front at a load that was high enough to force the impacting left wheel against the back of the wheel well. However, although this initial contact produced local barrier failure and nominal displacement, the rear-end contact as the bus was redirected was the principal cause of the extensive barrier damage and displacement.

3. Even if a more rigid barrier had been used, it is still probable that at least local failure of the barrier wall would have occurred during the rear-end contact.

4. Barrier failure could have been changed by a foundation of sufficient embedment to produce rolling of the barrier rather than lateral translation, but this is more undesirable because it produces ramping.

ACKNOWLEDGMENTS

The work reported here was conducted at the Southwest Research Institute for 21 transportation agencies in a pooled-funds study administered by the Federal Highway Administration. Special appreciation is expressed to Sidney L. Polynard, H. R. J. Walsh, and Morton Oskard, of the Federal Highway Administration Office of Research. The technical contribution of J. D. Michie of the Southwest Research Institute is recognized, and the work of Glenn Deel, who supervised the experimental investigations, and R. P. Guillot, B. M. Johnson, and C. F. Berger, Jr., who assisted Mr. Deel, all of the Southwest Research Institute, is acknowledged. The opinions, findings, and conclusions expressed are those of the authors and not necessarily those of the sponsors.

REFERENCES

1. Concrete Median Barriers and Parapets. Federal Highway Administration, Notice EN-20, March 1971.
2. J. D. Michie and M. E. Bronstad. Location, Selection, and Maintenance of Highway Traffic Barriers. NCHRP, Rept. 118, 1971.
3. E. R. Post, T. J. Hirsch, G. G. Hayes, and J. F. Nixon. Vehicle Crash Test and Evaluation of Median Barriers for Texas Highways. HRB, Highway Research Record 460, 1973, pp. 97-113.
4. M. E. Bronstad, L. R. Calcote, and C. E. Kimball. Concrete Median-Barrier Research. Texas Transportation Institute, Texas A&M Univ., College Station; Federal Highway Administration, June 1976.

Publication of this paper sponsored by Committee on Safety Appurtenances.

Control of Outdoor Advertising: The Georgia Experience

Charles F. Floyd and Sharon M. McGurn, Department of Real Estate and Urban Planning, University of Georgia

Federal legislation to control outdoor advertising on Interstate highways began with the passage of the bonus act in 1958. This act granted additional Interstate-system construction funds to states enacting appropriate controls. In 1965, the broader Highway Beautification Act, which withholds funds from all states failing to adopt acceptable legislation, was passed. Georgia responded to both laws and passed outdoor-advertising control acts that were typical of those in most states. An analysis of the Georgia experience in controlling billboards is the focus of this study. It is concluded that the legislation has failed to achieve its stated objectives. Loopholes in the act have permitted extensive billboard construction. The federal insistence on the use of eminent domain, rather than police power, to remove nonconforming signs and the meager appropriations for this purpose have meant that few signs have actually been removed. Recommendations are made to more effectively control billboard proliferation and to provide signs to give the motorist information that is more compatible with protection of the visual environment.

The preamble to the Highway Beautification Act of 1965 declared:

> The erection and maintenance of outdoor advertising signs, displays, and devices in areas adjacent to the Interstate system and the primary system should be controlled to protect the public investment in such highways, to promote the safety and recreational value of public travel, and to preserve natural beauty.

How effective has this act actually been in achieving these goals? This paper examines its practical effects in a typical state—Georgia—and attempts to answer this question and to formulate recommendations that will more effectively accomplish its stated objectives.

HISTORY OF OUTDOOR-ADVERTISING CONTROL REGULATIONS IN GEORGIA

In Georgia, attempts to pass legislation controlling outdoor advertising have been lengthy and frustrating. The first was in response to the bonus act of 1958, the federal carrot that offered additional interstate construction funds to any state adopting billboard controls. This law was struck down by the Georgia Supreme Court. With the passage of the Highway Beautification Act of 1965, Congress exchanged positive for negative incentives: A state failing to pass acceptable controls lost 10 percent of its federal-aid highway funds. However, Georgia then adopted additional legislation to avoid this federal stick.

Bonus Law and the Georgia Law of 1964

Soon after construction of the Interstate highway system began in 1956, strong concerns were expressed over the need to curb the spread of outdoor advertising along this 67 200-km (42 000-mile) national network (1). In 1958, Congress passed the so-called bonus act to encourage individual states to develop control measures and provide a degree of national uniformity should they decide to do so. Any state entering into an agreement with the federal government to control advertising along the Interstate highways that was consistent with national policy would receive a bonus of 0.5 percent of the construction cost of the highway project. The act provided for control of outdoor advertising within 210 m (660 ft) of the Interstate right-of-way. It permitted four classes of signs within the controlled area: (a) directional or other official signs; (b) on-premise signs; (c) signs within 19.2 km (12 miles) of an advertised activity; and (d) signs in the specific interest of the traveling public, i.e., signs containing information about places operated by the government, natural phenomena, historic sites, and locations of eating, lodging, camping, and vehicle services.

In 1959, an amendment was adopted that prevented controls from applying to those segments of the Interstate system that traversed (a) areas that had been zoned commercial or industrial within the boundaries of incorporated municipalities as such boundaries existed on September 21, 1959, and (b) other areas in which the state had clearly established land use as industrial or commercial as of September 21, 1959.

The 1958 act did not specify the methods to be used by a state for sign removal or acquisition of advertising rights. Any state that effected control by purchase or condemnation was declared eligible for federal reimbursement on a 90:10 ratio, provided that such cost did not exceed 5 percent of the cost of the Interstate right-of-way within the project. Twenty-five states entered