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SERB: A New High-Performance Self-Restoring Traffic Barrier

M.E. BRONSTAD, C.E. KIMBALL, JR., AND C.F. McDEVITT

This paper describes the development and evaluation of a unique guardrail system. Features of this barrier include a simple gravity-dependent self-restoring stage for automobile impacts that bottoms at a second stage that is capable of redirecting large vehicles. Screening of preliminary designs was accomplished by computer simulation and cost analyses. The prototype barrier design was revised into a final configuration based on crash test results. The self-restoring barrier (SERB) guardrail has successfully redirected vehicles that range from a 950-kg (2100-lb) mini automobile to a 18 000-kg (40 000-lb) intercity bus at 95 km/h (60 mph) and a 15° angle. A unique feature of the new system is the self-restoring elastic 0.3-m (11-in) deflection of the rail, which provides forgiving redirection for most passenger car impacts without damage or permanent deformation of the system.

This paper describes the development and evaluation of a unique high-performance guardrail system. Features of this barrier include a simple gravity-dependent self-restoring stage for automobile impacts that bottoms at a second stage that is capable of redirecting large vehicles. The finalized design is a product of an in-depth investigation conducted by Southwest Research Institute for the Federal Highway Administration. Design criteria were developed first and conceptual designs were subsequently screened by computer simulation and cost analyses. The barrier system selected for crash test evaluation is considered the best of all design concepts investigated during the course of the project. A total of seven crash tests were conducted on prototype and finalized design installations. Included in the evaluations were mini, subcompact, and full-sized cars as well as school and intercity buses.

BACKGROUND

In the early 1970s, crash test evaluations in the United States began to use heavy vehicles to evaluate high-performance barriers. The collapsing ring bridge rail (1) and the concrete median barrier were subjected to impacts by intercity buses (2) and tractor trailers (3). The conditions of impact varied considerably, since there was no recognized standard impact condition for these heavy vehicles. Indeed, there were no standard heavy vehicles specified for crash testing.

The objective of this study was to design high-performance guardrail and median-barrier concepts. It was recognized that many agencies were replacing flexible metal barriers with concrete in urban areas due to frequent requirements for damage repair. A goal of this design study was to provide the agencies with a forgiving flexible barrier that would not require significant maintenance and at the same time would provide containment and redirection of infrequent impacts by heavy buses and trucks. A survey of selected states that were known to have significant heavy-vehicle traffic was conducted to determine deflection limits for the systems. Selection of design vehicles was also a consideration. The final product of the investigations was the set of design criteria for the high-performance self-restoring barrier (SERB) system given below:

1. Impact severity: Provide forgiving redirection for subcompact car for impacts up to 95 km/h (60 mph) and 15° angle,
2. Strength: Contain and redirect an 18 000-kg (40 000-lb) intercity bus impacting at 95 km/h and 15° angle,
3. Damage repair: Allow no significant damage during typical shallow-angle impacts with cars, and
4. Cost: Minimize installation cost.

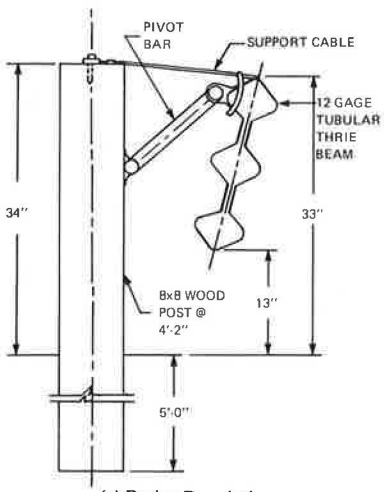
SERB BARRIER

The SERB barrier is a staged system designed to be self-restoring for most impacts that occur at shallow angles. The tubular Thrie beam is mounted on alternate posts by using a double-hinged pivot bar and cable assembly (Figure 1a). When impacted by a vehicle, the beam deflects up and backward, providing 0.3 m (11 in) of stroke before bottoming on the posts (Figure 1d). As the beam is displaced, the vehicle follows the upward motion, which provides a banking effect that enhances smooth redirection. After bottoming, the SERB guardrail is a very strong barrier 1.0 m (38 in) high capable of redirecting heavy vehicles that impact at 95 km/h and a 15° angle.

FINDINGS

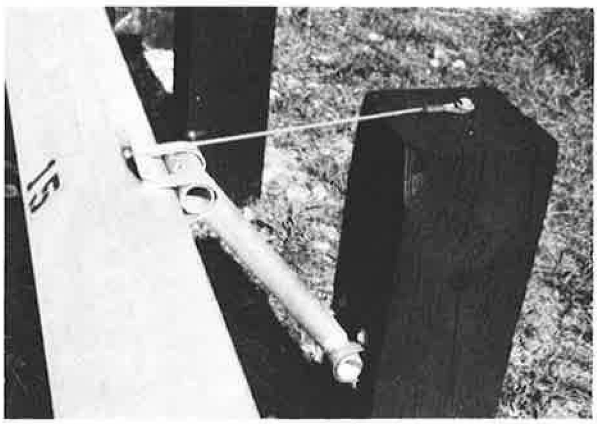
The first three crash tests were conducted on the prototype design shown in Figure 2 (all tests are summarized in Table 1). In this design, the tubular Thrie-beam rail is bolted directly to the single-hinged pivot bar. The rail 0.8 m (30 in) high became 0.9 m (35 in) high when it bottomed against the wood posts. Tests SRB-1 and SRB-2, which used passenger vehicles, were successful. Rollover of the school bus in test SRB-3 (Figure 3) led to the de-

Figure 1. Final SERB design.

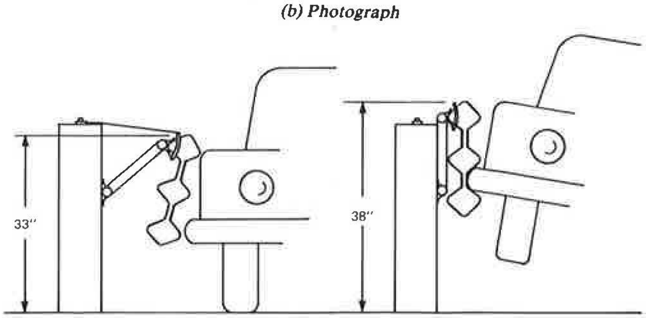


(a) Design Description

Note: 1 ft = 0.3 m; 1 in = 25 mm.



(b) Photograph



(c) At Impact *(d) At Bottom of Stroke*

sign modification described in Figure 1. Findings from the crash tests conducted on the finalized design are described in the following discussion.

Test SRB-4

The final barrier design installation was impacted with a 1974 Honda Civic that weighed 945 kg (2083 lb) at a speed of 88.0 km/h (54.7 mph) and a 17.1° angle. As shown in Figure 4, the vehicle was smoothly redirected and there was no barrier damage. Vehicle damage was limited to sheet-metal deformation (Figure 5).

Test SRB-5

A 1970 Chevrolet-Wayne school bus that weighed 9070 kg (20 000 lb) impacted the barrier at a speed of 97.4 km/h (60.5 mph) and a 13.8° angle. As shown in Figure 6, the bus was smoothly redirected and the maximum roll angle was 27°.

Damage to the installation included two beam sections, one post fractured below grade, one post split, most beam-pivot-bar attachment bolts sheared, and some support-cable lag bolts pulled out.

The bus damage was moderate during contact with the barrier; however, extensive damage occurred during recovery when the bus impacted another barrier installation. This damage prevented meaningful posttest photographs.

Figure 2. Prototype barrier installation.

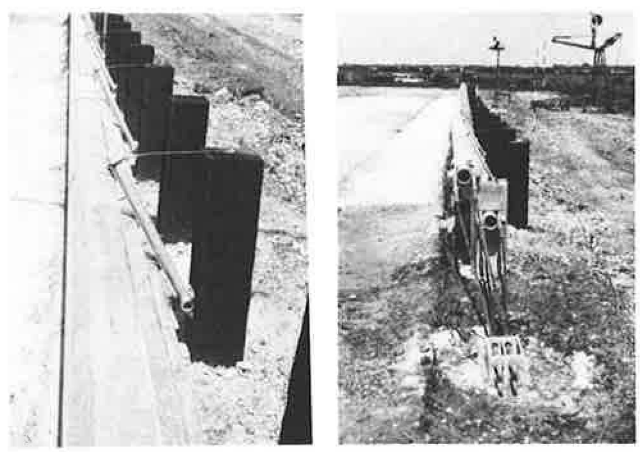


Table 1. Summary of crash test evaluations of SERB guardrail.

Test	Barrier Design	Vehicle	Vehicle Weight[a] (lb)	Impact Speed (mph)	Impact Angle (°)	Vehicle Acceleration[b] (g) Lateral	Vehicle Acceleration[b] (g) Longitudinal	Maximum Barrier Deflection Dynamic (in)	Maximum Barrier Deflection Permanent Post (in)	Maximum Barrier Deflection Permanent Rail (in)
SRB-1	Original	1974 Chevrolet Vega	2 650	58.6	17.2	5.6	-2.0	12.0	0	0
SRB-2	Original	1973 Chevrolet Impala	4 700	60.6	24.6	9.2	-6.6	29.4	6.0	4.0
SRB-3	Original	1972 International chassis with Wayne school bus body	20 000	56.9	17.5	5.9	-3.0	31.0	19.0	12.8
SRB-4	Modified	1974 Honda Civic	2 083	54.7	17.1	6.4	2.3	10.8	0	0
SRB-5	Modified	1970 Chevrolet chassis with Wayne school bus body	20 000	60.5	13.8	9.4	-1.2	36.0	11.1	10.0
SRB-6	Transition	1974 Oldsmobile Delta 88	4 832	56.2	25.3	6.4	-5.4	10.5	7.8	7.8
SRB-7	Modified	1956 GMC Scenicruiser	40 000	57.0	15.8	4.7	-3.3	47.1	19.5	21.8

Note: 1 lb = 0.45 kg; 1 mph = 1.6 km/h; 1 in = 25 mm.

[a]Weight includes vehicle, two anthropomorphic dummies, and instrumentation. Buses are ballasted with loose sandbags in seats. [b]50-ms average.

Figure 3. Test SRB-3.

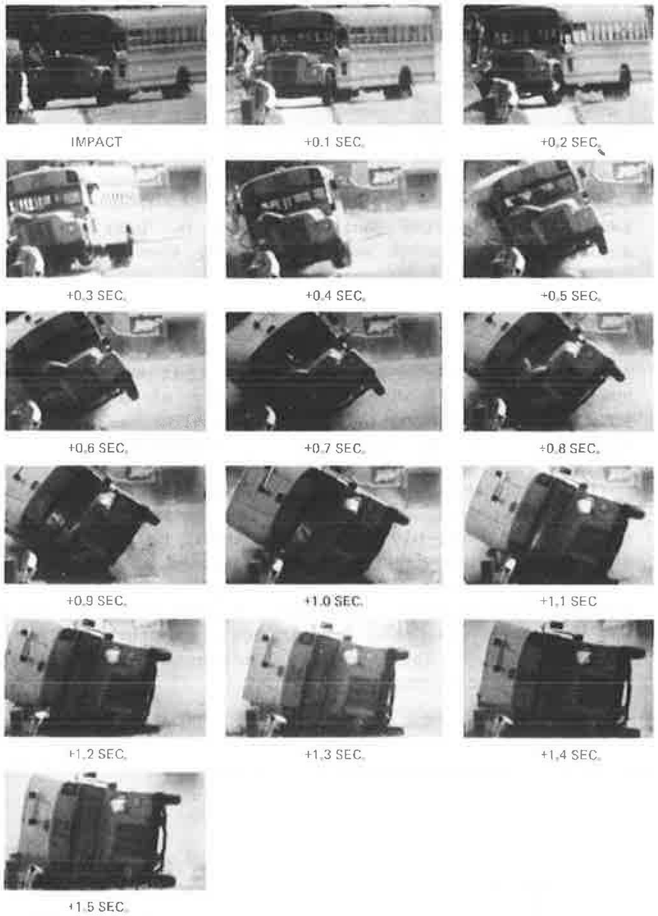


Figure 4. Test SRB-4.

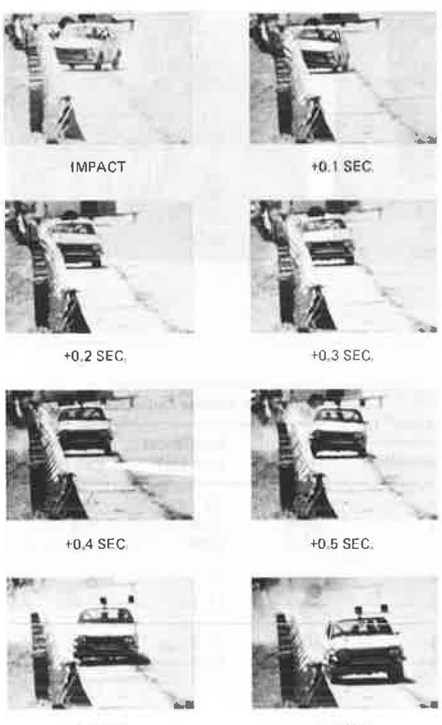


Figure 5. Vehicle and barrier condition after test SRB-4.

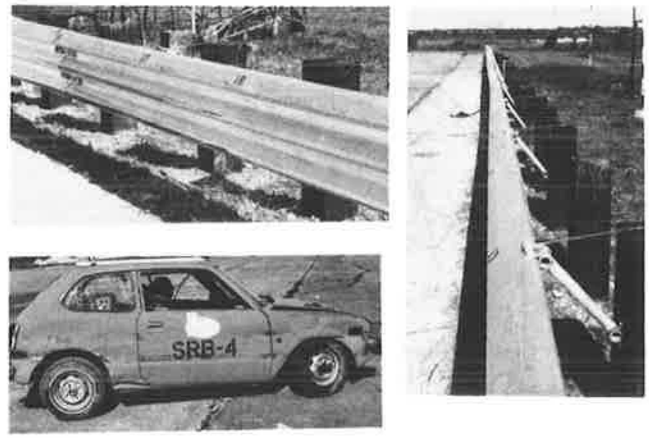


Figure 6. Test SRB-5.

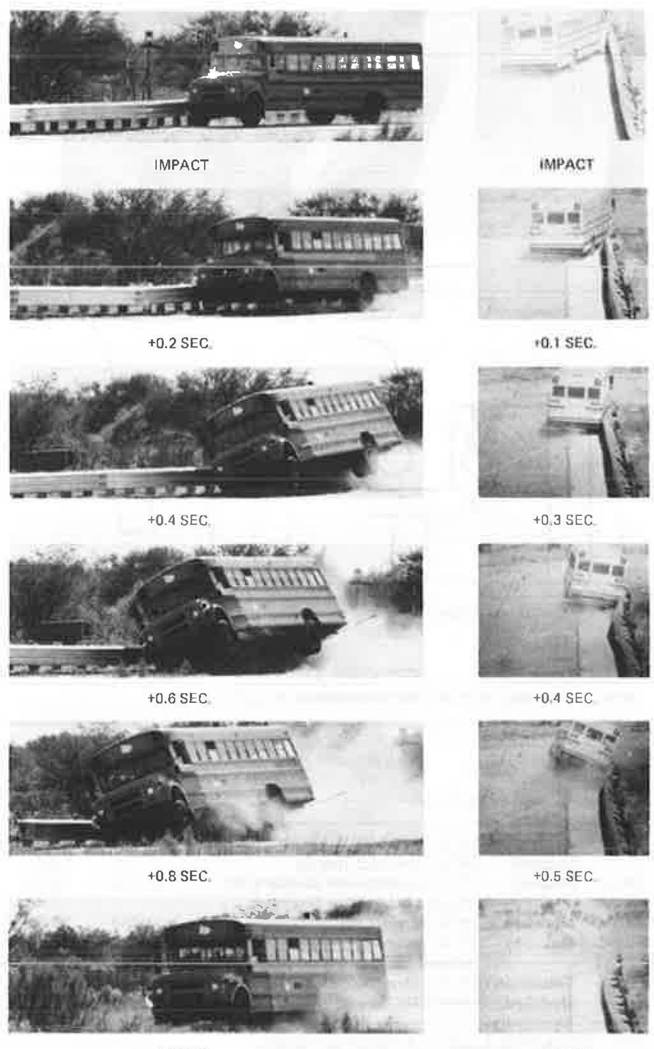


Figure 7. SERB end treatment.

Figure 8. Results of test SRB-6.

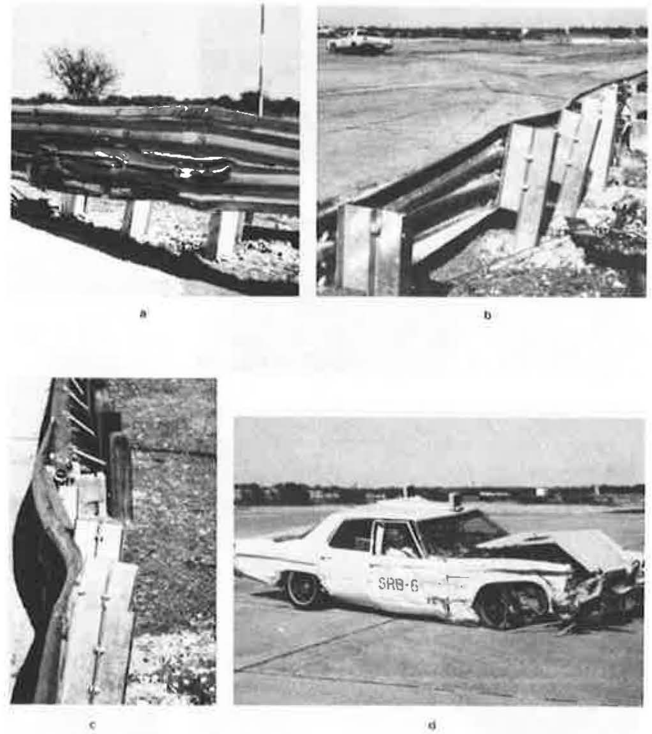
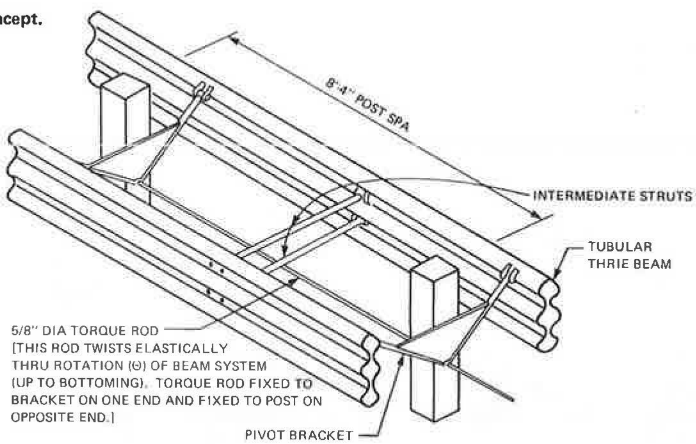


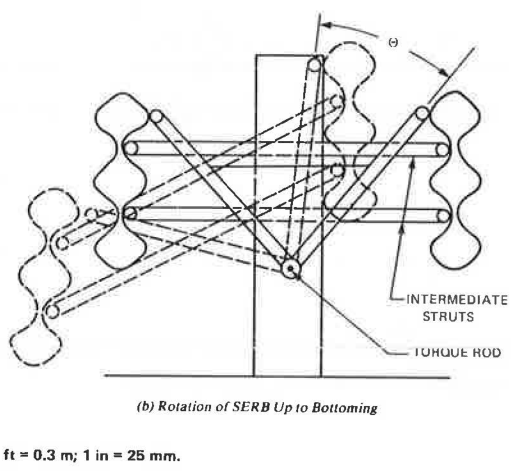
Figure 9. Test SRB-7.

Figure 10. Results of test SRB-7.

Figure 11. SERB median-barrier concept.



(a) Isometric View



(b) Rotation of SERB Up to Bottoming

Note: 1 ft = 0.3 m; 1 in = 25 mm.

SERB End Treatment

The end of the SERB guardrail features a rigid steel support post set in concrete; four cables provide longitudinal anchorage (Figure 2). In order to shield the rigid support post, an end treatment was designed that uses standard W-beam guardrail terminals. A transition from a guardrail breakaway cable terminal (BCT) to the rigid end post was effected as shown in Figure 7. Other W-beam terminals or a crash cushion could also be used at the end.

Test SRB-6

The SERB end treatment was subjected to evaluation according to Transportation Research Circular (TRC) 191 (4) criteria for transition sections, i.e., a 2040-kg (4500-lb) car that impacts at 95 km/h and a 25° angle at the most vulnerable location.

A 1974 Oldsmobile that weighed 2192 kg (4832 lb) impacted the system 4.5 m (14.6 ft) upstream of the rigid end post with a speed of 90.5 km/h (56.2 mph) and a 25.3° angle. The vehicle was smoothly redirected (Figure 8b); maximum beam deflection was 200 mm (7.8 in).

For the test conditions, vehicle damage was typical for impacts with rigid barrier systems (Figure 8d). Barrier damage (Figure 8a and c) consisted of one Thrie-beam section, a transition section, and two posts.

Test SRB-7

A 1956 GMC Scenicruiser intercity bus that weighed 18 140 kg (39 908 lb) impacted the barrier at a speed of 91.8 km/h (57 mph) and a 15.8° angle. As shown in Figure 9, the bus was smoothly redirected and the maximum roll angle was 38°.

Damage to the installation was moderate; it included three rail sections and five broken posts, as shown in Figure 10. Maximum dynamic deflection of the railing system was 1.2 m (4 ft). Damage to the bus included the sheet metal, window, and baggage-door area (Figure 10). The bus was driven from the test site.

CONCLUSIONS AND RECOMMENDATIONS

A high-performance guardrail system was developed in this project primarily by using computer simulation and crash test evaluation. The original design criteria were met by the final design configuration. A late inclusion of a mini-sized car in the test matrix posed no problem in terms of achieving desirable barrier performance.

Barrier Design

The original design of this barrier was accomplished by using BARRIER VII (5) computer simulations. It is noteworthy that no changes were made to the beam, post, or post spacing of the guardrail system during its development. The 75-mm (3-in) change in railing height and revised hinge details demonstrably improved the performance of the final barrier for school buses, as shown by test SRB-4, but neither of these changes is pertinent when the capability of the simulation model is considered. Comparisons of experimental and simulation values demonstrated that the SERB guardrail performed much as predicted. Modeling of the wood posts in soil has always presented simulation difficulties, and this best explains the superiority of the car simulations (no post movement) as compared with those for the bus.

The predictable behavior of the SERB concept would allow other barriers to be readily designed for either higher or lower service conditions. By varying post size and/or spacing, for example, a more economical system could be achieved. Of course, the performance of this system would be changed with regard to barrier capacity for vehicle containment and/or maximum deflections.

Demonstrated Performance

Demonstrated performance of this unique barrier includes the following results:

1. No barrier damage or permanent deformation during an impact at 88 km/h (55 mph) and a 17° angle although maximum barrier deflection was 280 mm (11 in);
2. Vehicle acceleration values near compliance with TRC 191 for both Honda and Vega impacts (in this regard, the SERB guardrail is currently unique);
3. Containment and redirection of a wide range of test vehicles at a nominal 95 km/h and 15° angle [test vehicles included 945-kg minicar, 9070-kg school bus, and 18 140-kg intercity bus, all of which were driveable after having left the barrier (the SERB guardrail is unique among all known barriers for this performance range)];
4. Barrier damage for an impact at 95 km/h and a 25° angle with a 2040-kg car does not compromise the serviceability of the SERB guardrail, although repairs would be desirable;
5. For the most severe strength test (intercity bus), the goal of 1.2-m maximum dynamic deflection was met; and
6. An end treatment that included transition to an approved guardrail terminal was evaluated at the length-of-need zone.

Recommendation

The SERB guardrail system described is recommended for immediate installation when serious consideration of heavy-vehicle containment is warranted. Cost of the system is considered competitive. It is estimated to be $21-$27/linear ft ($17-$24 for materials, $2-$4 for labor).

For median-barrier applications, a more-efficient use of dual beams is suggested in Figure 11; however, tests have not been conducted on this configuration. Figure 12 shows a SERB application for sawtooth medians.

SERB Advantages

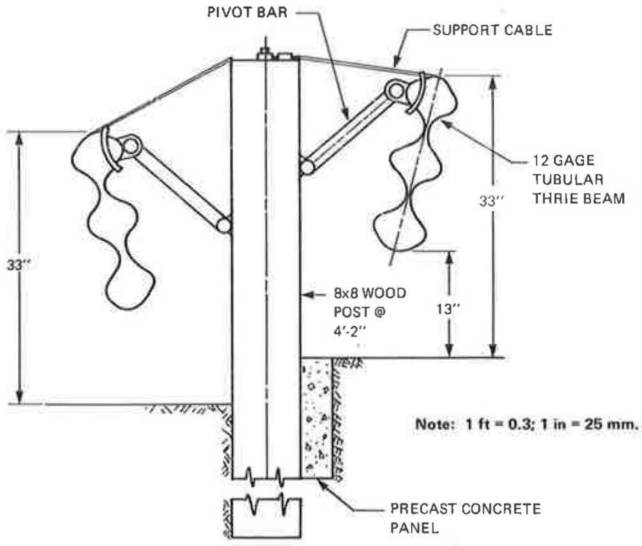
Advantages of the SERB guardrail systems when compared with other metal barrier systems include the following:

1. Damage repair from typical shallow-angle impacts is projected to be minimal;
2. Forgiving redirection is provided for all cars as well as containment of heavy vehicles under severe impact conditions;
3. The 1.2-m maximum deflection during the intercity bus test (a design goal) makes application of the SERB guardrail to current roadside clearances reasonable even when heavy-vehicle containment is a serious consideration.

Advantages of the SERB system when compared with concrete barriers include the following:

1. Stable redirection of all classes of cars with minimal rollover potential;
2. Demonstrated performance with heavy vehicles such as the school bus and the intercity bus;
3. Demonstrated well-behaved performance without

Figure 12. SERB median-barrier concept for sawtooth medians.



Note: 1 ft = 0.3; 1 in = 25 mm.

variables such as foundation support and rebar configurations, i.e., lightly reinforced to heavily reinforced concrete barriers and minimal to substantial foundation support; and

4. Definite advantage in performance for high angles of attack, i.e., those greater than 15°.

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