

more slowly for the soft-nose configuration B designs. Thus, the more sudden onset rate of loading for the harder nose design, which promotes a more brittle fracture of the wood, is attenuated. This action results in the specimen exhibiting tougher strength characteristics for the softer nose pendulum.

It is noted that configuration B is patterned to match the crush properties of a pre-1974 Chevrolet Vega. After 1974, a stiffer bumper and front end were produced to meet new U.S. Department of Transportation safety regulations. Hence, by using configuration B, the more conservative crushable nose is utilized in evaluating roadside appurtenances. At some time in the future, when most pre-1974 vehicles are no longer in service, a more rigid pendulum nose should be used.

To date, no full-scale vehicle tests have been performed on the Michigan sign support designs. Hence, a comparison between full-scale crash tests and pendulum test results cannot be made.

### CONCLUSIONS

A number of conclusions can be made from the findings:

1. With the exception of test M11 on the 150 × 200-mm (6 × 8-in) support standard, all configurations produced less than the maximum preferred momentum change specified by FHWA (1). Although test M12, a replication of test M11, did produce less than the preferred momentum change, it would seem prudent to use modifications 1 or 2 to achieve a higher degree of safety performance.
2. The two crushable nose designs are not equivalent based on momentum change of the pendulum and fracture energy of the support. A major part of the difference is due to the energy absorbed in the nose crush. In addition, it appears the slower buildup of force in the soft nose tests may attenuate the tendency for low-energy brittle fracture of the wood and thereby produce a tougher breakaway phenomenon.
3. The fracture mechanisms of the modified supports were generally consistent with (a) a shear failure occurring between the upper hole, through the lower hole, and to grade, and (b) flexure fractures occurring at the

upper hole, at the lower hole, and at grade. Knots or other wood discontinuities located in these failure planes would probably affect the results.

4. Since all specimens were tested with a concrete footing, any operational design based on these findings should include a similar foundation. We believe that a less rigid foundation and stress riser at grade level would increase the toughness of the fracture mechanism, thereby effecting a less conservative breakaway support.

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### Abridgment

## Breakaway Sign Testing, Phase 1

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Because of the damage to people and vehicles when an errant vehicle hits a fixed object, the state of New Jersey developed a breakaway system for large ground-mounted sign supports. Testing was conducted under various controlled conditions and indicated that the system met the appropriate criteria for a breakaway support. Subsequent to the testing, some modifications were made to the system, including the components used to restrain the breakaway section of the post to the fixed post segment.

After several years of experience it was found that the system was not performing as desired, although no injuries or deaths were reported as a result of hitting the

breakaway structures. Frequently, the restraint components failed, permitting the struck post to separate completely from the remaining post. Other components also were found to fail on occasion, although the system continued to function sufficiently to prevent any reported injuries.

At this time a detailed review of the breakaway system, including the results of investigations of actual sign impacts, became appropriate. Personnel from the state transportation department's research, design, construction, and inspection units studied the system, suggested necessary modification, and assisted in de-

Figure 1. Breakaway sign structure.

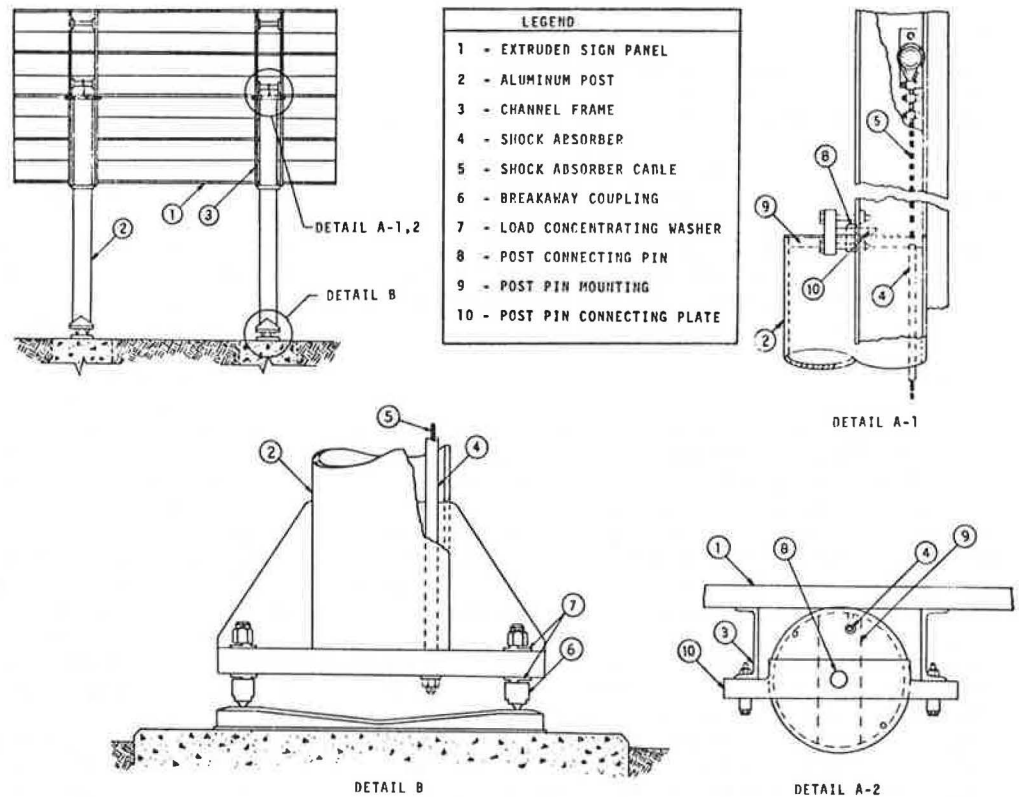


Table 1. Summary of breakaway test results.

Test	Test Conditions	Panel-to-Frame Attachments		Shock Absorber	
		Frame Slip (m)	Panel Dip (m)		
0	Basic sign design	0	0.3	Post pin jammed	No action
1	Maximum sign clips	0.2	0.3	Post pin jammed	Minimal action
2	Maximum sign clips, modified shock absorber	0.75	0.3	Post pin jammed	Minimal action
3	Sign panel bolted, spherical post pin, modified shock absorber, cable slack	0	1.2	Post separated successfully	Substantial action
4	Sign panel, conical post pin, modified shock absorber, cable slack	0	1.4	Post separated successfully	Substantial action

Note: 1 m = 3.3 ft.

veloping a work plan for future research and testing. From the analysis of impacts and group discussion, several minor modifications were implemented immediately. It was also agreed that controlled testing of the system was necessary to further isolate any problems and to verify proper functioning of the modified design.

Although actual vehicle crash tests would be necessary to measure momentum change and to test the reaction of the system under real life conditions, the cost of such tests limited their number. A system using a heavy truck and a steel cable was developed for use in the problem determination phase, although differences in the test conditions, such as lack of vehicle crush and the resulting longer impact duration, precluded measuring momentum change in a definable manner. However, it was felt that the conditions would be adequate to show

actual sign-structure performance well enough to define any improperly functioning components. To record the data, photographs were taken by normal-speed still and high-speed movie cameras. A videotape was also used to permit immediate playback of the tests.

It was decided to test the unmodified design initially to show the reaction of existing structures to impacts. Additional tests would be done to show the effects of various modifications, including sign-panel attachment methods and the post restraint system. Other modifications would be made based on observations of component performance during the tests.

#### BREAKAWAY SIGN SUPPORT

The New Jersey breakaway system consists of three basic parts other than the panel itself and the posts (Figure 1). The base of each post is connected to the anchor bolts with metal couplings and washers that break under vehicle impact but resist wind loads applied to the sign panel. The sign panel sits over a pin on the top of the post with the lower edge of the panel held to the post by a clamp. On impact the lower clamp breaks, and the post and attached pin are to drop free of the panel and rotate upward and away from the panel. Meanwhile, the post is still attached to the panel by a wire rope and aluminum tube (shock absorber) that extrudes and reduces the force applied to the panel during restraint of the free post. The system uses the panel as a part of the restraint system.

#### Problem Definition

Investigation of the field impacts showed consistent problems with release of the post from the sign panel and with the shock-absorbing system. Frequently, the panel mounting assembly slipped through clips used to hold the panel to the mounting assembly while little or no operation of the shock absorber was found.

### Test Structure

A breakaway sign structure with a 1.8 × 3.6-m (6 × 12-ft) extruded sign panel was identified as the critical size for the tests. This structure is the smallest capable of accepting the heavier of two post restraint designs. The extruded sign panel can handle up to 3 sign clips/m (1 sign clip/ft) of vertical panel size, more than other panel types. Additionally, this panel is the smallest used for breakaway signs and, consequently, also represents a lower limit for sign clip locations. Tests were designed to permit the independent analysis of modification (see Table 1.)

### FINDINGS

Shock-absorber performance was a source of major concern during testing. The shock-absorber connecting cable affects the operation of the breakaway system in two ways. First, acting as a hinge where post separation occurs, it rotates the post up and away from the impacting vehicle. Second, it transmits the impact energy to the sign panel. During initial tests, the hinge point jammed where post separation should occur. Separation eventually occurred at the expense of connecting hardware. Similar jamming results were noted when several field impacts were reviewed. It was suggested that the shock-absorber cable was having a negative effect on post separation. Pretensioning the cable is a procedure currently specified by New Jersey Department of Transportation standards (3). It was decided to test the effect of leaving this cable loose. It was hoped that it would free the connection where the post separation should occur, preventing jamming. However, post separation occurred only after destruction of the connecting hardware. It was decided that the connecting pin design was also a factor in the jamming. In standard installations this connection is accomplished by letting the weight of the sign rest on a round pin. During impact, several events must occur in order for the sign to function properly. The timing of events is critical. When the post rotates too far before the pin is freed of the weight of the sign, the mechanism will jam. Subsequent post performance is then negatively affected. It was felt that the system being used consistently did not allow enough post rotation. The design had been predicated on the theory that the post weight would pull the pin free before it could rotate far enough to jam. Apparently just allowing slack in the shock cable would not by itself ensure enough post drop to free the pin.

A modified pin was developed by simply rounding the top of the pin. In addition to using this modified pin, it was decided that a generous amount of slack should be put into the shock-absorber cable. When these conditions were tested, post separation occurred smoothly. Further, the shock-absorber slack was drawn taut with sufficient impulse to start the energy-absorbing action.

At this point, two things had been confirmed. First, the breakaway system with a vertical shock absorber can be effective, even on small sign sizes. Second, we could not depend only on post weight to effect post release. Indeed, the rounded post pin had prevented jamming since the post did not drop at all.

It was apparent after reviewing high-speed films of current tests that the impulse provided to the shock absorber was instrumental in initiating the proper action of the device. However, the breakaway design had evolved around a taut connecting cable in order to ensure that the panel would not separate from the pin unless impacted. Modifications to the pin connection were needed to allow a slack cable to be incorporated into

the design. Trading off advantages of the rounded pin against the horizontal resistance to wind forces provided by an unrounded pin resulted in a cone-shaped pin. The conical design is believed to provide an adequate area of horizontal contact so that wind forces alone will not cause the post to separate. A test run with the conical pin and slack in the shock-absorber cable performed satisfactorily. After impact, the cable was again drawn taut with enough impulse to initiate shock-absorber action. The system performed without any damage to the connecting hardware. This absence of hardware damage in successive tests where the sign performance was satisfactory led us to believe that testing further structural design modifications would not be necessary.

A second area of concern was the panel slippage. It had been observed from field impacts that a frame to which the sign panel is attached does not always remain attached to the panel during impact. Initially, the use of as many sign clips as possible was tested. Frame slipping initiated by the drag of the separated post continued to occur. As a result, during later tests the panel was secured to the frame with bolts. In these tests there was no frame slippage recorded; but, as a trade-off, the sign panel was pulled downward a greater amount during impact. It is a concern that the panel may dip low enough to hit the top of a vehicle passing under the sign.

Analysis of the latter tests led to the conclusion that bolting improves the performance of the shock absorber. Kinetic energy expended during frame slippage when clips are used is instead expended by the shock absorber when the panel is bolted. It was decided to observe the panel action related to the vehicle clearance during full-scale impacts with both bolted and clipped panels before a final judgment is made.

### RECOMMENDATIONS

Full-scale crash testing in accordance with the Recommended Procedures for Vehicular Crash Testing of Highway Appurtenances (4) is recommended to identify how the breakaway sign structure, with the proposed modifications, will function during an actual vehicle impact situation. [Since 1974, minor changes have occurred in these procedures (5).]

Testing is to be organized with two initial tests on the same size sign structure that was used during simulated impact testing. First, a maximum number of sign clips should be used and then bolts should be used to secure the sign panel.

An analysis of the panel dip causing secondary impacts with the vehicle under these conditions will be one indication of whether it is desirable to continue to consider bolting or friction clipping the sign panel. Further tests should then be run to provide heavy-vehicle impact data and should include an angle impact of about 15° as well as impacts with a larger sign size.

Full-scale tests are to include the conical pin and generous slack in the shock-absorber cable.

It is also recommended that the breakaway sign structure as modified should be installed in locations where it will be subjected to high winds. Its performance under field conditions should be observed for at least 1 year prior to recommending that existing specifications be changed.

### ACKNOWLEDGMENTS

The contents of this report reflect our views, and we are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily

reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation. This report was prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

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## Evaluation of Bolted-Base Steel Channel Signpost

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A recent survey has shown that the steel flanged channel post, or U-post, is the most widely used type of sign support in the United States. In the past, it has been common practice to drive the full-length U-post into the ground. To facilitate its installation, a simple stub-signpost support system has been developed. Initially, a relatively short stub post is driven into the ground. Then the signpost, with sign panel attached, is bolted to the stub. A retainer-spacer strap in the bolted connection serves to provide a snug fit between the signpost-to-stub connection and to help control the impact trajectory of the sign panel and the signpost. Static load tests and full-scale vehicle crash tests were conducted to evaluate the stub-signpost system. Crash tests of both single- and multiple-post sign configurations were conducted in accordance with current standards and guidelines. The stub-signpost system satisfied current safety criteria in all cases. This paper describes these tests and their results.

A recent survey (1) found that there are more than 10 million roadway signs on the 50 state highway systems. Millions more are used on city streets and county roads. This same survey also found that the steel U-post is the most widely used type of sign support.

It has been common practice to drive the full-length U-post into the ground to the desired embedment depth. Driving the post in this manner can be awkward and hazardous to the installation crew since the post may be up to 4.88 m (16 ft) in length or possibly longer. Equipment, such as a ladder or a lift truck, is necessary to drive the post from such heights. Installation may also be accomplished by inserting the pole in a drilled hole and backfilling with excavated soil. However, this method is usually more costly than driving the post.

To simplify the installation procedure for the U-post, the Franklin Steel Company developed the Eze-Erect system. Initially, a stub post, about 0.91 m (3 ft) in length, is driven into the ground. Then the signpost with sign panel attached for single-post installations is attached to the stub post with the Eze-Erect bolted connection. A retainer-spacer strap is used in the connection primarily to provide a close fit at the post-to-stub connection during normal loading conditions. It also helps control the impact trajectory of the signpost resulting from a vehicle collision, especially for low-speed impacts.

Static load tests and full-scale vehicle crash tests

were conducted to evaluate the Eze-Erect system. The crash tests were conducted in accordance with current standards and guidelines (2,3). This paper summarizes these tests and their results. Full details of the tests are presented in two research reports (4,5).

#### EZE-ERECT SYSTEM

Figure 1 shows the general details of the first-generation design of the Eze-Erect system. Further details of the first-generation retainer-spacer strap and the connection are shown in Figure 2. Offset in the strap was established as a result of static load tests of various bolted connections. These tests took place in February 1976 at Standard Pressed Steel Laboratories, Jenkintown, Pennsylvania. As shown, the top connector bolt was 1.3 cm (0.50 in) from the top of the stub post, and the connector bolts were on 12.7-cm (5-in) centers. Overlap dimension was 15.2 cm (6 in). Hardware consisted of four bolts, each bolt having two heavy-gauge plain washers, a lock washer, and a hex nut. The two connector bolts were 3.8 cm (1.5 in) long. All bolts were  $\frac{5}{16}$ -18 UNC, Grade 5. As discussed in this paper, both static and dynamic tests were conducted on the first-generation assembly at the Texas Transportation Institute (TTI) in March 1977.

Subsequent to the tests on the first-generation assembly, modifications were made as shown in Figure 3. The location of the top connector bolt was changed from 1.3 cm to 2.5 cm (0.5 to 1 in) from the top of the stubpost. Also, the hardware was reduced to four bolts and four nuts. All bolts were  $\frac{5}{16}$ -18 UNC  $\times$  3.8 cm (1.5 in) long, Grade 5. The bolt and nut are of the integral flange type to eliminate plain washers. The hex nut is a prevailing torque type to eliminate the lock washer. This assembly will be referred to hereafter as the second-generation assembly. Static and dynamic testing conducted on the second-generation assembly are discussed in subsequent sections of this paper.

It is noted that other bolted overlap configurations have been used with U-posts, without the retainer-spacer strap. However, to achieve the required wind resis-