New Jersey Breakaway Sign Testing

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ABSTRACT

Simulated and actual crash tests were conducted on a New Jersey breakaway sign structure. The tests were aimed at isolating and modifying those aspects of the system that were causing excessive damage to components as a result of vehicular impact and thus made it necessary to return the sign structure to the shop for repairs rather than reerect it in the field with a few parts changed. Before beneficial modifications were incorporated into the standard specifications, full-scale instrumented vehicular crash tests were also conducted, which confirmed that the modified system functioned well and demonstrated compliance with the latest safety standards as specified in NCHRP Report 230.

The New Jersey breakaway sign support system, used on large ground-mounted signs, was developed around 1968 in an effort to reduce damage to vehicles and injury to their occupants. The breakaway concept is based on two components: the breakaway couplings and the load-concentrating (LC) washers (Figures 1 and 2). The combination of the necked-down section of the couplings and the eccentric loading applied by the LC washers provides the sign structure with the ability to withstand wind loading and at the same time to easily break away under vehicle impact. The concept is based on the application of the wind load to the post in a horizontal direction, which results in a bending moment at the base of the support. A counteracting rotational moment, which cancels, or substantially minimizes, the wind-induced bending moment, is developed by the LC washer's eccentricity. However, when a vehicle impacts one of the sign's support posts (18 in. above the ground), the LC washers are not effective in cancelling the vehicle-induced bending because of the reduced moment arm (about one-tenth the wind-induced moment). As a result, the post and its base are moved in the direction of impact, which causes the couplings to bend and break at the necked-down section. The post then moves from its foundation and rotates about the unimpacted post out of the way of the errant vehicle. The post is restrained to the sign panel by a metal cable (with a shock-absorbing device) that prevents the post from flying completely free after impact. The restraint causes the post to rotate horizontally as well as vertically about the unimpacted post (Figure 3).

Vehicle crash tests conducted in 1970 (1) demonstrated that the system functioned with vehicle change in momentum well under the FHWA desirable safety criteria limit of 750 lb-sec. After several years of actual roadside experience, however, it was determined that the system was not performing as desired, although no deaths or serious injuries occurred. In each accident investigated, there was some type of mechanical malfunction, and as a result, the sign had to be returned to the shop for repairs rather than be reerected in the field with minor repairs.

A committee was formed and charged with the responsibility to review the field experience with the breakaway signs. The committee considered several possible deficiencies within the design, including the shock absorber, as causes of the poor field

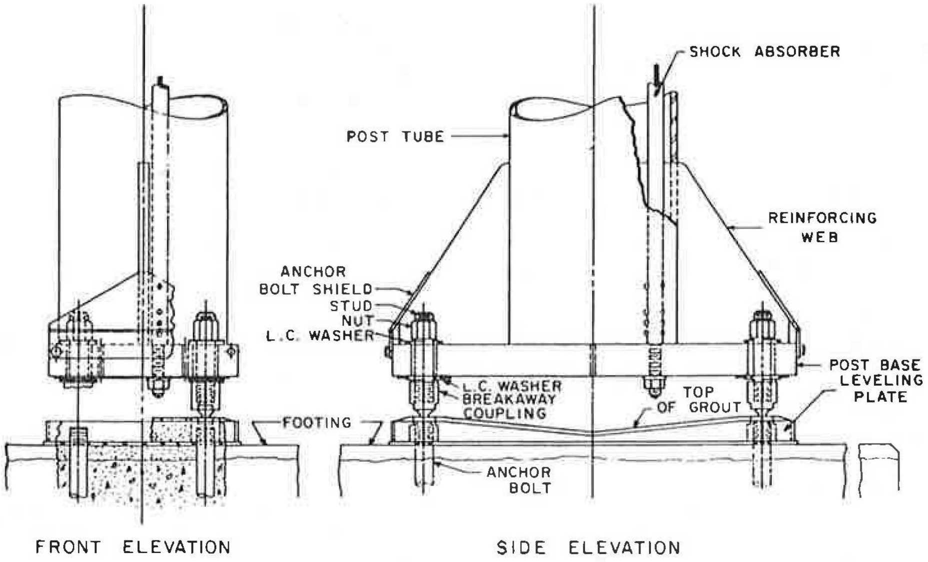


FIGURE 1 Breakaway base detail.

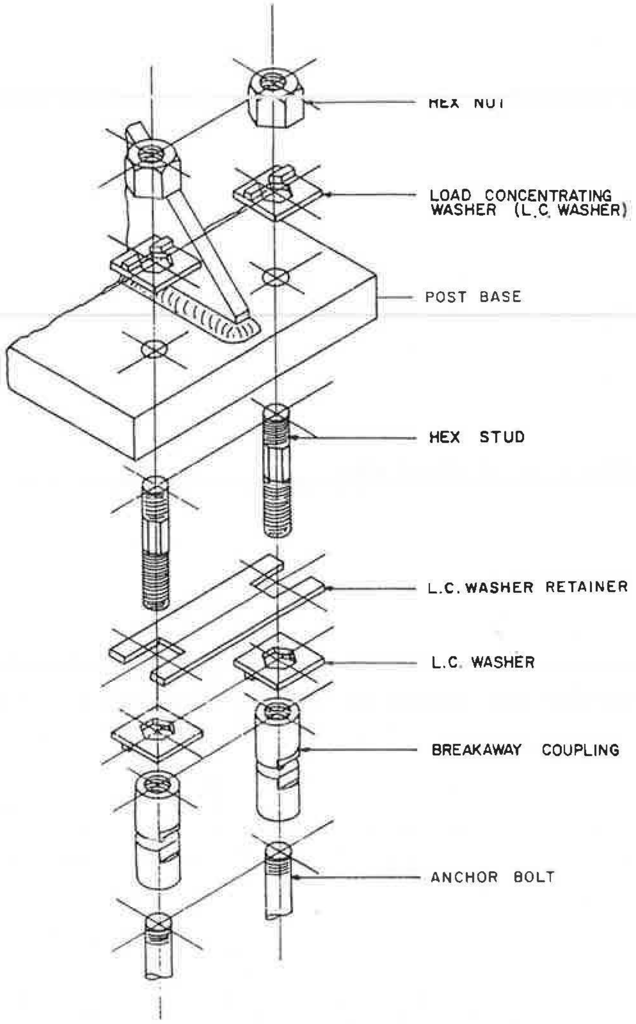


FIGURE 2 Breakaway coupling assembly.

performance. The committee modified the shock absorber design, as shown in Figure 4, and included it in the Standard Details (2) as of November 1974. The committee also suggested several other minor modifications to reduce hardware damage and recommended the testing program to isolate additional problems, verify the functioning of the modified design, and demonstrate conformance with safety standards (3-5).

STUDY PROCEDURES

The testing program was planned to proceed in three phases. Phase 1 was intended to identify and modify those items that prevented proper functioning of the system. Phase 2 was to confirm that the system, as modified, complies with nationally accepted safety standards. Phase 3 was to observe the modified sign structure under real accident conditions. (This phase was later dropped because in the 10-year experience with breakaways, no single structure has been struck more than once. When Phase 3 was proposed, an assumption had been made that certain structures, particularly those located in gore areas, would be impacted on a frequent basis. That assumption, however, was shown to be wrong.)

For Phase 1, a breakaway sign structure consisting of a sign panel 6 ft high by 12 ft wide and two 8-in. diameter support posts was erected. A truck equipped with a wire rope cable was used to pull one of the sign posts to simulate a vehicular impact. The impact transfer device (Figure 5), a wire rope sling, was wrapped around the post's base plate and pretensioned to stay in position. Once the couplings had broken and the post began to rotate forward, the cable sling fell to the ground and the post continued to rotate as under actual impact. High-speed cameras were used to photograph the sign structure operation during the event so that those aspects that prevented proper functioning of the system could be identified and modified.

Phase 2 was planned to be conducted by an independent testing agency utilizing more sophisticated techniques to certify compliance with national standards.

RESULTS AND DISCUSSION

Phase 1 consisted of five tests. In the first test, conducted with the test sign conforming to the existing plans so that data could be collected to identify the problem, several potential problems were spotted. One was the slipping of the channel frame on the impacted post, which is attached to the sign panel by clips (Figure 6). A second problem was the jamming of the post top pin (Figures 6 and 7), which must drop from its position under impact. To prevent sign panel slippage, the number of sign clips used was doubled (Figure 6) for the later tests. The jamming of the pin was a major concern because it could explain many other problems associated with the malfunction of the structure, such as loosened or broken sign panel clips, bent connecting plate, broken connecting-plate U-bolts, and miscellaneous weld failures. A suggestion to change the pin shape from cylindrical to conical was investigated and selected for further tests (Figure 7). The final simulated tests demonstrated that the conical post top pin released effectively without damage to the connecting hardware. Based on the test results, it was concluded that the system functioned acceptably as modified with the increased sign clip arrangement and the conical post top pin.

Phase 2 was begun by utilizing actual vehicles to impact a sign structure. Momentum change was determined from data collected from high-speed film and accelerometers. The effort was contracted to the Federal Aviation Administration (FAA) Experimental Center in Pomona, New Jersey. At the time, Transportation Research Circular (TRC) 191 (3) was the document listing the procedures for vehicle crash testing of highway appurtenances. This document required use of 2,250-lb vehicles and both high-speed (60-mph) and low-speed (20-mph) impacts.

Results of the tests indicated momentum changes in excess of the requirements of TRC 191. An investigation into why the momentum change was much greater than that documented when the system was originally tested in 1970 led to the discovery that the breakaway couplings did not meet the specification for hardness. When it was attempted to produce couplings that complied with the specifications, it was discovered that heat-treating to increase the hardness resulted in tensile strength above the maximum allowable in the specification. In the course of solving the hardness-tensile problem, a characteristic that greatly improved the breakaway function of the couplings was discovered--toughness, which, it was determined, should be quite low for good operation.

Investigation of available steels led to the discovery that steels processed with an elevated-temperature-draw (e.t.d.) process have the desired tensile strength to assure that the system can with-

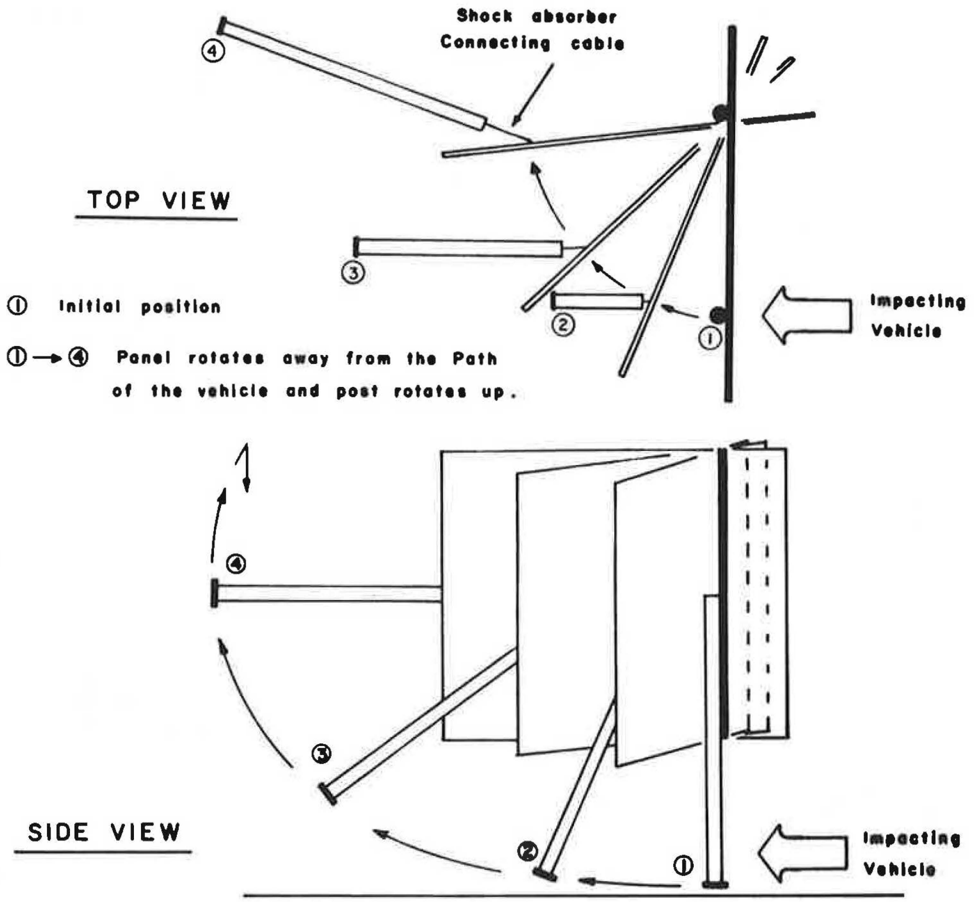


FIGURE 3 New Jersey breakaway sign support system: typical action during impact.

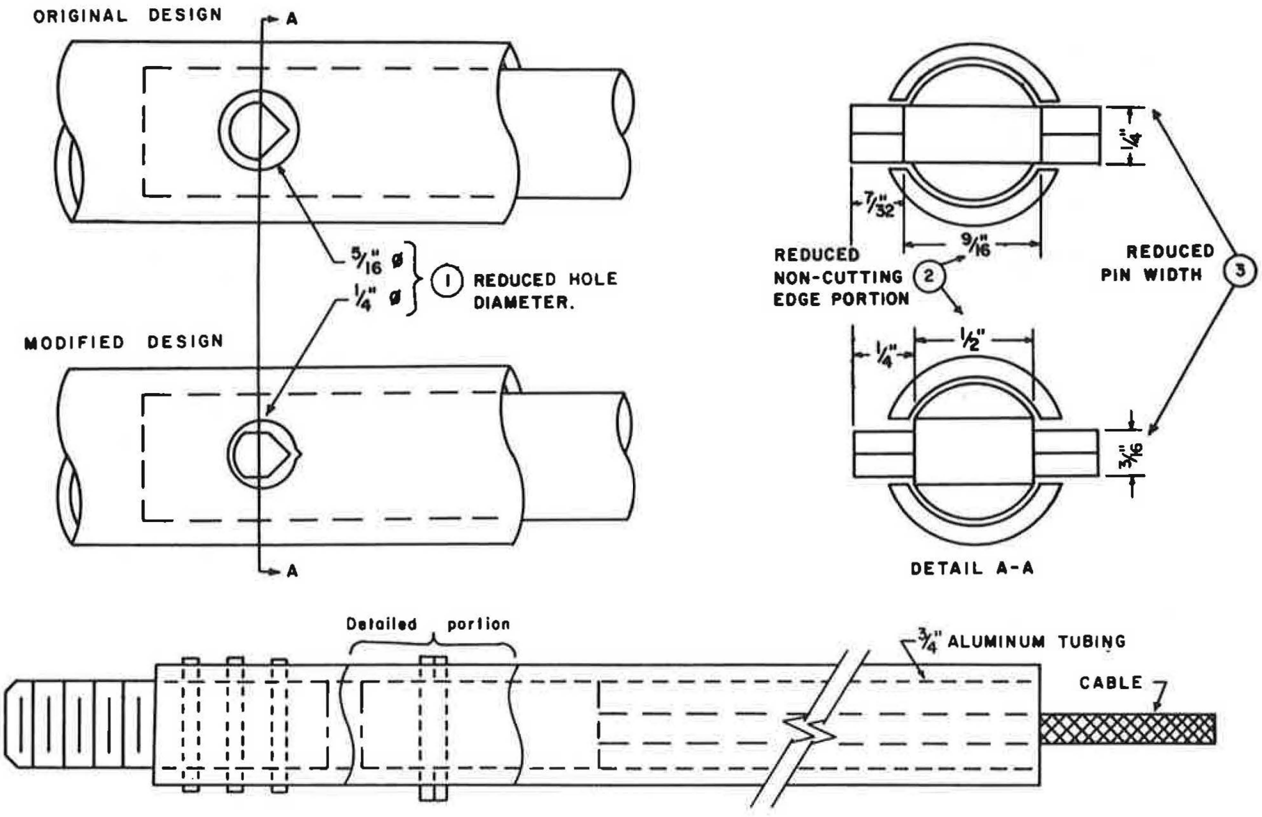


FIGURE 4 Shock absorber.

stand design wind loads and low toughness to ensure low-energy fracture on impact. A sample of a steel referred to as e.t.d. 4150-X, detailed in Table 1, was obtained and breakaway couplings were machined for testing. Laboratory tests conducted on these couplings indicated a high probability of desirable operation under vehicular impact. It should be noted that the critical section design of the couplings results in a neck-strengthening effect, which increases the coupling tensile strength by about 20 percent. Hence, the resulting coupling ultimate tensile strength will be in the range of 195,000 to 225,000 psi.

A pilot test was conducted by using a Chevrolet Chevette that was pushed into a test sign mounted on couplings made from the e.t.d. 4150-X steel. Data collected from film and vehicle damage showed insignificant damage to vehicle and structure and resulted in a momentum change well under the desirable safety limit of 750 lb-sec, and Phase 2 testing was thus resumed.

Unfortunately, during the time that a complying

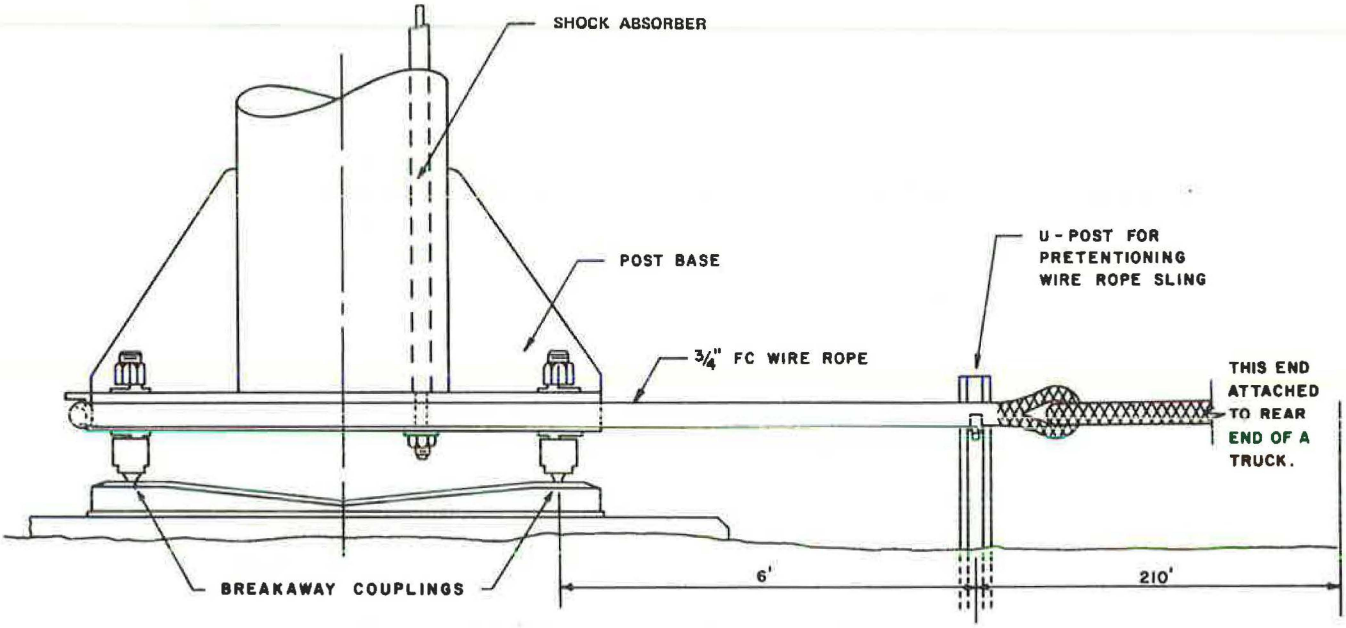


FIGURE 5 Impact transfer device used for simulating impacts.

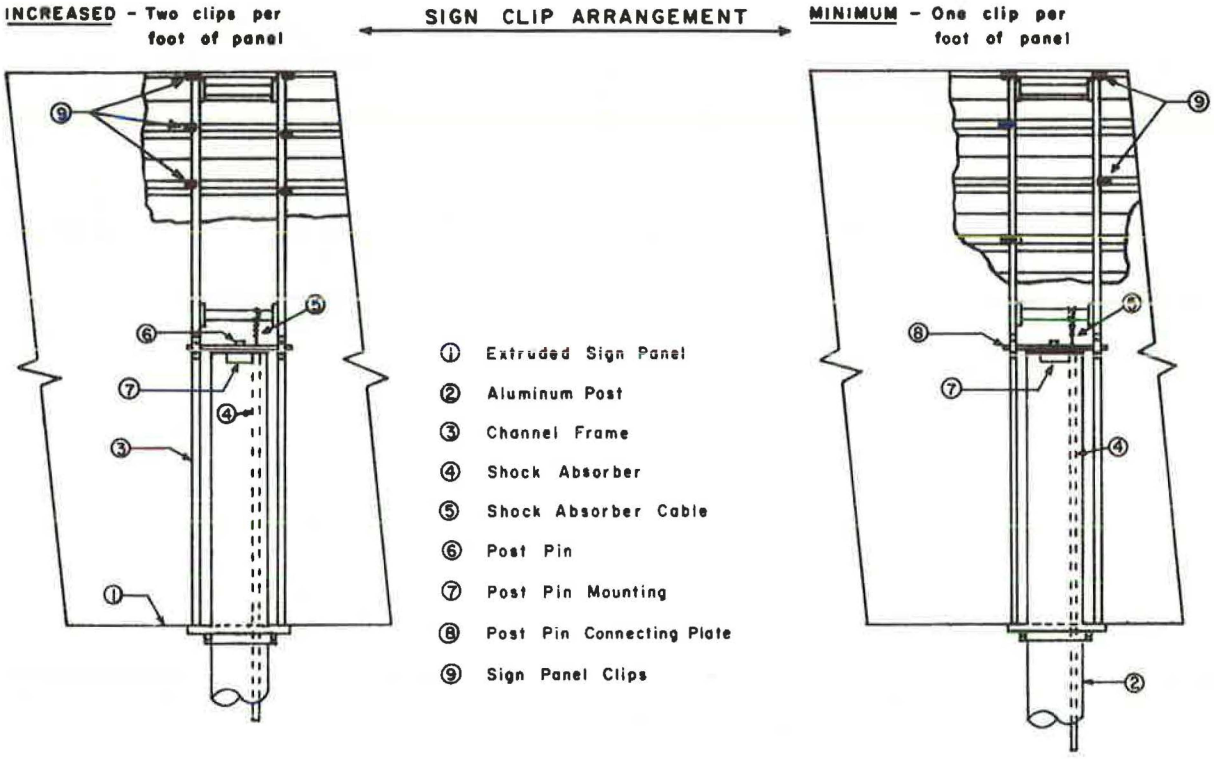
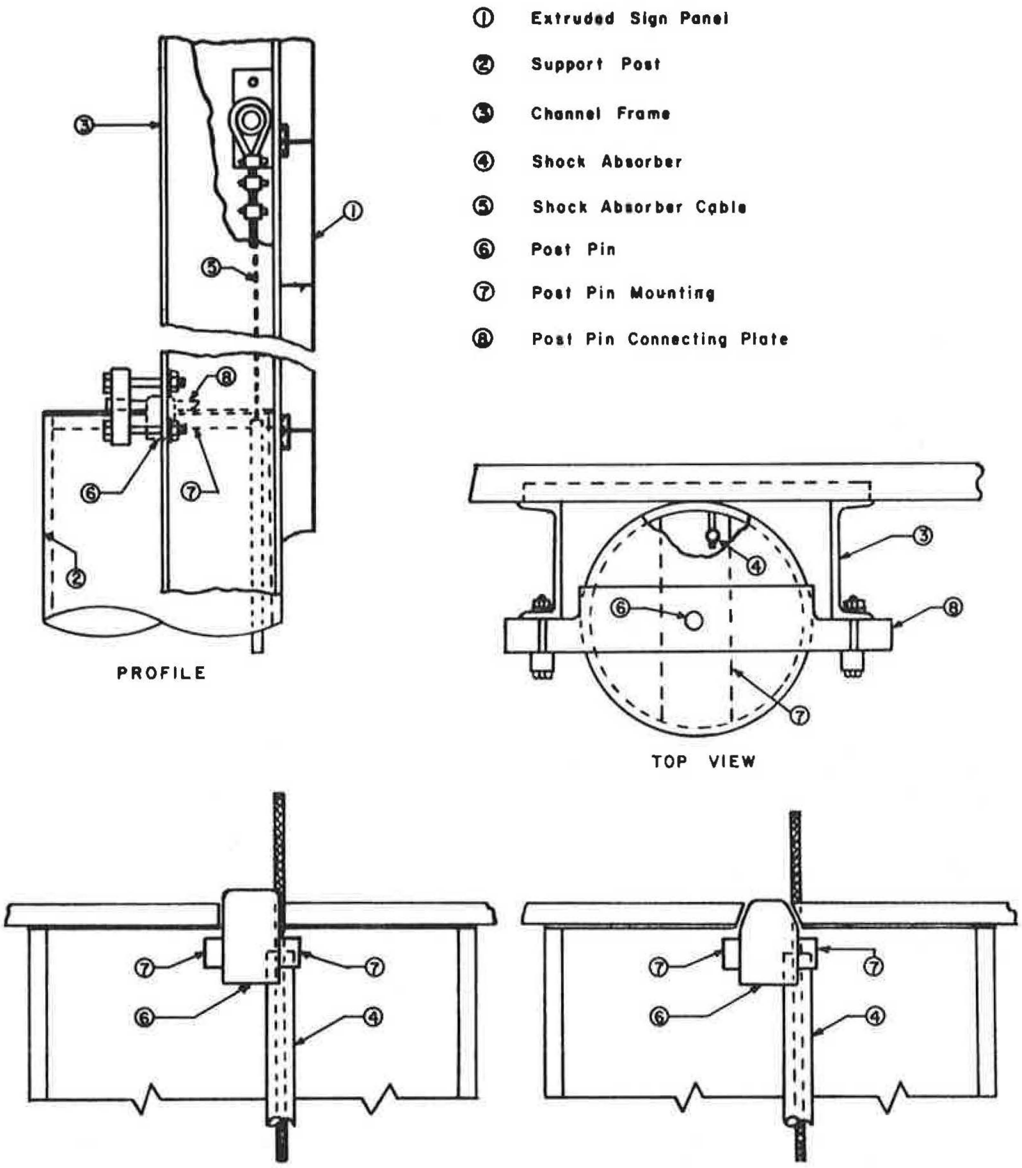


FIGURE 6 Sign panel attachment detail.



PROFILE

TOP VIEW

CYLINDRICAL POST PIN

CONICAL POST PIN

FIGURE 7 Post top connection detail.

TABLE 1 Mechanical and Chemical Properties for e.t.d. 4150-X Steel

Item	Amount
Chemical composition (%)	
Carbon	0.48 minimum
Manganese	0.75/1.00
Phosphorus	0.035 maximum
Sulfur	0.040 maximum[a]
Silicon	0.15/0.35
Chromium	0.80/1.10
Molybdenum	0.15/0.25
Tellurium or selenium	0.01 or 0.035
Mechanical property	
Tensile strength (psi)	165,000–185,000
Yield strength (psi)	155,000 (minimum)
Elongation (%)	9 mean (13 maximum)
Reduction of area (%)	34 mean (40 maximum)
Machinability (%)	56 of C-1212
Toughness (ft-lb)	10 (maximum at 70 degrees)

Note: e.t.d. 4150-X is a product of the LaSalle Steel Company, Hammond, Indiana.

[a] When tellurium is added, sulfur may be 0.04/0.06 percent.

steel was being investigated, the FAA facility was reorganized and testing could not be continued there. Southwest Research Institute (SWRI) was selected to conduct the full-scale testing, now under the guidelines of NCHRP Report 230. The revised testing procedures now required use of 1,800-lb vehicles instead of 2,250-lb ones. There was some concern about the use of the lighter vehicles because the pilot test had used a 2,250-lb Chevette. The concern proved to be unwarranted when an additional pilot test conducted with a Volkswagen Rabbit weighing 1,800 lb also resulted in a vehicle change of momentum well within the standards.

Three full-scale vehicle crash tests were conducted on a sign structure with a 14 x 18-ft panel mounted on two 12-in.-diameter support posts. The three crash tests were conducted with late-model Honda Civic sedans in the 1,800-lb weight class. Test conditions corresponded to Tests 62 and 63 of NCHRP Report 230 and an additional test similar to Test 63 but at a 25-degree angle. The three tests

TABLE 2 SWRI Test Conditions and Results

	Test		
	NJ-1	NJ-2	NJ-3
Test vehicle year[a]	1977	1978	1978
Vehicle weight (lb)	1,771	1,812	1,743
Impact speed (film) (mph)	20.8	59.9	61.4
Impact location	Left support	Right support	Right support
Impact angle[b] (degrees)	0	0	25
Offset distance[c] (in.)	0	15	22
Impact duration (sec)	0.24	0.09	0.115
Exit speed (mph)			
Film	15.5	54.5	54.6
Accelerometer	15.9	53.9	54.1
Change in momentum (lb-sec)			
Film	429	445	541
Accelerometer	402	508	571
Maximum 50-msec avg acceleration *(g)* (accelerometer)			
Longitudinal	-3.5	-6.4	-5.6
Lateral	-0.2	2.1	1.0
Occupant risk[d] (ΔV)			
Longitudinal (ft/sec) (15)	7.8	9.9	11.4
Lateral (ft/sec) (15)	0.5	-1.9	-1.0
a_{long} (15)	n/a	n/a	n/a
a_{lat} (15)	n/a	n/a	n/a

Note: n/a = occupant did not travel specified distance.

[a] All test vehicles were Honda Civics.

[b] Angle from axis perpendicular to sign panel plane.

[c] Distance from vehicle to pole centerline, positive to left.

[d] Numbers in parentheses are recommended values for NCHRP Report 230 *(4)*.

conducted demonstrated full conformance with the safety requirements of TRC 191 and NCHRP Report 230. The test conditions and results are summarized in Table 2.

There was some concern that the conical post top pin design might allow high wind loads to cause the sign panel to ride up and off the pin. A review of the potential problem indicated that this is very unlikely to happen except under some very unusual combinations of terrain and wind speed and direction. The use of a taut shock absorber cable connection, as currently required, should prevent such an occurrence and no problem is expected.

IMPLEMENTATION OF FINDINGS

The full-scale validation tests conducted at SWRI (6) confirmed that the modified breakaway sign system functions well within safety standards and with minimal hardware damage. It is hence recommended that the conical post top pin design and the special low-toughness material (e.t.d. 4150-X) be incorporated into the New Jersey breakaway sign standard drawings and specifications. The increased sign clip arrangement, which was also found to be a desirable modification, is already included in the standard specifications.

Because the modified New Jersey breakaway sign system has not been used except in testing, monitoring of field installations to ensure proper functioning in high winds is desirable.

SUMMARY AND CONCLUSIONS

The New Jersey breakaway sign support system was designed to break away on impact to reduce vehicle damage and prevent occupant injury. Accident experience has indicated that changes could be made to improve the performance of the breakaway sign structure by reducing the amount of sign repair needed after a vehicular impact occurred.

Several important modifications were made and the system was tested under various simulated and actual impact test conditions. Based on available literature, the modified New Jersey breakaway sign support is at this time the only breakaway system to have been tested in full compliance with the latest testing procedures (NCHRP Report 230) and to demonstrate compliance with the latest safety evaluation criteria.

Because the modified system's performance was well under the current safety limits and resulted in minimal damage to the sign structure, the modified system, which includes changes made to the post top pin connection and the breakaway coupling material, is recommended for use.

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Analysis of Accidents Involving Breakaway-Cable-Terminal End Treatments

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ABSTRACT

This paper includes an analysis of 50 accidents involving breakaway-cable-terminal (BCT) end treatments and 19 accidents involving median-breakaway-cable-terminal (MBCT) end treatments as used in Kentucky. The primary data base consisted of Kentucky accident records for the years 1980-1982; selected accidents were included that occurred before 1980 and after 1982. An attempt was made to document each accident with a police report, photographs, and a maintenance repair form. Results showed that the BCT end treatment performed properly in 60 percent of the accidents; that is, the end treatment performed as it was designed, with the wooden posts breaking away or the guardrail redirecting the vehicle. Only five impacts were known to involve small cars and the BCT performed improperly in four of those accidents. It should be noted that the BCT used in Kentucky is similar to the design tested and evaluated as part of the NCHRP studies and included in the AASHTO barrier guide. The primary difference was that before 1982, most BCTs in Kentucky were installed so that the last 125 ft of rail were placed on a simple curve (4.5 degrees) and there was a 6-ft offset rather than a parabolic flare with a 4-ft offset. However, Kentucky's MBCT design utilizes two BCTs joined together at the end section, and it varies considerably from the design tested as part of the NCHRP studies. The MBCT end treatment performed properly in 50 percent of the accidents. Problems related to stiffness of the end treatment are most apparent when impact angles are shallow. A recommendation was made to remove any existing MBCT designs from gore locations and replace them with crash cushions. A turned-down end treatment design was proposed for consideration at median installations.

The performance of guardrail end treatments has been a subject of concern to highway engineers for many years. A concerted effort was begun in the mid-1960s to evaluate guardrail design and recommend warrants for guardrail use. The work was funded through NCHRP Project 15-1 and a review of current practice was performed by Cornell Aeronautical Laboratory (1). The next study funded by NCHRP was a compilation of recommended practices for locating, designing, and maintaining guardrails and median barriers (2). Results reported from the study were based on a comprehensive literature review, a state-of-the-art