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Abridgment

Crash Tests of Omnidirectional Slip-Base Sign Supports

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Omnidirectional sign supports with triangular slip bases, which are similar to those successfully tested elsewhere on single-support appurtenances, were tested on multilegged sign installations. Four tests that were performed with 2150-lb vehicles determined compliance with American Association of State Highway and Transportation Officials specifications for vehicle momentum change. The supports were hit from two directions at two speeds, and each test resulted in a momentum change below 750 lb·s. In all the tests, vehicle damage and impact severity were light. The omnidirectional hinge design cannot hold the sign panel upright after one support is removed, but the entire design performs safely.

This study consisted of four full-scale crash tests to determine the impact performance of a triangular omnidirectional slip-base sign support that has an all-direction upper post hinge. [More information about these tests is provided elsewhere (1).] Testing details were taken from Transportation Research Circular 191 (2).

The support design (Figure 1) included base posts set in concrete, intermediate posts bolted to the base, and upper posts spliced to the intermediate posts (all W6x12 sections). The base posts, each topped by a triangular 1.5-in-thick plate, were set in 2-ft-diameter, 4-ft 9-in deep concrete foundations and had the plate top set flush with the ground line. Intermediate 8-ft-long posts that had matching triangular plates were attached to the bases, and three 6-in-long 1-1/8-in-diameter bolts were torqued to 110 lbf•ft. To permit the sign to be erected at 90° and 30° to the direction of vehicle travel, the left base plate was made circular rather than triangular and had two sets of three bolt slots offset by 60°. Two right bases were installed, also offset 60° from each other, so that the sign could thus be erected in either position. The 7-ft 6-in long upper posts were spliced to the intermediate posts with two 0.375-in-thick hinge plates. These plates were bolted to the drilled upper posts through holes and to the drilled intermediate posts through slots in the plates with 5/8-in bolts torqued to 170 lbf•ft for tests 29 and 30 and 190 lbf•ft for tests 31 and 32. An 8.5x16.5-ft (140 ft²) aluminum sign panel, which had three 2-3/8- by 1-1/4- by 3/16-in Z-bars, was mounted on the upper posts above the splice plates. The bottom of the panel was 7 ft above the ground. The Z-bars were attached to the sign panel with 1/4-in bolts on 16-in centers and to each post with two 1/4-in bolts.

During impact, the triangular plate on the intermediate post slips free of the base and, as the post rotates back, the splice plates bend to form a hinge. As bending continues, the bolts holding the slotted splice plate to the intermediate post pull free and the intermediate post is separated from the rest of the support.

The W6x12 post section tested is the largest post size to be used with this slip-base design. Successful tests of the W6x12 post would qualify smaller post sizes for use with this base. The two-support installation tested is typical for sign panels of up to 147 ft² erected on flat terrain and designed to withstand winds up to 80 mph (zone B). All of the bolt torques used initially were determined to be sufficient to withstand the loads developed by 80-mph winds. The hinge-bolt torques were increased for the last two tests in an attempt to keep the sign panel upright on a single support after impact.

All test vehicles were 1973 Chevrolet Vegas weighing approximately 2150 lb and speeds were near the 20- and 60-mph requirements. Vehicle test weights were reduced about 100 lb from the usual 2250 lb, recognizing that future test-weight requirements will be reduced. The actual test weights achieved could not be further reduced by using the vehicles available without extensive alterations. The impact angles were 90° and 30° to the sign face, which corresponds to a car traveling parallel to and at 60° to the pavement, respectively. Based on previous tests of triangular slip bases, these impact angles would produce the maximum vehicle velocity change and a reasonably expected impact condition for the roadway situations previously described.

RESULTS

Results of four full-scale crash tests of the omnidirectional slip-base sign support are summarized in Table 1.

In the first test (test 29), impact was perpendicular to the sign face at 27.7 mph and resulted in a 726-lb•s vehicle momentum. The slip-base bolts, torqued to 110 lbf•ft, separated on impact as designed, but the upper hinge bolts, torqued to 170 lbf•ft, remained in place and pulled the sign panel downward and backward and pitched the car -3° (upward) before the hinge released. The car traveled 11 ft during that period before the hinge released and traveled another 5 ft until the post flew free of the car.

The displaced sign panel then contacted the car roof. This secondary impact, which was directly over the front seat and about 1 ft to the right of center, resulted in a dent about 4 ft long, 3-7 in wide, and less than 1 in deep. This impact was not severe and presented no apparent hazard to vehicle

Figure 1. Omnidirectional slip-base sign support.

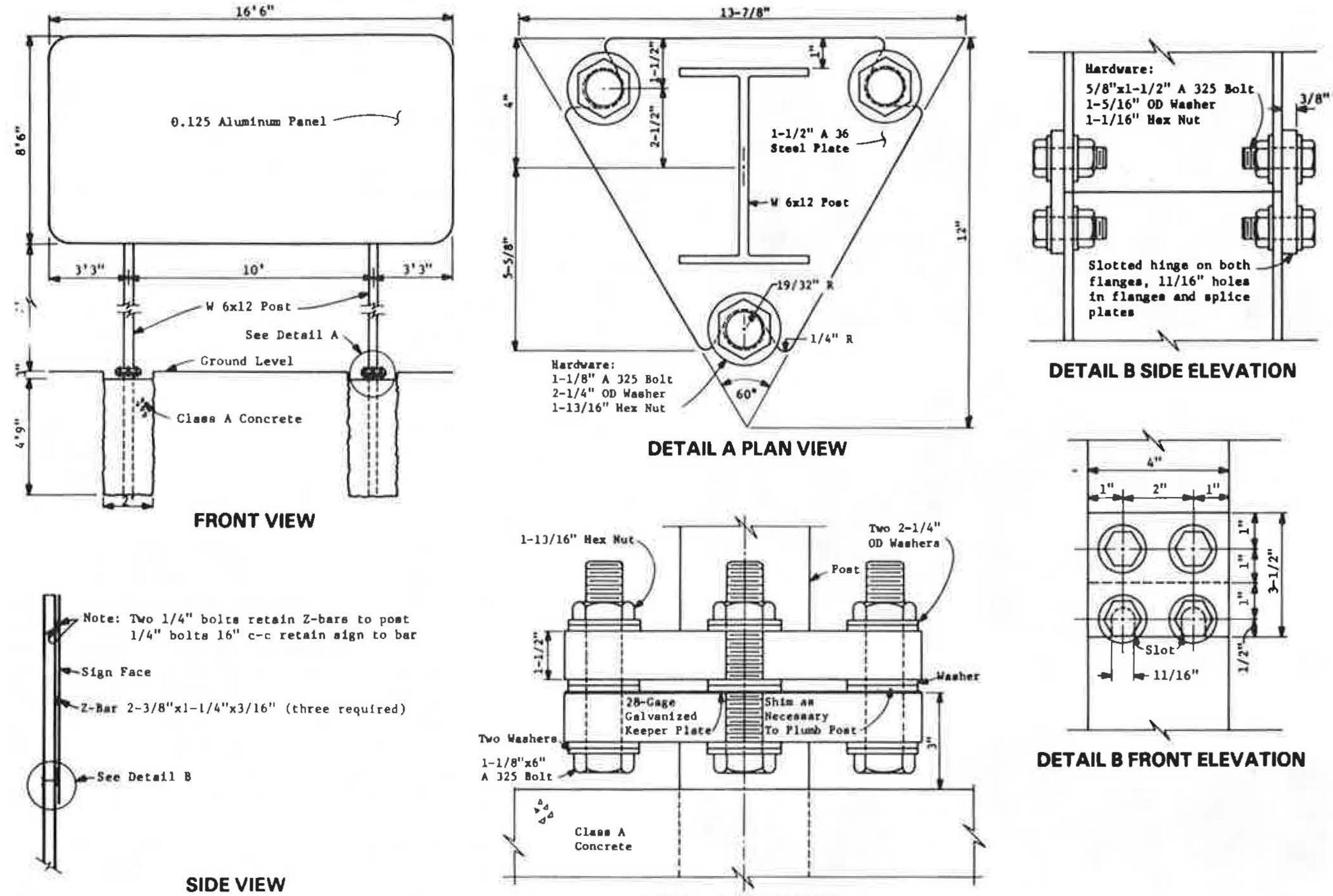


Table 1. Test results.

Measurement	Test 29	Test 30	Test 31	Test 32
Impact condition				
Speed (mph)	27.7	21.0	64.9	59.4
Angle (°)	90	30	30	90
Weight (lb)	2155	2130	2200	2160
Contact				
Time (ms)	489	257	78	85
Distance (ft)	16.0	8.5	6.8	6.8
Exit speed (mph)	20.3/19.8[a]	15.4	59.9	55.3
Exit angle (°)	90	30	30	90
Maximum yaw	0	0	0	0
Maximum roll	0	0	0	0
Maximum pitch	-3	-2	-2	-2
Momentum change (lb·s)	726/775[a]	543	501	403
Decelerations (*g*)				
50-ms avg				
Longitudinal	NA	NA	4.02	3.45
Lateral	NA	NA	1.89	1.26
Maximum peak				
Longitudinal	NA	NA	7.42	7.20
Lateral	NA	NA	9.24	6.72
Avg continuous				
Longitudinal	NA	NA	2.40	1.31
Lateral	NA	NA	0.42	0.42
Vehicle damage				
TAD	FC-3	FC-3	FC-4	FC-4
SAE	12FCEN9	12FCEN1	12FCEN2	12FCEN2

Note: TAD = Traffic Accident Data Project, SAE = Society of Automotive Engineers, and NA = not available.

[a]Result of secondary impact of sign panel and car roof after loss of contact with post.

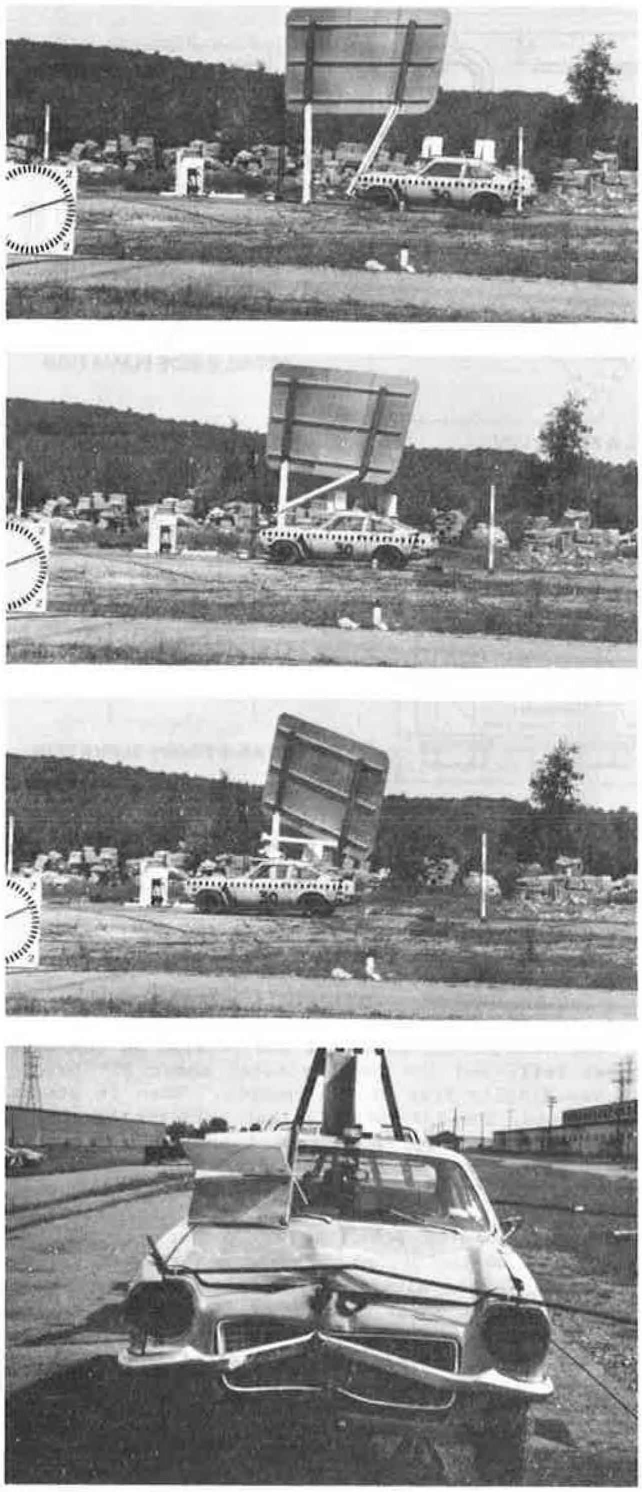
occupants, but an additional 49-lb·s momentum was lost.

The nonimpacted post bent and twisted as the sign panel fell, and the panel rotated about 80° before it was finally free of the vehicle. When it struck the ground, the 1/4-in bolts that held the lower two Z-bars to the upper post failed and left only the two 1/4-in bolts at the top Z-bar to support the panel. Both hinge plates on the nonimpacted post pulled free of the outboard bolts (those farthest from the impacted post) as the other end of the panel fell to the ground. Two of the riveted vertical seams in the aluminum sign panel were torn open below the first Z-bar because of the panel's twisting. These were later repaired with 1/4-in bolts for subsequent tests. The sign panel came to rest face down and rotated about 80° from its original position, and the nonimpacted support was still attached at both the base and the hinge.

The impacted post, which sustained a small dent at bumper height on the upstream flange, was thrown 45 ft from its base and about 8 ft to the right (away from traffic). The upper post remained undamaged and attached to the Z-bars. Both slotted splice plates pulled free from the intermediate post and remained attached to the upper post, although they were bent and not reusable.

Vehicle damage was limited to a 9-in-deep, 21-in-wide dent in the bumper, grill, and hood. The car's trajectory was unaffected by the impact and it exited along the same path on which it entered. Vehicle decelerations were not available because of equipment malfunction.

Figure 2. Typical impact sequence and vehicle damage resulting from test 30.



For the second test (test 30), impact was at 30° (nearly parallel to the sign panel) at 21.0 mph, which resulted in a 543-lb•s vehicle momentum change. Both base bolts were torqued to 110 lbf•ft and hinge bolts to 170 lbf•ft; they released as designed, i.e., the base bolts on impact and the hinge bolts after about 1.0 ft of vehicle travel. During that time, the sign bottom dropped only about 3 in and rotated back about 5° (see Figure 2).

After the hinge released, the intermediate post remained attached to the upper post by the right-hand bolt on the downstream splice plate. The sign rotated about 40° more after hinge release and came to rest still partly attached to the nonimpacted post; it was turned approximately 45° from its original position. The sign panel was undamaged except for the lower left corner being bent when it hit the ground. Both upper posts remained fully attached to the Z-bars. The nonimpacted intermediate post twisted slightly but was reusable for another test.

The impacted intermediate post sustained a small dent in the upstream flange at bumper height and bent flanges at the top of the intermediate section where the splice plates remained almost straight. None of the nonimpacted components sustained permanent damage, and the hinge release resulted from the slotted splice plates simply pulling free of the 5/8-in bolts; there was no bending of the plates.

Vehicle damage was limited to a 9-in-deep, 19-in-wide dent in the bumper, grill, and hood. The car did not deviate from its path and exited along the impact trajectory. Again, vehicle decelerations were not available.

For the third test (test 31), impact was again at 30° to the sign panel, and impact speed was 64.9 mph, which resulted in a 501-lb•s vehicle momentum change. The base bolts, torqued to 110 lbf•ft, released on impact. The hinge bolts were torqued to 190 lbf•ft in an attempt to keep the sign panel upright after one support was removed, but this increased torque did not appear to have an adverse effect on hinge release, which occurred about 7 ms after impact, before the sign panel could either rotate or drop, and after the car traveled about 0.6 ft.

After hinge release, the intermediate post remained partly attached to the upper post, then slipped free of the splice plates, and then flew end-over-end 125 ft downstream and 15 ft to the right. The sign dropped to the ground, bending one corner while rotating back about 25° from its original position. As in the previous lower-speed test, the upper posts remained fully attached to the Z-bars and there was no permanent damage to any of the nonimpacted components. Again, the impacted post sustained only a dent from the impact and bends in the flanges at the splice-plate bolt locations.

Vehicle damage was again limited to a large front-end dent. This time it was 12 in deep and 28 in across in the bumper, grill, and hood. However, damage to the fan and radiator prevented this car from being driven away. As in the previous tests, the impact resulted in no change in the path of the vehicle.

For the final test (test 32), a 0.25-in-diameter cable tether was attached to the top of the intermediate post and the bottom of the upper post to eliminate the flying post experienced in the previous high-speed test. The post was impacted at 90° (perpendicular to the sign panel) at 59.4 mph and had a 403-lb•s vehicle momentum change. The base bolts (torqued to 110 lbf•ft) released on impact, and the hinge bolts (torqued to 190 lbf•ft) released after about 0.6 ft of vehicle travel.

After the hinge released, the intermediate post remained partly attached to the upper post by the downstream splice plate. This attachment held until after loss of contact between the post and car, when the posts separated and the only remaining connection was the 0.25-in tether cable. The additional moving mass of the tethered intermediate post caused the sign to rotate about 110° from its original position, which was significantly more than if the intermediate post had been allowed to fly free after complete separation of the splice plates. The intermediate post remained tethered until both it and the sign panel hit the ground. The tether then snapped and the post bounced about 5 ft away to the right.

As in the previous tests, the upper posts remained fully attached to the Z-bars. The nonimpacted post was twisted 90° clockwise and bent about 18 in above the base plate. The sign panel's lower left corner was bent when it hit the ground and the lower right edge bent as it was folded against its support by the extreme rotation. The impacted support sustained a dent on the upstream flange where it was struck by the bumper and sustained bent flanges where it separated from the downstream splice plate.

Vehicle damage was again limited to a large dent in the front of the car, 12 in deep and 24 in wide in the bumper, grill, and hood. As in the previous high-speed test, it precluded driving the car from the scene after impact.

FINDINGS

All four impacts with the posts resulted in changes in vehicle momentum below the preferred 750 lb•s. Decelerations were tolerable in the two tests measured, and no violent vehicle reactions or abrupt changes of vehicle direction occurred. Impact was deliberately off center in the two high-speed impacts, but even then the vehicles exited on the same trajectories along which they entered. In all cases, the slip bases released as designed, but the lack of downstream flange continuity across the hinge (as in the one-direction design) prevented the sign panel from remaining upright on the nonimpacted support.

Based on these four tests, the following findings can be stated:

1. The omnidirectional sign support tested meets American Association of State Highway and Transportation Officials (AASHTO) criteria for momentum transfer, and all of the resulting momentum changes were below 750 lb•s;
2. Vehicle damage was light in all cases, and the lower-speed tests resulted in slightly lighter damage than the high-speed tests;
3. Off-center impact in the high-speed tests did not adversely affect vehicle trajectory or appurtenance performance;
4. The impacted posts were dented by the vehicle bumper, and the flange ends were bent at the hinge;
5. The nonimpacted posts sustained greater damage than the impacted ones because they were bent and twisted when the sign panels fell;
6. The sign panel sustained a bent lower left corner in each test when it hit the ground; during the first test, one of the riveted vertical seams separated due to twisting of the panel; and
7. The slotted splice plates on the nonimpacted post did not develop enough resistance to maintain the sign in an upright position.

ACKNOWLEDGMENT

The research reported in this paper was conducted in cooperation with the Federal Highway Administration, U.S. Department of Transportation.

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Guardrail Installation and Improvement Priorities

J. W. HALL

The methodology and findings of a detailed study of New Mexico traffic crashes involving impacts with guardrails, selected fixed objects, or overturning are described. Analysis of computerized accident records for 1978 and 1979 found that guardrail accidents were more often characterized by rural conditions, unfamiliar drivers, and snow-covered roads. Guardrail accidents tend to be less severe than other single-vehicle crashes. Field studies were conducted at the sites of 113 pairs of guardrail and nearby run-off-the-road crashes. Roadway geometrics were similar at both types of sites; both had significant downgrades and curvature to the left. Roadside slopes behind the guardrail did not differ significantly from front slopes at the run-off-the-road sites. Highly significant correlations were found among certain crash-site parameters. Average values of roadway and roadside characteristics at both types of crash sites were more adverse than for the roadway system in general. The research has developed a severity-reduction model that can be used to prioritize sites that warrant guardrail installation or upgrading.

The intent of guardrail is to reduce the severity of impact for motorists who have left the roadway. Guardrails should be designed to lessen the injury to occupants of vehicles that strike it and to safely redirect vehicles back to the roadway.

It is possible to learn something of guardrail use from accident records. Data from 1978 Fatal Accident Reporting System (FARS) records (1) indicate that more than half of the fatal accidents in the United States involve a single vehicle. Approximately 27 percent of all fatal accidents involve fixed objects, and of these approximately one-ninth involved vehicles that have struck guardrail. Another substantial component of the fatal-accident experience in this country involves noncollision accidents (primarily overturning), which account for approximately 11 percent of the fatal accidents nationwide.

In an attempt to determine the nature of the guardrail accident problem in New Mexico, an analysis was conducted of 1978 and 1979 New Mexico accident data. Of the 100 000 reported accidents during this two-year period, 22 percent of all accidents involved either fixed objects or overturning, and these accidents accounted for 42 percent of all fatal accidents. Guardrail was involved in 1.8 percent of the fatal accidents. The fixed-object and