BASE-BENDING SINGLE SIGNPOSTS

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ABRIDGMENT

•EXPERIMENTAL work on the evaluation of base-bending single signposts was conducted by researchers at Wayne State University in 1970. Study of base-bending single signposts was the initial effort of a multiphase program (11). Primary data reduction was based on photogrammetric information obtained from three high-speed cameras. Backup information was obtained from a fifth wheel attached to the tow vehicle and speed traps. Photogrammetric techniques were evolved to be used in conjunction with the development at Wayne State University of a new, simplified methodology for the analysis of high-speed motion picture data, planned ultimately to provide three-dimensional kinematic information. The signpost study contributed to the initial steps in this direction.

STUDY APPROACH

Signposts may be categorized as either base-shearing or base-bending, depending on mode of failure on vehicular impact. Generally speaking, single metal signposts supporting small or medium sign markers are base-bending structures and will be passed over by an impacting vehicle. When heavier single metal posts are required to support large signs, base-shearing features are ordinarily designed into the post near ground level, permitting the signposts, upon impact, to fly up and allowing the vehicle to pass beneath.

Base-bending signposts have been investigated at the University of Cincinnati (1, 2, 5), the General Motors Corporation (3), and the Unistrut Corporation (4). With the exception of two 50-mph tests in the series performed at the University of Cincinnati, all others were conducted at lower impact speeds.

The single metal signpost experimental program at Wayne State University was designed to answer specific research questions by evaluating kinematic and phenomenological response of the post configurations under consideration over the full operational range of all significant impact parameters. The large number and wide ranges of these parameters made a full factorial test program impractical, and, accordingly, a structural fractional factorial experimental design was employed (7).

DISCUSSION OF TESTS

The physical testing period for the signpost tests began in August 1970 and extended through December of that year. Full-scale crash tests were conducted on a runway at Willow Run Airport near Ypsilanti, Michigan.

Three single signposts were tested: 2-in. (nominal) diameter steel pipe, 2½-in. (nominal) diameter steel pipe, and 8-lb/ft steel flanged-channel signposts.

Except in two cases (tests 13 and 17), in which the signposts were embedded in concrete (12 in. in diameter) to a depth of 3½ ft, all signposts were driven into the sandy loam soil to specified depths of 3½, 4, and 4½ ft.

The 2-in. steel-pipe signposts were 13½ ft long and carried 1½-ft by 2-ft by 0.081-in. aluminum sign markers; the 2½-in. steel-pipe signposts were 14 ft long and displayed 2-ft by 2½-ft by 0.081-in. aluminum sign markers; the 8-lb/ft flanged-channel signposts were 15½ ft long and carried 4-ft by 5-ft by ¾-in. plywood sign markers. The size of the sign marker for each post was determined according to design specifications of the Michigan Department of State Highways (6).

Vehicle damage was observed as slight, moderate, or severe. Because all vehicles after the first two tests were equipped with a modified bumper, all damage assessments are relative.

Table 1 gives a summary of the results of the 16 single signpost tests conducted during the testing period.

Typically, the phenomenological response of the single steel-pipe signposts to impact showed nearly instantaneous formation of a plastic hinge at the point of initial contact, followed by plastic hinge formations approximately 6 to 12 in. below ground level. During the formation of these hinges, the upper portion of the signpost tended to remain inertially fixed, resulting in the angular inclination of the post toward the vehicle as it traveled along its path following impact. This angle of inclination, referred to as the post deflection angle, is the maximum angle as measured from a vertical reference line. As the signpost wrapped around the front of the vehicle, it was often pulled from the ground. A third area of plastic hinge formation sometimes occurred when the signpost contacted the hood of the vehicle.

Initial response of the 8-lb/ft flanged-channel signposts was similar to that described previously. As the post bent, however, the $^3/_8$-in. steel bolts, tying the 4-lb/ft channels together on 16-in. centers, sheared, permitting the channels to bend independently, flare open, and be torn from the ground. In the final test of the year, in which the signpost was embedded in frozen soil, the channel on the impact side was sheared at the bumper impact point, and the adjacent channel was bent at ground level and was ruptured in tension at the bumper point. The remainder of the post remained intact. The sign marker, as was the case for each test involving a plywood sign, became detached from the signpost and fell closely within the signpost area after the vehicle passed beneath. In this test the marker struck the top of the vehicle above the windshield and contacted the car a second time on the trunk lid.

INTERPRETATION OF RESULTS

The data from which kinematic responses of the vehicle were measured were taken from the high-speed movies by observing a convenient target attached to the side of the crash vehicle. For purposes of comparison, the average values of deceleration during the time required for the vehicle to move 2 ft following impact has been defined as the maximum deceleration. This corresponds to the maximum deceleration as defined by Cook and Bodocsi (5) in the lower speed signpost tests conducted by them at the University of Cincinnati and permits comparison of full-scale crash tests on similar signposts.

Table 1. Signpost test data.

Test No.	Soil Embedment (ft)	Signpost	Vehicle Weight (lb)	Impact Velocity (mph)	ΔV (mph)	a_{max} (g) (2 ft) (ft/sec²)	a_{avg} (g) (4 ft) (ft/sec²)	Post Deflection (deg)	Damage: Passenger	Damage: Driver	Damage: Vehicle
1	4	2 in.	3,720	44.3	-2.8	—	-1.8	24.5	N[a]	N	Slight
2	3½	2 in.	3,720	45	—	—	—	30	—	—	Slight
3	4½	2 in.	3,720	57.6	-5.9	—	-2.6	44.2	N	N	Slight
4	3½	2½ in.	3,720	37.5	-3.4	-1.3	-1.8	30.4	N	N	Slight
5	4½	2½ in.	3,720	58.2	-3.2	-4.5	-4.3	52.8	N	N	Slight
6	3½	2 in.	3,720	48.2	-2.6	-2.1	-2.1	50.8	N	N	Moderate
7	4½	2 in.	3,720	36.7	-4.0	-1.2	-1.5	28.1	N	N	Moderate
8	3½	2 in.	2,455	65.4	-1.2	-2.1	-2.1	69.4	N	N	Moderate
9	3½	2 in.	3,400	59.2	-1.0	-0.7	-1.2	66.6	N	N	Moderate
10	3½	2 in.	3,265	63.4	-1.8	-2.7	-2.8	70.1	N	N	Moderate
11	3½	2½ in.	3,345	48.7	-4.2	-0.6	-1.6	56.2	N	N	Moderate
13	3½ C[b]	2½ in.	3,265	48.9	-5.7	-4.1	-4.7	45.1	M[c]	M	Severe
15	3½	2½ in.	2,826	71.3	-7.6	-5.9	-6.6	62.6	M	M	Severe
16	3½	8 lb/ft	4,500	54.8	-3.6	-3.5	-3.8	45.8	N	N	Slight
17	3½ C	8 lb/ft	4,500	57.7	—	—	—	44.6	—	—	Slight
18	3½	8 lb/ft	2,514	30.3	-8.4	-4.5	-4.4[d]	84.3[e]	M	M	Moderate

[a]N = no probable injury.
[b]C = concrete.
[c]M = marginal (secondary impact probable).
[d]Calculation based on 3 ft.
[e]Not equivalent to other deflections because of base-shearing action of signpost.

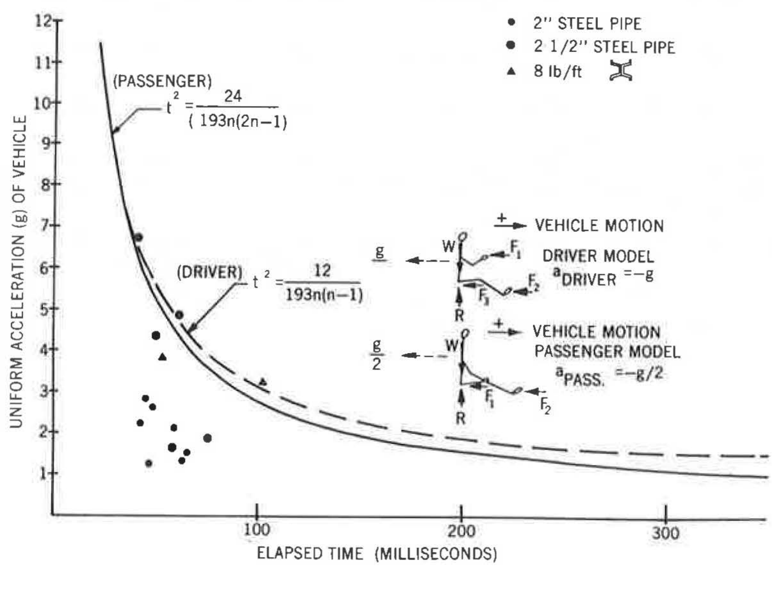
The average value of deceleration of the vehicle is that that occurs during the time period required for the vehicle to move 4 ft following impact. The 4-ft distance was chosen because, for all practical purposes, the significant part of the impact event was complete during the corresponding time frame. Additionally, this tended to provide a standard with which kinematic and phenomenological results could be compared.

The significance of the post deflection angle is that it provides an estimate of probable vehicle passenger compartment penetration. As might be anticipated, physical tests indicate that increases in post deflection angles are related somewhat proportionately to increases in impact velocities. It appears that specification of minimum signpost heights can minimize the possibility of passenger compartment penetration by the signpost at high speeds.

In addition to making phenomenological observations of both signpost and crash vehicle and obtaining the associated kinematic data, we wished to provide some degree of probable occupant injury assessment. As indicated in other reports (2, 9, 10), a definitive relation associating occupant injury with vehicle decelerations does not currently exist. Researchers have used the Stapp curve and the Cornell Aeronautical Laboratory (CAL) suggested limits of tolerable deceleration as a gross means of possible evaluation for occupant injury. Results of the Wayne State University signpost impact tests indicate no probable injury for any properly restrained occupant under either the Stapp or CAL criteria. However, in an effort to provide unrestrained occupant injury assessment criteria, a simple engineering model was devised on the basis of certain reasonable assumptions. In Figure 1, it is presumed that, below the vehicle acceleration-time curve, no secondary contact of the occupants will occur within the vehicle and, consequently, no injury will occur. Above the vehicle deceleration-time curve, secondary impact within the vehicle is probable with occurrence of injury likely.

The curves shown in Figure 1 are based on the assumption that the driver of the vehicle has approximately 12 in. to move inside the vehicle before contacting the vehicle. It is presumed that the unrestrained driver, upon impact, can apply sufficient force to his body to cause an absolute deceleration of 1 g to his body. The 1-g value is presumed from the fact that most people when lying face down can produce a sufficient force on their body with their hands and arms to sustain a 1-g acceleration in a push-up maneuver. Similarly, for the passenger a distance of 24 in. and a force of 0.5 g have been assumed. The 0.5 g would result as a minimum from frictional forces applied to

Figure 1. Unrestrained occupant injury assessment curve.



the passenger by the seat cushion. In Figure 1, n is the number of g's of deceleration of the vehicle during the duration of impact t.

For the curves shown in Figure 1, some of the average values of deceleration during the impact period (as previously defined) fall within the marginal area. Calculations indicate that, in test 13, the driver would impact the wheel at 2.4 ft/sec and the passenger would impact the interior of the vehicle at 3.9 ft/sec. In test 15, comparable values would be 0 and 7.7 ft/sec respectively.

CONCLUSIONS

On the basis of the 16 full-scale crash tests performed on single signposts, including unrestrained occupant injury assessments, the following single signpost recommendations are made:

1. Two-in. steel pipe signposts driven to an embedment depth of 3½ ft in soil should be used,
2. A minimum signpost height above ground of 9 ft is desirable, and
3. Single 2½-in. steel pipe signposts and single 8 lb/ft flanged channel signposts are adequate where the single 2-in. signposts cannot be used; however, they should be driven in soil to an embedment depth of 3½ ft (placement in concrete is not recommended).

ACKNOWLEDGMENT

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