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).

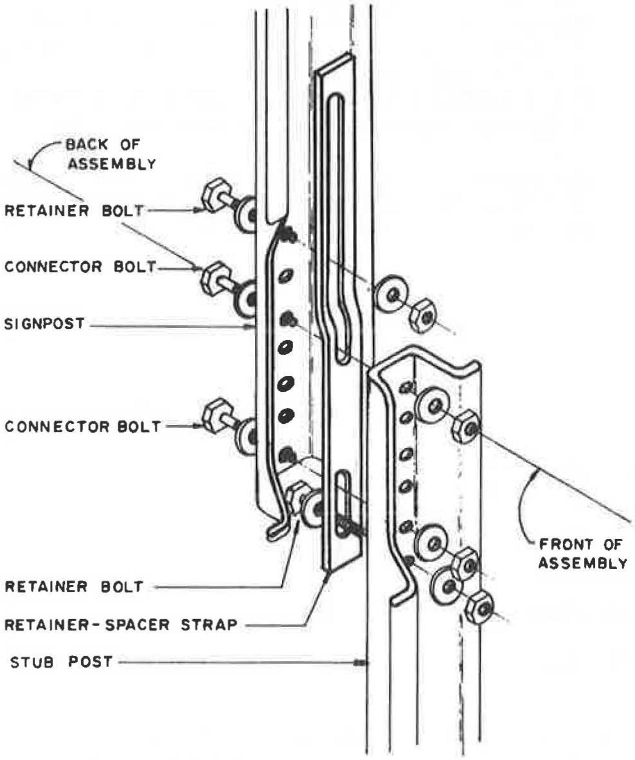
EZE-ERECT SYSTEM

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 $^5/_{16}$-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 stub post. Also, the hardware was reduced to four bolts and four nuts. All bolts were $^5/_{16}$-18 UNC × 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-

Figure 1. Eze-Erect signpost assembly.



tance, overlaps from 30.5 cm (12 in) to 152.4 cm (60 in) are required. The impact performance of such configurations has not been determined.

STATIC TESTS

Tests were conducted to determine the static load capacity of the first- and second-generation Eze-Erect assemblies. The signpost-stub assembly was loaded in a cantilevered test arrangement in the static tests.

Table 1 contains details and results of the tests. Note that in test 2, failure was due to fracture in the web section of the stub post. Failure occurred at the top connector bolt hole. A similar failure occurred in the full-scale crash test of the first-generation assembly. Distance from the top of the stub post to the top connector bolt hole was increased from 1.3 to 2.5 cm (0.5 to 1 in) to correct this problem (see Figure 3). Tests of the 3-kg/m (2-lb/ft) and the 4.5-kg/m (3-lb/ft) sign post (tests 1 and 2) were not repeated with the second-generation assembly. However, reductions in the moment capacity of the second-generation assembly due to a reduction in the connector bolt spacing from 12.7 to 10.2 cm (5 to 4 in) should be offset to a large extent by the increase in the distance of the top connector bolt hole from the top of the stub from 1.3 to 2.5 cm.

Direction of loading for the data in Table 1 was normal to the front of the assembly (see Figure 1 for front of assembly). Each assembly was also loaded in a direction normal to the rear of the assembly, and the results were similar to those shown.

Figure 2. First-generation retainer-spacer strap.

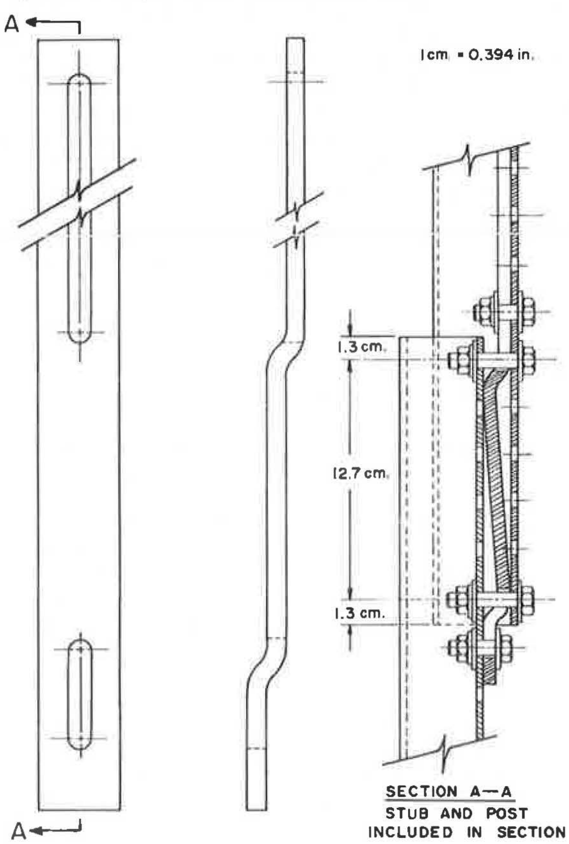


Figure 3. Second-generation retainer-spacer strap.

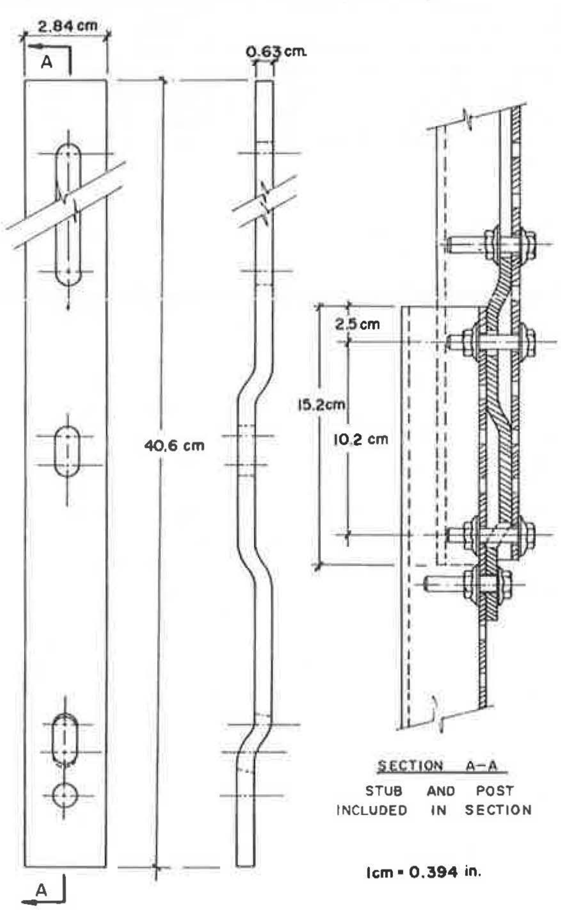


Table 1. Static test data.

Test No.	Eze-Erect Assembly Generation	Signpost Size[a] (kg/m)	Stubpost Size[a] (kg/m)	Load at Failure[b] (N)	Bending Moment at Failure (N·m)	Cause of Failure
1	First	3.0	4.1	1250	3048	Excessive deflection
2	First	4.5	4.5	1637	3743	Web of base post split
3	Second	6.0	6.0	1370	4380	Bolt fractured

Note: 1 kg/m = 0.67 lb/ft; 1 N = 0.225 lbf; 1 N·m = 0.737 lbf-ft.
[a]Signposts and stubposts were Franklin Steel Company U-posts, rolled from rail steel.
[b]Direction of load was normal to front of assembly (normal to front of sign panel that would be mounted on post).

Table 2. Failure moment of Eze-Erect assembly versus failure moment of signpost.

Signpost Size (kg/m)	Elastic Section Modulus[a] (cm^3)	Plastic Section Modulus[a] (cm^3)	Moment at Initial Yielding[b,c] (N·m)	Fully Plastic Moment[b] (N·m)	Eze-Erect Failure Moment (N·m)
3.0	3.77	4.59	1559	1898	3048
4.5	6.88	8.85	2848	3661	3743
6.0	9.18	11.64	3797	4814	4179

Note: 1 kg/m = 0.67 lb/ft; 1 cm^3 = 0.061 in^3; 1 N·m = 0.737 lbf-ft.
[a]Values furnished by Franklin Steel Company.
[b]Based on minimum yield of 413.4 MPa (59.9 kips/in^2) for rail steel.
[c]Moment at which flexure stress equals 413.4 MPa in extreme fibers.

Figure 4. Single-post sign installation.

For comparative purposes, consider the failure moment of the Eze-Erect assembly versus the predicted failure moment of the individual signpost, as given in Table 2. In all cases, the Eze-Erect assembly transmitted a moment greater than the "elastic" moment of the individual post. In fact, in two of the three tests, the Eze-Erect assembly transmitted a moment greater than the fully plastic moment of the individual post. It is noted that the ultimate strength of rail steel normally exceeds 758 MPa (110 kips/in^2).

FULL-SCALE CRASH TESTS

Six full-scale crash tests were conducted on the Eze-Erect system. Initially, four single-post installations were tested with the first-generation Eze-Erect assembly. Subsequently, two tests on three-post installations were made in which the second-generation Eze-Erect

Figure 5. Close-up of Eze-Erect assembly.

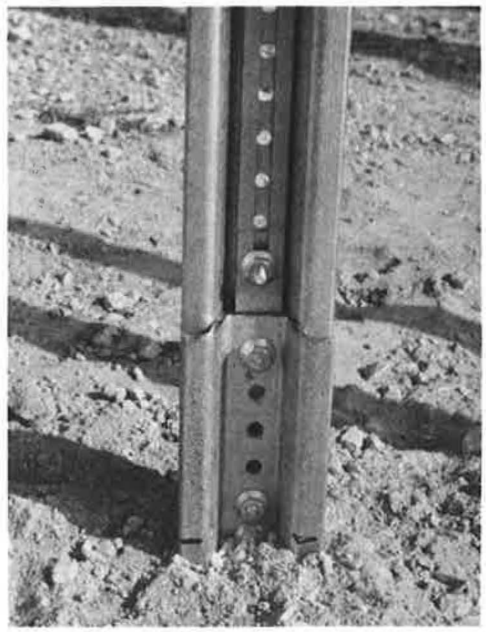


Figure 6. Single-post installation details.

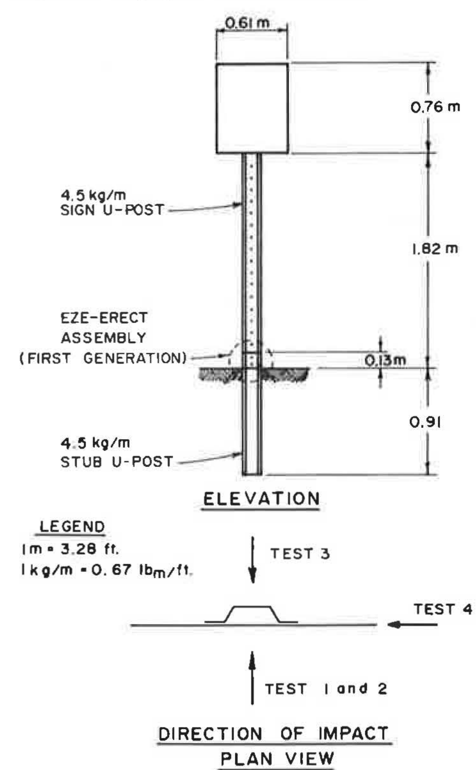


Figure 7. Three-post sign installation.

assembly was used. The single-post installation and the Eze-Erect assembly are shown in Figures 4 and 5. Details of the installation appear in Figure 6. The three-post installation is shown in Figures 7 and 8.

The tests were conducted in accordance with the recommended guidelines in NCHRP Report 153 (2). Soil at the test site also met the criteria outlined in NCHRP Report 153. Table 3 gives other details of the tests.

The test vehicles were 1971-1973 Chevrolet Vegas; each weighed 1034 kg (2280 lb). Electronic instrumen-

Figure 8. Three-post installation details.

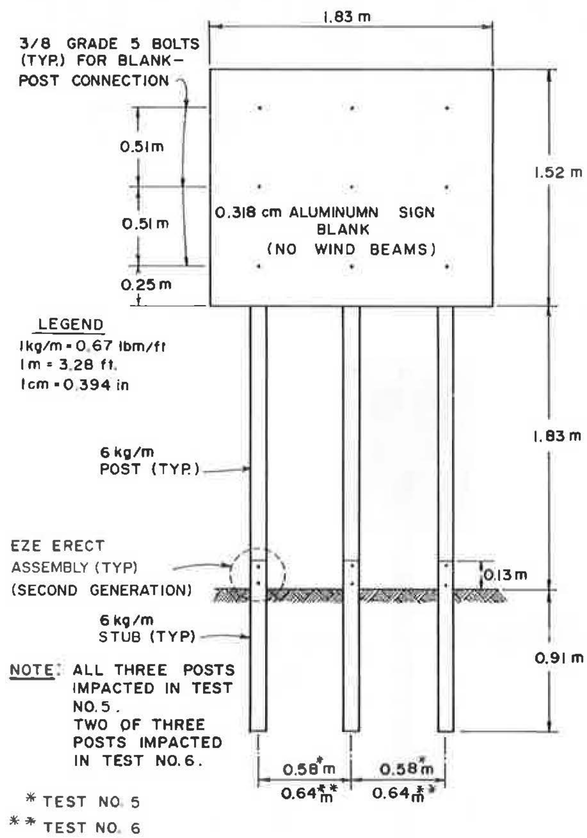


Table 3. Test conditions.

Test No.	Type of Installation	No. of Post Impacted	Eze-Erect Assembly Generation	Impact Speed (km/h)	Direction of Impact
1	Single-post	1	First	36.5	
2	Single-post	1	First	95.9	
3	Single-post	1	First	27.7	
4	Single-post	1	First	26.7	
5	Three-post	3	Second	29.9	
6	Three-post	2	Second	30.1	

Note: 1 km/h = 0.62 mph.

Table 4. Summary of test results.

Test No.	Type of Impact	Impact Speed (km/h)	Change in Momentum (N·s)*	Penetration of Passenger Compartment by Test Article	Vehicle Damage Classification: TAD	Vehicle Damage Classification: SAE	Refurbishment Required on Sign Installation
1	Single-post, head-on	36.5	846	No	FL-1	12FLEN1	Both stub and signpost would have to be replaced; sign panel could be reused; web of stub fractured at top connector bolt hole
2	Single-post, head-on	95.9	797	No	FR-1	12FREN1	Complete installation would have to be replaced
3	Single-post, rear hit	27.7	1638	No	FL-1	12FLEN1	Stub post would have to be replaced; signpost could probably be straightened and reused; sign panel would need to be rescreened
4	Single-post, side hit	26.7	1593	No	FR-2	12FREN1	Complete installation would have to be replaced
5	Three of three-post hit, head-on	29.9	2884	No	FD-2	Unavailable	All signposts would have to be replaced; all stub posts and the sign panel were reusable
6	Two of three-post hit, head-on	30.1	2056	No	FD-2	Unavailable	Two signposts would have to be replaced; third signpost and sign panel were bent but could possibly have been straightened; all stub posts were reusable

Note: 1 km/h = 0.62 mph; 1 N·s = 0.22 lb·s.

*Based on accelerometer data; change in momentum computed according to guidelines in section 7, part 2, of NCHRP Report 153 (2).

Figure 9. Stub after test 1.

Figure 10. Stub after test 2.

Figure 11. Stubs after test 5.

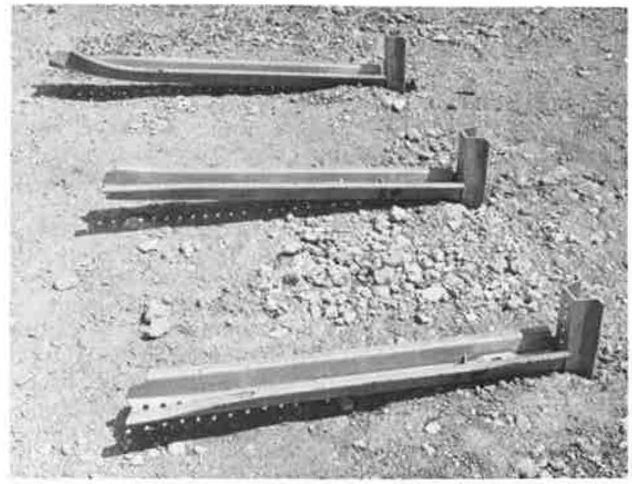
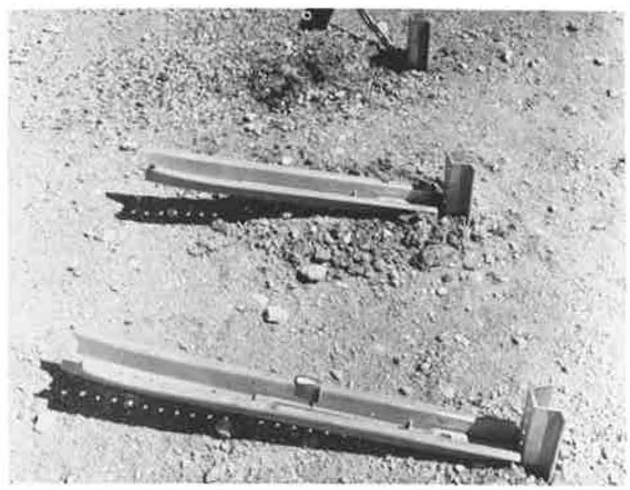


Figure 12. Stubs after test 6.



tation consisted of two longitudinal accelerometers. High-speed cameras were used to record vehicle time-displacement data.

Table 4 summarizes the results of the four single-post tests and the two multiple-post tests. In all tests, the change in momentum values was below the desirable limit of 3338 N•s (750 lb•s) and well below the upper limit of 4895 N•s (1100 lb•s) as recommended by the American Association of State Highway and Transportation Officials (AASHTO) (3). In no test did the test article penetrate the passenger compartment; in fact, the windshield was not broken in any of the tests. Damage to the vehicle was minor, and the vehicle was operable after each test.

After completion of tests 1 and 2, it was ascertained that low-speed impacts are more critical for this type of installation than high-speed impacts. In other words, impacts at speeds of approximately 16.1 km/h (10 mph) to 48.3 km/h (30 mph) cause higher changes in momentum than do impacts at higher speeds. This is due to the impact behavior of rail steel—it tends to fracture, rather than yield, especially at the higher speeds, and thus offers lower resistance to impact. Such behavior is a desirable characteristic for a signpost. As a result, the remainder of the test program was conducted at low speeds.

Considerable improvements were observed in the dynamic behavior of the second-generation Eze-Erect assembly (tests 5 and 6) over that of the first-generation assembly (tests 1 through 4). Figures 9 and 10 show the assembly damage after tests 1 and 2. Note the tear in the top of the stub post. Figures 11 and 12 show the assembly after tests 5 and 6. In tests 5 and 6 there was no damage to the stub, and with minor soil retamping the stub would be reusable.

CONCLUSIONS

The Eze-Erect assembly (a bolted stub-signpost connection) provides a simple but effective device for installing a steel U-post sign support system. Use of the bolted stud-signpost connection will reduce the hazard associated with driving full-length posts. Special equipment such as a lift truck or other devices needed to obtain the required heights for driving will not be required since the stub can be driven from ground level. Another desirable feature of the system is that the sign panel can be mounted to the signpost prior to erection of the post.

Results from a limited number of static load tests indicate that the Eze-Erect assembly does not compromise the elastic strength of the installation. In other words, the bolted connection was shown to have the bending moment capacity of the individual signpost itself.

Full-scale vehicle crash tests were conducted to evaluate the impact performance of the Eze-Erect assembly for a full range of impact speeds and impact angles. Both single-post and multiple-post installations were crash tested. The tests were conducted in accordance with current guidelines (2). Soil at the test site met the recommended criteria (2). In all tests, the change in momentum values was below the desirable limit of 3338 N•s (750 lb•s) and well below the upper limit of 4895 N•s (1100 lb•s) as recommended by AASHTO (3). In no test did the test article penetrate the passenger compartment; in fact, the windshield was not broken in any of the tests. Damage to the vehicle was minor, and the vehicle was operable after each test.

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