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LATERAL STABILITY OF POSTS FOR DEEP BEAM GUARD RAIL
Second Progress Report

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LATERAL STABILITY OF POSTS FOR DEEP BEAM GUARD RAIL

This report describes a second series of field tests of guard post stability and a strength comparison of three steel post sections, as a supplementary investigation to earlier tests described in Research Report 230, "Evaluation of the Lateral Stability of Posts for Deep Beam Guard Rail" (June 1955). This second series of field tests was summarized in a letter to W. W. McLaughlin on December 19, 1957. The tests were conducted on September 30 and October 1, 1957.

FIELD TESTS

The site for the field tests was the median strip between roadways on US 12, 1 mi west of US 24 in Wayne County. The soil condition was uniform throughout the test area to a depth of 5 ft, consisting of a fine sand classified as an A-3 soil in the Highway Research Board System.

The field tests consisted of determining load-deflection relationships, ultimate loads, and modes of failure for the following three phases of post loading:

Phase 1. Load applied to the posts perpendicular to the line of the guard rail, 1.5 ft above the ground line.

Phase 2. Load applied to the posts parallel to the line of the guard rail, 1.5 ft above the ground line.

Phase 3. Load applied to the center post perpendicular to the line of the rail of a two-panel, three-post guard rail (two lengths of rail supported on three posts).

The post types tested included 6- by 4-in. standard wide flange (WF) steel; 6- by 4-in. Z cross-section steel manufactured by the Syro Steel Company of Girard, Ohio; and 6- by 8-in. rectangular oak. All the oak posts were 7 ft long and were embedded 4 ft 4 in. The Z posts were 5 ft 9 in. and were embedded 3 ft 9 in. The WF steel was of two lengths, 6 ft 9 in. and 5 ft 9 in., embedded 4 ft 9 in. and 3 ft 9 in., respectively. A testing schedule showing the post lengths, embedment lengths, and the number of posts tested for each phase of loading is given in Table 1.

TABLE 1
TESTING SCHEDULE

Loading Phase	Post Type	Post Length	Embedment Length	Number Tested
1	6 x 4 WF	5 ft 9 in.	3 ft 9 in.	4
	6 x 4 WF	6 ft 9 in.	4 ft 9 in.	5
	6 x 8 oak	7 ft 0 in.	4 ft 4 in.	4
	6 x 4 Z	5 ft 9 in.	3 ft 9 in.	4
2	6 x 4 WF	5 ft 9 in.	3 ft 9 in.	3
	6 x 4 WF	6 ft 9 in.	4 ft 9 in.	5
	6 x 8 oak	7 ft 0 in.	4 ft 4 in.	3
	6 x 4 Z	5 ft 9 in.	3 ft 9 in.	3
3	6 x 4 WF	5 ft 9 in.	3 ft 9 in.	3
	6 x 8 oak	7 ft 0 in.	4 ft 4 in.	3
	6 x 4 Z	5 ft 9 in.	3 ft 9 in.	3

All steel posts were driven into the soil with a pneumatic hammer. The wood posts were placed in dug holes, and the soil backfilled and tamped in layers around the posts.

All loads were gradually applied 1.5 ft above the ground line of the posts in a horizontal plane by means of a Type D-8 Caterpillar tractor. The loads were measured with a Brush oscillograph, which recorded strains on a calibrated eyebar, providing a continuous record of the load applied to each post. Typical tests in progress for the three loading phases are shown in Fig. 1.

POST STABILITY TEST RESULTS

Perpendicular Loading (Phase 1)

For the posts subjected to normal loading (Phase 1), the displacements of the posts were measured 1 ft above the ground line at various magnitudes of applied loading.

Maximum loads and load-deflection curves for this phase are shown in Figs. 2 and 3. The maximum load for each post subjected to normal loading was governed by the soil resistance, resulting in soil failure. Each of the posts remained completely intact after testing. The tests produced these results:

1. Average load resistance for the deeper embedded WF post was 57 percent greater than the wood, and 98 percent greater than the shorter WF posts.

2. Average load resistance of the Z post was about 10 percent greater than the shorter WF post.

3. The wood post exhibited the greatest displacement for initial loads, and the long and short WF posts exhibited the least deformation of any posts for any applied load.

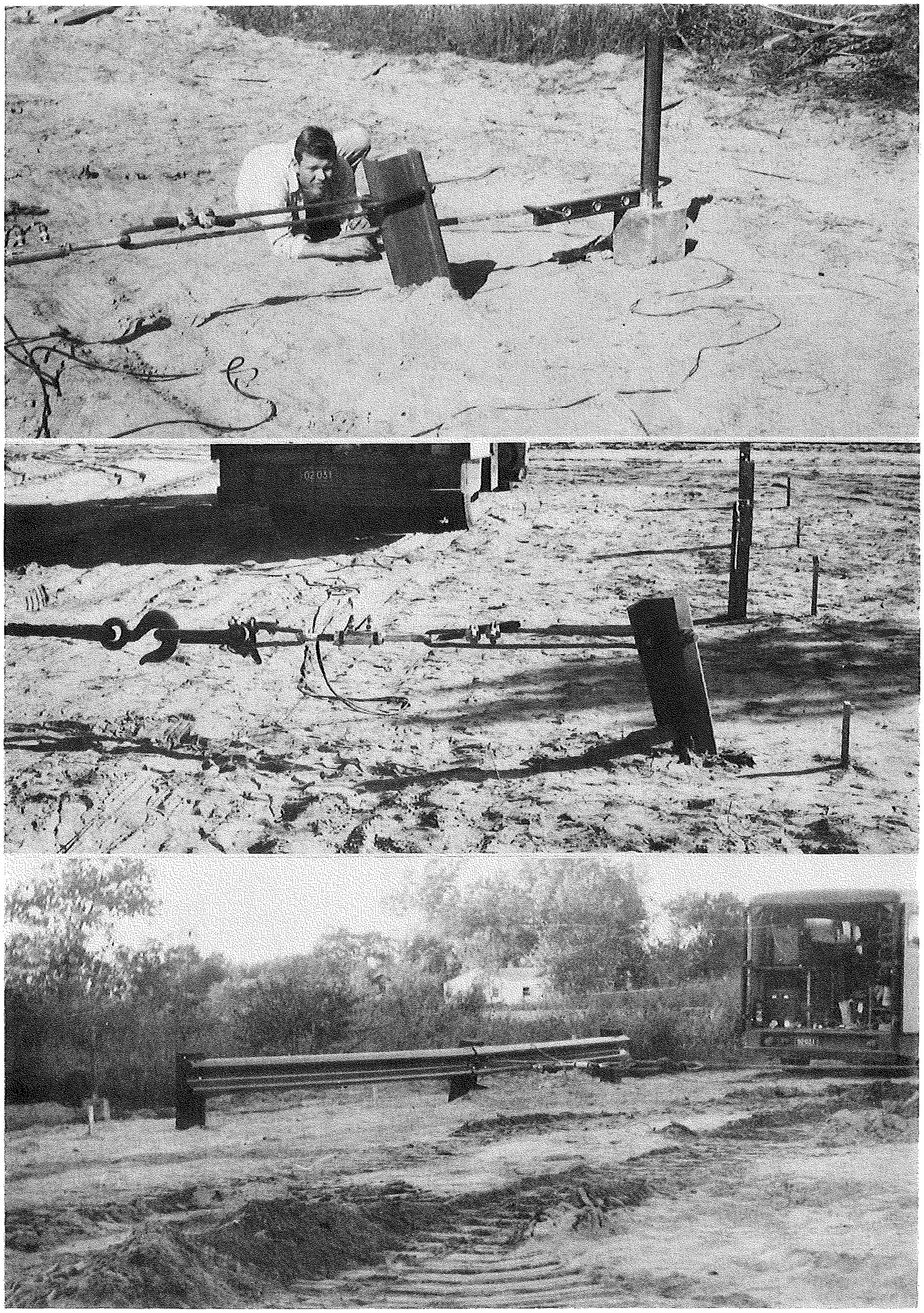


Figure 1. Typical load tests in progress: normal load test on WF post (top), parallel load test on Z post (center), and guard rail test with wood posts (bottom).

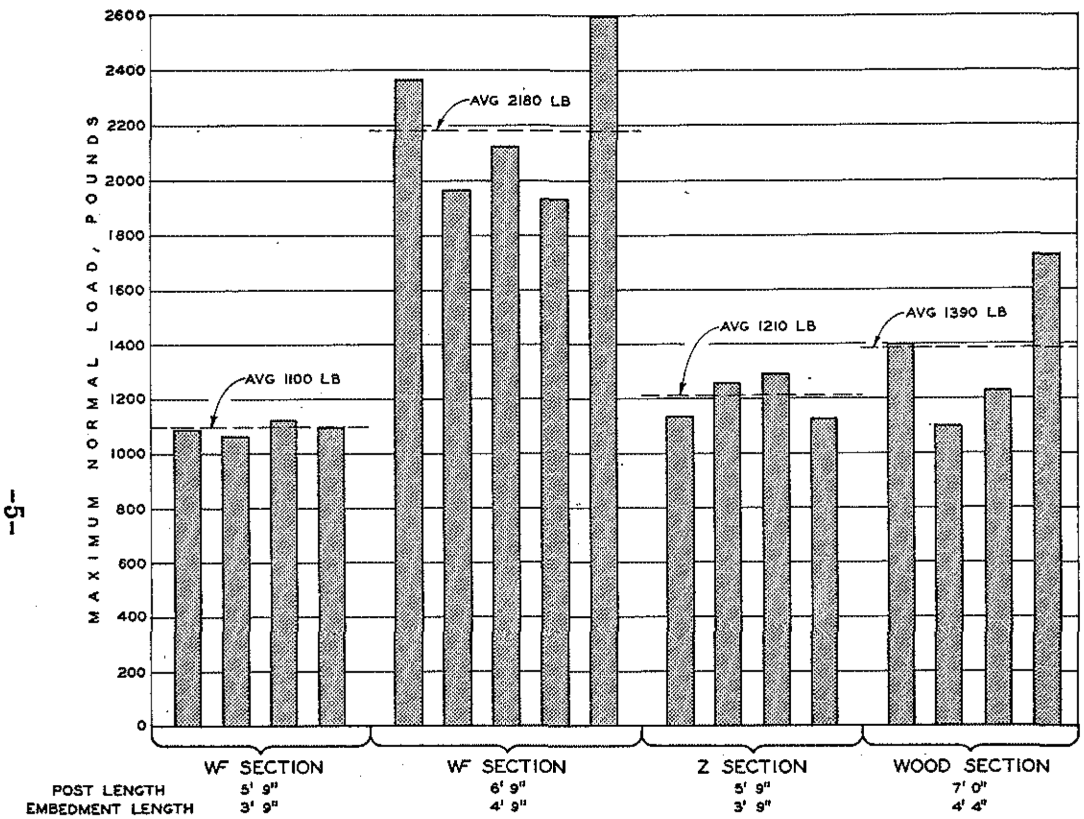


Figure 2. Maximum loads for normal loading tests.

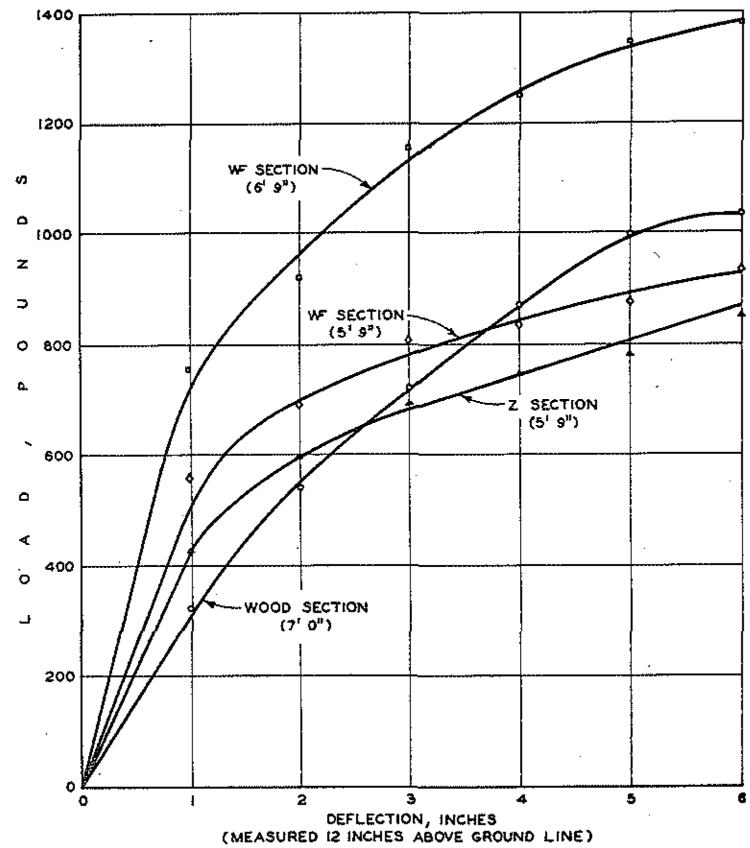


Figure 3. Load deflection curves for normal loading tests.

4. Maximum loads were governed by soil resistance, and all posts remained completely intact after the tests.

Parallel Loading (Phase 2)

Maximum loads and types of post failure for parallel loading (Phase 2) are shown in Fig. 4. Typical WF and Z post failures are shown in Fig. 5.

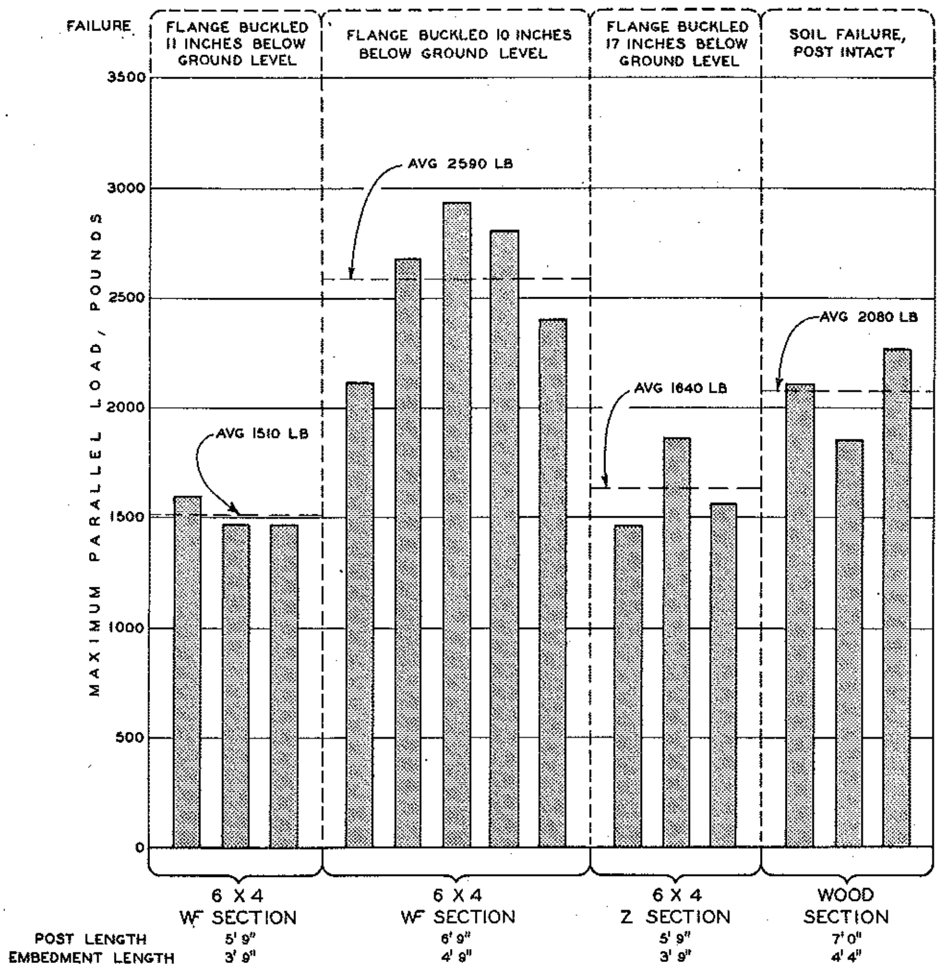


Figure 4. Maximum load and manner of failure for parallel loading tests. "Failure" represents average of specimens tested.

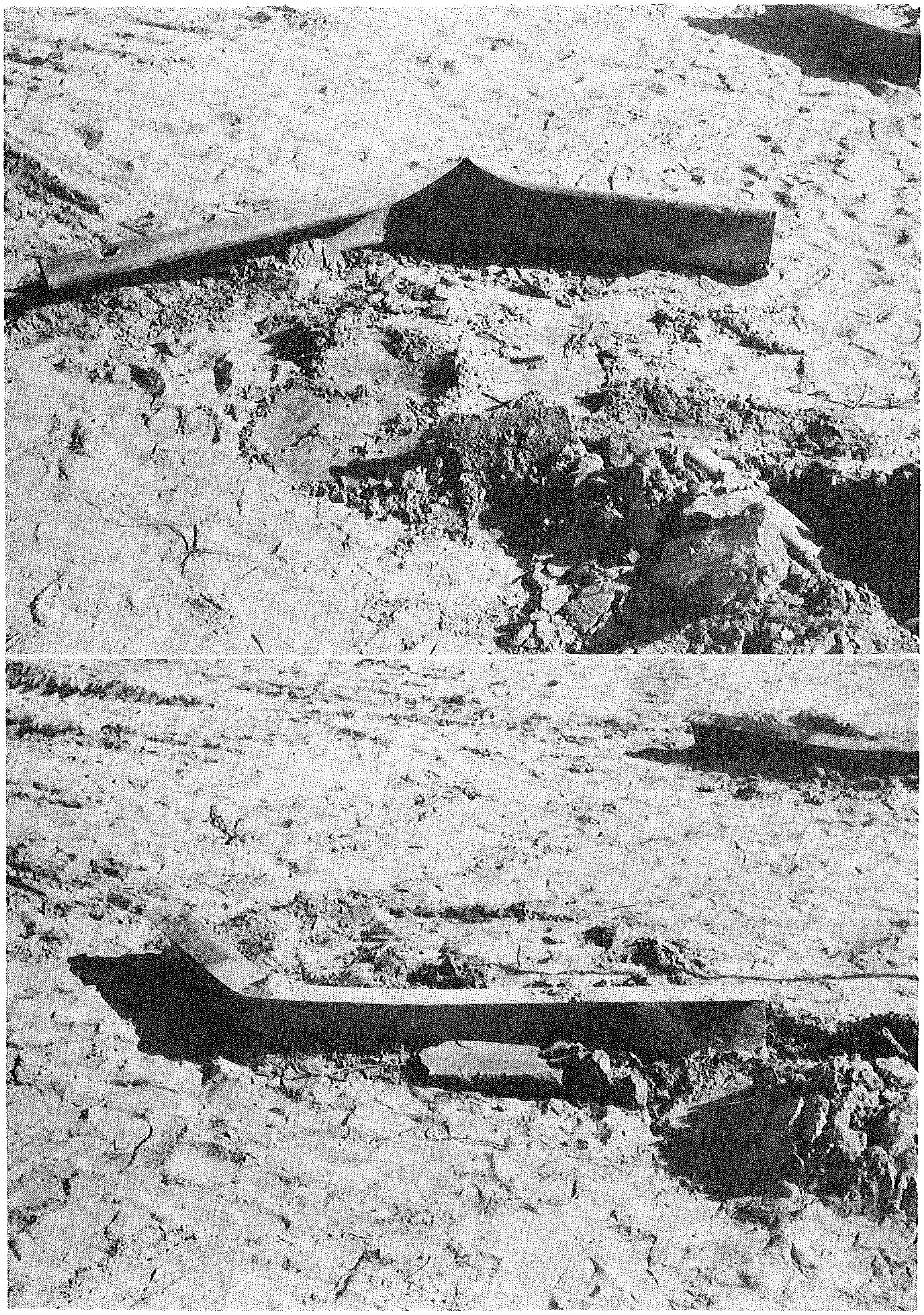


Figure 5. Typical steel post failures in parallel load tests: buckled flange failures of a Z section (top) and a WF section (bottom).

The test produced these results:

1. Average load resistance for the deeper embedded WF post was 24 percent greater than the wood and 71 percent greater than the shorter WF post.

2. Average load resistance of the Z post was about 9 percent greater than the shorter WF post.

3. Maximum loads were governed by post strength for all the steel posts, and by soil resistance for the wood posts. All steel posts failed by flange buckling, but the wood posts again remained intact.

Three-Post Guard Rail Loading (Phase 3)

Results of the three-post guard rail loading (Phase 3) are tabulated in Table 2, which includes maximum loads for the WF, wood, and Z posts,

TABLE 2
THREE-POST GUARD RAIL TESTS

Section	Post Length	Embedment Length	Maximum Normal Load, lb	Post Position	Type of Failure
WF	5 ft 9 in.	3 ft 9 in.	2670	Left	Bolt tore through slot in rail, post remained intact
				Center	Flange bent at post top, otherwise intact
				Right	Post twisted in ground but remained intact
Wood	7 ft 0 in.	4 ft 4 in.	2440	Left	Bolt tore through slot in rail, post remained intact
				Center	Post intact, no damage
				Right	Post twisted in ground but remained intact
Z	5 ft 9 in.	3 ft 9 in.	2600	Left	Bolt tore through slot in rail, post remained intact
				Center	Flange buckled 12 in. below ground line, and bent at post top
				Right	Post twisted in ground, flange buckled 9 in. below ground line

and the modes of failure for each. The test produced the following results:

1. Average load resistance of each of the three guard rail post set-ups was essentially the same.

2. Maximum loads were governed primarily by soil resistance.

3. In the case of the steel WF and Z posts, some permanent damage occurred to at least one post of each set-up, while all the wood posts remained intact.

THEORETICAL ANALYSIS

In addition to the post stability field tests, an analysis was made of the relative strengths of the steel WF and Z posts treated as cantilever beams with a concentrated load placed 1.5 ft from the fixed end. Also included in this analysis was a steel S post submitted for investigation by the Acme Highway Products Corporation of Buffalo, New York. Cross-sections of each of these three steel posts are shown in Fig. 6, and the post properties are tabulated in Table 3.

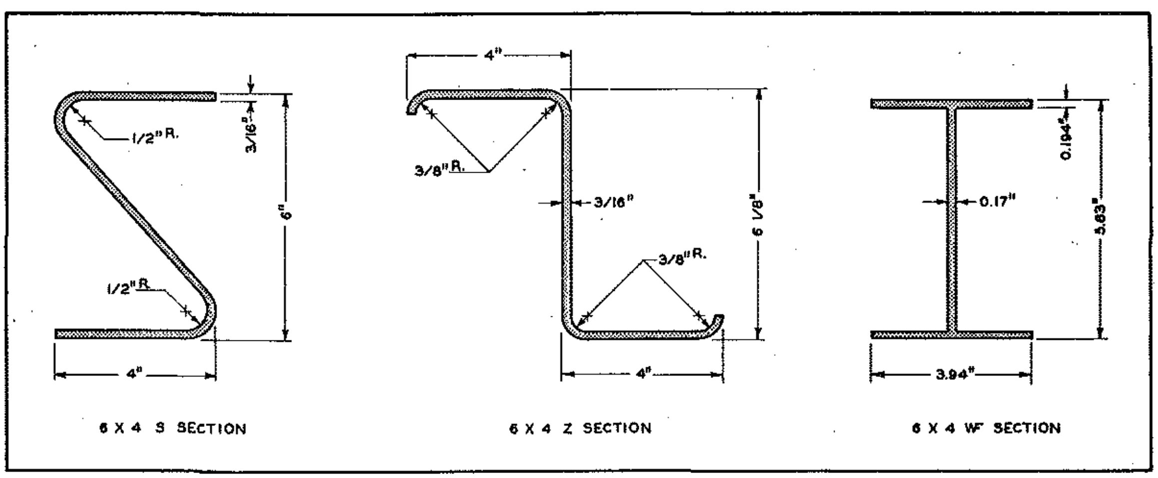
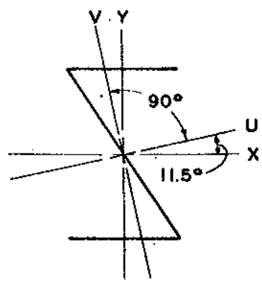
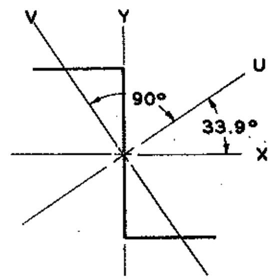
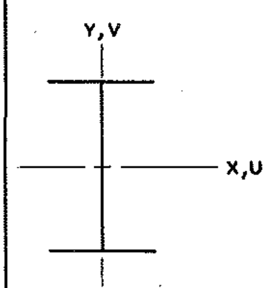


Figure 6. Steel post cross sections.

TABLE 3
STEEL POST PROPERTIES

	S Section	Z Section	WF Section
Moment of Inertia			
I_x, in.^{4}	14.99	15.71	14.80
I_y, in.^{4}	3.96	8.32	1.89
I_u, in.^{4}	15.47	21.82	14.80
I_v, in.^{4}	3.49	2.22	1.89

All Sections 3/16" thick; u and v are principal axes.

To point out the variation of maximum stress occurring in each post with loads applied at various angles to the post, their relative strengths with respect to various planes of applied loading are shown in Fig. 7, for the same loading conditions and steel material properties.

Results of the comparative analysis of the three steel posts were as follows:

1. For angles of loading from 0 to 85° from the pavement centerline (parallel to the guard rail), the S post would be stronger than the WF post for the same embedment length, soil, and loading conditions.

2. The Z post would be stronger than the WF post for angles of loading from 0 to 80° from the pavement centerline under the same loading conditions.

3. Another analysis, for the case of a cantilever subjected to pure torsion, indicated maximum shearing stresses in the S and Z posts to be approximately 80 and 89 percent, respectively, of those in the WF post for the same applied torque.

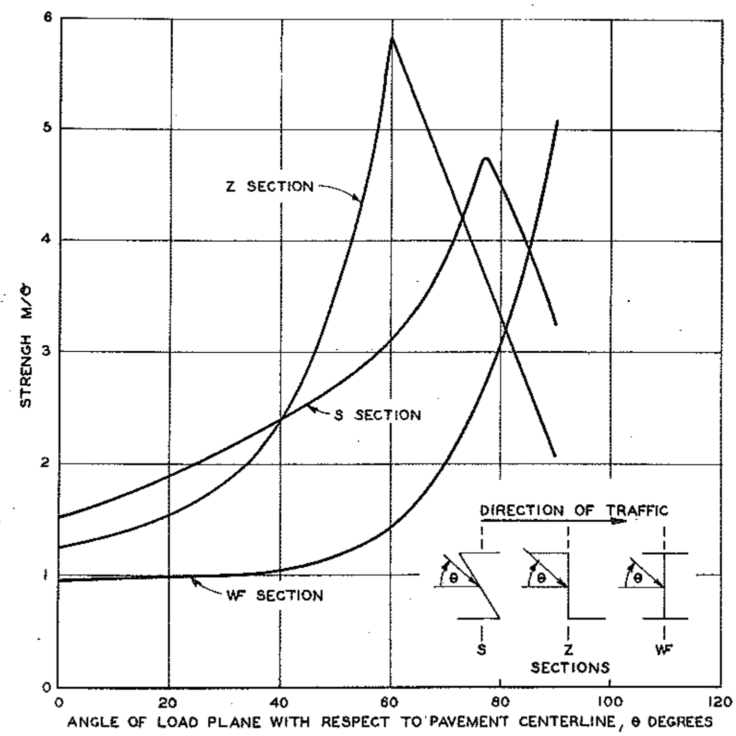


Figure 7. Relative strength for various planes of loading.

DISCUSSION OF FAILURE TYPES

The stability or load carrying capacity of a guard post is governed either by its individual strength, or by the ultimate resistance of the soil in which it is embedded. As was pointed out in the 1957 letter mentioned earlier, the ultimate strength of the wood post far exceeds the individual strength of any steel post considered here. However, even in the relatively stiff cohesive clay soil encountered in the first series of field tests--the 1955 series described in Research Report 230--the load resistance of the wood post was controlled by the ultimate resistance of the soil. It should be reiterated that in the first series of field tests, the average load capacity of oak posts with an embedment length of 4 ft 11 in., was about 46 percent greater than for WF steel posts with an embedment length of 4 ft 7 in. This points out the fact that the wood post gives better stability values in cohesive soils than the steel posts and poorer values in sand, but in either case stability was limited by soil failure without structural damage to the wood post.

CONCLUSIONS

The proper embedment length for soil stability which will develop the structural strength of the posts depends, of course, on the type and condition of the soil. For the steel posts considered here, and for soil conditions and angles of loading likely to be encountered, an embedment length of 4 ft 9 in. would be more satisfactory than 3 ft 9 in.

As a result of the 1957 letter mentioned earlier, the Z steel post was approved by the Department as a comparable substitute for the previously acceptable WF post, both of these being alternates for the standard wood post, and both having a required embedment length of 4 ft 9 in.

Since the transverse load capacity, as governed by soil resistance, varies directly with the bearing width of the post in contact with the soil, and approximately as the square of the depth of embedment, it is further concluded that on the basis of the theoretical analysis, the Acme S post considered here, with an embedment length of 4 ft 9 in. is comparable to the WF post, and consequently would also make a suitable alternate to the wood post.