EVALUATION OF TELESPAR TUBING FOR USE AS HIGHWAY SIGN SUPPORTS

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At the December 10, 1963 meeting of the Committee for Investigation of New Materials, Telespar tubing manufactured by the Unistrut Corp. of Detroit was considered for use as highway sign supports. The Committee asked the Research Laboratory Division for a performance study, including cost analysis.

The 1961 AASHO "Specifications for the Design and Construction of Structural Supports for Highway Signs" were used in the evaluation, and provide for selection of sign supports of the closed- or open-section types on the basis of prescribed allowable stresses occurring under certain stated wind load conditions. Thus, the structural adequacy of any type of sign support can be determined without regard to its equivalence to previously accepted sign supports.

The Telespar tubing considered for use as a sign support is roll-formed from 12-gage (0.105-in. US Steel gage) SAE 1010 steel conforming to the requirements for "Cold-Rolled Carbon Steel Sheets, Commercial Quality" (ASTM Designation A 366). The cold-rolled steel sheets are galvanized by the hot-dip process prior to forming with a coating thickness of 1.25 oz per sq ft, meeting the specifications for "Zinc-Coated (Galvanized) Iron or Steel Sheets, Coils and Cut Lengths" (ASTM Designation A 93). The tubing is corner-welded by high-frequency resistance welding with the corner-weld zinc coated after fabrication.

The tubing is furnished in various square cross-sections, and also in one 2- by 3-in. rectangular section. The square tube sizes range from 1 to 2-1/2 in., and are available in increments of 1/4 in. Both the rectangular and square tubes are perforated with holes on 1-in. centers on all four sides. The hole diameters are 11/32 in. for the 1- and 1-1/4-in. square sections, and 7/16 in. for the 1-1/2 through 2-1/2 in. sizes and 2- by 3-in. section. The square tubing is of the telescopic type; that is, the sections slide one inside another.

The tubing evaluation had four phases. The first consisted of a theoretical analysis governed by the AASHO Specifications. The second involved performance testing under simulated field conditions. The third consisted of determining the embedment depth for the Telespar sign supports. The fourth comprised a cost comparison with currently accepted supports, including replacement expense.

Theoretical Analysis

From the AASHO Specifications design criteria, allowable moments were computed for Telespar tubing sizes 1-1/2 through 2-1/2 in. square, and the 2- by 3-in. rectangular section. Similar computations were made for currently accepted sign supports. From the computed moments design curves were prepared, and analysis commenced subject to the following assumptions:

1. Maximum wind speed throughout the State is 80 mph.
2. The supports are rigidly fixed at ground level.
3. They are without splices for their entire length.
4. Bolted back-to-back sections develop the full strength of the entire section.
5. Load distribution is unequal when using two or three supports of unequal height.

Permissible stresses and section moduli for the various sign support types are given in Table 1. The yield stresses for open and back-to-back sections, pipes, and Telespar tubes are as given by ASTM A 15, ASTM A 53, and the 1962 SAE Handbook, respectively. Flexure and shear stresses are computed in conformance with the AASHO Specifications.

TABLE 1
PERMISSIBLE STRESSES AND SECTION MODULI

Type	Dimension or Weight	Minimum Yield Stress, psi	Maximum Allowable Flexural Stress, psi	Maximum Allowable Shear Stress, psi	Minimum Section Modulus, in.^{3}
Open Section	2-lb per ft 3-lb per ft 4-lb per ft	50,000	39,500	24,200	0.19 0.31 0.44
Open Section "back-to-back"	6-lb per ft 8-lb per ft	50,000	39,500	24,200	1.02 1.75
Pipe	3 in. diam 4 in. diam	30,000	23,700	14,500	1.73 3.21
Telespar Tubes	1-1/2 in. square 1-3/4 in. square 2 in. square 2-1/4 in. square 2-1/2 in. square 2 by 3 in. rectangular	44,000	34,800	21,200	0.17 0.26 0.37 0.50 0.64 0.65

Section moduli for the standard supports are required minimum specification values, while those for the Telespar tubes are manufacturer's values.

The design curves computed on the basis of these assumptions and conditions for signs mounted on one, two, and three supports are shown in Fig. 1. Because an unequal load distribution was assumed for two- and three-support signs due to unequal support heights, the allowable sign areas given in Fig. 1 for two or three supports of unequal length would be conservative if the supports were actually of equal height. In such cases it is suggested that design curves for one-support signs be used, multiplying allowable sign area for one support by two or three to obtain allowable area for the desired number of supports.

Since the AASHO Specifications stipulate a maximum design eccentricty for a one-support sign of 0.15 times the sign width from point of load application to the sign's center of gravity, the shear caused by this eccentric loading was also computed. However, the developed shear in the Telespar tubes as well as in the current standard supports was found to be insignificant with respect to currently used sign widths.

Test Methods and Materials

The structural testing consisted of a series of flexural and torsional tests designed to verify the analytical work. In addition, tension tests were performed on samples from the Telespar tubes to determine mechanical properties of the material. The Telespar tubes selected for testing were the square sizes 1-3/4 through 2-1/2 in., and tested sample supports of weights. A total of 16 flexural and 16 torsional tests were performed on supports without splices for the full sample length. Six samples of the Telespar tubes with anchor post splices were subjected to both types of tests. Galvanized samples of the 3- and 4-lb per ft supports were supplied by the Pollak Steel Co. and 2- and 3-lb per ft galvanized samples were submitted by the Franklin Steel Division, Borg-Warner Corp. Samples of galvanized Telespar tubing were furnished by the Unistrut Corp. Average cross-sectional and physical properties of the supports tested are given in Fig. 2 and Table 2, respectively.

Flexural Tests

Two samples of each support were tested as cantilever beams, as illustrated in Fig. 3. The load increments were applied at a point 10 ft from the fixed end, and vertical incremental deflections measured with a

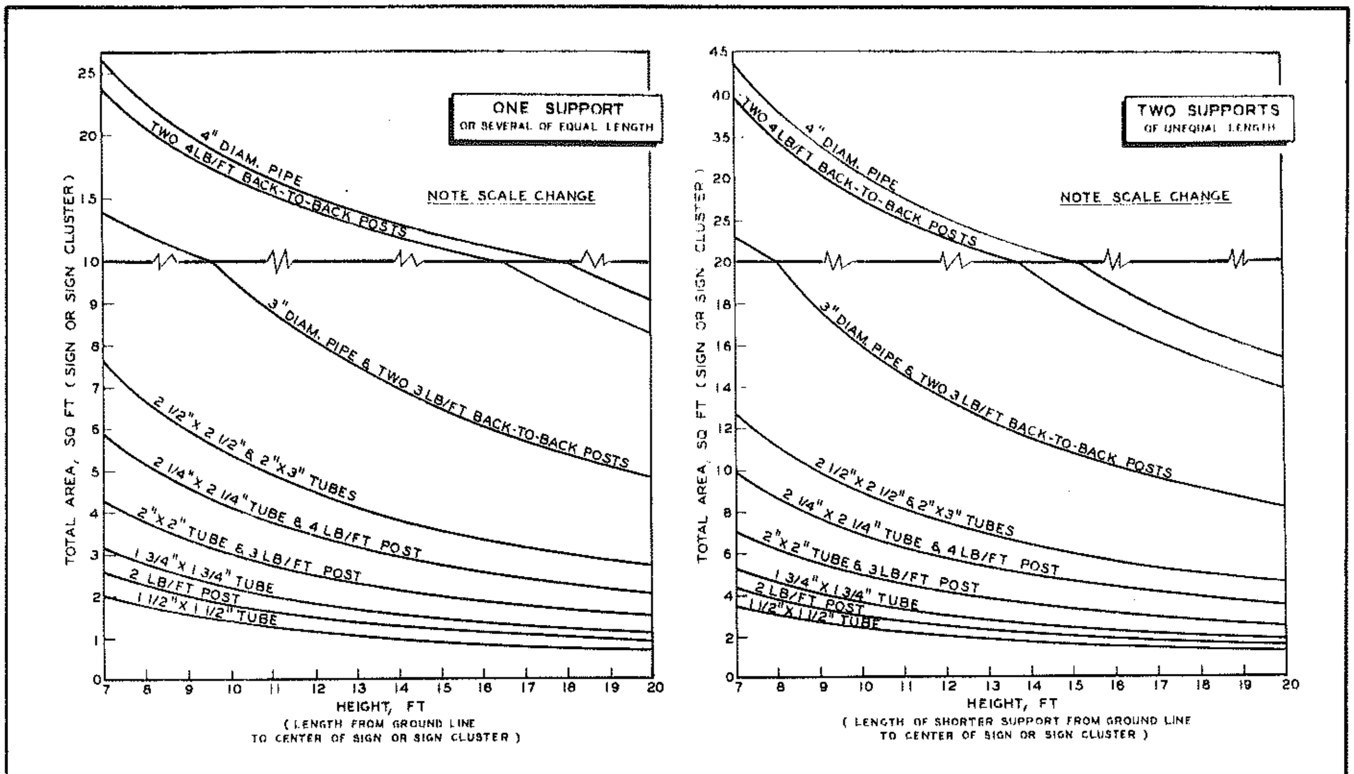
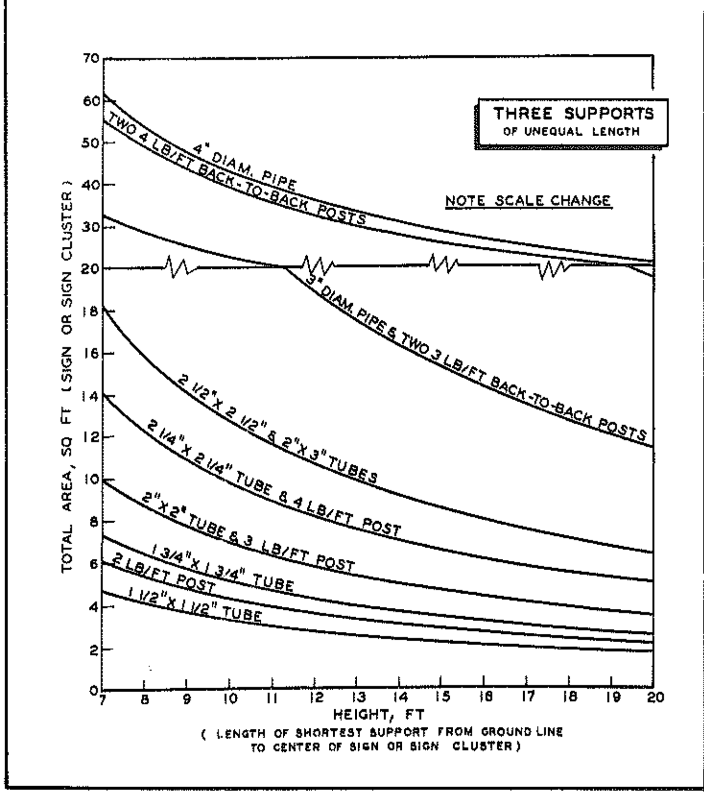

Figure 1. Allowable sign areas for mounting on one support or various combinations of supports.

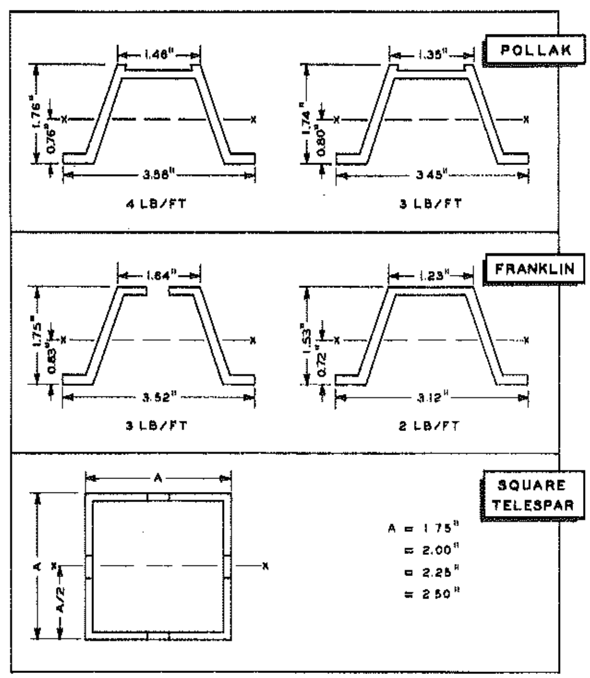

Figure 2. Average cross-sections of test specimens.

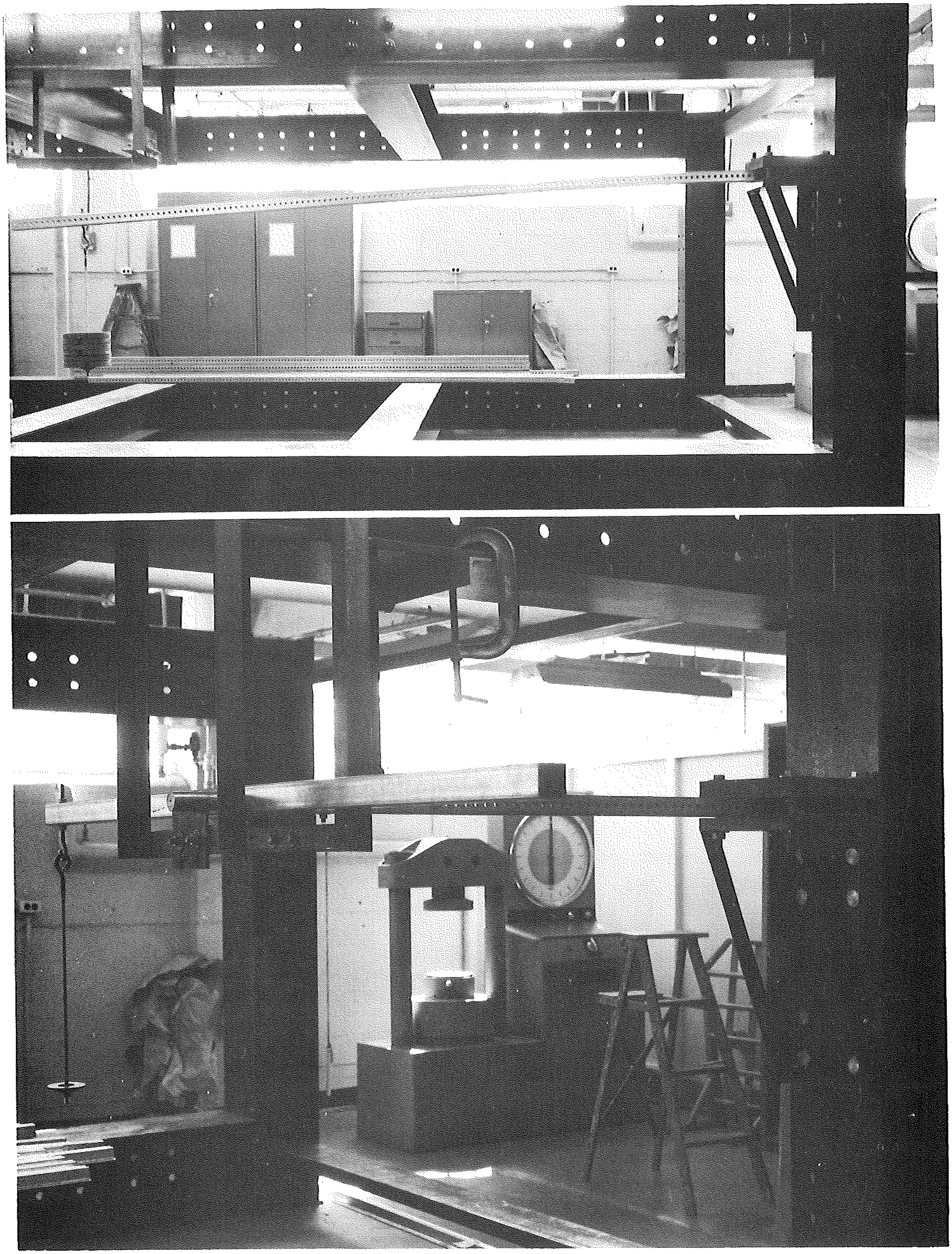

Figure 3. Laboratory set-up for flexural and torsional testing.

graduated scale from a horizontal reference plane suspended above the point of load application.

Telespar specimens (with the anchor post splice) were prepared according to manufacturer's recommendations that the anchor post should extend 12 in. above the ground line, with the supports inserted approximately 12 in. into the anchor post. The two sections were bolted together with two 3/8-in. diam straight bolts or two special corner bolts (available from the manufacturer) placed in the third and fifth hole from the top of the anchor posts. The required bolt torque is given as 20 to 30 lb, or until the bolt is "snug." Bolts must conform to the requirements of "Specifications for steel Machine Bolts and Nuts and Tap Bolts" (ASTM Designation A 307).

TABLE 2
PHYSICAL PROPERTIES

Type	Weight, lb/ft	Area, sq in.	I_{x-x}, in.^{4}	S_{x-x}, in.^{3}	J, in.^{3}
2 lb/ft Franklin	2.26	0.62	0.20	0.25	0.003
3 lb/ft Franklin	3.22	0.85	0.34	0.37	0.006
3 lb/ft Pollak	3.32	0.82	0.34	0.36	0.006
4 lb/ft Pollak	4.24	1.76	0.44	0.44	0.015
1-3/4 in. sq Telespar	2.15	0.50	0.24	0.28	0.559
2 in. sq Telespar	2.32	0.61	0.40	0.40	0.752
2-1/4 in. sq Telespar	2.73	0.70	0.57	0.51	0.945
2-1/2 in. sq Telespar	3.12	0.79	0.80	0.64	1.162

In testing these samples the anchor post extended 12 in. beyond the fixed end. To eliminate possible variability through use of two different types of bolts, all specimens were bolted together with 3/8-in. diam straight bolts, inserted in the proper holes perpendicular to the plane of bending. A 20 ft-lb torque was applied to all bolts. Two samples of each post size were tested using the same procedure as for samples without splices.

The test results are shown in Fig. 4. From the linear slope of the curves for open-section posts (Franklin and Pollak), it is evident that the flexural stress did not exceed the specified yield stress for this material. The slope of the curves for the Telespar posts becomes somewhat nonlinear before the yield strength of the material is reached, perhaps because of local stress concentrations resulting from forming, welding, and punching operations. In the case of Telespar tubes with the anchor post splice, the bolted splice appears to act as a unit, when subject to bending only.

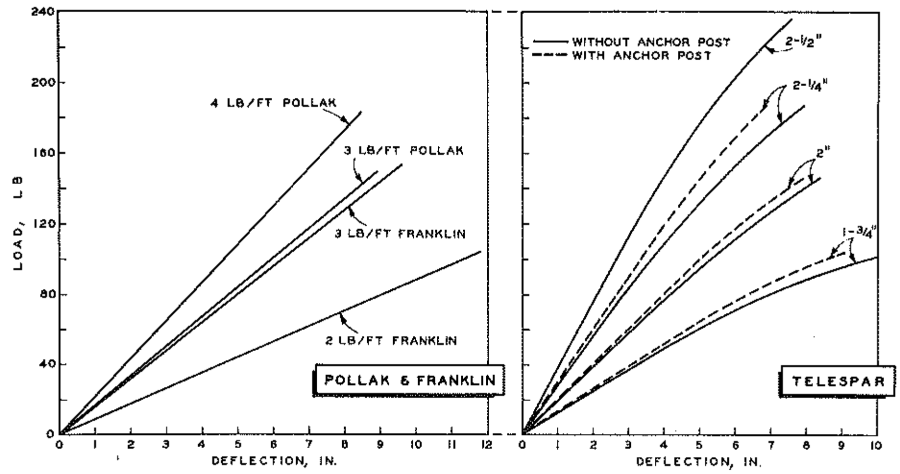

Figure 4. Load-deflection curves for tested specimens.

Torsional Tests

The test set-up for torsional tests is also shown in Fig. 3. The moment arm consisted of a 2-in. square, 6 ft 4 in. long tube, and an 18- by 1-3/4-in. square bar machined to 1-1/2 in. diam for a distance of 12 in. from one end. The round portion of the bar was inserted through a hole in the moment arm at its center of gravity, and welded to the arm so that 5 in. of round bar extended from each side of the arm. This moment arm was supported in adjustable supports, one on each side of the arm. One end of the sample was inserted over the square portion of the pivot bar and the other fixed against rotation. For each successively larger size of tube, appropriate sleeves were inserted over the square bar to ensure a tight fit. In the case of open-section post types, a steel plate with four symmetrically spaced holes was welded to one end of the specimen, which was then bolted to a similar plate attached to the square portion of the pivot bar.

The load was applied to the moment arm 36 in. from its center of rotation. The vertical deflection of a 24-in. pointer, attached to the specimen through its longitudinal centrodial axis, was measured with a graduated scale from a horizontal reference plane suspended over the pointer. This vertical deflection was converted to degrees of angle of twist and the load converted to inch-pounds of torque. Because of the two different methods of attaching the specimens to the moment arm, the length of the two different types of support samples varied. Thus, to compare the results, the angles of twist for all specimens were converted to angle per 41-1/2 in. of length.

The Telespar samples (with anchor post splice) were prepared in a manner identical to that described for flexure test samples, and tested with 12 in. of the anchor post extending beyond the fixed end of the sample. Two samples of each tube size or post type were tested.

The test results are shown in torque-angle of twist curves in Fig. 5. The torsional resistance of the open-section post types is very low compared to that of the Telespar tubes. The curves also verify that shear in one-support signs resulting from applying the load eccentrically is of little consequence regardless of support type, because the linear slope of the curves extends far above the maximum torque obtained by applying the AASHO specification requirements to this type of sign. The curves for Telespar tubes with anchor post indicates that slippage of splice occurs at the outset of the test, but after this initial take-up in the splice the curves have linear slopes until yielding occurs.

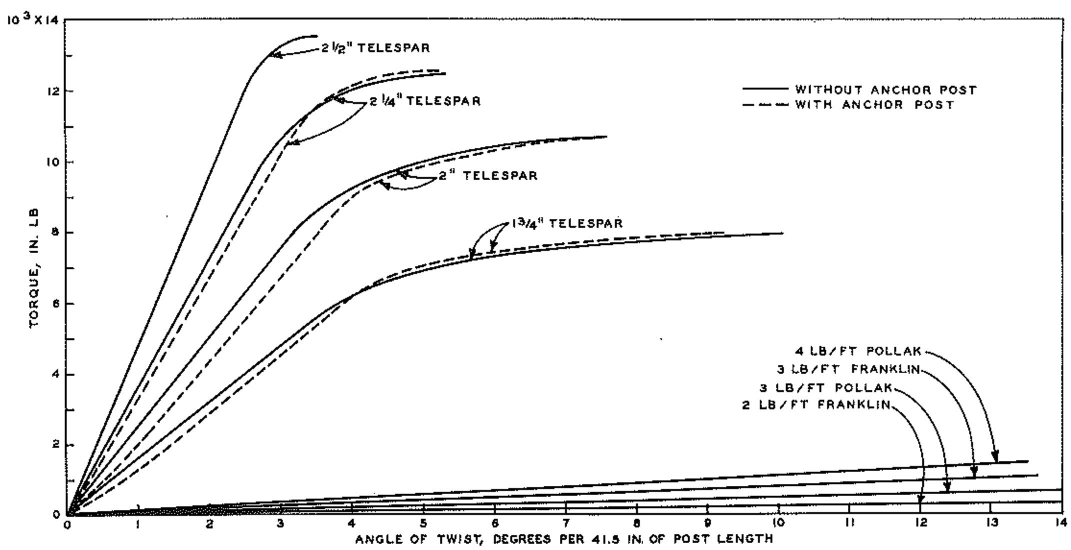

Figure 5. Torque-angle of twist curves for sign supports.

Tension Tests

Tension tests were performed on 12 standard test specimens prepared in accordance with the "Specifications for Tension Testing of Metallic Materials" (ASTM Designation E 8). The specimens were taken from three 2-in. square non-perforated tubes, with one specimen from each of the four sides. The strain was measured with a 2-in. gage length mechanical strain gage. Tests results were as follows:

Property	Test Values			Minimum SAE Values
	Max	Min	Avg	
Yield strength, psi*	47,530	39,850	42,550	44,000
Ultimate strength, psi	57,170	53,370	54,540	53,000
Elongation (2-in. gage), percent	31	25	28	20

* Based on 0.2-percent offset

Embedment Depth

The embedment depth of a sign support is a function of its horizontal load capacity, height of load application above ground line, width of embedded section, and soil pressure. The relationship of these functions is given in the AASHO Specifications and was used in determining embedment depths for the various Telespar tubes.

Since Traffic Division plan SF-81 requires a minimum embedment depth of 3.5 ft for all open-section sign posts, it is possible, by applying the AASHO requirements, to determine the maximum developed soil pressure for these accepted posts. The maximum soil pressure determined in this manner was 1800 psf, which was used as an allowable soil pressure in calculating the following minimum embedment depths for the Telespar tubes:

Size	Embedment Depth, ft
1-1/2-in. square	2-3/4
1-3/4-in. square	3-1/4
2-in. square	3-3/4
2-1/4-in. square	4-1/4
2-1/2-in. square	4-3/4
2- by 3-in. rectangular	5-1/4

Cost Analysis

To compare unit costs per foot of Telespar tubing with those of open-section post types, cost quotations covering several sizes were requested from the Unistrut Corp. The reply included prices of tubes galvanized with 1.25-oz zinc coating as per ASTM Designation A 93 (manufacturer's standard finish), and galvanized tubes with an average 2-oz coating as per ASTM Designation A 123, the latter weight being the one specified by the Department. Price per foot for each coating class, based on a lot size of 500 sign supports of 12-ft length for four square sizes of tubing, are as follows:

Size	1.25-oz Coating	2-oz Coating
1-3/4-in. square	48¢	61¢
2-in. square	52¢	67¢
2-1/4-in. square	56¢	74¢
2-1/2-in. square	61¢	80¢

By comparison, the cost per foot for a 3-lb per ft galvanized sign support is 33¢ as quoted by the Office of Maintenance from a purchase order of 6300 pieces of 12-ft sections from Franklin Steel.

Although the initial cost of the Telespar tubes is higher than that of currently used sign supports, certain features of the tubes offset this initial cost difference:

1. The telescoping feature makes the anchor post system possible. Driving a short piece into the ground is easier than driving full-length sign supports. Signs may be assembled in the shop during inclement weather, and erection by attaching to anchor posts eliminates ladders or scaffolds.

2. Because of the telescoping principle, supports are easily spliced when additional height is needed, or when damaged sign supports are repaired.

3. Parts of damaged sign support are re-usable as anchor posts, splices, or brackets for sign cluster mounting.

4. The anchor post system is ideal for detour and construction signing projects, since the signs can be installed initially with the legend reversed to the traffic flow, and when the detour or construction begins the sign assemblies can easily be lifted out and reversed so the legend faces traffic.

5. The square cross-section provides four flat sides for sign mounting. Thus, signs can be mounted at right angles to each other without use of the special fittings required for currently used sign supports.

6. The torsional strength of a square tube is much greater than that of an open section. Thus, fluttering of signs in high winds is eliminated or reduced. The torsional strength advantage over open sections is sufficient in some cases to eliminate the use of two supports on smaller signs.

Since the Telespar tubes were only recently introduced as sign supports, very little information is available concerning the advantages of this type of support, on which to base an estimate of savings to be realized by its use as sign supports. It appears that substantial savings would result from reduced replacement costs of damaged sign supports, especially if the anchor post system is used since it is understood that in most cases the anchor post of a damaged sign support is re-usable and the salvage value of damaged but re-usable supports is high.

To calculate the anticipated savings on replacements in terms of dollars, the Office of Maintenance was contacted for information concerning the quantity of damaged sign supports per year. However, it was learned that such information was available only through study of financial records concerning damage of Departmental property. Because of the time and labor that would be required in searching such records, that approach to the problem was abandoned. Instead the Wayne County Road Commission, which recently has been using the Telespar tubes extensively for sign supports, was contacted regarding resulting savings. A reply dated July 10, 1964 from W. A. Doktor, Highway District Supervisor II (Signs) indicated satisfactory performance of the Telespar tubes as sign supports, as well as for miscellaneous uses both in the field and shop. His evaluation is based on the use of almost 20,000 lin ft of tubing. Several paragraphs of the letter concerning the use, installation, purchasing, and transportation of Telespar tubes may be quoted:

"To illustrate some of our experiences with the use of Telespar Tubing for Traffic Sign Supports, we have been able to take advantage of the high torsional strength of this product as compared with the flanged channel section which was commonly used by the County, thus eliminating the necessity in many cases of using two flanged channel posts for the mounting of a 36" x 36" panel by the use of only one 2" Telespar Post, thereby reducing our cost in labor and equipment. This in itself has been a considerable saving to us and helped to defray the difference in the cost of one product over the other.

"In many cases where we had used one flanged channel post to support a given size panel, for example 24" x 24" or 20" x 30", quite frequently in high winds, we had complaints of fluttering. This was eliminated by the installation of one Telespar Post with the same size panel and, once again due to the high torsional value of the tubular section, the fluttering was eliminated and these complaints are no longer registered.

"One of the major advantages of this new method on which it is hard to place a monetary value, even with our experience, is the fact that when a post of flanged channel or round pipe is hit by a moving vehicle, it is generally bent to a point where it is very difficult and almost impossible to straighten. Usually the sign has to be removed from the existing post and a new post installed, bringing the damaged post back to our sign shop and placing it on a pile. Whenever time will permit we may salvage a small portion of these posts for some other end use. I would say an estimated 80% of the flanged channel posts damaged in the field are beyond salvage-ability and as a result over a period of a year, there is quite a pile of damaged posts accumulated in our yard which periodically have to be sold for scrap value in order to dispose of them.

"The Telespar Post presents somewhat of a different problem in view of the fact that the post, if mounted with the anchor post method which is the utilization of a larger size tube of approximately three or four feet in length, depending on soil conditions, is driven into the ground and permitted to stick out of the ground surface a short distance and the next quarter inch smaller size tube inserted, fastened by means of bolts and a sign mounted at the top of the post. When this is hit, it has been our experience that if hit hard enough, the post will shear itself off at approximately the ground level. The original installation can usually be repaired in the field merely with a hack saw, a few nuts and bolts and a piece of another tube to form one of the several ways of splicing and the sign is erected in a matter of a short time. At the writing of this letter, with the separate scrap piles in our sign shop yard, we have approximately 40 feet of damaged Telespar which eventually can, in part at least, be used for splicing and miscellaneous other uses, vs. a good truckload of channel.

"Wayne County annually erects approximately 4,000 posts on State Routes and 2,000 posts on County Routes to support traffic signs. In an effort to determine the driving ability of one over the other, last winter when the weather was approximately 3 degrees above zero, we conducted a test using a power air hammer as our driving equipment and drove for a depth of 42" into the frozen ground. The flanged channel type of post took a time element of 3 minutes 25 seconds. With a 2" Telespar Post, using the same equipment with the exception of changing the driving head from one style to another, it took only 55 seconds. One of the advantages of driving Telespar Posts utilizing their new concept of the anchor post method, is the fact that all sign installation work can be done from ground level and there is no necessity of getting up on the back of a truck or a ladder in order to accomplish the driving of the post. This in itself is a safety factor as well as a labor saving medium.

"Our method of purchasing this material is in standard mill lengths of 20 and 24 feet and as the occasion arises, we cut, in our own shop, the lengths we need to accomplish a given installation, thereby eliminating the necessity of stocking a terrific inventory of multiple sizes. This has reduced the handling and storage problem in our yard considerably over the material we formerly used and it has permitted us to be versatile in obtaining the desired lengths as need them. This in itself is a considerable saving in our opinion over our former inventory method for sign posts.

"The ease in transporting and handling the material not only in the yard, but to the jobsite is another factor that really should be taken into consideration in the over-all evaluation of this material."

Conclusions

1. The open-section posts tested conformed to the minimum cross-sectional properties specified in Traffic Division plan SF-81. The cross-sectional properties for the four sizes of Telespar tubing submitted for testing were found to conform to the manufacturer's values used in the mathematical analysis.

2. An average yield strength of 42,550 psi (based on 12 tension tests as determined by the 0.2-percent offset method) was obtained for the Telespar tube material. Although this result is 3.3-percent less than the estimated minimum value of 44,000 psi given by the SAE Handbook for cold-formed 1010 steel, this deviation is considered less than the experimental error involved, and the 44,000-psi yield strength used in prior analysis of the Telespar tubing was not revised.

3. Flexure test results on open-section sign supports indicated that the material did not yield until after the theoretical load capacity was exceeded. In the case of the Telespar tubes, the load-deflection curves deviated somewhat from a straight line before the theoretical load capacity was reached. Such behavior of structural members subject to cold-forming and punching operations is generally expected, because of initial or residual stresses present in the member. However, in this case, the apparent effect of these initial stresses is extremely small and reduction in theoretical load capacity is not deemed necessary.

4. The fluttering of one-support sign assemblies in high winds has long been recognized as an undesirable feature associated with open-section sign supports. Based on the torsion tests results, this problem could be greatly reduced and in most cases eliminated, by using square or rect-

angular Telespar tubes. For example, for the 2-in. square Telespar tube and the 3 lb per ft Franklin post (which will accomodate equal sign areas), the angle of twist for the 3 lb per ft posts is approximately 33 times as great as for the 2-in. Telespar tube.

5. The structural tests verify that use of Telespar tubes as sign supports for the types of sign structures considered in this report, designed in accordance with the requirements of the AASHO specifications, will lead to a safe structure.

Recommendations

Based on the results of this evaluation and study, it is recommended that the Telespar tubes be approved for use as sign supports. Because little data are available on which to base an analysis of the economic feasibility of either type of sign support, it is suggested that initial approval be limited to a large-scale installation of signs erected on Telespar tubes for the purpose of obtaining information concerning installation and maintenance costs. In case approval for a large-scale installation is given, the Office of Maintenance should be requested to keep the necessary records of costs for the Telespar project as well as for an equal number of similar signs erected on open-section sign posts. Comparison of these cost records should furnish valuable information for future recommendations on the type of support to be specified.

With respect to galvanizing, it is recommended that galvanized Telespar tubes conform to current Departmental specifications for sign supports. The allowable sign areas and minimum length of embedment for various Telespar tube sizes as given in this report should be followed when installing Telespar sign supports.