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# THE STRUCTURAL CHARACTERISTICS OF A PLASTIC FIBERGLASS OVERHEAD SIGN SUPPORT STRUCTURE

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As part of the Research Laboratory's program for design and development of overhead sign support structures, L. T. Oehler of the Laboratory met M. Hoffman of the Traffic Division and representatives of Gar Wood Industries, Inc. in August, 1955, to discuss the feasibility of using plastic fiberglass material for overhead sign support structures. On the basis of a small model which was test loaded at that meeting, this did not appear very feasible.

During the following year, the Research Laboratory developed the design and specification for the present MSHD aluminum overhead sign support structures. Gar Wood Industries continued their experimental work with plastic fiberglass for overhead sign support structures, building and testing a full-size model which they exhibited at their plant in another meeting in September, 1957. This model was a product much improved over the previous model; the fabricator stated that it would meet the strength and deflection standards of the MSHD specifications for such structures.

At the request of Mr. Bauerle, Director of the Traffic Division, one 60-ft. plastic fiberglass structure was purchased on the basis ". . . that it perform according to the Michigan State Highway Department Specifications . . ." A testing program was organized at Mr. Bauerle's request to evaluate this structure, and is reported here.

The Gar Wood overhead sign support structures consist of a horizontal unit composed of 20-, 25-, and 30-ft. sections in the form of equilateral triangular space frame trusses, bolted together through molded couplings on the three main chord members. Each of these three main chord members is supported on two vertical end units consisting of two tubes, interconnected by cross members and diagonals.

All the individual members of the structure are plastic fiberglass tubes. These tubes are fabricated by forming fiberglass and either epoxy or polyester resin around a liner tube. Fittings and couplings made from fiberglass or polyester resin are integrally bonded to the tubes with a special adhesive formulated from an epoxy resin. These structures are intended to provide span lengths from 50 to 80 ft. in 5-ft. increments, and to support 300 sq. ft. of sign area weighing 8 lb. per sq. ft. anywhere on the span.

On January 29, 1958, a load test was conducted on the horizontal unit of the 60-ft. structure purchased by the Department. The details of this horizontal unit are shown in Figure 1. The main longitudinal members have a nominal outside diameter of 4-3/4 in. with a nominal fiberglass thickness of 1/4 in. The secondary diagonal members have a nominal outside diameter of 2-1/2 in., with a nominal fiberglass thickness of 1/4 in. The equilateral triangular cross section is 55 in. on each side, and longitudinal panel points are spaced at 55 in. This unit is composed of two 30-ft. sections bolted together through molded fiberglass couplings with six 5/8-in. diameter No. 302 stainless steel bolts, with self-locking nuts. The diagonal members are fitted to the main chords through molded fiberglass couplings, with two 5/16-in. diameter, aluminum alloy 2024-T4 bolts through two of the stiffener legs on the coupling.

In addition to the load test on the 60-ft. span structure, a series of tests was carried out to determine the structural characteristics of the molded chord couplings and the diagonal-to-chord connections. Finally, tests were made on a number of specific samples to ascertain some of the physical properties of the fiberglass material itself.

## TEST PROCEDURE, INSTRUMENTATION, AND TEST RESULTS

### Load Test of 60-ft. Span Horizontal Truss Unit

This test was divided in three loading phases. First, the structure was loaded to 3000 lb. in 500-lb. increments at center span with the load applied on one side of the truss in the vertical plane position. Second, with the truss in the same position as above, The structure was loaded to 6000 lb. in 1000-lb. increments at center span with the load applied at the centroid of the triangular cross section. Third, the structure was rotated

90 deg. and loaded symmetrically at center span to 9000 lb. in 1000-lb. increments.

For all three of the above phases of loading, the truss was supported at the ends on a steel frame utilizing a type of end connection support similar to that which would be employed under actual conditions. All loads were applied to the structure through a precalibrated dynamometer by a jack and pulley arrangement. Ten sets of type A-12, SR-4 strain gages were attached to various diagonal members and to strategic points on the chord members. The live load strains were measured with a Baldwin SR-4 static strain indicator. A Brush oscillograph was used to determine the natural frequency of the structure's vibration. Live load and residual center deflections for all phases of loading were obtained by two 1/32-in. division scales suspended from the ceiling along both sides of the truss at center span. Photographs of the instrumentation and phases of loading are shown in Figures 2, 3, and 4.

The test results for the previously described loading program are as follows:

1. Center Deflection for Concentrated Load at Midspan

   First Loading Phase: average loaded side deflection was 0.56 in. per 1000 lb., average unloaded side deflection was 0.37 in. per 1000 lb., and maximum residual deflection was 0.09 in.

   Second Loading Phase: average center deflection was 0.49 in. per 1000 lb. and no residual deflection was noted during this phase of the test.

   Third Loading Phase: average center deflection was 0.50 in. per 1000 lb. and maximum residual deflection was 0.09 in.

2. Loads and Stresses

   As a result of the load test, the following maximum loads and stresses were recorded:

| MEMBER | MAX. LOAD (lb.) | MAX. STRESS (psi) |
|---|---|---|
| Chord connection | 27,880 | 10,370 |
| Chord | 24,120 | 8,970 |
| Diagonal | 3,130 | 3,960 |
| Strut | 1,560 | 1,970 |

### 3. Natural Frequency of Vibration

Natural frequency of vibration was 5.2 cycles per second.

Inspection of the structure before, during, and after testing revealed no defects or structural failure.

## Ultimate Load Tests of Truss Connections

Ultimate tensile load tests were made on three of the molded chord-to-chord couplings, and on six of the molded diagonal-to-chord connections. Three of the latter connections were bonded with epoxy resin, and the other three with polyester resin. Special jigs were designed for testing, and all specimens were loaded on a Riehle 300,000-lb. capacity hydraulic testing machine.

The results of the tensile tests on both the chord-to-chord and diagonal-to-chord connections are shown in Table 1. Photographs of a typical failure of each of the two types of connection are shown in Figure 5.

## Tests of Physical Properties of Plastic Fiberglass as a Material

The ultimate tensile and compressive stresses of the plastic fiberglass material were determined from samples of 4-3/4-in. or 2-1/2-in. diameter tubes, as prescribed by the American Society for Testing Materials. Type A-1, SR-4 strain gages were applied to six samples of plastic fiberglass tube to determine the stress-strain relationships of the material. All strains were recorded on a four-channel Sanborn recording oscillograph. In order to determine the effect of temperature on the ultimate compressive strength of the material, compression tests were made on eight tube samples which had been heated to 175 F. for 23 hrs., and eight samples which had been cooled to 0 F. for 23 hrs. All of the testing involving the properties of the material was made on a Riehle 300,000-lb. capacity hydraulic testing machine.

The results of the tests on the fiberglass material for physical properties are shown in Table 2. Photographs of failure of tension and compression specimens are shown in Figure 6. The ultimate compressive stress was increased by approximately 16 percent at the 0 deg. temperature, and decreased by approximately 10 percent at the 175 deg. temperature. These percentages of increase or decrease are based on the ultimate compressive strength at room temperature, 70 F.

# EVALUATION AND CONCLUSION

In evaluating the results of these tests and judging characteristics of the proposed fiberglass designs, two fundamental design factors, strength and stiffness, have to be considered. The Research Laboratory has previously adopted strength and stiffness design criteria for aluminum overhead sign support structures. In addition, designs have been evolved for two basic types and areas of signs to be used on these structures. Based on these established design criteria for overhead sign support structures and the results of the series of tests and analyses conducted in this study, the following conclusions have been drawn.

It appears that the 50-ft. and 60-ft. fiberglass structures would satisfactorily support 300 sq. ft. of illuminated sign area. It should be pointed out that the center deflection per 100 lb. of applied loading for the 60-ft. span fiberglass structure was twice that of the 60-ft. aluminum structure designed for the same sign loading. However, the anticipated live load deflections for these two span designs do not seem critical enough to justify an outright rejection. From the standpoint of strength, these two span designs should be more than adequate.

In the case of the 70-ft. structure, although satisfactory in strength, the resulting frequency of vibration and live load deflection with 300 sq. ft. of illuminated sign loading, would be objectionable. However, this structure should be satisfactory for 200 sq. ft. of non-illuminated sign loading, and the resulting frequency of vibration would be essentially equivalent to that of the MSHD Aluminum designs; the resulting live load deflections would not be objectionable.

For the 80-ft. structure, maximum stresses for 300 sq. ft. of illuminated sign loading would be approximately 20 percent greater than allowed under MSHD design criteria. The resulting natural frequency of vibration and live load deflection for either of the two types and areas of sign loading would be critical and, in the opinion of the Research Laboratory, would not be acceptable.

## Limitations

It should be emphasized that the conclusions above are based primarily on the results of the tests described here. There are two important physical properties of the material, fatigue characteristics and creep phenomena, about which relatively little data are established.

Further, the durability of the material under conditions encountered in actual service, and subsequent effects on the material's physical characteristics cannot be determined at this time.

In addition, plastic fiberglass as a structural material poses some problems concerning uniformity of product and methods of control or inspection. The conventional structural materials, such as aluminum or steel, have an established pattern of product uniformity, developed by certain manufacturing procedures and material analyses.

From the limited information the Laboratory has been able to obtain, however, plastic fiberglass material would not be as uniform a product as aluminum or steel. This results from two factors: first, the product is more like concrete in nature, where certain ingredients are mixed in certain proportions to obtain the final material. Second, the ingredients and the mix proportions would be the manufacturer's secret; changes could and would be made as desired or as experimentation dictated. Thus it would be much more difficult for the Department to determine with the same degree of assurance (as for an aluminum or steel structure) that a plastic fiberglass structure meets the Department's standard of quality.

## Recommendation

Considering these factors, the Laboratory finds that general acceptance of these structures is not warranted at this time. However, the performance of an experimental 60-ft. plastic fiberglass structure which has been erected near the intersection of US-16 and M-78 between Lansing and East Lansing, will be followed by Research Laboratory personnel. With this information and continuing research into the properties and behavior of this material, a definite conclusion of the use of these structures can be made at a later date.

## TABLE 1

## ULTIMATE TENSILE LOAD TESTS OF TRUSS CONNECTIONS

| Truss Component | Specimens Tested | Average Ultimate Load (lb.) |
|---|---|---|
| Chord to Chord Connection | 3 | 67,170 |
| Diagonal to Chord Connection Epoxy Resin | 3 | 14,280 |
| Diagonal to Chord Connection Polyester Resin | 3 | 11,400 |

## TABLE 2

## PHYSICAL PROPERTIES OF PLASTIC FIBERGLASS MATERIAL

| Physical Property | Specimens Tested | Average Ultimate Load (lb.) | Average Ultimate Stress (psi)* |
|---|---|---|---|
| Ultimate Compressive Stress | 6 | 23,125 | 29,000 |
| Ultimate Tensile Stress | 3 | 5,233 | 81,000 |
| Modulus of Elasticity Tension | 3 | --- | $3.66 \times 10^6$ |
| Modulus of Elasticity Compression | 3 | --- | $3.76 \times 10^6$ |
| Average Modulus of Elasticity | - | --- | $3.7 \times 10^6$ |
| Yield Point | 9 | --- | None |
| Ultimate Compressive Stress 0 F. | 8 | 86,600 | 33,700 |
| Ultimate Compressive Stress 175 F. | 8 | 67,300 | 26,100 |

*All stresses were computed using the average cross sectional area of the plastic fiberglass tube only, i.e. the area of the entire tube, minus the area of the liner tube.

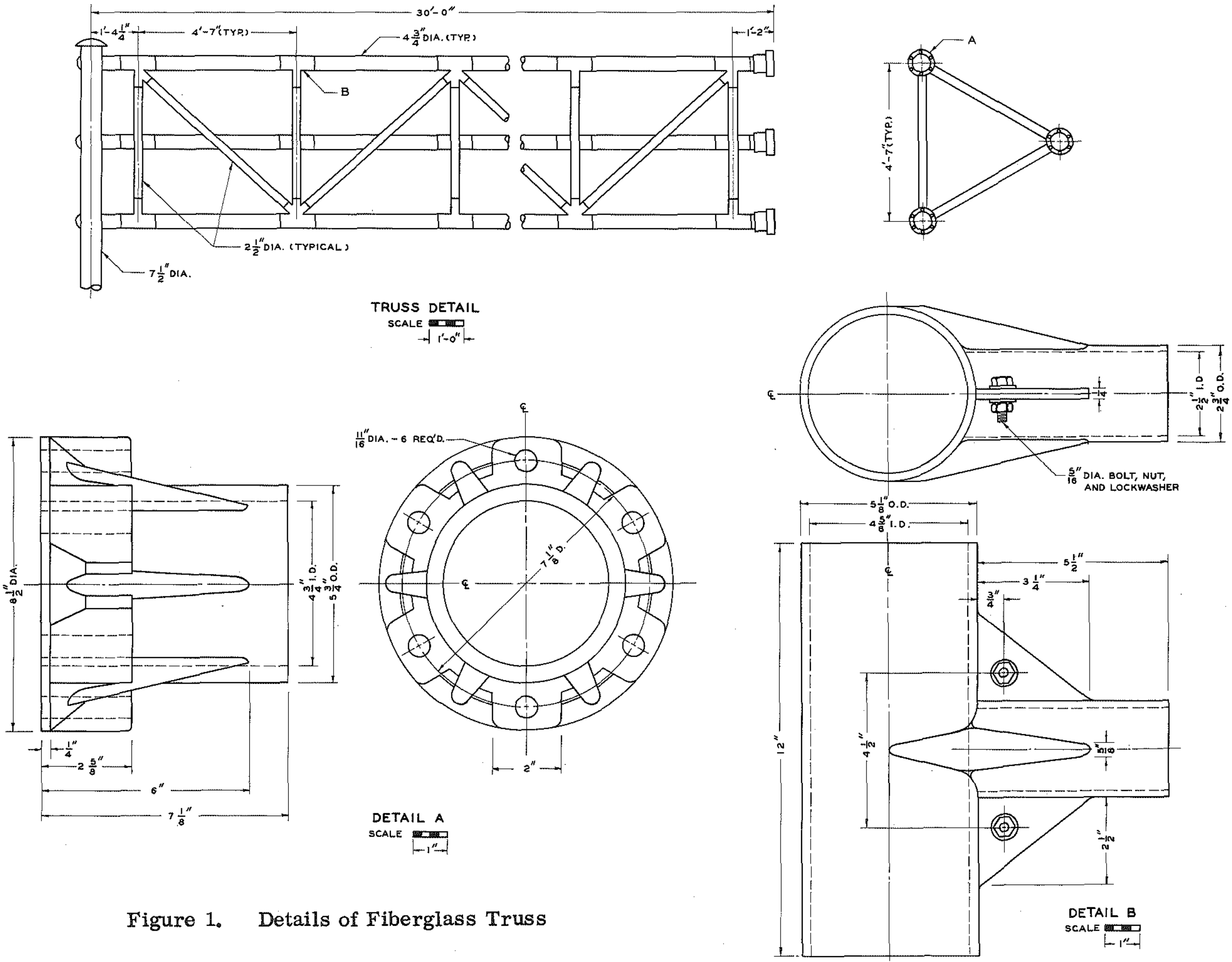


Figure 1. Details of Fiberglass Truss

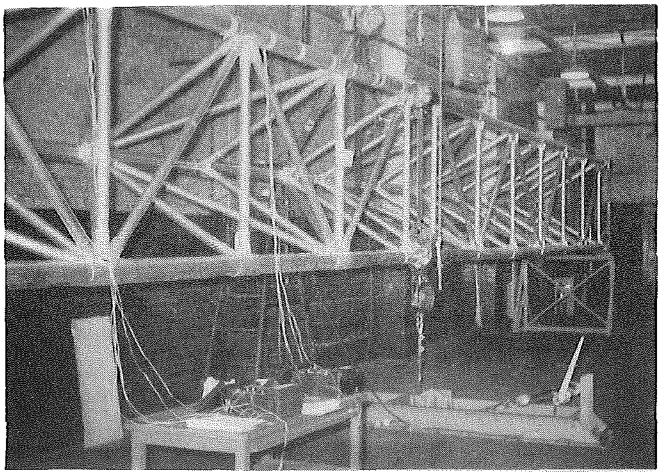


Figure 2. **60-ft. plastic fiberglass truss loaded at** center span in the vertical plane position with load applied on one side.

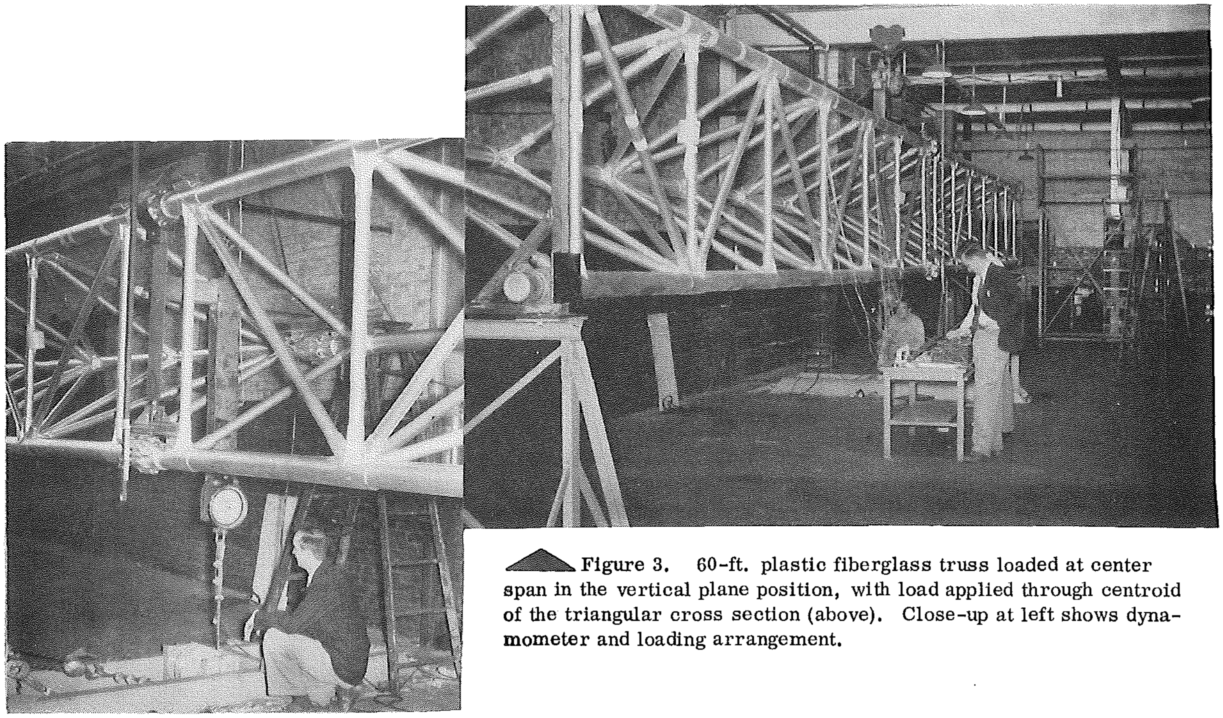


Figure 3. 60-ft. plastic fiberglass truss loaded at center span in the vertical plane position, with load applied through centroid of the triangular cross section (above). Close-up at left shows dynamometer and loading arrangement.

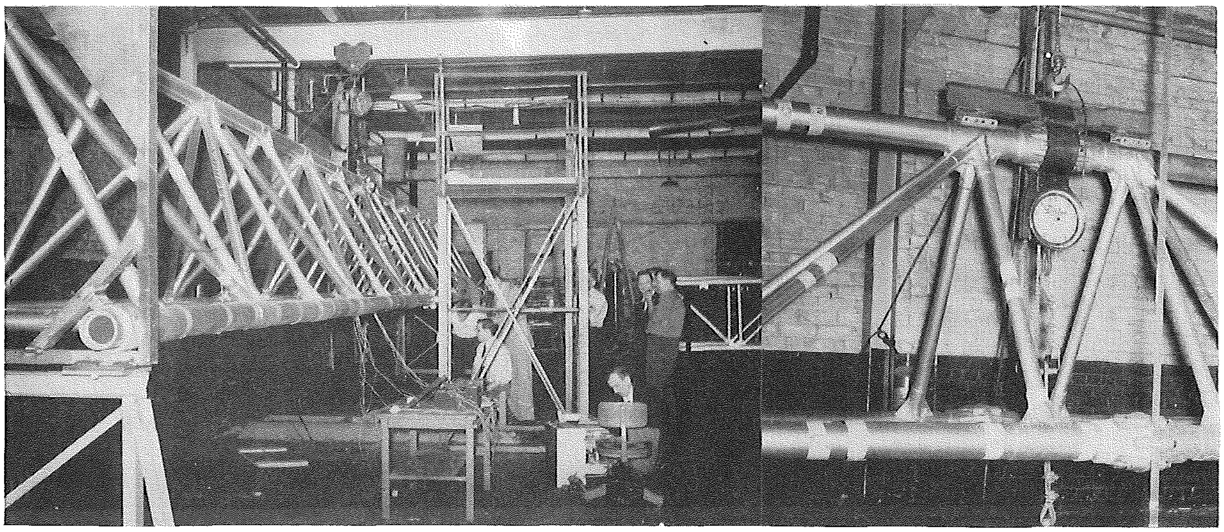


**Figure 4. 60-ft. plastic fiberglass truss loaded at center span in the horizontal plane position (left). View at right shows dynamometer and loading arrangement.**

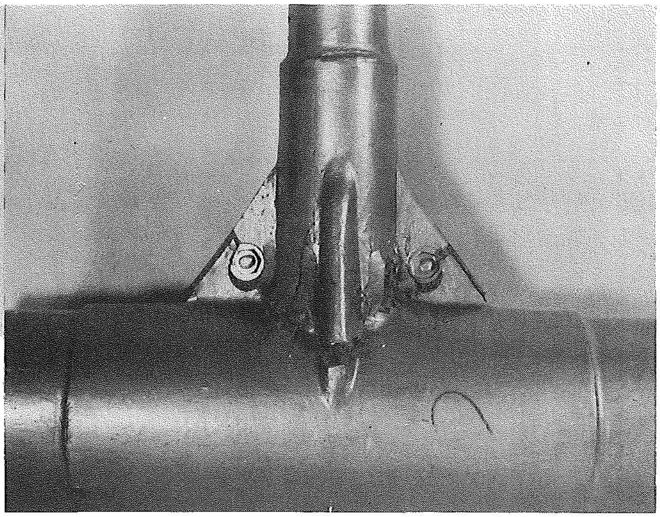
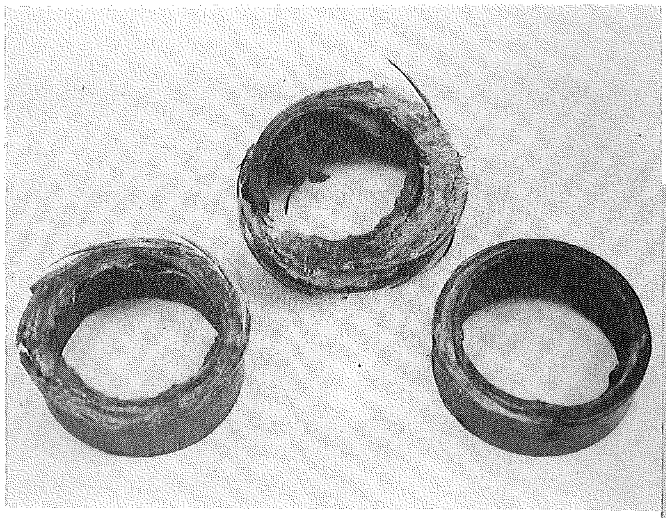


Figure 5. Typical failures of each of the two types of plastic fiberglass chord connections after ultimate tensile load tests, the chord-to-chord connection above and the diagonal-to-chord connection at right.



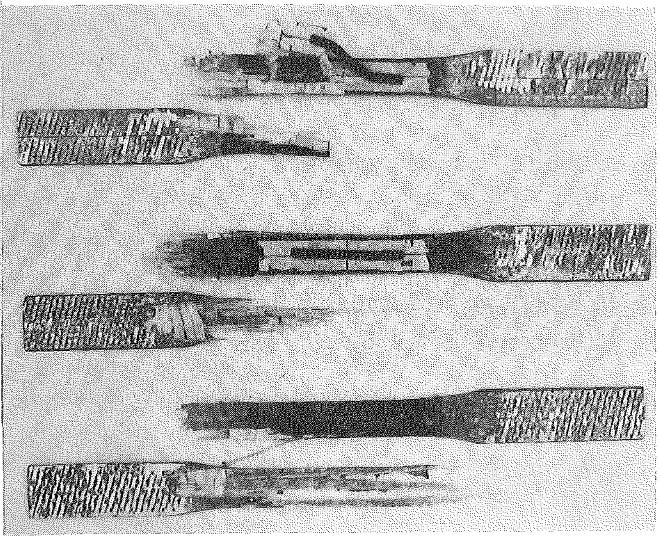


Figure 6. Typical failures of plastic fiberglass material as a result of ultimate compressive load tests (above) and ultimate tensile load tests (right).