# FATIGUE OF SANDWICH CONSTRUCTIONS FOR AIRCRAFT

## Fiberglas-honeycomb Core Material with Fiberglas-laminate or Aluminum Facings, Tested in Shear

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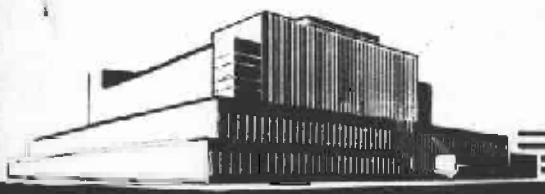

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

# FATIGUE OF SANDWICH CONSTRUCTIONS FOR AIRCRAFT[1]

## Fiberglas-Honeycomb Core Material with Fiberglas-Laminate or Aluminum Facings, Tested in Shear[2]

By

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## Summary and Conclusions

A limited number of tests (43) have been made at the Forest Products Laboratory to determine the shear fatigue properties of an assembled sandwich panel of fiberglas-honeycomb core material and fiberglas-laminate or aluminum facings. The tests have been made at a ratio of minimum to maximum loading of 0.1. The results of these tests and the corresponding S-N curve are presented. The results of the tests indicate a fatigue strength at 30 million cycles of approximately 42 percent of the static strength for the condition of loading used.

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[1] This progress report is one of a series prepared and distributed by the Forest Products Laboratory under U.S. Navy, Bureau of Aeronautics No. NBA-PO-NAer 00619, Amend. No. 1, and U.S. Air Force No. USAF-PO-(33-038)48-41E. Results here reported are preliminary and may be revised as additional data become available. Original report published in 1948.

[2] This is the fourth of a series of reports intended to offer a comparison of the shear fatigue properties of different sandwich materials. Forest Products Laboratory Report No. 1559 discusses cellular cellulose acetate tested in shear; Report No. 1559-A discusses aluminum face and paper honeycomb core sandwich material tested in shear; and Report No. 1559-B discusses aluminum face and end-grain balsa core material tested in shear.

[3] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

## Introduction

Experiments were conducted at the Forest Products Laboratory to determine the shear fatigue characteristics of typical sandwich panels having fiberglas-honeycomb core material. The facing materials employed were (1) six-ply fiberglas laminate impregnated with a high-temperature-setting laminating resin, resin A,[4] and (2) 0.020-inch aluminum bonded to the core with a high-temperature-setting phenol resin, resin N.

The general testing procedures and the nomenclature applied to these tests are similar to those used in previous tests by the Forest Products Laboratory in testing aluminum face and paper honeycomb core sandwich material.[2]

## Description of Material and Specimens

The fiberglas-honeycomb core material was received from a commercial manufacturer in blocks approximately 3-3/8 by 17 by 18 inches with a cell size of 3/16 inch in the 17-inch direction. The blocks were sawn perpendicular to the flutes with a bandsaw to a thickness of 0.500 ±0.005 inch, and glued together to form the finished core. Two 18- by 30-inch cores, used with the fiberglas-laminate facings, had an overall density of 7.3 pounds per cubic foot. The 18- by 36-inch core used with the aluminum facings had an overall density of 7.8 pounds per cubic foot.[4]

Fiberglas faces were made of six plies of cross-laminated glass cloth impregnated with 45 to 50 percent of resin A by weight, and the panels were made in a press as described in method 1 of glass cloth-to-glass cloth honeycomb panel-assembly techniques, Forest Products Laboratory Report No. 1574.[4] The aluminum facings and fiberglas core were assembled and pressed as described in method 5 of aluminum to paper honeycomb panel-assembly techniques of the same report.

The specimens were cut from the assembled panels with a high-speed steel circular saw to a width and length of 2 and 5.67 inches, respectively. The sandwich blocks with aluminum facings were glued to the 1/2-inch

[4] Additional information on fabrication can be obtained from Forest Products Laboratory Report No. 1574, "Fabrication of Lightweight Sandwich Panels of the Aircraft Type," March 1954. The resins and adhesives referred to here are described in appendix 3 of that report.

shear plates, as described in Forest Products Laboratory Report No. 1559-A,[2] except that 40 pounds pressure per square inch was used. Specimens with fiberglas-laminate facings were glued with adhesive M primary and adhesive N secondary, the latter being cured at 40 pounds pressure per square inch at 220° F. for 40 minutes.

The results of 43 fatigue tests and 49 control tests are presented in this report.

## Testing

All tests were made by methods similar to those described in Forest Products Laboratory Report No. 1559-A.[2]

The first tests were conducted on specimens with fiberglas-laminate facings to produce shear deformation in the LR plane. Twenty-eight fatigue tests were made, and the S-N curve (fig. 1) was drawn through the average values. Five fatigue specimens were also tested to produce shear deformation in the LT plane.

The foregoing tests indicated no shear weakness in the glue line; so it was considered probable that the fatigue characteristics of specimens with aluminum facings might be similar. Fatigue tests were made on 10 sandwich specimens with aluminum facings to produce shear deformation in the LR plane.

Failure of the fatigue specimens tested in the LR plane was prolonged, and there was much deformation between the facings (fig. 2). The load dropped off and was reapplied several times before positive signs of failure were apparent. The first definite visible fractures were shear failures of the cell wall, either parallel or perpendicular to the flutes. These failures became evident in the breaking off of the resin between adjacent threads of the cloth, which left unsupported threads perpendicular to the crack. A continuation of the test produced additional failures in the cell walls. In some cases, there was evidence of node-to-node glue-line failure in the later stages of failure. Finally, after much deformation, the face was pulled from the core (fig. 3).

Failure of fatigue specimens tested in the LT plane was less prolonged, and there was comparatively slight deformation before failure. Except for these variations, the failure was similar to that described in the preceding paragraph.

There was no discernible difference between the failures of control and fatigue specimens. The variation in control strength probably resulted from nonuniformity of the fiberglas-honeycomb material due to the variations in the size of cells, the percent of resin, and the properties of the impregnated glass cloth.

## Presentation of Data

Table 1 presents the results of the individual control and fatigue tests. Values are calculated as in Forest Products Laboratory Report No. 1559-A.[2] The control strengths varied from 96 to 144 pounds per square inch in the LR plane and from 233 to 243 pounds per square inch in the LT plane. Fatigue and control specimens were selected alternately from the panel, and the average of the 2, 3, or 4 controls adjacent to a fatigue specimen was used as the corresponding control strength.

The results of the fatigue tests are plotted in figure 1 and the S-N curve is drawn through the average values.

## Analysis of Data

The scatter of points around the S-N curve (fig. 1) may be attributed principally to variations in the core material. It was evident from visual examination that there was considerable nonuniformity in the cell size of the cores.

Although the curve was originally drawn through the points corresponding to specimens with fiberglas-laminate facings tested in the LR plane, it may be seen that the results for specimens with aluminum facings plot around the same line. As in previous tests,[2] it is difficult to predict the endurance limit of the sandwich material. It does appear, however, that the S-N curve tends to level out beyond 3 million cycles and may be similar to the dotted portion of figure 1.

The shear strength of fiberglas-honeycomb core material tested in the LT plane was approximately twice that of the same material tested in the LR plane. However, the results from five specimens with fiberglas-laminate facings indicated that the fatigue properties for the LT plane are similar or slightly better than those for the LR plane (fig. 1). No specimens with aluminum facings were tested in the LT plane.

There was no evidence of a weakness of the glue line between the core and facings of either construction. The final failure did take place in this plane, but only after considerable deformation and shear failure of the core material. From these tests it appears that the glue bond between core and facings is satisfactory.

Table 1.--Shear fatigue strength of sandwich constructions having fiberglas-honeycomb cores and fiberglas-laminate or aluminum facings[1]

| Fatigue tests | | | | | Control tests | |
|---|---|---|---|---|---|---|
| Specimen No. | Maximum repeated shear stress | Control strength | Ratio of maximum repeated stress to control strength | Cycles to failure | Specimen No. | Shear strength |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| | P.s.i. | P.s.i. | Percent | | | P.s.i. |
| **SANDWICH MATERIAL OF FIBERGLAS-HONEYCOMB CORE AND FIBERGLAS-LAMINATE FACINGS** | | | | | | |
| **Panel 1 -- LR Direction[2]** | | | | | | |
| F5-1- 1 | 58.0 | 107.2 | 54.0 | 1,014,000 | F5-1- 2 | 103.9 |
| 3 | 75.0 | 109.0 | 68.8 | 3,900 | 4 | 110.4 |
| 5 | 90.0 | 110.8 | 81.3 | 116 | 6 | 114.0 |
| 7 | 87.2 | 115.3 | 75.6 | 3,200 | 8 | 114.8 |
| 9 | 72.0 | 116.7 | 61.7 | 105,400 | 10 | 120.6 |
| 11 | 52.5 | 118.4 | 44.4 | 4,866,800 | 12 | 121.3 |
| 13 | 56.5 | 118.4 | 47.7 | 2,060,500 | 14 | 117.1 |
| 15 | 58.9 | 119.1 | 49.5 | 1,801,100 | 16 | 117.4 |
| 17 | 47.1 | 116.4 | 40.5 | 33,898,200+ | 18 | 118.8 |
| 21 | 48.8 | 111.0 | 44.0 | 16,273,400 | 20 | 112.3 |
| 23 | 44.0 | 105.1 | 41.8 | 35,192,000+ | 22 | 101.1 |
| | | | | | 24 | 101.9 |
| **Panel 1 -- LT Direction[2]** | | | | | | |
| F5-1-1a | 154.4 | 236.8 | 65.3 | 66,900 | F5-1-2a | 233.8 |
| 3a | 178.0 | 233.4 | 76.4 | 4,700 | 4a | 239.9 |
| 5a | 131.0 | 237.4 | 55.2 | 1,542,800 | 6a | 233.1 |
| 7a | 107.0 | 241.4 | 44.4 | 31,263,300+ | 8a | 243.0 |
| 9a | 95.0 | 238.0 | 39.9 | 30,039,900+ | | |
| **Panel 2 -- LR Direction[2]** | | | | | | |
| F5-2- 2 | 61.4 | 100.6 | 61.0 | 193,700 | F5-2- 1 | 96.3 |
| 4 | 48.7 | 106.3 | 45.8 | 14,994,400 | 3 | 103.5 |
| 6 | 45.6 | 100.8 | 45.3 | 3,996,000 | 5 | 103.5 |
| 8 | 81.9 | 110.1 | 74.3 | 5,200 | 7 | 102.0 |
| 10 | 89.0 | 113.3 | 78.5 | 1,700 | 9 | 111.8 |
| 12 | 77.0 | 114.8 | 67.0 | 19,400 | 11 | 104.1 |
| 16 | 60.7 | 115.0 | 52.8 | 246,200 | 13 | 123.1 |
| 18 | 78.0 | 132.2 | 59.0 | 36,800 | 15 | 124.5 |
| 20 | 92.3 | 129.5 | 71.2 | 1,900 | 17 | 130.0 |
| 22 | 80.0 | 123.6 | 64.7 | 6,700 | 19 | 144.5 |
| 28 | 100.2 | 125.0 | 80.3 | 258 | 21 | 110.8 |
| 30 | 66.1 | 120.1 | 55.0 | 221,200 | 23 | 131.4 |
| 32 | 70.6 | 117.8 | 60.0 | 6,800 | 25 | 119.5 |
| 34 | 105.0 | 120.4 | 87.2 | 53 | 27 | 122.1 |
| 36 | 80.4 | 118.0 | 68.1 | 4,800 | 29 | 133.3 |
| 38 | 68.6 | 120.4 | 57.0 | 244,500 | 31 | 115.5 |
| 40 | 80.0 | 117.6 | 68.0 | 3,600 | 33 | 113.0 |
| | | | | | 35 | 107.6 |
| | | | | | 37 | 120.5 |
| | | | | | 39 | 127.6 |
| **SANDWICH MATERIAL OF FIBERGLAS-HONEYCOMB CORE AND ALUMINUM FACINGS** | | | | | | |
| **Panel 3 -- LR Direction[2]** | | | | | | |
| A5-1- 1 | 57.3 | 121.9 | 47.0 | 3,985,600 | A5-1- 2 | 122.7 |
| 3 | 52.0 | 116.7 | 44.5 | 5,986,100 | 4 | 117.8 |
| 5 | 53.6 | 121.7 | 44.1 | 13,488,100 | 6 | 120.5 |
| 12 | 97.0 | 125.8 | 77.2 | 700 | 9 | 109.7 |
| 14 | 87.0 | 124.4 | 70.0 | 4,700 | 11 | 126.7 |
| 15 | 76.8 | 121.7 | 63.0 | 84,900 | 13 | 121.1 |
| 17 | 54.3 | 128.7 | 42.2 | 20,362,000 | 16 | 125.2 |
| 22 | 108.9 | 129.5 | 84.0 | 20 | 18 | 130.1 |
| 24 | 54.8 | 133.0 | 41.2 | 12,265,100 | 20 | 129.3 |
| 29 | 69.0 | 133.9 | 51.5 | 323,500 | 21 | 130.3 |
| | | | | | 23 | 132.9 |
| | | | | | 30 | 136.1 |
| | | | | | 35 | 132.6 |

[1] Specimens loaded at rate of 900 cycles per minute in direct-stress fatigue machine. Ratio of minimum to maximum load was 0.10. Control specimens tested in a hydraulic testing machine at a head speed of 0.01 inch per minute.

[2] LR and LT directions are in accordance with nomenclature used in Forest Products Laboratory Report No. 1553.

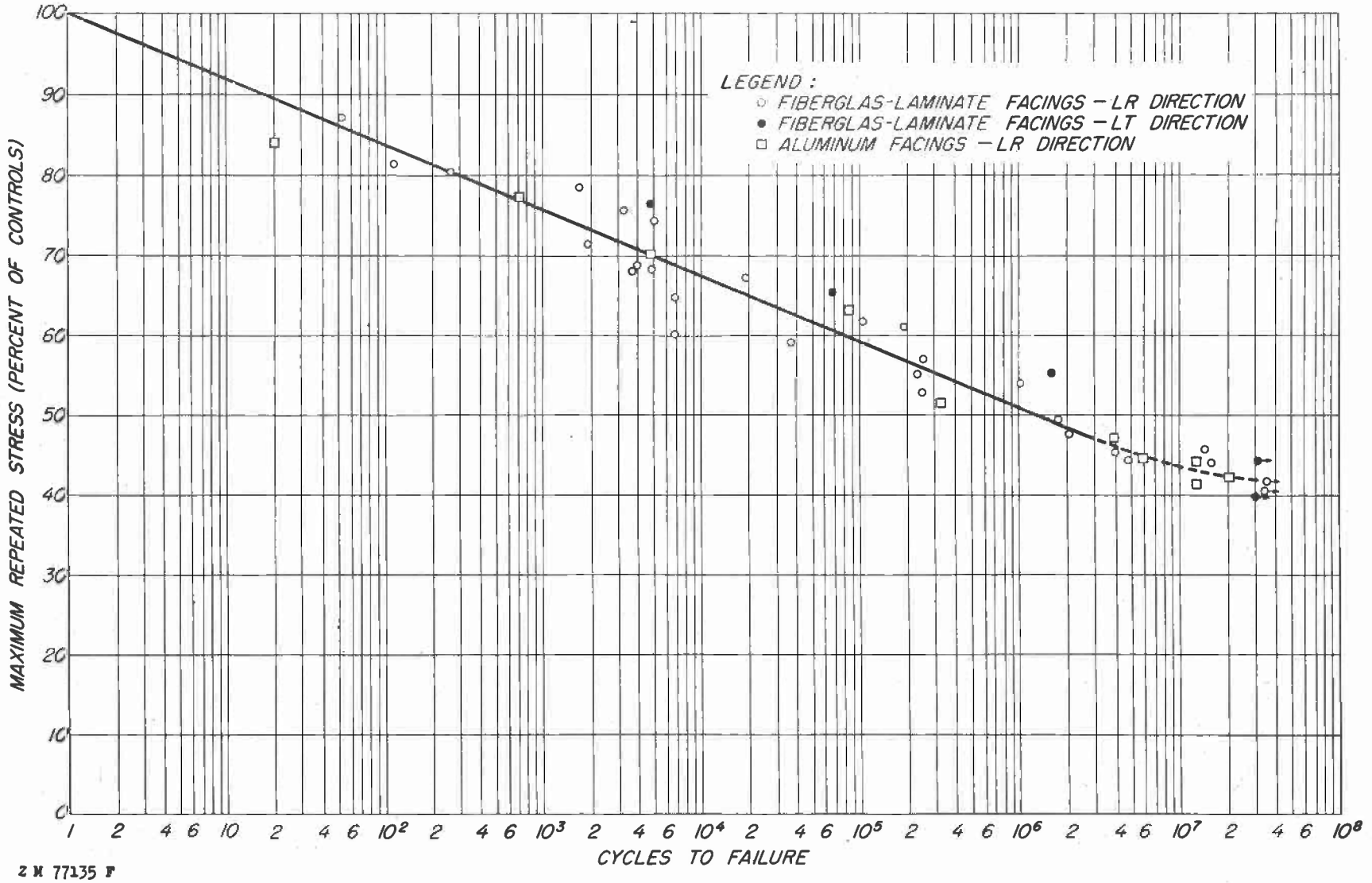


**Figure 1.--S-N curve for sandwich constructions tested in shear. Fiberglas-honeycomb cores and fiberglas-laminate or aluminum facings. Ratio of minimum to maximum stress (range ratio) was 0.10.**

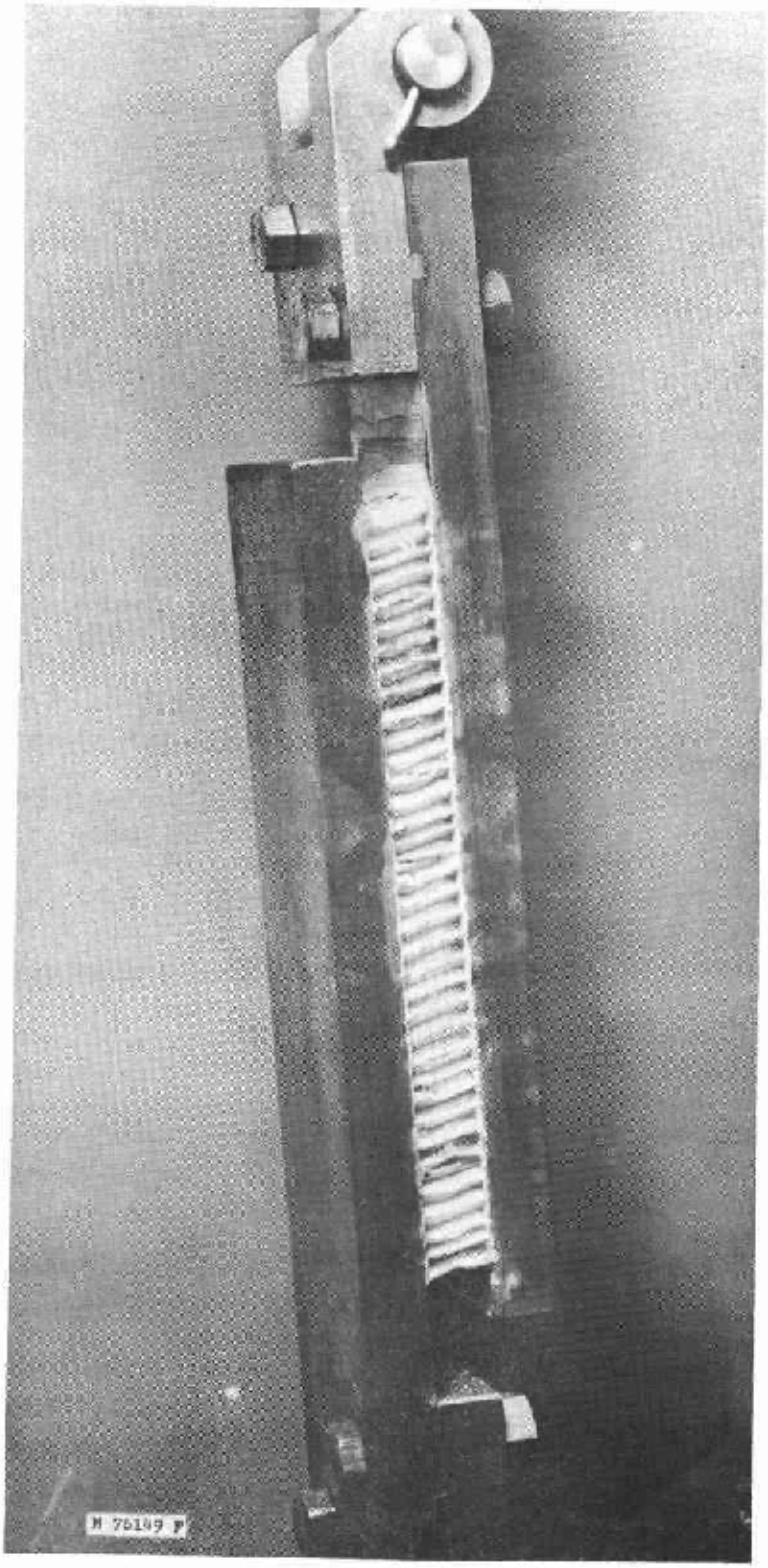


Figure 2.--Typical sandwich specimen of fiberglas-honeycomb core and fiberglas-laminate facings after partial failure in shear fatigue test. Note deformation of core material. Shear failure of cell walls is not apparent from photograph.
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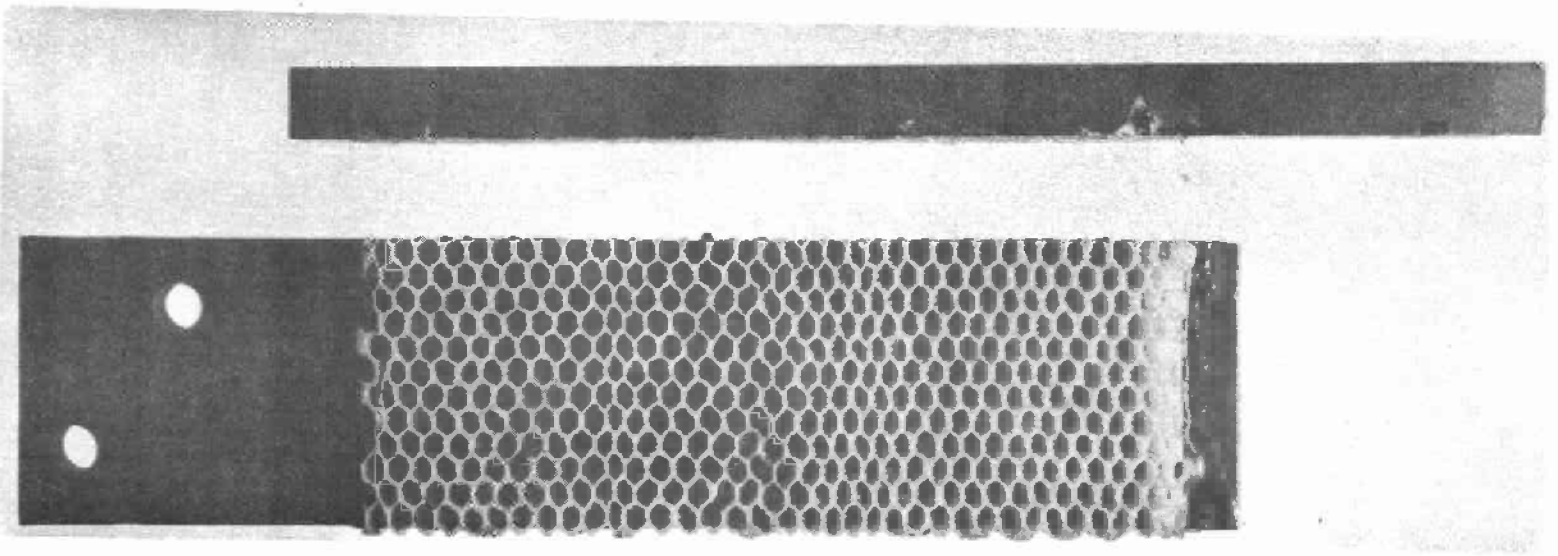

Figure 3.—Typical sandwich specimen of fiberglas-honeycomb core and fiberglas-laminate facings after complete failure in shear fatigue test. Separation of core and facing took place after shear failure of core cell walls.

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