FATIGUE OF SANDWICH CONSTRUCTIONS FOR AIRCRAFT

Fiberglas-Laminate Face and End-Grain Balsa Core Sandwich Material Tested in Shear

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In Cooperation with the University of Wisconsin

FATIGUE OF SANDWICH CONSTRUCTIONS FOR AIRCRAFT[1]

(Fiberglas-Laminate Face and End-Grain Balsa Core Sandwich Material Tested in Shear)[2]

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Summary and Conclusions

A limited number of tests (14) have been made at the Forest Products Laboratory to determine the shear fatigue properties of an assembled sandwich panel with fiberglas-laminate facings and end-grain balsa core. 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 58 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, Amendment 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 1948.

[2]This is the fifth 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 celloluse acetate tested in shear; Report No. 1559-A discusses aluminum face and paper honeycomb core sandwich material tested in shear; Report No. 1559-B discusses aluminum face and end-grain balsa core sandwich material tested in shear; and Report No. 1559-C discusses fiberglas-honeycomb core material with fiberglas-laminate or aluminum facings 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 a typical assembled sandwich panel. The facing material employed was six-ply fiberglas-laminate impregnated with a high-temperature-setting laminating resin, A,[4] and the core material was 1/2-inch end-grain balsa.

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

Description of Material and Specimens

The balsa used as the core material in these specimens was cut from a single block of selected balsa lumber. The cutting of the block, the numbering and weighing of slabs, and the assembly of the core were accomplished by the same methods discussed in Report No. 1559-B. The weight of the individual slabs was unusually uniform in that the density of each was 6.4 pounds per cubic foot.

Fiberblas facings were made from six plies of cross-laminated glass cloth impregnated with 45 to 50 percent of resin A by weight. Facings and core were assembled in a press as described in method 1 in glass-cloth-to-balsa panel-assembly techniques of a previous report.[5]

One sandwich panel 24 by 24 inches was fabricated for these tests. The specimens were cut from the panel with a high-speed steel circular saw to a width and length of 2 and 5.67 inches, respectively. The sandwich blocks were glued to the 1/2-inch shear plates (which had been previously sprayed with a gluable metal-priming adhesive, M) with a high-temperature-setting phenolic resin, N, in a press at 240° F. and at a pressure of 150 pounds per square inch for 1 hour.

The results of 14 fatigue tests and 15 control tests are presented in this report.

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[4]Additional information on the adhesives referred to in this report is contained in appendix 1.

[5]Forest Products Laboratory Report No. 1574, "Fabrication of Lightweight Sandwich Panels of the Aircraft Type," June 1947.

Testing

The conditioning and testing of both fatigue and control specimens were similar to the methods described in Forest Products Laboratory Report No. 1559-B.

As in the previous tests of specimens with balsa core material, the failure of the fatigue specimens was rapid once failure had begun. Final failure of the specimen was a combination of (1) shear failure parallel to the grain of the core, (2) some shear failure perpendicular to the core near the glue line, and (3) shear failure of the glue line. It is not possible to say which of these failures was the initial failure, but in some cases it was evident that there was shear failure along the grain of the core before complete failure took place.

The load on static specimens was applied at the rate of 0.01-inch deformation per minute, and when the maximum load was reached, the specimen failed suddenly.

Typical failures of fatigue shear specimens are shown in figure 1. Failures resulting from static shear tests were similar. In all cases, the final failure was a combination of the three types of failure mentioned above.

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-B. The control strengths varied from 266 to 308 pounds per square inch, even though the average density of the cores was the same for each specimen.

The results of the 14 fatigue tests are plotted in figure 2, and the S-N curve is drawn through the average values.

Analysis of Data

It will be seen from figure 2 that the plotted points fall very well around the S-N curve. Further, although the general trend of the curve is similar, it lies above the comparable curve for aluminum-face and end-grain balsa core sandwich material previously tested. The difference between the curves may be due to (1) differences in facing material and resin characteristics, (2) variations in gluing methods, and (3) the effect of core orientation, as mentioned in the following paragraph.

In specimens with fiberglas facings, there was always considerable failure of the core parallel to the grain direction, whereas specimens with aluminum facings often had no evidence of this type of failure. Specimens with fiberglas facings failed, on the average, approximately 25 percent in the core near the glue line and 75 percent in the glue line (fig. 1); but specimens with aluminum facings failed almost 100 percent in the core near the glue line. No explanation is offered for this variation in failure, but it may be partially due to the differences in amount and type of bonding resin employed. Further, a comparison of the specimens that failed in fatigue shows that the shear stress of specimens with fiberglas facings was applied about midway between the LT and LR planes, whereas in tests of specimens with aluminum facings the core was oriented to produce shear stress along the LT plane.

APPENDIX 1

Description of Resins and Adhesives

Resin A. A high-temperature-setting, high-viscosity, contact-pressure, laminating resin of the polyester type.

Adhesive M. A high-temperature-setting mixture of thermosetting resin and synthetic rubber.

Adhesive N. A high-temperature-setting, acid-catalyzed, phenol resin.

Table 1.--Shear fatigue strength of fiberglas-laminate face and end-grain balsa core sandwich material[1]

Results of fatigue tests					Results of control tests	
Specimen No.	Maximum: repeated shear stress	Control strength	Ratio of maximum: repeated shear 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.
F3-2-1	180.0	274.5	65.6	1,452,500	F3-2-2	281.0
-3	160.0	274.5	58.3	23,184,600	-4	278.4
-5	220.0	274.5	80.1	60,600	-6	270.9
-7	170.0	274.5	62.0	6,089,300	-8	276.1
-9	165.0	274.5	60.0	16,058,900	-10	266.3
					Average	274.5
F3-2-13	175.0	280.0	62.5	5,680,300	F3-2-12	273.8
-15	191.8	280.0	68.5	4,024,900	-14	281.9
-17	200.0	280.0	71.5	1,802,100	-16	291.1
-19	232.0	280.0	82.9	26,300	-18	283.7
					-20	269.3
					Average	280.0
F3-2-21	253.0	293.8	86.1	5,100	F3-2-22	286.9
-23	219.0	293.8	74.5	186,900	-24	296.9
-25	262.0	293.8	89.2	3,100	-26	292.7
-27	165.9	293.8	56.5	30,127,200+	-28	307.9
-29	228.0	293.8	77.6	139,300	-30	284.8
					Average	293.8

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

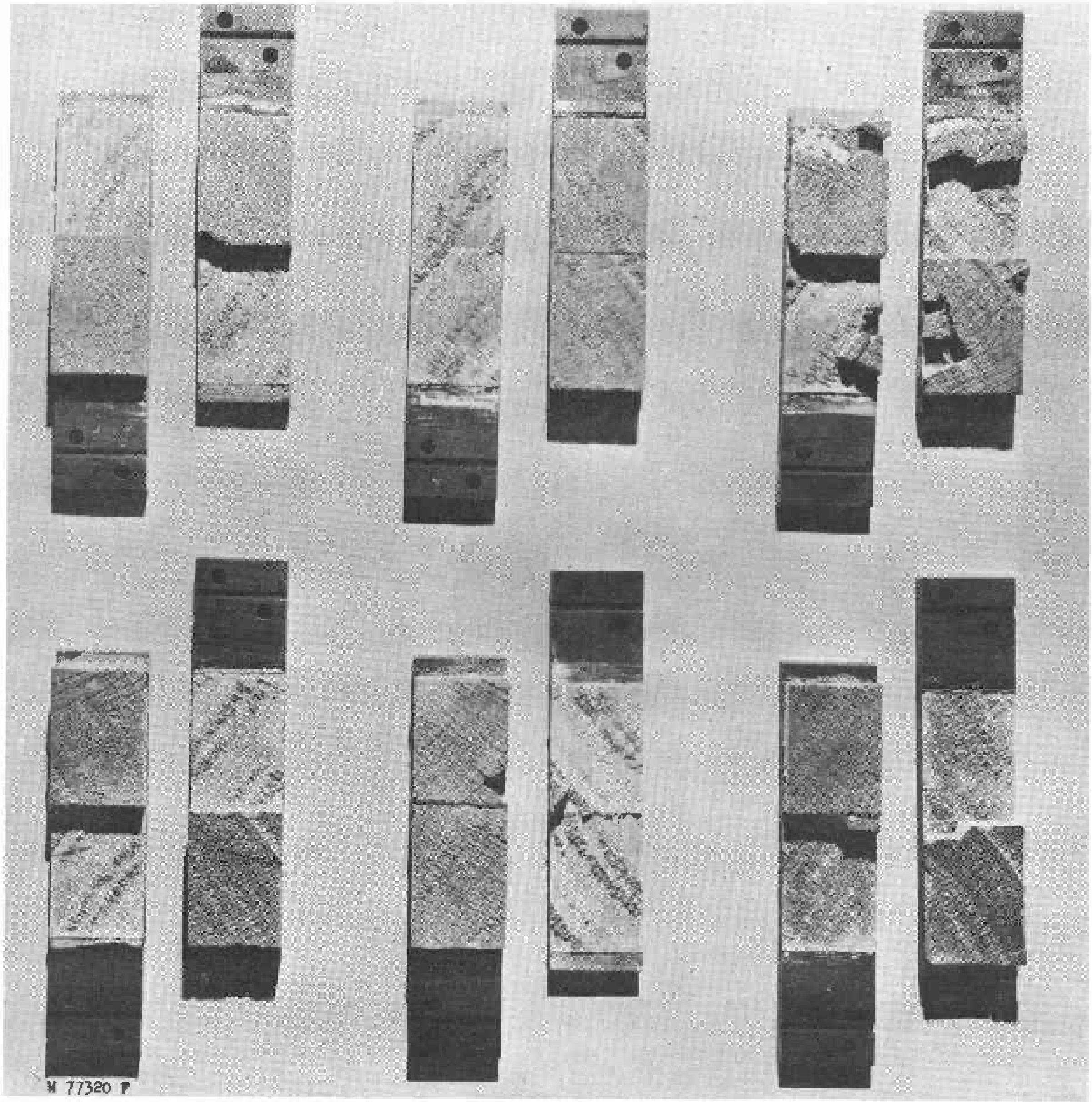

Figure 1.--Typical failures of fatigue shear specimens from fiberglas-laminate face and end-grain balsa core sandwich panel.

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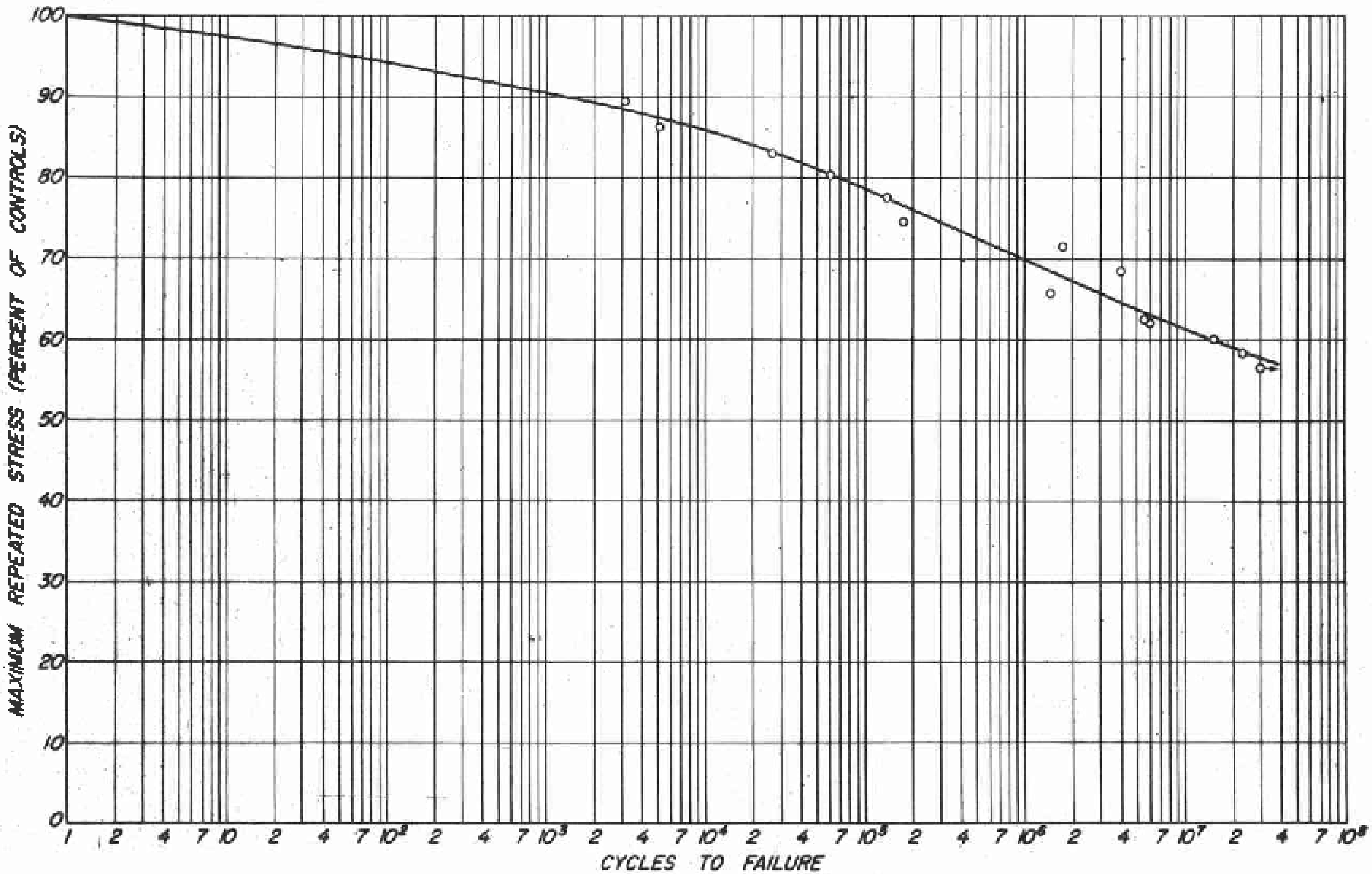

Figure 2.--S-N curve for fiberglas-laminate face and end-grain balsa core sandwich material tested in shear. Ratio of minimum to maximum stress (range ratio) was 0.10.

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