

SHEAR-FATIGUE PROPERTIES OF VARIOUS SANDWICH CONSTRUCTION

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

In Cooperation with the University of Wisconsin

SHEAR-FATIGUE PROPERTIES OF VARIOUS SANDWICH CONSTRUCTIONS¹

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Summary

Shear-fatigue curves for eight different sandwich core materials are presented in this report. These curves are based on Forest Products Laboratory tests of sandwich constructions in which failure was not influenced by weakness in the core-to-facing bond. They are therefore considered to be indicative of the shear-fatigue properties that might be expected from these core materials when adequate bonding methods are employed.

Introduction

If plates of sandwich construction are designed so that their facings are elastically stable under the intended loads, the most critical stress to which the core is subjected is shear. The consideration of the effect of repeated shear stresses on the core material and on the bonds between the core and facings is therefore important.

The purpose of this report is to summarize the results of the shear-fatigue studies of various sandwich constructions made at the Forest Products Laboratory in cooperation with the ANC-23 Panel on Sandwich Construction for Aircraft. Sandwich constructions made of nine different types of cores, with aluminum or glass-fabric-laminate facings, were tested. The core materials were: Paper honeycomb, end-grain balsa, glass-fabric honeycomb, cellular hard rubber, cellular cellulose acetate, perforated aluminum honeycomb, foamed-in-place alkyd isocyanate, expanded aluminum honeycomb, and a waffle-type material of resin-impregnated glass-fiber mat. Separate reports have been issued on each sandwich construction tested.³

¹This report is one of a series prepared and distributed by the Forest Products Laboratory under U. S. Navy, Bureau of Aeronautics Order No. NAer 01319 and U. S. Air Force No. AF-18(600)-70. Results here reported are preliminary and may be revised as additional data become available.

²Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

³See list of detailed reports on individual sandwich constructions at end of this report.

Fabrication of Sandwich Constructions

All of the sandwich constructions tested were assembled by procedures that, at the time of fabrication, were considered to be representative of procedures used in industry to produce similar sandwich constructions. Most of the test panels were assembled at the Forest Products Laboratory, but two of the sandwich constructions were purchased elsewhere.

Recent developments and improvements in techniques may provide better bonds in those sandwich constructions that failed largely in the core-to-facing bond.

Testing

All fatigue specimens were tested in a direct-stress fatigue machine. The ratio of minimum to maximum stress (range ratio) was 0.10, and loads were applied at the rate of 900 cycles per minute. Static shear tests of control specimens were made in a testing machine at a head speed of 0.01 inch per minute. The details of a typical frame shear specimen, as used in these tests, are shown in figure 1.

Further details of test procedures are given in Forest Products Laboratory Report No. 1559-A.²

Presentation and Discussion of Data

A brief summation of data on the various sandwich constructions tested is given in table 1. Information is included on the density of the core material, the shear strength as determined from the control tests, the type of fatigue failure, and a reference to the report wherein details regarding tests of each construction are given. If the failure was primarily or entirely a core failure, the fatigue results are representative of the fatigue characteristics of the core material. If failure was due to an inadequate bond between the core and facings, it is possible that the shear strength and the fatigue characteristics may be changed considerably by a different method of bonding.

It may be noted from table 1 that there is sometimes considerable variation between the static shear strengths for a particular material. This may be due to differences in the core material or in the core-to-facing bond. The average shear strength given is the average of all control specimens tested for the particular type of sandwich and core direction.

Most of the sandwich constructions failed completely or primarily in the core (table 1), and the bond between core and facings was thus considered to be satisfactory. In some constructions, however, the specimens failed largely or completely in the bond. This shows that some difficulty might be expected in producing a satisfactory bond for these constructions by the techniques

recommended at the time of these studies. Methods may now be available that permit fabrication of such sandwich constructions so that the properties of the core material may be developed.

Typical S-N (stress versus number of cycles to failure) curves for sandwich constructions made from the various core materials are shown in figures 2 and 3. These curves are based on specimens that failed completely or predominately in the core material and thus are considered representative of the shear-fatigue properties of the core material. Curves for specimens that failed predominately in the core-to-facing bond are not shown in this report, since they reflect the effect of an inadequate bond between core and facings and are thus not indicative of the properties of the core material. The average fatigue strength of a core material, in pounds per square inch, can be obtained from figures 2 and 3 by multiplying the percent of control strength by the average strengths given in table 1.

No fatigue curves are shown for the perforated aluminum honeycomb in the LT plane, the waffle-type core material, and the expanded aluminum honeycomb in the LT plane.

List of Detailed Reports on Shear-fatigue Tests of Sandwich Constructions

The following Forest Products Laboratory publications discuss the shear-fatigue properties of different sandwich constructions, under the general title, "Fatigue of Sandwich Constructions for Aircraft":

- (1) 1559-A, "Aluminum Face and Paper Honeycomb Core Sandwich Material," 1947.
- (2) 1559-B, "Aluminum Face and End-grain Balsa Core Sandwich Material," 1948.
- (3) 1559-C, "Aluminum or Fiberglas-laminate Face and Fiberglas Honeycomb Core Sandwich Material," 1948.
- (4) 1559-D, "Fiberglas-laminate Face and End-grain Balsa Core Sandwich Material," 1948.
- (5) 1559-E, "Aluminum or Fiberglas-laminate Face and Cellular-hard-rubber Core Sandwich Material," 1948.
- (6) 1559-F, "Cellular Cellulose Acetate Core Material with Aluminum or Fiberglas-laminate Facings," 1948.
- (7) 1559-G, "Fiberglas-laminate Facing and Paper Honeycomb Core Sandwich Material," 1949.
- (8) 1559-H, "Aluminum Facing and Aluminum Honeycomb Core Sandwich Material," 1949.

Table 1.--Density, static shear strength, and type of fatigue failure of various sandwich constructions tested in shear fatigue at the Forest Products Laboratory

Core material	Facing material	Density of core material	Static shear strength	Type of Reference
			Direction ¹ : Minimum: Maximum: Average: failure	: Fatigue : (Forest Products Laboratory Report No.)
		Lb. per cu. ft.	P.s.i. : P.s.i. : P.s.i. : P.s.i.	
Paper honeycomb	Aluminum	5.9	LR : 183.1 : 216.9 : 200.0 : Core	1559-A
Do.....	Glass-fabric laminate	6.0	(: LR : 185.2 : 270.2 : 237.2 : Core and :)	1559-G
			(: LT : 221.2 : 288.9 : 245.9 : bond :)	
End-grain balsa	Aluminum	5.1-8.3	..... : 227.0 : 453.4 : 311.3 : Core	1559-B
Do.....	Glass-fabric laminate	6.4	..... : 266.3 : 307.9 : 282.8 : Core and : bond	1559-D
Glass-fabric honeycomb	Aluminum or glass-fabric laminate	7.3-7.8	(: LR : 96.3 : 144.5 : 118.5 : Core :)	1559-C
			(: LT : 233.1 : 243.0 : 237.4 :do.... :)	
Cellular hard rubber	.....do.....	.....	84.6 : 159.7 : 110.2 :do....	1559-E
Cellular cellulose acetate	.....do.....	.....	PA : 89.1 : 165.1 : 126.8 :do....	1559-F
			(: PE : 153.7 : 197.0 : 173.7 :do.... :)	

Table 1.--Density, static shear strength, and type of fatigue failure of various sandwich constructions tested in shear fatigue at the Forest Products Laboratory (Continued)

Core material	Facing material	Density of core material	Static shear strength	Type of Reference
			Minimum: Maximum: Average: failure	fatigue : (Forest Products Laboratory Report No.)
			Direction	
		Lb. per cu. ft.	P.s.i. : P.s.i. : P.s.i.	
Perforated aluminum	Aluminum	5.6	IR : 145.4 : 160.8 : 151.2 : Core :)	1559-H
honeycomb			LT : 270.6 : 306.2 : 285.0 : Core and :)	
			(: : : : bond :)	
Waffle-type material ²	Glass-fabric laminate	11.0	85.9 : 142.1 : 113.9 : Bond :)	1559-I
			(: : : : : :)	
Foamed-in-place	.....do.....	8.9-10.0	PA : 95.9 : 131.4 : 113.9 : Core :)	1559-J
alkyd isocyanate			PE : 111.1 : 135.5 : 124.4 : do. :)	
			(: : : : : :)	
Expanded aluminum	Aluminum	5.7	IR : 189.3 : 213.2 : 200.7 : Core and :)	1559-K
honeycomb			LT : 336.2 : 387.4 : 368.3 : Bond :)	
			(: : : : : :)	

¹Plane in which shear stress is applied. IR and LT, as related to honeycomb materials, are shown in figure 4. PA and PE indicate planes parallel or perpendicular, respectively, to the direction of extrusion or foaming.

²Resin-impregnated glass-fiber mat.

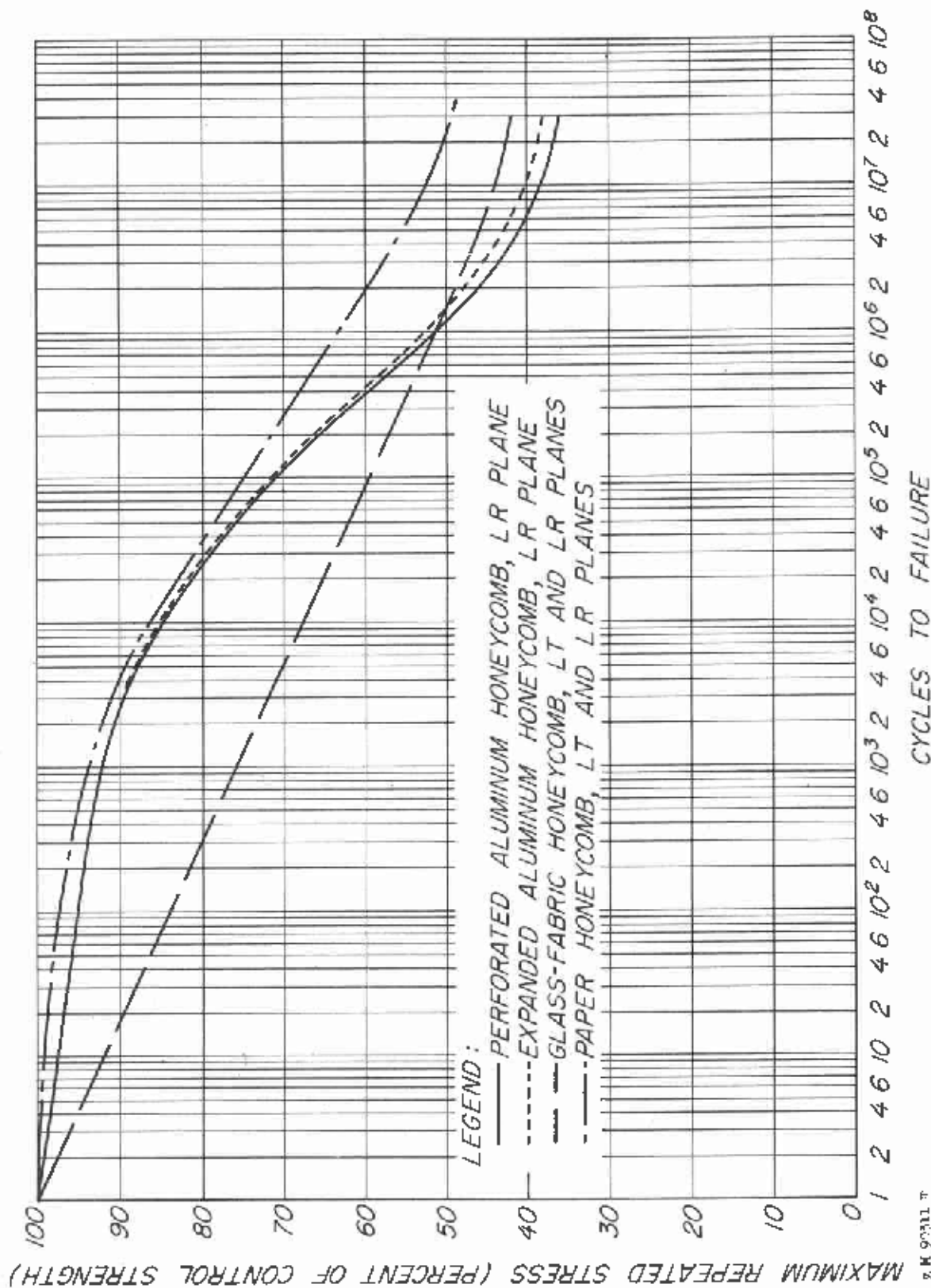
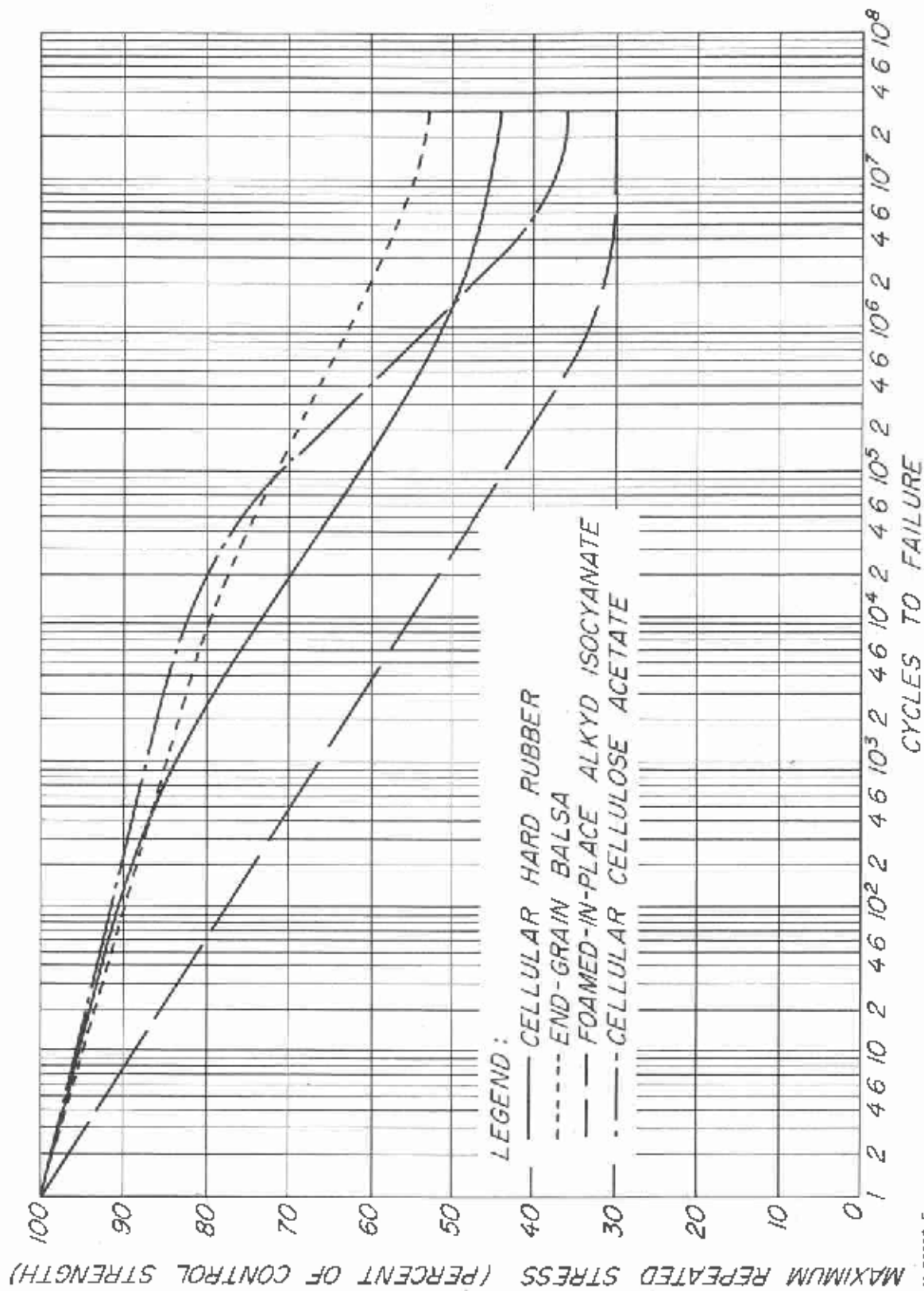


Figure 2.--S-N curves for four types of low-density, honeycomb-core materials, tested in shear. The ratio of minimum to maximum stress (range ratio) was 0.10.



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Figure 3.--S-N curves for four types of low-density core materials, tested in shear. The ratio of minimum to maximum stress (range ratio) was 0.10.

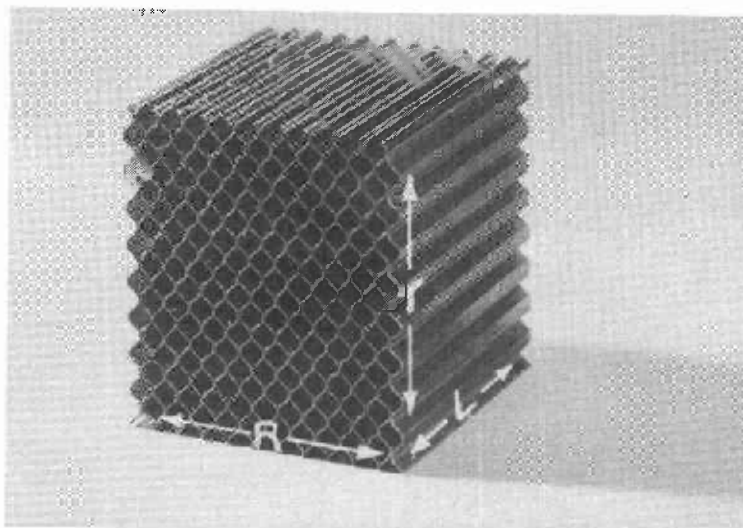


Figure 4.--Block of honeycomb material showing directional orientation, referred to as L (longitudinal), T (tangential), and R (radial).

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