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SUMMARY OF RESEARCH BY FOREST PRODUCTS LABORATORY ON SANDWICH CONSTRUCTIONS FOR AIRCRAFT

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FOREWORD

This report was prepared by the Forest Products Laboratory, U. S. Department of Agriculture, under U. S. Air Force Contract No. AF 33(616)-56-9. The contract was initiated under Project No. 7340, "Rubber, Plastics, and Composite Materials," Task No. 73402, "Sandwich Construction." The work was administered under the direction of the Materials Laboratory, Directorate of Laboratories, Wright Air Development Center, with Mr. W. E. Dirkes, acting as project engineer.

This report covers work conducted from August 1956 to August 1957.

ABSTRACT

Developments in the program of research in sandwich construction for aircraft conducted by the U. S. Forest Products Laboratory during fiscal year 1957 are summarized. The approach has been in general to derive design criteria mathematically and then to check by test. Seven technical reports issued during the fiscal year are abstracted.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

R. T. SCHWARTZ
Chief, Organic Materials Branch
Materials Laboratory

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INTRODUCTION

This annual report outlines progress in research on sandwich constructions for aircraft conducted by the U. S. Forest Products Laboratory[1] during fiscal year 1957. It is the sixth of such annual reports, and information on previous work is given in annual reports for fiscal years 1952 through 1956.

Research on sandwich construction has been concerned, for the most part, with determining design criteria. Involved are theoretical analyses with experimental verification wherever possible. It has also been necessary to evaluate properties of sandwich components to obtain values of parameters which appear in various design formulas.

The work has been divided into categories and each category assigned an item number. The following descriptions are titled by the item number.

Item A-7.--Strength of Normally Loaded Sandwich Panels

Work on this item was completed with the publication of Report No. 1847-A, which was issued in December 1956.

Item 51-1.--Methods of Bonding Various Metals

The adhesive bonding characteristics of AZ31-H24 magnesium alloy given various types of chemical and electrolytical surface treatments were compared. Small 3- by 4-inch pieces of the metal were treated by deoxidize (chromic acid-sodium nitrate), modified deoxidize (chromic acid-acetic acid), Iridite 15, Dow 7, Dow 17, Manodyze, and HAE methods. Lap-joint panels were then prepared from these treated pieces using FM-47 Film,

[1]Manuscript released by author for publication as a WADC Technical Report August 1957

Scotchweld AF-6, Metlbond 4021, Epon VIII, and Redux 775 Film adhesives. In addition to original dry strength tests of specimens from these panels, tests were made after exposure of the panels for 150 hours at 250° F., after 6 months at 120° F. and 97 percent relative humidity, and after 30-days' exposure in a salt-water spray chamber. Panels have also been exposed to tidewater in Florida.

The original bonding properties of these treated magnesium surfaces varied considerably depending on the type of adhesive used. The FM-47 Film, Epon VIII, and Redux 775 Film adhesives gave highest strengths (2,000 to 3,000 pounds per square inch) to surfaces given the deoxidize treatments. The Scotchweld AF-6 and Metlbond 4021 adhesives, however, did not generally produce high-strength bonds to these surfaces, but gave best bonding to surfaces treated by the Dow 7, Dow 17, and HAE methods. Performance of all five adhesives was approximately the same on surfaces treated with Iridite 15.

Only the bonds made with Redux 775 Film showed an appreciable reduction in strength when exposed for 150 hours at 250° F. Exposure of the panels for 6 months at 120° F. and 97 percent relative humidity or for 30 days to salt-water spray produced extreme corrosion on the panels treated by the deoxidize methods. In general, the exposure of the panels for 6 months to 120° F. and 97 percent relative humidity condition caused a greater deterioration in bond strength than the 30-day salt-water spray exposure. The exceptions were with Scotchweld AF-6 and Metlbond 4021 bonds to deoxidize surfaces, where the exposure to salt water for 30 days

was the most injurious. The best general performance was obtained on surfaces treated with Dow 17 and bonded with Scotchweld AF-6 Film; there bond strength, after all exposures, was in the range of 2,500 to 3,000 pounds per square inch.

All experimental work has been completed on this project. Results from exposure of the bonded panels in the tidewater site, however, are incomplete. A report is being prepared on this initial work.

Item 51-3.--Design Values for Core Materials

Work on this item was completed with the publication of Report No. 1855 in September 1956 and Report No. 1861 in March 1957.

Item 51-4.--Curved Sandwich Panels Subjected to Combinations of Edgewise Direct and Shear Loads and Uniformly Distributed Normal Loads

Tests were made to determine buckling loads of curved panels under axial compression and curved panels in shear. Computations have been completed for cylinders of sandwich with orthotropic cores in axial compression and for similar cylinders in torsion. This item was concluded and remaining work included in Item 57-3.

Item 54-1.--Determination of Basic Properties of Metal-Bonding Adhesives

This work includes a theoretical analysis of the behavior of lap joints under load and evaluation of properties of adhesives by conduction of torsion, tension, and compression tests of end-bonded tubular metal specimens. Analysis of lap-joint stresses was completed and numerical computations are in progress. Tests of adhesives recently received have been completed and results are being analyzed.

Item 56-3.--Reliability of Adhesive-Bonded Aluminum Joints

A survey was made among representative aircraft fabricators and adhesive manufacturers to obtain information on the reliability of adhesive-bonding processes for metals, based on the variability of lap-joint strength data. The range of the coefficient of variation for these metal-bonding tests was generally from 6.4 to 16.2 percent with most of the adhesive storage and production control data in the range above 10 percent. The results of this study were published in Report No. 1862.

Item 56-4.--Damping Characteristics of Sandwich Strips and Panels

The apparatus constructed consists of two heavy weights with a common center of gravity; each is fastened to a facing of a sandwich panel and so supported that free relative vibration of the weights is possible, thus subjecting the core of the sandwich panel to vibratory shear loads. A loudspeaker unit was mounted between the weights to supply the energy loss due to damping. The capacity of this unit was found to be insufficient to produce shear stresses in the sandwich core of values about equal to the proportional limit, and it is being replaced by a barium-titanate crystal.

Item 56-5.--Buckling of Flat Sandwich Panels Subjected to Edgewise Bending and Shear Loads

Theoretical analyses on sandwich under edgewise bending and compression were presented in Reports 1857, issued in September 1956; and 1857-A, issued in November 1956. Analyses, including shear loads as well as bending and compression, were presented in Report 1859, issued in November 1956.

Experimental verification of analysis for sandwich in edgewise bending was obtained in two tests. A supplementary report on these tests is in preparation.

Item 57-1.--Revision of Part I of ANC-23 Bulletin Entitled, "Sandwich Construction for Aircraft"

Visits were made by personnel of the Forest Products Laboratory to most of the aircraft companies, parts fabricators, and material suppliers concerned with the use of sandwich construction in aircraft. Current fabrication practices, adhesive and resin types in use, and photographs of typical parts, jigs, and processes were obtained. A rough draft of the revision was prepared.

Item 57-2.--Evaluation of Cores for Structural Sandwich

This study comprises evaluation of aluminum honeycomb cores of different alloys and cores of other configuration to determine standard design values. Included will be tests to determine properties of adhesive-bonded metal honeycomb at elevated temperatures.

Tests have been completed on a few samples of aluminum honeycomb core of 5052 alloy. Results are being analyzed.

Item 57-3.--Design Curves for Sandwich Panels

Design curves are being computed for the critical loads of sandwich cylinders subjected to external pressure.

The critical loads of curved sandwich panels, obtained from tests under Item 51-4, were found to be smaller -- rather than greater -- than the

computed critical loads for complete cylinders. This was quite unexpected. It had been assumed that curved plates would act as curved cylinders to which added restraints are applied. This information makes necessary an analysis of curved isotropic plates that can be expanded to include curved sandwich panels. The method of analysis chosen is that of virtual work which, with the aid of electronic computers, should lead to the required result. This work is going forward.

Item 57-4.--Bending and Torsion of Sandwich Panels of Varying Thickness

Various aircraft parts of sandwich construction can be made of a single sandwich panel with a core varying in thickness. It is proposed to devise general formulas for the strength and stiffness of such parts, verify the formulas by test, and determine design criteria. Work has not been started.

Item 57-5.--Buckling of Flat Triangular and Rhombic Panels of Sandwich Construction Due to Edgewise Loads

The critical loads of homogeneous plates of triangular- and rhombic-plan form subjected to edgewise loads have been found by a columnation process. It is proposed to extend these solutions to flat sandwich panels. Work has not been started.

Item 57-6.--Statistically Designed Study to Determine Factors Contributing to Variance in Strength of Bonded Metal Lap Joints

It is planned to study the extent to which minor variations in surface characteristics, bonding conditions, operation of bonding equipment, specimen preparation, and testing procedures cause the variation in the

strength of adhesive-bonded metal lap joints observed from specimen to specimen within panels, between panels, between pressing runs, and between bonding runs. To be investigated are such variables as the effect of bending of the metal sheets, time in the etch bath, age of the etching solution, rinse and drying variables for the metal sheet, amount of adhesive applied, adhesive lot, relative humidity at the time of applying adhesive, pressure and temperature variables in press, different operators, type of cutting used in preparing specimens, and testing techniques. This will be a statistically designed study to attempt to correlate contributions of each effect to the overall coefficient of variation in joint strengths. The detailed work plan for this study has not been completed.

REPORTS ON RESEARCH IN SANDWICH CONSTRUCTION

ISSUED BY THE U. S. FOREST PRODUCTS LABORATORY[2]

FISCAL YEAR 1957

FPL Report No.	Title
1847-A	Supplement to: Deflection and Stresses in a Uniformly Loaded, Simply Supported, Rectangular Sandwich Plate. Experimental Verification of Theory.

Mathematics developed for estimating deflections, stresses, and strains in simply supported sandwich panels under uniform load were presented in Report No. 1847. The experimental verification of the mathematics is based on tests of panels with aluminum-alloy faces and honeycomb cores. Results are presented in Report No. 1847-A.

1855	Mechanical Properties of Aluminum Multiwave Cores.

Results of tests of aluminum multiwave cores for use in structural sandwich construction are presented. Test results showed this type of core to have strength and rigidity values comparable to values for cores of true honeycomb configuration. Design values of various core properties are given.

1857	Elastic Buckling of a Simply Supported Rectangular Sandwich Panel Subjected to Combined Edgewise Bending and Compression.

A mathematical analysis is presented of the buckling of simply supported rectangular sandwich panels subject to combined edgewise bending and compression. A Rayleigh-Ritz method using a double Fourier series is employed. Design curves for panels subject to edgewise bending and having equal facings and isotropic cores are included.

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[2] Previous reports on this program are abstracted in "Summary of Research by Forest Products Laboratory on Sandwich Construction for Aircraft," WADC TR 52-184, Supplements 1, 2, 3, and 4.

FPL Report No.	Title
1857-A	Supplement to: Elastic Buckling of a Simply Supported Rectangular Sandwich Panel Subjected to Combined Edgewise Bending and Compression. Results for Panels with Facings of Either Equal or Unequal Thickness and with Orthotropic Cores.

Supplementary design curves are presented for panels subjected to edgewise bending and having unequal facings and orthotropic cores.

1859	Elastic Buckling of a Simply Supported Rectangular Sandwich Panel Subjected to Combined Edgewise Bending, Compression, and Shear.

A mathematical analysis, based on the Rayleigh-Ritz energy method, of the elastic buckling of simply supported rectangular sandwich panels subjected to combined edgewise bending, compression, and shear is presented. Design curves for panels subjected to combined edgewise bending and shear and having unequal facings and orthotropic cores are included.

1861	Mechanical Properties of Glass-Fabric Honeycomb Cores.

This report presents the results of tests of commercially produced glass-fabric honeycomb cores for use in structural sandwich construction. It suggests design values of the mechanical properties of these cores at 73° F. and 50 percent relative humidity and at 100° F. and 100 percent relative humidity. Data are presented in tabular form and as stress-strain curves.

1862	General Survey of Data on the Reliability of Metal-Bonding Adhesive Processes.

A survey made among a number of representative aircraft fabricators showed that the coefficient of variation of the strength of standard lap joints at room temperature varied from 6.4 to 16.2 percent and was not greater for one type of adhesive than for another.