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SUMMARY OF RESEARCH BY FOREST PRODUCTS LABORATORY ON COMPOSITE CONSTRUCTION FOR FLIGHT VEHICLES

Donald G. Coleman

Forest Products Laboratory

FEBRUARY 1960

Statement A
Approved for Public Release

WRIGHT AIR DEVELOPMENT DIVISION

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FOREST PRODUCTS LABORATORY ON
COMPOSITE CONSTRUCTION FOR FLIGHT VEHICLES**

Donald G. Coleman

Forest Products Laboratory

FEBRUARY 1960

Materials Laboratory
Contract No. AF 33(616)58-1
Project No. 7340

WRIGHT AIR DEVELOPMENT CENTER
AIR RESEARCH AND DEVELOPMENT COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

FOREWORD

This report was prepared by the U. S. Forest Products Laboratory under USAF Contract No. AF 33(616)58-1. This contract was initiated under Project No. 7340, "Rubber, Plastics, and Composite Materials," Task No. 73402, "Sandwich Construction." It 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 July 1957 to July 1958.

ABSTRACT

Developments in the program of research in composite construction for flight vehicles conducted by the U. S. Forest Products Laboratory during 1958 are summarized. In general the approach has been to derive design criteria mathematically, and then to check by test. Four technical reports issued during the fiscal year are abstracted.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:



W. E. DIRKES
Chief, Plastics Branch
Non-Metallic Materials Div.
Materials Laboratory

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Introduction

This annual report by the U. S. Forest Products Laboratory¹ outlines progress in research on composite construction for flight vehicles conducted during fiscal year 1958. Information on previous work in this program was published in WADC Technical Report 52-184 and supplements 1 through 5 for fiscal years 1952 through 1957.

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 that appear in various design formulas.

The work has been divided into categories and each category assigned an item number.

Item 51-1. Methods of Bonding Various Metals

An investigation was completed on the adhesive bonding properties of magnesium alloy surfaces when given various chemical and electrolytic treatments. FPL Report No. 1865 is being published to summarize the results of this investigation.

AZ31-H24 magnesium alloy was used principally in this study, but some limited work was also done on HK31-H24 magnesium alloy. Surfaces were treated by chemical deoxidize methods and by the following commercial treating processes: Iridite 15, Dow 7, Dow 17, Manodyze, and HAE. Small lap-joint panels were prepared with five metal-bonding adhesives, ranging from low-modulus to high-modulus structural types. These bonded panels were then exposed, without any protective paint coating, to a variety of conditions that included 150 hours at 250° F., 30 days in a salt-water spray chamber, 6 months at 120° F. and 97 percent relative humidity, and 3 months' Florida tidewater exposure. Lap-joint shear tests were made after the completion of the exposures.

Highest bond strengths in the original dry tests were usually obtained with the high-modulus adhesives to the magnesium surfaces given deoxidize treatments. The bonds made to the surfaces treated by this method, however, generally deteriorated when exposed to salt-water spray or high humidity conditions, and there was severe corrosion of

¹Manuscript released by author for publication as a WADC Technical Report, **January 1960.**

the magnesium sheets. Surfaces treated by the anodize methods were found, in most instances, to originally produce higher bond strengths when bonded with the less rigid (low-modulus) adhesives. This was particularly true when the metal surface coating resulting from the anodize treatment was brittle. These anodize-treated surfaces resulted in a better performance of the adhesive bonds in the high-humidity and salt-water spray exposures. The best overall bonding performance obtained in the investigation, including both original dry strength and after exposure to high humidity and salt-water spray, was obtained with a low-modulus adhesive, Scotchweld AF-6 Film, applied to the magnesium treated by an acid anodize method, Dow 17.

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 torsion, tension, and compression tests of end-bonded tubular specimens. A theoretical analysis of lap-joint stresses was presented in FPL Report No. 1864 in October 1957. A comparison of the results of this theory with the theory of Goland and Reissner gave maximum normal stresses much higher, and maximum shear stresses much lower, than the theory of Goland and Reissner. Tests of tubular specimens bonded with Epon 422J adhesive were made. Experimental techniques are being developed for experimentally verifying theoretical analyses for lap-joint stresses.

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

An apparatus and testing procedure was developed to vibrate sandwich core specimens in shear. The specimen is vibrated at resonant frequency of a system employing heavy masses that is attached to the specimen to produce cyclic shear forces. The amplitude of vibration can be chosen to produce any desired shear stress. Measurements of forces and displacements allow determination of energy absorbed; hence, damping capacity. Tests can be run at various stress amplitudes until fatigue failures occur. Several cores of aluminum honeycomb have been tested to determine damping characteristics and fatigue strength. A report describing apparatus in detail and results of tests is being prepared.

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

A report on results of tests of panels in edgewise bending is being prepared.

Item 57-1. Revision of Part I of ANC-23 Bulletin

Part I of the ANC-23 Bulletin, originally published in February 1951, was revised in a preliminary review copy to include current practice on the fabrication, inspection, durability, and repair of composite construction for flight vehicles. This preliminary copy is now being reviewed by industry prior to its final revision and publication.

Item 57-2. Evaluation of Cores for Structural Sandwich

This study comprises evaluation of properties of various cores to determine standard design values. A detailed working plan was prepared in February 1958. Tests were begun on a variety of honeycomb cores, including aluminum honeycomb of 5052H39 foil, 5056 foil, and 2024-T4 foil, and heat-resistant plastic honeycombs of glass and asbestos fibers.

Item 57-3. Design Curves for Sandwich Panels

A large-deflection analysis of the axial equilibrium loads of curved plates is being carried forward. Design curves for cylinders with isotropic facings and orthotropic or isotropic cores under external pressure have been computed. Generalization of previous design criteria for sandwich cylinders in axial compression and in torsion were made, and computations of design curves carried out for orthotropic honeycomb cores in addition to previous curves for isotropic cores. FPL Reports No. 1830 and 1840 presenting this data were prepared in December 1957 and January 1958, respectively. Design curves for flat sandwich in edge compression were prepared to include methods for short panels and presented in FPL Report No. 1854 in January 1958.

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

A Saint Venant torsion analysis was made for sandwich construction. A general analysis for sandwich is being applied to the special case of a rectangular panel twisted by forces acting at its corners. The results of this analysis will be compared with the results of the Saint Venant analysis.

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

This item was discontinued in October 1957.

Item 57-6. Determine Factors Contributing to Variance in Strengths of Metal-Bonding Adhesives at Elevated Temperatures

A work plan was prepared and approved, and materials were ordered, for a study to determine statistically the variability of the strengths of bonds obtained with heat-resistant adhesives to Type 301 stainless steel, and also to determine some of the principal sources of any joint strength variability.

Item 58-1. Sandwich with Orthotropic Facings and Honeycomb Cores

An analysis was made of the properties of glass-fabric laminates tested at the Laboratory. From this analysis parameters representing such orthotropic facings were evaluated. Application of this information was used to obtain design curves for simply supported flat sandwich with orthotropic facings and cores in edgewise compression. A report on this is being prepared.

Item 58-2. Study of Sandwich Panels with Dissimilar Facings

Work on this item has just begun with a preliminary review of existing analysis for flat sandwich panels in edgewise compression.

REPORTS ON RESEARCH IN SANDWICH CONSTRUCTION ISSUED BY THE

U. S. FOREST PRODUCTS LABORATORY, FISCAL YEAR 1958

FPL
Report
No.

Title and Summary

1830 Buckling of Cylinders of Sandwich Construction in Axial
 Compression.

This report presents a theoretical analysis for the behavior of long, circular, cylindrical shells of sandwich construction under axial compression load. Families of curves are presented for use in designing shells of sandwich construction having isotropic facings and orthotropic or isotropic cores. Tests showed that the theory applied reasonably well to curved panels of sizes sufficient to include at least one ideal buckle, and thus the theory is not limited to long, complete cylinders.

1840 Buckling of Sandwich Cylinders in Torsion.

This report presents a mathematical analysis leading to the critical stress that determines the buckling of cylinders of sandwich construction in torsion. The analysis is complete for cylinders of finite length having orthotropic or isotropic facings and cores. Curves are given for buckling coefficients for cylinders with isotropic facings and orthotropic or isotropic cores.

1854 Compressive Buckling Curves for Sandwich Panels with
 Isotropic Facings and Isotropic or Orthotropic Cores.

This report presents curves and formulas for use in computing the buckling of flat panels of sandwich construction under edge-wise compression loads. Included are curves for constructions with isotropic facings and either isotropic or orthotropic cores.

1864 Stresses in a Lap Joint with Elastic Adhesive.

A theoretical solution is presented for the displacements and stresses in the adhesive of a lap joint loaded in tension. The solution applies to anti-symmetrical joints with arbitrary lap, adhesive thickness, and plate thickness and to any combination of materials. Some numerical results are included.

<p>U. S. Forest Products Laboratory, Madison, Wis. SUMMARY OF RESEARCH ON COMPOSITE CONSTRUCTION FOR FLIGHT VEHICLES, by Donald G. Coleman. January 1960. 5p. (Proj. 7340; Task 73402) (WADC TR 52-184, Suppl 6) (Contract AF 33(616)-58-1)</p> <p>Unclassified report</p> <p>Developments in the program of research in composite construction for flight vehicles conducted by the U. S. Forest Products Lab. during 1958 are summarized. In general the approach has been to derive design criteria mathematically, and then to check by test. Four technical reports issued during the fiscal year are abstracted.</p> <p>(over)</p>	<p>UNCLASSIFIED</p>	<p>UNCLASSIFIED</p>
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