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INVESTIGATION OF ENVIRONMENTAL DETERIORATION ON NOMEX HONEYCOMB COMPOSITES

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COMPOSITES DIVISION

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ARMY MATERIALS AND MECHANICS RESEARCH CENTER
Watertown, Massachusetts 02172

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ABSTRACT

This study investigates the response of Nomex honeycomb, an aircraft construction material, to external environmental influences.

The objective is to determine the changes in mechanical properties of Nomex honeycomb, both as bare honeycomb and as part of a composite structure, due to exposure to a high-temperature, high-humidity environment.

Static compression and plate shear mechanical tests were performed to assess effects of temperature and humidity. In addition, moisture uptake was determined.

Shear strength was found to be only slightly affected by the test conditions; compressive strength was not affected; water uptake is 2% by weight.

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INTRODUCTION

Nomex honeycomb is being used as a replacement for aluminum honeycomb in various sandwich panel applications and is also being considered for use in helicopter rotor blades. Current helicopter rotor blades usually have a steel or aluminum main load-carrying member (spar), with the airfoil section a lightweight structure of either skin and honeycomb or skin and rib. The skins are usually aluminum, although fiberglass cloth has been used; the honeycomb is also usually aluminum, although some nonmetallic honeycomb (glass phenolic) has been used.

Future helicopter rotor blades, such as those for the Utility Tactical Transport Aircraft System (UTTAS) will use either a metal or a composite spar, composite skins, and Nomex honeycomb. The change to Nomex honeycomb was made because of the corrosion experienced in the aluminum honeycomb and the compatibility of Nomex honeycomb with composite structures.

Questions about the suitability of Nomex honeycomb for this application have been raised by the reported loss of strength from Nomex fabric after brief periods of outdoor aging.* Before this material can be fully qualified for aircraft applications, its response to external environmental influences must be determined. The objective of this study is to determine the changes in mechanical properties of Nomex honeycomb, both as bare honeycomb and as part of a composite structure, due to exposure to a high-temperature, high-humidity environment.

In a helicopter rotor blade, the core is subjected to compressive and shear loadings. Compressive loading is a result of aerodynamic forces and shear loading results from torsional, in-plane, and flapwise bending moments. Accordingly, compressive and shear properties were used as the criteria for performance in this evaluation.

EXPERIMENTAL PROCEDURE

A. Sample Fabrication

All samples were fabricated from a single lot of HRH-10 Nomex honeycomb manufactured by the Hexcel Corporation. This material had 1/8" cells, a density of 3 pounds per cubic foot, and was 1 inch thick. This is representative of the core material to be used in the rotor blades. The honeycomb samples were exposed as 10" by 10" squares which were cut into specimens just prior to bonding. The 10" by 10" squares were all cut from a single 4 ft by 8 ft sheet of honeycomb.

American Cyanamid FM 123-2 epoxy film adhesive was used for all bonding operations, either to composite face sheets for compression tests or to aluminum plates for shear tests. All bonding operations were carried out in a 50-ton laboratory press having heated platens. The following cure cycle was used for all bonding: 2 hours at 250 F and 50 psi.

*TTCP, Private Communication, 1974, Dr. George R. Thomas, Army Materials and Mechanics Research Center, and Peter Dunn, Defense Science Laboratories, Maribynong, Australia.

Specimens for compression testing were 3" by 3" squares of honeycomb which were stabilized by adhesively bonding four-ply 0° to 90° face sheets to the upper and lower surfaces of the honeycomb.* Specimens for shear testing were 2" by 7", cut in both the length (L) and width (W) directions, and were bonded to the cleaned aluminum plates of the shear fixtures.

The test procedures followed are similar to those described in the DuPont bulletin on Nomex honeycomb, August 1969, and Hexcel Report LSR 931402. Compression and shear properties were measured using an Instron Model TT-C-1 testing unit equipped with a compression cell.

B. Test Procedures

1. Compression

The compression test is a static compression of the honeycomb in the cell d direction as shown in Figure 1. The failure mode is buckling of the cell walls. The test configuration and apparatus are shown in Figure 2. The samples are bonded to the face sheets to stabilize the core, preventing core shear which would give scattered results.

2. Shear

The shear test is a plate shear that deforms the honeycomb cells perpendicular to their axes (d direction). The 2" x 7" honeycomb sample is bonded to two specially designed thick aluminum plates. The failure mode involves collapsing of the cell walls at a 45° angle to the cell axis. The test configuration and apparatus are shown in Figure 3. The test fixture included a holder for a strain gage extensometer which was used to measure the shear modulus of the honeycomb. In use, the test fixture is compressed at a nominally static rate.

3. Environmental

a. Temperature and Humidity

Environmental degradation of the honeycomb was simulated by exposing it to 190° F at 95% relative humidity. Both Tenny TR-14 and Blue M Model AC-7602 HR environmental chambers were used for the exposure. The Blue M chamber is shown in Figure 4. Two test cycles were run, the first lasting 15 weeks and the second 9 weeks. Groups of the 10" by 10" test samples were removed from the test chamber

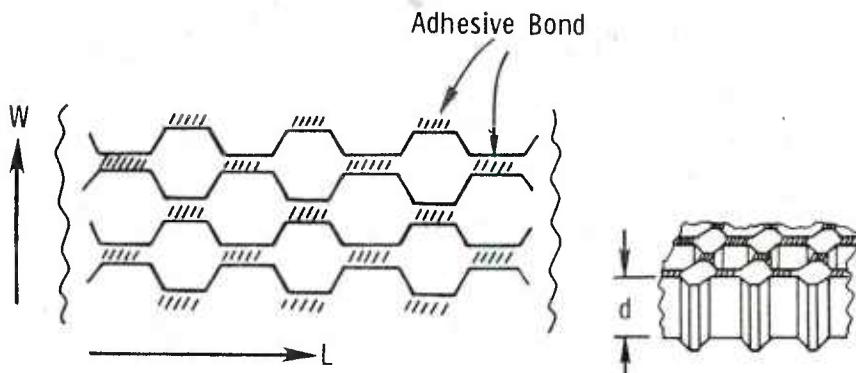


Figure 1. Diagram of honeycomb structure.

*Fabricated from SP-250-SFI tape, Minnesota Mining and Manufacturing Company.

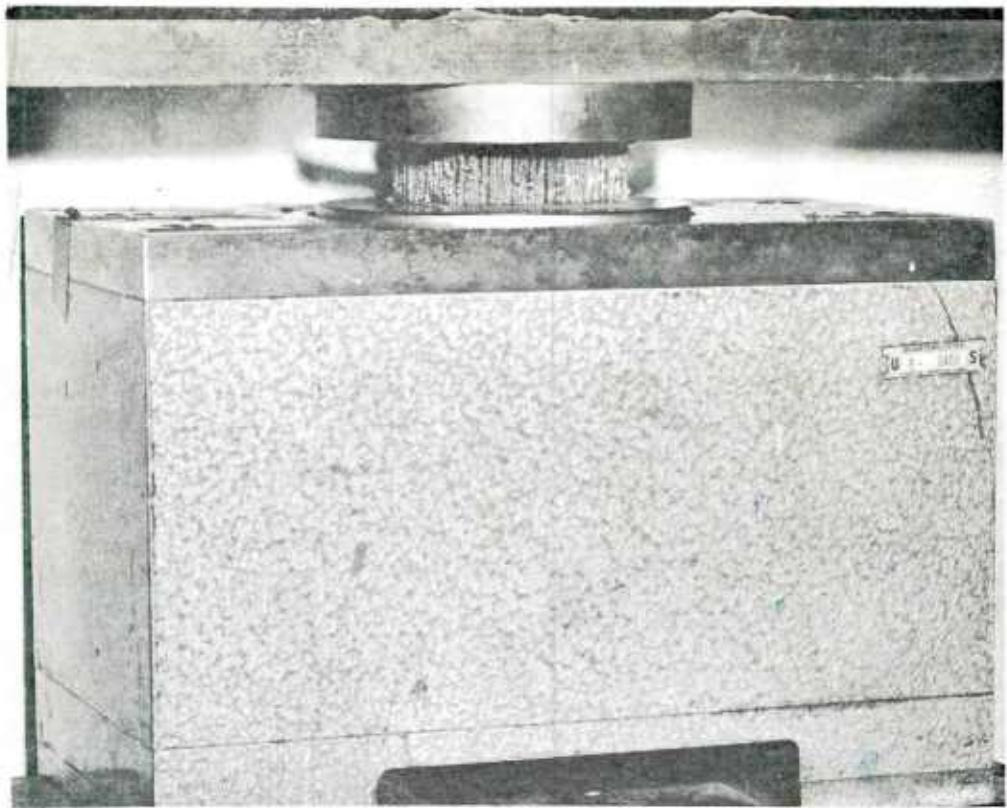


Figure 2. Compression sample in Instron testing machine.
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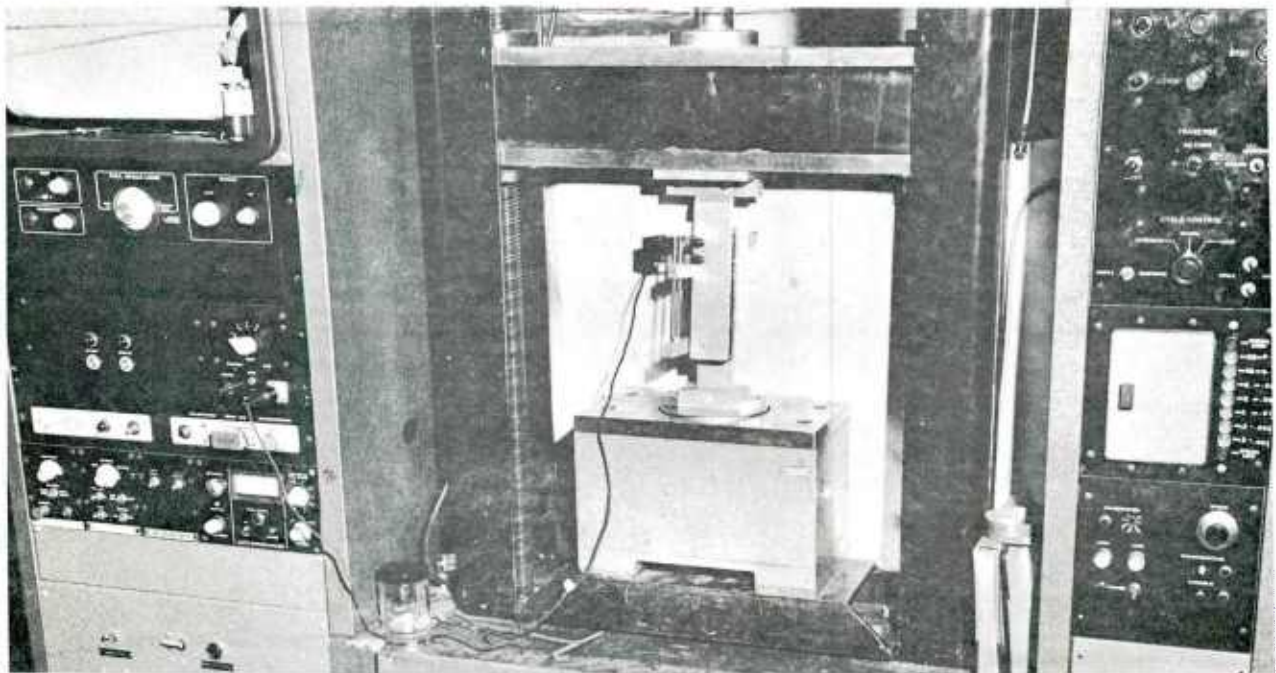


Figure 3. Shear test fixture mounted in Instron unit.

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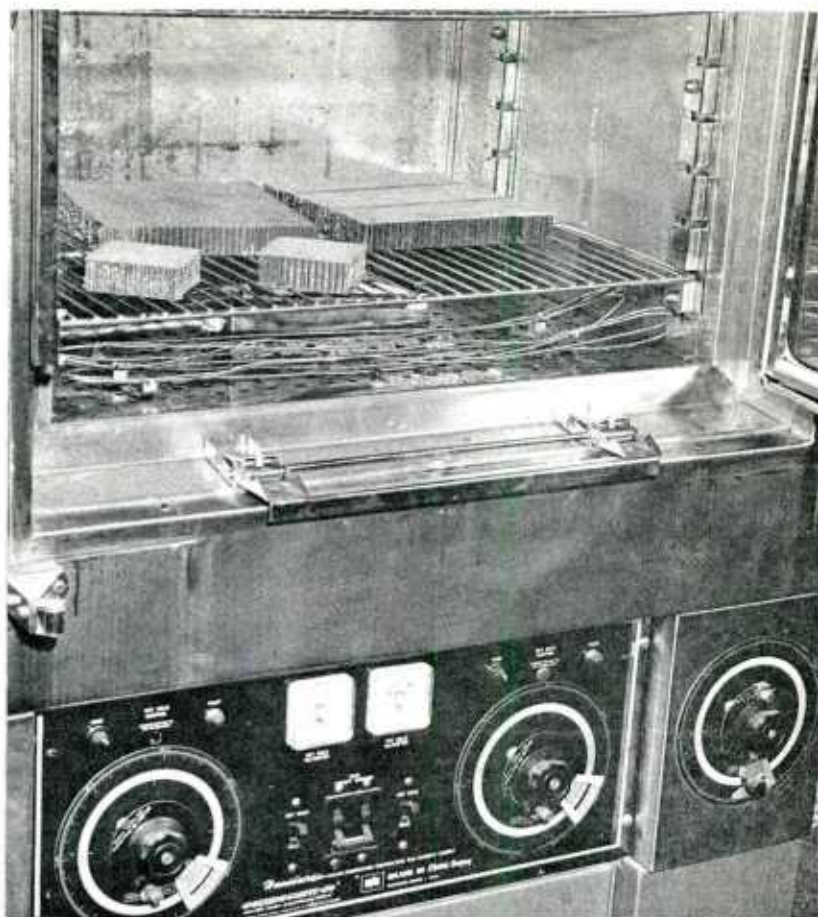


Figure 4. Blue M chamber used for environmental testing.
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at two-week intervals, air-blown dry of any condensation and stored in sealed plastic bags until the mechanical tests could be run.

b. Moisture Uptake

Two separate methods were used to determine the sorption characteristics of the Nomex honeycomb. First, the samples were stored in an environmental chamber maintained at 190 F and 95% relative humidity. The samples were removed daily, air-blown dry of condensation, weighed, and then replaced in the chamber. For the second method, samples were stored in two jars of distilled water. One jar was stored in the laboratory at 72 F, the other was stored in the chamber at 190 F. Samples were removed from the jars periodically, air-blown dry of standing water, weighed, and replaced.

Both tests were carried out for six weeks, after which time final weight had stabilized.

c. Moisture Permeability of Face Sheets

The moisture permeability of a skin material representative of that to be used in helicopter rotor blades was measured using a cup cell apparatus. This test procedure has been used at AMMRC for film materials with low water vapor permeability. The cup cell configuration is shown in Figure 5. The water on the upper side of the test sample permeates the sample and evaporates from the lower

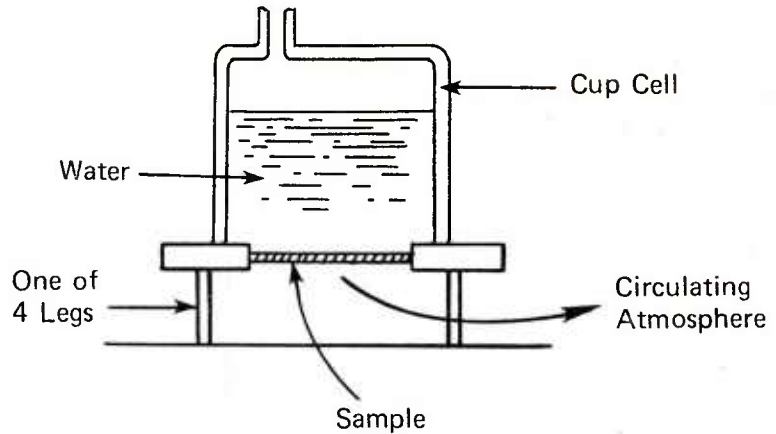


Figure 5. Schematic of cup cell apparatus.

side of the sample. During the test, the cells are stored in an environmental chamber held at 50 C and 50% relative humidity. The cells are removed and weighed periodically to determine water loss as a function of time. The head (water pressure in addition to atmospheric pressure) generated by the 2-inch column of water standing in the cup cell was not considered a significant factor.

RESULTS

A. Compression

The compression test data are shown in Figure 6. The slope of the least-squares line through the data is essentially zero, indicating the compressive strength of the honeycomb has not changed. The unexposed control samples averaged about 360 psi which is within the range of values for this material reported by the manufacturer.

B. Shear

The shear data are shown in Figure 7. The upper curve is for the L direction along the ribbons, and lower curve is for the W direction across the ribbons. The slopes of the two curves are approximately equal and correspond to about -4×10^{-3} psi strength loss per hour of exposure. The unexposed control samples averaged 138 psi for the L direction and 83 psi for the W direction. These values are 16% below the reported value for the L direction, but about equal to the reported value for the W direction.

An attempt was also made to obtain shear modulus data. However, problems were experienced with binding in the extensometer holder which prevented obtaining accurate results.

C. Moisture Uptake

The curves for water vapor uptake of the honeycomb at 190 F and 95% relative humidity are shown in Figure 8. The curves stabilize at about 2% weight gain after approximately 600 hours and show moisture content. Since the experiment was started with samples at laboratory conditions, the moisture content at zero time is that for equilibrium at approximately standard temperature and pressure.

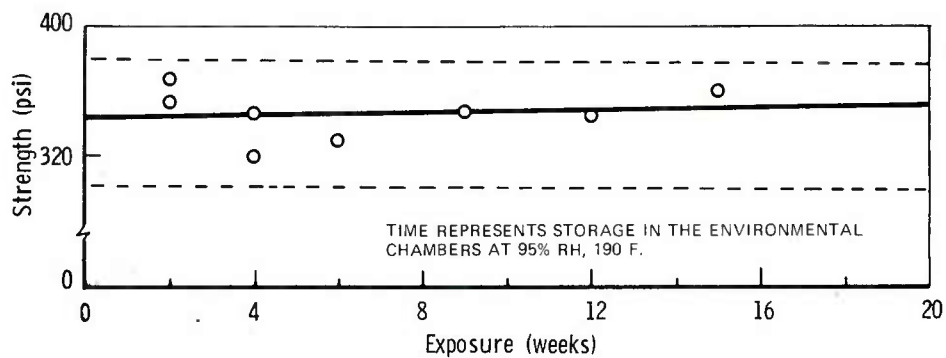


Figure 6. Compression test data.

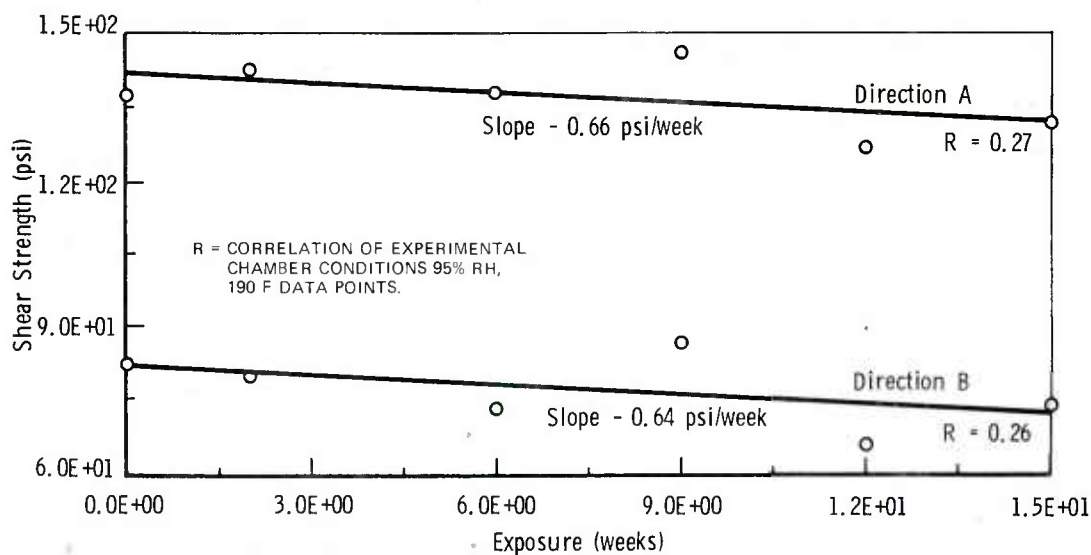


Figure 7. Shear test data.

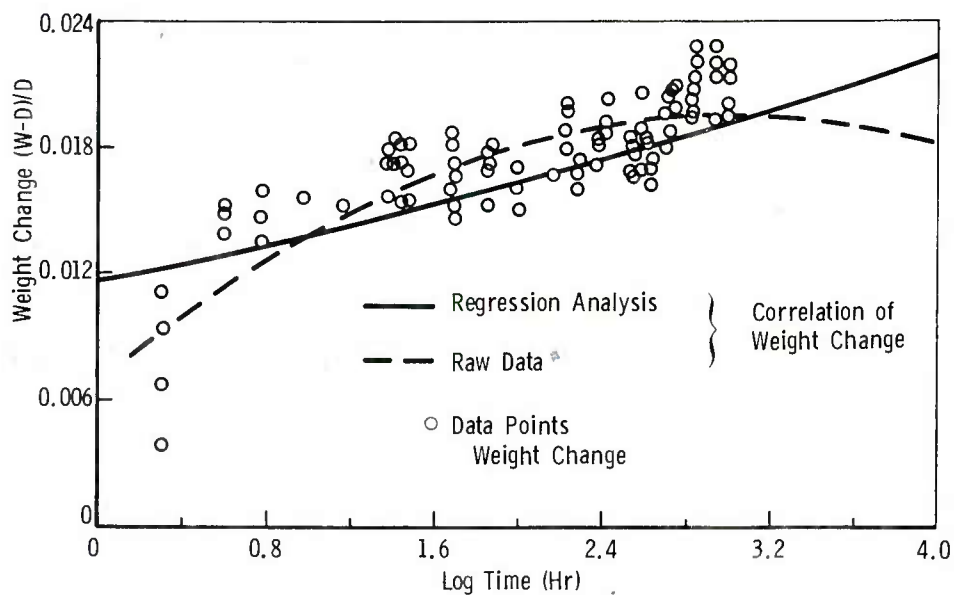


Figure 8. Water uptake for honeycomb at 190 F, 95% RH.

D. Water Permeability

The results of the cup cell permeation experiments are shown in Table 1.

Table 1. WATER PERMEATION OF CROSS-PLIED GLASS EPOXY

Sample	Bulk Permeability g-mil/24 hr - 100 in. ²
1Y	0.686
1G	1.72
2	1.35
4	19.05
8	1.52

Discarding the results of sample 4, which seem to be due to porosity caused by excess resin bleed-out or by poor edge sealing in the cell, the average is 1.32 g-mil/24 hours - 100 square inches.

DISCUSSION

A. Compression

The data show no effect of high-temperature/high-humidity environment on the compression strength of the honeycomb.

B. Shear

In order for conditions on the inside of the rotor blade to reach environmental test conditions, the blades would have to be kept in direct sunlight in a tropical environment. The blades would be exposed to these conditions for about 6 hours per day. The shear strength of the honeycomb would drop 8 to 9 psi after one year of exposure.

C. Water Vapor Uptake

A typical helicopter blade cross section could be approximated by an isosceles triangle 18 inches high and 6 inches wide at the base. The moisture permeability of the skin is such that the sorption or water uptake of the honeycomb is the controlling factor in the moisture content of the structure, i.e., the moisture permeates the skin faster than it is absorbed by the honeycomb. The amount of water necessary to achieve saturation of the honeycomb (of the model blade structure) would permeate through the skin in about 48 hours; this water could then be taken up by the honeycomb to reach 2% (by weight) and moisture saturation over a somewhat longer time, about 34 weeks. This condition is based on the structure being in a constant temperature and constant humidity regime.

CONCLUSIONS

a. The test methods were valid in that they produced values for the control specimens which were close to literature values.

b. Compressive strength is unaffected by high-temperature/high-humidity environments.

c. Shear strength is slightly affected.

d. Maximum water uptake is 2% by weight. Evaluation of the relationships between this fact and performance characteristics such as blade balance is beyond the scope of this investigation.

e. The minimal effect of high temperature and high humidity on the performance of the honeycomb should allow its use in helicopter rotor blades without major degradation of mechanical properties.

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Honeycomb laminates
Deterioration