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# EFFECT OF TEMPERATURE, HUMIDITY, AND LOADING RATE ON THE SHEAR PROPERTIES OF TACTICAL SHELTER CORE MATERIALS



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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Honeycomb core shear specimens were prepared and tested using five types of core material, two test methods, and four test conditions. The objective was to determine the effect of loading rate, temperature, and environmental exposure on the shear strength of the various core materials. The results indicated that the core shear strengths were relatively unaffected by loading rate. For all core materials tested, the shear strength decreased with increasing temperature; and humidity aging further decreased the strength. Core shear strength was also found to decrease with increasing core thickness; and the beam shear test method was found to produce higher apparent shear strengths than the plate shear test method. Lastly, glass/phenolic cores (HRP & HTP) were less affected by temperature and humidity than were the paper (WRII), Nomex (HRH-10), or balsa cores.

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| Sandwich | End Grain Balsa |

PREFACE

This report covers work performed during the period from January 1981 to May 1983 under Air Force Contract Nos. F33615-80-C-5011 and F33615-82-C-5039. The work was administered under the direction of the Systems Support Division of the Air Force Wright Aeronautical Laboratories/Materials Laboratory, Wright-Patterson Air Force Base, Ohio. Mr. John Rhodehamel (AFWAL/MLSE) was the Program Project Engineer.

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# SECTION 1
## BACKGROUND AND INTRODUCTION

The Air Force and other DoD services have employed lightweight, air-transportable shelters for many years. These shelters are made with wall, floor, and roof panels having a sandwich construction. In order to minimize weight without sacrificing strength, many of these sandwich panels consist of a resin impregnated honeycomb core adhesively bonded to aluminum skins. In some designs however, factors other than weight must be considered. Floor panels, for example, may require core materials with high impact resistance. A core material with high impact resistance is end-grain balsa wood. Shelters incorporating these types of materials are in use throughout the world, and are thereby exposed to a wide variety of environments.

Recently, the services initiated a number of programs to develop hardened tactical shelters which would provide some degree of protection against nuclear, biological, chemical, and ballistic effects. It is believed that a shelter wall subjected to nuclear overpressure would undergo extremely rapid shear loading. Therefore, this report describes the results of a program to determine the combined effects of loading rate, temperature, and environmental exposure on the shear properties of various core materials.

## SECTION 2
## MATERIALS

A total of five different types of honeycomb core of various thicknesses, cell sizes, and densities were tested during this investigation. Table 1 lists the various core types and their physical characteristics which were included in the program. The HRP, HTP, and balsa cores were added after the effort was already well underway, and as a result, were not tested as extensively as the WR-II and HRH-10 cores.

WR-II is a phenolic resin impregnated Kraft paper honeycomb core designed primarily for use in the construction of portable shelters. HRH-10 is a phenolic resin impregnated Nomex[1] honeycomb core designed for high strength and toughness. Both the WR-II and HRH-10 cores were supplied by Hexcel. HRP and HTP are both phenolic resin impregnated glass fabric honeycomb intended for elevated temperature applications. While the HRP core is manufactured by Hexcel, and the HTP core by Orbitex Division of Ciba Geigy, both were provided for this investigation by the Shelter Repair Depot at McClellan AFB. End-grain balsa is a non-honeycomb core material which, contrary to honeycomb cores, has isotropic properties. For this program, the balsa core was supplied by the Baltek Corporation.

Most of the test specimens used in this study consisted of a sandwich structure comprised of 0.040 inch (1mm) 6061T6 aluminum skins bonded to honeycomb core with a 250°F curing epoxy film adhesive representative of one used in the manufacture of portable tactical shelters. Some of the balsa core specimens, however, were evaluated with Kevlar[1] facings. The Kevlar composites for these specimens were fabricated and bonded to the balsa core by DuPont. The surface preparation for the aluminum facings was the optimized FPL acid etch (ASTM D2651, Method G). Both the honeycomb and balsa cores were cleaned with dry, oil-free filtered, compressed air prior to bonding.

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[1]Trademark, E. I. DuPont De Nemours Co.

TABLE 1

SHELTER HONEYCOMB CORE MATERIALS

| Material Designation | Cell Size | | Density | | Thickness | |
|---|---|---|---|---|---|---|
| | inch | mm | lb/ft$^3$ | Kgs/m$^3$ | inch | mm |
| HRH-10 | 1/4 | 6.4 | 4.8 | 76.9 | 1/2 | 12.7 |
| | 1/4 | 6.4 | 4.8 | 76.9 | 2 | 50.8 |
| | 1/4 | 6.4 | 4.8 | 76.9 | 3 | 76.2 |
| WR-II | 3/8 | 9.5 | 3.8 | 60.9 | 1/2 | 12.7 |
| | 3/8 | 9.5 | 3.8 | 60.9 | 2 | 50.8 |
| HRP | 3/8 | 9.5 | 4.5 | 72.1 | 1-1/2 | 38.1 |
| HTP | 3/8 | 9.5 | 3.2 | 51.3 | 7/8 | 22.2 |
| | 3/8 | 9.5 | 4.5 | 72.1 | 7/8 | 22.2 |
| Balsa | N/A | N/A | 8.6 | 187.8 | 1/2 | 12.7 |
| | N/A | N/A | 8.6 | 187.8 | 1 | 25.4 |
| | N/A | N/A | 8.6 | 187,8 | 2 | 50.8 |

# SECTION 3
# TEST PLAN

Two types of tests are used for measuring the shear properties of sandwich core material. The first is commonly referred to as plate shear and is described by ASTM standard C273. The second is commonly referred to as beam shear and is described by ASTM standard C393. For this investigation, it was originally decided to utilize the plate shear procedure because ASTM recommends plate shear as the preferred technique. For reasons which will be discussed later, it was found that the plate shear procedure could not be used for the two or three inch thick cores. Consequently, the beam shear technique was utilized for the bulk of the tests conducted during this program with occasional plate shear tests being conducted on the 1/2 inch core for purposes of comparing the two methods.

As indicated in the introduction, the purpose of this study was to determine the effect of loading rate, temperature, and environmental exposure on the shear strength of the various core materials listed in Table 1. Table 2 outlines the test matrix carried out. The two higher test speeds were selected so that each was about eighty times as fast as the preceding rate.

## 3.1 PLATE SHEAR

The plate shear test specimen, shown in Figure 1, consists of a sandwich core material which is adhesively bonded between two steel plates. The test assembly is placed into the test machine and a load applied diagonally through opposite corners of the sandwich core. The specimen size for this investigation was limited because of the dimensions of the chamber for -65°F (-54°C) and 200°F (93°C) testing. The size selected was 2 inches (5.08 cm) wide and 6 inches (15.24 cm) long. According to ASTM C273 the specimen width shall not be less than twice the thickness; and the length shall not be less than 12 times the thickness, except as agreed to between the purchaser and the

TABLE 2

CORE SHEAR TEST MATRIX[1]

| Core Type | Test Conditions °F (°C) | in./min. (cm/min.) | Core Thickness inch (mm) | Sandwich Skin |
|---|---|---|---|---|
| HRH-10 | -65, 72, 200, HHA[2] (-54) (22) (93) | 0.05 4 300 (0.127) (10.2) (762) | 1/2 2 3 (12.7) (50.8) (76.2) | Aluminum[4] |
| WR-II | -65, 72, 200, HHA[2] (-54) (22) (93) | 0.05 4 300 (0.127) (10.2) (762) | 1/2 2 (12.7) (50.8) | Aluminum[4] |
| HRP | -65, 72, 200, HHA[2] (-54) (22) (93) | 0.05 4 300 (0.127) (10.2) (762) | 1-1/2 (38.1) | Aluminum[4] |
| HTP[3] | -65, 72, 200, HHA[2] (-54) (22) (93) | 0.05 4 300 (0.127) (10.2) (762) | 7/8 (22.2) | Aluminum[4] |
| Balsa | -65, 72, 200, HHA[2] (-54) (22) (93) | 0.05 (0.127) | 1/2 1 2 (12.7) (25.4) (50.8) | Aluminum[4] |
| Balsa | -65, 72, 200, HHA[2] (-54) (22) (93) | 0.05 (0.127) | 1 (25.4) | Kevlar[5] |

[1] Tests to be performed in both the "L" (ribbon) and "W" (transverse to ribbon) direction on the honeycomb cores but in only one direction on the balsa core.

[2] HHA = Hot humid aging; tested at 200°F (93°C) after two weeks at 200°F (93°C) and 95-100% R.H.

[3] HTP core was tested for two core densities.

[4] 0.040 inch (1 mm) thick 6061 T6 alloy.

[5] 0.145 (3.7 mm) thick composite.

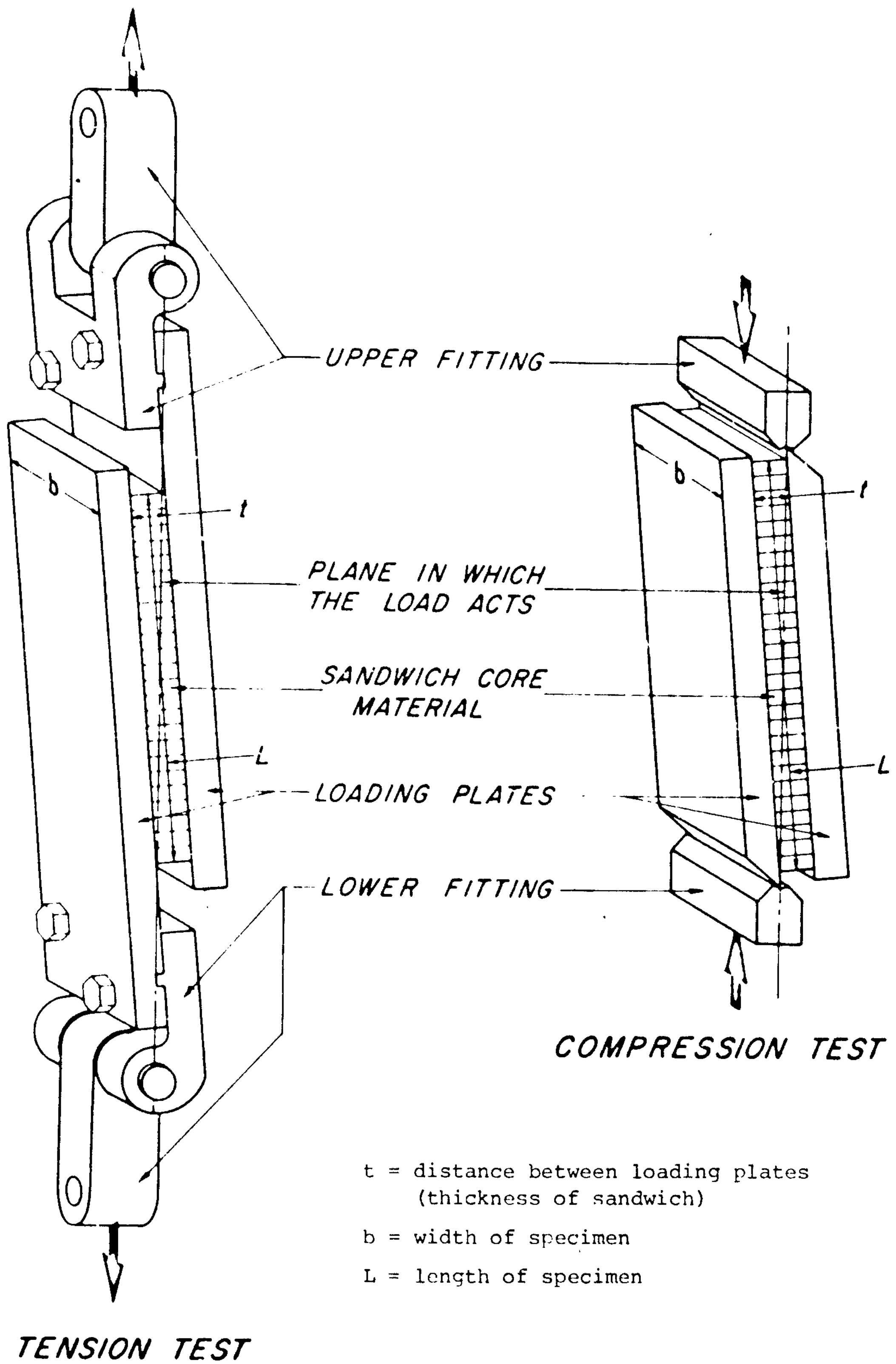


Figure 1. Plate Shear Specimens Showing Loading Plates for Tension or Compression and Plane of Applied Loads (From ASTM C273).

manufacturer. The specimen dimensions noted above meet these requirements for 1/2 inch (1.27 cm) thick, but not for 2 inch (5.08 cm) or 3 inch (7.62 cm) thick core. Advice was sought from honeycomb core manufacturers and other parties interested in the study. The consensus was that the specimen size could deviate from the specification so long as the honeycomb core failures were in shear. Proceeding on this basis, plate shear specimens with the dimensions indicated above were prepared and tested.

Plate shear specimens were prepared with 1/2 inch (1.27 cm) HRH-10 core and tested at 0.05 in/min (0.13 cm/min) and 4 in/min (10.16 cm/min). A room temperature curing adhesive was used for bonding the core to the steel plates. Shear tests on these specimens were performed at -65°F (-54°C), 72°F (22°C), and 200°F (93°C) in both the "L" and "W" direction. All of the failure modes were observed to be "shear". Specimens were then prepared with 2 inch 5.08 cm) and 3 inch (7.62 cm) core. Some shear failures were obtained for 2 inch (5.08 cm) core at test speeds of 0.05 and 4 in/min (0.13 and 10.16 cm/min). However, at speeds of 300 in/min (762 cm/min) with the 2 inch (5.08 cm) core and at all test speeds with the 3 inch (7.62 cm) core, the failure mode for every test was debonding of the core from the steel plates. Figure 2 illustrates a valid shear failure and Figure 3 illustrates a debonding failure. It was thus necessary to consider the beam shear test as an alternative to the plate shear test since the size limitations imposed the test chamber prevented the use of plate shear samples long enough to insure shear failure for the thicker cores.

### 3.2 BEAM SHEAR

The beam shear specimen consists of honeycomb core material which is adhesively bonded between aluminum facing sheets. This sandwich specimen is tested in flexure with the load being applied at the two quarter-span points as shown in Figures 4 and 5. This flexure (or beam) specimen may be used to determine the core shear strength, compressive or tensile strength of the facings,

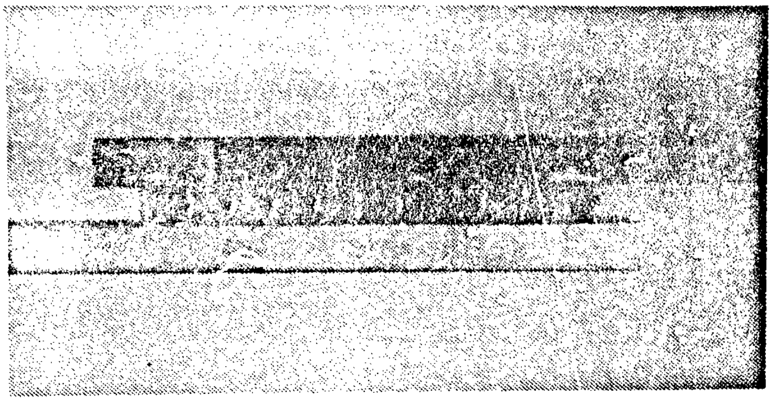

Figure 2. Shear Failure, Plate Shear Method.

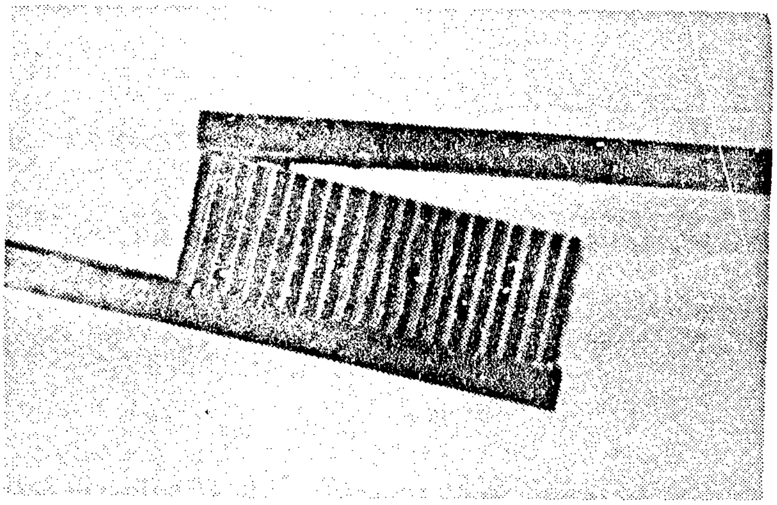

Figure 3. Debonding Failure, Plate Shear Method.

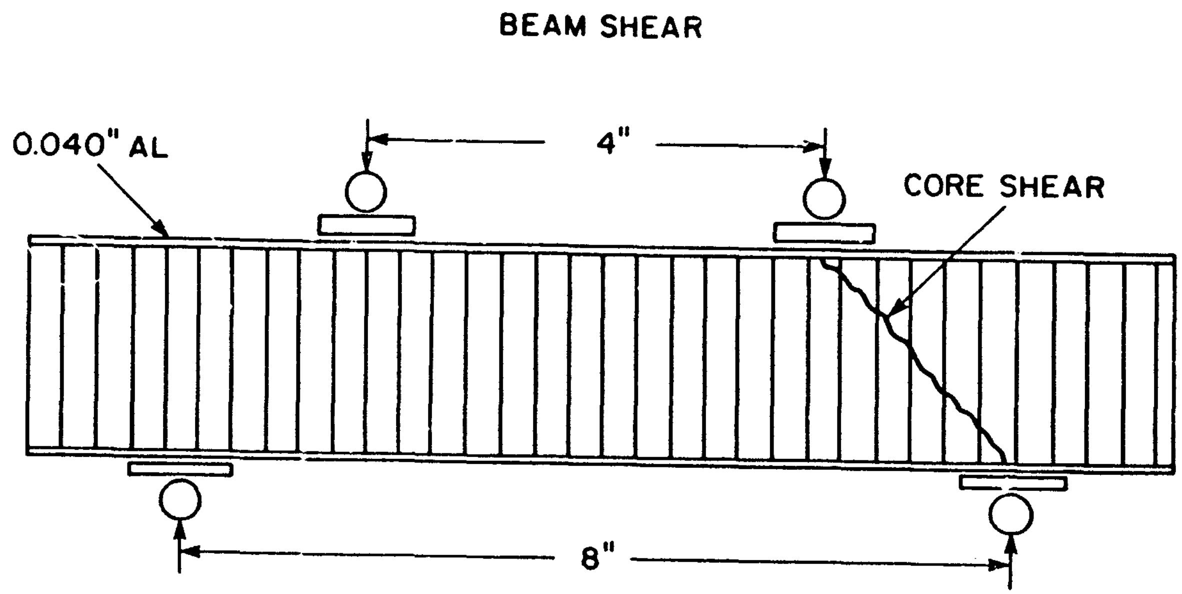


Figure 4. Beam Shear Specimen.

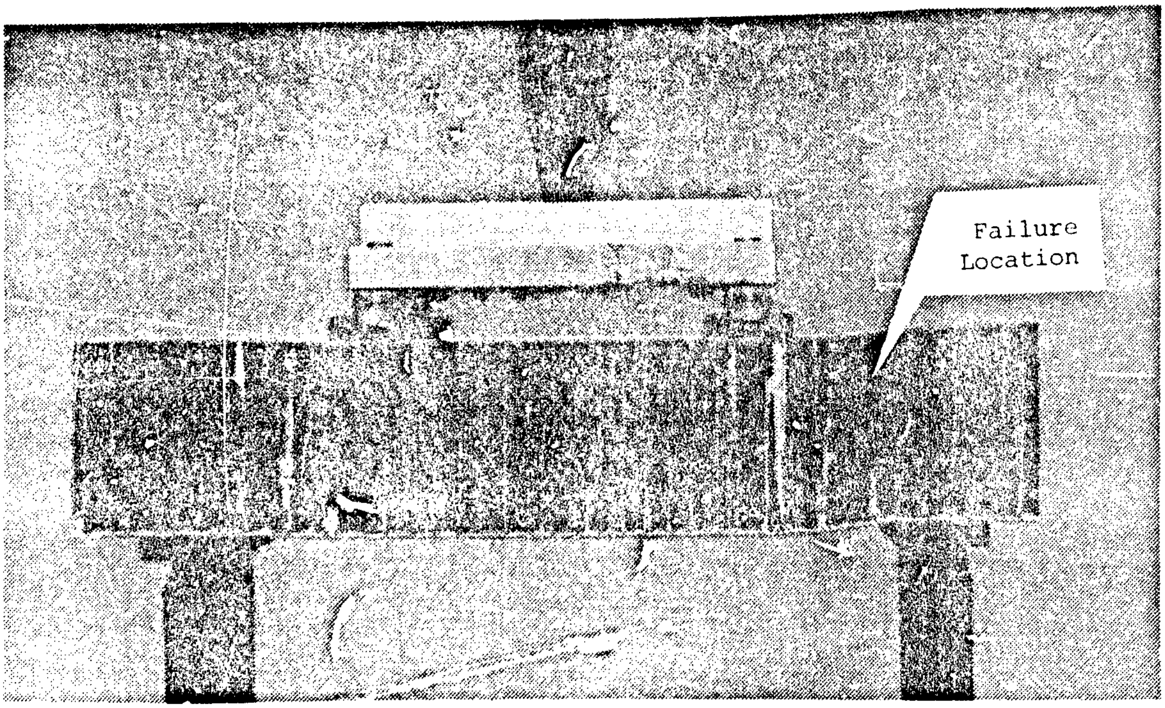


Figure 5. Shear Failure, Beam Method.

or to evaluate the bond between core and facings. The failure mode can be changed by altering such things as core material or core characteristics, facing material or thickness, adhesive, and/or the support span. With honeycomb core in the beam shear test, a shear failure is one which occurs through the core at about a 45° angle from one facing skin to another as illustrated in Figures 4 and 5. With end-grain balsa core, a shear failure is a series of vertical fracture running from one face to the other, as illustrated in Figure 6. For the same reasons as discussed in Section 3.1, the beam shear specimen was limited in size, especially length, by the dimensions of the environmental test chambers. This limitation led to the use of a specimen 10 inches (25.4 cm) long and 3 inches (7.62 cm) wide. The specimen thickness depended on the thickness of core used. As illustrated in Figure 4, the test span length was 8 inches (20.3 cm). Once again advice was sought from honeycomb core manufacturers and other parties interested in the program, and again it was the consensus that this specimen configuration was satisfactory only if the specimens failed in core shear. Honeycomb core sandwich beam specimens were fabricated and tested with particular attention to the failure mode. The prepared panels were of sufficient size that three replicate specimens could be cut and tested for each test condition.

Beam shear tests were run on specimens of varying core thicknesses and types, and at varying test speeds. All failures with this specimen design were core shear failures. The test matrix presented in Table 2 was subsequently carried out using the beam shear test method.

### 3.3 HUMIDITY AGING AND TEST PROCEDURE

The one remaining procedure which had to be defined in order to conduct the investigation was the method by which the humidity agings would be carried out. The two options were to (a) bond on the loading plates or facing skins prior to humidity aging or (b) carry out the humidity aging first and bond on the loading plates

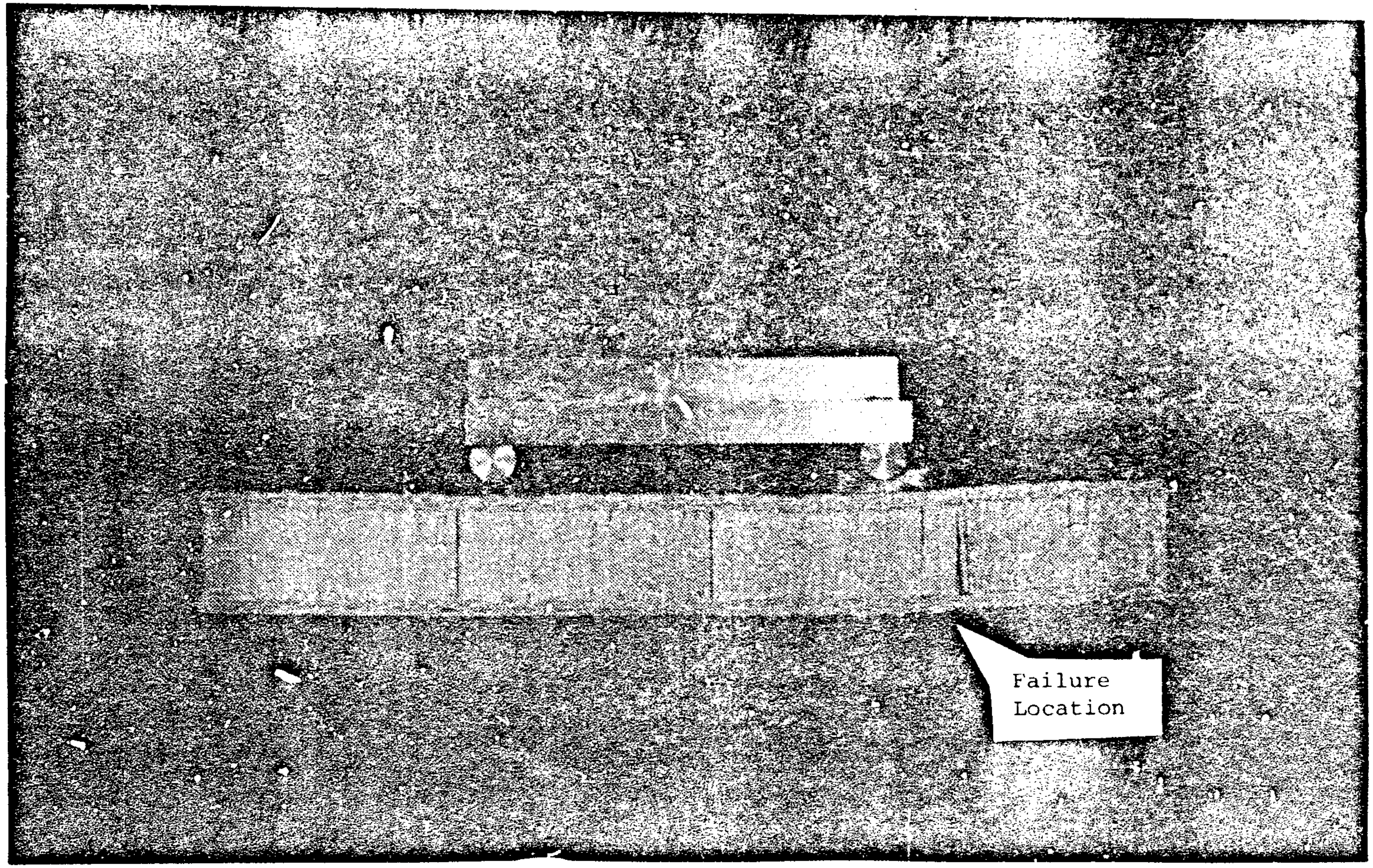


Figure 6. End-Grain Balsa Beam Shear Failure.

or facing skins after completion of the humidity exposure. In either case, the overriding criteria would be whether the specimens failed in the core shear mode or not.

Honeycomb plate shear specimens were prepared and aged for two weeks at 200°F (93°C) and 95-100% R.H., and then tested at 200°F (93°C). The failure mode for specimens bonded before humidity ging was debonding between the adhesive and the supporting steel plate. The failure mode for specimens bonded after humidity aging was also debonding, but between the adhesive and the honeycomb core.

Honeycomb beam shear specimens were also prepared, humidity aged, and tested. The failure mode for specimens bonded before humidity aging was debonding between the adhesive and the aluminum face sheets. Specimens which were bonded after humidity aging did fail in core shear; however, it appeared that the honeycomb core was being dried during the bonding operation. Both room temperature and 250°F (121°C) curing adhesives were tried. Drying probably occurred with the room temperature curing adhesive because the time required for cure was a minimum of 24 hours and with the elevated temperature curing adhesive because of the heat.

At this point it was decided to modify the beam shear specimen by bonding the skins to the core before humidity aging but to vent each cell in the honeycomb core by drilling small holes in the skins and adhesive layer. This would allow moisture to saturate the honeycomb core and eliminate the opportunity for dry out prior to testing. Some specimens were fabricated, aged, and tested using this technique and the tests appeared successful in producing core shear failure modes. Figure 7 illustrates a honeycomb panel with each cell vented and Figure 8 illustrates a balsa panel with perforated skins. In the case of the balsa core panels, care was taken that the holes drilled in the skin did not extend into the core. Holes were drilled in both skins and the panels were cut into three individual test specimens before

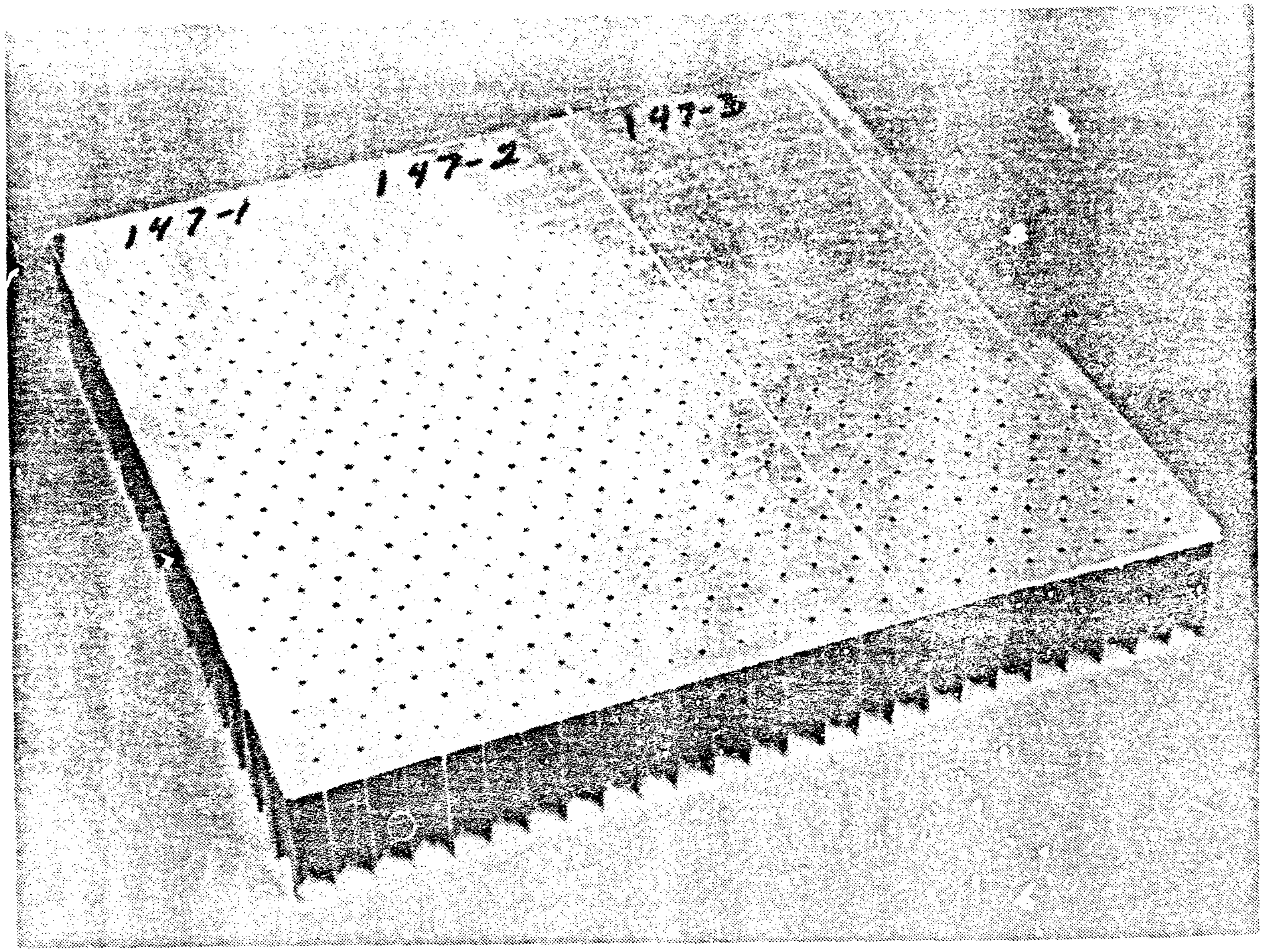


Figure 7. Beam Shear Panel for Humidity Exposure.

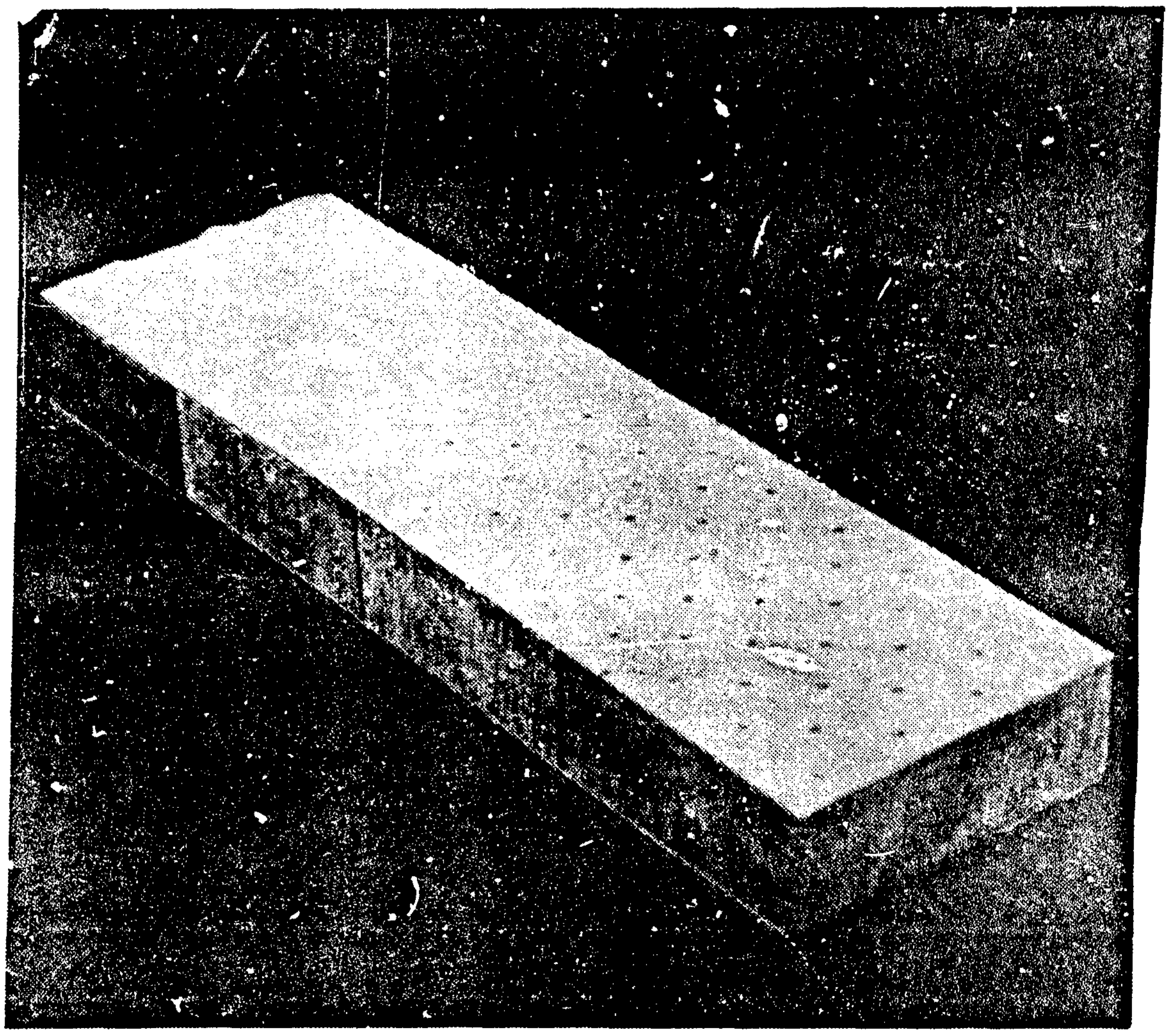

Figure 8. Bonded End-Grain Balsa Specimen After Humidity Exposure.

humidity aging. Once again honeycomb manufacturers and parties interested in the program were surveyed, and the consensus was favorable for using this method so long as the failure mode was core shear. This technique was consequently used for all humidity aged specimens.

## SECTION 4
## DISCUSSION OF RESULTS

With the approach, materials section, and test plan established, the goals of this study merit review before proceeding with a discussion of the results. The first and most important objective of this study was to determine if the shear strength of honeycomb core is significantly affected by test speed. Other objectives included (a) determining the effects of temperature and humidity on core shear strength, (b) comparing the shear properties of end-grain balsa core with honeycomb core, and (c) comparing the core shear strength obtained with the beam shear method versus the plate shear method.

### 4.1 PLATE SHEAR TEST RESULTS

Plate shear specimens were prepared and tested for 1/2 inch (1.27 cm) thick HRH-10 (Nomex) honeycomb core at -65°F (-54°C), 72°F (22°C), and 200°F (93°C) in both the "L" and "W" directions. the results are presented in Table 3 and represent an average of six tests each in the "L" direction and three each in the "W" direction. From the limited data obtained it would appear that core shear strength increases with increasing test speed. This is true for all three test temperatures in the "L" direction and for two test temperatures in the "W" direction. In addition, core shear strength is observed to decrease as the test temperature increases. This is true for both the core directions. The results also indicate that core shear in the "W" direction is 50-55% of that in the "L" direction. Data at high test speeds or after humidity aging are not presented because the failures were not "shear", but debonding as illustrated in Figure 3.

A very limited amount of plate shear data was obtained for 2 inch (5.08 cm) thick HRH-10 honeycomb core and is presented in Table 4. Once again, the reason for the limited data is the difficulty in obtaining good core shear failures. It does appear, however, that the core shear strength increases slightly as

TABLE 3

HRH-10 CORE SHEAR STRENGTH BY PLATE SHEAR METHOD

| Core Thickness | | Condition of Test[1] | | Testing Speed | | Ultimate Strength[2] | | Standard Deviation | |
|---|---|---|---|---|---|---|---|---|---|
| (In) | (Cm) | (°F) | (°C) | (In/Min) | (Cm/Min) | (PSI) | (MPa) | (PSI) | (MPa) |
| "L" DIRECTION | | | | | | | | | |
| 1/2 | 1.27 | 72 | 22 | 0.05 | 0.13 | 333.5 | 2.30 | 3.5 | 0.02 |
| 1/2 | 1.27 | 72 | 22 | 4 | 10.16 | 350.2 | 2.41 | 11.9 | 0.08 |
| 1/2 | 1.27 | -65 | -54 | 0.05 | 0.13 | 365.6 | 2.52 | 22.3 | 0.15 |
| 1/2 | 1.27 | -65 | -54 | 4 | 10.16 | 402.0 | 2.77 | 17.3 | 0.12 |
| 1/2 | 1.27 | 200 | 93 | 0.05 | 0.13 | 285.3 | 1.97 | 20.0 | 0.14 |
| 1/2 | 1.27 | 200 | 93 | 4 | 10.16 | 318.2 | 2.19 | 31.0 | 0.21 |
| "W" DIRECTION | | | | | | | | | |
| 1/2 | 1.27 | 72 | 22 | 0.05 | 0.13 | 174.2 | 1.20 | 5.8 | 0.04 |
| 1/2 | 1.27 | 72 | 22 | 4 | 10.16 | 176.7 | 1.22 | 5.2 | 0.04 |
| 1/2 | 1.27 | -65 | -54 | 0.05 | 0.13 | 200.6 | 1.38 | 11.8 | 0.08 |
| 1/2 | 1.27 | -65 | -54 | 4 | 10.16 | 195.8 | 1.35 | 15.4 | 0.11 |
| 1/2 | 1.27 | 200 | 93 | 0.05 | 0.13 | 145.6 | 1.00 | 7.7 | 0.05 |
| 1/2 | 1.27 | 200 | 93 | 4 | 10.16 | 159.2 | 1.10 | 6.5 | 0.04 |

1 Specimens were conditioned at temperature 10 minutes prior to test.

2 Values represent average of six tests in the "L" direction and three tests in the "W" direction.

TABLE 4

HRH-10 CORE SHEAR STRENGTH BY PLATE SHEAR METHOD

"L" DIRECTION

| Core Thickness | | Condition of Test | | Testing Speed | | Ultimate Strength | | Standard Deviation | |
|---|---|---|---|---|---|---|---|---|---|
| (In) | (Cm) | (°F) | (°C) | (In/Min) | (Cm/Min) | (PSI) | (MPa) | (PSI) | (MPa) |
| 2 | 5.08 | 72 | 22 | 0.05 | 0.13 | 261.1 | 1.80 | 7.8 | 0.05 |
| 2 | 5.08 | 72 | 22 | 4 | 10.16 | 263.3 | 1.81 | 9.6 | 0.07 |
| 2 | 5.08 | 200 | 93 | 0.05 | 0.13 | 218.2 | 1.50 | 6.2 | 0.04 |
| "W" DIRECTION | | | | | | | | | |
| 2 | 5.08 | 72 | 22 | 0.05 | 0.13 | 166.4 | 1.15 | 8.4 | 0.06 |
| 2 | 5.08 | 72 | 22 | 4 | 10.16 | 171.1 | 1.18 | 1.7 | 0.01 |

Note: Specimens were conditioned at temperature 10 minutes prior to test.

test speed increases. The values obtained in the "W" direction are 60-65% of those in the "L" direction. In the "W" direction, the 2 inch (5.07 cm) thick core shear strength is only slightly less than that of 1/2 inch (1.27 cm) core. In the "L" direction, however, the core shear strength for 2 inch (5.07 cm) core is only 75-80% of that obtained for 1/2 inch (1.27 cm) core.

Although very little data were accumulated using the plate shear test method, it appears that the core shear strength increases slightly with increasing test speed. In the results presented here, an increase of about 10% was observed for an eighty-fold increase in test speed.

## 4.2 BEAM SHEAR TEST RESULTS

Beam shear specimens were fabricated and tested according to the test matrix in Table 2. Originally, all the data in the "L" direction was to be an average of six individual specimens, and the data in the "W" direction an average three specimens. Since the standard deviation appeared to be very low, however, it was determined that three replicate tests would be sufficient for both core directions. The specimen design and test procedures were described in Section 3.2. Special attention was given each test specimen to ensure that the failure mode was indeed core shear.

### 4.2.1 WR-II Core Shear

Specimens were fabricated and evaluated with both 1/2 and 2 inch (1.27 and 5.08 cm) thick WR-II (paper/phenolic) honeycomb core. Tests were performed in both the "L" and "W" directions at temperatures from -65°F (-54°C) to 200°F (93°C), after humidity exposure, and at test speeds of 0.05, 4, and 300 in/min (0.13, 10.16, and 762 cm/min.).

In general, the WR-II core shear strength appeared to be unaffected by the test speed. In fact, the shear strength usually was less a 4 in/min (10.16 cm/min) than that at either

0.05 in/min (0.13 cm/min) or 300 in/min (762 cm/min). One test variable between the two slower test speeds and the faster was the test machine. The tests at the two slower speeds were carried out on a Baldwin Universal Test Machine while the tests at the higher speed were conducted on an MTS Test Machine. Specimen mounting was identical on each type of test machine and as illustrated in Figures 4 and 5. Some comparative testing was performed on these two machines and it was found that this variable seemed to be negligble. These results are discussed and presented in Section 5.2 of this report.

Test conditions which did affect the the WR-II core shear strength included temperature, humidity aging, core direction, and thickness. The core shear strength is reduced as the test temperature is increased; and it is further reduced after hot humid aging. The values obtained for the "W" direction are about 50-55% of those for the "L" direction. The core shear strength for the 2 inch (5.08 cm) core is about 70% of that for the 1/2 inch (1.27 cm) core.

The data obtained for the WR-II core are presented in Tables 5 through 8. All specimens failed in core shear with the complete failure clearly visible after test, as shown in Figure 9.

4.2.2 HRH-10 Core Shear

Specimens were fabricated and evaluated with 1/2, 2, and 3 inch (1.27, 5.08, and 7.62 cm) thick HRH-10 (Nomex) honeycomb core. Tests were performed in both the "L" and "W" directions at temperatures from -65°F (-54°C) to 200°F (93°C), after humidity exposure, and at speeds of 0.05, 4, and 30 in/min (0.13, 10.16, and 762 cm/min).

The HRH-10 honeycomb core results exhibit, in general, the same pattern as results for the WR-II honeycomb core. Testing speed did not appear to have a significant detrimental effect on the core shear strength. Once again the

TABLE 5

WR-II CORE SHEAR STRENGTH BY BEAM SHEAR METHOD IN THE "L" DIRECTION

| Core Thickness | | Condition of Test[1] | | Testing Speed | | Ultimate Strength | | Standard Deviation | |
|---|---|---|---|---|---|---|---|---|---|
| (In) | (Cm) | (°F) | (°C) | (In/Min) | (Cm/Min) | (PSI) | (MPa) | (PSI) | (MPa) |
| 1/2 | 1.27 | -65 | -54 | 0.05 | 0.13 | 391.7 | 2.70 | 6.7 | 0.05 |
| 1/2 | 1.27 | -65 | -54 | 4 | 10.16 | 297.3 | 2.05 | 15.4 | 0.11 |
| 1/2 | 1.27 | -65 | -54 | 300 | 762 | 353.5 | 2.44 | 7.4 | 0.05 |
| 1/2 | 1.27 | 72 | 22 | 0.05 | 0.13 | 334.6 | 2.31 | 20.5 | 0.14 |
| 1/2 | 1.27 | 72 | 22 | 4 | 10.16 | 271.6 | 1.87 | 11.6 | 0.08 |
| 1/2 | 1.27 | 72 | 22 | 300 | 762 | 406.3 | 2.80 | 17.7 | 0.13 |
| 1/2 | 1.27 | 200 | 93 | 0.05 | 0.13 | 241.7 | 1.67 | 8.7 | 0.06 |
| 1/2 | 1.27 | 200 | 93 | 4 | 10.16 | 168.1 | 1.16 | 3.6 | 0.02 |
| 1/2 | 1.27 | 200 | 93 | 300 | 762 | 274.0 | 1.89 | 8.5 | 0.06 |
| 1/2 | 1.27 | HHA[2] | | 0.05 | 0.13 | 178.9 | 1.23 | 5.6 | 0.04 |
| 1/2 | 1.27 | HHA | | 4 | 10.16 | 186.5 | 1.28 | 3.2 | 0.02 |
| 1/2 | 1.27 | HHA | | 300 | 762 | 114.9 | 0.79 | 4.9 | 0.03 |

[1] Specimens were conditioned at temperature 10 minutes prior to test for -65°F (-54°C) and 200°F (93°C), and 6 minutes for HHA tests.

[2] HHA = 200°F (93°C) after two weeks @ 200°F (93°C) and 95-100% Relative Humidity.

TABLE 6

WF-II CORE SHEAR STRENGTH BY BEAM SHEAR METHOD IN THE "W" DIRECTION

| Core Thickness | | Condition of Test[1] | | Testing Speed | | Ultimate Strength | | Standard Deviation | |
|---|---|---|---|---|---|---|---|---|---|
| (In) | (Cm) | (°F) | (°C) | (In/Min) | (Cm/Min) | (PSI) | (MPa) | (PSI) | (MPa) |
| 1/2 | 1.27 | -65 | -54 | 0.05 | 0.13 | 206.2 | 1.42 | 12.5 | 0.09 |
| 1/2 | 1.27 | -65 | -54 | 4 | 10.16 | 137.4 | 0.95 | 6.5 | 0.04 |
| 1/2 | 1.27 | -65 | -54 | 300 | 762 | 227.8 | 1.57 | 9.3 | 0.06 |
| 1/2 | 1.27 | 72 | 22 | 0.05 | 0.13 | 175.6 | 1.21 | 3.6 | 0.02 |
| 1/2 | 1.27 | 72 | 22 | 4 | 10.16 | 142.7 | 0.98 | 1.3 | 0.01 |
| 1/2 | 1.27 | 72 | 22 | 300 | 762 | 188.7 | 1.30 | 3.2 | 0.02 |
| 1/2 | 1.27 | 200 | 93 | 0.05 | 0.13 | 101.6 | 0.70 | 1.6 | 0.01 |
| 1/2 | 1.27 | 200 | 93 | 4 | 10.16 | 116.5 | 0.80 | 2.1 | 0.01 |
| 1/2 | 1.27 | 200 | 93 | 300 | 762 | 154.8 | 1.07 | 5.9 | 0.04 |
| 1/2 | 1.27 | HHA[2] | | 0.05 | 0.13 | 115.8 | 0.80 | 5.4 | 0.04 |
| 1/2 | 1.27 | HHA | | 4 | 10.16 | 126.6 | 0.87 | 11.5 | 0.08 |
| 1/2 | 1.27 | HHA | | 300 | 762 | 94.6 | 0.65 | 1.7 | 0.01 |

[1]Specimens were conditioned at temperature 10 minutes prior to test for -65°F (-54°C) and 200°F (93°C), and 6 minutes for HHA tests.

[2]HHA = 200°F (93°C) after two weeks @ 200°F (93°C) and 95-100% Relative Humidity.

TABLE 7

WR-II CORE SHEAR STRENGTH BY BEAM SHEAR METHOD IN THE "L" DIRECTION

| Core Thickness | | Condition of Test[1] | | Testing Speed | | Ultimate Strength | | Standard Deviation | |
|---|---|---|---|---|---|---|---|---|---|
| (in.) | (cm) | (°F) | (°C) | (in/min) | (cm/min) | (psi) | (MPa) | (psi) | (MPa) |
| 2 | 5.08 | -65 | -54 | 0.05 | 0.13 | 248.7 | 1.71 | 12.2 | 0.08 |
| 2 | 5.08 | -65 | -54 | 4 | 10.16 | 166.7 | 1.15 | 15.5 | 0.11 |
| 2 | 5.08 | -65 | -54 | 300 | 762 | 218.3 | 1.50 | 11.1 | 0.08 |
| 2 | 5.08 | 72 | 22 | 0.05 | 0.13 | 213.2 | 1.47 | 15.6 | 0.11 |
| 2 | 5.08 | 72 | 22 | 4 | 10.16 | 190.7 | 1.31 | 3.5 | 0.02 |
| 2 | 5.08 | 72 | 22 | 300 | 762 | 294.6 | 2.03 | 31.5 | 0.22 |
| 2 | 5.08 | 200 | 93 | 0.05 | 0.13 | 187.1 | 1.29 | 2.4 | 0.02 |
| 2 | 5.08 | 200 | 93 | 4 | 10.16 | 117.3 | 0.81 | 3.5 | 0.02 |
| 2 | 5.08 | 200 | 93 | 300 | 762 | 191.7 | 1.32 | 11.6 | 0.08 |
| 2 | 5.08 | HHA[2] | | 0.05 | 0.13 | 138.0 | 0.95 | 1.7 | 0.01 |
| 2 | 5.08 | HHA | | 4 | 10.16 | 139.8 | 0.96 | 1.2 | 0.01 |
| 2 | 5.08 | HHA | | 300 | 762 | 157.5 | 1.09 | 5.1 | 0.04 |

[1] Specimens were conditioned at temperature 10 mins. prior to test for -65°F (-54°C) and 200°F (93°C), and 6 mins. for HHA tests.

[2] HHA = 200°F (93°C) after 2 wks. @ 200°F (93°C) and 95-100% Relative Humidity.

TABLE 8

WF-II CORE SHEAR STRENGTH BY BEAM SHEAR METHOD IN THE "W" DIRECTION

| Core Thickness | | Condition of Test[1] | | Testing Speed | | Ultimate Strength | | Standard Deviation | |
|---|---|---|---|---|---|---|---|---|---|
| (in.) | (cm) | (°F) | (°C) | (in/min) | (cm/min) | (psi) | (MPa) | (psi) | (MPa) |
| 2 | 5.08 | -65 | -54 | 0.05 | 0.13 | 154.7 | 1.07 | 9.5 | 0.07 |
| 2 | 5.08 | -65 | -54 | 4 | 10.16 | 115.2 | 0.79 | 0.7 | 0.00 |
| 2 | 5.08 | -65 | -54 | 300 | 762 | 144.7 | 1.00 | 15.9 | 0.11 |
| 2 | 5.08 | 72 | 22 | 0.05 | 0.13 | 140.0 | 0.96 | 2.2 | 0.02 |
| 2 | 5.08 | 72 | 22 | 4 | 10.16 | 107.1 | 0.74 | 2.6 | 0.02 |
| 2 | 5.08 | 72 | 22 | 300 | 762 | 125.1 | 0.86 | 4.2 | 0.03 |
| 2 | 5.08 | 200 | 93 | 0.05 | 0.13 | 98.6 | 0.68 | 4.6 | 0.03 |
| 2 | 5.08 | 200 | 93 | 4 | 10.16 | 74.0 | 0.51 | 0.7 | 0.00 |
| 2 | 5.08 | 200 | 93 | 300 | 762 | 95.6 | 0.66 | 1.1 | 0.01 |
| 2 | 5.08 | HHA[2] | | 0.05 | 0.13 | 56.7 | 0.39 | 2.5 | 0.02 |
| 2 | 5.08 | HHA | | 4 | 10.16 | 64.2 | 0.44 | 1.4 | 0.01 |
| 2 | 5.03 | HHA | | 300 | 762 | 98.1 | 0.68 | 3.5 | 0.02 |

[1] Specimens were conditioned at temperature 10 mins prior to test for -65°F (-54°C) and 200°F (93°C), and 6 mins. for HHA tests.

[2] HHA = 200°F (93°C) after 2 wks. @ 200°F (93°C) and 95-100% Relative Humidity.

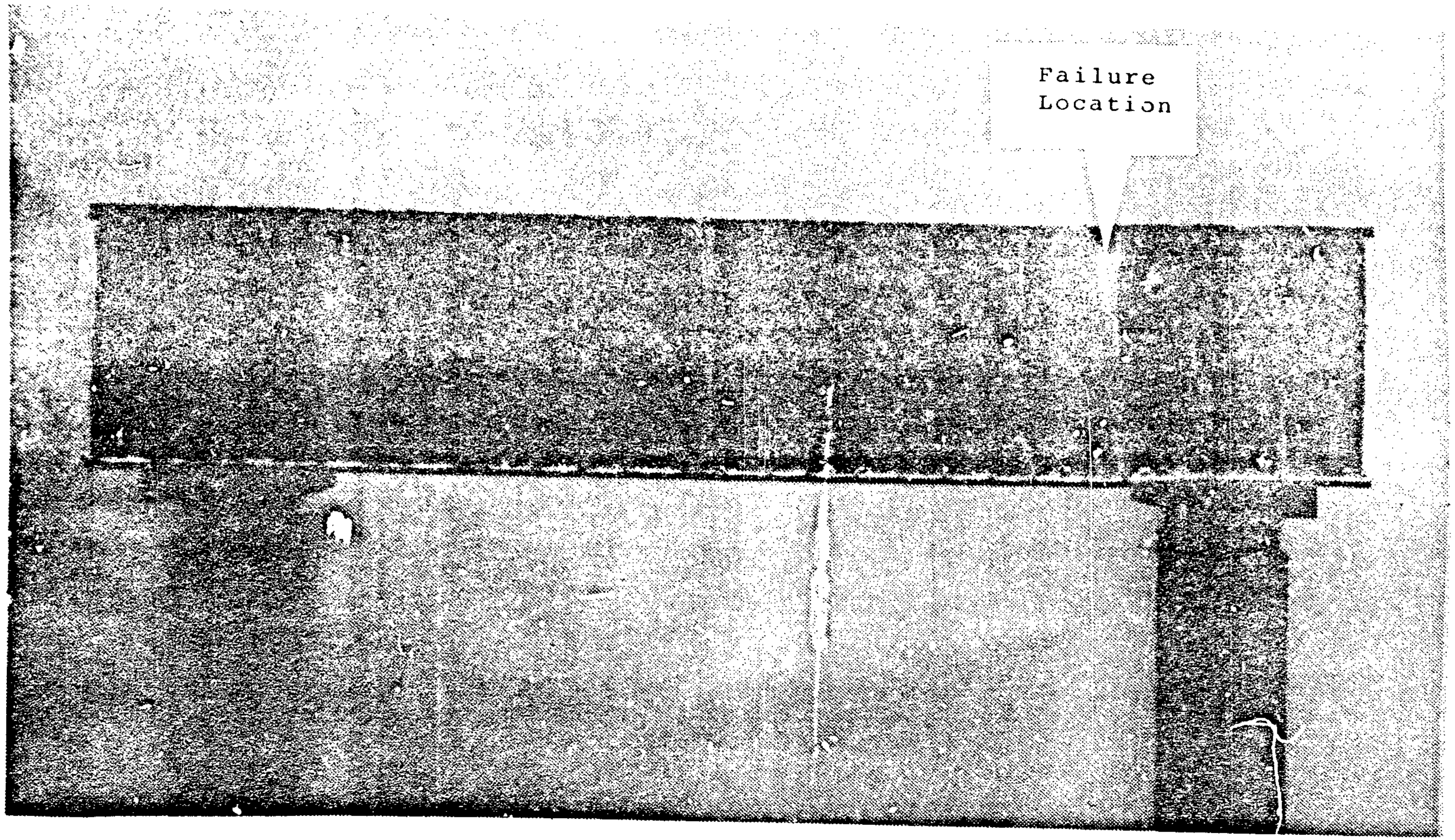


Figure 9. WR-II Specimen After Beam Shear Test.

core shear strength was usually somewhat lower at 4 in/min (10.16 cm/min) than that at either 0.05 in/min (0.13 cm/min) or 300 in/min (762 cm/min).

As with the WR-II core, the HRH-10 core shear strength is reduced as the temperature is increased; and it is further reduced after hot humid aging. The strength for the HRH-10 core obtained in the "W" direction is about 50-55% of that in the "L" direction. The core shear strength for the 2 inch (5.08 cm) core is about 70% that of the 1/2 inch (1.27 cm) core; and the core strength for the 3 inch (7.62 cm) core is about 60% that of the 1/2 inch (1.27 cm) core.

The data obtained for the HRH-10 core are presented in Tables 9 through 14. All specimens failed in core shear but unlike the WR-II core, the failures were visible only with the load applied. After the load is removed the specimen appears to be untested. Figure 10 illustrates an HRH-10 specimen both loaded and unloaded after failure.

#### 4.2.3 HRP and HTP Honeycomb Core Shear

Specimens were fabricated and evaluated with 1-1/2 inch (3.81 cm) thick HRP (glass/phenolic) honeycomb core and with 7/8 inch (2.22 cm) thick HTP honeycomb core having two core densities. Tests were performed in both the "L" and "W" directions at temperatures from -65°F (-54°C) to 200°F (93°C) after humidity exposure, and at speeds of 0.05, 4, and 300 in/min (0.13, 10.16, and 762 cm/min).

The test results for the HRP and HTP honeycomb samples are presented in Tables 15 through 19. Testing speed did not appear to have a significant detrimental effect on the shear strength of either the HRP or HTP core, although the strength at 4 in/min (10.16 cm/min) was somewhat less than at either 0.05 in/min (0.13 cm/min) or 300 in/min (762 cm/min).

While in the case of both the WR-II and HRH-10 cores the shear strength decreased with increasing temperature, this

TABLE 9

HRH-10 CORE SHEAR STRENGTH BY BEAM SHEAR METHOD IN THE "L" DIRECTION

| Core Thickness | | Condition of Test[1] | | Testing Speed | | Ultimate Strength | | Standard Deviation | |
|---|---|---|---|---|---|---|---|---|---|
| (in.) | (cm) | (°F) | (°C) | (in/min) | (cm/min) | (psi) | (MPa) | (psi) | (MPa) |
| 1/2 | 1.27 | -65 | -54 | 0.05 | 0.13 | 480.5 | 3.31 | 5.4 | 0.04 |
| 1/2 | 1.27 | -65 | -54 | 4 | 10.16 | 363.2 | 2.50 | 13.1 | 0.09 |
| 1/2 | 1.27 | -65 | -54 | 300 | 762 | 490.1 | 3.38 | 20.9 | 0.14 |
| 1/2 | 1.27 | 72 | 22 | 0.05 | 0.13 | 420.7 | 2.90 | 61.1 | 0.42 |
| 1/2 | 1.27 | 72 | 22 | 4 | 10.16 | 328.0 | 2.26 | 2.2 | 0.02 |
| 1/2 | 1.27 | 72 | 22 | 300 | 762 | 439.6 | 3.03 | 8.2 | 0.06 |
| 1/2 | 1.27 | 200 | 93 | 0.05 | 0.13 | 306.8 | 2.11 | 13.4 | 0.09 |
| 1/2 | 1.27 | 200 | 93 | 4 | 10.16 | 312.6 | 2.15 | 9.4 | 0.06 |
| 1/2 | 1.27 | 200 | 93 | 300 | 762 | 366.0 | 2.52 | 1.9 | 0.01 |
| 1/2 | 1.27 | HHA[2] | | 0.05 | 0.13 | 172.4 | 1.19 | 15.0 | 0.10 |
| 1/2 | 1.27 | HHA | | 4 | 10.16 | 295.2 | 2.03 | 2.5 | 0.02 |
| 1/2 | 1.27 | HHA | | 300 | 762 | 364.4 | 2.51 | 5.6 | 0.04 |

[1] Specimens were conditioned at temperature 10 mins. prior to test for -65°F (-54°C) and 200°F (93°C), and 6 mins. for HHA tests.

[2] HHA = 200°F (93°C) after 2 wks. @ 200°F (93°C) and 95-100% Relative Humidity.

TABLE 10

HRH-10 CORE SHEAR STRENGTH BY BEAM SHEAR METHOD IN THE "W" DIRECTION

| Core Thickness | | Condition of Test[1] | | Testing Speed | | Ultimate Strength | | Standard Deviation | |
|---|---|---|---|---|---|---|---|---|---|
| (in.) | (cm) | (°F) | (°C) | (in/min) | (cm/min) | (psi) | (MPa) | (psi) | (MPa) |
| 1/2 | 1.27 | -65 | -54 | 0.05 | 0.13 | 223.8 | 1.54 | 2.9 | 0.02 |
| 1/2 | 1.27 | -65 | -54 | 4 | 10.16 | 183.1 | 1.26 | 3.2 | 0.02 |
| 1/2 | 1.27 | -65 | -54 | 300 | 762 | 237.1 | 1.63 | 4.8 | 0.03 |
| 1/2 | 1.27 | 72 | 22 | 0.05 | 0.13 | 202.9 | 1.40 | 2.8 | 0.02 |
| 1/2 | 1.27 | 72 | 22 | 4 | 10.16 | 173.6 | 1.20 | 1.4 | 0.01 |
| 1/2 | 1.27 | 72 | 22 | 300 | 762 | 196.3 | 1.35 | 8.9 | 0.06 |
| 1/2 | 1.27 | 200 | 93 | 0.05 | 0.13 | 167.2 | 1.15 | 2.9 | 0.02 |
| 1/2 | 1.27 | 200 | 93 | 4 | 10.16 | 169.3 | 1.17 | 3.7 | 0.03 |
| 1/2 | 1.27 | 200 | 93 | 300 | 762 | 192.8 | 1.33 | 3.5 | 0.02 |
| 1/2 | 1.27 | HHA[2] | | 0.05 | 0.13 | 170.6 | 1.18 | 1.5 | 0.01 |
| 1/2 | 1.27 | HHA | | 4 | 10.16 | 175.4 | 1.21 | 3.0 | 0.02 |
| 1/2 | 1.27 | HHA | | 300 | 762 | 136.7 | 0.94 | 3.2 | 0.02 |

[1] Specimens were conditioned at temperature 10 mins. prior to test for -65°F (-54°C) and 200°F (93°C), and 6 mins. for HHA tests.

[2] HHA = 200°F (93°C) after 2 wks. @ 200°F (93°C) and 95-100% Relative Humidity.

TABLE 11

HRH-10 CORE SHEAR STRENGTH BY BEAM SHEAR METHOD IN THE "L" DIRECTION

| Core Thickness | | Condition of Test[1] | | Testing Speed | | Ultimate Strength | | Standard Deviation | |
|---|---|---|---|---|---|---|---|---|---|
| (in.) | (cm) | (°F) | (°C) | (in/min) | (cm/min) | (psi) | (MPa) | (psi) | (MPa) |
| 2 | 5.08 | -65 | -54 | 0.05 | 0.13 | 294.5 | 2.03 | 6.0 | 0.04 |
| 2 | 5.08 | -65 | -54 | 4 | 10.16 | 254.0 | 1.75 | 8.4 | 0.06 |
| 2 | 5.08 | -65 | -54 | 300 | 762 | 309.0 | 2.13 | 4.8 | 0.03 |
| 2 | 5.08 | 72 | 22 | 0.05 | 0.13 | 281.5 | 1.94 | 0.4 | 0.00 |
| 2 | 5.08 | 72 | 22 | 4 | 10.16 | 241.4 | 1.66 | 0.8 | 0.01 |
| 2 | 5.08 | 72 | 22 | 300 | 762 | 265.0 | 1.83 | 9.0 | 0.06 |
| 2 | 5.08 | 200 | 93 | 0.05 | 0.13 | 257.0 | 1.77 | 3.9 | 0.03 |
| 2 | 5.08 | 200 | 93 | 4 | 10.16 | 187.4 | 1.29 | 1.2 | 0.01 |
| 2 | 5.08 | 200 | 93 | 300 | 762 | 241.5 | 1.66 | 10.1 | 0.07 |
| 2 | 5.08 | HHA[2] | | 0.05 | 0.13 | 194.4 | 1.34 | 0.5 | 0.00 |
| 2 | 5.08 | HHA | | 4 | 10.16 | 192.6 | 1.33 | 4.3 | 0.03 |
| 2 | 5.08 | HHA | | 300 | 762 | 250.9 | 1.73 | 8.2 | 0.06 |

[1] Specimens were conditioned at temperature 10 mins. prior to test for -65°F (-54°C) and 200°F (93°C), and 6 mins. for HHA tests.

2 HHA = 200°F (93°C) after 2 wks. @ 200°F + 95-100% Relative Humidity.

TABLE 12

HRH-10 CORE SHEAR STRENGTH BY BEAM SHEAR METHOD IN THE "W" DIRECTION

| Core Thickness | | Condition of Test[1] | | Testing Speed | | Ultimate Strength | | Standard Deviation | |
|---|---|---|---|---|---|---|---|---|---|
| (in.) | (cm) | (°F) | (°C) | (in/min) | (cm/min) | (psi) | (MPa) | (psi) | (MPa) |
| 2 | 5.08 | -65 | -54 | 0.05 | 0.13 | 142.2 | 0.98 | 1.1 | 0.01 |
| 2 | 5.08 | -65 | -54 | 4 | 10.16 | 117.8 | 0.81 | 5.4 | 0.04 |
| 2 | 5.08 | -65 | -54 | 300 | 762 | 180.7 | 1.26 | 5.4 | 0.04 |
| 2 | 5.08 | 72 | 22 | 0.05 | 0.13 | 147.0 | 1.01 | 4.2 | 0.03 |
| 2 | 5.08 | 72 | 22 | 4 | 10.16 | 113.7 | 0.78 | 3.1 | 0.02 |
| 2 | 5.08 | 72 | 22 | 300 | 726 | --- | --- | --- | --- |
| 2 | 5.08 | 200 | 93 | 0.05 | 0.13 | 106.5 | 0.73 | 3.4 | 0.02 |
| 2 | 5.08 | 200 | 93 | 4 | 10.16 | 103.8 | 0.72 | 2.7 | 0.02 |
| 2 | 5.08 | 200 | 93 | 300 | 762 | 152.8 | 1.05 | 3.2 | 0.02 |
| 2 | 5.08 | HHA[2] | | 0.05 | 0.13 | 127.0 | 0.88 | 2.1 | 0.01 |
| 2 | 5.08 | HHA | | 4 | 10.16 | 104.6 | 0.72 | 1.9 | 0.01 |
| 2 | 5.08 | HHA | | 300 | 762 | 143.3 | 0.99 | 4.0 | 0.03 |

[1] Specimens were conditioned at temperature 10 min. prior to test for -65°F (-54°C) and 200°F (93°C), and 6 mins. for HHA tests.

[2] HHA = 200°F (93°C) after 2 wks. @ 200°F (93°C) and 95-100% Relative Humidity.

TABLE 13

HRH-10 CORE SHEAR STRENGTH BY BEAM SHEAR METHOD IN THE "L" DIRECTION

| Core Thickness | | Condition of Test[1] | | Testing Speed | | Ultimate Strength | | Standard Deviation | |
|---|---|---|---|---|---|---|---|---|---|
| (in.) | (cm) | (°F) | (°C) | (in/min) | (cm/min) | (psi) | (MPa) | (psi) | (MPa) |
| 3 | 7.62 | -65 | -54 | 0.05 | 0.13 | 242.2 | 1.67 | 5.5 | 0.04 |
| 3 | 7.62 | -65 | -54 | 4 | 10.16 | 198.1 | 1.36 | 3.1 | 0.02 |
| 3 | 7.62 | -65 | -54 | 300 | 762 | 263.8 | 1.82 | 1.8 | 0.01 |
| 3 | 7.62 | 72 | 22 | 0.05 | 0.13 | 195.8 | 1.35 | 4.4 | 0.03 |
| 3 | 7.62 | 72 | 22 | 4 | 10.16 | 172.4 | 1.19 | 6.7 | 0.05 |
| 3 | 7.62 | 72 | 22 | 300 | 762 | 259.3 | 1.79 | 11.2 | 0.08 |
| 3 | 7.52 | 200 | 93 | 0.05 | 0.13 | 206.8 | 1.42 | 4.5 | 0.03 |
| 3 | 7.62 | 200 | 93 | 4 | 10.16 | 190.4 | 1.31 | 4.3 | 0.03 |
| 3 | 7.62 | 200 | 93 | 300 | 762 | 236.0 | 1.63 | 3.3 | 0.02 |
| 3 | 7.62 | HHA[2] | | 0.05 | 0.13 | 197.7 | 1.36 | 13.4 | 0.09 |
| 3 | 7.62 | HHA | | 4 | 10.16 | 183.5 | 1.26 | 9.2 | 0.06 |
| 3 | 7.62 | HHA | | 300 | 762 | 234.9 | 1.62 | 4.6 | 0.03 |

[1]Specimens were conditioned at temperature 10 mins. prior to test for -65°F (-54°C) and 200°F (93°C), and 6 mins. for HHA tests.

[2]200°F (93°C) after 2 wks. @ 200°F (93°C) and 95-100% Relative Humidity.

TABLE 14

HRH-10 CORE SHEAR STRENGTH BY BEAM SHEAR METHOD IN THE "W" DIRECTION

| Core Thickness | | Condition of Test[1] | | Testing Speed | | Ultimate Strength | | Standard Deviation | |
|---|---|---|---|---|---|---|---|---|---|
| (in.) | (cm) | (°F) | (°C) | (in/min) | (cm/min) | (psi) | (MPa) | (psi) | (MPa) |
| 3 | 7.62 | -65 | -54 | 0.05 | 0.13 | 147.9 | 1.02 | 6.2 | 0.04 |
| 3 | 7.62 | -65 | -54 | 4 | 10.16 | 118.4 | 0.82 | 2.1 | 0.01 |
| 3 | 7.62 | -65 | -54 | 300 | 762 | 171.6 | 1.18 | 6.0 | 0.04 |
| 3 | 7.62 | 72 | 22 | 0.05 | 0.13 | 137.2 | 0.95 | 4.7 | 0.03 |
| 3 | 7.62 | 72 | 22 | 4 | 10.16 | 113.1 | 0.78 | 1.9 | 0.01 |
| 3 | 7.62 | 72 | 22 | 300 | 762 | 156.7 | 1.08 | 0.7 | 0.00 |
| 3 | 7.62 | 200 | 93 | 0.05 | 0.13 | 117.9 | 0.81 | 1.8 | 0.01 |
| 3 | 7.62 | 200 | 93 | 4 | 10.16 | 112.2 | 0.77 | 2.4 | 0.02 |
| 3 | 7.62 | 200 | 93 | 300 | 762 | 149.7 | 1.03 | 1.5 | 0.01 |
| 3 | 7.62 | HHA[2] | | 0.05 | 0.13 | 117.7 | 0.81 | 0.1 | 0.00 |
| 3 | 7.62 | HHA | | 4 | 10.16 | 102.3 | 0.70 | 1.9 | 0.01 |
| 3 | 7.62 | HHA | | 300 | 762 | 140.0 | 0.96 | 8.9 | 0.06 |

[1] Specimens were conditioned at temperature 10 mins. prior to test for -65°F (-54°C) and 200°F (93°C), and 6 mins. for HHA tests.

[2] HHA = 200°F (93°C) after 2 wks. @ 200°F (93°C) and 95-100% Relative Humidity.

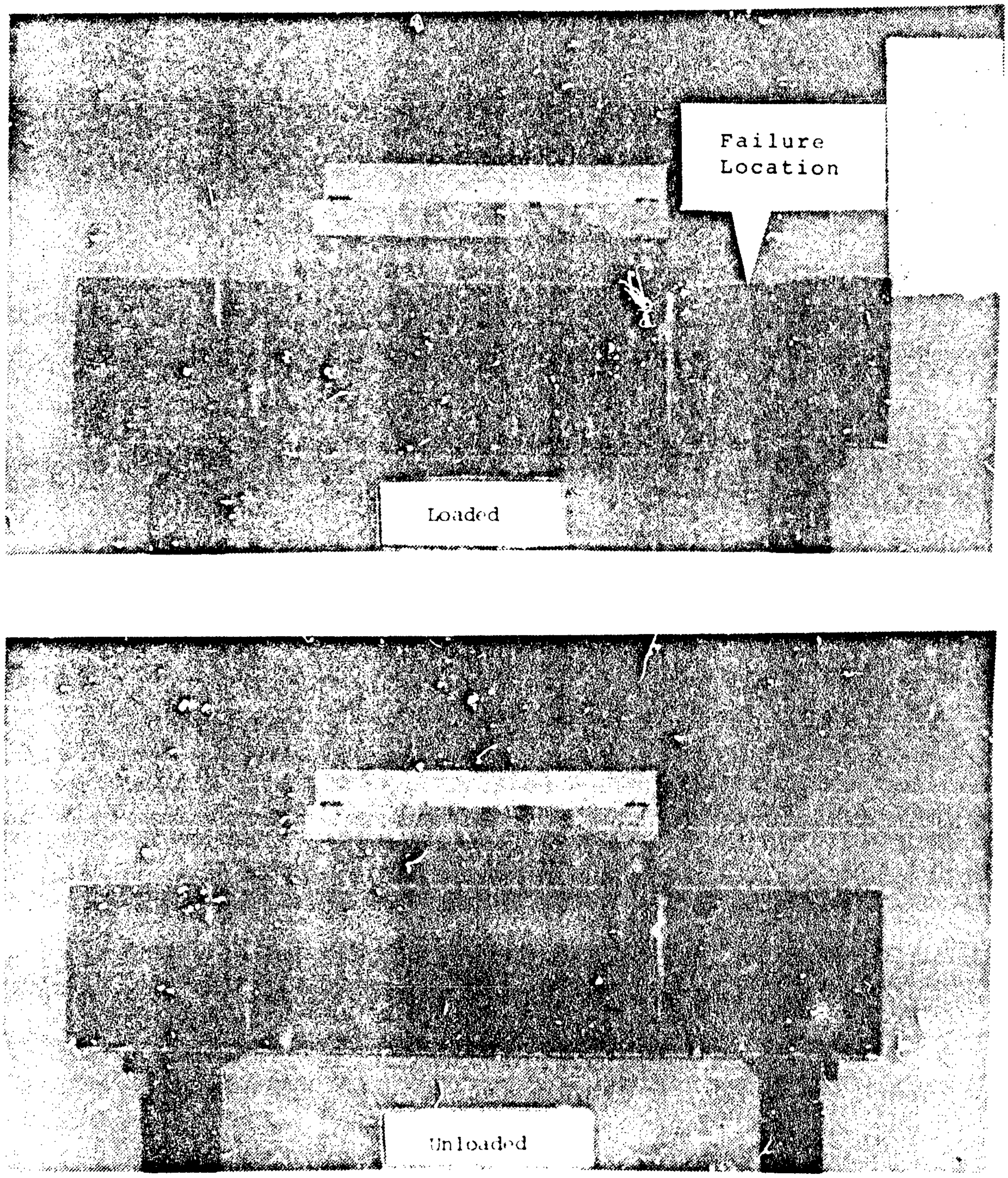


Figure 10 HRH-10 Specimen Under Load and With Load Removed.

TABLE 15

HRP CORE SHEAR STRENGTH BY BEAM SHEAR METHOD IN THE "L" DIRECTION

| Core Thickness (in.) | Core Thickness (cm) | Condition of Test[1] (°F) | Condition of Test[1] (°C) | Testing Speed (in/min) | Testing Speed (cm/min) | Ultimate Strength (psi) | Ultimate Strength (MPa) | Standard Deviation (psi) | Standard Deviation (MPa) |
|---|---|---|---|---|---|---|---|---|---|
| 1.5 | 3.81 | -65 | -54 | 0.05 | 0.13 | 270.5 | 1.86 | 11.5 | 0.08 |
| 1.5 | 3.81 | -65 | -54 | 4 | 10.16 | 207.7 | 1.43 | 9.2 | 0.06 |
| 1.5 | 3.81 | -65 | -54 | 300 | 762 | 293.4 | 2.02 | 11.2 | 0.08 |
| 1.5 | 3.81 | 72 | 22 | 0.05 | 0.13 | 264.8 | 1.82 | 7.0 | 0.05 |
| 1.5 | 3.81 | 72 | 22 | 4 | 10.16 | 211.2 | 1.46 | 1.8 | 0.01 |
| 1.5 | 3.81 | 72 | 22 | 300 | 762 | 289.4 | 1.99 | 19.3 | 0.13 |
| 1.5 | 3.81 | 200 | 93 | 0.05 | 0.13 | 246.8 | 1.70 | 3.4 | 0.02 |
| 1.5 | 3.81 | 200 | 93 | 4 | 10.16 | 206.9 | 1.43 | 7.2 | 0.05 |
| 1.5 | 3.81 | 200 | 93 | 300 | 762 | 271.5 | 1.87 | 17.5 | 0.12 |
| 1.5 | 3.81 | HHA[2] | | 0.05 | 0.13 | 220.1 | 1.52 | 10.8 | 0.07 |
| 1.5 | 3.81 | HHA | | 4 | 10.16 | 146.8 | 1.01 | 11.1 | 0.08 |
| 1.5 | 3.81 | HHA | | 300 | 762 | 281.1 | 1.94 | 11.7 | 0.08 |

[1] Specimens were conditioned at temperature 10 mins. prior to test for -65°F (-54°C) and 200°F (93°C), and 6 mins. for HHA tests.

[2] HHA = 200°F (93°C) after 2 wks. @ 200°F (93°C) and 95-100% Relative Humidity.

TABLE 16

HRP CORE SHEAR STRENGTH BY BEAM SHEAR METHOD IN THE "W" DIRECTION

| Core Thickness | | Condition of Test[1] | | Testing Speed | | Ultimate Strength | | Standard Deviation | |
|---|---|---|---|---|---|---|---|---|---|
| (in.) | (cm) | (°F) | (°C) | (in/min) | (cm/min) | (psi) | (MPa) | (psi) | (MPa) |
| 1.5 | 3.81 | -65 | -54 | 0.05 | 0.13 | 165.4 | 1.14 | 5.8 | 0.04 |
| 1.5 | 3.81 | -65 | -54 | 4 | 10.16 | 122.9 | 0.85 | 2.8 | 0.02 |
| 1.5 | 3.81 | -65 | -54 | 300 | 762 | 171.4 | 1.18 | 10.6 | 0.07 |
| 1.5 | 3.81 | 72 | 22 | 0.05 | 0.13 | 181.1 | 1.25 | 5.2 | 0.04 |
| 1.5 | 3.81 | 72 | 22 | 4 | 10.16 | 133.5 | 0.92 | 1.8 | 0.01 |
| 1.5 | 3.81 | 72 | 22 | 300 | 762 | 187.7 | 1.29 | 0.8 | 0.01 |
| 1.5 | 3.81 | 200 | 93 | 0.05 | 0.13 | 178.2 | 1.23 | 4.7 | 0.03 |
| 1.5 | 3.81 | 200 | 93 | 4 | 10.16 | 140.6 | 0.97 | 2.4 | 0.02 |
| 1.5 | 3.81 | 200 | 93 | 300 | 762 | 190.9 | 1.32 | 7.9 | 0.05 |
| 1.5 | 3.81 | HHA[2] | | 0.05 | 0.13 | 148.8 | 1.03 | 22.2 | 0.15 |
| 1.5 | 3.81 | HHA | | 4 | 10.16 | 128.4 | 0.88 | 7.8 | 0.05 |
| 1.5 | 3.81 | HHA | | 300 | 762 | 160.2 | 1.10 | 6.2 | 0.04 |

[1] Specimens were conditioned at temperature 10 mins. prior to test for -65°F (-54°C) and 200°F (93°C), and 6 mins. for HHA tests.

[2] HHA = 200°F (93°C) after 2 wks. @ 200°F (93°C) and 95-100% Relative Humidity.

TABLE 17

HTI CORE SHEAR STRENGTH BY BEAM SHEAR METHOD IN THE "L" DIRECTION
3.2 LBS FT$^3$ (51.3 Kg/m$^3$) DENSITY

| Core Thickness | | Condition of Test[1] | | Testing Speed | | Ultimate Strength | | Standard Deviation | |
|---|---|---|---|---|---|---|---|---|---|
| (in.) | (cm) | (°F) | (°C) | (in/min) | (cm/min) | (psi) | (MPa) | (psi) | (MPa) |
| 7/8 | 2.22 | -65 | -54 | 0.05 | 0.13 | 164.4 | 1.13 | 9.4 | 0.06 |
| 7/8 | 2.22 | -65 | -54 | 4 | 10.16 | 138.2 | 0.95 | 5.2 | 0.04 |
| 7/8 | 2.22 | 72 | 22 | 0.05 | 0.13 | 170.1 | 1.17 | 1.0 | 0.01 |
| 7/8 | 2.22 | 72 | 22 | 4 | 10.16 | 131.3 | 0.90 | 7.0 | 0.05 |
| 7/8 | 2.22 | 72 | 22 | 300 | 762 | 190.5 | 1.31 | 5.5 | 0.04 |
| 7/8 | 2.22 | 200 | 93 | 0.05 | 0.13 | 158.7 | 1.09 | 4.8 | 0.03 |
| 7/8 | 2.22 | 200 | 93 | 4 | 10.16 | 134.6 | 0.93 | 7.0 | 0.05 |
| 7/8 | 2.22 | 200 | 93 | 300 | 762 | 178.8 | 1.23 | 11.9 | 0.08 |
| 7/8 | 2.22 | HHA[2] | | 4 | 10.16 | 127.1 | 0.88 | 10.3 | 0.07 |
| 7/8 | 2.22 | HHA | | 300 | 762 | 155.1 | 1.07 | 3.1 | 0.02 |

[1] Specimens were conditioned at temperature 10 mins. prior to test for -65°F (-54°C) and 200°F (93°C), and 6 mins. for HHA tests.

[2] HHA = 200°F (93°C) after 2 wks. @ 200°F (93°C) and 95-100% Relative Humidity.

TABLE 18

HTP CORE SHEAR STRENGTH BY BEAM SHEAR METHOD IN THE "W" DIRECTION, 3.2 LBS/FT$^3$ (51.3 Kg/m$^3$) DENSITY

| Core Thickness | | Condition of Test | | Testing Speed | | Ultimate Strength | | Standard Deviation | |
|---|---|---|---|---|---|---|---|---|---|
| (in.) | (cm) | (°F) | (°C) | (in/min) | (cm/min) | (psi) | (MPa) | (psi) | (MPa) |
| 7/8 | 2.22 | 72 | 22 | 0.05 | 0.13 | 103.7 | 0.7 | 0.0 | 0.00 |
| 7/8 | 2.22 | 72 | 22 | 4 | 10.16 | 98.1 | 0.7 | 0.2 | 0.00 |
| 7/8 | 2.22 | 72 | 22 | 300 | 762 | 113.9 | 0.8 | 1.3 | 0.01 |
| 7/8 | 2.22 | 200 | 93 | 300 | 762 | 106.3 | 0.7 | 7.7 | 0.05 |
| 7/8 | 2.22 | HHA[2] | | 300 | 762 | 90.6 | 0.6 | 1.3 | 0.01 |

[1] Specimens were conditioned at temperature 10 mins. prior to test for -65°F (-54°C) and 200°F (93°C), and 6 mins. for HHA tests.

[2] HHA = 200°F (93°C) after 2 wks. @ 200°F (93°C) and 95-100% Relative Humidity.

TABLE 19

HTP CORE SHEAR STRENGTH BY BEAM SHEAR METHOD
4.5 LBS/FT$^3$ (72.1 kg/m$^3$) DENSITY

| Core Thickness | | Condition of Test[1] | | Testing Speed | | Ultimate Strength | | Standard Deviation | |
|---|---|---|---|---|---|---|---|---|---|
| (in.) | (cm) | (°F) | (°C) | (in/min) | (cm/min) | (psi) | (MPa) | (psi) | (MPa) |
| | | | | "L" Direction | | | | | |
| 7/8 | 2.22 | -65 | -54 | 300 | 762 | 349.5 | 2.40 | 3.7 | 0.03 |
| 7/8 | 2.22 | HHA[2] | | 0.05 | 0.13 | 180.2 | 1.20 | 11.7 | 0.08 |
| | | | | "W" Direction | | | | | |
| 7/8 | 2.22 | -65 | -54 | 0.05 | 0.13 | 171.7 | 1.18 | 8.4 | 0.06 |
| 7/8 | 2.22 | -65 | -54 | 4 | 10.16 | 157.4 | 1.08 | 6.2 | 0.04 |
| 7/8 | 2.22 | 200 | 93 | 0.05 | 0.13 | 182.8 | 1.26 | 7.0 | 0.05 |
| 7/8 | 2.22 | 200 | 93 | 4 | 10.16 | 168.1 | 1.16 | 2.9 | 0.02 |

[1] Specimens were conditioned at temperature 10 mins. prior to test for -65°F (-54°C) and 200°F (93°C), and 6 mins. for HHA tests.

[2] HHA = 200°F (93°C) after 2 wks. @ 200°F (93°C) and 95-100% Relative Humidity.

was not the case for either the HRP or HTP cores over the temperature range utilized in this study. Very little or no change in strength was observed for either the HRP or HTP core over the temperature range of -65°F (-54°C) to 200°F (93°C). Also, these core materials appeared to be only slightly affected, if at all, by the high humidity and elevated temperature condition.

All of the HRP and HTP specimens failed in core shear. Like the HRH-10 core, and unlike the WR-II core, the failures were visible only when the specimens were under load.

As mentioned previously, the HRP and HTP core materials, were added late in the program. Unfortunately, not enough HRP or HTP core was supplied to carry out the entire test matrix listed in Table 2.

### 4.2.4 Balsa Core Shear

End-grain balsa was supplied in thicknesses of 1/2, 1, and 2 inches (.27, 2.54, and 5.08 cm). Test results for the balsa can be directly compared to the data obtained for WR-II and HRH-10 honeycomb for the 1/2 and 2 inch (1.27 and 5.08 cm) thicknesses. Tables 20 and 21 present the data for these three core materials at various test conditions. Data are presented for both the "L" and "W" directions for the honeycomb cores. Since end-grain balsa is non-directional; that is, it will have the same shear strength, or nearly so, regardless of the direction at which the specimens are cut from the panels; it was tested in only one direction. Further, the balsa core was tested at only one test speed, 0.05 in/min (0.13 cm/min).

Examination of the data in Tables 20 and 21 indicates that the balsa core exhibits shear strengths approximately 75% greater than HRH-10 honeycomb in the "L" direction and approximately 100% greater than that obtained with WR-II honeycomb in the "L" direction. When the balsa shear strength is compared to that for the "W" direction of the two honeycomb materials, the differences are even greater, with the balsa strength about

TABLE 20

CORE SHEAR STRENGTH OF 1/2 INCH (1.27 CM) THICK CORE

| Core Material | Test Direction | Test Condition[1] | | Ultimate Strength | | Standard Deviation | |
|---|---|---|---|---|---|---|---|
| | | °F | °C | psi | MPa | psi | MPa |
| WR-II | L | -65 | -54 | 391 / | 2.70 | 6.7 | 0.05 |
| WR-II | W | -65 | -54 | 206.2 | 1.42 | 12.5 | 0.09 |
| HRH-10 | L | -65 | -54 | 480.5 | 3.31 | 5.4 | 0.04 |
| HRH-10 | W | -65 | -54 | 223.8 | 1.54 | 2.9 | 0.02 |
| Balsa | N.A. | -65 | -54 | 630.8 | 4.35 | 6.3 | 0.04 |
| WR-II | L | 72 | 22 | 334.6 | 2.31 | 20.5 | 0.14 |
| WR-II | W | 72 | 22 | 175.6 | 1.21 | 3.6 | 0.02 |
| HRH-10 | L | 72 | 22 | 420.7 | 2.90 | 61.6 | 0.43 |
| HRH-10 | W | 72 | 22 | 202.9 | 1.40 | 2.8 | 0.02 |
| Balsa | N.A. | 72 | 22 | 729.3 | 5.02 | 61.2 | 0.42 |
| WR-II | L | 200 | 93 | 241.7 | 1.67 | 8.7 | 0.06 |
| WR-II | W | 200 | 93 | 101.6 | 0.70 | 1.6 | 0.01 |
| HRH-10 | L | 200 | 93 | 306.8 | 2.11 | 13.4 | 0.09 |
| HRH-10 | W | 200 | 93 | 167.2 | 1.15 | 2.9 | 0.02 |
| Balsa | N.A. | 200 | 93 | 554.3 | 3.82 | 26.0 | 0.18 |
| WR-II | L | HHA[2] | | 178.9 | 1.23 | 5.6 | 0.04 |
| WR-II | W | HHA | | 115.8 | 0.80 | 5.4 | 0.04 |
| HRH-10 | L | HHA | | 172.4 | 1.19 | 15.0 | 0.10 |
| HRH-10 | W | HHA | | 170.6 | 1.18 | 1.5 | 0.01 |
| Balsa | N.A. | HHA | | 303.6 | 2.09 | 38.1 | 0.26 |

[1] Specimens were conditioned at temperature 10 mins. prior to test for -65°F (-54°C) and 200°F (93°C), and for 6 mins. for HHA tests.

[2] HHA = 200°F (93°C) after 2 wks. @ 200°F (93°C) and 95-100% relative humidity.

TABLE 21

CORE SHEAR STRENGTH OF 2 INCH (5.08 CM) THICK CORE

| Core Material | Test Direction | Test Condition[1] | | Ultimate Strength | | Standard Deviation | |
|---|---|---|---|---|---|---|---|
| | | °F | °C | psi | MPa | psi | MPa |
| WR-II | L | -65 | -54 | 248.7 | 1.71 | 12.2 | 0.08 |
| WR-II | W | -65 | -54 | 154.7 | 1.07 | 9.5 | 0.07 |
| HRH-10 | L | -65 | -54 | 294.5 | 2.03 | 6.0 | 0.04 |
| HRH-10 | W | -65 | -54 | 142.2 | 0.98 | 1.1 | 0.01 |
| Balsa | N.A. | -65 | -54 | 505.7 | 3.48 | 106.3 | 0.07 |
| WR-II | L | 72 | 22 | 213.2 | 1.47 | 15.6 | 0.11 |
| WR-II | W | 72 | 22 | 140.0 | 0.96 | 2.2 | 0.02 |
| HRH-10 | L | 72 | 22 | 281.5 | 1.94 | 0.4 | 0.00 |
| HRH-10 | W | 72 | 22 | 147.0 | 1.01 | 4.2 | 0.03 |
| Balsa | N.A. | 72 | 22 | 495.2 | 3.41 | 116.8 | 0.80 |
| WR-II | L | 200 | 93 | 187.1 | 1.29 | 2.4 | 0.02 |
| WR-II | W | 200 | 93 | 98.6 | 0.68 | 4.6 | 0.03 |
| HRH-10 | L | 200 | 93 | 257.0 | 1.77 | 3.9 | 0.03 |
| HRH-10 | W | 200 | 93 | 106.5 | 0.73 | 3.4 | 0.02 |
| Balsa | N.A. | 200 | 93 | 413.7 | 2.85 | 69.2 | 0.48 |
| WR-II | L | HHA[2] | | 138.0 | 0.95 | 1.7 | 0.01 |
| WR-II | W | HHA | | 56.7 | 0.39 | 2.5 | 0.02 |
| HRH-10 | L | HHA | | 194.4 | 1.34 | 0.5 | 0.00 |
| HRH-10 | W | HHA | | 127.0 | 0.88 | 2.1 | 0.01 |
| Balsa | N.A. | HHA | | 308.6 | 2.13 | 16.6 | 0.11 |

[1]Specimens were conditioned at temperature 10 mins. prior to test for -65°F (-54°C) and 200°F (93°C), and 6 mins. for HHA tests.

[2]HHA = 200°F (93°C) after 2 wks. @ 200°F (93°C) and 95-100% Relative Humidity.

triple that of the HRH-10, and quadruple that of the WR-II. The data also indicates that balsa is generally affected by test temperature and environmental conditions in the same manner as the honeycomb cores. That is, the core shear strength decreases both as temperature increases and by humidity aging. Also, as the thickness increases, the apparent core shear strength decreases.

Although end-grain balsa exhibited a considerably greater shear strength than either WR-II or HRH-10 honeycomb material, it also has a much greater density. If the density is taken into consideration, and specific shear strength valles computed (shear strength ÷ density), the advantage of balsa core becomes less evident. In fact, the specific strength of honeycomb core in the "L" direction is slightly higher than that of the balsa core. In the "W" direction on the other hand, the honeycomb core does exhibit a significantly lower specific shear strength than the isotropic balsa core. Table 22 lists specific[1] core shear strength data for the three materials listed in Tables 20 and 21 (honeycomb "L" direction only). Figure 11 graphically compares the specific core shear strength of the balsa with the honeycomb materials in the "L" direction.

End-grain balsa was also tested in a 1 inch (2.54 cm) thickness. Specimens of this core thickness were tested with both aluminum and Kevlar skins. Table 23 presents the data obtained for 1 inch (2.54 cm) core and both skin types. For both types of skin, the test temperature and environmental conditions have the same effect on core shear strength as observed for the honeycomb and balsa materials in Tables 20 and 21. The core shear strengths obtained with Kevlar skins are greater than those obtained with the aluminum skin, but this is probably an effect of skin thickness. The aluminum skins were 0.040 inch (0.1 cm) thick while the Kevlar skins were 0.145 inch (0.37 cm) thick.

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[1] Normalized by density.

TABLE 22

SPECIFIC CORE SHEAR STRENGTH SUMMARY

| Core Material | Core Density (pcf)[2] | Core Thickness (in) | Test Temperature (°F) [°C] | Shear Strength[1] (psi)[3] | Specific Shear Strength (psi/pcf) |
|---|---|---|---|---|---|
| WR-II | 3.8 | 1/2 | (-65) [-54) | 391.7 | 103 |
| | | | (72) [22] | 334.6 | 88 |
| | | | (200) [93] | 241.7 | 64 |
| | | | HHA[4] | 178.9 | 47 |
| HRH-10 | 4.8 | 1/2 | (-65) [-54] | 480.5 | 100 |
| | | | (72) [22] | 420.7 | 88 |
| | | | (200) [93] | 306.8 | 64 |
| | | | HHA[4] | 172.4 | 36 |
| Balsa | 8.6 | 1/2 | (-65) [-54] | 630.8 | 73 |
| | | | (72) [22] | 729.3 | 85 |
| | | | (200) [93] | 554.3 | 64 |
| | | | HHA[4] | 303.6 | 35 |
| WR-II | 3.8 | 2 | (-65) [54] | 248.7 | 65 |
| | | | (72) [22] | 213.2 | 56 |
| | | | (200) [93] | 187.1 | 49 |
| | | | HHA[4] | 138.0 | 36 |
| HRH-10 | 4.8 | 2 | (-65) [-54] | 294.5 | 61 |
| | | | (72) [22] | 281.5 | 59 |
| | | | (200) [93] | 257.0 | 54 |
| | | | HHA[4] | 194.4 | 41 |
| Balsa | 8.6 | 2 | (-65) [-54] | 505.7 | 59 |
| | | | (72) [22] | 495.2 | 58 |
| | | | (200) [93] | 413.7 | 48 |
| | | | HHA[4] | 308.6 | 36 |

[1] For honeycomb core this value is for the "L" direction.

[2] PCF = pounds per cubic foot.

[3] psi = pounds per square inch.

[4] HHA = hot humid aging, tested at 200°F (93°C) after two weeks aging at 120°F (49°C) and 95-100% relative humidity.

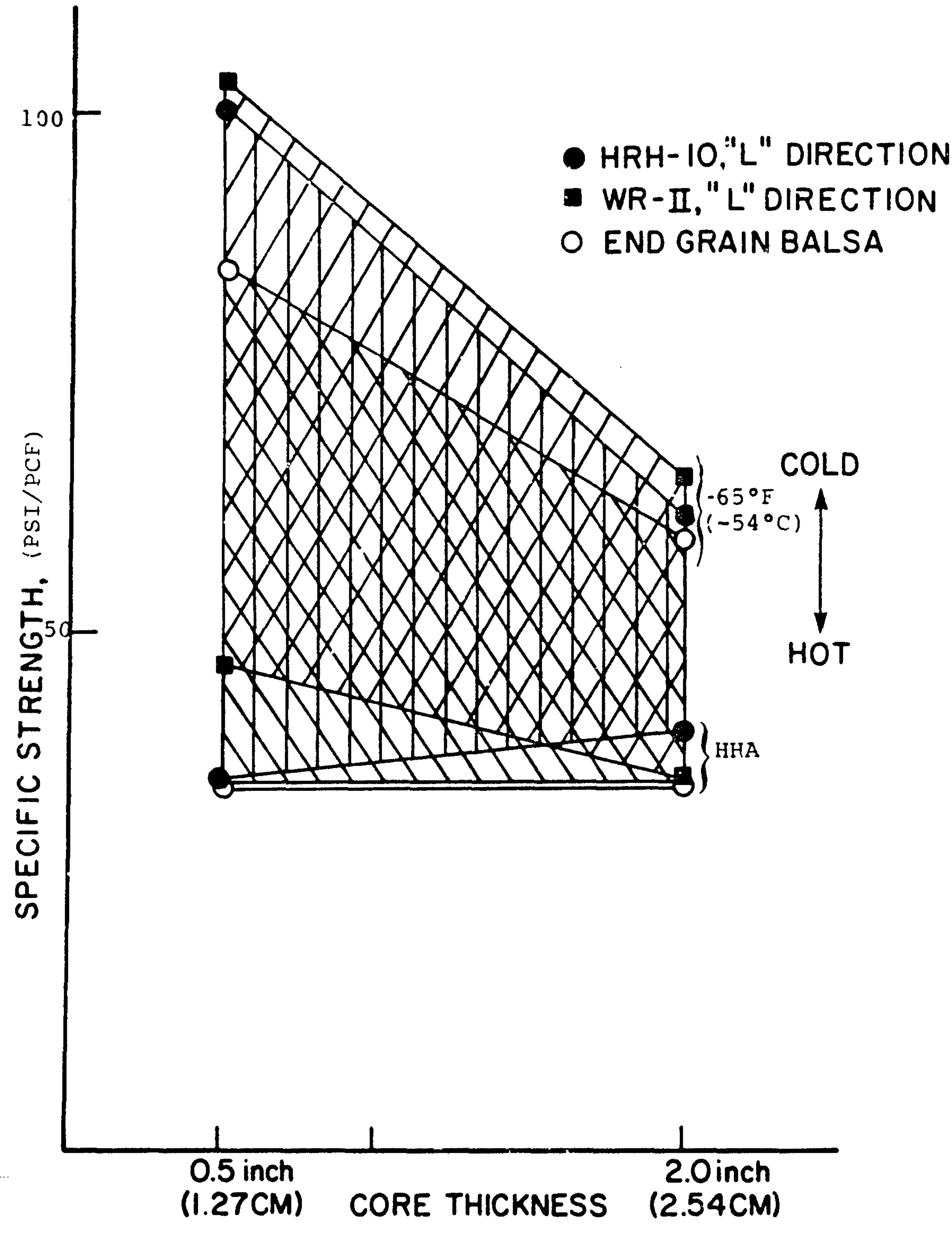


Figure 11. Specific Core Shear Strength.

TABLE 23

BEAM SHEAR RESULTS FOR 1 INCH (2.54 CM) THICK CORE

| Core Material | Skin Material | Test Condition | | Ultimate Strength | | Standard Deviation | |
|---|---|---|---|---|---|---|---|
| | | °F | °C | psi | MPa | psi | MPa |
| Balsa | Aluminum[1] | -65 | -54 | 617.3 | 4.25 | 6.1 | 0.04 |
| Balsa | Kevlar[2] | -65 | -54 | 571.9 | 3.94 | 92.5 | 0.64 |
| Balsa | Aluminum | 72 | 22 | 538.8 | 3.71 | 16.8 | 0.12 |
| Balsa | Kevlar | 72 | 22 | 737.3 | 5.08 | 11.0 | 0.08 |
| Balsa | Aluminum | 200 | 93 | 381.3 | 2.63 | 49.1 | 0.34 |
| Balsa | Kevlar | 200 | 93 | 638.1 | 4.40 | 97.8 | 0.67 |
| Balsa | Aluminum | HHA[3] | | 283.3 | 1.95 | 39.0 | 0.27 |
| Balsa | Kevlar | HHA | | 293.5 | 2.02 | 16.4 | 0.11 |

[1]Aluminum skins were 0.040 inch (0.1 cm) 6061-T6 bare.

[2]Kevlar skins were approximately 0.145 inch (0.37 cm) thick.

[3]HHA = 200°F (93°C) after 2 wks. @ 200°F (93°C) and 95-100% relative humidity.

## 4.3 PLATE VS. BEAM SHEAR TEST RESULTS

The last objective of the program was to determine if plate and beam shear yielded equivalent results. While only a limited amount of data was generated using plate shear, it appears to be enough to for a reasonable conclusion. Table 24 presents data which were obtained using both test methods for 1/2 and 2 inch (1.27 and 5.08 cm) HRH-10 honeycomb core in the "L" direction. The test speed was 0.05 in/min (0.13 cm/min) for all tests. In all cases the results obtained using the beam test method are higher (by 8-30%) than those obtained using the plate test method. This is consistent with results obtained by other investigators[1].

[1] Hexcel brochure TSB120, 1979.

TABLE 24

COMPARISON OF PLATE SHEAR VS.
BEAM SHEAR TEST RESULTS

| Test Condition[1] | | HRH-10, 1/2 inch (1.27 cm)[2] | | | | HRH-10, 2 inch (5.08 cm)[2] | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Plate | | Beam | | Plate | | Beam | |
| (°F) | (°C) | (psi) | (MPa) | (psi) | (MPa) | (psi) | (MPa) | (psi) | (MPa) |
| -65 | -54 | 365.6 | 2.52 | 480.5 | 3.31 | --- | --- | 294.5 | 2.03 |
| 72 | 22 | 333.5 | 2.30 | 420.7 | 2.90 | 261.1 | 1.80 | 281.5 | 1.94 |
| 200 | 93 | 285.3 | 1.97 | 306.8 | 2.11 | 218.2 | 1.81 | 257.0 | 1.77 |

[1]Specimens were conditioned at temperature 10 mins. prior to test for -65°F (-54°C) and 200°F (93°C), and 6 mins. for HHA tests. All tests were conducted at 0.05 in/min (0.13 cm/min).

[2]All data is for "L" direction.

## SECTION 5
## SUMMARY OF RESULTS

### 5.1 CORE SHEAR STRENGTH VS. TEST SPEED

Probably the most important objective of the program was to determine the effect of testing speed on core shear strengths. Examination of the data presented in Sections 4.1-4.2 indicates there is relatively little effect on honeycomb core shear strength due to test speed. To illustrate this point, all of the beam shear data accumulated for WR-II and HRH-10 core are summarized and presented in Table 25. For each testing speed, the core shear strengths for each of the four test conditions are averaged. In all cases the core shear strength is lower at 4 in/min (10.16 cm/min) than that at 0.05 in/min (0.13 cm/min); while at 300 in/min (762 cm/min) the strength is equal to or greater than that at 0.05 in/min (0.13 cm/min).

### 5.2 TEST MACHINE VARIATION VS. BEAM SHEAR STRENGTH

As mentioned previously (Section 4.2.1) shear tests were performed on two test machines. A Baldwin Universal Test Machine was used for 0.05 and 4 inches/min (0.13 and 10.16 cm/min), and an MTS machine was used for tests at 300 in/min (762 cm/min). Upon examination of the test data, it was noted that the core shear strength decreased as the test speed increased from 0.05 in/min (0.13 cm/min) to 4 in/min (10.16 cm/min), and then increased as the test speed was increased from 4 in/min (10.16 cm/min) to 300 in/min (762 cm/min). It seemed appropriate to determine if this behavior was due to testing machine variation. One of the test speeds (4 in/min) could easily be duplicated on both test machines. Beam shear specimens were consequently prepared using both HRH-10 and WR-II honeycomb core. Each type was tested at 4 in/min (10.16 cm/min) on both test machines. The results for the HRH-10 core indicate somewhat higher shear strengths were obtained at this test speed on the MTS machine than on the Baldwin machine. With the WR-II core, however, the

TABLE 25

AVERAGE[1] HONEYCOMB CORE SHEAR STRENGTH VS. TEST SPEED

| Test Speed | | 1/2 inch (1.27 cm) | | | | 2 inch (5.08 cm) | | | | 3 inch (7.62 cm) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | "L" | | "W" | | "L" | | "W" | | "L" | | "W" | |
| (in/min) | (cm/min) | (psi) | (MPa) | (psi) | (MPa) | (psi) | (MPa) | (psi) | (MPa) | (psi) | (MPa) | (psi) | (MPa) |
| **WR-II Core** | | | | | | | | | | | | | |
| 0.05 | 0.13 | 287 | 1.97 | 150 | 1.03 | 197 | 1.36 | 113 | 0.78 | --- | --- | --- | --- |
| 4 | 10.16 | 231 | 1.59 | 131 | 0.90 | 154 | 1.06 | 90 | 0.62 | --- | --- | --- | --- |
| 300 | 726 | 287 | 1.97 | 167 | 1.15 | 216 | 1.49 | 116 | 0.80 | --- | --- | --- | --- |
| **HRH-10 Core** | | | | | | | | | | | | | |
| 0.05 | 0.13 | 345 | 2.37 | 191 | 1.32 | 257 | 1.77 | 131 | 0.90 | 211 | 1.45 | 130 | 0.89 |
| 4 | 10.16 | 325 | 2.24 | 175 | 1.27 | 218 | 1.50 | 110 | 0.76 | 186 | 1.28 | 111 | 0.76 |
| 300 | 762 | 415 | 2.86 | 191 | 1.32 | 267 | 1.84 | 158 | 1.09 | 249 | 1.72 | 155 | 1.07 |

[1]*Average of four test conditions:*

(a) -65°F (-54°C)
(b) 72°F (22°C)
(c) 200°F (93°C)
(d) HHA

results are reversed, with the MTS machine producing the lower strengths. This variation was felt to be within the normal scatter range of material, processing, and test machine variables and indicates that the results are probably not significantly influenced by the type test machine used. The results obtained from these tests are presented in Table 26. No other plausible reasons for the test speed anamoly can be offered.

## 5.3 HONEYCOMB CORE SHEAR STRENGTH VS. TEST CONDITION

Another important objective of the program was to determine the effect of temperature and environmental exposure upon the shear strength of the honeycomb and balsa cores. Table 27 summarizes the data for all test speeds vs. the test condition. In nearly all cases, the shear strength for the WR-II core is reduced as the test temperature is increased and is further reduced after humidity aging. The HRH-10 honeycomb core is similarly affected by the test temperature as well as humidity aging, although to a lesser degree than WR-II core. Although there is less data to compare, the HTP and HRP honeycomb cores are considerably less affected by these temperatures than either the WR-II or HRH-10 core with the results being nearly equivalent for all three test temperatures used in this program. Also, while the core shear strength of the HRP and HTP cores is slightly reduced for the hot, humid aging condition, the effect is far less than in the case of the WRI-II and HRH-10 cores. The end-grain balsa core is affected by test temperature and humidity in a manner similar to the WR-II and HRH-10 cores. In nearly all cases, the shear strength decreases with increasing temperature; and is even further reduced after humidity aging.

TABLE 26

EFFECT OF TEST MACHINE TYPE ON BEAM SHEAR STRENGTH

| Type Core | Test Machine | Test Speed | | Beam Shear "L" | | Beam Shear "W" | |
|---|---|---|---|---|---|---|---|
| | | (in/min) | (cm/min) | (psi) | (MPa) | (psi) | (MPa) |
| HRH-10, 1/2 inch (1.27 cm) | Baldwin | 4 | 10.16 | 328 | 2.26 | 173 | 1.19 |
| HRH-10, 1/2 inch (1.27 cm) | MTS | 4 | 10.16 | 404 | 2.78 | 205 | 1.41 |
| WR-II, 2 inch (5.08 cm) | Baldwin | 4 | 10.16 | 271 | 1.87 | 143 | 0.99 |
| WR-II, 2 inch (5.08 cm) | MTS | 4 | 10.16 | 202 | 1.39 | 129 | 0.89 |

TABLE 27

EFFECT OF TEST CONDITION ON HONEYCOMB CORE SHEAR STRENGTH[1]

| Test Condition | | 1/2 inch (1.27 cm) WR-II | | | | 2 inch (5.08 cm) WR-II | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | "L" | | "W" | | "L" | | "W" | |
| (°F) | (°C) | (psi) | (MPa) | (psi) | (MPa) | (psi) | (MPa) | (psi) | (MPa) |
| -65 | -54 | 347 | 2.39 | 190 | 1.31 | 211 | 1.45 | 138 | 0.95 |
| 72 | 22 | 337 | 2.32 | 169 | 1.16 | 233 | 1.61 | 124 | 0.85 |
| 200 | 93 | 228 | 1.57 | 125 | 0.86 | 165 | 1.14 | 90 | 0.62 |
| HHA[2] | | 160 | 1.10 | 112 | 0.77 | 145 | 1.00 | 73 | 0.50 |

| Test Condition | | 1/2 inch (1.27 cm) HRH-10 | | 2 inch (5.08 cm) HRH-10 | | 3 inch (7.62 cm) HRH-10 | |
|---|---|---|---|---|---|---|---|
| (°F) | (°C) | "L" | "W" | "L" | "W" | "L" | "W" |
| -65 | -54 | 445 psi (3.07 MPa) | 215 psi (1.48 MPa) | 286 psi (1.97 MPa) | 147 psi (1.01 MPa) | 235 psi (1.62 MPa) | 146 psi (1.01 MPa) |
| 72 | 22 | 396 psi (2.73 MPa) | 191 psi (1.32 MPa) | 263 psi (1.81 MPa) | 131 psi (0.90 MPa) | 209 psi (1.44 MPa) | 136 psi (0.94 MPa) |
| 200 | 93 | 328 psi (2.26 MPa) | 176 psi (1.21 MPa) | 229 psi (1.58 MPa) | 121 psi (0.83 MPa) | 211 psi (1.45 MPa) | 127 psi (0.88 MPa) |
| HHA[2] | | 277 psi (1.91 MPa) | 161 psi (1.11 MPa) | 213 psi (1.47 MPa) | 125 psi (0.86 MPa) | 206 psi (1.42 MPa) | 120 psi (0.83 MPa) |

[1] Average of three test speeds unless otherwise noted

[2] HHA = 200°F (93°C) after 2 wks. @ 200°F (93°C) and 95-100% Relative Humidity

TABLE 27 (cont'd.)

EFFECT OF TEST CONDITION ON HONEYCOMB CORE SHEAR STRENGTH[1]

| Test Condition | | 7/8 inch (2.22 cm) HTP | | | | 1.5 inch (3.81 cm) HRP | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | "L" | | "W" | | "L" | | "W" | |
| (°F) | (°C) | (psi) | (MPa) | (psi) | (MPa) | (psi) | (MPa) | (psi) | (MPa) |
| -65 | -54 | 151.3[3] | 1.04 | --- | --- | 257.2 | 1.77 | 153.2 | 1.06 |
| 72 | 22 | 164.0 | 1.13 | 105.2 | 0.72 | 255.1 | 1.76 | 167.4 | 1.15 |
| 200 | 93 | 157.4 | 1.08 | 106.3[4] | 0.73 | 241.7 | 1.67 | 169.9 | 1.17 |
| HHA[2] | | 141.4[3] | 0.97 | 90.6[4] | 0.62 | 216.0 | 1.49 | 145.8 | 1.00 |

| Test Condition | | 1/2 inch (1.27cm) Balsa-Alum Skin | | 1 inch (2.54cm) Balsa-Alum Skin | | 2 inch (5.08cm) Balsa-Alum Skin | | 1 inch (2.54cm) Balsa-Kevlar Skin | |
|---|---|---|---|---|---|---|---|---|---|
| (°F) | (°C) | (psi) | (MPa) | (psi) | (MPa) | (psi) | (MPa) | (psi) | (MPa) |
| -65 | -54 | 630.8[4] | 4.35 | 617.3[4] | 4.25 | 505.7[4] | 3.48 | 571.9[4] | 3.94 |
| 72 | 22 | 729.3[4] | 5.02 | 538.8[4] | 3.71 | 445.2[4] | 3.41 | 737.3[4] | 5.08 |
| 200 | 93 | 554.3[4] | 3.82 | 381.3[4] | 2.63 | 413.7[4] | 2.85 | 638.1[4] | 4.40 |
| HHA[2] | | 303.6[4] | 2.09 | 283.3[4] | 1.95 | 308.6[4] | 2.13 | 293.5[4] | 2.02 |

[1]Average of three test speeds unless otherwise noted.

[2]HHA = 200°F (93°C) after 2 wks. @ 200°F (93°C) and 95-100% Relative Humidity.

[3]Average of two test speeds.

[4]One test speed only.

## SECTION 6
## CONCLUSIONS

Honeycomb core shear specimens were prepared and tested using five types of core materials, two type test methods, four test conditions, three test speeds, and several core thicknesses. The following is a list of conclusions or observations which summarize the results obtained:

- The measured shear strengths appear to be unaffected by test speed;

- Shear strengths measured using the beam method are slightly higher than those measured by the plate method;

- The apparent core shear strength goes down as core thickness goes up for all test speeds, all test conditions, and all materials tested;

- For all core materials tested, core shear strength decreases as test temperature increases, with humidity aging further reducing the core shear strength;

- Although data are limited, it appears that glass/phenolic cores (HRP and HTP) are less affected by temperature and humidity than paper (WR-II), Nomex (HRH-10), and end grain balsa cores.

- While end grain balsa has a significantly higher core shear strength than the other four core materials tested, the specific strengths (strength ÷ density) of the various different core materials are nearly equal if balsa is compared to "L" direction honeycomb properties.

- End grain balsa does have the advantage of being non-directional, so that on a specific strength basis, the "W" direction shear properties of the four types of honeycomb core tested are significantly lower than that of end-grain balsa.



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