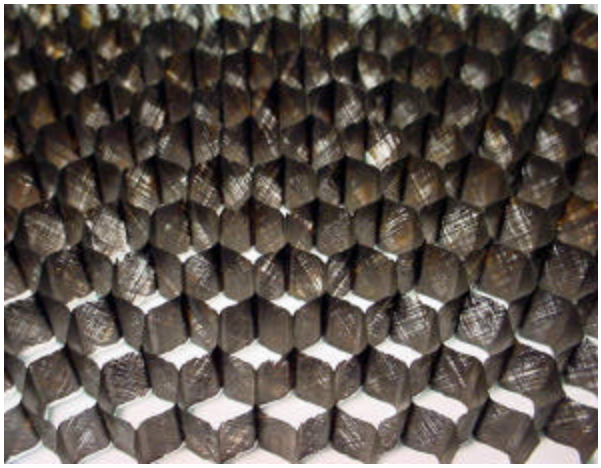
Flatwise Compression
L-Shear
Flatwise Tensile
Characteristics of
Lightweight Carbon Honeycomb Core



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ASTM Specifications: C273, C365, & C297

Ultracor Identifications
UCF-145-3/8-0.8, (±30°)
UCF-146-3/8-0.8, (±45°)
UCF-157-3/8-0.8, (±25°)

ABSTRACT

This report will describe the compressive, shear, and tensile properties of 0.8 lb/ft^3 Carbon honeycomb core. The honeycomb produced by Ultracor Incorporated is composed of YSH-70A fibers and a space qualified cyanate ester resin. The extremely low-density carbon honeycomb is the lightest honeycomb commercially available to the aerospace community. It is expected that this honeycomb material will be used in satellite solar arrays and other lightly loaded structures where weight, stability, and thermal conductivity are critical.

A number of tests were performed to determine the mechanical properties of the honeycomb core at various fiber orientations (±25°, ±30° & ±45°). Multiple honeycomb blocks of the same orientation were constructed to verify the testing results. The fiber orientation of ±30° was found to be optimal for both compressive and shear properties. Improvements were found in compressive data by using round specimens. Flatwise tensile properties were later determined as well.

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TABLE OF CONTENTS

1.0 INTRODUCTION

This report will discuss recent experiences with lightweight carbon honeycomb core in various fiber orientations (±25°, ±30° & ±45°), and in particular some of the data that has been assembled to document the properties of honeycomb shear in the ribbon (L) direction, honeycomb compression in the thickness (Z) direction, and flatwise tensile (FWT) properties. The honeycomb is composed of carbon pitch based fiber YSH-70A and a space qualified cyanate ester resin, RS-3.

To characterize the mechanical properties of the HC, a series of mechanical tests were performed. The mechanical properties investigated include core shear properties in the L-direction, stabilized flatwise compression properties, and flatwise tensile properties.

The test date, quantity, dimension, slice number, and orientation of each lot are specified in the following Table 1.1, 1.2 and 1.3.

Table 1.1: *Flatwise Compression (FWC) Test Matrix*

Test Date	Specimens Tested	Specimens Size (nominal)	Slice/Block Number	Orientation	Preparation	Specification
11/28/2000	5	3" x 3"	0486-06	±25°	As Received	ASTM C365
11/28/2000	5	3" x 3"	0487-06	±30°	As Received	ASTM C365
12/7/2000	4	4" Diam.	0487-10 & 12	±30°	As Received	ASTM C365
1/16/2001	2	4" Diam.	0491-08	±45°	Post Cured	ASTM C365
1/16/2001	2	4" Diam.	0487-02	±30°	Post Cured	ASTM C365

Table 1.2: *L-Shear Test Matrix*

Test Date	Specimens Tested	Specimens Size (nominal)	Slice/Block Number	Orientation	Preparation	Specification
12/13/2000	5	2" x 6"	0487	±30°	As Received	ASTM C273
12/15/2000	2	2" x 6"	0487	±30°	Post Cured	ASTM C273
12/15/2000	5	2" x 6"	0490-08 & 11	±45°	As Received	ASTM C273
12/19/2000	3	2" x 6"	0490-09	±45°	Post Cured	ASTM C273
12/19/2000	2	2" x 6"	0490-07	±45°	As Received	ASTM C273
12/19/2000	2	2" x 6"	0486-02	±25°	As Received	ASTM C273
12/21/2000	3	2" x 6"	0491-05 & 06	±45°	As Received	ASTM C273
12/28/2000	2	2" x 6"	0487-03	±30°	Plasma Treated	ASTM C273
12/28/2000	3	2" x 6"	0490-03	±45°	Plasma Treated	ASTM C273
1/22/2001	3	2" x 6"	0490-06	±45°	5% Resin Dipped	ASTM C273
1/22/2001	3	2" x 6"	0490-05	±45°	10% Resin Dipped	ASTM C273
1/22/2001	3	2" x 6"	0490-10	±45°	15% Resin Dipped	ASTM C273

Table 1.3: *Flatwise Tensile (FWT) Test Matrix*

Test Date	Specimens Tested	Specimens Size (nominal)	Slice/Block Number	Orientation	Preparation	Specification
03/06/2001	5	2" x 2"	0508-13	±30°	As Received	ASTM C297

2.0 EXPERIMENTAL METHODS

Five test blocks and three different orientations were constructed at Ultracor. Each block was measured and weighed to determine the density. The blocks were then sawed into 0.500" thick slices for testing and evaluation. Each test specimens were cut with scissors from the slices. Table 1.1 and 1.2 indicate which specimen was plasma treated, which was postcured, and which was tested as received. All specimens were identified with Ultracor's own unique identification number (Product ID + slice number + serial number). This enabled easy tracking of the specimen location with respect to slice/block. The specimens were then measured and entered into a spreadsheet.

Figure 2.1: *Stabilized Flatwise Compression Specimens (4" Diam.)*

Test specimen configurations were as specified in the respective test specifications. Stabilized flatwise compression (FWC) specimens were cut to a size of 3" x 3" per ASTM C365. Stabilized FWC were also cut to a size of 4" diameter to reduce edge effects during testing. Figure 2.1 shows typical specimen configurations. The core shear specimens were cut to a size of a minimum 2" x 6" per ASTM C273. The FWT specimens were cut to a size of 2" x 2" per ASTM C297. Stabilized FWC specimens were bonded with epoxy film adhesives to aluminum faceskins. Shear specimens and FWT specimens were directly bonded with epoxy film adhesives to steel fixtures.

3.0 TESTING

All specimens were tested at ambient temperature and humidity. Stabilized FWC tests were performed according to ASTM C365. Core shear tests were performed according to ASTM C273. FWT tests were performed according to ASTM C297. A detailed description of the test method followed is available in the referenced test specifications.

3.1 Stabilized Flatwise Compression

Stabilized FWC strength and modulus properties were determined using specimens instrumented with a deflectometer attachment and tested according to ASTM C365. Load, actuator stroke and deflectometer displacement data were recorded continuously until failure of the specimen. Figure 3.3 shows typical test setup for FWC. Refer to appendix B for values of individual specimen.

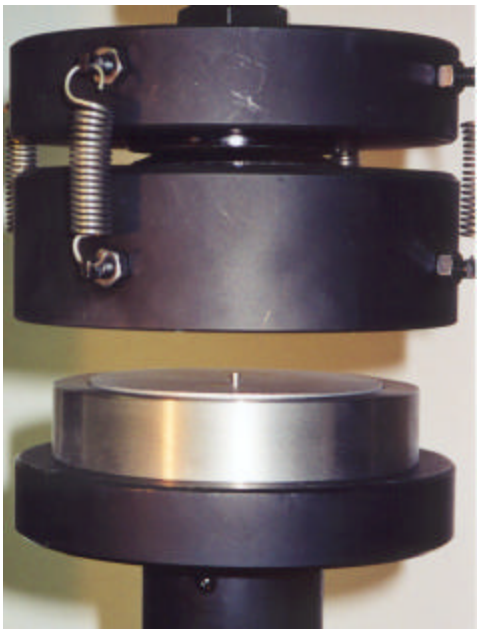


Figure 3.3: *Typical FWC Setup of 4" Diameter Specimens*

3.2 L-Shear

Shear strength parallel to the plane of the sandwich and shear modulus associated with strains in a plane normal to the core were determined using specimens tested according to ASTM C273. These tests were performed on the L-direction where the length of the specimen is along the core ribbon direction. These specimens were adhesively bonded to rigid steel plates and loaded in tension through dual clevis joints to ensure uniform load distribution across the width of the specimen. These specimens were also instrumented with an extensometer to measure shear modulus values. Load, actuator stroke and extensometer deflection data were recorded continuously until failure of the specimen. Figures 3.1 shows typical test and extensometer setup for the core shear tests in tension. Refer to appendix A for values of individual specimen.

Figure 3.1: *Typical Shear Test Setup*

3.3 Flatwise Tensile

FWT properties were determined according to ASTM C297. The specimens, with bonded loading blocks, were placed in a self-aligning loading fixture. The load was applied to the ends of the loading blocks in tension. A typical test setup for FWT is shown in Figure 3.4. Five specimens were tested for block number 0508. A summary of the specimens tested and their results are included in the Test Results Summary section in Appendix B.

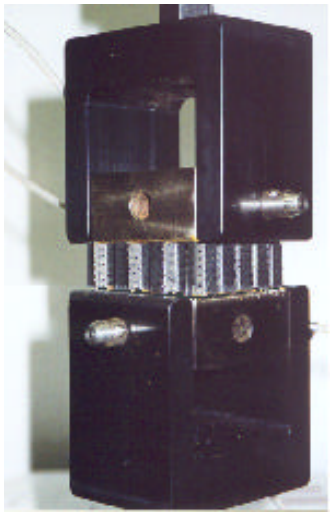


Figure 3.4: *Typical FWT Setup.*

4.0 RESULTS & DISCUSSION

There is an intimate relationship between the orientation of the fiber and the FWC and shear properties. Typically for FWC properties, the FWC strengths and moduli are much higher as there are more fibers parallel to the applied compressive load. Typically for shear properties, the closer the orientation is to the ±45°, the higher the shear strengths and moduli. However, the 0.8 lb/ft^3 lightweight carbon honeycomb core here does not follow the norm. The ±30° orientation HC were consistently higher in both strength and modulus properties than ±45°. Further clarification will be discussed in section 4.2.

4.1 Stabilized Flatwise Compression

Five specimens each were prepared and tested according to ASTM C365 specification. In order to reduce edge effects, a circular fixture shown in Figure 4.1 was designed and machined to accommodate round specimens. Round specimens were found to improve both the compressive strength and modulus. The coefficient of variation (COV) was also lowered. Four round specimens were prepared and tested according to ASTM C365. Postcuring the specimens at 450°F for 2 hours was also evaluated. The results are in Table 4.1. A comparison chart can be found in appendix B.

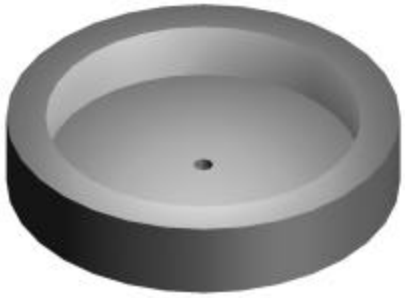


Figure 4.1: *Circular Fixture Accommodating 4" Diameter Specimens*

Table 4.1: *Flatwise Compression Test Summary*

Test Date	Specimens Tested	Specimens Size (nominal)	Slice/Block Number	Orientation	Preparation	FWC Strength (psi)	FWC Modulus (ksi)
11/28/2000	5	3" x 3"	0486-06	±25°	As Received	27	8.4
11/28/2000	5	3" x 3"	0487-06	±30°	As Received	26	7.9
12/7/2000	4	4" Diam.	0487-10 & 12	±30°	As Received	36	9.9
1/16/2001	2	4" Diam.	0491-08	±45°	Post Cured	23	3.8
1/16/2001	2	4" Diam.	0487-02	±30°	Post Cured	31	4.5

4.2 L-Shear

All the shear specimens were prepared and tested according to ASTM C273 specification. Some specimens were performed "as received", some were "post cured", some were "plasma treated", and some were "resin dipped" to determine the optimum process for highest shear properties. All three different orientations of ±25°, ±30° & ±45° were tested. The results are shown in Table 4.2. As discussed in section 4.0, the orientation of ±45° is optimum for core shear properties. However, the results in Table 4.2 shows that the orientation of ±30° is optimum for core shear properties. Ultracor

wanted to verify this phenomenon by manufacturing an additional ±45° block (block #0491). The results for block 0491 were essentially the same as the previous ±45° block (block #0490). A comparison chart can be found in appendix A.

Table 4.2: *L-Shear Test Summary*

Test Date	Specimens Tested	Slice/Block Number	Orientation	Preparation	L Shear Strength (psi)	L Shear Modulus (ksi)
12/13/2000	5	0487	±30°	As Received	26	21
12/15/2000	2	0487	±30°	Post Cured	25	26
12/15/2000	5	0490-08 & 11	±45°	As Received	20	14
12/19/2000	3	0490-09	±45°	Post Cured	19	18
12/19/2000	2	0490-07	±45°	As Received	20	21
12/19/2000	2	0486-02	±25°	As Received	26	18
12/21/2000	3	0491-05 & 06	±45°	As Received	21	16
12/28/2000	2	0487-03	±30°	Plasma Treated	27	22
12/28/2000	3	0490-03	±45°	Plasma Treated	21	20
1/22/2001	3	0490-06	±45°	5% Resin Dipped	23	17
1/22/2001	3	0490-05	±45°	10% Resin Dipped	24	18
1/22/2001	3	0490-10	±45°	15% Resin Dipped	25	18

The "as received" specimens were bonded directly to the steel plates after sawing. No washing, cleaning or any surface preparation were performed.

The "post cured" specimens were post cured at 450°F for 2 hours. Since the specimens were cured without stabilization, you will notice that the cell configuration may be warped. The worst-case scenario of cell configuration warpage after post curing is shown in Figure 4.1. While curing, the cell walls tend to relax causing expansion in the L-direction and contraction in the W-direction. The expansion in the L-direction may result in higher L-Shear properties.

The "plasma treated" specimens were sent out for plasma treatment according to 4th State HPS001 specification.

The "resin dipped" specimens were dipped in 5%, 10 %, and 15% resin by weight mixed with Methyl Ethyl Ketone (MEK). After dipping, specimens were cured at 350°F for at least 2 hours. Table 4.3 illustrates the final density and percent increase of each honeycomb core slice after dipping.

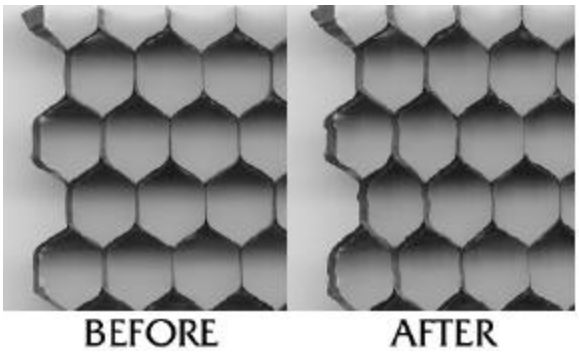


Figure 4.1: *Before and After Post Cure*

Table 4.3: *Resin Dipping Results*

Resin %	Slice #	L-Direction (in.)	W-Direction (in.)	Thickness (in.)	Weight before (lb)	Weight after (lb)	Density before (lb/ft^3)	Density after (lb/ft^3)	Percent Increase
5	490-06	6.60	8.60	0.497	0.0134	0.0144	0.824	0.885	7.4%
10	490-05	6.63	8.63	0.499	0.0134	0.0147	0.815	0.888	9.0%
15	490-10	6.60	8.70	0.498	0.0134	0.0152	0.813	0.919	13.1%

4.2 Flatwise Tensile

All the FWT specimens were prepared and tested according to ASTM C297 specification. All the specimens were plasma treated prior to testing. The failure modes for all five specimens were “core failure”. Individual results can be found in Appendix C.

5.0 SUMMARY

A successful testing program was conducted which investigated the mechanical characteristics of lightweight (0.80 lb/ft^3) carbon honeycomb core. A total of 59 specimens were prepared and tested by Ultracor. Due to a limited supply of materials, only two specimens per test batch were tested under some circumstances. It should be noted that this might not be acceptable under most acceptance testing. Caution must be taken when viewing average properties of such testing.

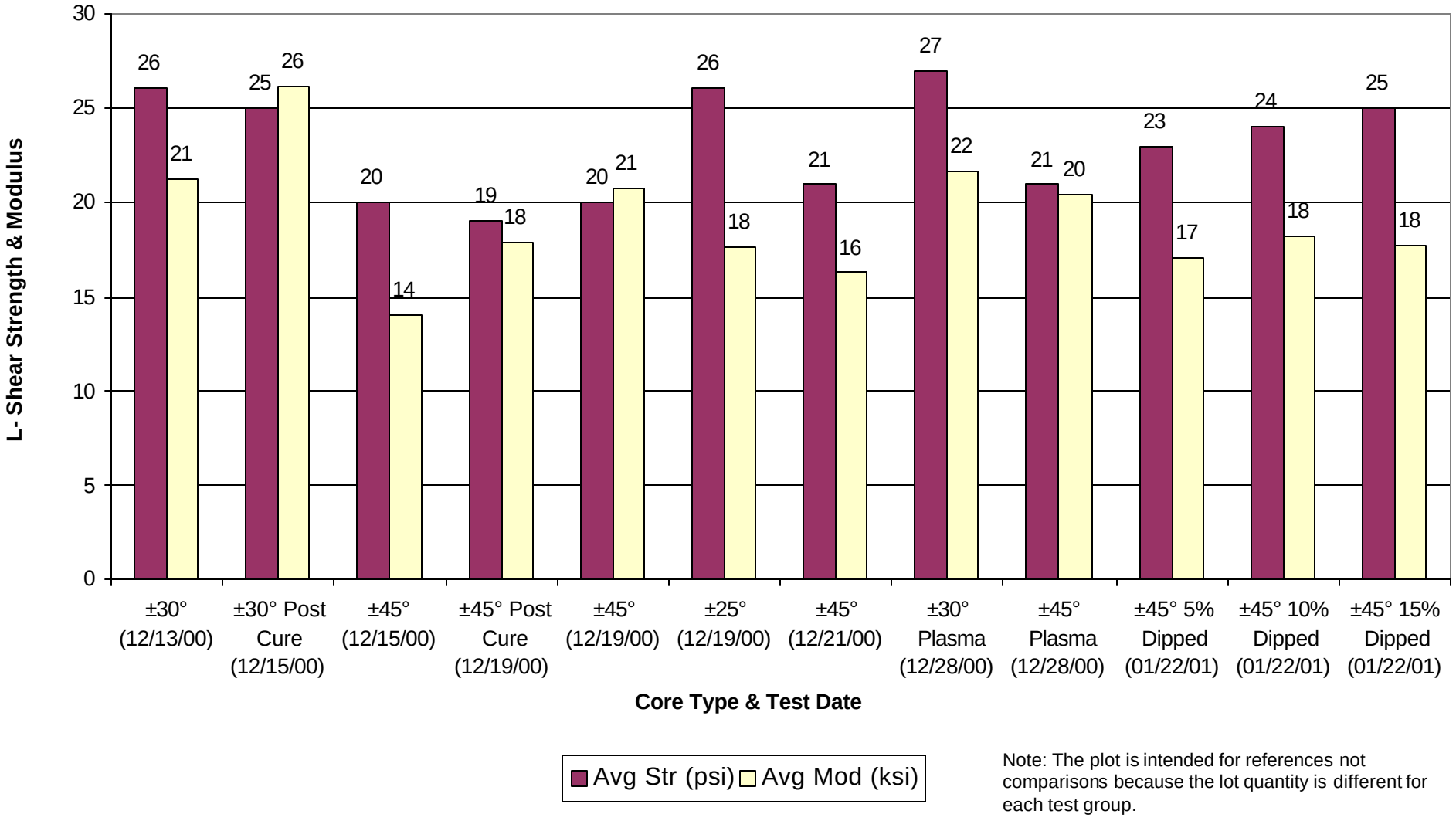
For FWC properties, the orientation of ±25° is favored as predicted. Round specimens of 4" diameter is recommended over 3" x 3" specimens due to edge effects during testing. Postcuring the specimens reduces the properties due to the warpage of the cell configurations.

For L-Shear properties, the orientation of ±30° is favored not as predicted. Many methods of preparation were examined to maximize the L-Shear properties. Specimens were "post cured", "plasma treated", and "resin dipped". There was a slight increase in the shear strength but no significant influence in the shear modulus.

APPENDIX A

L-Shear Properties

Lightweight Core



Note: The plot is intended for references not comparisons because the lot quantity is different for each test group.

YLA CELLULAR PRODUCTS CO.

L-Shear Prop of HC Cores (1K Cell)

Customer: Alcatel Space
PO#: A38079
Core Density: 0.82 pcf
YLACP Report #: 424

Temperature: 73 °F
Humidity: 36%
Operator: C. Le
Specification: ASTM C273

Test Date	Product Code	Spec ID	Area ($in.^2$)	Peak Stress (psi)	Modulus (ksi)	Failure Mode
12/13/2000	UCF-145-3/8-0.8	UCF-145-0487-7-1	13.50	24	21.7	Core shear failure.
	Block #: 0487	UCF-145-0487-7-2	12.74	27	23.0	Core shear failure.
	(±30°)	UCF-145-0487-8-1	13.50	26	17.0	Core shear failure.
		UCF-145-0487-8-2	13.65	25	21.6	Core shear failure.
		UCF-145-0487-11-1	13.59	26	23.3	Core shear failure.
Adhesive:	EA9657-K	Mean:	13.40	26	21.3	
Areal Wt.:	(0.08 psf)	Std Dev:	0.37	1	2.5	
Cured:	350°F/1.5 hrs	C.O.V.:	2.8%	4.5%	11.8%	
Ply:	1 ply per	Maximum:	13.65	27	23.3	
		Minimum:	12.74	24	17.0	

Customer: Alcatel Space
PO#: A38079
Core Density: 0.82 pcf
YLACP Report #: 426

Temperature: 72 °F
Humidity: 45%
Operator: C. Le
Specification: ASTM C273

Test Date	Product Code	Spec ID	Area ($in.^2$)	Peak Stress (psi)	Modulus (ksi)	Failure Mode
12/15/2000	UCF-145-3/8-0.8	UCF-145-0487-5-21*	13.23	24	33.7	Core shear failure.
	Block #: 0487	UCF-145-0487-5-22*	12.04	27	18.6	Core shear failure.
Adhesive:	EA9657-K	Mean:	12.64	25	26.1	
Areal Wt.:	(0.08 psf)	Std Dev:	0.84	2	10.7	
Cured:	350°F/1.5 hrs	C.O.V.:	6.7%	9.6%	40.9%	
Ply:	1 ply per	Maximum:	13.23	27	33.7	
		Minimum:	12.04	24	18.6	

Customer: Alcatel Space
PO#: A38079
Core Density: 0.82 pcf
YLACP Report #: 427

Temperature: 72 °F
Humidity: 45%
Operator: C. Le
Specification: ASTM C273

Test Date	Product Code	Spec ID	Area ($in.^2$)	Peak Stress (psi)	Modulus (ksi)	Failure Mode
12/15/2000	UCF-146-3/8-0.8	UCF-146-0490-8-21	12.85	21	NA	Unusable plot.
	Block #: 0490	UCF-146-0490-8-22	13.08	20	15.0	Core shear failure.
	(±45°)	UCF-146-0490-8-23	12.71	21	14.9	Core shear failure.
		UCF-146-0490-8-24	12.52	18	11.9	Core shear failure.
		UCF-146-0490-11-21	12.90	21	14.4	Core shear failure.
Adhesive:	EA9657-K	Mean:	12.81	20	14.0	
Areal Wt.:	(0.08 psf)	Std Dev:	0.21	1	1.5	
Cured:	350°F/1.5 hrs	C.O.V.:	1.6%	5.7%	10.6%	
Ply:	1 ply per	Maximum:	13.08	21	15.0	
		Minimum:	12.52	18	11.9	

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YLA CELLULAR PRODUCTS CO.

L-Shear Prop of HC Cores (1K Cell)

Customer: Alcatel Space
PO#: A38079
Core Density: 0.82 pcf
YLACP Report #: 428

Temperature: 72 °F
Humidity: 32%
Operator: C. Le
Specification: ASTM C273

Test Date	Product Code	Spec ID	Area ($in.^2$)	Peak Stress (psi)	Modulus (ksi)	Failure Mode
12/19/2000	UCF-146-3/8-0.8	UCF-146-0490-9-21*	14.47	20	16.2	Core shear failure.
	Slice #: 0490-09	UCF-146-0490-9-22*	13.74	18	18.6	Core shear failure.
	(±45°)	UCF-146-0490-9-23*	13.60	20	18.8	Core shear failure.
Adhesive:	EA9657-K	Mean:	13.94	19	17.9	
Areal Wt.:	(0.08 psf)	Std Dev:	0.47	1	1.5	
Cured:	350°F/1.5 hrs	C.O.V.:	3.3%	5.2%	8.2%	
Ply:	1 ply per	Maximum:	14.47	20	18.8	
		Minimum:	13.60	18	16.2	

Customer: Alcatel Space
PO#: A38079
Core Density: 0.82 pcf
YLACP Report #: 429

Temperature: 72 °F
Humidity: 32%
Operator: C. Le
Specification: ASTM C273

Test Date	Product Code	Spec ID	Area ($in.^2$)	Peak Stress (psi)	Modulus (ksi)	Failure Mode
12/19/2000	UCF-146-3/8-0.8	UCF-146-0490-7-21	13.77	20	20.2	Core shear failure.
	Slice #: 0490-07	UCF-146-0490-7-22	13.77	20	21.2	Core shear failure.
Adhesive:	EA9657-K	Mean:	13.77	20	20.7	
Areal Wt.:	(0.08 psf)	Std Dev:	0.00	0	0.7	
Cured:	350°F/1.5 hrs	C.O.V.:	0.0%	1.0%	3.5%	
Ply:	1 ply per	Maximum:	13.77	20	21.2	
		Minimum:	13.77	20	20.2	

Customer: Alcatel Space
PO#: A38079
Core Density: 0.82 pcf
YLACP Report #: 430

Temperature: 72 °F
Humidity: 32%
Operator: C. Le
Specification: ASTM C273

Test Date	Product Code	Spec ID	Area ($in.^2$)	Peak Stress (psi)	Modulus (ksi)	Failure Mode
12/19/2000	UCF-157-3/8-0.8	UCF-157-0486-2-21	13.55	26	16.0	Core shear failure.
	Slice #: 0486-02	UCF-157-0486-2-22	13.67	26	19.1	Core shear failure.
Adhesive:	EA9657-K	Mean:	13.61	26	17.6	
Areal Wt.:	(0.08 psf)	Std Dev:	0.09	0	2.2	
Cured:	350°F/1.5 hrs	C.O.V.:	0.7%	1.8%	12.5%	
Ply:	1 ply per	Maximum:	13.67	26	19.1	
		Minimum:	13.55	26	16.0	

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YLA CELLULAR PRODUCTS CO.

L-Shear Prop of HC Cores (1K Cell)

Customer: Alcatel Space
PO#: A38079
Core Density: 0.80 pcf
YLACP Report #: 431

Temperature: 70 °F
Humidity: 32%
Operator: C. Le
Specification: ASTM C273

Test Date	Product Code	Spec ID	Area ($in.^2$)	Peak Stress (psi)	Modulus (ksi)	Failure Mode
12/21/2000	UCF-146-3/8-0.8	UCF-146-0491-5-21	13.48	21	14.9	Core shear failure.
	Block #: 0491	UCF-146-0491-6-22	13.61	21	16.7	Core shear failure.
		UCF-146-0491-6-21	13.67	20	17.2	Core shear failure.
Adhesive:	EA9657-K	Mean:	13.59	21	16.3	
Areal Wt.:	(0.08 psf)	Std Dev:	0.10	1	1.2	
Cured:	350°F/1.5 hrs	C.O.V.:	0.7%	2.4%	7.3%	
Ply:	1 ply per	Maximum:	13.67	21	17.2	
		Minimum:	13.48	20	14.9	

Customer: Alcatel Space
PO#: A38079
Core Density: 0.82 pcf
YLACP Report #: 432

Temperature: 70 °F
Humidity: 26%
Operator: C. Le
Specification: ASTM C273

Test Date	Product Code	Spec ID	Area ($in.^2$)	Peak Stress (psi)	Modulus (ksi)	Failure Mode
12/28/2000	UCF-145-3/8-0.8	UCF-145-0487-3-21	12.87	29	19.1	Core shear failure.
	Block #: 0487	UCF-145-0487-3-22	12.57	26	24.3	Core shear failure.
Adhesive:	EA9657-K	Mean:	12.72	27	21.7	
Areal Wt.:	(0.08 psf)	Std Dev:	0.22	2	3.6	
Cured:	350°F/1.5 hrs	C.O.V.:	1.7%	8.0%	16.7%	
Ply:	1 ply per	Maximum:	12.87	29	24.3	
		Minimum:	12.57	26	19.1	

Customer: Alcatel Space
PO#: A38079
Core Density: 0.82 pcf
YLACP Report #: 433

Temperature: 70 °F
Humidity: 26%
Operator: C. Le
Specification: ASTM C273

Test Date	Product Code	Spec ID	Area ($in.^2$)	Peak Stress (psi)	Modulus (ksi)	Failure Mode
12/28/2000	UCF-146-3/8-0.8	UCF-146-0490-3-21	12.00	21	13.4	Core shear failure.
	Block #: 0490	UCF-146-0490-3-22	12.66	21	24.9	Core shear failure.
		UCF-146-0490-3-23	13.44	22	22.9	Core shear failure.
Adhesive:	EA9657-K	Mean:	12.70	21	20.4	
Areal Wt.:	(0.08 psf)	Std Dev:	0.72	1	6.1	
Cured:	350°F/1.5 hrs	C.O.V.:	5.7%	2.8%	30.1%	
Ply:	1 ply per	Maximum:	13.44	22	24.9	
		Minimum:	12.00	21	13.4	

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YLA CELLULAR PRODUCTS CO.

L-Shear Prop of HC Cores (1K Cell)

Customer: Alcatel Space
PO#: A38079
Core Density: 0.894 pcf
YLACP Report #: 446

Temperature: 74 °F
Humidity: 32%
Operator: C. Le
Specification: ASTM C273

Test Date	Product Code	Spec ID	Area ($in.^2$)	Peak Stress (psi)	Modulus (ksi)	Failure Mode
1/22/2001	UCF-146-3/8-0.8	UCF-146-0490-5-21*	13.59	24	18.5	Core shear failure.
	Slice #: 0490-05	UCF-146-0490-5-22*	13.29	23	16.5	Core shear failure.
	(±45°)	UCF-146-0490-5-23*	13.57	25	19.5	Core shear failure.
Adhesive:	AF 191	Mean:	13.48	24	18.2	
Areal Wt.:	(0.08 psf)	Std Dev:	0.16	1	1.5	
Cured:	350°F/1.5 hrs	C.O.V.:	1.2%	3.8%	8.4%	
Ply:	1 ply per	Maximum:	13.59	25	19.5	
		Minimum:	13.29	23	16.5	

Customer: Alcatel Space
PO#: A38079
Core Density: 0.879 pcf
YLACP Report #: 447

Temperature: 74 °F
Humidity: 32%
Operator: C. Le
Specification: ASTM C273

Test Date	Product Code	Spec ID	Area ($in.^2$)	Peak Stress (psi)	Modulus (ksi)	Failure Mode
1/22/2001	UCF-146-3/8-0.8	UCF-146-0490-6-21	13.50	22	15.1	Core shear failure.
	Slice #: 0490-06	UCF-146-0490-6-23	14.29	22	17.1	Core shear failure.
	(±45°)	UCF-146-0490-6-24	12.73	25	19.1	Core shear failure.
Adhesive:	AF 191	Mean:	13.51	23	17.1	
Areal Wt.:	(0.08 psf)	Std Dev:	0.78	2	2.0	
Cured:	350°F/1.5 hrs	C.O.V.:	5.8%	6.6%	11.8%	
Ply:	1 ply per	Maximum:	14.29	25	19.1	
		Minimum:	12.73	22	15.1	

Customer: Alcatel Space
PO#: A38079
Core Density: 0.919 pcf
YLACP Report #: 448

Temperature: 74 °F
Humidity: 32%
Operator: C. Le
Specification: ASTM C273

Test Date	Product Code	Spec ID	Area ($in.^2$)	Peak Stress (psi)	Modulus (ksi)	Failure Mode
1/22/2001	UCF-146-3/8-0.8	UCF-146-0490-10-21	13.59	25	17.4	Core shear failure.
	Slice #: 0490-10	UCF-146-0490-10-22	13.40	25	16.5	Core shear failure.
	(±45°)	UCF-146-0490-10-23	13.78	25	19.3	Core shear failure.
Adhesive:	AF 191	Mean:	13.59	25	17.7	
Areal Wt.:	(0.08 psf)	Std Dev:	0.19	0	1.4	
Cured:	350°F/1.5 hrs	C.O.V.:	1.4%	1.5%	8.0%	
Ply:	1 ply per	Maximum:	13.78	25	19.3	
		Minimum:	13.40	25	16.5	

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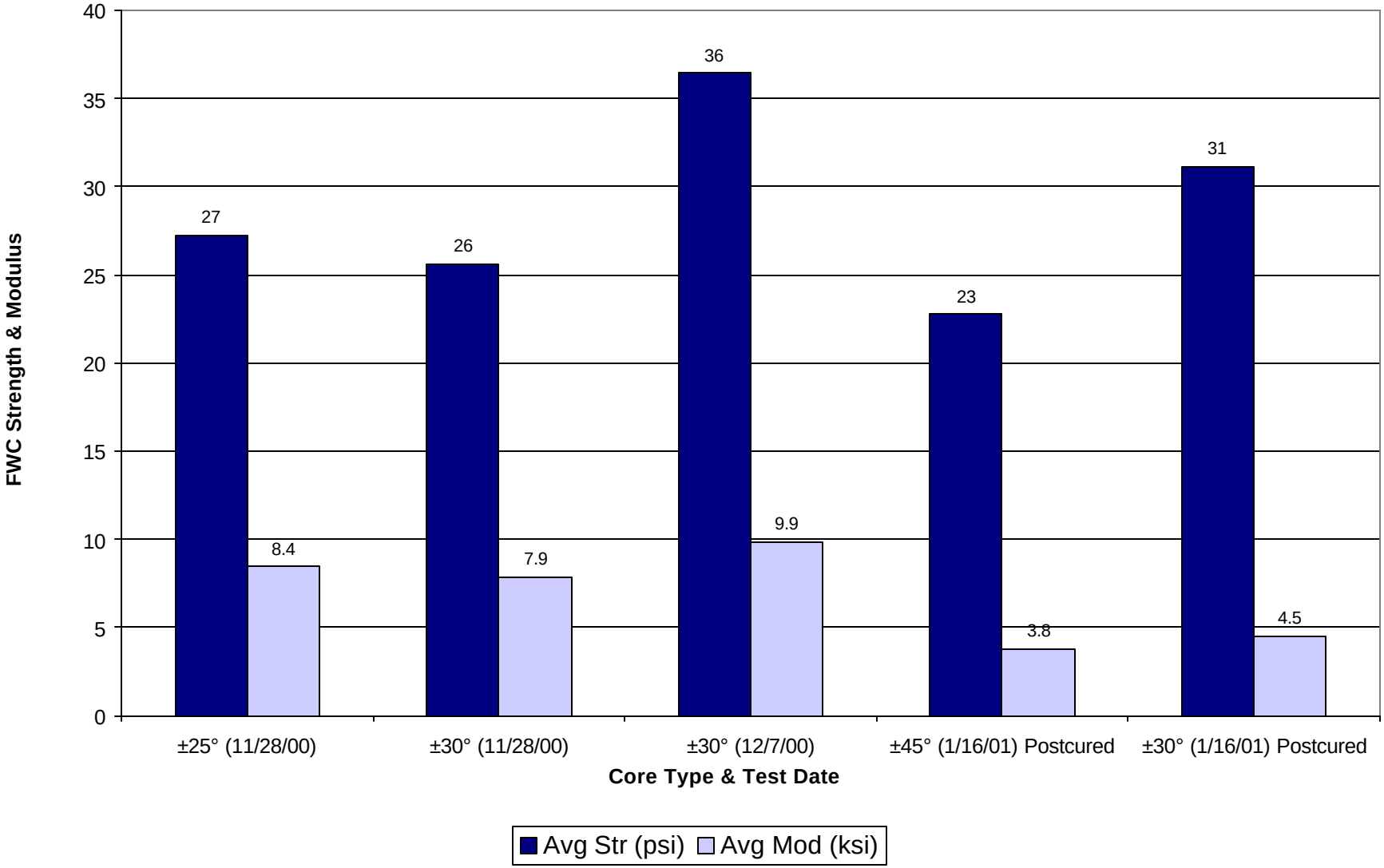
APPENDIX B

Flatwise Compression Properties

Lightweight Core



Note: The plot is intended for references not comparisons because the lot quantity is different for each test group.

YLA CELLULAR PRODUCTS CO.

Flatwise Compression Prop. of Sandwich Cores

Customer: Alcatel Space
PO#: A38079
Core Density: 0.82 pcf
YLACP Report #: 419

Temperature: 73 °F
Humidity: 35%
Operator: C. Le
Specification: ASTM C365 (Stabilized)

Test Date	Product Code	Spec ID	Area ($in.^2$)	Peak Stress (psi)	Modulus (ksi)	Failure Mode
11/28/2000	UCF-157-3/8-0.8	UCF-157-0486-6-1	9.00	30	8.2	Core buckling.
		UCF-157-0486-6-2	9.00	36	11.5	Core buckling.
	Slice #: 0486-06	UCF-157-0486-6-4	9.00	22	6.9	Core buckling.
	(±25°)	UCF-157-0486-6-5	9.00	25	9.1	Core buckling.
		UCF-157-0486-6-6	8.70	23	6.5	Core buckling.
Adhesive:	EA9657-K	Mean:	8.94	27	8.4	
Areal Wt.:	(0.08 psf)	Std Dev:	0.13	6	2.0	
Cured:	350°F/1.5 hrs	C.O.V.:	1.5%	20.7%	23.7%	
Ply:	1 ply per	Maximum:	9.00	36	11.5	
		Minimum:	8.70	22	6.5	

Customer: Alcatel Space
PO#: A38079
Core Density: 0.82 pcf
YLACP Report #: 420

Temperature: 73 °F
Humidity: 35%
Operator: C. Le
Specification: ASTM C365 (Stabilized)

Test Date	Product Code	Spec ID	Area ($in.^2$)	Peak Stress (psi)	Modulus (ksi)	Failure Mode
11/28/2000	UCF-145-3/8-0.8	UCF-145-0487-6-2	8.41	26	8.9	Core buckling.
		UCF-145-0487-6-3	8.41	28	9.4	Core buckling.
	Slice #: 0487-06	UCF-145-0487-6-4	8.41	23	8.1	Core buckling.
	(±30°)	UCF-145-0487-6-6	8.41	27	6.6	Core buckling.
		UCF-145-0487-6-1	8.41	24	6.4	Core buckling.
Adhesive:	EA9657-K	Mean:	8.41	26	7.9	
Areal Wt.:	(0.08 psf)	Std Dev:	0.00	2	1.3	
Cured:	350°F/1.5 hrs	C.O.V.:	0.0%	7.4%	16.5%	
Ply:	1 ply per	Maximum:	8.41	28	9.4	
		Minimum:	8.41	23	6.4	

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YLA CELLULAR PRODUCTS CO.

Flatwise Compression Prop. of Sandwich Cores

Customer: Alcatel Space
PO#: A38079
Core Density: 0.82 pcf
YLACP Report #: 421

Temperature: 77 °F
Humidity: 29%
Operator: C. Le
Specification: ASTM C365 (Stabilized & Round)

Test Date	Product Code	Spec ID	Area ($in.^2$)	Peak Stress (psi)	Modulus (ksi)	Failure Mode
12/7/2000	UCF-145-3/8-0.8	UCF-145-0487-10-1	12.57	35	9.8	Core buckling.
	Slice #: 0487-10 & 12	UCF-145-0487-10-2	12.57	35	9.6	Core buckling.
	(±30°)	UCF-145-0487-12-1	12.57	44	11.0	Core buckling.
		UCF-145-0487-12-2	12.57	32	9.0	Core buckling.
Adhesive:	EA9657-K	Mean:	12.57	36	9.9	
Areal Wt.:	(0.08 psf)	Std Dev:	0.00	5	0.9	
Cured:	350°F/1.5 hrs	C.O.V.:	0.0%	13.6%	8.8%	
Ply:	1 ply per	Maximum:	12.57	44	11.0	
		Minimum:	12.57	32	9.0	

Customer: Alcatel Space
PO#: A38079
Core Density: 0.80 pcf
YLACP Report #: 442

Temperature: 70 °F
Humidity: 20%
Operator: C. Le
Specification: ASTM C365 (Stabilized)

Test Date	Product Code	Spec ID	Area ($in.^2$)	Peak Stress (psi)	Modulus (ksi)	Failure Mode
1/16/2001	UCF-146-3/8-0.8	UCF-146-0491-8-1*	12.57	23	3.0	Core buckling.
	Slice #: 0491-08	UCF-146-0491-8-2*	12.57	23	3.8	Core buckling.
Adhesive:	FM300M	Mean:	12.57	23	3.4	
Areal Wt.:	(0.03 psf)	Std Dev:	0.00	0	0.6	
Cured:	350°F/1.5 hrs	C.O.V.:	0.0%	0.7%	16.6%	
Ply:	2 plies per	Maximum:	12.57	23	3.8	
		Minimum:	12.57	23	3.0	

Customer: Alcatel Space
PO#: A38079
Core Density: 0.82 pcf
YLACP Report #: 443

Temperature: 70 °F
Humidity: 20%
Operator: C. Le
Specification: ASTM C365 (Stabilized)

Test Date	Product Code	Spec ID	Area ($in.^2$)	Peak Stress (psi)	Modulus (ksi)	Failure Mode
1/16/2001	UCF-145-3/8-0.8	UCF-145-0487-2-1*	12.57	31	4.4	Core buckling.
	Slice #: 0487-02	UCF-145-0487-2-2*	12.57	32	4.6	Core buckling.
Adhesive:	FM300M	Mean:	12.57	31	4.5	
Areal Wt.:	(0.03 psf)	Std Dev:	0.00	1	0.1	
Cured:	350°F/1.5 hrs	C.O.V.:	0.0%	2.1%	1.7%	
Ply:	2 plies per	Maximum:	12.57	32	4.6	
		Minimum:	12.57	31	4.4	

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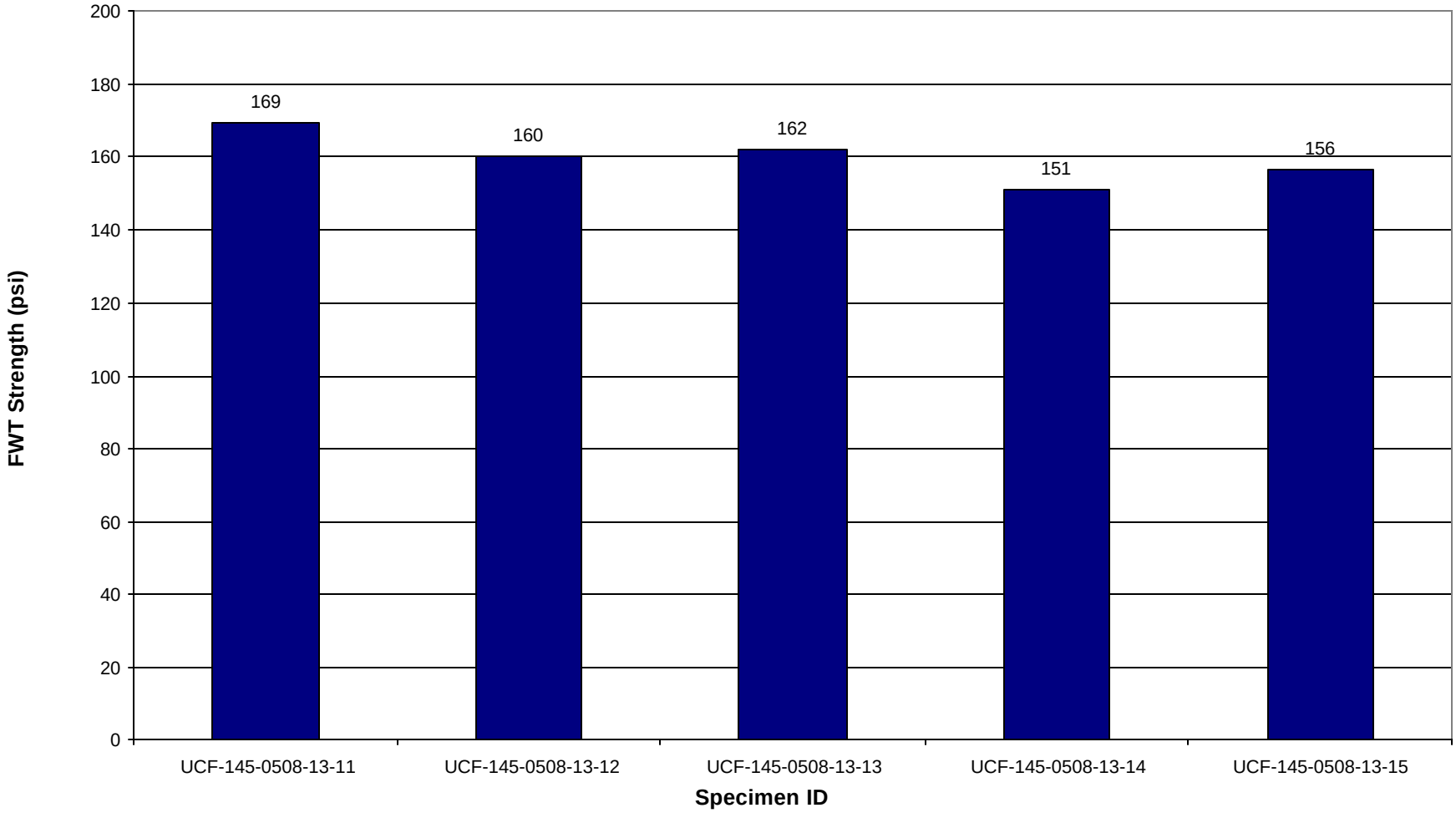
APPENDIX C

Flatwise Tensile Properties

Lightweight Core



Note: 98% Core Failure

Ultracor Incorporated

Flatwise Tenisle Properties

Core Density: 0.80 pcf
Description: Carbon Honeycomb Core
YLACP Report #: 455

Temperature: 76 °F
Humidity: 35%
Operator: C. Le
Specification: ASTM C297

Test Date	Product Code	Specimen ID	Width 1 (in.)	Width 2 (in.)	Thickness (in.)	Area ($in.^2$)	Peak Load (lbf)	Peak Stress (psi)	Failure Mode
3/6/2001	UCF-145-3/8-0.8	UCF-145-0508-13-11	2.00	2.00	0.500	4.00	677	169	95% Core failure.
		UCF-145-0508-13-12	2.00	2.00	0.500	4.00	639	160	98% Core failure.
	Slice #: 0508-13	UCF-145-0508-13-13	2.00	1.98	0.500	3.96	642	162	98% Core failure.
		UCF-145-0508-13-14	2.00	1.98	0.500	3.96	597	151	95% Core failure.
		UCF-145-0508-13-15	2.00	2.00	0.500	4.00	626	156	98% Core failure.
Adhesive:	AF 191	Mean:				3.98	636	160	
Nominal Wt.:	(0.08 psf)	Std Dev:				0.02	29	7	
Cured:	350°F/1.5 hrs	C.O.V.:				0.5%	4.5%	4.3%	
Ply:	1 ply per	Maximum:				4.00	677	169	
		Minimum:				3.96	597	151	

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