NASA Contractor Report 4609

Test Methods for Textile Composites

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Prepared for Langley Research Center
under Contract NAS1-19247

July 1994

Abstract

Various test methods commonly used for measuring properties of tape laminate composites were evaluated to determine their suitability for the testing of textile composites. Three different types of textile composites were utilized in this investigation: 2-Dimensional triaxial braids, stitched uniweave fabric and 3-Dimensional interlock woven fabric. Ten categories of material properties were investigated: Tension, Open-Hole Tension, Compression, Open-Hole Compression, In-Plane Shear, Filled-Hole Tension , Bolt Bearing, Interlaminar Tension, Interlaminar Shear and Interlaminar Fracture Toughness.

The main issue in the tension test program was the effect on strength of the specimen size compared to the material unit cell dimensions. Little or no effect on strength was observed for the 2-D braids which have the largest unit cell size of all material tested. The effect of specimen width to hole diameter ratio (W/D) was investigated in the open-hole tension. Results showed that the standard W/D=6 was adequate. A comparison of the Boeing Open Hole Compression, Zabora Fixture, NASA Short Block, NASA 1142, Modified IITRI, sandwich column, Boeing Compression After Impact and NASA ST-4 specimens was conducted in the compression test program. The Boeing Open Hole Compression, sandwich column, Boeing Compression After Impact and NASA ST-4 specimens were found to be inadequate for strength testing. Among the remaining methods. the NASA Short Block specimen consistently produced the highest mean strength. In the open hole compression tests, a comparison of the Boeing Open Hole Compression, Zabora Fixture, NASA Short Block, NASA 1142 and Modified IITRI was conducted for hole diameters up to 0.375". Results show that the Modified IITRI produced the highest mean strength, while the Boeing OHC produced the lowest. Both the Boeing Compression After Impact and NASA ST-4 gave good results for larger hole from 0.5" to 1.25". For the in-plane shear testing, a comparison of tube torsion, rail shear and compact shear specimens was conducted. Significant differences in both strength and modulus were obtained between these test methods. Testing was conducted only with the 2-D braided material for filled-hole tension strength and confirmed that, as for tape laminates, filled hole tension is the critical case when developing material design allowables for the Room Temperature/Dry environment. Testing for bolt bearing strength was conducted only with the 2-D braided material. As for tape laminates, the stabilized single shear bearing test is recommended. Testing for interlaminar tension was conducted with the 2-D braided material and 3-D woven materials using a C-shape and a L-shape specimens. Strength values from the L-shape configuration were slightly higher. Testing for interlaminar shear was conducted with the 2-D braided material and 3-D woven materials using the Short Beam Shear (SBS) and Compression Interlaminar Shear (CIS) specimens. Strength values obtained from the SBS specimen were consistantly higher than those from the CIS specimen. Testing for interlaminar fracture toughness was conducted only with the 2-D braided material using the Double Cantilever Beam and End Notched Flexure specimens. Results showed much higher toughness in this type material than in conventional laminated composites.

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1. Introduction

Carbon/Epoxy composites made from textile fiber preforms manufactured with a Resin-Transfer-Molding (RTM) process have potential for reducing costs and increasing damage tolerance of aerospace structures. While many standardized test methods are available for conventional tape laminates, these may not be directly applicable to textile composites. The main concern is that textile composites tend to be less homogeneous than conventional tape laminates. Thus, it was anticipated that some scaling effects may be observed and that larger size specimens may be required. The objective of the task described in this report was to evaluate existing test methods for measuring stiffness and strength properties of specimens loaded in tension, with and without holes, compression, with and without holes, shear and bolt bearing, and to make recommendations for changes in the test configuration. A secondary objective of this task was to increase the database of mechanical properties of textile composites in order to assist in the development of analytical models and the assessment of the benefits of textile composites for future applications.

As a result of a NASA Advanced Composite Technology (ACT) Program Steering Committee recommendation, this program was initiated out of the Mechanics of Materials Branch at the NASA Langley Research Center. This program was assembled to address critical technology needs for the ACT Program and other NASA funded programs.

This report describes work accomplished under Contract NAS1-19247 from the National Aeronautics and Space Administration, Langley Research Center, Hampton VA. Mr Clarence C. Poe Jr., NASA LaRC, was the NASA Technical Monitor. Bill Fedor of Boeing Aerospace Operations was the program manager. The Structures Technology organization of the Boeing Defense & Space Group, Helicopters Division was responsible for completing this task. Most of the specimen manufacturing was performed by Boeing Defense and Space Group Research and Engineering (Seattle, WA), while all the material testing was conducted at Integrated Technologies, Inc. (Intec, Bothell, WA.) Dr John Masters of Lockheed Engineering & Science contributed Section 4 of this report.

The objectives of this report are to summarize all the strength and stiffness properties measured for the various textile composites investigated, to assess the performance of various test methods and, where possible, to provide recommendations on preferred test configurations for textile composites.

2. Material Systems

Three different types of textile composites were utilized in this investigation: 2-Dimensional triaxial braids, stitched uniweave fabric and 3-Dimensional interlock woven fabric. Textile preforms were procured from their respective vendors mentioned below. All preforms were Resin Transfer Molded (RTM) and cured at Boeing Defense and Space Group, Seattle, WA. Hercules AS4 fibers is used for all fabrics. The resin system used for all materials is Shell RSL-1895, a two-part epoxy system with Shell Epon Curing Agent W formulated for RTM to have comparable properties to Hercules 3501-6 resin system. All details of the manufacturing process can be found in NASA CR 191505, "*Resin Transfer Molding of Textile Composites* ," (Ref. 1).

2.1 2-D Braided Composites

The 2-D braided fabric contains two types of tows, the longitudinal (axial, or 0°) tow and the braided (or bias) tows oriented at angle θ to the axial tow as illustrated in Figure 2.1. The braid pattern used is a 2X2 pattern, meaning that each braided tow goes over and under two tows at a time. All preforms were manufactured by Fiber Innovations Inc., Norwood, MA.

Three important braid parameters are braid angle, yarn size (measured in K, where 1K equals 1000 filaments), and proportion of fixed (0°) yarns. The four braids in Table 2.1 were designed to give three combinations of these parameters so that changes to mechanical properties due to changes in these parameters can be determined. The tow sizes were different for the first and third braids (SLL and LLL), the braid angles were different for the second and third braids (LLS and LLL), and the percentage of fixed yarns were different for the second and fourth braids (LLS and LSS). The 46% of axial tows for the first three braids is typical of a braid optimized for predominantly longitudinal loading. The 12% of axial tows for the fourth braid (LSS) is typical of a braid optimized for predominantly shear loading. The braids marked "-2" and "-3" are variations of the basic architectures used only in the interlaminar properties tests.

Table 2.1 Description of 2-D braided Composites Architectures

Name	Longitudinal Tow Size	Braided Tow Size	% Longitudinal Tow	Braid Angle [°]	Unit Cell Width [in]	Unit Cell Length [in]
SLL	30 K	6 K	46	70	0.458	0.083
LLS	36 K	15 K	46	45	0.415	0.207
LLL	75 K	15 K	46	70	0.829	0.151
LSS	6 K	15 K	12	45	0.415	0.207
SLL-2	15 K	3 K	46	70	0.349	0.063
LLS-2	30 K	12 K	47	45	0.349	0.175
LLS-3	15 K	6 K	47	45	0.262	0.131

The unit cell dimensions vary considerably and are typically quite large. The unit cell width is defined as twice the spacing of the axial tows, while the unit cell length is twice the distance, along an axial tow, between the intersections of an axial tow and a +θ tow (these factors of 2 are due to the fact that this is a 2X2 pattern).

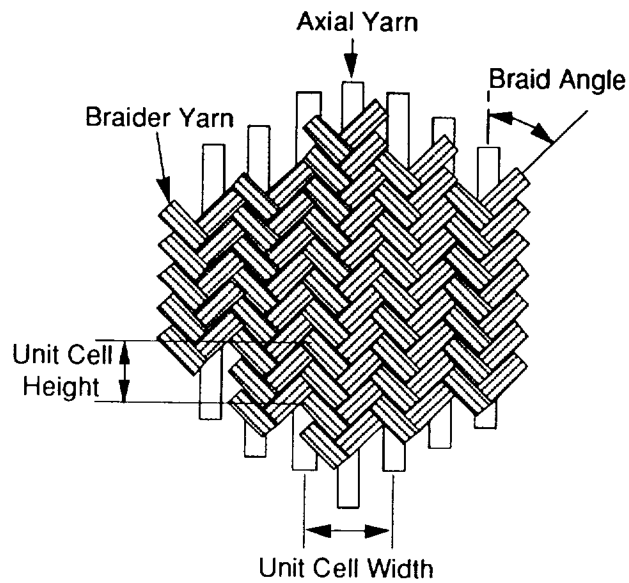


Figure 2.1 Illustration of 2-D Triaxial Braid Configuration.

2.2 Stitched Uniweave Composites

Stitched uniweave fabric consists of several plies of unidirectional graphite fibers woven with a light E-Glass tow (8 picks per inch). This fabric was produced by Textile Technologies Inc. (Style 4003-PW). Several of these layers were then stitched together through the thickness by Cooper Composites. All the materials used here have a quasi-isotropic [+45/0/-45/90]6s layup. As shown in Table 2.2, the variables examined relate to the stitching process itself. The effects of stitch material, pitch, spacing (between rows of stitches) and size are investigated with the five different configurations shown in Table 2.2.

Table 2.2 Description of Stitched Uniweave Materials

Name	Stitch Material	Stitches per inch	Stitch Spacing [in]	Stitch Tow Size
SU-1	S2 Glass	8	0.125	3 K
SU-2	S2 Glass	8	0.125	6 K
SU-3	Kevlar 29	8	0.125	6 K
SU-4	Kevlar 29	4	0.250	6 K
SU-5	Kevlar 29	8	0.125	12 K

2.3 3-D Interlock Woven Materials

Interlock woven fabric is a three-dimensional fabric in which yarns are interlaced through the thickness to improve interlaminar properties over conventional laminates. The warp tows run parallel to the weaving machine direction, with the weft tows running perpendicular to these. The interlock tows wrap around the weft tows in parallel to the warp tows. Three interlock configurations with different tow sizes were used as described in Table 2.3 and illustrated in Figure 2.2. All preforms were produced by Textile Technologies Inc. (TTI).

Table 2.3 Description of 3-D Interlock Woven Materials

Name	Description	Warp Tow	Weft Tow	Weaver Tow
OS-1	Through-the-thickness	24 K (59%)	12 K (33%)	6 K (7.4%)
OS-2	orthogonal interlock	12 K (58%)	6 K (37%)	3 K (6.1%)
TS-1	Through-the-thickness	24 K (57%)	12 K (33%)	6 K (9.8%)
TS-2	angle interlock	12 K (56%)	6 K (38%)	3 K (5.8%)
LS-1	Layer-to-layer interlock	24 K (58%)	12 K (34%)	6 K (6.8%)
LS-2		12 K (57%)	6 K (36%)	3 K (5.9%)

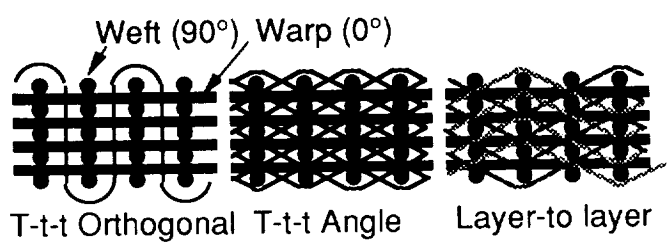


Figure 2.2 Depiction of 3-D Interlock Woven Materials.

3. Data Reduction Techniques

The different techniques used to analyze the experimental data described in the following chapters are documented here. These include specimen fiber volume measurement and thickness normalization, strength and stiffness properties calculation, and open hole strength analysis.

3.1 *Fiber Volume Measurements*

Resin digestion tests were performed on all panels used in this investigation to determine fiber volume fraction and void content. All resin digestion procedures are carried out using a microwave technique. The method consists of obtaining both the dry and submerged weight of a 0.5 inch by 0.5 inch composite specimen to determine its specific gravity. The specimen is placed in a reaction pressure vessel to which 25 to 30 ml of nitric acid is added. The reaction vessel is sealed and placed in a microwave oven for heating. The digestion is run in four stages, with each consecutive stage ramping to a higher pressure. Running the experiment at higher pressure enables the temperature to increase without boiling the acid. Upon complete digestion of the resin, the fibers are filtered from the acid and rinsed with water and acetone. After drying, the carbon fibers are weighted and their volume fraction determined. The fiber and resin densities used in the calculation were 1.80 g/cm^3 and 1.18 g/cm^3 respectively.

3.2 *Thickness Normalization*

One of the first difficulties encountered when examining the experimental data was the fact that there is some scatter in fiber volume fraction from plate to plate. This is especially true of the 2-D braided materials. In order to calculate stress and modulus from the data, a method to normalize these results had to be chosen. Typically, when dealing with tape or fabric laminates, a normalized thickness corresponding to a given fiber volume is determined and kept constant for all calculations. A similar approach is used in the present investigation. As illustrated in Figure 3.1, volume fraction and thickness data was obtained for each material system. The mean thickness and fiber volume was determined across all panels of a given material and nominal thickness. In general, the scatter was always much higher for the 2-D braided materials than for the other material systems. **The thickness corresponding to a 60% volume fraction was then calculated and used to calculate all stresses and moduli for that material form.**

The resulting thicknesses are listed in Table 3.1. Note that for the 2-D braided material, two thicknesses were used to look at the influence of this parameter. When referring to these materials in the text of this report, their nominal values of 1/8" and 1/4" will often be used for simplicity, although the actual value is somewhat different.

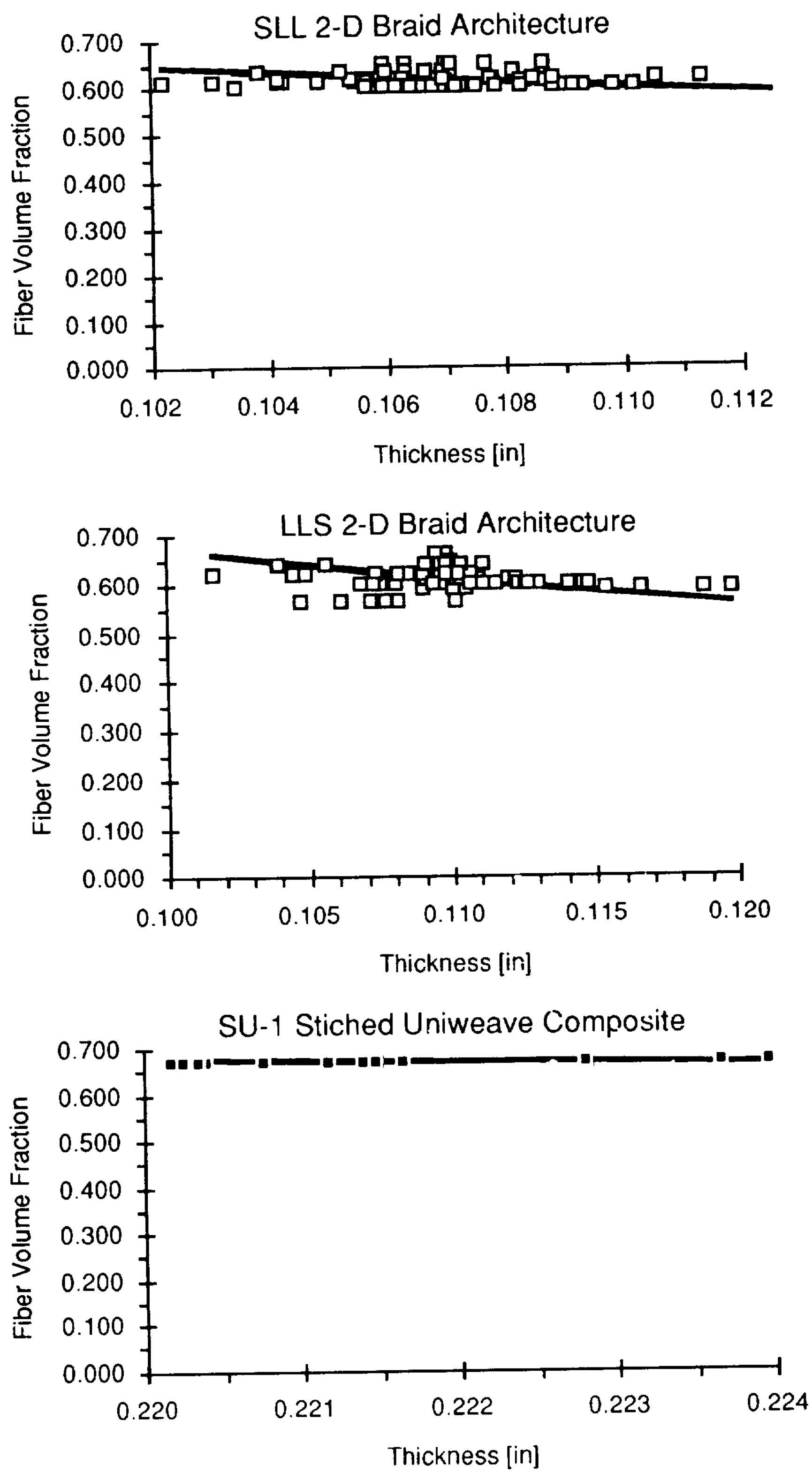


Figure 3.1 Example of Relationship between Fiber Volume Fraction and Thickness for SLL, LSS and SU-1 Specimens.

Table 3.1 Summary of Normalized Thicknesses

Name	Thickness [in]
SLL	0.110 or 0.215
LLL	0.114 or 0.229
LLS	0.112 or 0.220
LSS	0.111 or 0.215
LS-1	0.226
LS-2	0.230
OS-1	0.234
OS-2	0.226
TS-1	0.237
TS-2	0.228

Name	Thickness [in]
SU-1	0.247
SU-2	0.265
SU-3	0.261
SU-4	0.241
SU-5	0.274

3.3 Stress, Modulus and Poisson's Coefficient Calculation

The first issue that arises when reducing material testing data from load to stress is the question of how to define thickness. One observation made when analyzing the data generated in this test program was the higher than usual scatter in some of the results. Although this is somewhat inherent to the materials tested here, it was found that part of that scatter was due to the use of actual measured specimen thickness because of the variability in thickness and fiber volume fraction from panel to panel. Therefore, in this report, ultimate stress is defined as the specimen ultimate load divided by the specimen actual width and *nominal* thickness calculated in the previous section:

$$\sigma = \frac{P}{w\, t_{nom}}$$

where P is the load, w the specimen width and t_{nom} the nominal thickness

The specimen modulus was calculated by performing a linear regression of load versus axial strain The axial strain range used in the calculation is 1000 to 3000 microstrains. The specimen actual width and nominal thickness are used in the calculation. Similarly, the Poisson's coefficient was calculated by performing a linear regression of transverse versus axial strain over the same range of axial strain.

3.4 Open-Hole Data

When analyzing data from an open hole test, there are several ways to calculate and report stress at failure. The first approach is to use the gross stress defined as load divided by the cross-section area of the specimen away from the hole.

$$\sigma_{gross} = \frac{P}{w\, t_{nom}}$$

The second way is to use net stress by using the section area through the hole.

$$\sigma_{net} = \frac{P}{(w - d)\, t_{nom}}$$ where d is the hole diameter

Another way to reduce the data is to correct the gross stress with the width correction factor described in Ref. 2. This factor is defined as the ratio of stress concentration factor in the finite width coupon to stress concentration factor for a hole in an infinitely wide plate. Although this factor should vary with the elastic constants of the material, that correction factor is fairly small for the type of specimens typically used. Thus, it is customary to use the correction factor developed for a quasi-isotropic laminate for all laminates.

$$\frac{\sigma_\infty}{\sigma_{gross}} = \left[\frac{2 + \left(1 - \frac{d}{w}\right)^3}{3\left(1 - \frac{d}{w}\right)} \right]$$

For example, in the following chapters, testing of specimens with w/d = 4, 6 and 8 will be performed. Thus, for these specimens, the correction factor is equal to 1.076 for w/d=4, 1.031 for w/d=6 and 1.017 for w/d=8.

In order to analyze the data for the effect of hole size, a procedure similar to the Mar-Lin fitting technique is used (Ref. 3). After obtaining the mean strength for each hole diameter, a best fit curve was calculated by performing a linear regression of the logarithm of strength versus the logarithm of diameter:

$$\log \sigma = a \log d + b \qquad \text{or} \qquad \sigma = s\, d^a \qquad \text{with } s = 10^b$$

The parameter a can be roughly interpreted as the material sensitivity to hole diameter.

4. Strain Gage Size Sensitivity Study

Significant variations in displacement field homogeneity have been identified in textile composite specimens through the use of Moiré interferometry. Uniaxial tension test results indicate, for example, that local strains may vary by as much as a factor of two within the unit cells of laminates formed from 2-D triaxially braided preforms (Ref. 4). Test specimens must, therefore, be designed to encompass representative volumes of material within their test sections to obtain characteristic measures of mechanical response. The size and type of instrumentation used plays a similarly critical role in obtaining accurate measurements.

A series of tensile tests were conducted to determine the sensitivity of strain measurements to the size of the strain gage. The objective of this study was to establish a database which will be used to develop guidelines for the instrumentation of textile composites. Descriptions of the test specimens and test procedures employed in the study and the strain gages investigated are presented in the following sections. They are followed by a review of the test results.

4.1 *Test Specimens and Procedures.*

Samples of the four 2-D triaxial braids and the six 3-D weaves described earlier in this report were loaded in uniaxial tension. Strains in both the longitudinal direction (parallel to the 0° yarns) and the transverse direction (perpendicular to the 0° yarns) was measured.

Forty specimens were tested in the program. Because of limited quantities of material, only four specimens, 2 axial and 2 transverse, were used for each material type. The longitudinal or axial tension specimens were 1.5 in. wide and 10.0 in. long. The transverse tension specimens were 1.5 in. wide and 7.0 in. long. All specimens tested in this study were nominally 0.250 inches thick. Strain measurements were made over a 3 inch long section centered along the length of the specimen.

All tests were conducted on a 50 Kip servo-hydraulic test machine. It was programmed to run in displacement control at a ramp rate of 0.01 in/min. Strain was monitored throughout the test. Loading was halted at 3250 microstrain and the specimen was unloaded. Each specimen was loaded three times in this manner. Load, displacement, and strain were continuously recorded via a data acquisition system which monitored each channel once a second.

4.2 *Strain Gages Investigated.*

Six gage types were investigated in this study. They were chosen to provide a range of gage lengths from 0.125 inch to 0.500 inch, and widths ranging from 0.062 inches to 0.500 inches. Three of the gages featured square grids; three had rectangular grids. The length-to-width ratio of the rectangular gages was approximately 2 to 1. A total of nine strain gages (three of each type) were mounted on each specimen; six on one side and three on the other. Table 4.1 lists all gages used and their dimensions, resistance and cost per package of five gages.

Table 4.1 Strain Gage Description

Strain Gage Type	Gage Dimensions [in]	Resistance [Ohms]	Price [$/Pkg.]
EA-06-125BZ-350	0.125 x 0.062	350	17
EA-06-125AD-120	0.125 x 0.125	120	17
CEA-06-250UN-350	0.250 x 0.120	350	30
EA-06-250AE-350	0.250 x 0.250	350	32
CEA-06-500UW-350	0.500 x 0.180	350	48
EA-06-500AE-350	0.500 x 0.500	350	80

4.3 Experimental Results.

The strains recorded by each gage mounted on the specimen were used to compute modulus. The resulting moduli were then averaged together. Standard deviations and coefficients of variation were also computed to measure the scatter in the data.

The longitudinal and transverse tension tests results obtained for the 2-D braid materials are given in Tables 4.2 and 4.3, respectively. Test results obtained for the 3-D weave materials are listed in Tables 4.4 and 4.5. The tables list the average moduli measured for each gage type , i.e. the average of three gages per gage type, and the standard deviations of these measurements. The coefficients of variation of these measurements are given in parenthesis in the tables. These data have not been normalized to a common fiber volume or thickness. The thicknesses of the individual specimens are listed in Tables 4.2-4.5.

In most cases, the materials' moduli were computed over the 1000 to 3000 microstrain region of the stress-strain curves. The slopes of the curves were established through linear regression of the data. The two exceptions were the 2-D braid laminate LLL and the 3-D weave laminate LS1. They both apparently developed damage at approximately 2500 microstrain. The moduli in these cases were computed over narrower ranges since the gages reflected the damage development.

A review of these test results is necessarily restricted to qualitative assessments due to the limited amount of data available. Only three replicate gages could be mounted on the specimens and only two specimens were available for each material type. Qualitative assessments are, however, possible and general trends in the data are apparent.

4.4 2-D Braided Materials

A review of the data obtained for the four braided laminates indicates that the reproducibility of the measurements is greatly increased as the gage length increases. This is illustrated in Figure 4.1 which plots the coefficient of variation of the moduli measurements obtained for each gage type versus the gage length. Both the longitudinal and transverse test results are displayed in the figure. The gage length in this case has been normalized by dividing the strain gage's length by the material 's unit cell length. A vertical line marks the point at which the strain gage length is equal to the unit cell length. As the figure demonstrates, the data's coefficient of variation greatly decreases when the strain gage length exceeds the length of material's unit cell. In fact, the coefficient of variation exceeded 5% (as indicated by the horizontal line in the figure) in only two of the twenty-four cases in which the gage was longer than the unit cell.

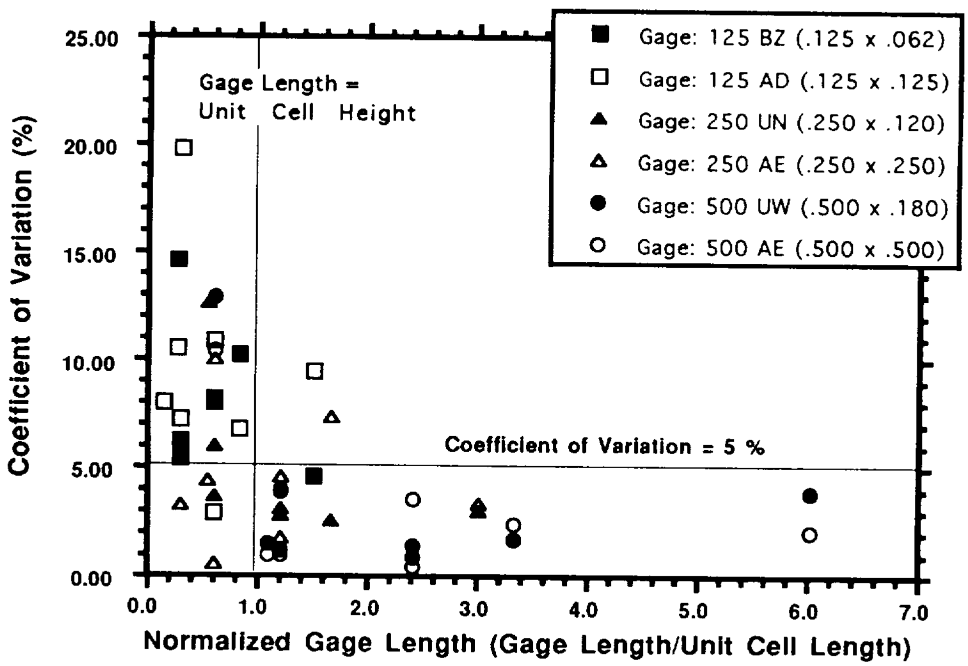


Figure 4.1 Coefficient of Variation of Moduli for each Gage Type.

While the coefficient of variation of the moduli measurements decreased with increasing gage length, there was no clear pattern to changes in mean moduli as strain gage length increased. Although there were several cases in which the moduli were lower as gage length increased, the change in moduli that accompanied an increase in strain gage length was within the scatter of the data in a majority of cases. It was apparent, however, that changes in modulus were small (i.e. less than 5%) when the gage length was increased beyond the unit cell length.

The data also permitted a comparison of the effect of strain gage width on the measurements. As in strain gage length sensitivity comparison discussed above, in a majority of cases the change in moduli that accompanied an increase in strain gage width was within the scatter of the data. However, when comparisons were possible, i.e. when changes in modulus exceeded the coefficients of variation of the moduli, the data indicated that increasing gage width decreased modulus. These changes exceeded 5% in several cases. No relationship between gage dimensions and unit cell dimensions was discerned, however.

4.5 3-D Woven Materials

Many of the trends noted for the braided laminates were also apparent when the woven laminate data listed in Tables 4.4 and 4.5 were examined. Scatter in the data, as monitored by the coefficient of variation, again decreased as gage length increased. Almost half of the modulus measurements made using the shortest, 0.125 in., gages had coefficients of variation in excess of 5%. The number of instances in which the coefficients of variation exceeded this value decreased markedly as gage length increased to 0.250 in. and 0.500 in.

Instances in which the measured modulus decreased as gage length increased were also evident in the woven laminate test results. However, as noted above for the braided laminates, the change in moduli that accompanied an increase in strain gage length was within the scatter of the data in a majority of cases. Increasing strain gage width had a similar effect on the measured moduli.

Table 4.2 2-D Braid Longitudinal Modulus Measurements

Material	Thick	Modulus [Msi]					
	[in]	125 BZ	125 AD	250 UN	250 AE	500 UW	500 AE
SLL	.219	-	8.78 ± 0.83 (9.5%)	9.25 ± 0.28 (3.0%)	-	8.74 ± 0.34 (3.9%)	-
SLL	.220	8.75 ± 0.40 (4.6%)	-	-	8.86 ± 0.30 (3.4%)	-	8.58 ± 0.18 (2.0%)
LLL	.218	8.61 ± 0.88 (10.2%)	-	-	9.14 ± 0.67 (7.3%)	-	9.06 ± 0.22 (2.4%)
LLL	.230	-	9.47 ± 0.64 (6.8%)	8.50 ± 0.22 (2.6%)	-	8.67 ± 0.15 (1.7%)	-
LLS	.222	10.06 ± 0.82 (8.2%)	-	-	9.81 ± 0.45 (4.6%)	-	9.52 ± 0.34 (3.6%)
LLS	.252	-	8.85 ± 0.96 (10.8%)	8.87 ± 0.25 (2.8%)	-	8.96 ± 0.08 (1.0%)	-
LSS	.221	-	4.79 ± 0.14 (2.9%)	4.77 ± 0.15 (3.1%)	-	4.92 ± 0.07 (1.4%)	-
LSS	.223	4.52 ± 0.36 (8.0%)	-	-	4.50 ± 0.08 (1.7%)	-	4.34 ± 0.02 (0.5%)

Table 4.3 2-D Braid Transverse Modulus Measurements

Material	Thick [in]	Modulus [Msi]					
		125 BZ	125 AD	250 UN	250 AE	500 UW	500 AE
SLL	.223	-	7.63 ± 0.80 (10.5%)	6.41 ± 0.81 (12.6%)	-	6.89 ± 0.10 (1.5%)	-
SLL	.223	6.84 ± 1.0 (14.6%)	-	-	6.32 ± 0.28 (4.4%)	-	6.29 ± 0.06 (1.0%)
LLL	.221	-	8.06 ± 0.65 (8.0%)	7.82	-	6.98 ± 0.90 (12.9%)	-
LLL	.223	7.03 ± 3.51 (50.0%)	-	-	6.41 ± 0.21 (3.3%)	-	6.64 ± 0.69 (10.4%)
LLS	.222	3.22 ± 0.20 (6.2%)	-	-	2.94 ± 0.28 (10.0%)	-	2.80 ± 0.12 (4.0%)
LLS	.250	-	2.68 ± 0.53 (19.8%)	2.51 ± 0.15 (6.0%)	-	2.79 ± 0.11 (3.9%)	-
LSS	.223	3.12 ± 0.17 (5.4%)	-	-	3.33 ± 0.02 (0.6%)	-	2.98 ± 0.03 (1.0%)
LSS	.222	-	3.07 ± 0.22 (7.2%)	3.22 ± 0.12 (3.7%)	-	3.21 ± 0.04 (1.2%)	-

Table 4.4 3-D Weave Longitudinal Modulus Measurements

Material	Thick [in]	Modulus [Msi]					
		125 BZ	125 AD	250 UN	250 AE	500 UW	500 AE
TS1	.230	11.59 ± .41 (3.5%)	-	-	12.04 ± .84 (7.0%)	-	11.62 ± .25 (2.0%)
TS1	.230	-	12.36 ± .51 (4.0%)	12.27 ± .09 (0.7%)	-	11.93 ± .19 (1.5%)	-
TS2	.226	11.42 ± .43 (3.8%)	-	-	10.49 ± .78 (7.4%)	-	10.94 ± .18 (1.6%)
TS2	.227	-	11.82 ± .55 (4.7%)	11.35 ± .04 (0.4%)	-	11.03 ± .10 (0.9%)	-
LS1	.222	-	13.06 ± .42 (3.2%)	13.32 ± .63 (4.7%)	-	12.65 ± .32 (2.5%)	-
LS1	.227	13.89 ± 3.54 (25.0%)	-	-	13.03 ± .40 (3.1%)	-	12.34 ± .26 (2.1%)
LS2	.231	-	12.14 ± .27 (2.2%)	12.26 ± .06 (0.5%)	-	11.72 ± .17 (1.5%)	-
LS2	.228	12.10 ± .62 (5.1%)	-	-	11.83 ± .43 (3.6%)	-	11.28 ± 06 (0.5%)
OS1	.228	-	11.28 ± .59 (5.2%)	12.71 ± .34 (2.7%)	-	11.41 ± .20 (1.8%)	-
OS1	.226	11.73 ± .60 (5.1%)	-	-	11.56 ± .75 (6.5%)	-	11.26 ± .21 (1.9%)
OS2	.230	-	10.69 ± .23 (2.2%)	11.07 ± .42 (3.8%)	-	10.45 ± .32 (3.1%)	-
OS2	.230	10.62 ± .25 (2.4%)	-	-	10.03 ± .40 (4.0%)	-	11.29 ± 1.0 (8.9%)

Table 4.5 3-D Weave - Transverse Modulus Measurements

Material	Thick	Modulus [Msi]					
	[in]	125 BZ	125 AD	250 UN	250 AE	500 UW	500 AE
TS1	.229	6.43 ± .48 (7.5%)	-	-	6.53 ± .19 (2.9%)	-	6.35 ± .06 (1.0%)
TS1	.229	-	6.44 ± .20 (3.1%)	6.76 ± .15 (2.2%)	-	6.49 ± .03 (0.5%)	-
TS2	.224	-	7.25 ± .33 (4.6%)	7.25 ± .36 (5.0%)	-	6.70 ± .07 (1.0%)	-
TS2	.231	7.32 ± .61 (8.3%)	-	-	6.83 ± .17 (2.5%)	-	6.78 ± .06 (0.9%)
LS1	.228	6.18 ± .29 (4.7%)	-	-	6.27 ± .02 (0.3%)	-	6.03 ± .26 (4.3%)
LS1	.223	-	6.15 ± .42 (6.8%)	6.41 ± .59 (9.2%)	-	6.35 ± .50 (7.9%)	-
LS2	.233	-	6.58 ± .61 (9.3%)	6.98 ± .41 (5.9%)	-	6.53 ± .05 (0.8%)	-
LS2	.231	6.70 ± .89 (13.3%)	-	-	6.89 ± .50 (7.3%)	-	6.58 ± 11 (1.7%)
OS1	.229	-	6.91 ± .43 (6.2%)	7.00 ± .16 (2.3%)	-	6.78 ± .06 (0.9%)	-
OS1	.225	7.17 ± .67 (9.3%)	-	-	6.91 ± .28 (4.1%)	-	6.75 ± .08 (1.2%)
OS2	.232	6.35 ± .14 (2.2%)	-	-	6.22 ± .07 (1.1%)	-	6.01 ± .09 (1.5%)
OS2	.232	-	6.20 ± .14 (2.3%)	6.21 ± .07 (1.1%)	-	6.14 ± .12 (2.0%)	-

5. In-Plane Tension Test Program

The behavior of textile composites under unidirectional tensile loading is examined in this chapter. Strength, stiffness and Poisson's coefficient are measured. The effect of specimen width and length is the main focus of the test method evaluation.

5.1 *Test Configuration*

The test matrix used for this program is shown in Table 5.1. A total of 156 2-D braided specimens, 15 stitched uniweave specimens and 18 3-D woven specimens were used. Specimen configuration effects were studied with the 2-D braided specimens, while the stitched uniweave and 3-D woven specimens used a single size, 2 inch wide by 7 inch long.

The basic specimen for this test program is the straight sided coupon described in ASTM D3039 and illustrated in Figure 5.1. This specimen was used to measure tension strength, modulus and Poisson's ratio. A dogbone specimen configuration in Figure 5.1b was also used for some of the tests. Beveled fiberglass tabs, with 5° taper angle and 0.050 inch thick, were bonded to the straight-sided specimens. The dogbone and transverse tension specimens were not tabbed since initial tests of such specimens resulted in failures within the test section. During testing, the specimen ends were gripped with hydraulic grips and the coupon loaded to failure at a stroke rate of 0.05 inches per minute.

An extensometer with a one inch gage length was used in all tests. The extensometer was attached at the center of the gage length with rubber bands and hot glue or M-Bond 200. A few specimens experienced extensometer slippage prior to failure, generally because of local fiber or matrix failure prior to final failure. Most specimens were also instrumented with longitudinal and transverse 1/2 inch square strain gages (Measurements Group Inc. EA-06-500AE-350).

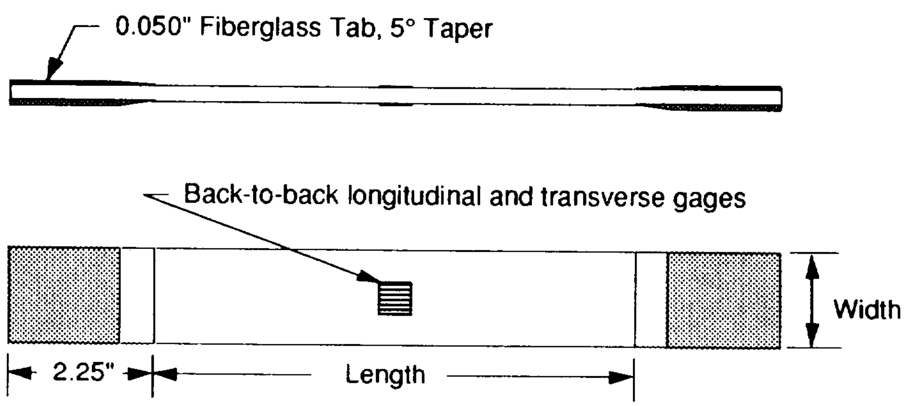


Figure 5.1.a Typical Tension Specimen Configuration.

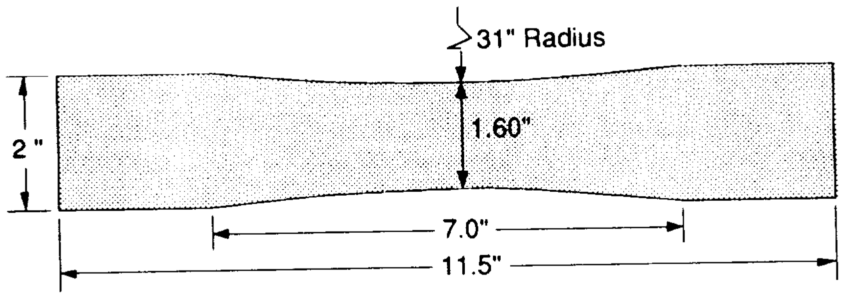


Figure 5.1.b Dogbone Tension Specimen Configuration.

Table 5.1 Test Matrix for Tension Test Program.

Gage Section Dimensions			Material Systems								
Width [in]	Length [in]	Note	SLL 1/8"	SLL 1/4"	LLS 1/8"	LLS 1/4"	LLL 1/8"	LLL 1/4"	LSS 1/8"	LSS 1/4"	Others (1)
1.00	3.50		3	3	3	3	3	3	3	3	
1.50	5.25		3	3	3	3	3	3	3	3	
2.00	5.50		3	3	3	3					
2.00	7.00		3	3	3	3	3	3	3	3	3
2.00	8.50		3	3	3	3					
2.50	8.75		3	3	3	3	3	3	3	3	
1.60	7.00	Dog-Bone	3		3		3		3		
1.50	7.00	Net-Shape	3		3		3		3		
2.00	7.00	Transverse	3		3		3		3		
			27	18	27	18	21	12	21	12	33

(1) Five Stitched Uniweave and Six 3-D Woven Materials.

5.2 2-D Braid Materials

5.2.1 Test Section Width, Length and Thickness Effects

One issue of interest in the tensile testing was the effect of the specimen width compared to the unit cell size of the materials. A certain minimum number of unit cells should be present across the test section to insure a representative failure mode. The baseline test section used here is 2 inches wide and 7 inches long. Specimens with a width ranging from 1 to 2.50 inches were tested to detect any sensitivity to width.

Results for the four braid types are shown in Figure 5.2, where strength and coefficient of variations (CoV) are reported. No clear trend can be identified, either by looking at the mean values or the CoV. It is interesting to note that the largest unit cell width is that of the LLL braid at about 0.83 inch and that a one inch wide coupon contains just over one cell. Yet, no difference was observed in strength.

Similarly, no trend can be identified between thin and thick specimen in terms of scatter. The difference in mean result between thin and thick specimens with a width greater or equal to 1.5 inch was +2.9% for SLL, +4.4% for LLS, +0.2% for LLL and 0% for LSS. Since these values are within the results scatter, there appears to be no significant difference between 1/8" and 1/4" thick specimens.

Finally, results for the SLL and LLS specimens are plotted in Figure 5.3 as a function of the specimen test section length. No trend in tension strength can be observed in changing the length from 5.5 to 8.75 inches.

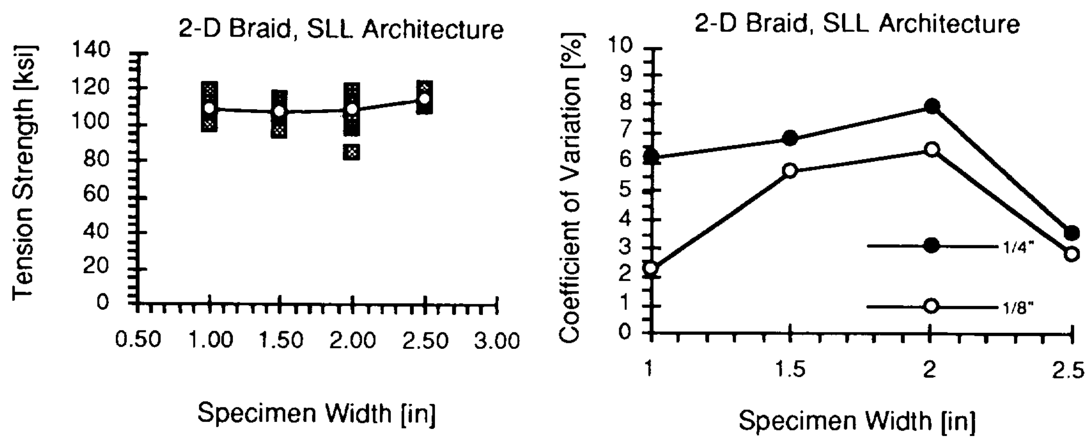


Figure 5.2.a Effect of Specimen Width on Tensile Strength of 2-D Braid SLL.

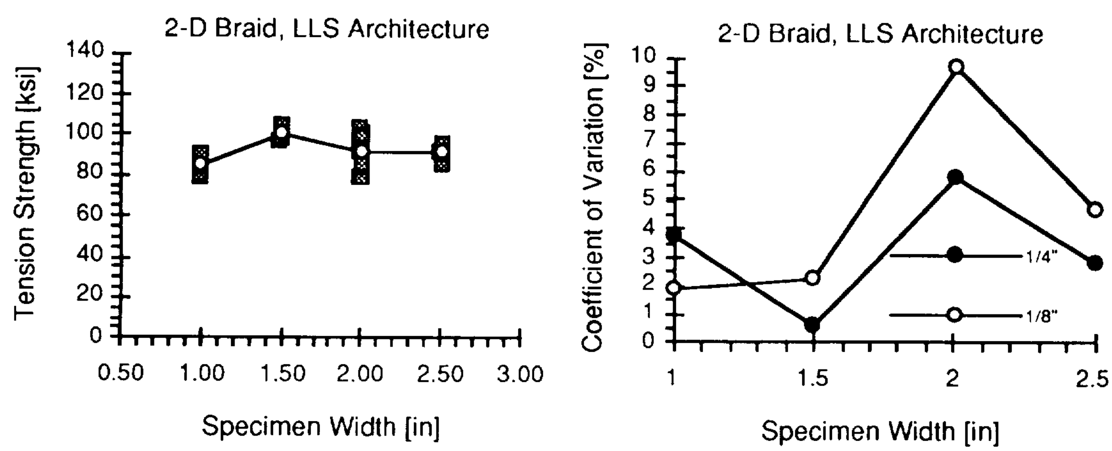


Figure 5.2.b Effect of Specimen Width on Tensile Strength of 2-D Braid LLS.

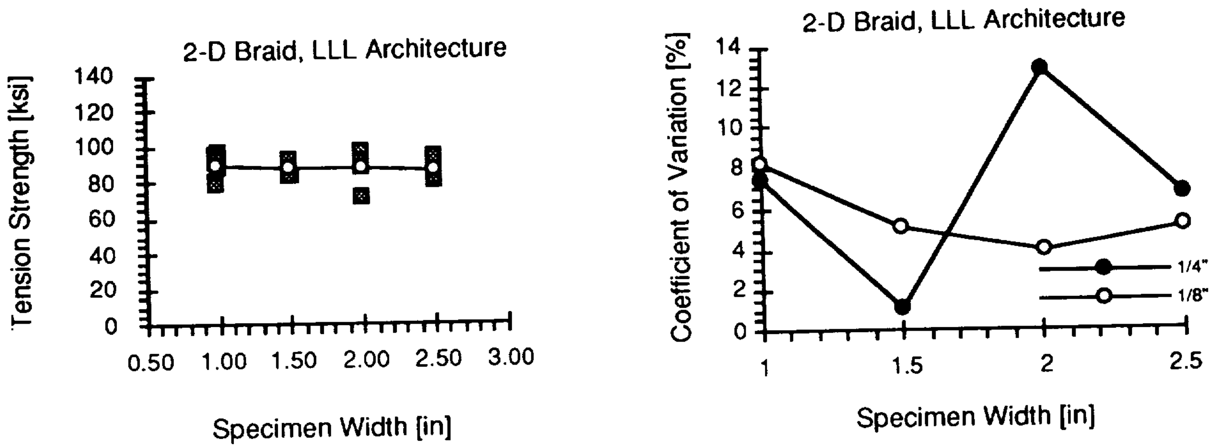


Figure 5.2.c Effect of Specimen Width on Tensile Strength of 2-D Braid LLL.

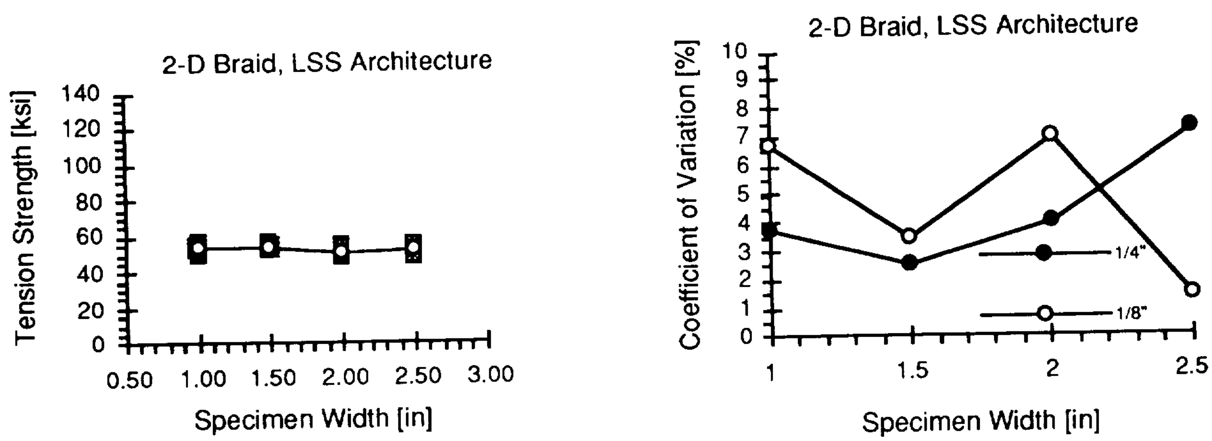


Figure 5.2.d Effect of Specimen Width on Tensile Strength of 2-D Braid LSS.

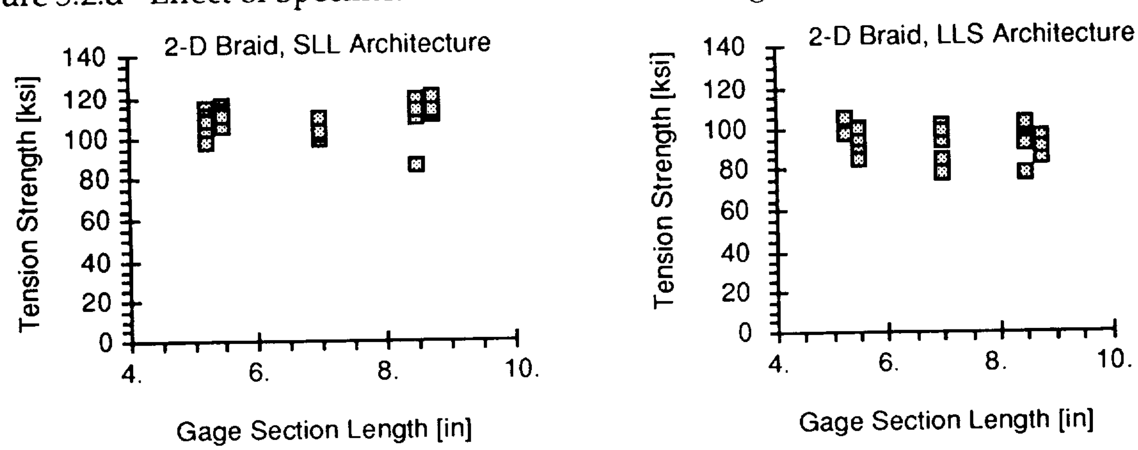


Figure 5.3 Effect of Specimen Length on Tensile Strength of 2-D Braids.

5.2.2 Longitudinal Tension Test Summary

The results from all the tension tests are summarized in Table 5.2. Since it was seen in the previous section that gage length and width had a minimal influence on the results, data from all specimen configurations were averaged together for each type of material. In this table, maximum strain refers to the last strain gage reading prior to failure, while nominal strain is simply the ultimate stress divided by modulus. Because of the possibility of local damage developing under the strain gage prior to failure, the maximum strain reading is not always very reliable and shows quite a bit of scatter. Therefore, it is listed here mostly for reference purpose. In design practice, the value used is always the nominal strain since materials are assumed to behave linearly to failure. Results for both thin and thick specimens are listed although there does not appear to be any significant difference between the two. Poisson's coefficient measurements were not very reliable in general and showed a very high scatter.

A particularly interesting comparison can be made between the SLL and LLL specimens where only the longitudinal and bias tow sizes have been changed by a factor of 2.5. This results in a 20% strength reduction and 5% modulus reduction.

As mentioned above, a dogbone shape coupon was considered as an alternative test configuration. A strength comparison with the baseline specimens is shown in Figure 5.4. A slightly higher strength is obtained in half the cases, and a slightly lower strength in the other two. Thus, there does not appear to be a strong reason to prefer the dogbone specimen which, in addition, is more expensive to prepare.

In all the previous tests, the specimens were cut from large panels. However, in certain structural elements, the material does not need to be cut and can be molded to net shape by folding the dry preform along the edge of the part. This fold results in a slightly different fiber orientation along the edge of the specimens. A series of tests was conducted to investigate this effect using a coupon with a 1.5 inch wide by 7 inches long test section . A strength comparison with the baseline is also shown in Figure 5.4. All net-shape specimens exhibited a higher strength. Two of the likely reasons for this are that the fiber architecture is different near the edge with more fibers oriented longitudinally, and possibly that free-edge stresses are reduced.

Table 5.2 Summary of Tension Properties of 2-D Braided Materials

Property	SLL 1/8″	SLL 1/4″	LLS 1/8″	LLS 1/4″	LLL 1/8″	LLL 1/4″	LSS 1/8″	LSS 1/4″
Strength [ksi]	109.9	107.9	90.9	92.9	88.3	87.1	52.3	53.0
Nominal Strain [μs]	11,272	10,943	8,724	9,063	9,536	9,416	10,608	10,600
CoV [%]	5.2	7.1	8.7	7.7	6.9	7.5	5.5	4.5
Modulus [msi]	9.75	9.86	10.42	10.25	9.26	9.25	4.93	5.00
CoV [%]	3.9	4.2	4.3	3.7	3.4	5.5	4.3	5.6
Max. Strain [μs]	12,437	11,760	9,103	9,047	9,754	11,309	12,165	12,154
CoV [%]	18.4	13.3	11.0	7.8	12.0	5.6	4.6	3.3
Poisson's Coefficient	0.155	0.171	0.613	0.616	0.152	0.130	0.709	0.787
CoV [%]	17.0	19.9	11.2	7.3	18.8	26.0	12.6	11.2

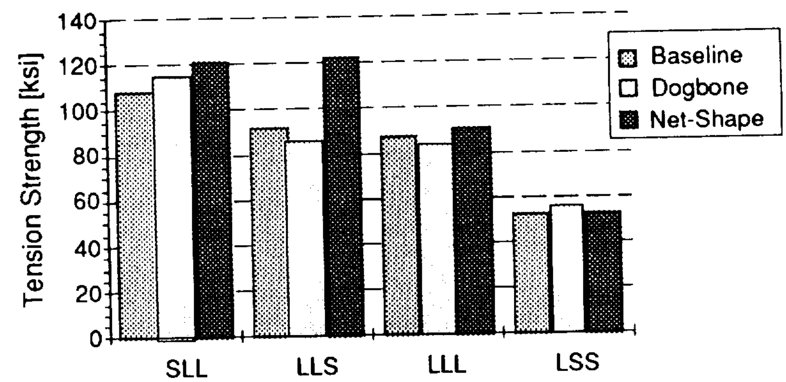


Figure 5.4 Tensile Strength of Baseline, Dogbone and Net-Shape 2-D Braided Specimens.

5.2.3 Transverse Tension

A series of tests was also conducted along the material transverse direction using specimens with a 2 inches wide by 7 inches long gage section. In this test, no fiber is running along the test direction and all the load is carried by the bias yarns. Thus, this test is very well suited to assess the strength penalty due to the crimp in these tows. As shown in Figure 5.5 and Table 5.3, surprisingly low strength and strain were obtained. Once again, the comparison of SLL and LLL shows that the increased tow size leads to a strength and modulus reduction of 12% and 6% respectively.

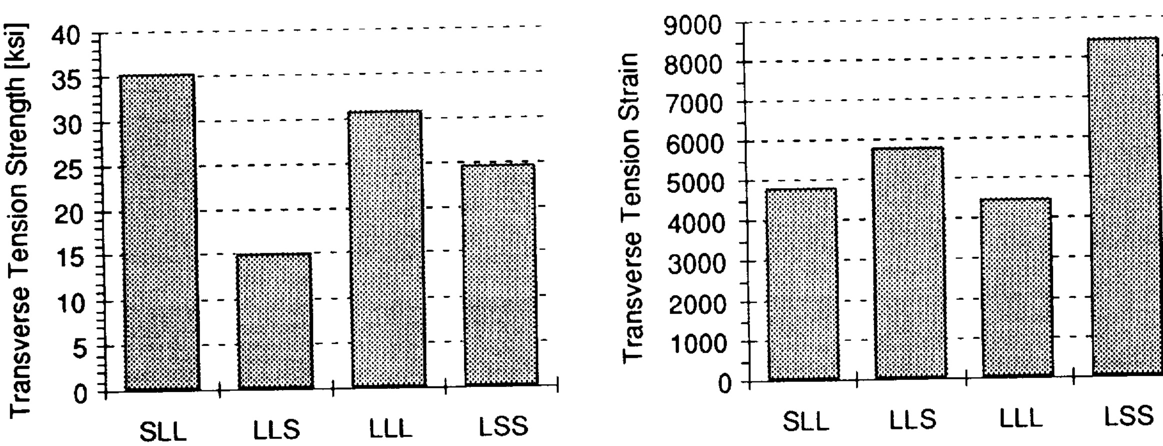


Figure 5.5 Transverse Tension Strength and Nominal Strain for 2-D Braided Materials.

Table 5.3 Summary of Transverse Tension Properties of 2-D Braided Materials

Property	SLL	LLS	LLL	LSS
Strength [ksi]	35.2	15.2	30.9	24.7
Nominal Strain [μs]	4810	5840	4490	8440
CoV [%]	7.0	5.5	7.4	4.7
Modulus [msi]	7.32	2.60	6.87	2.92
CoV [%]	5.8	6.0	1.7	1.5

5.3 <u>Stitched Uniweave Materials</u>

All stitched uniweave materials were tested using the baseline specimen and a test section of 2 by 7 inches. Strength and stiffness properties are summarized in Table 5.4 and Figure 5.6 for all five materials. Overall, the scatter in the results was much less than for the 2-D braids. The failure strains were also higher, indicating that the stitching and weaving process introduces less of a strain concentration than the braiding process. Material SU-1 with the smaller fiberglass stitches performed best, while material SU-5 with the large Kevlar stitches performed worst. Unfortunately, most failures occurred near or under the fiberglass tabs due in part to the fact that these were fairly thick specimens for which a load introduction through shear will introduce some stress concentration in the outer plies.

Table 5.4 Summary of Longitudinal Tension Properties of Stitched Uniweave Materials

Property	SU-1	SU-2	SU-3	SU-4	SU-5
Strength [ksi]	85.8	75.9	79.0	82.2	70.3
Nominal Strain [μs]	12,410	11,700	11,430	11,630	10,460
CoV [%]	3.0	2.1	1.6	2.8	9.0
Modulus [msi]	6.92	6.49	6.91	7.06	6.72
CoV [%]	0.8	1.5	2.0	0.3	0.8
Poisson's Coefficient	0.306	0.293	0.341	0.303	0.304

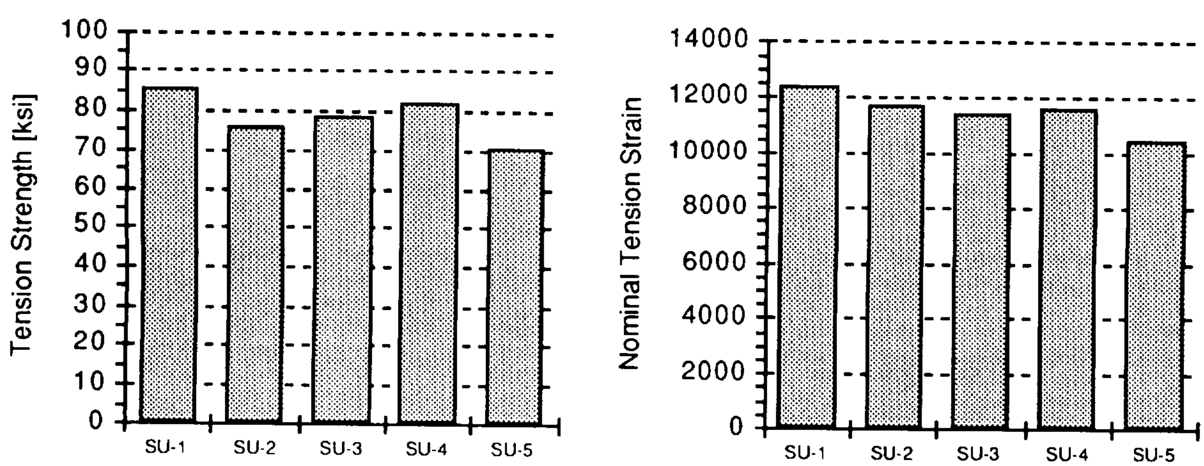


Figure 5.6 Summary of Longitudinal Tension Strengths and Nominal Strains of Stitched Uniweave Materials.

5.4 *3-D Woven Materials*

The 3-D woven materials were tested using the baseline specimen with a test section of 2 by 7 inches. Strength and stiffness properties are summarized in Table 5.5 and Figure 5.7 for all six materials. In two of three cases, the -2 material with the larger tow size performed rather poorly. The Poisson's coefficient for this type of material is always very low and for that reason, measurements exhibited a lot of scatter.

Table 5.5 Summary of Longitudinal Tension Properties of 3-D Woven Materials

Property	OS-1	OS-2	TS-1	TS-2	LS-1	LS-2
Strength [ksi]	137.4	92.9	137.6	131.8	138.9	96.1
Nominal Strain [μs]	11,900	7,890	10,950	11,350	11,300	7,870
CoV [%]	2.9	2.6	1.8	1.5	7.3	5.1
Modulus [msi]	11.55	11.78	12.57	11.61	12.29	12.22
CoV [%]	1.8	0.4	0.6	0.1	2.0	0.4
Poisson's Coefficient	0.034	0.046	0.060	0.040	0.060	0.040
CoV [%]	14.9	9.8	7.2	19.0	7.2	19.0

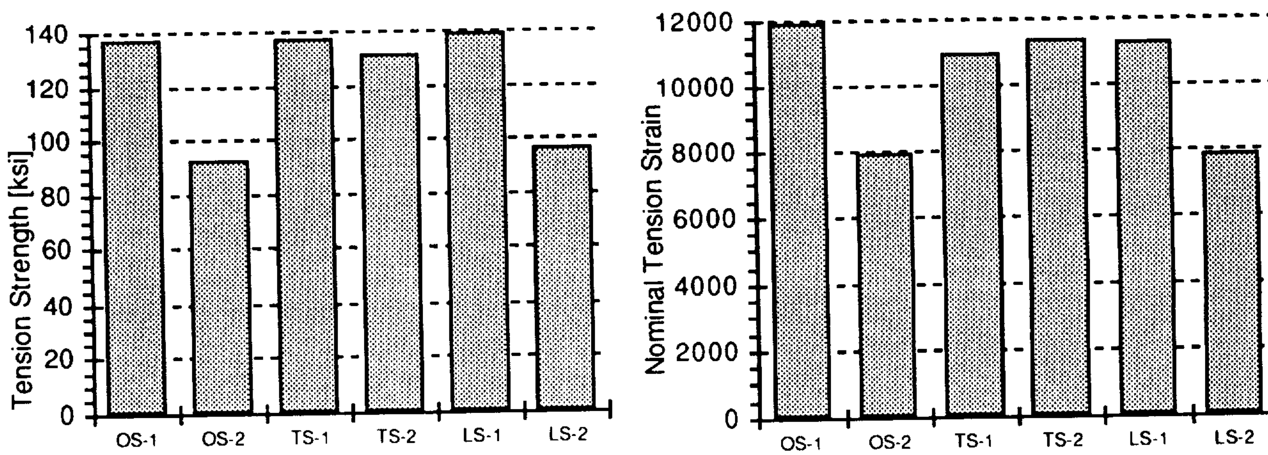


Figure 5.7 Comparison of Longitudinal Tension Strengths and Nominal Strains of 3-D Woven Materials.

5.5 *Test Recommendations*

The main concern in this test program was whether there are any scaling effects due to the unit cell size compared to the specimen size. Based on the data shown here, very little, if any, effects were observed from varying the specimen width and length. Specimens as narrow as about 2 unit cells were tested with little difference from larger one. Thus, for the materials evaluated here, the standard specimen width of 1.5 inch would be considered adequate compared to unit cell sizes of 0.4 inch to 0.5 inch.

Another concern in unnotched tension tests is to obtain a good failure mode inside the test section and away from the tab region. Most laminated materials tend to fail close to the tabs where small stress concentrations cannot be avoided. However, for the 2-D braided materials, failure was obtained within the test section, mostly due to the fact that the material itself contains stress concentrations due to tow waviness and crimp more severe than at the edge of the tabs so as to induce failure in the gage section. The use of a dogbone specimen produced strength results which are not significantly different from the straight sided specimen. Therefore, the use of a dogbone specimen is probably not worth the extra cost of specimen machining. Conversely, for the stitched uniweave material, since the material appears to contain less severe stress concentrations, failure usually occurred in the tab regions. The use of thinner specimens is recommended for this type of material.

Scatter in the results for the 2-D braided materials was slightly higher than for other materials and Poisson's coefficient measurements were particularly poor. This suggests the use of a somewhat larger number of specimens in order to obtain statistically adequate test data and to avoid taking a penalty when calculating B-basis allowables.

6. Open-Hole Tension Test Program

The strength of textile composites with open holes under unidirectional tensile loading is examined in this chapter. The effect of specimen width and hole diameter is the main focus of the test method evaluation.

6.1 Test Configuration

A straight-sided coupon with no tabs was used in this test program, as shown in Figure 6.1. The length was kept constant and the width varied as indicated below in the test matrix. All holes were drilled with ST carbide drill bits. Specimens were gripped in hydraulic grips and loaded to failure at a rate of 0.05 in/min. No strain measurements were taken and only load and machine stroke were recorded during these tests.

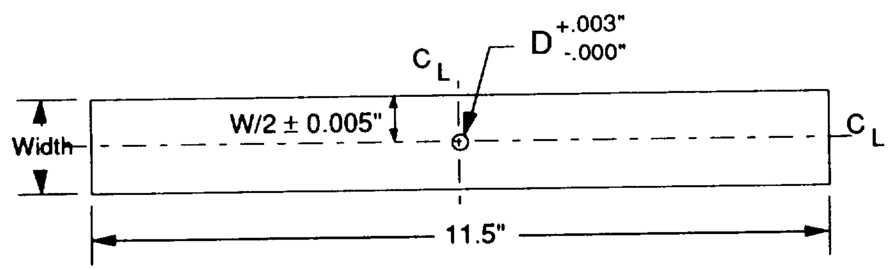


Figure 6.1 Open Hole Specimen Configuration.

The test matrix used for the Open Hole Tension test program is shown in Table 6.1. Because the objective is the evaluation of the test method, the first parameter of interest is the specimen width to hole diameter ratio. A ratio of W/D equal to 6 is typically used in testing composite materials. However, since material availability can be sometimes limited, it is of interest to find out how small a specimen can be used while still obtaining adequate data. Conversely, as in the tension test program, one needs to verify whether the large unit cell size has any influence and whether larger specimens than usual need to be used. Two material systems, SLL and LLS, were tested more extensively to investigate this effect on both thin and thick specimens. A second effect, more important from a mechanics of material point of view is the hole diameter since it is well known that strength is strongly dependent on the notch size for composite materials. Fewer tests were conducted on the other two 2-D braid architectures, LLL and LSS. Only 1.50 inch wide specimens were tested in this case. For all other material systems, i.e., stitched uniweave and 3-D woven angle interlock, 1.50 inch wide specimens were also used.

Table 6.1 Test Matrix for Open Hole Tension Test Program

Dimensions			Material Systems								
Width [in]	Diameter [in]	W/D	SLL 1/8"	SLL 1/4"	LLS 1/8"	LLS 1/4"	LLL 1/8"	LLL 1/4"	LSS 1/8"	LSS 1/4"	Others (1)
1.50	.375	4	3	3	3	3					3
1.50	.250	6	3	3	3	3					3
1.50	.188	8	3	3	3	3					3
2.25	.562	4	3	3	3	3	3	3	3	3	
2.25	.375	6	3	3	3	3	3	3	3	3	
2.25	.281	8	3	3	3	3	3	3	3	3	
3.00	.750	4	3	3	3	3					
3.00	.500	6	3	3	3	3					
3.00	.375	8	3	3	3	3					
			27	27	27	27	9	9	9	9	99

(1) Five Stitched Uniweave and Six 3-D Woven Materials.

6.2 *2-D Braid Materials*

6.2.1 Width to Diameter Ratio Effect

When analyzing data from an open hole test, there are several ways to calculate and report stress at failure. As described in Section 3.4, the options are gross stress, net stress and stress corrected to infinite plate width. As an example, these three stresses are shown in Figure 6.2 for two braid architectures, SLL and LLS. This data was obtained for 1/8" specimens with a 3/8" hole using three test configurations with w/d=4, 6 and 8. If there is no material or specimen sensitivity to w/d and if the finite width correction factor is accurate, the corrected stress should be the same for all test configurations. The data shown in Figure 6.2 indicates that this is roughly the case and that the corrected stress remains constant within the data scatter. On the other hand, net stress clearly varies with w/d and is not the best way to report the data. Since the values obtained are always higher, it is also a less conservative approach when using the data for design purpose. Therefore, stress calculated with the infinite width plate correction factor will be used in this report for all open hole tests. Other stresses can always be calculated if necessary from the raw data presented in Appendix A. Further more, this method is customarily used when determining composite material allowables. Also, several series of specimens were tested with both a varying hole diameter and w/d. Without a way of correcting the effect of w/d, it would not be possible to determine the influence of the hole diameter.

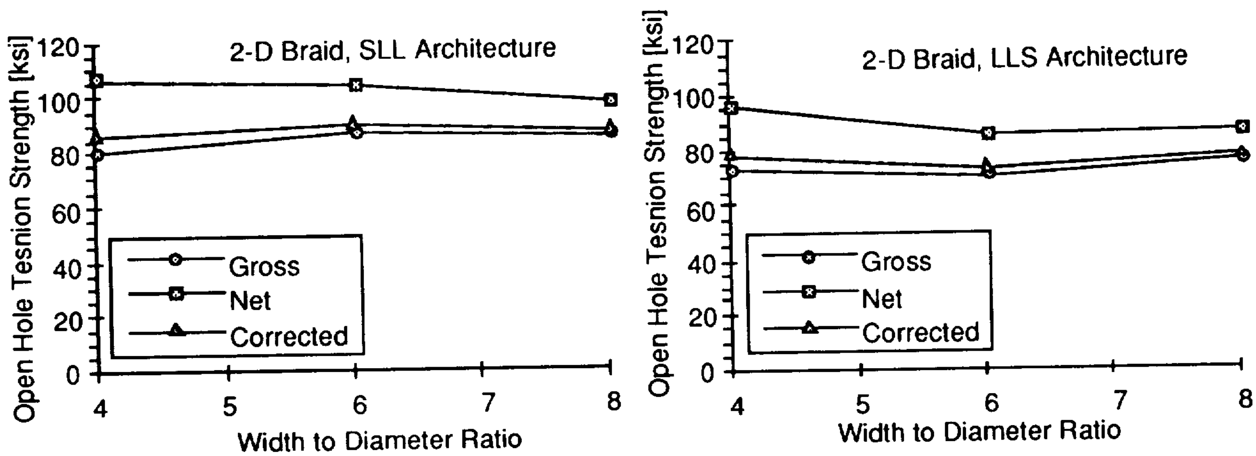


Figure 6.2 Comparison of Gross, Net and Corrected Stress in SLL and LLS 1/8" Thick Specimens with a 3/8" Diameter Hole.

6.2.2 Thickness Effect

Testing was conducted with two different thicknesses for all architectures, but data is available at a common hole diameter only for the SLL and LLS with a 3/8" hole diameter. This data, shown in Figure 6.3, reveals a certain sensitivity to thickness when a specimen with a low w/d is used. For instance, at w/d=4, the mean strength of the 1/4" specimens is 17% below that of the 1/8" ones. At w/d=8, the difference is reduced to 5%. For the LLS architecture, the difference is 16% at w/d=4, and 8% at w/d=8.

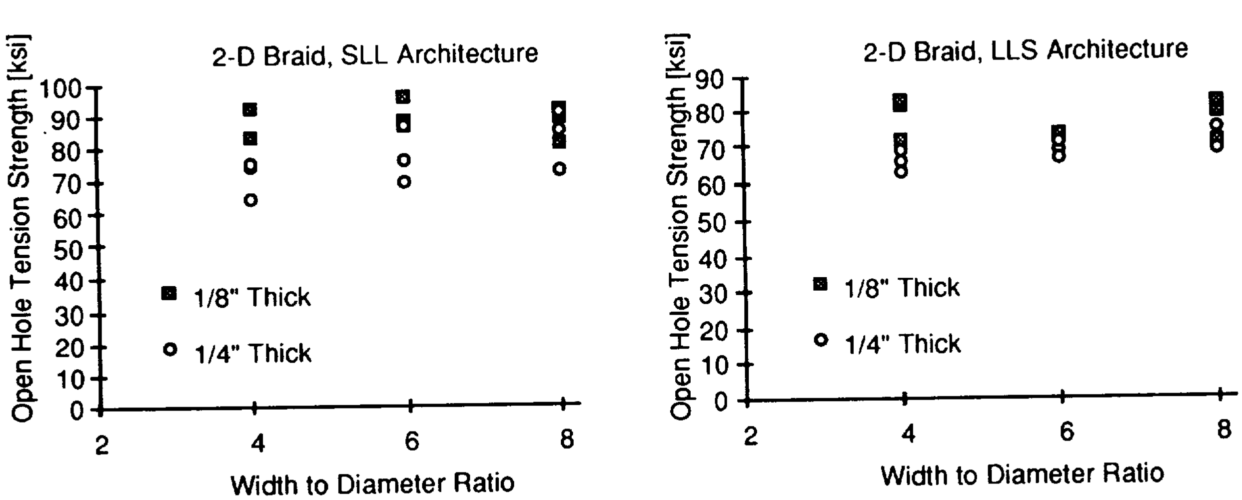


Figure 6.3 Comparison of Open Hole Tensile Strength in SLL and LLS 1/8" and 1/4" Thick Specimens with a 3/8" Diameter Hole.

6.2.3 Hole Size Effect

The parameter with the strongest influence is the hole diameter and it is well known that the strength of notched composite materials is sensitive to the notch size itself. Results for the four braid architectures are shown in Figure 6.4.a to 6.4.d. Because of the thickness sensitivity mentioned in the previous section, data from 1/8" and 1/4" specimens were separated. Unnotched strength (i.e., d = 0) is also indicated in each plot for reference.

The curve fitting technique described in Section 3.4 was used to help interpret the data and establish a relationship between strength and hole diameter. Note that unnotched strength is not used in this fitting process. Because of the scatter in data and the variability from panel to panel, this technique is very helpful in identifying series of data points for a given material which differ from the overall trend in behavior. However, it is also possible that fitting the whole range of hole diameters with a single curve is not completely accurate. For instance, at small hole diameters, i.e., hole sizes less than the unit cell width, one could expect a slightly different behavior and notch sensitivity than in specimens with a hole much larger than a unit cell. The results for the SLL architecture are fairly typical of the data obtained. For instance, for the 1/8" specimens, note that two points fall below the trend, for d=0.28" and d=0.56". Similarly, for the 1/8" LLS architecture, the data for d=0.25" and d=0.50" do not follow the general trend.

In general, the data for the thick specimens is always lower than for the thin specimens and appears to be slightly more consistent for the various hole diameters. However, the low values are partially due to the fact that the data was obtained in several cases from specimen with a low w/d. Also, there appears to be more difference between the two thicknesses at small diameters than at large diameters.

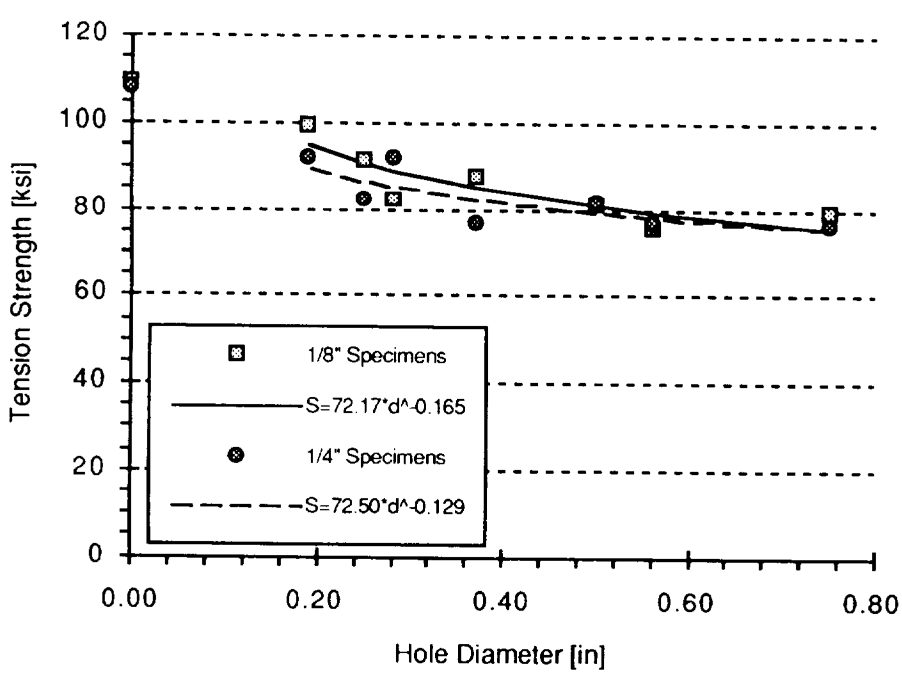


Figure 6.4.a Effect of Hole Diameter on Tension Strength of SLL Specimens.

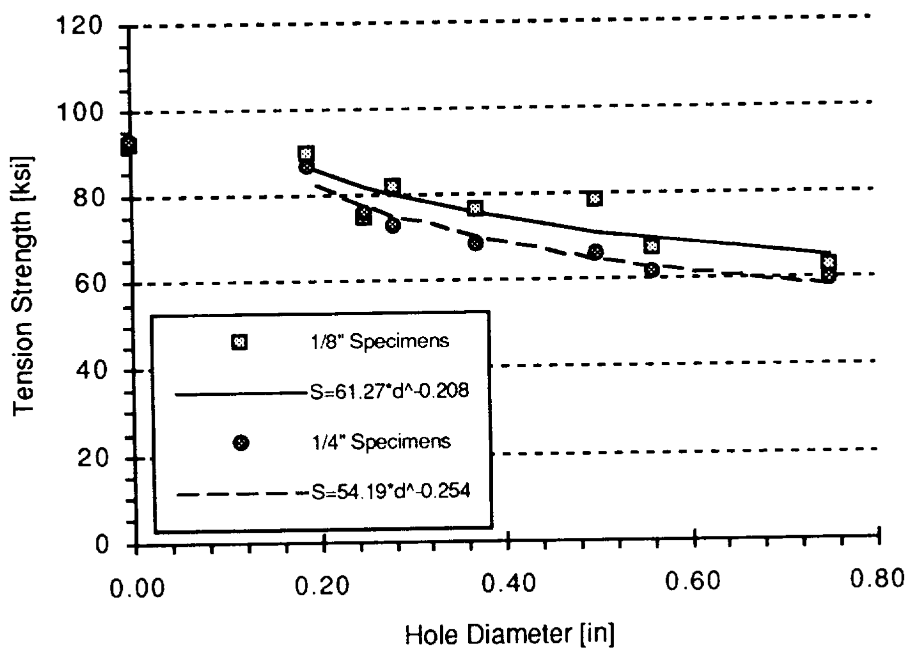


Figure 6.4.b Effect of Hole Diameter on Tension Strength of LLS Specimens.

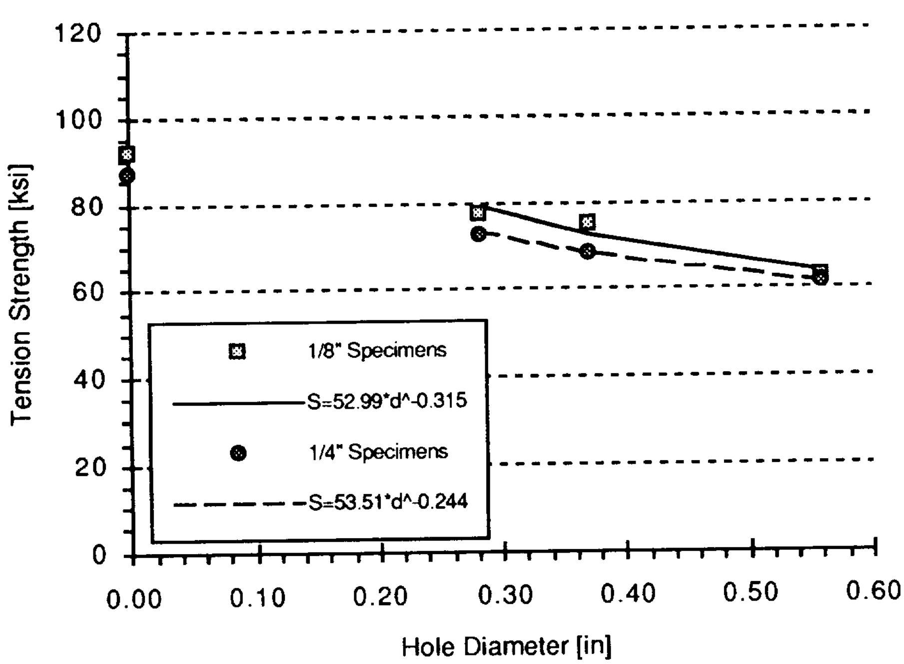


Figure 6.4.c Effect of Hole Diameter on Tension Strength of LLL Specimens.

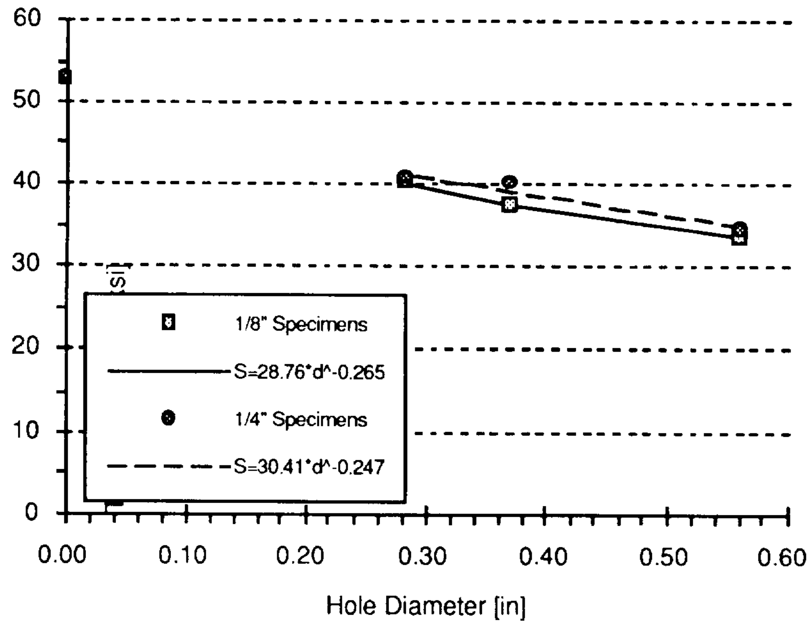


Figure 6.4.d Effect of Hole Diameter on Tension Strength of LSS Specimens.

6.2.4 Summary

Mean stresses corrected to infinite plate width and coefficients of variation are shown for each configuration in Table 6.2. Most coefficients of variation are below 7%. Once again, the comparison of SLL and LLL allows to assess the strength penalty due to the use of larger tow sizes.

Table 6.2 Mean Stress and CoV for Open Hole Tension Tests of 2-D Braided Materials

Hole Diameter [in]	Property	SLL 1/8"	SLL 1/4"	LLS 1/8"	LLS 1/4"	LLL 1/8"	LLL 1/4"	LSS 1/8"	LSS 1/4"
0.188 W/D = 8	Strength [ksi] CoV [%]	99.1 3.5	91.8 9.0	89.5 4.6	86.2 2.1				
0.250 W/D = 6	Strength [ksi] CoV [%]	91.4 6.7	82.2 18.5	74.3 6.6	75.6 2.2				
0.281 W/D = 8	Strength [ksi] CoV [%]	82.4 3.5	91.7 1.5	81.5 0.9	72.7 3.0	77.5 9.2	72.7 3.0	40.3 7.9	40.8 3.7
0.375 W/D = 4, 6, 8 (1)	Strength [ksi] CoV [%]	87.6 5.4	76.9 11.4	76.3 6.4	68.4 4.9	74.8 2.5	68.4 4.9	37.3 5.9	40.1 5.0
0.500 W/D = 6	Strength [ksi] CoV [%]	81.0 6.7	81.9 4.4	78.0 4.8	65.8 4.2				
0.562 W/D = 4	Strength [ksi] CoV [%]	75.5 4.0	77.0 4.5	66.7 3.9	61.6 5.0	62.8 4.8	61.6 5.0	33.6 6.7	34.7 4.6
0.750 W/D = 4	Strength [ksi] CoV [%]	79.2 2.3	76.2 8.0	62.9 3.8	59.7 5.2				

(1) Average Result for W/D = 4, 6 and 8

6.3 Stitched Uniweave Materials

A more limited series of open-hole tension tests was conducted with stitched uniweave materials and mean stresses corrected to infinite plate width are shown in Figure 6.5 and Table 6.3. The results for all five materials were quite similar, indicating that the type of stitching used appears to have little influence on the strength. Therefore, a single curve appears to be sufficient to fit all the data. Once again, very little scatter in the data was observed for this type of material.

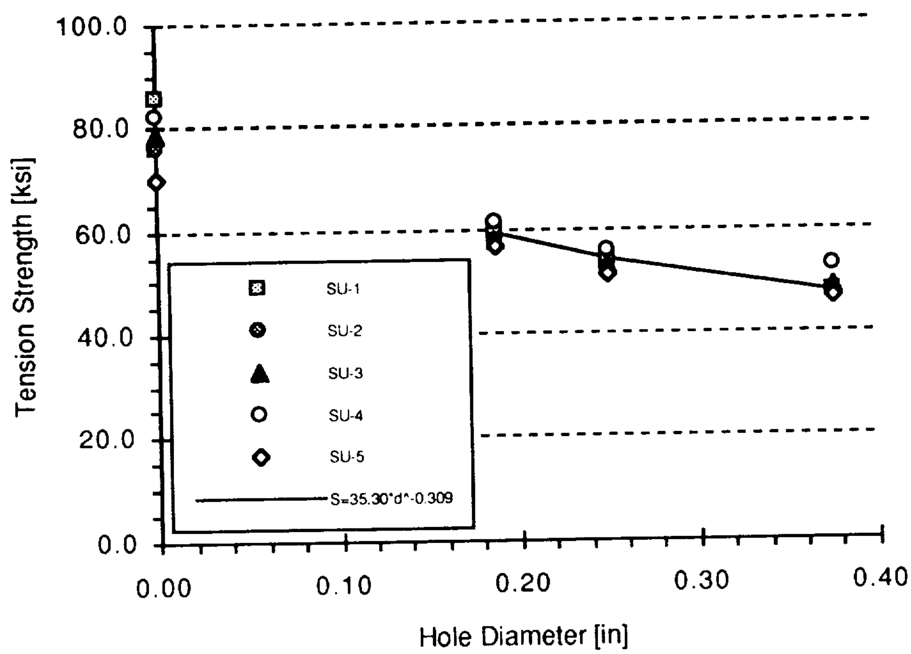


Figure 6.5 Effect of Hole Diameter on Open Hole Tension Strength of Stitched-Uniweave Materials.

Table 6.3 Mean Strength and CoV for Open Hole Tests of Stitched-Uniweave Materials

Hole Diameter [in]	Property	SU-1	SU-2	SU-3	SU-4	SU-5
0.188	Strength [ksi]	59.2	58.0	58.0	61.3	56.6
W/D = 4	CoV [%]	0.9	1.8	4.6	0.9	2.8
0.250	Strength [ksi]	54.1	52.4	53.0	55.9	51.4
W/D = 6	CoV [%]	2.8	0.8	7.1	2.0	2.7
0.375	Strength [ksi]	47.8	47.0	48.5	52.6	46.8
W/D = 8	CoV [%]	5.1	0.9	3.0	3.1	4.2

6.4 *3-D Woven Materials*

A limited series of open-hole tension tests was conducted with 3-D woven materials and results are shown in Figure 6.6 and Table 6.4. The lack of a clear trend and the limited data made it difficult to use the log-log fitting technique here for three of the materials, OS-2, LS-2 and LS-1. Based on the best fit curves obtained for the other three materials, an exponent of -0.25 was chosen for these three materials and the value of the constant was chosen to fit two of the three data points. The results of this operation are shown in Figure 6.7.a to 6.7.c. Since the exponents are approximately the same in all the curve fits, a comparison of the constants can be used to compare the notch sensitivity of the different configurations. This comparison indicates that the -2 configurations (with the smaller tow sizes) suffer a strength penalty of 21% for OS, 15% for LS and 15% for TS. Among the -1 configurations, LS-1 is the strongest by about 15% compared to TS-1.

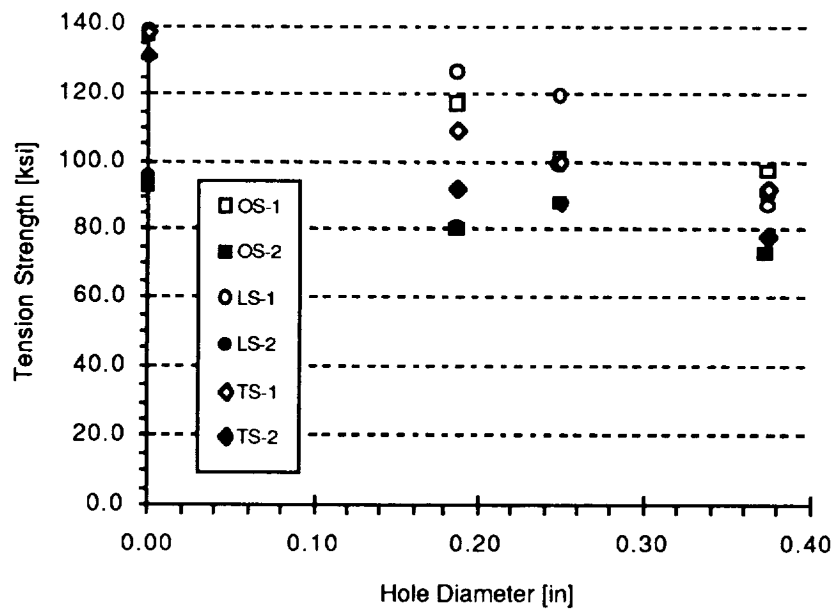


Figure 6.6 Open Hole Tension Strength Data for 3-D Woven Materials.

Table 6.4 Mean Strength and CoV for Open Hole Tests of 3-D Woven Materials

Hole Diameter [in]	Property	OS-1	OS-2	LS-1	LS-2	TS-1	TS-2
0.188	Strength [ksi]	117.5	80.0	126.5	80.9	109.3	92.6
W/D = 4	CoV [%]	0.9	12.1	0.3	17.1	2.7	5.0
0.250	Strength [ksi]	101.2	87.9	119.2	99.3	100.4	87.9
W/D = 6	CoV [%]	12.8	1.6	6.8	0.8	3.5	4.8
0.375	Strength [ksi]	97.7	72.9	87.1	90.3	92.2	78.2
W/D = 8	CoV [%]	12.2	17.8	5.1	5.0	0.3	3.6

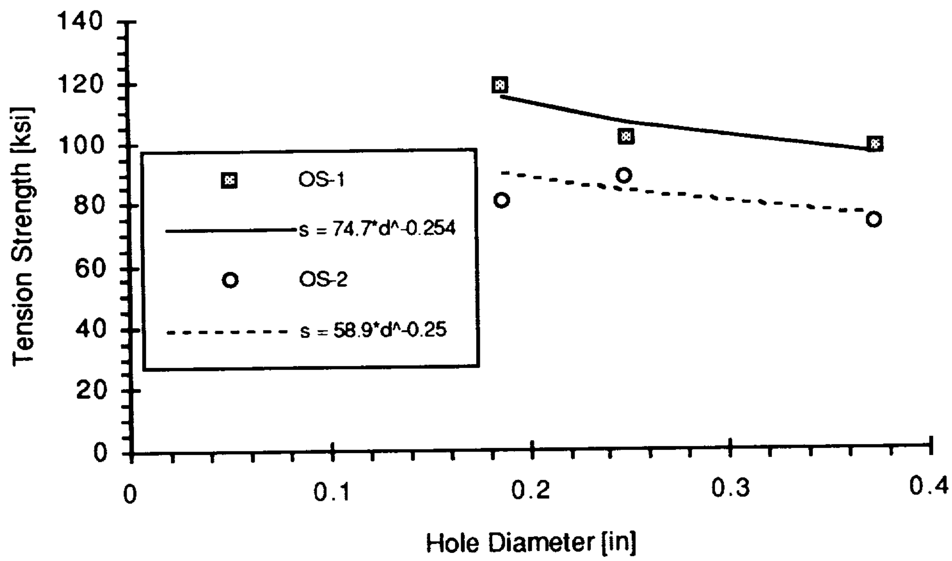


Figure 6.7.a Effect of Hole Diameter on Open Hole Tension Strength of 3-D Woven Materials OS-1 and OS-2.

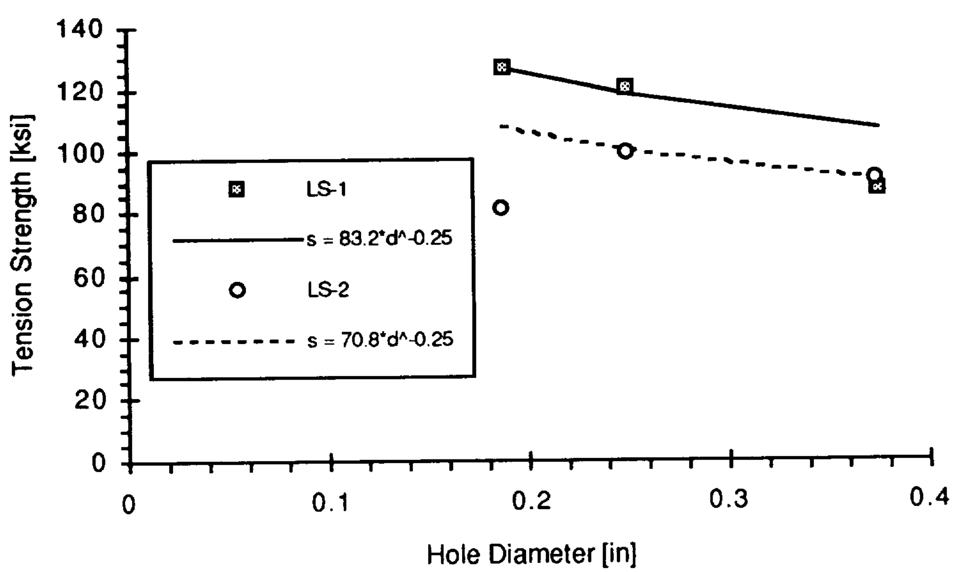


Figure 6.7.b Effect of Hole Diameter on Open Hole Tension Strength of 3-D Woven Materials LS-1 and LS-2.

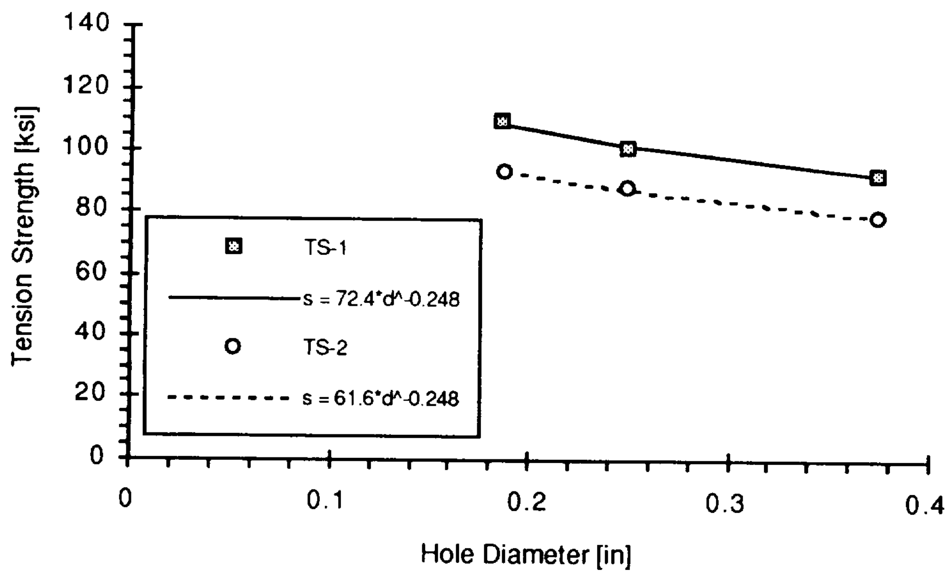


Figure 6.7.c Effect of Hole Diameter on Open Hole Tension Strength of 3-D Woven Materials TS-1 and TS-2.

6.5 *Test Recommendations*

The standard straight-sided untabbed specimen configuration performed well in all the testing done here. The two parameters that were seen to influence the test are the specimen thickness and width to diameter ratio (W/D). For all 2-D braided materials, thicker specimens exhibited a lower strength, but this is not necessarily a consequence of the test method. When using the correction factor for infinite plate width, little effect of W/D was observed for the thin (1/8") specimens. For the thick specimens (1/4"), a lower strength was obtained for W/D=4. Therefore, a ratio of W/D=6 is recommended as a minimum. Also, the use of multiple hole sizes and the log-log fit of strength versus diameter was particularly useful in detecting anomalies.

7. In-Plane Compression Test Program

The strength of textile composites under unidirectional compressive loading is examined in this chapter. In contrast to tension testing, a large number of test fixtures and specimen configurations are available for compression testing. Thus, the main focus of this investigation is a comparison of the different methods.

7.1 *Test Configurations*

Seven different techniques, described below, were evaluated in this investigation using the test matrix shown in Table 7.1. Sketches of the different configurations are shown in Figures 7.1.a to 7.1.c.

Sandwich column compression specimens were tested in the Zabora Sandwich Compression fixture. The specimen ends are machined with a shallow 10° "V" in order to match the specimen ends to the fixture.

The NASA short block fixture is the smallest specimen of all used. The loaded edges are clamped over 0.3" and no side support is provided. Load is introduced by contact across the specimen cross-section and thus specimen machining and alignment in the fixture is extremely important. Because the specimen is very short, a slower loading rate of 0.025" per minute is recommended.

The modified IITRI is a straight specimen with unbevelled fiberglass tabs. Instead of using the special IITRI loading fixture, the specimen is gripped in the test machine with hydraulic grips. Special attention to machining the specimen tabs is taken to insure that the tab surfaces are parallel. Care is also taken in aligning the specimen so that no initial bending is induced in the specimen.

The Boeing Compression After Impact (CAI) fixture utilizes a rectangular 4" by 6" specimen. The loaded edges are clamped in the fixture over 0.3", while the sides are simply supported between rails which are snug but not tight so that the specimen can slide between them. Load is introduced by contact against the specimen ends, and thus, parallelism of the ends is important. The standard loading rate of 0.05" per minute is used.

The NASA ST-4 specimen is very similar to the Boeing CAI specimen and is described in the NASA 1092 ST-4 specification (Ref. 5). The only difference is that a larger 5" by 10" specimen is used.

The Boeing Open Hole Compression and Zabora fixtures were used also to test unnotched specimens. The specimen is a straight untabbed 1.5" by 12" coupon.

Table 7.1 Test Matrix for Compression Test Program.

Dimensions			Material Systems								
Width [in]	Length [in]	Note	SLL 1/8″	SLL 1/4″	LLS 1/8″	LLS 1/4″	LLL 1/8″	LLL 1/4″	LSS 1/8″	LSS 1/4″	Others (1)
Sandwich Column											
3.00	6.00		3		3		3		3		
1.50	6.00		3		3						
2.25	6.00		3		3						
3.00	2.00		3		3						
3.00	8.00		3		3						
3.00	6.00	Core Effect	3		3						
NASA Short Block											
1.50	1.50			3		3		3		3	3
1.50	1.00			3		3					
1.50	2.00			3		3					
NASA ST-4											
5.00	10.0			3		3		3		3	
Boeing CAI											
4.00	6.00			3		3		3		3	
Modified IITRI											
1.50	1.00		3	3	3	3	3		3		
1.50	1.50			3		3		3		3	3
1.50	2.00			3		3					
1.50	1.50	Transverse		3		3		3		3	3
Boeing OHC											
1.50	12.00										
1.50	12.00	Net-Shape	3		3		3		3		
Zabora Fixture											
1.50	11.50		3		3		3		3		
			27	27	27	27	12	15	12	15	99

(1) Five Stitched Uniweave and Six 3-D Woven Materials.

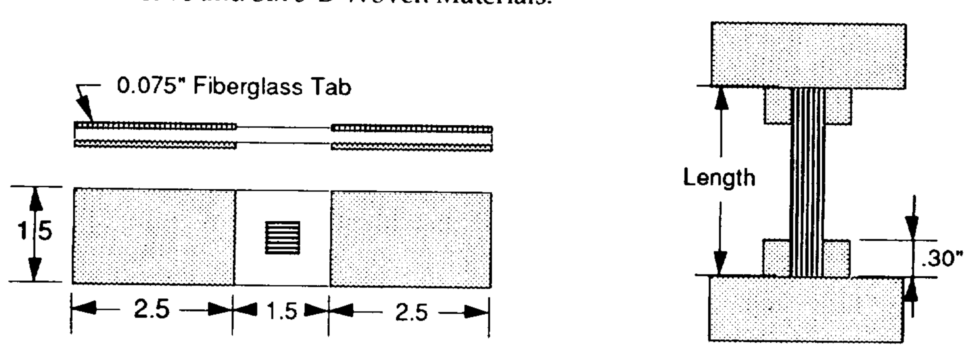


Figure 7.1.a Modified IITRI Specimen and NASA Short Block Specimen.

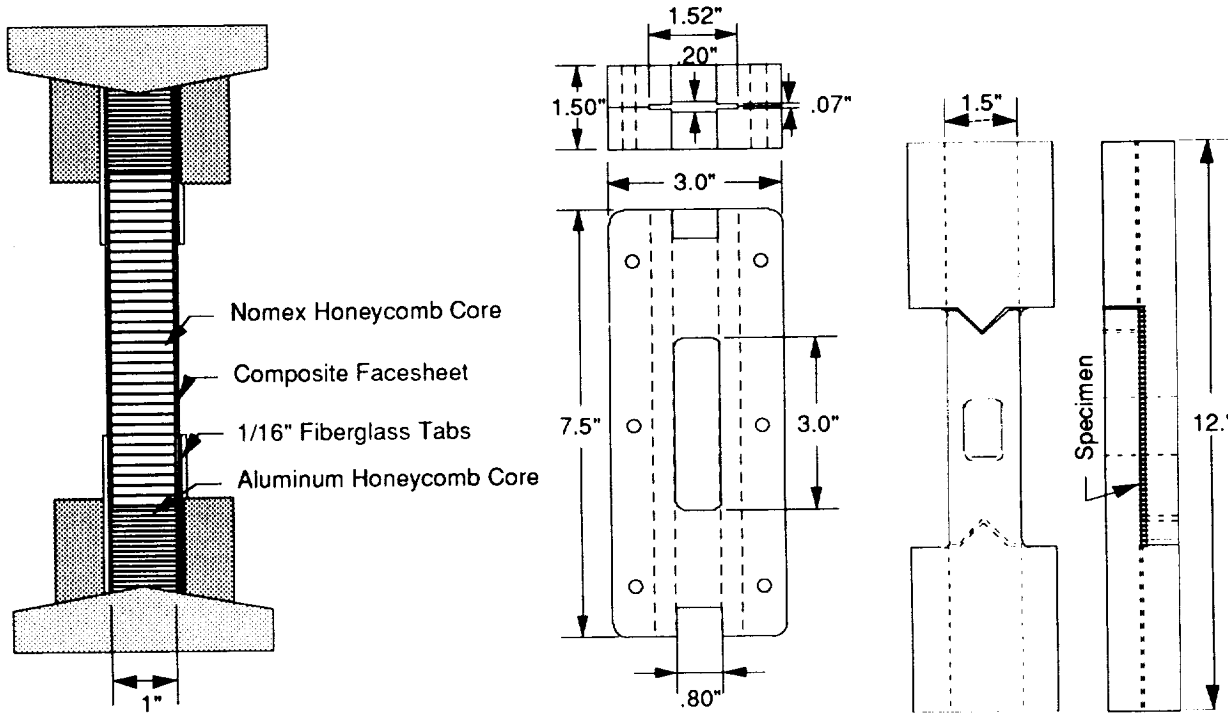


Figure 7.1.b Sandwich Column Specimen, Zabora Fixture and Boeing OHC Fixture .

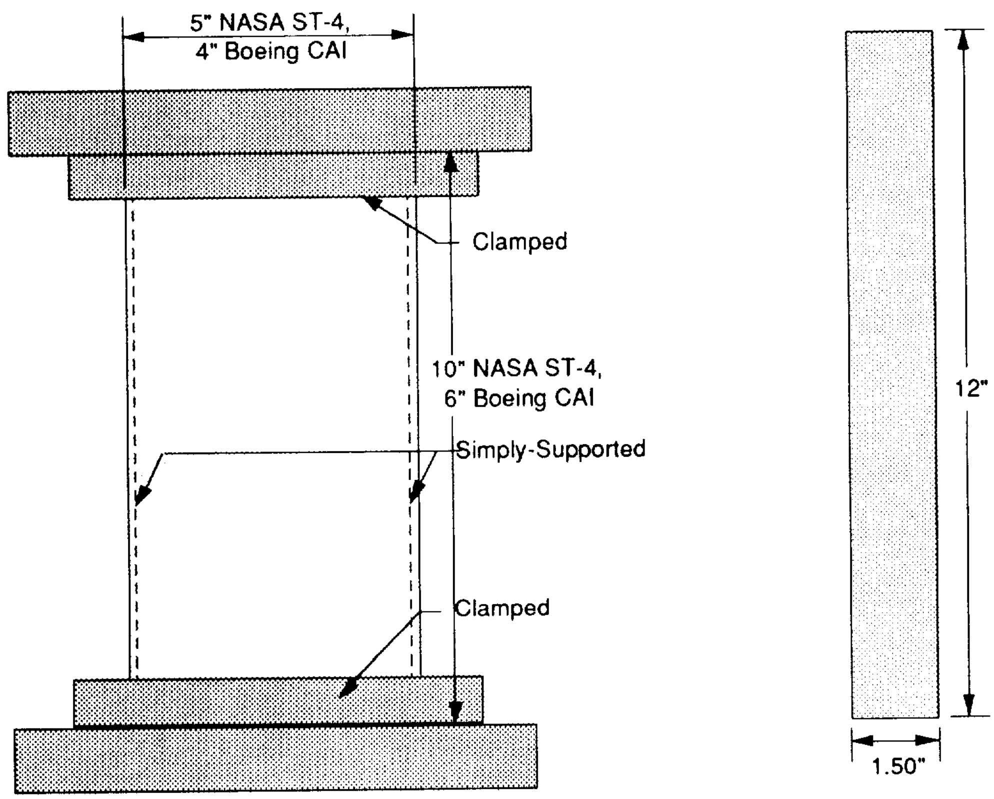


Figure 7.1.c NASA ST-4 or Boeing CAI Specimen and Boeing OHC or Zabora Fixture Specimen.

7.2 *2-D Braid Materials*

7.2.1 Test Section Length and Thickness Effects

The main concern in compression testing is whether the test fixture provides adequate support to prevent failure by global specimen instability. Thus, specimen gage length and thickness are of prime interest. On the other hand, just as in tensile testing, a certain minimum number of unit cells should be present across the test section to insure a representative failure mode. This effect was investigated with the SLL and LLS braid for the NASA Short Block and modified IITRI methods. The baseline test section used here is 1/4 inch thick, 1.5 inches wide and 1.5 inches long. Specimens were also tested with a length of 1 and 2 inches to detect any sensitivity to length, and with a thickness of 1/8 inch to detect sensitivity to thickness.

Results for the two braid types are shown in Figure 7.2 and 7.3, where strength is reported. In general, there does not appear to be a very strong trend for the range of values tested, although the 2 inch gage length seemed to lead to more scatter and slightly lower values. Note that one set of data, the 1 inch long LLS NASA Short Block test, is much above the other results and appears to be an anomaly for which no cause could be identified. Moduli measured with these configurations are shown in Figure 7.4 where no effect from gage length can be observed.

Also, at a gage length of 1 inch, little difference was found between 1/8" and 1/4" thick specimen. For instance, for the SLL specimens the strength of the 1/8" is 4% below that of the 1/4" specimen when both are tested with the modified IITRI method. However, when examining strain data obtained using back-to-back gages, the 1/8" specimen does exhibit some non-linearity in behavior which indicates some stability problem.

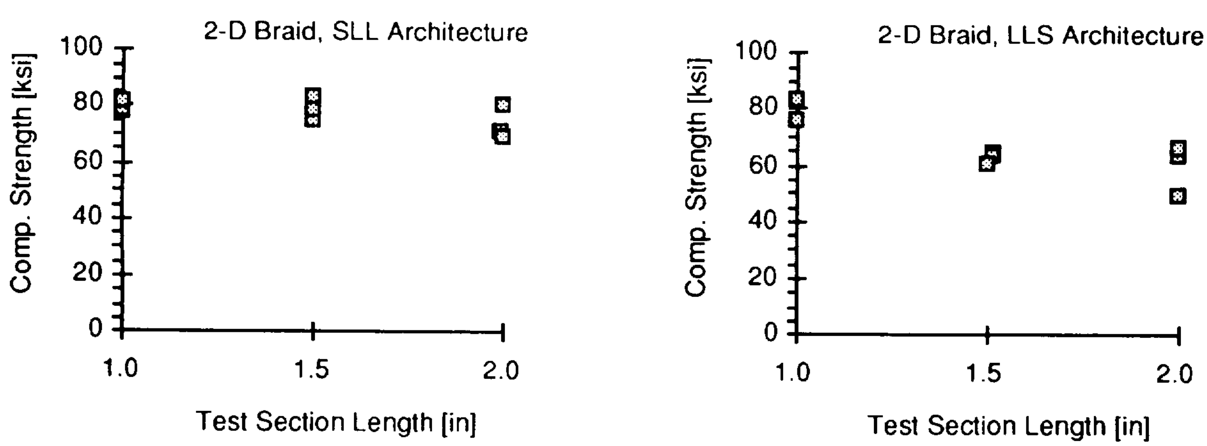


Figure 7.2 Test Section Length Effect on Compression Strength in NASA Short Block Test Configuration.

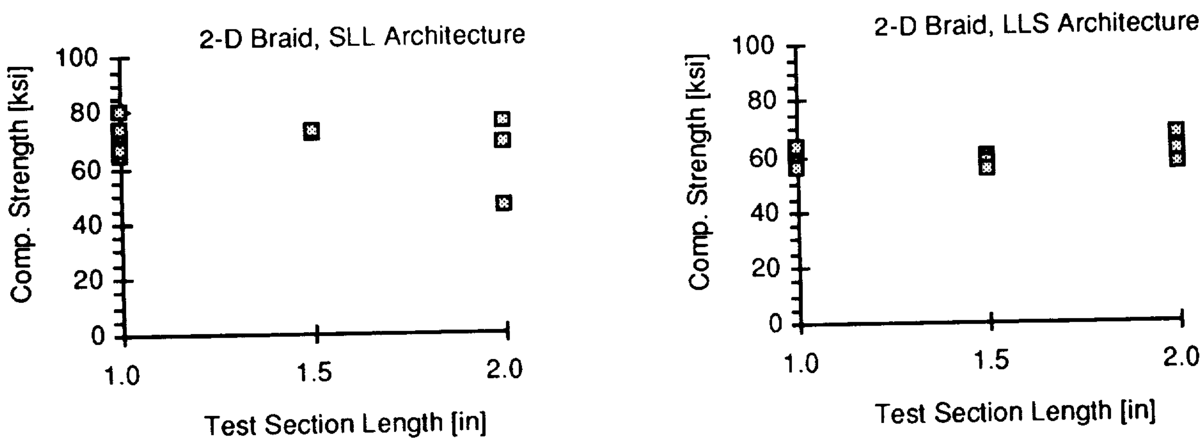


Figure 7.3 Test Section Length Effect on Compression Strength in modified IITRI Test Configuration.

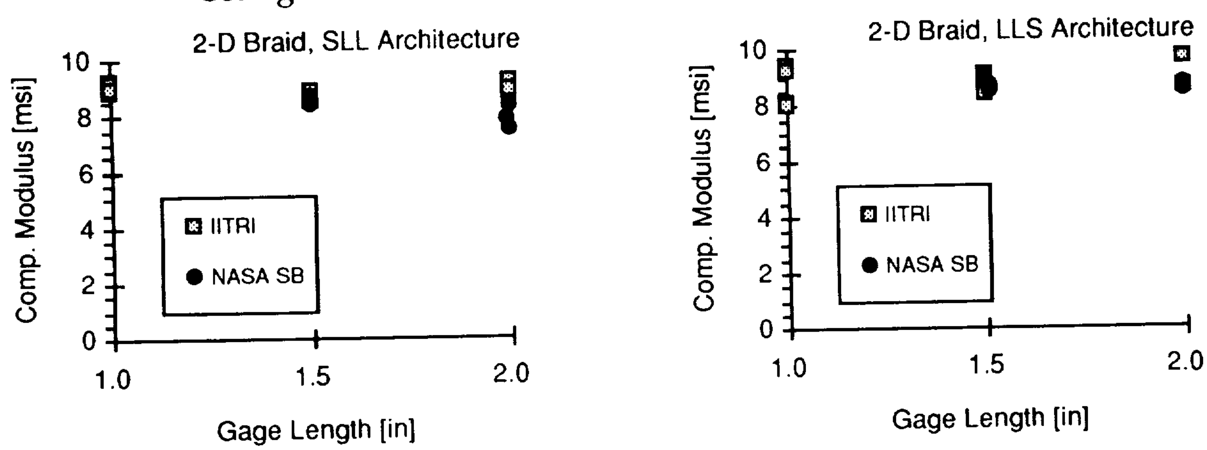


Figure 7.4 Test Section Length Effect on Compression Modulus in NASA Short Block and modified IITRI Test Configurations.

7.2.2 Longitudinal Compression

The compression stiffness modulus and ultimate strength were determined for all four braids using the NASA Short Block, modified IITRI, NASA ST-4, Boeing CAI and Zabora test methods. The moduli are reported in Figure 7.5. The NASA Short Block test method always resulted in lower moduli, while the Zabora fixture usually produced slightly higher values.

The strength and nominal strain (defined as the stress divided by nominal modulus) of all five test methods are summarized in Figure 7.6.a to 7.6.b for all four materials. The NASA Short Block and Zabora test methods gave the highest results each in two of the four cases. The modified IITRI and Boeing CAI test method consistently gave lower results than the NASA Short Block by 10 to 15%. Results from the NASA ST-4 were always much below the others, indicating that this method is not suitable for this type of testing. This is in part due to the large test section, which does not provide adequate stability to test unnotched or unflawed specimens to failure. A summary of the compression properties is provided in Table 7.2. The strength value from the NASA Short Block, modified IITRI and Zabora fixture tests are reported, while the moduli are the averages of the NASA Short Block, modified IITRI and Zabora tests. In terms of scatter, the Short Block test method produced the lowest coefficients of variation. One possible explanation for the higher strength of the Short Block specimen than the modified IITRI specimen is the difference in load introduction and the fact that both these specimens are fairly thick: in the Short Block test, load is introduced by contact over the whole specimen cross-section, resulting in a uniform loading through-the-thickness, while in the modified IITRI specimen, load is introduced in shear in the outer plies of the specimen, thus resulting in slightly higher stress levels in these plies near the tabs.

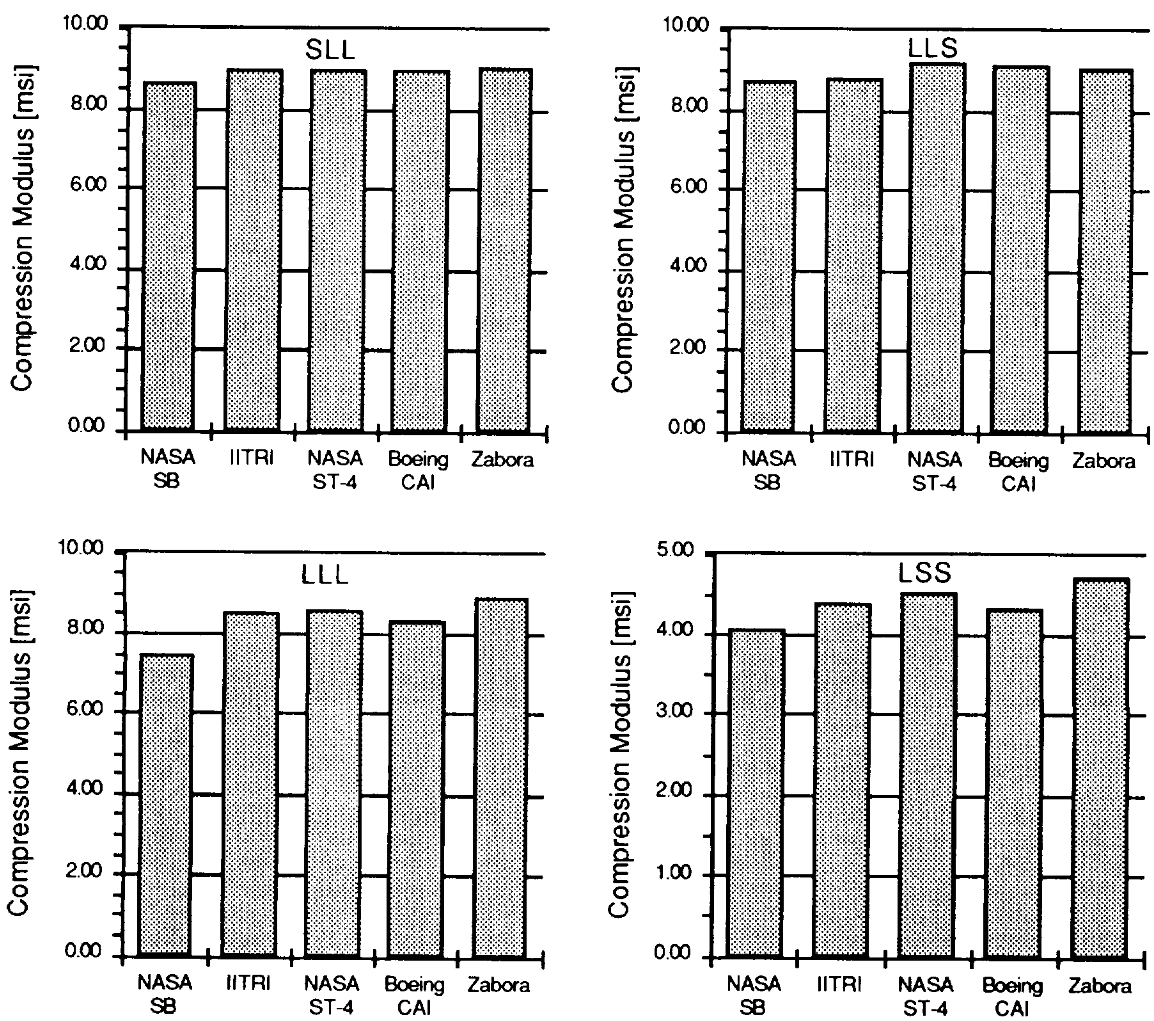


Figure 7.5 Compression Modulus of 2-D Braided Materials.

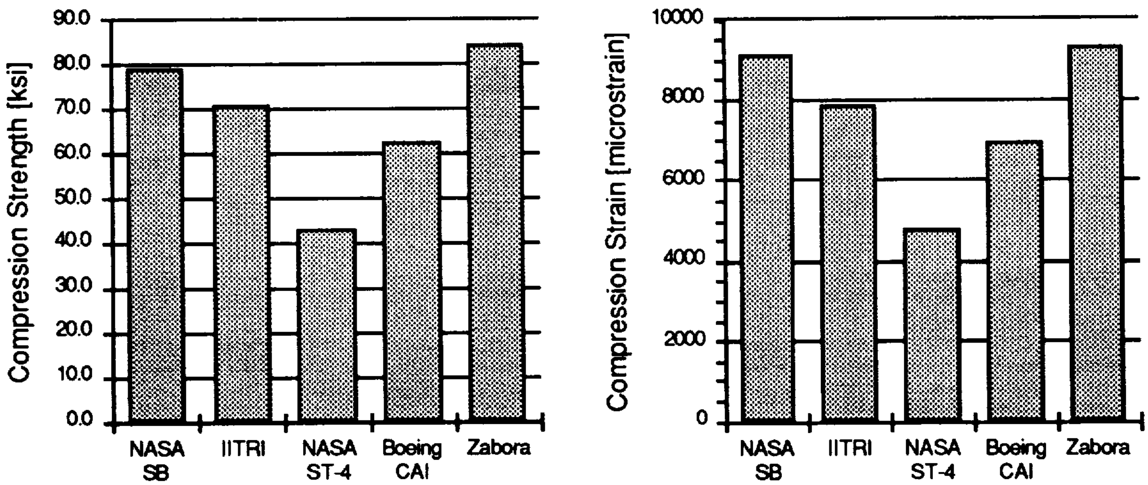


Figure 7.6.a Compression Strength and Nominal Strain of SLL Braid

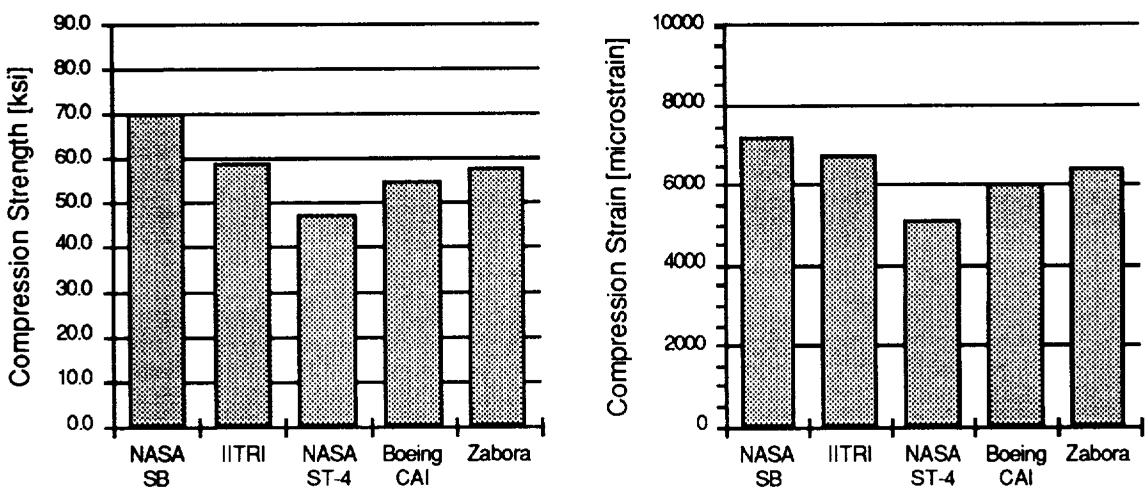


Figure 7.6.b Compression Strength and Nominal Strain of LLS Braid

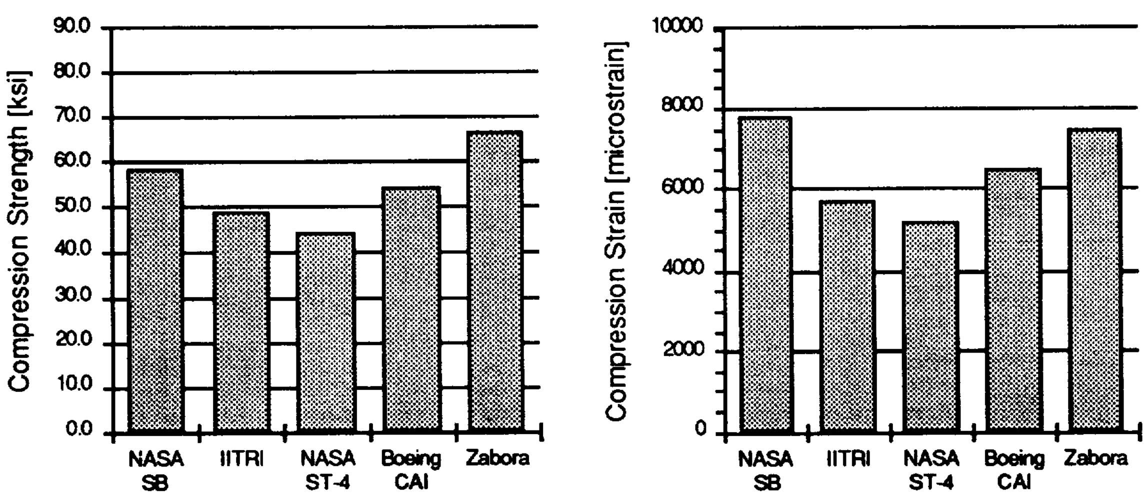


Figure 7.6.c Compression Strength and Nominal Strain of LLL Braid

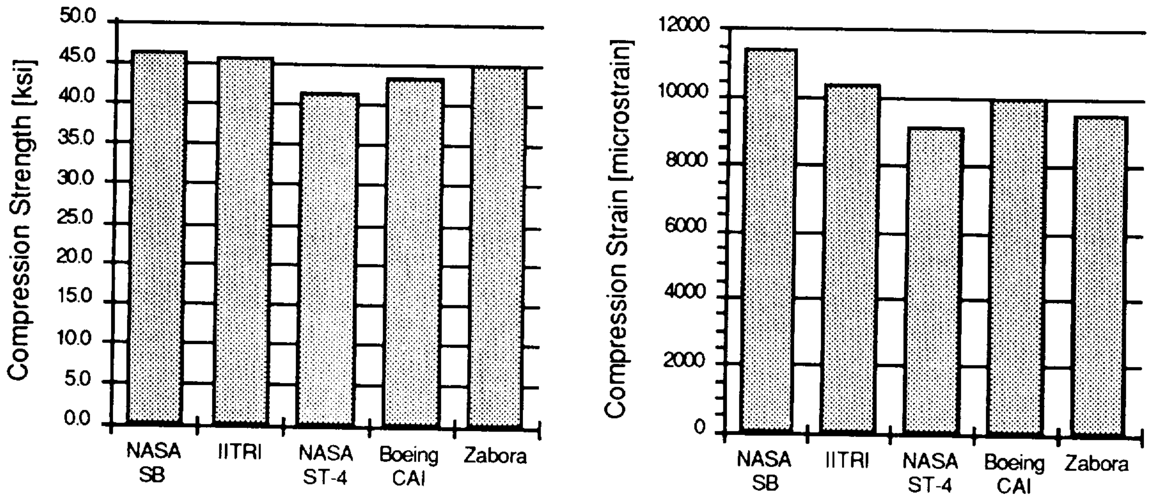


Figure 7.6.d Compression Strength and Nominal Strain of LSS Braid

Table 7.2 Summary of Longitudinal Compression Properties for 2-D Braid Materials

Property	SLL	LLS	LLL	LSS
NASA SB Strength [ksi]	78.8	62.8	58.6	46.2
CoV [%]	3.7	2.7	7.7	1.7
Nominal Strain [μs]	9140	7211	6995	11391
Mod. IITRI Strength [ksi]	70.6	59.2	48.7	45.5
CoV [%]	6.4	5.3	10.8	5.9
Nominal Strain [μs]	7860	6743	5699	10378
Zabora Strength [ksi]	84.4	58.0	66.6	44.9
CoV [%]	14.2	4.2	5.4	3.9
Nominal Strain [μs]	9328	6405	7467	9511
Modulus [msi]	8.92	8.82	8.37	4.38
CoV [%]	2.9	5.4	8.5	7.3

7.2.3 Sandwich Column

The results of the sandwich column specimens were not included in the previous discussion since they were not satisfactory for two reasons. The first problem with the sandwich specimens is that no fiber volume fraction measurements were obtained on the facesheet materials because the specimens were delivered as a complete sandwich. Thus a normalized thickness corresponding to a 60% fiber volume fraction could not be established as for the other tests. Instead, a nominal 0.0625" thickness was used for all specimens. The second problem is that no material strength data could be generated with this specimen configuration. The failure mode of this specimen is always a structural failure mode rather than a material failure mode. In all tests, failure occurred when one of the facesheets separated from the core due to either core or bond failure.

Results from these tests are summarized in Table 7.3. Moduli measured with this method were usually lower than when measured with the other test methods, possibly due to the use of nominal thickness. In one case (LLS), the modulus was much higher and in another (LLL) much lower, with no available explanation for this.

Table 7.3 Sandwich Column Compression Properties for 2-D Braid Materials.

Property	SLL	LLS	LLL	LSS
Strength [ksi]	28.2	34.3	16.3	16.7
CoV [%]	8.3	6.1	6.5	1.2
Nominal Strain [μs]	3650	3020	2990	4870
Modulus [msi]	7.74	11.34	5.46	3.43
CoV [%]	3.8	2.5	3.2	1.2

7.2.4 Boeing Open Hole Compression Fixture

The results of the Boeing Open Hole Compression fixture were also not included in the previous discussion since they were not satisfactory. Abnormally high strength results were obtained in several cases probably due to friction or interference between the fixture and specimen.

7.2.5 Transverse Compression

Specimens of each material were tested in the transverse direction with the modified IITRI method. This is particularly interesting for this type of material since there are no fibers running directly along the loading direction and all the load is carried by the braided tows. As seen in Table 7.4, the transverse strength of the SLL, LLS and LLL architecture is relatively poor. The change in tow size between the SLL and LLL has a particularly drastic effect and leads to a 25% strength reduction, but practically no change in modulus.

Table 7.4 Summary of Transverse Compression Properties for 2-D Braid Materials Using Modified IITRI Test Method

Property	SLL	LLS	LLL	LSS
Strength [ksi]	42.1	25.3	31.6	43.1
CoV [%]	3.4	10.1	4.8	2.1
Nominal Strain [μs]	5805	8377	4252	14224
Modulus [msi]	7.25	3.03	7.42	3.03
CoV [%]	2.2	1.8	1.3	4.7

7.3 Stitched Uniweaves Materials

7.3.1 Longitudinal Compression

The testing of the stitched uniweave material was conducted with the NASA Short Block and modified IITRI specimens only. Results are shown in Table 7.5. The conclusions from these tests are very similar to the ones found in the previous section. The Short Block test gave higher strength values by 9 to 14 %, but a slightly lower modulus by 4 to 8 % compared to the modified IITRI. The best strength was achieved by the SU-1material with the 3K S2-Glass stitch. For the Kevlar stitches, increasing the stitch spacing or yarn size actually gave slightly higher results, but in general, the influence of the stitching type is small. Also, as for other properties, the coefficients of variation for this type of material were less than for the 2-D braid.

Table 7.5 Summary of Transverse Compression Properties for Stitched Uniweave Materials

Property	SU-1	SU-2	SU-3	SU-4	SU-5
Mod. IITRI Strength [ksi]	52.3	44.9	45.5	49.7	46.8
CoV [%]	1.0	1.8	3.5	0.8	0.7
Nominal Strain [μs]	8235	7414	7477	7470	7519
NASA SB Strength [ksi]	57.0	51.1	52.0	54.9	53.8
CoV [%]	3.3	3.3	2.5	1.8	5.1
Nominal Strain [μs]	9783	8759	8875	8559	9061
Mod. IITRI Modulus [msi]	6.35	6.06	6.09	6.65	6.22
CoV [%]	0.9	0.8	1.3	0.4	0.5
NASA SB Modulus [msi]	5.83	5.84	5.86	6.41	5.93
CoV [%]	2.6	0.9	0.8	0.2	0.8

7.3.2 Transverse Compression

Compression testing was also conducted in the transverse direction using the modified IITRI method. As shown in Table 7.6, although the layup is quasi-isotropic, the strength results are surprisingly higher than in the longitudinal direction, ranging from 4.5% for the SU-1 to 21.8% for the SU-5 (when comparing the modified IITRI method in both cases). Modulus showed much less difference between the two directions, except for SU-5 (9.4% difference). One possible explanation is that the stitching runs parallel to the 0° direction and induced more fiber distortion in the 0° ply than in the 90° ply.

Table 7.6 Summary of Transverse Compression Properties for Stitched Uniweave Materials Using the Modified IITRI Test Method

Property	SU-1	SU-2	SU-3	SU-4	SU-5
Strength [ksi]	54.7	51.1	52.1	53.5	57.0
CoV [%]	3.9	1.8	3.3	3.7	1.6
Nominal Strain [μs]	8623	8343	8336	7881	8365
Modulus [msi]	6.34	6.12	6.25	6.79	6.81
CoV [%]	2.6	.9	0.8	0.2	0.8

7.4 3-D Woven Materials

7.4. 1 Longitudinal Compression

Testing of the 3-D woven materials leads to the same conclusion as before, with the Short Block Method yielding the highest strength in all but one case as shown in Table 7.7. Unlike in the previous case, the difference in moduli between the two test method was smaller. In terms of tow size influence (the difference between the -1 and -2 material), the smaller tow size (-1) usually produced a slightly higher strength and modulus. The orthogonal interiock (OS architecture) produced better strength results, possibly because of the lesser distortion induced in the 0° fibers. Coefficients of variations were in general low.

Table 7.7 Summary of Longitudinal Compression Properties for 3-D Woven Materials.

Property	OS-1	OS-2	TS-1	TS-2	LS-1	LS-2
Mod. IITRI Strength [ksi]	84.0	77.8	76.2	63.8	76.7	62.2
CoV [%]	5.0	7.3	5.0	3.4	3.4	2.4
Nominal Strain [μs]	7661	7615	6990	6167	6713	5649
NASA SB Strength [ksi]	87.0	90.6	75.4	70.2	81.7	79.9
CoV [%]	3.3	6.0	1.5	6.0	4.8	8.4
Nominal Strain [μs]	7895	8714	7198	6952	7282	7315
Mod. IITRI Modulus [msi]	10.96	10.21	10.9	10.35	11.43	11.01
CoV [%]	0.9	1.1	1.2	1.0	1.0	0.6
NASA SB Modulus [msi]	11.03	10.40	10.48	10.09	11.23	10.92
CoV [%]	1.6	6.5	2.9	2.6	1.3	1.5

7.4.2 Transverse Compression

As for the previous materials, testing was also conducted in the transverse direction with the modified IITRI method. Assuming that the nominal strains at failure are equal for loading in the longitudinal and transverse directions, the strengths and moduli for the transverse direction should be about 60% of those in the longitudinal direction based on the 0° and 90° fiber percentages. As seen in Table 7.8, except for the LS-1 and LS-2 weaves, the nominal strains at failure were similar and those for the weaves with the largest yarns (-1) were somewhat less than those with the smallest yarns(-2). The nominal strains at failure for the LS-1 and LS-2 weaves were significantly less than the others, and that for LS-1 somewhat greater than for LS-2. The transverse strength deviated from 60% of the longitudinal strengths accordingly. The median value for the transverse moduli was 57%.

Table 7.8 Summary of Longitudinal Compression Properties for 3-D Woven Materials the Using Modified IITRI Test

Property	OS-1	OS-2	TS-1	TS-2	LS-2	LS-2
Strength [ksi]	41.3	52.2	37.2	52.7	32.4	27.8
CoV [%]	2.3	1.4	7.1	3.8	14.4	20.2
Nominal Strain [μs]	6729	8875	6410	7197	5264	4371
Modulus [msi]	6.14	5.88	5.80	7.32	6.15	6.35
CoV [%]	2.7	1.0	0.8	2.3	1.4	0.2

7.5 *Test Recommendations*

An A or B basis allowable increases with increasing mean value and decreases with increasing coefficient of variation (CoV). Thus, the test method that would produce the maximum allowable would maximize the mean and minimize the CoV. Test data for the different materials were pooled, and means and CoVs were calculated for the NASA short block, modified IITRI and Zabora methods. The CoVs for the various materials can be pooled together directly since they are non-dimensional quantities, but the means cannot. Thus, a normalized metric for the mean was calculated as follows:

1) Means for each material were calculated with:

$$\bar{x}_m = \frac{1}{N} \sum_{n=1}^{N} \bar{x}_{mn}$$

where m is the material number, n the test method number, N the number of test methods and $\bar{x}_{mn}$ the mean value for a given test method and material combination.

2) A mean deviation from $\bar{x}_m$ was calculated for each test method with:

$$\overline{\Delta x_n} = \frac{1}{M} \sum_{m=1}^{M} \frac{\bar{x}_{mn} - \bar{x}_m}{\bar{x}_m}$$

where M is the number of materials for a given test method.

Values of $\overline{\Delta x_n}$ and CoV for the strengths and moduli are given in Table 7.9 and plotted in Figures 7.7 to 7.10.

The results indicate that the modified IITRI test method gave the largest allowable for compression moduli, but the NASA Short Block and Zabora methods gave the largest allowable for strength. Note however that the number of data points for this method was much smaller. Also, because of the side supports on the specimen, there is a possibility of some load being lost through friction in the fixture. In terms of mean strength, the NASA Short Block test method gave consistently higher results than the modified IITRI method by about 9% to 12 %.

In terms of stability, a length to thickness ratio (L/t) of less than 10 is recommended for the modified IITRI and NASA Short Block method. A ratio of 6 appears to be a good compromise in terms of having a sufficiently large test section and good stability. Both the NASA ST-4 and Boeing CAI specimens are inadequate for compression testing of unnotched specimens because of their lack of stability.

Table 7.9 Mean Deviations $\overline{\Delta x_n}$ and CoVs for Unnotched Compression Test Methods

		Test Method					
Material	Property	Modified IITRI		NASA Short Block		Zabora	
		$\overline{\Delta x_n}$	CoV	$\overline{\Delta x_n}$	CoV	$\overline{\Delta x_n}$	CoV
2-D Braids	Modulus	2.1 %	6.4 %	-7.7 %	4.0 %	5.6 %	3.3 %
	Strength	-6.7 %	8.5 %	2.1 %	3.9 %	4.6 %	6.9 %
Stitched Uniweave	Modulus	2.5 %	0.9 %	-2.5 %	2.1 %	n/a	n/a
	Strength	-5.9 %	1.5 %	5.9 %	3.2 %	n/a	n/a
3-D Woven	Modulus	0.2 %	1.5 %	-0.2 %	2.8 %	n/a	n/a
	Strength	-4.9 %	4.4 %	4.9 %	5.0 %	n/a	n/a

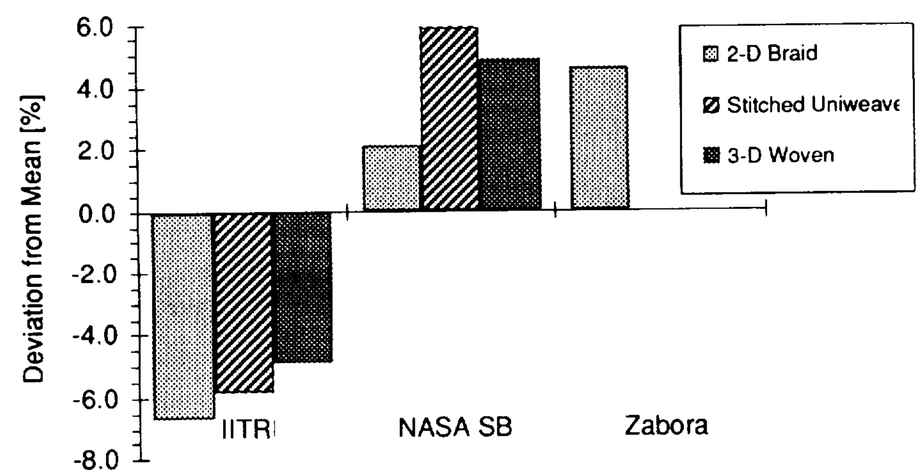


Figure 7.7 Deviation from Mean Strength for Unnotched Compression Test Methods.

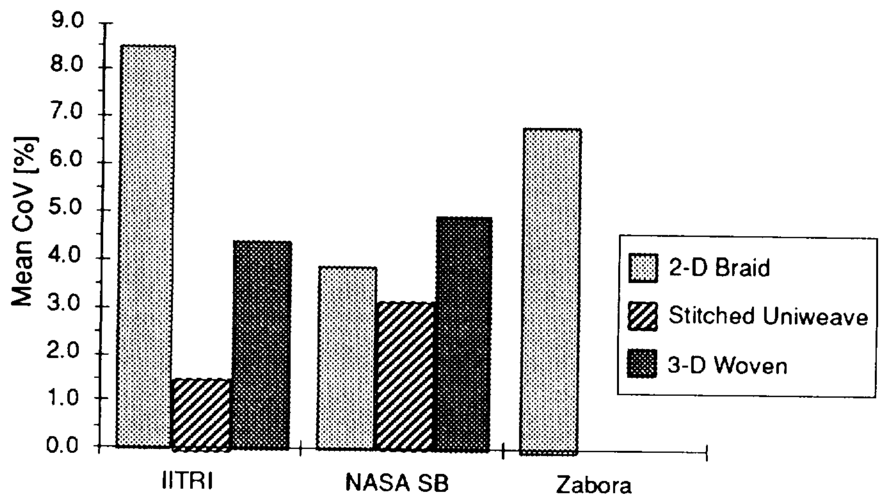


Figure 7.8 Mean Strength CoVs for Unnotched Compression Test Methods.

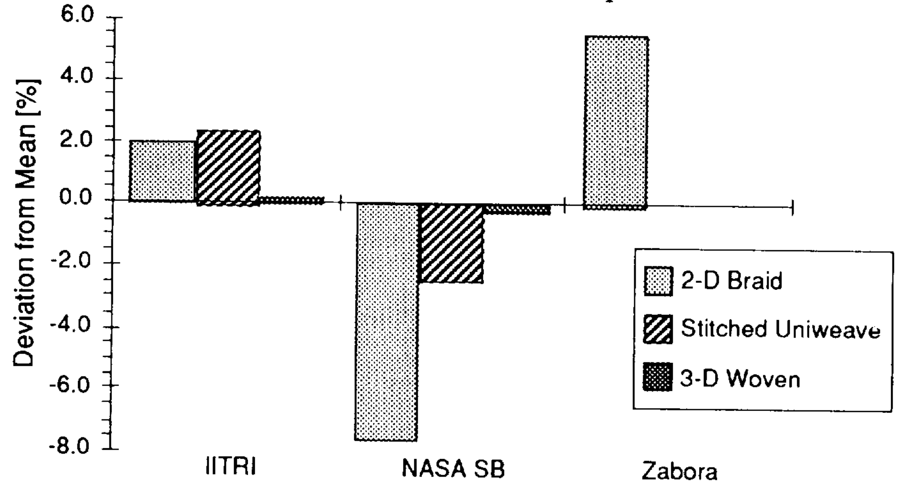


Figure 7.9 Deviation from Mean Modulus for Unnotched Compression Test Methods.

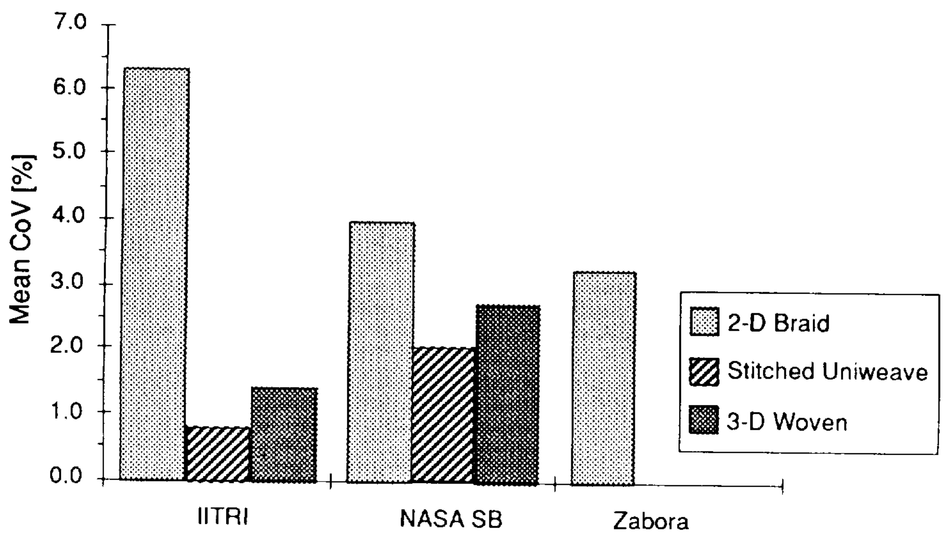


Figure 7.10 Mean Modulus CoVs for Unnotched Compression Test Methods.

8. Open Hole Compression Test Program

The strength of textile composites with open holes under unidirectional compression loading is examined in this chapter. The test methods and the effect of hole diameter are the main focus of this test program.

8.1 *Test Configurations*

Six of the seven test methods discussed in Chapter 7 were used as shown in Table

Table 8.1 Test Matrix for Open Hole Compression Test Program.

Dimensions [in]			Material Systems								
Width	Diameter	W/D	SLL 1/8"	SLL 1/4"	LLS 1/8"	LLS 1/4"	LLL 1/8"	LLL 1/4"	LSS 1/8"	LSS 1/4"	Others (1)
Boeing Open Hole Comp.											
1.50	.375	4	3		3						
1.50	.250	6	3		3		3		3		3
1.50	.188	8	3		3						
NASA Short Block											
1.50	.375	4		3		3					
1.50	.250	6		3		3		3		3	
1.50	.188	8		3		3					
NASA 1142											
1.50	.375	4		3		3					
1.50	.250	6		3		3		3		3	
1.50	.188	8		3		3					
Modified IITRI											
1.50	.375	4		3		3		3		3	3
1.50	.250	6		3		3		3		3	3
1.50	.188	8		3		3		3		3	3
Zabora Fixture											
1.50	.375	4	3		3		3		3		
1.50	.250	6	3		3		3		3		
1.50	.188	8	3		3		3		3		
Boeing CAI Fixture											
4.00	0.500	4		3		3					
4.00	0.800	5		3		3		3		3	
4.00	1.000	8		3		3					
NASA ST-4											
5.00	1.250	4		3		3					
			18	39	18	39	12	18	12	18	132

(1) Five Stitched Uniweave and Six 3-D Woven Materials

8.1. The sandwich column was dropped because of its complexity to manufacture and its poor performance in the previous test program. In addition to these, the NASA 1142 method, shown in Figure 8.1, was also considered (Ref. 6). Because both the hole diameter and the width to diameter ratio are varied simultaneously, the correction factor for infinite width was used again to calculate the strength and make it possible to study the influence of hole diameter. However, no direct comparison of the influence of W/D can be made. No strain gages were used on these specimens.

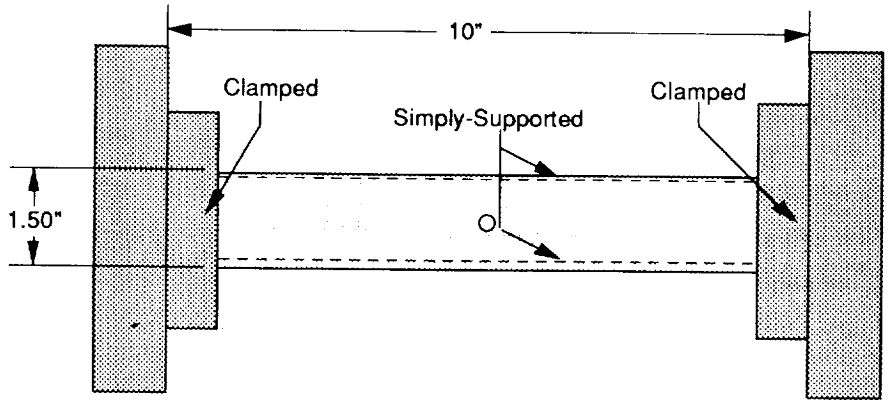


Figure 8.1 NASA 1142 Specimen Configuration.

8.2 *2-D Braid Materials*

8.2.1 Test Method Comparison

Five of the seven test methods were compared directly: the Boeing Open Hole Compression (OHC) fixture, the NASA Short Block specimen, the NASA 1142 specimen, the modified IITRI specimen and the Zabora Test Fixture. Two of the 2-D braided materials, the SLL architecture and the LLS architecture were used for this comparison. Some sets of data seem to show a high scatter, while others do not. Possible explanations are variability in material quality or a material sensitivity to hole position with respect to architecture due to the non-uniform nature of the material.

Mean values and CoVs for all test methods are shown in Figures 8.2 and 8.3, respectively, and Table 8.2. As in previous sections, the column marked "Strain" is the nominal strain obtained by dividing ultimate stress by the average compression modulus measured in the previous section.

No single method produced the highest strengths for all materials. On the other hand, the Boeing OHC and Zabora test methods typically produced the highest CoVs. The thinnest materials (1/8") were tested with these two methods; perhaps local instabilities caused the large CoVs. The CoVs for the LSS material were the lowest, even for the 1/8" thick material. This is possibly due to the fact that this is a rather soft layup which is not as notch sensitive as the other two.

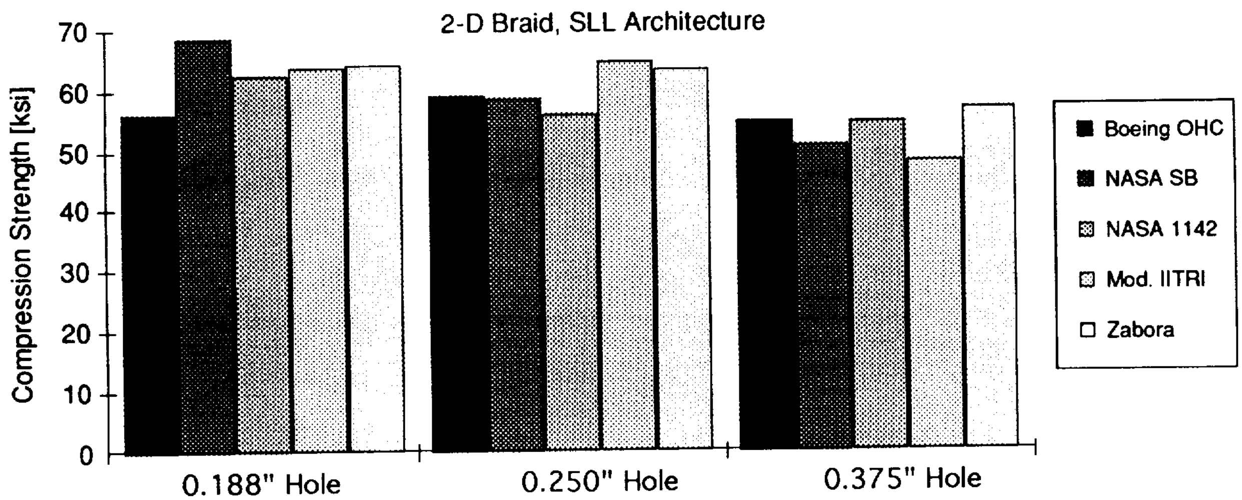


Figure 8.2.a Comparison of Open Hole Compression Strength for Various Test Methods of SLL Materials.

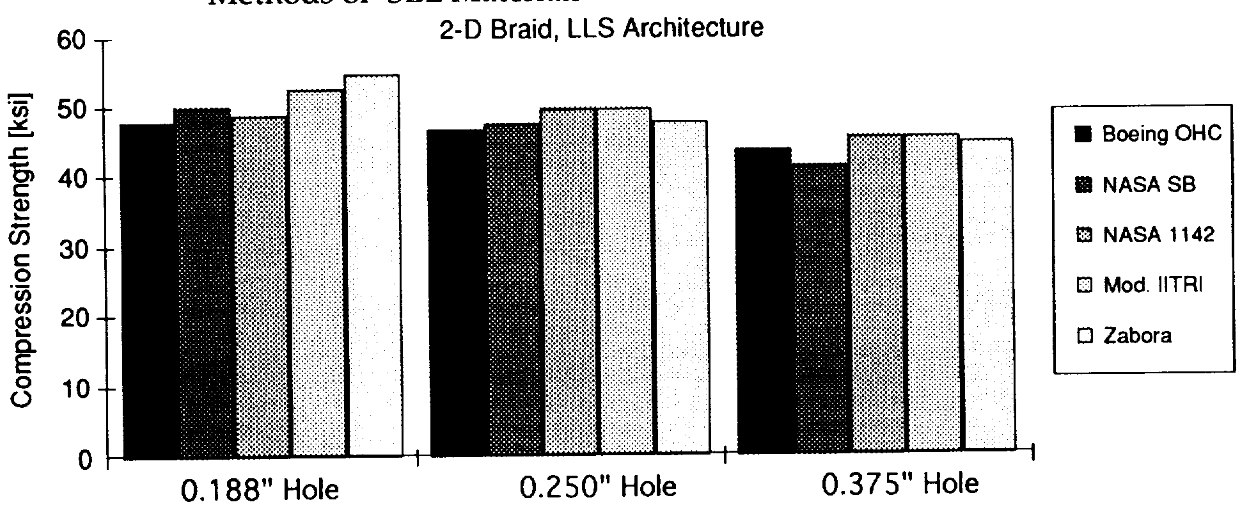


Figure 8.2.b Comparison of Open Hole Compression Strength for Various Test Methods of LLS Materials.

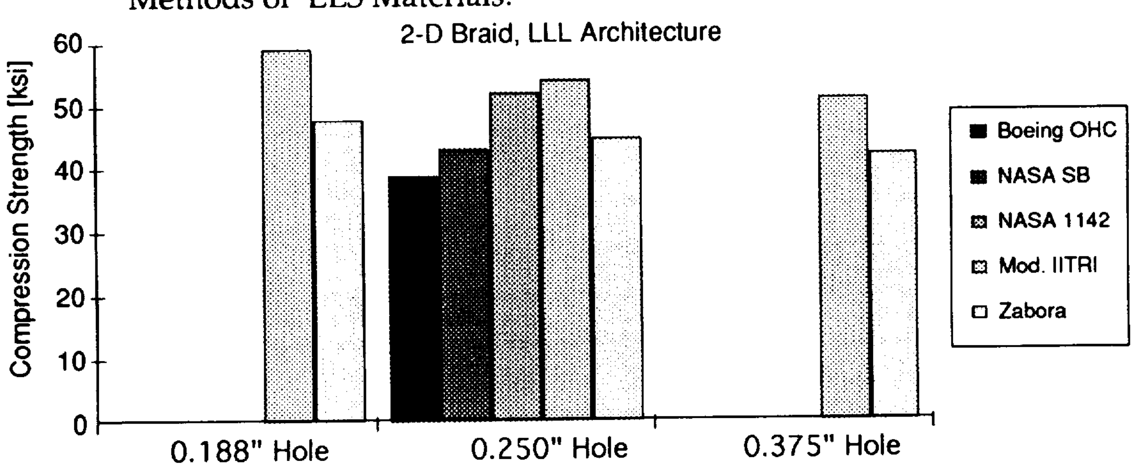


Figure 8.2.c Comparison of Open Hole Compression Strength for Various Test Methods of LLL Materials.

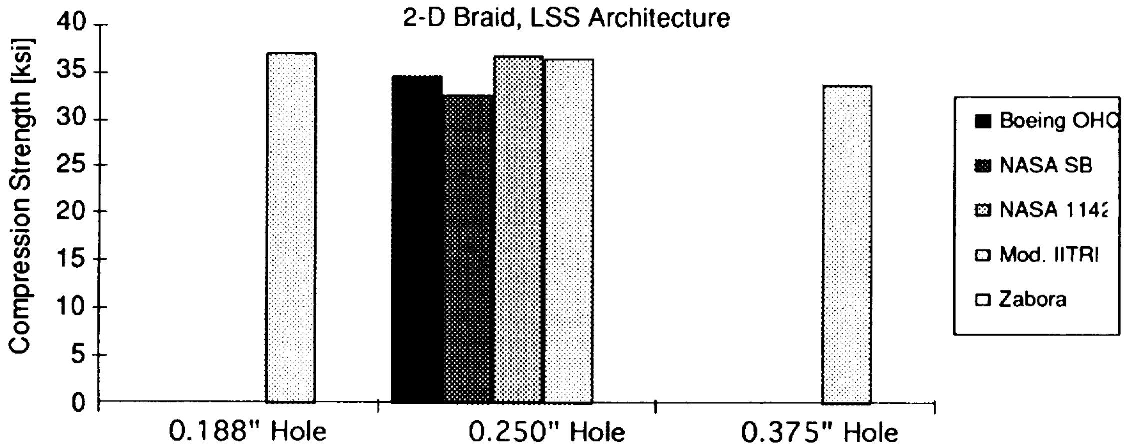


Figure 8.2.d Comparison of Open Hole Compression Strength for Various Test Methods of LSS Materials.

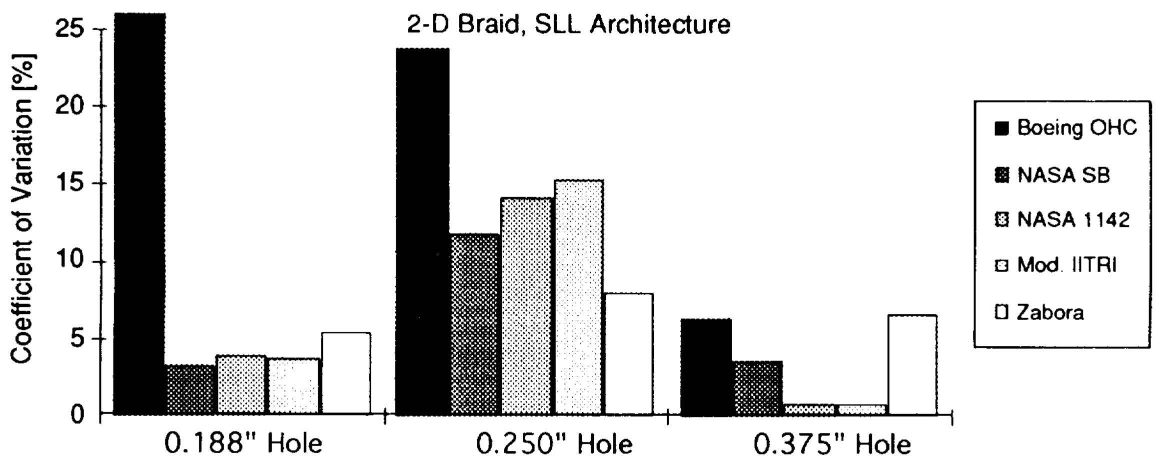


Figure 8.3.a Comparison of Coefficient of Variations for Open Hole Compression Test Methods of SLL Materials.

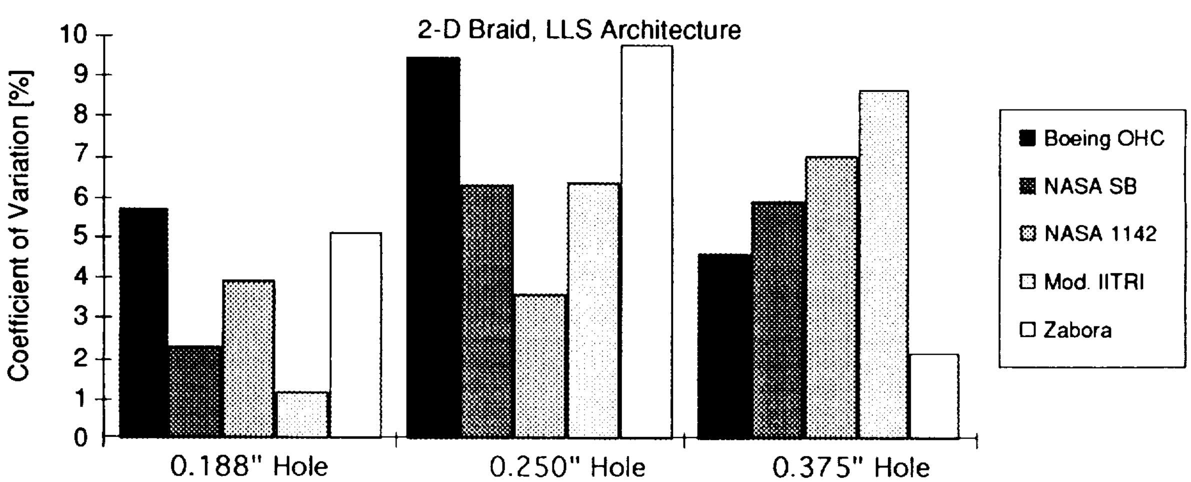


Figure 8.3.b Comparison of Coefficient of Variations for Open Hole Compression Test Methods of LLS Materials.

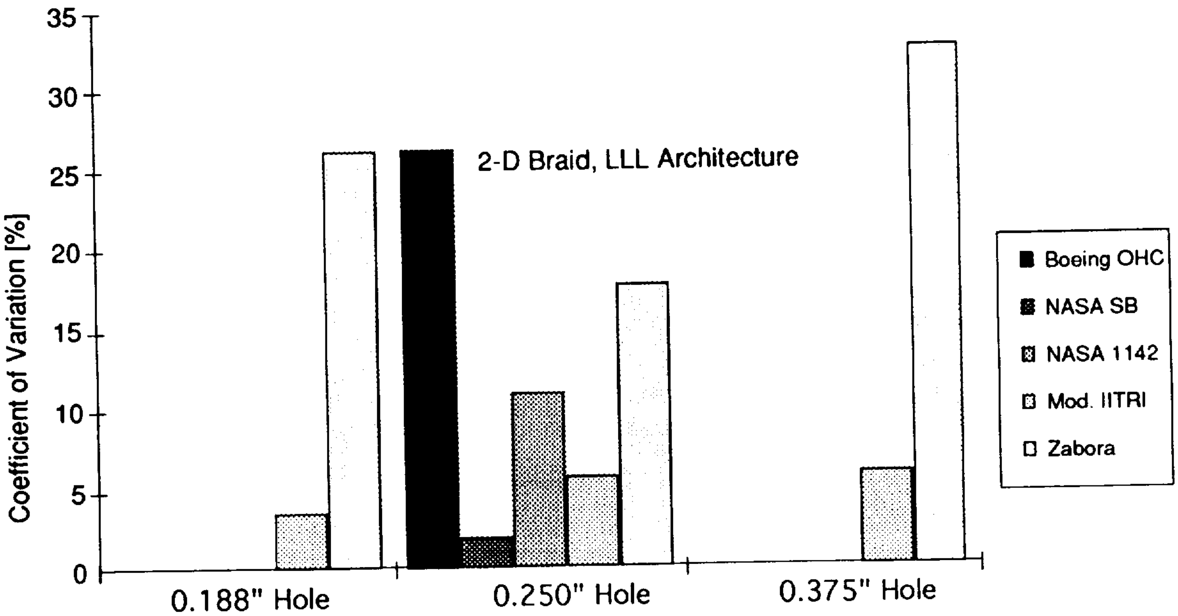


Figure 8.3.c Comparison of Coefficient of Variations for Open Hole Compression Test Methods of LLL Materials.

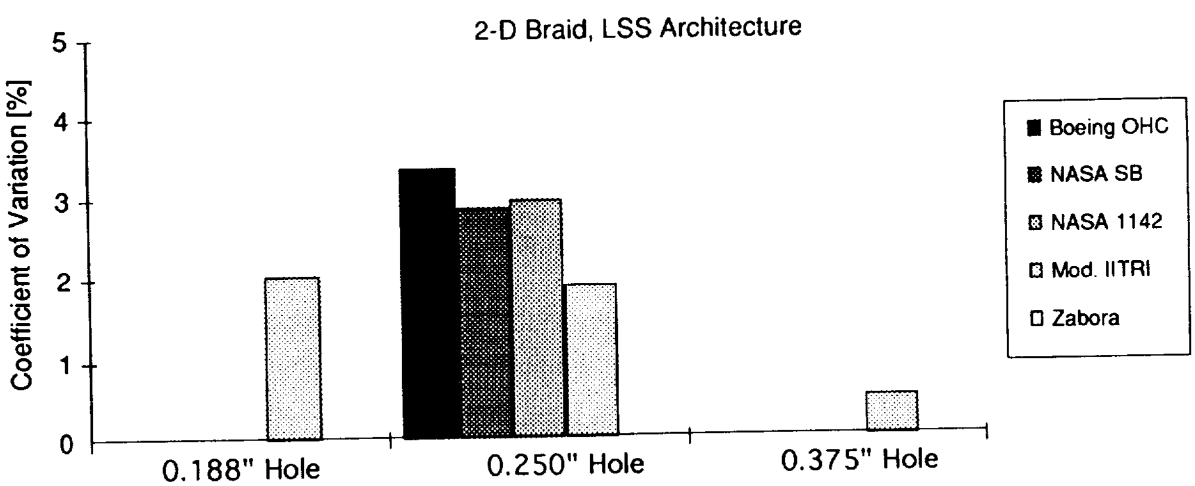


Figure 8.3.d Comparison of Coefficient of Variations for Open Hole Compression Test Methods of LSS Materials.

Table 8.2 Summary of Open Hole Compression Test Results for 2-D Braided Materials

	SLL			LLS			LLL			LSS		
D [in]	Stress [ksi]	Strain	CoV [%]	Stress [ksi]	Strain	CoV [%]	Stress [ksi]	Strain	CoV [%]	Stress [ksi]	Strain	CoV [%]
Boeing Open Hole Compression												
0.188	56.0	6281	25.9	47.4	5380	5.8						
0.250	59.1	6630	23.9	46.4	5259	9.5	39.1	4669	26.2	34.4	7848	3.3
0.375	54.8	6139	6.4	43.4	4924	4.6						
NASA Short Block												
0.188	68.5	7684	3.3	50.0	5669	2.3						
0.250	58.7	6585	11.9	47.0	5333	6.3	43.1	5155	2.0	32.8	7489	2.9
0.375	50.9	5707	3.5	41.1	4661	5.9						
NASA 1142 Fixture												
0.188	62.7	7034	3.9	48.9	5542	3.9						
0.250	55.8	6252	14.2	49.5	5610	3.6	51.8	6185	11.0	36.8	8405	3.0
0.375	54.6	6116	0.9	45.2	5121	7.1						
Modified IITRI Specimen												
0.188	64.0	7172	3.7	52.6	5958	1.2	58.7	7018	3.5	37.0	8447	2.0
0.250	64.6	7247	15.5	49.4	5601	6.4	53.9	6438	5.7	36.6	8352	1.9
0.375	48.1	5392	0.8	45.3	5138	8.7	51.1	6102	5.9	33.8	7734	0.5
Zabora Fixture												
0.188	64.2	7201	5.4	54.7	6202	5.1	47.5	5677	26.0			
0.250	63.6	7135	7.9	47.5	5380	9.8	44.4	5310	17.9			
0.375	56.9	6379	6.6	44.7	5066	2.2	42.5	5079	32.3			
Boeing CAI Fixture												
0.500	54.5	6107	12.7	40.7	4617	3.1						
0.800	41.6	4667	3.6	35.9	4073	5.7	38.7	4623	2.0	31.4	7164	0.6
1.000	41.6	4667	4.1	32.3	3658	4.3						
NASA ST-4 Fixture												
1.250	36.8	4122	14.6	30.6	3465	6.0						

8.2.2 Hole Size Effect

In addition to the test methods compared in the previous section, the NASA ST-4 and Boeing CAI specimens were used to examine the open hole compression strength in the presence of larger holes than the ones used in the other specimens. As for the open hole tension tests, the log-log fitting technique of strength versus hole diameter was used to analyze the results. For each hole diameter, the results from different test methods were averaged together when available. Some series of results with a high CoV or a low mean due to a premature failure in one of the specimen, were eliminated in certain cases from this average whenever it was possible to reduce the overall scatter for a given diameter. Results for all four 2-D braids are shown in Figure 8.4 and a rather good fit is obtained in all cases. For reference purpose, the mean compression strength is also indicated in each plot. For the hole diameters of 0.188", 0.250" and 0.375", the specimens were only 1.50" wide; thus, for the 0.375" diameter hole, the ligaments on either side of the hole are only 0.563" wide. The unit cell widths, which ranged from 0.415" to 0.829" for the braids were essentially as wide or wider than the ligaments. On the other hand, the CAI and ST-4 specimen have a good amount of material in the net section. When looking at the data point corresponding to the 0.375" hole in Figure 8.4, one can see that it lies within the normal scatter of the curve fit across all hole sizes. Thus, this would indicate that the small number of material unit cells in the net section did not significantly influence the results.

Once again, an interesting observation of the tow size effect can be made by comparing SLL and LLL. For a hole diameters of 0.188", SLL is about 26% stronger than LLL. However, for a larger hole diameter of 0.800", the difference is only 7%. This is possibly due to the fact that for large hole diameters, materials appear to be more homogenous compared to the hole size and thus, the coarse architecture of LLL makes less of a difference. The effect of changing the braid angle from 70° to 45° is seen in comparing the results of LLL and LLS. Interestingly, in term of stress, there is not much difference between the two. Finally, the LSS material with its high percentage of 45° appears to have little sensitivity to the notch size.

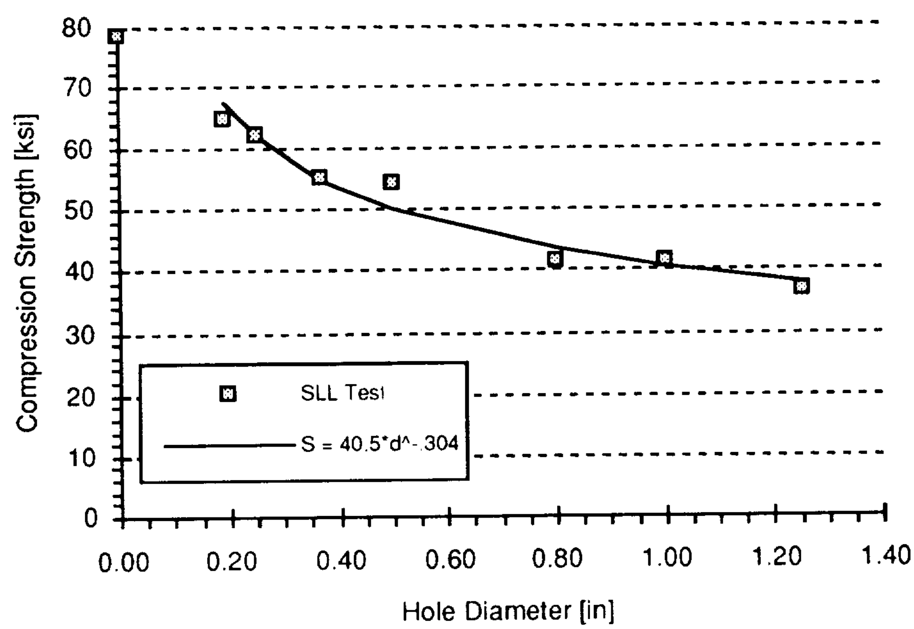


Figure 8.4.a Effect of Hole Diameter on Open Hole Compression Strength of 2-D Braided Materials SLL.

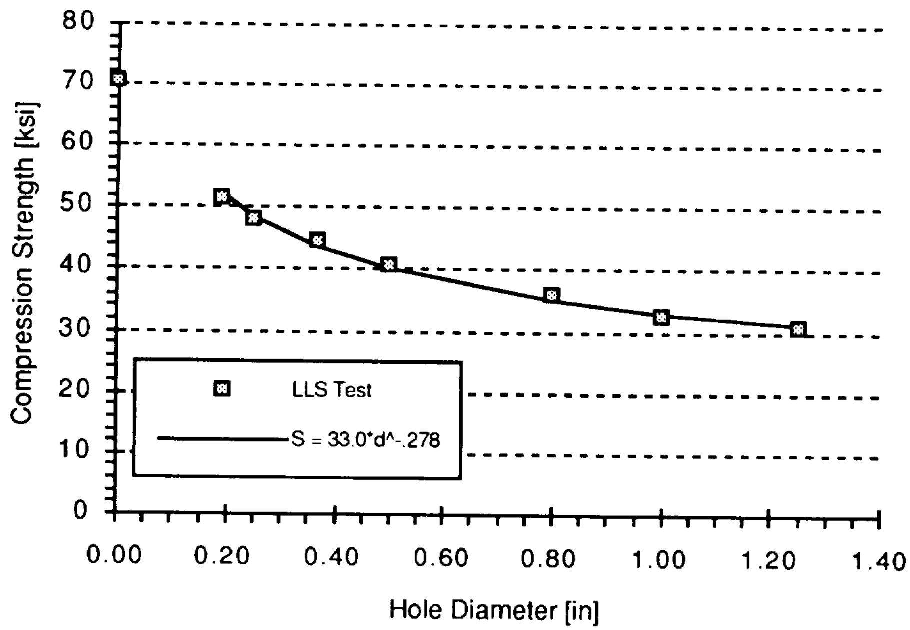


Figure 8.4.b Effect of Hole Diameter on Open Hole Compression Strength of 2-D Braided Materials LLS.

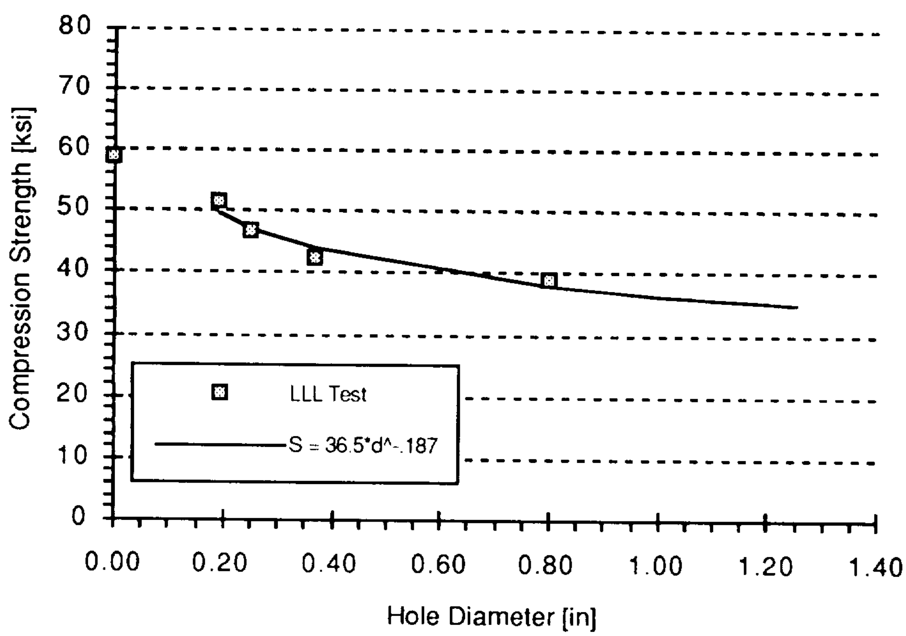


Figure 8.4.c Effect of Hole Diameter on Open Hole Compression Strength of 2-D Braided Material LLL.

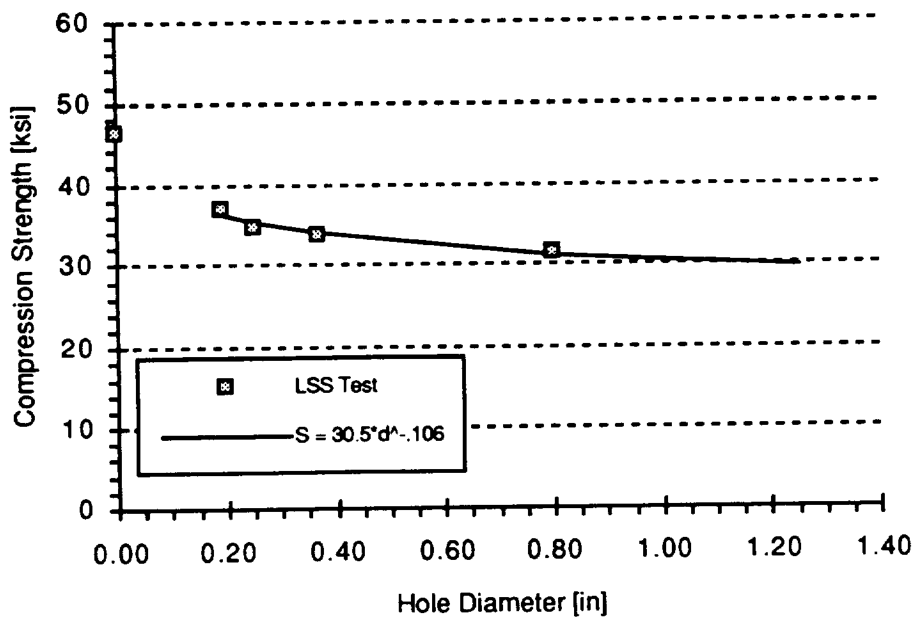


Figure 8.4.d Effect of Hole Diameter on Open Hole Compression Strength of 2-D Braided Material LSS.

8.3 *Stitched Uniweave Materials*

Stitched uniweave materials were tested only with the Boeing OHC specimen and modified IITRI methods. Results from this testing are summarized in Table 8.3. A comparison of the two methods for the 1/4" hole shows that the average difference is only 2.1% , with, unlike for the 2-D braided materials, the modified IITRI being the lower. A comparison of the mean CoV for each method is shown in Figure 8.5 and reveals that both method are fairly similar. Note that in general, the scatter is much lower than for the 2-D braids.

A comparison of the five materials is shown in Figure 8.6, where nominal strains are calculated with the compression modulus; not much difference is observed between the different types of stitching: SU-1 fared best, with SU-3 12% lower. Using the same log-log fit of strength versus hole diameter as in the open-hole tension test program, a comparison of SU-1 and SU-3 is shown in Figure 8.7, where SU-3 appears to be somewhat more notch sensitive than SU-1.

Table 8.3 Summary of Open Hole Compression Test Results for Stitched Uniweave Materials.

		SU-1	SU-2	SU-3	SU-4	SU-5
Boeing OHC	Strength [ksi]	47.3	42.1	40.1	40.6	45.8
0.250" Hole	CoV [%]	4.2	1.8	4.1	1.8	1.2
Mod. IITRI	Strength	47.9	42.4	45.0	46.3	46.8
0.188" Hole	CoV	2.2	2.1	1.0	3.4	0.8
Mod. IITRI	Strength	44.5	39.5	40.7	43.0	43.0
0.250" Hole	CoV	3.4	7.2	4.7	2.1	3.5
Mod. IITRI	Strength	42.9	37.3	37.8	39.0	39.0
0.375" Hole	CoV	3.3	3.5	1.2	0.9	1.2

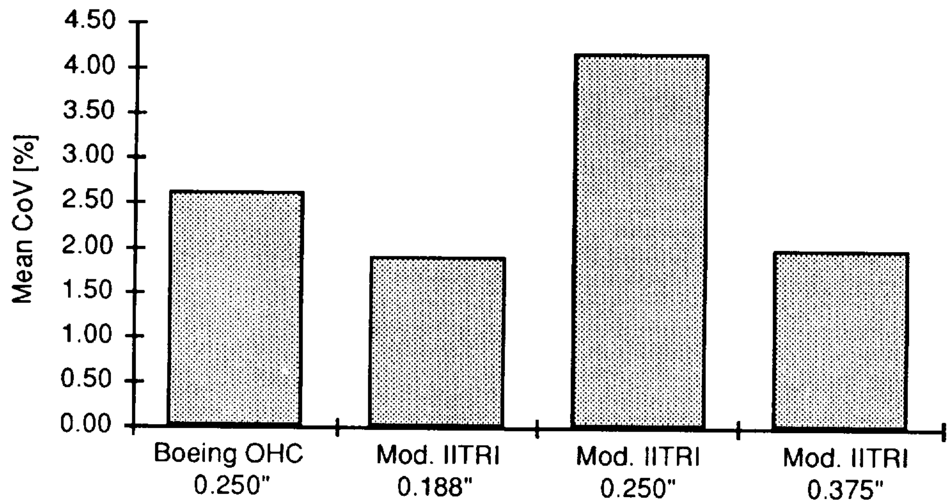


Figure 8.5 Comparison of Mean Coefficient of Variation for all Stitched Uniweave Open Hole Compression Tests.

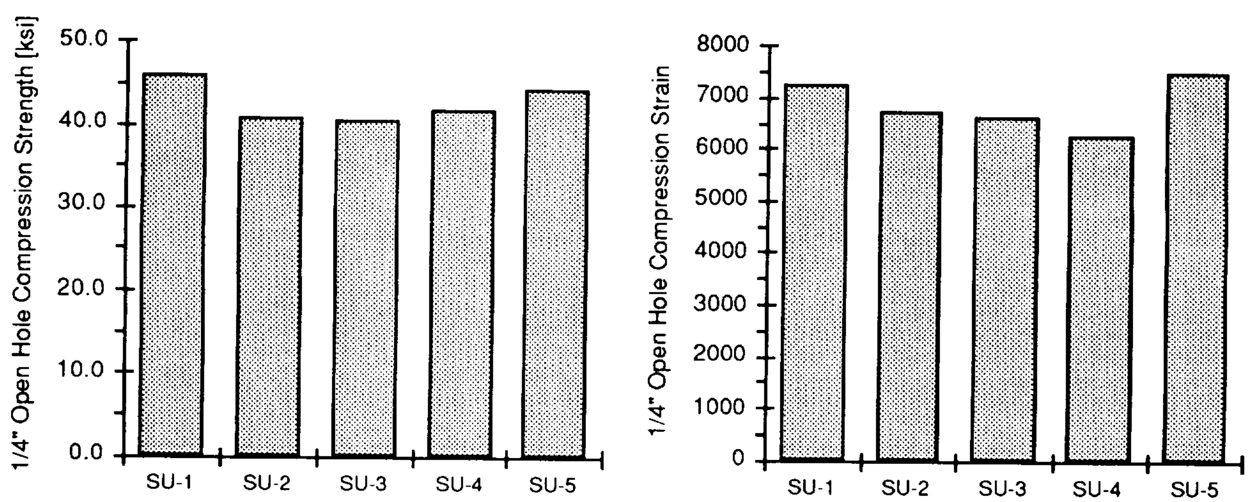


Figure 8.6 Comparison of 1/4" Open Hole Compression Strength and Nominal Strains for Stitched Uniweave Materials.

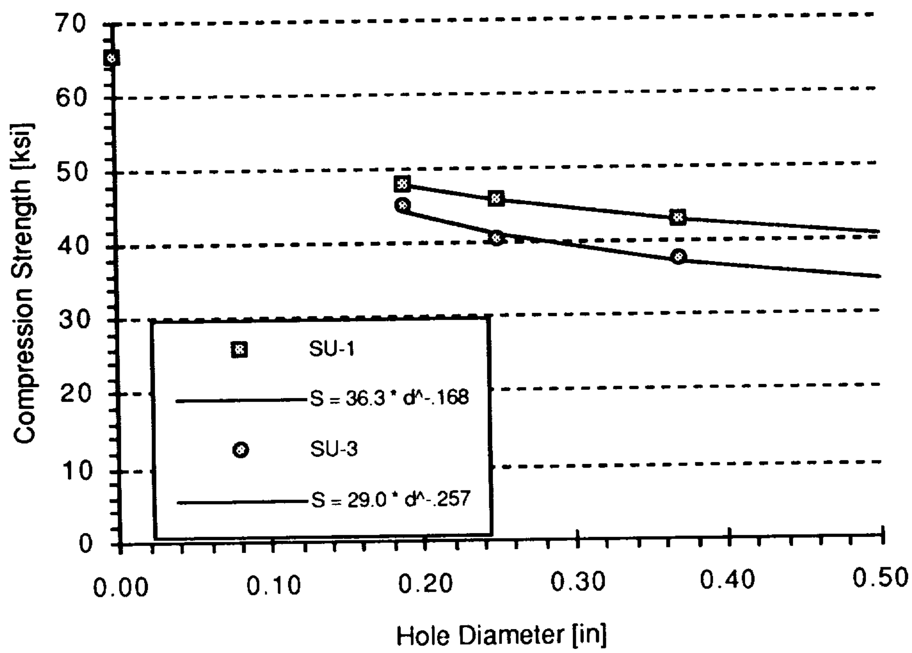


Figure 8.7 Effect of Hole Diameter on Open Hole Compression Strength of Stitched Uniweave Materials.

8.4 *3-D Woven Materials*

The results of the open hole compression testing of the 3-D woven materials are summarized in Table 8.4. The average difference between Boeing OHC and modified IITRI is only about 2.4% and the average CoV is about 6%. A comparison of the six materials is shown in Figure 8.8. The OS-1 configuration yielded the highest strength, while OS-2 produced the lowest. Other configurations exhibited fairly similar strengths.

Table 8.4 Summary of Open Hole Compression Test Results for 3-D Woven Materials

		OS-1	OS-2	LS-1	LS-2	TS-1	TS-2
Boeing OHC	Strength [ksi]	66.2	n/a	63.3	58.3	55.8	55.8
0.250" Hole	CoV [%]	2.3		9.7	5.1	2.2	6.2
Mod. IITRI	Strength [ksi]	70.3	71.3	62.9	58.5	63.2	59.3
0.188" Hole	CoV [%]	4.4	4.3	7.7	5.5	3.8	3.2
Mod. IITRI	Strength [ksi]	68.7	46.8	61.8	60.2	56.3	59.2
0.250" Hole	CoV [%]	6.1	8.2	4.1	7.5	3.7	6.3
Mod. IITRI	Strength [ksi]	61.5	53.6	56.6	51.6	51.3	49.2
0.375" Hole	CoV [%]	2.3	4.4	14.4	9.4	2.1	5.4

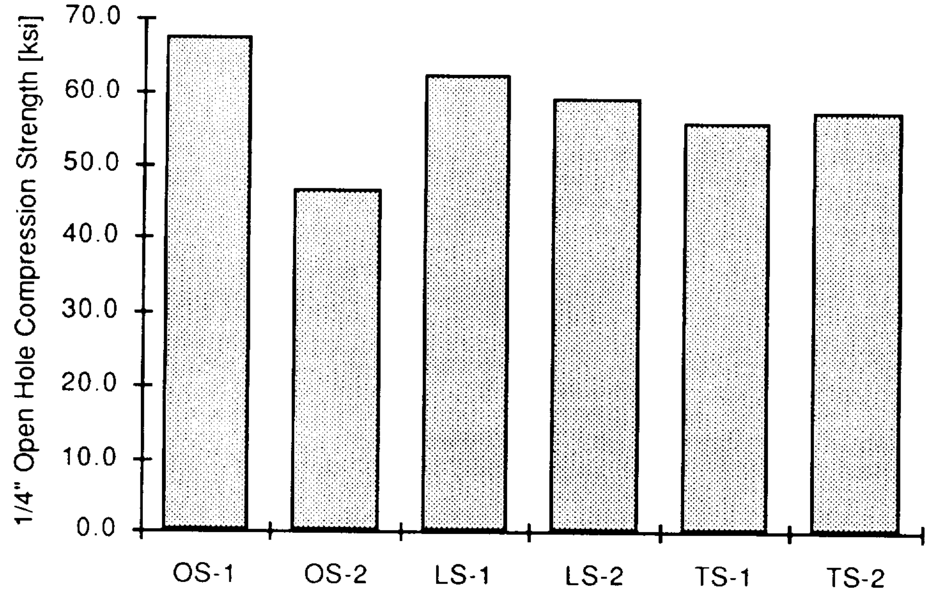


Figure 8.8 Comparison of 1/4" Open Hole Compression Strength for 3-D Woven Materials.

8.5 *Test Recommendations*

The open-hole compression test methods were analyzed to determine which method would give the maximum allowable in a manner similar to that which was used to compare the unnotched compression test methods. For these tests, only material varied, but here, both material and hole diameter vary. Thus, the normalized mean of strengths was calculated as follows:

1) Means for each material and hole diameter were calculated with:

$$\bar{x}_{km} = \frac{1}{N} \sum_{n=1}^{N} \bar{x}_{kmn}$$

where n is the test method number, m the material number, k is the hole size number, N is the number of test methods and $\bar{x}_{kmn}$ is the mean for a given hole diameter, material and test method.

2) A mean deviation from $\bar{x}_{km}$ was calculated for each test method with:

$$\overline{\Delta x}_{n} = \frac{1}{K} \sum_{k=1}^{K} \overline{\Delta x}_{kn}$$

where K is the number of hole diameters and

$$\overline{\Delta x}_{kn} = \frac{1}{M} \sum_{m=1}^{M} \frac{\bar{x}_{kmn} - \bar{x}_{km}}{\bar{x}_{km}}$$

where M is the number of materials for a given test method and hole diameter.

Five methods are retained for this comparison: the Boeing Open Hole Compression fixture, the NASA Short Block, the NASA 1142 specimen, the modified IITRI and the Zabora fixture. Values of $\overline{\Delta x_{kn}}$ and $\overline{\Delta x_n}$ are given in Table 8.5 and values of $\overline{\Delta x_n}$ and mean COV are plotted in Figures 8.9 and 8.10.

The modified IITRI method gave the highest mean strengths (+3%) followed by the NASA 1142 method (+1%); CoVs were small (<6%) and essentially equal. The CoV for the NASA Short Block was less than 5%, but the strengths were typically 2% below the mean. The strengths for the Zabora method were only slightly below the mean, but the CoV was the highest. The strengths for the Boeing OHC method were the lowest, and the CoV was next to the highest. As noted previously, the CoVs for the Zabora and Boeing OHC test methods were very high for the 1/8" thick 2-D braids. All of the other methods were only used for 1/4" thick materials.

Table 8.5 Mean deviations $\overline{\Delta x_{kn}}$ and $\overline{\Delta x_n}$ for Open-Hole Compression Test Methods.

Hole Diameter [in]	Test Method				
	Boeing OHC	NASA SB	Zabora	NASA 1142	Mod. IITRI
0.188	-9.1 %	3.4 %	-0.4 %	-2.3 %	7.0 %
0.250	-1.7 %	-4.7 %	-0.1 %	2.9 %	2.2 %
0.375	1.0 %	-5.3 %	-0.1 %	2.9 %	1.0 %
$\overline{\Delta x_n}$	-3.2 5	-2.2 %	-0.2 %	1.2 %	3.4 %

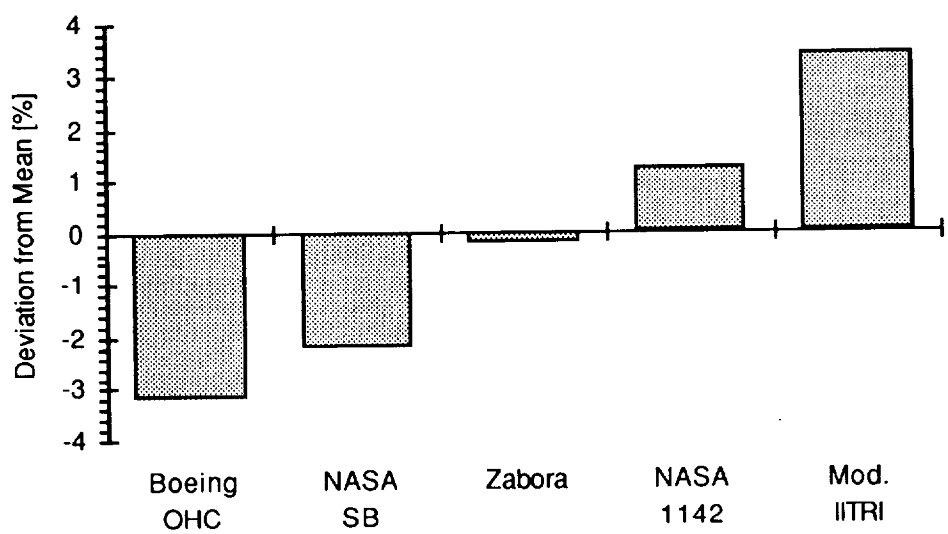


Figure 8.9 Normalized Mean Deviations for Open Hole Compression Test Methods in 2-D Braided Materials.

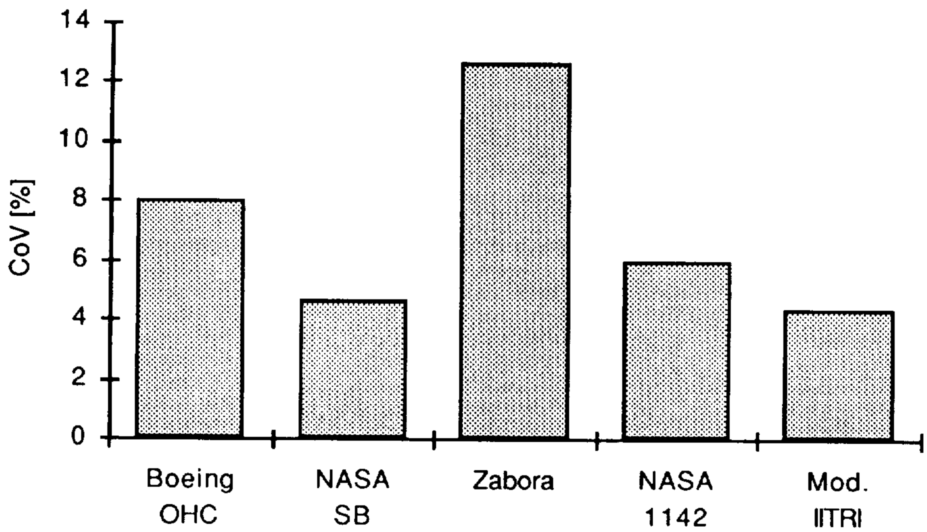


Figure 8.10 CoVs for Open Hole Compression Test Methods in 2-D Braided Materials.

9. In-Plane Shear Test Program

9.1 *Test Configurations*

Three test methods were considered for shear testing as shown in Table 9.1: tube torsion, a modified rail shear and a compact shear specimen. Tube torsion tests were conducted at The Pennsylvania State University and all details of the testing can be found in Reference 7. Special end fixtures were designed for the tube torsion test. These consisted of an inner metal plug, pressure fitted inside the tube by cooling in liquid nitrogen, and an outer two part collar clamped around the composite tube. A single tension bolt is fitted in the center of the end fitting to allow for biaxial tension-torsion loading, although this feature was not used here. Eight 1/4″ by 1/8″ strain gage rosettes were used on the first few test specimens, with that number reduced to four on later specimens. As indicated in Table 9.1, tubes of two different diameters were tested, 1.25″ and 2.33″.

The modified rail shear method uses a specimen, shown in Figure 9.1, similar in shape to the standard rail shear test but in a different fixture. The main difference is that the fixture consists of two vertical rails clamped to a rigid base instead of being hinged. Serrated rails and three attachment bolts per side are used for load introduction. All 2-D braided specimens were 1/8″ thick, while all other specimens were 1/4″ thick. All specimens were tabbed with fiberglass tabs.

The third test method uses a compact shear specimen configuration developed by Ifju. Although similar in concept to the rail shear specimen, the coupon geometry is somewhat different. A specially developed shear strain gage is used to measure the average shear strain over the entire test section. The test results presented in this section can also be found with more details in Reference 8.

Table 9.1 Test Matrix for Shear Properties

	SLL	LLS	LLL	LSS	Others (1)
Small Tube, 1.25″	8	8	4	4	
Large Tube, 2.33″	8	8	4	4	
Rail Shear	3	3	3	3	3
Compact Shear	6	6	6	6	4 (2)

(1) Five Stitched Uniweave and Six 3-D Woven
(2) Five 3-D Woven only

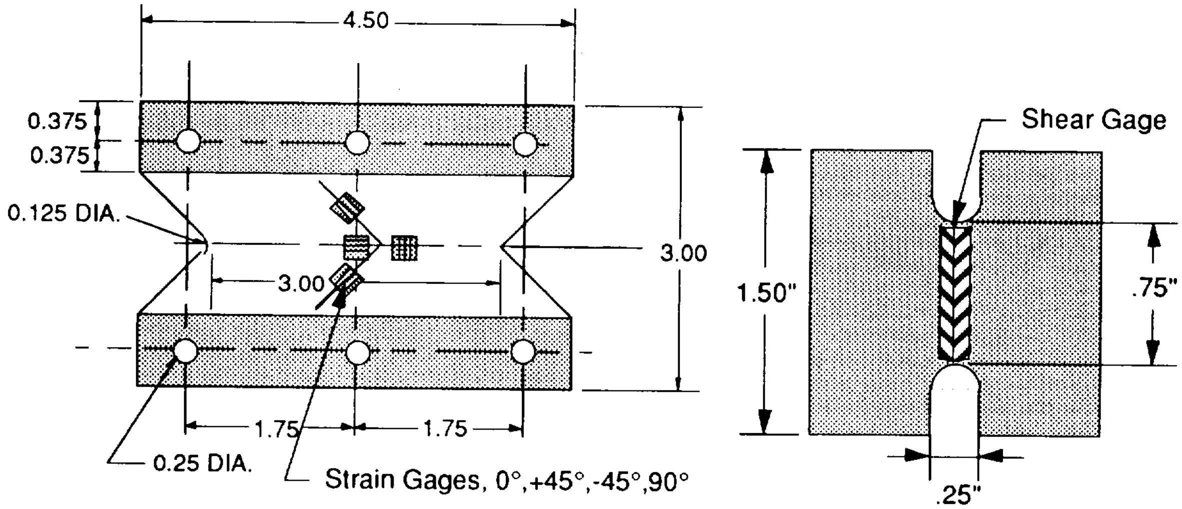


Figure 9.1 Rail Shear Specimen and Compact Shear Specimen.

9.2 2-D Braid Materials

Results from the tube torsion tests are summarized in Table 9.2. Because these specimens were produced differently from all the other specimens used so far, the normalized thickness could not be used. Instead, an estimated fiber volume fraction was calculated based on the braiding machine setup, tow sizes and tube thickness. The measured results were then normalized to the nominal 60% fiber volume used in this report. The results from the Rail Shear and Compact Shear specimens are shown in Table 9.3. All these results are compared graphically in Figures 9.2 and 9.3. For $[0_i/\pm\theta_j]$ tape laminates, the shear modulus is a maximum for $\theta = 45°$ and increases with increasing percentage of θ plies. One would expect the 2-D braids to behave similarly. Indeed, the shear modulus for LLS (45° and 54% braid) is greater than those for SLL (70° and 54% braid) and LLL (70° and 54%) braid, which are about equal, and the shear modulus for LSS (45° and 88% braid) is greater than that for LLS.

The results contain much scatter. For the shear modulus, the difference between highest and lowest data is about 45% for SLL, 28% for LLS, 32% for LLL and 36% for LSS. Similarly for strengths, the differences are 70% for SLL, 73% for LLS, 71% for LLL, and 77% for LSS. Small tubes and compact shear specimens made of LSS tended to fail outside the test section and were not included in the calculation of 77%. The LSS braid was the strongest of the 2-D braids.

Table 9.2 Summary of Tube Torsion Test Results for 2-D Braids

Property	SLL Large	SLL Small	LLS Large	LLS Small	LLL Large	LLL Small	LSS Large	LSS Small
Estimated Fiber Volume Fraction [%]	51	53	50	55	46	45	50	56
Norm. Strength [ksi]	11.9	11.0	16.5	11.8	11.5	15.3	>25 (1)	18.1
CoV [%]	8.9	2.4	6.5	4.5	1.6	4.7	n/a	3.6
Norm. Modulus [msi]	1.33	1.14	2.18	1.87	1.35	1.59	3.57	2.90
CoV [%]	9.7	7.9	7.7	10.0	22.1	6.7	4.7	28.0

(1) No specimen was failed during test

Table 9.3 Summary of Rail Shear and Ifju Fixture Test Results for 2-D Braids

Property	SLL Rail	SLL Compact	LLS Rail	LLS Compact	LLL Rail	LLL Compact	LSS Rail	LSS Compact
Strength [ksi]	18.7	17.6	18.2	19.5	17.3	18.9	32.0	18.9
CoV [%]	8.8	3.5	13.9	3.0	4.0	3.5	25.2	3.9
Modulus [msi]	1.51	1.65	2.39	1.94	1.78	1.35	3.93	3.18
CoV [%]	4.6	3.7	5.0	3.7	10.4	3.1	8.0	3.3

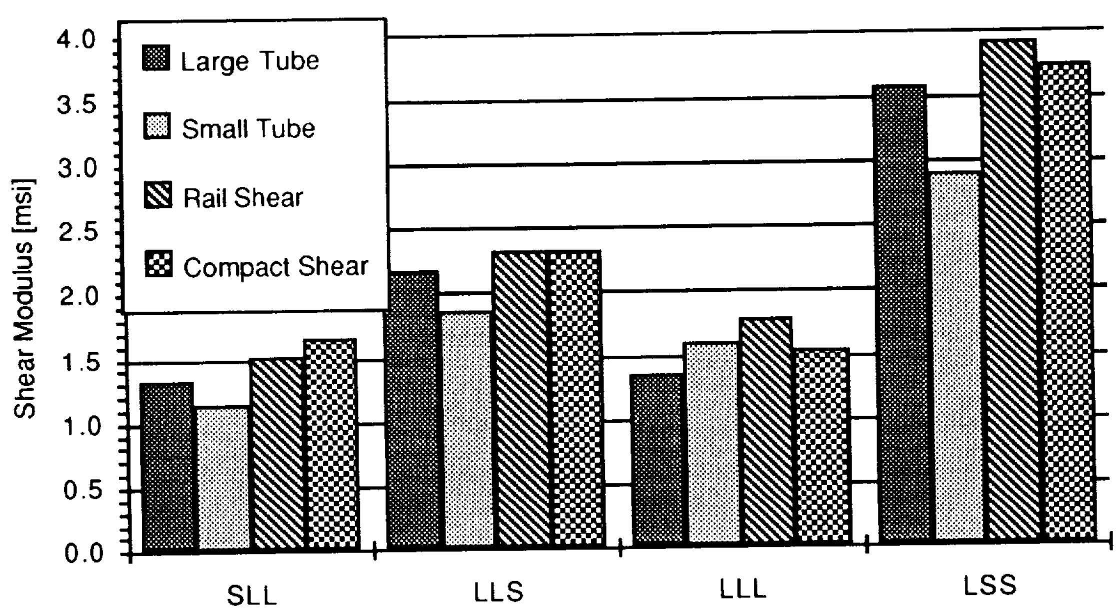


Figure 9.2 Comparison of Shear Modulus by Various Test Methods for 2-D Braided Materials.

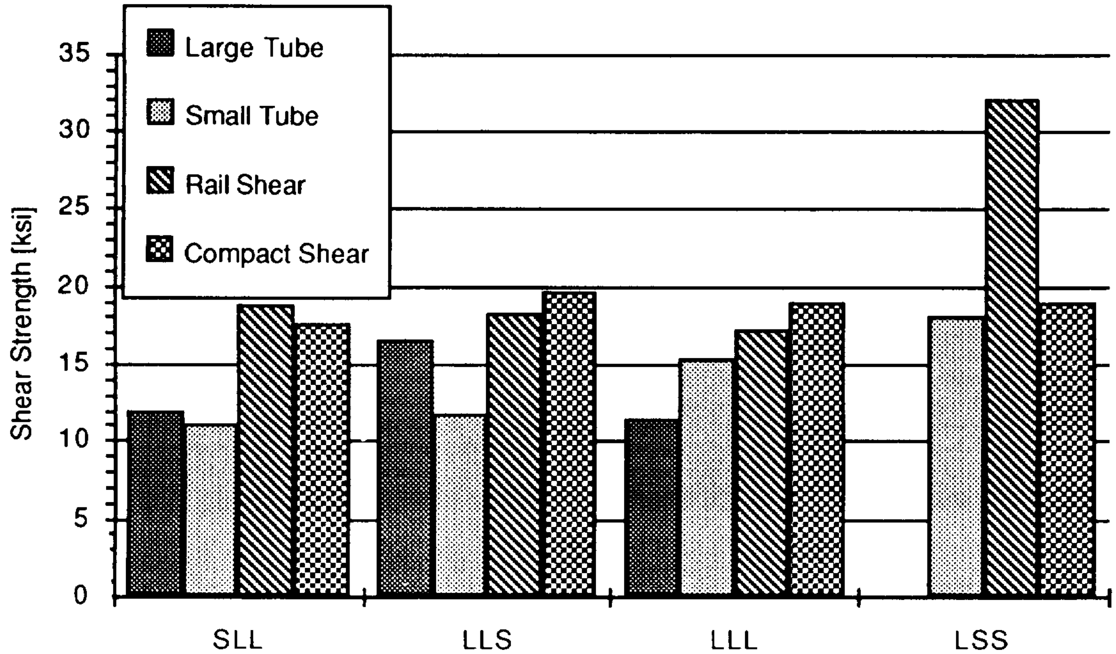


Figure 9.3 Comparison of Shear Strength Various Test Methods for 2-D Braided Materials.

9.3 *Stitched Uniweave Materials*

Only the modified rail shear method was used for the stitched uniweave materials. Bearing and shear-out failures at the attachment holes were obtained for all specimens. Shear modulus was measured and is reported in Table 9.4 and illustrated in Figure 9.4. Strength is also indicated for reference in this Table in order to provide a lower bound to the actual shear strength of the material. The use of thinner specimen with a larger number of attachment holes and with a larger distance between holes and specimen edge is therefore recommended.

Table 9.4 Shear Properties of Stitched Uniweave Materials

Property	SU-1	SU-2	SU-3	SU-4	SU-5
Strength [ksi] (1)	21.6	20.6	21.0	22.6	20.5
CoV [%]	12.7	6.5	3.7	8.1	4.7
Modulus [msi]	2.41	2.30	2.32	2.62	2.35
CoV [%]	0.6	7.1	3.6	1.5	1.2

(1) All specimens failed in bearing

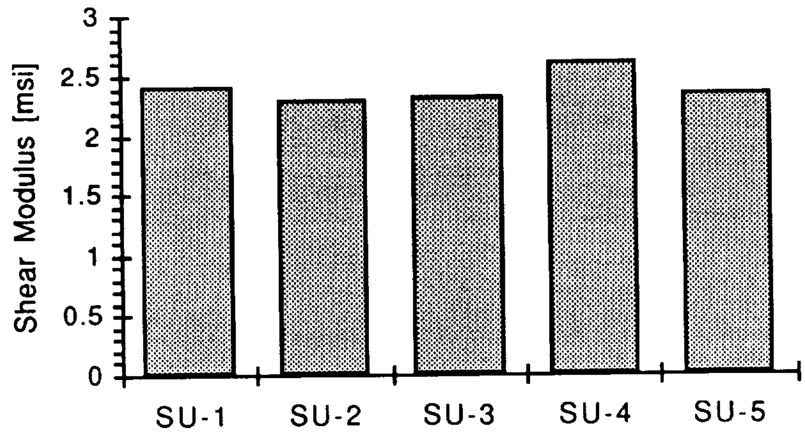


Figure 9.4 Shear Modulus of Stitched Uniweave Materials.

9.4 *3-D Woven Materials*

Both the modified rail shear method and the compact shear specimen method were used for the 3-D woven materials. Bearing failures at the attachment holes were obtained for many specimens with the rail shear method. Strength and shear modulus were measured and reported in Table 9.5. Moduli measured by the two methods are compared in Figure 9.5. A slightly higher value was consistently obtained with the compact shear specimen. The many bearing failures confirmed that the present rail shear configuration is not adequate, especially for thick specimens. As in the previous section, the use of thinner specimen with a larger number of attachment holes and with a larger distance between holes and specimen edge is recommended for the rail shear method.

Table 9.5 Shear Properties of 3-D Woven Materials

Test	Property	OS-1	OS-2	TS-1	TS-2	LS-1	LS-2
Rail Shear	Strength [ksi]	13.8 (1)	20.4 (2)	12.7 (1)	11.3 (2)	8.0	9.1
	CoV [%]	37.6	5.5	0.7	22.2	3.8	2.1
	Modulus [msi]	0.57	0.54	0.62	0.71	0.73	0.70
	CoV [%]	2.7	1.7	7.9	2.7	5.2	4.1
Compact Shear	Strength [ksi]	10.1	n/a	11.2	11.3	9.7	10.2
	CoV [%]	2.6		2.7	0.8	2.6	1.5
	Modulus [msi]	0.72	n/a	0.77	0.83	0.85	0.81
	CoV [%]	3.9		2.3	6.9	6.4	4.7

(1) One of three specimens failed in bearing

(2) All specimens failed in bearing

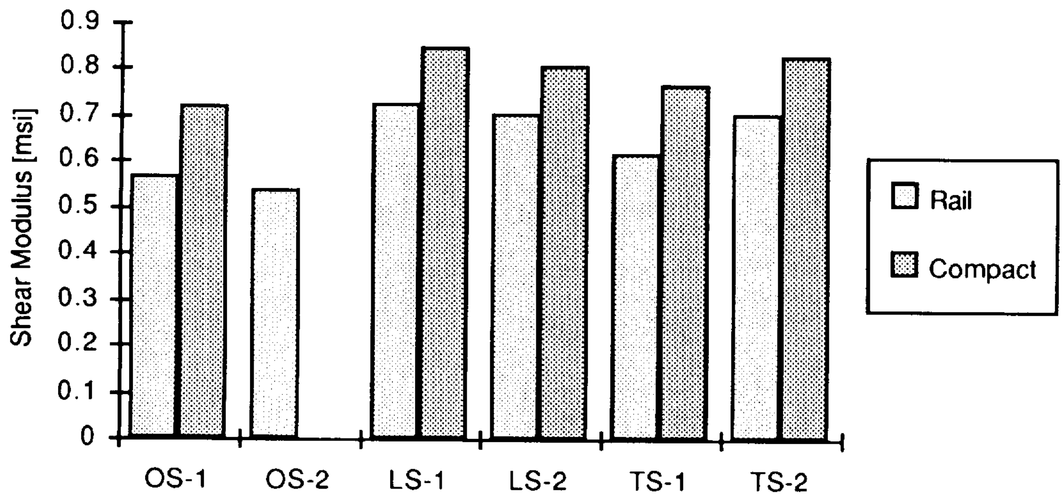


Figure 9.5 Shear Modulus of 3-D Woven Materials with Rail Shear and Compact Shear Specimen Methods.

9.5 *Test Recommendations*

The in-plane shear test methods were analyzed to determine which method would give the maximum allowable in the same manner as the unnotched compression test methods in Section 7.5. All the rail shear specimens for stitched uniweave and some 3-D woven materials failed at the attachment holes and those strengths could not be included in this analysis. Values of $\overline{\Delta x_n}$ for strength and modulus are given in Table 9.6 and values of $\overline{\Delta x_n}$ and CoV are plotted in Figures 9.6 and 9.7. In general, the rail shear and compact shear tests gave the largest mean values of modulus and strength and the smallest CoVs for modulus and the largest CoVs for strength. The modulus CoV was smallest for the compact shear specimen. A special strain gage was used for the compact shear specimen that extended across the entire 0.75" test section. Likewise, the modulus CoVs for the tubes and rail shear specimens would probably have been smaller had larger strain gages been used. It was not expected that the tube specimens would give the lowest values of strength because tubes have no free edges and are believed to have the most uniform state of shear stress. However, the difference between manufacturing methods for the tubes and flat plates could have caused the strengths for tubes to be less than those for rail and compact shear specimens. Therefore, it would probably be best to use a tube torsion test for braids that will be used for closed section structures and rail shear or compact shear specimens for braids that will be used for open section structures.

Table 9.6 Normalized Mean Deviations $\overline{\Delta x_n}$ for Shear Test Methods

Property	Test Method			
	Large Tube	Small Tube	Rail	Compact
Strength	-16.3 %	-21.7 %	17.8 %	22.5 %
Modulus	-1.8 %	-9.9 %	13.6 %	-1.9 %

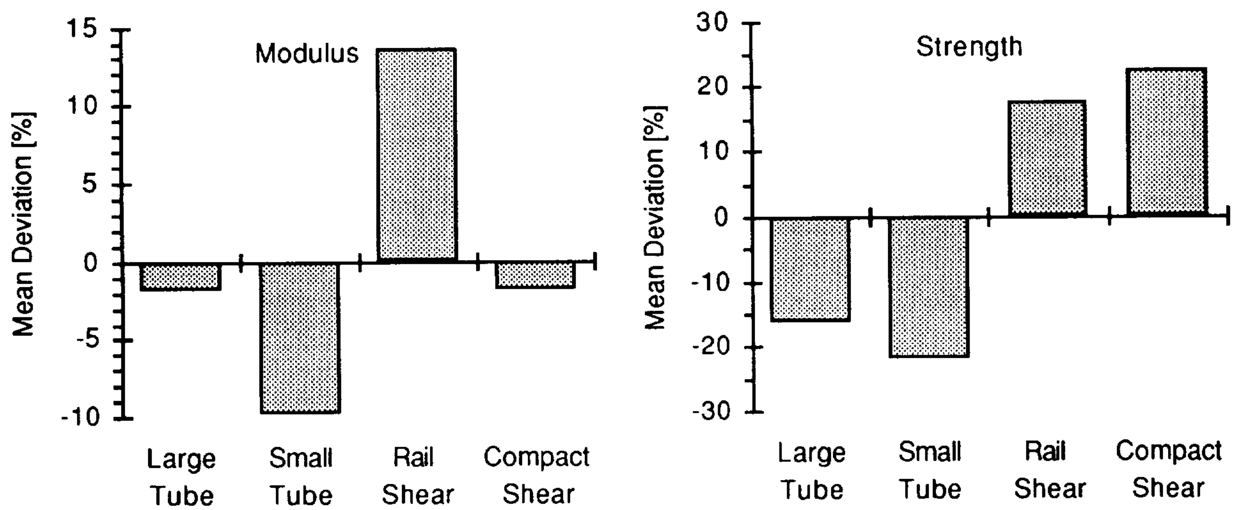


Figure 9.6 Mean Deviations for In-plane Shear Test Methods.

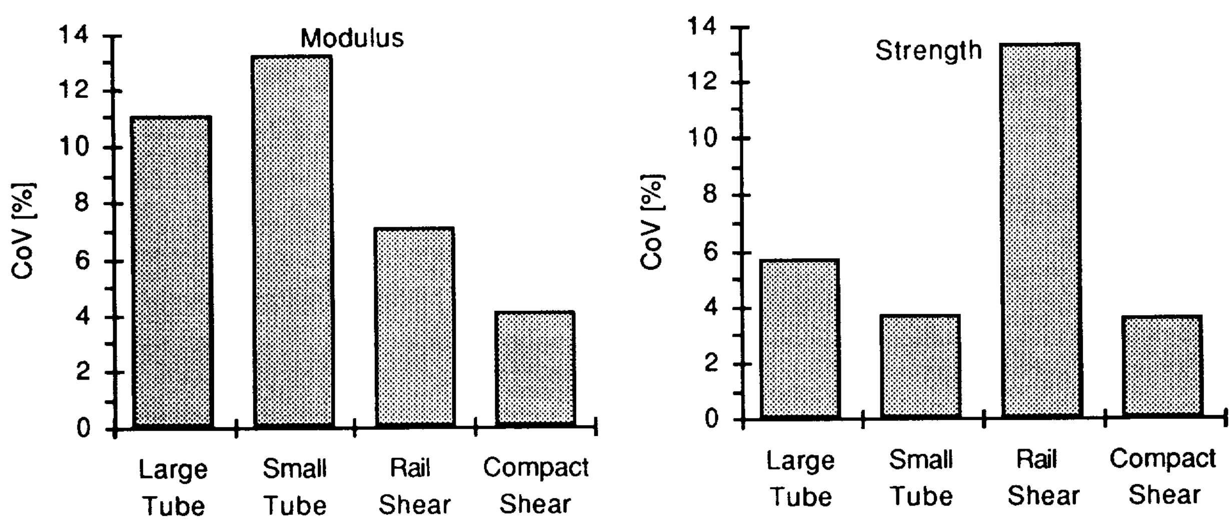


Figure 9.7 CoVs for In-plane Shear Test Methods.

10. Filled-Hole Test Program

Past experience with composite laminates has shown that installing a fully torqued fastener in an open-hole specimen often reduces the notch tension strength and thus makes this condition critical for design considerations. The likely cause of that effect is that the clamping force of the fastener induces through-the-thickness compressive stresses around the edge of the hole which delay the onset of delamination. Since delamination tends to reduce the stress concentration in the longitudinal fibers adjacent to the hole, reducing delamination decreases strength. Therefore, a limited test program was conducted to verify if this was also the case with the materials considered in this investigation.

10.1 *Test Configuration*

Because of limited material availability, only three of the 2-D braids were used as indicated in Table 10.1. The same specimen configuration as in the open hole test was used with a 1/4" titanium Hilok fastener installed in specimen identical to the open-hole tension specimen. Once again, the influence of the width to diameter ratio (W/D) was considered.

Table 10.1 Filled Hole Tension Test Program

Width [in]	W/D	SLL	LLS	LLL
1.00	4	3		
1.50	6	3	3	3
2.00	8	3		

10.2 *2-D Braids*

Results of the test program are shown in Table 10.2. As for the open hole tests, the simple correction factor for infinite plate width was applied to the strength data. A comparison of net stress, gross stress and corrected stress is shown in Figure 10.1 for the SLL material. Results show that the corrected stress is the least sensitive to W/D. Little difference is seen between W/D=6 and W/D=8, but the result for W/D=4 is slightly lower (by 4%) than the other two results, thus indicating that a specimen with W/D=6 is sufficiently wide. Filled and open hole strength results are compared in Figure 10.2. As expected, a small strength reduction is observed with the installation of a fastener, on the order of 9% for SLL, 14% for LLS and 12% for LLL. This confirms that, as for tape laminates, filled hole tension is the critical case when developing material design allowables for the Room Temperature/Dry environment. As in previous tests, increasing the tow size (going from SLL to LLL) leads to a reduction in strength on the order of 15%.

Table 10.2 Filled Hole Tension Test Program

W/D	Property	SLL	LLS	LLL
4	Stress [ksi] CoV [%]	81.2 4.6		
6	Stress [ksi] CoV [%]	84.2 8.7	71.5 7.9	72.0 2.7
8	Stress [ksi] CoV [%]	84.7 1.7		

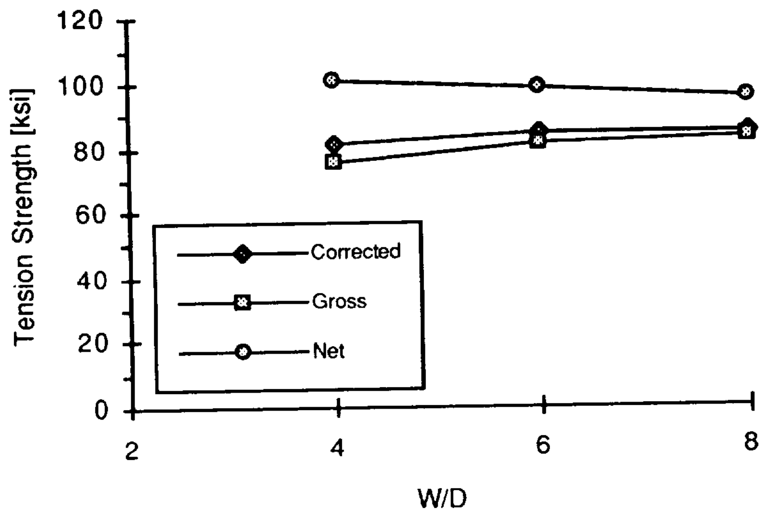


Figure 10.1 Comparison of Net, Gross and Corrected Stress for Filled Hole Tension Test of SLL Braid.

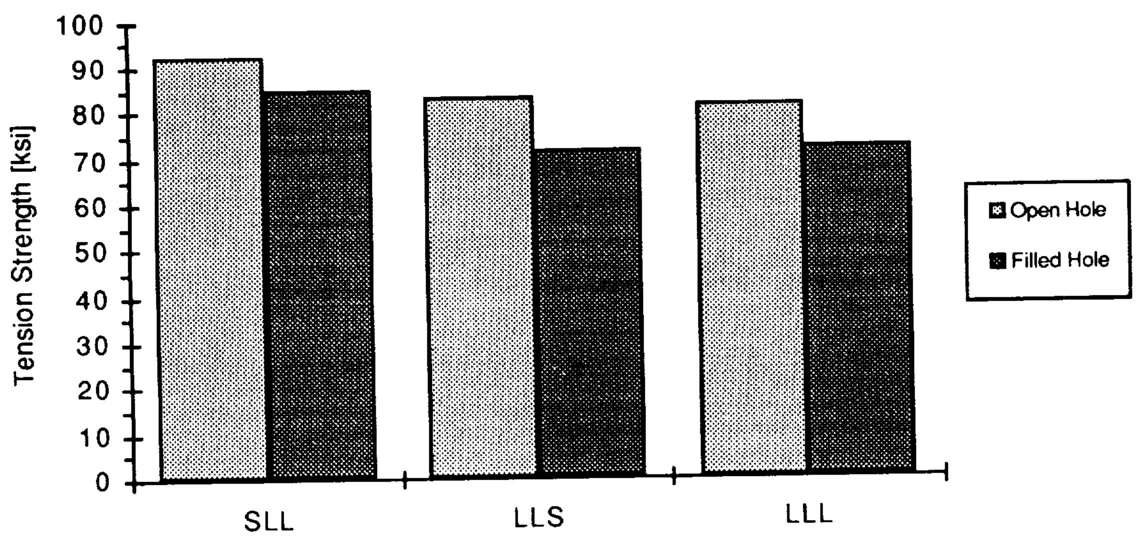


Figure 10.2 Comparison of Open and Filled Hole Tension Strength Data for 2-D Braided Material.

11. Bolt-Bearing Test Program

The last in-plane property examined in this investigation is the testing of textile composites for bolt bearing strength. Although not strictly a material property in itself, bearing strength is a key parameter for the design of composite structures. Different test specimens representing various types of joint configurations are typically used for this purpose.

11.1 *Test Configuration*

Three basic specimens, shown in Figure 11.1, were selected for this investigation: the unstabilized single shear specimen, the stabilized single shear specimen and the double shear specimen. Because of limited material availability, only the 2-D braided materials are considered here as shown in the test matrix in Table 11.1. For each test configuration, the influence of two geometric parameters is examined: the distance of the hole center to the edge of the specimen and the width of the specimen. Several edge to diameter ratios (e/D) and width to diameter ratios (W/D) are included. Note that when testing laminated composites, ratios of W/D = 6 and e/D = 3 are typical. A 1/4" titanium Hilok fastener is used for all tests. The influence of fastener torque is also considered in the double shear bearing test: in one series of tests, a fastener with no nut is inserted in the hole as a simple pin (no clamp-up) and in the other, the installation torque is doubled to increase clamp-up and possibly induce some damage.

Table 11.1 Bolt-Bearing Test Matrix

W/D	e/D	SLL	LLS	LLL	SLL	LLS	LLL
		Stabilized Single Shear Bearing			Double Shear Bearing		
4	2	3	3		3	3	
4	3	3	3		3	3	
4	4	3	3		3	3	
6	2	3	3		3	3	
6	3	3	3	3	3	3	
6	4	3	3		3	3	
8	2	3	3		3	3	
8	3	3	3		3	3	
8	4	3	3		3	3	
		Unstabilized Single Shear Bearing					
6	2	3	3				
6	3	3	3	3			
6	4	3	3				
		Double Shear, Over-torqued Fastener					
6	3	3	3				
		Double Shear, Pinned Fastener					
6	3	3	3				

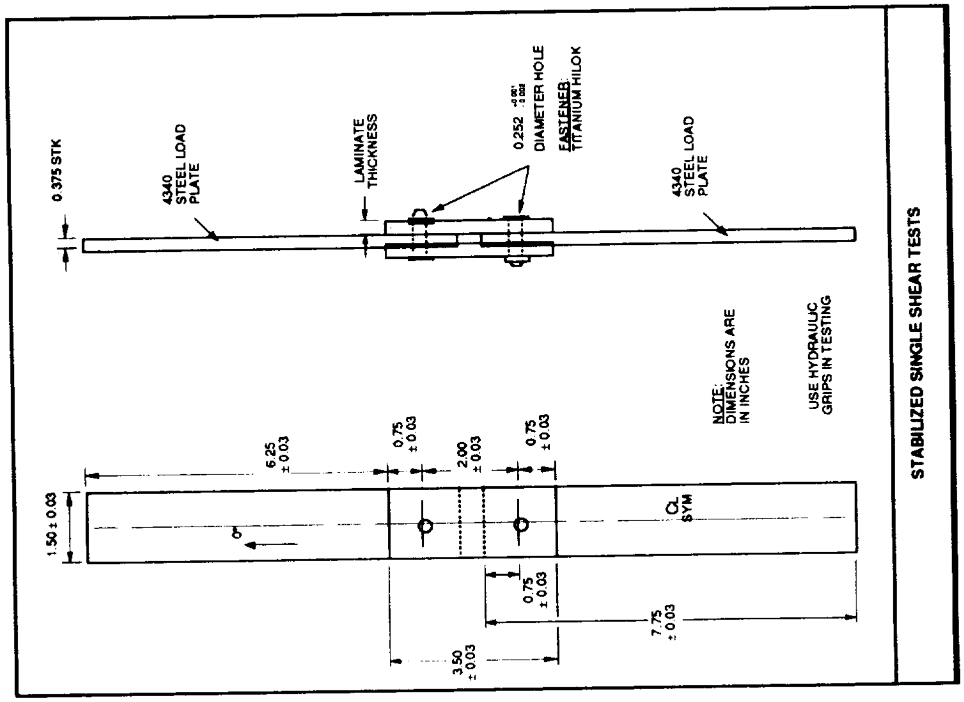


Figure 11.1a Baseline Dimensions for Stabilized Single-Shear Specimen.

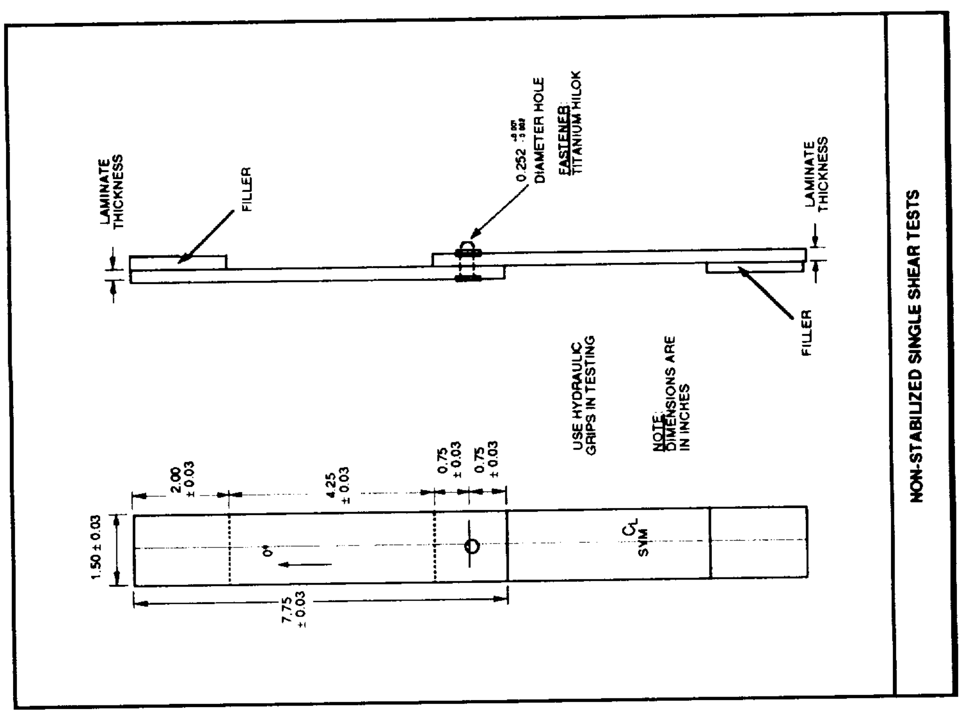


Figure 11.1b Baseline Dimensions for Unstabilized Single-Shear Specimen.

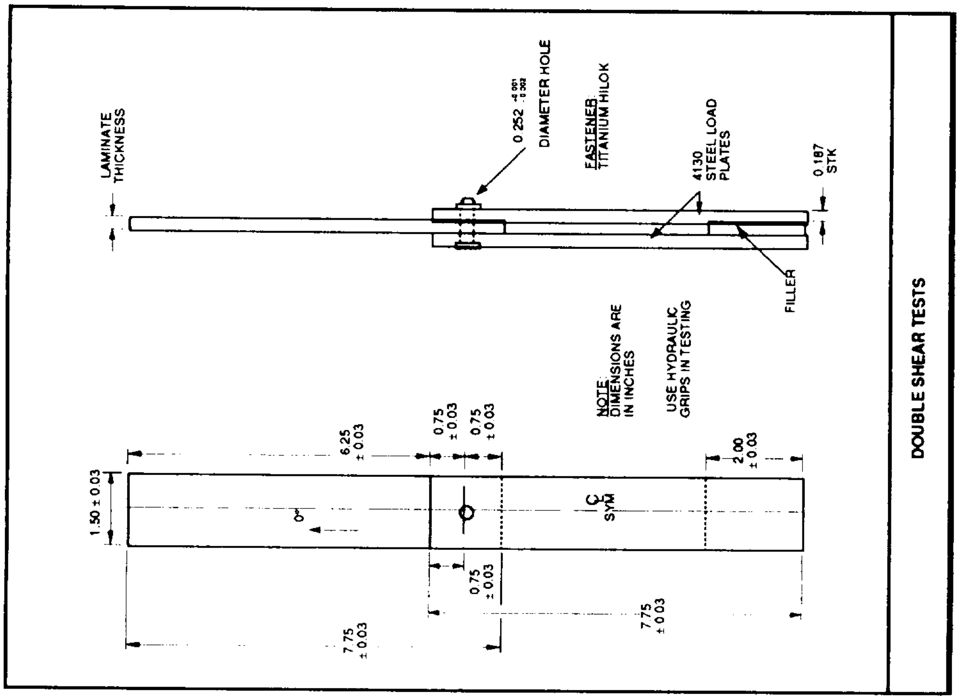


Figure 11.1c Baseline Dimensions for Double-Shear Specimen.

11.2 2-D Braids

When examining load versus stroke test results, non-linearity due to damage developing around the hole is usually seen prior to final failure. Two load levels are therefore identified: limit load, which is defined as the load corresponding to a permanent hole elongation equal to 2% of the hole diameter, and ultimate load which is simply the maximum load reached during the test. However, for most bearing tests, the ratio of ultimate to limit load is typically less than the safety factor used for design (typically 1.5), thus making the ultimate condition more critical. Therefore, in most of this discussion, ultimate strength will be considered.

Tables 11.2 to 11.4 summarize the ultimate strength and coefficient of variation results of the various configurations. Strength was calculated as the ratio of load divided by nominal thickness and hole diameter. In general, all the data exhibited moderate scatter, with an average CoV of 5.2% for LLS, 2.6% for SLL in the single shear tests, and an average CoV of 4.9% for LLS and 3.1% for SLL in the double shear tests.

The influence of the specimen dimensions is examined first by looking at the results for the SLL and LLS materials. The first test considered involves the stabilized single shear specimen. As shown in Figure 11.2, W/D appears to have little or no effect on strength. On the other hand, the edge distance (e/D) has a definite effect on the results.

In all cases, a ratio of e/D=2 leads to much lower strength. For the SLL architecture, little or no difference is seen between e/D=3 and e/D=4. For the LLS architecture, a slight increase is seen when going from e/D=3 to e/D=4, possibly due to the fact that the unit cell size of this material is about 2.5 times larger than for SLL. The very same conclusion is drawn for the unstabilized single shear test shown in Figure 11.3.

A different behavior is seen for the double shear bearing test as shown in Figure 11.4. For both SLL and LLS, ultimate strength continually increases with increasing e/D. Limit strength is seen to be much less dependent on e/D. This is due to the fact that local bearing failure occurs first, followed by a progressive shearing out of the fastener. In specimens with larger edge distance, failed material tends to accumulate between the loading plates, delaying the final shear-out failure and increasing strength.

Finally, the results of all test configurations with W/D=6 and e/D=3 are compared in Figure 11.5. The lowest bearing strength is obtained for the pinned double shear specimen for which no load is transferred through friction. At the opposite end, the double shear bearing strength is the highest. However, this type of bolted joint configuration is not the most likely in typical structures. The stabilized single shear specimen is usually considered to be more representative and gives slightly higher results than the unstabilized configuration. Using the stabilized single shear as a baseline, the pinned double shear is 18% lower for SLL and 2% lower for LLS; the unstabilized single shear is 10% lower for SLL and 7% lower for LLS; and the double shear is 42% higher for SLL and 48% higher for LLS. The difference between SLL and LLL is about 9% for stabilized single shear due to the increased tow size.

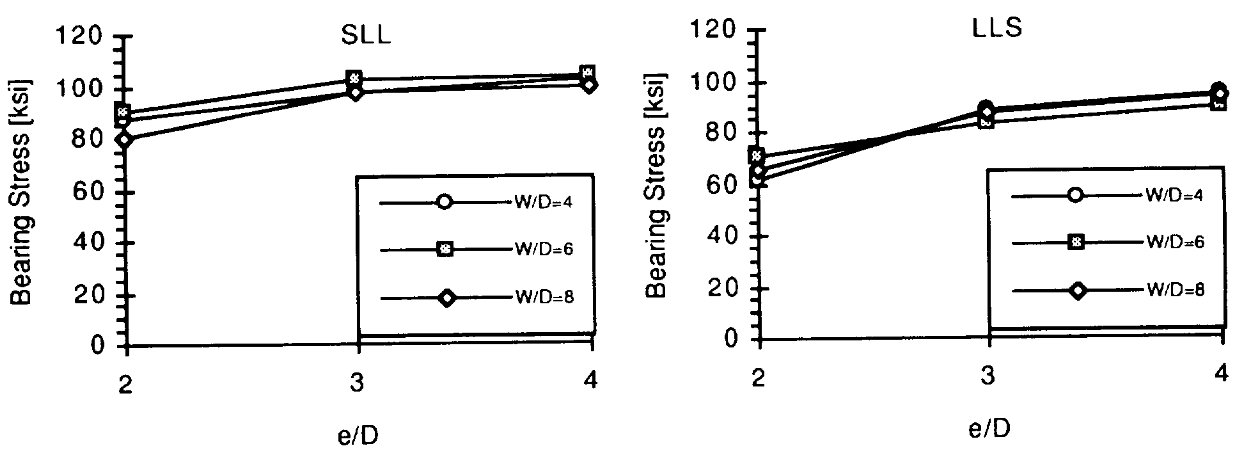
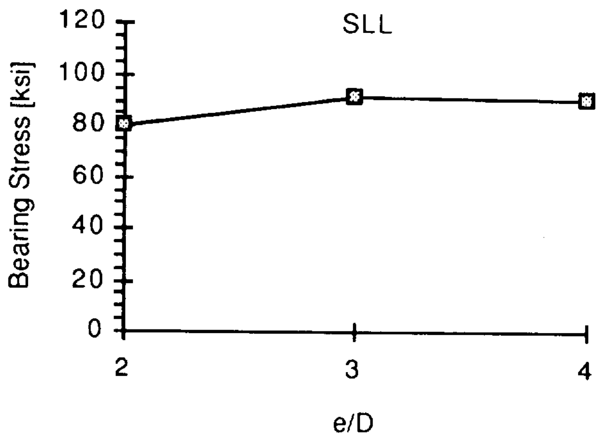


Figure 11.2 Effect of W/D and e/D on Stabilized Single Shear Bearing Ultimate Strength of 2-D Braided Materials SLL and LLS.



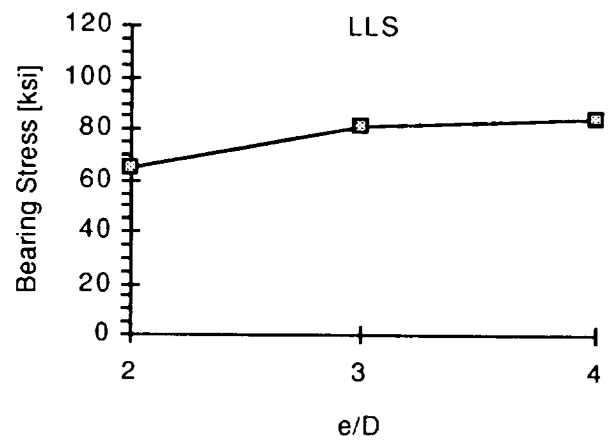


Figure 11.3 Effect of e/D on Unstabilized Single Shear Bearing Ultimate Strength of 2-D Braided Materials SLL and LLS.

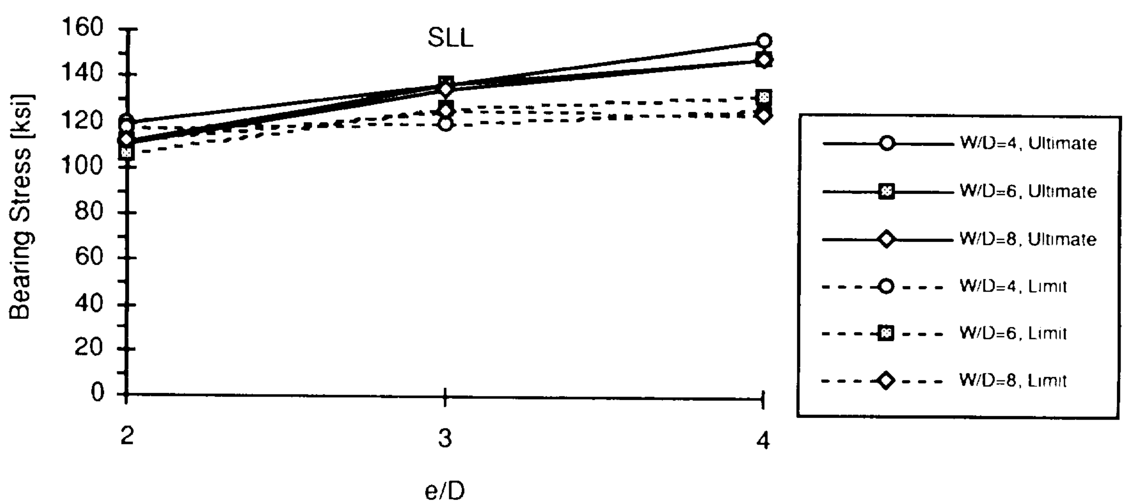


Figure 11.4.a Effect of W/D and e/D on Double Shear Bearing Ultimate Strength of 2-D Braided Materials SLL.

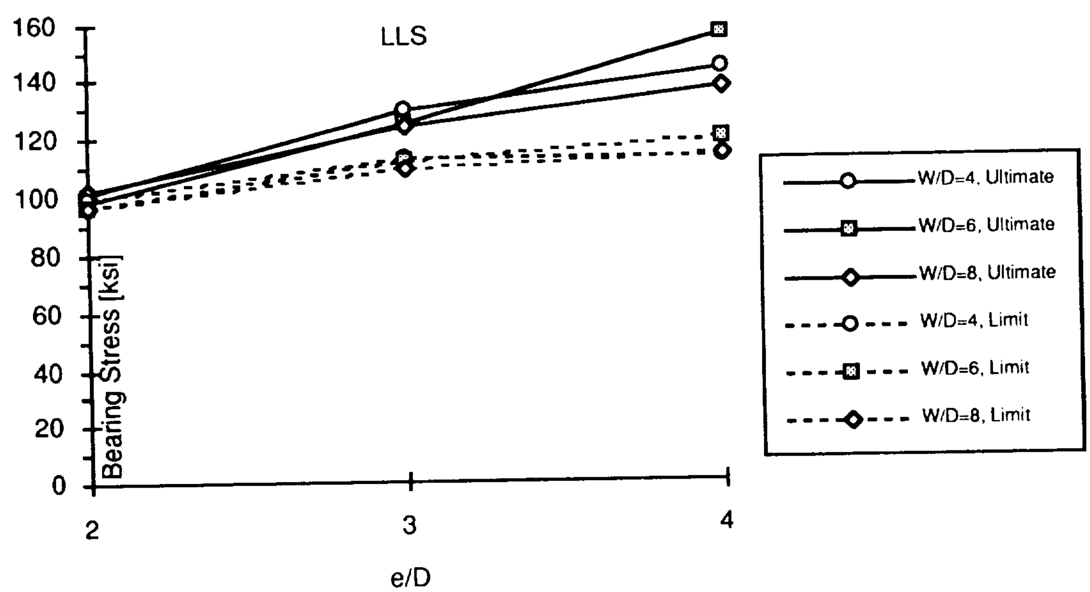


Figure 11.4.b Effect of W/D and e/D on Double Shear Bearing Ultimate Strength of 2-D Braided Materials LLS.

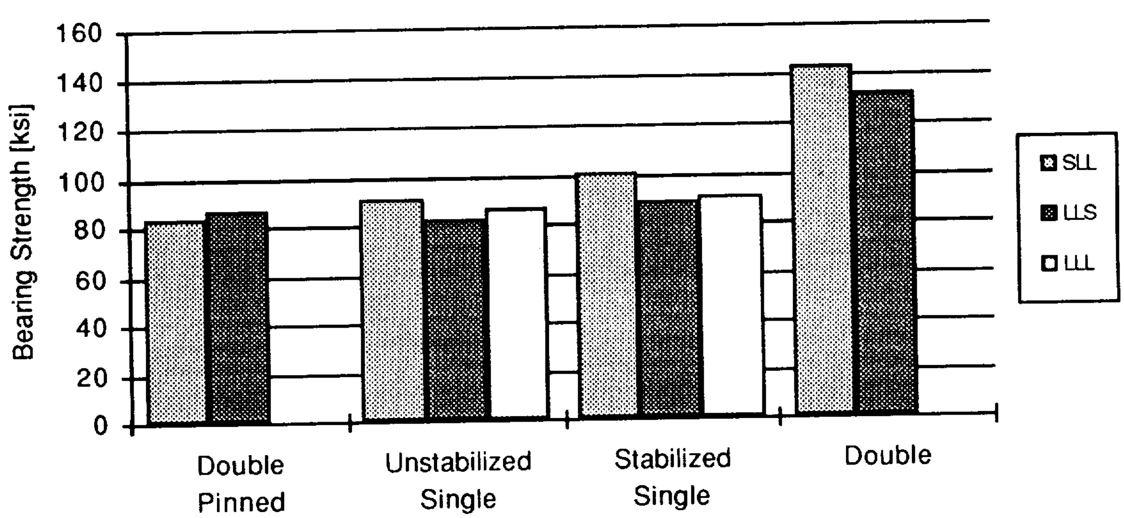


Figure 11.5 Comparison of all Bearing Tests with W/D=6 and e/D=3 for 2-D Braided Materials.

Table 11.2 Stabilized Single Shear Bearing Ultimate Strength Results for 2-D Braids

		SLL		LLS		LLL	
W/D	e/D	Strength [ksi]	CoV [%]	Strength [ksi]	CoV [%]	Strength [ksi]	CoV [%]
4	2	87.5	0.5	61.7	10.6		
4	3	98.3	3.8	88.8	3.2		
4	4	102.4	1.1	94.7	1.8		
6	2	90.6	4.6	70.9	5.4		
6	3	103.1	1.0	83.6	13.0	91.0	2.4
6	4	103.4	3.1	89.0	2.9		
8	2	80.2	5.6	65.8	6.4		
8	3	98.0	1.7	87.5	0.3		
8	4	100.2	2.2	93.6	3.3		

Table 11.3 Unstabilized Single Shear Bearing Ultimate Strength Results for 2-D Braids

		SLL		LLS		LLL	
W/D	e/D	Strength [ksi]	CoV [%]	Strength [ksi]	CoV [%]	Strength [ksi]	CoV [%]
6	2	80.0	2.9	64.6	3.2		
6	3	91.7	5.6	80.8	3.1	87.3	12.1
6	4	90.6	3.7	84.7	5.8		

Table 11.4 Double Shear Bearing Ultimate Strength Results for 2-D Braids

		SLL		LLS	
W/D	e/D	Strength [ksi]	CoV [%]	Strength [ksi]	CoV [%]
4	2	119.7	3.1	101.4	2.1
4	3	136.5	5.6	129.1	2.8
4	4	156.9	3.3	143.5	3.3
6	2	111.5	3.9	98.4	4.1
6	3	136.5	2.6	124.4	11.7
6	4	148.6	4.1	154.8	2.3
8	2	110.2	1.2	101.7	9.8
8	3	134.9	1.8	124.0	1.1
8	4	148.1	2.7	137.0	6.8
Pinned Fastener					
6	3	83.2	11.2	87.4	7.5
Over-torqued Fastener					
6	3	142.5	7.6		

12. Interlaminar Tension

The interlaminar tension strength of 2-D braided and 3-D woven specimens was determined using two specimen configuration, a C-shaped specimen and a L-shaped specimen.

12.1 Specimen Configurations

Both configurations rely on the same mechanism, the application of a bending moment around a curved geometry, to generate an out-of-plane tension loading in the specimen. The first configuration is a C-shaped specimen illustrated in Figure 12.1. As shown in the test matrix in Table 12.1, four combinations of width and midplane radius are used. The braids marked "-2" and "-3" are variations of the basic architectures used in the previous test programs. The characteristics of these architectures are shown in Table 2.1. The second configuration is a more common L-shaped flange bending specimen, shown in Figure 12.2. Only one size specimen was used to test both 2-D braided and 3-D woven materials. For both specimens, the attachment to the test machine included hinged joints arranged such that the bending moment in the specimen radius can be easily determined by multiplying the load by the offset from the load application line to the radius.

For both test results, moments were converted to interlaminar stress with the simplified formula based on beam theory (see for instance Reference 9):

$$\sigma_{zz} = \frac{3 \cdot M}{2 \cdot R \cdot t}$$

where M is the bending moment per unit width, R is the midplane radius and t the thickness.

A more exact solution for an homogeneous orthotropic solution is give in Reference 10. Using that analysis, the calculated value for the peak interlaminar stress would be 3.3% higher for the C1 configuration, 7.8% for the C2 one and 8.1% higher for the L specimen. However, given the highly inhomogeneous nature of the material tested, it is not very clear whether the more exact solution is actually more accurate.

Table 12.1 Interlaminar Tension Test Matrix

Config	Thick. [in]	Width [in]	Midplane Radius [in]	SLL	LLS	LLL	LLS-2	LLS-3	SLL-2	3-D Weaves
C1-1	0.13	1	0.255	3			3	3	3	
C1-2	0.13	2	0.255	3			3	3	3	
C2-1	0.17	1	0.305	3			3	3	3	
C2-2	0.17	2	0.305	3			3	3	3	
L	0.25	2	0.315	3	6	3	3	3	3	3

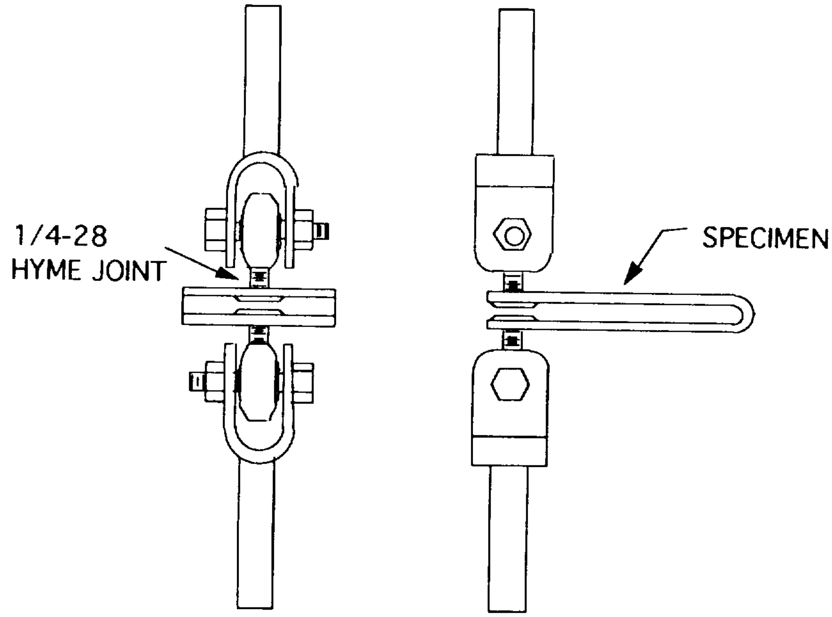


Figure 12.1 Interlaminar Tension C-Shape Specimen.

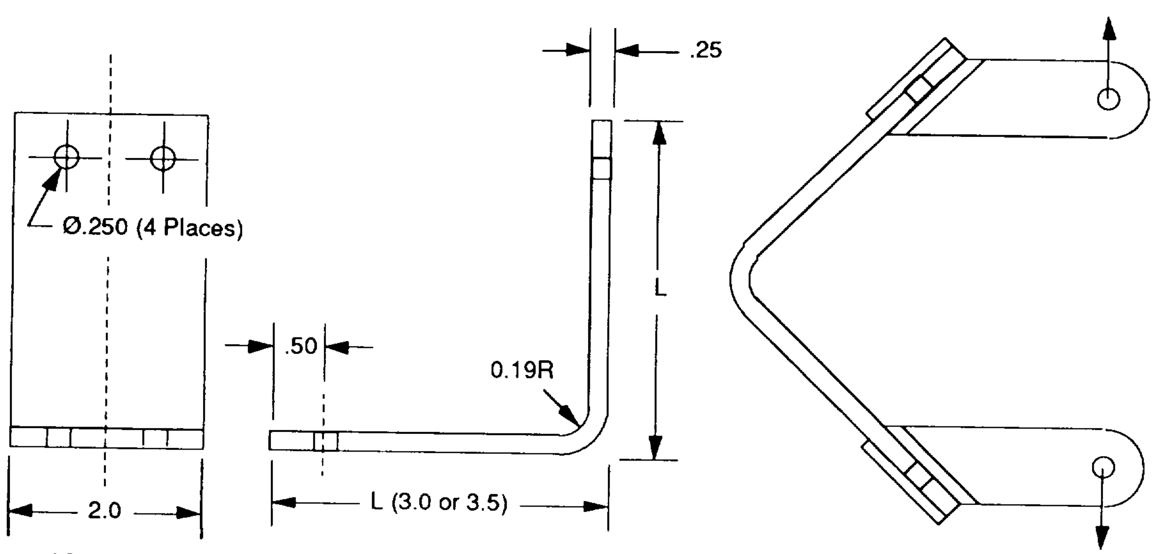


Figure 12.2 Interlaminar Tension L-Shape Specimen.

12.2 *2-D Braids Materials*

A summary of the average ultimate out-of- plane tension stress from the C-section out-of-plane tension test is shown in Figure 12.3 and Table 12.2. Coefficients of variation were large, up to 24%, although not uncommon for this type of testing. Failures were visible as interlaminar cracks in the radius, sometimes along many layer interfaces, although there was no consistent location of the failures through the thickness: some were nearer the inner radius, others nearer the outer radius. The waviness of the layer interfaces caused by the textile architectures was clearly visible along the crack length. Considering the scatter, there appears to be little influence on the results from the width of the specimens. The results from the 90° flange bend out-of-plane tension tests are shown in Figure 12.4 and Table 12.3. The 2-D braided specimens all failed as intended by out-of-plane tension in the radius, which was visible by interlaminar cracks in the radius, often along many layer interfaces.

The strength values obtained with the C-shape specimens ranged from 2.5 ksi to 4.3 ksi, while these obtained with the L-shape were higher, ranging from 3.6 ksi to 4.8 ksi. These values are similar to those measured in laminated specimens. As reported in Reference 9, where an AS4/3501-6 all unidirectional L-shape specimen was used, a definite relation was observed between interlaminar tension strength and specimen thickness, with the strength decreasing for increasing thicknesses. Reported values ranged from 11.8 ksi for a .077" thick specimen, to 2.5 ksi for 0.26" thick specimen. The main cause for that effect was attributed to the fact that the laminate quality in the radius area tends to degrade with increasing thickness due to the manufacturing process.

Table 12.2 Interlaminar Tension Strength Measured with C-Shape Specimen

Config.		SLL	LLS-2	LLS-3	SLL-2
C1-1	Strength [ksi]	3.2	2.9	3.0	3.2
	CoV [%]	15	11	17	16
C1-2	Strength [ksi]	2.5	2.7	3.0	2.8
	CoV [%]	5	10	9	11
C2-1	Strength [ksi]	3.4	4.0	2.5	4.3
	CoV [%]	18	7	6	13
C2-2	Strength [ksi]	3.1	3.7	2.7	3.8
	CoV [%]	1	24	8	8

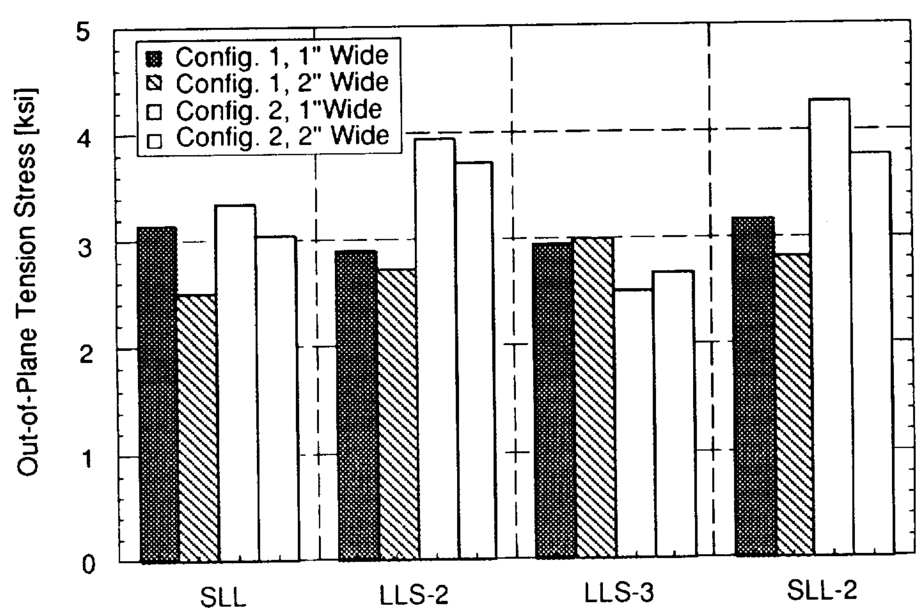


Figure 12.3 Interlaminar Tension Strength Measured with C-Shape Specimen.

Table 12.3 Interlaminar Tension Strength Measured with L-Shape Specimen

Config.		SLL	LLS	LLL	TS-1	TS-2	OS-1	OS-2	LS-1	LS-2
L	Strength [ksi]	4.8	4.2	3.6	2.2	3.0	3.5	2.9	2.7	2.2
	CoV [%]	17	12	5	5	9	5	6	16	4

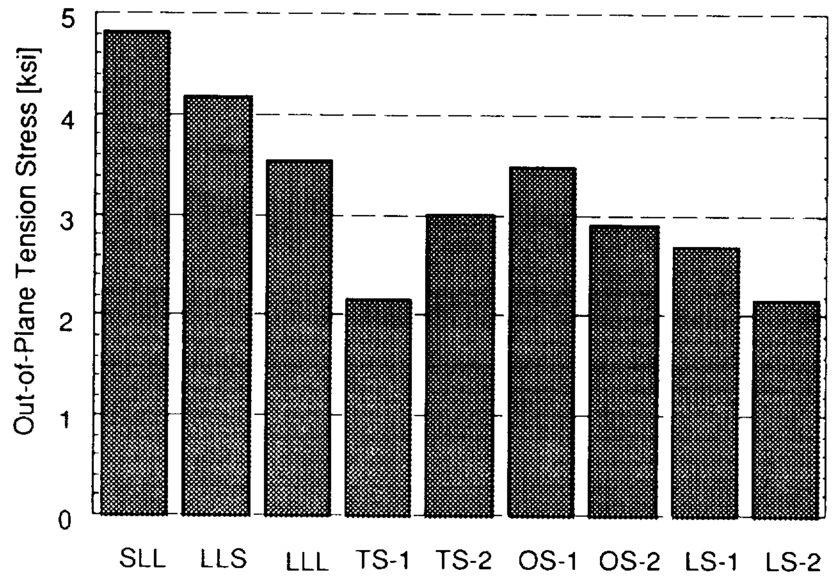


Figure 12.4 Interlaminar Tension Strength Measured with L-Shape Specimen.

12.3 *3-D Woven Materials*

The 3D angle interlock specimens failed by in-plane tension at the inner radius, with some evidence of out-of-plane tension or interlaminar shear failures as well. Some of these specimens also had compressive in-plane failures on the outer radius. Therefore, all the values shown in Figure 12.4 and Table 12.3 should be considered lower bounds to the actual strength.

13. Interlaminar Shear

The interlaminar shear strength of the 2-D braided material and 3-D woven material was determined using two specimen configurations, the Compression Interlaminar Shear (CIS) specimen and Short Beam Shear (SBS) specimen.

13.1 *Test Configurations*

Both specimen configurations are illustrated in Figure 13.1. Three specimens of each material system were tested as indicated in Table 13.1. All Compression Interlaminar Shear specimens were tested in a modified D695 compression fixture shown in Boeing specification BSS 7260 (see Appendix C). The load rate was 0.05 inch per minute. The shear stress was calculated assuming a uniform shear stress distribution:

$$\tau_{xz} = \frac{P}{d \cdot w}$$

where P is the ultimate load
w is the specimen width
d is the distance between notches

All Short Beam Shear testing was performed according to ASTM D2344. A small flexure fixture with 1/8" diameter support rods, 1/4" diameter loading rod and a 1.0: span was used. The load rate was also 0.05 inch per minute. The shear stress was calculated assuming a parabolic stress distribution through-the-thickness:

$$\tau_{xz} = \frac{0.75 \cdot P}{w \cdot t}$$

where P is the ultimate load
w is the specimen width
t is the thickness

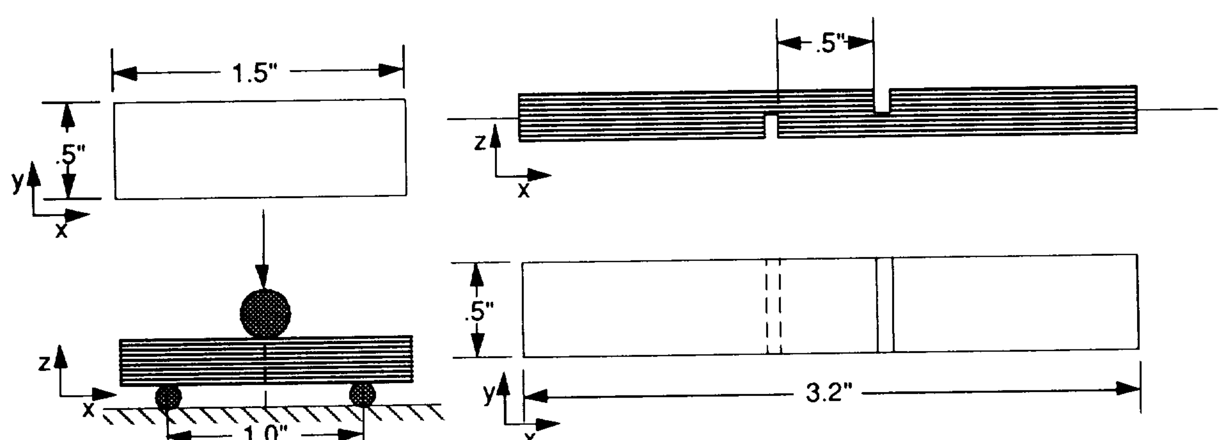


Figure 13.1 Short Beam Shear and Compression Interlaminar Shear Specimens.

Table 13.1 Interlaminar Shear Test Matrix

Config.	Width [in]	Length [in]	Thickness [in]	SLL	LLS	LLL	LSS	3-D Woven(1)
CIS	0.5	3.2	0.25	3	3	3	3	3
SBS	0.5	1.5	0.25	3	3	3	3	3

(1) Six configurations, OS-1, OS-2, LS-1, LS-2, TS-1, TS-2.

13.3 *2-D Braided Materials*

A summary of the average interlaminar shear stresses from the Short Beam Shear and Compression Interlaminar Shear tests is shown in Figure 13.2 and Table 13.2. The failures for the short beam shear specimens occured in the y-z plane at either the left or right support rod. The failures for the compression interlaminar shear specimens occured in the x-y plane between the notches. The shear failures were generally along a layer of fixed yarns (braid) or along a layer of warp yarns (weave), although occasionally the crack jumped between interfaces. Some specimens broke into two pieces showing the wavy failure surface due to the textile architecture.

The main conclusion from this set of tests is that the short beam shear test gave consistently higher interlaminar shear strengths than the compression interlaminar shear tests by about 20% on average. Coefficients of variation were lower as well. These values are somewhat low when compared to comparable laminated material systems where interlaminar shear strengths in the range of 12 ksi to 17 ksi are typical.

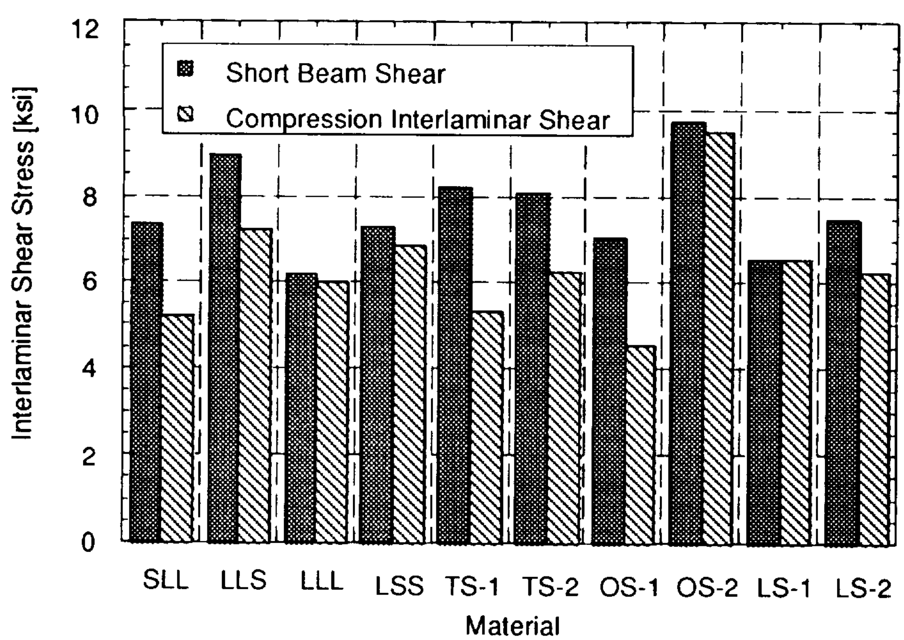


Figure 13.2 Interlaminar Shear Strength Measured with Short Beam Shear and Compression Interlaminar Shear Test Methods

Table 13.2 Interlaminar Shear Strength in 2-D Braided Materials

Config.		SLL	LLS	LLL	LSS
CIS	Strength [ksi]	5.2	7.2	6.0	6.9
	CoV [%]	12	10	5.3	10
SBS	Strength [ksi]	7.4	9.0	6.2	7.3
	CoV [%]	5.5	1.9	11	6.7

13.3 *3-D Woven Materials*

A summary of the average interlaminar shear stresses from the Short Beam Shear and Compression Interlaminar Shear tests is shown in Figure 13.2 and Table 13.3. The failures for the short beam shear specimens were like those of the braided materials except for the three OS-2 specimens, which failed in tension on the lower surface. Significant permanent deformation was visible after the loads were removed only for the OS-1 and OS-2 specimens. The failures for the compression interlaminar shear specimens were also like those of the braided materials between the notches except for one OS-2 specimen, which failed in compression at the two notched sections. A replacement from this group was tested which failed in shear.

Much as for the braided materials, the short beam shear test gave consistently higher interlaminar shear strengths than the compression interlaminar shear tests by about 27% on average. Also the OS-2 material appears to have a higher interlaminar shear strength than the other materials and different failure modes.

Table 13.3 Interlaminar Shear Strength in 3-D Woven Materials

Config.		TS-1	TS-2	OS-1	OS-2	LS-1	LS-2
CIS	Strength [ksi]	5.3	6.3	4.5	9.5	6.6	6.2
	CoV [%]	9.4	6.6	15	22	7.2	11
SBS	Strength [ksi]	8.2	8.1	7.0	9.7	6.6	7.5
	CoV [%]	5.0	1.8	1.2	4.9	9.2	8.4

14. Interlaminar Fracture Toughness

The mode I and mode II interlaminar fracture toughness of the braided materials are examined in this chapter. These were determined using the Double Cantilever Beam (DCB) and End Notch Flexure (ENF) test configurations.

14.1 Test Configurations

Four 2-D braided architectures were used in this test program. Three specimens of each kind were used as indicated in Table 14.1. The braids marked "-2" and "-3" are variations of the basic architectures used in the previous test programs. The characteristics of these architectures are shown in Table 2.1. All specimens were 0.5" wide and 0.25" thick. In all cases, the delamination was propagated along the 0° direction.

All Double Cantilever Beam specimens were tested according to Boeing specification BSS 7273 (see Appendix C). A bonded block hinge was used to load the specimen instead of the triangular grips specified in BSS 7273. The edge of the specimen was painted white to illustrate the progression of the crack more clearly. The crack was initially extended by 0.5 inch to move the crack tip away from the effects of the Kapton tape used to form the initial crack. A crack approximately one inch long was extended three times for each specimen. The load rate was 1 in per minute. The actual crack length was measured with calipers and the area under the load-displacement curve was calculated by the test software. Both the area and initiation methods were used to calculate the mode I fracture toughness G_{Ic}:

Area Method:

$$G_{Ic} = \frac{E}{A.W} \; (\text{in.lb} / \text{in}^2)$$

Initiation Method:

$$G_{Ic} = \frac{3 \cdot P \cdot Y}{2 \cdot W \cdot a} \; (\text{in.lb} / \text{in}^2)$$

where E is the area under the load-deflection curve
A is the increase in crack length
W is the specimen width
P is the peak load prior to crack extension
a is the crack length
Y is the deflection corresponding to P

All End Notch Flexure specimens were tested in a small test fixture with 1/4" diameter loading rods and 4" span. The load rate was 0.1 in per minute. The crack was initially extended in flexure by 0.5 inch to move the crack tip away from the Kapton tape used to form the initial crack. The crack was extended three times for each specimen. The compliance was calculated from the actual slope of the load-deflection curve between 33% and 66% of the ultimate load for each crack growth. The actual crack length was recorded for each crack but a nominal crack length of 1 inch was used in the calculation as specified. The values for G_{IIc} were calculated with the equation given in the specification:

$$G_{IIc} = \frac{9 \cdot a^2 \cdot P^2 \cdot C}{2 \cdot W \cdot \left(2 \cdot L^3 + 3 \cdot a^3\right)} \quad (\text{in.lb} / \text{in}^2)$$

where C is the compliance
L is half the length of the loading span
W is the specimen width
P is the peak load prior to crack extension
a is the crack length

Table 14.1 Interlaminar Toughness Test Matrix

	SLL	LLS-2	LLS-3	SLL-2
DCB	3	3	3	3
ENF	3	3	3	3

Note: Each specimen tested for 3 crack extensions

14.2 *2-D Braided Materials*

Results for the mode I fracture toughness tests are shown in Table 14.2 and Figure 14.1. The scatter in the results is extremely large, especially considering the fact that 15 repeats of each test were conducted. The average values themselves are extremely high compared to the typical values measured in laminated composite materials (by a factor of 3 to 5). The results from both the area and initiation method gave comparable results considering the scatter in the results. There appears to be some correlation between the bias fiber angle and the toughness: the two architectures with 70° bias angle gave much higher results than the ones with a 45° angle.

The probable cause for these high values is that the crack did not propagate in a resin-rich layer between plies as in a laminate. Although the 2-D braids are still formed by putting down successive layers of material, nesting of the different plies does occur. When looking at the edge of the specimen, the crack path was not straight but rather followed a "scalloped" pattern going around the tows. Also, when examining the surface of the delamination, it appears that failure did not progress between layers of material but inside a braided layer. Parts of the same bias tow were observed on both sides of the fracture surface, with a thin layer of the tow on one side and the majority of the tow on the other side. This also implies that some fiber breakage must occur where a bias tow on the surface of a braided ply enters the ply to pass underneath the other tows. That could significantly increase the energy necessary to separate the material, much as fiber bridging in tape laminates.

Results for the mode II fracture toughness tests are shown in Table 14.2 and Figure 14.2. As above, the scatter in the results is extremely large, especially considering the fact that 15 repeats of each test were conducted. The energy release rate values are also two or three times higher than for tape laminates with similar resin systems, much for the same reason as for the mode I results..

Table 14.2 Interlaminar Toughness Test Results

	SLL	LLS-2	LLS-3	SLL-2
Area Method				
G_{IC} [in-lb/in^2]	7.03	4.72	4.49	7.43
CoV [%]	33.2	38.1	17.7	33.7
Initiation Method				
G_{IC} [in-lb/in^2]	7.89	4.72	5.19	7.18
CoV [%]	40.5	20.8	20.8	13.2
G_{IIC} [in-lb/in^2]	13.1	13.4	11.6	14.4
CoV [%]	21	17	19	20

Note: Each specimen tested for 3 crack extensions

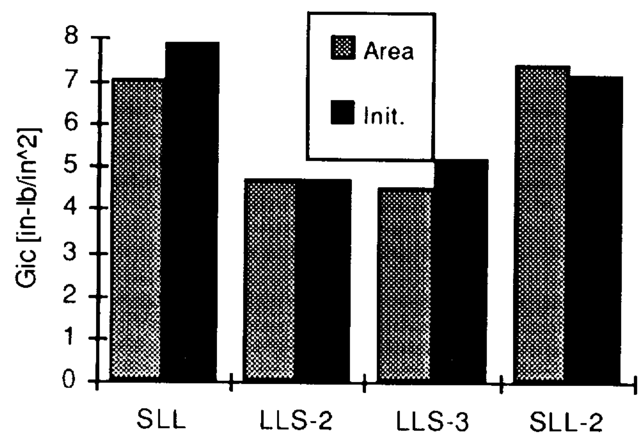


Figure 14.1 Mode I Fracture Toughness in 2-D Braided Materials.

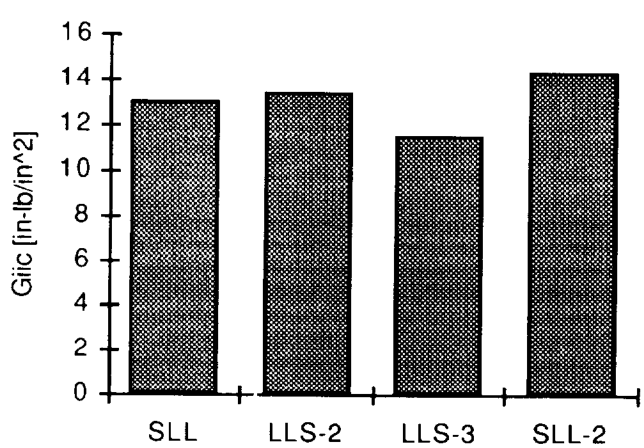


Figure 14.2 Mode II Fracture Toughness in 2-D Braided Materials.

15. Conclusions

Only the main conclusion from each test program is briefly summarized here. Because of the large variety of tests conducted, the reader should refer to each subsection for the conclusions relating to a specific material or test type.

Tension

The main issue in the tension test program was the effect on strength of the specimen size compared to the material unit cell dimensions. Little or no effect on strength was observed for the 2-D braids which have the largest unit cells of all material tested. Therefore, the standard specimen width of 1.5″ is recommended.

Open Hole Tension

The effect of specimen width to hole diameter ratio (W/D) was investigated. Results showed that the standard W/D=6 was adequate.

Compression

A comparison of the Boeing Open Hole Compression, Zabora Fixture, NASA Short Block, NASA 1142, Modified IITRI, sandwich column, Boeing Compression After Impact and NASA ST-4 specimens was conducted. The NASA Short Block specimen and Zabora fixture consistently produced the highest mean strength, but the Zabora fixture was evaluated only for a limited number of 2-D braids.

Open Hole Compression

A comparison of the Boeing Open Hole Compression, Zabora Fixture, NASA Short Block, NASA 1142 and Modified IITRI was conducted for hole diameters up to 0.375″. Results show that the Modified IITRI produced the highest mean strength, while the Boeing OHC produced the lowest. Both the Boeing Compression After Impact and NASA ST-4 gave good results for larger hole from 0.5″ to 1.25″.

In-plane Shear

A comparison of tube torsion, rail shear and compact shear specimens was conducted. Significant differences in both strength and modulus were obtained between these test methods. The compact shear specimen produced on average strength data 30% to 40% greater than the tube torsion, while the rail shear method experienced numerous bearing failures at the attachment holes.

Filled-Hole Tension

Testing was conducted only with the 2-D braided material and confirmed that, as for tape laminates, filled hole tension is the critical case when developing material design allowables for the Room Temperature/Dry environment. The standard W/D=6 specimen configuration appeared to be adequate for this type of testing.

Bolt Bearing

Testing was conducted only with the 2-D braided material. As for tape laminates, the stabilized single shear bearing test with W/D=6 and e/D=3 is recommended.

Interlaminar Tension

Testing for interlaminar tension was conducted with the 2-D braided material and 3-D woven materials using a C-shape and a L-shape specimens. Strength values from the L-shape configuration were slightly higher than those with the C-shape specimens, possibly due to the lesser fiber distortion in the L-shape specimen. The 3-D weaves did not fail actually in interlaminar tension but showed transverse cracks indicative of in-plane failure.

Interlaminar Shear

Testing for interlaminar shear was conducted with the 2-D braided material and 3-D woven materials using the Short Beam Shear (SBS) and Compression Interlaminar Shear (CIS) specimens. Strength values obtained from the SBS specimen were consistently higher than those from the CIS specimen.

Interlaminar Fracture Toughness

Testing for interlaminar fracture toughness was conducted only with the 2-D braided material using the Double Cantilever Beam and End Notched Flexure specimens. Results showed much higher toughness in this type material than in conventional laminated composites.

Observations on 2-D Braided Material

Unnotched tension and compression strength appear to be lower than expected in a conventional tape laminate. However, in the presence of holes, the 2-D braids appear to be less notch sensitive in tension. As seen from the comparison of the SLL and LLL architectures, the larger tow size reduces strength and stiffness, but on the other hand, the larger tow size can reduce the cost of manufacturing the preform. The transverse strength in 2-D braids seems to be relatively low in tension, compression and shear. Since only a limited amount of testing was conducted in that direction, this should be an area of further investigation.

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Appendix A Test Data

All the individual test data are included in this appendix as reported by Intec. Note that stresses in these spreadsheets are normalized by the actual specimen thickness. Most specimens are labeled using the following convention: BH2-A-BC-X, where:

A = Material Form	01	=	2-D Braid SLL
	02	=	2-D Braid LSS
	03	=	2-D Braid LLL
	04	=	2-D Braid LSS
	05	=	3-D Weave TS-1
	06	=	3-D Weave TS-2
	07	=	3-D Weave OS-1
	08	=	3-D Weave OS-2
	09	=	3-D Weave LS-1
	10	=	3-D Weave LS-2
	11	=	Stitched Uniweave SU-1
	12	=	Stitched Uniweave SU-2
	13	=	Stitched Uniweave SU-3
	14	=	Stitched Uniweave SU-4
	15	=	Stitched Uniweave SU-5
B = Task Number	1	=	Unidirectional Properties
	2	=	Strain Gage Study
	3	=	Tension Test Program
	4	=	Open Hole Tension Test Program
	5	=	Compression Test Program
	6	=	Open Hole Compression Test Program
	7	=	In-Plane Shear Test Program

C = Test Type and Configuration (A-Z)

X = Repetition Number

Tension Test Program

Project #: BH0002

Textile Test Method Development

Task 3

Tension Test Program

2-D Braided Architectures

Material AS4/Shell 1895

Intec Engineer Maryann Einarson

Boeing Engineer Mark Fedro

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions gage length (in)	Nominal Dimensions Width (in)	Nominal Dimensions Thick (in)	Avg Width (in)	Avg Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Exten Strain (με)	Ultimate Axial gage Strain (με)	Ultimate Trans Strain (με)	Axial Modulus Exten. (msi)	Axial Modulus Gage (msi)	Poisson's Ratio
BH2-01-3A-x	1	T7-SLL-B-3B	2-D	0.600	Baseline	7.0	2.00	1/8	2.0022	0.1058	8.6	22.53	106.36	na	12,451	-1,221	9.29	9.55	0.127
	2	T7-SLL-B-3B	SLL	0.600	Tension				1.9987	0.1074	10.4	21.62	100.73	9,998	10,258	-1,164	10.02	9.96	0.140
	3	T7-SLL-B-3B		0.600	1/8"				1.9997	0.1074	9.8	22.74	105.87	na	na	-901	9.62	9.99	0.138
						Average			2.0002	0.1069	9.6	22.30	104.32	9,998	11,355	-1,095	9.64	9.83	0.135
						Std. Dev.						0.60	3.12				0.36	0.25	0.007
						% COV						2.67	2.99				3.77	2.51	5.32
BH2-02-3A-x	1	T7-LLS-B-XA	2-D	0.599	Baseline	7.0	2.00	1/8	2.0000	0.1076	10.1	17.63	81.94	8,450	8,362	-5,524	9.39	10.28	0.639
	2	T7-LLS-B-XA	LLS	0.599	Tension				2.0002	0.1081	9.9	17.41	80.51	7,251	8,307	-5,367	10.39	10.28	0.630
	3	T7-LLS-B-XA		0.599	1/8"				1.9995	0.1097	12.8	20.76	94.62	na	na	-5,332	11.35	10.99	0.572
						Average			1.9999	0.1085	10.9	18.60	85.69	7,851	8,335	-5,408	10.38	10.52	0.614
						Std. Dev.						1.87	7.77				0.98	0.41	0.036
						% COV						10.1	9.1				9.4	3.9	5.9
BH2-03-3A-x	1	T7-LLL-B-3B	2-D	0.661	Baseline	7.0	2.00	1/8	2.0032	0.1108	5.2	20.29	91.39	11,458	na	-1,284	9.42	9.37	0.148
	2	T7-LLL-B-3B	LLL	0.661	Tension				2.0025	0.1088	5.6	21.13	96.95	11,192	na	-1,323	10.05	9.96	0.161
	3	T7-LLL-B-3B		0.661	1/8"				2.0027	0.1095	5.7	21.94	100.05	9,810	na	-1,050	9.56	9.96	0.174
						Average			2.0028	0.1097	5.5	21.12	96.13	10,820		-1,219	9.68	9.76	0.161
						Std. Dev.						0.83	4.39				0.33	0.34	0.013
						% COV						3.9	4.6				3.4	3.5	7.9
BH2-04-3A-x	1	T7-LSS-B-3B	2-D	0.629	Baseline	7.0	2.00	1/8	2.0030	0.1073	6.4	10.83	50.37	11,993	12,552	-9,643	4.78	4.71	0.696
	2	T7-LSS-B-3B	LSS	0.629	Tension				2.0010	0.1067	7.1	10.78	50.51	11,934	11,770	-8,635	4.79	4.89	0.676
	3	T7-LSS-B-3B		0.629	1/8"				2.0055	0.1053	8.1	12.20	57.75	13,092	12,703	-10,847	5.06	5.32	0.766
						Average			2.0032	0.1064	7.2	11.27	52.88	12,340	12,342	-9,708	4.88	4.97	0.713
						Std. Dev.						0.81	4.22				0.16	0.32	0.047
						% COV						7.1	8.0				3.2	6.3	6.6
BH2-01-3B-x	1	T7-SLL-B-3A	2-D	0.647	Width	3.50	1.00	1/8	1.0023	0.1070	8.4	12.25	114.22	12,254	11,657	-1,409	10.14	10.22	0.148
	2	T7-SLL-B-3A	SLL	0.647	Effect				1.0030	0.1077	8.8	11.66	107.97	na	na	-1,510	9.38	9.50	0.181
	3	T7-SLL-B-3A		0.647	1/8"				1.0023	0.1077	7.8	11.74	108.79	15,514	na	-776	8.30	9.06	0.131
	4*	T7-SLL-B-3A		0.647					1.0023	0.1087	8.5	11.74	107.79	11,426	na	-1,052	9.25	9.72	0.134
						Average			1.0026	0.1080	8.4	11.85	109.69	13,065	11,657	-1,187	9.27	9.62	0.149
						Std. Dev						0.27	3.05				0.76	0.48	0.023
						% COV						2.3	2.8				8.1	5.0	15.5
BH2-01-3C-x	1	T7-SLL-B-1A	2-D	0.635	Width	5.25	1.50	1/8	1.5012	0.1071	8.4	16.84	104.74	na	10,569	-1,668	10.78	10.74	0.191
	2	T7-SLL-B-1A	SLL	0.635	Effect				1.5005	0.1070	7.0	17.63	109.82	8,116	11,890	-1,395	9.79	9.51	0.137
	3	T7-SLL-B-1A		0.635	1/8"				1.5002	0.1070	7.2	18.85	117.49	10,776	12,188	-1,928	10.33	9.94	0.185
						Average			1.5006	0.1070	7.5	17.77	110.68	9,446	11,549	-1,664	10.30	10.06	0.171
						Std. Dev						1.01	6.42				0.50	0.63	0.029
						% COV						5.7	5.8				4.8	6.2	17.2

Project #: ᴅH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Material: AS4/Shell 1895

Textile Test Method Development

Task 3

Tension Test Program

2-D Braided Architectures

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions gage length (in)	Nominal Dimensions Width (in)	Nominal Dimensions Thick (in)	Avg Width (in)	Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Exten. Strain (με)	Ultimate Axial gage Strain (με)	Ultimate Trans Strain (με)	Axial Modulus Exten. (msi)	Axial Modulus Gage (msi)	Poisson's Ratio
BH2-01-3D-x	1	T7-SLL-B-3A	2-D	0.647	Width	8.75	2.50	1/8	2.5010	0.1071	12.1	30.06	112.22	12,744	11,587	-832	9.63	10.24	0.104
	2	T7-SLL-B-3A	SLL	0.647	Effect				2.5005	0.1063		30.81	115.88	9,590	11,615	-1,530	10.48	10.33	0.156
	3	T7-SLL-B-3A		0.647	1/8"				2.5012	0.1059		31.82	120.09	11,971	na	-1,470	9.97	10.02	0.144
							Average		2.5009	0.1065	12.1	30.90	116.07	11,435	11,601	-1,277	10.03	10.19	0.135
							Std. Dev.					0.88	3.94				0.43	0.16	0.027
							% COV					2.9	3.4				4.2	1.6	20.2
BH2-02-3B-x	1	T7-LLS-B-YA	2-D	0.589	Width	3.50	1.00	1/8	1.0020	0.1198	7.6	10.10	84.13	8,450	na	-6,857	10.23	9.93	0.720
	2	T7-LLS-B-YA	LLS	0.589	Effect				1.0000	0.1189	6.9	9.91	83.37	9,270	8,899	-6,364	9.59	9.98	0.625
	3	T7-LLS-B-YA		0.589	1/8"				1.0000	0.1166	6.4	9.68	83.00	na	na	na	9.45	9.66	0.600
	4*	T7-LLS-B-YA		0.589					1.0010	0.1154	7.5	10.09	87.35	6,358	na	-6,291	10.40	10.27	0.579
							Average		1.0008	0.1177	7.1	9.95	84.46	8,026	8,899	-6,504	9.92	9.96	0.631
							Std. Dev.					0.20	1.98				0.47	0.25	0.062
							% COV					2.0	2.3				4.7	2.5	9.9
BH2-02-3C-x	1	T7-LLS-B-4B	2-D	0.618	Width	5.25	1.50	1/8	1.5017	0.1083	10.8	17.15	105.42	9,508	11,027	-7,864	10.82	10.57	0.666
	2	T7-LLS-B-4B	LLS	0.618	Effect				1.5035	0.1107	10.9	16.76	100.73	9,425	10,126	-5,638	10.16	10.16	0.573
	3	T7-LLS-B-4B		0.618	1/8"				1.5012	0.1085	9.4	17.51	107.50	9,256	9,681	-6,359	11.83	11.38	0.612
							Average		1.5021	0.1092	10.4	17.14	104.55	9,396	10,278	-6,620	10.94	10.70	0.617
							Std. Dev.					0.38	3.47				0.84	0.62	0.047
							% COV					2.2	3.3				7.7	5.8	7.6
BH2-02-3D-x	1	T7-LLS-B-YA	2-D	0.589	Width	8.75	2.50	1/8	2.5014	0.1101	14.4	25.54	92.74	11,897	na	-5,197	9.60	10.43	0.570
	2	T7-LLS-B-YA	LLS	0.589	Effect				2.5025	0.1090	13.9	23.77	87.12	8,208	8,075	-3,413	9.97	10.81	0.561
	3	T7-LLS-B-YA		0.589	1/8"				2.5045	0.1105	11.8	26.01	93.98	na	8,292	-4,431	11.35	11.16	0.465
							Average		2.5028	0.1099	13.4	25.11	91.28	10,052	8,183	-4,347	10.31	10.80	0.532
							Std. Dev.					1.18	3.66				0.92	0.36	0.059
							% COV					4.7	4.0				9.0	3.4	11.0
BH2-03-3B-x	1	T7-LLL-B-2A	2-D	0.638	Width	3.50	1.00	1/8	0.9990	0.1073	7.1	9.18	85.61	11,421	9,711	-1,492	10.41	9.89	0.149
	2	T7-LLL-B-2A	LLL	0.638	Effect				0.9957	0.1058	8.2	10.24	97.22	17,267	na	na	10.00	10.12	0.192
	3	T7-LLL-B-2A		0.638	1/8"				1.0000	0.1078	7.9	11.09	102.91	9,050	na	na	10.09	9.63	0.116
	4*	T7-LLL-B-2A		0.638					0.9990	0.1058	2.1	10.89	103.08	7,970	na	-1,895	10.49	9.69	0.136
							Average		0.9979	0.1065	6.3	10.35	97.21	11,427	9,711	-1,693	10.25	9.83	0.148
							Std. Dev.					0.86	8.19				0.24	0.22	0.032
							% COV					8.3	8.4				2.3	2.2	21.7
BH2-03-3C-x	1	T7-LLL-B-2A	2-D	0.638	Width	5.25	1.50	1/8	1.5030	0.1132	3.2	14.24	83.68	na	na	-1,242	8.71	8.63	0.143
	2	T7-LLL-B-2A	LLL	0.638	Effect				1.5003	0.1121	2.6	14.26	84.84	na	na	na	9.19	9.25	0.153
	3	T7-LLL-B-2A		0.638	1/8"				1.4997	0.1088	2.6	15.53	95.15	na	10,944	-1,371	9.81	9.61	0.146
							Average		1.5010	0.1114	2.8	14.68	87.89		10,944	-1,307	9.24	9.16	0.147
							Std. Dev.					0.74	6.31				0.55	0.50	0.005
							% COV					5.0	7.2				5.9	5.4	3.4

Project #: dH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development

Task 3

Tension Test Program

2-D Braided Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions gage length (in)	Nominal Dimensions Width (in)	Nominal Dimensions Thick (in)	Avg Width (in)	Avg Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Exten Strain (με)	Ultimate Axial gage Strain (με)	Ultimate Trans Strain (με)	Axial Modulus Exten (msi)	Axial Modulus Gage (msi)	Poisson's Ratio
BH2-03-3D-x	1	T7-LLL-B-1B	2-D	0.606	Width	8.75	2.50	1/8	2.5030	0.1101	8.4	23.20	105.84	8,784	8,607	-1,111	10.28	10.17	0.162
	2	T7-LLL-B-1B	LLL	0.606	Effect				2.5030	0.1079	7.1	25.21	118.58	11,124	na	-1,667	9.87	9.93	0.199
	3	T7-LLL-B-1B		0.606	1/8"				2.5023	0.1073	7.0	23.03	106.62	9,677	na	-906	8.81	10.09	0.092
						Average			2.5028	0.1084	7.5	23.81	110.35	9,862	8,607	-1,228	9.65	10.07	0.151
						Std. Dev.						1.21	7.14				0.76	0.12	0.055
						% COV						5.1	6.5				7.8	1.2	36.1
BH2-04-3B-x	1	T7-LSS-B-4B	2-D	0.619	Width	3.50	1.00	1/8	1.0012	0.1094	3.5	5.42	49.48	11,472	11,001	-8,916	4.81	5.17	0.778
	2	T7-LSS-B-4B	LSS	0.619	Effect				0.9990	0.1109	3.2	6.19	55.84	13,307	12,459	-9,716	4.95	5.17	0.744
	3	T7-LSS-B-4B		0.619	1/8"				1.0000	0.1048	3.8	5.90	56.30	10,327	11,340	-9,185	6.39	5.42	0.710
						Average			0.9993	0.1067	3.5	5.83	53.87	11,702	11,600	-9,272	5.38	5.25	0.74
						Std. Dev.						0.39	3.81				0.87	0.14	0.03
						% COV						6.6	7.1				16.2	2.7	4.6
BH2-04-3C-x	1	T7-LSS-B-4A	2-D	0.645	Width	5.25	1.50	1/8	1.5000	0.1072	7.0	9.10	56.60	12,511	12,484	-10,000	5.41	5.22	0.758
	2	T7-LSS-B-4A	LSS	0.645	Effect				1.5020	0.1052	8.3	9.54	60.39	12,991	12,560	-11,556	5.30	5.43	0.815
	3	T7-LSS-B-4A		0.645	1/8"				1.5010	0.1048	7.3	8.92	56.70	12,749	12,347	-6,303	5.12	5.22	0.458
						Average			1.5010	0.1057	7.5	9.19	57.90	12,750	12,464	-9,286	5.28	5.29	0.677
						Std. Dev.						0.32	2.16				0.14	0.12	0.192
						% COV						3.5	3.7				2.7	2.3	28.3
BH2-04-3D-x	1	T7-LSS-B-4B	2-D	0.619	Width	8.75	2.50	1/8	2.5010	0.1035	8.6	14.50	56.00	12,822	11,792	-9,525	5.32	5.42	0.730
	2	T7-LSS-B-4B	LSS	0.619	Effect				2.5023	0.1042	7.7	14.10	54.09	17,088	12,587	-9,496	4.87	4.95	0.682
	3	T7-LSS-B-4B		0.619	1/8"				2.5043	0.1044		14.25	54.52	13,687	12,386	-9,507	4.76	5.07	0.701
						Average			2.5026	0.1040	8.2	14.28	54.87	14,532	12,255	-9,509	4.98	5.15	0.705
						Std. Dev.						0.20	1.00				0.30	0.24	0.024
						% COV						1.4	1.8				6.0	4.7	3.4
BH2-01-3E-x	1	T7-SLL-B-4B	2-D	0.611	Gage length	8.50	2.00	1/8	2.0047	0.1049	9.2	25.40	120.82	9,146	12,040	-2,016	10.70	10.78	0.193
	2	T7-SLL-B-4B	SLL	0.611	Effect				2.0027	0.1067	9.4	25.49	119.25	11,211	12,659	-1,419	9.75	9.95	0.184
	3	T7-SLL-B-4B		0.611	1/8"				2.0053	0.1084	11.0	26.11	120.13	na	12,446	-1,514	9.62	10.18	0.151
						Average			2.0042	0.1067	9.9	25.67	120.07	10,178	12,382	-1,650	10.02	10.30	0.176
						Std. Dev.						0.39	0.79				0.59	0.43	0.022
						% COV						1.5	0.7				5.9	4.2	12.5
BH2-01-3F-x	1	T7-SLL-B-4B	2-D	0.611	Gage length	5.50	2.00	1/8	2.0025	0.1042	8.9	25.50	122.25	9,013	na	-1,464	10.33	10.33	0.164
	2	T7-SLL-B-4B	SLL	0.611	Effect				2.0000	0.1042	9.2	24.17	116.02	15,843	12,758	-2,097	10.91	10.25	0.198
	3	T7-SLL-B-4B		0.611	1/8"				2.0010	0.1087	9.5	24.78	113.95	13,220	12,008	-1,440	9.57	9.86	0.148
						Average			2.0012	0.1057	9.2	24.82	117.40	12,692	12,383	-1,667	10.27	10.15	0.170
						Std. Dev.						0.67	4.32				0.67	0.25	0.026
						% COV						2.7	3.7				6.6	2.5	15.1
BH2-02-3E-x	1	T7-LLS-B-XB	2-D	0.608	Gage length	8.50	2.00	1/8	2.0040	0.1102	9.5	21.70	98.29	na	9,153	-6,619	11.68	11.22	0.680
	2	T7-LLS-B-XB	LLS	0.608	Effect				2.0020	0.1103	10.5	17.45	79.00	7,100	na	-6,716	9.60	9.61	0.759
	3	T7-LLS-B-XB		0.608	1/8"				2.0025	0.1120	12.5	21.25	94.75	9,261	na	-6,124	9.75	10.34	0.652
						Average			2.0028	0.1108	10.8	20.13	90.68	8,180	9,153	-6,486	10.35	10.39	0.697
						Std. Dev.						2.33	10.27				1.16	0.81	0.056
						% COV						11.6	11.3				11.2	7.8	8.0

Project #: BH0002

Textile Test Method Development

Task 3

Tension Test Program

2-D Braided Architectures

Material: AS4/Shell 1895

intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions: gage length (in)	Nominal Dimensions: Width (in)	Nominal Dimensions: Thick (in)	Avg Width (in)	Avg Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Exten Strain (με)	Ultimate Axial gage Strain (με)	Ultimate Trans Strain (με)	Axial Modulus Exten (msi)	Axial Modulus Gage (msi)	Poisson's Ratio
BH2-02-3F-x	1	T7-LLS-B-XB	2-D	0.608	Gage length	5.50	2.00	1/8	2.0033	0.1092	13.5	20.26	92.64	na	na	-5,847	11.53	10.75	0.627
	2	T7-LLS-B-XB	LLS	0.608	Effect				2.0022	0.1090	10.0	18.67	85.55	12,808	na	-5,311	9.89	10.00	0.507
	3	T7-LLS-B-XB		0.608	1/8"				2.0021	0.1092	12.7	22.17	101.44	11,586	na	-6,411	9.72	10.93	0.615
							Average		2.0025	0.1091	12.1	20.37	93.21	12,197		-5,856	10.38	10.56	0.583
							Std. Dev.					1.75	7.96				1.00	0.49	0.066
							% COV					8.6	8.5				9.6	4.7	11.3
BH2-01-3G-x	1	T7-SLL-B-4B	2-D	0.611	Dogbone		2.00	1/8	1.5785	0.1031	9.7	19.80	121.70	13,564	na	-1,172	10.10	10.31	0.110
	2	T7-SLL-B-4B	SLL	0.611	1/8"				1.5990	0.1022	9.7	21.38	130.79	14,063	na	-1,036	10.64	10.41	0.120
	3	T7-SLL-B-4B		0.611					1.5975	0.1043	10.5	19.83	119.07	13,184	na	-1,227	10.39	9.93	0.107
							Average		1.5917	0.1032	10.0	20.34	123.85	13,603		-1,145	10.37	10.22	0.113
							Std. Dev.					0.90	6.15				0.27	0.25	0.007
							% COV					4.4	5.0				2.6	2.5	5.9
BH2-02-3G-x	1	T7-LLS-B-XB	2-D	0.608	Dogbone		2.00	1/8	1.6025	0.1123	11.1	14.89	82.75	9,050	9,031	-4,671	10.33	9.89	0.519
	2	T7-LLS-B-XB	LLS	0.608	1/8"				1.6015	0.1110	9.4	16.82	94.63	9,517	10,159	-7,053	11.04	10.44	0.626
	3	T7-LLS-B-XB		0.608					1.5995	0.1091	8.8	14.90	85.37	8,281	n a	-4,868	10.73	10.34	0.580
							Average		1.6012	0.1108	9.8	15.54	87.59	8,949	9,595	-5,531	10.70	10.22	0.575
							Std. Dev.					1.11	6.24				0.35	0.29	0.053
							% COV					7.2	7.1				3.3	2.9	9.3
BH2-03-3G-x	1	T7-LLL-B-3B	2-D	0.661	Dogbone		2.00	1/8	1.5990	0.1084	6.8	13.10	75.58	8,629	8,784	-596	10.13	10.03	0.123
	2	T7-LLL-B-3B	LLL	0.661	1/8"				1.5995	0.1096	5.8	15.77	89.97	10,776	na	na	9.98	9.32	0.122
	3	T7-LLL-B-1B		0.661					1.5980	0.1074	6.5	17.04	99.26	17,152	na	-823	10.02	10.19	0.121
							Average		1.5988	0.1085	6.4	15.30	88.27	12,186	8,784	-709	10.04	9.85	0.122
							Std. Dev.					2.01	11.93				0.08	0.46	0.001
							% COV					13.1	13.5				0.8	4.7	0.9
BH2-04-3G-x	1	T7-LSS-B-3B	2-D	0.641	Dogbone		2.00	1/8	1.6015	0.1105	9.0	10.11	57.13	13,472	13,777	-9,884	5.09	4.93	0.657
	2	T7-LSS-B-3B	LSS	0.641	1/8"				1.6045	0.1085	9.1	9.93	57.05	13,261	13,389	-10,422	5.06	4.93	0.705
	3	T7-LSS-B-3B		0.641					1.6040	0.1085	8.8	10.18	58.49	13,188	13,370	-10,636	5.23	5.09	0.715
							Average		1.6033	0.1092	9.0	10.07	57.56	13,307	13,512	-10,314	5.13	4.98	0.692
							Std. Dev.					0.13	0.81				0.09	0.09	0.031
							% COV					1.3	1.4				1.8	1.9	4.5
BH2-01-3H-x	1	T5-SLL-A-2	2-D	0.501	Net-Shape		1.50	1/8	1.5175	0.1096	7.0	20.48	123.20	13,275	12,856	-1,184	9.19	9.51	0.185
	2	T5-SLL-A-3	SLL	0.515	1/8"				1.5053	0.1100	6.5	19.77	119.47	12,900	na	-1,717	9.26	9.35	0.185
	3	T5-SLL-A-3		0.515					1.5015	0.1129	7.2	20.33	119.94	12,639	na	na	9.59	9.22	0.178
							Average		1.5081	0.1108	6.9	20.19	120.87	12,938	12,856	-1,451	9.35	9.36	0.183
							Std. Dev.					0.37	2.03				0.21	0.15	0.004
							% COV					1.8	1.7				2.3	1.6	2.1
BH2-02-3H-x	1	T5-LLS-A-4	2-D	0.549	Net-Shape		1.50	1/8	1.5038	0.1101	7.0	20.54	123.99	12,680	11,959	-7,930	9.54	9.88	0.611
	2	T5-LLS-A-11	LLS	0.515	1/8"				1.5073	0.1152	9.3	20.55	118.30	13,385	na	-8,452	9.18	9.48	0.672
	3	T5-LLS-A-11		0.515					1.5030	0.1188	9.4	20.90	117.07	13,152	na	-9,504	8.91	8.88	0.647
							Average		1.5047	0.1147	8.6	20.66	119.79	13,072	11,959	-8,629	9.21	9.41	0.643
							Std. Dev.					0.21	3.70				0.32	0.50	0.030
							% COV					1.0	3.1				3.5	5.3	4.7

Project #: BH0002

Textile Test Method Development

Task 3

Tension Test Program

2-D Braided Architectures

Material: AS4/Shell 1895

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions gage length (in)	Nominal Dimensions Width (in)	Nominal Dimensions Thick (in)	Avg Width (in)	Avg Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Exten Strain (με)	Ultimate Axial gage Strain (με)	Ultimate Trans Strain (με)	Axial Modulus Exten (msi)	Axial Modulus Gage (msi)	Poisson's Ratio
BH2-03-3H-x	1	T7-LLL-A-5	2-D	0.546	Net-Shape		1.50	1/8	1.5000	0.1106	2.3	13.81	83.27	na	na	na	8.34	9.57	0.124
	2	T7-LLL-A-6	LLL	0.578	1/8"				1.4958	0.1134	2.7	17.39	102.49	12,090	na	-212	8.32	8.68	0.093
	3	T7-LLL-A-6		0.578					1.4963	0.1154	3.0	15.72	91.01	10,817	na	-372	8.45	8.51	0.105
							Average		1.4974	0.1132	2.7	15.64	92.26	11,453	na	-292	8.37	8.92	0.108
							Std. Dev.					1.79	9.67				0.07	0.57	0.016
							% COV					11.4	10.5				0.8	6.4	14.6
BH2-04-3H-x	1	T7-LSS-A-8	2-D	0.542	Net-Shape		1.50	1/8	1.4997	0.1164	4.9	9.12	52.25	12,387	11,956	-7,173	4.78	4.80	0.571
	2	T7-LSS-A-9	LSS	0.526	1/8"				1.5000	0.1153	5.4	8.76	50.66	11,618	11,503	-8,517	4.83	4.88	0.702
	3	T7-LSS-A-9		0.526					1.5000	0.1138	6.8	8.76	51.31	12,804	na	-8,852	4.68	5.04	0.696
							Average		1.4999	0.1152	5.7	8.88	51.41	12,270	11,729	-8,180	4.76	4.91	0.656
							Std. Dev.					0.21	0.80				0.08	0.12	0.074
							% COV					2.4	1.6				1.7	2.5	11.2
BH2-01-3I-x	1	T7-SLL-C-1A	2-D	0.574	Baseline	7.0	2.00	1/4	1.9965	0.2092	19.1	47.13	112.87	11,494	11,690	-1,669	9.96	10.20	0.184
	2	T7-SLL-C-1A	SLL	0.574	Tension				2.0007	0.2104	18.8	43.83	104.11	10,789	11,312	-1,924	9.62	9.66	0.207
	3	T7-SLL-C-1A		0.574	1/4"				2.0002	0.2144	16.3	44.09	102.83	11,179	11,967	-1,606	9.01	9.21	0.172
							Average		1.9991	0.2113	18.1	45.02	106.60	11,154	11,656	-1,733	9.53	9.69	0.188
							Std. Dev.					1.83	5.46				0.48	0.50	0.018
							% COV					4.1	5.1				5.1	5.1	9.5
BH2-02-3I-x	1	T7-LLS-C-4B	2-D	0.582	Baseline	7.0	2.00	1/4	2.0020	0.2177	22.1	44.34	101.75	10,464	na	-6,504	11.04	10.67	0.626
	2	T7-LLS-C-4B	LLS	0.582	Tension				2.0008	0.2180	19.2	37.31	85.53	7,709	9,313	-5,052	10.44	9.62	0.543
	3	T7-LLS-C-4B		0.582	1/4"				2.0025	0.2175	20.3	43.34	99.49	9,457	9,666	-6,025	11.00	10.45	0.605
							Average		2.0018	0.2177	20.5	41.66	95.59	9,210	9,490	-5,860	10.83	10.25	0.591
							Std. Dev.					3.80	8.79				0.34	0.56	0.043
							% COV					9.1	9.2				3.1	5.4	7.3
BH2-03-3I-x	1	T7-LLL-C-1B	2-D	0.641	Baseline	7.0	2.00	1/4	2.0042	0.2217	9.5	32.56	73.29	8,066	8,105	-461	9.35	9.66	0.100
	2	T7-LLL-C-1B	LLL	0.641	Tension				2.0010	0.2232	8.0	40.01	89.60	11,549	10,394	-1,175	8.64	9.56	0.096
	3	T7-LLL-C-1B		0.641	1/4"				2.0030	0.2225	8.8	41.60	93.34	na	na	-1,157	8.90	8.91	0.097
							Average		2.0027	0.2224	8.8	38.06	85.41	9,808	9,250	-931	8.96	9.37	0.098
							Std. Dev.					4.83	10.66				0.36	0.41	0.002
							% COV					12.7	12.5				4.0	4.3	2.2
BH2-04-3I-x	1	T7-LSS-C-1B	2-D	0.642	Baseline	7.0	2.00	1/4	2.0027	0.2088	16.4	22.89	54.73	11,993	12,122	-10,622	5.19	5.30	0.830
	2	T7-LSS-C-1B	LSS	0.642	Tension				2.0025	0.2050	15.8	22.88	55.74	13,596	12,210	-10,464	4.87	5.25	0.780
	3	T7-LSS-C-1B		0.642	1/4"				2.0013	0.2025	13.8	21.33	52.63	11,897	11,880	-9,136	4.99	5.11	0.718
							Average		2.0022	0.2054	15.3	22.37	54.37	12,495	12,071	-10,074	5.02	5.22	0.776
							Std. Dev.					0.90	1.58				0.16	0.10	0.056
							% COV					4.0	2.9				3.2	1.9	7.3

Project #: BH0002

Textile Test Method Development

Task 3

Tension Test Program

2-D Braided Architectures

Material: AS4/Shell 1895

intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions gage length (in)	Nominal Dimensions Width (in)	Nominal Dimensions Thick (in)	Avg Width (in)	Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Exten. Strain (με)	Ultimate Axial gage Strain (με)	Ultimate Trans Strain (με)	Axial Modulus Exten. (msi)	Axial Modulus Gage (msi)	Poisson's Ratio
BH2-01-3J-x	1	T7-SLL-C-5B	2-D	0.599	Width	3.50	1.00	1/4	1.0022	0.2152	8.0	21.56	99.98	10,185	10,255	-2,000	9.75	9.85	0.220
	2	T7-SLL-C-5B	SLL	0.599	Effect				1.0012	0.2138	5.4	23.57	110.10	14,287	15,297	-2,418	9.34	9.46	0.209
	3	T7-SLL-C-5B		0.599	1/4"				1.0020	0.2133	12.2	24.40	114.16	16,301	13,168	-1,910	8.98	9.52	0.196
	4*	T7-SLL-C-5B		0.599					1.0005	0.2127	8.6	25.45	119.62	14,520	12,249	-1,474	9.98	10.17	0.139
	5*	T7-SLL-C-5B		0.599					1.0022	0.2123		23.33	109.64	11,220	na	-2,121	9.36	10.05	0.204
							Average		1.0016	0.2135	8.6	23.66	110.70	13,303	12,742	-1,984	9.48	9.81	0.194
							Std. Dev.					1.44	7.21				0.39	0.31	0.032
							% COV					6.1	6.5				4.1	3.2	16.5
BH2-01-3K-x	1	T7-SLL-C-4B	2-D	0.616	Width	5.25	1.50	1/4	1.4995	0.2150	17.0	35.78	111.01	9,361	na	-1,211	12.10	9.95	0.143
	2	T7-SLL-C-4B	SLL	0.616	Effect				1.4990	0.2156	14.9	34.97	108.22	12,520	na	-797	9.84	9.72	0.116
	3	T7-SLL-C-4B		0.616	1/4"				1.5000	0.2162	14.7	31.45	97.01	10,648	na	-1,095	10.02	9.10	0.136
							Average		1.4995	0.2156	15.5	34.07	105.41	10,843	na	-1,034	10.65	9.59	0.132
							Std. Dev.					2.30	7.41				1.25	0.44	0.014
							% COV					6.8	7.0				11.8	4.6	10.5
BH2-01-3L-x	1	T7-SLL-C-5B	2-D	0.599	Width	8.75	2.50	1/4	2.5002	0.2118	33.0	60.27	113.82	11,406	11,721	-2,135	9.71	10.29	0.212
	2	T7-SLL-C-5B	SLL	0.599	Effect				2.5013	0.2121	23.0	64.48	121.56	11,968	na	-2,001	10.04	10.53	0.206
	3	T7-SLL-C-5B		0.599	1/4"				2.5023	0.2122	36.0	61.20	115.26	15,408	na	-1,671	9.68	10.44	0.194
							Average		2.5013	0.2120	30.7	61.98	116.88	12,927	11,721	-1,936	9.81	10.42	0.204
							Std. Dev.					2.21	4.12				0.20	0.12	0.009
							% COV					3.6	3.5				2.1	1.2	4.5
BH2-02-3J-x	1	T7-LLS-C-4B	2-D	0.582	Width	3.50	1.00	1/4	1.0017	0.2200	4.9	17.21	78.09	7,901	na	-5,132	10.08	10.12	0.681
	2	T7-LLS-C-4B		0.582	Effect				1.0000	0.2208	5.9	17.51	79.28	8,789	7,987	-5,171	10.05	10.02	0.611
	3	T7-LLS-C-4B	LLS	0.582	1/4"				0.9997	0.2217	6.8	18.46	83.31	9,251	8,331	-5,761	9.79	10.45	0.679
							Average		1.0003	0.2219	5.9	17.73	80.23	8,647	8,159	-5,355	9.97	10.20	0.657
							Std. Dev.					0.65	2.74				0.16	0.22	0.040
							% COV					3.7	3.4				1.6	2.2	6.0
BH2-02-3K-x	1	T7-LLS-C-3A	2-D	0.624	Width	5.25	1.50	1/4	1.4990	0.2233	22.4	32.12	95.95	10,634	na	-5,502	10.10	9.74	0.538
	2	T7-LLS-C-3A	LLS	0.624	Effect				1.5010	0.2248	23.2	32.55	96.46	9,435	na	na	10.32	9.84	0.538
	3	T7-LLS-C-3A		0.624	1/4"				1.4995	0.2198	22.5	32.27	97.93	9,476	na	-6,102	10.51	10.15	0.564
							Average		1.4998	0.2226	22.7	32.31	96.78	9,848		-5,802	10.31	9.91	0.547
							Std. Dev.					0.22	1.03				0.21	0.21	0.015
							% COV					0.7	1.1				2.0	2.1	2.8
BH2-02-3L-x	1	T7-LLS-C-7B	2-D	0.605	Width	8.75	2.50	1/4	2.5023	0.2238	34.0	50.54	90.26	9,088	na	-6,086	9.93	10.39	0.640
	2	T7-LLS-C-7B	LLS	0.605	Effect				2.5028	0.2175	36.0	52.77	96.94	8,923	na	-5,748	10.55	11.08	0.623
	3	T7-LLS-C-7B		0.605	1/4"				2.5045	0.2141	28.0	50.09	93.40	9,082	na	-4,983	10.19	11.19	0.620
							Average		2.5032	0.2185	32.7	51.13	93.53	9,031		-5,606	10.23	10.88	0.627
							Std. Dev.					1.44	3.34				0.31	0.44	0.011
							% COV					2.8	3.6				3.1	4.0	1.7

Project #: BH0002

Textile Test Method Development

Task 3

Tension Test Program

2-D Braided Architectures

Material: AS4/Shell 1895

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions gage length (in)	Nominal Dimensions Width (in)	Nominal Dimensions Thick (in)	Avg Width (in)	Avg Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Exten. Strain (με)	Ultimate Axial gage Strain (με)	Ultimate Trans Strain (με)	Axial Modulus Exten. (msi)	Axial Modulus Gage (msi)	Poisson's Ratio
BH2-03-3J-x	1	T5-LLL-C-1B	2-D	0.632	Width	3.50	1.00	1/4	0.9989	0.2192	5.9	20.97	95.80	na	15,047	-1,021	9.62	10.00	0.122
	2	T5-LLL-C-1B	LLL	0.632	Effect				1.0000	0.2201	3.2	20.23	91.93	10,423	na	na	9.73	9.81	0.162
	3	T5-LLL-C-1B		0.632	1/4"				0.9995	0.2173	4.1	18.15	83.58	9,682	na	-959	9.33	10.39	0.181
							Average		0.9996	0.2196	4.4	19.79	90.44	10,052	15,047	-990	9.56	10.07	0.155
							Std. Dev.					1.46	6.25				0.21	0.29	0.030
							% COV					7.4	6.9				2.2	2.9	19.5
BH2-03-3K-x	1	T7-LLL-C-1B	2-D	0.641	Width	5.25	1.50	1/4	1.5010	0.2193	7.8	31.26	94.99	5,649	na	-1,127	9.45	9.68	0.125
	2	T7-LLL-C-1B	LLL	0.641	Effect				1.5007	0.2236	6.3	30.89	92.07	10,936	na	-776	8.80	8.69	0.132
	3	T7-LLL-C-1B		0.641	1/4"				1.5000	0.2184	6.8	31.54	96.29	11,220	11,690	-1,024	8.82	8.81	0.087
							Average		1.5006	0.2204	7.0	31.23	94.45	9,268	11,690	-976	9.02	9.06	0.115
							Std. Dev.					0.33	2.16				0.37	0.54	0.024
							% COV					1.0	2.3				4.1	6.0	21.3
BH2-03-3L-x	1	T5-LLL-C-1B	2-D	0.632	Width	8.75	2.50	1/4	2.5047	0.2111	26.0	51.62	97.64	12,611	na	-705	9.44	9.90	0.115
	2	T5-LLL-C-1B	LLL	0.632	Effect				2.5035	0.2133	22.0	53.38	99.98	10,864	na	-1,437	9.75	10.42	0.184
	3	T5-LLL-C-1B		0.632	1/4"				2.5005	0.2170	24.0	46.78	86.21	6,375	na	-499	9.40	10.42	0.156
							Average		2.5029	0.2138	24.0	50.59	94.61	9,950		-880	9.53	10.25	0.151
							Std. Dev.					3.42	7.37				0.19	0.30	0.034
							% COV					6.8	7.8				2.0	3.0	22.8
BH2-04-3J-x	1	T7-LSS-C-1A	2-D	0.622	Width	3.50	1.00	1/4	1.0003	0.2124	7.9	12.15	57.17	9,641	11,683	-12,670	5.22	5.61	0.979
	2	T7-LSS-C-1A	LSS	0.622	Effect				0.9990	0.2080	5.5	12.03	57.88	14,534	12,262	-11,852	5.19	5.38	0.875
	3	T7-LSS-C-1A		0.622	1/4"				1.0010	0.2056	7.7	11.72	56.96	4,454	11,678	-11,795	12.93	5.44	0.880
	4*	T7-LSS-C-1A		0.622	1/4"				0.9990	0.2043	5.6	11.15	54.63	12,277	11,676	-11,029	5.23	5.32	0.845
							Average		0.9998	0.2076	6.7	11.76	56.66	10,226	11,825	-11,837	5.21	5.44	0.895
							Std. Dev.					0.45	1.68				0.02	0.06	0.019
							% COV					3.8	2.5				0.4	2.3	6.5
BH2-04-3K-x	1	T7-LSS-C-1B	2-D	0.642	Width	5.25	1.50	1/4	1.5070	0.2018	8.8	16.72	54.97	12,666	12,602	-9,763	4.96	4.91	0.681
	2	T7-LSS-C-1B	LSS	0.642	Effect				1.5018	0.2032	8.4	16.99	55.68	13,197	12,712	-10,122	4.97	5.16	0.744
	3	T7-LSS-C-1B		0.642	1/4"				1.5032	0.2042	11.0	17.23	56.14	12,465	12,646	-9,835	5.20	5.06	0.694
	4*	T7-LSS-C-1B		0.642					1.5035	0.2068	8.3	17.71	56.95	13,623	12,643	-9,944	5.26	5.13	0.702
							Average		1.5039	0.2040	9.1	17.16	55.94	12,988	12,651	-9,916	5.10	5.07	0.705
							Std Dev.					0.42	0.83				0.15	0.11	0.027
							% COV					2.4	1.5				3.0	2.2	3.9
BH2-04-3L-x	1	T7-LSS-C-1A	2-D	0.622	Width	8.75	2.50	1/4	2.5023	0.2045	16.0	30.11	58.85	12,478	11,622	-7,500	5.41	5.73	0.825
	2	T7-LSS-C-1A	LSS	0.622	Effect				2.5040	0.2018	14.8	27.56	54.55	12,282	12,274	-10,254	5.20	5.11	0.759
	3	T7-LSS-C-1A		0.622	1/4"				2.5000	0.1991	13.6	26.07	52.38	14,200	12,147	-9,262	5.26	4.99	0.708
							Average		2.5021	0.2018	14.8	27.91	55.26	12,987	12,014	-9,005	5.29	5.27	0.764
							Std Dev.					2.04	3.29				0.11	0.40	0.059
							% COV					7.3	6.0				2.1	7.5	7.7

Project #: BH0002

Textile Test Method Development

Task 3

Tension Test Program

2-D Braided Architectures

intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Material: AS4/Shell 1895

intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions gage length (in)	Width (in)	Thick (in)	Avg Width (in)	Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Exten. Strain (με)	Ultimate Axial gage Strain (με)	Ultimate Trans Strain (με)	Axial Modulus Exten. (msi)	Axial Modulus Gage (msi)	Poisson's Ratio
BH2-01-3M-x	1	T5-SLL-C-1B	2-D	0.623	Gage length	8.50	2.00	1/4	2.0038	0.2037	34.0	36.90	90.42	9,058	8,723	-892	10.18	10.73	0.134
	2	T5-SLL-C-1B	SLL	0.623	Effect				2.0017	0.2060	34.0	46.82	113.55	31,022	11,924	-1,040	10.54	10.99	0.140
	3	T5-SLL-C-1B		0.623	1/4"				2.0020	0.2090	34.0	48.51	115.94	11,718	11,661	-1,278	10.44	10.66	0.146
							Average		2.0025	0.2062	34.0	44.08	106.63	17,266	10,769	-1,070	10.39	10.79	0.140
							Std. Dev.					6.27	14.10				0.19	0.18	0.006
							% COV					14.2	13.2				1.8	1.6	4.5
BH2-01-3N-x	1	T5-SLL-C-1B	2-D	0.623	Gage length	5.50	2.00	1/4	2.0005	0.2067		48.05	116.23	na	na	na	9.79	9.92	
	2	T5-SLL-C-1B	SLL	0.623	Effect				2.0015	0.2080		45.49	109.27	11,232	11,151	-1,084	10.41	10.65	0.150
	3	T5-SLL-C-1B		0.623	1/4"				1.9997	0.2133	21.0	47.72	111.86	16,154	na	-665	9.42	9.91	0.140
							Average		2.0006	0.2093	21.0	47.09	112.45	13,693	11,151	-874	9.87	10.16	0.145
							Std. Dev.					1.39	3.52				0.51	0.43	0.007
							% COV					3.0	3.1				5.1	4.2	5.1
BH2-02-3M-x	1	T7-LLS-C-4A	2-D	0.570	Gage length	8.50	2.00	1/4	2.0010	0.2266		40.96	90.27	10,126	9,562	-6,850	10.00	9.88	0.674
	2	T7-LLS-C-4A	LLS	0.570	Effect				1.9987	0.2204		40.31	91.52	9,572	na	-6,450	9.74	9.93	0.615
	3	T7-LLS-C-4A		0.570	1/4"				2.0000	0.2190		45.33	103.49	8,455	na	-6,563	10.77	10.66	0.641
							Average		1.9999	0.2220		42.20	95.09	9,384	9,562	-6,621	10.17	10.16	0.643
							Std. Dev.					2.73	7.30				0.53	0.44	0.030
							% COV					6.5	7.7				5.3	4.3	4.6
BH2-02-3N-x	1	T7-LLS-C-4A	2-D	0.570	Gage length	5.50	2.00	1/4	2.0000	0.2236		41.54	92.81	14,296	na	-6,013	9.71	9.57	0.634
	2	T7-LLS-C-4A	LLS	0.570	Effect				1.9997	0.2206		41.89	94.96	10,181	na	-6,119	9.96	10.26	0.615
	3	T7-LLS-C-4A		0.570	1/4"				2.0015	0.2203		43.98	99.74	8,858	9,426	-6,424	11.04	10.43	0.647
							Average		2.0004	0.2216		42.47	95.84	11,111	9,426	-6,185	10.24	10.08	0.632
							Std. Dev.					1.32	3.55				0.71	0.45	0.016
							% COV					3.1	3.7				6.9	4.5	2.5

Project #: BH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development

Task TT

Tension Test Program

2-D Braided Architectures

AS4/Shell 1895

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dim Length (in)	Nominal Dim Width (in)	Nominal Dim Thick (in)	Avg Width (in)	Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Axial Modulus Gage (msi)
BH2-01-3Q-X	1	T7-SLL-B-8B	2-D	0.615	Transverse	11.5	2.00	1/8	1.9972	0.1078	4.1	7.16	33.24	7.15
	2	T7-SLL-B-8B	SLL	0.615	Tension				1.9972	0.1068	3.5	8.24	38.65	7.32
	3	T7-SLL-B-8B		0.615	1/8"				1.9975	0.1063	4.8	7.74	36.46	8.05
							Average		1.9973	0.1069	4.1	7.71	36.12	7.51
							Std. Dev.					0.54	2.72	0.48
							% COV					7.04	7.54	6.38
BH2-02-3Q-x	1	T7-LLS-B-11A	2-D	0.538	Transvers	11.5	2.00	1/8	1.9972	0.1089	1.6	3.59	16.50	2.85
	2	T7-LLS-B-11A	LLS	0.538	Tension				1.9973	0.1059	1.6	3.35	15.84	2.65
	3	T7-LLS-B-11A		0.538	1/8"				1.9982	0.1070	1.7	3.22	15.06	2.62
							Average		1.9976	0.1072	1.6	3.39	15.80	2.71
							Std. Dev.					0.19	0.72	0.13
							% COV					5.52	4.56	4.67
BH2-03-3Q-x	1	T7-LLL-B-4A	2-D	0.602	Transverse	11.5	2.00	1/8	2.0035	0.1115		6.49	29.04	6.89
	2	T7-LLL-B-4A	LLL	0.602	Tension				2.0017	0.1140		7.16	31.39	6.97
	3	T7-LLL-B-4A		0.602	1/8"				2.0010	0.1141		7.50	32.86	6.92
							Average		2.0021	0.1132		7.05	31.10	6.93
							Std. Dev.					0.51	1.93	0.04
							% COV					7.29	6.20	0.58
BH2-04-3Q-x	1	T7-LSS-B-6A	2-D	0.623	Transverse	11.5	2.00	1/8	1.9962	0.1047	4.0	5.42	25.93	3.06
	2	T7-LSS-B-6A	LSS	0.623	Tension				1.9968	0.1000	4.1	5.27	26.38	3.26
	3	T7-LSS-B-6A		0.623	1/8"				1.9977	0.0993	3.9	5.78	29.12	3.33
							Average		1.9969	0.1013	4.0	5.49	27.14	3.21
							Std. Dev.					0.26	1.73	0.14
							% COV					4.78	6.36	4.26

Modulus calculations based on 0.1-0.3% axial strain

Project #: BH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development

Task 3 and 8

Tension Test Program

3-D Woven Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions gage length (in)	Width (in)	Thick (in)	Avg Width (in)	Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Exten. Strain ($\mu\varepsilon$)	Ultimate Axial gage Strain ($\mu\varepsilon$)	Ultimate Trans Strain ($\mu\varepsilon$)	Axial Modulus Exten. (msi)	Axial Modulus Gage (msi)	Poisson's Ratio
BH2-05-3A-x	1	T7-TS1-A-2B	3-D	0.643	Baseline	7.0	1.50	1/4	1.4998	0.2193	34.0	49.12	149.33	10,100	na	na	13.32	13.48	0.065
	2	T7-TS1-A-2B	TS-1	0.643	Tension				1.4983	0.2208	27.0	47.84	144.64	10,570	na	na	12.46	13.57	0.057
	3	T7-TS1-A-2B		0.643	1/8"				1.4992	0.2224	19.5	49.82	149.41	12,181	na	na	12.50	13.43	0.057
							Average		1.4991	0.2208	26.8	48.93	147.79	10,950			12.76	13.49	0.060
							Std. Dev.					1.00	2.73				0.49	0.07	0.00
							% COV					2.1	1.8				3.83	0.50	8.07
BH2-06-3A-x	1	T7-TS2-A-1B	3-D	0.610	Baseline	7.0	1.50	1/4	1.4993	0.2257		45.77	135.27	12,169	na	909	11.31	11.76	0.047
	2	T7-TS2-A-1B	TS-2	0.610	Tension				1.4997	0.2259	43.0	44.28	130.71	11,714	na	164	10.91	11.75	0.043
	3	T7-TS2-A-1B		0.610	1/8"				1.5003	0.2259	44.0	45.34	133.80	11,469	11,907	1,209	11.61	11.72	0.031
							Average		1.4998	0.2258	43.5	45.13	133.26	11,784	11,907	761	11.28	11.74	0.040
							Std. Dev.					0.77	2.33				0.35	0.02	0.01
							% COV					1.7	1.7				3.11	0.15	21.24
BH2-07-3A-x	1	T7-OS1-A-2B	3-D	0.614	Baseline	7.0	1.50	1/4	1.5020	0.2264	17.0	49.39	145.23	na	na	961	12.06	12.16	0.030
	2	T7-OS1-A-2B	OS-1	0.614	Tension				1.4985	0.2263	17.0	46.34	136.63	na	na	1,105	12.20	11.91	0.033
	3	T7-OS1-A-2B		0.614	1/8"				1.4973	0.2276	18.0	48.64	142.76	na	na	176	12.24	11.62	0.041
							Average		1.4993	0.2268	17.3	48.12	141.54			748	12.17	11.90	0.034
							Std. Dev.					1.59	4.43				0.10	0.27	0.01
							% COV					3.3	3.1				0.80	2.27	16.61
BH2-08-3A-x	1	T7-OS2-A-2A	3-D	0.578	Baseline	7.0	1.50	1/4	1.5002	0.2327		31.61	90.56	8,473	na	-132	10.47	11.38	0.049
	2	T7-OS2-A-2A	OS-2	0.578	Tension				1.4850	0.2325	22.0	31.97	92.60	10,522	na	-109	9.43	11.41	0.050
	3	T7-OS2-A-2A		0.578	1/8"				1.5008	0.2316	26.0	30.47	87.66	8,576	na	-79	10.55	11.52	0.040
							Average		1.4953	0.2323	24.0	31.35	90.27	9,190		-107	10.15	11.44	0.046
							Std. Dev.					0.78	2.48				0.62	0.08	0.01
							% COV					2.5	2.7				6.13	0.66	10.95
BH2-09-3A-x	1	T7-LS1-A-7A	3-D	0.656	Baseline	7.0	1.50	1/4	1.4983	0.2141	16.0	43.51	135.64	10,688	na	5,085	12.34	12.72	0.060
	2	T7-LS1-A-7A	LS-1	0.656	Tension				1.4983	0.2142	14.0	51.15	159.41	12,307	na	1,053	13.28	13.29	0.052
	3	T7-LS1-A-7A		0.656	1/8"				1.4993	0.2143	14.0	46.39	144.39	11,256	na	1,118	12.89	12.87	0.062
							Average		1.4987	0.2142	14.7	47.02	146.48	11,417		2,419	12.84	12.96	0.058
							Std. Dev.					3.86	12.02				0.47	0.29	0.01
							% COV					8.2	8.2				3.69	2.28	9.47
BH2-10-3A-x	1	T7-LS2-A-2B	3-D	0.610	Baseline	7.0	1.50	1/4	1.5027	0.2251		31.70	93.71	9,977	8,078	200	12.03	12.40	0.050
	2	T7-LS2-A-2B	LS-2	0.610	Tension				1.4983	0.2251	24.0	35.20	104.40	8,810	9,670	73	12.03	12.49	0.054
	3	T7-LS2-A-2B		0.610	1/8"				1.4988	0.2244	26.0	32.38	96.28	na	7,903	217	12.48	12.53	0.044
							Average				25.0	33.09	98.13	9,393	8,550	164	12.18	12.47	0.049
							Std. Dev.					1.86	5.58				0.26	0.07	0.01
							% COV					5.6	5.7				2.13	0.55	10.50

Project #: BH0002

intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development

Task 8

Tension Test Program

Stitched Uniweave Architectures

Material: AS4/Shell 1895

intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions gage length (in)	Nominal Dimensions Width (in)	Nominal Dimensions Thick (in)	Avg Width (in)	Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Exten Strain (με)	Ultimate Axial gage Strain (με)	Ultimate Trans Strain (με)	Axial Modulus Exten (msi)	Axial Modulus Gage (msi)	Poisson's Ratio
BH2-11-3A-x	1	T7-SUW-G3K8A-1	SU-1	0.670	Baseline	7.0	1.50	1/4	1.5003	0.2202	18.0	32.28	97.72	14,255	13,500	-3,755	7.59	7.84	0.307
	2	T7-SUW-G3K8A-1		0.670	Tension				1.4982	0.2203	13.0	32.44	98.31	13,767	13,710	-4,210	7.76	7.76	0.309
	3	T7-SUW-G3K8A-1		0.670	1/8"				1.5002	0.2204	13.0	30.75	93.01	12,599	12,880	-3,863	7.74	7.70	0.302
Average											14.7	31.82	96.35	13,540	13,364	-3,943	7.69	7.77	0.306
Std. Dev.												0.93	2.91				0.09	0.07	0.00
% COV												2.9	3.0				1.22	0.89	1.19
BH2-12-3A-x	1	T7-SUW-G6K8A-1	SU-2	0.652	Baseline	7.0	1.50	1/4	1.4998	0.2452	30.0	30.84	83.88	13,363	na	-3,834	6.99	7.04	0.304
	2	T7-SUW-G6K8A-1		0.652	Tension				1.4990	0.2446	28.0	30.13	82.18	13,000	na	-3,565	6.79	7.12	0.294
	3	T7-SUW-G6K8A-1		0.652	1/8"				1.4975	0.2421	28.0	29.56	81.53	12,303	na	-3,299	7.11	6.99	0.280
Average											28.7	30.18	82.53	12,889		-3,566	6.96	7.05	0.293
Std. Dev.												0.64	1.21				0.16	0.07	0.01
% COV												2.1	1.5				2.31	0.93	4.19
BH2-13-3A-x	1	T7-SUW-K6K8A-1	SU-3	0.692	Baseline	7.0	1.50	1/4	1.5053	0.2532	25.4	30.96	81.22	11,815	12,474	-3,963	7.21	6.96	0.329
	2	T7-SUW-K6K8A-1		0.692	Tension				1.5008	0.2524	26.9	31.47	83.10	13,152	12,178	-4,126	6.80	7.24	0.349
	3	T7-SUW-K6K8A-1		0.692	1/8"				1.4957	0.2515	22.5	30.39	80.77	13,028	12,451	-3,918	6.69	7.24	0.344
Average											24.9	30.94	81.70	12,665	12,368	-4,002	6.90	7.14	0.341
Std. Dev.												0.54	1.24				0.27	0.16	0.01
% COV												1.8	1.5				3.97	2.29	2.97
BH2-14-3A-x	1	T7-SUW-K6K4A-1	SU-4	0.621	Baseline	7.0	1.50	1/4	1.5035	0.2324	15.0	29.49	84.39	13,031	na	-3,934	7.06	7.32	0.298
	2	T7-SUW-K6K4A-1		0.621	Tension				1.4982	0.2317	19.0	29.03	83.65	na	na	-3,875	7.29	7.33	0.303
	3	T7-SUW-K6K4A-1		0.621	1/8"				1.4995	0.2317	18.0	30.64	88.21	12,870	na	-3,978	7.27	7.38	0.307
Average											17.3	29.72	85.42	12,950		-3,929	7.21	7.34	0.303
Std. Dev.												0.83	2.45				0.13	0.03	0.00
% COV												2.8	2.9				1.75	0.41	1.47
BH2-15-3A-x	1	T7-SUW-K12K8A-1	SU-5	0.650	Baseline	7.0	1.50	1/4	1.5042	0.2538	19.0	30.34	79.47	11,906	na	-3,576	7.17	7.27	0.298
	2	T7-SUW-K12K8A-1		0.650	Tension				1.4983	0.2531	14.0	30.49	80.39	12,122	na	-3,642	7.30	7.32	0.307
	3	T7-SUW-K12K8A-1		0.650	1/8"				1.4977	0.2526	21.0	25.86	68.36	10,170	10,405	-3,073	7.07	7.22	0.309
Average											18.0	28.90	76.07	11,399	10,405	-3,430	7.18	7.27	0.304
Std. Dev.												2.63	6.69				0.12	0.05	0.01
% COV												9.1	8.8				1.62	0.64	1.83

Open-Hole Tension Test Program

Project #: BH0002
intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro
No instrumentation

Textile Test Method Development

Task 4

Open Hole Tension Test Program

2-D Braided Architectures

Material: AS4/Shell 1895

intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions Thick. (in)	Width (in)	Diam (in)	W/D	D/t	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-01-4A-x	1	T7-SLL-B-1B	2-D	0.600	0.125	1.50	3/8	4	3.00	1.5028	0.1093	0.3725	6.9	12.68	77.17	102.60	hole	
	2	T7-SLL-B-1B	SLL	0.600						1.5018	0.1102	0.3725	8.6	12.79	77.30	102.80	hole	
	3	T7-SLL-B-1B		0.600						1.5027	0.1093	0.3725	9.9	14.11	85.88	114.19	hole	
							Avg.			1.5024	0.1096	0.3725	8.5	13.19	80.12	106.53		
							Std Dev						1.5	0.80	4.99	6.63		
							% COV						17.8	6.0	6.2	6.2		
BH2-01-4B-x	1	T7-SLL-B-1B	2-D	0.600	0.125	1.50	1/4	6	2.00	1.5015	0.1090	0.2485	7.5	13.95	85.24	102.14	hole	
	2	T7-SLL-B-1B	SLL	0.600						1.5015	0.1098	0.2490	6.6	14.12	85.62	102.64	hole	
	3	T7-SLL-B-2B		0.610						1.5000	0.1125	0.2485	8.6	15.70	93.04	111.51	hole	
							Avg.			1.5010	0.1104	0.2487	7.6	14.59	87.96	105.43		
							Std Dev						1.0	0.97	4.40	5.27		
							% COV						13.2	6.6	5.0	5.0		
BH2-01-4C-x	1	T7-SLL-B-1A	2-D	0.635	0.125	1.50	3/16	8	1.50	1.4997	0.1082	0.1875	8.5	15.49	95.49	109.14	hole	
	2	T7-SLL-B-1A	SLL	0.635						1.5023	0.1063	0.1880	7.0	16.64	104.16	119.06	hole	
	3	T7-SLL-B-1B		0.600						1.5032	0.1073	0.1880	8.2	16.00	99.17	113.35	hole	
							Avg.			1.5017	0.1073	0.1878	7.9	16.04	99.61	113.85		
							Std Dev						0.8	0.58	4.35	4.98		
							% COV						10.0	3.6	4.4	4.4		
BH2-02-4A-x	1	T7-LLS-B-3A	2-D	0.658	0.125	1.50	3/8	4	3.00	1.5040	0.1098	0.3730	8.3	12.60	76.28	101.43	hole	
	2	T7-LLS-B-3A	LLS	0.658						1.5027	0.1095	0.3730	6.0	11.11	67.52	89.82	hole	
	3	T7-LLS-B-3A		0.658						1.5020	0.1095	0.3730	8.0	12.92	78.56	104.51	hole	
							Avg.			1.5029	0.1096	0.3730	7.4	12.21	74.12	98.59		
							Std Dev						1.3	0.97	5.83	7.75		
							% COV						16.8	7.9	7.9	7.9		
BH2-02-4B-x	1	T7-LLS-B-3A	2-D	0.622	0.125	1.50	1/4	6	2.00	1.5013	0.1097	0.2490	8.0	12.73	77.32	92.69	hole	
	2	T7-LLS-B-3A	LLS	0.622						1.5010	0.1090	0.2485	7.4	11.19	68.39	81.96	hole	
	3	T7-LLS-B-4A		0.645						1.5002	0.1100	0.2480	8.1	12.31	74.60	89.37	hole	
							Avg.			1.5008	0.1096	0.2485	7.8	12.31	73.44	88.01		
							Std Dev						0.4	0.80	4.57	5.49		
							% COV						4.8	6.5	6.2	6.2		
BH2-02-4C-x	1	T7-LLS-B-3B	2-D	0.641	0.125	1.50	3/16	8	1.50	1.5025	0.1103	0.1885	8.8	13.97	84.27	96.36	hole	
	2	T7-LLS-B-4B	LLS	0.618						1.5017	0.1107	0.1880	10.0	15.20	91.46	104.55	hole	
	3	T7-LLS-B-3A		0.622						1.5020	0.1085	0.1875	9.8	15.09	92.60	105.80	hole	
							Avg.			1.5021	0.1098	0.1880	9.5	14.75	89.44	102.24		
							Std Dev						0.6	0.68	4.52	5.13		
							% COV						6.7	4.6	5.0	5.0		

Project #: **BH0002**
intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro
No instrumentation

Textile Test Method Development

Task 4

Open Hole Tension Test Program

2-D Braided Architectures

Material: AS4/Shell 1895

intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions Thick. (in)	Nominal Dimensions Width (in)	Nominal Dimensions Diam. (in)	W/D	D/t	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-01-4D-x	1	T7-SLL-B-2A	2-D	0.620	0.125	2.25	9/16	4	4.50	2.2505	0.1067	0.5625	6.6	18.05	75.19	100.25	hole	
	2	T7-SLL-B-2A	SLL	0.620						2.2505	0.1057	0.5625	7.0	17.12	71.99	95.98	hole	
	3	T7-SLL-B-2A		0.620						2.2505	0.1062	0.5625	6.8	16.71	69.94	93.24	hole	
							Avg.			2.2505	0.1062	0.5625	6.8	17.29	72.37	96.49		
							Std Dev						0.2	0.69	2.65	3.53		
							% COV						2.9	4.0	3.7	3.7		
BH2-01-4E-x	1	T7-SLL-B-1B	2-D	0.600	0.125	2.25	3/8	6	3.00	2.2507	0.1088	0.3735		20.76	84.75	101.62	hole	
	2	T7-SLL-B-1B	SLL	0.600						2.2520	0.1073	0.3730		21.07	87.17	104.47	hole	
	3	T7-SLL-B-2A		0.620						2.2517	0.1078	0.3730		22.70	93.49	112.05	hole	
							Avg			2.2514	0.1080	0.3732		21.51	88.47	106.05		
							Std Dev							1.04	4.51	5.39		
							% COV							4.8	5.1	5.1		
BH2-01-4F-x	1	T7-SLL-B-2A	2-D	0.620	0.125	2.25	9/32	8	2.25	2.2513	0.1113	0.2820	12.0	20.67	82.47	94.27	hole	
	2	T7-SLL-B-2A	SLL	0.620						2.2533	0.1088	0.2810	11.5	19.30	78.70	89.91	hole	
	3	T7-SLL-B-2A		0.620						2.2555	0.1085	0.2815	11.8	20.02	81.81	93.47	hole	
							Avg.			2.2534	0.1096	0.2815	11.8	20.00	80.99	92.55		
							Std Dev						0.3	0.69	2.01	2.32		
							% COV						2.1	3.4	2.5	2.5		
BH2-02-4D-x	1	T7-LLS-B-3B	2-D	0.641	0.125	2.25	9/16	4	4.50	2.2490	0.1040	0.5625	6.8	15.75	67.34	89.80	hole	pre-test fiber damage
	2	T7-LLS-B-3B	LLS	0.641						2.2503	0.1097	0.5625	5.8	16.06	65.08	86.76	hole	
	3	T7-LLS-B-3B		0.641						2.2500	0.1097	0.5625	5.7	14.88	60.30	80.41	hole	
							Avg.			2.2498	0.1078	0.5625	6.1	15.56	64.24	85.66		
							Std Dev						0.6	0.61	3.59	4.79		
							% COV						10.0	3.9	5.6	5.6		
BH2-02-4E-x	1	T7-LLS-B-3A	2-D	0.622	0.125	2.25	3/8	6	3.00	2.2505	0.1107	0.3725	14.0	17.83	71.59	85.79	hole	
	2	T7-LLS-B-3A	LLS	0.622						2.2518	0.1082	0.3725	13.0	17.87	73.37	87.91	hole	
	3	T7-LLS-B-3B		0.641						2.2515	0.1112	0.3725	12.0	17.88	71.44	85.60	hole	
							Avg.			2.2513	0.1100	0.3725	13.0	17.86	72.13	86.43		
							Std Dev						1.0	0.03	1.07	1.28		
							% COV						7.7	0.1	1.5	1.5		
BH2-02-4F-x	1	T7-LLS-B-3B	2-D	0.641	0.125	2.25	9/32	8	2.25	2.2522	0.1103	0.2815	12.8	20.03	80.61	92.12	hole	
	2	T7-LLS-B-3B	LLS	0.641						2.2550	0.1098	0.2820	14.5	20.08	81.07	92.66	hole	
	3	T7-LLS-B-3B		0.641						2.2522	0.1092	0.2815	14.5	20.34	82.73	94.55	hole	
							Avg.			2.2531	0.1098	0.2817	13.9	20.15	81.47	93.11		
							Std Dev						1.0	0.17	1.12	1.27		
							% COV						7.0	0.8	1.4	1.4		

Project #: BH0002
Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro
No instrumentation

Textile Test Method Development

Task 4

Open Hole Tension Test Program

2-D Braided Architectures

Material AS4/Shell 1895

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions Thick. (in)	Width (in)	Diam. (in)	W/D	D/t	Avg Width (in)	Avg Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-03-4D-x	1	T7-LLL-B-2B	2-D	0.607	0.125	2.25	9/16	4	4.50	2.2510	0.1168	0.5625	2.5	14.55	55.32	73.76	hole	some delamination
	2	T7-LLL-B-2B	LLL	0.607						2.2505	0.1172	0.5625	3.0	15.82	60.00	79.99	hole	some delamination
	3	T7-LLL-B-2B		0.607						2.2510	0.1095	0.5625	3.3	14.60	59.23	78.97	hole	some delamination
							Avg.			2.2508	0.1145	0.5625	2.9	14.99	58.18	77.57		
							Std Dev						0.4	0.72	2.51	3.34		
							% COV						13.8	4.8	4.3	4.3		
BH2-03-4E-x	1	T7-LLL-B-2B	2-D	0.607	0.125	2.25	3/8	6	3.00	2.2515	0.1092	0.3730		18.17	73.93	88.60	hole	Failed throughout
	2	T7-LLL-B-2B	LLL	0.607						2.2500	0.1147	0.3730		19.09	73.99	88.70	hole	specimen
	3	T7-LLL-B-2B		0.607						2.2518	0.1090	0.3725		18.66	76.02	91.09	hole	Very noisy prior to
							Avg.			2.2511	0.1109	0.3728		18.64	74.65	89.46		failure
							Std Dev							0.46	1.19	1.41		
							% COV							2.5	1.6	1.6		
BH2-03-4F-x	1	T7-LLL-B-2B	2-D	0.607	0.125	2.25	9/32	8	2.25	2.2537	0.1085	0.2810	6.2	19.24	78.68	89.89	hole	Matl weave ripped
	2	T7-LLL-B-2B	LLL	0.607						2.2527	0.1082	0.2815	5.8	21.52	88.32	100.93	hole	around hole
	3	T7-LLL-B-1A		0.644						2.2533	0.1078	0.2815	5.5	17.99	74.04	84.61	hole	
							Avg.			2.2532	0.1082	0.2813	5.8	19.58	80.35	91.81		
							Std Dev						0.4	1.79	7.28	8.33		
							% COV						6.0	9.1	9.1	9.1		
BH2-04-4D-x	1	T7-LSS-B-3A	2-D	0.658	0.125	2.25	9/16	4	4.50	2.2517	0.1087	0.5620	5.5	8.36	34.16	45.53	hole	failed diagonally
	2	T7-LSS-B-3A	LSS	0.658						2.2500	0.1073	0.5250	6.5	7.76	32.13	41.91	hole	failed diagonally
	3	T7-LSS-B-3A		0.658						2.2498	0.1055	0.5625	5.0	7.31	30.78	41.05	hole	failed diagonally
							Avg.			2.2505	0.1072	0.5498	5.7	7.81	32.36	42.83		
							Std Dev						0.8	0.53	1.70	2.38		
							% COV						13.5	6.8	5.3	5.5		
BH2-04-4E-x	1	T7-LSS-B-3A	2-D	0.658	0.125	2.25	3/8	6	3.00	2.2517	0.1053	0.3725	8.0	8.67	36.57	43.82	Hole	Failed diagonally
	2	T7-LSS-B-3A	LSS	0.658						2.2503	0.1097	0.3725	8.0	9.68	39.21	46.99	Hole	Failed diagonally
	3	T7-LSS-B-3A		0.658						2.2515	0.1052	0.3725	7.0	8.88	37.50	44.94	Hole	Failed diagonally
							Avg.			2.2512	0.1067	0.3725	7.7	9.08	37.76	45.25		
							Std Dev						0.6	0.53	1.34	1.61		
							% COV						7.5	5.8	3.5	3.6		
BH2-04-4F-x	1	T7-LSS-B-3A	2-D	0.658	0.125	2.25	9/32	8	2.25	2.2513	0.1042	0.2815	8.5	9.39	40.06	45.78	hole	Failed diagonally
	2	T7-LSS-B-3A	LSS	0.658						2.2518	0.1022	0.2810	7.8	9.54	41.47	47.38	hole	Failed diagonally
	3	T7-LSS-B-4A		0.645						2.2518	0.1085	0.2815	8.5	10.82	44.29	50.61	hole	Failed diagonally
							Avg.			2.2517	0.1049	0.2813	8.3	9.92	41.94	47.93		
							Std Dev						0.4	0.78	2.15	2.46		
							% COV						4.9	7.9	5.1	5.1		

Project #: **BH0002**
Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro
No instrumentation

Textile Test Method Development

Task 4

Open Hole Tension Test Program

2-D Braided Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions Thick. (in)	Width (in)	Diam. (in)	W/D	D/t	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-01-4G-x	1	T7-SLL-B-2A	2-D	0.620	0.125	3.00	3/4	4	6.00	3.0023	0.1106	0.7510		24.13	72.68	96.92	hole	
	2	T7-SLL-B-1B	SLL	0.600						3.0023	0.1035	0.7500		24.80	79.83	106.42	hole	
	3	T7-SLL-B-2B		0.610						3.0025	0.1056	0.7500		23.69	74.70	99.58	hole	
							Avg.			3.0024	0.1066	0.7503		24.21	75.74	100.97		
							Std Dev							0.56	3.69	4.90		
							% COV							2.3	4.9	4.9		
BH2-01-4H-x	1	T7-SLL-B-2B	2-D	0.610	0.125	3.00	1/2	6	4.00	3.0028	0.1057	0.5030	17.1	23.86	75.20	90.33	hole	
	2	T7-SLL-B-2B	SLL	0.610						3.0007	0.1067	0.5005	17.0	26.64	83.21	99.86	hole	
	3	T7-SLL-B-2B		0.610						3.0022	0.1083	0.4990	15.0	27.05	83.21	99.80	hole	
							Avg.			3.0019	0.1069	0.5008	16.4	25.85	80.54	96.66		
							Std Dev						1.2	1.74	4.62	5.49		
							% COV						7.2	6.7	5.7	5.7		
BH2-01-4I-x	1	T7-SLL-B-2B	2-D	0.610	0.125	3.00	3/8	8	3.00	3.0027	0.1070	0.3730	11.0	29.46	91.69	104.70	hole	
	2	T7-SLL-B-2B	SLL	0.610						3.0008	0.1060	0.3730	15.0	28.69	90.20	103.00	hole	
	3	T7-SLL-B-1B		0.610						3.0035	0.1055	0.3725	17.0	26.07	82.27	93.92	hole	
							Avg.			3.0023	0.1062	0.3728	14.3	28.07	88.05	100.54		
							Std Dev						3.1	1.78	5.06	5.79		
							% COV						21.3	6.3	5.7	5.8		
BH2-02-4G-x	1	T7-LLS-B-3B	2-D	0.641	0.125	3.00	3/4	4	6.00	3.0028	0.1056	0.7510		20.18	63.63	84.85	hole	
	2	T7-LLS-B-3A	LLS	0.622						3.0040	0.1098	0.7500		18.75	56.85	75.77	hole	
	3	T7-LLS-B-4A		0.564						3.0025	0.1072	0.7505		19.80	61.54	82.04	hole	
							Avg.			3.0031	0.1075	0.7505		19.58	60.67	80.89		
							Std Dev							0.74	3.47	4.65		
							% COV							3.8	5.7	5.7		
BH2-02-4H-x	1	T7-LLS-B-4A	2-D	0.564	0.125	3.00	1/2	6	4.00	3.0040	0.1047	0.5000	18.7	24.12	76.66	91.97	hole	
	2	T7-LLS-B-4A	LLS	0.564						3.0040	0.1078	0.5005	20.4	26.53	81.94	98.32	hole	
	3	T7-LLS-B-4A		0.564						3.0020	0.1077	0.5010	16.4	25.43	78.67	94.42	hole	
							Avg.			3.0033	0.1067	0.5005	18.5	25.36	79.09	94.91		
							Std Dev						2.0	1.21	2.66	3.20		
							% COV						10.9	4.8	3.4	3.4		
BH2-02-4I-x	1	T7-LLS-B-4A	2-D	0.564	0.125	3.00	3/8	8	3.00	3.0023	0.1062	0.3725	14.0	26.03	81.66	93.23	hole	
	2	T7-LLS-B-4A	LLS	0.564						3.0023	0.1102	0.3730	15.0	27.13	82.02	93.66	hole	
	3	T7-LLS-B-3A		0.564						3.0022	0.1082	0.3735	16.0	23.36	71.94	82.16	hole	
							Avg.			3.0023	0.1082	0.3730	15.0	25.51	78.54	89.68		
							Std Dev						1.0	1.94	5.72	6.52		
							% COV						6.7	7.6	7.3	7.3		

Project #: BH0002
Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro
No instrumentation

Textile Test Method Development
Task 4
Open Hole Tension Test Program
2-D Braided Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions Thick. (in)	Width (in)	Diam. (in)	W/D	D/t	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-01-4J-x	1	T5-SLL-A-1	2-D	0.520	0.125	1.50	1/4	6	2.00	1.5382	0.1128	0.2490	6.8	14.73	84.87	101.26	hole	
	2	T5-SLL-A-1	SLL	0.501						1.5287	0.1123	0.2495	6.7	16.06	93.52	111.76	hole	
	3	T5-SLL-A-2		0.501		Net-shape				1.5455	0.1118	0.2495	7.1	15.21	88.00	104.94	hole	
							Avg			1.5375	0.1123	0.2493	6.9	15.33	88.80	105.99		
							Std Dev						0.2	0.67	4.38	5.33		
							% COV						3.0	4.4	4.9	5.0		
BH2-02-4J-x	1	T5-LLS-A-3	2-D	0.528	0.125	1.50	1/4	6	2.00	1.5329	0.1133	0.2485	6.2	14.77	85.02	101.47	hole	
	2	T5-LLS-A-3	LLS	0.528						1.5322	0.1143	0.2495	9.8	15.55	88.77	106.03	hole	
	3	T5-LLS-A-4		0.549		Net-shape				1.5378	0.1108	0.2495	8.0	15.31	89.82	107.22	hole	
							Avg.			1.5343	0.1128	0.2492	8.0	15.21	87.87	104.91		
							Std Dev						1.8	0.40	2.52	3.04		
							% COV						22.5	2.6	2.9	2.9		
BH2-03-4J-x	1	T7-LLL-A-4	2-D	0.503	0.125	1.50	1/4	6	2.00	1.5437	0.1272	0.2495	4.3	15.56	79.27	94.55	hole	
	2	T7-LLL-A-4	LLL	0.503						1.5457	0.1230	0.2490	4.5	14.22	74.80	89.16	hole	
	3	T7-LLL-A-5		0.546		Net-shape				1.5478	0.1112	0.2500	4.9	12.05	70.03	83.52	hole	
							Avg.			1.5457	0.1204	0.2495	4.6	13.94	74.70	89.08		
							Std Dev						0.3	1.77	4.62	5.51		
							% COV						6.7	12.7	6.2	6.2		
BH2-04-4J-x	1	T7-LSS-A-6	2-D	0.556	0.125	1.50	1/4	6	2.00	1.5267	0.1105	0.2495	4.7	7.20	42.67	51.00	hole	All failed at 45 deg lines
	2	T7-LSS-A-6	LLL	0.556						1.5487	0.1112	0.2495	5.0	6.75	39.18	46.71	hole	
	3	T7-LSS-A-8		0.542		Net-shape				1.5277	0.1135	0.2495	4.5	7.05	40.68	48.62	hole	
							Avg.			1.5343	0.1117	0.2495	4.7	7.00	40.84	48.78		
							Std Dev						0.2	0.23	1.75	2.15		
							% COV						5.1	3.3	4.3	4.4		
BH2-01-4K-x	1	T7-SLL-C-1A	2-D	0.574	0.250	1.50	3/8	4	1.50	1.5017	0.2183	0.3725	15.0	22.28	67.96	90.37	hole	
	2	T7-SLL-C-1A	SLL	0.574						1.5007	0.2190	0.3730	13.0	19.29	58.70	78.11	hole	
	3	T7-SLL-C-1A		0.574						1.4993	0.2190	0.3730	15.0	22.50	68.52	91.22	hole	
							Avg.			1.5006	0.2188	0.3728	14.3	21.36	65.06	86.57		
							Std Dev						1.2	1.79	5.52	7.34		
							% COV						8.1	8.4	8.5	8.5		

Project #: **BH0002**
intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro
No instrumentation

Textile Test Method Development

Task 4

Open Hole Tension Test Program

2-D Braided Architectures

Material: AS4/Shell 1895

intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions Thick. (in)	Width (in)	Diam. (in)	W/D	D/t	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-01-4L-x	1	T7-SLL-C-1A	2-D	0.574	0.250	1.50	1/4	6	1.00	1.5007	0.2193	0.2480	13.0	22.46	68.24	81.75	hole	
	2	T7-SLL-C-1A	SLL	0.574						1.5505	0.2205	0.2480	16.0	24.44	71.49	85.10	hole	
	3	T7-SLL-C-2B		0.578						1.5002	0.2243	0.2495	18.0	31.21	92.74	111.24	hole	
							Avg.			1.5171	0.2214	0.2485	15.7	26.04	77.49	92.69		
							Std Dev						2.5	4.59	13.31	16.15		
							% COV						16.1	17.6	17.2	17.4		
BH2-01-4M-x	1	T7-SLL-C-2A	2-D	0.597	0.250	1.50	3/16	8	0.75	1.5010	0.2240	0.1875	12.8	31.46	93.57	106.93	hole	
	2	T5-SLL-C-1A	SLL	0.593						1.5025	0.2070	0.1880	14.0	29.82	95.88	109.59	hole	
	3	T7-SLL-C-1A		0.574						1.5023	0.2173	0.1880	15.2	26.33	80.64	92.18	hole	
							Avg.			1.5019	0.2161	0.1878	14.0	29.20	90.03	102.90		
							Std Dev						1.2	2.62	8.21	9.38		
							% COV						8.6	9.0	9.1	9.1		
BH2-02-4K-x	1	T7-LLS-C-6A	2-D	0.611	0.250	1.50	3/8	4	1.50	1.4992	0.2200	0.3730	15.0	20.27	61.46	81.81	hole	
	2	T7-LLS-C-6A	LLS	0.611						1.5002	0.2193	0.3720	16.0	21.13	64.22	85.39	hole	
	3	T7-LLS-C-6A		0.611						1.5003	0.2200	0.3725	15.0	19.35	58.62	77.99	hole	
							Avg.			1.4999	0.2198	0.3725	15.3	20.25	61.43	81.73		
							Std Dev						0.6	0.89	2.80	3.70		
							% COV						3.8	4.4	4.6	4.5		
BH2-02-4L-x	1	T7-LLS-C-6A	2-D	0.611	0.250	1.50	1/4	6	1.00	1.4993	0.2202	0.2485	20.0	23.63	71.58	85.81	hole	
	2	T7-LLS-C-6A	LLS	0.611						1.4997	0.2208	0.2490	20.0	24.59	74.25	89.03	hole	
	3	T7-LLS-C-7A		0.608						1.5012	0.2232	0.2490	19.0	24.53	73.22	87.78	hole	
							Avg.			1.5001	0.2214	0.2488	19.7	24.25	73.02	87.54		
							Std Dev						0.6	0.54	1.34	1.63		
							% COV						2.9	2.2	1.8	1.9		
BH2-02-4M-x	1	T7-LLS-C-6B	2-D	0.629	0.250	1.50	3/16	8	0.75	1.5022	0.2198	0.1880	15.0	27.37	82.88	94.74	hole	
	2	T7-LLS-C-4B	LLS	0.582						1.5013	0.2210	0.1885	16.5	28.37	85.50	97.78	hole	
	3	T7-LLS-C-6A		0.611						1.5022	0.2198	0.1880	17.5	28.43	86.09	98.41	hole	
							Avg.			1.5019	0.2202	0.1882	16.3	28.06	84.83	96.98		
							Std Dev						1.3	0.60	1.71	1.96		
							% COV						7.7	2.1	2.0	2.0		
BH2-01-4N-x	1	T7-SLL-C-2A	2-D	0.597	0.250	2.25	9/16	4	2.25	2.2483	0.2162	0.5620	18.0	33.50	68.93	91.90	hole	
	2	T7-SLL-C-2A	SLL	0.597						2.2502	0.2190	0.5650	15.0	36.42	73.91	98.69	hole	
	3	T7-SLL-C-2A		0.597						2.2492	0.2215	0.5655	14.6	34.03	68.31	91.25	hole	
							Avg.			2.2492	0.2189	0.5642	15.9	34.65	70.38	93.94		
							Std Dev						1.9	1.56	3.07	4.12		
							% COV						11.7	4.5	4.4	4.4		

Project #: BH0002

Intec Engineer Maryann Einarson

Boeing Engineer Mark Fedro

No instrumentation

Textile Test Method Development

Task 4

Open Hole Tension Test Program

2-D Braided Architectures

Material AS4/Shell 1895

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions Thick (in)	Width (in)	Diam (in)	W/D	D/t	Avg Width (in)	Avg Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-01-4O-x	1	T7-SLL-C-1A	2-D	0.574	0.250	2.25	3/8	6	1.50	2.2512	0.2188	0.3725	31.0	35.55	72.16	86.47	Hole	
	2	T7-SLL-C-1A	SLL	0.574						2.2515	0.2173	0.3730	25.0	32.21	65.83	78.90	Hole	
	3	T7-SLL-C-2A		0.597						2.2485	0.2237	0.3730	23.0	40.80	81.13	97.26	Hole	
							Avg			2.2504	0.2199	0.3728	26.3	36.19	73.04	87.54		
							Std Dev						4.2	4.33	7.69	9.23		
							% COV						15.8	12.0	10.5	10.5		
BH2-01-4P-x	1	T7-SLL-C-2A	2-D	0.597	0.250	2.25	9/32	8	1.13	2.2518	0.2173	0.2810	16.0	43.66	89.21	101.93	hole	
	2	T7-SLL-C-2A	SLL	0.597						2.2538	0.2157	0.2815	18.8	43.17	88.81	101.49	hole	
	3	T7-SLL-C-2A		0.597						2.2543	0.2195	0.2810	18.5	44.49	89.91	102.71	hole	
							Avg.			2.2533	0.2175	0.2812	17.8	43.77	89.31	102.04		
							Std Dev						1.5	0.67	0.56	0.62		
							% COV						8.7	1.5	0.6	0.6		
BH2-02-4N-x	1	T7-LLS-C-6B	2-D	0.629	0.250	2.25	9/16	4	2.25	2.2490	0.2237	0.5625	18.0	29.62	58.88	78.52	hole	
	2	T7-LLS-C-6B	LLS	0.629						2.2495	0.2205	0.5625	16.0	26.81	54.05	72.07	hole	
	3	T7-LLS-C-6B		0.629						2.2483	0.2177	0.5625	16.1	28.62	58.48	77.99	hole	
							Avg.			2.2489	0.2206	0.5625	16.7	28.35	57.14	76.20		
							Std Dev						1.1	1.42	2.68	3.58		
							% COV						6.7	5.0	4.7	4.7		
BH2-02-4O-x	1	T7-LLS-C-6A	2-D	0.611	0.250	2.25	3/8	6	1.50	2.2505	0.2225	0.3730	27.0	32.79	65.48	78.49	hole	
	2	T7-LLS-C-6A	LLS	0.611						2.2512	0.2185	0.3730	27.0	32.12	65.30	78.27	hole	
	3	T7-LLS-C-6B		0.629						2.2503	0.2260	0.3725	24.0	34.11	67.07	80.37	hole	
							Avg			2.2507	0.2223	0.3728	26.0	33.01	65.95	79.05		
							Std Dev						1.7	1.01	0.97	1.16		
							% COV						6.7	3.1	1.5	1.5		
BH2-02-4P-x	1	T7-LLS-C-6B	2-D	0.629	0.250	2.25	9/32	8	1.13	2.2522	0.2317	0.2815	17.3	36.75	70.44	80.50	hole	
	2	T7-LLS-C-6B	LLS	0.629						2.2528	0.2257	0.2820	17.2	34.82	68.49	78.29	hole	
	3	T7-LLS-C-6B		0.629						2.2525	0.2225	0.2815	18.0	34.95	69.74	79.69	hole	
							Avg			2.2525	0.2266	0.2817	17.5	35.51	69.55	79.49		
							Std Dev						0.4	1.08	0.99	1.12		
							% COV						2.5	3.0	1.4	1.4		
BH2-03-4N-x	1	T7-LLL-C-1A	2-D	0.622	0.250	2.25	9/16	4	2.25	2.2490	0.2210	0.5625	19.0	35.68	71.79	95.73	hole	
	2	T7-LLL-C-1A	LLL	0.622						2.2490	0.2212	0.5625	14.0	32.73	65.80	65.80	hole	
	3	T7-LLL-C-1A		0.622						2.2498	0.2207	0.5630	8.0	28.21	56.82	75.79	hole	
							Avg			2.2493	0.2209	0.5627	13.7	32.21	64.80	79.11		
							Std Dev						5.5	3.76	7.53	15.24		
							% COV						40.3	11.7	11.6	19.3		

Project #: **BH0002**
Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro
No instrumentation

Textile Test Method Development

Task 4

Open Hole Tension Test Program

2-D Braided Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions Thick. (in)	Width (in)	Diam (in)	W/D	D/t	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-03-4O-x	1	T7-LLL-C-1A	2-D	0.622	0.250	2.25	3/8	6	1.50	2.2498	0.2200	0.3750	10.5	36.93	74.61	89.54	hole	
	2	T7-LLL-C-1A	LLL	0.622						2.2520	0.2230	0.3755	11.5	38.24	76.15	91.38	hole	
	3	T7-LLL-C-1A		0.622						2.2492	0.2210	0.3760	11.0	39.24	78.94	94.79	hole	
							Avg.			2.2503	0.2213	0.3755	11.0	38.14	76.57	91.90		
							Std Dev						0.5	1.16	2.20	2.67		
							% COV						4.5	3.0	2.9	2.9		
BH2-03-4P-x	1	T7-LLL-C-1A	2-D	0.622	0.250	2.25	9/32	8	1.13	2.2538	0.2177	0.2815	9.7	39.30	80.11	91.54	hole	
	2	T7-LLL-C-1A	LLL	0.622						2.2527	0.2180	0.2820	11.0	38.80	79.01	90.32	hole	
	3	T7-LLL-C-1B		0.641						2.2522	0.2173	0.2810	12.0	41.85	85.50	97.69	hole	
							Avg.			2.2529	0.2177	0.2815	10.9	39.98	81.54	93.18		
							Std Dev						1.2	1.64	3.47	3.95		
							% COV						10.6	4.1	4.3	4.2		
BH2-04-4N-x	1	T7-LSS-C-2A	2-D	0.612	0.250	2.25	9/16	4	2.25	2.2505	0.2222	0.5615	10.3	16.43	32.86	43.79	hole	failed diagonally
	2	T7-LSS-C-2A	LSS	0.612						2.2502	0.2212	0.5615	11.8	15.37	30.88	41.15	hole	failed diagonally
	3	T7-LSS-C-2A		0.612						2.2500	0.2167	0.5620	11.2	15.06	30.89	41.18	hole	failed diagonally
							Avg.			2.2502	0.2200	0.5617	11.1	15.62	31.55	42.04		
							Std Dev						0.8	0.72	1.14	1.51		
							% COV						6.8	4.6	3.6	3.6		
BH2-04-4O-x	1	T7-LSS-C-2A	2-D	0.612	0.250	2.25	3/8	6	1.50	2.2525	0.2145	0.3755	none	17.76	36.76	44.11	hole	
	2	T7-LSS-C-2A	LSS	0.612						2.2500	0.2238	0.3750	none	19.24	38.20	45.84	hole	
	3	T7-LSS-C-2A		0.612						2.2510	0.2202	0.3715	none	19.50	39.35	47.12	hole	
							Avg.			2.2512	0.2195	0.3740		18.83	38.10	45.69		
							Std Dev							0.94	1.30	1.51		
							% COV							5.0	3.4	3.3		
BH2-04-4P-x	1	T7-LSS-C-2A	2-D	0.612	0.250	2.25	9/32	8	1.13	2.2525	0.2188	0.2815	15.2	19.57	39.70	45.37	hole	failed diagonally
	2	T7-LSS-C-2A	LSS	0.612						2.2532	0.2170	0.2815	16.0	20.15	41.21	47.10	hole	failed diagonally
	3	T7-LSS-C-1B		0.642						2.2478	0.2000	0.2810	16.0	18.67	41.53	47.46	hole	failed diagonally
							Avg.			2.2512	0.2119	0.2813	15.7	19.46	40.81	46.64		
							Std Dev						0.5	0.75	0.98	1.12		
							% COV						2.9	3.8	2.4	2.4		
BH2-01-4Q-x	1	T7-SLL-C-2A	2-D	0.597	0.250	3.00	3/4	4	3.0	3.0030	0.2233	0.7505		48.12	71.75	95.65	hole	
	2	T7-SLL-C-1A	SLL	0.593						2.9997	0.2217	0.7500		41.52	62.42	83.24	hole	
	3	T7-SLL-C-2B		0.578						3.0030	0.2187	0.7500		47.72	72.67	96.86	hole	
							Avg.			3.0019	0.2213	0.7502		45.79	68.95	91.92		
							Std Dev							3.70	5.67	7.54		
							% COV							8.1	8.2	8.2		

Project #: BH0002

Intec Engineer: Maryann Einarson

Boeing Engineer: Mark Fedro

No instrumentation

Textile Test Method Development

Task 4

Open Hole Tension Test Program

2-D Braided Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions Thick. (in)	Width (in)	Diam. (in)	W/D	D/t	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-01-4R-x	1	T7-SLL-C-2B	2-D	0.578	0.250	3.00	1/2	6	2.0	3.0015	0.2213	0.4995	45.0	53.89	81.12	97.31	hole	
	2	T7-SLL-C-2B	SLL	0.578						3.0013	0.2237	0.4990	37.0	50.48	75.20	90.20	hole	
	3	T7-SLL-C-2B		0.578						3.0003	0.2180	0.4995		49.54	75.73	90.85	hole	
							Avg.			3.0011	0.2210	0.4993	41.0	51.30	77.35	92.79		
							Std Dev						5.7	2.29	3.27	3.93		
							% COV						13.8	4.5	4.2	4.2		
BH2-01-4S-x	1	T7-SLL-C-2B	2-D	0.578	0.250	3.00	3/8	8	1.5	3.0012	0.2208	0.3725	47.0	57.64	86.97	99.29	hole	
	2	T7-SLL-C-2B	SLL	0.578						3.0033	0.2232	0.3725	42.0	53.95	80.49	91.89	hole	
	3	T7-SLL-C-1A		0.574						3.0040	0.2183	0.3725	40.0	46.31	70.61	80.60	hole	
							Avg.			3.0028	0.2208	0.3725	43.0	52.63	79.36	90.60		
							Std Dev						3.6	5.78	8.24	9.41		
							% COV						8.4	11.0	10.4	10.4		
BH2-02-4Q-x	1	T7-LLS-C-6B	2-D	0.629	0.250	3.00	3/4	4	3.0	3.0015	0.2189	0.7500		35.17	53.53	71.37	hole	
	2	T7-LLS-C-6A	LLS	0.611						3.0007	0.2217	0.7510		38.82	58.36	77.85	hole	
	3	T7-LLS-C-7A		0.608						3.0025	0.2126	0.7505		36.06	56.50	75.32	hole	
							Avg.			3.0016	0.2177	0.7505		36.68	56.13	74.84		
							Std Dev							1.90	2.44	3.27		
							% COV							5.2	4.3	4.4		
BH2-02-4R-x	1	T7-LLS-C-7A	2-D	0.608	0.250	3.00	1/2	6	2.0	3.0012	0.2160	0.5035	42.0	44.16	68.11	81.84	hole	
	2	T7-LLS-C-7A	LLS	0.608						3.0008	0.2187	0.4995	37.0	40.88	62.28	74.72	hole	
	3	T7-LLS-C-7A		0.608						3.0020	0.2142	0.5005	37.5	41.48	64.51	77.41	hole	
							Avg.			3.0013	0.2163	0.5012	38.8	42.17	64.97	77.99		
							Std Dev						2.8	1.75	2.94	3.60		
							% COV						7.1	4.1	4.5	4.6		
BH2-02-4S-x	1	T7-LLS-C-7A	2-D	0.608	0.250	3.00	3/8	8	1.5	3.0017	0.2187	0.3715	34.0	48.80	74.35	84.85	hole	
	2	T7-LLS-C-7A	LLS	0.608						3.0020	0.2200	0.3725	40.0	44.56	67.47	77.03	hole	
	3	T7-LLS-C-6A		0.611						3.0028	0.2187	0.3730	21.0	44.93	68.43	78.13	hole	
							Avg			3.0024	0.2193	0.3728	30.9	45.20	68.66	78.39		
							Std Dev						9.5	0.80	1.32	1.50		
							% COV						30.8	1.8	1.9	1.9		

Project #: BH0002
intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro
No instrumentation

Textile Test Method Development

Task 4 & 8

Open Hole Tension Test Program

3-D Woven Interlock Architectures

Material: AS4/Shell 1895

intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions Thick. (in)	Width (in)	Diam. (in)	W/D	D/t	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-05-4K-x	1	T7-TS1-A-2B	3-D	0.643	0.250	1.50	3/8	4	1.50	1.5015	0.2224	0.3740	27.0	30.45	91.20	121.45	hole	
	2	T7-TS1-A-2B	TS-1	0.643						1.5007	0.2209	0.3740	28.0	30.62	92.38	123.04	hole	
	3	T7-TS1-A-2B		0.643						1.5000	0.2199	0.3745	24.0	30.43	92.24	122.93	hole	
							Avg.						26.3	30.50	91.94	122.47		
							Std Dev							0.10	0.64	0.89		
							% COV							0.3	0.7	0.7		
BH2-05-4L-x	1	T7-TS1-A-2B	3-D	0.643	0.250	1.50	1/4	6	1.00	1.5010	0.2213	0.2500	35.0	35.33	106.35	127.61	hole	
	2	T7-TS1-A-2B	TS-1	0.643						1.5003	0.2228	0.2500	32.0	35.34	105.75	126.89	hole	
	3	T7-TS1-A-2B		0.643						1.5015	0.2254	0.2500	31.0	33.28	98.34	117.99	hole	
							Avg.						32.7	34.65	103.48	124.16		
							Std Dev							1.19	4.46	5.36		
							% COV							3.4	4.3	4.3		
BH2-05-4M-x	1	T7-TS1-A-2B	3-D	0.643	0.250	1.50	3/16	8	0.75	1.5002	0.2216	0.1870	29.4	37.84	113.83	130.04	hole	
	2	T7-TS1-A-2B	TS-1	0.643						1.4995	0.2191	0.1870	27.5	39.38	119.87	136.95	hole	
	3	T7-TS1-A-2B		0.643						1.4992	0.2182	0.1870	36.8	37.42	114.39	130.70	hole	
							Avg.						31.2	38.21	116.03	132.56		
							Std Dev							1.03	3.34	3.82		
							% COV							2.7	2.9	2.9		
BH2-06-4K-x	1	T7-TS2-A-1B	3-D	0.610	0.250	1.50	3/8	4	1.50	1.4993	0.2261	0.3740	17.8	23.94	70.61	94.08	hole	
	2	T7-TS2-A-1B	TS-2	0.610						1.4982	0.2234	0.3740	16.8	25.72	76.85	102.41	hole	
	3	T7-TS2-A-1B		0.610						1.4985	0.2227	0.3745	21.4	24.96	74.81	99.73	hole	
							Avg.						18.7	24.87	74.09	98.74		
							Std Dev							0.89	3.18	4.25		
							% COV							3.6	4.3	4.3		
BH2-06-4L-x	1	T7-TS2-A-1B	3-D	0.610	0.250	1.50	1/4	6	1.00	1.4998	0.2229	0.2490	17.8	27.66	82.74	99.21	hole	
	2	T7-TS2-A-1B	TS-2	0.610						1.4993	0.2233	0.2490	24.2	29.52	88.18	105.75	hole	
	3	T7-TS2-A-1B		0.610						1.4985	0.2230	0.2490	23.2	30.36	90.85	108.96	hole	
							Avg.						21.7	29.18	87.26	104.64		
							Std Dev							1.38	4.13	4.97		
							% COV							4.7	4.7	4.7		
BH2-06-4M-x	1	T7-TS2-A-1B	3-D	0.610	0.250	1.50	3/16	8	0.75	1.4977	0.2285	0.1875	27.7	29.73	86.88	99.31	hole	
	2	T7-TS2-A-1B	TS-2	0.610						1.4978	0.2258	0.1875	27.5	30.90	91.36	104.43	hole	
	3	T7-TS2-A-1B		0.610						1.4987	0.2246	0.1875		32.82	97.49	111.43	hole	
							Avg.							31.15	91.91	105.06		
							Std Dev							1.56	5.33	6.08		
							% COV							5.0	5.8	5.8		

Project #: **BH0002**
Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro
No instrumentation

Textile Test Method Development
Task 4 & 8
Open Hole Tension Test Program
3-D Woven Interlock Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions Thick. (in)	Width (in)	Diam. (in)	W/D	D/t	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-07-4K-x	1	T7-OS1-A-2B	3-D	0.614	0.250	1.50	3/8	4	1.50	1.5035	0.2311	0.3750	25.0	33.58	96.64	128.75	hole	
	2	T7-OS1-A-2B	OS-1	0.614						1.5002	0.2297	0.3750	26.0	34.59	100.37	133.82	hole	
	3	T7-OS1-A-2B		0.614						1.4998	0.2282	0.3745	22.0	27.36	79.93	106.53	hole	failed in grips
							Avg.						24.3	31.84	92.31	123.03		
							Std Dev							3.92	10.88	14.52		
							% COV							12.3	11.8	11.8		
BH2-07-4L-x	1	T7-OS1-A-2B	3-D	0.614	0.250	1.50	1/4	6	1.00	1.4998	0.2259	0.2500	29.0	36.85	108.77	130.53	hole	
	2	T7-OS1-A-2B	OS-1	0.614						1.5010	0.2266	0.2500	29.0	37.00	108.77	130.50	hole	
	3	T7-OS1-A-2B		0.614						1.5005	0.2279	0.2500	28.0	29.29	85.65	102.78	hole	
							Avg.						28.7	34.38	101.06	121.27		
							Std Dev							4.41	13.35	16.02		
							% COV							12.8	13.2	13.2		
BH2-07-4M-x	1	T7-OS1-A-2B	3-D	0.614	0.250	1.50	3/16	8	0.75	1.4995	0.2294	0.1870	26.2	40.81	118.66	135.56	hole	
	2	T7-OS1-A-2B	OS-1	0.614						1.4988	0.2285	0.1870	31.4	40.49	118.25	135.11	hole	
	3	T7-OS1-A-2B		0.614						1.5000	0.2275	0.1870	29.3	40.11	117.53	134.27	hole	
							Avg.						29.0	40.47	118.15	134.98		
							Std Dev							0.35	0.57	0.66		
							% COV							0.9	0.5	0.5		
BH2-08-4K-x	1	T7-OS2-A-2A	3-D	0.578	0.250	1.50	3/8	4	1.50	1.5028	0.2358	0.3740	15.5	22.55	51.50	84.72	hole	
	2	T7-OS2-A-2A	OS-2	0.578						1.5002	0.2359	0.3745	15.5	25.09	70.91	94.51	hole	
	3	T7-OS2-A-2A		0.578						1.4995	0.2358	0.3735	20.3	25.48	72.07	95.97	hole	
							Avg.						17.1	24.37	64.83	91.73		
							Std Dev							1.59	11.56	6.12		
							% COV							6.5	17.8	6.7		
BH2-08-4L-x	1	T7-OS2-A-2A	3-D	0.578	0.250	1.50	1/4	6	1.00	1.5013	0.2348	0.2490	25.0	29.37	83.32	99.89	hole	
	2	T7-OS2-A-2A	OS-2	0.578						1.4992	0.2330	0.2495	19.3	28.39	81.27	97.50	hole	
	3	T7-OS2-A-2A		0.578						1.4995	0.2324	0.2495	22.5	28.75	82.51	98.98	hole	
							Avg.						22.3	28.84	82.37	98.79		
							Std Dev							0.50	1.03	1.21		
							% COV							1.7	1.3	1.2		
BH2-08-4M-x	1	T7-OS2-A-2A	3-D	0.578	0.250	1.50	3/16	8	0.75	1.5043	0.2334	0.1865	19.7	22.97	65.42	74.67	hole	
	2	T7-OS2-A-2A	OS-2	0.578						1.4998	0.2339	0.1870	21.8	28.68	81.76	93.41	hole	
	3	T7-OS2-A-2A		0.578						1.4980	0.2339	0.1870	24.9	28.22	80.55	92.04	hole	
							Avg.						22.1	26.62	75.91	86.71		
							Std Dev							3.17	9.11	10.44		
							% COV							11.9	12.0	12.0		

Project #: **BH0002**
Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro
No instrumentation

Textile Test Method Development

Task 4 & 8

Open Hole Tension Test Program
3-D Woven Interlock Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions Thick. (in)	Width (in)	Diam. (in)	W/D	D/t	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-09-4K-x	1	T7-LS1-A-7B	3-D	0.631	0.250	1.50	3/8	4	1.50	1.4982	0.2128	0.3740	16.8	28.45	89.24	118.93		delamination above hole for all specimens
	2	T7-LS1-A-7B	LS-1	0.631						1.4978	0.2133	0.3745	15.1	27.85	87.18	116.25		
	3	T7-LS1-A-7B		0.631						1.4970	0.2135	0.3745	14.8	25.76	80.60	107.50		
							Avg.						15.6	27.35	85.68	114.22		
							Std Dev							1.41	4.51	5.98		
							% COV							5.2	5.3	5.2		
BH2-09-4L-x	1	T7-LS1-A-7B	3-D	0.631	0.250	1.50	1/4	6	1.00	1.4998	0.2132	0.2490	22.0	38.66	120.88	144.95		delamination at hole for all specimens
	2	T7-LS1-A-7B	LS-1	0.631						1.4983	0.2140	0.2490	26.5	42.01	131.00	157.11		
	3	T7-LS1-A-7B		0.631						1.4998	0.2145	0.2490	28.7	36.77	114.29	137.04		
							Avg						25.7	39.15	122.06	146.36		
							Std Dev							2.65	8.42	10.11		
							% COV							6.8	6.9	6.9		
BH2-09-4M-x	1	T7-LS1-A-7A	3-D	0.656	0.250	1.50	3/16	8	0.75	1.4977	0.2144	0.1900	7.4	41.93	130.60	149.58	hole	
	2	T7-LS1-A-5B	LS-1	0.646						1.5003	0.2098	0.1875	36.1	42.25	134.26	153.43	hole	with delamination
	3	T7-LS1-A-5B		0.646						1.5037	0.2081	0.1875	39.2	42.25	135.05	154.29	hole	with delamination
							Avg						27.6	42.14	133.30	152.43		
							Std Dev							0.18	2.37	2.51		
							% COV							0.4	1.8	1.6		
BH2-10-4K-x	1	T7-LS2–A-2B	3-D	0.610	0.250	1.50	3/8	4	1.50	1.4983	0.2307	0.3735	23.2	27.26	78.85	105.03	hole	
	2	T7-LS2-A-2B	LS-2	0.610						1.4978	0.2274	0.3745	24.8	29.94	87.89	117.19	hole	
	3	T7-LS2-A-2B		0.610						1.4980	0.2246	0.3745	27.3	29.40	87.39	116.52	hole	
							Avg.						25.1	28.87	84.71	112.91		
							Std Dev							1.42	5.08	6.83		
							% COV							4.9	6.0	6.1		
BH2-10-4L-x	1	T7-LS2–A-2B	3-D	0.610	0.250	1.50	1/4	6	1.00	1.4963	0.2246	0.2490	16.4	33.14	98.63	118.32	hole	
	2	T7-LS2-A-2B	LS-2	0.610						1.4980	0.2249	0.2485	21.0	33.37	99.04	118.73	hole	
	3	T7-LS2-A-2B		0.610						1.4988	0.2236	0.2490	28.1	32.85	98.01	117.54	hole	
							Avg						21.8	33.12	98.56	118.20		
							Std Dev							0.26	0.52	0.61		
							% COV							0.8	0.5	0.5		
BH2-10-4M-x	1	T7-LS2–A-2B	3-D	0.610	0.250	1.50	3/16	8	0.75	1.4987	0.2282	0.1870	20.8	22.06	64.51	73.71		failed away from hole for all specimens
	2	T7-LS2-A-2B	LS-2	0.610						1.4990	0.2257	0.1870	26.9	29.23	86.42	98.73		
	3	T7-LS2-A-2B		0.610						1.4985	0.2242	0.1870	27.8	30.83	91.76	104.84		
							Avg						25.2	27.37	80.89	92.43		
							Std Dev							4.67	14.44	16.50		
							% COV							17.1	17.9	17.9		

Project #: BH0002
intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development

Task 8

Open Hole Tension Test Program
Stitched Uniweave Architectures

Material: AS4/Shell 1895

intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions Thick. (in)	Width (in)	Diam. (in)	W/D	D/t	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-11-4K-x	1	T7-SUW-G3K8A1	SU-1	0.670	0.250	1.50	3/8	4	1.50	1.4990	0.2240	0.3745	16.8	17.44	51.95	69.25	hole	
	2	T7-SUW-G3K8A1		0.670						1.4997	0.2237	0.3750	12.9	16.03	47.79	63.72	hole	
	3	T7-SUW-G3K8A1		0.670						1.4995	0.2228	0.3740	15.1	15.96	47.77	63.65	hole	
							Avg.						14.9	16.48	49.17	65.54		
							Std Dev							0.84	2.41	3.21		
							% COV							5.1	4.9	4.9		
BH2-11-4L-x	1	T7-SUW-G3K8A1	SU-1	0.670	0.250	1.50	1/4	6	1.00	1.5027	0.2215	0.2495	14.8	18.86	56.67	67.98	hole	
	2	T7-SUW-G3K8A1		0.670						1.5005	0.2208	0.2495	14.7	19.58	59.11	70.90	hole	
	3	T7-SUW-G3K8A1		0.670						1.4985	0.2217	0.2495	13.8	19.88	59.85	71.81	hole	
							Avg.						14.4	19.44	58.55	70.22		
							Std Dev							0.52	1.66	2.02		
							% COV							2.7	2.8	2.9		
BH2-11-4M-x	1	T7-SUW-G3K8A1	SU-1	0.670	0.250	1.50	3/16	8	0.75	1.4990	0.2204	0.1880	20.5	21.61	65.42	74.81	hole	
	2	T7-SUW-G3K8A1		0.670						1.4995	0.2212	0.1880	19.8	21.75	65.58	74.98	hole	
	3	T7-SUW-G3K8A1		0.670						1.5010	0.2214	0.1875	18.9	21.40	64.40	73.59	hole	
							Avg.						19.7	21.59	65.13	74.46		
							Std Dev							0.18	0.64	0.76		
							% COV							0.8	1.0	1.0		
BH2-12-4K-x	1	T7-SUW-G6K8A1	SU-2	0.652	0.250	1.50	3/8	4	1.50	1.4995	0.2440	0.3755	15.6	17.53	47.92	63.93	hole	
	2	T7-SUW-G6K8A1		0.652						1.5000	0.2442	0.3755	15.6	17.32	47.29	63.08	hole	
	3	T7-SUW-G6K8A1		0.652						1.4982	0.2444	0.3745	14.3	17.20	46.98	62.63	hole	
							Avg.						15.2	17.35	47.39	63.21		
							Std Dev							0.17	0.48	0.66		
							% COV							1.0	1.0	1.0		
BH2-12-4L-x	1	T7-SUW-G6K8A1	SU-2	0.652	0.250	1.50	1/4	6	1.00	1.5030	0.2451	0.2495	14.9	20.15	54.71	65.60	hole	
	2	T7-SUW-G6K8A1		0.652						1.5005	0.2449	0.2495	19.8	20.39	55.49	66.56	hole	
	3	T7-SUW-G6K8A1		0.652						1.5000	0.2440	0.2500	15.9	20.11	54.95	65.94	hole	
							Avg.						16.9	20.22	55.05	66.03		
							Std Dev							0.15	0.40	0.49		
							% COV							0.7	0.7	0.7		
BH2-12-4M-x	1	T7-SUW-G6K8A1	SU-2	0.652	0.250	1.50	3/16	8	0.75	1.5035	0.2437	0.1875	22.0	22.38	61.07	69.77	hole	
	2	T7-SUW-G6K8A1		0.652						1.5010	0.2435	0.1875	22.2	22.56	61.73	70.55	hole	
	3	T7-SUW-G6K8A1		0.652						1.5015	0.2439	0.1880	21.4	23.13	63.17	72.21	hole	
							Avg.						21.9	22.69	61.99	70.84		
							Std Dev							0.39	1.07	1.24		
							% COV							1.7	1.7	1.8		

Project #: BH0002
intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development

Task 8
Open Hole Tension Test Program
Stitched Uniweave Architectures

Material: AS4/Shell 1895

intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions Thick. (in)	Width (in)	Diam. (in)	W/D	D/t	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-13-4K-x	1	T7-SUW-K6K8A-1	SU-3	0.920	0.250	1.50	3/8	4	1.50	1.5027	0.2450	0.3750	15.4	17.96	48.79	65.02	hole	
	2	T7-SUW-K6K8A-1		0.609						1.4978	0.2459	0.3740		17.95	48.75	64.97	hole	
	3	T7-SUW-K6K8A-1		0.609						1.4977	0.2488	0.3745	12.0	17.00	45.99	61.33	hole	
							Avg.						13.7	17.64	47.84	63.77		
							Std Dev							0.55	1.60	2.12		
							% COV							3.1	3.3	3.3		
BH2-13-4L-x	1	T7-SUW-K6K8A-1	SU-3	0.609	0.250	1.50	1/4	6	1.00	1.4982	0.2471	0.2490	17.3	20.22	54.62	65.51	hole	
	2	T7-SUW-K6K8A-1		0.609						1.4975	0.2465	0.2490		21.44	58.08	69.66	hole	
	3	T7-SUW-K6K8A-1		0.609						1.5028	0.2462	0.2490	16.1	18.67	50.46	60.48	hole	
							Avg.						16.7	20.11	54.39	65.22		
							Std Dev							1.39	3.81	4.59		
							% COV							6.9	7.0	7.0		
BH2-13-4M-x	1	T7-SUW-K6K8A-1	SU-3	0.609	0.250	1.50	3/16	8	0.75	1.5010	0.2484	0.1870	20.9	22.33	59.88	68.40	hole	
	2	T7-SUW-K6K8A-1		0.609						1.4965	0.2500	0.1875	21.0	23.32	62.34	71.27	hole	
	3	T7-SUW-K6K8A-1		0.609						1.5007	0.2518	0.1875		21.33	56.44	64.50	hole	
							Avg.						21.0	22.33	59.55	68.06		
							Std Dev							1.00	2.96	3.39		
							% COV							4.5	5.0	5.0		
BH2-14-4K-x	1	T7-SUW-K6K4A1	SU-4	0.621	0.250	1.50	3/8	4	1.50	1.4978	0.2336	0.3745	17.2	18.23	52.11	69.49	hole	
	2	T7-SUW-K6K4A1		0.621						1.5002	0.2338	0.3745	16.1	17.19	49.02	65.33	hole	
	3	T7-SUW-K6K4A1		0.621						1.4983	0.2339	0.3745	16.9	17.49	49.91	66.55	hole	
							Avg.						16.7	17.64	50.35	67.12		
							Std Dev							0.54	1.59	2.14		
							% COV							3.0	3.2	3.2		
BH2-14-4L-x	1	T7-SUW-K6K4A1	SU-4	0.621	0.250	1.50	1/4	6	1.00	1.5060	0.2336	0.2500	19.5	19.87	56.48	67.72	hole	
	2	T7-SUW-K6K4A1		0.621						1.5035	0.2340	0.2500	17.2	19.92	56.63	67.92	hole	
	3	T7-SUW-K6K4A1		0.621						1.5005	0.2344	0.2500	16.9	19.17	54.52	65.41	hole	
							Avg.						17.9	19.65	55.87	67.02		
							Std Dev							0.42	1.18	1.39		
							% COV							2.1	2.1	2.1		
BH2-14-4M-x	1	T7-SUW-K6K4A1	SU-4	0.621	0.250	1.50	1/5	8	0.75	1.5010	0.2313	0.1880	17.3	21.75	62.64	71.61	hole	
	2	T7-SUW-K6K4A1		0.621						1.5020	0.2317	0.1875	17.4	22.01	63.25	72.28	hole	
	3	T7-SUW-K6K4A1		0.621						1.5005	0.2320	0.1875	17.1	21.60	62.05	70.91	hole	
							Avg.						17.3	21.79	62.65	71.60		
							Std Dev							0.21	0.60	0.68		
							% COV							1.0	1.0	1.0		

Project #: BH0002

Intec Engineer: Maryann Einarson

Boeing Engineer: Mark Fedro

Textile Test Method Development

Task 8

Open Hole Tension Test Program

Stitched Uniweave Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions Thick. (in)	Width (in)	Diam. (in)	W/D	D/t	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-15-4K-x	1	T7-SUW-K12K8A1	SU-5	0.650	0.250	1.50	3/8	4	1.50	1.4953	0.2537	0.3750	13.2	17.32	45.65	60.93	hole	
	2	T7-SUW-K12K8A1		0.650						1.5063	0.2544	0.3750	15.5	17.61	45.96	61.19	hole	
	3	T7-SUW-K12K8A1		0.650						1.4937	0.2549	0.3745	16.3	18.66	49.02	65.42	hole	
							Avg.						15.0	17.86	46.88	62.52		
							Std Dev							0.71	1.86	2.52		
							% COV							3.9	4.0	4.0		
BH2-15-4L-x	1	T7-SUW-K12K8A1	SU-5	0.650	0.250	1.50	1/4	6	1.00	1.5033	0.2541	0.2500	20.1	20.64	54.03	64.81	hole	
	2	T7-SUW-K12K8A1		0.650						1.4998	0.2539	0.2500	14.6	20.98	55.10	66.12	hole	
	3	T7-SUW-K12K8A1		0.650						1.4960	0.2535	0.2500	16.5	19.82	52.26	62.75	hole	
							Avg.						17.1	20.48	53.80	64.56		
							Std Dev							0.60	1.43	1.70		
							% COV							2.9	2.7	2.6		
BH2-15-4M-x	1	T7-SUW-K12K8A1	SU-5	0.650	0.250	1.50	3/16	8	0.75	1.5018	0.2456	0.1875	21.0	22.21	60.21	68.80	hole	
	2	T7-SUW-K12K8A1		0.650						1.5082	0.2535	0.1875	20.5	23.11	60.45	69.03	hole	
	3	T7-SUW-K12K8A1		0.650						1.4965	0.2541	0.1875	21.2	23.39	61.50	70.31	hole	
							Avg.						20.9	22.90	60.72	69.38		
							Std Dev							0.62	0.69	0.81		
							% COV							2.7	1.1	1.2		

Compression Test Program

Project #: BH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development
Task 5
Compression Test Program
2-D Braided Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions: total Length (in)	Nominal Dimensions: tab Length (in)	Nominal Dimensions: gage length (in)	Nominal Dimensions: Width (in)	Avg Width (in)	Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Axial 1 Strain (με)	Ultimate Axial 2 Strain (με)	Ultimate Trans Strain (με)	Axial Modulus: Axial 1 (msi)	Axial Modulus: Axial 2 (msi)	Axial Modulus: Average (msi)	Poisson's Ratio
BH2-01-5A-x	1	T7SLLB9SA,9SB	2-D		Baseline	12	3.0	6.0	3.00	3.0013	1.1070	14.6	15.74	41.95	-5,557	-5,688	1,069	7.57	7.60	7.58	0.188
	2	T7SLLB9SA,9SB	SLL		Comp					3.0022	1.1040	15.1	17.34	46.21	-5,704	-6,656	1,051	7.49	7.33	7.41	0.160
	3	T7SLLB9SA,9SB			Sandwhich					3.0017	1.1045	15.4	19.60	52.24	-7,008	-7,291	1,115	7.44	7.46	7.45	0.158
										3.0017	1.1052	15.0	17.56	46.80	-6,090	-6,545	1,078	7.50	7.46	7.48	0.169
													1.94	5.17				0.07	0.13	0.09	0.017
													11.05	11.04				0.90	1.80	1.23	9.94
BH2-02-5A-x	1	T7LLSB7SA,7SB	2-D		Baseline	12	3.0	6.0	3.00	2.9983	1.1513	15.0	22.71	60.58	-5,792	-5,197	3,302	10.86	11.79	11.33	0.614
	2	T7LLSB7SA,7SB	LLS		Comp					3.0000	1.1482	19.3	23.47	62.59	-5,557	-5,268	3,833	11.39	12.13	11.76	0.677
	3	T7LLSB7SA,7SB			Sandwhich					2.9998	1.1438		23.59	62.90	-5,818	-5,506	3,500	11.20	11.79	11.49	0.603
										2.9994	1.1478	17.2	23.25	62.02	-5,722	-5,324	3,545	11.15	11.90	11.53	0.631
													0.48	1.26				0.27	0.20	0.22	0.040
													2.05	2.03				2.40	1.66	1.90	6.32
BH2-03-5A-x	1	T7LLLB3SA,3SB	2-D		Baseline	12	3.0	6.0	3.00	2.9977	1.0953	6.3	10.95	29.22	-5,478	-5,047	1,009	5.58	5.58	5.58	0.194
	2	T7LLLB3SA,3SB	LLL		Comp					2.9992	1.0953		12.04	32.12	-5,637	-6,007	1,133	5.68	5.39	5.53	0.187
	3	T7LLLB3SA,3SB			Sandwhich					2.9962	1.0992		10.66	28.46	-5,081	-5,755	1,115	5.69	4.83	5.26	0.192
										2.9977	1.0966	6.3	11.22	29.93	-5,399	-5,603	1,086	5.65	5.27	5.46	0.191
													0.73	1.93				0.06	0.39	0.17	0.004
													6.51	6.46				1.09	7.35	3.16	1.89
BH2-04-5A-x	1	T7LSSB5SB,5SA	2-D		Baseline	12	3.0	6.0	3.00	2.9970	1.0892	7.0	10.76	28.71	-9,474	na	8,640	3.50	3.39	3.44	0.751
	2	T7LSSB5SB,5SA	LSS		Comp					2.9987	1.0882	10.3	10.70	28.54	-9,873	na	8,581	3.41	3.36	3.39	0.767
	3	T7LSSB5SB,5SA			Sandwhich					2.9998	1.0968		10.95	29.20	-9,817	-9,885	8,413	3.44	3.49	3.47	0.770
										2.9985	1.0914	8.7	10.80	28.82	-9,721	-9,885	8,545	3.45	3.42	3.43	0.763
													0.13	0.34				0.04	0.07	0.04	0.010
													1.22	1.19				1.22	2.03	1.18	1.34
BH2-01-5B-x	1	T7SLLB9SA,9SB	2-D		Sandwich	12	3.0	6.0	1.50	1.5030	1.1043	8.5	9.18	48.84	-6,868	-6,500		7.40	7.72	7.56	
	2	T7SLLB9SA,9SB	SLL		Width					1.4982	1.1097	8.6	9.26	49.46	-6,610	-6,646		7.64	7.69	7.66	
	3	T7SLLB9SA,9SB			Effect					1.5027	1.1080	7.6	8.87	47.22	-6,554	-6,532		7.35	7.56	7.45	
										1.5013	1.1073	8.2	9.10	48.51	-6,677	-6,559		7.46	7.66	7.56	
													0.21	1.16				0.15	0.08	0.10	
													2.27	2.38				2.07	1.10	1.38	
BH2-01-5C-x	1	T7SLLB9SA,9SB	2-D		Sandwich	12	3.0	6.0	2.25	2.2513	1.1050	13.2	14.87	52.85	-7,224	-7,961		7.50	7.00	7.25	
	2	T7SLLB9SA,9SB	SLL		Width					2.2520	1.1060	11.7	12.83	45.57	-5,281	-6,493		7.99	7.28	7.64	
	3	T7SLLB9SA,9SB			Effect					2.2513	1.1037	13.1	13.70	48.68	-5,490	-6,532		7.43	7.71	7.57	
										2.2516	1.1049	12.7	13.80	49.04	-5,998	-6,995		7.64	7.33	7.49	
													1.03	3.65				0.31	0.36	0.21	
													7.44	7.45				4.04	4.88	2.77	
BH2-02-5B-x	1	T7LLSB7SA,7SB	2-D		Sandwich	12	3.0	6.0	1.50	1.5022	1.1400	8.2	11.59	61.72	-5,576	-5,704		11.40	11.08	11.24	
	2	T7LLSB7SA,7SB	LLS		Width					1.4975	1.1473	9.4	10.86	58.02	-4,956	-5,960		11.70	10.26	10.98	
	3	T7LLSB7SA,7SB			Effect					1.4947	1.1477	8.7	11.93	63.88	-5,744	-6,171		11.24	11.67	11.45	
										1.4981	1.1450	8.8	11.46	61.21	-5,425	-5,945		11.45	11.00	11.22	
													0.55	2.96				0.23	0.71	0.24	
													4.78	4.84				2.04	6.44	2.12	
BH2-02-5C-x	1	T7LLSB7SA,7SB	2-D		Sandwich	12	3.0	6.0	2.25	2.2482	1.1462	15.4	17.46	62.12	-5,432	-5,590		11.56	11.56	11.56	
	2	T7LLSB7SA,7SB	LLS		Width					2.2470	1.1490	14.4	17.39	61.92	-5,976	-5,172		10.68	12.14	11.41	
	3	T7LLSB7SA,7SB			Effect					2.2495	1.1517	16.4	18.29	65.03	-6,008	na		11.24	11.17	11.20	
										2.2482	1.1489	15.4	17.71	63.02	-5,805	-5,381		11.16	11.62	11.39	
													0.50	1.74				0.45	0.49	0.18	
													2.81	2.76				4.00	4.21	1.60	

Project #: BH0002

intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Material: AS4/Shell 1895

Textile Test Method Development

Task 5

Compression Test Program

2-D Braided Architectures

intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions: total Length (in)	Nominal Dimensions: tab Length (in)	Nominal Dimensions: gage length (in)	Nominal Dimensions: Width (in)	Avg Width (in)	Avg Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Axial 1 Strain (με)	Ultimate Axial 2 Strain (με)	Ultimate Trans Strain (με)	Axial Modulus: Axial 1 (msi)	Axial Modulus: Axial 2 (msi)	Axial Modulus: Average (msi)	Poisson's Ratio
BH2-01-5D-x	1	T7SLLB7SD.7SA	2-D		Sand Gage	8	3.0	2.0	3.00	3.0033	1.1055	17.2	19.47	51.85	-7,338	-7,191		7.67	7.56	7.62	
	2	T7SLLB7SD.7SA	SLL		Length					3.0023	1.1038	16.4	21.34	56.86	-6,866	-8,345		7.65	8.63	8.14	
	3	T7SLLB7SD.7SA			Effect					3.0005	1.1048	15.2	18.16	48.41	-6,599	-6,214		7.71	7.97	7.84	
										3.0021	1.1047	16.3	19.65	52.37	-6,934	-7,250		7.67	8.06	7.87	
													1.60	4.25				0.03	0.54	0.26	
													8.14	8.11				0.38	6.69	3.33	
BH2-01-5E-x	1	T7SLLB7SD.7SA	2-D		Sand. Gage	14	3.0	8.0	3.00	2.9973	1.1155	14.7	18.50	49.36	-5,953	-7,193		8.65	6.89	7.77	
	2	T7SLLB7SD.7SA	SLL		Length					2.9975	1.1090	14.7	17.14	45.76	-5,775	-5,581		8.09	8.27	8.18	
	3	T7SLLB7SD.7SA			Effect					2.9955	1.1035	14.5	15.02	40.11	-5,113	-5,013		7.85	8.09	7.97	
										2.9968	1.1093	14.6	16.89	45.08	-5,614	-5,929		8.20	7.75	7.97	
													1.75	4.66				0.41	0.75	0.21	
													10.38	10.35				4.99	9.73	2.59	
BH2-02-5D-x	1	T7LLSB7SA.7SB	2-D		Sand. Gage	8	3.0	2.0	3.00	2.9987	1.1475	21.7	24.04	64.13	-6,250	-5,974		10.62	11.02	10.82	
	2	T7LLSB7SA.7SB	LLS		Length					2.9992	1.1473	18.3	24.69	65.86	-5,821	-6,423		11.04	11.15	11.10	
	3	T7LLSB7SA.7SB			Effect					3.0025	1.1420	15.8	23.70	63.15	-5,880	-6,040		11.22	10.63	10.92	
										3.0001	1.1456	18.6	24.14	64.38	-5,984	-6,146		10.96	10.93	10.95	
													0.50	1.37				0.31	0.27	0.14	
													2.09	2.13				2.81	2.47	1.28	
BH2-02-5E-x	1	T7LLSB7SD.9SA	2-D		Sand. Gage	14	3.0	8.0	3.00	2.9972	1.1478	20.9	23.47	62.65	-5,605	-5,738		11.69	11.13	11.41	
	2	T7LLSB7SD.9SA	LLS		Length					2.9948	1.1502	17.2	23.99	64.08	-7,068	-4,637		9.88	12.55	11.22	
	3	T7LLSB7SD.9SA			Effect					2.9980	1.1583	19.3	20.71	55.27	-4,740	-5,050		11.63	11.53	11.58	
										2.9967	1.1521	19.1	22.72	60.67	-5,804	-5,142		11.07	11.74	11.40	
													1.76	4.73				1.03	0.74	0.18	
													7.75	7.80				9.28	6.26	1.59	
BH2-01-5F-x	1	T7SLLB7SC.7SB	2-D		Sandwich	12	3.0	6.0	3.00	3.0022	1.1080		17.82	47.48	-6,049	-5,997		7.99	7.99	7.99	
	2	T7SLLB7SC.7SB	SLL		Core					2.9993	1.1078	16.6	18.71	49.91	-5,898	-6,354		8.38	8.16	8.27	
	3	T7SLLB7SC.7SB			Effect					2.9990	1.1032	16.7	19.90	53.08	-7,552	-6,785		8.08	7.79	7.94	
										3.0002	1.1063	16.7	18.81	50.16	-6,500	-6,379		8.15	7.98	8.07	
													1.04	2.81				0.20	0.19	0.18	
													5.55	5.60				2.45	2.34	2.20	
BH2-02-5F-x	1	T7LLSB9SB.7SC	2-D		Sandwich	12	3.0	6.0	3.00	3.0002	1.1447	19.4	20.38	54.35	-5,240	-4,936		10.64	11.09	10.87	
	2	T7LLSB9SB.7SC	LLS		Core					3.0013	1.1452	18.7	22.81	60.81	-5,345	-5,481		11.70	11.35	11.53	
	3	T7LLSB9SB.7SC			Effect					3.0002	1.1462	21.5	23.76	63.36	-5,551	-5,514		11.89	11.60	11.75	
										3.0006	1.1453	19.9	22.32	59.50	-5,379	-5,310		11.41	11.35	11.38	
													1.74	4.64				0.68	0.25	0.46	
													7.81	7.81				5.92	2.23	4.03	
BH2-01-5G-x	1	T7-SLL-C-4B	2-D	0.619	NASA SB	1.5			1.50	1.5023	0.2131	19.5	24.24	75.73	-8,561	-10,775	2,311	8.53	8.53	8.53	0.207
	2	T7-SLL-C-4B	SLL	0.619	Baseline					1.5017	0.2127	24.1	25.27	79.12	-10,090	-8,955	1,819	8.63	8.98	8.81	0.165
	3	T7-SLL-C-3B		0.619						1.5000	0.2152		26.81	83.05	-9,983	-10,944	1,542	8.84	8.63	8.74	0.119
										1.5013	0.2136	21.8	25.44	79.30	-9,545	-10,225	1,891	8.67	8.71	8.69	0.163
													1.29	3.66				0.16	0.24	0.14	0.044
													5.08	4.62				1.85	2.70	1.64	26.87
BH2-02-5G-x	1	T7-LLS-C-4A	2-D	0.570	NASA SB	1.5			1.50	1.5190	0.2210	19.2	21.43	63.83	-7,972	-7,806	3,534	7.72	9.20	8.46	0.516
	2	T7-LLS-C-4A	LLS	0.570	Baseline					1.5168	0.2213	16.9	21.26	63.34	na	na	na	8.45	8.81	8.63	0.594
	3	T7-LLS-C-3A		0.624						1.5017	0.2188	14.3	20.16	61.36	na	-6,678	3,880	7.88	10.24	9.06	0.490
										1.5125	0.2204	16.8	20.95	62.84	-7,972	-7,242	3,707	8.02	9.42	8.72	0.533
													0.69	1.31				0.39	0.74	0.31	0.054
													3.29	2.08				4.81	7.84	3.53	10.19

Project #: BH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development

Task 5

Compression Test Program

2-D Braided Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions: total Length (in)	Nominal Dimensions: tab Length (in)	Nominal Dimensions: gage length (in)	Nominal Dimensions: Width (in)	Avg Width (in)	Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Axial 1 Strain (με)	Ultimate Axial 2 Strain (με)	Ultimate Trans Strain (με)	Axial Modulus: Axial 1 (msi)	Axial Modulus: Axial 2 (msi)	Axial Modulus: Average (msi)	Poisson's Ratio
BH2-03-5G-x	1	T5-LLL-C-1A	2-D	0.611	NASA SB	1.5			1.50	1.5188	0.2117	14.1	20.49	63.72	-7,791	-9,788	1,073	7.53	8.15	7.84	0.105
	2	T5-LLL-C-1A	LLL	0.611	Baseline					1.5190	0.2134	11.1	21.87	67.49	-8,617	-10,728	1,785	9.42	7.13	8.28	0.109
	3	T5-LLL-C-1A		0.611						1.5163	0.2137	13.1	18.73	57.81	-7,605	-7,243	731	8.16	7.91	8.03	0.113
										1.5181	0.2129	12.8	20.36	63.01	-8,004	-9,253	1,196	8.37	7.73	8.05	0.109
													1.58	4.88				0.96	0.53	0.22	0.004
													7.74	7.75				11.46	6.84	2.71	3.55
BH2-04-5G-x	1	T7-LSS-C-2B	2-D	0.581	NASA SB	1.5			1.50	1.5013	0.2224	12.8	14.70	44.02	na	-13,020	na	4.23	4.36	4.29	0.646
	2	T7-LSS-C-2B	LSS	0.581	Baseline					1.5018	0.2231	14.0	15.22	45.43	na	-12,306	na	3.64	3.79	3.71	0.661
	3	T7-LSS-C-2B		0.581						1.5012	0.2228	11.1	14.90	44.54	na	na	na	3.72	3.80	3.76	0.644
										1.5014	0.2228	12.6	14.94	44.67		-12,663		3.86	3.98	3.92	0.650
													0.26	0.72				0.32	0.33	0.32	0.009
													1.76	1.60				8.29	8.23	8.24	1.45
BH2-01-5H-x	2	T7-SLL-C-5A	2-D	0.606	NASA SB	1.0			1.50	1.5018	0.2117		25.01	78.66	-28,473			8.66		8.66	
	3	T7-SLL-C-5A	SLL	0.606	gage length					1.5028	0.2118	22.5	25.29	79.45	-30,457			6.50		6.50	
	4	T7-SLL-C-5A		0.606						1.5013	0.2124	25.8	26.30	82.47	-28,946			7.21		7.21	
										1.5020	0.2120	25.8	25.53	80.19	-29,292			7.46		7.46	
													0.68	2.01				1.10		1.10	
													2.66	2.51				14.78		14.78	
BH2-01-5I-x	1	T7-SLL-C-1B	2-D	0.608	NASA SB	2.0			1.50	1.5008	0.2216	22.3	23.06	69.32	-10,062	-9,362		6.97	8.22	7.59	
	2	T7-SLL-C-5A	SLL	0.606	gage length					1.5007	0.2134	24.4	25.96	81.08	-11,470	-9,261		8.21	8.55	8.38	
	3	T7-SLL-C-1B		0.608						1.5008	0.2212	16.6	22.30	67.16	-10,336	-10,050		6.49	8.12	7.30	
										1.5008	0.2187	21.1	23.77	72.52	-10,623	-9,557		7.22	8.30	7.76	
													1.93	7.49				0.89	0.23	0.56	
													8.13	10.33				12.34	2.74	7.20	
BH2-02-5H-x	1	T7-LLS-C-7B	2-D	0.605	NASA SB	1.0			1.50	1.5013	0.2284		24.96	72.78	-30,533			5.75		5.75	
	2	T7-LLS-C-7B	LLS	0.605	gage length					1.5022	0.2258	25.0	27.64	81.49	-29,373			7.69		7.69	
	3	T7-LLS-C-7B		0.605						1.5013	0.2191	25.2	24.92	75.76	-30,228			6.99		6.99	
										1.5019	0.2209	25.2	24.92	76.68	-30,228			7.34		7.34	
													1.92	4.05				0.50		0.50	
													7.70	5.29				6.81		6.81	
BH2-02-5I-x	1	T7-LLS-C-3A	2-D	0.624	NASA SB	2.0			1.50	1.5012	0.2213	19.5	20.96	63.08	-7,690	-8,498		9.32	7.82	8.57	
	2	T7-LLS-C-3A	LLS	0.624	gage length					1.5017	0.2201	19.5	22.00	66.56	-8,138	na		9.96	7.51	8.73	
	3	T7-LLS-C-3A		0.624						1.5018	0.2182	15.1	16.20	49.44	-6,160	-6,526		8.38	8.87	8.63	
												18.0	19.72	59.69	-7,329	-7,512		9.22	8.07	8.64	
													3.09	9.05				0.79	0.72	0.08	
													15.67	15.16				8.61	8.86	0.94	
BH2-01-5J-x	1	T7-SLL-C-1A	2-D	0.574	NASA	10.0			5.00	5.0025	0.2071	29.0	42.97	41.47	-3,316	-5,287	na	10.08	8.57	9.33	0.152
	2	T7-SLL-C-1A	SLL	0.574	ST-4					5.0017	0.2120		45.75	43.15	-5,379	-3,523	1,699	8.35	9.85	9.10	0.332
	3	T7-SLL-C-5A		0.601						5.0055	0.2136	41.0	49.26	46.07	-5,868	-3,620	1,429	9.30	8.95	9.13	0.075
												35.0	45.99	43.56	-4,855	-4,143	1,564	9.24	9.12	9.18	0.186
													3.15	2.33				0.86	0.65	0.12	0.132
													6.85	5.34				9.34	7.16	1.34	70.64
BH2-02-5J-x	1	T5-LLS-C-2A	2-D	0.599	NASA	10.0			5.00	5.0090	0.2258	35.0	54.75	48.40	-7,168	-3,881	5,164	9.13	8.38	8.76	0.514
	2	T5-LLS-C-2A	LLS	0.599	ST-4					5.0113	0.2261	37.0	51.93	45.83	-7,069	-2,905	6,769	8.43	9.45	8.94	0.797
	3	T7-LLS-C-1A		0.575						5.0085	0.2192	44.0	49.12	44.75	-7,931	na	na	7.76	11.07	9.42	0.891
												38.7	51.93	46.33	-7,389	-3,393	5,966	8.44	9.64	9.04	0.734
													2.82	1.88				0.69	1.36	0.34	0.196
													5.42	4.05				8.13	14.07	3.77	26.77

Project #: BH0002

intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development

Task 5
Compression Test Program
2-D Braided Architectures

Material: AS4/Shell 1895

intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions: total Length (in)	tab Length (in)	gage length (in)	Width (in)	Avg Width (in)	Avg Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Axial 1 Strain (με)	Ultimate Axial 2 Strain (με)	Ultimate Trans Strain (με)	Axial Modulus: Axial 1 (msi)	Axial 2 (msi)	Average (msi)	Poisson's Ratio
BH2-03-5J-x	1	T5-LLL-C-1A	2-D	0.611	NASA	10.0			5.00	5.0080	0.2235	43.0	47.84	42.75	-4,303	-5,447	na	9.69	7.99	8.84	0.108
	2	T5-LLL-C-2A	LLL	0.621	ST-4					5.0010	0.2291	42.0	53.67	46.85	-6,930	-3,908	1,901	8.24	8.74	8.49	0.159
	3	T5-LLL-C-2A		0.621						5.0005	0.2311	36.0	51.29	44.38	-6,369	-4,089	1,413	7.66	9.36	8.51	0.223
												40.3	50.93	44.66	-5,867	-4,482	1,657	8.53	8.70	8.61	0.163
													2.93	2.06				1.05	0.69	0.20	0.058
													5.76	4.62				12.28	7.92	2.27	35.35
BH2-04-5J-x	1	T7-LSS-C-2B	2-D	0.581	NASA	10.0			5.00	5.0025	0.2159	38.0	43.53	40.30	-10,811	-9,468	8,992	4.40	4.76	4.58	0.803
	2	T7-LSS-C-4A	LSS	0.578	ST-4					5.0032	0.2074	38.0	46.93	45.23	-12,083	-12,011	9,194	4.59	4.48	4.53	0.709
	3	T7-LSS-C-4A		0.578						4.9998	0.2133	33.0	42.56	39.91	-11,120	-8,671	9,193	4.35	4.90	4.62	0.805
												36.3	44.34	41.81	-11,338	-10,050	9,126	4.45	4.71	4.58	0.772
													2.29	2.96				0.12	0.21	0.05	0.055
													5.18	7.09				2.78	4.53	1.00	7.11
BH2-01-5K-x	1	T5-SLL-C-1B	2-D	0.623	Boeing	10.0			4.00	4.0013	0.2060		52.01	63.09	-7,010	-6,833	1,346	9.62	9.16	9.39	0.158
	2	T5-SLL-C-1B	SLL	0.623	CAI					4.0023	0.2041	50.0	58.25	71.31	-6,265	-9,356	na	10.51	8.64	9.57	0.112
	3	T5-SLL-C-1B		0.623	fixture					4.0015	0.2038	50.0	51.62	63.30	-7,519	-6,262	1,773	9.16	9.68	9.42	0.189
												50.0	53.96	65.90	-6,931	-7,484	1,560	9.76	9.16	9.46	0.153
													3.72	4.68				0.68	0.52	0.10	0.039
													6.89	7.11				7.00	5.67	1.04	25.37
BH2-02-5K-x	1	T7-LLS-C-1A	2-D	0.575	Boeing	10.0			4.00	4.0082	0.2196	47.4	49.37	56.08	-6,267	-6,218	3,400	9.08	9.34	9.21	0.471
	2	T7-LLS-C-1A	LLS	0.575	CAI					4.0085	0.2188	48.0	49.13	56.01	-6,009	-6,264	3,145	9.52	9.26	9.39	0.489
	3	T5-LLS-C-2B		0.584	fixture					4.0013	0.2197	40.0	46.02	52.35	-6,373	-6,035	3,298	8.54	9.05	8.80	0.508
												45.1	48.17	54.82	-6,216	-6,172	3,281	9.05	9.22	9.13	0.492
													1.87	2.13				0.49	0.15	0.30	0.019
													3.88	3.89				5.41	1.62	3.33	3.93
BH2-03-5K-x	1	T5-LLL-C-1A	2-D	0.611	Boeing	10.0			4.00	4.0000	0.2289	45.0	52.84	57.72	-6,635	-7,272	1,293	8.46	8.55	8.50	0.153
	2	T5-LLL-C-1A	LLL	0.611	CAI					4.0088	0.2137	40.0	47.36	55.29	-6,290	-6,232	1,573	8.72	9.08	8.90	0.183
	3	T5-LLL-C-1A		0.611	fixture					4.0095	0.2081	42.0	48.51	58.13	-7,341	-6,180	796	8.46	9.67	9.06	0.154
												42.3	49.57	57.05	-6,755	-6,561	1,220	8.55	9.10	8.82	0.163
													2.89	1.54				0.15	0.56	0.29	0.017
													5.83	2.69				1.77	6.13	3.25	10.20
BH2-04-5K-x	1	T7-LSS-C-2B	2-D	0.581	Boeing	10.0			4.00	4.0358	0.2206	30.0	36.77	41.29	-10,813	-11,806	8,964	4.34	4.37	4.35	0.673
	2	T7-LSS-C-2B	LSS	0.581	CAI					4.0010	0.2234	34.0	37.58	42.04	-12,746	-12,174	na	4.07	4.20	4.13	0.720
	3	T7-LSS-C-2B		0.581	fixture					4.0012	0.2208	35.0	37.45	42.40	-12,800	-12,849	na	4.13	4.16	4.15	0.692
												33.0	37.27	41.91	-12,120	-12,276	8,964	4.18	4.24	4.21	0.695
													0.44	0.56				0.14	0.11	0.12	0.024
													1.17	1.34				3.42	2.58	2.94	3.46
BH2-01-5L-x	1	T7-SLL-B-1A	2-D	0.635	IITRI	6.0	2.5	1.0	1.50	1.4993	0.1067		11.13	69.61	-9,562	-7,195	1,254	8.18	10.04	9.11	0.181
	2	T7-SLL-B-1A	SLL	0.635	Baseline					1.5030	0.1060		11.55	72.50	-10,131	-7,286	1,293	8.77	9.88	9.32	0.162
	3	T7-SLL-B-1A		0.635						1.5010	0.1060		11.10	69.77	-7,040	-8,554	1,200	9.11	9.83	9.47	0.163
													11.26	70.63	-8,911	-7,678	1,249	8.68	9.92	9.30	0.169
													0.25	1.63				0.47	0.11	0.18	0.011
													2.23	2.30				5.43	1.15	1.93	6.30
BH2-02-5L-x	1	T7-LLS-B-4B	2-D	0.618	IITRI	6.0	2.5	1.0	1.50	1.5015	0.1017		10.25	67.13	-7,287	-6,766	4,168	10.02	10.69	10.35	0.583
	2	T7-LLS-B-4B	LLS	0.618	Baseline					1.5020	0.1045		9.63	61.35	-5,842	na	3,026	10.42	9.68	10.05	0.447
	3	T7-LLS-B-4B		0.618						1.5000	0.1073		10.58	65.69	-7,286	na	4,207	9.58	7.25	8.41	0.380
													10.15	64.73	-6,805	-6,766	3,800	10.00	9.21	9.61	0.470
													0.48	3.01				0.42	1.77	1.04	0.104
													4.73	4.65				4.24	19.19	10.86	22.07

Project #: BH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development
Task 5
Compression Test Program
2-D Braided Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions: total Length (in)	tab Length (in)	gage length (in)	Width (in)	Avg Width (in)	Avg Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Axial 1 Strain (με)	Ultimate Axial 2 Strain (με)	Ultimate Trans Strain (με)	Axial Modulus: Axial 1 (msi)	Axial 2 (msi)	Average (msi)	Poisson's Ratio
BH2-03-5L-x	1	T7-LLL-B-2A	2-D	0.638	IITRI	6.0	2.5	1.0	1.50	1.5015	0.1073		6.87	42.60	-4,857	-4,295	720	9.40	6.29	7.85	0.106
	2	T7-LLL-B-2A	LLL	0.638	Baseline					1.5010	0.1083		10.21	62.77	-5,595	-7,727	719	9.64	9.40	9.52	0.145
	3	T7-LLL-B-2A		0.638						1.5010	0.1083	7.5	9.58	58.94	-6,993	-5,236	1,820	9.36	9.72	9.54	0.180
												7.5	8.89	54.77	-5,815	-5,753	1,086	9.47	8.47	8.97	0.144
													1.78	10.71				0.15	1.90	0.97	0.037
													20.00	19.56				1.60	22.39	10.86	25.73
BH2-04-5L-x	1	T7-LSS-B-4B	2-D	0.619	IITRI	6.0	2.5	1.0	1.50	1.5033	0.1050	7.3	7.58	48.05	-13,945	-12,722	9,333	4.57	4.76	4.66	0.633
	2	T7-LSS-B-4B	LSS	0.619	Baseline					1.5010	0.1040		8.18	52.40	na	-14,722	10,504	3.73	4.85	4.29	0.622
	3	T7-LSS-B-4B		0.619						1.5000	0.1040		8.11	51.98	-15,104	-15,108	10,346	4.56	4.93	4.75	0.625
												7.3	7.96	50.81	-14,524	-14,184	10,061	4.29	4.85	4.57	0.627
													0.33	2.40				0.48	0.09	0.24	0.006
													4.09	4.73				11.25	1.84	5.33	0.90
BH2-01-5M-x	1	T7-SLL-C-3B	2-D	0.601	IITRI	6.5	2.5	1.5	1.50	1.5008	0.2195	11.8	23.24	70.53	-7,169	-8,223	1,666	8.62	8.75	8.68	0.180
	2	T7-SLL-C-3B	SLL	0.601	Baseline					1.5010	0.2185	20.5	23.25	70.88	-9,302	-8,327	1,036	8.30	8.57	8.43	0.120
	3	T7-SLL-C-3B		0.601						1.5007	0.2168		23.43	72.01	-8,917	-8,370	949	8.91	8.77	8.84	0.123
												16.2	23.31	71.14	-8,463	-8,307	1,217	8.61	8.70	8.65	0.141
													0.11	0.77				0.30	0.11	0.20	0.034
													0.47	1.09				3.51	1.31	2.36	23.90
BH2-02-5M-x	1	T7-LLS-C-3A	2-D	0.624	IITRI	6.5	2.5	1.5	1.50	1.5015	0.2228		19.90	59.48	-7,350	-6,274	3,586	8.65	9.33	8.99	0.546
	2	T7-LLS-C-3A	LLS	0.624	Baseline					1.5000	0.2209		18.97	57.23	-6,743	-7,196	4,260	8.69	8.26	8.48	0.565
	3	T7-LLS-C-3A		0.624						1.4995	0.2210		18.28	55.15	-6,132	-6,755	3,769	8.42	8.30	8.36	0.538
													19.05	57.29	-6,742	-6,742	4,015	8.59	8.63	8.61	0.549
													0.81	2.17				0.19	0.03	0.08	0.019
													4.27	3.78				2.23	0.30	0.96	3.44
BH2-03-5M-x	1	T7-LLL-C-1B	2-D	0.641	IITRI	6.5	2.5	1.5	1.50	1.5025	0.2218		17.39	52.19	-5,982	-6,595	1,008	9.11	8.52	8.81	0.141
	2	T7-LLL-C-1B	LLL	0.641	Baseline					1.5000	0.2217		15.50	46.62	-5,990	-5,343	671	8.93	8.62	8.77	0.129
	3	T7-LLL-C-1B		0.641						1.5010	0.2214		14.01	42.16	-4,759	-5,024	956	8.67	9.41	9.04	0.165
													15.63	46.99	-5,577	-5,654	878	8.90	8.85	8.88	0.145
													1.69	5.02				0.22	0.49	0.15	0.018
													10.82	10.69				2.47	5.55	1.64	12.45
BH2-04-5M-x	1	T7-LSS-C-1A	2-D	0.622	IITRI	6.5	2.5	1.5	1.50	1.5007	0.2038	12.0	13.86	45.32	-13,825	-12,186	11,217	4.55	4.76	4.65	0.783
	2	T7-LSS-C-1A	LSS	0.622	Baseline					1.5000	0.2025	12.1	14.10	46.40	-12,715	-12,881	10,239	4.79	4.72	4.75	0.700
	3	T7-LSS-C-1A		0.622						1.5010	0.2018	12.8	14.05	46.39	-13,560	-12,862	10,069	4.66	5.10	4.88	0.774
												12.3	14.00	46.04	-13,367	-12,643	10,508	4.67	4.86	4.76	0.752
													0.12	0.62				0.12	0.21	0.11	0.046
													0.89	1.35				2.61	4.33	2.40	6.09
BH2-01-5N-x	1	T7-SLL-C-4B	2-D	0.619	IITRI	6.0	2.5	1.0	1.50	1.5008	0.2225	16.1	23.76	71.14	-7,340	-9,391		10.04	7.95	9.00	
	2	T7-SLL-C-4B	SLL	0.619	Gage length					1.5007	0.2195		20.76	63.04	-7,305	-7,496		8.45	9.09	8.77	
	3	T7-SLL-C-4B		0.619	Effect					1.5000	0.2182		25.88	79.09	-7,427	-11,711		8.98	9.18	9.08	
	4*	T7-SLL-C-4B		0.619						1.5010	0.2173		21.37	65.50	-5,829	-9,766		9.24	8.59	8.91	
												16.1	22.94	69.69	-6,975	-9,591		9.18	8.70	8.94	
													2.35	7.12				0.66	0.57	0.13	
													10.23	10.22				7.23	6.51	1.50	

Project #: BH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Material: AS4/Shell 1895

Textile Test Method Development
Task 5
Compression Test Program
2-D Braided Architectures

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions total Length (in)	tab Length (in)	gage length (in)	Width (in)	Avg Width (in)	Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Axial 1 Strain (με)	Ultimate Axial 2 Strain (με)	Ultimate Trans Strain (με)	Axial Modulus Axial 1 (msi)	Axial 2 (msi)	Average (msi)	Poisson's Ratio
BH2-01-5O-x	1	T7-SLL-C-5A	2-D	0.601	IITRI	7.0	2.5	2.0	1.50	1.4998	0.2146	13.1	14.59	45.33	-5,060	-5,242		8.97	8.77	8.87	
	2	T7-SLL-C-5A	SLL	0.601	Gage length					1.4995	0.2169		21.97	67.54	-7,798	-7,630		9.00	9.14	9.07	
	3	T7-SLL-C-5A		0.601	Effect					1.5000	0.2149		24.60	76.32	-8,781	-9,079		9.14	8.71	8.93	
												13.1	20.39	63.06	-7,213	-7,317		9.04	8.87	8.96	
													5.19	15.97				0.09	0.23	0.10	
													25.46	25.32				0.98	2.58	1.15	
BH2-02-5N-x	1	T5-LLS-C-2A	2-D	0.599	IITRI	6.0	2.5	1.0	1.50	1.5000	0.2247		18.47	54.80	-7,549	-7,275		7.70	8.07	7.88	
	2	T5-LLS-C-2A	LLS	0.599	Gage length					1.4995	0.2249		20.86	61.83	-6,892	-7,311		9.02	9.18	9.10	
	3	T5-LLS-C-2A		0.599	Effect					1.4990	0.2265		20.67	60.86	-7,888	-7,190		8.34	8.78	8.56	
													20.00	59.16	-7,443	-7,259		8.35	8.68	8.51	
													1.32	3.81				0.66	0.56	0.61	
													6.62	6.45				7.91	6.50	7.16	
BH2-02-5O-x	1	T7-LLS-C-7B	2-D	0.605	IITRI	7.0	2.5	2.0	1.50	1.5010	0.2175	12.4	18.89	57.86	-6,590	-7,064		9.90	9.56	9.73	
	2	T7-LLS-C-7B	LLS	0.605	Gage length					1.5000	0.2160	19.5	20.36	62.84	-7,082	-7,940		9.02	8.61	8.82	
	2	T7-LLS-C-7B		0.605	Effect					1.5018	0.2148	18.4	22.39	69.40	-7,379	-9,626		8.95	8.65	8.80	
												16.8	20.55	63.37	-6,684	-8,210		9.29	8.94	9.12	
													1.76	5.78				0.53	0.54	0.53	
													8.55	9.13				5.72	6.00	5.85	
BH2-01-5P-x	1	T7-SLL-B-3B	2-D	0.600	Boeing	12.0			1.50	1.5008	0.1079		13.63	84.19	-8,373	-11,143		9.42	9.17	9.30	
	2	T7-SLL-B-4B	SLL	0.611	OH fixture					1.5002	0.1068		21.64	135.09	-7,435	na		9.29	9.46	9.38	
	3	T7-SLL-B-3B		0.600	baseline					1.4998	0.1090		15.09	92.36	-2,842	na		8.58	9.65	9.12	
													14.36	88.27	-6,217	-11,143		9.10	9.43	9.26	
													1.03	5.77				0.45	0.24	0.13	
													7.20	6.54				5.00	2.57	1.45	
BH2-02-5P-x	1	T7-LLS-B-XA	2-D	0.599	Boeing	12.0			1.50	1.5007	0.1114	9.1	10.20	60.99	-6,474	-7,296		10.91	9.21	10.06	
	2	T7-LLS-B-XB	LLS	0.608	OH fixture					1.5013	0.1094	8.7	9.17	55.84	-4,810	-6,080		10.94	10.34	10.64	
	3	T7-LLS-B-XA		0.599	baseline					1.5092	0.1112	8.6	10.16	60.57	-5,758	-7,198		10.99	9.15	10.07	
												8.8	9.84	59.13	-5,347	-6,858		10.95	9.57	10.26	
													0.58	2.86				0.04	0.67	0.33	
													5.92	4.83				0.36	6.99	3.22	
BH2-03-5P-x	1	T7-LLL-B-1A	2-D	0.644	Boeing	12.0			1.50	1.5020	0.1075		20.41	126.37	-5,319	-8,951		24.11	15.36	19.74	
	2	T7-LLL-B-3B	LLL	0.661	OH fixture					1.5050	0.1130	11.0	11.42	67.14	-5,746	-9,207		10.71	8.29	9.50	
	3	T7-LLL-B-3B		0.661	baseline					1.5020	0.1129	8.8	9.82	57.90	-4,812	-8,969		10.43	7.59	9.01	
												9.9	13.88	83.80	-5,292	-9,042		15.08	10.41	12.75	
													5.71	37.15				7.82	4.30	6.06	
													41.13	44.33				51.86	41.29	47.52	
BH2-04-5P-x	1	T7-LSS-B-3B	2-D	0.629	Boeing	12.0			1.50	1.5010	0.1067	6.5	7.02	43.84	-10,120	-11,896		5.16	4.49	4.82	
	2	T7-LSS-B-3B	LSS	0.629	OH fixture					1.5003	0.1070	6.0	6.91	43.06	-13,636	-9,751		4.87	4.57	4.72	
	3	T7-LSS-B-3B		0.629	baseline					1.4983	0.1071	6.2	7.11	44.31	-10,576	-13,276		5.15	4.51	4.83	
												6.2	7.01	43.74	-11,444	-11,641		5.06	4.52	4.79	
													0.10	0.63				0.17	0.04	0.06	
													1.40	1.45				3.30	0.86	1.34	
BH2-01-5R-x	3	T5-SLL-A-9	2-D	0.520	Boeing	12.0			1.50	1.5238	0.1103	11.8	13.05	77.65	-8,233	-6,329		11.44	10.73	11.08	
	4	T5-SLL-A-12	SLL	0.433	OH fixture					1.5302	0.1209	8.5	11.63	62.89	-8,488	-10,332		7.62	7.13	7.37	
	5	T5-SLL-A-12		0.433	net-shape					1.5212	0.1209	10.1	11.34	61.69	-10,333	na		8.58	6.82	7.70	
												10.1	12.01	67.41	-9,038	-8,330		9.21	8.22	8.72	
													0.92	8.89				1.99	2.17	2.05	
													7.62	13.19				21.57	26.42	23.56	

Project #: BH0002

Intec Engineer: Maryann Einerson
Boeing Engineer: Mark Fedro

Textile Test Method Development
Task 5
Compression Test Program
2-D Braided Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions: total Length (in)	Nominal Dimensions: tab Length (in)	Nominal Dimensions: gage length (in)	Nominal Dimensions: Width (in)	Avg Width (in)	Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Axial 1 Strain (με)	Ultimate Axial 2 Strain (με)	Ultimate Trans Strain (με)	Axial Modulus: Axial 1 (msi)	Axial Modulus: Axial 2 (msi)	Axial Modulus: Average (msi)	Poisson's Ratio
BH2-02-5R-x	1	T5-LLS-A-12	2-D	0.513	Boeing	12.0			1.50	1.5285	0.1216	8.5	9.73	52.37	-8,237	-6,618		8.00	7.10	7.55	
	2	T5-LLS-A-12	LLS	0.513	OH fixture					1.5282	0.1161	7.7	10.49	59.13	-7,742	-7,234		8.21	8.25	8.23	
	3	T7-LLS-A-16		0.486	net-shape					1.5205	0.1173	8.8	10.48	58.75	-7,769	-7,425		8.05	8.32	8.18	
												8.3	10.23	56.75	-7,916	-7,092		8.09	7.89	7.99	
													0.44	3.80				0.11	0.68	0.38	
													4.26	6.69				1.37	8.65	4.74	
BH2-03-5R-x	1	T7-LLL-A-3	2-D	0.538	Boeing	12.0			1.50	1.5295	0.1239	10.7	11.71	61.78	-7,347	-10,741		8.81	6.13	7.47	
	2	T7-LLL-A-3	LLL	0.538	OH fixture					1.5273	0.1220	10.0	10.94	58.71	-7,548	-9,653		8.57	6.20	7.39	
	3	T7-LLL-A-8		0.522	net-shape					1.5267	0.1157	10.0	11.03	62.45	-8,882	-8,349		7.15	8.23	7.69	
												10.2	11.23	60.98	-7,926	-9,581		8.18	6.85	7.52	
													0.42	1.99				0.90	1.19	0.16	
													3.75	3.27				10.95	17.41	2.10	
BH2-04-5R-x	1	T7-LSS-A-10	2-D	0.520	Boeing	12.0			1.50	1.5202	0.1161	3.8	5.18	29.36	-11,684	-12,047		4.54	4.36	4.45	
	2	T7-LSS-A-10	LSS	0.520	OH fixture					1.5255	0.1151	5.0	5.35	30.47	-8,231	-9,658		4.36	4.44	4.40	
	3	T7-LSS-A-11		0.512	net-shape					1.5148	0.1192	3.7	5.95	32.95	-8,723	-11,259		4.66	4.01	4.34	
												4.2	5.49	30.93	-9,546	-10,988		4.52	4.27	4.40	
													0.40	1.84				0.15	0.23	0.06	
													7.36	5.94				3.39	5.41	1.30	
BH2-01-5W-x	1	T7-SLL-C-4A	2-D	0.605	Transverse	6.5		1.50	1.50	1.5005	0.2218	12.6	13.08	39.28	-5,589			6.91		6.91	
	2	T7-SLL-C-4A	SLL	0.605	IITRI					1.5010	0.2201	10.1	13.95	42.23	-5,830			7.05		7.05	
	3	T7-SLL-C-4A		0.605						1.4993	0.2193	12.4	13.78	41.92	-5,700			7.30		7.30	
												11.7	13.60	41.14	-5,706			7.09		7.09	
													0.46	1.62				0.20		0.20	
													3.41	3.93				2.77		2.77	
BH2-02-5W-x	1	T7-LLS-C-1B	2-D	0.584	Transverse	6.5		1.50	1.50	1.5003	0.2221	7.5	90.02	270.17				2.97		2.97	
	2	T7-LLS-C-1B	LLS	0.584	IITRI					1.5007	0.2204	6.4	87.27	263.82	-9,639			2.99		2.99	
	3	T7-LLS-C-1B		0.584						1.4980	0.2195	6.8	74.05	225.21	-6,971			3.10		3.10	
												6.9	83.78	253.06	-8,305			3.02		3.02	
													8.54	24.33				0.07		0.07	
													10.19	9.62				2.32		2.32	
BH2-03-5W-x	1	T7-LLL-C-4A	2-D	0.602	Transverse	6.5		1.50	1.50	1.4800	0.2269	6.7	10.93	32.55				7.38		7.38	
	2	T7-LLL-C-4A	LLL	0.602	IITRI					1.4812	0.2270	7.9	10.12	30.10				7.53		7.53	
	3	T7-LLL-C-4A		0.602						1.4797	0.2263	9.3	11.05	33.00	-4,547			7.58		7.58	
												8.0	10.70	31.88				7.50		7.50	
													0.51	1.56				0.10		0.10	
													4.73	4.89				1.37		1.37	
BH2-04-5W-x	1	T7-LSS-C-6A	2-D	0.592	Transverse	6.5		1.50	1.50	1.5003	0.2185	14.0	14.04	42.83	-18,722			2.84		2.84	
	2	T7-LSS-C-6A	LSS	0.592	IITRI					1.4988	0.2178	13.1	13.60	41.66	-15,748			3.03		3.03	
	3	T7-LSS-C-6A		0.592						1.5005	0.2175	14.0	14.18	43.44	-16,746			3.12		3.12	
												13.7	13.94	42.64	-17,072			3.00		3.00	
													0.30	0.90				0.15		0.15	
													2.16	2.12				4.90		4.90	
BH2-01-5X-x	1	T7-SLL-B-8B	2-D	0.615	Unnotched	11.0			1.16	1.1565	0.1059	9.1	12.10	98.83	-13,640	-10,450		9	9.63	9.23	
	2	T7-SLL-B-8B	SLL	0.615	Comp					1.1560	0.1054	8.3	10.90	89.44	-12,340	-5,767		9.27	9.05	9.16	
	3	T7-SLL-B-8B		0.615	1/8"					1.1570	0.1042	8.7	9.91	82.23	-10,860	-6,885		9.04	10.79	9.92	
												8.7	10.97	90.16	-12,280	-7,701		9.05	9.82	9.44	
													1.10	8.33				0.23	0.88	0.42	
													10.02	9.23				2.52	8.98	4.42	

Project #: BH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development
Task 5
Compression Test Program
2-D Braided Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions: total Length (in)	Nominal Dimensions: tab Length (in)	Nominal Dimensions: gage length (in)	Nominal Dimensions: Width (in)	Avg Width (in)	Avg Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Axial 1 Strain (με)	Ultimate Axial 2 Strain (με)	Ultimate Trans Strain (με)	Axial Modulus: Axial 1 (msi)	Axial Modulus: Axial 2 (msi)	Axial Modulus: Average (msi)	Poisson's Ratio
BH2-02-5X-x	1	T7-LLS-B-11A	2-D	0.538	Unnotched	11.0			1.16	1.1550	0.1087	6.1	7.27	57.93	-6,429	-6,165		9.40	9.72	9.56	
	2	T7-LLS-B-11A	LLS	0.538	Comp					1.1575	0.1067	5.8	7.33	59.40	-7,074	-6,523		8.75	9.40	9.07	
	3	T7-LLS-B-11A		0.538	1/8"					1.1575	0.1048	6.5	7.85	64.72	-6,292	-7,776		10.31	9.24	9.77	
												6.1	7.48	60.68	-6,598	-6,821		9.49	9.45	9.47	
													0.32	3.57				0.78	0.25	0.36	
													4.23	5.88				8.26	2.61	3.80	
BH2-03-5X-x	1	T7-LLL-B-4A	2-D	0.602	Unnotched	11.0			1.16	1.1550	0.1121	5.9	8.65	66.79	-7,579	-7,847		8.81	9.73	9.27	
	2	T7-LLL-B-4A	LLL	0.602	Comp					1.1535	0.1132	6.0	9.29	71.15	-7,020	-10,280		10.11	7.81	8.96	
	3	T7-LLL-B-4A		0.602	1/8"					1.1555	0.1144	7.5	8.39	63.44	na	-7,564		8.55	8.93	8.74	
												6.5	8.77	67.12	-7,300	-8,564		9.15	8.82	8.99	
													0.47	3.86				0.84	0.97	0.27	
													5.31	5.76				9.14	10.94	2.98	
BH2-04-5X-x	1	T7-LSS-B-6A	2-D	0.623	Unnotched	11.0			1.16	1.1575	0.1050	5.1	5.87	46.61	-11,090	-10,470		5.18	5.27	5.22	
	2	T7-LSS-B-6A	LSS	0.623	Comp					1.1585	0.1026	5.1	6.05	50.87	-13,920	-12,250		4.96	5.13	5.05	
	3	T7-LSS-B-6A		0.623	1/8"					1.1590	0.1009	4.8	5.64	48.28	-12,670	-11,290		4.70	5.39	5.05	
												5.0	5.79	48.59	-12,560	-11,337		4.95	5.26	5.11	
													0.23	2.14				0.24	0.13	0.10	
													3.93	4.41				4.84	2.46	2.01	

Project #: BH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development
Task 5&8
Compression Test Program
3-D Woven Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions total Length (in)	tab Length (in)	gage length (in)	Nom. Dim. Width (in)	Thick (in)	Avg Width (in)	Avg Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Axial 1 Strain (με)	Ultimate Axial 2 Strain (με)	Axial Modulus Axial 1 (msi)	Axial Modulus Axial 2 (msi)	Axial Modulus Average (msi)
BH2-05-5G-x	1	T7-TS1-A-2A	3-D	0.628	NASA SB	1.5			1.50	1/4	1.5005	0.2235		26.59	79.28	-8,047	-7,194	10.41	11.15	10.78
	2	T7-TS1-A-2A	TS-1	0.628	Baseline						1.5005	0.2233		27.28	81.42	-8,889	-6,197	10.95	11.37	11.16
	3	T7-TS1-A-2A		0.628							1.4993	0.2235		26.60	79.39	-7,095	-6,985	11.16	11.67	11.41
											Average			26.82	80.03	-8,010	-6,792	10.84	11.40	11.12
											Std. Dev.			0.40	1.20			0.39	0.26	0.32
											% COV			1.48	1.50			3.58	2.26	2.86
BH2-06-5G-x	1	T7-TS2-A-2B	3-D	0.632	NASA SB	1.5			1.50	1/4	1.5010	0.2078	17.7	22.48	72.06	-7,414	-5,900	11.00	10.58	10.79
	2	T7-TS2-A-2B	TS-2	0.632	Baseline						1.5005	0.2128		24.32	76.18	-6,976	-7,647	10.71	11.02	10.87
	3	T7-TS2-A-2B		0.632							1.5005	0.2177		25.32	77.53	-6,096	-8,968	11.02	10.65	10.84
											Average			24.04	75.26	-6,829	-7,505	10.91	10.75	10.83
											Std. Dev.			1.44	2.85			0.17	0.24	0.04
											% COV			6.00	3.78			1.58	2.21	0.37
BH2-07-5G-x	1	T7-OS1-A-3B	3-D	0.643	NASA SB	1.5			1.50	1/4	1.5007	0.2276	28.1	31.62	92.58	-10,529	-7,321	11.07	11.45	11.26
	2	T7-OS1-A-3B	OS-1	0.643	Baseline						1.5003	0.2270	28.7	30.29	88.95	-9,656	-7,713	11.01	11.39	11.20
	3	T7-OS1-A-3B		0.643							1.5010	0.2268		29.63	87.04	-8,507	-7,812	11.66	11.46	11.56
														30.52	89.52	-9,564	-7,615	11.25	11.43	11.34
														1.01	2.82			0.36	0.03	0.19
														3.32	3.15			3.20	0.30	1.69
BH2-08-5G-x	1	T7-OS2-A-3A	3-D	0.564	NASA SB	1.5			1.50	1/4	1.5010	0.2353		31.96	90.50	-10,623	-9,163	10.11	9.83	9.97
	2	T7-OS2-A-3A	OS-2	0.564	Baseline						1.5010	0.2351		31.51	89.30	-10,061	-7,298	10.20	11.05	10.63
	3	T7-OS2-A-3A		0.564							1.5005	0.2353		28.55	80.87	-9,000	-10,005	9.46	9.18	9.32
											Average			30.67	86.89	-9901	-8822	9.92	10.02	9.97
											Std. Dev.			1.85	5.25			0.40	0.95	0.65
											% COV			6.04	6.04			4.06	9.49	6.55
BH2-09-5G-x	1	T7-LS1-A-5B	3-D	0.646	NASA SB	1.5			1.50	1/4	1.5033	0.2116	27.4	28.62	89.98	-8,253	-6,767	10.57	13.36	11.96
	2	T7-LS1-A-5B	LS-1	0.646	Baseline						1.5035	0.2142		26.21	81.38	-6,769	-6,698	11.52	11.86	11.69
	3	T7-LS1-A-5B		0.646							1.4987	0.2113	27.5	28.33	89.47	-6,832	-8,180	12.76	11.56	12.16
											Average			27.72	86.94	-7,285	-7,215	11.61	12.26	11.94
											Std. Dev.			1.31	5.72			1.10	0.97	0.24
											% COV			4.74	6.58			9.47	7.89	1.98
BH2-10-5G-x	1	T7-LS2-A-2A	3-D	0.653	NASA SB	1.5			1.50	1/4	1.5008	0.2136		24.89	77.62	-7,555	-6,652	12.04	11.20	11.62
	2	T7-LS2-A-2A	LS-2	0.653	Baseline						1.5008	0.2130		29.17	91.26	-7,579	-8,350	11.54	12.39	11.97
	3	T7-LS2-A-2A		0.653							1.5010	0.2211		28.50	85.86	-8,369	-7,386	10.61	11.90	11.25
											Average			27.52	84.91	-7,834	-7,463	11.40	11.83	11.61
											Std. Dev			2.30	6.87			0.73	0.60	0.36
											% COV			8.37	8.09			6.38	5.07	3.07
BH2-05-5M-x	1	T7-TS1-A-3A	3-D	0.615	IITRI	6.5	2.5	1.5	1.50	1/4	1.5018	0.2370	19.9	27.11	76.16	-7,317	-7,415	10.73	10.79	10.76
	2	T7-TS1-A-3A	TS-1	0.615	Baseline						1.4980	0.2411	19.0	25.74	71.26	-6,750	-6,904	10.69	10.82	10.76
	3	T7-TS1-A-3A		0.615							1.5007	0.2342	17.5	28.48	81.03	-6,866	-8,345	11.12	11.18	11.15
											Average			27.11	76.15	-6,978	-7,555	10.85	10.93	10.89
											Std. Dev			1.37	4.88			0.24	0.22	0.23
											% COV			5.06	6.41			2.22	1.98	2.09

Project #: BH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development

Task 5&8
Compression Test Program
3-D Woven Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions total Length (in)	tab Length (in)	gage length (in)	Nom Dim Width (in)	Thick (in)	Avg Width (in)	Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Axial 1 Strain (με)	Ultimate Axial 2 Strain (με)	Axial Modulus Axial 1 (msi)	Axial 2 (msi)	Average (msi)
BH2-06-5M-x	1	T7-TS2-A-2B	3-D	0.632	IITRI	6.5	2.5	1.5	1.50	1/4	1.4990	0.2165		22.42	69.10	-6,152	-6,689	11.19	10.88	11.03
	2	T7-TS2-A-2B	TS-2	0.632	Baseline						1.4972	0.2093	21.6	22.07	70.45	-6,833	-6,010	11.08	11.40	11.24
	3	T7-TS2-A-2B		0.632							1.4973	0.2066	20.0	20.97	67.78	-6,208	-5,872	11.31	11.41	11.36
											Average			21.82	69.11	-6,398	-6,190	11.19	11.23	11.21
											Std. Dev.			0.76	1.34			0.12	0.30	0.17
											% COV			3.48	1.94			1.06	2.70	1.49
BH2-07-5M-x	1	T7-OS1-A-3B	3-D	0.643	IITRI	6.5	2.5	1.5	1.50	1/4	1.5000	0.2269	25.4	27.76	81.58	-7,952	-7,456	11.40	10.99	11.20
	2	T7-OS1-A-3B	OS-1	0.643	Baseline						1.4975	0.2250		29.95	88.90	-8,353	-7,799	11.19	11.55	11.37
	3	T7-OS1-A-3B		0.643							1.4972	0.2241		30.47	90.80	-7,918	-8,345	11.62	11.44	11.53
											Average			29.39	87.09	-8,074	-7,867	11.40	11.33	11.37
											Std. Dev.			1.44	4.87			C.22	0.30	0.17
											% COV			4.89	5.59			1.90	2.61	1.48
BH2-08-5M-x	1	T7-OS2-A-3A	3-D	0.564	IITRI	6.5	2.5	1.5	1.50	1/4	1.5028	0.2389		24.15	67.26	-7,127	-7,971	9.80	9.67	9.74
	2	T7-OS2-A-3A	OS-2	0.564	Baseline						1.4993	0.2372		27.48	77.26	-7,944	-8,832	9.90	9.59	9.74
	3	T7-OS2-A-3A		0.564							1.4985	0.2372		27.33	76.90	-8,036	-9,186	9.90	9.28	9.59
														27.33	73.80	-7,702	-8,663	9.87	9.51	9.69
														1.88	5.67			0.05	0.20	0.08
														6.89	7.68			0.56	2.12	0.87
BH2-09-5M-x	1	T7-LS1-A-6A	3-D	0.637	IITRI	6.5	2.5	1.5	1.50	1/4	1.5003	0.2133		26.89	84.02	-7,849	-7,069	11.94	11.97	11.95
	2	T7-LS1-A-6A	LS-1	0.637	Baseline						1.4993	0.2137		25.12	78.38	-6,567	-6,651	12.33	11.95	12.14
	3	T7-LS1-A-6A		0.637							1.4995	0.2133		25.93	81.06	-6,855	-7,099	12.44	11.91	12.18
											Average			25.93	81.15	-7,090	-6,940	12.24	11.94	12.09
											Std. Dev.			0.89	2.82			0.27	0.03	0.12
											% COV			3.43	3.48			2.18	0.23	1.00
BH2-10-5M-x	1	T7-LS2-A-2A	3-D	0.653	IITRI	6.5	2.5	1.5	1.50	1/4	1.4997	0.2093	19.5	20.94	66.69	-5,686	-5,415	12.23	12.07	12.15
	2	T7-LS2-A-2A	LS-2	0.653	Baseline						1.4977	0.2107	20.5	21.34	67.63	-6,559	-4,730	12.11	11.89	12.00
	3	T7-LS2-A-2A		0.653							1.4990	0.2142	20.5	21.93	68.31	-5,513	-6,306	11.99	11.46	11.73
											Average		20.2	21.93	67.54	-5,919	-5,484	12.11	11.81	11.96
											Std. Dev.			0.50	0.81			0.12	0.31	0.21
											% COV			2.28	1.20			0.99	2.65	1.80
BH2-05-5W-x	1	T7-TS1-A-3A	3-D	0.615	Trans	6.5	2.5	1.5	1.50	1/4	1.5000	0.2330	10.6	13.97	39.98	na	na	5.87	5.87	5.87
	2	T7-TS1-A-3A	TS-1	0.615	IITRI						1.4992	0.2303	9.8	13.52	39.16	na	na	6.00	5.91	5.95
	3	T7-TS1-A-3A		0.615	Baseline						1.4990	0.2283	10.7	12.16	35.53	na	-5,500	6.02	6.14	6.08
											Average		10.4	12.16	38.22		-5,500	5.96	5.97	5.97
											Std Dev			0.94	2.37			0.08	0.14	0.11
											% COV			7.75	6.20			1.38	2.42	1.77
BH2-06-5W-x	1	T7-TS2-A-2A	3-D	0.634	Trans	6.5	2.5	1.5	1.50	1/4	1.4990	0.2275	15.1	18.27	53.58	-8,091	-7,042	7.42	7.51	7.46
	2	T7-TS2-A-2A	TS-2	0.634	IITRI						1.5000	0.2260	14.8	17.26	50.90	-7,000	-6,959	7.46	7.46	7.46
	3	T7-TS2-A-2A		0.634	Baseline						1.4997	0.2256	15.4	18.56	54.85	-7,935	-7,645	7.09	7.33	7.21
											Average		15.1	18.56	53.11	-7,675	-7,215	7.33	7.43	7.38
											Std Dev			0.68	2.01			0.20	0.09	0.15
											% COV			3.68	3.79			2.76	1.24	1.97

Project #: BH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development
Task 5&8
Compression Test Program
3-D Woven Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions: total Length (in)	Nominal Dimensions: tab Length (in)	Nominal Dimensions: gage length (in)	Nom. Dim.: Width (in)	Nom. Dim.: Thick (in)	Avg Width (in)	Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Axial 1 Strain (με)	Ultimate Axial 2 Strain (με)	Axial Modulus: Axial 1 (msi)	Axial Modulus: Axial 2 (msi)	Axial Modulus: Average (msi)
BH2-07-5W-x	1	T7-OS1-A-3A	3-D	0.610	Trans	6.5	2.5	1.5	1.50	1/4	1.4990	0.2335	12.9	14.45	41.28	-7,268	-6,216	6.23	6.43	6.33
	2	T7-OS1-A-3A	OS-1	0.610	IITRI						1.5000	0.2324	12.9	14.15	40.61	na	-5,256	5.97	6.11	6.04
	3	T7-OS1-A-3A		0.610	Baseline						1.5002	0.2318	11.5	14.83	42.66	-7,999	-5,038	6.13	6.16	6.14
											Average		12.4	14.83	41.52	-7,634	-5,503	6.11	6.23	6.17
											Std. Dev.			0.34	1.04			0.13	0.17	0.15
											% COV			2.29	2.51			2.15	2.75	2.37
BH2-08-5W-x	1	T7-OS2-A-3A	3-D	0.564	Trans	6.5	2.5	1.5	1.50	1/4	1.4993	0.2386	14.1	17.91	50.06	-6,862	-8,848	5.70	5.53	5.62
	2	T7-OS2-A-3A	OS-2	0.564	IITRI						1.4982	0.2367	13.8	17.41	49.10	-8,245	-7,221	5.67	5.44	5.56
	3	T7-OS2-A-3A		0.564	Baseline						1.4973	0.2356	11.8	17.62	49.96	-8,083	-6,479	5.76	5.50	5.63
											Average			17.62	49.70	-7,730	-7,516	5.71	5.49	5.60
											Std. Dev.			0.25	0.53			0.04	0.05	0.04
											% COV			1.42	1.06			0.76	0.84	0.69
BH2-09-5W-x	1	T7-LS1-A-6A	3-D	0.637	Trans	6.5	2.5	1.5	1.50	1/4	1.5012	0.2139		12.78	39.79	-6,181	-6,112	6.60	6.54	6.57
	2	T7-LS1-A-6A	LS-1	0.637	IITRI						1.4983	0.2135	9.6	10.19	31.87	-3,893	-4,780	6.50	6.53	6.52
	3	T7-LS1-A-6A		0.637	Baseline						1.5005	0.2137	8.3	9.91	30.89	-4,644	-6,278	6.42	6.36	6.39
											Average			9.91	34.19	-4,906	-5,723	6.51	6.48	6.50
											Std. Dev.			1.58	4.88			0.09	0.10	0.09
											% COV			15.96	14.28			1.38	1.57	1.41
BH2-10-5W-x	1	T5-LS2-A-1B	3-D	0.629	Trans	6.5	2.5	1.5	1.50	1/4	1.5013	0.2227	7.1	7.35	21.99	-3,479	-3,767	6.67	6.46	6.56
	2	T5-LS2-A-1B	LS-2	0.629	IITRI						1.4995	0.2222		10.45	31.37	-4,660	-4,899	6.60	6.51	6.56
	3	T5-LS2-A-1B		0.629	Baseline						1.4995	0.2219	10.3	10.89	32.71	-5,036	-5,201	6.55	6.58	6.57
											Average			10.89	28.69	-4,392	-4,622	6.61	6.52	6.56
											Std. Dev.			1.93	5.84			0.06	0.06	0.00
											% COV			17.69	20.36			0.89	0.93	0.05

Project #: BH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development
Task 8
Compression Test Program
Stitched Uniweave Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nom. Dim. total Length (in)	gage length (in)	Width (in)	Avg Width (in)	Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Axial 1 Strain (με)	Ultimate Axial 2 Strain (με)	Axial Modulus Axial 1 (msi)	Axial 2 (msi)	Average (msi)
BH2-11-5G-x	1	T7-SUW-G3K8B1	SU-1	0.668	NASA SB Baseline	1.5	1.5	1.50	1.4990	0.2238	18.2	20.29	60.47	-8,252	-8,112	6.92	6.59	6.75
	2	T7-SUW-G3K8B1		0.668					1.5010	0.2231		21.60	64.46	-7,419	-8,057	5.67	6.99	6.33
	3	T7-SUW-G3K8B1		0.668					1.5015	0.2238		21.56	64.16	-7,285	-10,047	7.32	5.18	6.25
											18.2	21.15	63.04	-7,652	-8,739	6.64	6.25	6.44
												0.75	2.23			0.86	0.95	0.27
												3.52	3.53			12.93	15.20	4.18
BH2-12-5G-x	1	T7-SUW-G6K8B1	SU-2	0.644	NASA SB Baseline	1.5	1.5	1.50	1.5002	0.2453		20.49	55.68	-12,700	-8,427	6.36	6.33	6.34
	2	T7-SUW-G6K8B1		0.644					1.5000	0.2452		20.90	56.83	na	-9,507	6.23	6.28	6.25
	3	T7-SUW-G6K8B1		0.644					1.5005	0.2454	18.3	19.61	53.25	-7,805	-11,614	6.25	6.41	6.33
											18.3	20.34	55.26	-10,253	-9,849	6.28	6.34	6.31
												0.66	1.83			0.07	0.06	0.05
												3.25	3.31			1.13	1.02	0.77
BH2-13-5G-x	1	T7-SUW-K6K8B1	SU-3	0.635	NASA SB Baseline	1.5	1.5	1.50	1.4965	0.2383	19.3	20.84	58.43	-10,033	na	6.42	6.37	6.39
	2	T7-SUW-K6K8B1		0.635					1.4990	0.2362	15.9	20.35	57.48	-8,339	-8,852	6.07	6.64	6.36
	3	T7-SUW-K6K8B1		0.635					1.4990	0.2367	17.5	19.87	56.01	na	-8,741	6.85	6.40	6.62
											17.6	20.35	57.31	-9,186	-8,797	6.45	6.47	6.46
												0.48	1.22			0.39	0.15	0.14
												2.37	2.13			6.02	2.31	2.24
BH2-14-5G-x	1	T7-SUW-K6K4B1	SU-4	0.648	NASA SB Baseline	1.5	1.5	1.50	1.4990	0.2304	17.9	20.06	58.08	-10,225	-5,802	6.83	6.72	6.78
	2	T7-SUW-K6K4B1		0.648					1.4990	0.2305	19.1	19.99	57.86	-12,500	-8,874	6.71	6.48	6.60
	3	T7-SUW-K6K4B1		0.648					1.4995	0.2297	18.3	19.43	56.43	-8,315	-6,825	7.03	6.50	6.77
											18.4	19.83	57.46	-10,347	-7,167	6.86	6.57	6.71
												0.34	0.90			0.16	0.13	0.10
												1.73	1.56			2.31	1.98	1.49
BH2-15-5G-x	1	T7-SUW-K12K8B1	SU-5	0.654	NASA SB Baseline	1.5	1.5	1.50	1.4995	0.2577	21.1	22.01	56.98	-9,552	-10,327	5.95	6.60	6.28
	2	T7-SUW-K12K8B1		0.654					1.4995	0.2555	19.1	21.02	54.86	-13,485	-7,241	6.32	6.19	6.25
	3	T7-SUW-K12K8B1		0.654					1.4990	0.2577	22.0	23.25	60.18	-9,438	-14,898	6.65	6.26	6.46
											20.7	22.09	57.34	-10,825	-10,822	6.31	6.35	6.33
												1.12	2.68			0.35	0.22	0.11
												5.07	4.68			5.55	3.47	1.78
BH2-11-5M-x	1	T7-SUW-G3K8B1	SU-1	0.668	IITRI Baseline	6.5	1.5	1.50	1.4990	0.2221	18.2	19.49	58.54	-8,760	-8,383	7.27	6.97	7.12
	2	T7-SUW-G3K8B1		0.668					1.5000	0.2228	16.0	19.17	57.36	-7,418	-6,985	7.21	6.73	6.97
	3	T7-SUW-G3K8B1		0.668					1.4995	0.2228	17.5	19.48	58.31	-8,428	-8,742	7.18	6.94	7.06
											17.2	19.38	58.07	-8,202	-8,037	7.22	6.88	7.05
												0.18	0.63			0.04	0.13	0.07
												0.94	1.08			0.60	1.89	1.05
BH2-12-5M-x	1	T7-SUW-G6K8B1	SU-2	0.644	IITRI Baseline	6.5	1.5	1.50	1.4995	0.2436	17.0	17.51	47.93	-6,357	-7,231	6.52	6.63	6.57
	2	T7-SUW-G6K8B1		0.644					1.4985	0.2452	16.7	17.95	48.84	-7,724	-7,661	6.61	6.61	6.61
	3	T7-SUW-G6K8B1		0.644					1.5000	0.2463	16.0	18.14	49.10	-7,637	-8,112	6.44	6.54	6.49
											16.6	17.86	48.62	-7,239	-7,668	6.52	6.59	6.56
												0.32	0.61			0.09	0.04	0.06
												1.81	1.26			1.30	0.68	0.93

Project #: BH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development
Task 8
Compression Test Program
Stitched Uniweave Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nom. Dim. total Length (in)	Nom. Dim. gage length (in)	Nom. Dim. Width (in)	Avg Width (in)	Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Axial 1 Strain (με)	Ultimate Axial 2 Strain (με)	Axial Modulus Axial 1 (msi)	Axial Modulus Axial 2 (msi)	Axial Modulus Average (msi)
BH2-13-5M-x	1	T7-SUW-K6K8B1	SU-3	0.635	IITRI	6.5	1.5	1.50	1.5005	0.2366	14.7	17.13	48.24	-7,886	-6,417	6.53	6.70	6.62
	2	T7-SUW-K6K8B1		0.635	Baseline				1.5043	0.2358	16.3	18.32	51.65	-7,131	-8,361	6.80	6.80	6.80
	3	T7-SUW-K6K8B1		0.635					1.4927	0.2354	15.2	18.01	51.27	-7,581	-7,675	6.77	6.83	6.80
											15.4	17.82	50.39	-7,533	-7,484	6.70	6.78	6.74
												0.62	1.87			0.15	0.07	0.10
												3.47	3.71			2.16	0.97	1.55
BH2-14-5M-x	1	T7-SUW-K6K4B1	SU-4	0.648	IITRI	6.5	1.5	1.50	1.4980	0.2298	17.4	18.08	52.52	-7,693	-7,679	7.06	6.94	7.00
	2	T7-SUW-K6K4B1		0.648	Baseline				1.5000	0.2304	16.5	17.94	51.91	-7,560	-7,624	6.97	6.92	6.95
	3	T7-SUW-K6K4B1		0.648					1.4985	0.2307	16.3	17.80	51.49	-7,868	-7,310	6.97	6.88	6.93
											16.7	17.94	51.97	-7,707	-7,538	7.00	6.91	6.96
												0.14	0.52			0.05	0.03	0.04
												0.78	1.00			0.70	0.42	0.54
BH2-15-5M-x	1	T7-SUW-K12K8B1	SU-5	0.654	IITRI	6.5	1.5	1.50	1.5035	0.2585	17.4	19.14	49.24	-7,168	-6,347	6.66	6.46	6.56
	2	T7-SUW-K12K8B1		0.654	Baseline				1.4980	0.2597	18.0	19.31	49.64	-7,680	-7,975	6.63	6.53	6.58
	3	T7-SUW-K12K8B1		0.654					1.5130	0.2595	17.5	19.45	49.54	-8,435	-5,622	6.70	6.49	6.60
											17.6	19.30	49.47	-7,761	-6,648	6.67	6.49	6.58
												0.16	0.21			0.03	0.04	0.02
												0.82	0.42			0.49	0.55	0.26
BH2-11-5W-x	1	T7-SUW-G3K8B2	SU-1	0.668	Trans	6.5	1.5	1.50	1.5000	0.2213	20.5	21.09	63.54	-10,298		6.90		
	2	T7-SUW-G3K8B2		0.668	IITRI				1.4990	0.2217	18.7	19.53	58.77	-9,663		7.07		
	3	T7-SUW-G3K8B2		0.668	Baseline				1.5000	0.2221	20.0	20.17	60.54	-8,860		7.23		
											19.7	20.27	60.95	-9,607		7.07		
												0.79	2.41			0.17		
												3.88	3.95			2.38		
BH2-12-5W-x	1	T7-SUW-G6K8B2	SU-2	0.644	Trans	6.5	1.5	1.50	1.4997	0.2428	19.3	19.97	54.85	-8,762		6.62		
	2	T7-SUW-G6K8B2		0.644	IITRI				1.4992	0.2434	18.8	20.24	55.49	-9,375		6.72		
	3	T7-SUW-G6K8B2		0.644	Baseline				1.5003	0.2442	19.9	20.69	56.47	-9,326		6.66		
											19.3	20.30	55.60	-9,154		6.66		
												0.36	0.82			0.05		
												1.78	1.47			0.74		
BH2-13-5W-x	1	T7-SUW-K6K8B2	SU-3	0.635	Trans	6.5	1.5	1.50	1.5020	0.2395	18.1	20.27	56.35	-8,629		6.78		
	2	T7-SUW-K6K8B2		0.635	IITRI				1.5035	0.2378	18.1	19.86	55.54	-8,741		6.82		
	3	T7-SUW-K6K8B2		0.635	Baseline				1.5007	0.2354	20.1	21.14	59.86	-9,018		6.99		
											18.8	20.42	57.25	-8,796		6.87		
												0.65	2.30			0.11		
												3.21	4.01			1.62		
BH2-14-5W-x	1	T7-SUW-K6K4B2	SU-4	0.648	Trans	6.5	1.5	1.50	1.4992	0.2305	18.9	20.12	58.23	-8,508		7.09		
	2	T7-SUW-K6K4B2		0.648	IITRI				1.4990	0.2293	18.3	19.08	55.51	-7,885		7.13		
	3	T7-SUW-K6K4B2		0.648	Baseline				1.5005	0.2280		18.81	54.97	-7,901		7.19		
											18.6	19.34	56.24	-8,098		7.14		
												0.69	1.75			0.05		
												3.59	3.11			0.70		

Project #: BH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Material: AS4/Shell 1895

Textile Test Method Development
Task 8
Compression Test Program
Stitched Uniweave Architectures

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nom. Dim. total Length (in)	Nom. Dim. gage length (in)	Nom. Dim. Width (in)	Avg Width (in)	Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Axial 1 Strain (με)	Ultimate Axial 2 Strain (με)	Axial Modulus Axial 1 (msi)	Axial Modulus Axial 2 (msi)	Axial Modulus Average (msi)
BH2-15-5W-x	1	T7-SUW-K12K8B 2	SU-5	0.654	Trans	6.5	1.5	1.50	1.4990	0.2581	22.8	23.85	61.64	-8,828		7.24		
	2	T7-SUW-K12K8B2		0.654	IITRI				1.4988	0.2579	21.9	23.21	60.06	-7,997		7.30		
	3	T7-SUW-K12K8B2		0.654	Baseline				1.5000	0.2578	21.5	23.21	60.02	-8,249		7.19		
											22.1	23.42	60.57	-8,358		7.24		
												0.37	0.92			0.05		
												1.56	1.52			0.74		

Open-Hole Compression Test Program

Project #: BH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Material: AS4/Shell 1895

Textile Test Method Development

Task 6

Open Hole Compression Test Program

2-D Braided Architectures

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions Thick. (in)	Nominal Dimensions Width (in)	Nominal Dimensions Diam. (in)	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-01-6A-x	1	T7-SLL-B-3B	2-D	0.600	Boeing	0.125	1.5	3/8	1.5005	0.1066	0.3740		8.11	50.71	67.54	hole	
	2	T7-SLL-B-3B	SLL	0.600	OH Comp				1.4995	0.1066	0.3735		8.98	56.21	74.85	hole	
	3	T7-SLL-B-3B		0.600					1.5020	0.1069	0.3735		8.02	49.95	66.48	hole	
								Avg.	1.5007	0.1067	0.3737		8.37	52.29	69.63		
								Std. Dev.					0.53	3.42	4.56		
								% COV					6.33	6.53	6.55		
BH2-01-6B-x	1	T7-SLL-B-1A	2-D	0.635	Boeing	0.125	1.5	1/4	1.5015	0.1060	0.2495		11.24	70.62	84.69	hole	
	2	T7-SLL-B-1A	SLL	0.635	OH Comp				1.5015	0.1053	0.2490		6.93	43.88	52.60	hole	
	3	T7-SLL-B-1A		0.635					1.5007	0.1038	0.2500		10.13	65.01	78.01	hole	
								Avg.	1.5012	0.1050	0.2495		9.43	59.84	71.77		
								Std. Dev.					2.24	14.10	16.93		
								% COV					23.70	23.57	23.59		
BH2-01-6C-x	1	T7-SLL-B-3B	2-D	0.600	Boeing	0.125	1.5	3/16	1.5013	0.1062	0.1865		7.79	48.87	55.80	hole	
	2	T7-SLL-B-3B	SLL	0.600	OH Comp				1.5015	0.1083	0.1870		7.63	46.93	53.61	hole	
	3	T7-SLL-B-3B		0.600					1.5008	0.1093	0.1875		11.77	71.74	81.98	hole	
								Avg.	1.5012	0.1079	0.1870		9.06	55.85	63.80		
								Std. Dev.					2.34	13.80	15.78		
								% COV					25.87	24.70	24.74		
BH2-02-6A-x	1	T7-LLS-B-XA	2-D	0.599	Boeing	0.125	1.5	3/8	1.5000	0.1124	0.3740		6.41	37.99	50.61	hole	
	2	T7-LLS-B-XA	LLS	0.599	OH Comp				1.5000	0.1131	0.3730		6.99	41.20	54.84	hole	
	3	T7-LLS-B-XA		0.599					1.5017	0.1115	0.3740		6.89	41.14	54.79	hole	
								Avg.	1.5006	0.1123	0.3737		6.76	40.11	53.41		
								Std. Dev.					0.31	1.84	2.42		
								% COV					4.63	4.57	4.54		
BH2-02-6B-x	1	T7-LLS-B-4B	2-D	0.618	Boeing	0.125	1.5	1/4	1.5010	0.1049	0.2500		6.76	42.93	51.50	hole	
	2	T7-LLS-B-4B	LLS	0.618	OH Comp				1.5012	0.1074	0.2500		7.68	47.62	57.13	hole	
	3	T7-LLS-B-4B		0.618					1.5015	0.1103	0.2505		8.17	49.32	59.20	hole	
								Avg.	1.5012	0.1075	0.2502		7.53	46.62	55.95		
								Std. Dev.					0.71	3.31	3.98		
								% COV					9.47	7.10	7.12		
BH2-02-6C-x	1	T7-LLS-B-XA	2-D	0.599	Boeing	0.125	1.5	3/16	1.5003	0.1141	0.1865		7.85	45.85	52.36	hole	
	2	T7-LLS-B-XA	LLS	0.599	OH Comp				1.5013	0.1147	0.1860		7.35	42.70	48.74	hole	
	3	T7-LLS-B-XA		0.599					1.5037	0.1148	0.1865		8.26	47.86	54.64	hole	
								Avg.	1.5018	0.1145	0.1863		7.82	45.47	51.91		
								Std. Dev.					0.46	2.60	2.98		
								% COV					5.83	5.72	5.73		
BH2-03-6B-x	1	T7-LLL-B-1A	2-D	0.644	Boeing	0.125	1.5	1/4	1.5028	0.1086	0.2505		8.45	51.81	62.17	hole	
	2	T7-LLL-B-1A	LLL	0.644	OH Comp				1.5007	0.1061	0.2500		5.65	35.50	42.60	hole	
	3	T7-LLL-B-1A		0.644					1.5030	0.1058	0.2500		5.38	33.83	40.58	hole	
								Avg.	1.5022	0.1068	0.2502		6.50	40.38	48.45		
								Std. Dev.					1.70	9.93	11.93		
								% COV					26.19	24.60	24.62		

Project #: aH0002 Material: AS4/Shell 1895

intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development
Task 6
Open Hole Compression Test Program
2-D Braided Architectures

intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions Thick. (in)	Nominal Dimensions Width (in)	Nominal Dimensions Diam. (in)	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-04-6B-x	1	T7-LSS-B-3B	2-D	0.629	Boeing	0.125	1.5	1/4	1.5005	0.1053	0.2500		5.67	35.85	43.02	hole	
	2	T7-LSS-B-3B	LSS	0.629	OH Comp				1.5000	0.1076	0.2500		5.68	35.19	42.22	hole	
	3	T7-LSS-B-4A		0.645					1.4995	0.1060	0.2500		5.35	33.63	40.36	hole	
								Avg.	1.5000	0.1063	0.2500		5.56	34.89	41.87		
								Std. Dev.					0.19	1.14	1.36		
								% COV					3.37	3.26	3.26		
BH2-01-6D-x	1	T7-SLL-C-5A	2-D	0.601	NASA	0.250	1.5	3/8	1.5015	0.2096	0.3745	11.0	15.61	49.60	66.08	hole	
	2	T7-SLL-C-4B	SLL	0.619	Short block				1.5032	0.2143	0.3755	15.1	15.63	48.51	64.67	hole	
	3	T7-SLL-C-1B		0.608					1.5013	0.2251	0.3745	14.5	14.68	43.45	57.89	hole	
								Avg.	1.5020	0.2163	0.3748	13.5	15.31	47.19	62.88		
								Std. Dev.					0.54	3.28	4.38		
								% COV					3.55	6.96	6.96		
BH2-01-6E-x	1	T7-SLL-C-5A	2-D	0.601	NASA	0.250	1.5	1/4	1.5013	0.2108	0.2490	19.5	20.48	64.72	77.58	hole	
	2	T7-SLL-C-5A	SLL	0.601	Short block				1.5012	0.2114	0.2490	18.5	18.67	58.84	70.54	hole	
	3	T7-SLL-C-1B		0.608					1.5002	0.2239	0.2490	15.6	16.10	47.93	57.47	hole	
								Avg.	1.5009	0.2154	0.2490	17.9	18.42	57.16	68.53		
								Std. Dev.					2.20	8.52	10.21		
								% COV					11.95	14.90	14.90		
BH2-01-6F-x	1	T7-SLL-C-5A	2-D	0.601	NASA	0.250	1.5	3/16	1.5017	0.2090	0.1870		22.50	71.68	81.88	hole	
	2	T7-SLL-C-5A	SLL	0.601	Short block				1.5017	0.2095	0.1875		21.82	69.35	79.24	hole	
	3	T7-SLL-C-5A		0.601					1.5015	0.2102	0.1875		21.07	66.77	76.30	hole	
								Avg.	1.5016	0.2096	0.1873		21.80	69.27	79.14		
								Std. Dev.					0.72	2.45	2.79		
								% COV					3.28	3.54	3.52		
BH2-02-6D-x	1	T7-LLS-C-4B	2-D	0.582	NASA	0.250	1.5	3/8	1.5020	0.2172	0.3740	11.5	12.24	37.52	49.96	hole	specimens 1,2,&3 porous
	2	T7-LLS-C-4B	LLS	0.582	Short block				1.5005	0.2165	0.3755	12.2	12.93	39.81	53.10	hole	
	3	T7-LLS-C-4B		0.582					1.5000	0.2190	0.3755	12.9	13.10	39.88	53.20	hole	
	5	T5-LLS-C-2B		0.584					1.5002	0.2226	0.3750	11.5	11.60	34.74	46.31	hole	
	6	T7-LLS-C-1B		0.584					1.5017	0.2215	0.3740		12.26	36.86	49.09	hole	
	7	T7-LLS-C-1B		0.584					1.5007	0.2208	0.3740		13.69	41.31	55.02	hole	
								Avg.	1.5008	0.2216	0.3743	12.0	12.52	37.64	50.14		Avg of 5,6,&7
								Std. Dev.					1.07	3.35	4.45		
								% COV					8.54	8.91	8.87		
BH2-02-6E-x	1	T5-LLS-C-2A	2-D	0.599	NASA	0.250	1.5	1/4	1.5183	0.2267	0.2490	13.8	14.32	41.60	49.76	hole	
	2	T5-LLS-C-2A	LLS	0.599	Short block				1.5177	0.2240	0.2490	16.0	16.23	47.74	57.12	hole	
	3	T5-LLS-C-2A		0.599					1.5185	0.2246	0.2490	14.6	15.27	44.77	53.55	hole	
								Avg.	1.5182	0.2251	0.2490	14.8	15.27	44.71	53.48		
								Std. Dev.					0.96	3.07	3.68		
								% COV					6.25	6.87	6.87		
BH2-02-6F-x	1	T7-LLS-C-1A	2-D	0.575	NASA	0.250	1.5	3/16	1.5015	0.2194	0.1870		16.67	50.60	57.80	hole	
	2	T7-LLS-C-1A	LLS	0.575	Short block				1.5013	0.2218	0.1870		16.20	48.64	55.56	hole	
	3	T7-LLS-C-1A		0.575					1.5012	0.2178	0.1870		15.94	48.75	55.69	hole	
								Avg.	1.5013	0.2197	0.1870		16.27	49.33	56.35		
								Std. Dev.					0.37	1.10	1.26		
								% COV					2.27	2.23	2.23		

Project #: dH0002

Material: AS4/Shell 1895

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development

Task 6

Open Hole Compression Test Program

2-D Braided Architectures

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions Thick. (in)	Nominal Dimensions Width (in)	Nominal Dimensions Diam. (in)	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-03-6E-x	1	T5-LLL-C-1B	2-D	0.632	NASA	0.250	1.5	1/4	1.5002	0.2169	0.2490	14.2	14.58	44.80	53.72	hole	
	2	T5-LLL-C-1B	LLL	0.632	Short block				1.4993	0.2128	0.2490	13.6	14.05	44.04	52.81	hole	
	3	T5-LLL-C-1B		0.632					1.5000	0.2111	0.2490	13.6	14.50	45.79	54.90	hole	
								Avg.	1.4998	0.2136	0.2490	13.8	14.38	44.88	53.81		
								Std. Dev.					0.29	0.88	1.05		
								% COV					1.99	1.96	1.95		
BH2-04-6E-x	1	T7-LSS-C-1B	2-D	0.642	NASA	0.250	1.5	1/4	1.4980	0.1997	0.2500	9.9	10.47	34.99	42.00	hole	
	2	T7-LSS-C-1B	LSS	0.642	Short block				1.4995	0.1967	0.2490	10.3	10.40	35.25	42.27	hole	
	3	T7-LSS-C-1B		0.642					1.5003	0.1962	0.2490	9.7	9.94	33.77	40.50	hole	
								Avg.	1.4993	0.1976	0.2493	10.0	10.27	34.67	41.59		
								Std. Dev.					0.29	0.79	0.96		
								% COV					2.79	2.28	2.30		
BH2-01-6G-x	1	T7-SLL-C-4B	2-D	0.619	NASA	0.250	1.5	3/8	1.4997	0.2167	0.3740	14.3	16.33	50.25	66.94	hole	
	2	T7-SLL-C-4B	SLL	0.619	1142-BIO				1.5005	0.2186	0.3740	12.9	16.55	50.47	67.22	hole	
	3	T7-SLL-C-4B		0.619					1.4998	0.2212	0.3740	16.0	16.27	49.05	65.34	hole	
								Avg.	1.5000	0.2188	0.3740	14.4	16.38	49.92	66.50		
								Std. Dev.					0.15	0.76	1.02		
								% COV					0.90	1.53	1.53		
BH2-01-6H-x	1	T7-SLL-C-9B	2-D	0.584	NASA	0.250	1.5	1/4	1.4998	0.2085	0.2495	14.5	14.72	47.07	56.46	hole	
	2	T7-SLL-C-9B	SLL	0.584	1142-BIO				1.5000	0.2101	0.2500	18.0	18.12	57.50	69.00	hole	
	3	T7-SLL-C-9B		0.584					1.4985	0.2166	0.2495	18.4	19.55	60.23	72.26	hole	
								Avg.	1.4994	0.2117	0.2497	17.0	17.46	54.93	65.91		
								Std. Dev.					2.48	6.95	8.34		
								% COV					14.21	12.65	12.66		
BH2-01-6I-x	1	T7-SLL-C-5A	2-D	0.601	NASA	0.250	1.5	3/16	1.5025	0.2136	0.1870	17.9	19.60	61.07	69.76	hole	
	2	T7-SLL-C-5A	SLL	0.601	1142-BIO				1.5000	0.2128	0.1880	19.0	19.40	60.78	69.49	hole	
	3	T7-SLL-C-5A		0.601					1.4993	0.2138	0.1885	17.2	20.81	64.92	74.26	hole	
								Avg.	1.5006	0.2134	0.1878	18.0	19.94	62.26	71.17		
								Std. Dev.					0.76	2.31	2.68		
								% COV					3.83	3.71	3.76		
BH2-02-6G-x	1	T7-LLS-C-4A	2-D	0.570	NASA	0.250	1.5	3/8	1.5035	0.2171	0.3740	12.5	12.79	39.18	52.15	hole	
	2	T7-LLS-C-4A	LLS	0.570	1142-BIO				1.5032	0.2159	0.3740	12.1	14.62	45.05	59.97	hole	
	3	T7-LLS-C-4A		0.570					1.5033	0.2180	0.3740	12.6	14.33	43.73	58.21	hole	
								Avg.	1.5033	0.2170	0.3740	12.4	13.91	42.65	56.78		
								Std. Dev.					0.98	3.08	4.10		
								% COV					7.07	7.23	7.23		
BH2-02-6H-x	1	T7-LLS-C-4A	2-D	0.570	NASA	0.250	1.5	1/4	1.5030	0.2171	0.2495	12.0	15.56	47.68	57.17	hole	
	2	T7-LLS-C-3A	LLS	0.624	1142-BIO				1.5015	0.2246	0.2500	12.2	15.55	46.12	55.33	hole	
	3	T7-LLS-C-3A		0.624					1.5020	0.2231	0.2495	15.6	16.54	49.37	59.20	hole	
								Avg.	1.5022	0.2216	0.2497	13.3	15.88	47.72	57.23		
								Std. Dev.					0.57	1.63	1.94		
								% COV					3.58	3.41	3.39		

Project #: αH0002 Material AS4/Shell 1895

Intec Engineer Maryann Einarson

Boeing Engineer Mark Fedro

Textile Test Method Development
Task 6
Open Hole Compression Test Program
2-D Braided Architectures

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions Thick (in)	Nominal Dimensions Width (in)	Nominal Dimensions Diam (in)	Avg Width (in)	Avg Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-02-6I-x	1	T7-LLS-C-3A	2-D	0.624	NASA	0.250	1.5	3/16	1.5025	0.2171	0.1870	15.5	16.01	49.09	56.07	hole	
	2	T7-LLS-C-3A	LLS	0.624	1142-BIO				1.5025	0.2159	0.1870	15.0	15.25	47.01	53.70	hole	
	3	T7-LLS-C-3A		0.624					1.5015	0.2159	0.1870	16.2	16.48	50.83	58.06	hole	
								Avg.	1.5022	0.2163	0.1870	15.6	15.91	48.98	55.94		
								Std Dev					0.62	1.91	2.19		
								% COV					3.90	3.90	3.91		
BH2-03-6H-x	1	T5-LLL-C-1A	2-D	0.611	NASA	0.250	1.5	1/4	1.5015	0.2215	0.2495	14.5	17.82	53.58	64.25	hole	
	2	T5-LLL-C-1A	LLL	0.611	1142-BIO				1.5060	0.2264	0.2500	14.6	15.20	44.58	53.46	hole	
	3	T5-LLL-C-2A		0.621					1.5022	0.2246	0.2495	17.0	18.84	55.85	66.98	hole	
								Avg.	1.5032	0.2242	0.2497	15.4	17.29	51.34	61.56		
								Std. Dev.					1.88	5.96	7.15		
								% COV					10.86	11.61	11.61		
BH2-04-6H-x	1	T7-LSS-C-2B	2-D	0.580	NASA	0.250	1.5	1/4	1.4988	0.2155	0.2500	9.6	11.40	35.29	42.36	hole	
	2	T7-LSS-C-2B	LSS	0.580	1142-BIO				1.5015	0.2200	0.2500	11.1	11.93	36.12	43.33	hole	
	3	T7-LSS-C-1B		0.642					1.4990	0.2000	0.2500	10.3	11.26	37.56	45.08	hole	
								Avg.	1.4998	0.2118	0.2500	10.3	11.53	36.32	43.59		
								Std. Dev.					0.35	1.15	1.38		
								% COV					3.07	3.17	3.17		
BH2-01-6J-x	1	T7-SLL-C-3B	2-D	0.601	NASA	0.250	5.0	1.25	5.0012	0.2174	1.2500		42.97	39.52	52.68	hole	
	2	T7-SLL-C-1B	SLL	0.608	ST-4				5.0013	0.2214	1.2500		34.19	30.88	41.17	hole	
	3	T7-SLL-C-9B		0.584					5.0002	0.2079	1.2500		33.23	31.97	42.63	hole	
								Avg.	5.0009	0.2156	1.2500		36.80	34.12	45.49		
								Std. Dev.					5.37	4.70	6.27		
								% COV					14.59	13.78	13.78		
BH2-02-6J-x	1	T7-LLS-C-1A	2-D	0.575	NASA	0.250	5.0	1.25	5.0002	0.2231	1.2500		33.44	29.98	39.97	hole	
	2	T7-LSS-C-2B	LLS	0.581	ST-4				5.0008	0.2239	1.2500		29.97	26.77	35.69	hole	
	3	T7-LLS-C-1B		0.584					4.9980	0.2193	1.2500		30.44	27.77	37.03	hole	
								Avg.	4.9997	0.2221	1.2500		31.28	28.17	37.57		
								Std Dev					1.88	1.64	2.19		
								% COV					6.02	5.83	5.83		
BH2-01-6M-x	1	T7-SLL-C-4B	2-D	0.619	Boeing	0.250	4.0	1.00	4.0008	0.2153	0.8000		34.29	39.81	49.76	hole	buckled, #2 failed away from hole
	2	T7-SLL-C-1B	SLL	0.608	CAI				4.0020	0.2193	0.8015		23.95	27.29	34.12	away	
	3	T7-SLL-C-1B		0.608					4.0010	0.2158	0.8000		32.37	37.49	46.86	hole	
								Avg.	4.0013	0.2168	0.8005		33.33	38.65	48.31		
								Std Dev.					5.50	6.66	8.32		
								% COV					16.50	17.24	17.22		
BH2-01-6N-x	1	T7-SLL-C-1B	2-D	0.608	Boeing	0.250	4.0	0.80	4.0015	0.2182	0.8000		35.21	40.34	50.41	hole	
	2	T7-SLL-C-1B	SLL	0.608	CAI				4.0030	0.2192	0.8015		34.74	39.59	49.50	hole	
	3	T7-SLL-C-1B		0.608					4.0027	0.2209	0.8000		32.91	37.21	46.51	hole	
								Avg.	4.0024	0.2194	0.8005		34.29	39.05	48.81		
								Std Dev					1.22	1.63	2.04		
								% COV					3.54	4.17	4.18		

Project #: BH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Material: AS4/Shell 1895

Textile Test Method Development

Task 6

Open Hole Compression Test Program

2-D Braided Architectures

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions Thick. (in)	Width (in)	Diam. (in)	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-01-6O-x	1	T7-SLL-C-3B	2-D SLL	0.601	Boeing CAI	0.250	4.0	0.50	4.0008	0.2216	0.5000	27.5	39.42	44.47	50.82	hole	
	2	T7-SLL-C-3B		0.601					4.0020	0.2247	0.5000	39.5	48.92	54.41	62.18	hole	
	3	T7-SLL-C-3B		0.601					4.0025	0.2198	0.4995	36.3	50.17	57.03	65.16	hole	
								Avg.	4.0018	0.2220	0.4998	34.4	46.17	51.97	59.39		
								Std. Dev.					5.88	6.63	7.57		
								% COV					12.73	12.75	12.74		
BH2-02-6M-x	1	T7-LLS-C-1A	2-D LLS	0.575	Boeing CAI	0.250	4.0	1.00	4.0020	0.2243	0.5000		27.75	30.91	35.33	hole	
	2	T7-LLS-C-1B		0.584					3.9992	0.2182	0.5000		25.86	29.63	33.87	hole	
	3	T5-LLS-C-2B		0.584					3.9985	0.2290	0.4995		25.66	28.02	32.02	hole	
								Avg.	3.9999	0.2239	0.4998		26.42	29.52	33.74		
								Std. Dev.					1.15	1.45	1.66		
								% COV					4.36	4.91	4.91		
BH2-02-6N-x	1	T5-LLS-C-2A	2-D LLS	0.599	Boeing CAI	0.250	4.0	0.80	4.0038	0.2253	0.8000		31.69	35.14	43.91	hole	
	2	T5-LLS-C-2A		0.599					4.0098	0.2233	0.8000		28.41	31.73	39.64	hole	
	3	T5-LLS-C-2B		0.584					3.9992	0.2237	0.8010		30.77	34.39	43.01	hole	
								Avg.	4.0043	0.2241	0.8003		30.29	33.76	42.19		
								Std. Dev.					1.69	1.79	2.25		
								% COV					5.59	5.30	5.33		
BH2-02-6O-x	1	T5-LLS-C-2B	2-D LLS	0.584	Boeing CAI	0.250	4.0	0.50	4.0020	0.2181	0.5000	30.4	36.33	41.62	47.56	hole	
	2	T5-LLS-C-2B		0.584					4.0015	0.2205	0.4995	29.2	35.47	40.20	45.93	hole	
	3	T5-LLS-C-2B		0.584					4.0020	0.2163	0.4995	25.6	34.14	39.43	45.06	hole	
								Avg.	4.0018	0.2183	0.4997	28.4	35.31	40.42	46.18		
								Std. Dev.					1.10	1.11	1.27		
								% COV					3.12	2.74	2.75		
BH2-03-6N-x	1	T5-LLL-C-1A	2-D LLL	0.611	Boeing CAI	0.250	4.0	0.80	4.0092	0.2176	0.8005		33.49	38.39	47.97	hole	
	2	T5-LLL-C-2A		0.621					4.0008	0.2277	0.8005		33.56	36.84	46.06	hole	
	3	T5-LLL-C-2A		0.621					4.0020	0.2252	0.8000		34.69	38.49	48.10	hole	
								Avg.	4.0040	0.2235	0.8003		33.91	37.91	47.38		
								Std. Dev.					0.67	0.92	1.14		
								% COV					1.99	2.44	2.42		
BH2-04-6N-x	1	T7-LSS-C-4A	2-D LSS	0.579	Boeing CAI	0.250	4.0	0.80	3.9995	0.2156	0.8015		25.97	30.11	37.66	hole	
	2	T7-LSS-C-4A		0.579					4.0020	0.2122	0.8015		25.66	30.21	37.78	hole	
	3	T7-LSS-C-2B		0.581					4.0030	0.2202	0.8005		25.88	29.36	36.70	hole	
								Avg.	4.0015	0.2160	0.8012		25.84	29.90	37.38		
								Std. Dev.					0.16	0.46	0.59		
								% COV					0.62	1.56	1.58		
BH2-01-6P-x	1	T7-SLL-C-9B	2-D SLL	0.584	Modified IITRI	0.250	1.5	3/8	1.4800	0.2199	0.3765		14.33	44.03	59.05	hole	
	2	T7-SLL-C-9B		0.584					1.4780	0.2141	0.3745		14.13	44.65	59.80	hole	
	3	T7-SLL-C-9B		0.584					1.4730	0.2102	0.3760		14.07	45.44	61.02	hole	
								Avg.	1.4770	0.2148	0.3757		14.18	44.71	59.95		
								Std. Dev.					0.14	0.71	0.99		
								% COV					0.96	1.59	1.66		

Project #: BH0002

Intec Engineer Maryann Einarson

Boeing Engineer Mark Fedro

Material AS4/Shell 1895

Textile Test Method Development

Task 6

Open Hole Compression Test Program

2-D Braided Architectures

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions Thick (in)	Nominal Dimensions Width (in)	Nominal Dimensions Diam (in)	Avg Width (in)	Avg Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-01-6Q-x	1	T7-SLL-C-4A	2-D	0.605	Modified	0.250	1.5	1/4	1.4998	0.2149	0.2520		16.76	52.00	62.50	hole	
	2	T7-SLL-C-4A	SLL	0.605	IITRI				1.4990	0.2147	0.2515		21.07	65.46	78.66	hole	
	3	T7-SLL-C-4A							1.4973	0.2155	0.2520		22.83	70.77	85.09	hole	
								Avg.	1.4987	0.2150	0.2518		20.22	62.74	75.42		
								Std Dev					3.12	9.67	11.64		
								% COV					15.45	15.42	15.43		
BH2-01-6R-x	1	T7-SLL-C-9B	2-D	0.584	Modified	0.250	1.5	3/16	1.5005	0.2098	0.1870		19.79	62.85	71.80	hole	
	2	T7-SLL-C-9B	SLL	0.584	IITRI				1.5003	0.2138	0.1870		20.01	62.38	71.26	hole	
	3	T7-SLL-C-9B		0.584					1.4988	0.2212	0.1870		21.17	63.84	72.94	hole	
								Avg.	1.4999	0.2150	0.1870		20.32	63.03	72.00		
								Std. Dev.					0.74	0.75	0.86		
								% COV					3.65	1.18	1.19		
BH2-02-6P-x	1	T7-LLS-C-3B	2-D	0.611	Modified	0.250	1.5	3/8	1.5000	0.2220	0.3745		12.53	37.63	50.15	hole	
	2	T7-LLS-C-3B	LLS	0.611	IITRI				1.5010	0.2212	0.3750		14.59	43.95	58.59	hole	
	3	T7-LLS-C-3B		0.611					1.5010	0.2207	0.3755		14.66	44.25	59.01	hole	
								Avg.	1.5007	0.2213	0.3750		13.93	41.94	55.92		
								Std Dev					1.21	3.74	5.00		
								% COV					8.69	8.91	8.94		
BH2-02-6Q-x	1	T7-LLS-C-1B	2-D	0.584	Modified	0.250	1.5	1/4	1.5010	0.2225	0.2495		14.90	44.62	53.52	hole	
	2	T7-LLS-C-1B	LLS	0.584	IITRI				1.5000	0.2235	0.2505		16.89	50.38	60.48	hole	
	3	T7-LLS-C-1B		0.584					1.5000	0.2246	0.2500		15.72	46.66	55.99	hole	
								Avg.	1.5003	0.2235	0.2500		15.84	47.22	56.66		
								Std. Dev.					1.00	2.92	3.53		
								% COV					6.32	6.18	6.22		
BH2-02-6R-x	1	T7-LLS-C-3B	2-D	0.611	Modified	0.250	1.5	3/16	1.5005	0.2227	0.1870		17.09	51.15	58.44	hole	
	2	T7-LLS-C-3B	LLS	0.611	IITRI				1.4983	0.2224	0.1875		17.26	51.80	59.21	hole	
	3	T7-LLS-C-3B		0.611					1.5015	0.2234	0.1870		16.90	50.38	57.55	hole	
								Avg.	1.5001	0.2228	0.1872		17.08	51.11	58.40		
								Std Dev					0.18	0.71	0.83		
								% COV					1.05	1.39	1.42		
BH2-03-6P-x	1	T7-LLL-C-4A	2-D	0.602	Modified	0.250	1.5	3/8	1.5007	0.2284	0.3730		17.32	50.54	67.26	hole	
	2	T7-LLL-C-4A	LLL	0.602	IITRI				1.5008	0.2287	0.3730		16.26	47.37	63.03	hole	
	3	T7-LLL-C-4A		0.602					1.4993	0.2290	0.3735		15.39	44.83	59.70	hole	
								Avg.	1.5003	0.2287	0.3732		16.32	47.58	63.33		
								Std Dev					0.97	2.86	3.79		
								% COV					5.92	6.02	5.99		
BH2-03-6Q-x	1	T7-LLL-C-4A	2-D	0.602	Modified	0.250	1.5	1/4	1.5003	0.2275	0.2505		16.81	49.26	59.13	hole	
	2	T7-LLL-C-4A	LLL	0.602	IITRI				1.5020	0.2287	0.2505		18.28	53.21	63.86	hole	
	3	T7-LLL-C-4A		0.602					1.5005	0.2283	0.2500		18.80	54.87	65.84	hole	
								Avg	1.5009	0.2282	0.2503		17.96	52.45	62.94		
								Std Dev					1.03	2.88	3.45		
								% COV					5.75	5.50	5.48		

Project #: BH0002

Material: AS4/Shell 1895

Textile Test Method Development

Task 6

Open Hole Compression Test Program

2-D Braided Architectures

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions Thick. (in)	Nominal Dimensions Width (in)	Nominal Dimensions Diam. (in)	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-03-6R-x	1	T7-LLL-C-4A	2-D	0.602	Modified	0.250	1.5	3/16	1.5010	0.2264	0.1880		20.35	59.90	68.47	hole	
	2	T7-LLL-C-4A	LLL	0.602	IITRI				1.5023	0.2250	0.1880		20.18	59.70	68.24	hole	
	3	T7-LLL-C-4A		0.602					1.5008	0.2239	0.1880		19.06	56.73	64.85	hole	
								Avg.	1.5014	0.2251	0.1880		19.86	58.78	67.19		
								Std. Dev.					0.70	1.78	2.03		
								% COV					3.53	3.02	3.02		
BH2-04-6P-x	1	T7-LSS-C-6A	2-D	0.592	Modified	0.250	1.5	3/8	1.5008	0.2252	0.3735		10.11	29.91	39.83	hole	
	2	T7-LSS-C-6A	LSS	0.592	IITRI				1.5003	0.2228	0.3735		10.21	30.54	40.66	hole	
	3	T7-LSS-C-6A		0.592					1.5007	0.2185	0.3735		10.15	30.96	41.22	hole	
								Avg.	1.5006	0.2222	0.3735		10.16	30.47	40.57		
								Std. Dev.					0.05	0.52	0.70		
								% COV					0.50	1.72	1.72		
BH2-04-6Q-x	1	T7-LSS-C-6A	2-D	0.592	Modified	0.250	1.5	1/4	1.5015	0.2126	0.2500		11.68	36.60	43.91	hole	
	2	T7-LSS-C-6A	LSS	0.592	IITRI				1.5008	0.2174	0.2500		11.48	35.18	42.21	hole	
	3	T7-LSS-C-6A		0.592					1.4993	0.2230	0.2500		11.23	33.58	40.30	hole	
								Avg.	1.5006	0.2177	0.2500		11.46	35.12	42.14		
								Std. Dev.					0.23	1.51	1.80		
								% COV					1.97	4.30	4.28		
BH2-04-6R-x	1	T7-LSS-C-6A	2-D	0.592	Modified	0.250	1.5	3/16	1.4995	0.2167	0.1880		11.49	35.36	40.43	hole	
	2	T7-LSS-C-6A	LSS	0.592	IITRI				1.5000	0.2170	0.1880		11.80	36.26	41.45	hole	
	3	T7-LSS-C-6A		0.592					1.4998	0.2177	0.1880		11.96	36.63	41.88	hole	
								Avg.	1.4998	0.2171	0.1880		11.75	36.08	41.25		
								Std. Dev.					0.24	0.65	0.75		
								% COV					2.03	1.81	1.81		
BH2-01-6S-x	4	T7-SLL-B-8A	2-D	0.601	Zabora	0.125	1.5	3/8	1.4978	0.1079	0.3750	8.0	8.17	50.54	67.42	hole	
	5	T7-SLL-B-8A	SLL	0.601	Fixture				1.4975	0.1068	0.3750	7.7	8.56	53.52	71.39	hole	
	6	T7-SLL-B-8A		0.601					1.4973	0.1057	0.3755	8.5	9.29	58.75	78.42	hole	
								Avg.	1.4975	0.1068	0.3752	8.1	8.67	54.27	72.41		
								Std. Dev.					0.57	4.16	5.57		
								% COV					6.61	7.66	7.69		
BH2-01-6T-x	1	T7-SLL-B-8A	2-D	0.601	Zabora	0.125	1.5	1/4	1.4978	0.1060	0.2520	6.7	9.46	59.59	71.65	hole	
	2	T7-SLL-B-8A	SLL	0.601	Fixture				1.4980	0.1073	0.2515	9.6	9.91	61.66	74.10	hole	
	3	T7-SLL-B-8A		0.601					1.4960	0.1075	0.2515	7.6	10.99	68.34	82.15	hole	
								Avg.		0.1069	0.2517	8.0	10.12	63.20	75.96		
								Std. Dev.					0.79	4.57	5.49		
								% COV					7.78	7.23	7.23		
BH2-01-6U-x	1	T7-SLL-B-8A	2-D	0.601	Zabora	0.125	1.5	3/16	1.4975	0.1092	0.1890	9.3	10.31	63.08	72.19	hole	
	2	T7-SLL-B-8A	SLL	0.601	Fixture				1.4973	0.1072	0.1890	10.6	10.94	68.17	78.01	hole	
	3	T7-SLL-B-8A		0.601					1.4977	0.1064	0.1890	9.1	9.83	61.70	70.61	hole	
								Avg.	1.4975	0.1076	0.1890	9.7	10.36	64.32	73.61		
								Std. Dev.					0.55	3.41	3.90		
								% COV					5.35	5.29	5.30		

Project #: BH0002

Material AS4/Shell 1895

intec Engineer Maryann Einarson

Boeing Engineer Mark Fedro

Textile Test Method Development

Task 6

Open Hole Compression Test Program

2-D Braided Architectures

intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions Thick. (in)	Nominal Dimensions Width (in)	Nominal Dimensions Diam. (in)	Avg Width (in)	Avg Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-02-6S-x	4	T7-LLS-B-11B	2-D	0.601	Zabora	0.125	1.5	3/8	1.4973	0.1116	0.3750	5.2	7.04	42.12	56.19	hole	
	5	T7-LLS-B-11B	LLS	0.601	Fixture				1.4982	0.1126	0.3750	6.3	6.77	40.11	53.50	hole	
	6	T7-LLS-B-11B		0.601					1.4970	0.1127	0.3755	5.7	7.00	41.48	55.37	hole	
								Avg	1.4975	0.1123	0.3752	5.7	6.93	41.23	55.02		
								Std Dev					0.15	1.03	1.38		
								% COV					2.12	2.49	2.51		
BH2-02-6T-x	1	T7-LLS-B-11B	2-D	0.601	Zabora	0.125	1.5	1/4	1.4975	0.1107	0.2520	6.0	6.93	41.82	50.28	hole	
	2	T7-LLS-B-11B	LLS	0.601	Fixture				1.4978	0.1073	0.2520	4.6	7.68	47.79	57.46	hole	
	3	T7-LLS-B-11B		0.601					1.4975	0.1068	0.2515	5.9	8.44	52.77	63.42	hole	
								Avg.	1.4976	0.1083	0.2518	5.5	7.68	47.46	57.05		
								Std. Dev.					0.75	5.48	6.58		
								% COV					9.82	11.55	11.53		
BH2-02-6U-x	1	T7-LLS-B-11B	2-D	0.601	Zabora	0.125	1.5	3/16	1.4975	0.1094	0.1890	7.7	8.90	54.31	62.16	hole	
	2	T7-LLS-B-11B	LLS	0.601	Fixture				1.4975	0.1107	0.1890	6.3	8.57	51.69	59.15	hole	
	3	T7-LLS-B-11B		0.601					1.4973	0.1112	0.1890	5.7	9.48	56.96	65.19	hole	
								Avg.	1.4974	0.1104	0.1890	6.6	8.98	54.32	62.17		
								Std. Dev.					0.46	2.64	3.02		
								% COV					5.14	4.86	4.86		
BH2-03-6S-x	4	T7-LLL-B-4B	2-D	0.622	Zabora	0.125	1.5	3/8	1.4982	0.1126	0.3755	6.1	8.56	50.70	67.66	hole	
	5	T7-LLL-B-4B	LLL	0.622	Fixture				1.4972	0.1140	0.3755	5.6	9.08	53.19	70.99	hole	
	6	T7-LLL-B-4B		0.622					1.4977	0.1156	0.3760	7.4	8.56	49.41	65.97	hole	
								Avg.	1.4977	0.1141	0.3757	6.4	8.73	51.10	68.21		
								Std. Dev.					0.30	1.92	2.56		
								% COV					3.44	3.76	3.75		
BH2-03-6T-x	1	T7-LLL-B-4B	2-D	0.622	Zabora	0.125	1.5	1/4	1.4975	0.1167	0.2515	6.8	7.42	42.47	51.04	hole	
	2	T7-LLL-B-4B	LLL	0.622	Fixture				1.4977	0.1171	0.2520	7.5	8.33	47.52	57.13	hole	
	3	T7-LLL-B-4B		0.622					1.4968	0.1149	0.2510	6.7	8.80	51.19	61.51		failed away from hole
								Avg.	1.4973	0.1162	0.2515	7.0	8.19	47.06	56.56		
								Std. Dev.					0.70	4.38	5.26		
								% COV					8.57	9.31	9.29		
BH2-03-6U-x	1	T7-LLL-B-4B	2-D	0.622	Zabora	0.125	1.5	3/16	1.4977	0.1101	0.1880	7.5	9.80	59.47	68.01	hole	
	2	T7-LLL-B-4B	LLL	0.622	Fixture				1.4970	0.1121	0.1875	9.4	10.95	65.28	74.63	hole	
	3	T7-LLL-B-4B		0.622					1.4972	0.1137	0.1880	7.6	8.35	49.07	56.12		failed away from hole
								Avg.	1.4973	0.1119	0.1878	8.2	9.70	57.94	66.25		
								Std Dev					1.30	8.21	9.38		
								% COV					13.42	14.17	14.16		
BH2-04-6S-x	4	T7-LSS-B-6B	2-D	0.602	Zabora	0.125	1.5	3/8	1.4982	0.1049	0.3760		4.81	30.61	40.86	hole	
	5	T7-LSS-B-6B	LLL	0.602	Fixture				1.4978	0.1049	0.3760	4.3	4.79	30.47	40.69	hole	
	6	T7-LSS-B-6B		0.602					1.4972	0.1043	0.3760	3.8	4.69	30.02	40.09	hole	
								Avg.	1.4977	0.1047	0.3760	4.1	4.76	30.37	40.54		
								Std Dev.					0.06	0.31	0.41		
								% COV					1.35	1.02	1.00		

Project #: ▫H0002 Material. AS4/Shell 1895

intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development

Task 6

Open Hole Compression Test Program

2-D Braided Architectures

intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions Thick. (in)	Nominal Dimensions Width (in)	Nominal Dimensions Diam. (in)	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-04-6T-x	1	T7-LSS-B-6B	2-D	0.602	Zabora	0.125	1.5	1/4	1.4982	0.1026	0.2520	3.9	5.36	34.84	41.88	hole	
	2	T7-LSS-B-6B	LLL	0.602	Fixture				1.4980	0.1020	0.2515	5.6	6.26	41.01	49.28	hole	
	3	T7-LSS-B-6B		0.602					1.4973	0.1031	0.2520	5.8	6.06	39.27	47.22	hole	
								Avg.	1.4978	0.1025	0.2518	5.1	5.89	38.37	46.13		
								Std. Dev.					0.48	3.18	3.82		
								% COV					8.07	8.29	8.28		
BH2-04-6U-x	1	T7-LSS-B-6B	2-D	0.602	Zabora	0.125	1.5	3/16	1.4975	0.1043	0.1880	5.9	6.65	42.61	48.73	hole	
	2	T7-LSS-B-6B	LLL	0.602	Fixture				1.4967	0.1044	0.1880	5.9	6.36	40.72	46.57	hole	
	3	T7-LSS-B-6B		0.602					1.4975	0.1031	0.1880	5.4	5.76	37.33	42.69	hole	
								Avg.	1.4972	0.1039	0.1880	5.7	6.26	40.22	45.99		
								Std. Dev.					0.45	2.68	3.06		
								% COV					7.25	6.65	6.66		

Project #: BH0002

Textile Test Method Development

Task 6 & 8

Open Hole Compression Test Program

3-D Woven Architectures

Material: AS4/Shell 1895

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro
No instrumentation

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions Thick. (in)	Width (in)	Diam. (in)	W/D	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-05-6B-x	1	T7-TS1-A-2A	3-D	0.628	Boeing	0.250	1.5	1/4	6	1.5007	0.2342	0.2500		19.32	54.97	65.96	hole	
	2	T7-TS1-A-2A	TS-1	0.628	OH Comp					1.5007	0.2321	0.2495		18.79	53.96	64.72	hole	
	3	T7-TS1-A-2A		0.628						1.4992	0.2340	0.2495		19.62	55.93	67.10	hole	
								Avg.		1.5002	0.2334	0.2497		19.24	54.95	65.93		
								Std. Dev.						0.42	0.99	1.19		
								% COV						2.18	1.80	1.81		
BH2-06-6B-x	1	T7-TS2-A-2B	3-D	0.632	Boeing	0.250	1.5	1/4	6	1.4992	0.2155	0.2510		19.83	61.37	73.71	hole	
	2	T7-TS2-A-2B	TS-2	0.632	OH Comp					1.5000	0.2086	0.2520		17.89	57.17	68.71	hole	
	3	T7-TS2-A-2B		0.632						1.5002	0.2067	0.2510		17.82	57.47	69.02	hole	
								Avg.		1.4998	0.2103	0.2513		18.51	58.67	70.48		
								Std. Dev.						1.14	2.35	2.80		
								% COV						6.16	4.00	3.98		
BH2-07-6B-x	1	T7-OS1-A-3B	3-D	0.643	Boeing	0.250	1.5	1/4	6	1.5005	0.2236	0.2510		22.53	67.16	80.65	hole	
	2	T7-OS1-A-3B	OS-1	0.643	OH Comp					1.5015	0.2242	0.2515		22.98	68.28	82.02	hole	
	3	T7-OS1-A-3B		0.643						1.5013	0.2253	0.2520		21.94	64.85	77.94	hole	
								Avg.		1.5011	0.2244	0.2515		22.48	66.76	80.20		
								Std. Dev.						0.52	1.75	2.08		
								% COV						2.32	2.62	2.59		
BH2-09-6B-x	1	T7-LS1-A-5A	3-D	0.628	Boeing	0.250	1.5	1/4	6	1.4985	0.2510	0.2510		20.10	53.44	64.19	hole	
	2	T7-LS1-A-7A	LS-1	0.656	OH Comp					1.4992	0.2510	0.2510		19.15	50.89	61.13	hole	
	3	T7-LS1-A-7A		0.656						1.4980	0.2525	0.2510		22.99	60.78	73.01	hole	
								Avg.		1.4986	0.2515	0.2510		20.75	55.04	66.11		
								Std. Dev.						2.00	5.13	6.17		
								% COV						9.64	9.33	9.34		
BH2-10-6B-x	1	T7-LS2-A-2A	3-D	0.653	Boeing	0.250	1.5	1/4	6	1.4995	0.2124	0.2520		18.64	58.54	70.37	hole	
	2	T7-LS2-A-2A	LS-2	0.653	OH Comp					1.5010	0.2083	0.2520		19.17	61.30	73.67	hole	
	3	T7-LS2-A-2A		0.653						1.5017	0.2084	0.2520		20.57	65.72	78.98	hole	
								Avg.		1.5007	0.2097	0.2520		19.46	61.86	74.34		
								Std. Dev.						1.00	3.62	4.34		
								% COV						5.12	5.86	5.84		
BH2-05-6P-x	1	T7-TS1-A-2A	3-D	0.628	Modified	0.250	1.5	3/8	4.0	1.5005	0.2248	0.3740	8.9	16.59	49.19	65.52	hole	
	2	T7-TS1-A-2A	TS-1	0.628	IITRI					1.5018	0.2250	0.3745	11.0	17.28	51.13	68.12	hole	
	3	T7-TS1-A-2A		0.628						1.5005	0.2246	0.3740	14.0	17.08	50.67	67.50	hole	
								Avg.		1.5009	0.2248	0.3742	11.3	16.98	50.33	67.04		
								Std. Dev.						0.36	1.02	1.36		
								% COV						2.09	2.02	2.03		
BH2-05-6Q-x	1	T7-TS1-A-2A	3-D	0.628	Modified	0.250	1.5	1/4	6	1.5008	0.2359	0.2490	10.3	18.63	52.63	63.10		#1 Failed below hole
	2	T7-TS1-A-2A	TS-1	0.628	IITRI					1.4995	0.2363	0.2495	11.1	20.01	56.47	67.74	hole	
	3	T7-TS1-A-2A		0.628						1.5005	0.2356	0.2495	17.4	19.58	55.38	66.43	hole	
								Avg.		1.5003	0.2359	0.2493	12.9	19.41	54.83	65.76		
								Std. Dev.						0.71	1.98	2.39		
								% COV						3.64	3.61	3.64		

Project #: BH0002

Textile Test Method Development

Task 6 & 8

Open Hole Compression Test Program

3-D Woven Architectures

Material: AS4/Shell 1895

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro
No instrumentation

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions Thick. (in)	Width (in)	Diam. (in)	W/D	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-05-6R-x	1	T7-TS1-A-2A	3-D	0.628	Modified	0.250	1.5	3/16	8	1.5018	0.2274	0.1880	16.9	23.05	67.48	77.14	hole	
	2	T7-TS1-A-2A	TS-1	0.628	IITRI					1.5005	0.2285	0.1885	15.3	21.95	64.03	73.23	hole	
	3	T7-TS1-A-2A		0.628						1.5005	0.2283	0.1880	15.6	21.38	62.41	71.35	hole	
								Avg.		1.5009	0.2281	0.1882	15.9	22.13	64.64	73.91		
								Std. Dev.						0.85	2.59	2.95		
								% COV						3.84	4.01	4.00		
BH2-06-6P-x	1	T7-TS2-A-2B	3-D	0.632	Modified	0.250	1.5	3/8	4	1.4990	0.2081	0.3750	10.5	14.75	47.30	63.08	hole	
	2	T7-TS2-A-2B	TS-2	0.632	IITRI					1.4988	0.2081	0.3750	13.4	15.72	50.41	67.23	hole	
	3	T7-TS2-A-2B		0.632						1.4985	0.2118	0.3750	14.0	16.41	51.71	68.97	hole	
								Avg.		1.4988	0.2093	0.3750	12.6	15.63	49.81	66.43		
								Std. Dev.						0.83	2.27	3.03		
								% COV						5.34	4.55	4.56		
BH2-06-6Q-x	1	T7-TS2-A-2B	3-D	0.632	Modified	0.250	1.5	1/4	6	1.4995	0.2132	0.2505	14.7	18.23	57.01	68.45	hole	
	2	T7-TS2-A-2B	TS-2	0.632	IITRI					1.4992	0.2176	0.2500	16.0	20.24	62.04	74.46	hole	
	3	T7-TS2-A-2B		0.632						1.4978	0.2229	0.2505	18.1	20.45	61.25	73.55	hole	
								Avg.		1.4988	0.2179	0.2503	16.3	19.64	60.10	72.15		
								Std. Dev.						1.23	2.70	3.24		
								% COV						6.24	4.50	4.49		
BH2-06-6R-x	1	T7-TS2-A-2B	3-D	0.632	Modified	0.250	1.5	3/16	8	1.5010	0.2078	0.1870	17.8	20.29	65.05	74.30	hole	
	2	T7-TS2-A-2B	TS-2	0.632	IITRI					1.4978	0.2086	0.1875	16.6	20.37	65.21	74.54	hole	
	3	T7-TS2-A-2B		0.632						1.4980	0.2108	0.1880	14.5	19.20	60.80	69.52	hole	
								Avg.		1.4989	0.2091	0.1875	16.3	19.95	63.68	72.79		
								Std. Dev.						0.65	2.50	2.83		
								% COV						3.28	3.93	3.89		
BH2-07-6P-x	1	T7-OS1-A-3B	3-D	0.643	Modified	0.250	1.5	3/8	4	1.5005	0.2293	0.3750	10.8	19.51	56.70	75.60	hole	
	2	T7-OS1-A-3B	OS-1	0.643	IITRI					1.4978	0.2303	0.3755	14.9	20.31	58.88	78.58	hole	
	3	T7-OS1-A-3B		0.643						1.4995	0.2313	0.3750	15.4	20.25	58.38	77.85	hole	
								Avg.		1.4993	0.2303	0.3752	13.7	20.02	57.99	77.34		
								Std. Dev.						0.45	1.14	1.55		
								% COV						2.23	1.96	2.01		
BH2-07-6Q-x	1	T7-OS1-A-3B	3-D	0.643	Modified	0.250	1.5	1/4	6	1.4995	0.2338	0.2520		22.32	63.66	76.52	hole	
	2	T7-OS1-A-3B	OS-1	0.643	IITRI					1.4982	0.2307	0.2540		24.92	72.11	86.83	hole	
	3	T7-OS1-A-3B		0.643						1.4978	0.2272	0.2550		22.65	66.57	80.23	hole	
								Avg.		1.4985	0.2306	0.2537		23.30	67.44	81.19		
								Std. Dev.						1.42	4.29	5.22		
								% COV						6.08	6.36	6.43		
BH2-07-6R-x	1	T7-OS1-A-3B	3-D	0.643	Modified	0.250	1.5	3/16	8	1.4992	0.2248	0.1900		22.99	68.23	78.13	hole	
	2	T7-OS1-A-3B	OS-1	0.643	IITRI					1.4983	0.2259	0.1900		24.54	72.51	83.04	hole	
	3	T7-OS1-A-3B		0.643						1.4958	0.2259	0.1900		24.95	73.83	84.57	hole	
								Avg.		1.4978	0.2255	0.1900		24.16	71.52	81.91		
								Std. Dev.						1.03	2.92	3.36		
								% COV						4.28	4.09	4.10		

Project #: BH0002

Textile Test Method Development

Task 6 & 8

Open Hole Compression Test Program

3-D Woven Architectures

Material: AS4/Shell 1895

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro
No instrumentation

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions Thick. (in)	Width (in)	Diam. (in)	W/D	Avg Width (in)	Avg Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-08-6P-x	1	T7-OS2-A-3A	3-D	0.564	Modified	0.250	1.5	3/8	4	1.4963	0.2392	0.3745		16.42	45.89	61.20	hole	
	2	T7-OS2-A-3A	OS-2	0.564	IITRI					1.4985	0.2369	0.3745		17.68	49.80	66.40	hole	
	3	T7-OS2-A-3A		0.564						1.4987	0.2348	0.3740		16.38	46.55	62.03	hole	
								Avg		1.4978	0.2369	0.3743		16.83	47.41	63.21		
								Std. Dev.						0.74	2.10	2.79		
								% COV						4.39	4.42	4.41		
BH2-08-6Q-x	1	T7-OS2-A-3A	3-D	0.564	Modified	0.250	1.5	1/4	6	1.4992	0.2400	0.2495		16.74	46.52	55.81	hole	
	2	T7-OS2-A-3A	OS-2	0.564	IITRI					1.5003	0.2385	0.2500		15.04	42.03	50.43	hole	
	3	T7-OS2-A-3A		0.564						1.4980	0.2378	0.2500		14.27	40.06	48.08	hole	
								Avg.		1.4992	0.2388	0.2498		15.35	42.87	51.44		
								Std. Dev.						1.26	3.31	3.96		
								% COV						8.23	7.73	7.70		
BH2-08-6R-x	1	T7-OS2-A-3A	3-D	0.564	Modified	0.250	1.5	3/16	8	1.5040	0.2481	0.1900		22.67	60.75	69.54	hole	
	2	T7-OS2-A-3A	OS-2	0.564	IITRI					1.4990	0.2485	0.1900		23.90	64.17	73.48	hole	
	3	T7-OS2-A-3A		0.564						1.4990	0.2458	0.1900		24.59	66.74	76.43	hole	
								Avg.		1.5007	0.2475	0.1900		23.72	63.89	73.15		
								Std. Dev.						0.97	3.00	3.46		
								% COV						4.10	4.70	4.73		
BH2-09-6P-x	1	T7-LS1-A-5B	3-D	0.646	Modified	0.250	1.5	3/8	4	1.4997	0.2105	0.3740		20.03	63.44	84.52	hole	
	2	T7-LS1-A-5B	LS-1	0.646	IITRI					1.4997	0.2132	0.3745		14.99	46.89	62.50	hole	
	3	T7-LS1-A-5B		0.646						1.4992	0.2117	0.3740		18.41	58.02	77.30	hole	
								Avg.		1.4995	0.2118	0.3742		17.81	56.12	74.77		
								Std. Dev.						2.57	8.43	11.22		
								% COV						14.45	15.03	15.01		
BH2-09-6Q-x	1	T7-LS1-A-6A	3-D	0.637	Modified	0.250	1.5	1/4	6	1.5023	0.2177	0.2495		19.42	59.39	71.22	hole	
	2	T7-LS1-A-6A	LS-1	0.637	IITRI					1.4975	0.2163	0.2490		20.98	64.77	77.68	hole	
	3	T7-LS1-A-6A		0.637						1.4988	0.2153	0.2500		20.45	63.36	76.05	hole	
								Avg.		1.4996	0.2164	0.2495		20.28	62.51	74.98		
								Std. Dev.						0.79	2.79	3.36		
								% COV						3.91	4.46	4.48		
BH2-09-6R-x	1	T7-LS1-A-5A	3-D	0.628	Modified	0.250	1.5	3/16	8	1.5005	0.2136	0.1875		20.67	64.49	73.70	hole	
	2	T7-LS1-A-5A	LS-1	0.628	IITRI					1.4993	0.2109	0.1870		19.46	61.55	70.32	hole	
	3	T7-LS1-A-5A		0.628						1.5000	0.2098	0.1875		22.66	71.99	82.28	hole	
								Avg.		1.4999	0.2114	0.1873		20.93	66.01	75.43		
								Std. Dev.						1.62	5.39	6.17		
								% COV						7.72	8.16	8.18		
BH2-10-6P-x	1	T7-LS2-A-2A	3-D	0.653	Modified	0.250	1.5	3/8	4	1.5008	0.2129	0.3750		14.78	46.26	61.67	hole	
	2	T7-LS2-A-2A	LS-2	0.653	IITRI					1.4990	0.2136	0.3750		17.75	55.43	73.93	hole	
	3	T7-LS2-A-2A		0.653						1.4980	0.2141	0.3750		16.93	52.78	70.40	hole	
								Avg		1.4993	0.2135	0.3750		16.49	51.49	68.67		
								Std. Dev						1.53	4.72	6.31		
								% COV						9.30	9.17	9.19		

Project #: BH0002

Textile Test Method Development

Task 6 & 8

Open Hole Compression Test Program

3-D Woven Architectures

Material: AS4/Shell 1895

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro
No instrumentation

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions Thick. (in)	Nominal Dimensions Width (in)	Nominal Dimensions Diam. (in)	W/D	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-10-6Q-x	1	T7-LS2-A-2A	3-D	0.653	Modified	0.250	1.5	1/4	6	1.5000	0.2128	0.2505		18.40	57.64	69.20	hole	
	2	T7-LS2-A-2A	LS-2	0.653	IITRI					1.4990	0.2192	0.2500		20.63	62.80	75.37	hole	
	3	T7-LS2-A-2A		0.653						1.4980	0.2234	0.2500		21.25	63.51	76.23	hole	
									Avg.	1.4990	0.2184	0.2502		20.09	61.32	73.60		
									Std. Dev.					1.50	3.20	3.83		
									% COV					7.46	5.22	5.21		
BH2-10-6R-x	1	T7-LS2-A-2A	3-D	0.653	Modified	0.250	1.5	3/16	8	1.5000	0.2108	0.1895		20.35	64.37	73.68	hole	
	2	T7-LS2-A-2A	LS-2	0.653	IITRI					1.4990	0.2111	0.1895		20.48	64.72	74.09	hole	
	3	T7-LS2-A-2A		0.653						1.4995	0.2122	0.1895		18.54	58.28	66.71	hole	
									Avg.	1.4995	0.2113	0.1895		19.79	62.45	71.49		
									Std. Dev.					1.08	3.62	4.15		
									% COV					5.48	5.80	5.80		

Project #: BH0002

Textile Test Method Development

Task 8

Open Hole Compression Test Program

Stitched Uniweave Architectures

Material: AS4/Shell 1895

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro
No instrumentation

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions Thick. (in)	Width (in)	Diam. (in)	W/D	Avg Width (in)	Avg Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-11-6B-x	1	T7-SUW-G3K8B1	SU-1	0.668	Boeing OH Comp	0.250	1.5	1/4	6	1.5000	0.2231	0.2510	13.5	16.30	48.72	58.51	hole	
	2	T7-SUW-G3K8B1		0.668						1.4995	0.2235	0.2515	14.0	17.71	52.85	63.50	hole	
	3	T7-SUW-G3K8B1		0.668						1.5000	0.2238	0.2495	12.8	16.97	50.55	60.64	hole	
								Avg.					13.4	16.99	50.71	60.88		
								Std. Dev.						0.71	2.07	2.51		
								% COV						4.15	4.08	4.12		
BH2-12-6B-x	1	T7-SUW-G6K8B1	SU-2	0.644	Boeing OH Comp	0.250	1.5	1/4	6	1.5010	0.2467	0.2500	9.7	16.31	44.05	52.85	hole	
	2	T7-SUW-G6K8B1		0.644						1.5000	0.2466	0.2510	11.6	16.47	44.53	53.48	hole	
	3	T7-SUW-G6K8B1		0.644						1.5010	0.2469	0.2510	10.9	15.90	42.90	51.51	hole	
								Avg.					10.7	16.23	43.83	52.61		
								Std. Dev.						0.29	0.84	1.01		
								% COV						1.81	1.91	1.91		
BH2-13-6B-x	1	T7-SUW-K6K8B1	SU-3	0.635	Boeing OH Comp	0.250	1.5	1/4	6	1.5067	0.2381	0.2500	13.0	14.58	40.64	48.72	hole	
	2	T7-SUW-K6K8B1		0.635						1.4958	0.2403	0.2500	12.1	15.37	42.75	51.33	hole	
	3	T7-SUW-K6K8B1		0.635						1.4985	0.2418	0.2495	10.9	15.71	43.35	52.01	hole	
								Avg.					12.0	15.22	42.25	50.69		
								Std. Dev.						0.58	1.43	1.74		
								% COV						3.81	3.38	3.43		
BH2-14-6B-x	1	T7-SUW-K6K4B1	SU-4	0.648	Boeing OH Comp	0.250	1.5	1/4	6	1.4995	0.2298	0.2515	12.2	13.97	40.54	48.71	hole	
	2	T7-SUW-K6K4B1		0.648						1.5010	0.2313	0.2500	9.9	14.49	41.73	50.07	hole	
	3	T7-SUW-K6K4B1		0.648						1.5037	0.2329	0.2500	9.6	14.27	40.74	48.87	hole	
								Avg.					10.6	14.24	41.00	49.21		
								Std. Dev.						0.26	0.64	0.74		
								% COV						1.83	1.55	1.51		
BH2-15-6B-x	1	T7-SUW-K12K8B1	SU-5	0.654	Boeing OH Comp	0.250	1.5	1/4	6	1.5017	0.2616	0.2495	10.2	18.36	46.74	56.05	hole	
	2	T7-SUW-K12K8B1		0.654						1.5067	0.2626	0.2500	13.1	18.10	45.74	54.84	hole	
	3	T7-SUW-K12K8B1		0.654						1.4950	0.2634	0.2495	9.8	18.38	46.68	56.03	hole	
								Avg.					11.0	18.28	46.39	55.64		
								Std. Dev.						0.16	0.56	0.69		
								% COV						0.85	1.20	1.24		
BH2-11-6P-x	1	T7-SUW-G3K8B1	SU-1	0.668	Modified IITRI	0.250	1.5	3/8	4	1.4992	0.2219	0.3740		14.39	43.25	57.63	hole	
	2	T7-SUW-G3K8B1		0.668						1.5000	0.2219	0.3740		15.33	46.06	61.35	hole	
	3	T7-SUW-G3K8B1		0.668						1.4988	0.2224	0.3740		14.57	43.71	58.24	hole	
								Avg.						14.76	44.34	59.08		
								Std. Dev.						0.50	1.50	2.00		
								% COV						3.38	3.39	3.38		
BH2-11-6Q-x	1	T7-SUW-G3K8B1	SU-1	0.668	Modified IITRI	0.250	1.5	1/4	6	1.5008	0.2212	0.2510		15.81	47.63	57.20	hole	
	2	T7-SUW-G3K8B1		0.668						1.4990	0.2207	0.2505		16.62	50.24	60.33	hole	
	3	T7-SUW-G3K8B1		0.668						1.5010	0.2207	0.2510		15.61	47.11	56.58	hole	
								Avg.						16.01	48.33	58.03		
								Std. Dev.						0.53	1.68	2.01		
								% COV						3.34	3.47	3.46		

Project #: BH0002

Textile Test Method Development

Task 8

Open Hole Compression Test Program

Stitched Uniweave Architectures

Material AS4/Shell 1895

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro
No instrumentation

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions Thick (in)	Nominal Dimensions Width (in)	Nominal Dimensions Diam (in)	W/D	Avg Width (in)	Avg Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-11-6R-x	1	T7-SUW-G3K8B1	SU-1	0.668	Modified IITRI	0.250	1.5	3/16	8	1.5000	0.2241	0.1875		17.04	50.70	57.94	hole	
	2	T7-SUW-G3K8B1		0.668						1.4990	0.2241	0.1875		17.78	52.93	60.50	hole	
	3	T7-SUW-G3K8B1		0.668						1.5000	0.2240	0.1875		17.57	52.30	59.77	hole	
Avg														17.46	51.97	59.40		
Std Dev														0.38	1.15	1.32		
% COV														2.18	2.22	2.22		
BH2-12-6P-x	1	T7-SUW-G6K8B1	SU-2	0.644	Modified IITRI	0.250	1.5	3/8	4	1.5000	0.2469	0.3740		13.30	35.91	47.84	hole	
	2	T7-SUW-G6K8B1		0.644						1.5000	0.2467	0.3740		14.25	38.51	51.30	hole	
	3	T7-SUW-G6K8B1		0.644						1.4978	0.2461	0.3745		13.83	37.51	50.02	hole	
Avg.														13.79	37.31	49.72		
Std Dev.														0.48	1.31	1.75		
% COV														3.45	3.51	3.51		
BH2-12-6Q-x	1	T7-SUW-G6K8B1	SU-2	0.644	Modified IITRI	0.250	1.5	1/4	6	1.4990	0.2454	0.2505		15.77	42.86	51.46	hole	
	2	T7-SUW-G6K8B1		0.644						1.5018	0.2404	0.2530		13.98	38.73	46.57	hole	
	3	T7-SUW-G6K8B1		0.644						1.5003	0.2453	0.2505		15.97	43.39	52.08	hole	
Avg.														15.24	41.66	50.04		
Std Dev.														1.10	2.55	3.02		
% COV														7.19	6.13	6.03		
BH2-12-6R-x	1	T7-SUW-G6K8B1	SU-2	0.644	Modified IITRI	0.250	1.5	3/16	8	1.5005	0.2473	0.1880		16.31	43.95	50.25	hole	
	2	T7-SUW-G6K8B1		0.644						1.4995	0.2469	0.1875		16.48	44.52	50.88	hole	
	3	T7-SUW-G6K8B1		0.644						1.4990	0.2470	0.1875		16.97	45.83	52.39	hole	
Avg.														16.59	44.77	51.17		
Std Dev.														0.34	0.97	1.10		
% COV														2.07	2.16	2.15		
BH2-13-6P-x	1	T7-SUW-K6K8B1	SU-3	0.635	Modified IITRI	0.250	1.5	3/8	4	1.4967	0.2399	0.3740		13.86	38.61	51.47	hole	
	2	T7-SUW-K6K8B1		0.635						1.5078	0.2396	0.3740		13.66	37.81	50.28	hole	
	3	T7-SUW-K6K8B1		0.635						1.5010	0.2400	0.3750		13.77	38.22	50.95	hole	
Avg														13.76	38.21	50.90		
Std Dev														0.10	0.40	0.60		
% COV														0.73	1.05	1.17		
BH2-13-6Q-x	1	T7-SUW-K6K8B1	SU-3	0.635	Modified IITRI	0.250	1.5	1/4	6	1.4977	0.2357	0.2510		14.74	41.76	50.16	hole	
	2	T7-SUW-K6K8B1		0.635						1.5098	0.2362	0.2505		15.50	43.47	52.11	hole	
	3	T7-SUW-K6K8B1		0.635						1.4993	0.2377	0.2510		16.21	45.49	54.63	hole	
Avg														15.48	43.57	52.30		
Std Dev														0.74	1.87	2.24		
% COV														4.75	4.29	4.28		
BH2-13-6R-x	1	T7-SUW-K6K8B1	SU-3	0.635	Modified IITRI	0.250	1.5	3/16	8	1.4940	0.2444	0.1875		17.17	47.02	53.77	hole	
	2	T7-SUW-K6K8B1		0.635						1.4913	0.2444	0.1875		17.11	46.95	53.71	hole	
	3	T7-SUW-K6K8B1		0.635						1.5027	0.2433	0.1875		17.57	48.05	54.90	hole	
Avg														17.28	47.34	54.13		
Std Dev														0.25	0.62	0.67		
% COV														1.45	1.30	1.24		

Project #: BH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro
No instrumentation

Textile Test Method Development

Task 8

Open Hole Compression Test Program
Stitched Uniweave Architectures

Material: AS4/Shell 1895

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions Thick (in)	Nominal Dimensions Width (in)	Nominal Dimensions Diam. (in)	W/D	Avg Width (in)	Avg Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-14-6P-x	1	T7-SUW-K6K4B1	SU-4	0.648	Modified IITRI	0.250	1.5	3/8	4	1.4983	0.2312	0.3735		12.98	37.47	49.91	hole	
	2	T7-SUW-K6K4B1		0.648						1.5007	0.2312	0.3740		13.22	38.10	50.75	hole	
	3	T7-SUW-K6K4B1		0.648						1.4990	0.2317	0.3740		13.05	37.58	50.07	hole	
											Avg			13.08	37.71	50.24		
											Std. Dev.			0.12	0.34	0.45		
											% COV			0.94	0.90	0.89		
BH2-14-6Q-x	1	T7-SUW-K6K4B1	SU-4	0.648	Modified IITRI	0.250	1.5	1/4	6	1.4975	0.2360	0.2515		15.32	43.36	52.11	hole	
	2	T7-SUW-K6K4B1		0.648						1.4995	0.2293	0.2505		15.15	44.07	52.91	hole	
	3	T7-SUW-K6K4B1		0.648						1.4970	0.2302	0.2505		14.69	42.62	51.19	hole	
											Avg.			15.05	43.35	52.07		
											Std. Dev.			0.33	0.72	0.86		
											% COV			2.17	1.67	1.65		
BH2-14-6R-x	1	T7-SUW-K6K4B1	SU-4	0.648	Modified IITRI	0.250	1.5	3/16	8	1.4990	0.2289	0.1875		15.84	46.17	52.77	hole	
	2	T7-SUW-K6K4B1		0.648						1.4983	0.2354	0.1880		16.61	47.10	53.85	hole	
	3	T7-SUW-K6K4B1		0.648						1.4960	0.2365	0.1875		16.88	47.70	54.54	hole	
											Avg.			16.44	46.99	53.72		
											Std. Dev.			0.54	0.77	0.89		
											% COV			3.28	1.65	1.66		
BH2-15-6P-x	1	T7-SUW-K12K8B1	SU-5	0.654	Modified IITRI	0.250	1.5	3/8	4	1.4990	0.2591	0.3740		15.09	38.86	51.78	hole	
	2	T7-SUW-K12K8B1		0.654						1.4975	0.2585	0.3735		14.78	38.18	50.86	hole	
	3	T7-SUW-K12K8B1		0.654						1.4948	0.2577	0.3740		14.70	38.17	50.90	hole	
											Avg.			14.86	38.40	51.18		
											Std. Dev.			0.21	0.40	0.52		
											% COV			1.39	1.04	1.01		
BH2-15-6Q-x	1	T7-SUW-K12K8B1	SU-5	0.654	Modified IITRI	0.250	1.5	1/4	6	1.4975	0.2596	0.2505	15.8	17.71	45.55	54.70	hole	
	2	T7-SUW-K12K8B1		0.654						1.4952	0.2586	0.2510	13.4	17.05	44.09	52.99	hole	
	3	T7-SUW-K12K8B1		0.654						1.5107	0.2584	0.2510	14.5	16.68	42.74	51.25	hole	
											Avg.		14.6	17.15	44.13	52.98		
											Std. Dev.			0.52	1.41	1.72		
											% COV			3.04	3.19	3.25		
BH2-15-6R-x	1	T7-SUW-K12K8B1	SU-5	0.654	Modified IITRI	0.250	1.5	3/16	8	1.4977	0.2642	0.1880	14.6	18.77	47.44	54.25	hole	
	2	T7-SUW-K12K8B1		0.654						1.5100	0.2645	0.1880	15.2	19.20	48.08	54.92	hole	
	3	T7-SUW-K12K8B1		0.654						1.4930	0.2640	0.1880	14.2	18.75	47.57	54.42	hole	
											Avg		14.7	18.91	47.70	54.53		
											Std Dev			0.25	0.34	0.34		
											% COV			1.34	0.71	0.63		

In-Plane Shear Test Program

Project #. BH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development

Task 7

In-Plane ShearTest Program

2-D Braided Architectures

AS4/Shell 1895

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Tabbed	Notch Length (in)	Avg Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Shear Stress (ksi)	Ultimate +45 Strain (με)	Ultimate -45 Strain (με)	Ultimate 0° Strain (με)	Ultimate 90° Strain (με)	Shear Modulus Axial 1 (msi)	Shear Modulus Axial 2 (msi)	Shear Modulus Average (msi)	Failure Mode	Comments
BH2-01-7A-x	1	T7-SLL-B-3A	2-D	0.647	N	3.0060	0.1082	3.2	6.55	20.14	5,759	-9,531	-445	-4,423				shear	Failed just off center, along braid
	4	T7-SLL-B-8B	SLL	0.615	Y	3.0085	0.1068	5.5	6.29	19.58	6,086	-6,948	-171	-937	1.62	1.42	1.52	shear	Failed just off center, along braid
	5	T7-SLL-B-8B		0.615	Y	3.0075	0.1044	6.0	6.44	20.49	6,847	-6,370	-263	-2,094	1.67	1.67	1.67	shear	Failed along braid in gage section
	6	T7-SLL-B-8B		0.615	Y	3.0140	0.1091	4.5	5.38	16.37	7,109	-5,205	42	2,821	1.46	1.49	1.48	shear	Failed at notch, along braid
					Average			4.8	6.16	19.14	6,681	-6,174	-131	-70	1.58	1.53	1.55		
					Std. Dev.				0.57	2.17					0.11	0.13	0.10		
					% COV				9.29	11.31					6.94	8.60	6.64		
BH2-02-7A-x	1	T7-LLS-B-YA	2-D	0.589	N	3.0030	0.1207	4.2	5.55	15.30	3,879	-4,709	-406	1,078				shear	Failed at notch
	4	T7-LLS-B-11A	LLS	0.538	Y	3.0100	0.1062	4.3	6.81	21.30	4,730	-4,681	-1,118	-212	2.22	2.53	2.38	shear	Failed just off center, along braid
	5	T7-LLS-B-11A		0.538	Y	2.9895	0.1058	4.1	5.21	16.46	3,088	-3,429	-71	11	2.62	2.45	2.54	shear	Failed at notch
	6	T7-LLS-B-11A		0.538	Y	3.0050	0.1137	3.8	6.88	20.15	6,883	-3,658	858	2,970	2.22	2.68	2.45	shear	Failed at notch
					Average			4.2	6.11	18.30	4,900	-3,923	-110	923	2.36	2.55	2.46		
					Std. Dev.				0.95	2.53					0.23	0.12	0.08		
					% COV				15.51	13.83					9.83	4.51	3.24		
BH2-03-7A-x	1	T7-LLL-B-3B	2-D	0.661	N	3.0090	0.1118	4.7	6.19	18.41	na	-6,107	-688	1,443	2.02	1.95	1.99	shear	Failed at notch
	2	T7-LLL-B-3B	LLL	0.661	N	3.0060	0.1159	4.5	5.73	16.43	5,846	-5,342	108	-2	1.44	1.68	1.56	shear	Failed just off center, along braid
	3	T7-LLL-B-3B		0.661	N	3.0085	0.1097	3.7	5.85	17.74	4,242	-6,284	761	-1,918	2.08	1.68	1.88	shear	Failed at notch
					Average			4.3	5.92	17.53	5,044	-5,911	60	-159	2.99	2.08	1.87		
					Std. Dev.				0.24	1.01					0.35	0.16	0.22		
					% COV				4.07	5.74					11.87	7.60	11.99		
BH2-04-7A-x	1	T7-LSS-B-4A	2-D	0.645	N	3.0055	0.1043	5.7	6.70	21.38	1,785	-2,596	-2,296	1,216				bearing	
	4	T7-LSS-B-6A	LSS	0.623	Y	3.0085	0.1088	10.1	11.62	35.51	5,112	-4,923	-550	1,444	3.44	3.87	3.65	shear	Failed at notch
	5	T7-LSS-B-6A		0.623	Y	3.0090	0.1013	5.4	12.42	40.74	4,925	-4,776	-759	1,913	4.33	4.61	4.47	shear	Partial failure along 0 deg braid
	6	T7-LSS-B-6A		0.623	Y	3.0070	0.1012	8.0	12.17	39.99	5,385	-4,285	-1,683	4,364	4.06	5.06	4.56	shear	and partial failure along 45 deg
					Average			5.7	10.73	34.41	5,141	-4,661	-997	2,574	3.94	4.51	4.23		
					Std. Dev.				0.41	2.83					0.46	0.60	0.50		
					% COV				3.83	8.22					11.59	13.36	11.82		

Nominal dimensions:
thickness = 0.125 in
notch length=3.0 in
width= 3.0 in
length=4.5 in

Project #: BH0002

Intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development

Task 7 & 8

In-Plane ShearTest Program

3-D Woven Architecture

AS4/Shell 1895

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Tabbed	Notch Length (in)	Avg Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Shear Stress (ksi)	Ultimate +45 Strain (με)	Ultimate -45 Strain (με)	Shear Modulus Axial 1 (msi)	Shear Modulus Axial 2 (msi)	Shear Modulus Average (msi)	Failure Mode	Comments
BH2-05-7A-x	1	T7-TS1-A-3A	3-D	0.615	Y	3.0080	0.2264	5.7	8.96	13.16			0.602	0.676	0.639	Shear	Failed at notch
	2	T7-TS1-A-3A	TS1	0.615	Y	3.0070	0.2292	7.4	9.08	13.17			0.696	0.696	0.696	Bearing	bearing failure
	3	T7-TS1-A-3A		0.615	Y	3.0050	0.2250	5.3	9.05	13.38			0.620	0.596	0.608	Shear	Failed at notch
					Average			6.1	9.03	13.24			0.639	0.656	0.648		Extreme Extension -
					Std. Dev.				0.06	0.12			0.050	0.053	0.045		w/o Abrupt Load Drop
					% COV				0.67	0.93			7.84	8.07	6.93		
BH2-06-7A-x	1	T7-TS2-A-2A	3-D	0.634	Y	3.0035	0.2323		6.78	9.72			0.681	0.695	0.688	Bearing	Extreme Extension -
	2	T7-TS2-A-2A	TS2	0.634	Y	3.0030	0.2303		6.68	9.66	14	-11,760	0.658	0.716	0.687	Bearing	w/o Abrupt Load Drop
	3	T7-TS2-A-2A		0.634	Y	3.0045	0.2272		9.69	14.20			0.718	0.747	0.732	Bearing	Failure at notch
					Average				7.72	11.19	14	-11,760	0.686	0.719	0.702		
					Std. Dev.				1.71	2.60			0.030	0.026	0.026		
					% COV				22.20	23.28			4.39	3.63	3.69		
BH2-07-7A-x	1	T7-OS1-A-3A	3-D	0.610	Y	3.0020	0.2315		5.50	7.91		-12,420	0.561	0.604	0.583	Bearing	Damage along centerline
	2	T7-OS1-A-3A	OS1	0.610	Y	2.9900	0.2324		11.92	17.16			0.590	0.576	0.583		Failed at notch
	3	T7-OS1-A-3A		0.610	Y	3.0020	0.2315		11.66	16.78			0.568	0.547	0.558		Failed at notch
					Average				9.70	13.95		-12,420	0.573	0.576	0.574		
					Std. Dev.				3.64	5.23			0.015	0.029	0.015		
					% COV				37.51	37.50			2.61	5.02	2.55		
BH2-08-7A-x	1	T7-OS2-A-3A	3-D	0.564	Y	2.9995	0.2418		13.61	18.77			0.490	0.517	0.503	Bearing	
	2	T7-OS2-A-3A	OS2	0.564	Y	2.9965	0.2386		13.17	18.42			0.475	0.531	0.503	Bearing	Extreme Extension -
	3	T7-OS2-A-3A		0.564	Y	2.9980	0.2381	12.3	14.65	20.52			0.518	0.525	0.522	Bearing	w/o Abrupt Load Drop
					Average			12.3	13.81	19.24			0.494	0.525	0.510		
					Std. Dev.				0.76	1.13			0.022	0.007	0.011		
					% COV				5.51	5.87			4.41	1.37	2.08		
BH2-09-7A-x	1	T7-LS1-A-5B	3-D	0.646	Y	3.0050	0.2109		5.54	8.74	7,581	-6,512	0.710	0.765	0.738	Shear	Failed at notch
	2	T7-LS1-A-5A	LS1	0.646	Y	2.9835	0.2161	5.1	5.14	7.97			0.675	0.838	0.756	Shear	Failed at notch
	3	T7-LS1-A-5A		0.646	Y	3.0000	0.2111	4.6	5.52	8.71	6,904	-5,723	0.774	0.861	0.817	Shear	Failed at notch
					Average			4.9	5.40	8.48	7,243	-6,118	0.720	0.821	0.770		
					Std. Dev.				0.22	0.43			0.050	0.050	0.042		
					% COV				4.15	5.13			6.97	6.05	5.40		
BH2-10-7A-x	1	T5-LS2-A-1B	3-D	0.629	Y	3.0065	0.2217		6.27	9.40	9,193		0.668	0.720	0.694	Shear	Failed at notch
	2	T5-LS2-A-1B	LS2	0.629	Y	2.9970	0.2208	5.8	6.18	9.34	8,198	-9,285	0.733	0.763	0.748	Shear	Failed at notch
	3	T5-LS2-A-1B		0.629	Y	2.9940	0.2208	5.8	6.43	9.73	10	-8,217	0.718	0.779	0.749	Shear	Failed at notch
					Average			5.8	6.29	9.49	5,800	-8,751	0.706	0.754	0.730		
					Std. Dev.				0.13	0.21			0.034	0.030	0.031		
					% COV				2.03	2.21			4.85	4.04	4.31		

Nominal Dimensions
Thickness=0.25 in
Notch Length=3.0 in
Width=3.0 in
Length=4.5 in

Project #: BH0002

intec Engineer: Maryann Einarson
Boeing Engineer: Mark Fedro

Textile Test Method Development

Task 8

In-Plane ShearTest Program

SUW Architectures

AS4/Shell 1895

intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Tabbed	Notch Length (in)	Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Shear Stress (ksi)	Ultimate +45 Strain ($\mu\varepsilon$)	Ultimate -45 Strain ($\mu\varepsilon$)	Ultimate 0° Strain ($\mu\varepsilon$)	Ultimate 90° Strain ($\mu\varepsilon$)	Shear Modulus Axial 1 (msi)	Shear Modulus Axial 2 (msi)	Shear Modulus Average (msi)	Failure Mode	Comments
BH2-11-7A-x	1	T7-SUW-G3K8B-2	SU-1	0.668	Y	3.0060	0.2236		13.40	19.93	3,790	-3,300	32	214	2.53	2.77	2.65		Bearing bolt sheared off
	2	T7-SUW-G3K8B-2		0.668	Y	3.0025	0.2233	16.3	17.33	25.84	5,031	-4,925	-124	538	2.58	2.80	2.69	bearing	Top left hole
	3	T7-SUW-G3K8B-2		0.668	Y	2.9760	0.2233	17.0	17.19	25.86	5,262	-4,561	-283	75	2.53	2.81	2.67	bearing	Top left hole
					Average			16.7	15.97	23.88	4,694	-4,262	-125	276	2.55	2.79	2.67		
					Std. Dev.				2.23	3.42					0.03	0.02	0.02		
					% COV				13.96	14.33					1.17	0.59	0.69		
BH2-12-7A-x	1	T7-SUW-G6K8B-2	SU-2	0.644	Y	3.0000	0.2434		15.00	20.55	4,533	-3,833	31	421	2.25	2.44	2.35	bearing	Top left hole
	2	T7-SUW-G6K8B-2		0.644	Y	2.9945	0.2441	16.9	17.19	23.52	5,224	-4,776	-34	339	2.30	2.57	2.43	bearing	Top left hole
	3	T7-SUW-G6K8B-2		0.644	Y	2.9860	0.2462		16.74	22.77	4,622	-3,799	134	20	2.47	2.92	2.70	bearing	Test with 8 gages
					Average			16.9	16.31	22.28	4,793	-4,136	44	260	2.34	2.64	2.49		Bottom right hole
					Std. Dev.				1.15	1.55					0.12	0.25	0.18		
					% COV				7.08	6.94					4.95	9.37	7.29		
BH2-13-7A-x	1	T7-SUW-K6K8B-2	SU-3	0.635	Y	2.9985	0.2400	10.9	15.68	21.79	4,322	-4,222			2.43	2.48	2.46	bearing	Top left hole
	2	T7-SUW-K6K8B-2		0.635	Y	3.0055	0.2407	16.0	17.06	23.58	4,571	-4,727	-370	598	2.65	2.62	2.64	bearing	Top left hole
	3	T7-SUW-K6K8B-2		0.635	Y	2.9945	0.2400	16.0	16.50	22.95	4,639	-4,484	-315	169	2.33	2.63	2.48	bearing	Top left hole
					Average			14.3	16.41	22.78	4,511	-4,478	-343	384	2.47	2.58	2.52		
					Std. Dev.				0.69	0.91					0.17	0.08	0.10		
					% COV				4.21	3.99					6.70	3.25	3.90		
BH2-14-7A-x	1	T7-SUW-K6K4B-2	SU-4	0.648	Y	3.0060	0.2316	13.8	14.69	21.09	3,952	-3,837	33	367	2.71	2.64	2.68	bearing	Top left hole
	2	T7-SUW-K6K4B-2		0.648	Y	2.9970	0.2312	16.7	16.95	24.45	4,415	-4,620	283	116	2.77	2.69	2.73	bearing	Bottom right hole
	3	T7-SUW-K6K4B-2		0.648	Y	3.0080	0.2310	15.5	17.47	25.14	4,553	-4,585	303	83	2.69	2.85	2.77	bearing	Bottom right hole
					Average			15.3	16.37	23.56	4,307	-4,347	206	189	2.72	2.73	2.73		
					Std. Dev.				1.48	2.17					0.04	0.11	0.05		
					% COV				9.04	9.19					1.55	3.96	1.75		
BH2-15-7A-x	1	T7-SUW-K12K8B-2	SU-5	0.654	Y	3.0080	0.2560	17.5	17.77	23.07	4,599	-4,664	-373	639	2.48	2.63	2.56		Bolt failure
	2	T7-SUW-K12K8B-2		0.654	Y	2.9975	0.2547	15.5	16.99	22.26	4,568	-4,477	-440	447	2.41	2.59	2.50	bearing	Top left hole
	3	T7-SUW-K12K8B-2		0.654	Y	2.9960	0.2550	15.7	15.92	20.84	4,066	-4,259	-269	52	2.59	2.47	2.53	bearing	Top left hole
					Average			16.2	16.89	22.06	4,411	-4,467	-361	379	2.49	2.56	2.53		
					Std. Dev.				0.93	1.13					0.09	0.08	0.03		
					% COV				5.49	5.12					3.54	3.31	1.05		

Filled-Hole Tension Test Program

intec

Project #: **BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters**

Temperature: RT

Filled Hole Tension Results

Specimen ID	Test Cell ID	Test Type	Mat. Class	Mat Desc.	Nom W/D	Average Dimensions Width (in)	Length (in)	Thickness (in)	Hole Dia (in)	Test Date	Ult Load (lbs)	Ult Net Stress (ksi)	Ult Gross Stress (ksi)	Failure Mode
BH4-007	137a	FHT	1	SLL	4	0.999	10.01	0.1045	0.2520	10/11/93	7878	100.96	75.49	Failed at fastener
BH4-008	137a	FHT	1	SLL	4	0.999	10.01	0.1044	0.2515	10/11/93	8228	105.42	78.88	Failed at fastener
BH4-009	137a	FHT	1	SLL	4	1.000	10.01	0.1080	0.2520	10/11/93	8650	107.04	80.08	Failed at fastener
					Average:	**0.999**	**10.01**	**0.1056**	**0.2518**		**8252**	**104.47**	**78.15**	
					COV	*0.08%*	*0.02%*	*1.93%*	*0.11%*		*4.68%*	*3.02%*	*3.05%*	
BH4-010	137b	FHT	1	SLL	6	1.500	10.00	0.1075	0.2515	10/11/93	12116	90.30	75.16	Failed at fastener and spark. Aud. 6500 lbs
BH4-011	137b	FHT	1	SLL	6	1.500	10.01	0.1029	0.2515	10/11/93	13751	107.04	89.10	Failed at fastener
BH4-012	137b	FHT	1	SLL	6	1.500	10.00	0.1015	0.2515	10/11/93	14390	113.49	94.46	Failed at fastener
					Average:	**1.500**	**10.00**	**0.1040**	**0.2515**		**13419**	**103.61**	**86.24**	
					COV	*0.01%*	*0.03%*	*2.99%*	*0.00%*		*8.74%*	*11.55%*	*11.55%*	
BH4-013	137c	FHT	1	SLL	8	2.000	10.00	0.1036	0.2525	10/11/93	18597	102.73	89.76	Failed at fastener. Aud 8600 lbs
BH4-014	137c	FHT	1	SLL	8	1.999	10.00	0.1078	0.2530	10/11/93	18153	96.43	84.22	Failed at fastener. Aud 7200 lbs
BH4-015	137c	FHT	1	SLL	8	2.000	10.01	0.1059	0.2525	10/11/93	17994	97.25	84.97	Failed at fastener. Aud 11200 lbs
					Average:	**2.000**	**10.00**	**0.1058**	**0.2527**		**18248**	**98.80**	**86.32**	
					COV	*0.03%*	*0.05%*	*2.00%*	*0.11%*		*1.71%*	*3.47%*	*3.48%*	
BH4-127	238a	FHT	2	LLS	4	1.000	10.01	0.1066	0.2515	10/11/93	7307	91.57	68.54	Failed at fastener
BH4-128	238a	FHT	2	LLS	4	0.999	10.01	0.1060	0.2515	10/11/93	6897	87.11	65.17	Failed at fastener. Aud at 5800
BH4-129	238a	FHT	2	LLS	4	0.999	10.01	0.1044	0.2510	10/11/93	6332	81.09	60.71	Failed at fastener with spark. Aud at 4200
					Average:	**0.999**	**10.01**	**0.1057**	**0.2513**		**6845**	**86.59**	**64.81**	
					COV	*0.06%*	*0.00%*	*1.08%*	*0.11%*		*7.15%*	*6.07%*	*6.06%*	
BH4-130	238b	FHT	2	LLS	6	1.499	9.99	0.1119	0.2520	10/11/93	11797	84.55	70.34	Failed at fastener. Aud at 5800
BH4-131	238b	FHT	2	LLS	6	1.501	9.99	0.1096	0.2515	10/11/93	12151	88.74	73.87	Failed at fastener. Aud at 5750
BH4-132	238b	FHT	2	LLS	6	1.500	9.99	0.1083	0.2520	10/11/93	11247	83.28	69.28	Failed at fastener. Aud at 6000
					Average:	**1.500**	**9.99**	**0.1099**	**0.2518**		**11732**	**85.52**	**71.16**	
					COV	*0.05%*	*0.01%*	*1.66%*	*0.11%*		*3.88%*	*3.34%*	*3.38%*	
BH4-133	238c	FHT	2	LLS	8	1.999	9.99	0.1158	0.2515	10/11/93	17883	88.36	77.25	Failed at fastener. Aud at 11400
BH4-134	238c	FHT	2	LLS	8	2.000	10.00	0.1165	0.2510	10/11/93	16230	79.68	69.68	Failed at fastener. Aud at 12000
BH4-135	238c	FHT	2	LLS	8	2.000	10.01	0.1055	0.2515	10/11/93	15905	86.27	75.42	Failed at fastener. Aud at 11200
					Average:	**2.000**	**10.00**	**0.1126**	**0.2513**		**16673**	**84.77**	**74.12**	
					COV	*0.02%*	*0.11%*	*5.49%*	*0.11%*		*6.36%*	*5.34%*	*5.33%*	
BH4-250	339b	FHT	3	LLL	6	1.499	10.01	0.1128	0.2520	10/11/93	11765	83.64	69.58	Failed at fastener. Aud 4100 lbs
BH4-251	339b	FHT	3	LLL	6	1.500	10.01	0.1124	0.2515	10/11/93	12310	87.80	73.07	Failed at fastener. Aud 4300 lbs
BH4-252	339b	FHT	3	LLL	6	1.500	10.00	0.1126	0.2510	10/11/93	11742	83.52	69.54	Failed at fastener. Aud 3200 lbs
					Average:	**1.499**	**10.01**	**0.1126**	**0.2515**		**11939**	**84.99**	**70.73**	
					COV	*0.01%*	*0.02%*	*0.19%*	*0.20%*		*2.69%*	*2.86%*	*2.86%*	

Notes: Net stress calculated from: Load/actual thickness/(actual width -actual hole diameter)
Gross stress calculated from: Load/actual thickness/actual width

Bolt Bearing Test Program

Intec

Project #: BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters

Stabilized Single Shear Bearing

Temperature: RT

Specimen ID	Test Cell ID	Test Type	Mat. Class	Mat Desc.	Nominal Dims W/D	e/D	Average Dimensions Width	Length	Thickness	Hole Dia 1	Hole Dia 2	Edge Dist 1	Edge Dist 2	Test Date	Failure Load Limit	Ult	Bearing Stress Limit	Ultimate	Failure Mode
							(in)	*(in)*	*(in)*	*(in)*	*(in)*	*(in)*	*(in)*		*(lbs)*	*(lbs)*	*(ksi)*	*(ksi)*	
BH4-16	141a	SSSB	1	SLL	4	3	1.000	3.49	0.1097	0.2515	0.2515	0.629	0.628	10/6/93	4943	5138	90.12	93.67	Bearing at holes 1 and 4
BH4-17	141a	SSSB	1	SLL	4	3	0.999	3.49	0.1080	0.2520	0.2515	0.622	0.627	10/6/93	4943	5138	91.58	95.19	Bearing at holes 1 and 4
BH4-18	141a	SSSB	1	SLL	4	3	0.999	3.50	0.1072	0.2510	0.2515	0.628	0.628	10/6/93	5168	5425	96.42	101.21	Bearing at holes 1 and 4
BH4-19	141a	SSSB	1	SLL	4	3	0.999	3.50	0.1058	0.2515	0.2515	0.627	0.628	10/6/93	5168	5425	97.67	102.52	Bearing at holes 1 and 4
BH4-20	141a	SSSB	1	SLL	4	3	0.999	3.49	0.1048	0.2510	0.2510	0.626	0.630	10/6/93	5331	5591	101.70	106.66	Bearing at holes 1 and 4
BH4-21	141a	SSSB	1	SLL	4	3	1.002	3.49	0.1040	0.2515	0.2520	0.626	0.624	10/6/93	5331	5591	102.52	107.52	Bearing at holes 1 and 4
							1.000	**3.49**	**0.1066**	**0.2514**	**0.2515**	**0.626**	**0.627**		**5147**	**5385**	**96.67**	**101.13**	
							0.11%	*0.13%*	*1.98%*	*0.15%*	*0.13%*	*0.39%*	*0.31%*		*3.39%*	*3.81%*	*5.26%*	*5.67%*	
BH4-22	141b	SSSB	1	SLL	4	2	0.999	3.50	0.1103	0.2520	0.2520	0.377	0.377	10/6/93	4779	4783	86.69	86.77	End margin shear out at holes 1 and 4
BH4-23	141b	SSSB	1	SLL	4	2	0.999	3.49	0.1087	0.2520	0.2520	0.375	0.370	10/6/93	4779	4783	87.92	88.00	End margin shear out at holes 1 and 4
BH4-24	141b	SSSB	1	SLL	4	2	0.999	3.49	0.1079	0.2520	0.2520	0.375	0.370	10/6/93	4820	4831	85.64	89.56	End margin shear out at holes 1 and 4
BH4-25	141b	SSSB	1	SLL	4	2	0.999	3.50	0.1072	0.2520	0.2525	0.377	0.380	10/6/93	4820	4831	86.23	90.17	End margin shear out at holes 1 and 4
BH4-26	141b	SSSB	1	SLL	4	2	0.999	3.50	0.1073	0.2520	0.2520	0.377	0.377	10/6/93	4711	4778	87.79	89.03	End margin shear out at holes 1 and 4
BH4-27	141b	SSSB	1	SLL	4	2	1.001	3.50	0.1066	0.2520	0.2526	0.379	0.379	10/6/93	4711	4778	88.42	89.67	End margin shear out at holes 1 and 4
							0.999	**3.49**	**0.1080**	**0.2520**	**0.2522**	**0.376**	**0.376**		**4703**	**4797**	**87.12**	**88.87**	
							0.06%	*0.15%*	*1.23%*	*0.00%*	*0.10%*	*0.35%*	*1.18%*		*1.52%*	*0.55%*	*1.25%*	*1.42%*	
BH4-28	141c	SSSB	1	SLL	4	4	1.000	3.63	0.1094	0.2510	0.2510	0.875	0.877	10/6/93	5205	5649	95.20	103.32	Bearing at holes 1 and 4
BH4-29	141c	SSSB	1	SLL	4	4	1.000	3.63	0.1071	0.2510	0.2510	0.875	0.878	10/6/93	5205	5649	97.23	105.52	Bearing at holes 1 and 4
BH4-30	141c	SSSB	1	SLL	4	4	0.998	3.63	0.1069	0.2510	0.2515	0.875	0.878	10/6/93	5387	5534	100.79	103.54	Bearing at holes 1 and 4
BH4-31	141c	SSSB	1	SLL	4	4	0.998	3.63	0.1049	0.2510	0.2510	0.878	0.881	10/6/93	5387	5534	102.69	105.49	Bearing at holes 1 and 4
BH4-32	141c	SSSB	1	SLL	4	4	0.999	3.63	0.1044	0.2510	0.2515	0.878	0.880	10/6/93	5299	5654	101.50	108.30	Bearing at holes 1 and 4
BH4-33	141c	SSSB	1	SLL	4	4	1.001	3.63	0.1101	0.2510	0.2515	0.880	0.879	10/6/93	5299	5654	96.30	102.75	Bearing at holes 1 and 4
							0.999	**3.63**	**0.1071**	**0.2510**	**0.2513**	**0.876**	**0.879**		**5297**	**5612**	**98.96**	**104.82**	
							0.09%	*0.01%*	*2.12%*	*0.00%*	*0.11%*	*0.23%*	*0.16%*		*1.54%*	*1.08%*	*3.13%*	*1.97%*	
BH4-34	141d	SSSB	1	SLL	6	2	1.500	3.50	0.1087	0.2520	0.2515	0.376	0.375	10/6/93	N/A	4674	N/A	85.98	End margin shear out at holes 1 and 4
BH4-35	141d	SSSB	1	SLL	6	2	1.500	3.50	0.1053	0.2520	0.2530	0.377	0.383	10/6/93	N/A	4674	N/A	88.77	End margin shear out at holes 1 and 4
BH4-36	141d	SSSB	1	SLL	6	2	1.501	3.50	0.1049	0.2530	0.2520	0.380	0.379	10/6/93	5041	5141	96.14	98.05	End margin shear out at holes 1 and 4
BH4-37	141d	SSSB	1	SLL	6	2	1.500	3.49	0.1063	0.2515	0.2520	0.375	0.374	10/6/93	5041	5141	94.82	96.70	End margin shear out at holes 1 and 4
BH4-38	141d	SSSB	1	SLL	6	2	1.501	3.50	0.1092	0.2515	0.2530	0.374	0.382	10/6/93	N/A	5087	N/A	93.20	End margin shear out at holes 1 and 3
BH4-39	141d	SSSB	1	SLL	6	2	1.499	3.50	0.1117	0.2530	0.2515	0.375	0.375	10/6/93	N/A	5087	N/A	91.12	End margin shear out at holes 1 and 3
							1.500	**3.50**	**0.1077**	**0.2522**	**0.2522**	**0.376**	**0.378**		**5041**	**4967**	**95.48**	**92.30**	
							0.04%	*0.08%*	*2.44%*	*0.27%*	*0.27%*	*0.52%*	*1.03%*		*0.00%*	*4.60%*	*0.98%*	*5.01%*	
BH4-40	141e	SSSB	1	SLL	6	3	1.500	3.50	0.1074	0.2530	0.2520	0.632	0.629	10/6/93	5440	5581	101.33	103.98	Bearing at holes 1 and 4
BH4-41	141e	SSSB	1	SLL	6	3	1.499	3.50	0.1059	0.2520	0.2520	0.629	0.627	10/6/93	5440	5581	102.74	105.40	Bearing at holes 1 and 4
BH4-42	141e	SSSB	1	SLL	6	3	1.500	3.49	0.1052	0.2520	0.2520	0.628	0.629	10/6/93	N/A	5659	N/A	107.56	Bearing at holes 1 and 4
BH4-43	141e	SSSB	1	SLL	6	3	1.501	3.49	0.1087	0.2515	0.2520	0.627	0.622	10/6/93	N/A	5659	N/A	106.12	Bearing at holes 1 and 4
BH4-44	141e	SSSB	1	SLL	6	3	1.500	3.48	0.1075	0.2525	0.2530	0.625	0.622	10/6/93	5267	5712	97.96	106.24	Bearing at holes 1 and 4
BH4-45	141e	SSSB	1	SLL	6	3	1.500	3.48	0.1074	0.2530	0.2520	0.621	0.626	10/6/93	5267	5712	98.05	106.34	Bearing at holes 1 and 4
							1.500	**3.49**	**0.1067**	**0.2523**	**0.2522**	**0.627**	**0.626**		**5354**	**5651**	**100.02**	**105.93**	
							0.03%	*0.25%*	*0.89%*	*0.24%*	*0.16%*	*0.58%*	*0.48%*		*1.87%*	*1.04%*	*2.40%*	*1.12%*	
BH4-46	141f	SSSB	1	SLL	6	4	1.500	3.63	0.1084	0.2520	0.2525	0.875	0.876	10/6/93	5319	5624	97.21	102.78	Bearing at holes 1 and 4
BH4-47	141f	SSSB	1	SLL	6	4	1.499	3.63	0.1076	0.2530	0.2535	0.875	0.871	10/6/93	5319	5624	98.90	104.57	Bearing at holes 1 and 4
BH4-48	141f	SSSB	1	SLL	6	4	1.499	3.63	0.1082	0.2515	0.2520	0.876	0.874	10/6/93	5223	5502	96.51	101.67	Bearing at holes 1 and 4
BH4-49	141f	SSSB	1	SLL	6	4	1.502	3.63	0.1082	0.2520	0.2520	0.875	0.876	10/6/93	5223	5502	96.57	101.73	Bearing at holes 1 and 4
BH4-50	141f	SSSB	1	SLL	6	4	1.500	3.63	0.1079	0.2530	0.2520	0.874	0.873	10/6/93	5575	5881	103.35	109.03	Bearing at holes 1 and 4
BH4-51	141f	SSSB	1	SLL	6	4	1.501	3.63	0.1084	0.2520	0.2520	0.875	0.873	10/6/93	5575	5881	102.84	108.49	Bearing at holes 1 and 4
							1.500	**3.63**	**0.1083**	**0.2523**	**0.2523**	**0.875**	**0.874**		**5372**	**5660**	**99.23**	**104.71**	
							0.07%	*0.02%*	*0.59%*	*0.24%*	*0.24%*	*0.08%*	*0.21%*		*3.03%*	*3.05%*	*3.14%*	*3.16%*	

Notes: Limit load calculated from an offset of 2% hole diameter (0.005 in). If failure occurred before offset load, N/A is recorded.
Bearing stress calculated from: Load/2/actual thickness/nominal hole diameter
Hole 1: First specimen, fastener head side. Hole 2: First specimen, Hilok side. Hole 3: Second specimen, Hilok side. Hole 4: Second specimen, fastener head side. (See diagram in report)

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Project #: BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters

Stabilized Single Shear Bearing

Temperature: RT

Specimen ID	Test Cell ID	Test Type	Mat. Class	Mat Desc.	Nominal Dims W/D	Nominal Dims e/D	Average Dimensions Width (in)	Length (in)	Thickness (in)	Hole Dia 1 (in)	Hole Dia 2 (in)	Edge Dist 1 (in)	Edge Dist 2 (in)	Test Date	Failure Load Limit (lbs)	Failure Load Ult (lbs)	Bearing Stress Limit (ksi)	Bearing Stress Ultimate (ksi)	Failure Mode
BH4-52	141g	SSSB	1	SLL	8	2	2.001	3.50	0.1133	0.2525	0.2520	0.371	0.375	10/6/93	N/A	4381	N/A	77.35	End margin shear out at holes 1 and 4
BH4-53	141g	SSSB	1	SLL	8	2	2.000	3.50	0.1114	0.2510	0.2505	0.374	0.376	10/6/93	N/A	4381	N/A	78.68	End margin shear out at holes 1 and 4
BH4-54	141g	SSSB	1	SLL	8	2	2.004	3.49	0.1112	0.2535	0.2515	0.370	0.375	10/6/93	4630	4672	83.31	84.05	End margin shear out at holes 1 and 4
BH4-55	141g	SSSB	1	SLL	8	2	2.001	3.50	0.1105	0.2515	0.2525	0.371	0.369	10/6/93	4630	4672	83.85	84.60	End margin shear out at holes 1 and 4
BH4-56	141g	SSSB	1	SLL	8	2	2.000	3.50	0.1081	0.2515	0.2525	0.372	0.373	10/6/93	N/A	4127	N/A	76.36	End margin shear out at holes 1 and 4
BH4-57	141g	SSSB	1	SLL	8	2	2.001	3.50	0.1076	0.2525	0.2520	0.375	0.374	10/6/93	N/A	4127	N/A	76.71	End margin shear out at holes 1 and 4
							2.001	**3.50**	**0.1103**	**0.2521**	**0.2518**	**0.372**	**0.373**		**4630**	**4393**	**83.58**	**79.62**	
							0.08%	*0.06%*	*1.94%*	*0.36%*	*0.30%*	*0.48%*	*0.65%*		*0.00%*	*5.55%*	*0.46%*	*4.69%*	
BH4-58	141h	SSSB	1	SLL	8	3	2.001	3.50	0.1089	0.2525	0.2520	0.619	0.631	10/6/93	5180	5294	95.16	97.26	End margin shear out at holes 1 and 3
BH4-59	141h	SSSB	1	SLL	8	3	2.000	3.50	0.1064	0.2525	0.2520	0.622	0.631	10/6/93	5180	5294	97.35	99.50	End margin shear out at holes 1 and 3
BH4-60	141h	SSSB	1	SLL	8	3	2.002	3.50	0.1067	0.2520	0.2520	0.632	0.628	10/6/93	4917	5484	92.21	102.84	Bearing at holes 1 and 4
BH4-61	141h	SSSB	1	SLL	8	3	2.001	3.50	0.1095	0.2515	0.2525	0.629	0.632	10/6/93	4917	5484	89.82	100.18	Bearing at holes 1 and 4
BH4-62	141h	SSSB	1	SLL	8	3	2.002	3.50	0.1067	0.2520	0.2520	0.629	0.628	10/6/93	5240	5335	98.23	100.02	Bearing at holes 1 and 4
BH4-63	141h	SSSB	1	SLL	8	3	2.002	3.50	0.1071	0.2525	0.2520	0.624	0.629	10/6/93	5240	5335	97.82	99.60	Bearing at holes 1 and 4
							2.001	**3.50**	**0.1075**	**0.2522**	**0.2521**	**0.626**	**0.629**		**5112**	**5371**	**95.10**	**99.90**	
							0.05%	*0.08%*	*1.21%*	*0.16%*	*0.08%*	*0.76%*	*0.26%*		*3.01%*	*1.67%*	*3.80%*	*1.79%*	
BH4-64	141i	SSSB	1	SLL	8	4	2.000	3.63	0.1126	0.2520	0.2520	0.879	0.875	10/6/93	5223	5513	92.85	98.01	Bearing at holes 1 and 4
BH4-65	141i	SSSB	1	SLL	8	4	2.001	3.63	0.1085	0.2520	0.2515	0.878	0.877	10/6/93	5223	5513	96.28	101.62	Bearing at holes 1 and 4
BH4-66	141i	SSSB	1	SLL	8	4	2.002	3.63	0.1066	0.2530	0.2520	0.875	0.880	10/6/93	5228	5617	98.13	105.43	Bearing at holes 1 and 4
BH4-67	141i	SSSB	1	SLL	8	4	2.001	3.63	0.1147	0.2530	0.2520	0.874	0.879	10/6/93	5228	5617	91.13	97.91	Bearing at holes 1 and 4
BH4-68	141i	SSSB	1	SLL	8	4	2.000	3.63	0.1099	0.2520	0.2520	0.880	0.875	10/6/93	5119	5346	93.17	97.30	Bearing at holes 1 and 4
BH4-69	141i	SSSB	1	SLL	8	4	1.999	3.63	0.1092	0.2520	0.2520	0.875	0.875	10/6/93	5119	5346	93.74	97.90	Bearing at holes 1 and 4
							2.000	**3.63**	**0.1102**	**0.2523**	**0.2519**	**0.877**	**0.877**		**5190**	**5492**	**94.22**	**99.70**	
							0.05%	*0.02%*	*2.66%*	*0.20%*	*0.08%*	*0.27%*	*0.26%*		*1.06%*	*2.23%*	*2.70%*	*3.22%*	
BH4-136	242a	SSSB	2	LLS	4	2	1.000	3.50	0.1083	0.2515	0.2515	0.373	0.373	10/8/93	N/A	3861	N/A	71.30	Shear out at holes 1 and 4
BH4-137	242a	SSSB	2	LLS	4	2	1.000	3.50	0.1057	0.2520	0.2520	0.372	0.381	10/8/93	N/A	3861	N/A	73.08	Shear out at holes 1 and 4
BH4-138	242a	SSSB	2	LLS	4	2	1.000	3.50	0.1078	0.2525	0.2525	0.373	0.380	10/8/93	N/A	3415	N/A	63.34	Shear out at holes 1 and 3
BH4-139	242a	SSSB	2	LLS	4	2	0.998	3.50	0.1078	0.2515	0.2530	0.374	0.364	10/8/93	N/A	3415	N/A	63.35	Shear out at holes 1 and 3
BH4-140	242a	SSSB	2	LLS	4	2	1.000	3.50	0.1080	0.2620	0.2520	0.373	0.365	10/8/93	2230	3060	41.28	56.46	End margin splitting at hole 1. Shear out hole 4.
BH4-141	242a	SSSB	2	LLS	4	2	0.992	3.49	0.1054	0.2510	0.2515	0.372	0.382	10/8/93	2230	3060	42.32	57.88	End margin splitting at hole 1. Shear out hole 4.
							0.998	**3.50**	**0.1072**	**0.2518**	**0.2521**	**0.373**	**0.374**		**2230**	**3442**	**41.80**	**64.24**	
							0.31%	*0.09%*	*1.21%*	*0.21%*	*0.23%*	*0.24%*	*2.20%*		*0.00%*	*10.55%*	*1.76%*	*10.57%*	
BH4-142	242b	SSSB	2	LLS	4	3	1.000	3.50	0.1076	0.2510	0.2525	0.624	0.628	10/8/93	4314	4807	80.22	89.39	Bearing hole 1. Interlaminar shear out of 0 plies at hole 3
BH4-143	242b	SSSB	2	LLS	4	3	1.000	3.50	0.1074	0.2515	0.2520	0.622	0.622	10/8/93	4314	4807	80.33	89.52	Bearing hole 1. Interlaminar shear out of 0 plies at hole 3
BH4-144	242b	SSSB	2	LLS	4	3	0.999	3.50	0.1073	0.2515	0.2515	0.623	0.623	10/8/93	4845	5154	90.31	96.07	Bearing at hole 1 and 4
BH4-145	242b	SSSB	2	LLS	4	3	0.999	3.51	0.1076	0.2515	0.2520	0.624	0.622	10/8/93	4845	5154	90.10	95.84	Bearing at hole 1 and 4
BH4-146	242b	SSSB	2	LLS	4	3	0.999	3.51	0.1078	0.2525	0.2525	0.627	0.627	10/8/93	4781	4904	88.67	90.96	Interlaminar shear out of 0 plies at holes 1 and 4
BH4-147	242b	SSSB	2	LLS	4	3	0.992	3.49	0.1061	0.2515	0.2520	0.622	0.631	10/8/93	4781	4904	90.11	92.44	Interlaminar shear out of 0 plies at holes 1 and 4
							0.998	**3.50**	**0.1073**	**0.2516**	**0.2521**	**0.623**	**0.625**		**4646**	**4955**	**86.62**	**92.37**	
							0.32%	*0.21%*	*0.57%*	*0.20%*	*0.15%*	*0.28%*	*0.59%*		*5.58%*	*3.23%*	*5.72%*	*3.24%*	
BH4-148	242c	SSSB	2	LLS	4	4	1.000	3.65	0.1105	0.2525	0.2525	0.879	0.880	10/8/93	4577	5215	82.84	94.39	Bearing at hole 1 and 4
BH4-149	242c	SSSB	2	LLS	4	4	1.000	3.65	0.1099	0.2525	0.2530	0.887	0.880	10/8/93	4577	5215	83.27	94.88	Bearing at hole 1 and 4
BH4-150	242c	SSSB	2	LLS	4	4	0.998	3.65	0.1101	0.2510	0.2515	0.883	0.878	10/8/93	5025	5406	91.28	98.20	Bearing at hole 1 and 4
BH4-151	242c	SSSB	2	LLS	4	4	0.998	3.65	0.1093	0.2510	0.2520	0.879	0.879	10/8/93	5025	5406	91.94	98.92	Bearing at hole 1 and 4
BH4-152	242c	SSSB	2	LLS	4	4	0.999	3.65	0.1089	0.2520	0.2520	0.876	0.875	10/8/93	4966	5240	91.19	96.22	Bearing at hole 1 and 4
BH4-153	242c	SSSB	2	LLS	4	4	0.989	3.65	0.1067	0.2515	0.2520	0.875	0.875	10/8/93	4966	5240	93.07	98.20	Bearing at hole 1 and 4
							0.997	**3.65**	**0.1092**	**0.2518**	**0.2522**	**0.880**	**0.878**		**4856**	**5287**	**88.93**	**96.80**	
							0.43%	*0.02%*	*1.25%*	*0.27%*	*0.20%*	*0.52%*	*0.26%*		*4.48%*	*1.76%*	*5.18%*	*1.98%*	

Notes: Limit load calculated from an offset of 2% hole diameter (0.005 in). If failure occurred before offset load, N/A is recorded.
Bearing stress calculated from: Load/actual thickness/nominal hole diameter
Hole 1: First specimen, fastener head side. Hole 2: First specimen, Hilok side. Hole 3: Second specimen, Hilok side. Hole 4: Second specimen, fastener head side. (See diagram in report)

intec

Project #: BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters

Temperature: RT

Stabilized Single Shear Bearing

Specimen ID	Test Cell ID	Test Type	Mat. Class	Mat Desc.	Nominal Dims W/D	Nominal Dims e/D	Average Dimensions Width (in)	Length (in)	Thickness (in)	Hole Dia 1 (in)	Hole Dia 2 (in)	Edge Dist 1 (in)	Edge Dist 2 (in)	Test Date	Failure Load Limit (lbs)	Failure Load Ult (lbs)	Bearing Stress Limit (ksi)	Bearing Stress Ultimate (ksi)	Failure Mode
BH4-154	242d	SSSB	2	LLS	6	2	1.500	3.50	0.1110	0.2510	0.2510	0.380	0.377	10/8/93	N/A	4179	N/A	75.33	Interlaminar shear out of 0 plies at holes 1 and 4
BH4-155	242d	SSSB	2	LLS	6	2	1.500	3.50	0.1110	0.2510	0.2505	0.378	0.375	10/8/93	N/A	4179	N/A	75.32	Interlaminar shear out of 0 plies at holes 1 and 4
BH4-156	242d	SSSB	2	LLS	6	2	1.498	3.49	0.1103	0.2510	0.2515	0.376	0.378	10/8/93	2970	3862	53.86	70.04	Interlaminar shear out of 0 plies at holes 2 and 4
BH4-157	242d	SSSB	2	LLS	6	2	1.489	3.48	0.1067	0.2505	0.2510	0.377	0.376	10/8/93	2970	3862	55.66	72.38	Interlaminar shear out of 0 plies at holes 2 and 4
BH4-158	242d	SSSB	2	LLS	6	2	1.490	3.49	0.1049	0.2510	0.2505	0.377	0.373	10/8/93	2892	3697	55.12	70.46	Interlaminar shear out of 0 plies at holes 1 and 3
BH4-159	242d	SSSB	2	LLS	6	2	1.489	3.49	0.1035	0.2505	0.2510	0.380	0.384	10/8/93	2892	3697	55.90	71.46	Interlaminar shear out of 0 plies at holes 1 and 3
							1.494	**3.49**	**0.1079**	**0.2506**	**0.2509**	**0.378**	**0.377**		**2931**	**3913**	**55.13**	**72.50**	
							0.38%	*0.17%*	*3.05%*	*0.10%*	*0.15%*	*0.40%*	*1.00%*		*1.54%*	*5.60%*	*1.65%*	*3.22%*	
BH4-160	242e	SSSB	2	LLS	6	3	1.500	3.50	0.1068	0.2505	0.2505	0.626	0.618	10/8/93	3723	4216	69.70	78.93	Bearing at hole 1 and 4
BH4-161	242e	SSSB	2	LLS	6	3	1.502	3.50	0.1136	0.2505	0.2505	0.632	0.626	10/8/93	3723	4216	65.55	74.23	Bearing at hole 1 and 4
BH4-162	242e	SSSB	2	LLS	6	3	1.500	3.50	0.1095	0.2505	0.2505	0.626	0.624	10/8/93	4901	5152	89.49	94.07	Interlaminar shear out of 0 plies at holes 1 and 4
BH4-163	242e	SSSB	2	LLS	6	3	1.490	3.50	0.1072	0.2505	0.2510	0.626	0.626	10/8/93	4901	5152	91.41	96.09	Interlaminar shear out of 0 plies at holes 1 and 4
BH4-164	242e	SSSB	2	LLS	6	3	1.490	3.50	0.1058	0.2510	0.2500	0.630	0.625	10/8/93	4880	5108	92.22	96.53	Interlaminar shear out of 0 plies at holes 1 and 3
BH4-165	242e	SSSB	2	LLS	6	3	1.489	3.50	0.1064	0.2505	0.2510	0.627	0.624	10/8/93	4880	5108	91.76	96.05	Interlaminar shear out of 0 plies at holes 1 and 3
							1.495	**3.50**	**0.1082**	**0.2506**	**0.2506**	**0.628**	**0.624**		**4501**	**4825**	**83.36**	**89.31**	
							0.40%	*0.07%*	*2.70%*	*0.08%*	*0.15%*	*0.43%*	*0.45%*		*13.40%*	*9.79%*	*14.75%*	*11.21%*	
BH4-166	242f	SSSB	2	LLS	6	4	1.500	3.65	0.1059	0.2510	0.2505	0.875	0.868	10/8/93	4529	4820	85.53	91.03	Bearing at hole 1 and 4
BH4-167	242f	SSSB	2	LLS	6	4	1.500	3.65	0.1066	0.2510	0.2510	0.876	0.875	10/8/93	4529	4820	85.00	90.46	Bearing at hole 1 and 4
BH4-168	242f	SSSB	2	LLS	6	4	1.499	3.65	0.1070	0.2505	0.2510	0.876	0.877	10/8/93	5079	5139	94.96	96.09	Bearing at hole 1 and 4
BH4-169	242f	SSSB	2	LLS	6	4	1.490	3.66	0.1058	0.2500	0.2505	0.877	0.876	10/8/93	5079	5139	96.04	97.18	Bearing at hole 1 and 4
BH4-170	242f	SSSB	2	LLS	6	4	1.490	3.66	0.1055	0.2505	0.2505	0.877	0.877	10/8/93	4700	4945	89.13	93.77	Bearing at hole 1 and 4
BH4-171	242f	SSSB	2	LLS	6	4	1.490	3.65	0.1057	0.2505	0.2505	0.874	0.882	10/8/93	4700	4945	88.96	93.60	Bearing at hole 1 and 4
							1.495	**3.65**	**0.1061**	**0.2506**	**0.2507**	**0.876**	**0.876**		**4769**	**4968**	**89.94**	**93.69**	
							0.36%	*0.06%*	*0.55%*	*0.15%*	*0.10%*	*0.12%*	*0.54%*		*5.28%*	*2.89%*	*5.16%*	*2.84%*	
BH4-172	242g	SSSB	2	LLS	8	2	2.000	3.50	0.1106	0.2510	0.2510	0.370	0.373	10/8/93	3476	3790	62.84	68.51	Interlaminar shear out of 0 plies at holes 1 and 4
BH4-173	242g	SSSB	2	LLS	8	2	2.001	3.50	0.1120	0.2515	0.2510	0.371	0.373	10/8/93	3476	3790	62.09	67.70	Interlaminar shear out of 0 plies at holes 1 and 4
BH4-174	242g	SSSB	2	LLS	8	2	2.001	3.50	0.1083	0.2510	0.2510	0.373	0.372	10/8/93	N/A	3371	N/A	62.23	Interlaminar shear out of 0 plies at holes 1 and 4
BH4-175	242g	SSSB	2	LLS	8	2	2.001	3.50	0.1101	0.2510	0.2515	0.373	0.380	10/8/93	N/A	3371	N/A	61.22	Interlaminar shear out of 0 plies at holes 1 and 4
BH4-176	242g	SSSB	2	LLS	8	2	2.002	3.51	0.1091	0.2510	0.2510	0.374	0.376	10/8/93	N/A	3849	N/A	70.56	Interlaminar shear out of 0 plies at holes 1 and 4
BH4-177	242g	SSSB	2	LLS	8	2	1.999	3.51	0.1085	0.2510	0.2505	0.374	0.375	10/8/93	N/A	3849	N/A	70.95	Interlaminar shear out of 0 plies at holes 1 and 4
							2.001	**3.50**	**0.1098**	**0.2511**	**0.2510**	**0.373**	**0.375**		**3476**	**3670**	**62.46**	**66.86**	
							0.04%	*0.05%*	*1.28%*	*0.08%*	*0.13%*	*0.44%*	*0.77%*		*0.00%*	*6.35%*	*0.85%*	*6.24%*	
BH4-178	242h	SSSB	2	LLS	8	3	2.001	3.50	0.1087	0.2515	0.2515	0.621	0.623	10/8/93	4771	4871	87.76	89.60	Bearing at hole 1 and 4
BH4-179	242h	SSSB	2	LLS	8	3	2.000	3.50	0.1086	0.2505	0.2510	0.620	0.618	10/8/93	4771	4871	87.89	89.73	Bearing at hole 1 and 4
BH4-180	242h	SSSB	2	LLS	8	3	2.000	3.50	0.1099	0.2510	0.2515	0.630	0.631	10/8/93	4559	4880	82.97	88.81	Bearing at hole 1 and 4
BH4-181	242h	SSSB	2	LLS	8	3	2.000	3.50	0.1117	0.2500	0.2510	0.624	0.627	10/8/93	4559	4880	81.66	87.40	Bearing at hole 1 and 4
BH4-182	242h	SSSB	2	LLS	8	3	2.001	3.51	0.1095	0.2510	0.2510	0.626	0.624	10/8/93	4903	4904	89.57	89.60	Interlaminar shear out of 0 plies at holes 1 and 4
BH4-183	242h	SSSB	2	LLS	8	3	2.000	3.51	0.1105	0.2505	0.2505	0.625	0.624	10/8/93	4903	4904	88.76	88.79	Interlaminar shear out of 0 plies at holes 1 and 4
							2.000	**3.50**	**0.1098**	**0.2508**	**0.2511**	**0.624**	**0.624**		**4744**	**4885**	**86.44**	**88.99**	
							0.02%	*0.02%*	*1.05%*	*0.21%*	*0.15%*	*0.57%*	*0.70%*		*3.27%*	*0.31%*	*3.80%*	*0.99%*	
BH4-184	242i	SSSB	2	LLS	8	4	2.002	3.63	0.1110	0.2505	0.2510	0.874	0.875	10/8/93	5261	5427	94.79	97.78	Bearing at hole 1 and 4
BH4-185	242i	SSSB	2	LLS	8	4	2.001	3.63	0.1102	0.2510	0.2500	0.875	0.875	10/8/93	5261	5427	95.48	98.49	Bearing at hole 1 and 4
BH4-186	242i	SSSB	2	LLS	8	4	2.001	3.63	0.1092	0.2505	0.2505	0.872	0.874	10/8/93	5064	5205	92.78	95.36	Bearing at hole 1 and 4
BH4-187	242i	SSSB	2	LLS	8	4	2.000	3.63	0.1101	0.2505	0.2510	0.874	0.877	10/8/93	5064	5205	91.96	94.52	Bearing at hole 1 and 4
BH4-188	242i	SSSB	2	LLS	8	4	2.000	3.63	0.1089	0.2510	0.2510	0.876	0.876	10/8/93	N/A	5037	N/A	92.48	Bearing at hole 1 and 4
BH4-189	242i	SSSB	2	LLS	8	4	2.000	3.63	0.1055	0.2505	0.2505	0.875	0.876	10/8/93	N/A	5037	N/A	95.49	Bearing at hole 1 and 4
							2.001	**3.63**	**0.1092**	**0.2507**	**0.2507**	**0.874**	**0.875**		**5163**	**5223**	**93.75**	**95.69**	
							0.04%	*0.03%*	*1.78%*	*0.10%*	*0.16%*	*0.14%*	*0.13%*		*2.20%*	*3.35%*	*1.77%*	*2.29%*	

Notes: Limit load calculated from an offset of 2% hole diameter (0.005 in). If failure occurred before offset load, N/A is recorded.
Bearing stress calculated from: Load/actual thickness/nominal hole diameter
Hole 1: First specimen, fastener head side. Hole 2: First specimen, Hilok side. Hole 3: Second specimen, Hilok side. Hole 4: Second specimen, fastener head side. (See diagram in report)

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Project #: BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters

Stabilized Single Shear Bearing

Temperature: RT

Specimen ID	Test Cell ID	Test Type	Mat. Class	Mat Desc.	Nominal Dims W/D	Nominal Dims e/D	Average Dimensions Width (in)	Length (in)	Thickness (in)	Hole Dia 1 (in)	Hole Dia 2 (in)	Edge Dist 1 (in)	Edge Dist 2 (in)	Test Date	Failure Load Limit (lbs)	Failure Load Ult (lbs)	Bearing Stress Limit (ksi)	Bearing Stress Ultimate (ksi)	Failure Mode
BH4-262	343e	SSSB	3	LLL	6	3	1.500	3.50	0.1091	0.2505	0.2505	0.623	0.625	10/8/93	4904	5261	89.93	96.47	Interlaminar shear out at hole 1. Bearing at hole 4
BH4-263	343e	SSSB	3	LLL	6	3	1.500	3.50	0.1068	0.2505	0.2505	0.623	0.624	10/8/93	4904	5261	91.86	98.55	Interlaminar shear out at hole 1. Bearing at hole 4
BH4-264	343e	SSSB	3	LLL	6	3	1.500	3.50	0.1080	0.2510	0.2510	0.624	0.626	10/8/93	N/A	5028	N/A	93.11	Bearing at holes 1 and 4
BH4-265	343e	SSSB	3	LLL	6	3	1.501	3.50	0.1083	0.2505	0.2510	0.625	0.626	10/8/93	N/A	5028	N/A	92.85	Bearing at holes 1 and 4
BH4-266	343e	SSSB	3	LLL	6	3	1.501	3.50	0.1078	0.2500	0.2505	0.626	0.626	10/8/93	N/A	5279	N/A	97.91	Bearing at holes 1 and 4
BH4-267	343e	SSSB	3	LLL	6	3	1.501	3.50	0.1077	0.2500	0.2505	0.625	0.627	10/8/93	N/A	5279	N/A	98.06	Bearing at holes 1 and 4
							1.500	**3.50**	**0.1079**	**0.2504**	**0.2507**	**0.624**	**0.626**		**4904**	**5189**	**90.90**	**96.16**	
							0.04%	*0.03%*	*0.70%*	*0.15%*	*0.10%*	*0.19%*	*0.16%*		*0.00%*	*2.41%*	*1.51%*	*2.66%*	

Notes: Limit load calculated from an offset of 2% hole diameter (0.005 in). If failure occurred before offset load, N/A is recorded.
Bearing stress calculated from: Load/actual thickness/nominal hole diameter
Hole 1: First specimen, fastener head side. Hole 2: First specimen, Hilok side. Hole 3: Second specimen, Hilok side. Hole 4: Second specimen, fastener head side. (See diagram in report)

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Project #: BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters

Temperature: RT

Unstabilized Single Shear Results

Specimen ID	Test Cell ID	Test Type	Mat. Class	Mat Desc	Nominal Dims W/D	Nominal Dims e/D	Average Dimensions Width (in)	Length (in)	Thickness (in)	Hole Dia (in)	Test Date	Failure Load Limit (lbs)	Failure Load Ult (lbs)	Bearing Stress Limit (ksi)	Bearing Stress Ultimate (ksi)	Failure Mode
BH4-70	145a	USSB	1	SLL	6	2	1.500	7.25	0.1117	0.2510	10/13/93	2156	2251	77.24	80.64	Shear out on nut side. Aud at 1500 lbs
BH4-71	145a	USSB	1	SLL	6	2	1.500	7.25	0.1109	0.2505	10/13/93	2156	2251	77.74	81.17	Shear out on nut side. Aud at 1500 lbs
BH4-72	145a	USSB	1	SLL	6	2	1.398	7.25	0.1106	0.2510	10/13/93	2077	2097	75.12	75.85	Shear out on bolt side. Aud at 1600 lbs
BH4-73	145a	USSB	1	SLL	6	2	1.492	7.25	0.1086	0.2505	10/13/93	2077	2097	76.48	77.23	Shear out on bolt side. Aud at 1600 lbs
BH4-74	145a	USSB	1	SLL	6	2	1.499	7.25	0.1102	0.2510	10/13/93	2104	2179	76.40	79.13	Shear out on bolt side. Aud at 1250 lbs
BH4-75	145a	USSB	1	SLL	6	2	1.500	7.25	0.1125	0.2510	10/13/93	2104	2179	74.80	77.46	Shear out on bolt side. Aud at 1250 lbs
							1.481	**7.25**	**0.1107**	**0.2508**		**2112**	**2176**	**76.30**	**78.58**	
							2.78%	*0.04%*	*1.20%*	*0.10%*		*1.71%*	*3.17%*	*1.51%*	*2.66%*	
BH4-76	145b	USSB	1	SLL	6	3	1.501	7.25	0.1052	0.2520	10/13/93	2298	2358	87.38	89.66	Bearing on bolt side. Aud at 1400 lbs
BH4-77	145b	USSB	1	SLL	6	3	1.500	7.25	0.1041	0.2505	10/13/93	2298	2358	88.27	90.58	Bearing on bolt side. Aud at 1400 lbs
BH4-78	145b	USSB	1	SLL	6	3	1.502	7.25	0.1026	0.2510	10/13/93	2579	2674	100.52	104.23	Bearing on both sides of fastener. Aud at 1850 lbs
BH4-79	145b	USSB	1	SLL	6	3	1.500	7.25	0.1049	0.2505	10/13/93	2579	2674	98.31	101.93	Bearing on both sides of fastener. Aud at 1850 lbs
BH4-80	145b	USSB	1	SLL	6	3	1.501	7.25	0.1051	0.2510	10/13/93	2269	2509	86.37	95.51	Bearing on bolt side. Aud at 1250 lbs
BH4-81	145b	USSB	1	SLL	6	3	1.501	7.25	0.1051	0.2505	10/13/93	2269	2509	86.40	95.54	Bearing on bolt side. Aud at 1250 lbs
							1.501	**7.25**	**0.1045**	**0.2509**		**2382**	**2514**	**91.21**	**96.24**	
							0.04%	*0.03%*	*0.95%*	*0.23%*		*6.43%*	*5.62%*	*7.06%*	*6.11%*	
BH4-82	145c	USSB	1	SLL	6	4	1.501	7.25	0.1067	0.2510	10/13/93	2557	2578	95.86	96.64	Bearing on bolt side. Aud at 1700 lbs
BH4-83	145c	USSB	1	SLL	6	4	1.501	7.25	0.1061	0.2510	10/13/93	2557	2578	96.41	97.21	Bearing on bolt side. Aud at 1700 lbs
BH4-84	145c	USSB	1	SLL	6	4	1.502	7.25	0.1038	0.2510	10/13/93	2335	2373	90.00	91.46	Bearing on bolt side. Aud at 1650 lbs
BH4-85	145c	USSB	1	SLL	6	4	1.500	7.25	0.1048	0.2510	10/13/93	2335	2373	89.11	90.56	Bearing on bolt side. Aud at 1650 lbs
BH4-86	145c	USSB	1	SLL	6	4	1.500	7.25	0.1054	0.2510	10/13/93	2257	2494	85.63	94.62	Bearing on bolt side. Aud at 1800 lbs
BH4-87	145c	USSB	1	SLL	6	4	1.500	7.25	0.1054	0.2510	10/13/93	2257	2494	85.70	94.69	Bearing on bolt side. Aud at 1800 lbs
							1.501	**7.25**	**0.1054**	**0.2510**		**2383**	**2482**	**90.45**	**94.20**	
							0.04%	*0.03%*	*0.96%*	*0.00%*		*5.84%*	*3.71%*	*5.25%*	*2.86%*	
BH4-190	246a	USSB	2	LLS	6	2	1.498	7.25	0.1080	0.2520	10/13/93	N/A	1797	N/A	66.54	Shear out at bolt side. Aud at 1050 lbs
BH4-191	246a	USSB	2	LLS	6	2	1.499	7.25	0.1103	0.2520	10/13/93	N/A	1797	N/A	65.20	Shear out at bolt side. Aud at 1050 lbs
BH4-192	246a	USSB	2	LLS	6	2	1.499	7.24	0.1108	0.2515	10/13/93	1838	1870	66.37	67.51	Shear out at bolt side. Aud at 1100 lbs
BH4-193	246a	USSB	2	LLS	6	2	1.499	7.24	0.1096	0.2520	10/13/93	1838	1870	67.11	68.26	Shear out at bolt side. Aud at 1100 lbs
BH4-194	246a	USSB	2	LLS	6	2	1.500	7.24	0.1131	0.2520	10/13/93	1717	1742	60.72	61.60	Shear out at bolt side. Aud at 1150 lbs
BH4-195	246a	USSB	2	LLS	6	2	1.499	7.24	0.1120	0.2520	10/13/93	1717	1742	61.32	62.21	Shear out at bolt side. Aud at 1150 lbs
							1.499	**7.24**	**0.1106**	**0.2519**		**1778**	**1803**	**63.88**	**65.22**	
							0.03%	*0.03%*	*1.62%*	*0.08%*		*3.94%*	*3.19%*	*5.20%*	*4.25%*	
BH4-196	246b	USSB	2	LLS	6	3	1.500	7.25	0.1028	0.2515	10/13/93	1998	2170	77.72	84.41	Bearing on both sides of fastener. Aud at 1300 lbs
BH4-197	246b	USSB	2	LLS	6	3	1.499	7.25	0.1028	0.2520	10/13/93	1998	2170	77.78	84.48	Bearing on both sides of fastener. Aud at 1300 lbs
BH4-198	246b	USSB	2	LLS	6	3	1.500	7.25	0.1028	0.2525	10/13/93	2083	2271	81.02	88.34	Bearing on bolt side. Aud at 1450 lbs
BH4-199	246b	USSB	2	LLS	6	3	1.500	7.25	0.1029	0.2515	10/13/93	2083	2271	81.00	88.31	Bearing on bolt side. Aud at 1450 lbs
BH4-200	246b	USSB	2	LLS	6	3	1.499	7.25	0.1049	0.2520	10/13/93	2249	2325	85.74	88.64	Bearing on bolt side. Aud at 1400 lbs
BH4-201	246b	USSB	2	LLS	6	3	1.500	7.26	0.1058	0.2520	10/13/93	2249	2325	85.00	87.87	Bearing on bolt side. Aud at 1400 lbs
							1.500	**7.25**	**0.1037**	**0.2519**		**2110**	**2255**	**81.38**	**87.01**	
							0.03%	*0.02%*	*1.30%*	*0.15%*		*5.41%*	*3.12%*	*4.21%*	*2.30%*	
BH4-202	246c	USSB	2	LLS	6	4	1.500	7.25	0.1044	0.2520	10/13/93	2208	2268	84.57	86.87	Bearing on bolt side. Aud at 1700 lbs
BH4-203	246c	USSB	2	LLS	6	4	1.500	7.25	0.1028	0.2515	10/13/93	2208	2268	85.94	88.28	Bearing on bolt side. Aud at 1700 lbs
BH4-204	246c	USSB	2	LLS	6	4	1.499	7.24	0.1039	0.2520	10/13/93	N/A	2281	N/A	87.83	Bearing on both sides of fastener. Aud at 1850 lbs
BH4-205	246c	USSB	2	LLS	6	4	1.500	7.24	0.1050	0.2520	10/13/93	N/A	2281	N/A	86.90	Bearing on both sides of fastener. Aud at 1850 lbs
BH4-206	246c	USSB	2	LLS	6	4	1.499	7.25	0.1064	0.2520	10/13/93	2340	2541	87.96	95.51	Bearing on bolt side. Aud at 1700 lbs
BH4-207	246c	USSB	2	LLS	6	4	1.499	7.25	0.1084	0.2520	10/13/93	2340	2541	86.32	93.74	Bearing on bolt side. Aud at 1700 lbs
							1.499	**7.25**	**0.1052**	**0.2519**		**2274**	**2363**	**86.20**	**89.85**	
							0.04%	*0.08%*	*1.91%*	*0.08%*		*3.35%*	*5.83%*	*1.62%*	*4.20%*	

Notes: Limit load calculated from an offset of 2% hole diameter (0.005 in) or first zero slope. If failure occurred before offset load, N/A is recorded.
Bearing stress calculated from: Load/actual thickness/nominal hole diameter

intec

Project #: BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters

Temperature: RT

Unstabilized Single Shear Results

Specimen ID	Test Cell ID	Test Type	Mat. Class	Mat Desc.	Nominal Dims W/D	Nominal Dims e/D	Average Dimensions Width (in)	Length (in)	Thickness (in)	Hole Dia (in)	Test Date	Failure Load Limit (lbs)	Failure Load Ult (lbs)	Bearing Stress Limit (ksi)	Bearing Stress Ultimate (ksi)	Failure Mode
BH4-280	347b	USSB	3	LLL	6	3	1.499	7.26	0.1132	0.2515	10/13/93	2435	2799	86.07	98.93	Bearing on bolt side. Aud at 1200 lbs
BH4-281	347b	USSB	3	LLL	6	3	1.499	7.26	0.1129	0.2515	10/13/93	2435	2799	86.27	99.17	Bearing on bolt side. Aud at 1200 lbs
BH4-282	347b	USSB	3	LLL	6	3	1.499	7.26	0.1134	0.2515	10/13/93	2454	2543	86.55	89.69	Interlaminar shear nut side. Bearing bolt side. Aud at 1250 lbs
BH4-283	347b	USSB	3	LLL	6	3	1.499	7.26	0.1124	0.2515	10/13/93	2454	2543	87.33	90.50	Interlaminar shear nut side. Bearing bolt side. Aud at 1250 lbs
BH4-284	347b	USSB	3	LLL	6	3	1.499	7.26	0.1150	0.2505	10/13/93	N/A	2131	N/A	74.15	Shear out on bolt side. Aud at 1300 lbs
BH4-285	347b	USSB	3	LLL	6	3	1.498	7.25	0.1163	0.2510	10/13/93	N/A	2131	N/A	73.29	Shear out on bolt side. Aud at 1300 lbs
							1.499	**7.26**	**0.1139**	**0.2513**		**2445**	**2491**	**86.55**	**87.62**	
							0.04%	*0.03%*	*1.30%*	*0.17%*		*0.45%*	*12.10%*	*0.64%*	*13.12%*	

Notes: Limit load calculated from an offset of 2% hole diameter (0.005 in) or first zero slope. If failure occurred before offset load, N/A is recorded.
Bearing stress calculated from: Load/actual thickness/nominal hole diameter

intec

Project #: BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters

Double Shear Bearing

Temperature: RT

Specimen ID	Test Cell ID	Test Type	Mat. Class	Mat Desc.	Nominal Dims W/D	Nominal Dims e/D	Average Dimensions Width (in)	Length (in)	Thickness (in)	Hole Dia (in)	Edge Dist (in)	Test Date	Failure Load Limit (lbs)	Failure Load Ult (lbs)	Bearing Stress Limit (ksi)	Bearing Stress Ultimate (ksi)	Failure Mode
BH4-088	149a	DSB	1	SLL	4	2	0.999	7.25	0.1034	0.2530	0.379	10/13/93	3233	3350	125.03	129.55	Shear out. Aud at 2800 lbs
BH4-089	149a	DSB	1	SLL	4	2	0.999	7.26	0.1038	0.2520	0.377	10/13/93	3008	3208	115.97	123.68	Shear out. Aud at 3050 lbs
BH4-090	149a	DSB	1	SLL	4	2	1.000	7.25	0.1037	0.2530	0.380	10/13/93	3067	3077	118.28	118.67	Shear out. Aud at 3020 lbs
							0.999	**7.254**	**0.104**	**0.253**	**0.379**		**3103**	**3212**	**119.76**	**123.97**	
							0.03%	*0.02%*	*0.17%*	*0.23%*	*0.40%*		*3.76%*	*4.25%*	*3.93%*	*4.39%*	
BH4-091	149b	DSB	1	SLL	4	3	0.999	7.24	0.1107	0.2530	0.631	10/13/93	3302	3899	119.37	140.95	Shear out. Aud at 3000 lbs
BH4-092	149b	DSB	1	SLL	4	3	1.000	7.24	0.1078	0.2525	0.626	10/13/93	3309	3820	122.74	141.70	Shear out. Aud at 3075 lbs
BH4-093	149b	DSB	1	SLL	4	3	1.000	7.25	0.1054	0.2530	0.626	10/14/93	3119	3504	118.41	133.02	Shear out. Aud at 2730 lbs
							0.999	**7.243**	**0.108**	**0.253**	**0.628**		**3243**	**3741**	**120.17**	**138.56**	
							0.04%	*0.04%*	*2.45%*	*0.11%*	*0.41%*		*3.32%*	*5.59%*	*1.90%*	*3.47%*	
BH4-094	149c	DSB	1	SLL	4	4	1.000	7.24	0.1121	0.2520	0.877	10/14/93	3496	4461	124.73	159.16	Shear out. Aud at 3200 lbs
BH4-095	149c	DSB	1	SLL	4	4	0.999	7.24	0.1104	0.2520	0.877	10/14/93	3489	4206	126.47	152.46	Shear out. Aud at 1100 lbs
BH4-096	149c	DSB	1	SLL	4	4	1.001	7.25	0.1078	0.2535	0.876	10/14/93	3496	4230	129.70	156.93	Shear out. Aud at 3380 lbs
							1.000	**7.243**	**0.110**	**0.253**	**0.877**		**3494**	**4299**	**126.97**	**156.18**	
							0.09%	*0.05%*	*1.96%*	*0.34%*	*0.10%*		*0.12%*	*3.28%*	*1.99%*	*2.18%*	
BH4-097	149d	DSB	1	SLL	6	2	1.501	7.25	0.1113	0.2510	0.372	10/14/93	3019	3144	108.52	113.01	Shear out. Aud at 3200 lbs
BH4-098	149d	DSB	1	SLL	6	2	1.501	7.25	0.1105	0.2510	0.369	10/14/93	2936	3103	106.30	112.34	Shear out. Aud at 2950 lbs
BH4-099	149d	DSB	1	SLL	6	2	1.500	7.25	0.1100	0.2510	0.373	10/14/93	2817	2919	102.41	106.11	Shear out. Aud at 2850 lbs
							1.501	**7.252**	**0.111**	**0.251**	**0.371**		**2924**	**3055**	**105.74**	**110.49**	
							0.03%	*0.04%*	*0.57%*	*0.00%*	*0.49%*		*3.47%*	*3.92%*	*2.93%*	*3.44%*	
BH4-100	149e	DSB	1	SLL	6	3	1.500	7.26	0.1102	0.2510	0.623	10/14/93	3424	3830	124.25	138.98	Shear out. Aud at 2850 lbs
BH4-101	149e	DSB	1	SLL	6	3	1.500	7.26	0.1064	0.2515	0.621	10/14/93	3413	3755	128.37	141.23	Shear out. Aud at 3080 lbs
BH4-102	149e	DSB	1	SLL	6	3	1.499	7.25	0.1038	0.2510	0.623	10/14/93	3254	3638	125.39	140.19	Shear out. Aud at 2850 lbs
							1.500	**7.255**	**0.107**	**0.251**	**0.622**		**3364**	**3741**	**126.00**	**140.13**	
							0.03%	*0.03%*	*3.03%*	*0.11%*	*0.19%*		*2.83%*	*2.59%*	*1.69%*	*0.80%*	
BH4-103	149f	DSB	1	SLL	6	4	1.500	7.25	0.1026	0.2510	0.880	10/14/93	3704	4182	144.48	163.12	Shear out. Aud at 3730 lbs
BH4-104	149f	DSB	1	SLL	6	4	1.499	7.25	0.1032	0.2510	0.874	10/14/93	3232	3883	125.29	150.53	Shear out. Aud at 3180 lbs
BH4-105	149f	DSB	1	SLL	6	4	1.499	7.25	0.1026	0.2515	0.873	10/14/93	3213	4154	125.30	162.00	Shear out. Aud at 3220 lbs
							1.499	**7.250**	**0.103**	**0.251**	**0.876**		**3383**	**4073**	**131.69**	**158.55**	
							0.04%	*0.02%*	*0.35%*	*0.11%*	*0.43%*		*8.22%*	*4.05%*	*8.41%*	*4.40%*	
BH4-106	149g	DSB	1	SLL	8	2	1.999	7.25	0.1023	0.2520	0.372	10/15/93	2859	3022	111.83	118.20	Shear out. Aud at 1450 lbs
BH4-107	149g	DSB	1	SLL	8	2	2.000	7.25	0.1034	0.2530	0.379	10/15/93	2976	3055	115.16	118.22	Shear out. Aud at 2990 lbs
BH4-108	149g	DSB	1	SLL	8	2	2.000	7.25	0.1072	0.2520	0.374	10/15/93	2870	2984	107.14	111.40	Shear out. Aud at 2850 lbs
							2.000	**7.251**	**0.104**	**0.252**	**0.375**		**2902**	**3020**	**111.38**	**115.94**	
							0.02%	*0.03%*	*2.46%*	*0.23%*	*0.98%*		*2.23%*	*1.18%*	*3.62%*	*3.39%*	
BH4-109	149h	DSB	1	SLL	8	3	1.999	7.25	0.1021	0.2530	0.623	10/15/93	3236	3741	126.84	146.63	Shear out. Aud at 3175 lbs
BH4-110	149h	DSB	1	SLL	8	3	2.000	7.24	0.1036	0.2525	0.632	10/15/93	3184	3619	122.97	139.77	Shear out. Aud at 2900 lbs
BH4-111	149h	DSB	1	SLL	8	3	2.000	7.25	0.1052	0.2520	0.628	10/15/93	3302	3732	125.57	141.92	Shear out. Aud at 2550 lbs
							2.000	**7.248**	**0.104**	**0.253**	**0.628**		**3241**	**3697**	**125.13**	**142.78**	
							0.02%	*0.05%*	*1.51%*	*0.20%*	*0.76%*		*1.82%*	*1.84%*	*1.57%*	*2.46%*	

Notes: Limit load calculated from an offset of 2% hole diameter (0.005 in). If failure occurred before offset load, N/A is recorded
Bearing stress calculated from Load/actual thickness/nominal hole diameter

intec

Project #: BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters

Double Shear Bearing

Temperature: RT

Specimen ID	Test Cell ID	Test Type	Mat. Class	Mat Desc.	Nominal Dims W/D	Nominal Dims e/D	Average Dimensions Width (in)	Length (in)	Thickness (in)	Hole Dia (in)	Edge Dist (in)	Test Date	Failure Load Limit (lbs)	Failure Load Ult (lbs)	Bearing Stress Limit (ksi)	Bearing Stress Ultimate (ksi)	Failure Mode
BH4-112	149i	DSB	1	SLL	8	4	1.999	7.24	0.1045	0.2525	0.877	10/15/93	3371	4000	129.10	153.18	Shear out. Aud at 2900 lbs
BH4-113	149i	DSB	1	SLL	8	4	2.001	7.25	0.1048	0.2525	0.878	10/15/93	3119	4185	119.05	159.73	Shear out. Aud at 3100 lbs
BH4-114	149i	DSB	1	SLL	8	4	2.001	7.25	0.1053	0.2520	0.877	10/15/93	3292	3988	125.09	151.54	Shear out. Aud at 3050 lbs
							2.000	**7.247**	**0.105**	**0.252**	**0.877**		**3261**	**4058**	**124.41**	**154.82**	
							0.06%	*0.05%*	*0.39%*	*0.11%*	*0.07%*		*3.95%*	*2.72%*	*4.07%*	*2.80%*	
BH4-115	149j	DSB	1	SLL	6	3	1.503	7.25	0.1075	0.2510	0.630	10/15/93	1454	2514	54.12	93.57	Bearing with some shear out. Aud at 1225 lbs
BH4-116	149j	DSB	1	SLL	6	3	1.500	7.25	0.1076	0.2510	0.630	10/15/93	1588	2313	59.02	85.97	Shear out. Aud at 1400 lbs
BH4-117	149j	DSB	1	SLL	6	3	1.500	7.25	0.1082	0.2510	0.627	10/15/93	1809	2008	66.86	74.21	Shear out. Aud at 1700 lbs
							1.501	**7.252**	**0.108**	**0.251**	**0.629**		**1617**	**2278**	**60.00**	**84.59**	*Note: Finger tight torque*
							0.12%	*0.00%*	*0.38%*	*0.00%*	*0.26%*		*11.09%*	*11.18%*	*10.71%*	*11.53%*	
BH4-118	149k	DSB	1	SLL	6	3	1.500	7.24	0.1088	0.2515	0.624	10/15/93	3649	4218	134.11	155.03	Shear out. Aud at 3350 lbs
BH4-119	149k	DSB	1	SLL	6	3	1.500	7.25	0.1079	0.2510	0.623	10/15/93	3608	3868	133.71	143.35	Shear out. Aud at 3600 lbs
BH4-120	149k	DSB	1	SLL	6	3	1.501	7.25	0.1075	0.2510	0.619	10/15/93	3253	3626	121.00	134.88	Shear out. Aud at 2850 lbs
							1.500	**7.245**	**0.108**	**0.251**	**0.622**		**3503**	**3904**	**129.61**	**144.42**	*Note: High torque (90 in-lb)*
							0.05%	*0.05%*	*0.62%*	*0.11%*	*0.38%*		*6.22%*	*7.62%*	*5.75%*	*7.00%*	
BH4-208	250a	DSB	2	LLS	4	2	0.999	7.25	0.1073	0.2520	0.372	10/14/93	2762	2891	102.98	107.79	Shear out. Aud at 1770 lbs.
BH4-209	250a	DSB	2	LLS	4	2	0.999	7.26	0.1068	0.2520	0.373	10/14/93	2799	2824	104.82	105.75	Shear out. Aud at 2710 lbs.
BH4-210	250a	DSB	2	LLS	4	2	0.998	7.26	0.1069	0.2520	0.372	10/14/93	2757	2773	103.15	103.74	Shear out. Aud at 1850 lbs.
							0.998	**7.255**	**0.107**	**0.252**	**0.372**		**2773**	**2829**	**103.65**	**105.76**	
							0.03%	*0.02%*	*0.23%*	*0.00%*	*0.16%*		*0.83%*	*2.09%*	*0.98%*	*1.91%*	
BH4-211	250b	DSB	2	LLS	4	3	0.999	7.26	0.1112	0.2520	0.627	10/14/93	3156	3681	113.51	132.39	Shear out. Aud at 3000 lbs.
BH4-212	250b	DSB	2	LLS	4	3	0.999	7.25	0.1110	0.2520	0.625	10/14/93	3054	3486	110.04	125.60	Shear out. Aud at 2950 lbs.
BH4-213	250b	DSB	2	LLS	4	3	0.999	7.25	0.1116	0.2515	0.625	10/14/93	3248	3635	116.38	130.25	Shear out. Aud at 2550 lbs.
							0.999	**7.255**	**0.111**	**0.252**	**0.625**		**3153**	**3601**	**113.31**	**129.41**	
							0.03%	*0.02%*	*0.28%*	*0.11%*	*0.18%*		*3.08%*	*2.83%*	*2.80%*	*2.68%*	
BH4-214	250c	DSB	2	LLS	4	4	1.002	7.25	0.1061	0.2520	0.875	10/14/93	3303	3867	124.48	145.74	Shear out. Aud at 2900 lbs.
BH4-215	250c	DSB	2	LLS	4	4	0.999	7.25	0.1061	0.2520	0.873	10/14/93	3177	4134	119.79	155.88	Shear out. Aud at 2550 lbs.
BH4-216	250c	DSB	2	LLS	4	4	0.999	7.25	0.1054	0.2525	0.873	10/14/93	3087	4007	117.19	152.12	Shear out. Aud at 2775 lbs.
							1.000	**7.254**	**0.106**	**0.252**	**0.874**		**3189**	**4003**	**120.49**	**151.25**	
							0.16%	*0.01%*	*0.41%*	*0.11%*	*0.15%*		*3.40%*	*3.34%*	*3.07%*	*3.39%*	
BH4-217	250d	DSB	2	LLS	6	2	1.499	7.25	0.1043	0.2520	0.379	10/14/93	2665	2689	102.25	103.18	Shear out. Aud at 2000 lbs.
BH4-218	250d	DSB	2	LLS	6	2	1.500	7.26	0.1031	0.2820	0.371	10/14/93	2528	2674	98.13	103.79	Shear out. Aud at 1850 lbs.
BH4-219	250d	DSB	2	LLS	6	2	1.499	7.25	0.1024	0.2520	0.371	10/14/93	2874	2874	112.28	112.28	Shear out. Aud at 2300 lbs.
							1.499	**7.254**	**0.103**	**0.262**	**0.374**		**2689**	**2746**	**104.22**	**106.42**	
							0.05%	*0.02%*	*0.92%*	*6.61%*	*1.24%*		*6.48%*	*4.06%*	*6.99%*	*4.78%*	
BH4-220	250e	DSB	2	LLS	6	3	1.500	7.24	0.1128	0.2520	0.622	10/14/93	3541	3860	125.60	136.92	Shear out. Aud at 2300 lbs.
BH4-221	250e	DSB	2	LLS	6	3	1.501	7.24	0.1114	0.2515	0.624	10/14/93	3204	3555	115.03	127.63	Shear out. Aud at 2650 lbs.
BH4-222	250e	DSB	2	LLS	6	3	1.499	7.24	0.1113	0.2520	0.625	10/14/93	3306	3649	118.80	131.12	Shear out. Aud at 3150 lbs.
							1.500	**7.242**	**0.112**	**0.252**	**0.624**		**3350**	**3688**	**119.81**	**131.89**	
							0.08%	*0.01%*	*0.72%*	*0.11%*	*0.24%*		*5.16%*	*4.24%*	*4.47%*	*3.56%*	

Notes: Limit load calculated from an offset of 2% hole diameter (0.005 in). If failure occurred before offset load, N/A is recorded.
Bearing stress calculated from Load/actual thickness/nominal hole diameter

Interlaminar Tension Test Program

Intec

Project #: BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters

Temperature: RT

Flange Bend Results

Specimen ID	Test Cell ID	Test Type	Mat. Class	Panel ID	Nominal Dimensions Width (in)	Nominal Dimensions Flange Length (in)	Nominal Dimensions Thick (in)	Average Dimensions Width (in)	Average Dimensions Length (in)	Average Dimensions Thickness (in)	Average Dimensions Edge Distance (in)	Test Date	Ultimate Load (lbs)	Out-of-Plane Tension Stress (ksi)	Failure Mode
BH4-501	153	FB2-2	1	T5-SLL-01	2.00	3.5	0.25	2.016	3.497	0.2512	0.422	12/16/93	86.2	3.89	Failure of mult ply interfaces in radius
BH4-502	153	FB2-2	1	T5-SLL-01	2.00	3.5	0.25	2.033	3.507	0.2494	0.423	12/16/93	117.1	5.30	Failure of mult ply interfaces in radius
BH4-503	153	FB2-2	1	T5-SLL-01	2.00	3.5	0.25	2.016	3.502	0.2504	0.424	12/16/93	116.3	5.28	Failure of mult ply interfaces in radius
								2.022	**3.502**	**0.2503**	**0.423**		**106.5**	**4.82**	
								0.49%	*0.15%*	*0.36%*	*0.18%*		*16.5%*	*16.7%*	
BH4-504	254	FB2-2	2	T5-LLS-01	2.00	3.5	0.250	1.968	3.424	0.2493	0.425	12/16/93	91.2	4.21	Failure of mult ply interfaces in radius
BH4-505	254	FB2-2	2	T5-LLS-01	2.00	3.5	0.250	2.016	3.402	0.2479	0.423	12/16/93	75.3	3.41	Failure of mult ply interfaces in radius
BH4-506	254	FB2-2	2	T5-LLS-01	2.00	3.5	0.250	2.021	3.382	0.2477	0.423	12/16/93	97.4	4.40	Failure of mult ply interfaces in radius
BH4-510	456	FB2-2	2	T7-LLS-02	2.00	3.5	0.250	2.020	3.480	0.2485	0.420	12/16/93	92.5	4.22	Failure of mult ply interfaces in radius
BH4-511	456	FB2-2	2	T7-LLS-02	2.00	3.5	0.250	2.016	3.469	0.2498	0.422	12/16/93	85.1	3.85	Failure of mult ply interfaces in radius
BH4-512	456	FB2-2	2	T7-LLS-02	2.00	3.5	0.250	2.032	3.479	0.2497	0.422	12/16/93	109.7	4.94	Failure of mult ply interfaces in radius
								2.012	**3.439**	**0.2488**	**0.423**		**91.9**	**4.17**	
								1.11%	*1.24%*	*0.37%*	*0.42%*		*12.6%*	*12.3%*	
BH4-507	355	FB2-2	3	T7-LLL-01	2.00	3.5	0.250	2.018	3.434	0.2526	0.418	12/16/93	76.7	3.40	Failure of mult ply interfaces in radius
BH4-508	355	FB2-2	3	T7-LLL-01	2.00	3.5	0.250	2.030	3.448	0.2529	0.416	12/16/93	78.9	3.48	Failure of mult ply interfaces in radius
BH4-509	355	FB2-2	3	T7-LLL-01	2.00	3.5	0.250	2.040	3.426	0.2520	0.420	12/16/93	85.7	3.77	Failure of mult ply interfaces in radius
								2.029	**3.436**	**0.2525**	**0.418**		**80.4**	**3.55**	
								0.55%	*0.31%*	*0.19%*	*0.51%*		*5.8%*	*5.4%*	
BH4-513	557	FB2-2	5	TS-1	2.00	3.5	0.250	2.025	2.997	0.2470	0.425	12/16/93	48.4	2.06	Inplane tension at inner radius.
BH4-514	557	FB2-2	5	TS-1	2.00	3.5	0.250	2.026	2.965	0.2473	0.426	12/16/93	51.7	2.19	Inplane tension at inner radius.
BH4-515	557	FB2-2	5	TS-1	2.00	3.5	0.250	2.046	2.965	0.2502	0.424	12/16/93	55.3	2.28	Inplane tension at inner radius.
								2.032	**2.975**	**0.2482**	**0.425**		**51.8**	**2.18**	
								0.58%	*0.62%*	*0.70%*	*0.21%*		*6.7%*	*5.0%*	
BH4-516	658	FB2-2	6	TS-2-15	2.00	3.5	0.250	1.978	3.003	0.2485	0.420	12/16/93	65.2	2.83	Inplane tension at inner radius.
BH4-517	658	FB2-2	6	TS-2-15	2.00	3.5	0.250	2.035	2.979	0.2479	0.419	12/16/93	69.2	2.91	Inplane tension at inner radius.
BH4-518	658	FB2-2	6	TS-2-15	2.00	3.5	0.250	2.032	2.979	0.2463	0.419	12/16/93	78.7	3.35	Inplane tension at inner radius.
								2.015	**2.987**	**0.2476**	**0.419**		**71.0**	**3.03**	
								1.61%	*0.46%*	*0.45%*	*0.19%*		*9.8%*	*9.2%*	
BH4-519	759	FB2-2	7	OS-1	2.00	3.5	0.250	2.030	2.974	0.2475	0.420	12/16/93	82.2	3.47	Inplane tension at inner radius.
BH4-520	759	FB2-2	7	OS-1	2.00	3.5	0.250	2.028	3.022	0.2484	0.418	12/16/93	86.8	3.68	Inplane tension at inner radius.
BH4-521	759	FB2-2	7	OS-1	2.00	3.5	0.250	2.014	2.990	0.2486	0.424	12/16/93	78.5	3.33	Inplane tension at inner radius.
								2.024	**2.995**	**0.2481**	**0.421**		**82.5**	**3.50**	
								0.43%	*0.83%*	*0.24%*	*0.75%*		*5.0%*	*5.1%*	
BH4-522	860	FB2-2	8	OS-2	2.00	3.5	0.250	2.044	3.006	0.2488	0.426	12/16/93	72.0	3.01	Inplane tension at inner radius.
BH4-523	860	FB2-2	8	OS-2	2.00	3.5	0.250	2.027	3.004	0.2481	0.423	12/16/93	63.7	2.70	Inplane tension at inner radius.
BH4-524	860	FB2-2	8	OS-2	2.00	3.5	0.250	2.027	2.999	0.2489	0.422	12/16/93	71.5	3.01	Inplane tension at inner radius.
								2.033	**3.003**	**0.2486**	**0.423**		**69.1**	**2.91**	
								0.47%	*0.11%*	*0.17%*	*0.45%*		*6.7%*	*6.3%*	

Notes: Out-of-plane Tension Stress calculated from: 3*Ult moment/2/Mid-ply radius/actual thickness/actual width (see report for calculation of moment arm)

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Project #: BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters

Temperature: RT

Flange Bend Results

Specimen ID	Test Cell ID	Test Type	Mat. Class	Panel ID	Nominal Dimensions			Average Dimensions				Test Date	Ultimate Load	Out-of-Plane Tension Stress	Failure Mode
					Width	Flange Length	Thick	Width	Length	Thick-ness	Edge Distance				
					(in)	*(in)*	*(in)*	*(in)*	*(in)*	*(in)*	*(in)*		*(lbs)*	*(ksi)*	
BH4-525	961	FB2-2	9	LS-1	2.00	3.5	0.250	2.031	3.045	0.2513	0.418	12/16/93	73.5	3.08	Inplane tension at inner radius.
BH4-526	961	FB2-2	9	LS-1	2.00	3.5	0.250	2.040	3.019	0.2505	0.423	12/16/93	66.7	2.78	Inplane tension at inner radius.
BH4-527	961	FB2-2	9	LS-1	2.00	3.5	0.250	2.027	3.028	0.2496	0.425	12/16/93	52.7	2.22	Inplane tension at inner radius.
								2.033	**3.031**	**0.2505**	**0.422**		**64.3**	**2.69**	
								0.33%	*0.43%*	*0.33%*	*0.85%*		*16.5%*	*16.10%*	
BH4-528	1062	FB2-2	10	LS-2	2.00	3.5	0.250	2.028	2.957	0.2484	0.426	12/16/93	50.7	2.13	Inplane tension at inner radius.
BH4-529	1062	FB2-2	10	LS-2	2.00	3.5	0.250	2.026	2.970	0.2483	0.427	12/16/93	50.5	2.13	Inplane tension at inner radius.
BH4-530	1062	FB2-2	10	LS-2	2.00	3.5	0.250	2.013	2.941	0.2481	0.427	12/16/93	54.3	2.29	Inplane tension at inner radius.
								2.022	**2.956**	**0.2483**	**0.427**		**51.8**	**2.18**	
								0.39%	*0.48%*	*0.07%*	*0.21%*		*4.1%*	*4.39%*	

Notes: Out-of-plane Tension Stress calculated from: 3*Ult moment/2/Mid-ply radius/actual thickness/actual width (see report for calculation of moment arm)

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Project #: BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters

Temperature: RT

C-Section Results

Specimen ID	Test Cell ID	Test Type	Mat. Class	Panel ID	Nominal Midply Radius	Average Dimensions Width	Depth	Length	Thick-ness	Moment Arm	Test Date	Ultimate Load	Ultimate Moment	Out-of-Plane Tension Stress	Failure Mode
					(in)	*(in)*	*(in)*	*(in)*	*(in)*	*(in)*		*(lbs)*	*(in-lbs)*	*(ksi)*	
BH4-419	A1a	CS1-1	A	572-015	0.255	1.002	0.643	3.51	0.1290	2.935	11/8/93	23.70	69.56	3.17	Failure of mult ply interfaces in radius
BH4-420	A1a	CS1-1	A	572-015	0.255	1.001	0.640	3.51	0.1280	2.935	11/8/93	26.90	78.95	3.62	Failure of mult ply interfaces in radius
BH4-421	A1a	CS1-1	A	572-015	0.255	1.000	0.640	3.51	0.1293	2.935	11/8/93	20.10	58.99	2.68	Failure of mult ply interfaces in radius
					Average:	**1.001**	**0.641**	**3.51**	**0.1288**			**23.57**	**69.17**	**3.16**	
					COV	*0.08%*	*0.27%*	*0.01%*	*0.51%*			*14.44%*	*14.44%*	*14.88%*	
BH4-422	A1b	CS1-2	A	572-015	0.255	2.000	0.642	3.51	0.1303	2.935	11/9/93	36.50	107.13	2.42	Failure of mult ply interfaces in radius
BH4-423	A1b	CS1-2	A	572-015	0.255	2.001	0.641	3.51	0.1305	2.935	11/9/93	40.30	118.28	2.66	Failure of mult ply interfaces in radius
BH4-424	A1b	CS1-2	A	572-015	0.255	2.001	0.641	3.50	0.1300	2.935	11/9/93	37.50	110.06	2.49	Failure of mult ply interfaces in radius
					Average:	**2.001**	**0.641**	**3.51**	**0.1303**			**38.10**	**111.82**	**2.52**	
					COV	*0.03%*	*0.12%*	*0.04%*	*0.19%*			*5.17%*	*5.17%*	*5.02%*	
BH4-425	A5a	CS2-1	A	572-014	0.305	1.001	0.774	3.51	0.1675	2.915	11/9/93	41.60	121.26	3.56	Failure of mult ply interfaces in radius
BH4-426	A5a	CS2-1	A	572-014	0.305	1.001	0.774	3.51	0.1670	2.915	11/10/93	31.20	90.95	2.68	Failure of mult ply interfaces in radius
BH4-427	A5a	CS2-1	A	572-014	0.305	1.001	0.774	3.51	0.1675	2.915	11/10/93	44.50	129.72	3.81	Failure of mult ply interfaces in radius
					Average:	**1.001**	**0.774**	**3.51**	**0.1673**			**39.10**	**113.98**	**3.35**	
					COV	*0.01%*	*0.02%*	*0.00%*	*0.17%*			*17.89%*	*17.89%*	*17.74%*	
BH4-428	A5b	CS2-2	A	572-014	0.305	2.001	0.773	3.51	0.1685	2.915	11/12/93	71.30	207.84	3.03	Failure of mult ply interfaces in radius
BH4-429	A5b	CS2-2	A	572-014	0.305	1.997	0.774	3.51	0.1688	2.915	11/12/93	72.00	209.88	3.06	Failure of mult ply interfaces in radius
BH4-430	A5b	CS2-2	A	572-014	0.305	2.000	0.774	3.51	0.1680	2.915	11/12/93	72.70	211.92	3.10	Failure of mult ply interfaces in radius
					Average:	**1.999**	**0.773**	**3.51**	**0.1684**			**72.00**	**209.88**	**3.07**	
					COV	*0.11%*	*0.05%*	*0.02%*	*0.23%*			*0.97%*	*0.97%*	*1.16%*	
BH4-441	B2a	CS1-1	B	572-017	0.255	1.000	0.640	3.50	0.1263	2.935	11/8/93	24.00	70.44	3.28	Failure of mult ply interfaces in radius
BH4-442	B2a	CS1-1	B	572-017	0.255	1.000	0.638	3.50	0.1268	2.935	11/8/93	19.60	57.53	2.67	Failure of mult ply interfaces in radius
BH4-443	B2a	CS1-1	B	572-017	0.255	1.000	0.638	3.50	0.1280	2.935	11/8/93	20.60	60.46	2.78	Failure of mult ply interfaces in radius
					Average:	**1.000**	**0.639**	**3.50**	**0.1270**			**21.40**	**62.81**	**2.91**	
					COV	*0.04%*	*0.20%*	*0.01%*	*0.71%*			*10.78%*	*10.78%*	*11.23%*	
BH4-444	B2b	CS1-2	B	572-017	0.255	2.000	0.651	3.50	0.1293	2.935	11/9/93	39.00	114.47	2.60	Failure of mult ply interfaces in radius
BH4-445	B2b	CS1-2	B	572-017	0.255	2.001	0.638	3.50	0.1240	2.935	11/9/93	43.80	128.55	3.05	Failure of mult ply interfaces in radius
BH4-446	B2b	CS1-2	B	572-017	0.255	2.003	0.638	3.50	0.1288	2.935	11/9/93	37.80	110.94	2.53	Failure of mult ply interfaces in radius
					Average:	**2.001**	**0.643**	**3.50**	**0.1273**			**40.20**	**117.99**	**2.73**	
					COV	*0.06%*	*1.20%*	*0.03%*	*2.28%*			*7.90%*	*7.90%*	*10.24%*	
BH4-447	B6a	CS2-1	B	572-010	0.305	0.998	0.775	3.54	0.1673	2.915	11/10/93	43.50	126.80	3.74	Failure of mult ply interfaces in radius
BH4-448	B6a	CS2-1	B	572-010	0.305	0.999	0.773	3.54	0.1688	2.915	11/10/93	45.60	132.92	3.88	Failure of mult ply interfaces in radius
BH4-449	B6a	CS2-1	B	572-010	0.305	1.001	0.773	3.54	0.1690	2.915	11/12/93	50.00	145.75	4.24	Failure of mult ply interfaces in radius
					Average:	**0.999**	**0.774**	**3.54**	**0.1683**			**46.37**	**135.16**	**3.95**	
					COV	*0.14%*	*0.09%*	*0.04%*	*0.56%*			*7.15%*	*7.15%*	*6.56%*	
BH4-450	B6b	CS2-2	B	572-010	0.305	2.000	0.774	3.54	0.1693	2.915	11/12/93	73.30	213.67	3.10	Failure of mult ply interfaces in radius
BH4-451	B6b	CS2-2	B	572-010	0.305	2.000	0.774	3.54	0.1698	2.915	11/12/93	112.90	329.10	4.77	Failure of mult ply interfaces in radius
BH4-452	B6b	CS2-2	B	572-010	0.305	2.000	0.774	3.54	0.1688	2.915	11/12/93	79.10	230.58	3.36	Failure of mult ply interfaces in radius
					Average:	**2.000**	**0.774**	**3.54**	**0.1693**			**88.43**	**257.78**	**3.74**	
					COV	*0.02%*	*0.02%*	*0.04%*	*0.30%*			*24.18%*	*24.18%*	*23.94%*	

Notes: Out-of-plane Tension Stress calculated from: 3*Ult moment/2/Midply radius/actual thickness/actual width
All failures occurred in the radius with visible cracks on multiple ply interfaces.

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Project #: **BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters**

Temperature: RT

C-Section Results

Specimen ID	Test Cell ID	Test Type	Mat. Class	Panel ID	Nominal Midply Radius (in)	Average Dimensions Width (in)	Depth (in)	Length (in)	Thick-ness (in)	Moment Arm (in)	Test Date	Ultimate Load (lbs)	Ultimate Moment (in-lbs)	Out-of-Plane Tension Stress (ksi)	Failure Mode
BH4-463	C3a	CS1-1	C	572-019	0.255	1.000	0.640	3.50	0.1275	2.935	11/8/93	25.80	75.72	3.49	Failure of mult ply interfaces in radius
BH4-464	C3a	CS1-1	C	572-019	0.255	1.001	0.639	3.50	0.1285	2.935	11/8/93	21.50	63.10	2.89	Failure of mult ply interfaces in radius
BH4-465	C3a	CS1-1	C	572-019	0.255	1.000	0.639	3.50	0.1285	2.935	11/8/93	18.70	54.88	2.51	Failure of mult ply interfaces in radius
					Average:	**1.001**	**0.639**	**3.50**	**0.1282**			**22.00**	**64.57**	**2.96**	
					COV	*0.04%*	*0.10%*	*0.04%*	*0.45%*			*16.26%*	*16.26%*	*16.71%*	
BH4-466	C3b	CS1-2	C	572-019	0.255	2.002	0.639	3.50	0.1293	2.935	11/9/93	45.70	134.13	3.05	Failure of mult ply interfaces in radius
BH4-467	C3b	CS1-2	C	572-019	0.255	2.002	0.640	3.50	0.1293	2.935	11/9/93	49.20	144.40	3.28	Failure of mult ply interfaces in radius
BH4-468	C3b	CS1-2	C	572-019	0.255	2.004	0.641	3.50	0.1288	2.935	11/9/93	40.90	120.04	2.74	Failure of mult ply interfaces in radius
					Average:	**2.003**	**0.640**	**3.50**	**0.1291**			**45.27**	**132.86**	**3.02**	
					COV	*0.06%*	*0.20%*	*0.02%*	*0.22%*			*9.21%*	*9.21%*	*9.07%*	
BH4-469	C7a	CS2-1	C	572-012	0.305	1.001	0.788	3.54	0.1688	2.915	11/12/93	31.70	92.41	2.69	Failure of mult ply interfaces in radius
BH4-470	C7a	CS2-1	C	572-012	0.305	0.999	0.786	3.53	0.1685	2.915	11/12/93	29.20	85.12	2.49	Failure of mult ply interfaces in radius
BH4-471	C7a	CS2-1	C	572-012	0.305	1.000	0.781	3.54	0.1683	2.915	11/12/93	28.10	81.91	2.40	Failure of mult ply interfaces in radius
					Average:	**1.000**	**0.785**	**3.54**	**0.1685**			**29.67**	**86.48**	**2.52**	
					COV	*0.13%*	*0.47%*	*0.08%*	*0.15%*			*6.22%*	*6.22%*	*5.97%*	
BH4-472	C7b	CS2-2	C	572-012	0.305	2.002	0.782	3.54	0.1693	2.915	11/12/93	57.70	168.20	2.44	Failure of mult ply interfaces in radius
BH4-473	C7b	CS2-2	C	572-012	0.305	1.997	0.784	3.54	0.1700	2.915	11/12/93	68.10	198.51	2.88	Failure of mult ply interfaces in radius
BH4-474	C7b	CS2-2	C	572-012	0.305	2.001	0.783	3.55	0.1695	2.915	11/12/93	65.00	189.48	2.75	Failure of mult ply interfaces in radius
					Average:	**2.000**	**0.783**	**3.54**	**0.1696**			**63.60**	**185.39**	**2.69**	
					COV	*0.11%*	*0.13%*	*0.17%*	*0.23%*			*8.40%*	*8.40%*	*8.29%*	
BH4-485	D4a	CS1-1	D	572-013	0.255	1.001	0.641	3.50	0.1495	2.935	11/8/93	22.90	67.21	2.64	Failure of mult ply interfaces in radius
BH4-486	D4a	CS1-1	D	572-013	0.255	1.003	0.639	3.50	0.1283	2.935	11/8/93	24.40	71.61	3.27	Failure of mult ply interfaces in radius
BH4-487	D4a	CS1-1	D	572-013	0.255	0.999	0.640	3.50	0.1295	2.935	11/8/93	27.20	79.83	3.63	Failure of mult ply interfaces in radius
					Average:	**1.001**	**0.640**	**3.50**	**0.1358**			**24.83**	**72.89**	**3.18**	
					COV	*0.21%*	*0.14%*	*0.08%*	*8.78%*			*8.79%*	*8.79%*	*15.71%*	
BH4-488	D4b	CS1-2	D	572-013	0.255	2.004	0.638	3.51	0.1293	2.935	11/9/93	47.90	140.59	3.19	Failure of mult ply interfaces in radius
BH4-489	D4b	CS1-2	D	572-013	0.255	1.999	0.639	3.51	0.1293	2.935	11/9/93	40.40	118.57	2.70	Failure of mult ply interfaces in radius
BH4-490	D4b	CS1-2	D	572-013	0.255	2.001	0.640	3.52	0.1290	2.935	11/9/93	39.00	114.47	2.61	Failure of mult ply interfaces in radius
					Average:	**2.001**	**0.639**	**3.51**	**0.1292**			**42.43**	**124.54**	**2.83**	
					COV	*0.11%*	*0.10%*	*0.25%*	*0.11%*			*11.28%*	*11.28%*	*11.12%*	
BH4-491	D8a	CS2-1	D	572-022	0.305	0.999	0.777	3.54	0.1683	2.915	11/12/93	52.40	152.75	4.47	Failure of mult ply interfaces in radius
BH4-492	D8a	CS2-1	D	572-022	0.305	0.999	0.776	3.54	0.1693	2.915	11/12/93	42.80	124.76	3.63	Failure of mult ply interfaces in radius
BH4-493	D8a	CS2-1	D	572-022	0.305	0.999	0.774	3.55	0.1675	2.915	11/12/93	55.50	161.78	4.75	Failure of mult ply interfaces in radius
					Average:	**0.999**	**0.776**	**3.54**	**0.1683**			**50.23**	**146.43**	**4.28**	
					COV	*0.04%*	*0.18%*	*0.14%*	*0.52%*			*13.18%*	*13.18%*	*13.68%*	
BH4-494	D8b	CS2-2	D	572-022	0.305	2.001	0.775	3.51	0.1685	2.915	11/12/93	83.10	242.24	3.53	Failure of mult ply interfaces in radius
BH4-495	D8b	CS2-2	D	572-022	0.305	1.999	0.774	3.52	0.1693	2.915	11/12/93	97.70	284.80	4.14	Failure of mult ply interfaces in radius
BH4-496	D8b	CS2-2	D	572-022	0.305	2.002	0.774	3.53	0.1690	2.915	11/12/93	86.50	252.15	3.66	Failure of mult ply interfaces in radius
					Average:	**2.001**	**0.774**	**3.52**	**0.1689**			**89.10**	**259.73**	**3.78**	
					COV	*0.09%*	*0.05%*	*0.26%*	*0.23%*			*8.57%*	*8.57%*	*8.45%*	

Notes: Out-of-plane Tension Stress calculated from 3*Ult moment/2*Midply radius/actual thickness/actual width
All failures occurred in the radius with visible cracks on multiple ply interfaces

Interlaminar Shear Test Program

Intec
Project #: **BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters**
Temperature: RT

Compression Interlaminar Shear

Specimen ID	Test Cell ID	Test Type	Mat. Class	Mat Desc	Panel ID	Average Dimensions Width (in)	Length (in)	Thickness (in)	Notch 1 Depth (in)	Notch 2 Depth (in)	Overlap (in)	Test Date	Failure Load Ultimate (lbs)	Shear Stress (ksi)	Failure Mode
BH4-001	109	CILS	1	SLL	T7-SLL-C-4A	0.501	3.18	0.2352	0.1275	0.1280	0.501	10/20/93	1461	5.82	Interlaminar shear
BH4-002	109	CILS	1	SLL	T7-SLL-C-4A	0.499	3.19	0.2283	0.1245	0.1245	0.501	10/20/93	1302	5.21	Interlaminar shear
BH4-003	109	CILS	1	SLL	T7-SLL-C-4A	0.500	3.19	0.2272	0.1240	0.1245	0.501	10/20/93	1141	4.56	Interlaminar shear
					Average:	**0.500**	**3.19**	**0.2302**	**0.1253**	**0.1257**	**0.501**		**1301**	**5.20**	
					COV	*0.18%*	*0.11%*	*1.88%*	*1.51%*	*1.61%*	*0.001*		*12.30%*	*12.18%*	
BH4-121	210	CILS	2	LLS	T7-LLS-C-3B	0.502	3.18	0.2138	0.1170	0.1180	0.504	10/20/93	1849	7.32	Interlaminar shear
BH4-122	210	CILS	2	LLS	T7-LLS-C-3B	0.500	3.19	0.2138	0.1180	0.1175	0.505	10/20/93	1633	6.46	Interlaminar shear
BH4-123	210	CILS	2	LLS	T7-LLS-C-3B	0.500	3.19	0.2138	0.1175	0.1175	0.505	10/20/93	2002	7.93	Interlaminar shear
					Average:	**0.501**	**3.19**	**0.2138**	**0.1175**	**0.1177**	**0.504**		**1828**	**7.24**	
					COV	*0.16%*	*0.04%*	*0.00%*	*0.43%*	*0.25%*	*0.002*		*10.14%*	*10.21%*	
BH4-241	311	CILS	3	LLL	T7-LLL-C-4A	0.500	3.17	0.2285	0.1245	0.1250	0.499	10/20/93	1461	5.86	Interlaminar shear
BH4-242	311	CILS	3	LLL	T7-LLL-C-4A	0.500	3.18	0.2298	0.1255	0.1260	0.500	10/20/93	1457	5.83	Interlaminar shear
BH4-243	311	CILS	3	LLL	T7-LLL-C-4A	0.499	3.18	0.2302	0.1255	0.1260	0.501	10/20/93	1598	6.40	Interlaminar shear
					Average:	**0.500**	**3.18**	**0.2295**	**0.1252**	**0.1257**	**0.500**		**1505**	**6.03**	
					COV	*0.10%*	*0.12%*	*0.38%*	*0.46%*	*0.46%*	*0.002*		*5.33%*	*5.29%*	
BH4-307	412	CILS	4	LSS	T7-LSS-C-6A	0.501	3.19	0.2283	0.1250	0.1250	0.501	10/20/93	1683	6.71	Interlaminar shear
BH4-308	412	CILS	4	LSS	T7-LSS-C-6A	0.498	3.19	0.2290	0.1245	0.1250	0.502	10/20/93	1915	7.66	Interlaminar shear
BH4-309	412	CILS	4	LSS	T7-LSS-C-6A	0.501	3.19	0.2240	0.1225	0.1225	0.501	10/20/93	1559	6.22	Interlaminar shear
					Average:	**0.500**	**3.19**	**0.2271**	**0.1240**	**0.1242**	**0.501**		**1719**	**6.86**	
					COV	*0.30%*	*0.05%*	*1.20%*	*1.07%*	*1.16%*	*0.002*		*10.51%*	*10.65%*	
BH4-373	513	CILS	5	TS-1	T7-TS1-A-3A	0.500	3.18	0.2212	0.1210	0.1215	0.501	10/20/93	1230	4.91	Interlaminar shear
BH4-374	513	CILS	5	TS-1	T7-TS1-A-3A	0.501	3.18	0.2218	0.1210	0.1205	0.502	10/20/93	1300	5.17	Interlaminar shear
BH4-375	513	CILS	5	TS-1	T7-TS1-A-3A	0.501	3.18	0.2215	0.1215	0.1210	0.501	10/20/93	1473	5.88	Interlaminar shear
					Average:	**0.501**	**3.18**	**0.2215**	**0.1212**	**0.1210**	**0.501**		**1334**	**5.32**	
					COV	*0.12%*	*0.05%*	*0.15%*	*0.24%*	*0.41%*	*0.001*		*9.37%*	*9.39%*	
BH4-379	614	CILS	6	TS-2	T7-TS2-A-2A	0.501	3.20	0.2318	0.1265	0.1270	0.505	10/20/93	1549	6.13	Interlaminar shear
BH4-380	614	CILS	6	TS-2	T7-TS2-A-2A	0.500	3.19	0.2305	0.1255	0.1260	0.503	10/20/93	1687	6.71	Interlaminar shear
BH4-381	614	CILS	6	TS-2	T7-TS2-A-2A	0.501	3.19	0.2282	0.1245	0.1250	0.503	10/20/93	1488	5.91	Interlaminar shear
					Average:	**0.501**	**3.19**	**0.2302**	**0.1255**	**0.1260**	**0.503**		**1575**	**6.25**	
					COV	*0.08%*	*0.15%*	*0.81%*	*0.80%*	*0.79%*	*0.002*		*6.47%*	*6.55%*	
BH4-385	715	CILS	7	OS-1	T7-OS1-A-3A	0.501	3.18	0.2312	0.1260	0.1270	0.500	10/20/93	980	3.92	Interlaminar shear
BH4-386	715	CILS	7	OS-1	T7-OS1-A-3A	0.501	3.18	0.2310	0.1265	0.1260	0.501	10/20/93	1333	5.31	Interlaminar shear
BH4-387	715	CILS	7	OS-1	T7-OS1-A-3A	0.499	3.18	0.2307	0.1260	0.1265	0.503	10/20/93	1102	4.39	Interlaminar shear
					Average:	**0.500**	**3.18**	**0.2309**	**0.1262**	**0.1265**	**0.501**		**1138**	**4.54**	
					COV	*0.20%*	*0.03%*	*0.11%*	*0.23%*	*0.40%*	*0.003*		*15.75%*	*15.65%*	

Notes: Shear Stress calculated from: Ultimate Load/Actual overlap/Actual width
All specimens tested in Modified D695 Compression Fixture (BSS7260). No strain gages were used

Intec
Project #: **BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters**
Temperature: RT

Compression Interlaminar Shear

Specimen ID	Test Cell ID	Test Type	Mat. Class	Mat Desc.	Panel ID	Average Dimensions: Width (in)	Length (in)	Thickness (in)	Notch 1 Depth (in)	Notch 2 Depth (in)	Overlap (in)	Test Date	Failure Load Ultimate (lbs)	Shear Stress (ksi)	Failure Mode
BH4-391	816	CILS	8	OS-2	T7-OS2-A-2A	0.501	3.18	0.2319	0.1400	0.1390	0.506	10/22/93	2764	10.91	Interlaminar shear
BH4-392	816	CILS	8	OS-2	T7-OS2-A-2A	0.502	3.18	0.2356	0.1380	0.1330	0.508	10/22/93	1982	7.79	Interlaminar shear
BH4-393	816	CILS	8	OS-2	T7-OS2-A-2A	0.501	3.18	0.2323	0.1400	0.1400	0.508	10/22/93	2971	11.67	Compressive failure, no interlaminar shear effect observed
BH4-393s	816	CILS	8	OS-2	T7-OS2-A-2A	0.501	3.18	0.2365	0.1350	0.1350	0.515	10/22/93	1964	7.63	Interlaminar shear
					Average:	**0.501**	**3.18**	**0.2341**	**0.1383**	**0.1368**	**0.509**		**2420**	**9.50**	
					COV	*0.10%*	*0.00%*	*0.94%*	*1.82%*	*2.64%*	*0.008*		*21.62%*	*22.04%*	
BH4-397	917	CILS	9	LS-1	T7-LS1-A-4A	0.500	3.18	0.2135	0.1160	0.1170	0.500	10/20/93	1587	6.35	Interlaminar shear
BH4-398	917	CILS	9	LS-1	T7-LS1-A-4A	0.501	3.18	0.2133	0.1170	0.1180	0.500	10/20/93	1785	7.14	Interlaminar shear
BH4-399	917	CILS	9	LS-1	T7-LS1-A-4A	0.501	3.18	0.2132	0.1170	0.1160	0.502	10/20/93	1581	6.29	Interlaminar shear
					Average:	**0.501**	**3.18**	**0.2133**	**0.1167**	**0.1170**	**0.501**		**1651**	**6.59**	
					COV	*0.07%*	*0.07%*	*0.08%*	*0.49%*	*0.85%*	*0.003*		*7.03%*	*7.16%*	
BH4-403	1018	CILS	10	LS-2	T5-LS2-A-1B	0.501	3.18	0.2278	0.1245	0.1240	0.498	10/20/93	1360	5.45	Interlaminar shear
BH4-404	1018	CILS	10	LS-2	T5-LS2-A-1B	0.501	3.18	0.2273	0.1240	0.1245	0.499	10/20/93	1711	6.86	Interlaminar shear
BH4-405	1018	CILS	10	LS-2	T5-LS2-A-1B	0.499	3.18	0.2278	0.1240	0.1245	0.499	10/20/93	1597	6.42	Interlaminar shear
					Average:	**0.500**	**3.18**	**0.2277**	**0.1242**	**0.1243**	**0.498**		**1556**	**6.24**	
					COV	*0.22%*	*0.06%*	*0.13%*	*0.23%*	*0.23%*	*0.001*		*11.51%*	*11.55%*	

Notes: Shear Stress calculated from: Ultimate Load/Actual overlap/Actual width
All specimens tested in Modified D695 Compression Fixture (BSS7260). No strain gages were used.

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Project #: **BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters**

Temperature: RT

Short Beam Shear Results

Specimen ID	Test Cell ID	Test Type	Mat. Class	Mat Descr.	Panel ID	Nominal Dimensions Width (in)	Nominal Dimensions Thick (in)	Nominal Dimensions Length (in)	Average Dimensions Width (in)	Average Dimensions Thick (in)	Average Dimensions Length (in)	Test Date	Ult Load (lbs)	Shear Stress (ksi)	Failure Mode
BH4-004	119	SBS	1	SLL	T7-SLL-C-4A	0.5	0.25	1.5	0.5017	0.2246	1.50	10/14/93	1141	7.59	Shear Left
BH4-005	119	SBS	1	SLL	T7-SLL-C-4A	0.5	0.25	1.5	0.5004	0.2272	1.50	10/14/93	1046	6.90	Shear Left
BH4-006	119	SBS	1	SLL	T7-SLL-C-4A	0.5	0.25	1.5	0.5010	0.2311	1.50	10/14/93	1174	7.61	Shear Right
					Average:	**0.500**	**0.25**	**1.50**	**0.501**	**0.23**	**1.50**		**1120**	**7.37**	
					COV	*0.00%*	*0.00%*	*0.00%*	*0.13%*	*1.42%*	*0.00%*		*5.93%*	*5.48%*	
BH4-124	220	SBS	2	LLS	T7-LLS-C-3B	0.5	0.25	1.5	0.5023	0.2166	1.50	10/14/93	1307	9.01	Shear Left
BH4-125	220	SBS	2	LLS	T7-LLS-C-3B	0.5	0.25	1.5	0.5010	0.2169	1.50	10/14/93	1274	8.79	Shear Left
BH4-126	220	SBS	2	LLS	T7-LLS-C-3B	0.5	0.25	1.5	0.5010	0.2168	1.50	10/14/93	1323	9.14	Shear Left
					Average:	**0.500**	**0.25**	**1.50**	**0.501**	**0.22**	**1.50**		**1301**	**8.98**	
					COV	*0.00%*	*0.00%*	*0.00%*	*0.15%*	*0.08%*	*0.00%*		*1.92%*	*1.94%*	
BH4-244	321	SBS	3	LLL	T7-LLS-B-10B	0.5	0.25	1.5	0.5018	0.2274	1.50	10/14/93	837	5.50	Shear Left
BH4-245	321	SBS	3	LLL	T7-LLS-B-10B	0.5	0.25	1.5	0.5003	0.2274	1.50	10/14/93	946	6.24	Shear Left
BH4-246	321	SBS	3	LLL	T7-LLS-B-10B	0.5	0.25	1.5	0.5023	0.2276	1.50	10/14/93	1050	6.89	Shear Right
					Average:	**0.500**	**0.25**	**1.50**	**0.502**	**0.23**	**1.50**		**944**	**6.21**	
					COV	*0.00%*	*0.00%*	*0.00%*	*0.21%*	*0.04%*	*0.00%*		*11.28%*	*11.18%*	
BH4-310	422	SBS	4	LSS	T7-LSS-C-6A	0.5	0.25	1.5	0.5010	0.2237	1.50	10/14/93	1080	7.23	Shear Left
BH4-311	422	SBS	4	LSS	T7-LSS-C-6A	0.5	0.25	1.5	0.5018	0.2262	1.50	10/14/93	1033	6.82	Shear Left
BH4-312	422	SBS	4	LSS	T7-LSS-C-6A	0.5	0.25	1.5	0.5017	0.2196	1.50	10/14/93	1145	7.79	Shear Left
					Average:	**0.500**	**0.25**	**1.50**	**0.502**	**0.22**	**1.50**		**1086**	**7.28**	
					COV	*0.00%*	*0.00%*	*0.00%*	*0.09%*	*1.49%*	*0.00%*		*5.18%*	*6.69%*	
BH4-376	523	SBS	5	TS-1	T7-TS1-A-3A	0.5	0.25	1.5	0.5007	0.2289	1.50	10/14/93	1212	7.93	Shear Left
BH4-377	523	SBS	5	TS-1	T7-TS1-A-3A	0.5	0.25	1.5	0.5007	0.2279	1.50	10/14/93	1323	8.70	Shear Right
BH4-378	523	SBS	5	TS-1	T7-TS1-A-3A	0.5	0.25	1.5	0.5005	0.2281	1.50	10/14/93	1228	8.07	Shear Right
					Average:	**0.500**	**0.25**	**1.50**	**0.501**	**0.23**	**1.50**		**1254**	**8.23**	
					COV	*0.00%*	*0.00%*	*0.00%*	*0.02%*	*0.25%*	*0.00%*		*4.78%*	*4.97%*	
BH4-382	624	SBS	6	TS-2	T7-TS2-A-2A	0.5	0.25	1.5	0.5027	0.2321	1.50	10/14/93	1283	8.25	Shear Left
BH4-383	624	SBS	6	TS-2	T7-TS2-A-2A	0.5	0.25	1.5	0.5012	0.2307	1.50	10/14/93	1226	7.95	Shear Left
BH4-384	624	SBS	6	TS-2	T7-TS2-A-2A	0.5	0.25	1.5	0.5003	0.2295	1.50	10/14/93	1240	8.10	Shear Left
					Average:	**0.500**	**0.25**	**1.50**	**0.501**	**0.23**	**1.50**		**1250**	**8.10**	
					COV	*0.00%*	*0.00%*	*0.00%*	*0.24%*	*0.57%*	*0.00%*		*2.38%*	*1.83%*	

Notes: Shear Stress calculated from: 0.75*Ultimate Load/Actual thickness/Actual width
All specimens tested according to ASTM D2344.

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Project #: **BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters**

Temperature: RT

Short Beam Shear Results

Specimen ID	Test Cell ID	Test Type	Mat. Class	Mat Descr.	Panel ID	Nominal Dimensions Width *(in)*	Nominal Dimensions Thick *(in)*	Nominal Dimensions Length *(in)*	Average Dimensions Width *(in)*	Average Dimensions Thick *(in)*	Average Dimensions Length *(in)*	Test Date	Ult Load (lbs)	Shear Stress (ksi)	Failure Mode
BH4-388	725	SBS	7	OS-1	T7-OS1-A-3A	0.5	0.25	1.5	0.5015	0.2299	1.50	10/14/93	1096	7.13	Shear Left
BH4-389	725	SBS	7	OS-1	T7-OS1-A-3A	0.5	0.25	1.5	0.5008	0.2299	1.50	10/14/93	1069	6.96	Shear Left
BH4-390	725	SBS	7	OS-1	T7-OS1-A-3A	0.5	0.25	1.5	0.5010	0.2298	1.50	10/14/93	1076	7.01	Shear Left
					Average:	**0.500**	**0.25**	**1.50**	**0.501**	**0.23**	**1.50**		**1080**	**7.03**	
					COV	*0.00%*	*0.00%*	*0.00%*	*0.07%*	*0.02%*	*0.00%*		*1.30%*	*1.21%*	
BH4-394	826	SBS	8	OS-2	T7-OS2-A-2A	0.5	0.25	1.5	0.5012	0.2376	1.50	10/14/93	1514	9.54	Tensile
BH4-395	826	SBS	8	OS-2	T7-OS2-A-2A	0.5	0.25	1.5	0.5015	0.2388	1.50	10/14/93	1499	9.39	Tensile
BH4-396	826	SBS	8	OS-2	T7-OS2-A-2A	0.5	0.25	1.5	0.5000	0.2388	1.50	10/14/93	1636	10.28	Tensile
					Average:	**0.500**	**0.25**	**1.50**	**0.501**	**0.24**	**1.50**		**1550**	**9.73**	
					COV	*0.00%*	*0.00%*	*0.00%*	*0.16%*	*0.29%*	*0.00%*		*4.85%*	*4.90%*	
BH4-400	927	SBS	9	LS-1	T7-LS1-A-4A	0.5	0.25	1.5	0.5013	0.2127	1.50	10/14/93	847	5.96	Shear Left
BH4-401	927	SBS	9	LS-1	T7-LS1-A-4A	0.5	0.25	1.5	0.5008	0.2124	1.50	10/14/93	931	6.56	Shear Left
BH4-402	927	SBS	9	LS-1	T7-LS1-A-4A	0.5	0.25	1.5	0.5012	0.2124	1.50	10/14/93	1017	7.16	Shear Left
					Average:	**0.500**	**0.25**	**1.50**	**0.501**	**0.21**	**1.50**		**932**	**6.56**	
					COV	*0.00%*	*0.00%*	*0.00%*	*0.05%*	*0.08%*	*0.00%*		*9.12%*	*9.20%*	
BH4-406	1028	SBS	10	LS-2	T5-LS2-A-1B	0.5	0.25	1.5	0.5013	0.2286	1.50	10/14/93	1250	8.18	Shear Left
BH4-407	1028	SBS	10	LS-2	T5-LS2-A-1B	0.5	0.25	1.5	0.5013	0.2291	1.50	10/14/93	1060	6.92	Shear Left
BH4-408	1028	SBS	10	LS-2	T5-LS2-A-1B	0.5	0.25	1.5	0.5008	0.2283	1.50	10/14/93	1132	7.42	Shear Left
					Average:	**0.500**	**0.25**	**1.50**	**0.501**	**0.23**	**1.50**		**1147**	**7.51**	
					COV	*0.00%*	*0.00%*	*0.00%*	*0.06%*	*0.16%*	*0.00%*		*8.36%*	*8.44%*	

Notes: Shear Stress calculated from: 0.75*Ultimate Load/Actual thickness/Actual width
All specimens tested according to ASTM D2344.

Fracture Toughness Test Program

intec

Project #: **BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters**

Temperature: RT **Double Cantilever Beam (Mode I) Results**

Specimen ID	Test Type	Mat. Class	Panel ID	Average Dimensions			Test Date	GIC-Area Method					GIC-Initiation Method				
				Width	Thick	Length		1	2	3	Avg.	*COV*	1	2	3	Avg.	*COV*
				(in)	*(in)*	*(in)*		*(in-lbs/in^2)*					*(in-lbs/in^2)*				
BH4-409	DCB	A	572-011L	0.5008	0.2529	13.0	11/2/93	6.84	4.87	6.23	5.98	*16.9%*	5.65	6.90	5.55	6.03	*12.5%*
BH4-410	DCB	A	572-011L	0.5014	0.2531	13.0	11/3/93	7.16	3.95	4.84	5.32	*31.2%*	5.19	5.87	6.01	5.69	*7.8%*
BH4-411	DCB	A	572-011L	0.5000	0.2545	13.0	11/3/93	6.29	5.74	5.28	5.77	*8.7%*	7.87	8.55	3.54	6.66	*40.8%*
BH4-412	DCB	A	572-011L	0.4990	0.2551	13.0	11/3/93	6.50	10.76	9.20	8.82	*24.4%*	7.41	12.37	13.93	11.24	*30.3%*
BH4-413	DCB	A	572-011L	0.4983	0.2555	13.0	11/3/93	6.49	9.00	12.37	9.29	*31.8%*	5.86	10.08	13.52	9.82	*39.0%*
			Average:	**0.4999**	**0.2542**	**13.0**					**7.03**					**7.89**	
			COV	*0.25%*	*0.46%*	*0.00%*						*33.2%*					*40.5%*
BH4-431	DCB	B	572-008U	0.5023	0.2525	13.0	11/2/93	See Note 2					See Note 2				
BH4-432	DCB	B	572-008U	0.5002	0.2523	13.0	11/2/93	5.21	3.93	4.20	4.44	*15.2%*	6.24	4.53	4.31	5.02	*21.0%*
BH4-433	DCB	B	572-008U	0.5000	0.2530	13.0	11/3/93	3.88	4.23	3.87	3.99	*5.2%*	6.67	5.28	3.84	5.26	*26.8%*
BH4-434	DCB	B	572-008U	0.5000	0.2533	13.0	11/3/93	3.10	3.40	4.76	3.75	*23.6%*	4.23	4.23	5.29	4.58	*13.4%*
BH4-435	DCB	B	572-008U	0.5008	0.2537	13.0	11/3/93	3.80	9.56	6.74	6.70	*43.0%*	4.82	3.57	3.66	4.02	*17.3%*
			Average:	**0.5007**	**0.2530**	**13.0**					**4.72**					**4.72**	
			COV	*0.19%*	*0.23%*	*0.00%*						*38.1%*					*20.8%*
BH4-453	DCB	C	572-004L	0.5000	0.2503	13.0	11/3/93	4.56	5.57	4.17	4.77	*15.2%*	4.72	5.42	5.03	5.06	*6.9%*
BH4-454	DCB	C	572-004L	0.4990	0.2513	13.0	11/3/93	5.57	5.27	4.62	5.15	*9.4%*	7.00	6.24	5.35	6.20	*13.4%*
BH4-455	DCB	C	572-004L	0.4987	0.2451	13.0	11/3/93	3.68	5.29	5.14	4.70	*18.9%*	6.37	6.01	6.63	6.34	*4.9%*
BH4-456	DCB	C	572-004L	0.4980	0.2520	13.0	11/4/93	3.77	4.70	2.99	3.82	*22.4%*	4.55	3.37	3.71	3.88	*15.7%*
BH4-457	DCB	C	572-004L	0.4982	0.2521	13.0	11/4/93	3.42	4.27	4.38	4.02	*13.1%*	4.68	4.28	4.49	4.49	*4.5%*
			Average:	**0.4988**	**0.2502**	**13.0**					**4.49**					**5.19**	
			COV	*0.16%*	*1.17%*	*0.00%*						*17.7%*					*20.8%*
BH4-475	DCB	D	572-008	0.4990	0.2557	13.0	11/4/93	5.57	6.55	5.47	5.86	*10.2%*	7.21	5.86	7.14	6.74	*11.2%*
BH4-476	DCB	D	572-008	0.5000	0.2565	13.0	11/4/93	6.81	7.20	8.48	7.50	*11.6%*	7.46	6.29	8.88	7.54	*17.2%*
BH4-477	DCB	D	572-008	0.4985	0.2574	13.0	11/4/93	6.73	6.95	5.78	6.49	*9.6%*	8.25	7.81	7.25	7.77	*6.4%*
BH4-478	DCB	D	572-008	0.4980	0.2581	13.0	11/4/93	5.57	12.25	7.38	8.40	*41.1%*	5.76	6.25	6.74	6.25	*7.8%*
BH4-479	DCB	D	572-008	0.4988	0.2583	13.0	11/4/93	6.19	6.40	14.16	8.92	*50.9%*	6.70	7.51	8.61	7.61	*12.6%*
			Average:	**0.4989**	**0.2572**	**13.0**					**7.43**					**7.18**	
			COV	*0.15%*	*0.43%*	*0.00%*						*33.7%*					*13.2%*

Notes: 1) Tests run in accordance with BSS 7273 using the area and initiation methods for calculation of GiC.
2) Operator error. Data was not reported.

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Project #: **BH0004 Out-of-Plane and Bearing Properties of RTM Textiles for Boeing Helicopters**

Temperature: RT **End Notch Flexure (Mode II) Results**

Specimen ID	Test Type	Mat. Class	Panel ID	Average Dimensions Width	Thick	Length	Test Date	GIIC 1	2	3	Avg.	COV
				(in)	*(in)*	*(in)*		*(in-lbs/in^2)*				
BH4-414	ENF	A	572-011L	0.4950	0.2565	13.0	10/26/93	14.32	18.55	14.92	15.93	*14.36%*
BH4-415	ENF	A	572-011L	0.4980	0.2560	13.0	10/26/93	10.16	16.43	10.84	12.48	*27.57%*
BH4-416	ENF	A	572-011L	0.4980	0.2585	13.0	10/26/93	10.16	16.10	14.04	13.43	*22.46%*
BH4-417	ENF	A	572-011L	0.4960	0.2545	13.0	10/26/93	14.36	11.20	15.15	13.57	*15.40%*
BH4-418	ENF	A	572-011L	0.4980	0.2545	13.0	10/26/93	9.28	10.06	11.30	10.21	*9.95%*
			Average:	**0.4970**	**0.2560**	**13.0**					**13.13**	
			COV	*0.28%*	*0.65%*	*0.00%*						*21.77%*
BH4-436	ENF	B	572-008U	0.5030	0.2540	13.0	10/26/93	12.07	11.34	20.11	14.51	*33.54%*
BH4-437	ENF	B	572-008U	0.5030	0.2525	13.0	10/26/93	12.16	12.33	14.49	13.00	*10.00%*
BH4-438	ENF	B	572-008U	0.4990	0.2522	13.0	10/27/93	14.17	11.86	15.85	13.96	*14.33%*
BH4-439	ENF	B	572-008U	0.4990	0.2503	13.0	10/27/93	10.82	12.46	13.83	12.37	*12.17%*
BH4-440	ENF	B	572-008U	0.4990	0.2485	13.0	10/27/93	12.99	13.48	12.46	12.98	*3.95%*
			Average:	**0.5006**	**0.2515**	**13.0**					**13.36**	
			COV	*0.44%*	*0.85%*	*0.00%*						*17.04%*
BH4-458	ENF	C	572-004L	0.5010	0.2518	13.0	10/27/93	9.93	9.12	8.77	9.27	*6.40%*
BH4-459	ENF	C	572-004L	0.5010	0.2520	13.0	10/27/93	11.82	10.78	12.95	11.85	*9.15%*
BH4-460	ENF	C	572-004L	0.5010	0.2515	13.0	10/27/93	12.13	12.97	15.61	13.57	*13.38%*
BH4-461	ENF	C	572-004L	0.5010	0.2518	13.0	10/27/93	12.60	10.71	15.91	13.07	*20.10%*
BH4-462	ENF	C	572-004L	0.5010	0.2485	13.0	10/27/93	10.58	11.40	8.95	10.31	*12.11%*
			Average:	**0.5010**	**0.2511**	**13.0**					**11.62**	
			COV	*0.00%*	*0.59%*	*0.00%*						*18.72%*
BH4-480	ENF	D	572-008	0.5060	0.2595	13.0	10/25/93	13.68	13.64	16.63	14.65	*11.73%*
BH4-481	ENF	D	572-008	0.5010	0.2580	13.0	10/25/93	13.31	15.74	17.93	15.66	*14.74%*
BH4-482	ENF	D	572-008	0.5010	0.2582	13.0	10/25/93	14.40	20.49	13.58	16.16	*23.37%*
BH4-483	ENF	D	572-008	0.5010	0.2582	13.0	10/25/93	10.42	14.90	15.14	13.48	*19.71%*
BH4-484	ENF	D	572-008	0.4990	0.2560	13.0	10/25/93	10.61	9.70	16.04	12.11	*28.29%*
			Average:	**0.5016**	**0.2580**	**13.0**					**14.41**	
			COV	*0.52%*	*0.49%*	*0.00%*						*19.89%*

Notes: Tests run in accordance with BMS 8-276 (para. 8.5.9).

Appendix B Typical Stress-Strain Curves

Typical stress-strain data are shown in this Appendix for the 2-D Braided, 3-D Woven and Stitched-Uniweave materials for a variety of test conditions.

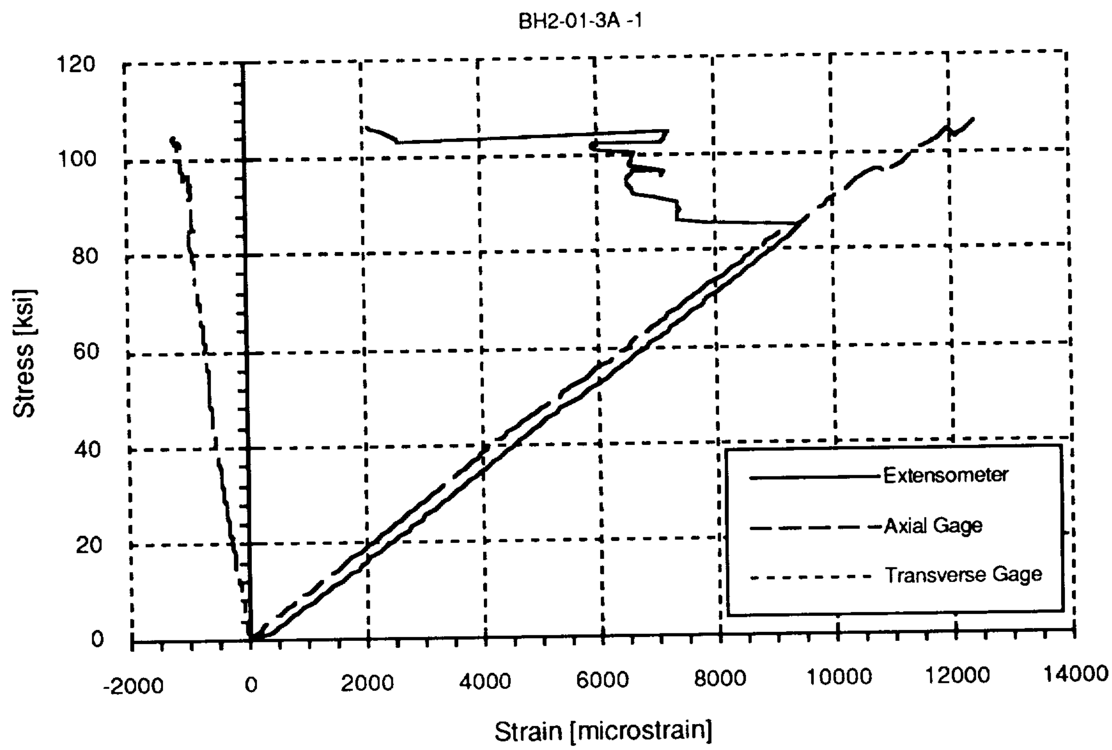


Figure B.1 Typical 0° Tension Test Strain Data for 2-D Braided Material SLL.

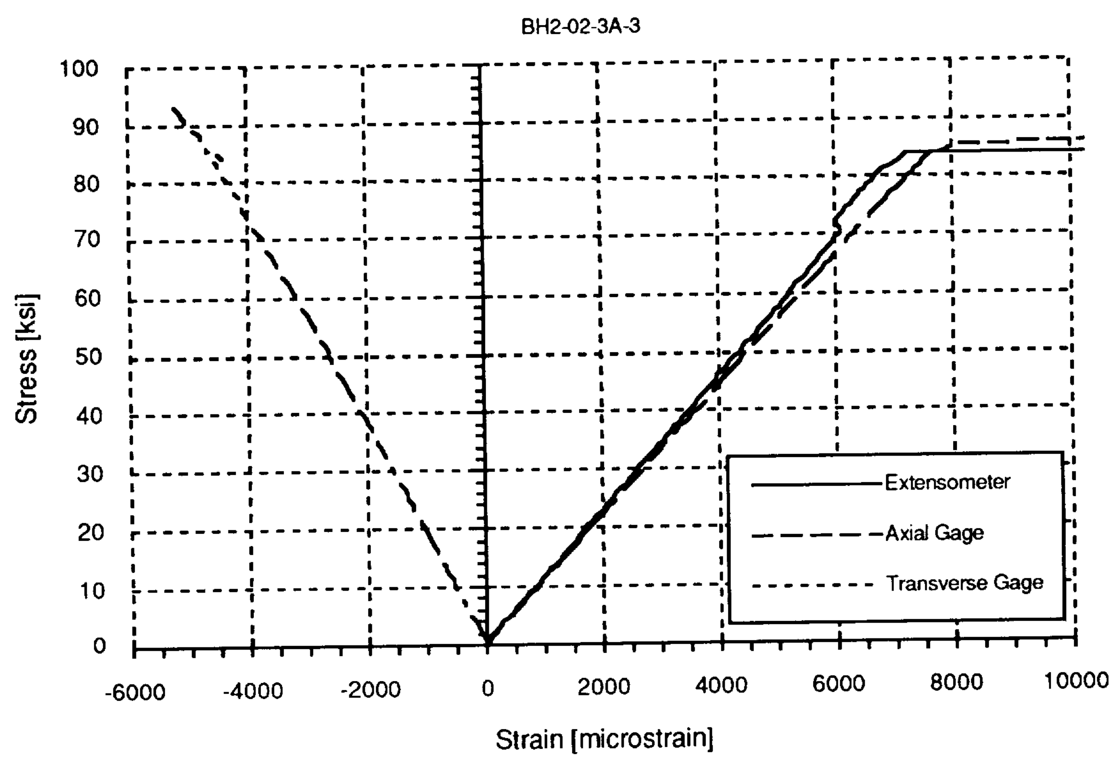


Figure B.2 Typical 0° Tension Test Strain Data for 2-D Braided Material LLL.

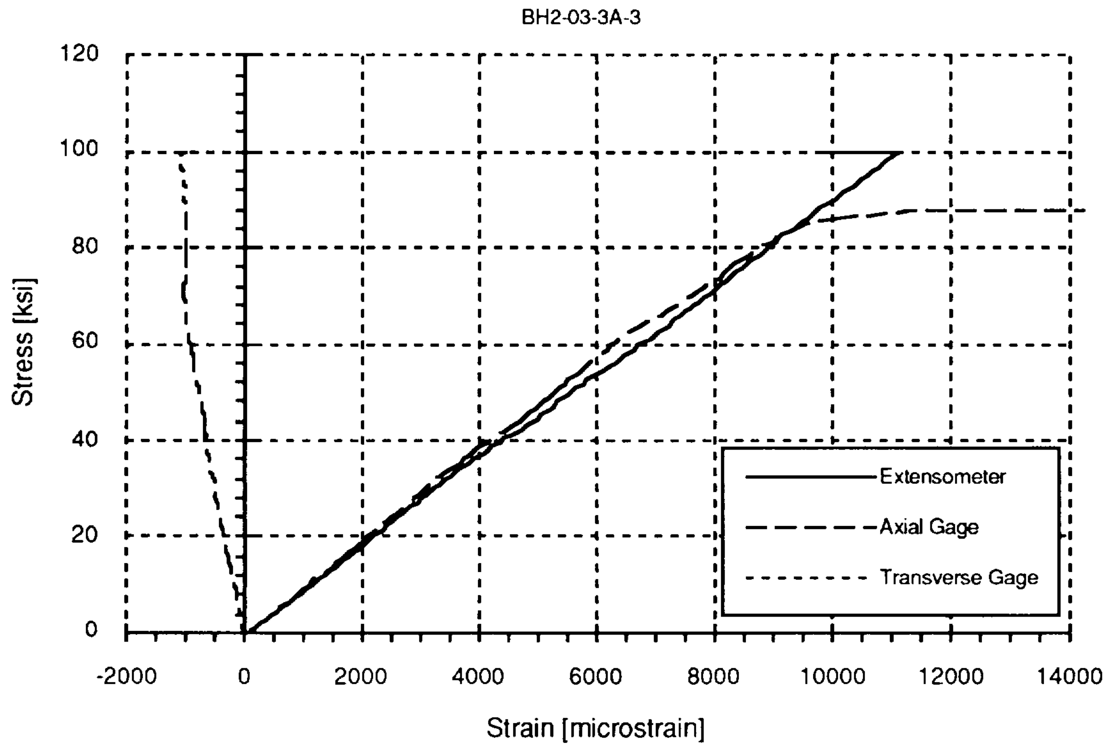


Figure B.3 Typical 0° Tension Test Strain Data for 2-D Braided Material LLS.

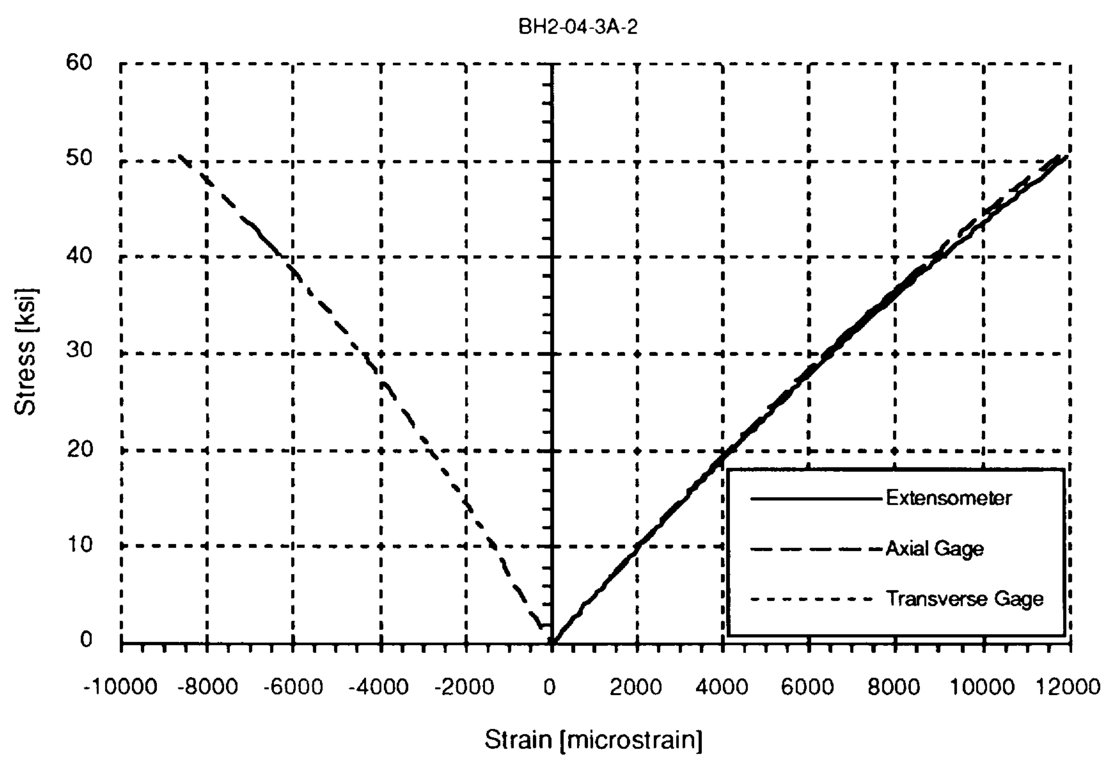


Figure B.4 Typical 0° Tension Test Strain Data for 2-D Braided Material LSS.

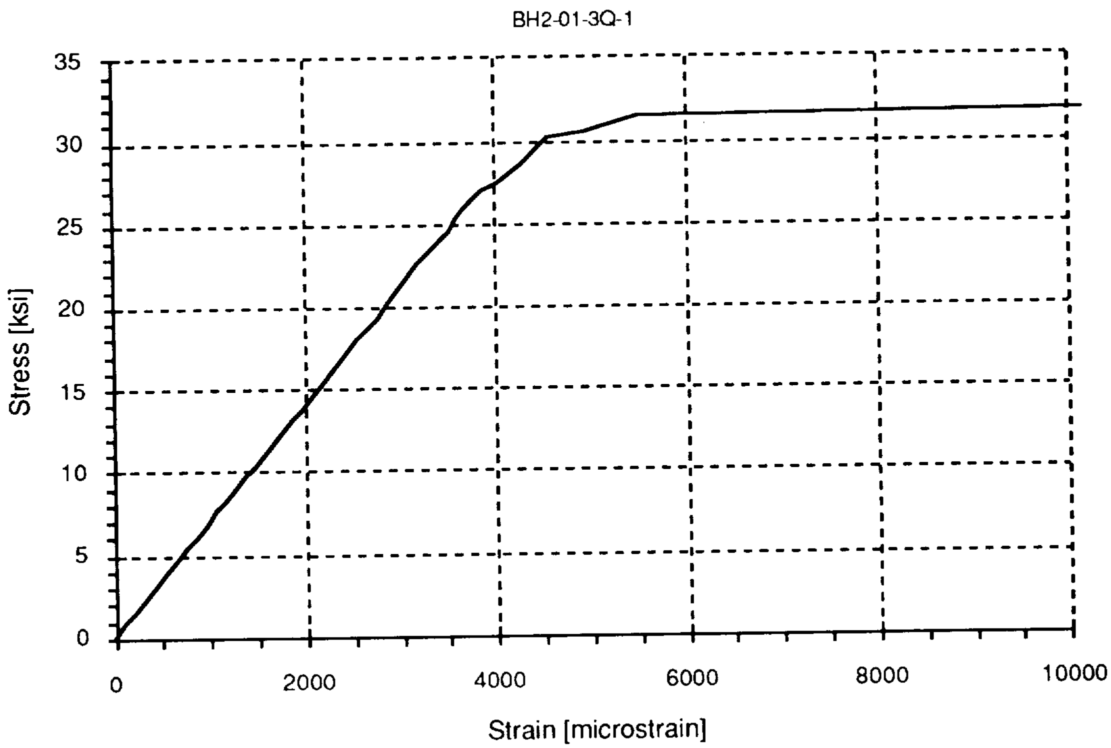


Figure B.5 Typical 90° Tension Test Strain Data for 2-D Braided Material SLL.

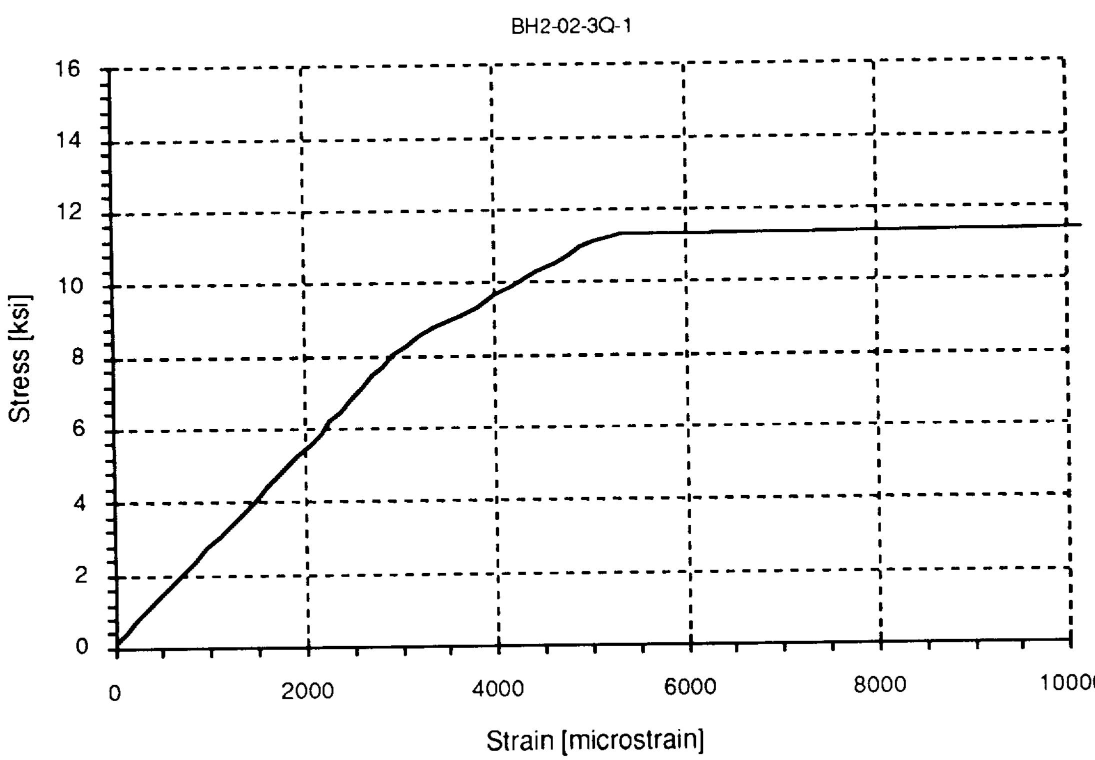


Figure B.6 Typical 90° Tension Test Strain Data for 2-D Braided Material LLL.

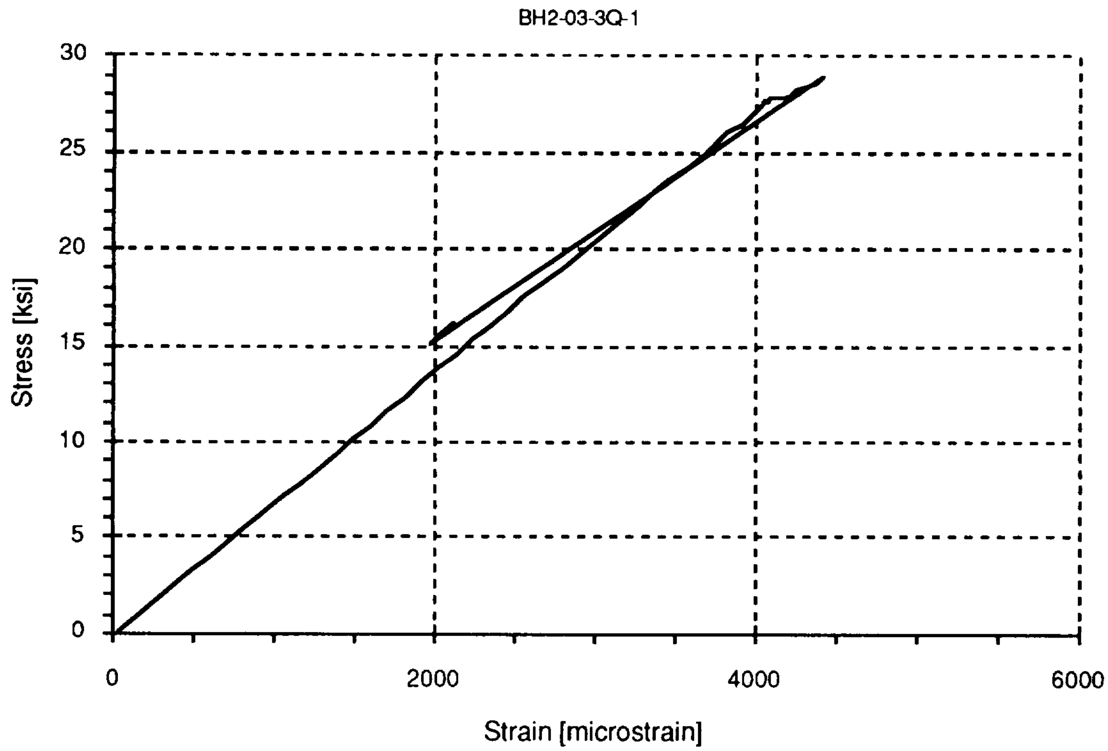


Figure B.7 Typical 90° Tension Test Strain Data for 2-D Braided Material LLS.

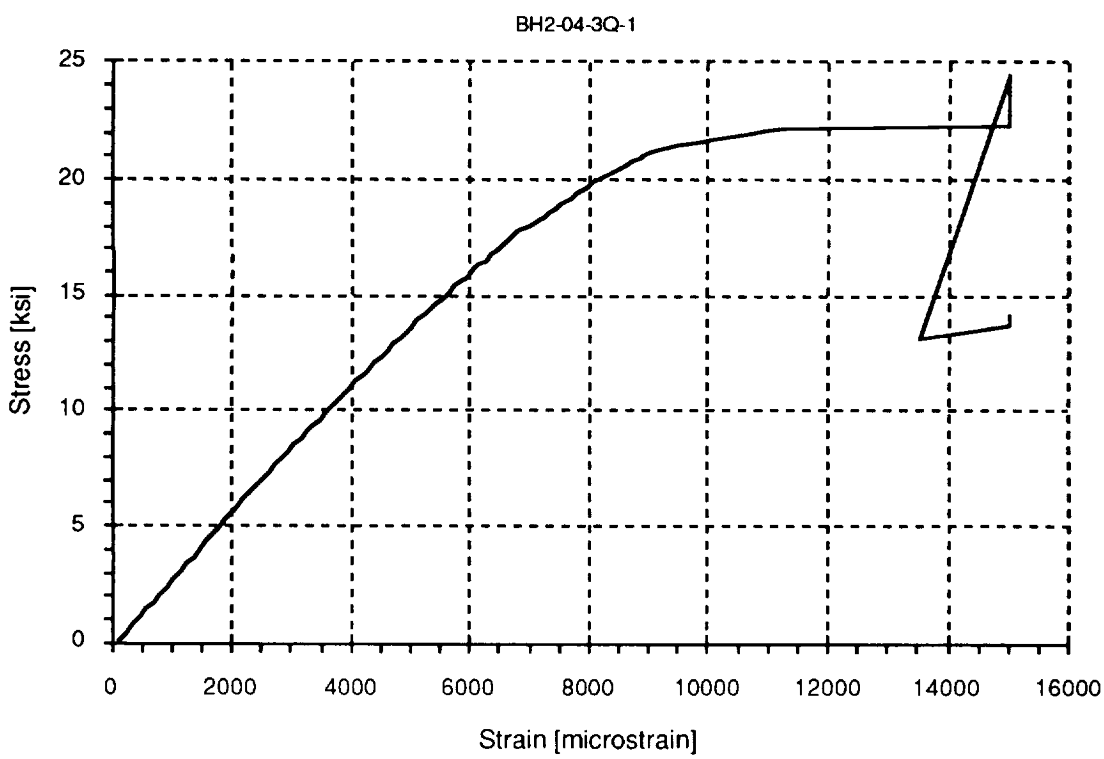


Figure B.8 Typical 90° Tension Test Strain Data for 2-D Braided Material LSS.

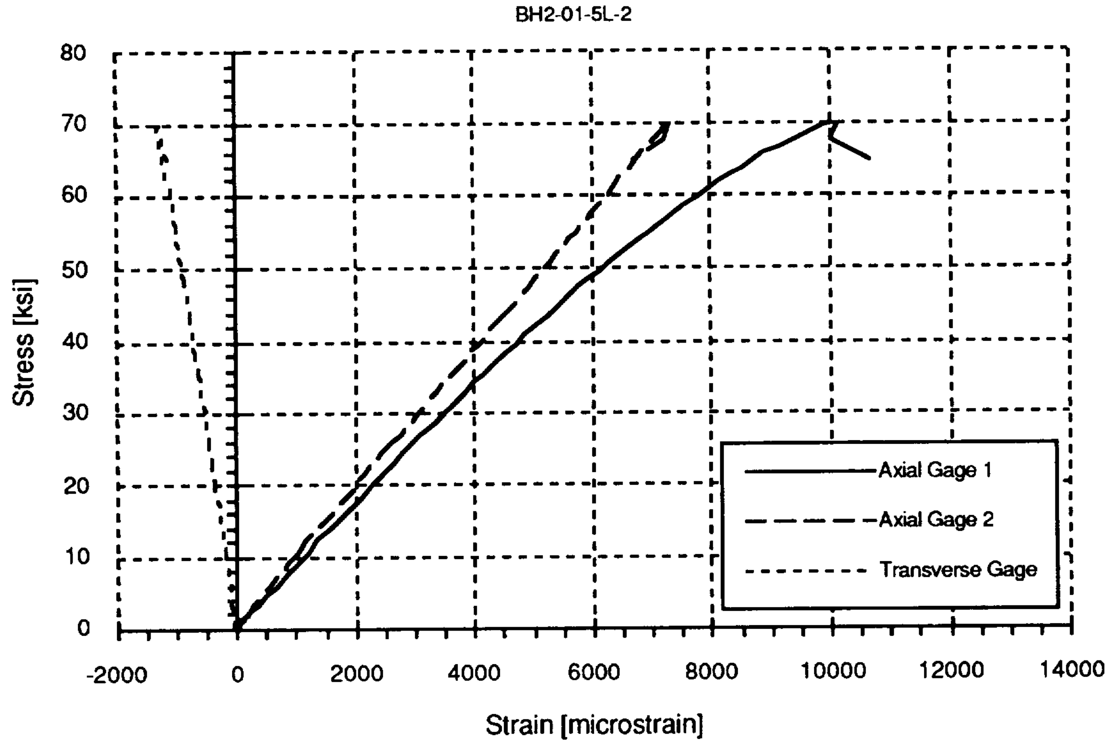


Figure B.9.a Typical IITRI Compression Test Strain Data for 2-D Braided Material SLL, (1/8" Thick, 1." Long).

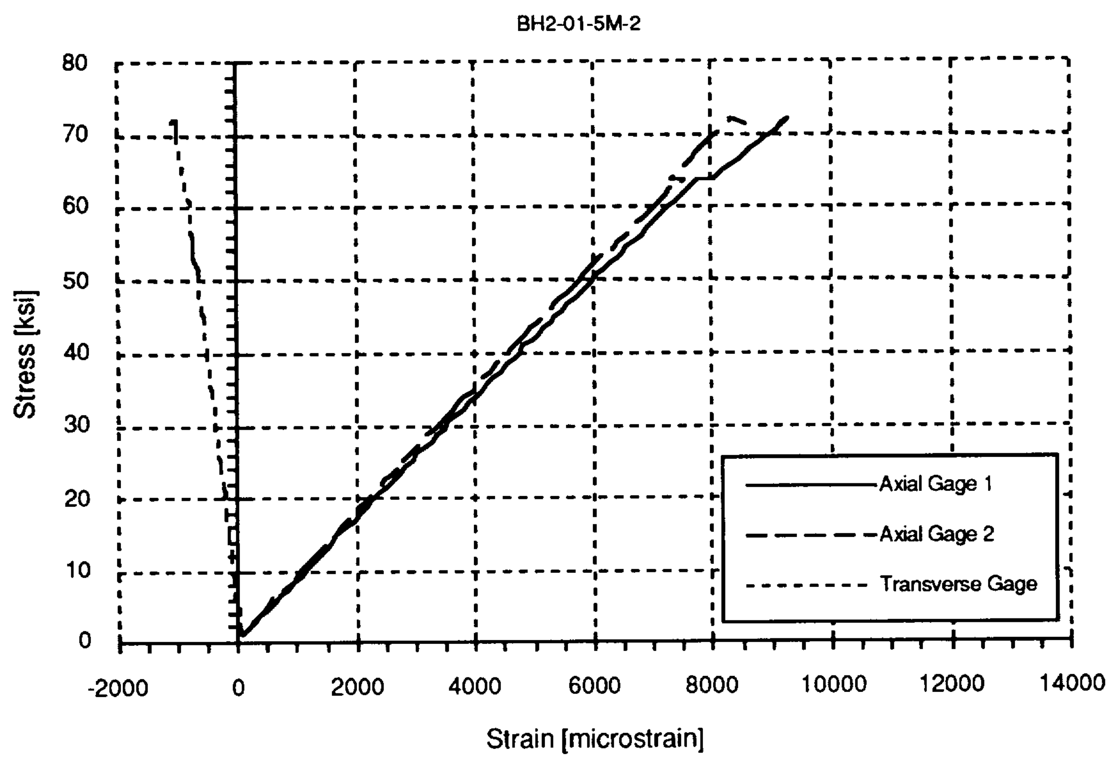


Figure B.9.b Typical IITRI Compression Test Strain Data for 2-D Braided Material SLL, (1/4" Thick, 1.5" Long).

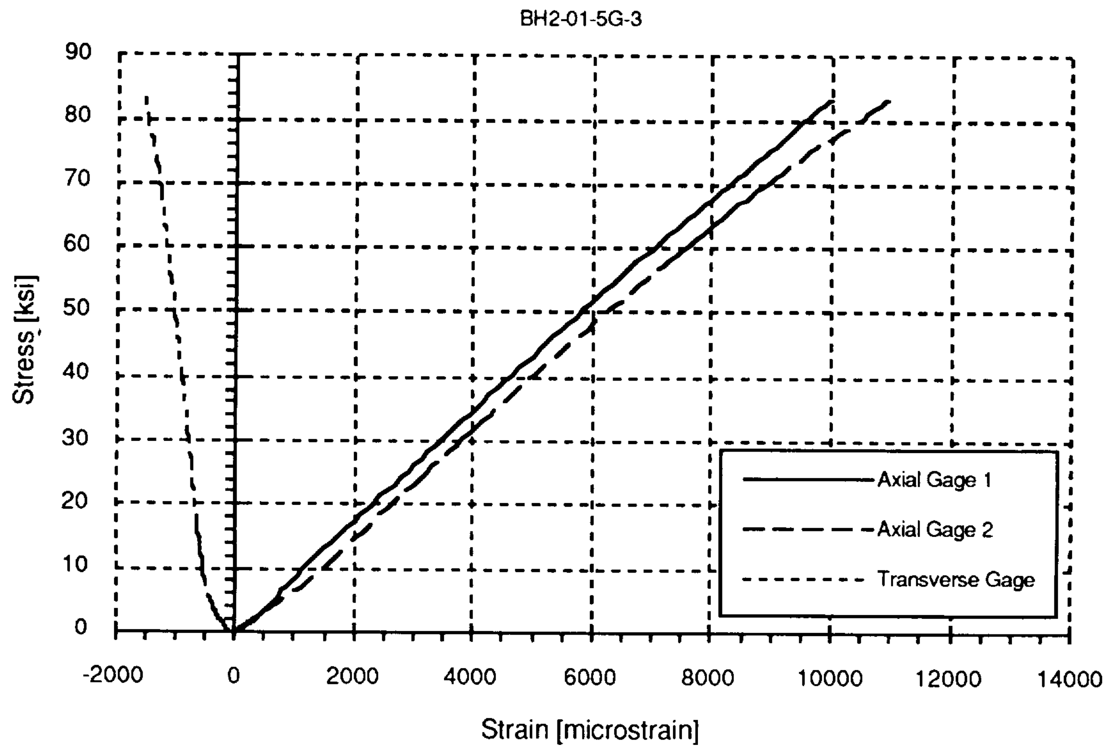


Figure B.9.c Typical Short Block Compression Test Strain Data for 2-D Braided Material SLL, (1/4" Thick, 1.5" Long).

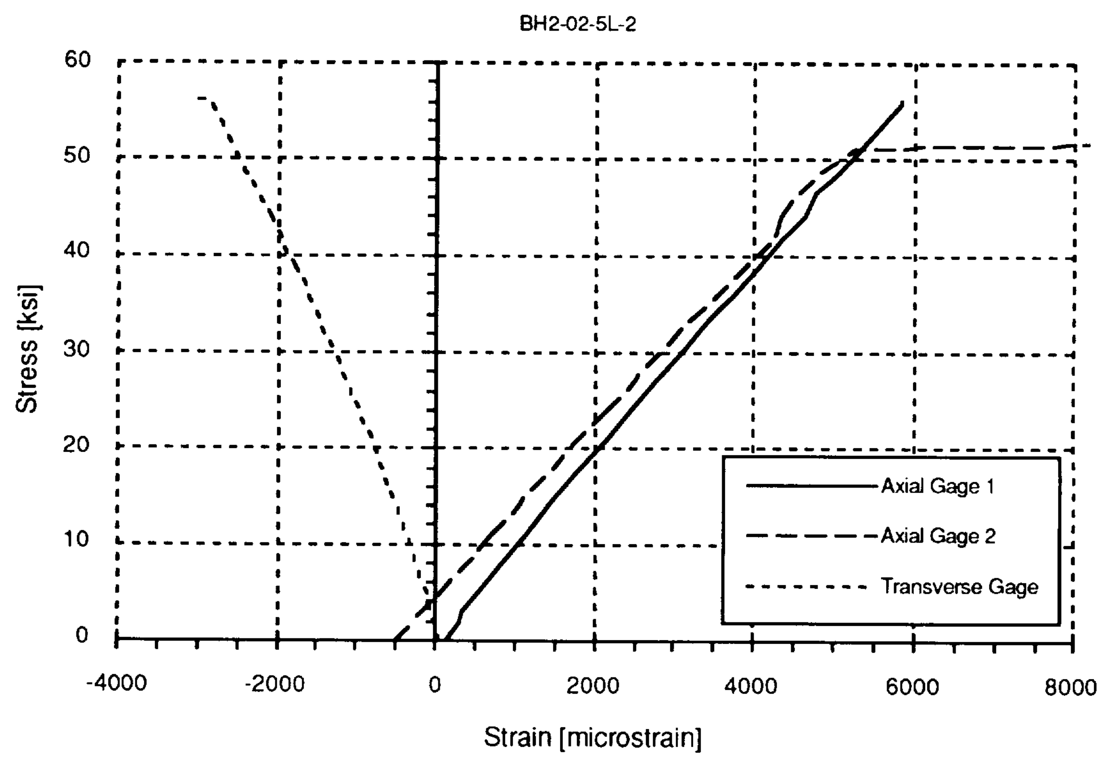


Figure B.10.a Typical IITRI Compression Test Strain Data for 2-D Braided Material LLS, (1/8" Thick, 1." Long).

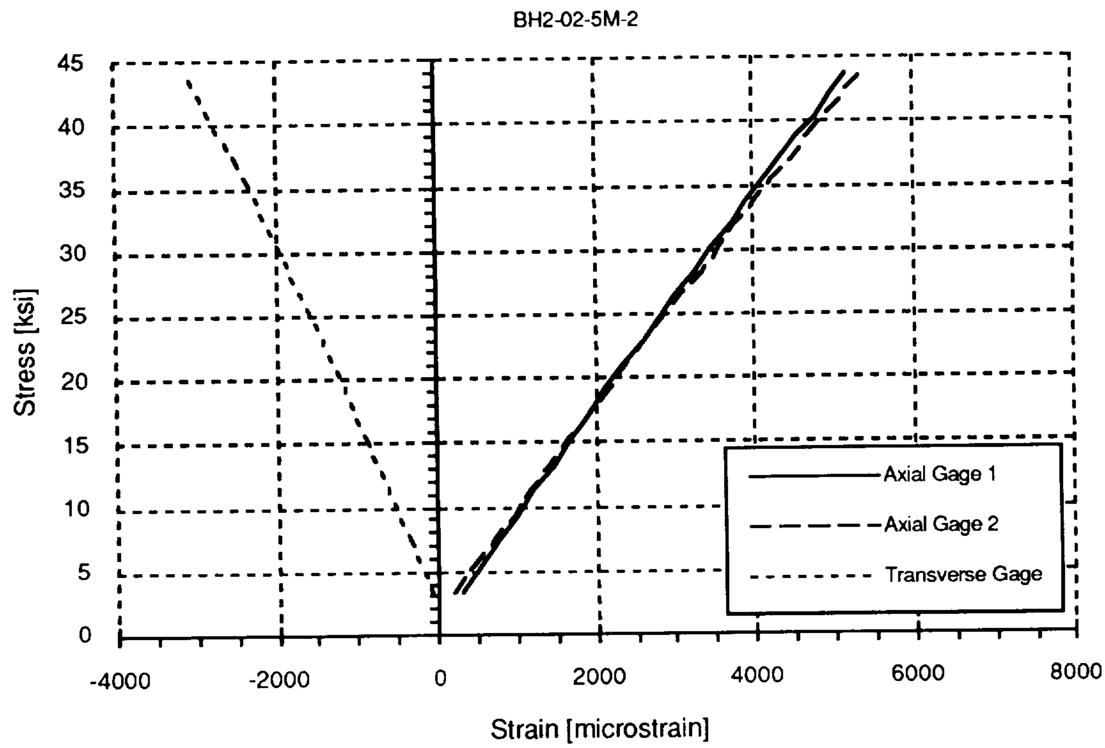


Figure B.10.b Typical IITRI Compression Test Strain Data for 2-D Braided Material LLS, (1/4" Thick, 1.5" Long).

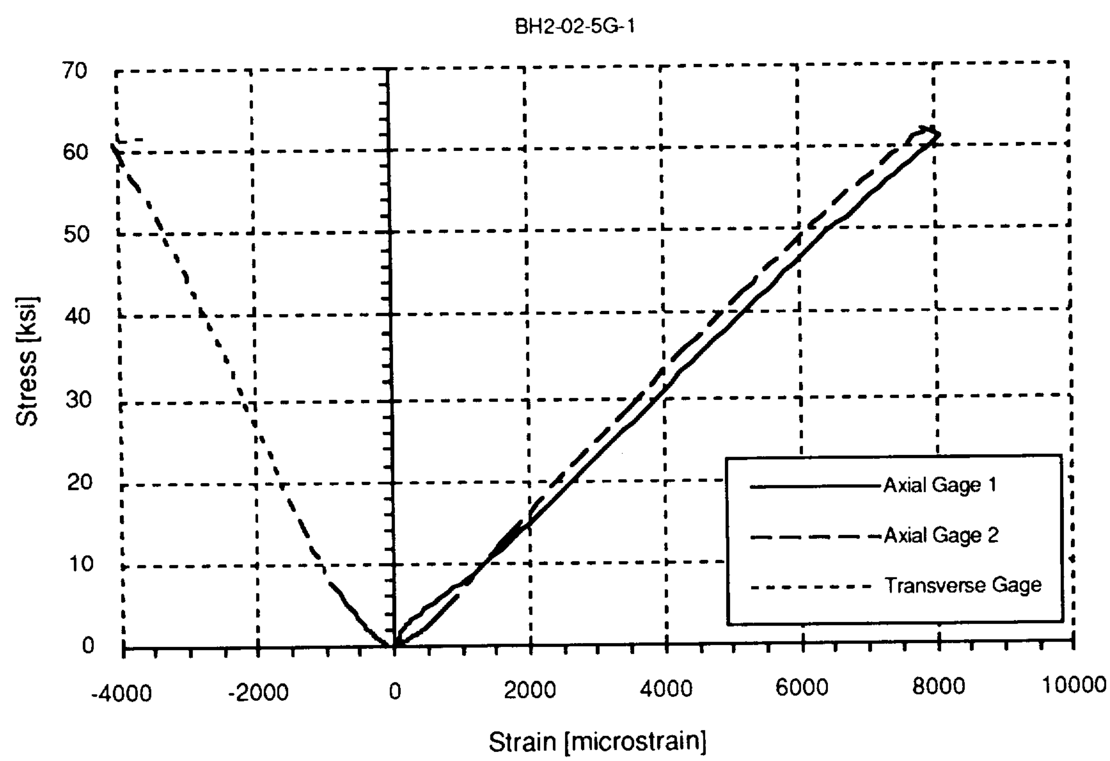


Figure B.10.c Typical Short Block Compression Test Strain Data for 2-D Braided Material LLS, (1/4" Thick, 1.5" Long).

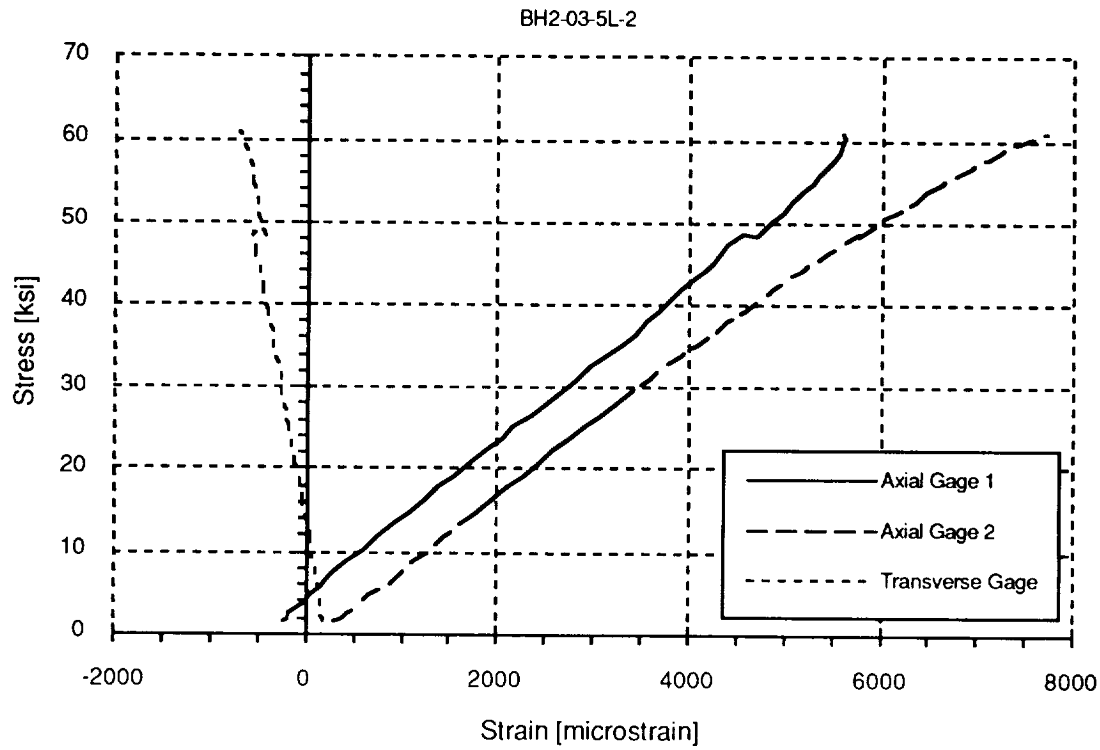


Figure B.11.a Typical IITRI Compression Test Strain Data for 2-D Braided Material LLL, (1/8" Thick, 1." Long).

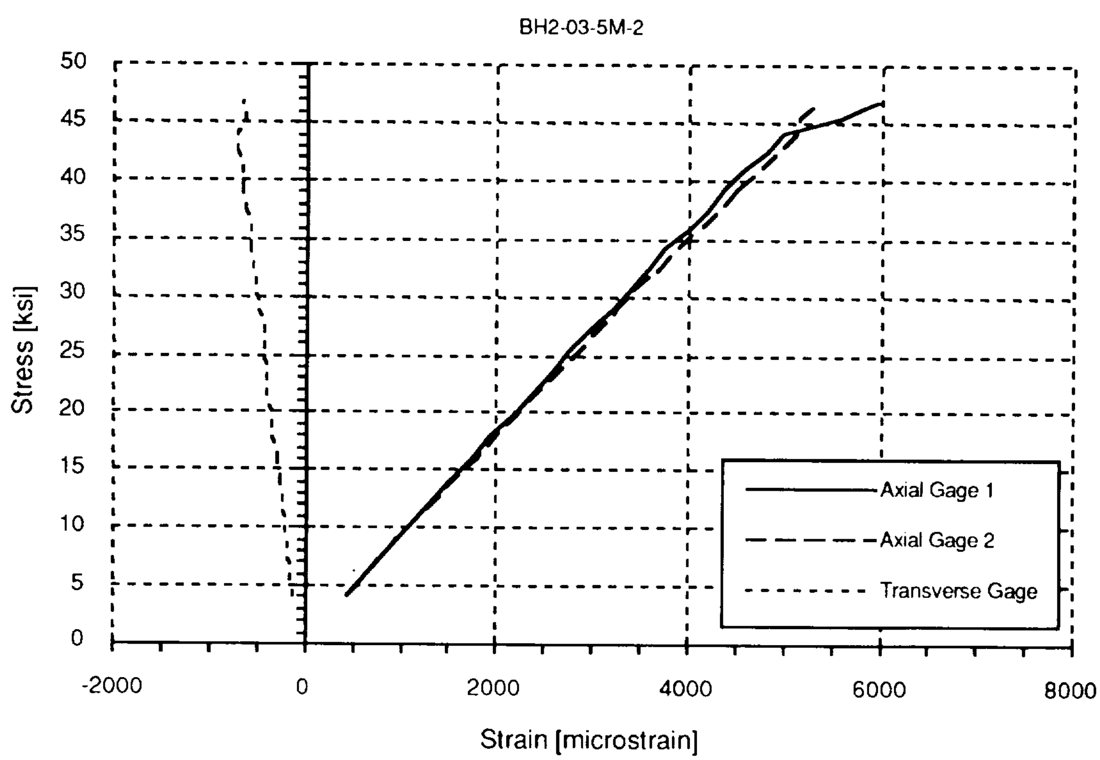


Figure B.11.b Typical IITRI Compression Test Strain Data for 2-D Braided Material LLL, (1/4" Thick, 1.5" Long).

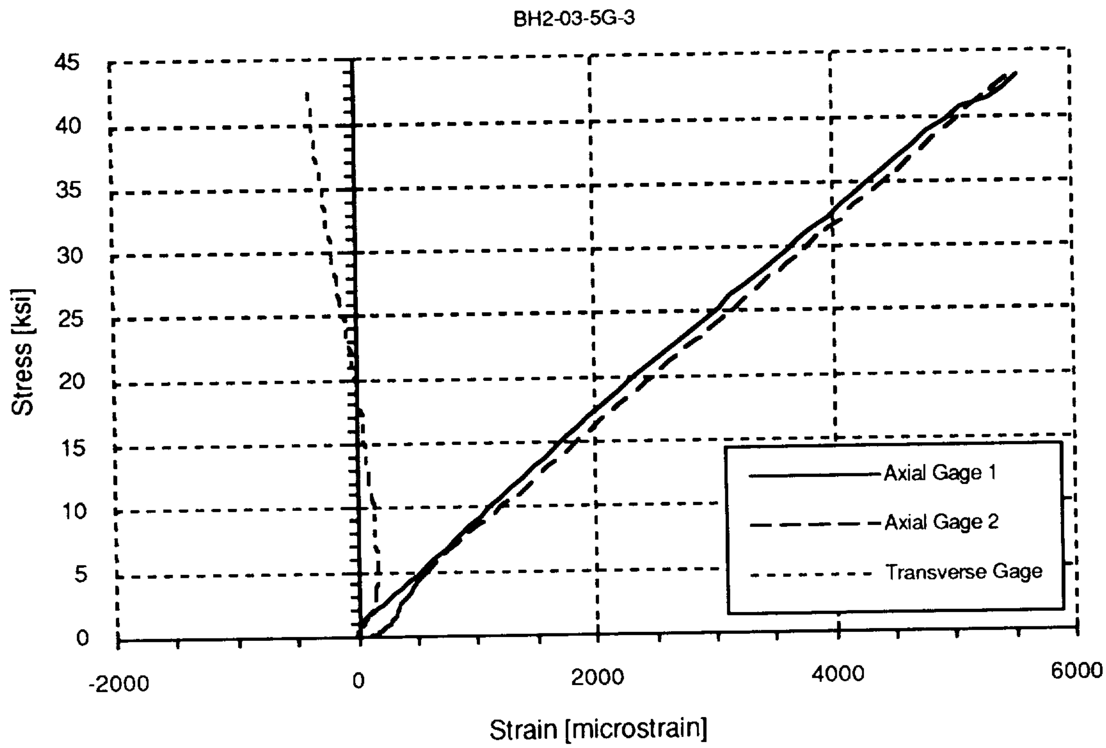


Figure B.11.c Typical Short Block Compression Test Strain Data for 2-D Braided Material LLL, (1/4" Thick, 1.5" Long).

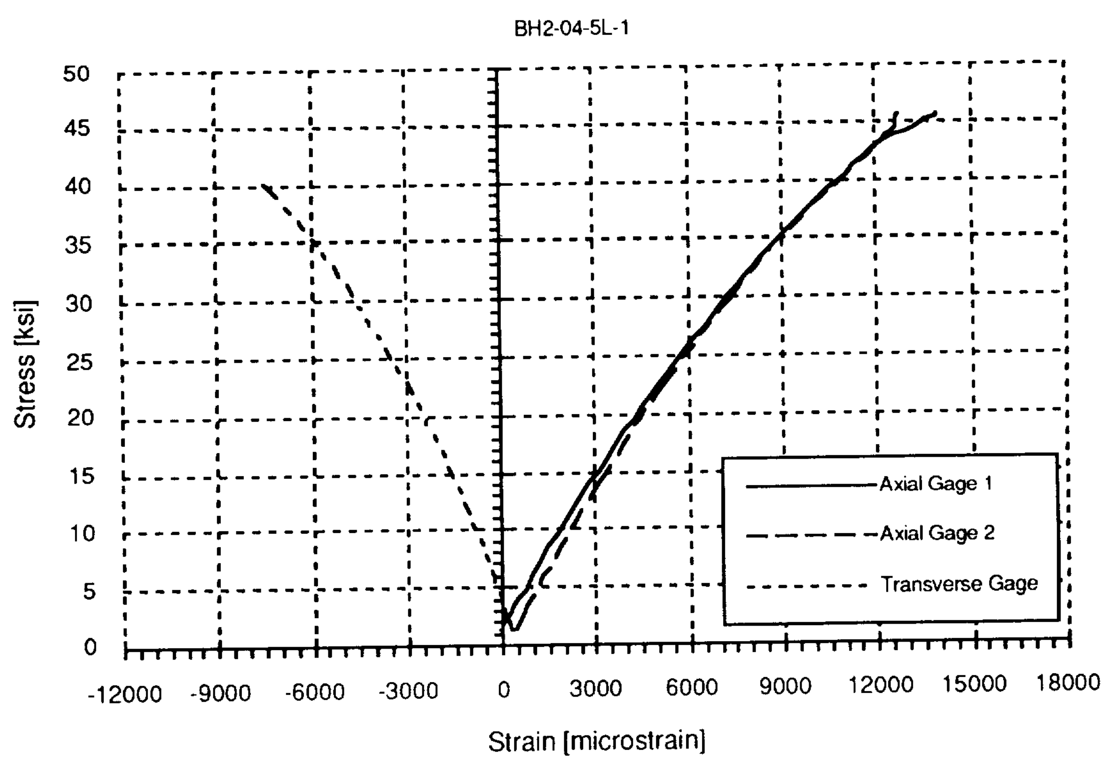


Figure B.12.a Typical IITRI Compression Test Strain Data for 2-D Braided Material LSS, (1/8" Thick, 1." Long).

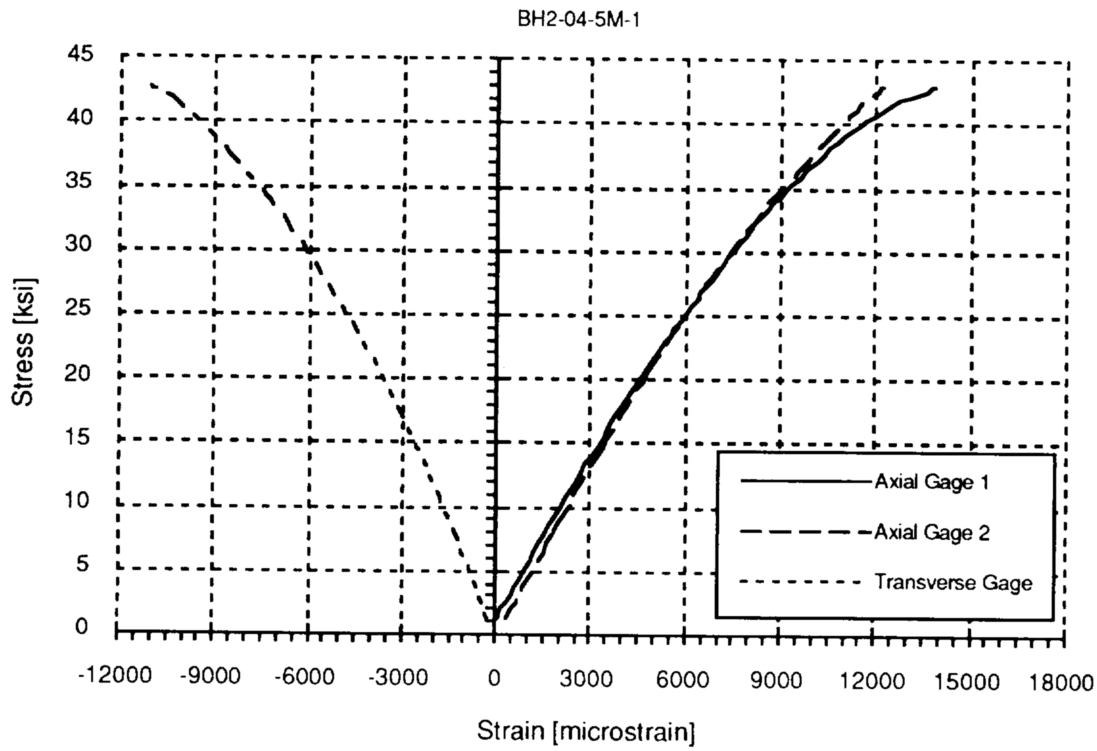


Figure B.12.b Typical IITRI Compression Test Strain Data for 2-D Braided Material LSS, (1/4" Thick, 1.5" Long).

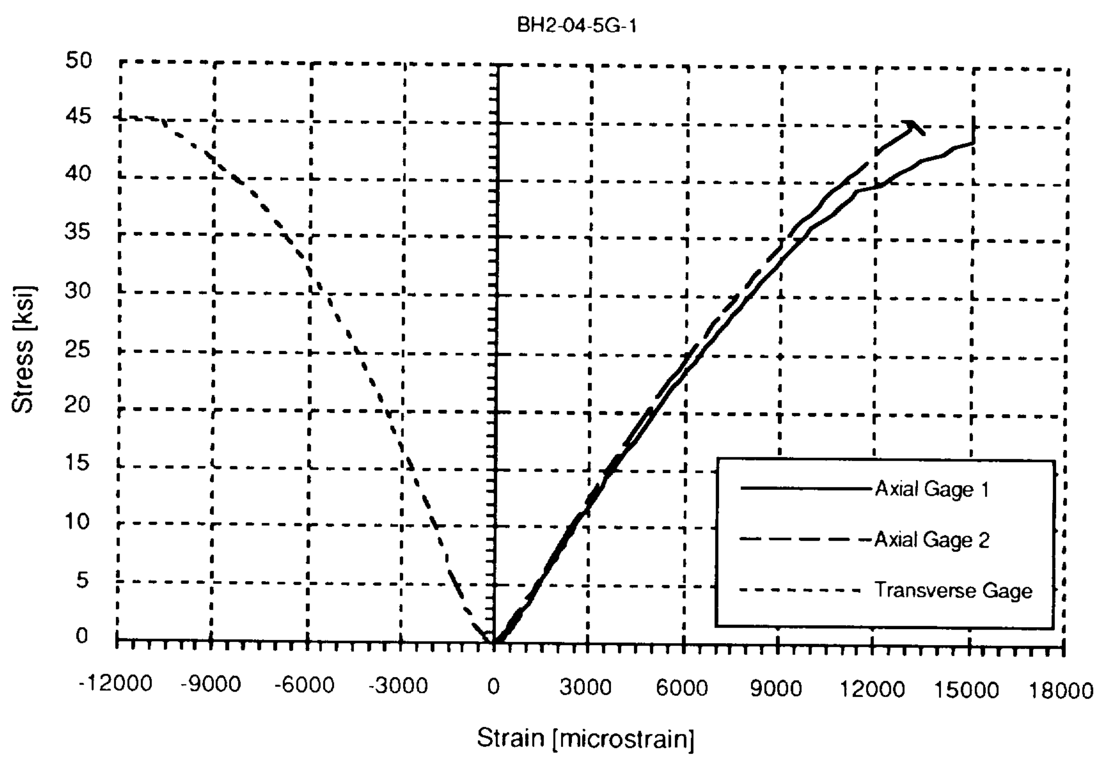


Figure B.12.c Typical Short Block Compression Test Strain Data for 2-D Braided Material LSS, (1/4" Thick, 1.5" Long).

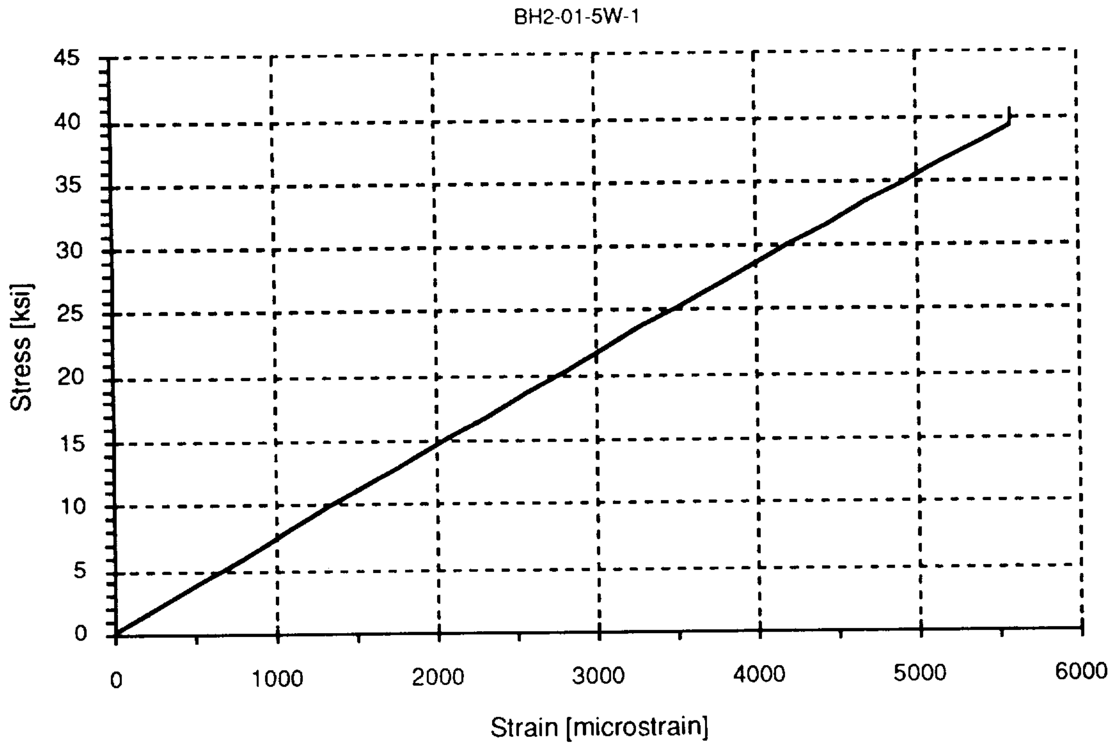


Figure B.13 Typical IITRI 90° Compression Strain Data for 2-D Braided Material SLL.

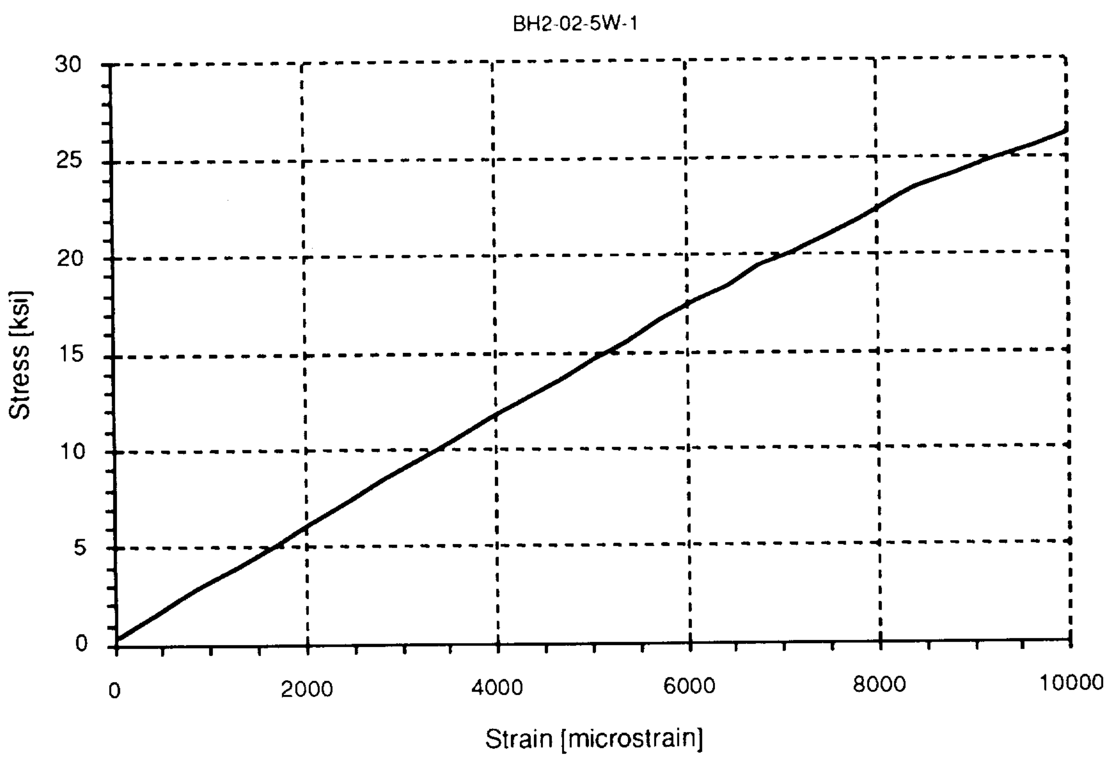


Figure B.14 Typical IITRI 90° Compression Strain Data for 2-D Braided Material LLL.

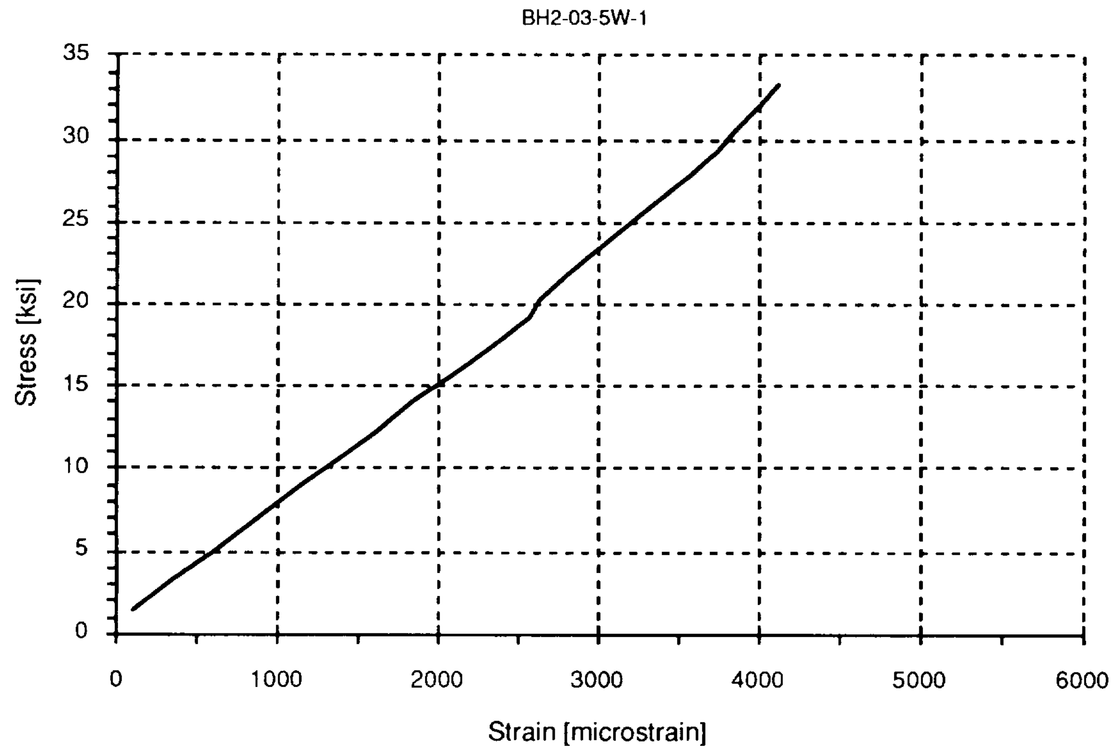


Figure B.15 Typical IITRI 90° Compression Strain Data for 2-D Braided Material LLS.

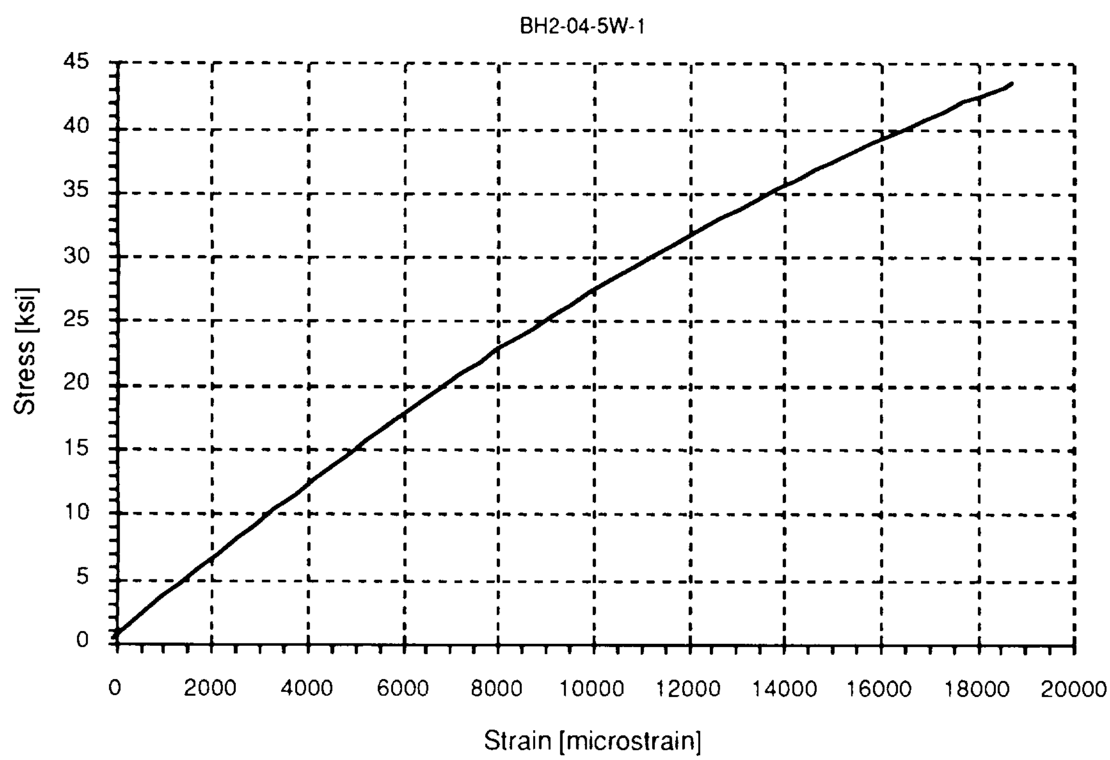


Figure B.16 Typical IITRI 90° Compression Strain Data for 2-D Braided Material LSS.

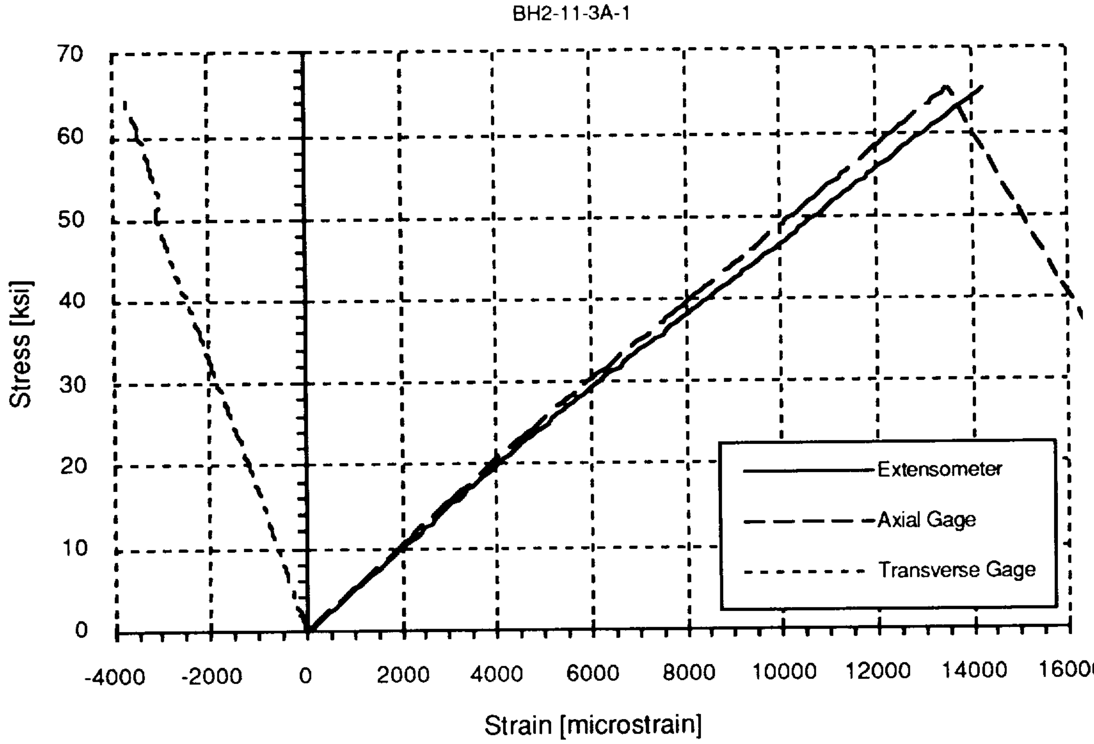


Figure B.17 Typical Tension Test Strain Data for Stitched Uniweave Material SU-1.

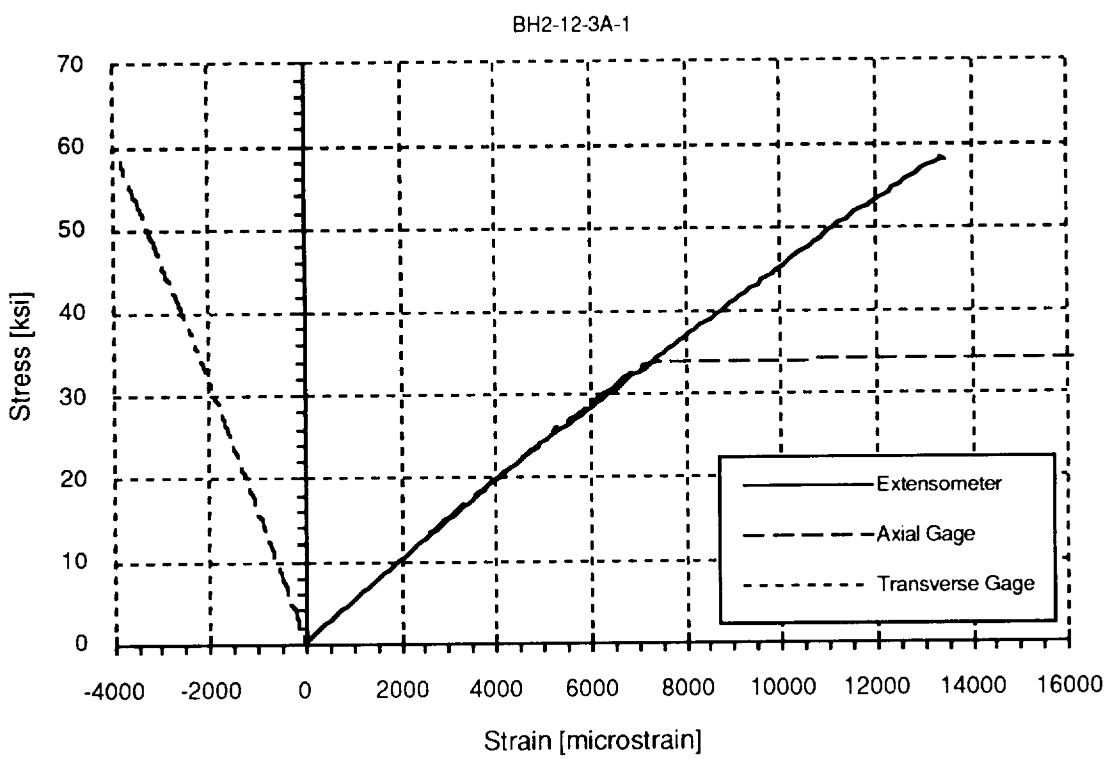


Figure B.18 Typical Tension Test Strain Data for Stitched Uniweave Material SU-2.

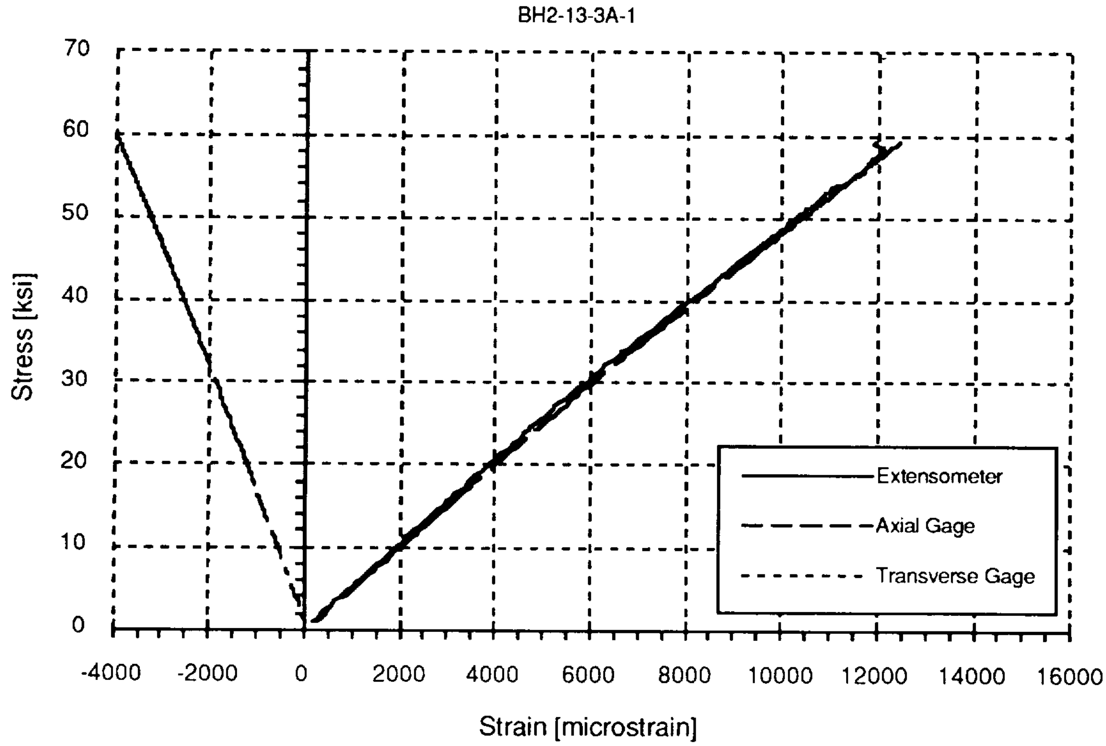


Figure B.19 Typical Tension Test Strain Data for Stitched Uniweave Material SU-3.

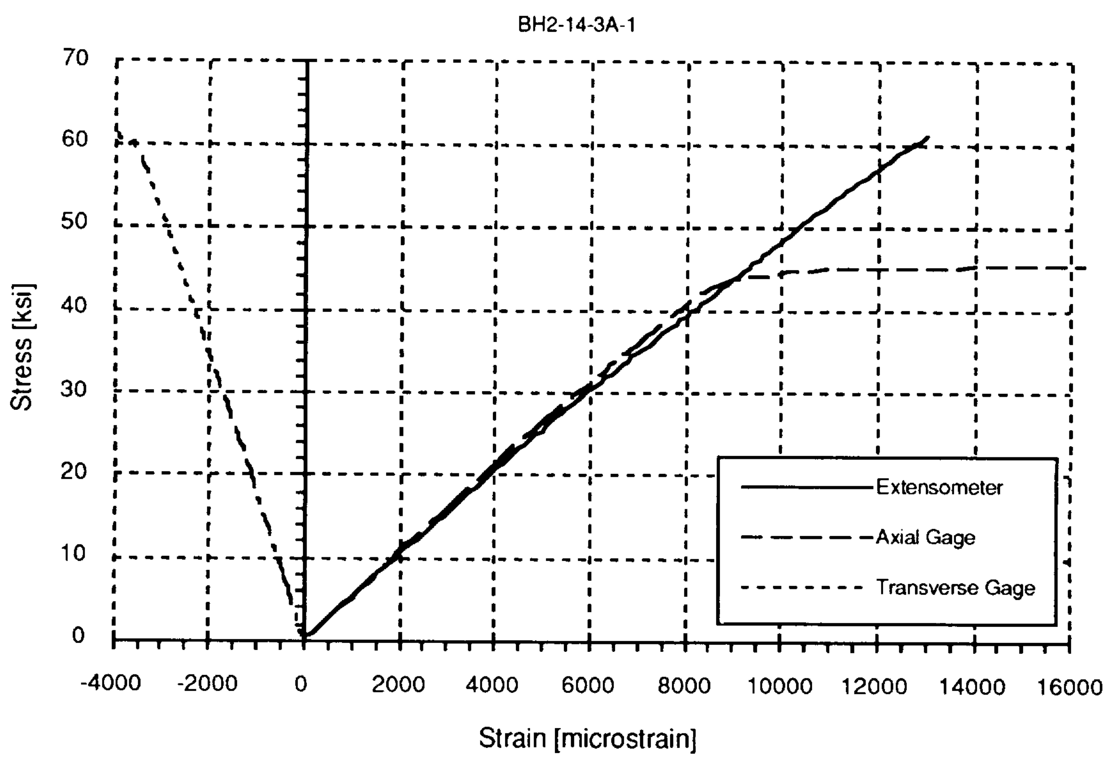


Figure B.20 Typical Tension Test Strain Data for Stitched Uniweave Material SU-4.

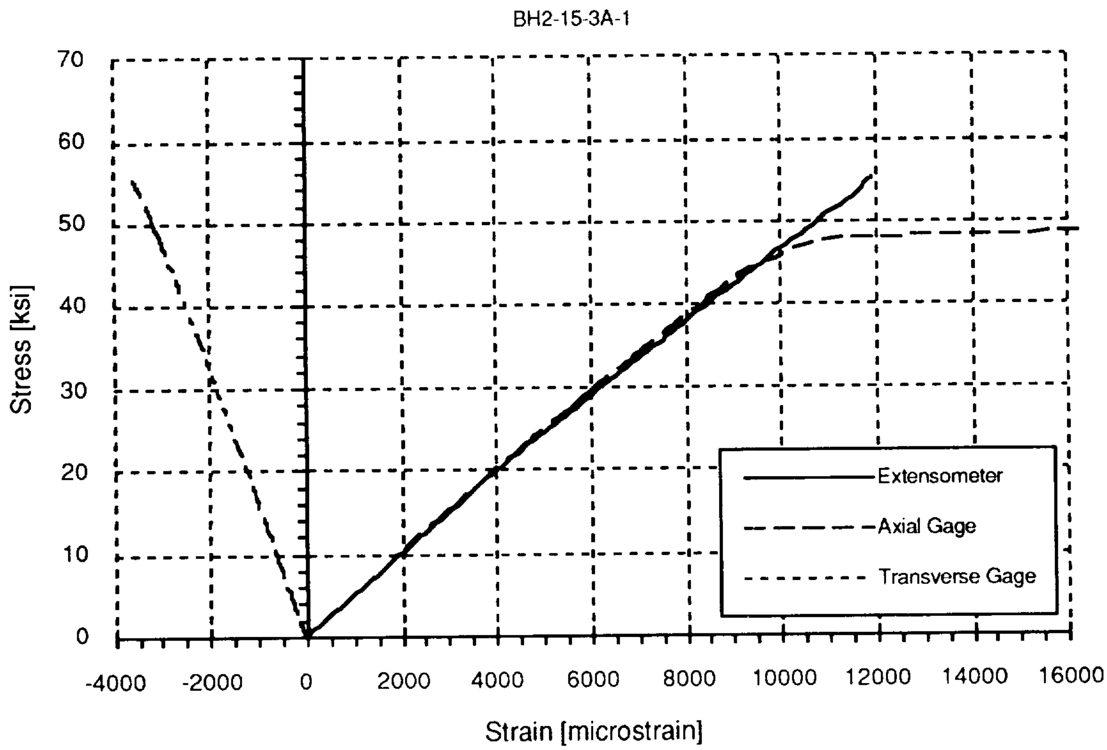


Figure B.21 Typical Tension Test Strain Data for Stitched Uniweave Material SU-5.

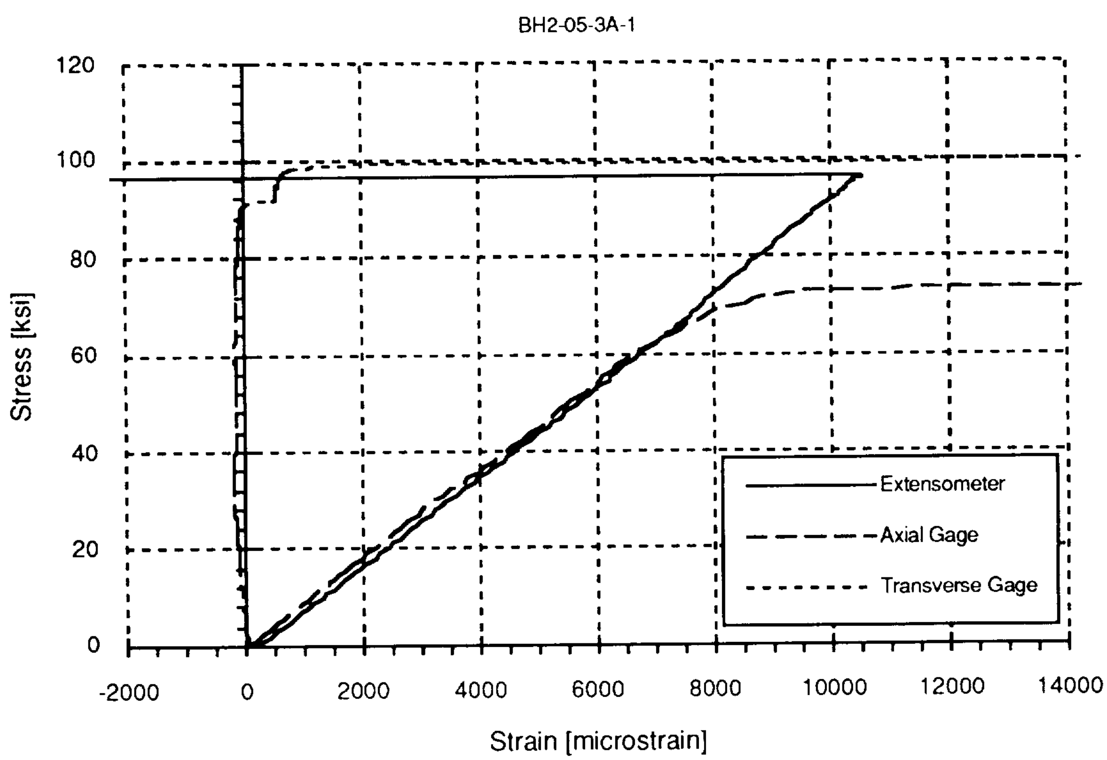


Figure B.22 Typical Tension Test Strain Data for 3-D Woven Material TS-1.

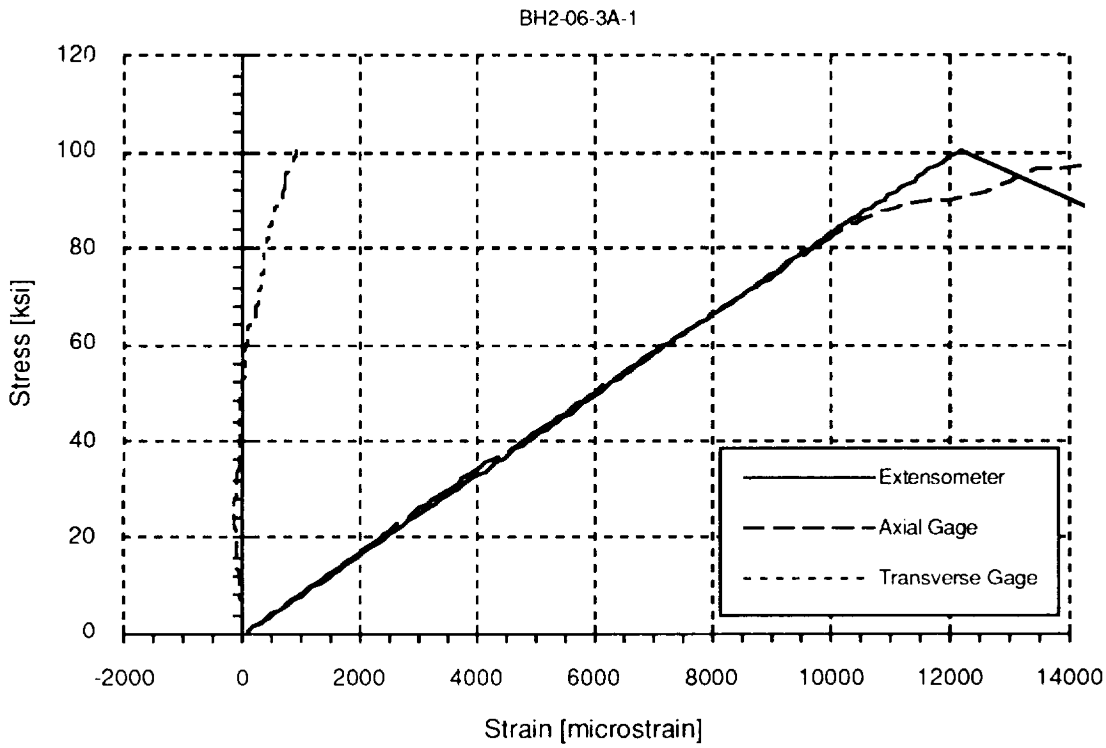


Figure B.23 Typical Tension Test Strain Data for 3-D Woven Material TS-2.

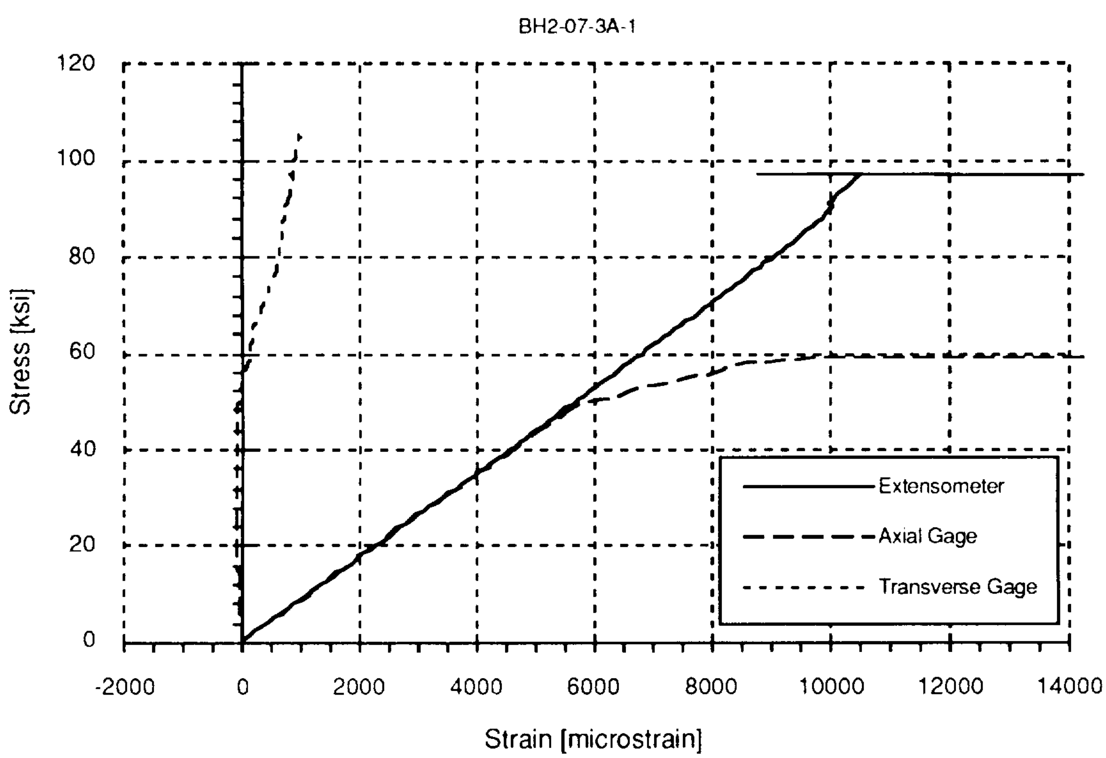


Figure B.24 Typical Tension Test Strain Data for 3-D Woven Material OS-1.

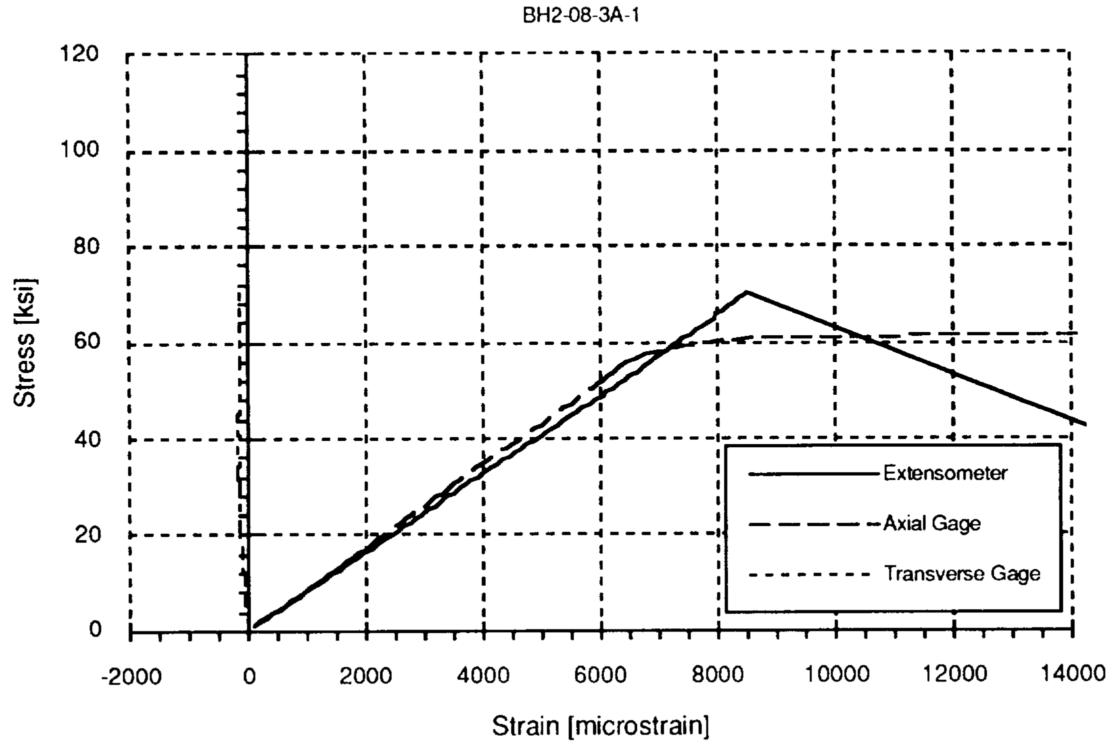


Figure B.25 Typical Tension Test Strain Data for 3-D Woven Material OS-2.

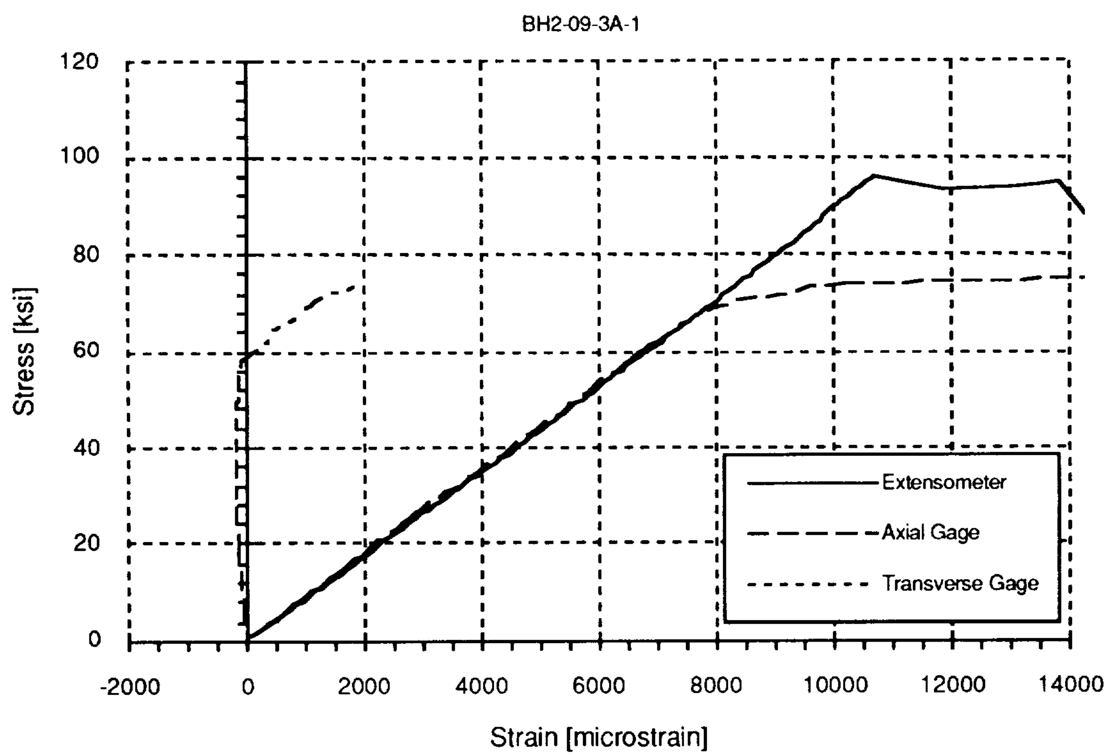


Figure B.26 Typical Tension Test Strain Data for 3-D Woven Material LS-1.

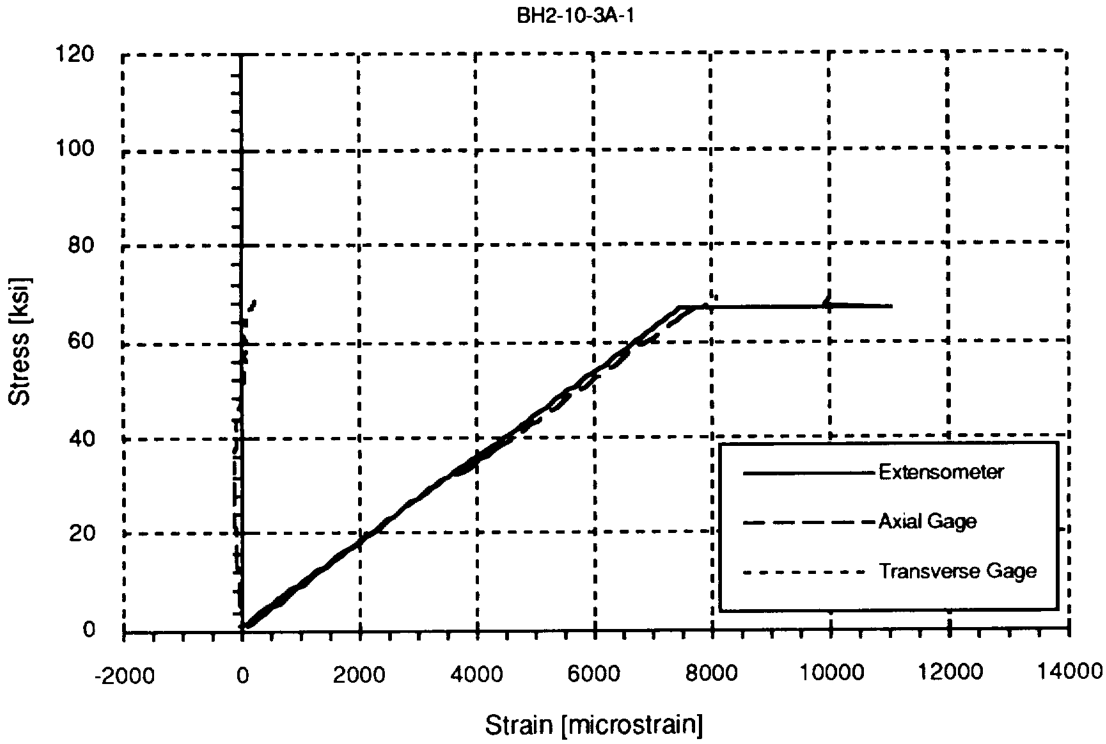


Figure B.27 Typical Tension Test Strain Data for 3-D Woven Material LS-2.

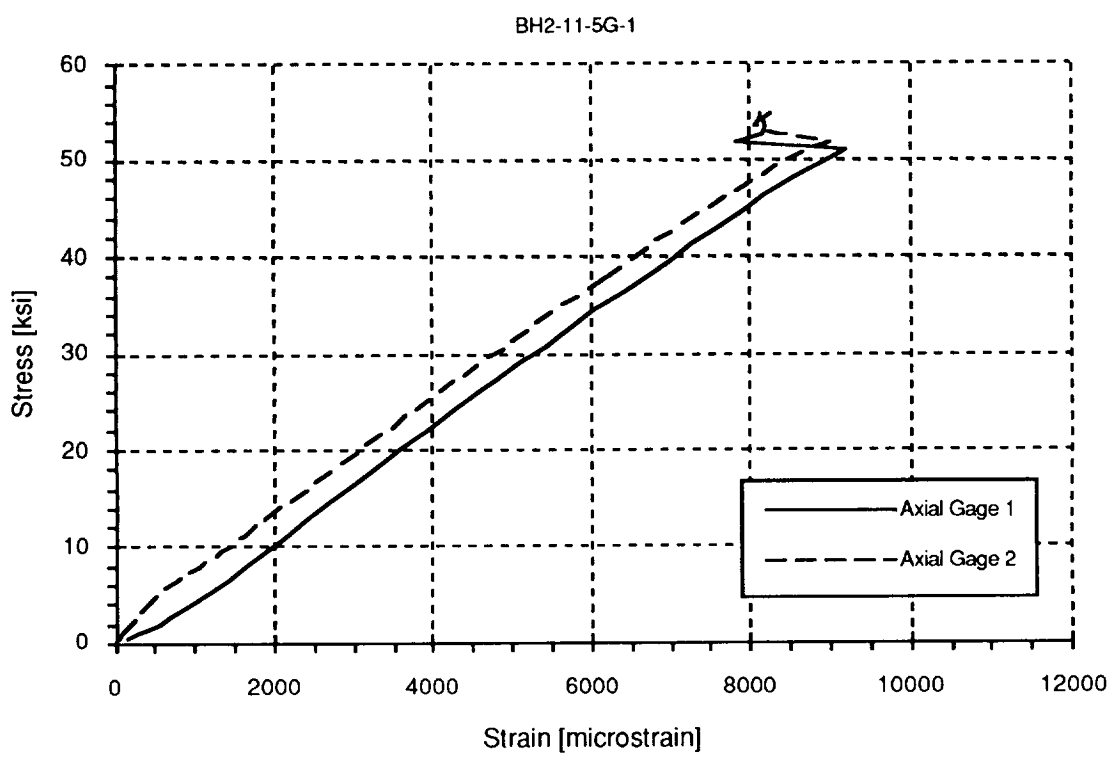


Figure B.28 Typical Short Block Compression Test Strain Data for Stitched Uniweave Material SU-1.

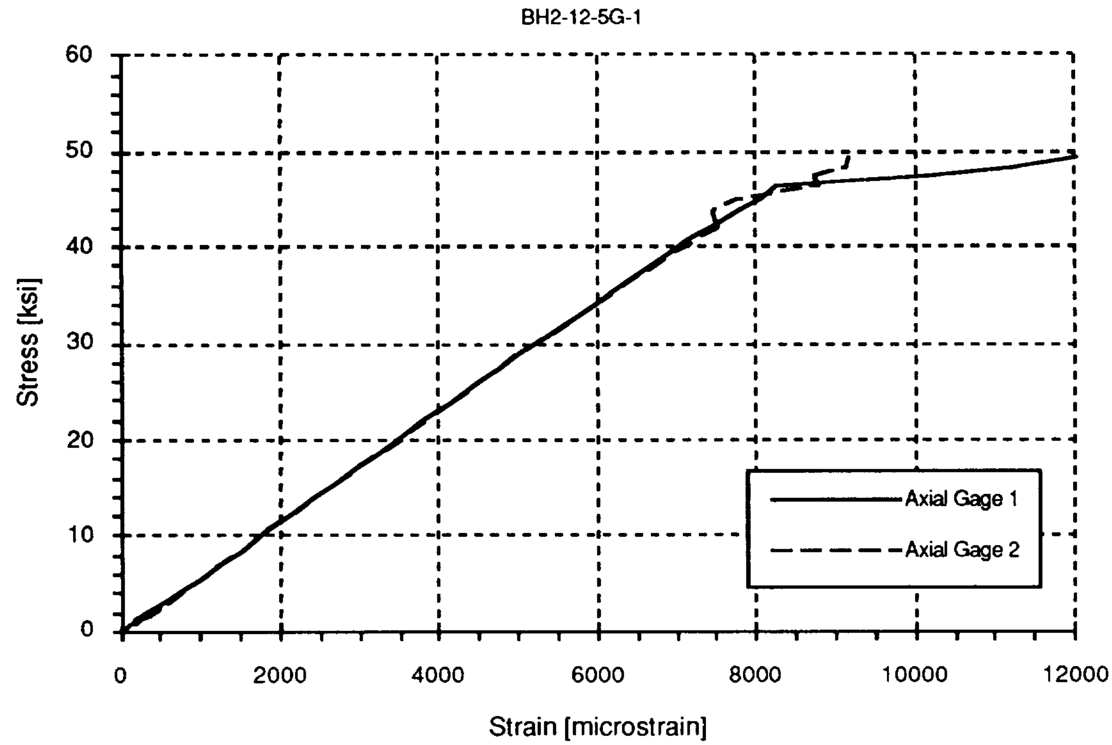


Figure B.29 Typical Short Block Compression Test Strain Data for Stitched Uniweave Material SU-2.

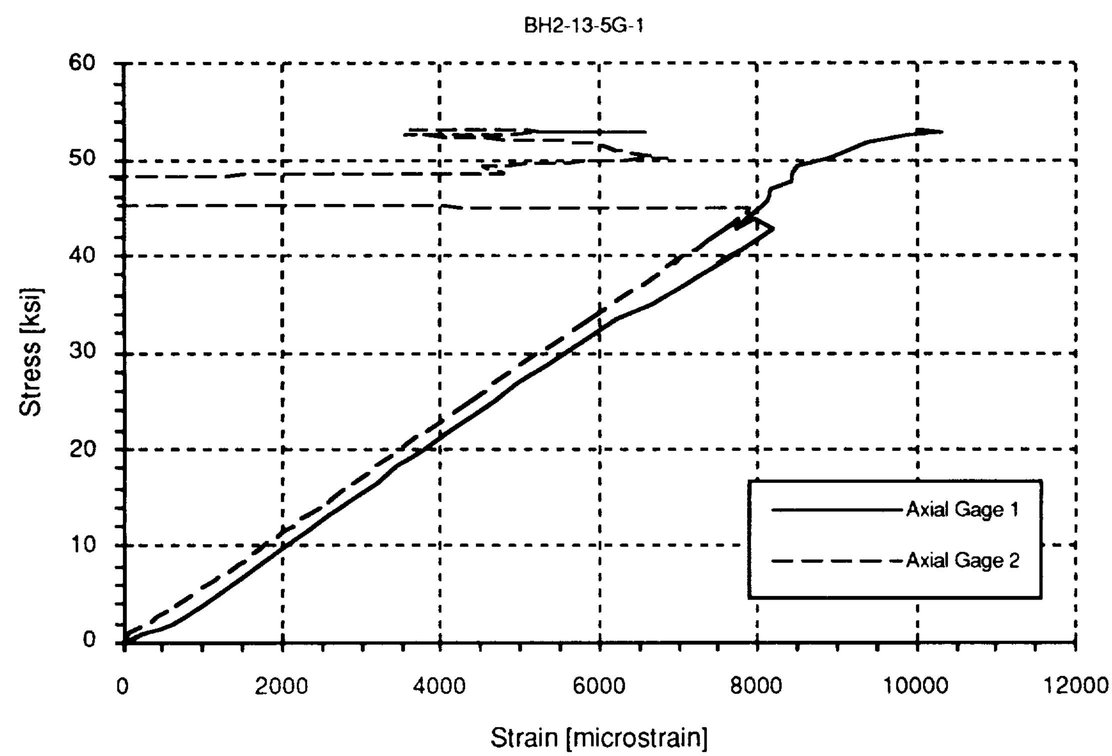


Figure B.30 Typical Short Block Compression Test Strain Data for Stitched Uniweave Material SU-3.

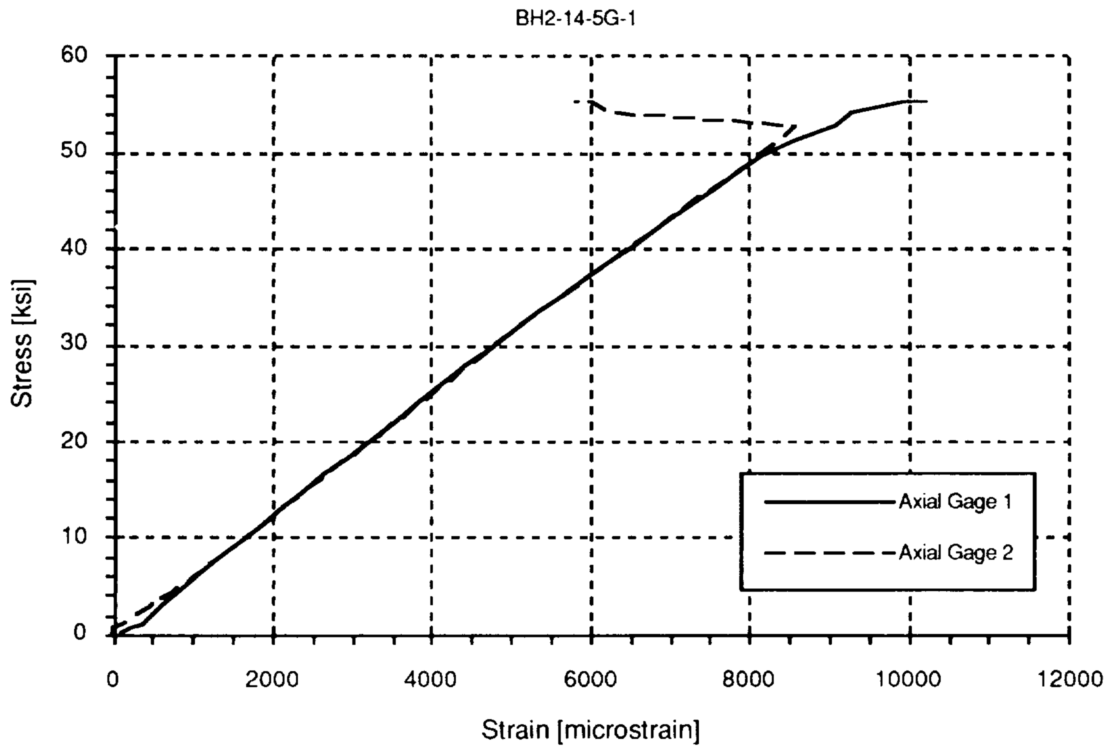


Figure B.31 Typical Short Block Compression Test Strain Data for Stitched Uniweave Material SU-4.

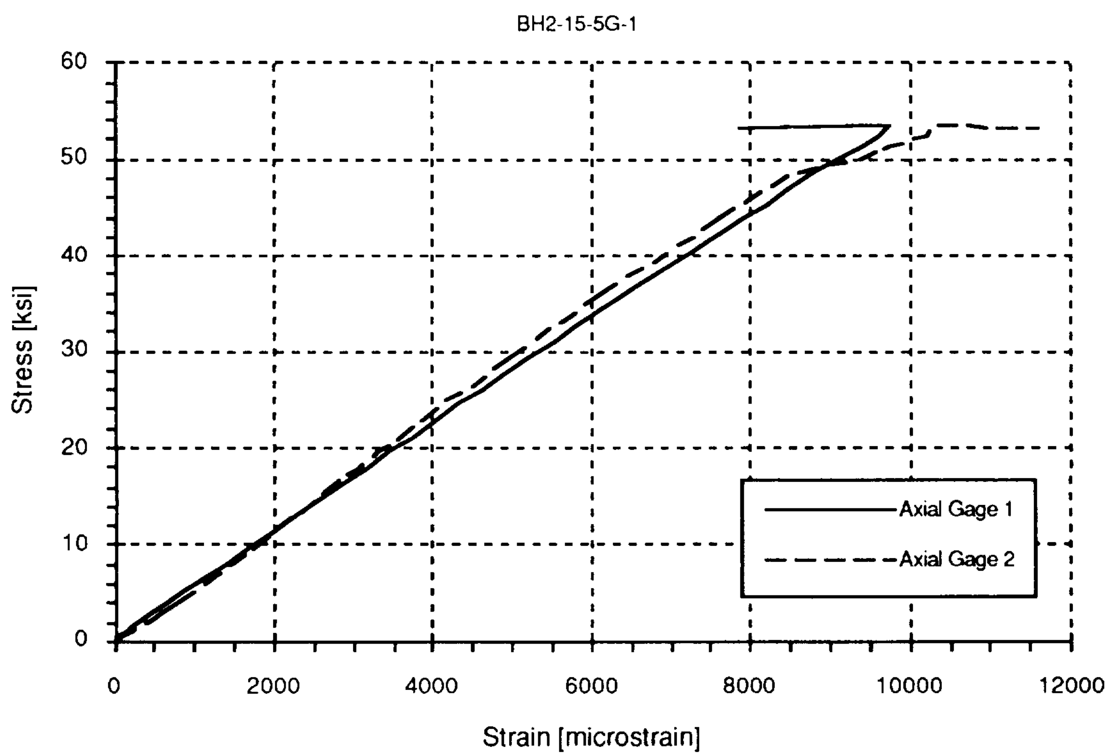


Figure B.32 Typical Short Block Compression Test Strain Data for Stitched Uniweave Material SU-5.

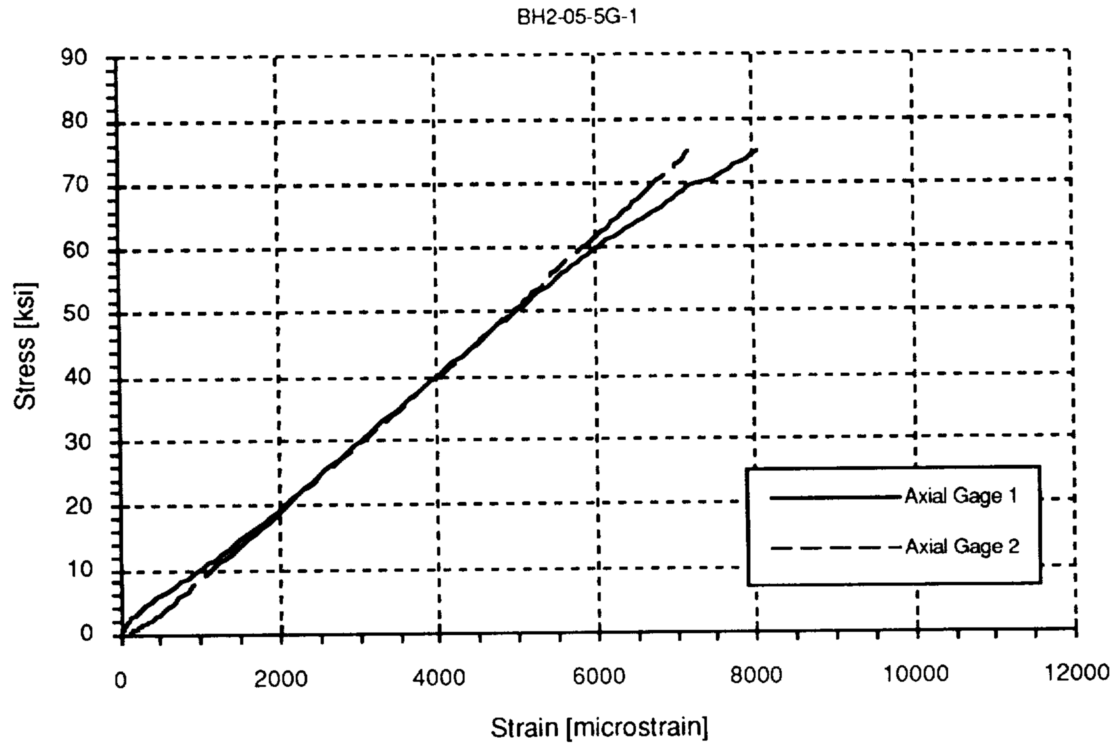


Figure B.33 Typical Short Block Compression Test Strain Data for 3-D Woven Material TS-1.

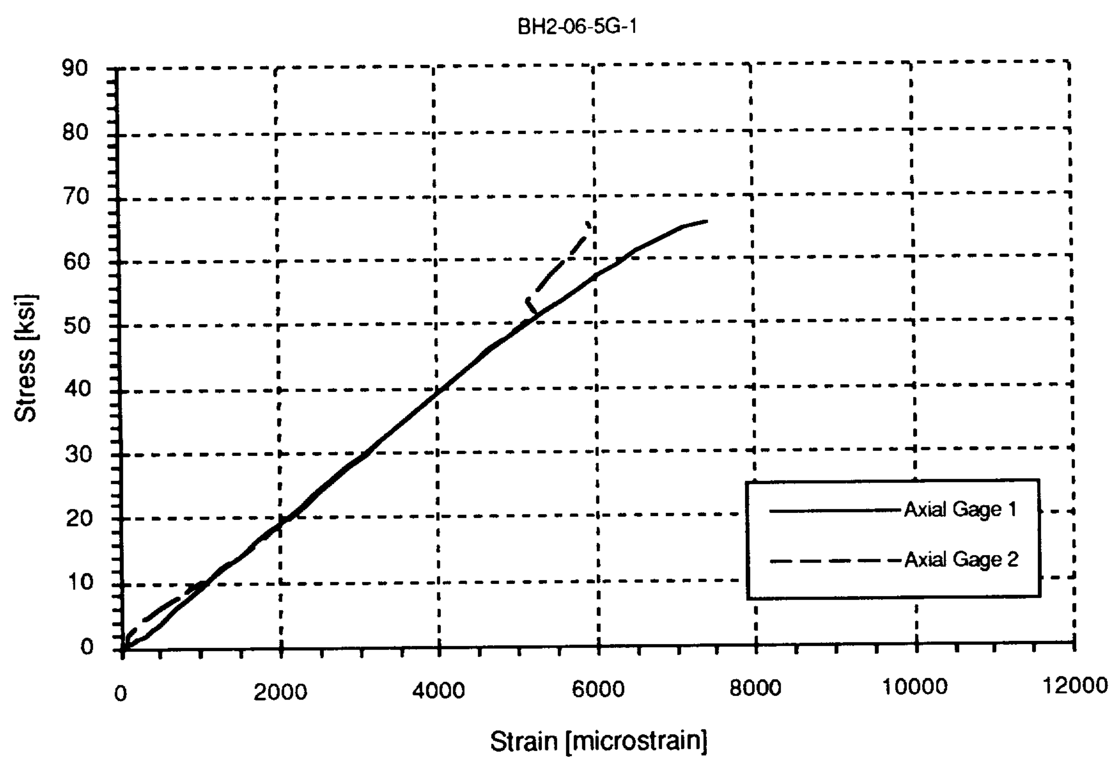


Figure B.34 Typical Short Block Compression Test Strain Data for 3-D Woven Material TS-2.

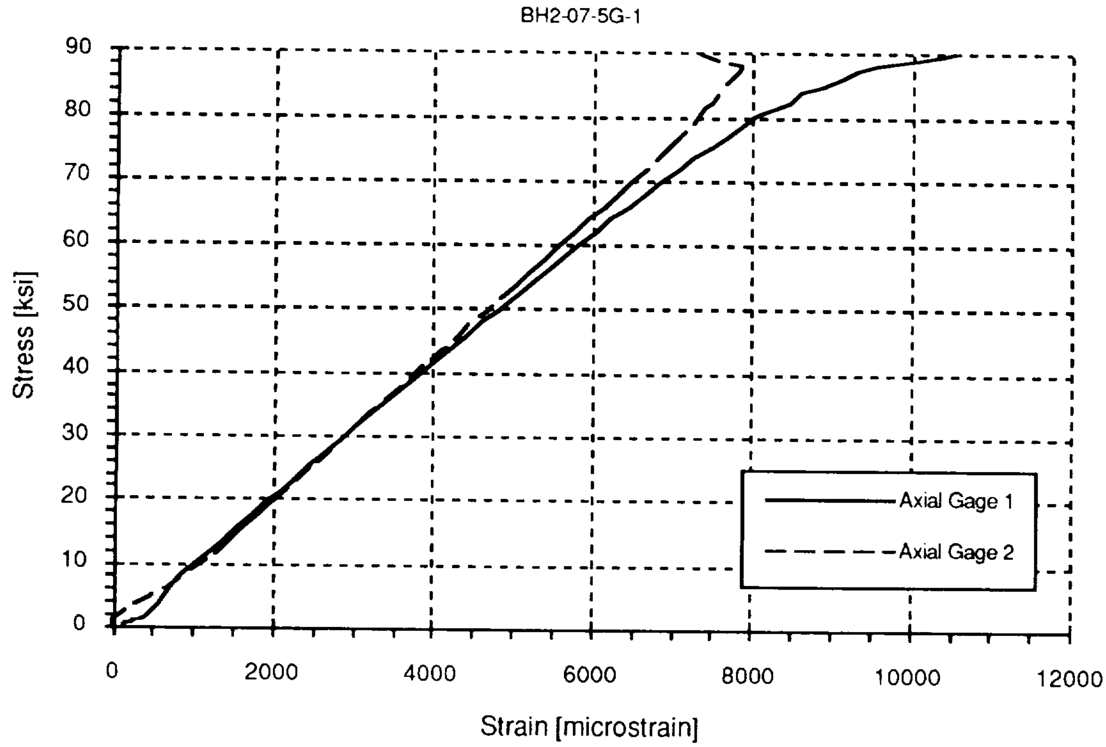


Figure B.35 Typical Short Block Compression Test Strain Data for 3-D Woven Material OS-1.

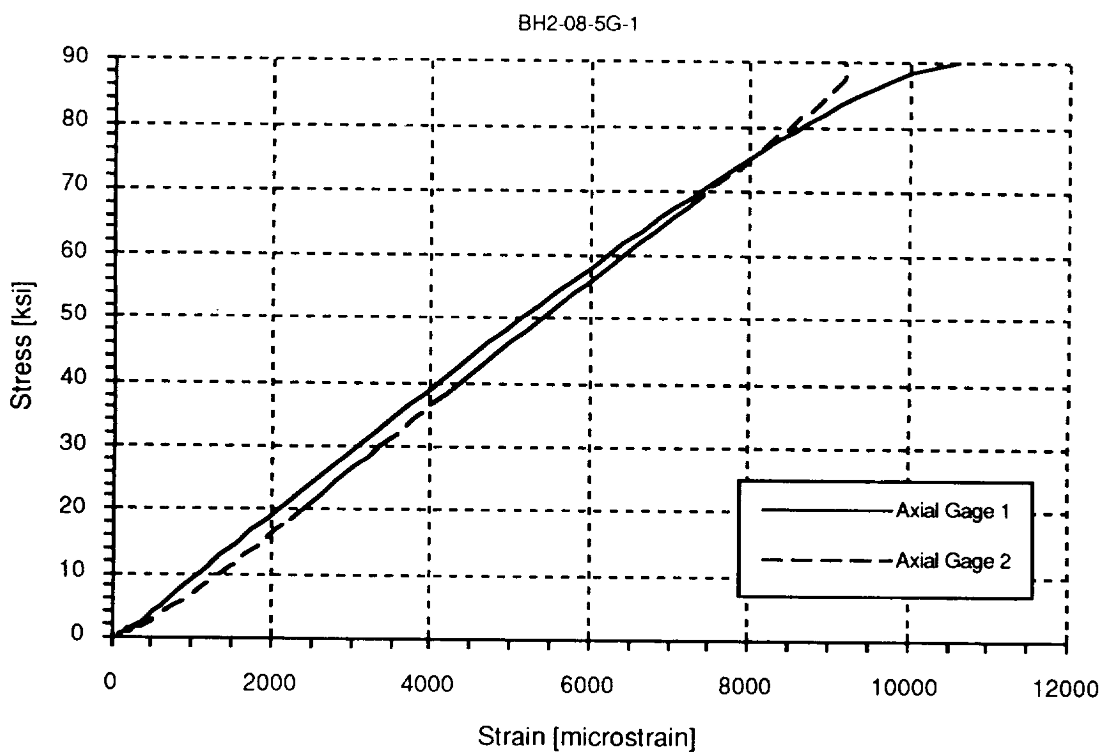


Figure B.36 Typical Short Block Compression Test Strain Data for 3-D Woven Material OS-2.

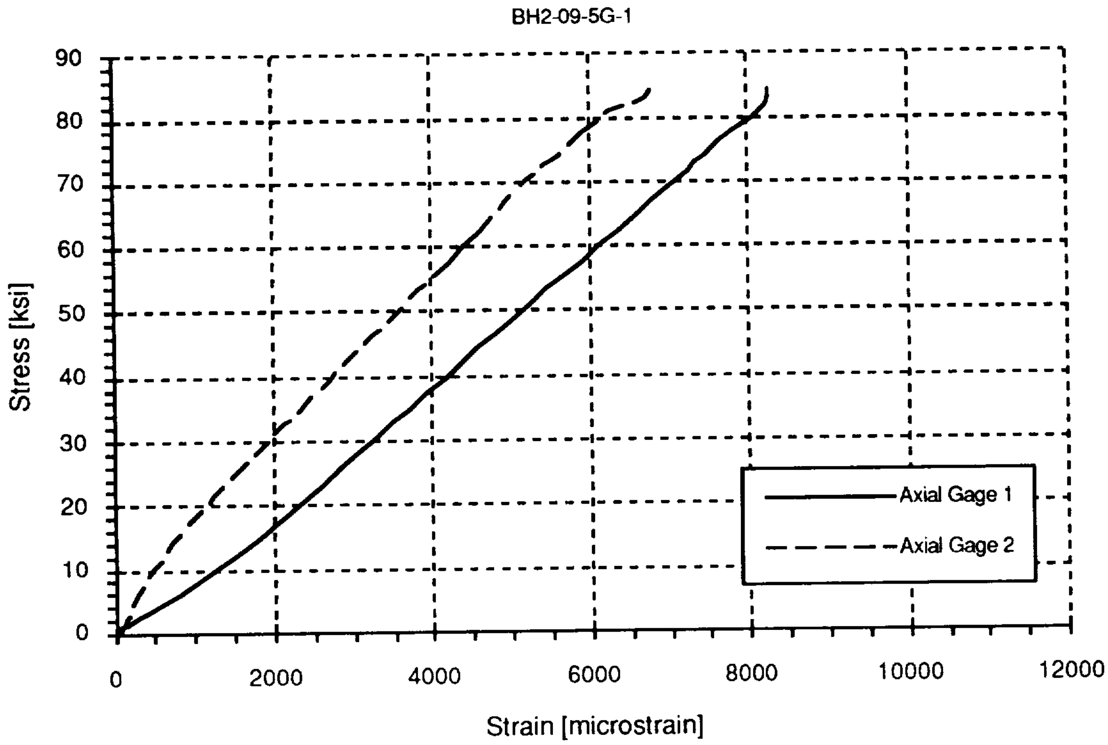


Figure B.37 Typical Short Block Compression Test Strain Data for 3-D Woven Material LS-1.

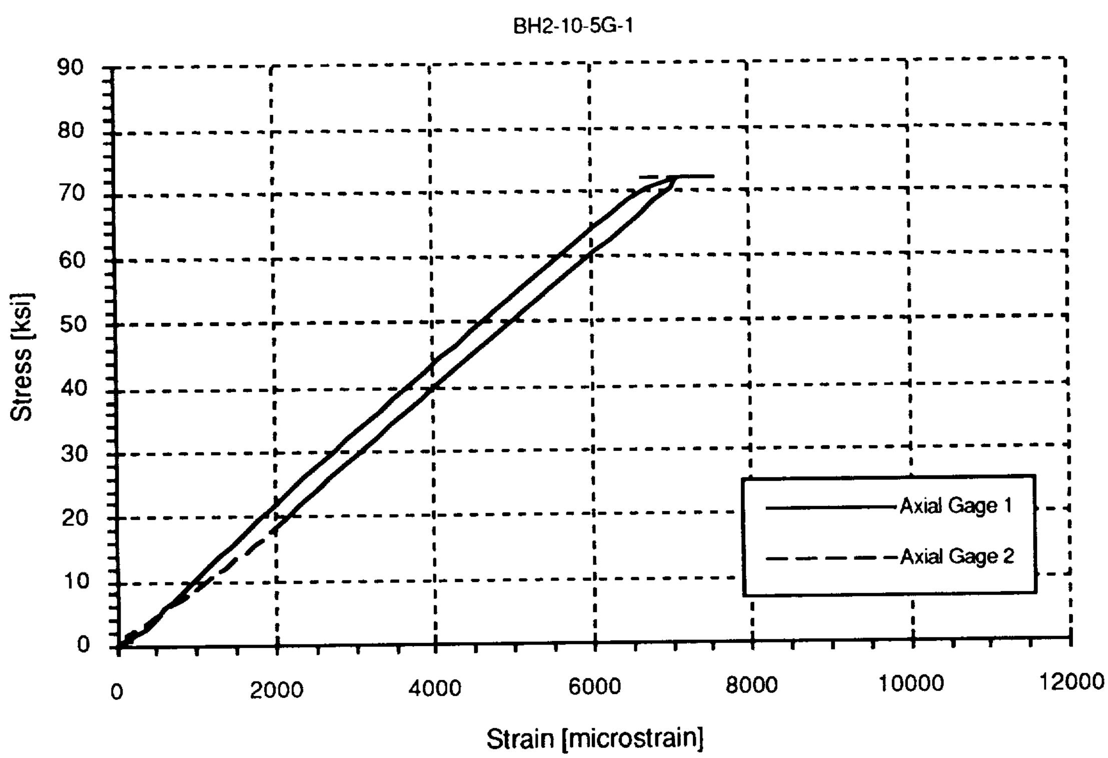
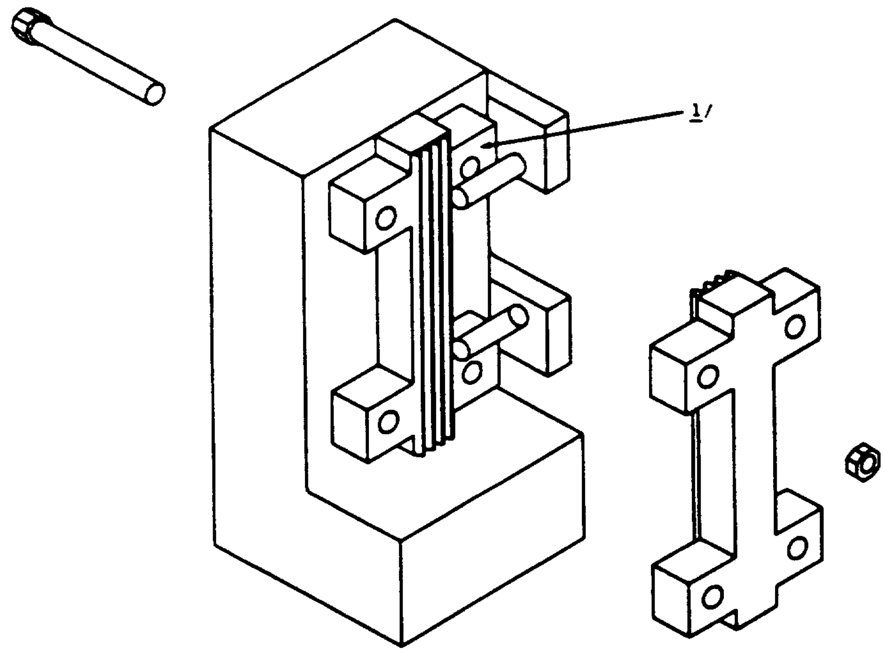


Figure B.38 Typical Short Block Compression Test Strain Data for 3-D Woven Material LS-2.

Appendix C Boeing Specifications

Copies of two Boeing specifications are included in this appendix for reference. The first specification, BSS 7260, illustrates the modified ASTM D695 compression fixture used for the compression interlaminar shear tests described in Section 13.1. The second specification, BSS 7273, describes the procedure used for the double cantilever beam tests described in Section 14.1.



General Note:

The inside faces of the assembled fixture shall close within ± 0.001 inch and shall be maintained to a finish of 32 Ra or better in accordance with ANSI B 46.1.

1/ OPTION: Relieve interior of bolting tangs a minimum of 0.02 inch.

MODIFIED D695 COMPRESSION FIXTURE FOR TYPE III
AND TYPE IV COMPRESSION TESTS

Figure 13

1 **SCOPE**

This standard describes the procedures for Mode I interlaminar fracture toughness testing of materials by applying a constant tensile crack opening displacement rate to a constant width and height double cantilever beam test specimen. The fracturing surfaces are pulled away from each other without sliding or shearing.

2 **APPLICABLE DOCUMENTS**

The current issue of the following references shall be part of this standard to the extent herein indicated.

ASTM E4 Verification of Testing Machines.

BAC 5317 Fiber Reinforced Composite Parts

3 **CONTENTS**

Not applicable to this specification.

4 **DEFINITIONS**

a. Area Method Interlaminar Fracture Toughness - The total interlaminar fracture energy combining several initiation and arrest events.

b. Brittle Crack Propagation - A sudden crack propagation with the absorption of no energy other than that stored elastically in the body.

c. Crack Starter - Nonbondable release sheet material (typically FEP for 250F and 350F curing systems and Kapton coated with a release agent listed in BAC 5317 for materials with higher processing temperatures) inserted between the middle prepreg plies during layup allowing initiation of interply cracking.

d. Crack Tip Position - Position from which a crack will begin propagating.

e. Crack Tip Sharpness - A qualitative measure of the crack tip depth or radius. Crack tip sharpness is a function of the material, where a brittle material produces a sharp crack tip (shallow tip/small radius) and a ductile material produces a less distinct crack tip (greater tip depth/large radius).

f. Ductile Crack Propagation - Slow crack propagation that is accompanied by noticeable plastic deformation and requires energy to be supplied from outside the body.

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BY D. B. Slaton	MFG R.G Christner	G_{1C} INTERLAMINAR FRACTURE TOUGHNESS FIBER-REINFORCED COMPOSITES	7273 1 of 6
CK'D	Q.C. R.A. Sevske	BOEING	
ENG	MAT'L R.G Christner	SPECIFICATION SUPPORT STANDARD	

4 **DEFINITIONS** (Continued)

g. Fiber Bridging - A phenomena where fibers begin to delaminate from both the top and bottom surfaces. Two crack tips are created which may increase the apparent fracture toughness.

h. Initiation Interlaminar Fracture Toughness - A measure of the minimum energy level required to resist crack initiation.

i. Surface Energy Interlaminar Fracture Toughness - A measure of the energy level associated with a materials resistance to delamination and crack propagation.

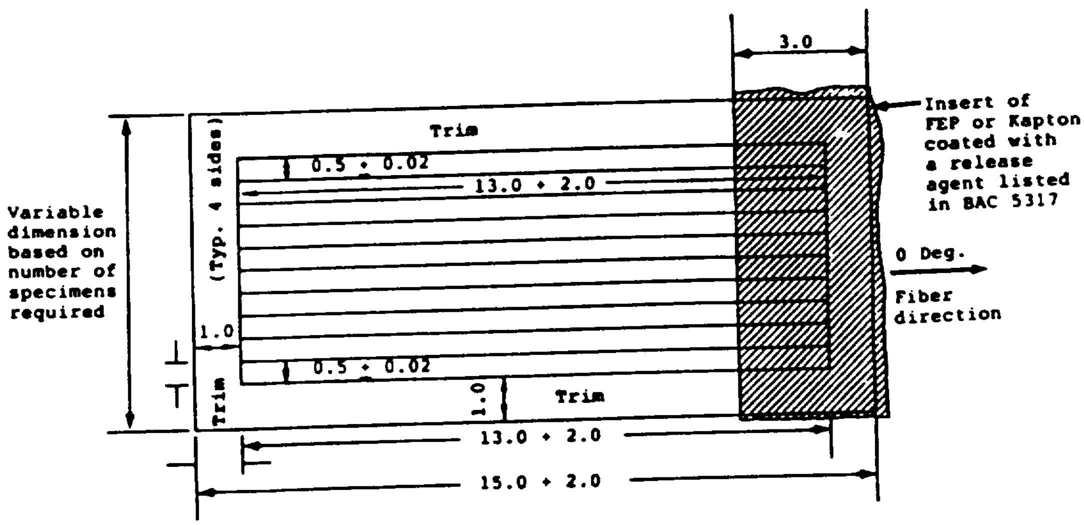
5 **TEST SPECIMEN REQUIREMENTS**

5.1 PANEL PREPARATION

a. A laminate test panel shall be layed up using an even number of prepreg plies as illustrated in Figure 1. Cured laminate thickness shall be 0.16 ± 0.01 inch. The number of plies shall be determined from the cured ply thickness as called out in the referenced specification. All plies shall be oriented in the zero direction.

b. A crack starter ply shall be placed between the middle plies as shown in Figure 2.

c. Panels shall be bagged and cured in accordance with the applicable process specification for the material.



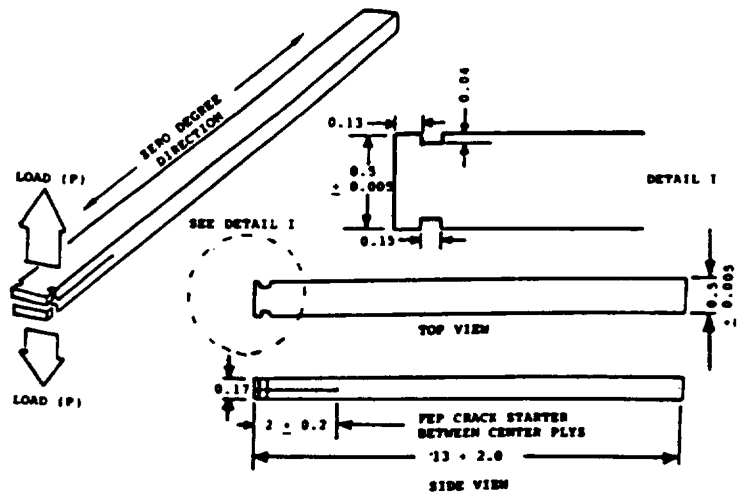
All dimensions in inches

DCB SPECIMEN AND PANEL GEOMETRY AND DIMENSIONS; PLAN VIEW

Figure 1

5.2 SPECIMEN PREPARATION

Machine specimens to the dimensions as shown in Figure 2.



CONSTANT WIDTH AND HEIGHT DOUBLE CANTILEVER BEAM (DCB) SPECIMEN

Figure 2

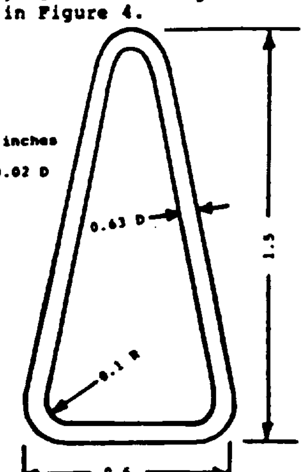
6 **EQUIPMENT/APPARATUS**

6.1 TEST MACHINE

Testing shall be performed with a constant displacement rate test machine. Test machine shall be verified in accordance with ASTM E4.

6.2 SPECIMEN GRIPS

Triangular specimen grips, as shown in Figure 3, are attached to the upper and lower beam halves as displayed in Figure 4.



SPECIMEN GRIPS

Figure 3

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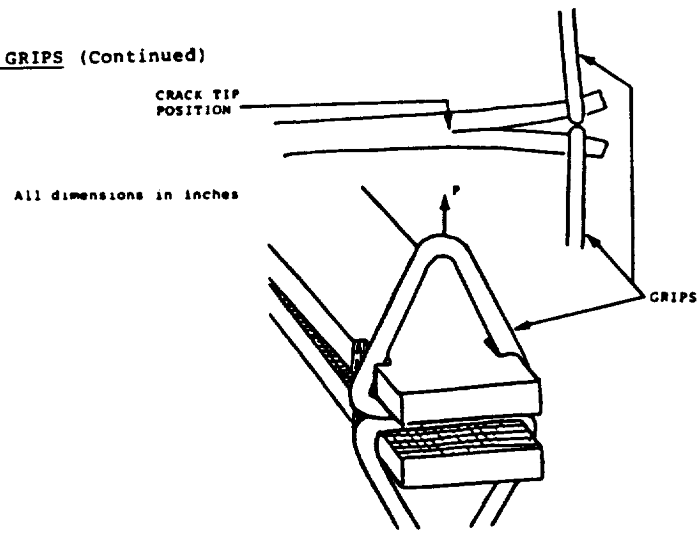
REVISED: "B" 10-21-88

6.2 SPECIMEN GRIPS (Continued)



POSITIONS OF THE TRIANGUALAR SPECIMEN GRIP IN THE DCB SPECIMEN

Figure 4

7 **PROCEDURE**

7.1 PARAMETERS/MEASUREMENTS

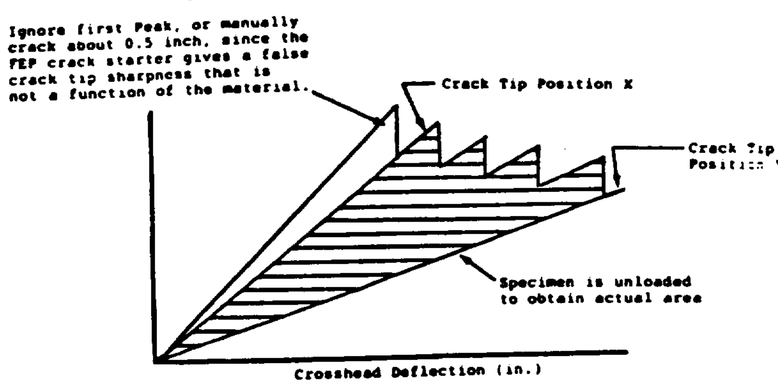
a. A minimum of five specimens shall be tested for each desired temperature. Room temperaure shall be 75 ± 10F.

b. A crosshead speed of 1.0 inch/min shall be maintained to produce a load deflection curve.

c. To measure crack tip position, each crack arrest position shall be marked on the edge of the specimen during loading with a visible marking pen. A 10X magnifying glass is recommended to visually observe and mark the crack tip position. Each crack tip position will correspond to an individual load line as shown in Figure 5.

******* Be sure to note whether bridging of fibers between upper
CAUTION and lower surfaces occurs. This phenomena can significantly
******* affect the results since more than one crack tip is fracturing.

d. The area illustrated in Figure 5 represents the energy absorbed between two known crack length positions.



AREA METHOD LOAD DEFLECTION CURVE AND DATA DETERMINATION

Figure 5

7.2 CALCULATION OF SURFACE ENERGY INTERLAMINAR FRACTURE TOUGHNESS

7.2.1 AREA METHOD

a. Area method G_{1C} interlaminar toughness is calculated from the following formula.

$$\text{Area Interlaminar Toughness} = \frac{E}{A \times B} \quad (\text{in-lb/in.}^2)$$

where

E = area of the load deflection curve between the initial and final crack positions.

A = crack length corresponding to E, initial crack tip to final crack tip (in.)

B = specimen width (in.)

b. To obtain the energy involved in fracture (in-lb/in^2), the area under the curve at two crack length positions seen in Figure 5 shall be measured.

c. Ignore 1st peak in calculation, or manually crack about 0.5 inch, since the FEP crack starter gives a false crack tip sharpness that is not a function of the material.

d. The area illustrated in Figure 5 represents the energy absorbed between two known crack length positions.

7.2.2 INITIATION METHOD

Initiation Method

G_{1C} interlaminar toughness is calculated from the following formula:

$$G_{1C} = \frac{3PY}{2B\,a} \qquad G_{1C} \text{ is in inch-pound/inch}^2$$

where

P = fracture load measured in pounds at the bottom of the small sawtooth excursions (arrest) or fracture load at tip of sawtooth excursion (initiation)

a = crack length measured visually in inches and recorded manually at its corresponding load position on the chart (arrest or initiation crack length)

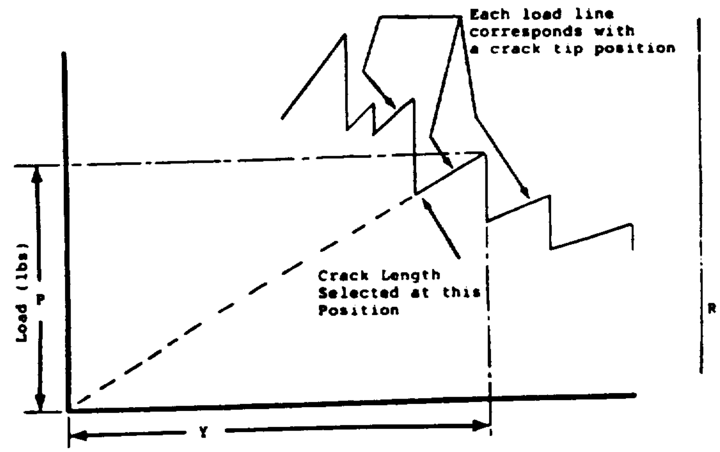
B = specimen width in inches (a specimen constant)

Y = calculated crosshead deflection in inches corresponding to load value P.

These parameters are shown in Figure 6.

7.2.2 INITIATION METHOD (Continued)

To measure the crosshead deflection Y for the G_{1C} initiation calculation, it is necessary to obtain the load-deflection curve origin by deliberately unloading along the dashed line as seen in Figure 6.



CROSSHEAD DEFLECTION (in.)

INITIATION METHOD LOAD-DEFLECTION CURVE AND DATA POINT DETERMINATION

Figure 6

8 **REPORTING**

Report specimen identification, test temperature, and G_{1C} to the nearest in-lb/in^2.

ORIGINAL ISSUE: 5-12-83
X-20800 REV. 8/86
REVISED: "B" 10-21-88

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
July 1994

3. REPORT TYPE AND DATES COVERED
Contractor Report

4. TITLE AND SUBTITLE
Test Methods for Textile Composites

5. FUNDING NUMBERS
NAS1-19247
WU 510-02-12-09

6. AUTHOR(S)
Pierre J. Minguet, Mark J. Fedro, and Christian K. Gunther

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Boeing Defense & Space Group
Helicopters Division
Philadelphia, PA 19142

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Langley Research Center
Hampton, VA 23681-0001

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
NASA CR-4609

11. SUPPLEMENTARY NOTES
Langley Technical Monitor: C. C. Poe, Jr.
Final Report - Task 7

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Unclassified-Unlimited

Subject Category 24

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Various test methods commonly used for measuring properties of tape laminate composites were evaluated to determine their suitability for the testing of textile composites. Three different types of textile composites were utilized in this investigation: 2-dimensional triaxial braids, stitched uniweave fabric, and 3-dimensional interlock woven fabric. Four 2-D braid architectures, five stitched laminates, and six 3-D woven architectures were tested. All preforms used AS4 fibers and were resin-transfer-molded with Shell RSL-1895 epoxy resin. Ten categories of material properties were investigated: Tension, Open-Hole Tension, Compression, Open-Hole Compression, In-Plane Shear, Filled-Hole Tension, Bolt Bearing, Interlaminar Tension, Interlaminar Shear and Interlaminar Fracture Toughness. Different test methods and specimen sizes were considered for each category of test. Strength and stiffness properties obtained with each of these methods are documented in this report for all the material systems mentioned above.

14. SUBJECT TERMS
Textile composites; Braiding; Weaving; Stitching; Mechanical testing; Tension; Compression; Shear; Bearing; Fracture toughness

15. NUMBER OF PAGES
228

16. PRICE CODE
A11

17. SECURITY CLASSIFICATION OF REPORT
Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102