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Test Methods for Textile Composites

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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 consistently 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.

Table of Contents

Abstract.....	III
Table of Contents.....	IV
List of Figures.....	VII
List of Tables.....	XI
1. Introduction.....	1
2. Material Systems.....	2
2.1 2-D Braided Composites.....	2
2.2 Stitched Uniweave Composites.....	3
2.3 3-D Interlock Woven Materials.....	4
3. Data Reduction Techniques.....	5
3.1 Fiber Volume Measurements.....	5
3.2 Thickness Normalization.....	5
3.3 Stress, Modulus and Poisson's Coefficient Calculation.....	7
3.4 Open-Hole Data.....	7
4. Strain Gage Size Sensitivity Study.....	9
4.1 Test Specimens and Procedures.....	9
4.2 Strain Gages Investigated.....	9
4.3 Experimental Results.....	10
4.4 2-D Braided Materials.....	11
4.5 3-D Woven Materials.....	12
5. In-Plane Tension Test Program.....	15
5.1 Test Configuration.....	15
5.2 2-D Braid Materials.....	16
5.2.1 Test Section Width, Length and Thickness Effects.....	16
5.2.2 Longitudinal Tension Test Summary.....	18
5.2.3 Transverse Tension.....	20
5.3 Stitched Uniweave Materials.....	21
5.4 3-D Woven Materials.....	22
5.5 Test Recommendations.....	22
6. Open-Hole Tension Test Program.....	24
6.1 Test Configuration.....	24
6.2 2-D Braid Materials.....	25
6.2.1 Width to Diameter Ratio Effect.....	25
6.2.2 Thickness Effect.....	26
6.2.3 Hole Size Effect.....	26
6.2.4 Summary.....	29
6.3 Stitched Uniweave Materials.....	30
6.4 3-D Woven Materials.....	31
6.5 Test Recommendations.....	33

7. In-Plane Compression Test Program.....	34
7.1 Test Configurations.....	34
7.2 2-D Braid Materials.....	37
7.2.1 Test Section Length and Thickness Effects.....	37
7.2.2 Longitudinal Compression.....	38
7.2.3 Sandwich Column.....	41
7.2.4 Boeing Open Hole Compression Fixture.....	42
7.2.5 Transverse Compression.....	42
7.3 Stitched Uniweaves Materials.....	43
7.3.1 Longitudinal Compression.....	43
7.3.2 Transverse Compression.....	43
7.4 3-D Woven Materials.....	44
7.4.1 Longitudinal Compression.....	44
7.4.2 Transverse Compression.....	44
7.5 Test Recommendations.....	45
8. Open Hole Compression Test Program.....	48
8.1 Test Configurations.....	48
8.2 2-D Braid Materials.....	49
8.2.1 Test Method Comparison.....	49
8.2.2 Hole Size Effect.....	53
8.3 Stitched Uniweave Materials.....	56
8.4 3-D Woven Materials.....	58
8.5 Test Recommendations.....	59
9. In-Plane Shear Test Program.....	62
9.1 Test Configurations.....	62
9.2 2-D Braid Materials.....	63
9.3 Stitched Uniweave Materials.....	65
9.4 3-D Woven Materials.....	66
9.5 Test Recommendations.....	67
10. Filled-Hole Test Program.....	69
10.1 Test Configuration.....	69
10.2 2-D Braids.....	69
11. Bolt-Bearing Test Program.....	71
11.1 Test Configuration.....	71
11.2 2-D Braids.....	73
12. Interlaminar Tension.....	78
12.1 Specimen Configurations.....	78
12.2 2-D Braids Materials.....	79
12.3 3-D Woven Materials.....	81
13. Interlaminar Shear.....	82
13.1 Test Configurations.....	82

13.3 2-D Braided Materials.....	83
13.3 3-D Woven Materials	84
14. Interlaminar Fracture Toughness.....	85
14.1 Test Configurations.....	85
14.2 2-D Braided Materials.....	86
15. Conclusions	88
References.....	90
Appendix A Test Data	A.1
Appendix B Typical Stress-Strain Curves.....	B.1
Appendix C Boeing Specifications.....	C.1

List of Figures

Figure 2.1	Illustration of 2-D Triaxial Braid Configuration.	3
Figure 2.2	Depiction of 3-D Interlock Woven Materials.	4
Figure 3.1	Example of Relationship between Fiber Volume Fraction and Thickness for SLL, LSS and SU-1 Specimens.	6
Figure 5.1.a	Typical Tension Specimen Configuration.	15
Figure 5.1.b	Dogbone Tension Specimen Configuration.	16
Figure 5.2.a	Effect of Specimen Width on Tensile Strength of 2-D Braid SLL.	17
Figure 5.2.b	Effect of Specimen Width on Tensile Strength of 2-D Braid LLS.	17
Figure 5.2.c	Effect of Specimen Width on Tensile Strength of 2-D Braid LLL.	18
Figure 5.2.d	Effect of Specimen Width on Tensile Strength of 2-D Braid LSS.	18
Figure 5.3	Effect of Specimen Length on Tensile Strength of 2-D Braids.	18
Figure 5.4	Tensile Strength of Baseline, Dogbone and Net-Shape 2-D Braided Specimens.	20
Figure 5.5	Transverse Tension Strength and Nominal Strain for 2-D Braided Materials.	20
Figure 5.6	Summary of Longitudinal Tension Strengths and Nominal Strains of Stitched Uniweave Materials.	21
Figure 5.7	Comparison of Longitudinal Tension Strengths and Nominal Strains of 3-D Woven Materials.	22
Figure 6.1	Open Hole Specimen Configuration.	24
Figure 6.2	Comparison of Gross, Net and Corrected Stress in SLL and LLS 1/8" Thick Specimens with a 3/8" Diameter Hole.	26
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.	26
Figure 6.4.a	Effect of Hole Diameter on Tension Strength of SLL Specimens.	27
Figure 6.4.b	Effect of Hole Diameter on Tension Strength of LLS Specimens.	28
Figure 6.4.c	Effect of Hole Diameter on Tension Strength of LLL Specimens.	28
Figure 6.4.d	Effect of Hole Diameter on Tension Strength of LSS Specimens.	29
Figure 6.5	Effect of Hole Diameter on Open Hole Tension Strength of Stitched-Uniweave Materials.	30
Figure 6.6	Open Hole Tension Strength Data for 3-D Woven Materials.	31
Figure 6.7.a	Effect of Hole Diameter on Open Hole Tension Strength of 3-D Woven Materials OS-1 and OS-2.	32
Figure 6.7.b	Effect of Hole Diameter on Open Hole Tension Strength of 3-D Woven Materials LS-1 and LS-2.	32
Figure 6.7.c	Effect of Hole Diameter on Open Hole Tension Strength of 3-D Woven Materials TS-1 and TS-2.	33
Figure 7.1.a	Modified IITRI Specimen and NASA Short Block Specimen.	35
Figure 7.1.b	Sandwich Column Specimen, Zabora Fixture and Boeing OHC Fixture.	36

Figure 7.1.c	NASA ST-4 or Boeing CAI Specimen and Boeing OHC or Zabora Fixture Specimen.	36
Figure 7.2	Test Section Length Effect on Compression Strength in NASA Short Block Test Configuration.	37
Figure 7.3	Test Section Length Effect on Compression Strength in modified IITRI Test Configuration.	38
Figure 7.4	Test Section Length Effect on Compression Modulus in NASA Short Block and modified IITRI Test Configurations.	38
Figure 7.5	Compression Modulus of 2-D Braided Materials.....	39
Figure 7.6.a	Compression Strength and Nominal Strain of SLL Braid	40
Figure 7.6.b	Compression Strength and Nominal Strain of LLS Braid	40
Figure 7.6.c	Compression Strength and Nominal Strain of LLL Braid.....	40
Figure 7.6.d	Compression Strength and Nominal Strain of LSS Braid.....	41
Figure 7.7	Deviation from Mean Strength for Unnotched Compression Test Methods.	46
Figure 7.8	Mean Strength CoVs for Unnotched Compression Test Methods.	47
Figure 7.9	Deviation from Mean Modulus for Unnotched Compression Test Methods.....	47
Figure 7.10	Mean Modulus CoVs for Unnotched Compression Test Methods.	47
Figure 8.1	NASA 1142 Specimen Configuration.....	49
Figure 8.2.a	Comparison of Open Hole Compression Strength for Various Test Methods of SLL Materials.....	50
Figure 8.2.b	Comparison of Open Hole Compression Strength for Various Test Methods of LLS Materials.....	50
Figure 8.2.c	Comparison of Open Hole Compression Strength for Various Test Methods of LLL Materials.	50
Figure 8.2.d	Comparison of Open Hole Compression Strength for Various Test Methods of LSS Materials.	51
Figure 8.3.a	Comparison of Coefficient of Variations for Open Hole Compression Test Methods of SLL Materials.	51
Figure 8.3.b	Comparison of Coefficient of Variations for Open Hole Compression Test Methods of LLS Materials.	51
Figure 8.3.c	Comparison of Coefficient of Variations for Open Hole Compression Test Methods of LLL Materials.....	52
Figure 8.3.d	Comparison of Coefficient of Variations for Open Hole Compression Test Methods of LSS Materials.....	52
Figure 8.4.a	Effect of Hole Diameter on Open Hole Compression Strength of 2-D Braided Materials SLL.....	54
Figure 8.4.b	Effect of Hole Diameter on Open Hole Compression Strength of 2-D Braided Materials LLS.....	55

Figure 8.4.c	Effect of Hole Diameter on Open Hole Compression Strength of 2-D Braided Material LLL.	55
Figure 8.4.d	Effect of Hole Diameter on Open Hole Compression Strength of 2-D Braided Material LSS.	56
Figure 8.5	Comparison of Mean Coefficient of Variation for all Stitched Uniweave Open Hole Compression Tests.	57
Figure 8.6	Comparison of 1/4" Open Hole Compression Strength and Nominal Strains for Stitched Uniweave Materials.	57
Figure 8.7	Effect of Hole Diameter on Open Hole Compression Strength of Stitched Uniweave Materials.	58
Figure 8.8	Comparison of 1/4" Open Hole Compression Strength for 3-D Woven Materials.	59
Figure 8.9	Normalized Mean Deviations for Open Hole Compression Test Methods in 2-D Braided Materials.	60
Figure 8.10	CoVs for Open Hole Compression Test Methods in 2-D Braided Materials.	61
Figure 9.1	Rail Shear Specimen and Compact Shear Specimen.	63
Figure 9.2	Comparison of Shear Modulus by Various Test Methods for 2-D Braided Materials.	64
Figure 9.3	Comparison of Shear Strength Various Test Methods for 2-D Braided Materials.	65
Figure 9.4	Shear Modulus of Stitched Uniweave Materials.	66
Figure 9.5	Shear Modulus of 3-D Woven Materials with Rail Shear and Compact Shear Specimen Methods.	67
Figure 9.6	Mean Deviations for In-plane Shear Test Methods.	68
Figure 9.7	CoVs for In-plane Shear Test Methods.	68
Figure 10.1	Comparison of Net, Gross and Corrected Stress for Filled Hole Tension Test of SLL Braid.	70
Figure 10.2	Comparison of Open and Filled Hole Tension Strength Data for 2-D Braided Material.	70
Figure 11.1a	Baseline Dimensions for Stabilized Single-Shear Specimen.	72
Figure 11.1b	Baseline Dimensions for Unstabilized Single-Shear Specimen.	72
Figure 11.1c	Baseline Dimensions for Double-Shear Specimen.	73
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.	74
Figure 11.3	Effect of e/D on Unstabilized Single Shear Bearing Ultimate Strength of 2-D Braided Materials SLL and LLS.	75
Figure 11.4.a	Effect of W/D and e/D on Double Shear Bearing Ultimate Strength of 2-D Braided Materials SLL.	75
Figure 11.4.b	Effect of W/D and e/D on Double Shear Bearing Ultimate Strength of 2-D Braided Materials LLS.	76
Figure 11.5	Comparison of all Bearing Tests with W/D=6 and e/D=3 for 2-	

	D Braided Materials.	76
Figure 12.1	Interlaminar Tension C-Shape Specimen.	79
Figure 12.2	Interlaminar Tension L-Shape Specimen.	79
Figure 12.3	Interlaminar Tension Strength Measured with C-Shape Specimen.	80
Figure 12.4	Interlaminar Tension Strength Measured with L-Shape Specimen.	81
Figure 13.1	Short Beam Shear and Compression Interlaminar Shear Specimens.	82
Figure 13.2	Interlaminar Shear Strength Measured with Short Beam Shear and Compression Interlaminar Shear Test Methods	83

List of Tables

Table 2.1	Description of 2-D braided Composites Architectures.....	2
Table 2.2	Description of Stitched Uniweave Materials.....	3
Table 2.3	Description of 3-D Interlock Woven Materials.....	4
Table 3.1	Summary of Normalized Thicknesses	7
Table 4.1	Strain Gage Description.....	10
Table 4.2	2-D Braid Longitudinal Modulus Measurements	12
Table 4.3	2-D Braid Transverse Modulus Measurements	13
Table 4.4	3-D Weave Longitudinal Modulus Measurements	13
Table 4.5	3-D Weave - Transverse Modulus Measurements	14
Table 5.1	Test Matrix for Tension Test Program.....	16
Table 5.2	Summary of Tension Properties of 2-D Braided Materials	19
Table 5.3	Summary of Transverse Tension Properties of 2-D Braided Materials	20
Table 5.4	Summary of Longitudinal Tension Properties of Stitched Uniweave Materials	21
Table 5.5	Summary of Longitudinal Tension Properties of 3-D Woven Materials	22
Table 6.1	Test Matrix for Open Hole Tension Test Program	25
Table 6.2	Mean Stress and CoV for Open Hole Tension Tests of 2-D Braided Materials	29
Table 6.3	Mean Strength and CoV for Open Hole Tests of Stitched-Uniweave Materials	30
Table 6.4	Mean Strength and CoV for Open Hole Tests of 3-D Woven Materials	31
Table 7.1	Test Matrix for Compression Test Program.....	35
Table 7.2	Summary of Longitudinal Compression Properties for 2-D Braid Materials	41
Table 7.3	Sandwich Column Compression Properties for 2-D Braid Materials.....	42
Table 7.4	Summary of Transverse Compression Properties for 2-D Braid Materials Using Modified IITRI Test Method.....	42
Table 7.5	Summary of Transverse Compression Properties for Stitched Uniweave Materials	43
Table 7.6	Summary of Transverse Compression Properties for Stitched Uniweave Materials Using the Modified IITRI Test Method	44

Table 7.7	Summary of Longitudinal Compression Properties for 3-D Woven Materials.	44
Table 7.8	Summary of Longitudinal Compression Properties for 3-D Woven Materials the Using Modified IITRI Test	45
Table 7.9	Mean Deviations $\overline{\Delta x_n}$ and CoVs for Unnotched Compression Test Methods	46
Table 8.1	Test Matrix for Open Hole Compression Test Program.....	48
Table 8.2	Summary of Open Hole Compression Test Results for 2-D Braided Materials	53
Table 8.3	Summary of Open Hole Compression Test Results for Stitched Uniweave Materials.	57
Table 8.4	Summary of Open Hole Compression Test Results for 3-D Woven Materials	58
Table 8.5	Mean deviations $\overline{\Delta x_{kn}}$ and $\overline{\Delta x_n}$ for Open-Hole Compression Test Methods.	60
Table 9.1	Test Matrix for Shear Properties	62
Table 9.2	Summary of Tube Torsion Test Results for 2-D Braids	64
Table 9.3	Summary of Rail Shear and Ifju Fixture Test Results for 2-D Braids.....	64
Table 9.4	Shear Properties of Stitched Uniweave Materials	65
Table 9.5	Shear Properties of 3-D Woven Materials.....	66
Table 9.6	Normalized Mean Deviations $\overline{\Delta x_n}$ for Shear Test Methods	68
Table 10.1	Filled Hole Tension Test Program	69
Table 10.2	Filled Hole Tension Test Program	70
Table 11.1	Bolt-Bearing Test Matrix	71
Table 11.2	Stabilized Single Shear Bearing Ultimate Strength Results for 2-D Braids	77
Table 11.3	Unstabilized Single Shear Bearing Ultimate Strength Results for 2-D Braids	77
Table 11.4	Double Shear Bearing Ultimate Strength Results for 2-D Braids	77
Table 12.1	Interlaminar Tension Test Matrix	78
Table 12.2	Interlaminar Tension Strength Measured with C-Shape Specimen.....	80
Table 12.3	Interlaminar Tension Strength Measured with L-Shape Specimen	81
Table 13.1	Interlaminar Shear Test Matrix	83
Table 13.2	Interlaminar Shear Strength in 2-D Braided Materials	84
Table 13.3	Interlaminar Shear Strength in 3-D Woven Materials	84
Table 14.1	Interlaminar Toughness Test Matrix	86
Table 14.2	Interlaminar Toughness Test Results	87

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 $\pm\theta$ tow (these factors of 2 are due to the fact that this is a 2X2 pattern).

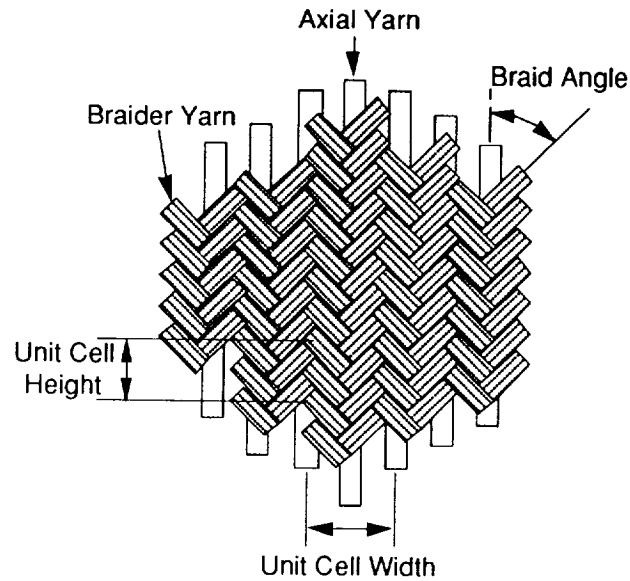


Figure 2.1 Illustration of 2-D Triaxial Braid Configuration.

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 orthogonal interlock	24 K (59%)	12 K (33%)	6 K (7.4%)
OS-2		12 K (58%)	6 K (37%)	3 K (6.1%)
TS-1	Through-the-thickness angle interlock	24 K (57%)	12 K (33%)	6 K (9.8%)
TS-2		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%)

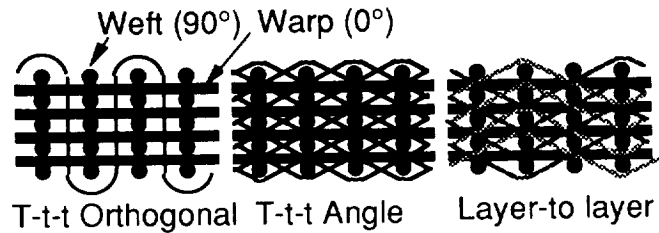


Figure 2.2 Depiction of 3-D Interlock Woven Materials.

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.

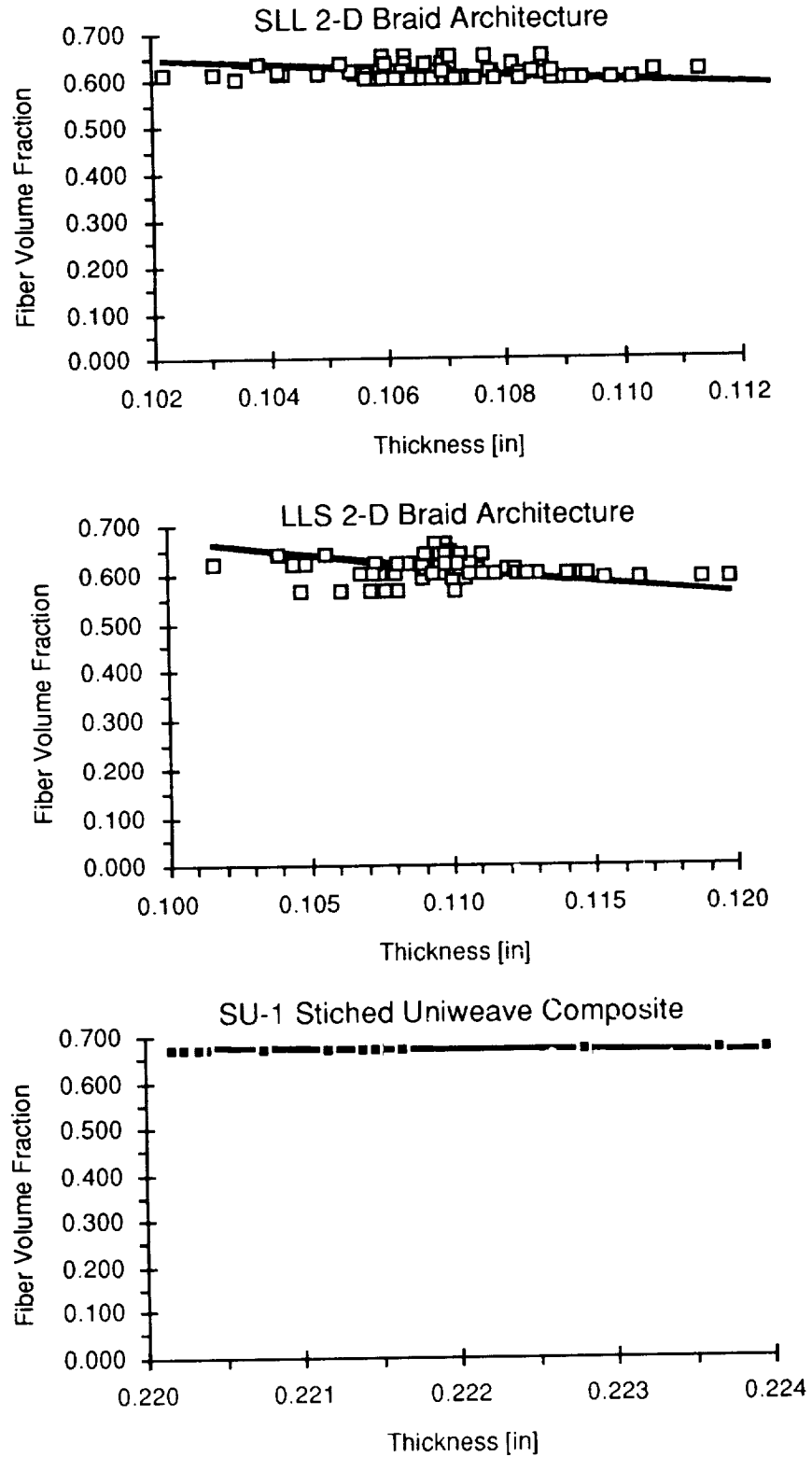


Figure 3.1 Example of Relationship between Fiber Volume Fraction and Thickness for SLL, LSS and SU-1 Specimens.

Table 3.1 Summary of Normalized Thicknesses

Name	Thickness [in]	Name	Thickness [in]
SLL	0.110 or 0.215	SU-1	0.247
LLL	0.114 or 0.229	SU-2	0.265
LLS	0.112 or 0.220	SU-3	0.261
LSS	0.111 or 0.215	SU-4	0.241
LS-1	0.226	SU-5	0.274
LS-2	0.230		
OS-1	0.234		
OS-2	0.226		
TS-1	0.237		
TS-2	0.228		

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.

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

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

$$\sigma_{\text{net}} = \frac{P}{(w - d) t_{\text{nom}}}$$

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.

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

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:

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

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.

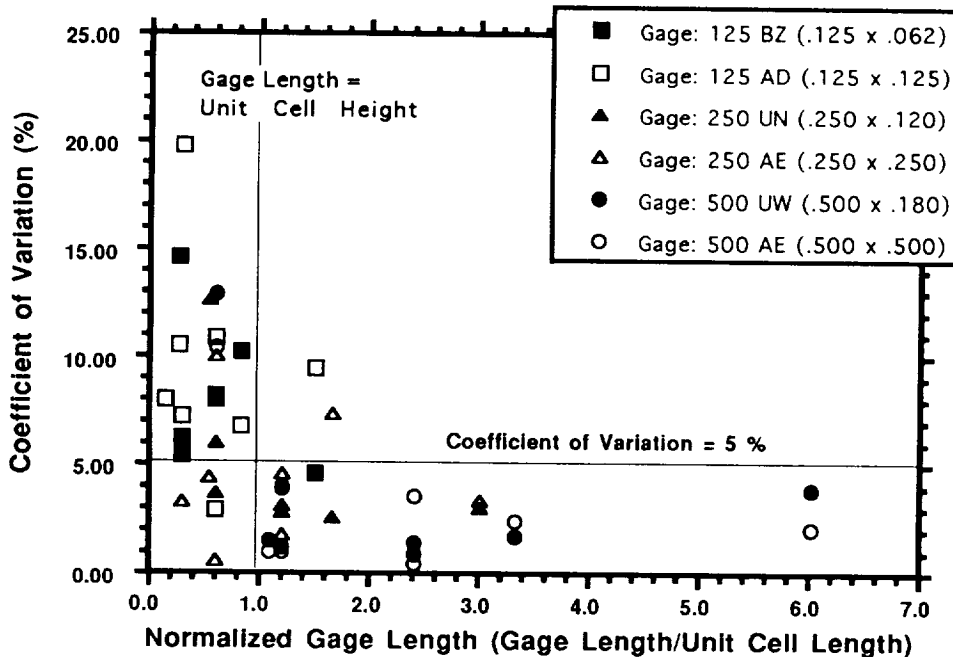


Figure 4.1 Coefficient of Variation of Moduli for each Gage Type.

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 [in]	Modulus [Msi]					
		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 [in]	Modulus [Msi]					
		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).

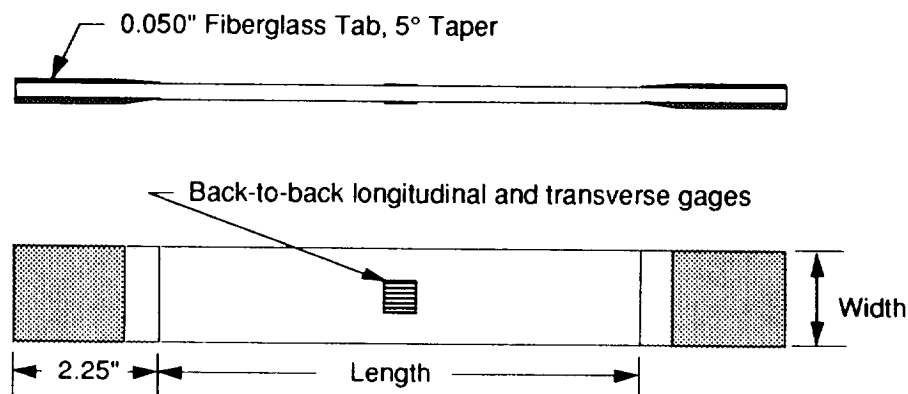


Figure 5.1.a Typical Tension Specimen Configuration.

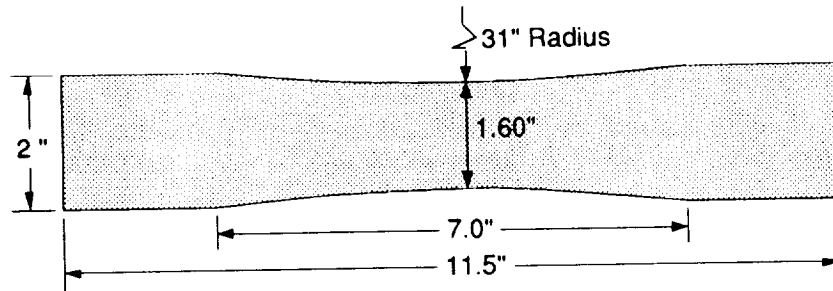


Figure 5.1.b Dogbone Tension Specimen Configuration.

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.

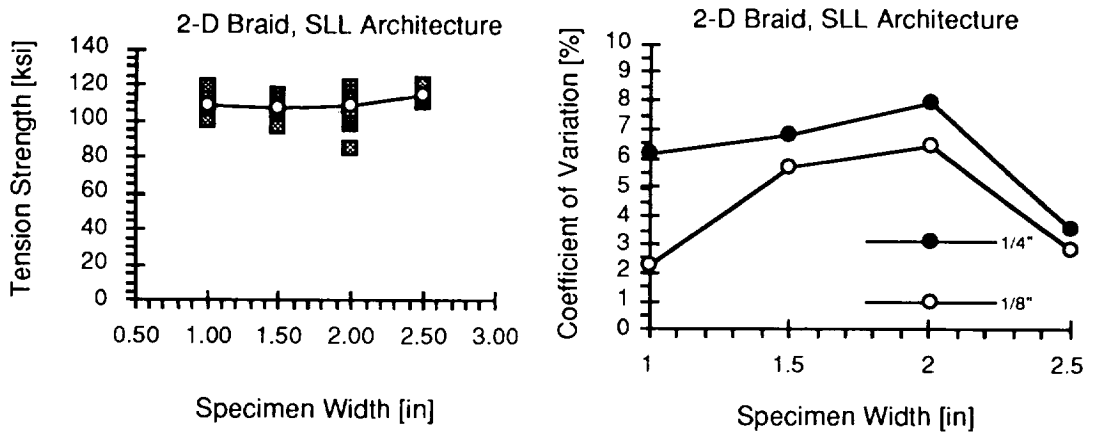


Figure 5.2.a Effect of Specimen Width on Tensile Strength of 2-D Braid SLL.

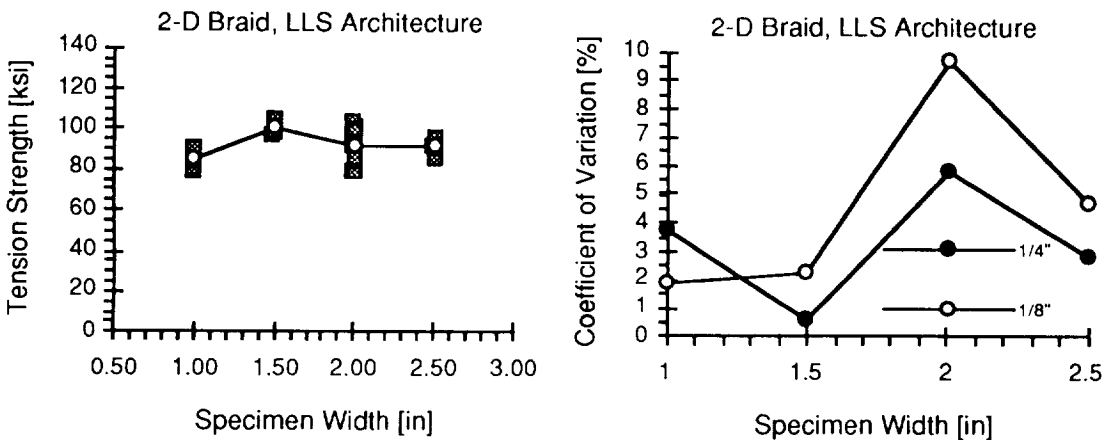


Figure 5.2.b Effect of Specimen Width on Tensile Strength of 2-D Braid LLS.

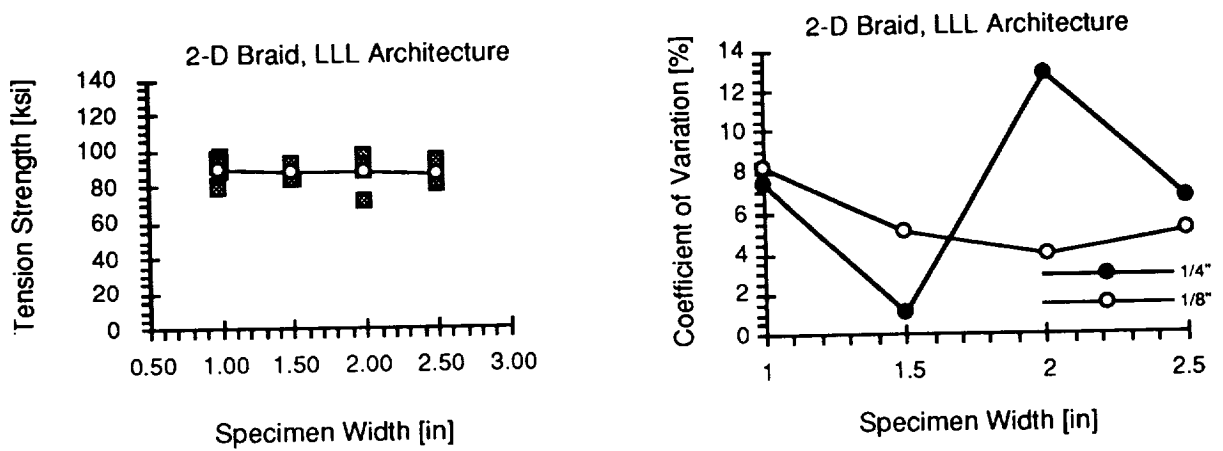


Figure 5.2.c Effect of Specimen Width on Tensile Strength of 2-D Braid LLL.

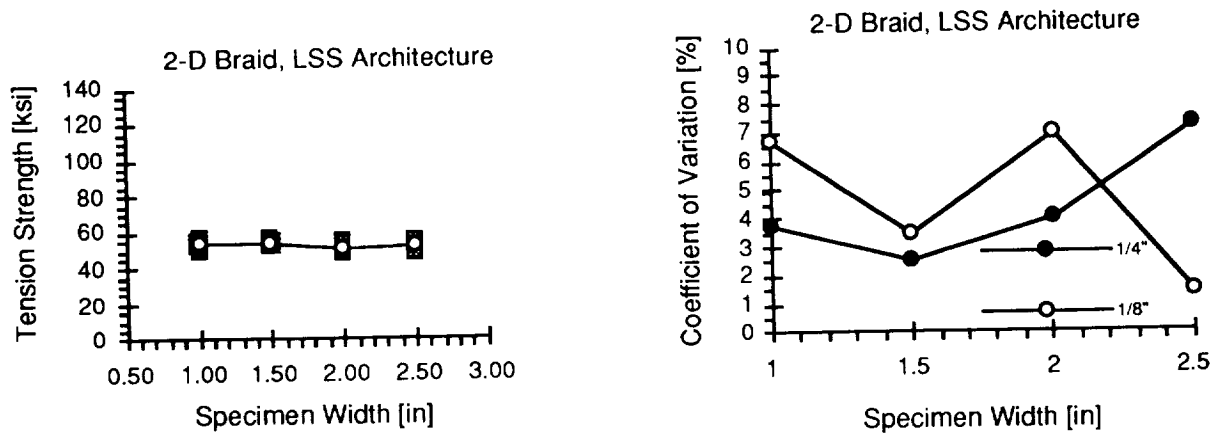


Figure 5.2.d Effect of Specimen Width on Tensile Strength of 2-D Braid LSS.

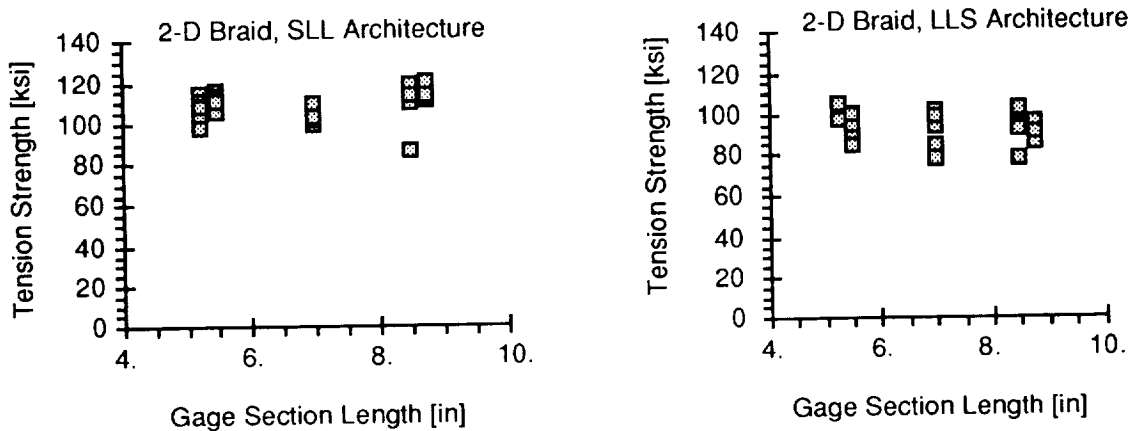


Figure 5.3 Effect of Specimen Length on Tensile Strength of 2-D Braids.

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 [μ s]	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 [μ s]	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

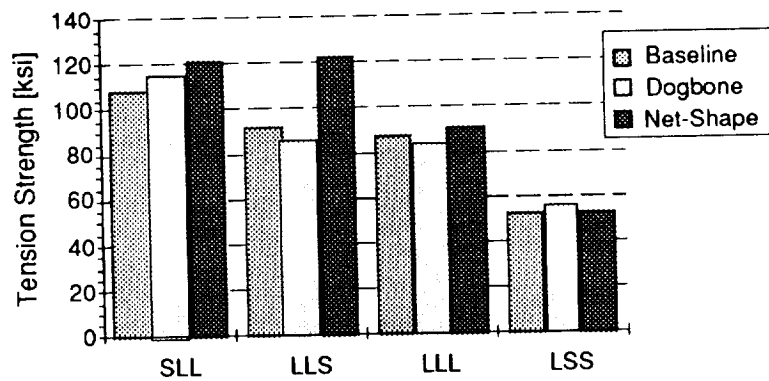


Figure 5.4 Tensile Strength of Baseline, Dogbone and Net-Shape 2-D Braided Specimens.

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.

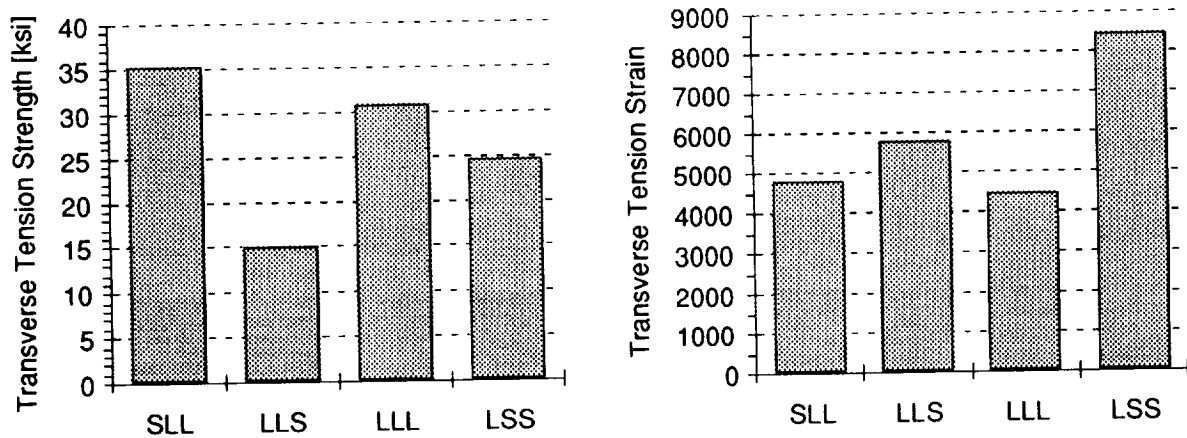


Figure 5.5 Transverse Tension Strength and Nominal Strain for 2-D Braided Materials.

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 [μ s]	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 Stitched Uniweave Materials

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 [μ s]	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

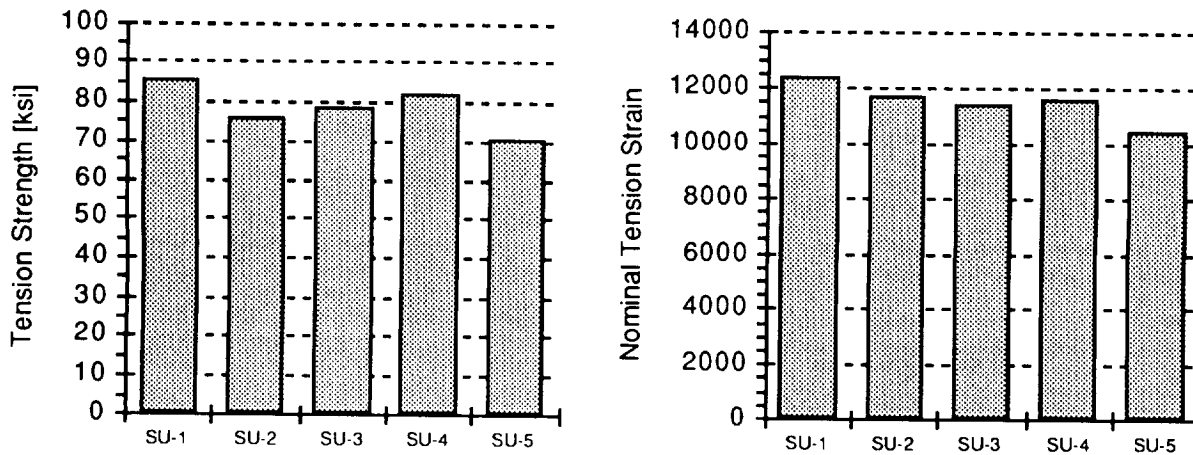


Figure 5.6 Summary of Longitudinal Tension Strengths and Nominal Strains of Stitched Uniweave Materials.

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 [μ s]	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

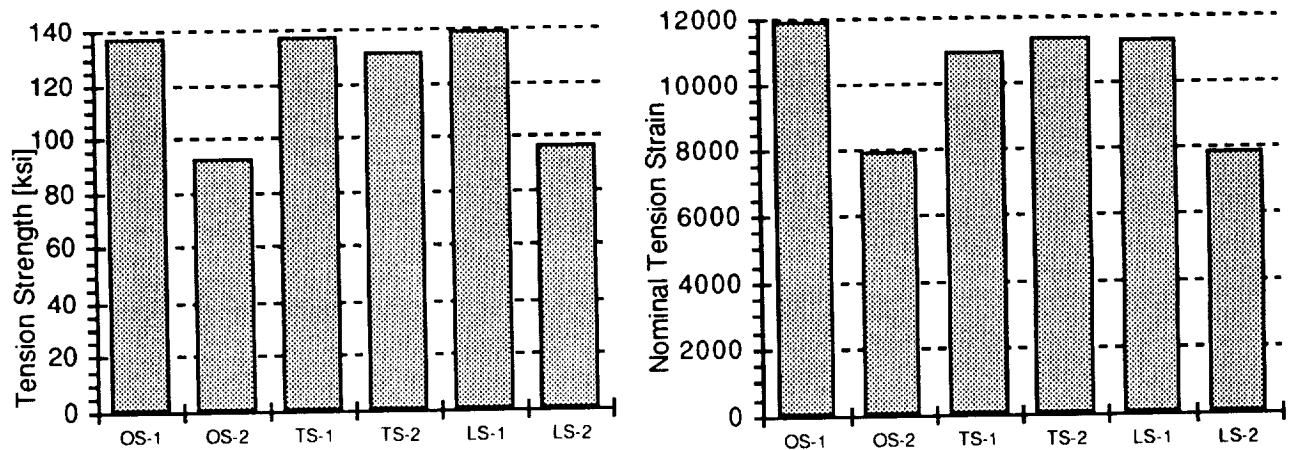


Figure 5.7 Comparison of Longitudinal Tension Strengths and Nominal Strains of 3-D Woven Materials.

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.

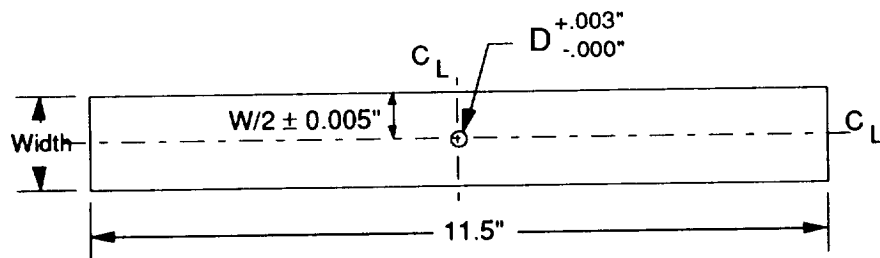


Figure 6.1 Open Hole Specimen Configuration.

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.

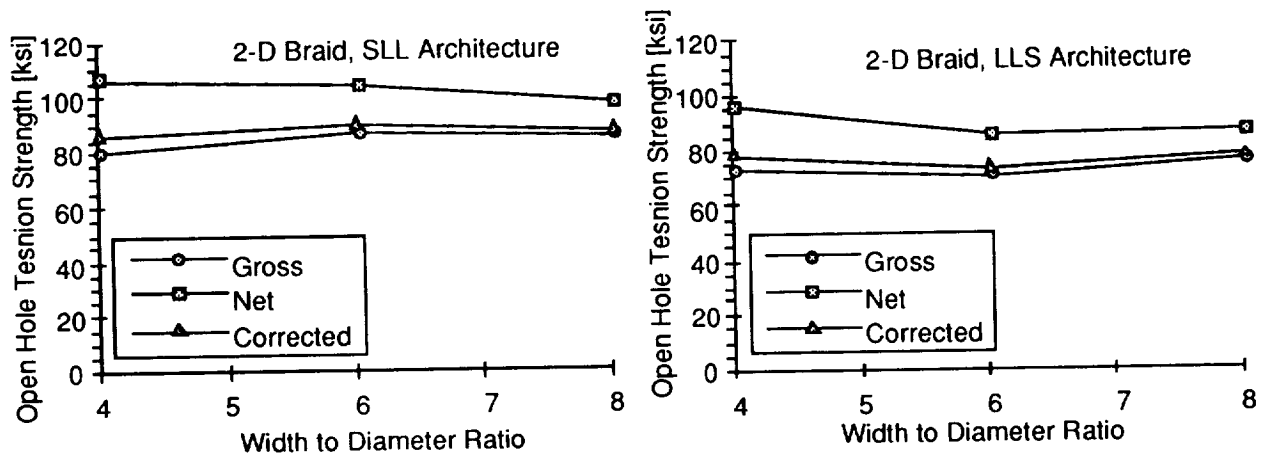


Figure 6.2 Comparison of Gross, Net and Corrected Stress in SLL and LLS 1/8" Thick Specimens with a 3/8" Diameter Hole.

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.

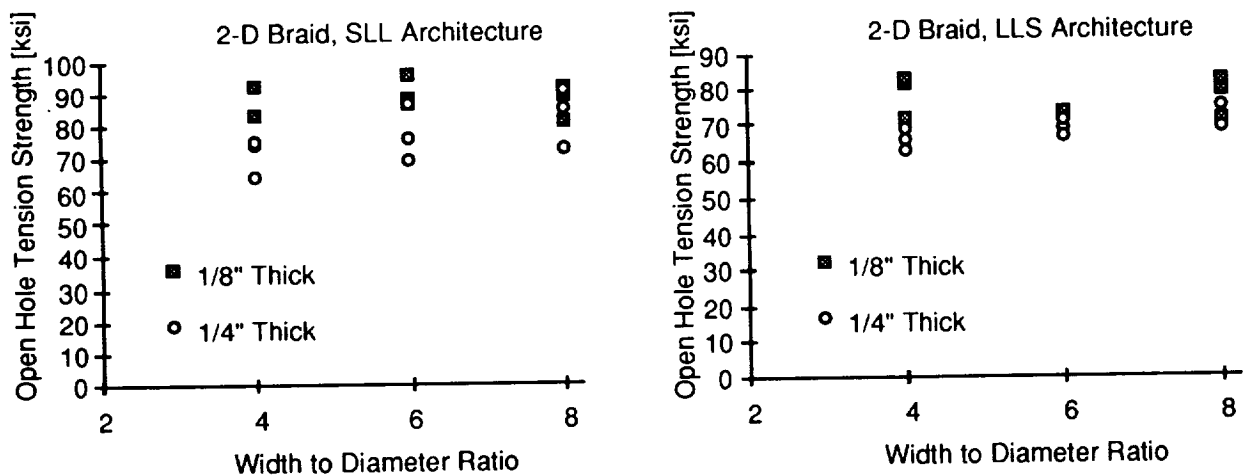


Figure 6.3 Comparison of Open Hole Tensile Strength in SLL and LLS 1/8" and 1/4" Thick Specimens with a 3/8" Diameter Hole.

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.

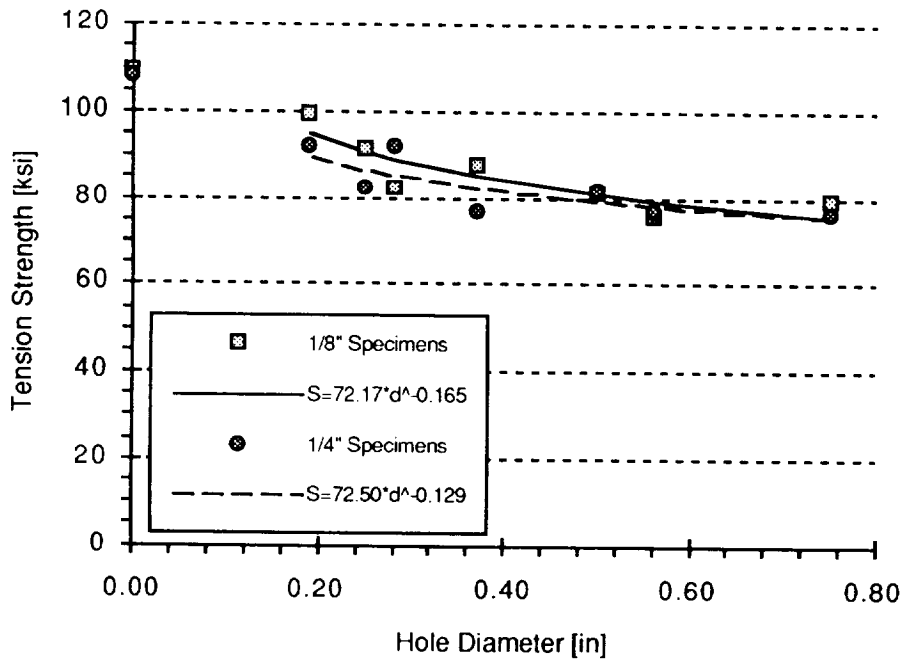


Figure 6.4.a Effect of Hole Diameter on Tension Strength of SLL Specimens.

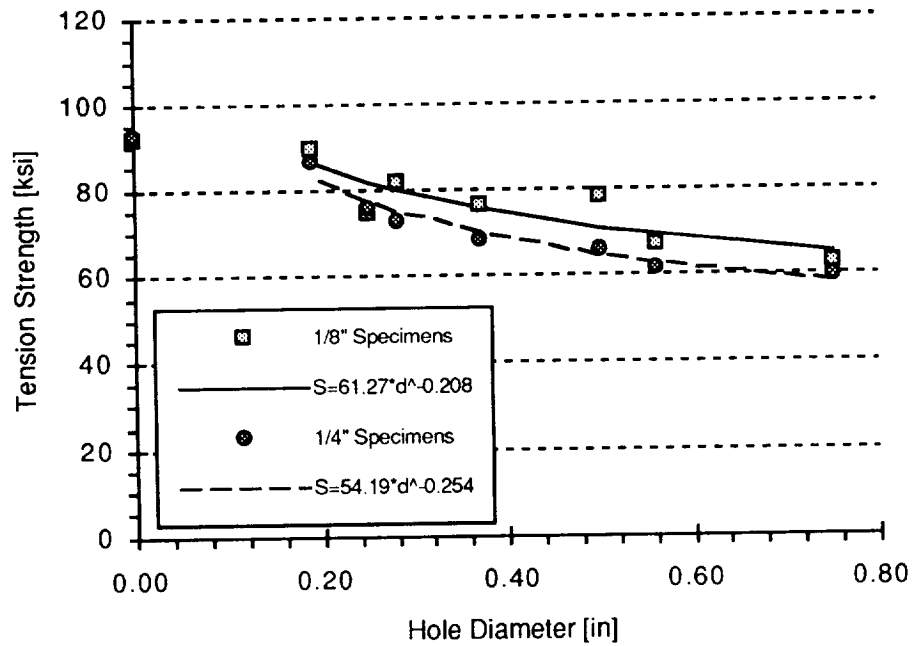


Figure 6.4.b Effect of Hole Diameter on Tension Strength of LLS Specimens.

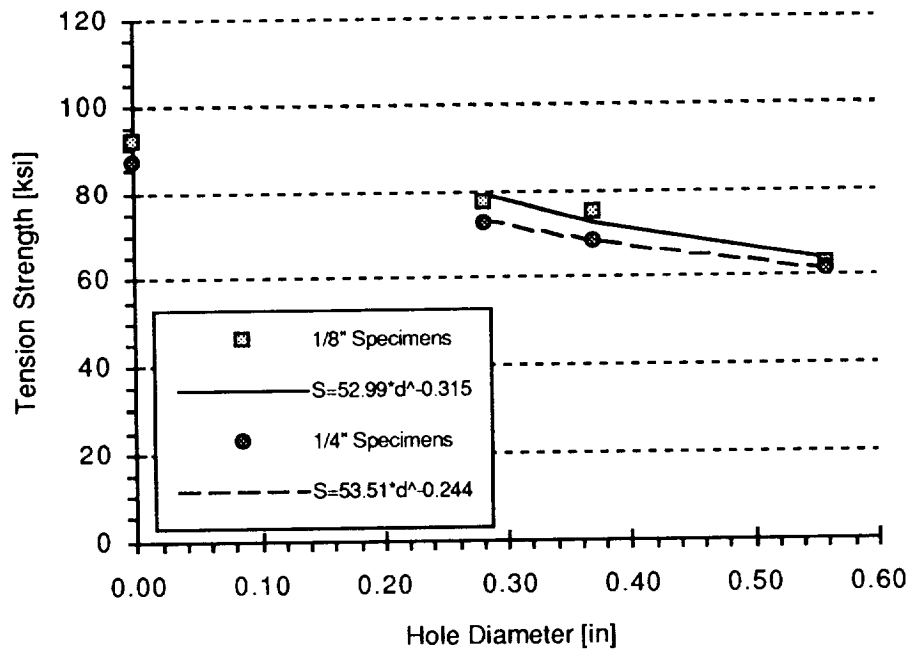


Figure 6.4.c Effect of Hole Diameter on Tension Strength of LLL Specimens.

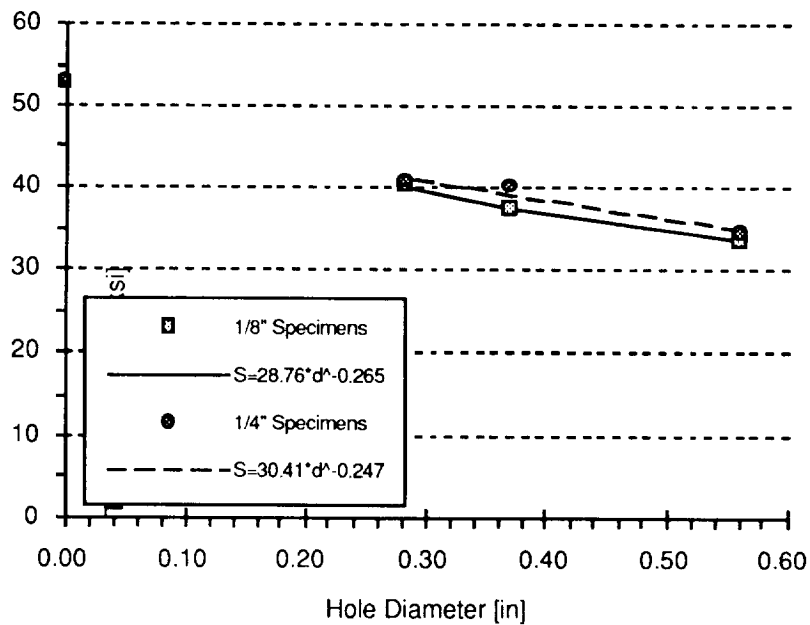


Figure 6.4.d Effect of Hole Diameter on Tension Strength of LSS Specimens.

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

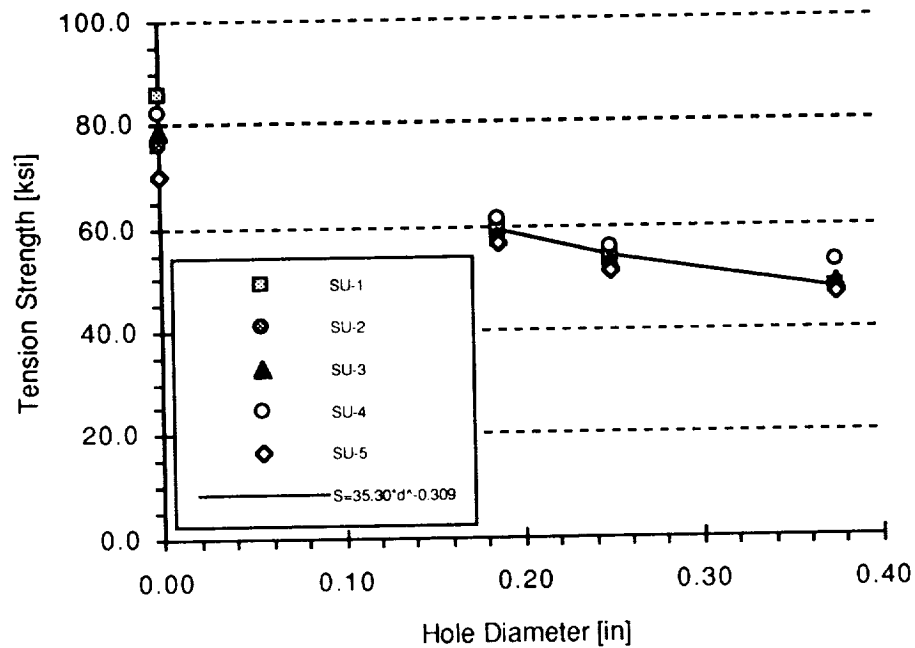


Figure 6.5 Effect of Hole Diameter on Open Hole Tension Strength of Stitched-Uniweave Materials.

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 W/D = 4	Strength [ksi]	59.2	58.0	58.0	61.3	56.6
	CoV [%]	0.9	1.8	4.6	0.9	2.8
0.250 W/D = 6	Strength [ksi]	54.1	52.4	53.0	55.9	51.4
	CoV [%]	2.8	0.8	7.1	2.0	2.7
0.375 W/D = 8	Strength [ksi]	47.8	47.0	48.5	52.6	46.8
	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.

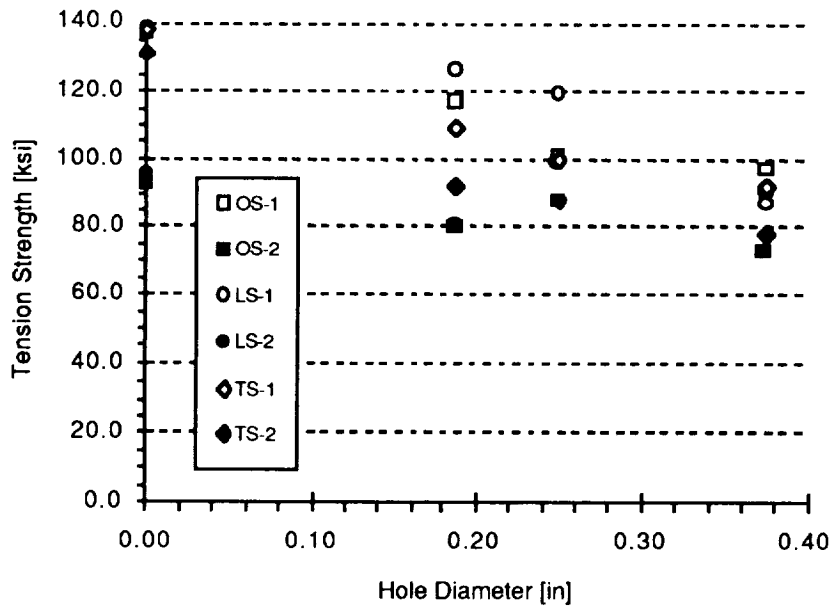


Figure 6.6 Open Hole Tension Strength Data for 3-D Woven Materials.

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

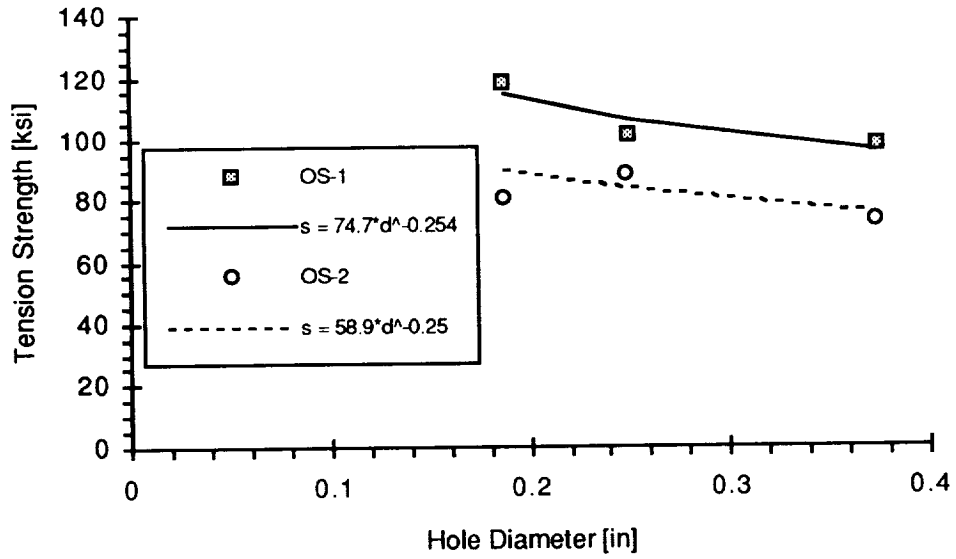


Figure 6.7.a Effect of Hole Diameter on Open Hole Tension Strength of 3-D Woven Materials OS-1 and OS-2.

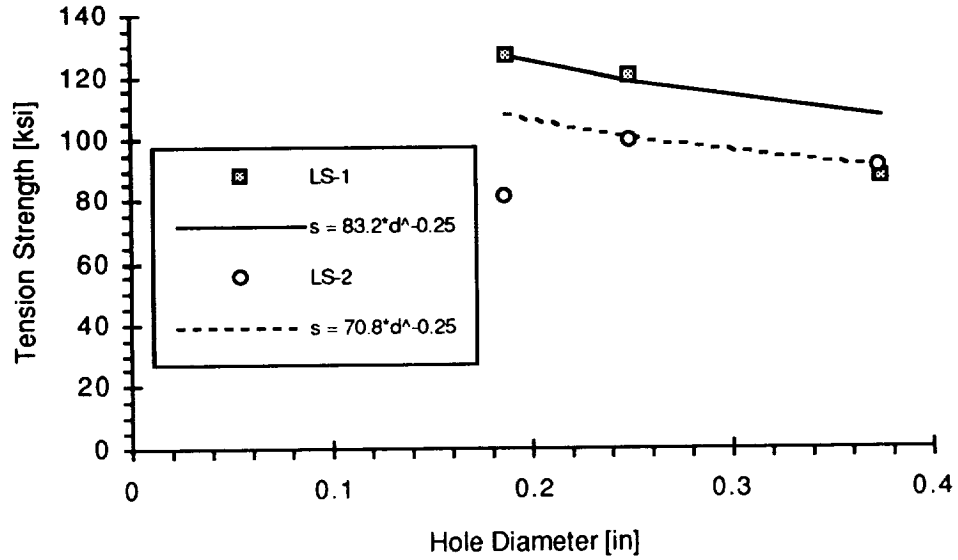


Figure 6.7.b Effect of Hole Diameter on Open Hole Tension Strength of 3-D Woven Materials LS-1 and LS-2.

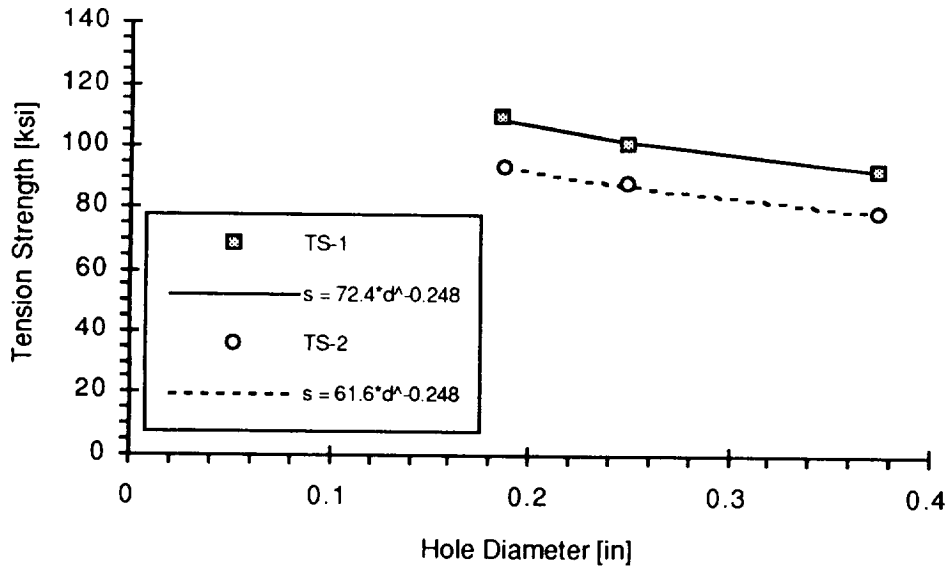


Figure 6.7.c Effect of Hole Diameter on Open Hole Tension Strength of 3-D Woven Materials TS-1 and TS-2.

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.

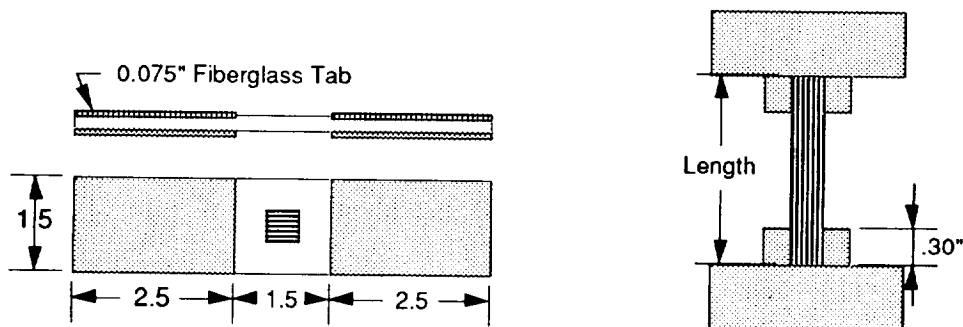


Figure 7.1.a Modified IITRI Specimen and NASA Short Block Specimen.

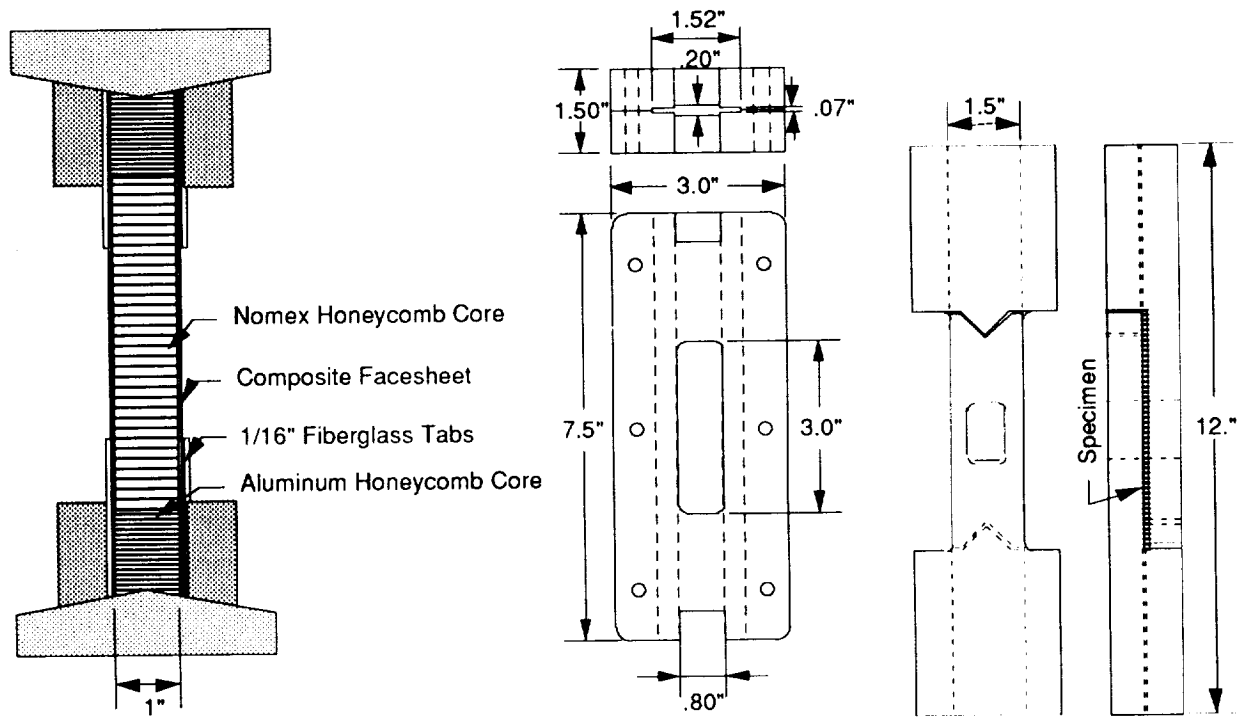


Figure 7.1.b Sandwich Column Specimen, Zabora Fixture and Boeing OHC Fixture .

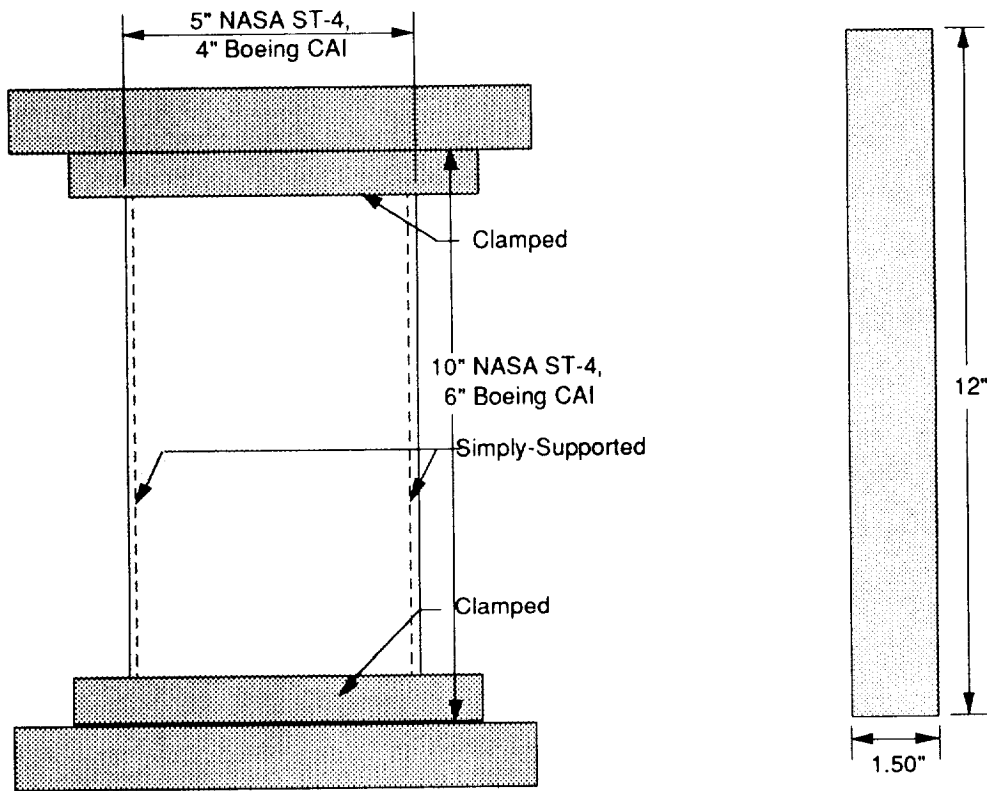


Figure 7.1.c NASA ST-4 or Boeing CAI Specimen and Boeing OHC or Zabora Fixture Specimen.

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.

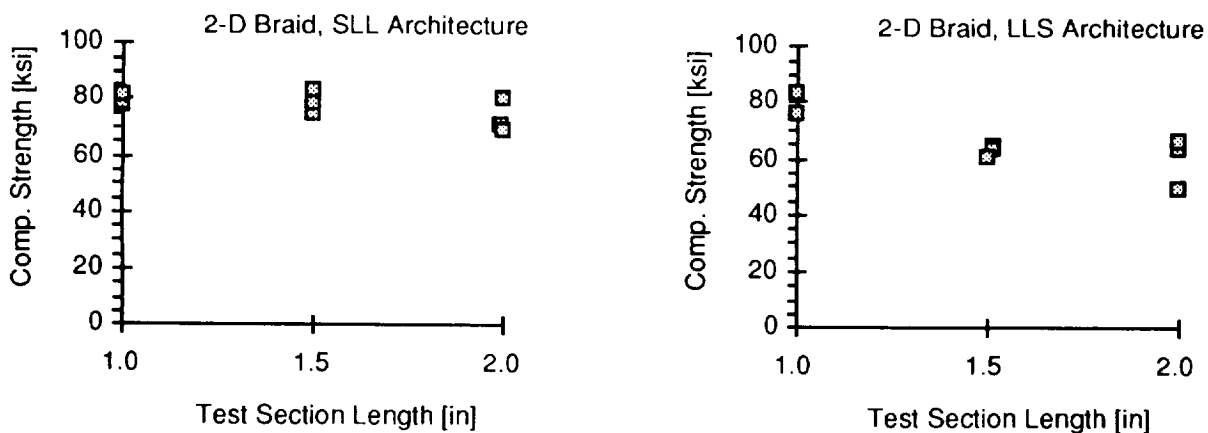


Figure 7.2 Test Section Length Effect on Compression Strength in NASA Short Block Test Configuration.

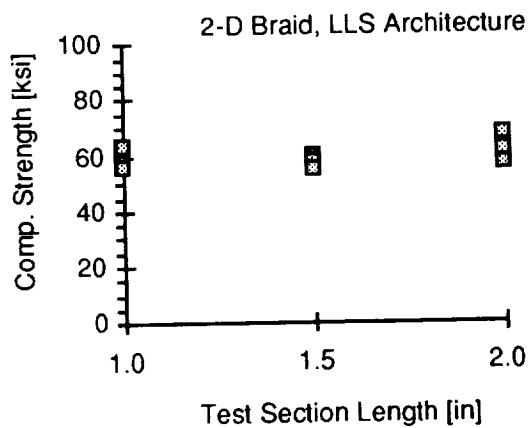
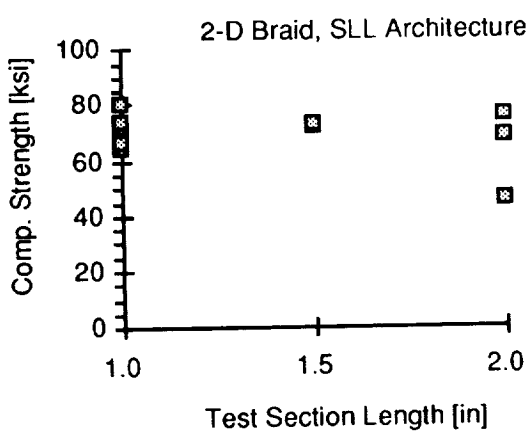


Figure 7.3 Test Section Length Effect on Compression Strength in modified IITRI Test Configuration.

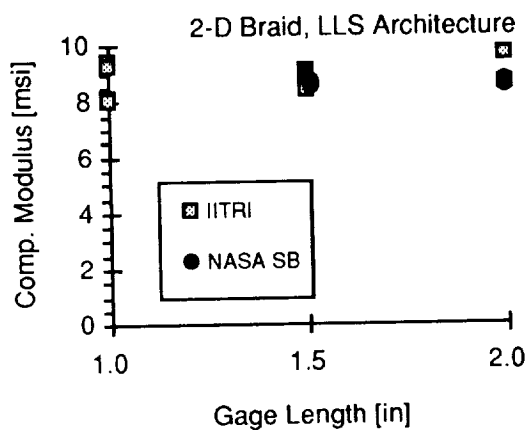
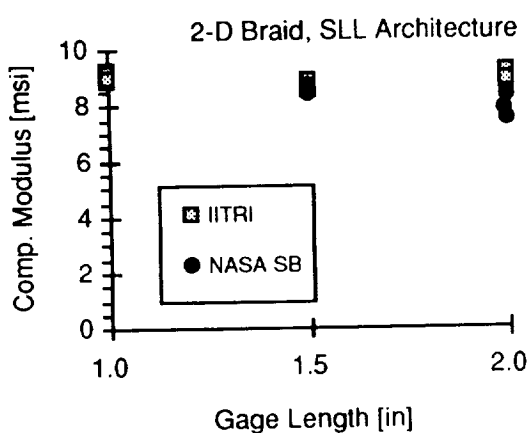


Figure 7.4 Test Section Length Effect on Compression Modulus in NASA Short Block and modified IITRI Test Configurations.

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.

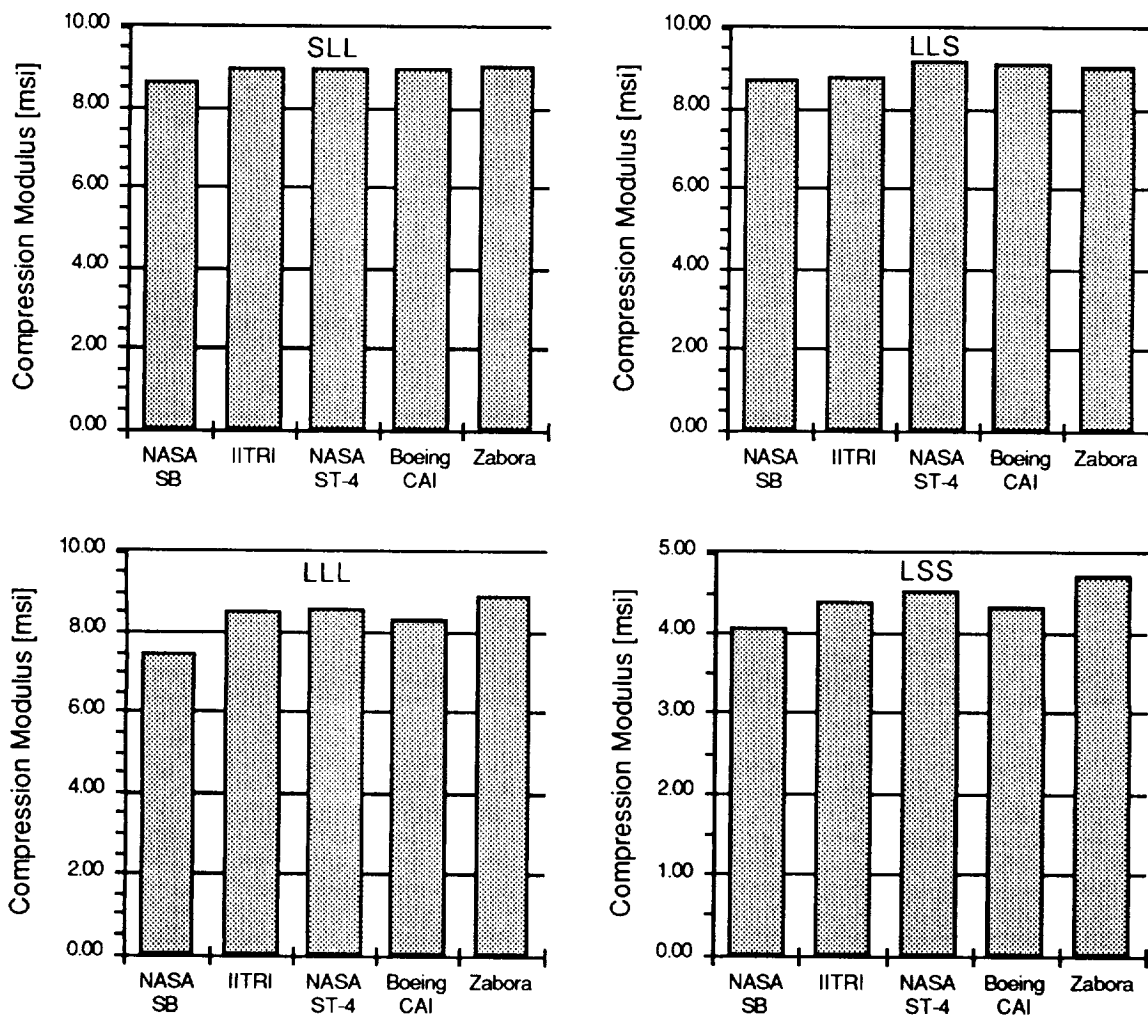


Figure 7.5 Compression Modulus of 2-D Braided Materials.

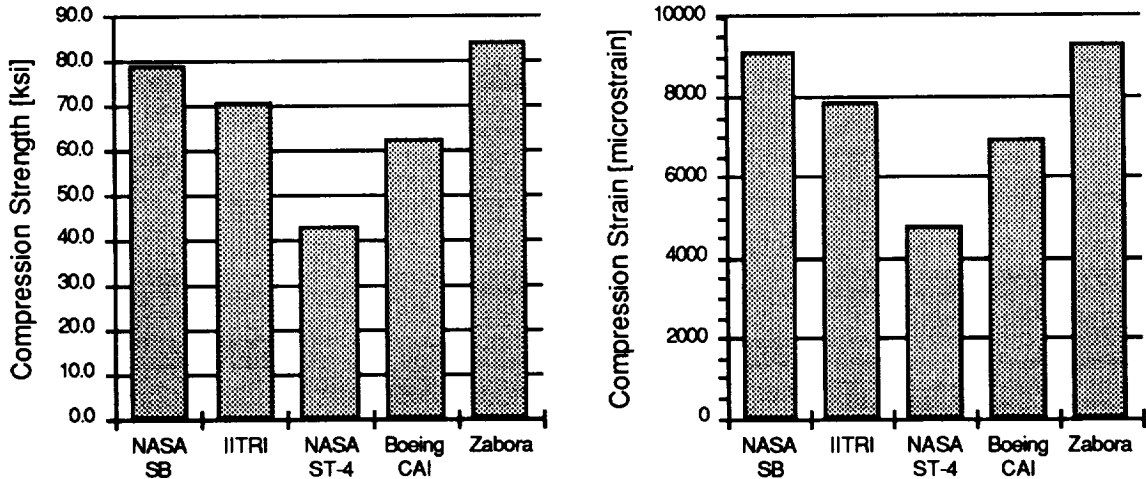


Figure 7.6.a Compression Strength and Nominal Strain of SLL Braid

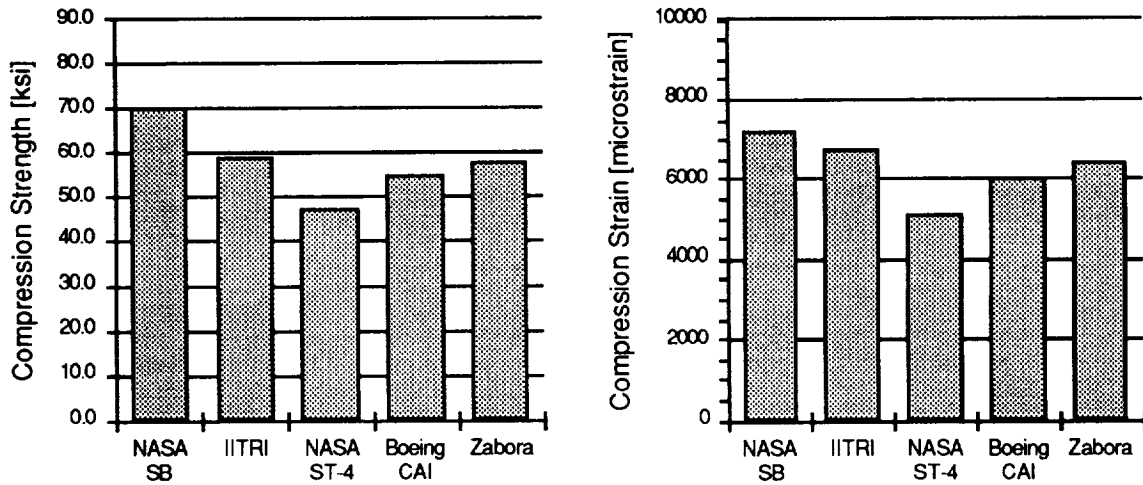


Figure 7.6.b Compression Strength and Nominal Strain of LLS Braid

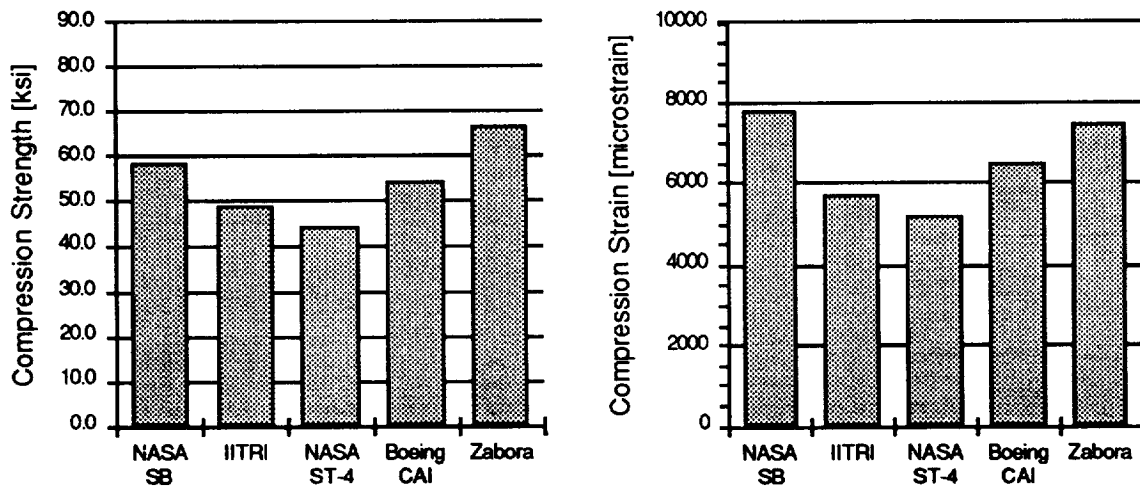


Figure 7.6.c Compression Strength and Nominal Strain of LLL Braid

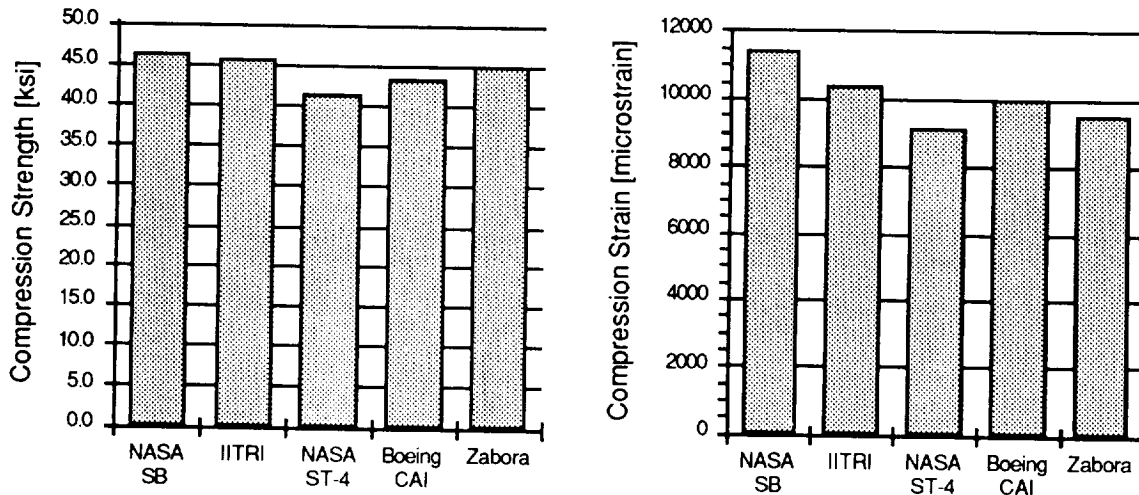


Figure 7.6.d Compression Strength and Nominal Strain of LSS Braid

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 [μ s]	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 [μ s]	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 [μ s]	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 [μ s]	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 [μ s]	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-1 material 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 [μ s]	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 [μ s]	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 [μ s]	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 interlock (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 [μ s]	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 [μ s]	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 [μ s]	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

Material	Property	Test Method					
		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

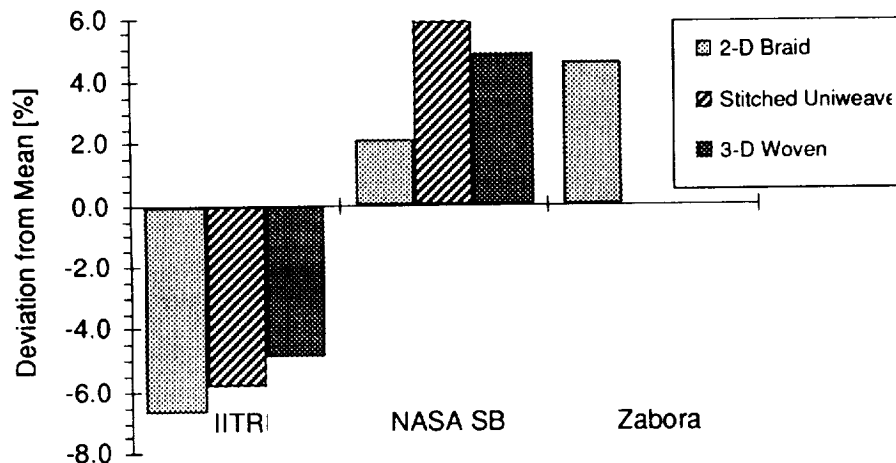


Figure 7.7 Deviation from Mean Strength for Unnotched Compression Test Methods.

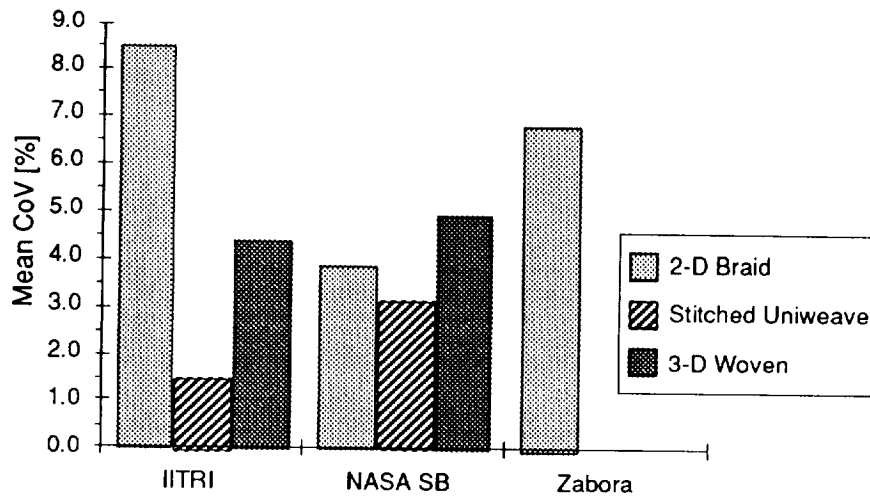


Figure 7.8 Mean Strength CoVs for Unnotched Compression Test Methods.

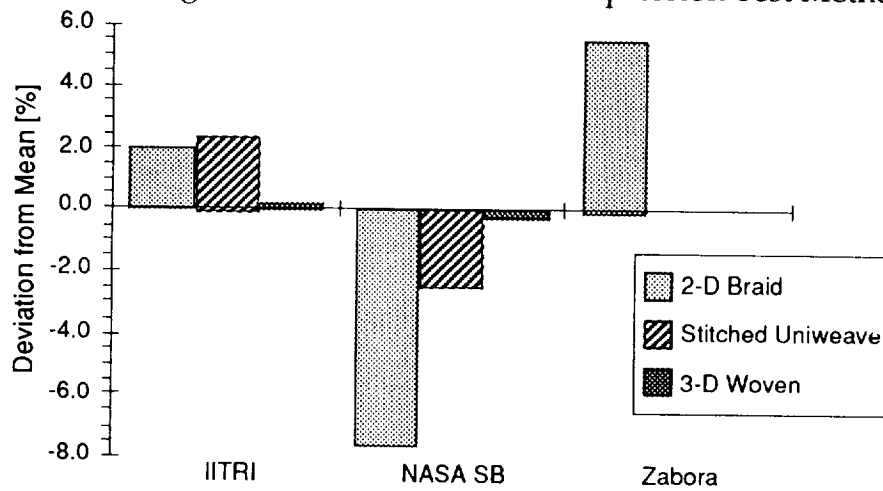


Figure 7.9 Deviation from Mean Modulus for Unnotched Compression Test Methods.

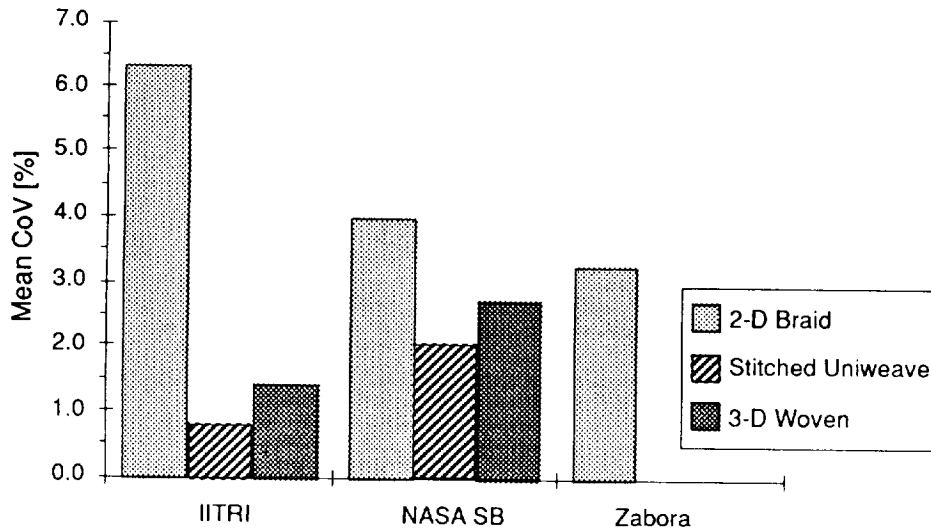


Figure 7.10 Mean Modulus CoVs for Unnotched Compression Test Methods.

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.

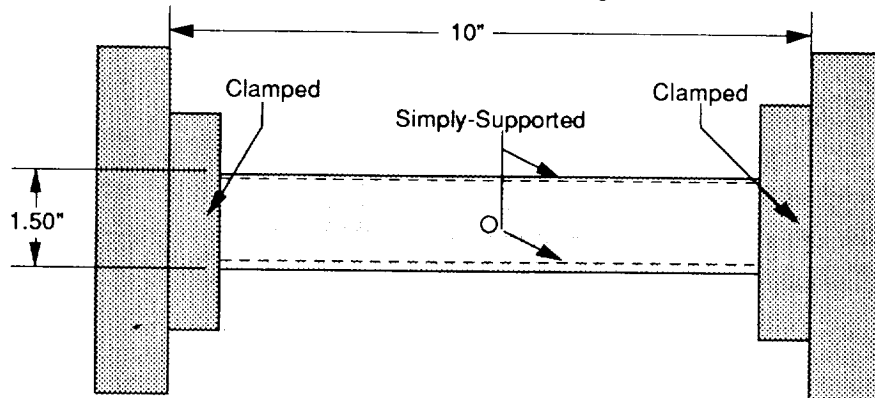


Figure 8.1 NASA 1142 Specimen Configuration.

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.

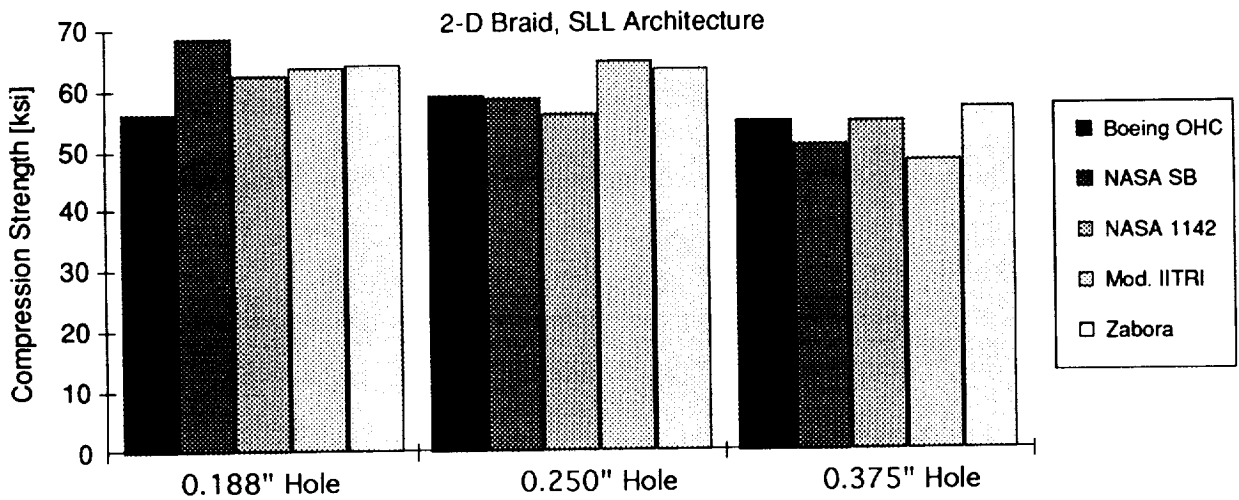


Figure 8.2.a Comparison of Open Hole Compression Strength for Various Test Methods of SLL Materials.

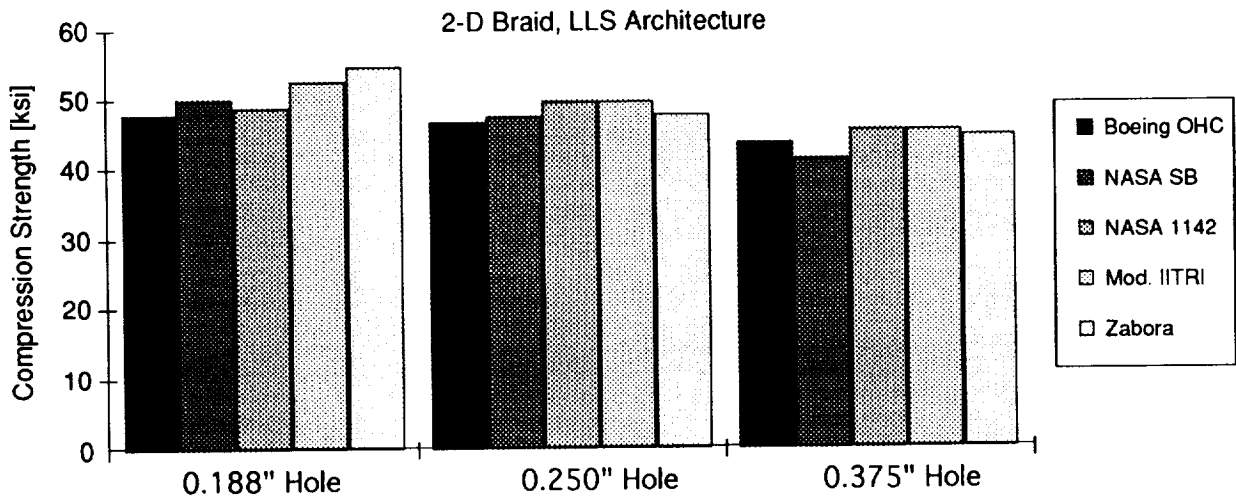


Figure 8.2.b Comparison of Open Hole Compression Strength for Various Test Methods of LLS Materials.

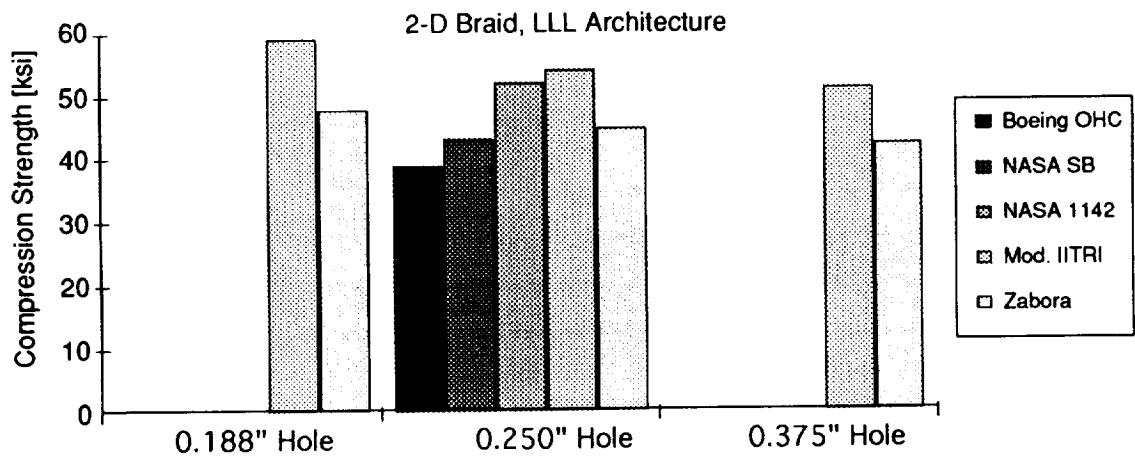


Figure 8.2.c Comparison of Open Hole Compression Strength for Various Test Methods of LLL Materials.

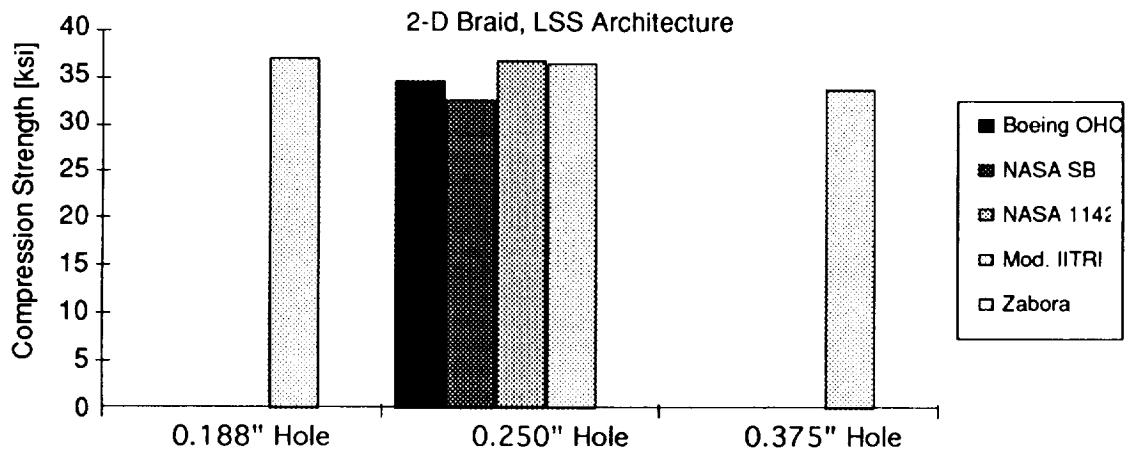


Figure 8.2.d Comparison of Open Hole Compression Strength for Various Test Methods of LSS Materials.

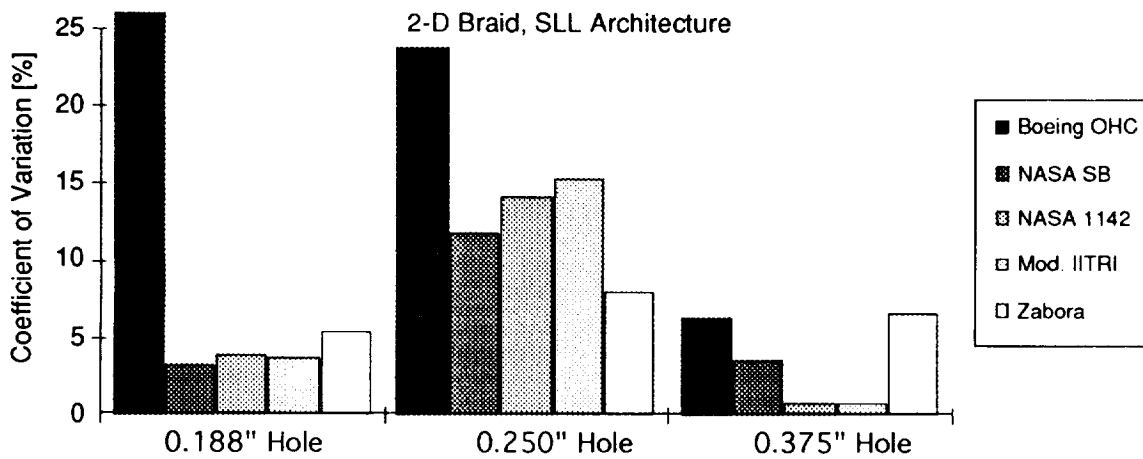


Figure 8.3.a Comparison of Coefficient of Variations for Open Hole Compression Test Methods of SLL Materials.

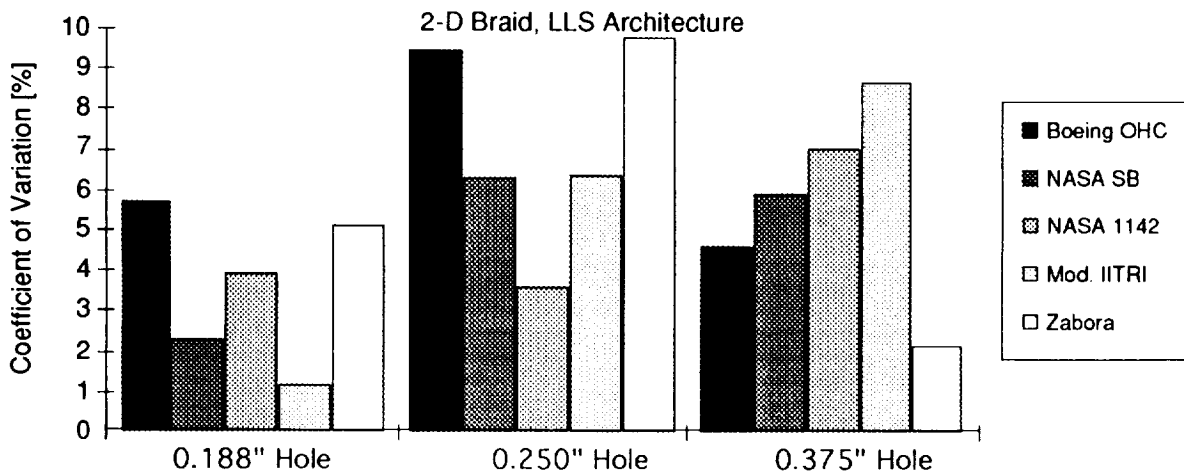


Figure 8.3.b Comparison of Coefficient of Variations for Open Hole Compression Test Methods of LLS Materials.

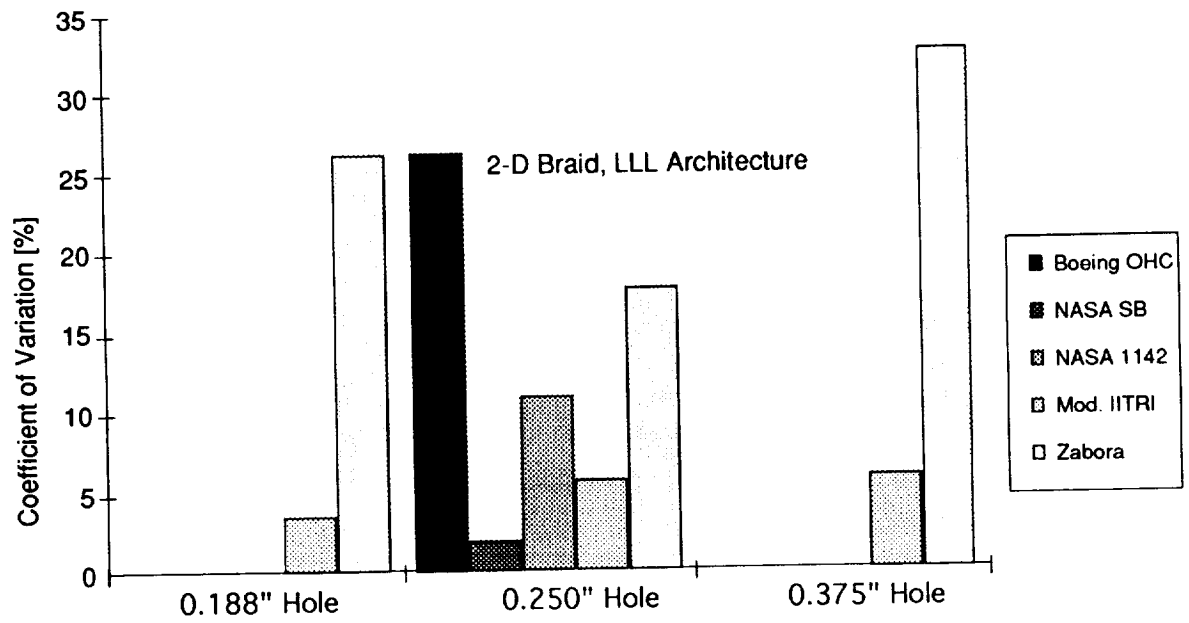


Figure 8.3.c Comparison of Coefficient of Variations for Open Hole Compression Test Methods of LLL Materials.

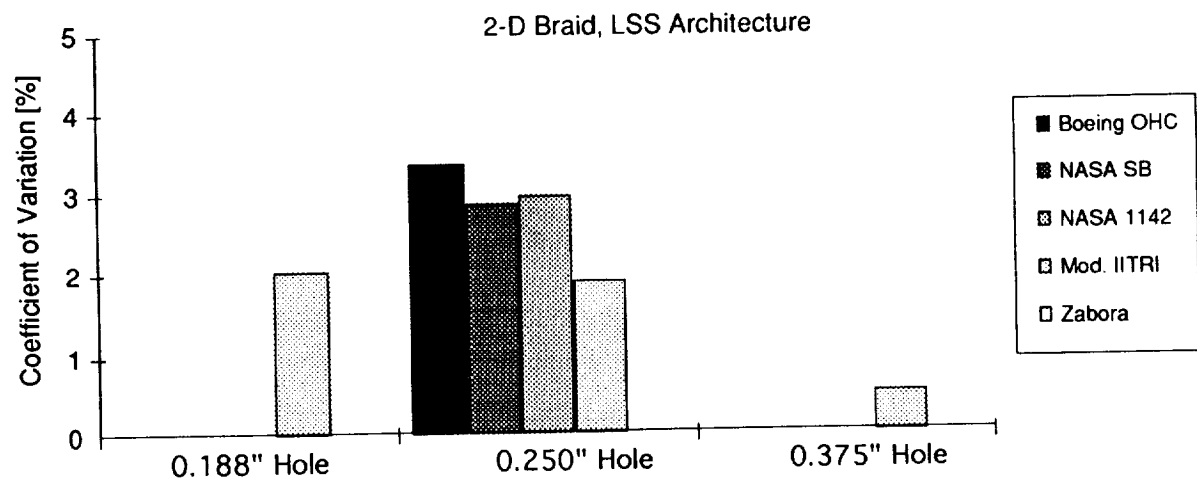


Figure 8.3.d Comparison of Coefficient of Variations for Open Hole Compression Test Methods of LSS Materials.

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

D [in]	SLL			LLS			LLL			LSS		
	Stress [ksi]	Strain	CoV [%]	Stress [ksi]	Strain	CoV [%]	Stress [ksi]	Strain	CoV [%]	Stress [ksi]	Strain	CoV [%]
<i>Boeing Open Hole Compression</i>												
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						
<i>NASA Short Block</i>												
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						
<i>NASA 1142 Fixture</i>												
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						
<i>Modified IITRI Specimen</i>												
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
<i>Zabora Fixture</i>												
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			
<i>Boeing CAI Fixture</i>												
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						
<i>NASA ST-4 Fixture</i>												
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.

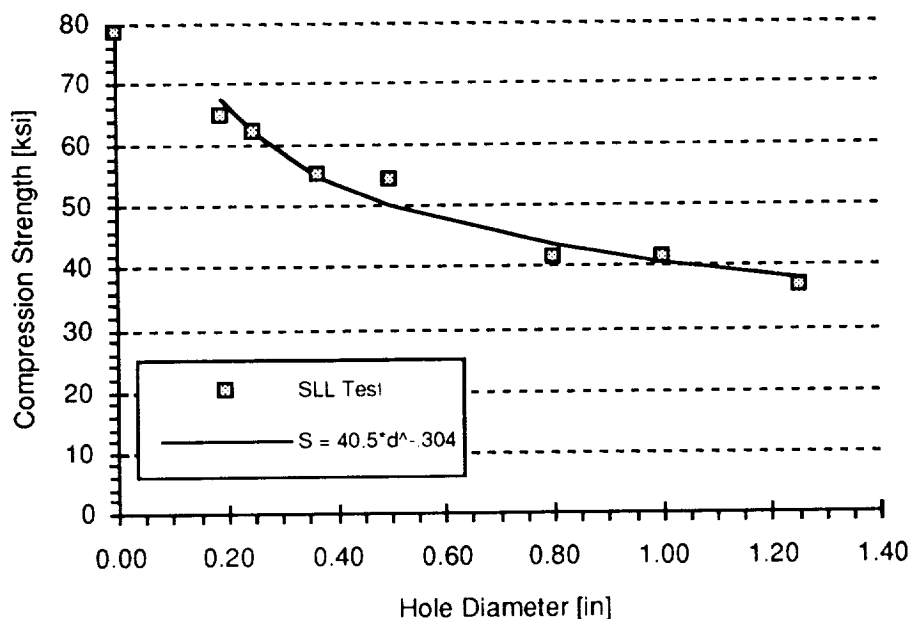


Figure 8.4.a Effect of Hole Diameter on Open Hole Compression Strength of 2-D Braided Materials SLL.

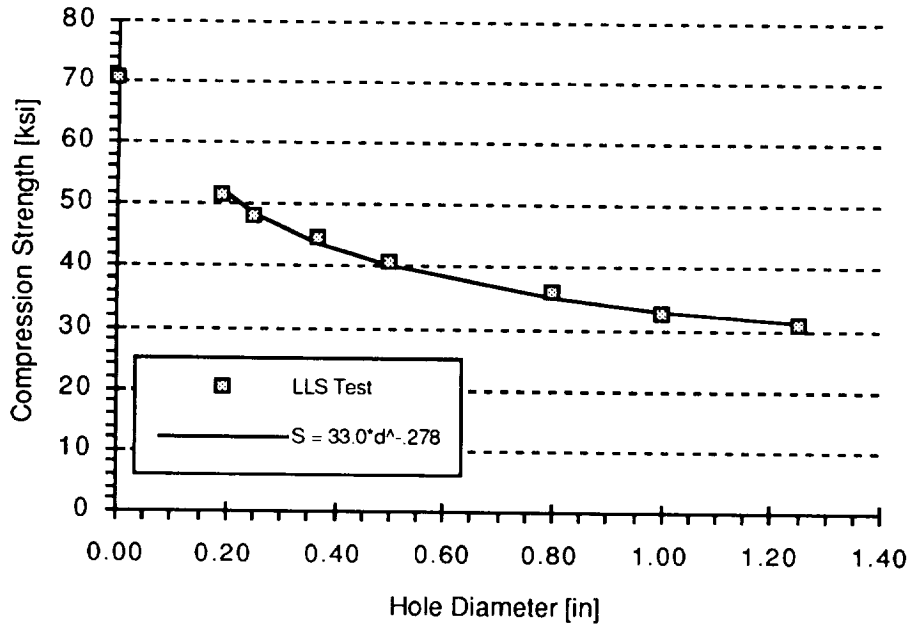


Figure 8.4.b Effect of Hole Diameter on Open Hole Compression Strength of 2-D Braided Materials LLS.

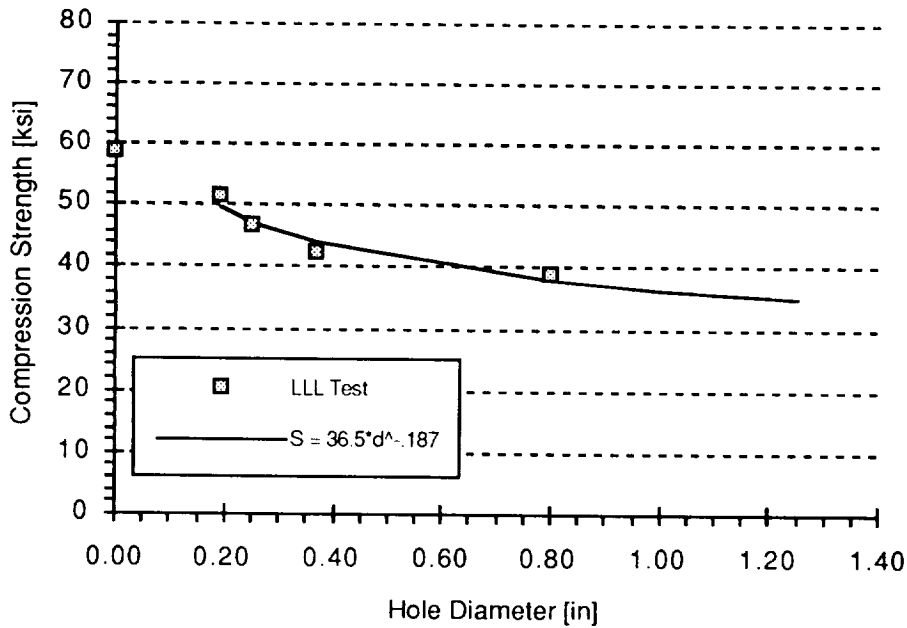


Figure 8.4.c Effect of Hole Diameter on Open Hole Compression Strength of 2-D Braided Material LLL.

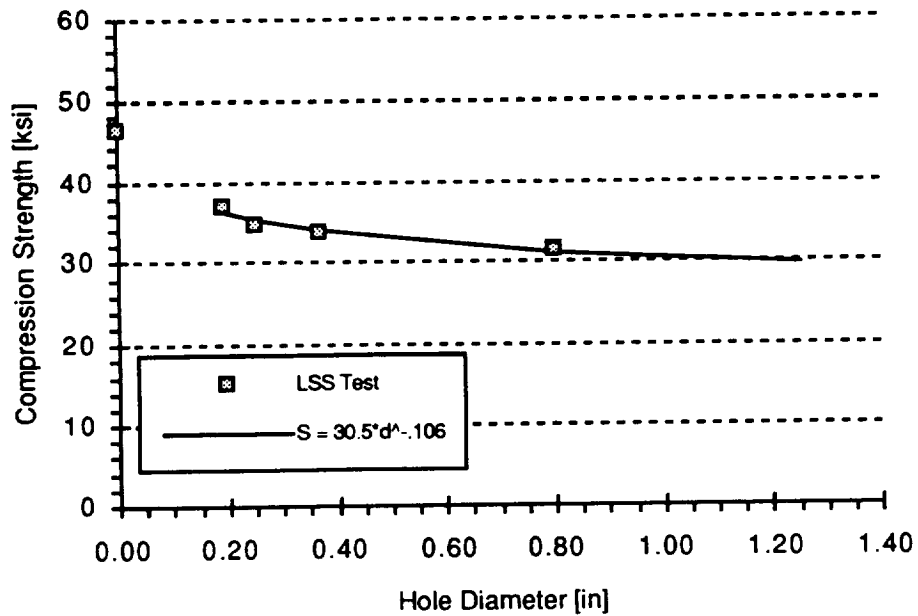


Figure 8.4.d Effect of Hole Diameter on Open Hole Compression Strength of 2-D Braided Material LSS.

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

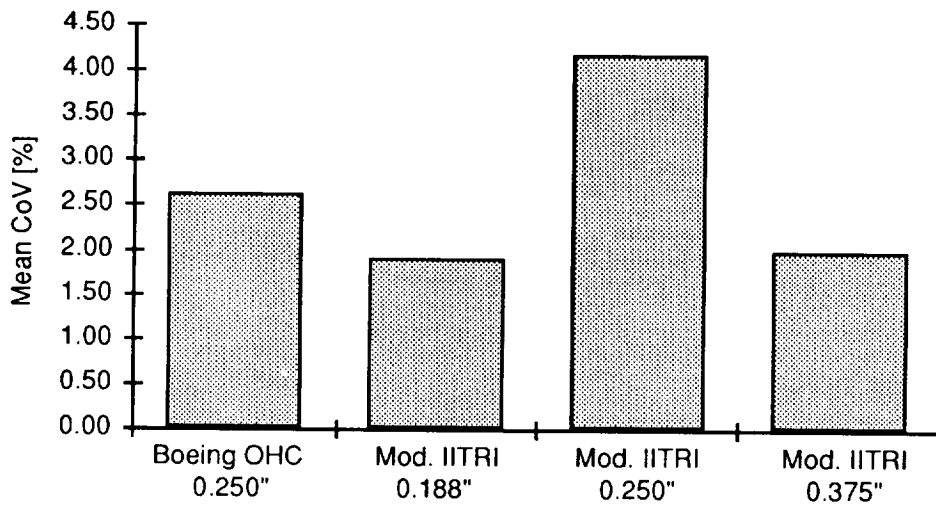


Figure 8.5 Comparison of Mean Coefficient of Variation for all Stitched Uniweave Open Hole Compression Tests.

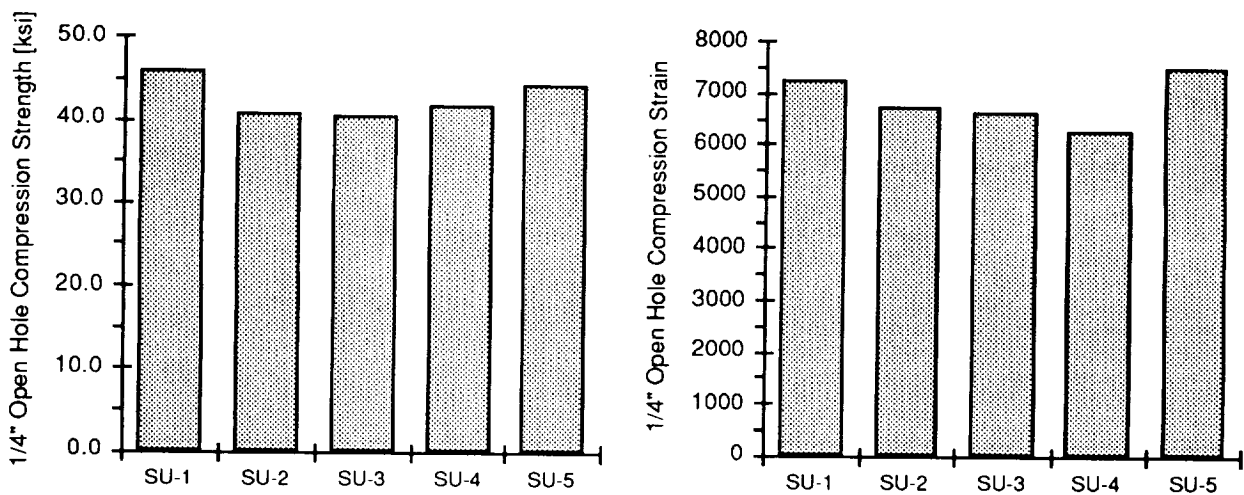


Figure 8.6 Comparison of 1/4" Open Hole Compression Strength and Nominal Strains for Stitched Uniweave Materials.

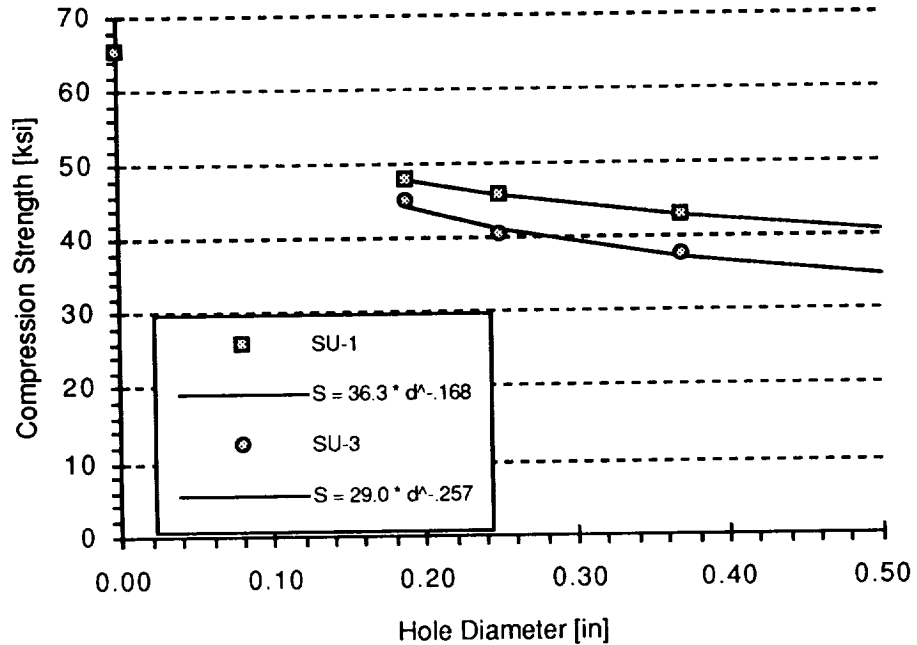


Figure 8.7 Effect of Hole Diameter on Open Hole Compression Strength of Stitched Uniweave Materials.

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

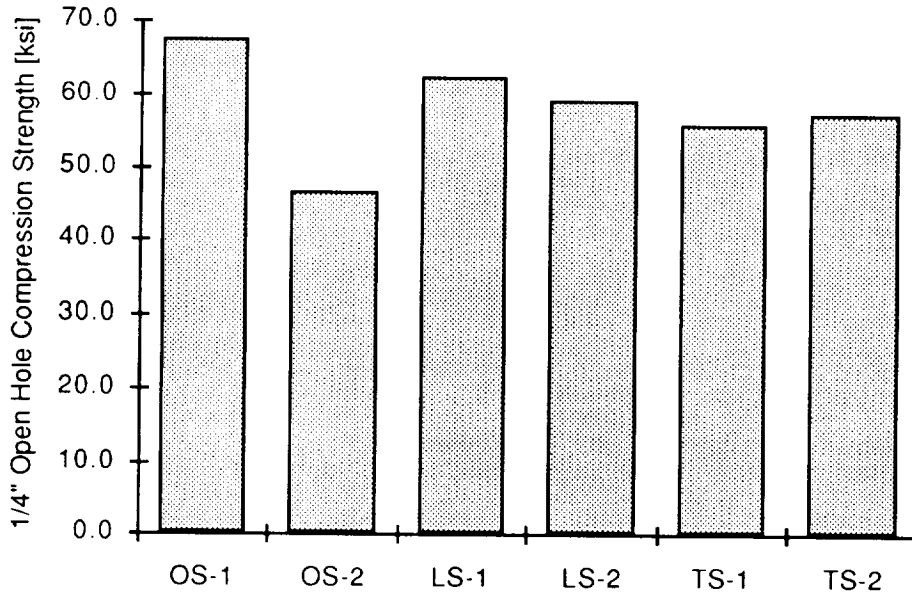


Figure 8.8 Comparison of 1/4" Open Hole Compression Strength for 3-D Woven Materials.

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 %

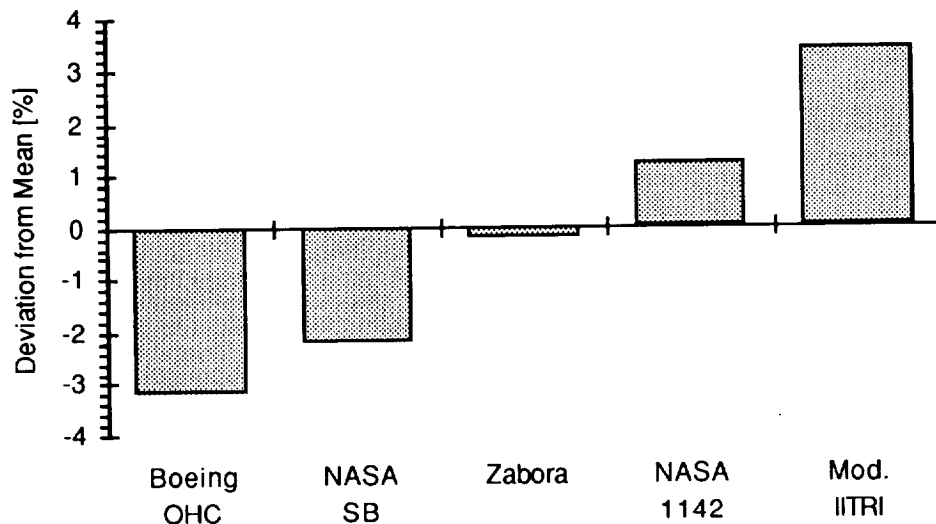


Figure 8.9 Normalized Mean Deviations for Open Hole Compression Test Methods in 2-D Braided Materials.

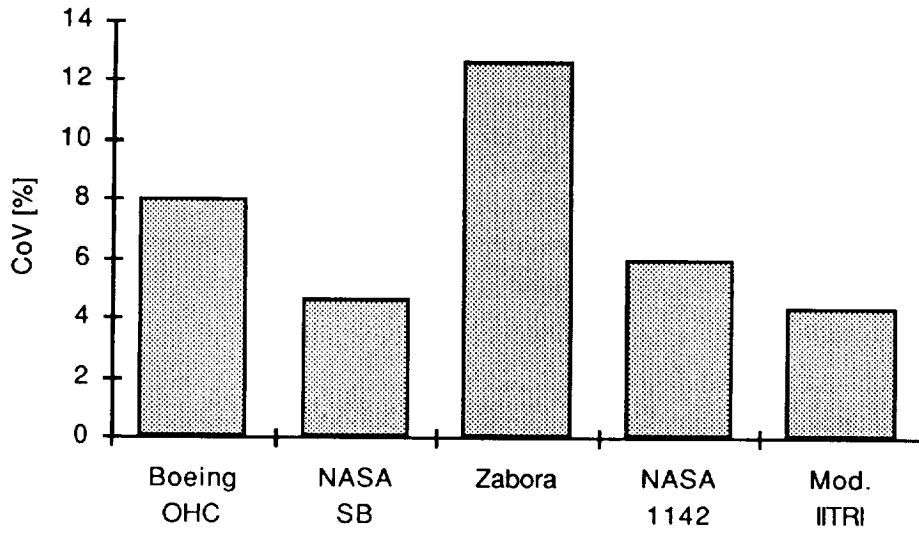


Figure 8.10 CoVs for Open Hole Compression Test Methods in 2-D Braided Materials.

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

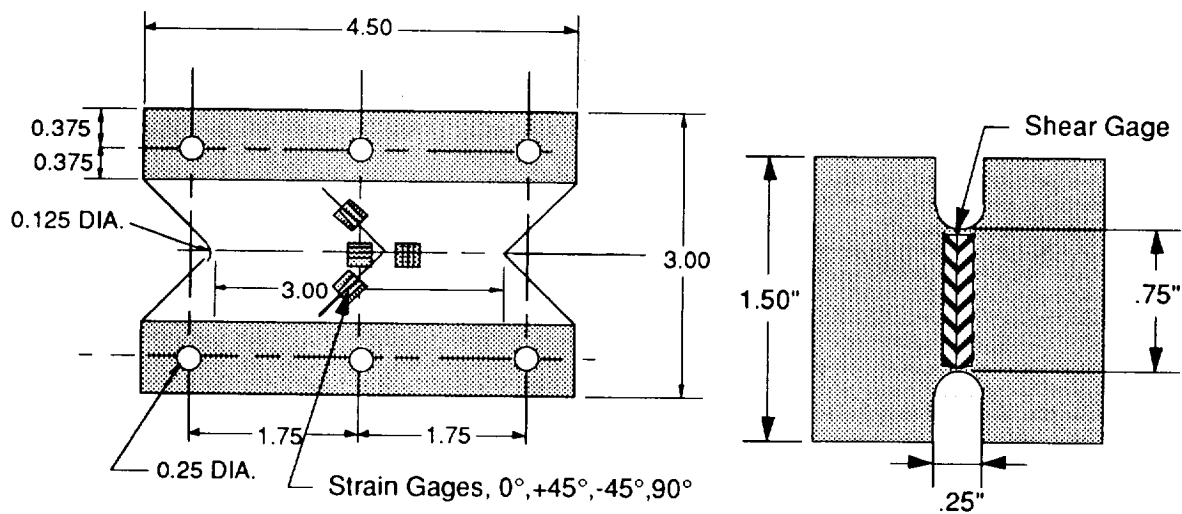


Figure 9.1 Rail Shear Specimen and Compact Shear Specimen.

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 $\theta = 45^\circ$ 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	SLL	LLS	LLS	LLL	LLL	LSS	LSS
	Large	Small	Large	Small	Large	Small	Large	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	SLL	LLS	LLS	LLL	LLL	LSS	LSS
	Rail	Compact	Rail	Compact	Rail	Compact	Rail	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

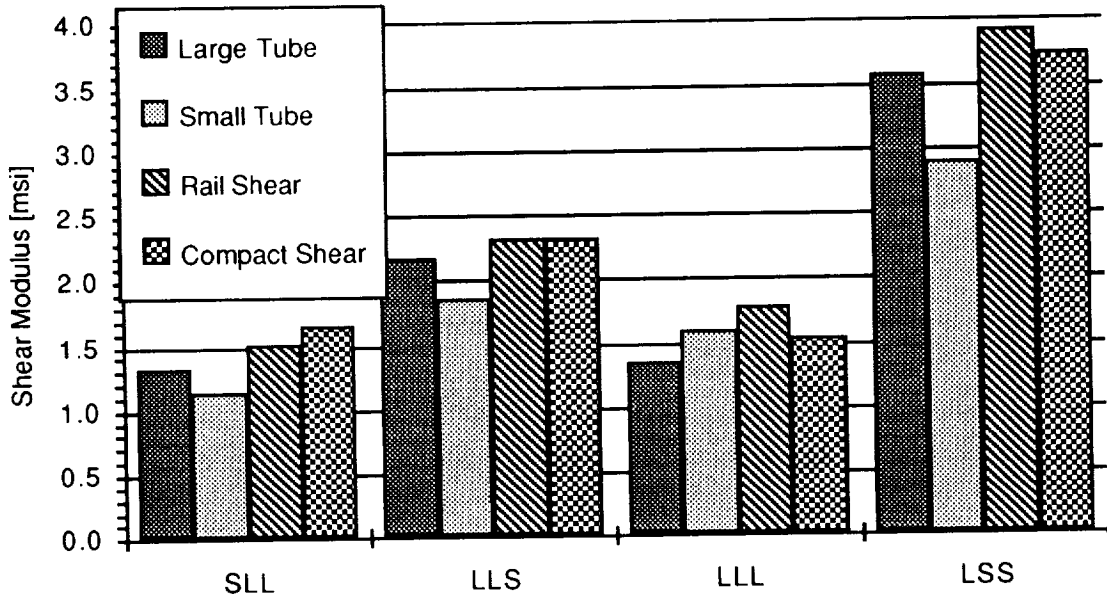


Figure 9.2 Comparison of Shear Modulus by Various Test Methods for 2-D Braided Materials.

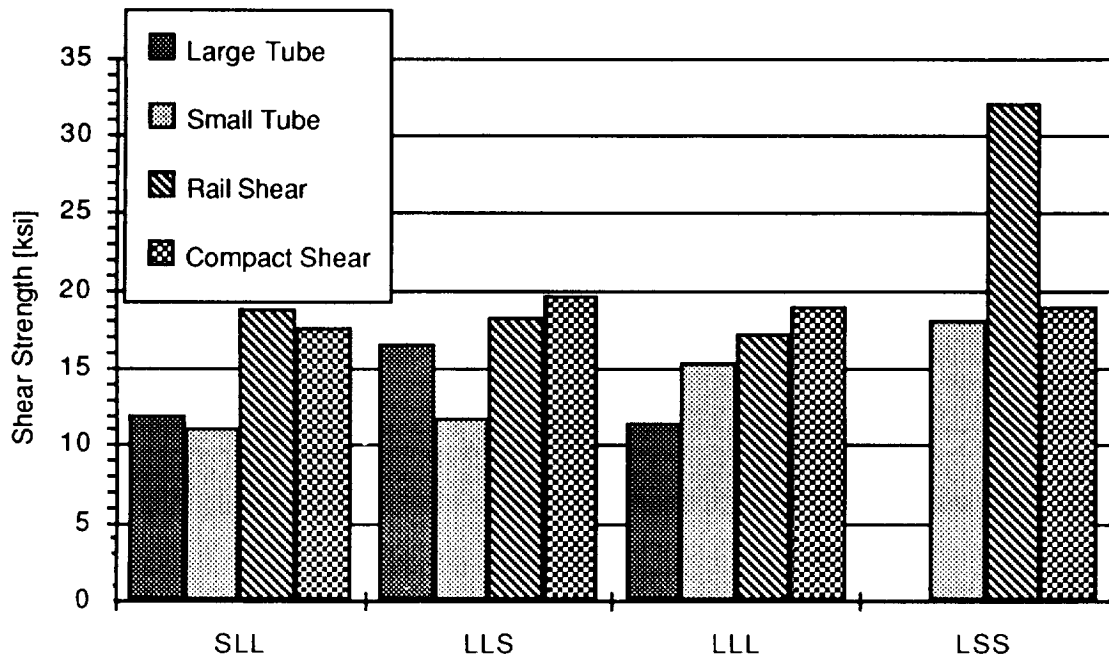


Figure 9.3 Comparison of Shear Strength Various Test Methods for 2-D Braided Materials.

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

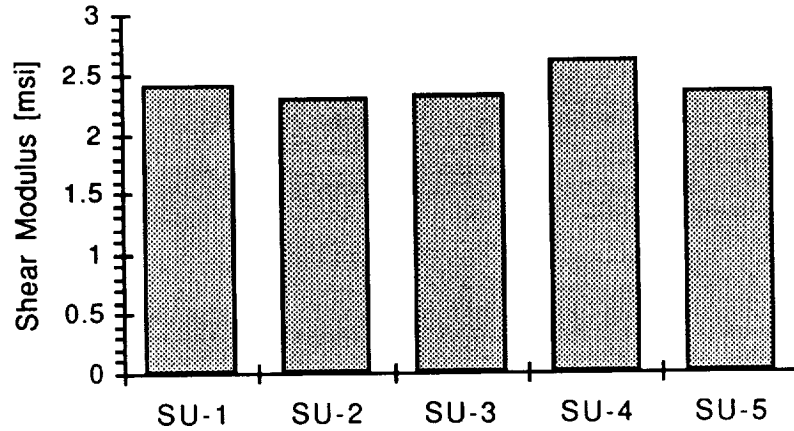


Figure 9.4 Shear Modulus of Stitched Uniweave Materials.

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

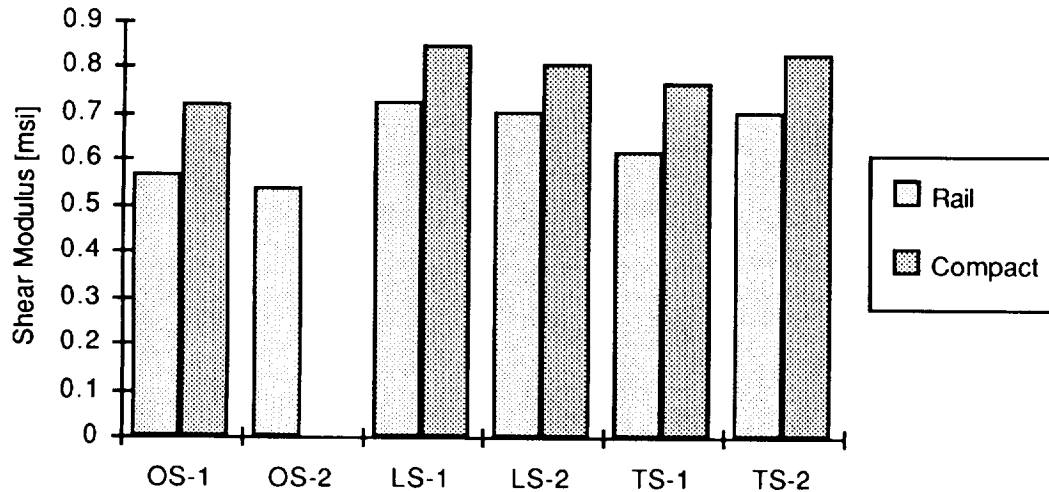


Figure 9.5 Shear Modulus of 3-D Woven Materials with Rail Shear and Compact Shear Specimen Methods.

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 %

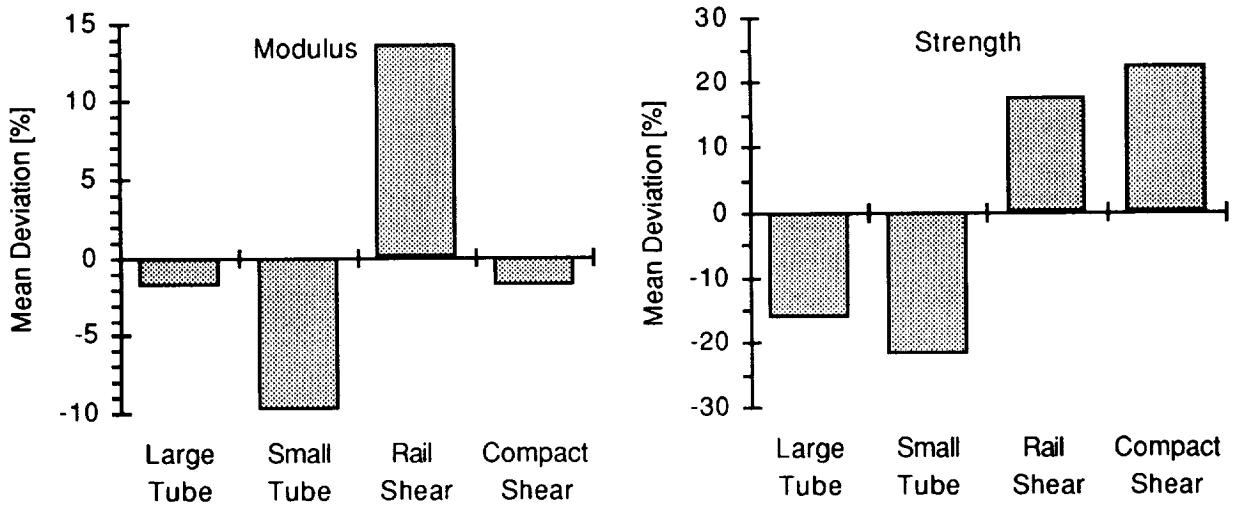


Figure 9.6 Mean Deviations for In-plane Shear Test Methods.

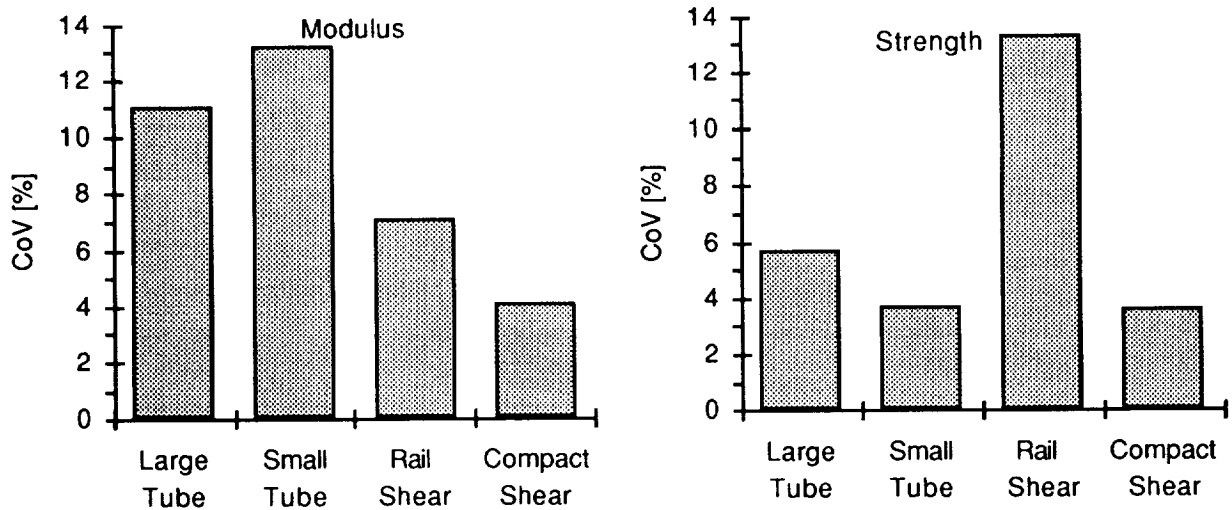


Figure 9.7 CoVs for In-plane Shear Test Methods.

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]	81.2		
	CoV [%]	4.6		
6	Stress [ksi]	84.2	71.5	72.0
	CoV [%]	8.7	7.9	2.7
8	Stress [ksi]	84.7		
	CoV [%]	1.7		

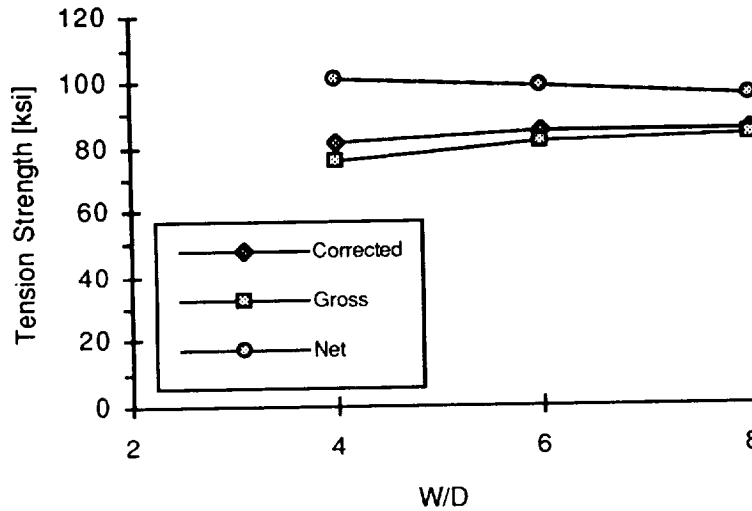


Figure 10.1 Comparison of Net, Gross and Corrected Stress for Filled Hole Tension Test of SLL Braided Material.

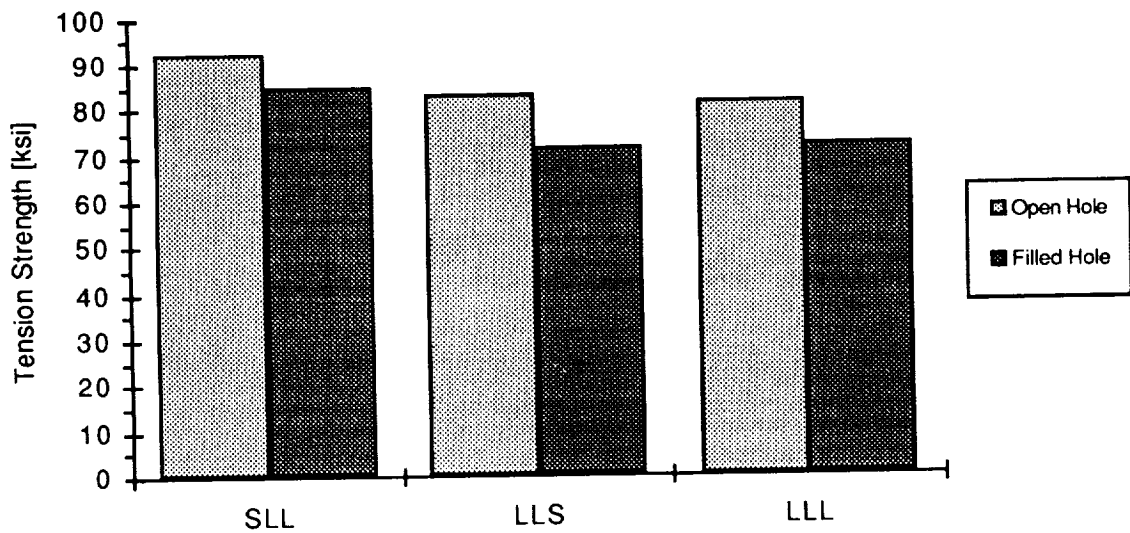


Figure 10.2 Comparison of Open and Filled Hole Tension Strength Data for 2-D Braided Material.

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				

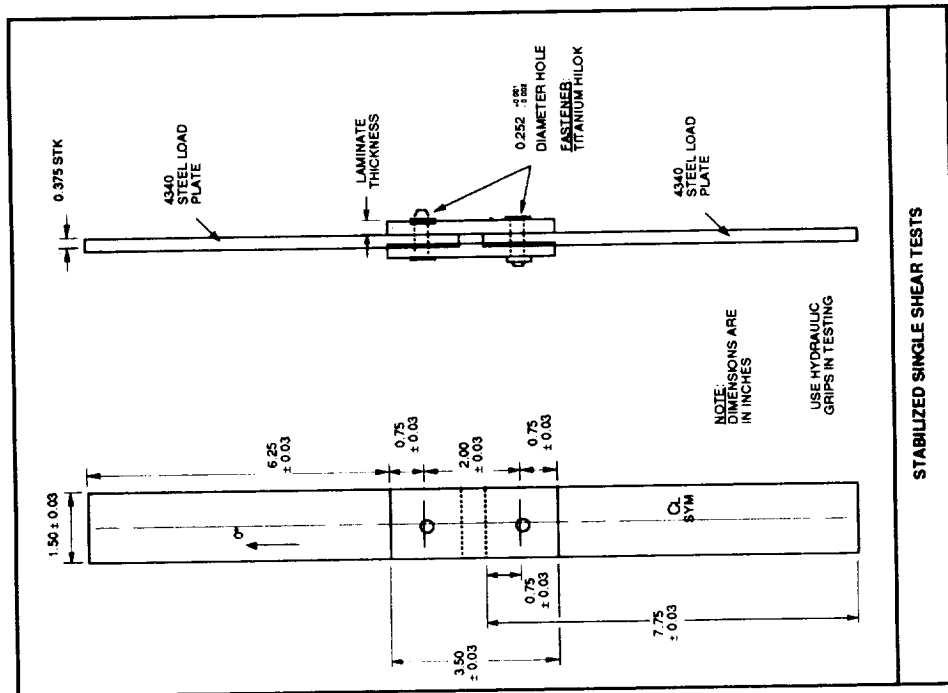


Figure 11.1a Baseline Dimensions for Stabilized Single-Shear Specimen.

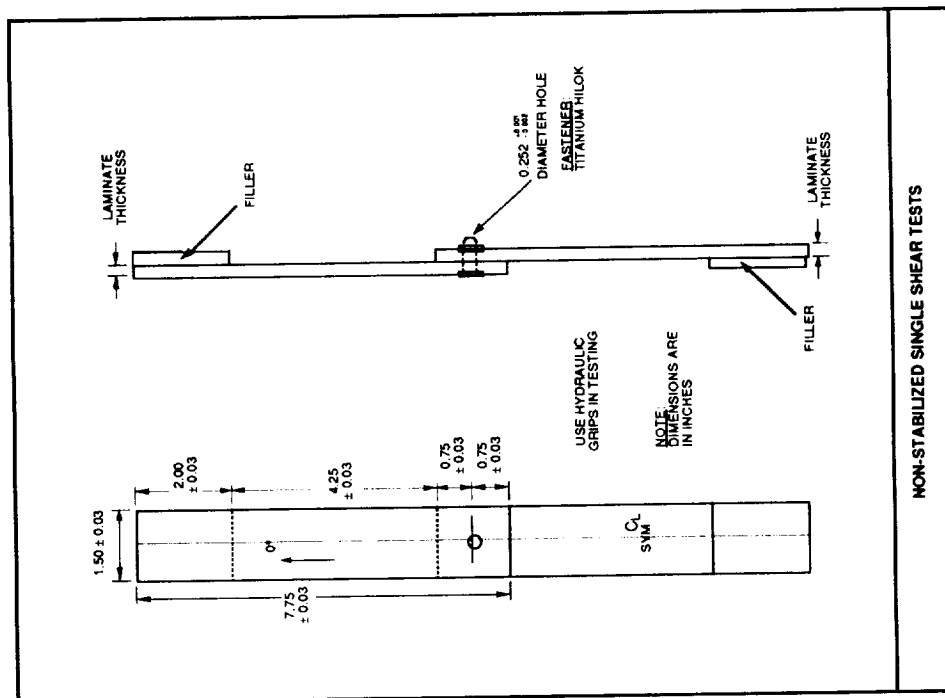


Figure 11.1b Baseline Dimensions for Unstabilized Single-Shear Specimen.

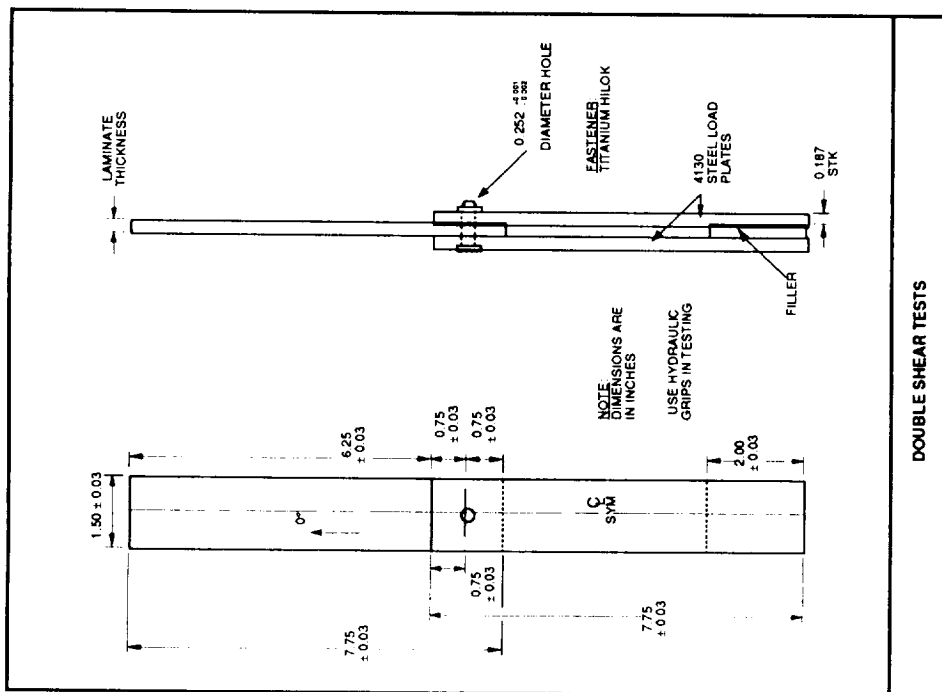


Figure 11.1c Baseline Dimensions for Double-Shear Specimen.

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 LLS is about 9% for stabilized single shear due to the increased tow size.

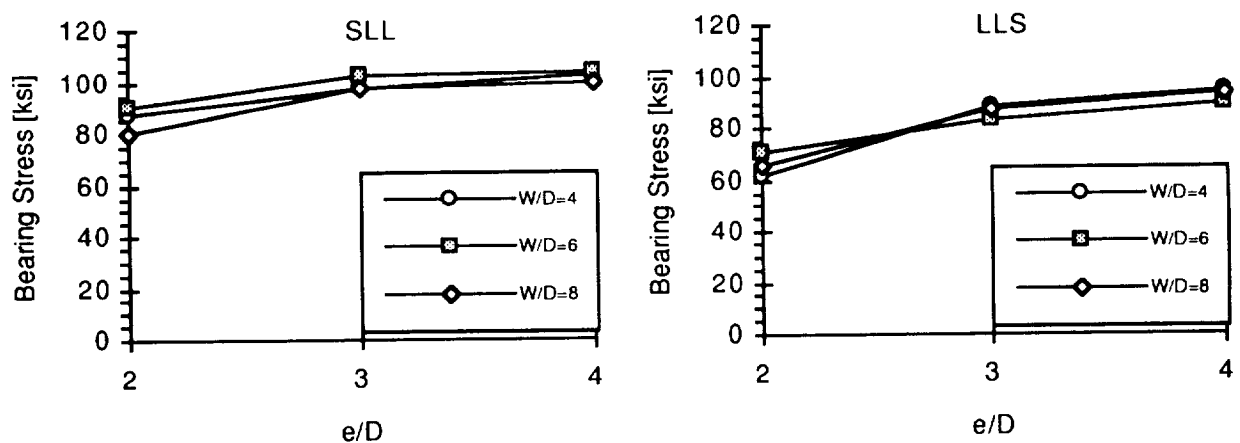


Figure 11.2 Effect of W/D and e/D on Stabilized Single Shear Bearing Ultimate Strength of 2-D Braided Materials SLL and LLS.

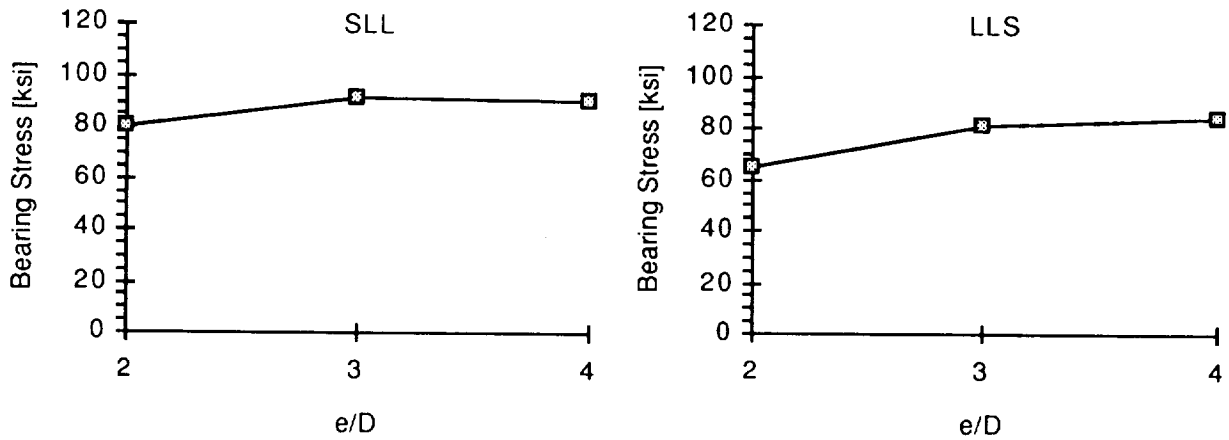


Figure 11.3 Effect of e/D on Unstabilized Single Shear Bearing Ultimate Strength of 2-D Braided Materials SLL and LLS.

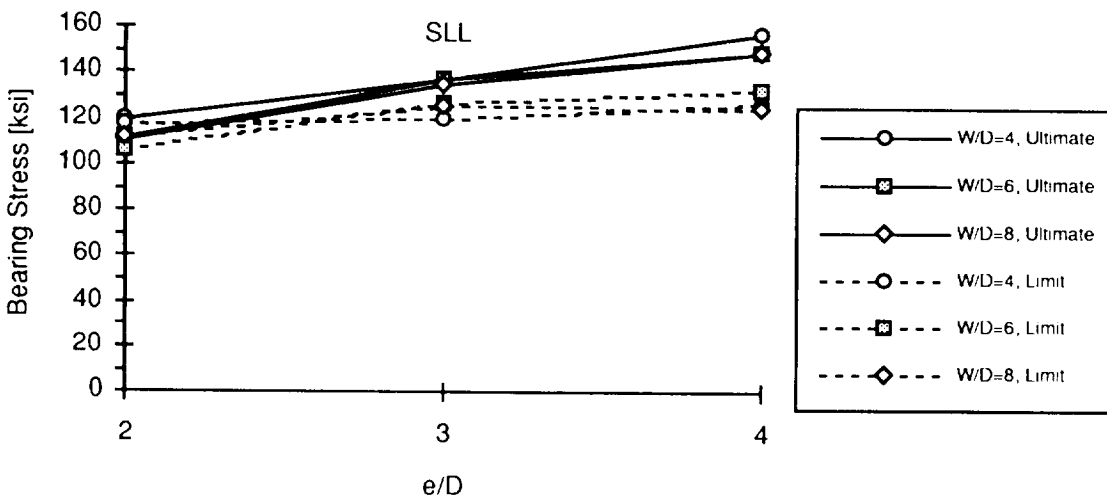


Figure 11.4.a Effect of W/D and e/D on Double Shear Bearing Ultimate Strength of 2-D Braided Materials SLL.

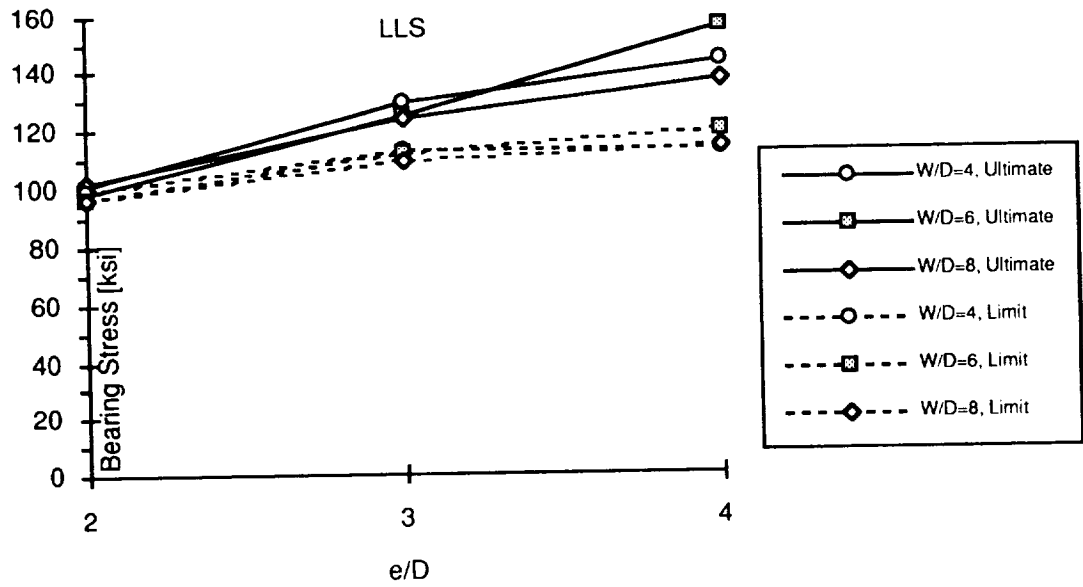


Figure 11.4.b Effect of W/D and e/D on Double Shear Bearing Ultimate Strength of 2-D Braided Materials LLS.

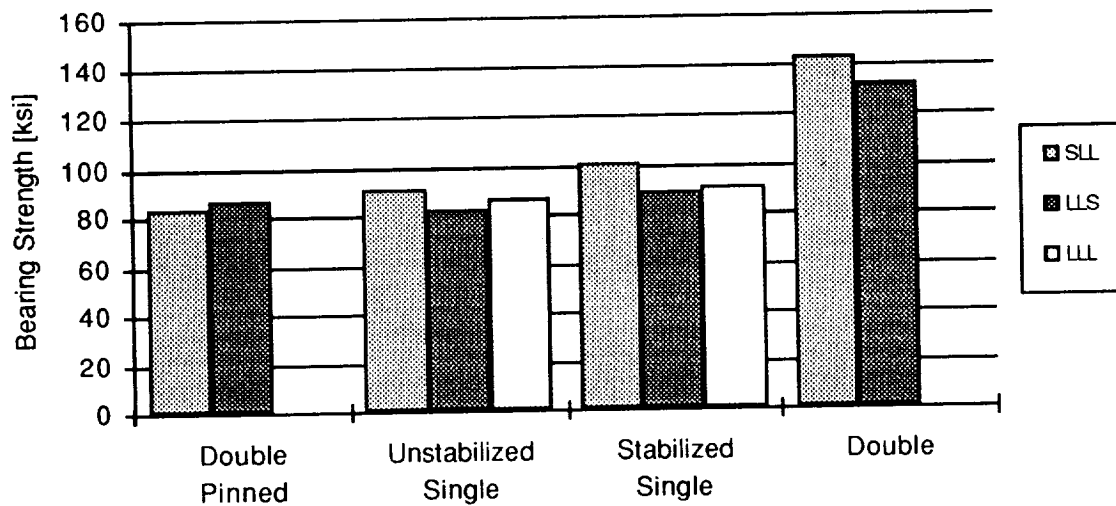


Figure 11.5 Comparison of all Bearing Tests with W/D=6 and e/D=3 for 2-D Braided Materials.

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

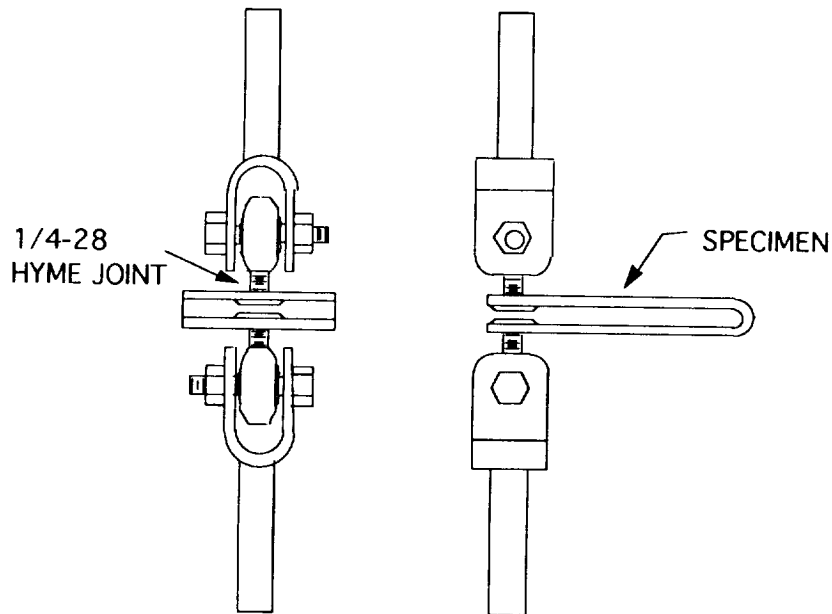


Figure 12.1 Interlaminar Tension C-Shape Specimen.

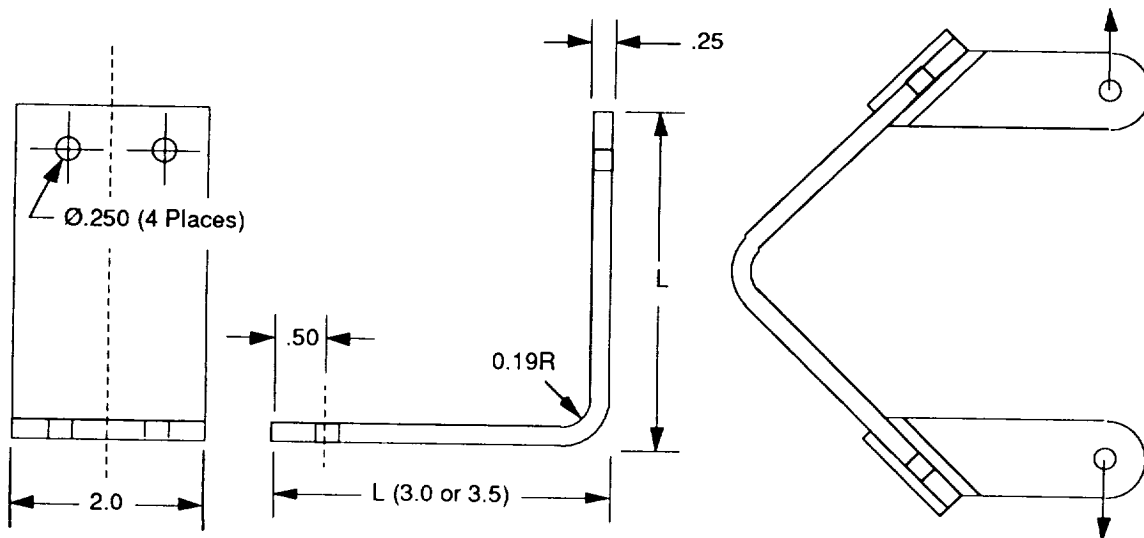


Figure 12.2 Interlaminar Tension L-Shape Specimen.

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

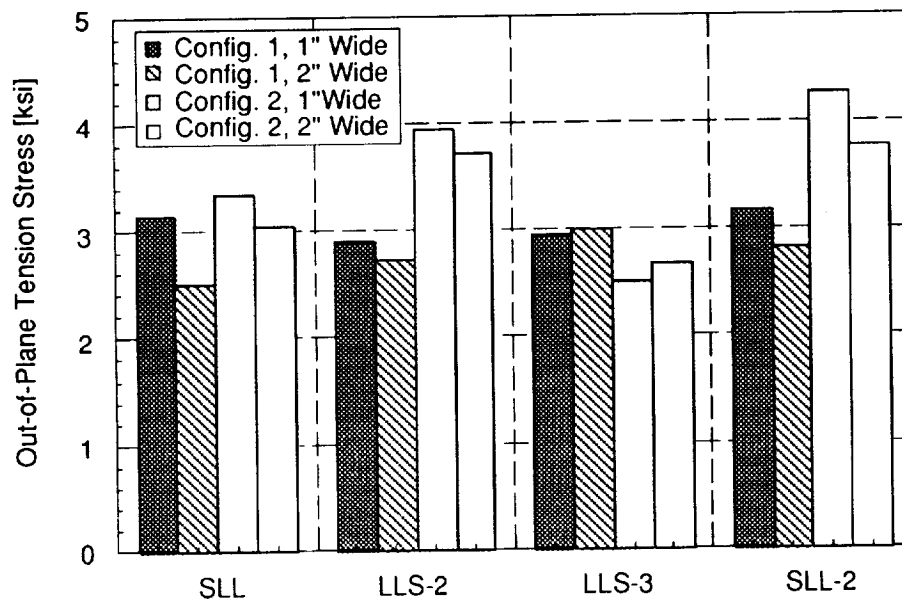


Figure 12.3 Interlaminar Tension Strength Measured with C-Shape Specimen.

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

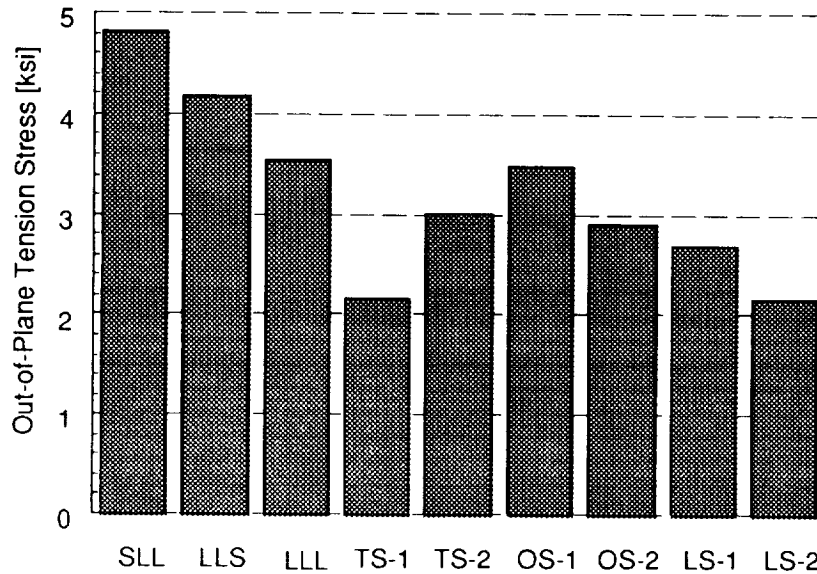


Figure 12.4 Interlaminar Tension Strength Measured with L-Shape Specimen.

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

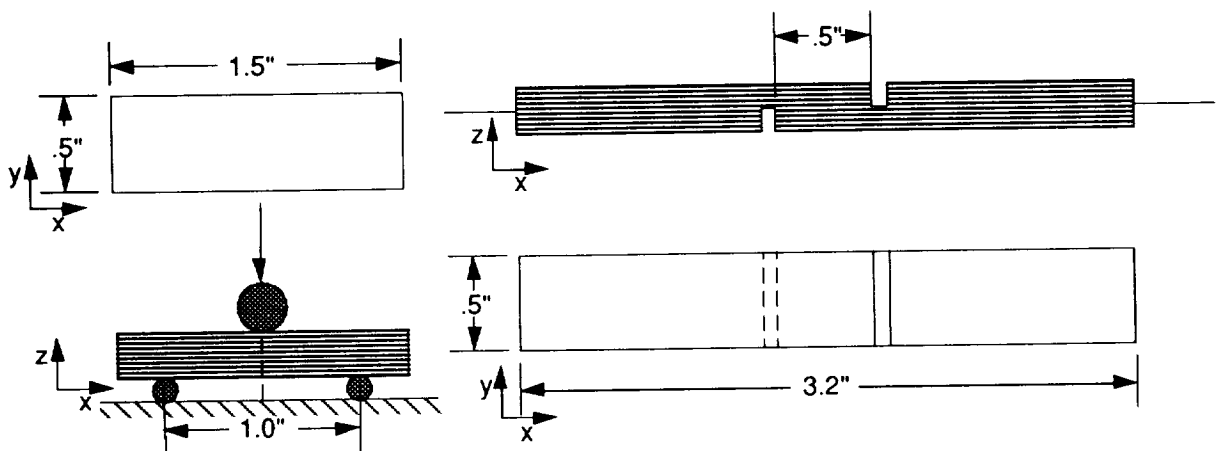


Figure 13.1 Short Beam Shear and Compression Interlaminar Shear Specimens.

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 occurred in the y-z plane at either the left or right support rod. The failures for the compression interlaminar shear specimens occurred 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.

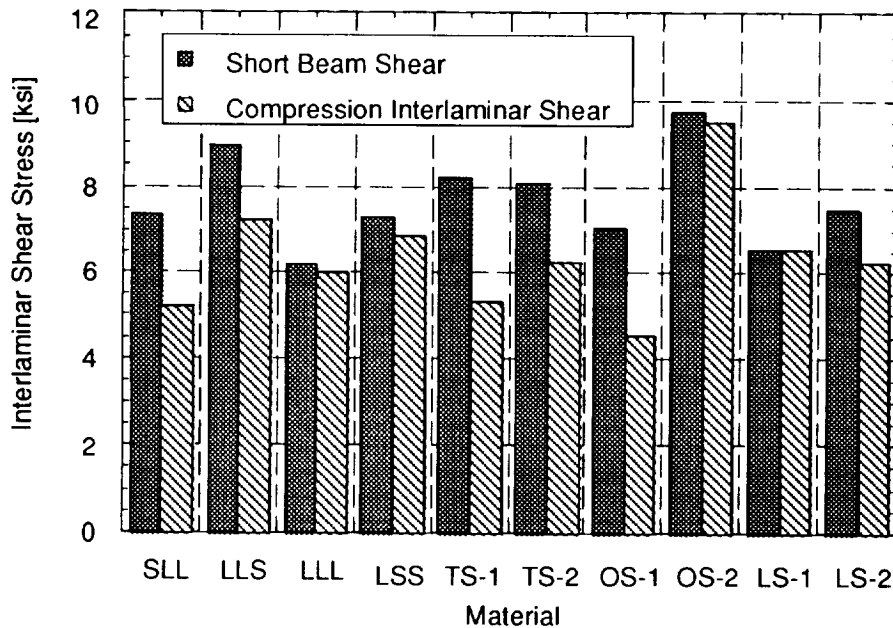


Figure 13.2 Interlaminar Shear Strength Measured with Short Beam Shear and Compression Interlaminar Shear Test Methods

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:

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

Initiation Method:

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

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:

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

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

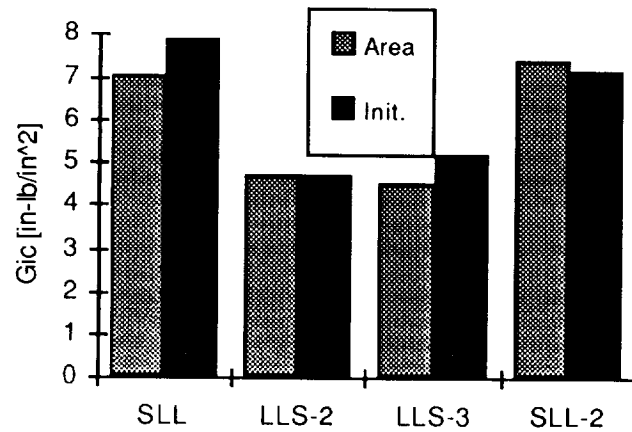


Figure 14.1 Mode I Fracture Toughness in 2-D Braided Materials.

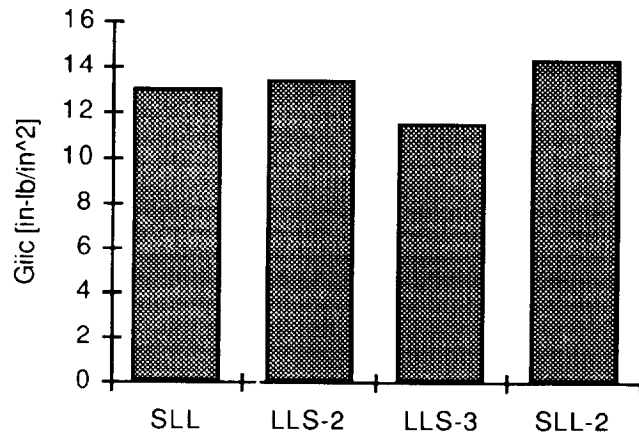


Figure 14.2 Mode II Fracture Toughness in 2-D Braided Materials.

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

Material AS4/Shell 1895

intec Engineer: Maryann Einartson
Boeing Engineer: Mark Fedio

Task 3
Tension Test Program
2-D Braided Architectures

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configurator Type	Nominal Dimensions			Avg Thick (in)	Avg Width (in)	Load at Audible (lbs)	Ultimate Load (lbs)	Ultimate Stress (ksi)	Ultimate Exten Strain (in/in)	Ultimate Axial gage Strain (in/in)	Ultimate Trans Strain (in/in)	Axial Modulus		Poisson's Ratio
						gauge length (in)	Width (in)	Thick (in)									Exten. (in/in)	Gage (in/in)	
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	104.36	na	12.451	-1.221	9.29	9.55	0.127
	2	T7-SLL-B-3B	SLL	0.600	Tension		1.9987	0.1074	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	SLL	0.600	1/8"		1.9997	0.1074	1.9997	0.1074	9.8	22.74	105.87	na	na	-901	9.62	9.99	0.138
						Average	2.0002	0.1069	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	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	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	LLS	0.599	1/8"		1.9995	0.1097	1.9995	0.1097	12.9	20.76	84.62	na	na	-5.332	11.35	10.99	0.572
						Average	1.9998	0.1085	1.9998	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	10.1			0.98	0.41	0.036	
						% COV					10.1	9.1				9.4	3.9	5.9	
BH2-03-3A-x	1	T7-LLS-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-LLS-B-3B	LLL	0.661	Tension		2.0025	0.1088	2.0025	0.1088	5.6	21.13	96.95	11.192	na	-1.323	10.05	9.86	0.161
	3	T7-LLS-B-3B	LLL	0.661	1/8"		2.0027	0.1095	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	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	4.6			0.33	0.34	0.013	
						% COV					3.9	20.3	4.8			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	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	LSS	0.629	1/8"		2.0055	0.1053	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	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	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	12.234	11.657	-1.409	10.14	10.22	0.148
	2	T7-SLL-B-3A	SLL	0.647	Effect		1.0030	0.1077	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	SLL	0.647	1/8"		1.0023	0.1077	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	SLL	0.647			1.0023	0.1087	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	1.0026	0.1080	8.4	11.85	109.69	13.065	11.657	-1.167	9.27	9.62	0.149
						Std. Dev.					0.27	3.05	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	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	SLL	0.635	1/8"		1.5002	0.1070	1.5002	0.1070	7.2	18.85	117.49	10.776	12.186	-1.928	10.33	9.94	0.185
						Average	1.5006	0.1070	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	6.42			0.50	0.63	0.029	
						% COV					5.7	5.8				4.8	6.2	17.2	

Material: ASA/Shell 1895

Textile Test Method Development

Project #: 01H0002

intec Engineer: Maryann Emanson
Boeing Engineer: Mark Fedro

Task 3
Tension Test Program
2-D Braided Architectures

intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions			Avg. Thickness (in)	Load Audible (kps)	Ultimate Load (kps)	Ultimate Stress (ksi)	Ultimate Exten. Strain (µε)	Ultimate Axial Strain (µε)	Ultimate Trans Strain (µε)	Axial Modulus		Poisson's Ratio		
						gauge length (in)	Width (in)	Thick (in)								Exten. (mksi)	Gage (mksi)			
BH2-01-3D-x	1	T7-SLL-B-3A	2-D	0.647	Width	8.75	2.50	1/8	0.1071	12.1	30.06	112.22	12.744	11.587	-8.32	9.63	10.24	0.104		
	2	T7-SLL-B-3A	SLL	0.647	Effect				2.5005	30.81	115.88	9.590	11.615	na	-1.530	10.48	10.33	0.156		
	3	T7-SLL-B-3A		0.647	1/8"				2.5012	31.82	120.09	11.971	na	na	-1.470	9.97	10.02	0.144		
									Average	12.1	30.90	116.07	11.435	11.601	10.03	10.19	0.135			
									Std. Dev.		0.88	3.94			0.43	0.16	0.27	4.2	1.6	20.2
									% 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	0.1198	7.6	10.10	84.13	8.450	na	-6.857	10.23	9.93	0.120		
	2	T7-LLS-B-YA	LLS	0.589	Effect				1.0000	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	6.4	9.68	83.00	na	na	na	9.45	9.66	0.600		
4*	T7-LLS-B-YA		0.589					1.0010	7.5	10.09	87.35	6.358	na	-6.291	10.40	10.27	0.579			
									Average	7.1	9.95	84.46	8.026	8.899	9.92	9.96	0.631			
									Std. Dev.		0.20	1.98			0.47	0.25	0.62	4.7	2.5	9.9
									% 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	0.1063	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	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	9.4	17.51	107.50	9.256	9.681	-6.359	11.83	11.38	0.612		
									Average	10.4	17.14	104.55	9.396	10.278	-6.620	10.94	10.70	0.617		
									Std. Dev.		0.38	3.47			0.64	0.62	0.47	5.8	7.6	
									% 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	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	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	11.8	26.01	93.88	na	8.292	-4.431	11.35	11.16	0.465		
									Average	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	0.92	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	0.0990	7.1	9.18	65.61	11.421	9.711	-1.492	10.41	9.89	0.149		
	2	T7-LLL-B-2A	LLL	0.638	Effect				0.9957	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	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	2.1	10.89	103.08	7.970	na	-1.895	10.49	9.69	0.136			
									Average	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	0.32	2.3	2.2	21.7
									% 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	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	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	2.6	15.53	95.15	na	10.944	-1.371	9.81	9.61	0.146		
									Average	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	5.9	5.4	3.4	
									% COV		5.0	7.2			5.9	5.4	3.4			

Project #: dHD002

Textile Test Method Development

Material AS4-Shell 1895

intec Engineer
Boeing Engineer

Task 3
Tension Test Program
2-D Braided Architectures

Manjann Emanson
Mark Fedro

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions			Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Exten Strain	Ultimate Axial Strain (µε)	Ultimate Trans Strain (µε)	Axial Modulus		Poisson's Ratio
						Gage length (in)	Width (in)	Thickness (in)							Exten (in/in)	Gage (in)	
BH2-03-3D-x	1	T7-LLL-B-1B	2-D	0.606	Width	8.75	2.50	1/8	8.4	23.20	105.84	8.784	8.607	-1.111	10.26	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	na	-1.667	9.87	9.93	0.199
	3	T7-LLL-B-1B	1/8"	0.606	1/8"	2.5023	0.1073	7.0	23.03	106.62	9.672	na	23.03	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	0.355	
% COV									5.1	6.5				7.8	1.2	36.1	
BH2-04-3E-x	1	T7-LSS-B-4B	2-D	0.619	Width	3.50	1.00	1/8	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	12.459	-9.716	4.95	5.17	0.740
	3	T7-LSS-B-4B	1/8"	0.619	1/8"	1.0000	0.1048	3.8	5.90	56.30	10.327	11.340	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	
BH2-04-3D-x	1	T7-LSS-B-4A	2-D	0.645	Width	5.25	1.50	1/8	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	12.560	-11.556	5.30	5.43	0.815
	3	T7-LSS-B-4A	1/8"	0.645	1/8"	1.5010	0.1048	7.3	8.92	56.70	12.749	12.749	12.749	-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	8.6	14.50	96.00	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	12.587	-9.496	4.87	4.95	0.682
	3	T7-LSS-B-4B	1/8"	0.619	1/8"	2.5043	0.1044	11.0	14.25	54.52	13.687	12.386	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	9.2	25.40	120.82	9.146	12.040	-2.016	10.70	10.78	0.183
	2	T7-SLL-B-4B	SLL	0.611	Effect	2.0027	0.1067	9.4	25.49	119.25	11.211	12.659	12.659	-1.419	9.75	9.95	0.184
	3	T7-SLL-B-4B	1/8"	0.611	1/8"	2.0053	0.1084	11.0	26.11	120.13	na	12.446	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	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	12.758	-2.097	10.91	10.25	0.198
	3	T7-SLL-B-4B	1/8"	0.611	1/8"	2.0010	0.1087	9.5	24.78	113.95	13.220	12.008	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	9.5	21.70	98.29	na	9.153	-6.618	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	na	-6.716	9.60	9.61	0.759
	3	T7-LLS-B-XB	1/8"	0.608	1/8"	2.0025	0.1120	12.5	21.25	94.75	9.261	na	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	

Material: ASA/Shell 1895

Textile Test Method Development

Task 3

Project #: BH0002
 Intec Engineer: Maryann Einerson
 Boeing Engineer: Mark Fedro

Tension Test Program
 2-D Braided Architectures

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions			Avg Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Strain (in/in)	Ultimate Axial Strain (in/in)	Ultimate Trans Strain (in/in)	Axial Modulus		Poisson's Ratio
						Gage length (in)	Width (in)	Thickness (in)								Exten (ksi)	Gage (msi)	
BH2-02-3F-x	1	T7-LLS-B-XB	2-D	0.608	Gage length Effect	5.50	2.00	1/8	2.0033	13.5	20.26	92.64	na	na	-5.847	11.53	10.75	0.627
	2	T7-LLS-B-XB	LLS	0.608	1/8"				2.0022	10.0	18.67	85.55	12.808	na	-5.311	9.89	10.00	0.507
	3	T7-LLS-B-XB	LLS	0.608	1/8"				2.0021	12.7	22.17	101.44	11.586	na	-6.411	9.72	10.93	0.615
Average									12.1	20.37	93.21	12.197		-5.856	10.38	10.56	0.583	
Std. Dev.									1.75	7.96	7.96	1.00		0.49	1.00	0.49	0.066	
% COV									8.6	8.5	8.5	9.6		4.7	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	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	9.7	21.38	130.79	14.063	na	-1.036	10.64	10.41	0.120
	3	T7-SLL-B-4B	SLL	0.611	1/8"				1.5975	10.5	18.83	119.07	13.184	na	-1.227	10.39	9.93	0.107
Average									10.0	20.34	123.85	13.603		-1.145	10.37	10.22	0.113	
Std. Dev.									0.90	6.15	6.15	0.27		0.25	0.27	0.25	0.007	
% COV									4.4	5.0	5.0	2.6		2.5	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	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	9.4	16.82	94.63	9.517	10.159	-7.053	11.04	10.44	0.626
	3	T7-LLS-B-XB	LLS	0.608	1/8"				1.5995	8.8	14.90	85.37	8.281	na	-4.868	10.73	10.34	0.580
Average									9.8	15.54	87.59	8.949	9.595	-5.531	10.70	10.22	0.575	
Std. Dev.									1.11	6.24	6.24	0.35		0.29	0.35	0.29	0.053	
% COV									7.2	7.1	7.1	3.3		2.9	3.3	2.9	9.3	
BH2-03-3G-x	1	T7-LLS-B-3B	2-D	0.661	Dogbone		2.00	1/8	1.5990	6.8	13.10	75.58	8.629	8.784	-5.86	10.13	10.03	0.123
	2	T7-LLS-B-3B	LLL	0.661	1/8"				1.5995	5.8	15.77	107.76	10.776	na	na	9.96	9.32	0.122
	3	T7-LLS-B-1B	LLL	0.661	1/8"				1.5980	6.5	17.04	99.26	17.152	na	-8.23	10.02	10.19	0.121
Average									6.4	15.30	88.27	12.186	8.784	-7.09	10.04	9.85	0.122	
Std. Dev.									2.01	11.93	11.93	0.08		0.08	0.08	0.08	0.046	
% COV									13.1	13.5	13.5	0.8		0.8	0.8	0.8	4.7	
BH2-04-3G-x	1	T7-LSS-B-3B	2-D	0.641	Dogbone		2.00	1/8	1.6015	9.0	10.11	57.13	13.472	13.777	-8.884	5.09	4.93	0.657
	2	T7-LSS-B-3B	LSS	0.641	1/8"				1.6045	9.1	9.93	57.05	13.261	13.389	-10.422	5.06	4.93	0.705
	3	T7-LSS-B-3B	LSS	0.641	1/8"				1.6040	8.8	10.18	58.49	13.188	13.370	-10.636	5.23	5.09	0.715
Average									9.0	10.07	57.56	13.307	13.512	-10.314	5.13	4.98	0.692	
Std. Dev.									0.13	0.81	0.81	0.09		0.09	0.09	0.09	0.031	
% COV									1.3	1.4	1.4	1.8		1.8	1.8	1.8	4.5	
BH2-01-3H-x	1	T5-SLL-A-2	2-D	0.501	Net-Shape		1.50	1/8	1.5175	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	6.5	19.77	119.47	12.900	na	-1.717	9.26	9.35	0.185
	3	T5-SLL-A-3	SLL	0.515	1/8"				1.5015	7.2	20.33	119.94	12.639	na	na	9.59	9.22	0.178
Average									6.9	20.19	120.87	12.938	12.856	-1.451	9.35	9.36	0.183	
Std. Dev.									0.37	2.03	2.03	0.21		0.21	0.21	0.15	0.004	
% COV									1.8	1.7	1.7	2.3		2.3	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	7.0	20.54	123.99	12.680	11.959	-7.830	9.54	9.88	0.611
	2	T5-LLS-A-11	LLS	0.515	1/8"				1.5073	9.3	20.55	118.30	13.385	na	-8.452	9.18	9.48	0.672
	3	T5-LLS-A-11	LLS	0.515	1/8"				1.5030	9.4	20.90	117.07	13.152	na	9.504	8.91	8.88	0.647
Average									8.6	20.66	119.79	13.072	11.959	-8.629	9.21	9.41	0.643	
Std. Dev.									0.21	3.70	3.70	0.32		0.32	0.32	0.50	0.630	
% COV									1.0	3.1	3.1	3.5		3.5	3.5	5.3	4.7	

Project #: BH0002

Textile Test Method Development

Material: AS4-Shell 1895

Task 3
Tension Test Program
2-D Braided Architectures

intec Engineer: Maryann Einarsen
Boeing Engineer: Mark Fedro

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions			Load at Audible Failure (kpsi)	Ultimate Stress (kpsi)	Ultimate Exten Strain (με)	Ultimate Axial Strain (με)	Ultimate Trans Strain (με)	Axial Modulus		Poisson's Ratio
						gauge length (in)	Width (in)	Thick (in)						Exten (ksi)	Gage (ksi)	
BH2-03-3H-x	1	T7-LLL-A-5	2-D	0.546	Net-Shape	1.50	1.5000	0.1106	2.3	13.81	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	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	10.817	na	-372	8.45	8.51	0.105
						Average	1.4974	0.1132	2.7	15.64	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	1.4997	0.1164	4.9	9.12	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	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	12.804	na	-8.852	4.68	5.04	0.696
						Average	1.4999	0.1152	5.7	8.88	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	2.000	0.2092	19.1	47.13	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	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	11.179	11.967	-1.606	9.01	9.21	0.172
						Average	1.9991	0.2113	18.1	45.02	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	2.0020	0.2177	22.1	44.34	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	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	9.457	9.656	-6.025	11.00	10.45	0.605
						Average	2.0018	0.2177	20.5	41.66	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	2.0042	0.2217	9.5	32.56	8.066	8.105	-4.61	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	-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	na	na	-1.157	8.90	8.91	0.097
						Average	2.0027	0.2224	8.8	38.06	85.41	9.808	-9.31	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	2.0027	0.2088	16.4	22.89	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	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	11.897	11.880	-9.136	4.99	5.11	0.718
						Average	2.0022	0.2054	15.3	22.37	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

Material: AS4/Shell 1895

Textile Test Method Development
 Task 3
 Tension Test Program
 2-D Braided Architectures

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

intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configurator Type	Nominal Dimensions				Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Exten. Strain (in)	Ultimate Axial Strain (in)	Ultimate Trans Strain (in)	Axial Modulus		Poisson's Ratio		
						gauge length (in)	Width (in)	Thick (in)	Width (in)								Exten. (msi)	Gage (msi)			
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		6.1	6.5			4.1	3.2	16.5		
						% COV															
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	-7.97	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	10.943	na	-1.034	10.65	9.59	0.132	
						Std. Dev.				2.30	7.41		6.8	7.0			11.8	4.6	10.5		
						% COV															
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	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		3.6	3.5			2.1	1.2	4.5		
						% COV															
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		0.65	2.74			1.6	2.2	6.0		
						% COV				3.7	3.4		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	9.475	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.				0.7	1.1		0.7	1.1			2.0	2.1	2.8		
						% COV															
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	-6.066	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		2.8	3.6			3.1	4.0	0.11		
						% COV															

Material: AS4/Shell 1895

Textile Test Method Development

Task 3

**Tension Test Program
2-D Braided Architectures**

Project #: BH0002

Intec Engineer: Maryann Einerson
Boeing Engineer: Mark Pedro

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions			Avg. Thick (in)	Load at Audible (kpsi)	Ultimate Stress (ksi)	Ultimate Strain (uc)	Ultimate Axial Strain (uc)	Ultimate Trans Strain (uc)	Axial Modulus		Poisson's Ratio
						gauge length (in)	Width (in)	Thickness (in)							Exten. (msi)	Gage (msi)	
BH2-03-3L-x	1	T5-LLL-C-1B	2-D	0.632	Width	3.50	1.00	1/4	0.9989	5.9	20.97	na	15.047	-1.021	9.62	10.00	0.122
	2	T5-LLL-C-1B	LLL	0.632	Effect				1.0000	3.2	20.23	10.423	na	na	9.73	9.81	0.162
	3	T5-LLL-C-1B		0.632	1/4"				0.9995	4.1	18.15	9.682	na	-9.59	9.33	10.39	0.181
						Average			0.9996	4.4	19.79	10.052	15.047	-9.90	9.56	10.07	0.155
						Std. Dev.					1.46	6.25			0.21	0.29	0.030
						% COV					7.4	2.2			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	7.8	31.26	5.649	na	-1.127	9.45	9.68	0.125
	2	T7-LLL-C-1B	LLL	0.641	Effect				1.5007	6.3	30.89	10.936	na	-7.76	8.80	8.69	0.132
	3	T7-LLL-C-1B		0.641	1/4"				1.5000	6.8	31.54	11.220	11.690	-1.024	8.82	8.81	0.087
						Average			1.5006	7.0	31.23	9.268	11.690	-9.76	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	6.75	2.50	1/4	2.5047	26.0	51.62	12.611	na	-7.05	9.44	9.90	0.115
	2	T5-LLL-C-1B	LLL	0.632	Effect				2.5035	22.0	53.38	10.864	na	-1.437	9.75	10.42	0.184
	3	T5-LLL-C-1B		0.632	1/4"				2.5005	24.0	46.78	6.375	na	-4.99	9.40	10.42	0.156
						Average			2.5029	24.0	50.59	9.950		-8.80	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
BH2-04-3L-x	1	T7-LSS-C-1A	2-D	0.622	Width	3.50	1.00	1/4	1.0003	7.9	12.15	9.641	11.683	-12.670	5.22	5.61	0.979
	2	T7-LSS-C-1A	LSS	0.622	Effect				0.9990	5.5	12.03	14.534	12.262	-11.852	5.19	5.38	0.875
	3	T7-LSS-C-1A		0.622	1/4"				1.0010	7.7	11.72	4.454	11.678	-11.795	12.93	5.44	0.980
						Average			0.9998	6.7	11.76	10.226	11.676	-11.029	5.23	5.32	0.845
						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	8.8	16.72	12.666	12.602	-9.763	4.96	4.91	0.681
	2	T7-LSS-C-1B	LSS	0.642	Effect				1.5018	8.4	16.99	13.197	12.712	-10.122	4.97	5.16	0.744
	3	T7-LSS-C-1B		0.642	1/4"				1.5032	11.0	17.23	12.465	12.646	-9.835	5.20	5.06	0.694
						Average			1.5035	8.3	17.71	13.623	12.643	-9.944	5.26	5.13	0.702
						Std. Dev.					17.16	55.94	12.651	-9.916	5.10	5.07	0.705
						% COV					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	16.0	30.11	58.85	12.478	-7.500	5.41	5.73	0.825
	2	T7-LSS-C-1A	LSS	0.622	Effect				2.5040	14.8	27.56	12.282	12.274	-10.254	5.20	5.11	0.759
	3	T7-LSS-C-1A		0.622	1/4"				2.5000	13.6	26.07	14.200	12.147	-9.262	5.26	4.99	0.708
						Average			2.5021	14.8	27.91	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
 Intec Engineer: Maryann Einerson
 Boeing Engineer: Mark Fedro
 Task 3
 Tension Test Program
 2-D Braided Architectures
 Material: AS4/Shell 1805

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions			Avg. Thick (in)	Load at Audible (lbf)	Ultimate Load (lbf)	Ultimate Stress (ksi)	Ultimate Exten. Strain (με)	Ultimate Axial Strain (με)	Ultimate Trans Strain (με)	Axial Modulus		Poisson's Ratio	
						Gage length (in)	Width (in)	Thick (in)								Exten. (mils)	Gage (mils)		
BH2-01-3M-x	1	T5-SLL-C-1B	2-D	0.623	Gage length	8.50	2.00	1/4	0.2037	34.0	36.90	90.42	9.058	6.723	-862	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	11.824	31.022	11.824	-1,040	10.54	10.99	0.140	
	3	T5-SLL-C-1B		0.623	1/4"		2.0020	0.2090	34.0	49.51	115.94	11.661	11.718	11.661	-1,278	10.44	10.66	0.146	
						Average			2.0025	0.2062	34.0	44.06	106.63	17.266	10.766	-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	0.2005		49.05	118.23	na	na	na	9.79	9.92	0.150	
	2	T5-SLL-C-1B	SLL	0.623	Effect		2.0015	0.2080	21.0	45.49	109.27	11.232	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	111.96	16.154	16,154	na	-665	9.42	9.91	0.140	
						Average			2.0006	0.2069	21.0	112.45	13.683	13,683	-874	9.87	10.16	0.145	
						Std. Dev.					1.39	3.82				0.81	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	0.2010		40.94	90.27	10.126	9.562	-8.850	10.00	9.88	0.574	
	2	T7-LLS-C-4A	LLS	0.570	Effect		1.9987	0.2204		40.31	91.52	9.572	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	8,455	na	-6,563	10.77	10.66	0.641	
						Average			1.9998	0.2220	42.20	95.09	9.384	9,384	-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	4.5		
BH2-02-3N-x	1	T7-LLS-C-4A	2-D	0.570	Gage length	5.50	2.00	1/4	0.2000		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	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	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 **Textile Test Method Development** **Task TT** **ASA/Shell 1895**
intec Engineer: Maryann Einarson **Tension Test Program**
Boeing Engineer: Mark Fedro **2-D Braided Architectures**

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dim.			Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Axial Modulus Gage (msi)
						Length (in)	Width (in)	Thick (in)					
BH2-01-3Q-X	1	T7-SLL-B-8B	2-D	0.615	Transverse Tension	11.5	2.00	1/8	1.9972	4.1	7.16	33.24	7.15
	2	T7-SLL-B-8B	SLL	0.615	Tension				1.9972	3.5	8.24	38.65	7.32
	3	T7-SLL-B-8B		0.615	1/8"				1.9975	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	0.54	0.72	7.54	0.48
% COV									7.04	7.04	7.54	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	1.6	3.59	16.50	2.85
	2	T7-LLS-B-11A	LLS	0.538	Tension				1.9973	1.6	3.35	15.84	2.65
	3	T7-LLS-B-11A		0.538	1/8"				1.9982	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	0.19	0.72	7.54	0.13
% COV									5.52	5.52	4.56	4.56	4.67
BH2-03-3Q-x	1	T7-LLL-B-4A	2-D	0.602	Transverse Tension	11.5	2.00	1/8	2.0035		6.49	29.04	6.89
	2	T7-LLL-B-4A	LLL	0.602	1/8"				2.0017		7.16	31.39	6.97
	3	T7-LLL-B-4A		0.602					2.0010		7.50	32.86	6.92
Average						2.0021			0.1132		7.05	31.10	6.93
Std. Dev.									0.51		0.51	1.93	0.04
% COV									7.29		7.29	6.20	0.58
BH2-04-3Q-x	1	T7-LSS-B-6A	2-D	0.623	Transverse Tension	11.5	2.00	1/8	1.9962	4.0	5.42	25.93	3.06
	2	T7-LSS-B-6A	LSS	0.623	1/8"				1.9968	4.1	5.27	26.38	3.26
	3	T7-LSS-B-6A		0.623					1.9977	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		0.26	1.73	0.14
% COV									4.78		4.78	6.36	4.26

Modulus calculations based on 0.1-0.3% axial strain

Material: ASA/Shell 1895

Project #: BH0002
intec Engineer: Maryann Emanson
Boeing Engineer: Mark Fedro
Task: 3 and 8
Tension Test Program
3-D Woven Architectures

Inlec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions				Avg. Thickness (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		Poisson's Ratio
					Configuration Type	Length (in)	Width (in)	Thickness (in)								Exten. (msi)	Gage (msi)	
BH2-05-3A-x	1	T7-TS1-A-2B	3-D	0.643	7.0	1.50	1/4	1.4998	0.2183	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				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	1/8"	0.643				1.4992	0.2224	19.5	49.82	149.41	12.181	na	na	12.50	13.43	0.057
										Average	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	7.0	1.50	1/4	1.4993	0.2257	45.77	135.27	11.31	11.76	na	909	11.31	11.76	0.047
	2	T7-TS2-A-1B	TS-2	0.610				1.4997	0.2259	43.0	44.28	130.71	11.714	na	164	10.81	11.75	0.043
	3	T7-TS2-A-1B	1/8"	0.610				1.5003	0.2259	44.0	45.34	133.80	11.469	11.907	1,206	11.61	11.72	0.031
										Average	45.13	133.28	11.784		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	7.0	1.50	1/4	1.5020	0.2264	17.0	49.39	145.23	na	na	na	12.06	12.16	0.030
	2	T7-OS1-A-2B	OS-1	0.614				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	1/8"	0.614				1.4973	0.2276	18.0	48.64	142.76	na	na	178	12.24	11.62	0.041
										Average	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	7.0	1.50	1/4	1.5002	0.2327	31.61	90.56	8.473	8.473	na	-132	10.47	11.38	0.049
	2	T7-OS2-A-2A	OS-2	0.578				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	1/8"	0.578				1.5008	0.2316	26.0	30.47	87.68	8.576	na	-79	10.55	11.52	0.040
										Average	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	0.68	10.95
BH2-09-3A-x	1	T7-LS1-A-7A	3-D	0.656	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				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	1/8"	0.656				1.4993	0.2143	14.0	46.39	144.39	11.256	na	1,118	12.89	12.87	0.062
										Average	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	7.0	1.50	1/4	1.5027	0.2251	31.70	83.71	9.977	9.977	na	200	12.03	12.40	0.050
	2	T7-LS2-A-2B	LS-2	0.610				1.4983	0.2251	24.0	35.20	104.40	8.810	na	73	12.03	12.49	0.054
	3	T7-LS2-A-2B	1/8"	0.610				1.4988	0.2244	26.0	32.38	96.28	na	7,903	217	12.48	12.53	0.044
										Average	33.09	98.13	9.393		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 Emerson
 Boeing Engineer: Mark Fedro

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

Material: ASA/Shell 1895

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions			Avg. Thickness (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Exten. (in)	Ultimate Axial Strain (in/in)	Ultimate Trans Strain (in/in)	Axial Modulus		Poisson's Ratio
						gauge length (in)	width (in)	thick (in)								Exten. (ms)	Gage (ms)	
BH2-11-3A-x	1	T7-SUW-G3K8A-1	SU-1	0.670	Baseline	7.0	1.50	1/4	1.5003	18.0	32.28	87.72	14.255	13.500	-3.755	7.59	7.84	0.307
	2	T7-SUW-G3K8A-1		0.670	Tension				1.4982	13.0	32.44	88.31	13.767	13.710	-4.210	7.76	7.76	0.309
	3	T7-SUW-G3K8A-1		0.670	1/8"				1.5002	13.0	30.75	83.01	12.599	12.880	-3.863	7.74	7.70	0.302
Average										14.7	31.82	86.35	13.540	13.364	-3.843	7.69	7.77	0.306
Std. Dev.											0.93	2.91				0.09	0.07	0.30
% 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	1.4988	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	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	28.0	29.58	81.53	12.303	na	-3.299	7.11	6.99	0.280
Average										28.7	30.18	82.53	12.899		-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	0.83	4.19
BH2-13-3A-x	1	T7-SUW-K6K8A-1	SU-3	0.682	Baseline	7.0	1.50	1/4	1.5053	25.4	30.96	81.22	11.815	12.474	-3.963	7.21	6.98	0.329
	2	T7-SUW-K6K8A-1		0.682	Tension				1.5008	26.9	31.47	83.10	13.152	12.178	-4.128	6.80	7.24	0.349
	3	T7-SUW-K6K8A-1		0.682	1/8"				1.4957	22.5	30.39	80.77	13.028	12.451	-3.918	6.89	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	0.18	0.01
% COV											1.8	1.6				3.97	2.28	2.97
BH2-14-3A-x	1	T7-SUW-K6K4A-1	SU-4	0.821	Baseline	7.0	1.50	1/4	1.5035	16.0	29.49	84.39	13.031	na	-3.834	7.06	7.32	0.298
	2	T7-SUW-K6K4A-1		0.821	Tension				1.4982	19.0	28.03	83.65	na	na	-3.875	7.29	7.33	0.303
	3	T7-SUW-K6K4A-1		0.821	1/8"				1.4995	18.0	30.84	88.21	12.870	na	-3.878	7.27	7.38	0.307
Average										17.3	29.72	85.42	12.850		-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	19.0	30.34	79.47	11.808	na	-3.576	7.17	7.27	0.298
	2	T7-SUW-K12K8A-1		0.650	Tension				1.4983	14.0	30.49	80.39	12.122	na	-3.842	7.30	7.32	0.307
	3	T7-SUW-K12K8A-1		0.650	1/8"				1.4977	21.0	25.86	68.38	10.170	10.405	-3.073	7.07	7.22	0.309
Average										18.0	28.90	76.07	11.389	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			W/D	D/I	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		
					Thick (in)	Width (in)	Diam (in)													
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				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. Std Dev % COV													8.5	13.19	80.12	106.53				
1.5024 0.1096 0.3725													1.5	0.80	4.99	6.63				
17.8 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. Std Dev % COV													7.6	14.59	87.96	105.43				
1.5010 0.1104 0.2487													1.0	0.97	4.40	5.27				
13.2 6.6 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. Std Dev % COV													7.9	16.04	99.61	113.85				
1.5017 0.1073 0.1878													0.8	0.58	4.35	4.98				
10.0 3.6 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. Std Dev % COV													7.4	12.21	74.12	98.59				
1.5029 0.1096 0.3730													1.3	0.97	5.83	7.75				
16.8 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. Std Dev % COV													7.8	12.31	73.44	88.01				
1.5008 0.1096 0.2485													0.4	0.80	4.57	5.49				
4.8 6.5 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. Std Dev % COV													9.5	14.75	89.44	102.24				
1.5021 0.1098 0.1880													0.6	0.68	4.52	5.13				
6.7 4.6 5.0																				

Project #: BH0002 **Task 4**
intec Engineer: Mayvann Einatson **Open Hole Tension Test Program**
Boeing Engineer: Mark Fedro **2-D Braided Architectures**
No instrumentation

Material: AS4/Shell 1895

intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions			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		
					Thick (in)	Width (in)	Diag. (in)													
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			2.2505	0.1057	0.5625	7.0	17.12	71.99	95.98	hole				
	3	T7-SLL-B-2A		0.620		2.2505			2.2505	0.1062	0.5625	6.8	16.71	69.94	93.24	hole				
Avg. Std Dev % COV													6.8	17.29	72.37	96.49				
Avg. Std Dev % COV													0.2	0.69	2.65	3.53				
Avg. Std Dev % 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			2.2520	0.1073	0.3730		21.07	87.17	104.47	hole				
	3	T7-SLL-B-2A		0.620		2.2517			2.2517	0.1078	0.3730		22.70	93.49	112.05	hole				
Avg. Std Dev % COV													21.51	88.47	106.05					
Avg. Std Dev % COV													1.04	4.51	5.39	5.1				
Avg. Std Dev % COV													4.8	5.1	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			2.2533	0.1088	0.2810	11.5	19.30	78.70	89.91	hole				
	3	T7-SLL-B-2A		0.620		2.2555			2.2555	0.1085	0.2815	11.8	20.02	81.81	93.47	hole				
Avg. Std Dev % COV													11.8	20.00	80.99	92.55				
Avg. Std Dev % COV													0.3	0.69	2.01	2.32				
Avg. Std Dev % 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			2.2503	0.1097	0.5625	5.8	16.06	65.08	86.76	hole				
	3	T7-LLS-B-3B		0.641		2.2500			2.2500	0.1097	0.5625	5.7	14.88	60.30	80.41	hole				
Avg. Std Dev % COV													6.1	15.56	64.24	85.66				
Avg. Std Dev % COV													0.6	0.61	3.59	4.79				
Avg. Std Dev % 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			2.2518	0.1082	0.3725	13.0	17.87	73.37	87.91	hole				
	3	T7-LLS-B-3B		0.641		2.2515			2.2515	0.1112	0.3725	12.0	17.88	71.44	85.60	hole				
Avg. Std Dev % COV													13.0	17.86	72.13	86.43				
Avg. Std Dev % COV													1.0	0.03	1.07	1.28				
Avg. Std Dev % 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			2.2550	0.1098	0.2820	14.5	20.08	81.07	92.66	hole				
	3	T7-LLS-B-3B		0.641		2.2522			2.2522	0.1092	0.2815	14.5	20.34	82.73	94.55	hole				
Avg. Std Dev % COV													13.9	20.15	81.47	93.11				
Avg. Std Dev % COV													1.0	0.17	1.12	1.27				
Avg. Std Dev % COV													7.0	0.8	1.4	1.4				

Project #: BH0002

intec Engineer: Maryann Emarson

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			D/t	Avg Width (in)	Avg Thick (in)	Hole Diameter (in)	Load at Audible (kps)	Ultimate Load (kps)	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	2.2510	0.1168	0.5625	2.5	14.55	55.32	73.76	hole	some delamination some delamination some delamination	
	2	T7-LLL-B-2B	LLL	0.607				2.2505	0.1172	0.5625	3.0	15.82	60.00	79.59	hole			
	3	T7-LLL-B-2B	LLL	0.607				2.2510	0.1095	0.5635	3.3	14.60	59.23	78.97	hole			
					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	2.2515	0.1092	0.3730		18.17	73.93	88.60	hole	Failed throughout specimen Very noisy prior to failure	
	2	T7-LLL-B-2B	LLL	0.607				2.2500	0.1147	0.3730		19.09	73.99	88.70	hole			
	3	T7-LLL-B-2B	LLL	0.607				2.2518	0.1090	0.3725		18.66	76.02	91.09	hole			
					Avg				2.2511	0.1109	0.3728		18.64	74.65	89.46			
					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	2.2537	0.1085	0.2810	6.2	19.24	78.68	89.89	hole	Matt weave ripped around hole	
	2	T7-LLL-B-2B	LLL	0.607				2.2527	0.1082	0.2815	5.8	21.52	88.32	100.93	hole			
	3	T7-LLL-B-1A	LLL	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								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	2.2517	0.1087	0.5620	5.5	8.36	34.16	45.53	hole	failed diagonally failed diagonally 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			
	3	T7-LSS-B-3A	LSS	0.658				2.2498	0.1055	0.5625	5.0	7.31	30.78	41.05	hole			
					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								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	2.2517	0.1053	0.3725	8.0	8.67	36.57	43.82	Hole	Failed diagonally Failed diagonally 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			
	3	T7-LSS-B-3A	LSS	0.658				2.2515	0.1052	0.3725	7.0	8.88	37.50	44.94	Hole			
					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								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	2.2513	0.1042	0.2815	8.5	9.39	40.05	45.78	hole	Failed diagonally Failed diagonally 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			
	3	T7-LSS-B-4A	LSS	0.645				2.2518	0.1085	0.2815	8.5	10.82	44.29	50.61	hole			
					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 **Material:** AS4/Shell 1895
intec Engineer: Maryann Einarson **Task 4**
Boeing Engineer: Mark Fedro
No instrumentation
Textile Test Method Development
Open Hole Tension Test Program
2-D Braided Architectures

intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions	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	SLL	0.610				3.0025	0.1056	0.7500		23.69	74.70	99.58	hole	
Avg. Std Dev % COV																
3.0024 0.1066 0.7503																
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	SLL	0.610				3.0022	0.1083	0.4990	15.0	27.05	83.21	99.80	hole	
Avg. Std Dev % COV																
3.0019 0.1069 0.5008																
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	25.46	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	SLL	0.610				3.0035	0.1055	0.3725	17.0	26.07	82.27	93.92	hole	
Avg. Std Dev % COV																
3.0023 0.1062 0.3728																
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	84.65	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	LLS	0.564				3.0025	0.1072	0.7505		19.80	61.54	82.04	hole	
Avg. Std Dev % COV																
3.0031 0.1075 0.7505																
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	LLS	0.564				3.0020	0.1077	0.5010	16.4	25.43	78.67	94.42	hole	
Avg. Std Dev % COV																
3.0033 0.1067 0.5005																
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	LLS	0.564				3.0022	0.1082	0.3735	16.0	23.36	71.94	82.16	hole	
Avg. Std Dev % COV																
3.0023 0.1082 0.3730																
1.0 1.94 7.6																

Project #: BH0002
 intec Engineer: Maryann Emarison
 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

Inlec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions			W/D	D/t	Avg. Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kpsi)	Ultimate Load (kpsi)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments				
					Thick (in)	Width (in)	Diam. (in)															
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						1.5455	0.1118	0.2495	7.1	15.21	88.00	104.94	hole					
													Avg. Std Dev % COV									
													1.5375 0.1123 0.2493		6.9 15.33 88.80 105.99		0.2 0.67 4.38 5.33		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						1.5378	0.1108	0.2495	8.0	15.31	89.82	107.22	hole					
													Avg. Std Dev % COV									
													1.5343 0.1128 0.2492		8.0 15.21 87.87 104.91		1.8 0.40 2.52 3.04		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						1.5478	0.1112	0.2500	4.9	12.05	70.03	83.52	hole					
													Avg. Std Dev % COV									
													1.5457 0.1204 0.2495		4.6 13.94 74.70 89.08		0.3 1.77 4.62 5.51		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						1.5277	0.1135	0.2495	4.5	7.05	40.68	48.62	hole					
													Avg. Std Dev % COV									
													1.5343 0.1117 0.2495		4.7 7.00 40.84 48.78		0.2 0.23 1.75 2.15		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. Std Dev % COV									
													1.5006 0.2188 0.3728		14.3 21.36 65.06 86.57		1.2 1.79 5.52 7.34		8.1 8.4 8.5 8.5			

Material: AS4/Shell 1895

Textile Test Method Development

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

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

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions			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		
					Thick (in)	Width (in)	Diam (in)												
BH2-01-4L-x	1	T7-SLL-C-1A	2-D	0.574	0.250	1.50	1/4	6	1.5007	0.2193	0.2480	13.0	22.46	66.24	81.75	hole			
	2	T7-SLL-C-1A	SLL	0.574	0.250	1.50	1/4	6	1.5505	0.2205	0.2480	16.0	24.44	71.49	85.10	hole			
	3	T7-SLL-C-2B		0.578	0.250	1.50	1/4	6	1.5002	0.2243	0.2495	18.0	31.21	92.74	111.24	hole			
Avg. Std Dev % COV												15.7	26.04	77.49	92.69	16.15	17.2	17.4	
BH2-01-4M-x	1	T7-SLL-C-2A	2-D	0.597	0.250	1.50	3/16	8	1.5010	0.2240	0.1875	12.8	31.46	93.57	106.93	hole			
	2	T5-SLL-C-1A	SLL	0.593	0.250	1.50	3/16	8	1.5025	0.2070	0.1880	14.0	29.82	95.88	109.59	hole			
	3	T7-SLL-C-1A		0.574	0.250	1.50	3/16	8	1.5023	0.2173	0.1880	15.2	26.33	80.64	92.18	hole			
Avg. Std Dev % COV												14.0	29.20	90.03	102.90	8.21	9.38	9.1	
BH2-02-4K-x	1	T7-LLS-C-6A	2-D	0.611	0.250	1.50	3/8	4	1.4992	0.2200	0.3730	15.0	20.27	61.46	81.81	hole			
	2	T7-LLS-C-6A	LLS	0.611	0.250	1.50	3/8	4	1.5002	0.2193	0.3720	16.0	21.13	64.22	85.39	hole			
	3	T7-LLS-C-6A		0.611	0.250	1.50	3/8	4	1.5003	0.2200	0.3725	15.0	19.35	58.62	77.99	hole			
Avg. Std Dev % COV												15.3	20.25	61.43	81.73	2.80	3.70	4.5	
BH2-02-4L-x	1	T7-LLS-C-6A	2-D	0.611	0.250	1.50	1/4	6	1.4993	0.2202	0.2465	20.0	23.63	71.58	85.81	hole			
	2	T7-LLS-C-6A	LLS	0.611	0.250	1.50	1/4	6	1.4997	0.2208	0.2490	20.0	24.59	74.25	89.03	hole			
	3	T7-LLS-C-7A		0.608	0.250	1.50	1/4	6	1.5012	0.2232	0.2490	19.0	24.53	73.22	87.78	hole			
Avg. Std Dev % COV												19.7	24.25	73.02	87.54	1.34	1.63	1.9	
BH2-02-4M-x	1	T7-LLS-C-6B	2-D	0.629	0.250	1.50	3/16	8	1.5022	0.2198	0.1880	15.0	27.37	82.88	94.74	hole			
	2	T7-LLS-C-4B	LLS	0.582	0.250	1.50	3/16	8	1.5013	0.2210	0.1885	16.5	28.37	85.50	97.78	hole			
	3	T7-LLS-C-6A		0.611	0.250	1.50	3/16	8	1.5022	0.2198	0.1880	17.5	28.43	86.09	98.41	hole			
Avg. Std Dev % COV												16.3	28.06	84.83	96.98	1.71	1.96	2.0	
BH2-01-4N-x	1	T7-SLL-C-2A	2-D	0.597	0.250	1.25	9/16	4	2.2463	0.2162	0.5620	18.0	33.50	68.93	91.90	hole			
	2	T7-SLL-C-2A	SLL	0.597	0.250	1.25	9/16	4	2.2502	0.2190	0.5650	15.0	36.42	73.91	98.69	hole			
	3	T7-SLL-C-2A		0.597	0.250	1.25	9/16	4	2.2492	0.2215	0.5655	14.6	34.03	68.31	91.25	hole			
Avg. Std Dev % COV												15.9	34.65	70.38	93.94	3.07	4.12	4.4	
Avg. Std Dev % COV												11.7	4.5	4.4	4.4				

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

Material AS4/Shell 1895

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

Textile Test Method Development

intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions	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	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	SLL	0.597	2.2485	0.2237	0.3730	23.0	40.80	81.13	97.26	Hole					
Avg Sid Dev % COV																	
2.2504 0.2199 0.3728 26.3 36.19 73.04 87.54																	
4.2 4.33 7.69 9.23 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	SLL	0.597	2.2543	0.2195	0.2810	18.5	44.49	89.91	102.71	hole					
Avg Sid Dev % COV																	
2.2533 0.2175 0.2812 17.8 43.77 89.31 102.04																	
1.5 0.67 0.56 0.62 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	LLS	0.629	2.2483	0.2177	0.5625	16.1	28.62	58.48	77.99	hole					
Avg Sid Dev % COV																	
2.2489 0.2206 0.5625 16.7 28.35 57.14 76.20																	
1.1 1.42 2.68 3.58 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	LLS	0.629	2.2503	0.2260	0.3725	24.0	34.11	67.07	80.37	hole					
Avg Sid Dev % COV																	
2.2507 0.2223 0.3728 26.0 33.01 65.95 79.05																	
1.7 1.01 0.97 1.16 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	LLS	0.629	2.2525	0.2225	0.2815	18.0	34.95	69.74	79.69	hole					
Avg Sid Dev % COV																	
2.2525 0.2266 0.2817 17.5 35.51 69.55 79.49																	
0.4 1.08 0.99 1.12 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	80.37	hole					
	3	T7-LLL-C-1A	LLL	0.622	2.2498	0.2207	0.5630	8.0	28.21	56.82	75.79	hole					
Avg Sid Dev % COV																	
2.2493 0.2209 0.5627 13.7 32.21 64.80 79.11																	
5.5 3.76 7.53 15.24 19.3																	
40.3 11.7 11.6																	

Material: AS4/Shell 1895

Textile Test Method Development

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

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

inlec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions		D/t	Avg Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (Ksr)	Net Ultimate Stress (Ksr)	Failure Location	Comments	
					Thick (in)	Width (in)											
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	0.250	2.25	3/8	6	1.50	2.2520	0.2230	0.3755	11.5	38.24	76.15	91.38	hole
	3	T7-LLL-C-1A	LLL	0.622	0.250	2.25	3/8	6	1.50	2.2492	0.2210	0.3760	11.0	39.24	78.94	94.79	hole
<p style="text-align: center;">Avg. 2.2503 0.2213 0.3755 Std Dev % COV</p>																	
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	0.250	2.25	9/32	8	1.13	2.2527	0.2180	0.2820	11.0	38.80	79.01	90.32	hole
	3	T7-LLL-C-1B	LLL	0.641	0.250	2.25	9/32	8	1.13	2.2522	0.2173	0.2810	12.0	41.85	85.50	97.69	hole
<p style="text-align: center;">Avg. 2.2529 0.2177 0.2815 Std Dev % COV</p>																	
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
	2	T7-LSS-C-2A	LSS	0.612	0.250	2.25	9/16	4	2.25	2.2502	0.2212	0.5615	11.8	15.37	30.88	41.15	hole
	3	T7-LSS-C-2A	LSS	0.612	0.250	2.25	9/16	4	2.25	2.2500	0.2167	0.5620	11.2	15.06	30.89	41.18	hole
<p style="text-align: center;">Avg. 2.2502 0.2200 0.5617 Std Dev % COV</p>																	
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	0.250	2.25	3/8	6	1.50	2.2500	0.2238	0.3750	none	19.24	38.20	45.84	hole
	3	T7-LSS-C-2A	LSS	0.612	0.250	2.25	3/8	6	1.50	2.2510	0.2202	0.3715	none	19.50	39.35	47.12	hole
<p style="text-align: center;">Avg. 2.2512 0.2195 0.3740 Std Dev % COV</p>																	
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
	2	T7-LSS-C-2A	LSS	0.612	0.250	2.25	9/32	8	1.13	2.2532	0.2170	0.2815	16.0	20.15	41.21	47.10	hole
	3	T7-LSS-C-1B	LSS	0.642	0.250	2.25	9/32	8	1.13	2.2478	0.2000	0.2810	16.0	18.67	41.53	47.46	hole
<p style="text-align: center;">Avg. 2.2512 0.2119 0.2813 Std Dev % COV</p>																	
BH2-01-4O-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	0.250	3.00	3/4	4	3.0	2.9997	0.2217	0.7500	41.52	62.42	83.24	hole	
	3	T7-SLL-C-2B	SLL	0.578	0.250	3.00	3/4	4	3.0	3.0030	0.2187	0.7500	47.72	72.67	96.86	hole	
<p style="text-align: center;">Avg. 3.0019 0.2213 0.7502 Std Dev % COV</p>																	
<p style="text-align: center;">Avg. 48.12 71.75 95.65 Std Dev 41.52 62.42 83.24 % COV 8.1 8.2 8.2</p>																	

failed diagonally
 failed diagonally
 failed diagonally

Project #: BH0002

intec Engineer: Maryann Emanson
 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	49.54	75.73	90.85	hole	
Avg. Std Dev % COV																
3.0011 0.2210 0.4993																
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. Std Dev % COV																
3.0028 0.2208 0.3725																
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	0.2128	0.7505		36.06	56.50	75.32	hole	
Avg. Std Dev % COV																
3.0016 0.2177 0.7505																
BH2-02-4R-x	1	T7-LLS-C-7A	2-D	0.608	0.250 3.00 1/2	6	2.0	3.0012	0.2180	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. Std Dev % COV																
3.0013 0.2163 0.5012																
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. Std Dev % COV																
3.0024 0.2193 0.3728																
Avg. Std Dev % COV																
30.9 9.5 1.32 68.66 1.50 1.9																
30.8 1.8 1.9																

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

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

Material: ASA/Shell 1895

Textile Test Method Development

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 Failure (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. Std Dev % COV																
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. Std Dev % COV																
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. Std Dev % COV																
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	0.2284	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. Std Dev % COV																
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. Std Dev % COV																
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	26.73	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. Std Dev % COV																
Avg. Std Dev % COV																

Project #: BH0002
 intec Engineer: Maryann Einerson
 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. Width Diam. (in) (in) (in)	W/D	D/I	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. Std Dev % COV																
BH2-07-4L-x	1	T7-OS1-A-2B	3-D	0.614	0.250 1.50 1/4	6	1.00	1.4988	0.2259	0.2500	29.0	36.85	108.77	130.53	hole	
	2	T7-OS1-A-2B	OS-1	0.614				1.5010	0.2286	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. Std Dev % COV																
BH2-07-4M-x	1	T7-OS1-A-2B	3-D	0.614	0.250 1.50 3/16	8	0.75	1.4985	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. Std Dev % COV																
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. Std Dev % COV																
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. Std Dev % COV																
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. Std Dev % COV																
											22.1	26.62	75.91	86.71		
											3.17	3.17	9.11	10.44		
											11.9	11.9	12.0	12.0		

Material: AS4/Shell 1895

Textile Test Method Development

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

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

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensions		W/D	D1	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
					Thick (in)	Width (in)											
BH2-09-4K-x	1	T7-LS1-A-7B	3-D	0.631	0.250	1.50	3/8	4	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.																	
Std Dev																	
% COV																	
BH2-09-4L-x	1	T7-LS1-A-7B	3-D	0.631	0.250	1.50	1/4	6	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.																	
Std Dev																	
% COV																	
BH2-09-4M-x	1	T7-LS1-A-7A	3-D	0.656	0.250	1.50	3/16	8	1.4977	0.2144	0.1900	7.4	41.83	130.60	149.58		with delamination with delamination
	2	T7-LS1-A-5B	LS-1	0.646					1.5003	0.2098	0.1875	36.1	42.25	134.26	153.43		
	3	T7-LS1-A-5B		0.646					1.5037	0.2081	0.1875	39.2	42.25	135.05	154.29		
Avg.																	
Std Dev																	
% COV																	
BH2-10-4K-x	1	T7-LS2-A-2B	3-D	0.610	0.250	1.50	3/8	4	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		
	3	T7-LS2-A-2B		0.610					1.4980	0.2246	0.3745	27.3	29.40	87.39	116.52		
Avg.																	
Std Dev																	
% COV																	
BH2-10-4L-x	1	T7-LS2-A-2B	3-D	0.610	0.250	1.50	1/4	6	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		
	3	T7-LS2-A-2B		0.610					1.4988	0.2236	0.2490	28.1	32.85	98.01	117.54		
Avg.																	
Std Dev																	
% COV																	
BH2-10-4M-x	1	T7-LS2-A-2B	3-D	0.610	0.250	1.50	3/16	8	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.																	
Std Dev																	
% COV																	

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			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
					Thick (in)	Width (in)	Diam. (in)										
BH2-11-4K-x	1	T7-SUW-G3KBA1	SU-1	0.670	0.250	1.50	3/8	4	1.4960	0.2240	0.3745	16.8	17.44	51.95	69.25	hole	
	2	T7-SUW-G3KBA1	SU-1	0.670	0.250	1.50	3/8	4	1.4997	0.2237	0.3750	12.9	16.03	47.79	63.72	hole	
	3	T7-SUW-G3KBA1	SU-1	0.670	0.250	1.50	3/8	4	1.4995	0.2228	0.3740	15.1	15.96	47.77	63.65	hole	
Avg. Std Dev % COV																	
14.9 0.84 2.41 4.9																	
BH2-11-4L-x	1	T7-SUW-G3KBA1	SU-1	0.670	0.250	1.50	1/4	6	1.5027	0.2215	0.2495	14.8	18.86	56.67	67.96	hole	
	2	T7-SUW-G3KBA1	SU-1	0.670	0.250	1.50	1/4	6	1.5005	0.2208	0.2495	14.7	19.58	59.11	70.90	hole	
	3	T7-SUW-G3KBA1	SU-1	0.670	0.250	1.50	1/4	6	1.4985	0.2217	0.2495	13.8	19.88	59.85	71.81	hole	
Avg. Std Dev % COV																	
14.4 0.52 1.86 2.02 2.7 2.8 2.9																	
BH2-11-4M-x	1	T7-SUW-G3KBA1	SU-1	0.670	0.250	1.50	3/16	8	1.4960	0.2204	0.1880	20.5	21.81	65.42	74.81	hole	
	2	T7-SUW-G3KBA1	SU-1	0.670	0.250	1.50	3/16	8	1.4995	0.2212	0.1880	19.8	21.75	65.58	74.98	hole	
	3	T7-SUW-G3KBA1	SU-1	0.670	0.250	1.50	3/16	8	1.5010	0.2214	0.1875	18.9	21.40	64.40	73.59	hole	
Avg. Std Dev % COV																	
19.7 0.18 0.84 0.78 0.8 1.0 1.0																	
BH2-12-4K-x	1	T7-SUW-G3KBA1	SU-2	0.652	0.250	1.50	3/8	4	1.4995	0.2440	0.3755	15.6	17.53	47.92	63.93	hole	
	2	T7-SUW-G3KBA1	SU-2	0.652	0.250	1.50	3/8	4	1.5000	0.2442	0.3755	15.8	17.32	47.29	63.09	hole	
	3	T7-SUW-G3KBA1	SU-2	0.652	0.250	1.50	3/8	4	1.4982	0.2444	0.3745	14.3	17.20	46.98	62.63	hole	
Avg. Std Dev % COV																	
15.2 0.17 0.35 0.48 0.66 0.66 0.66																	
BH2-12-4L-x	1	T7-SUW-G3KBA1	SU-2	0.652	0.250	1.50	1/4	6	1.5030	0.2451	0.2495	14.9	20.15	54.71	65.60	hole	
	2	T7-SUW-G3KBA1	SU-2	0.652	0.250	1.50	1/4	6	1.5005	0.2449	0.2495	19.8	20.39	55.48	66.56	hole	
	3	T7-SUW-G3KBA1	SU-2	0.652	0.250	1.50	1/4	6	1.5000	0.2440	0.2500	15.9	20.11	54.95	65.94	hole	
Avg. Std Dev % COV																	
16.9 0.15 0.40 0.49 0.7 0.7 0.7																	
BH2-12-4M-x	1	T7-SUW-G3KBA1	SU-2	0.652	0.250	1.50	3/16	8	1.5035	0.2437	0.1875	22.0	22.38	61.07	69.77	hole	
	2	T7-SUW-G3KBA1	SU-2	0.652	0.250	1.50	3/16	8	1.5010	0.2435	0.1875	22.2	22.56	61.73	70.55	hole	
	3	T7-SUW-G3KBA1	SU-2	0.652	0.250	1.50	3/16	8	1.5015	0.2439	0.1880	21.4	23.13	63.17	72.21	hole	
Avg. Std Dev % COV																	
21.9 0.39 1.07 1.24 1.7 1.7 1.8																	

Material: AS4/Shell 1805

Textile Test Method Development
 Task 6
 Open Hole Tension Test Program
 Stitched Unweave Architectures

Project #: BH0002
 Intec Engineer: Maryann Einatson
 Boeing Engineer: Mark Fedro

Intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Nominal Dimensional		W/D	D/I	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
					Thick (in)	Width (in)											
BH2-13-4K-x	1	T7-SUW-K8K4A-1	SU-3	0.820	0.250	1.50	3/8	4	1.50	1.5027	0.2450	0.3750	17.96	48.79	65.02	hole	
	2	T7-SUW-K8K4A-1	SU-3	0.809					1.4978	0.2459	0.3740	17.85	48.75	64.97	hole		
	3	T7-SUW-K8K4A-1	SU-3	0.809					1.4977	0.2468	0.3745	17.00	45.99	61.33	hole		
Avg. Std Dev % COV																	
									1.4977	0.2468	0.3745	13.7	17.84	47.84	63.77		
BH2-13-4L-x	1	T7-SUW-K8K4A-1	SU-3	0.809	0.250	1.50	1/4	6	1.00	1.4982	0.2471	0.2490	20.22	54.82	66.51	hole	
	2	T7-SUW-K8K4A-1	SU-3	0.809					1.4975	0.2465	0.2490	21.44	58.06	69.66	hole		
	3	T7-SUW-K8K4A-1	SU-3	0.809					1.5028	0.2462	0.2490	16.1	50.46	60.48	hole		
Avg. Std Dev % COV																	
									1.5028	0.2462	0.2490	16.7	20.11	54.39	65.22		
BH2-13-4M-x	1	T7-SUW-K8K4A-1	SU-3	0.809	0.250	1.50	3/16	8	0.75	1.5010	0.2494	0.1875	22.33	59.86	68.40	hole	
	2	T7-SUW-K8K4A-1	SU-3	0.809					1.4965	0.2500	0.1875	23.32	62.34	71.27	hole		
	3	T7-SUW-K8K4A-1	SU-3	0.809					1.5007	0.2518	0.1875	21.0	21.33	56.44	64.50	hole	
Avg. Std Dev % COV																	
									1.5007	0.2518	0.1875	21.0	22.33	59.55	68.06		
BH2-14-4K-x	1	T7-SUW-K8K4A1	SU-4	0.821	0.250	1.50	3/8	4	1.50	1.4978	0.2336	0.3745	18.23	62.11	69.49	hole	
	2	T7-SUW-K8K4A1	SU-4	0.821					1.5002	0.2336	0.3745	16.1	17.19	49.02	65.33	hole	
	3	T7-SUW-K8K4A1	SU-4	0.821					1.4983	0.2339	0.3745	16.9	17.49	49.91	66.55	hole	
Avg. Std Dev % COV																	
									1.4983	0.2339	0.3745	16.7	17.84	50.35	67.12		
BH2-14-4L-x	1	T7-SUW-K8K4A1	SU-4	0.821	0.250	1.50	1/4	6	1.00	1.5080	0.2336	0.2500	19.5	58.48	67.72	hole	
	2	T7-SUW-K8K4A1	SU-4	0.821					1.5035	0.2340	0.2500	17.2	19.92	56.63	67.92	hole	
	3	T7-SUW-K8K4A1	SU-4	0.821					1.5005	0.2344	0.2500	16.9	19.17	54.52	65.41	hole	
Avg. Std Dev % COV																	
									1.5005	0.2344	0.2500	17.9	19.65	55.87	67.02		
BH2-14-4M-x	1	T7-SUW-K8K4A1	SU-4	0.821	0.250	1.50	1/5	8	0.75	1.5010	0.2313	0.1880	21.75	62.64	71.61	hole	
	2	T7-SUW-K8K4A1	SU-4	0.821					1.5020	0.2317	0.1875	17.4	22.01	63.25	72.26	hole	
	3	T7-SUW-K8K4A1	SU-4	0.821					1.5005	0.2320	0.1875	17.1	21.80	62.05	70.91	hole	
Avg. Std Dev % COV																	
									1.5005	0.2320	0.1875	17.3	21.79	62.65	71.60		
													0.21	0.80	0.68		
													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			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
					Thick (in)	Width (in)	Diam (in)											
BH2-15-4K-x	1	T7-SUW-K12KBA1	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-K12KBA1		0.650					1.5063	0.2544	0.3750	15.5	17.61	45.96	61.19	hole		
	3	T7-SUW-K12KBA1		0.650					1.4937	0.2549	0.3745	16.3	18.66	49.02	65.42	hole		
Avg.																		
Std Dev																		
% COV																		
BH2-15-4L-x	1	T7-SUW-K12KBA1	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-K12KBA1		0.650					1.4998	0.2539	0.2500	14.6	20.98	55.10	66.12	hole		
	3	T7-SUW-K12KBA1		0.650					1.4960	0.2535	0.2500	16.5	19.82	52.26	62.75	hole		
Avg.																		
Std Dev																		
% COV																		
BH2-15-4M-x	1	T7-SUW-K12KBA1	SU-5	0.650	0.250	1.50	3/16	8	0.75	1.5018	0.2458	0.1875	21.0	22.21	60.21	69.80	hole	
	2	T7-SUW-K12KBA1		0.650					1.5082	0.2535	0.1875	20.5	23.11	60.45	69.03	hole		
	3	T7-SUW-K12KBA1		0.650					1.4965	0.2541	0.1875	21.2	23.39	61.50	70.31	hole		
Avg.																		
Std Dev																		
% COV																		

Compression Test Program

Project #: BH0002

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

Material: ASA/Shell 1895

invc Engineer: Maryann Emerson
Boeing Engineer: Mark Pedro

Invc Group ID	Invc #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions			Load at Break (kN)	Ultimate Load (kN)	Ultimate Stress (ksi)	Ultimate Strain (%)	Ultimate Trans. Strain (%)	Axial Modulus (ksi)		Poisson's Ratio				
						total Length (in)	tab Length (in)	gage Length (in)						Axial 1 (ksi)	Axial 2 (ksi)		Average (ksi)			
BH2-01-SA-x	1	T7SLLB95A,95B	2-D		Baseline	12	3.0	6.0	3.0013	1.1070	14.6	15.74	41.95	-5.537	-5.688	1.069	7.57	7.60	7.58	0.188
	2	T7SLLB95A,95B	SLL		Comp Sandwich				3.0022	1.1040	15.1	17.34	46.21	-5.704	-6.656	1.061	7.49	7.33	7.41	0.160
	3	T7SLLB95A,95B	SLL		Sandwich				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	0.08	0.017	
											11.05	11.04				0.90	1.80	1.23	9.94	
BH2-02-SA-x	1	T7LLSB75A,75B	2-D		Baseline	12	3.0	6.0	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	T7LLSB75A,75B	LLS		Comp Sandwich				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	T7LLSB75A,75B	LLS		Sandwich				2.9998	1.1438	17.2	23.59	62.90	-5.818	-5.506	3.500	11.20	11.79	11.48	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-SA-x	1	T7LLLB35A,35B	2-D		Baseline	12	3.0	6.0	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	T7LLLB35A,35B	LLL		Comp Sandwich				2.9972	1.0953	12.04	32.12	56.37	-6.007	-6.007	1.133	5.68	5.39	5.53	0.187
	3	T7LLLB35A,35B	LLL		Sandwich				2.9962	1.0932	10.66	28.46	50.81	-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-SA-x	1	T7LSSB55B,55A	2-D		Baseline	12	3.0	6.0	2.9970	1.0892	7.0	10.76	28.71	-9.474	na	8.640	3.50	3.39	3.44	0.751
	2	T7LSSB55B,55A	LSS		Comp Sandwich				2.9987	1.0882	10.3	10.70	28.54	-9.873	na	8.581	3.41	3.36	3.30	0.787
	3	T7LSSB55B,55A	LSS		Sandwich				2.9998	1.0968	10.95	20.20	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	
BH2-01-5C-x	1	T7SLLB95A,95B	2-D		Sandwich Width Effect	12	3.0	6.0	1.5030	1.1043	8.5	9.18	48.84	-6.868	-6.500		7.40	7.72	7.56	
	2	T7SLLB95A,95B	SLL		Sandwich Width Effect				1.4982	1.1097	8.6	9.26	49.46	-6.610	-6.646		7.64	7.69	7.66	
	3	T7SLLB95A,95B	SLL		Sandwich Width 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	2.39				2.07	1.10	1.38		
BH2-01-5C-x	1	T7SLLB95A,95B	2-D		Sandwich Width Effect	12	3.0	6.0	2.2513	1.1050	13.2	14.87	52.85	-7.224	-7.961		7.50	7.00	7.25	
	2	T7SLLB95A,95B	SLL		Sandwich Width Effect				2.2520	1.1060	11.7	12.83	45.57	-5.281	-6.483		7.99	7.28	7.64	
	3	T7SLLB95A,95B	SLL		Sandwich Width 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	-5.988	-6.895		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	T7LLSB75A,75B	2-D		Sandwich Width Effect	12	3.0	6.0	1.5022	1.1400	8.2	11.59	61.72	-5.576	-5.704		11.40	11.08	11.24	
	2	T7LLSB75A,75B	LLS		Sandwich Width Effect				1.4975	1.1473	9.4	10.86	58.02	-4.956	-5.960		11.70	10.26	10.98	
	3	T7LLSB75A,75B	LLS		Sandwich Width 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	T7LLSB75A,75B	2-D		Sandwich Width Effect	12	3.0	6.0	2.2482	1.1462	15.4	17.46	62.12	-5.432	-5.590		11.56	11.56	11.56	
	2	T7LLSB75A,75B	LLS		Sandwich Width Effect				2.2470	1.1490	14.4	17.39	61.92	-5.976	-5.172		10.68	12.14	11.41	
	3	T7LLSB75A,75B	LLS		Sandwich Width 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	11.38	
											0.50	1.74				4.00	4.21	1.60		
											2.81	2.76								

Material: ASA/Shell 1895

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

Project #: BH0002
in/c Engineer: Maryann Emanson
Boeing Engineer: Mark Fedro

In/c Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions			Avg. Thickness (in)	Avg. Width (in)	Load at Audible (Kpsi)	Ultimate Load (lbs)	Ultimate Stress (ksi)	Ultimate			Axial Modulus		Poisson's Ratio
						total Length (in)	tab Length (in)	gauge length (in)						Strain (in/in)	Strain (in/in)	Strain (in/in)	Trans. Strain (in/in)	Axial 1 (ksi)	
BH2-01-5D-x	1	17SL1B7SD.7SA	2-D		Sand Gauge Length Effect	3.0	3.0	3.00	3.0033	1.1055	17.2	19.47	51.85	-7.338	-7.181	7.67	7.56	7.62	
	2	17SL1B7SD.7SA	SLL			3.0023	1.1038	16.4	21.34	56.86	6.866	-6.866	-6.345	7.65	8.63	8.14	7.71	7.97	7.84
	3	17SL1B7SD.7SA				3.0005	1.1048	15.2	18.16	48.41	-6.598	-6.214	7.67	8.06	7.87	0.03	0.54	0.26	
						3.0021	1.1047	16.3	19.65	52.37	-6.934	-7.250	0.38	6.69	3.39	8.65	6.89	7.77	
BH2-01-5E-x	1	17SL1B7SD.7SA	2-D		Sand Gauge Length Effect	3.0	3.0	3.00	2.9973	1.1155	14.7	18.50	49.36	-5.953	-7.183	8.09	8.27	8.18	
	2	17SL1B7SD.7SA	SLL			2.9975	1.1090	14.7	17.14	45.76	-5.775	-5.581	7.85	8.09	7.97	11.04	11.15	11.10	
	3	17SL1B7SD.7SA				2.9955	1.1035	14.5	15.02	40.11	-5.113	-5.013	8.20	7.75	7.97	11.22	10.63	10.92	
						2.9968	1.1083	14.6	16.88	45.08	-5.614	-5.929	0.41	0.75	0.21	10.96	10.83	10.95	
						1.75	4.66	10.38	10.35				4.99	9.73	2.59	10.62	10.82		
BH2-02-5D-x	1	17LLS87SA.7SB	2-D		Sand Gauge Length Effect	3.0	2.0	3.00	2.9987	1.1475	21.7	24.04	64.13	-6.250	-5.974	11.68	11.13	11.41	
	2	17LLS87SA.7SB	LLS			2.9992	1.1473	18.3	24.69	63.86	-5.821	-6.423	11.04	11.15	11.10	11.22	10.63	10.92	
	3	17LLS87SA.7SB				3.0025	1.1420	15.8	23.70	63.15	-5.880	-6.040	11.22	10.63	10.92	11.68	11.13	11.41	
						3.0001	1.1456	18.6	24.14	64.38	-5.984	-6.146	0.31	0.27	0.14	2.81	2.47	1.28	
						0.50	1.37	2.08	2.13				11.68	11.13	11.41	11.68	11.13	11.41	
BH2-02-5E-x	1	17LLS87SD.8SA	2-D		Sand Gauge Length Effect	3.0	3.0	3.00	2.9972	1.1478	20.9	23.47	62.65	-5.605	-5.738	11.68	11.13	11.41	
	2	17LLS87SD.8SA	LLS			2.9948	1.1502	17.2	23.99	64.06	-7.068	-4.637	11.63	11.53	11.58	11.22	10.63	10.92	
	3	17LLS87SD.8SA				2.9980	1.1583	19.3	20.71	55.27	-4.740	-5.050	11.07	11.74	11.40	11.07	11.74	11.40	
						2.9967	1.1521	19.1	22.72	60.67	-5.804	-5.142	1.03	0.74	0.18	9.28	6.26	1.58	
						1.76	4.73	7.75	7.80				7.89	7.99	7.99	7.89	7.99	7.99	
BH2-01-5F-x	1	17SL1B7SC.7SB	2-D		Sandwich Core Effect	3.0	6.0	3.00	3.0022	1.1080	17.82	47.48	47.48	-6.049	-5.997	8.38	8.16	8.27	
	2	17SL1B7SC.7SB	SLL			2.9993	1.1078	16.6	18.71	49.91	-5.898	-6.354	8.08	7.79	7.84	7.89	7.99	7.99	
	3	17SL1B7SC.7SB				2.9990	1.1032	16.7	19.90	53.08	-7.552	-6.785	8.15	7.98	8.07	0.20	0.19	0.18	
						3.0002	1.1063	16.7	18.81	50.16	-6.500	-6.379	0.20	0.19	0.18	2.45	2.34	2.20	
						1.04	2.81	5.55	5.60				10.64	11.09	10.87	10.64	11.09	10.87	
BH2-02-5F-x	1	17LLS89SB.7SC	2-D		Sandwich Core Effect	3.0	6.0	3.00	3.0002	1.1447	19.4	20.38	54.35	-5.240	-4.936	11.70	11.35	11.53	
	2	17LLS89SB.7SC	LLS			3.0013	1.1452	18.7	22.81	60.81	-5.945	-5.481	11.89	11.60	11.78	11.41	11.35	11.53	
	3	17LLS89SB.7SC				3.0002	1.1462	21.5	23.76	63.36	-5.551	-5.514	11.41	11.35	11.38	0.68	0.25	0.46	
						3.0006	1.1453	19.9	22.32	59.50	-5.379	-5.310	5.92	2.23	4.03	5.92	2.23	4.03	
						1.74	4.64	7.81	7.81				8.53	8.53	8.53	8.53	8.53	8.53	
BH2-01-5G-x	1	17-SLL-C-4B	2-D	0.619	NASA SB Baseline	1.5		1.50	1.5023	0.2131	19.5	24.24	75.73	-8.561	-10.775	2.311	2.311	2.311	0.207
	2	17-SLL-C-4B	SLL	0.619					1.5017	0.2127	24.1	25.27	79.12	-10.090	-8.955	1.819	1.819	1.819	0.165
	3	17-SLL-C-3B		0.619					1.5000	0.2152	26.81	26.81	83.05	-9.983	-10.944	1.542	1.542	1.542	0.119
									1.5013	0.2136	21.8	25.44	79.30	-9.545	-10.225	1.891	1.891	1.891	0.163
BH2-02-5G-x	1	17-LLS-C-4A	2-D	0.570	NASA SB Baseline	1.5		1.50	1.5180	0.2210	19.2	21.43	63.83	-7.972	-7.806	3.534	3.534	3.534	0.516
	2	17-LLS-C-4A	LLS	0.570					1.5168	0.2213	16.9	21.26	63.34	na	na	na	na	na	0.165
	3	17-LLS-C-3A		0.624					1.5017	0.2188	14.3	20.16	61.36	na	-6.678	3.880	7.88	10.24	0.906
									1.5125	0.2204	16.8	20.95	62.84	-7.972	-7.242	3.707	3.707	3.707	0.530
											0.69	1.31	2.09	4.81	7.84	3.53	3.53	3.53	0.054
											3.29	2.09	4.81	7.84	3.53	3.53	3.53	3.53	0.109

Project #: BH0002

Material Engineer: Maryann Emerson
Boeing Engineer: Mark Fedro

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

Material: ASA/Shell1895

Inlec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions				Load at Audible (k/osc)	Ultimate Load (k/osc)	Ultimate Strain (%)	Ultimate Trans Strain (%)	Axial Modulus (ksi)		Poisson's Ratio				
						total length (in)	tab length (in)	gage length (in)	width (in)					Axial 1 (ksi)	Axial 2 (ksi)		Average (ksi)			
BH2-03-SG-x	1	T5-LL-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	na	7.53	8.15	7.84	0.105
	2	T5-LL-C-1A	LLL	0.611	Baseline				1.5190	0.2134	11.1	21.87	67.49	-8.617	-10.798	1.785	8.42	7.13	8.28	0.108
	3	T5-LL-C-1A		0.611					1.5163	0.2137	13.1	18.79	57.81	-7.605	-7.243	7.91	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		7.74	4.88				0.004	11.46	8.84	2.71	3.55
BH2-04-SG-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				1.5028	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	-12.663	na	3.72	3.80	3.76	0.644
									1.5014 0.2228		12.6	14.94	44.67	na	-12.663	na	3.66	3.88	3.92	0.650
									0.26		0.72					0.32	0.33	0.32	0.009	
									1.76		1.50	8.29	8.23	8.24	1.45		8.66			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	na		na	7.46	1.10	1.10	
	3	T7-SLL-C-5A	SLL	0.606	page length				1.5028	0.2118	25.29	79.45	-30.457	na		na	1.10	1.10	1.10	
	4	T7-SLL-C-5A		0.606					1.5013	0.2124	25.8	26.30	82.47	-28.946	na	7.21	7.21	7.21		
									1.5020 0.2120		25.6	25.63	80.19	-28.292	na	7.46	7.46	7.46		
									2.66		2.51					1.10	1.10	1.10		
BH2-01-5I-x	1	T7-SLL-C-1B	2-D	0.608	NASA SB	2.0		1.50	1.5008	0.2216	23.3	23.06	69.32	-10.062	-9.362	na	6.97	8.22	7.59	
	2	T7-SLL-C-5A	SLL	0.606	page length				1.5007	0.2134	24.4	25.96	81.08	-11.470	-9.261	na	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	na	6.49	8.12	7.30	
									1.5008 0.2187		21.1	23.77	72.52	-10.623	-9.557	na	7.22	8.30	7.76	
									1.93		7.49	8.13	10.33			0.89	0.23	0.56		
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	na		na	5.75			
	2	T7-LLS-C-7B	LLS	0.605	page length				1.5022	0.2258	25.0	27.64	81.49	-29.373	na	7.69				
	3	T7-LLS-C-7B		0.605					1.5013	0.2191	25.2	24.82	75.76	-30.228	na	6.99				
									1.5019 0.2209		25.2	24.92	76.68	-30.228	na	7.34				
									1.92		4.05					0.50				
									7.70		5.29					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	na	9.32	7.82	8.57	
	2	T7-LLS-C-3A	LLS	0.624	page 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	na	8.38	8.87	8.63	
									1.5019 0.2209		18.0	19.72	59.69	-7.329	-7.512	na	9.22	8.07	8.64	
									3.09		9.05					0.79	0.72	0.08		
									15.67		15.16					8.61	8.86	8.94		
BH2-01-5J-x	1	T7-SLL-C-1A	2-D	0.574	NASA ST-4	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					5.0017	0.2120	37.0	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
									5.0055 0.2136		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 ST-4	10.0		5.00	5.0090	0.2259	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					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	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 #: BR0002

Material: ASA/Snell 1895

Task 5
 Compression Test Program
 2-D Braided Architectures

Maynard Emerson
 Mark Fedro

Boeing Engineer

Boeing Plate #

Fiber Volume Fraction

Material Form

Boeing Configuration Type

total Length (in)

tab Length (in)

page length (in)

width (in)

width (in)

avg. thickness (in)

Load at Failure (lbs)

Ultimate Load (ksi)

Ultimate Stress (ksi)

Ultimate Strain (%)

Ultimate Strain (%)

Axial Modulus (ksi)

Axial Modulus (ksi)

Poisson's Ratio

Inspec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Boeing Configuration Type	total Length (in)	tab Length (in)	page length (in)	width (in)	width (in)	avg. thickness (in)	Load at Failure (lbs)	Ultimate Load (ksi)	Ultimate Stress (ksi)	Ultimate Strain (%)	Ultimate Strain (%)	Axial Modulus (ksi)		Poisson's Ratio		
																	Axial 1	Axial 2			
BH2-03-SJ-x	1	15-LLL-C-1A	2-D	0.611	NASA	10.0			5.00	0.0080	0.2235	47.84	42.75	-4.303	5.447	na	9.69	7.99	6.84	0.108	
	2	15-LLL-C-2A	LLL	0.621	ST-4	36.0			5.0010	0.2291	42.0	53.67	46.85	-6.930	-3.908	1.901	8.74	8.74	8.49	0.158	
	3	15-LLL-C-2A	LLL	0.621	ST-4	40.3			5.0005	0.2311	36.0	51.29	44.38	-6.368	-4.089	1.413	7.66	9.36	8.51	0.223	
BH2-04-SJ-x	1	17-LSS-C-2B	2-D	0.581	NASA	10.0			5.00	0.0025	0.2158	43.53	40.30	-10.811	-9.468	8.992	4.40	4.76	4.58	0.803	
	2	17-LSS-C-4A	LSS	0.578	ST-4	38.0			5.0032	0.2074	38.0	46.93	45.23	-12.083	-12.011	9.194	4.59	4.48	4.53	0.708	
	3	17-LSS-C-4A	LSS	0.578	ST-4	33.0			4.9998	0.2133	33.0	42.56	39.91	-11.120	-8.671	9.183	4.35	4.80	4.62	0.805	
BH2-01-SK-x	1	15-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	6.62	9.16	9.39	0.158	
	2	15-SLL-C-1B	SLL	0.623	CAI	50.0			4.0023	0.2041	50.0	58.25	71.31	-6.265	-9.356	na	10.51	8.64	9.57	0.112	
	3	15-SLL-C-1B	SLL	0.623	Boeing	50.0			4.0015	0.2038	50.0	51.62	63.30	-7.519	-6.262	1.773	9.16	9.68	9.42	0.189	
BH2-02-SK-x	1	17-LSS-C-1A	2-D	0.575	Boeing	10.0			4.00	4.0082	0.2196	49.37	56.08	-6.267	-6.218	3.400	9.08	9.34	9.21	0.471	
	2	17-LSS-C-1A	LLS	0.575	CAI	48.0			4.0085	0.2188	48.0	49.13	58.01	-6.008	-6.264	3.145	9.52	9.26	9.39	0.489	
	3	15-LLS-C-2B	LLS	0.584	Boeing	45.1			4.0013	0.2197	40.0	46.02	52.35	-6.373	-6.035	3.298	8.54	9.05	8.80	0.508	
BH2-03-SK-x	1	15-LLL-C-1A	2-D	0.611	Boeing	10.0			4.00	4.0000	0.2269	45.0	52.84	-6.535	-7.272	1.293	8.46	8.55	8.50	0.153	
	2	15-LLL-C-1A	LLL	0.611	CAI	42.0			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	15-LLL-C-1A	LLL	0.611	Boeing	42.3			4.0095	0.2081	42.0	48.51	58.13	-7.341	-6.180	2.96	8.46	8.67	8.06	0.154	
BH2-04-SK-x	1	17-LSS-C-2B	2-D	0.581	Boeing	10.0			4.00	4.0358	0.2206	36.77	41.29	-10.813	-11.806	8.864	4.34	4.37	4.35	0.673	
	2	17-LSS-C-2B	LSS	0.581	CAI	34.0			4.0010	0.2234	34.0	37.58	42.04	-12.746	-12.174	na	4.07	4.20	4.13	0.720	
	3	17-LSS-C-2B	LSS	0.581	Boeing	33.0			4.0012	0.2208	35.0	37.45	42.40	-12.800	-12.849	na	4.13	4.16	4.15	0.692	
BH2-01-SL-x	1	17-SLL-B-1A	2-D	0.635	IIFRI	6.0	2.5	1.0	1.50	1.4893	0.1067	11.13	69.61	-9.562	-7.195	1.254	8.18	10.04	9.11	0.181	
	2	17-SLL-B-1A	SLL	0.635	Baseline	10.0			1.5030	0.1060	11.55	72.50	-10.131	-7.286	1.293	8.77	9.88	9.32	0.162		
	3	17-SLL-B-1A	SLL	0.635	Boeing	11.10			1.5010	0.1060	11.10	69.77	-7.040	-8.554	1.200	9.11	9.83	9.47	0.163		
BH2-02-SL-x	1	17-LLS-B-4B	2-D	0.618	IIFRI	6.0	2.5	1.0	1.50	1.5015	0.1017	11.26	70.63	-8.911	-7.678	1.249	8.68	9.92	9.30	0.169	
	2	17-LLS-B-4B	LLS	0.618	Baseline	10.0			1.5020	0.1045	10.25	67.13	-7.287	-6.766	1.168	10.02	10.69	10.35	0.383		
	3	17-LLS-B-4B	LLS	0.618	Boeing	10.15			1.5000	0.1073	10.15	64.73	-6.805	-6.766	3.800	4.207	9.58	7.25	8.41	0.390	
											10.15	64.73	-6.805	-6.766	3.800	4.207	9.58	7.25	8.41	0.470	
											0.48	3.01	-0.42	1.77	1.04	0.42	4.24	1.919	10.86	22.07	
											4.73	4.65	-4.73	4.65							

Project #: BH0002

Material Engineer: Maryann Emerson
 Boeing Engineer: Mark Pedro

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

Material: ASA/Shell 1895

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions			Load at Audible (kN)	Ultimate Load (kN)	Ultimate Strain (%)	Ultimate Strain (µε)	Ultimate Strain (µε)	Ultimate Strain (µε)	Axial Modulus		Poisson's Ratio			
						total length (in)	tab length (in)	gauge length (in)							width (in)	avg thickness (in)		Axial 1 (ksi)	Axial 2 (ksi)	
BH2-03-SL-x	1	T7-LL-B-2A	2-D	0.638	ITRI	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-LL-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-LL-B-2A		0.638						1.5010	0.1083	7.5	58.94	-5.236	-1.820	1,820	9.36	9.72	9.54	0.180
BH2-04-SL-x	1	T7-LSS-B-4B	2-D	0.619	ITRI	6.0	2.5	1.0	1.50	1.5033	0.1050	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	4.20	0.622
	3	T7-LSS-B-4B		0.619						1.5000	0.1040	7.3	51.98	-15.104	-15.108	10,346	4.56	4.83	4.75	0.625
BH2-01-5M-x	1	T7-SLL-C-3B	2-D	0.601	ITRI	6.5	2.5	1.5	1.50	1.5008	0.2185	4.09	2.40	-8.463	-8.307	1,217	0.61	0.70	0.65	0.141
	2	T7-SLL-C-3B	SLL	0.601	Baseline					1.5010	0.2185	23.24	70.53	-7.169	-8.223	1,666	0.62	0.57	0.64	0.180
	3	T7-SLL-C-3B		0.601						1.5007	0.2168	23.43	72.01	-8.917	-8.370	949	0.91	0.77	0.84	0.123
BH2-02-5M-x	1	T7-LLS-C-3A	2-D	0.624	ITRI	6.5	2.5	1.5	1.50	1.5015	0.2228	19.90	59.48	-7.350	-6.274	3,596	0.65	0.33	0.99	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	0.69	0.26	0.48	0.565
	3	T7-LLS-C-3A		0.624						1.4995	0.2210	18.28	55.15	-6.132	-5.755	3,789	0.42	0.30	0.96	0.538
BH2-03-5M-x	1	T7-LL-C-1B	2-D	0.641	ITRI	6.5	2.5	1.5	1.50	1.5025	0.2218	19.05	57.29	-6.742	-6.742	4,015	0.59	0.63	0.61	0.549
	2	T7-LL-C-1B	LLL	0.641	Baseline					1.5010	0.2217	0.81	2.17				0.19	0.03	0.08	0.019
	3	T7-LL-C-1B		0.641						1.5010	0.2214	4.27	3.78				2.23	0.30	0.06	3.44
BH2-04-5M-x	1	T7-LSS-C-1A	2-D	0.622	ITRI	6.5	2.5	1.5	1.50	1.5007	0.2038	10.82	10.69				0.22	0.48	0.15	0.018
	2	T7-LSS-C-1A	LSS	0.622	Baseline					1.5000	0.2025	13.86	45.32	-13.825	-12.166	11,217	4.55	4.76	4.65	0.763
	3	T7-LSS-C-1A		0.622						1.5010	0.2018	14.10	46.40	-12.715	-12.881	10,239	4.79	4.72	4.75	0.700
BH2-01-5N-x	1	T7-SLL-C-4B	2-D	0.619	ITRI	6.0	2.5	1.0	1.50	1.5008	0.2225	12.3	14.00	-13.367	-12.643	10,508	4.67	4.86	4.78	0.752
	2	T7-SLL-C-4B	SLL	0.619	Gage length					1.5007	0.2195	23.76	71.14	-7.340	-9.391		10.04	7.95	9.00	6.09
	3	T7-SLL-C-4B		0.619	Effect					1.5000	0.2182	20.76	63.04	-7.305	-7.496		8.45	9.09	8.77	
	4*	T7-SLL-C-4B		0.619						1.5010	0.2173	25.88	79.09	-7.427	-11.711		8.98	9.18	9.08	
											21.97	65.50	-5.829	-9.766		9.24	8.59	8.91		
											16.1	22.94	-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		

Material: ASA/Shell 1895

Project #: BH0002
 inlec Engineer: Maryann Emerson
 Boeing Engineer: Mark Pedro

Task 5
 Compression Test Program
 2-D Braided Architectures

Textile Test Method Development

Inlec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions			Load at Failure (lbs)	Ultimate Load (lbs)	Ultimate Stress (ksi)	Ultimate Strain (µε)	Axial Modulus (ksi)	Poisson's Ratio
						total length (in)	tab length (in)	gage length (in)						
BH2-01-50-x	1	17-SLL-C-5A	2-D	0.601	WTRI	7.0	2.5	2.0	13.1	14.59	45.33	-5.242	8.97	8.87
	2	17-SLL-C-5A	SLL	0.601	Gage length Effect				24.60	67.54	-7.998	-7.630	9.00	9.14
	3	17-SLL-C-5A	SLL	0.601	Effect				20.39	75.32	-8.781	-9.078	9.04	8.87
BH2-02-5N-x	1	15-LLS-C-2A	2-D	0.599	WTRI	6.0	2.5	1.0	18.47	54.80	-7.548	-7.275	7.70	8.07
	2	15-LLS-C-2A	LLS	0.599	Gage length Effect				20.86	61.83	-6.892	-7.311	9.02	9.10
	3	15-LLS-C-2A	LLS	0.599	Effect				20.67	50.86	-7.888	-7.190	8.34	8.78
BH2-02-50-x	1	17-LLS-C-7B	2-D	0.605	WTRI	7.0	2.5	2.0	18.99	57.88	-6.590	-7.064	9.90	9.56
	2	17-LLS-C-7B	LLS	0.605	Gage length Effect				20.36	62.84	-7.082	-7.940	9.02	8.61
	2	17-LLS-C-7B	LLS	0.605	Effect				22.39	69.40	-7.378	-8.628	8.95	8.65
BH2-01-SP-x	1	17-SLL-B-3B	2-D	0.600	Boeing CH fixture baseline				13.63	84.19	-8.379	-11.143	9.42	9.17
	2	17-SLL-B-4B	SLL	0.611	CH fixture baseline	12.0			21.64	128.06	na	na	9.29	9.46
	3	17-SLL-B-3B	SLL	0.600	baseline				15.09	92.36	-2.842	na	8.59	9.53
BH2-02-SP-x	1	17-LLS-B-XA	2-D	0.598	Boeing CH fixture baseline	12.0			14.36	88.27	-6.217	-11.143	9.10	9.43
	2	17-LLS-B-XB	LLS	0.608	CH fixture baseline				1.00	5.77			0.45	0.24
	3	17-LLS-B-XA	LLS	0.599	baseline				7.20	6.54			5.00	2.57
BH2-03-SP-x	1	17-LLS-B-1A	2-D	0.644	Boeing CH fixture baseline	12.0			10.20	60.99	-6.474	-7.296	10.81	9.21
	2	17-LLS-B-3B	LLS	0.661	CH fixture baseline				9.17	55.84	-4.810	-6.060	10.94	10.34
	3	17-LLS-B-3B	LLS	0.661	baseline				10.16	60.57	-5.759	-7.198	10.99	9.15
BH2-04-SP-x	1	17-LSS-B-3B	2-D	0.629	Boeing CH fixture baseline	12.0			8.84	59.13	-5.347	-6.858	10.95	9.57
	2	17-LSS-B-3B	LSS	0.629	CH fixture baseline				0.58	2.86			0.04	0.33
	3	17-LSS-B-3B	LSS	0.629	baseline				5.82	4.63			0.36	6.99
BH2-01-5R-x	3	15-SLL-A-9	2-D	0.520	Boeing CH fixture net shape	12.0			20.41	126.37	-5.319	-8.951	24.11	15.36
	4	15-SLL-A-12	SLL	0.433	CH fixture net shape				11.0	67.14	-5.746	-9.207	10.71	8.29
	5	15-SLL-A-12	SLL	0.433	net shape				8.8	57.90	-4.812	-8.969	10.43	7.59

Project #: BH0002

insec Engineer: Maryann Emerson
Boeing Engineer: Mark Fedro

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

Material: AS4Shell 1895

Insec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions			Avg. Thickness (in)	Load at Failure (lbs)	Ultimate Load (lbs)	Ultimate Stress (ksi)	Ultimate Strain (in/in)	Ultimate Trans. Strain (in/in)	Axial Modulus (msi)		Poisson's Ratio	
						Total Length (in)	tab Length (in)	gauge length (in)							Axial 1	Axial 2		
BH2-02-SR-x	1	T5-LLS-A-12	2-D	0.513	Boeing	12.0		1.50	1.5285	0.1216	8.5	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	10.48	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	
BH2-03-SR-x	1	T7-LLS-A-3	2-D	0.538	Boeing	12.0		1.50	1.5285	0.1238	10.7	11.71	61.78	-7.347	-10.741	8.81	6.13	7.47
	2	T7-LLS-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	7.36
	3	T7-LLS-A-8	0.522	net-shape				1.5267	0.1157	10.0	11.00	62.45	-8.982	-8.349	7.15	8.23	7.69	
BH2-04-SR-x	1	T7-LSS-A-10	2-D	0.520	Boeing	12.0		1.50	1.5202	0.1161	3.8	5.18	26.36	-11.684	-12.047	4.54	4.36	4.45
	2	T7-LSS-A-10	LSS	0.520	OH fixture				1.5265	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	32.85	-8.723	-11.259	4.66	4.01	4.34	
BH2-01-SW-x	1	T7-SLL-C-4A	2-D	0.605	Transverse	6.5		1.50	1.5005	0.2218	12.6	13.08	38.28	-5.880		6.91		6.91
	2	T7-SLL-C-4A	SLL	0.605	ITTRI				1.5010	0.2201	10.1	13.85	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	
BH2-02-SW-x	1	T7-LLS-C-1B	2-D	0.584	Transverse	6.5		1.50	1.5003	0.2221	7.5	90.02	270.17		2.77		2.77	
	2	T7-LLS-C-1B	LLS	0.584	ITTRI				1.5007	0.2204	6.4	87.27	263.82	-9.639		2.97		2.97
	3	T7-LLS-C-1B	0.584					1.4980	0.2195	6.8	74.05	225.21	-9.771		3.10		3.10	
BH2-03-SW-x	1	T7-LLS-C-4A	2-D	0.602	Transverse	6.5		1.50	1.4800	0.2269	6.9	83.78	253.06	-8.305		3.02		3.02
	2	T7-LLS-C-4A	LLL	0.602	ITTRI				1.4812	0.2270	7.9	10.93	32.55		0.07		0.07	
	3	T7-LLS-C-4A	0.602					1.4797	0.2263	9.3	11.05	33.00	-4.547		2.32		2.32	
BH2-04-SW-x	1	T7-LSS-C-6A	2-D	0.592	Transverse	6.5		1.50	1.5003	0.2185	14.0	14.04	42.83	-18.722		7.38		7.38
	2	T7-LSS-C-6A	LSS	0.592	ITTRI				1.4988	0.2178	13.1	13.60	41.66	-15.748		2.84		2.84
	3	T7-LSS-C-6A	0.592					1.5005	0.2175	14.0	14.18	43.44	-16.746		3.12		3.12	
BH2-01-SX-x	1	T7-SLL-B-8B	2-D	0.615	Unnotched	11.0		1.16	1.1565	0.1058	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	10.80	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		
									10.02	10.02	9.23			2.52	8.98	4.42		

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

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

Material: AS4/Shell 1995

Inlec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions			Avg Thick (in)	Load/Avg Thick (k/ps)	Ultimate Load (k/ps)	Ultimate Stress (ksi)	Ultimate Strain		Ultimate Trans Strain (μr)	Axial Modulus		Poisson's Ratio	
						total length (in)	tab length (in)	page length (in)					Avg Width (in)	Avg Axial 1 (μr)		Avg Axial 2 (μr)	Axial 1 (msj)		Axial 2 (msj)
BH-2-02-5X-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	L1S	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	-5.292	-7.776		10.31	9.24	9.77
BH-2-03-5X-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
BH-2-04-5X-X	1	T7-LSS-B-6A	2-D	0.623	Unnotched	11.0		1.16	1.1675	0.1050	8.1	8.87	46.81	-11.090	-10.470		8.84	8.97	8.99
	2	T7-LSS-B-6A	LSS	0.623	Comp				1.1685	0.1026	5.1	6.05	60.87	-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
										6.0	5.78	48.59	-12.560	-11.337		4.85	5.26	5.11	
										3.93	0.23	2.14				4.84	2.46	2.01	
											4.41								

Project #: BH0002

intec Engineer: Maryann Emanson
Boeing Engineer: Mark Fedro

Textile Test Method Development
Task 518
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	Nominal Dimensions			Load at Audible (kN)	Ultimate Load (kN)	Ultimate Stress (ksi)	Ultimate Axial 1 Strain (in/in)	Ultimate Axial 2 Strain (in/in)	Axial Modulus	
							Length (in)	Width (in)	Thickness (in)						Axial 1 (ksi)	Axial 2 (ksi)
BH2-05-5G-x	1	T7-TS1-A-2A	3-D	0.628	NASA SB	1.5	1.50	1/4	1.5005	0.2233	26.59	79.28	-8.047	-7.194	10.41	11.15
	2	T7-TS1-A-2A	TS-1	0.628	Baseline	1.5	1.50	1/4	1.5005	0.2233	27.28	81.42	-8.889	-6.197	10.95	11.37
	3	T7-TS1-A-2A	0.528	0.628	Baseline	1.5	1.50	1/4	1.4993	0.2235	26.60	79.39	-7.095	-6.985	11.16	11.41
Average																
Std. Dev.																
% COV																
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	22.48	72.06	-7.414	-5.900	10.00	10.79
	2	T7-TS2-A-2B	TS-2	0.632	Baseline	1.5	1.50	1/4	1.5005	0.2128	24.32	76.18	-6.976	-7.647	10.71	11.02
	3	T7-TS2-A-2B	0.632	Baseline	1.5005	0.2177	25.32	77.53	-6.996	-8.968	11.02	10.65	10.87	10.84	10.83	
Average																
Std. Dev.																
% COV																
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	31.62	92.56	-10.529	-7.321	11.07	11.45
	2	T7-OS1-A-3B	OS-1	0.643	Baseline	1.5	1.50	1/4	1.5003	0.2270	30.29	88.85	-9.656	-7.713	11.01	11.39
	3	T7-OS1-A-3B	0.643	Baseline	1.5010	0.2268	29.63	87.04	-8.507	-7.812	11.66	11.46	11.56	11.56		
Average																
Std. Dev.																
% COV																
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
	2	T7-OS2-A-3A	OS-2	0.564	Baseline	1.5	1.50	1/4	1.5010	0.2351	31.51	89.30	-10.081	-7.298	10.20	11.05
	3	T7-OS2-A-3A	0.564	Baseline	1.5003	0.2353	28.55	80.87	-9.000	-10.005	9.46	9.18	9.32	9.32		
Average																
Std. Dev.																
% COV																
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	28.62	89.98	-8.253	-6.767	10.57	13.36
	2	T7-LS1-A-5B	LS-1	0.646	Baseline	1.5	1.50	1/4	1.5033	0.2142	26.21	81.38	-6.789	-6.698	11.52	11.86
	3	T7-LS1-A-5B	0.646	Baseline	1.4987	0.2113	27.5	28.33	89.47	-6.832	-8.180	12.76	11.56	12.16		
Average																
Std. Dev.																
% COV																
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
	2	T7-LS2-A-2A	LS-2	0.653	Baseline	1.5	1.50	1/4	1.5008	0.2130	28.17	91.26	-7.579	-6.350	11.54	12.39
	3	T7-LS2-A-2A	0.653	Baseline	1.5010	0.2211	28.50	85.86	-8.369	-7.386	10.61	11.90	11.25	11.25		
Average																
Std. Dev.																
% COV																
BH2-05-5M-x	1	T7-TS1-A-3A	3-D	0.615	IITRI	6.5	2.5	1.5	1.5018	0.2370	27.11	76.16	-7.317	-7.415	10.73	10.79
	2	T7-TS1-A-3A	TS-1	0.615	Baseline	6.5	2.5	1.5	1.4980	0.2411	19.0	25.74	71.26	-6.904	10.69	10.82
	3	T7-TS1-A-3A	0.615	Baseline	1.5007	0.2342	17.5	28.48	81.03	-6.866	-8.345	11.12	11.18	11.15		
Average																
Std. Dev.																
% COV																

Project #: BH0002
 intec Group ID: intec
 Boeing Engineer: Maryann Emanson
 Boeing Engineer: Mark Fedro

Task 588
 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 (Nom. Dim)				Avg. Thick (in)	Avg. Width (in)	Load at Audible (lbf)	Ultimate Load (lbf)	Ultimate Stress (ksi)	Ultimate Strain (µε)		Axial Modulus (mksi)		
						Total Length (in)	Tab Length (in)	gage length (in)	Width (in)						Thick (in)	Axial 1	Axial 2	Axial 1	Axial 2
BH2-06-5M-x	1	T7-TS2-A-2B	3-D	0.632	II TRI	6.5	2.5	1.5	1/4	1.4990	0.2165	22.42	69.10	-6.152	-6.689	11.19	10.86	11.03	
	2	T7-TS2-A-2B	TS-2	0.632	Baseline					1.4972	0.2093	22.07	70.45	-6.833	-6.010	11.40	11.24	11.36	
	3	T7-TS2-A-2B		0.632						1.4973	0.2066	20.0	67.78	-6.208	-5.872	11.31	11.41	11.36	
												Average		Average		Average		Average	
												Std. Dev.		Std. Dev.		Std. Dev.		Std. Dev.	
												% COV		% COV		% COV		% COV	
BH2-07-5M-x	1	T7-OS1-A-3B	3-D	0.643	II TRI	6.5	2.5	1.5	1/4	1.5000	0.2269	27.76	81.58	-7.952	-7.456	11.40	10.98	11.20	
	2	T7-OS1-A-3B	OS-1	0.643	Baseline					1.4975	0.2250	29.95	86.90	-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		Average		Average		Average	
												Std. Dev.		Std. Dev.		Std. Dev.		Std. Dev.	
												% COV		% COV		% COV		% COV	
BH2-08-5M-x	1	T7-OS2-A-3A	3-D	0.564	II TRI	6.5	2.5	1.5	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	-8.632	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	
												Average		Average		Average		Average	
												Std. Dev.		Std. Dev.		Std. Dev.		Std. Dev.	
												% COV		% COV		% COV		% COV	
BH2-09-5M-x	1	T7-LS1-A-6A	3-D	0.637	II TRI	6.5	2.5	1.5	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		Average		Average		Average	
												Std. Dev.		Std. Dev.		Std. Dev.		Std. Dev.	
												% COV		% COV		% COV		% COV	
BH2-10-5M-x	1	T7-LS2-A-2A	3-D	0.653	II TRI	6.5	2.5	1.5	1/4	1.4997	0.2083	19.5	20.94	-5.696	-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	-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	-5.513	-6.306	11.99	11.46	11.73	
												Average		Average		Average		Average	
												Std. Dev.		Std. Dev.		Std. Dev.		Std. Dev.	
												% COV		% COV		% COV		% COV	
BH2-05-5W-x	1	T7-TS1-A-3A	3-D	0.615	Trans II TRI	6.5	2.5	1.5	1/4	1.5000	0.2330	10.6	13.97	na	na	na	na	5.87	
	2	T7-TS1-A-3A	TS-1	0.615	II TRI					1.4992	0.2303	9.8	13.52	na	na	na	na	5.95	
	3	T7-TS1-A-3A		0.615	Baseline					1.4990	0.2293	10.7	12.16	na	na	na	na	6.02	
												Average		Average		Average		Average	
												Std. Dev.		Std. Dev.		Std. Dev.		Std. Dev.	
												% COV		% COV		% COV		% COV	
BH2-06-5W-x	1	T7-TS2-A-2A	3-D	0.634	Trans II TRI	6.5	2.5	1.5	1/4	1.4990	0.2275	15.1	18.27	-8.091	-7.042	7.42	7.51	7.46	
	2	T7-TS2-A-2A	TS-2	0.634	II TRI					1.5000	0.2260	14.8	17.26	-7.000	-6.859	7.46	7.46	7.46	
	3	T7-TS2-A-2A		0.634	Baseline					1.4997	0.2256	15.4	18.56	-7.935	-7.645	7.09	7.33	7.21	
												Average		Average		Average		Average	
												Std. Dev.		Std. Dev.		Std. Dev.		Std. Dev.	
												% COV		% COV		% COV		% COV	

Project #: BH0002

inlec Engineer: Maryann Emerson
Boeing Engineer: Mark Fedra

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

Material: AS4/Shell 1895

Inlec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nominal Dimensions (Nom. Dim.)				Avg. Thick (in)	Load at Audible (kips)	Ultimate Load (kips)	Ultimate Stress (ksi)	Ultimate Strain (in/in)	Axial Modulus (msi)	
						Total Length (in)	Tab Length (in)	Width (in)	Page Length (in)						Axial 1	Axial 2
BH2-07-5W-x	1	T7-OS1-A-3A	3-D OS-1	0.610	Trans	6.5	2.5	1.5	1/4	1.4900	0.2335	14.45	41.28	-7.268	6.23	6.43
	2	T7-OS1-A-3A	OS-1	0.610	ITRI	6.5	2.5	1.5	1/4	1.5000	0.2324	14.15	40.61	na	5.97	6.11
	3	T7-OS1-A-3A	OS-1	0.610	Baseline	6.5	2.5	1.5	1/4	1.5002	0.2318	14.83	42.66	-7.959	6.13	6.16
Average																
Std. Dev.																
% COV																
BH2-08-5W-x	1	T7-OS2-A-3A	3-D OS-2	0.564	Trans	6.5	2.5	1.5	1/4	1.4983	0.2386	17.91	50.06	-8.862	5.70	5.53
	2	T7-OS2-A-3A	OS-2	0.564	ITRI	6.5	2.5	1.5	1/4	1.4982	0.2367	17.41	49.10	-8.245	5.67	5.44
	3	T7-OS2-A-3A	OS-2	0.564	Baseline	6.5	2.5	1.5	1/4	1.4973	0.2356	17.62	49.96	-8.083	5.76	5.50
Average																
Std. Dev.																
% COV																
BH2-09-5W-x	1	T7-LS1-A-6A	3-D LS-1	0.637	Trans	6.5	2.5	1.5	1/4	1.5012	0.2139	12.78	39.79	-6.181	6.60	6.54
	2	T7-LS1-A-6A	LS-1	0.637	ITRI	6.5	2.5	1.5	1/4	1.4983	0.2135	10.18	31.87	-3.883	6.50	6.52
	3	T7-LS1-A-6A	LS-1	0.637	Baseline	6.5	2.5	1.5	1/4	1.5005	0.2137	9.81	30.89	-4.644	6.42	6.39
Average																
Std. Dev.																
% COV																
BH2-10-5W-x	1	T5-LS2-A-1B	3-D LS-2	0.629	Trans	6.5	2.5	1.5	1/4	1.5013	0.2227	7.35	21.99	-3.479	6.67	6.46
	2	T5-LS2-A-1B	LS-2	0.629	ITRI	6.5	2.5	1.5	1/4	1.4995	0.2222	10.45	31.37	-4.660	6.60	6.51
	3	T5-LS2-A-1B	LS-2	0.629	Baseline	6.5	2.5	1.5	1/4	1.4995	0.2219	10.89	32.71	-5.036	6.55	6.58
Average																
Std. Dev.																
% COV																

Project #: BH0002

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

intec Engineer: Maryann Enarson
Boeing Engineer: Mark Fedro

Material: AS4/Shell 1885

intec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nom. Dim.			Avg. Width (in)	Avg. Thick (in)	Load at Audible (lbs)	Ultimate Load (kps)	Ultimate Stress (ksi)	Ultimate Axial 1 Strain (uc)	Ultimate Axial 2 Strain (uc)	Axial Modulus (msil)		Average (msil)
						total length (in)	gauge length (in)	width (in)								Axial 1 (msil)	Axial 2 (msil)	
BH2-11-5G-x	1	T7-SUW-G3K8B1	SU-1	0.668	NASA SB	1.5	1.5	1.50	0.2238	18.2	20.29	60.47	-8.252	-8.112	6.92	6.59	6.75	
	2	T7-SUW-G3K8B1		0.668	Baseline	1.5	1.5	1.50	0.2231	21.56	64.16	-7.419	-8.057	-10.047	7.32	5.18	6.25	
	3	T7-SUW-G3K8B1		0.668		1.5	1.5	1.50	0.2238	18.2	21.15	63.04	-7.852	-8.739	6.64	6.25	6.44	
BH2-12-5G-x	1	T7-SUW-G6K8B1	SU-2	0.644	NASA SB	1.5	1.5	1.50	0.2453	20.49	55.68	-12.700	-4.427	-4.427	6.36	6.33	6.34	
	2	T7-SUW-G6K8B1		0.644	Baseline	1.5	1.5	1.50	0.2452	20.90	56.83	na	-9.507	-9.507	6.23	6.28	6.25	
	3	T7-SUW-G6K8B1		0.644		1.5	1.5	1.50	0.2454	18.3	19.61	53.25	-7.805	-11.614	6.25	6.41	6.33	
BH2-13-5G-x	1	T7-SUW-K6K4B1	SU-3	0.635	NASA SB	1.5	1.5	1.50	0.2383	19.3	20.84	58.43	-10.033	na	6.42	6.37	6.39	
	2	T7-SUW-K6K4B1		0.635	Baseline	1.5	1.5	1.50	0.2362	15.9	20.35	57.48	-8.339	-8.852	6.07	6.64	6.36	
	3	T7-SUW-K6K4B1		0.635		1.5	1.5	1.50	0.2367	17.5	19.87	56.01	na	-8.741	6.85	6.40	6.62	
BH2-14-5G-x	1	T7-SUW-K6K4B1	SU-4	0.648	NASA SB	1.5	1.5	1.50	0.2304	17.9	20.06	58.08	-10.225	-5.802	6.83	6.72	6.78	
	2	T7-SUW-K6K4B1		0.648	Baseline	1.5	1.5	1.50	0.2305	19.1	19.99	57.86	-12.500	-8.874	6.71	6.48	6.60	
	3	T7-SUW-K6K4B1		0.648		1.5	1.5	1.50	0.2297	18.3	19.43	56.43	-8.315	-6.825	7.03	6.50	6.77	
BH2-15-5G-x	1	T7-SUW-K12K8B1	SU-5	0.654	NASA SB	1.5	1.5	1.50	0.2577	18.4	19.83	57.46	-10.347	-7.167	6.86	6.57	6.71	
	2	T7-SUW-K12K8B1		0.654	Baseline	1.5	1.5	1.50	0.2577	20.7	22.09	57.34	-10.825	-10.822	6.31	6.35	6.33	
	3	T7-SUW-K12K8B1		0.654		1.5	1.5	1.50	0.2577	20.7	22.09	57.34	-10.825	-10.822	6.31	6.35	6.33	
BH2-11-5M-x	1	T7-SUW-G3K8B1	SU-1	0.668	IIIRI	6.5	1.5	1.50	0.2221	19.2	19.49	58.54	-8.760	-8.383	7.27	6.97	7.12	
	2	T7-SUW-G3K8B1		0.668	Baseline	6.5	1.5	1.50	0.2228	16.0	19.17	57.36	-7.418	-6.985	7.21	6.73	6.97	
	3	T7-SUW-G3K8B1		0.668		6.5	1.5	1.50	0.2228	17.5	19.48	58.31	-8.428	-8.742	7.18	6.94	7.06	
BH2-12-5M-x	1	T7-SUW-G6K8B1	SU-2	0.644	IIIRI	6.5	1.5	1.50	0.2436	17.0	17.51	47.98	-6.357	-7.231	6.52	6.63	6.57	
	2	T7-SUW-G6K8B1		0.644	Baseline	6.5	1.5	1.50	0.2452	16.7	17.95	48.84	-7.724	-7.661	6.61	6.61	6.61	
	3	T7-SUW-G6K8B1		0.644		6.5	1.5	1.50	0.2463	16.0	18.14	49.10	-7.637	-8.112	6.44	6.54	6.49	
BH2-12-5M-x	1	T7-SUW-G6K8B1	SU-2	0.644	IIIRI	6.5	1.5	1.50	0.2436	16.6	17.86	48.62	-7.239	-7.668	6.52	6.59	6.56	
	2	T7-SUW-G6K8B1		0.644	Baseline	6.5	1.5	1.50	0.2452	16.0	18.14	49.10	-7.637	-8.112	6.44	6.54	6.49	
	3	T7-SUW-G6K8B1		0.644		6.5	1.5	1.50	0.2463	16.6	17.86	48.62	-7.239	-7.668	6.52	6.59	6.56	
										1.81	1.26	0.61	0.32	0.61	1.30	0.68	0.83	

Project #: BH0002

intec Engineer: Maryann Enarson
Boeing Engineer: Mark Fedro

Textile Test Method Development
Task B
Compression Test Program
Stitched Unlweave Architectures

Material: AS4/Shell 1895

Inlec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nom. Dim.			Load at Audible (kpsi)	Ultimate Load (kpsi)	Ultimate Stress (ksi)	Ultimate Axial 1 Strain (µε)		Ultimate Axial 2 Strain (µε)		Axial Modulus (msi)		
						Length (in)	Width (in)	page				Avg. Thick. (in)	Axial 1	Axial 2	Axial 1	Axial 2	Average	
BH2-13-SM-x	1	T7-SUW-K6K8B1	SU-3	0.635	II TRI	6.5	1.50	1.5003	0.2356	14.7	17.13	48.24	-7.886	-6.417	6.53	6.70	6.62	
	2	T7-SUW-K6K8B1	SU-3	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	SU-3	0.635	Baseline			1.4927	0.2354	15.2	18.01	51.27	-7.581	-7.675	6.77	6.83	6.80	
BH2-14-SM-x	1	T7-SUW-K6K4B1	SU-4	0.648	II TRI	6.5	1.5	1.4980	0.2398	17.4	18.08	52.52	-7.693	-7.679	7.06	6.94	7.00	
	2	T7-SUW-K6K4B1	SU-4	0.648	Baseline			1.5000	0.2304	16.5	17.94	51.81	-7.560	-7.624	6.97	6.92	6.95	
	3	T7-SUW-K6K4B1	SU-4	0.648	Baseline			1.4985	0.2307	16.3	17.80	51.49	-7.858	-7.310	6.97	6.88	6.93	
BH2-15-SM-x	1	T7-SUW-K12K8B1	SU-5	0.654	II TRI	6.5	1.5	1.5035	0.2585	17.4	18.14	49.24	-7.168	-6.347	6.66	6.46	6.56	
	2	T7-SUW-K12K8B1	SU-5	0.654	Baseline			1.4980	0.2597	18.0	18.31	49.64	-7.680	-7.975	6.63	6.53	6.58	
	3	T7-SUW-K12K8B1	SU-5	0.654	Baseline			1.5130	0.2595	17.5	19.45	49.54	-8.435	-5.622	6.70	6.49	6.60	
BH2-11-SW-x	1	T7-SUW-G3K8B2	SU-1	0.668	Trans II TRI	6.5	1.5	1.5000	0.2213	20.5	21.09	63.54	-10.298		6.90			
	2	T7-SUW-G3K8B2	SU-1	0.668	Baseline			1.4990	0.2217	18.7	19.53	56.77	-9.663		7.07			
	3	T7-SUW-G3K8B2	SU-1	0.668	Baseline			1.5000	0.2221	20.0	20.17	60.54	-8.860		7.23			
BH2-12-SW-x	1	T7-SUW-G6K8B2	SU-2	0.644	Trans II TRI	6.5	1.5	1.4997	0.2428	19.3	19.97	64.85	-8.762		6.62			
	2	T7-SUW-G6K8B2	SU-2	0.644	Baseline			1.4992	0.2434	18.8	20.24	55.49	-9.375		6.72			
	3	T7-SUW-G6K8B2	SU-2	0.644	Baseline			1.5003	0.2442	19.9	20.69	56.47	-9.326		6.66			
BH2-13-SW-x	1	T7-SUW-K6K8B2	SU-3	0.635	Trans II TRI	6.5	1.5	1.5020	0.2385	18.1	20.27	56.35	-8.628		6.78			
	2	T7-SUW-K6K8B2	SU-3	0.635	Baseline			1.5005	0.2378	18.1	19.86	55.54	-8.741		6.82			
	3	T7-SUW-K6K8B2	SU-3	0.635	Baseline			1.5007	0.2354	20.1	21.14	59.86	-9.018		6.99			
BH2-14-SW-x	1	T7-SUW-K6K4B2	SU-4	0.648	Trans II TRI	6.5	1.5	1.4992	0.2305	18.6	20.42	57.25	-8.796		6.87			
	2	T7-SUW-K6K4B2	SU-4	0.648	Baseline			1.4990	0.2293	19.9	20.12	56.23	-8.508		7.09			
	3	T7-SUW-K6K4B2	SU-4	0.648	Baseline			1.5005	0.2280	18.1	19.08	55.51	-7.885		7.13			
									18.6	19.34	56.24	-8.098		7.14				
										3.59	3.11				0.70			

Project #: BH0002
 Intec Engineer: Maryann Emerson
 Boeing Engineer: Mark Fedro
 Task 8
 Compression Test Program
 Stitched Unlweave Architectures
 Material: AS4/Shell 1865

Textile Test Method Development

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Configuration Type	Nom. Dim.		Avg Thick Width (in)	Load at Audible (lbf)	Ultimate Load (lbf)	Ultimate Stress (ksi)	Ultimate Strain (με)		Axial Modulus (msi)	
						Length (in)	Width (in)					Axial 1	Axial 2	Axial 1	Axial 2
BH2-15-5W-x	1	T7-SUW-K12K8B2	SU-5	0.654	Trans	6.5	1.50	1.4990	22.8	23.85	61.64	-8.828	7.24	7.24	
	2	T7-SUW-K12K8B2	SU-5	0.654	ITRI			1.4968	21.9	23.21	60.06	-7.997	7.30	7.19	
	3	T7-SUW-K12K8B2	SU-5	0.654	Baseline			1.5000	21.5	23.21	60.02	-8.249	7.24	7.24	
									22.1	23.42	60.57	-8.358	7.24	7.24	
										0.37	0.92		0.05	0.74	
										1.56	1.52				

Open-Hole Compression Test Program

Material: AS4/Sheet 1895

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

Project #: PH0002
 Intec Engineer: Maryann Emerson
 Boeing Engineer: Mark Fedro

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Thickness (in)	Nominal Width (in)	Nominal Diameter (in)	Avg. Thickness (in)	Hole Diameter (in)	Load Audible (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	0.125	1.5	3/8	1.4995	0.1066	0.3735	8.98	56.21	74.85	hole
	3	T7-SLL-B-3B	SLL	0.600	OH Comp	0.125	1.5	3/8	1.5020	0.1069	0.3735	8.02	49.95	66.48	hole
Avg. Std. Dev. % COV											8.37	52.29	69.63		
Avg. Std. Dev. % COV											6.37	3.42	4.56		
Avg. Std. Dev. % 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	0.125	1.5	1/4	1.5015	0.1053	0.2490	6.93	43.88	52.60	hole
	3	T7-SLL-B-1A	SLL	0.635	OH Comp	0.125	1.5	1/4	1.5007	0.1038	0.2500	10.13	65.01	78.01	hole
Avg. Std. Dev. % COV											9.43	59.84	71.77		
Avg. Std. Dev. % COV											2.24	14.10	16.93		
Avg. Std. Dev. % 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	0.125	1.5	3/16	1.5015	0.1063	0.1870	7.63	46.93	53.61	hole
	3	T7-SLL-B-3B	SLL	0.600	OH Comp	0.125	1.5	3/16	1.5008	0.1093	0.1875	11.77	71.74	81.98	hole
Avg. Std. Dev. % COV											9.06	55.85	63.90		
Avg. Std. Dev. % COV											2.34	13.80	15.78		
Avg. Std. Dev. % 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	0.125	1.5	3/8	1.5000	0.1131	0.3730	6.99	41.20	54.84	hole
	3	T7-LLS-B-XA	LLS	0.599	OH Comp	0.125	1.5	3/8	1.5017	0.1115	0.3740	6.89	41.14	54.79	hole
Avg. Std. Dev. % COV											6.76	40.11	53.41		
Avg. Std. Dev. % COV											0.31	1.84	2.42		
Avg. Std. Dev. % 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	0.125	1.5	1/4	1.5012	0.1074	0.2500	7.68	47.62	57.13	hole
	3	T7-LLS-B-4B	LLS	0.618	OH Comp	0.125	1.5	1/4	1.5015	0.1103	0.2505	8.17	49.32	59.20	hole
Avg. Std. Dev. % COV											7.53	46.62	55.95		
Avg. Std. Dev. % COV											0.71	3.31	3.98		
Avg. Std. Dev. % 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	0.125	1.5	3/16	1.5013	0.1147	0.1860	7.35	42.70	48.74	hole
	3	T7-LLS-B-XA	LLS	0.599	OH Comp	0.125	1.5	3/16	1.5037	0.1148	0.1865	8.26	47.86	54.64	hole
Avg. Std. Dev. % COV											7.82	45.47	51.91		
Avg. Std. Dev. % COV											0.46	2.60	2.98		
Avg. Std. Dev. % 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	0.1066	0.2505	8.45	51.81	62.17	hole
	2	T7-LLL-B-1A	LLL	0.644	OH Comp	0.125	1.5	1/4	1.5007	0.1061	0.2500	5.65	35.50	42.60	hole
	3	T7-LLL-B-1A	LLL	0.644	OH Comp	0.125	1.5	1/4	1.5030	0.1058	0.2500	5.38	33.83	40.58	hole
Avg. Std. Dev. % COV											6.50	40.38	48.45		
Avg. Std. Dev. % COV											1.70	9.93	11.93		
Avg. Std. Dev. % COV											26.19	24.60	24.62		

Project #: 0100002

Intec Engineer: Maryann Einerson
Boeing Engineer: Mark Fedro

Material: AS4/Sheet 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		Avg. Thickness (in)	Avg. Width (in)	Avg. Hole Diameter (in)	Load at Audible Failure (lps)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments				
						Thick. (in)	Width (in)												
BH2-04-6B-x	1	T7-LSS-B-3B	2-D	0.629	Boeing	0.125	1.5	1/4	1.5000	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	LSS	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	49.60	66.08	hole				
	2	T7-SLL-C-4B	SLL	0.618	Short block				1.5002	0.2143	0.3755	15.1	48.51	64.67	hole				
	3	T7-SLL-C-1B	SLL	0.608					1.5013	0.2251	0.3745	14.5	44.68	43.45	hole				
										Avg.	1.5020	0.2163	0.3748	13.5	47.19	62.88			
										Std. Dev.				0.54	3.28	4.38			
										% COV				3.55	6.98	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	77.56	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	SLL	0.608					1.5002	0.2239	0.2490	15.6	16.10	47.93	57.47	hole			
										Avg.	1.5008	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	SLL	0.601					1.5015	0.2102	0.1875	21.07	66.77	76.30	hole				
										Avg.	1.5016	0.2098	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	49.06	hole	specimens 1,2,3,3 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	LLS	0.582					1.5000	0.2190	0.3755	12.9	13.10	39.86	53.20	hole			
	5	T5-LLS-C-2B	LLS	0.584					1.5002	0.2228	0.3750	11.5	11.60	34.74	46.31	hole			
	6	T7-LLS-C-1B	LLS	0.584					1.5017	0.2215	0.3740	12.26	36.86	49.06	hole				
	7	T7-LLS-C-1B	LLS	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
										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	LLS	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	57.90	hole				
	2	T7-LLS-C-1A	LLS	0.575	Short block				1.5013	0.2180	0.1870	16.20	48.64	55.56	hole				
	3	T7-LLS-C-1A	LLS	0.575					1.5012	0.2178	0.1870	15.84	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 #: alH0002

Inspec Engineer: Maryann Elancon
Boeing Engineer: Mark Fedro

Material: ASA/Sheet 1895

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

Inspec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions Thick, Width Diam. (in)	Avg. Thickness (in)	Avg. Width (in)	Avg. Diameter (in)	Hole Diameter (in)	Load at Audible (kps)	Ultimate Load (kps)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-03-6E-x	1	T5-LL-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-LL-C-1B	LLL	0.632	Short block		1.4993	0.2128	0.2490	13.6	14.05	44.04	52.81	hole		
	3	T5-LL-C-1B	LLL	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 1.05 1.99 1.98																
Std. Dev. % COV																
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		1.4985	0.1967	0.2490	10.3	10.40	35.25	42.27	hole		
	3	T7-LSS-C-1B	LLL	0.642			1.5003	0.1952	0.2490	9.7	9.94	33.77	40.50	hole		
Avg. 1.4983 0.1978 0.2493 10.0 10.27 34.87 41.99 0.76 0.94 2.29 2.28 2.30																
Std. Dev. % COV																
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-BHO		1.5005	0.2186	0.3740	12.9	16.55	50.47	67.22	hole		
	3	T7-SLL-C-4B	LLL	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 0.15 0.76 1.02 1.53 1.53																
Std. Dev. % COV																
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-BHO		1.5000	0.2101	0.2500	18.0	18.12	57.50	69.00	hole		
	3	T7-SLL-C-9B	LLL	0.584			1.4995	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 2.48 6.95 8.34 12.65 12.65																
Std. Dev. % COV																
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-BHO		1.5000	0.2128	0.1890	19.0	19.40	60.78	69.49	hole		
	3	T7-SLL-C-5A	LLL	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 2.31 2.68 3.71 3.76 3.76																
Std. Dev. % COV																
BH2-02-6G-x	1	T7-LLS-C-4A	2-D	0.570	NASA	0.250 1.5 3/8	1.5005	0.2171	0.3740	12.5	12.76	39.18	52.15	hole		
	2	T7-LLS-C-4A	LLS	0.570	1142-BHO		1.5002	0.2159	0.3740	12.1	14.62	45.05	59.97	hole		
	3	T7-LLS-C-4A	LLL	0.570			1.5003	0.2180	0.3740	12.6	14.33	43.73	58.21	hole		
Avg. 1.5003 0.2170 0.3740 12.4 13.91 42.65 56.78 0.98 3.08 4.10 7.07 7.23 7.23																
Std. Dev. % COV																
BH2-02-6H-x	1	T7-LLS-C-3A	2-D	0.624	NASA	0.250 1.5 1/4	1.5000	0.2171	0.2495	12.0	15.56	47.68	57.17	hole		
	2	T7-LLS-C-3A	LLS	0.624	1142-BHO		1.5015	0.2246	0.2500	12.2	15.55	46.12	55.33	hole		
	3	T7-LLS-C-3A	LLL	0.624			1.5020	0.2231	0.2495	15.6	16.54	49.37	59.20	hole		
Avg. 1.5002 0.2216 0.2497 13.3 15.88 47.72 57.23 0.57 1.63 1.94 3.58 3.41 3.39																
Std. Dev. % COV																

Project #: eH0002

intec Group ID

Boeing Engineer

Maryann Emanson

Mark Fedro

Textile Test Method Development

Task 6

Open Hole Compression Test Program

2-D Braided Architectures

Material AS4 Sheet 1895

intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Normal Dimensions Thick (in)	Normal Dimensions Width (in)	Normal Dimensions Diam (in)	Avg Thick (in)	Avg Width (in)	Hole Diameter (in)	Load at Audible (NPS)	Ultimate Load (kN)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments			
BH2-02-6H-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				1.5015	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.	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	68.98	hole				
													Avg.	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.	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	39.82	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.	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		29.67	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.	31.28	28.17	37.57				
													Std. Dev.	1.88	1.64	2.19				
													% COV	6.02	5.83	5.83				
BH2-01-6N-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				
	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	45.96	hole				
													Avg.	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.	34.29	39.05	48.81				
													Std. Dev.	1.22	1.63	2.04				
													% COV	3.54	4.17	4.18				

buckled #2 failed away from hole

Material: ASA/Shell 1895

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

Project #: PH0002
 inlec Engineer: Maryann Einerson
 Boeing Engineer: Mark Fedro

inlec Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Thick. (in)	Nominal Width (in)	Nominal Diam. (in)	Avg. Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load at Audible (kps)	Ultimate Load (kps)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-01-60-x	1	T7-SLL-C-3B	2-D	0.601	Boeing	0.250	4.0	0.50	4.0008	0.2216	0.5000	27.5	38.42	44.47	50.82	hole	
	2	T7-SLL-C-3B	SLL	0.601	CAI				4.0020	0.2247	0.5000	39.5	48.92	54.41	62.18	hole	
	3	T7-SLL-C-3B	SLL	0.601	CAI				4.0025	0.2198	0.4995	36.3	50.17	57.03	65.16	hole	
									Avg. 4.0018	0.2220	0.4998	34.4	5.88	6.63	7.57	12.74	
									Sid. Dev. 1.00	% COV 1.00							
BH2-02-6N-x	1	T7-LLS-C-1A	2-D	0.575	Boeing	0.250	4.0	1.00	4.0020	0.2243	0.5000	27.75	27.75	30.91	35.33	hole	
	2	T7-LLS-C-1B	LLS	0.584	CAI				3.9992	0.2182	0.5000	25.86	25.86	29.63	33.87	hole	
	3	T5-LLS-C-2B	LLS	0.594	CAI				3.9985	0.2290	0.4985	25.66	28.02	32.02	33.74	hole	
									Avg. 3.9999	0.2239	0.4988	26.42	26.42	29.52	33.74		
									Sid. Dev. 1.15	% COV 1.66							
BH2-02-6N-x	1	T5-LLS-C-2A	2-D	0.599	Boeing	0.250	4.0	0.80	4.0038	0.2253	0.8000	31.69	31.69	35.14	43.91	hole	
	2	T5-LLS-C-2A	LLS	0.599	CAI				4.0098	0.2233	0.8000	28.41	28.41	31.73	39.64	hole	
	3	T5-LLS-C-2B	LLS	0.584	CAI				3.9992	0.2237	0.8010	30.77	30.77	34.39	43.01	hole	
									Avg. 4.0043	0.2241	0.8003	30.29	30.29	33.76	42.19		
									Sid. Dev. 1.69	% COV 5.30							
BH2-02-60-x	1	T5-LLS-C-2B	2-D	0.584	Boeing	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	LLS	0.584	CAI				4.0015	0.2205	0.4995	29.2	35.47	40.20	45.93	hole	
	3	T5-LLS-C-2B	LLS	0.584	CAI				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		
									Sid. Dev. 1.10	% COV 3.12							
BH2-03-6N-x	1	T5-LLL-C-1A	2-D	0.611	Boeing	0.250	4.0	0.80	4.0092	0.2176	0.8005	33.49	33.49	38.39	47.97	hole	
	2	T5-LLL-C-2A	LLL	0.621	CAI				4.0098	0.2277	0.8005	33.56	33.56	36.84	46.06	hole	
	3	T5-LLL-C-2A	LLL	0.621	CAI				4.0020	0.2252	0.8000	34.69	34.69	38.49	48.10	hole	
									Avg. 4.0040	0.2235	0.8003	33.91	33.91	37.91	47.38		
									Sid. Dev. 0.67	% COV 1.99							
BH2-04-6N-x	1	T7-LSS-C-4A	2-D	0.579	Boeing	0.250	4.0	0.80	3.9995	0.2156	0.8015	25.97	25.97	30.11	37.66	hole	
	2	T7-LSS-C-4A	LSS	0.579	CAI				4.0020	0.2122	0.8015	25.66	25.66	30.21	37.78	hole	
	3	T7-LSS-C-2B	LSS	0.581	CAI				4.0030	0.2202	0.8005	25.88	25.88	29.36	36.70	hole	
									Avg. 4.0015	0.2160	0.8012	25.84	25.84	29.90	37.38		
									Sid. Dev. 0.16	% COV 1.56							
BH2-01-6P-x	1	T7-SLL-C-9B	2-D	0.584	Modified	0.250	1.5	3/8	1.4800	0.2109	0.3765	14.33	14.33	44.03	59.05	hole	
	2	T7-SLL-C-9B	SLL	0.584	IITRI				1.4780	0.2141	0.3745	14.13	14.13	44.65	59.80	hole	
	3	T7-SLL-C-9B	SLL	0.584	IITRI				1.4730	0.2102	0.3760	14.07	14.07	45.44	61.02	hole	
									Avg. 1.4770	0.2148	0.3757	14.18	14.18	44.71	59.95		
									Sid. Dev. 0.14	% COV 0.99							
												0.96	0.96	1.59	1.66		

Project #: dH0002

intec Engineer
Boeing Engineer

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	Thick (in)	Width (in)	Nominal Dimensions Thick (in) Width (in) Diam (in)	Avg Thick (in)	Avg Width (in)	Hole Diameter (in)	Load at Audible (kps)	Ultimate Load (kps)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
BH2-01-60-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	0.250	1.5		1.4900	0.2147	0.2515	21.07	65.46	78.66		hole	
	3	T7-SLL-C-4A	SLL	0.605	IITRI	0.250	1.5		1.4973	0.2155	0.2520	22.83	70.77	85.09		hole	
Avg: 1.4987 0.2150 0.2518 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	0.250	1.5		1.5003	0.2138	0.1870	20.01	62.38	71.26		hole	
	3	T7-SLL-C-9B	SLL	0.584	IITRI	0.250	1.5		1.4988	0.2212	0.1870	21.17	63.84	72.94		hole	
Avg: 1.4986 0.2150 0.1870 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	0.250	1.5		1.5010	0.2212	0.3750	14.59	43.95	58.59		hole	
	3	T7-LLS-C-3B	LLS	0.611	IITRI	0.250	1.5		1.5010	0.2207	0.3755	14.66	44.25	59.01		hole	
Avg: 1.5007 0.2213 0.3750 Std Dev: 1.21 3.74 5.00 % COV: 8.69 8.91 8.94																	
BH2-02-6O-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	0.250	1.5		1.5000	0.2235	0.2505	16.89	50.38	60.48		hole	
	3	T7-LLS-C-1B	LLS	0.584	IITRI	0.250	1.5		1.5000	0.2246	0.2500	15.72	46.66	55.99		hole	
Avg: 1.5003 0.2235 0.2500 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	0.250	1.5		1.4983	0.2224	0.1875	17.26	51.80	59.21		hole	
	3	T7-LLS-C-3B	LLS	0.611	IITRI	0.250	1.5		1.5015	0.2234	0.1870	16.90	50.38	57.55		hole	
Avg: 1.5001 0.2228 0.1872 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	0.250	1.5		1.5008	0.2287	0.3730	16.26	47.37	63.03		hole	
	3	T7-LLL-C-4A	LLL	0.602	IITRI	0.250	1.5		1.4993	0.2290	0.3735	15.39	44.83	59.70		hole	
Avg: 1.5003 0.2287 0.3732 Std Dev: 0.97 2.86 3.79 % COV: 5.92 6.02 5.99																	
BH2-03-6O-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	0.250	1.5		1.5020	0.2287	0.2505	18.28	53.21	63.86		hole	
	3	T7-LLL-C-4A	LLL	0.602	IITRI	0.250	1.5		1.5005	0.2283	0.2500	18.80	54.87	65.84		hole	
Avg: 1.5009 0.2282 0.2503 Std Dev: 1.03 2.88 3.45 % COV: 5.75 5.50 5.48																	

Material: AS4/Shell 1895

Project #: 9H0002
 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 Thickness (in)	Nominal Width (in)	Nominal Diameter (in)	Avg. Width (in)	Avg. Thick (in)	Hole Diameter (in)	Load Audible (kpsi)	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	68.47	hole	
	2	T7-LLL-C-4A	LLL	0.602	IITRI				1.5023	0.2250	0.1880	19.06	59.70	68.24	68.24	hole	
	3	T7-LLL-C-4A	LLL	0.602	IITRI				1.5008	0.2239	0.1880	19.86	58.78	64.85	64.85	hole	
Avg. 1.5014 0.2251 0.1880 Sid. Dev. 3.53 3.02 2.03 3.02 % COV 2.3 2.1 1.3 2.1																	
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	39.83	hole	
	2	T7-LSS-C-6A	LSS	0.592	IITRI				1.5003	0.2228	0.3735	10.21	30.54	40.66	40.66	hole	
	3	T7-LSS-C-6A	LSS	0.592	IITRI				1.5007	0.2185	0.3735	10.15	30.96	41.22	41.22	hole	
Avg. 1.5006 0.2222 0.3735 Sid. Dev. 0.50 0.52 0.70 0.50 1.72 1.72 % COV 3.3 3.3 3.3 3.3 3.3 3.3																	
BH2-04-6O-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	43.91	hole	
	2	T7-LSS-C-6A	LSS	0.592	IITRI				1.5008	0.2174	0.2500	11.48	35.18	42.21	42.21	hole	
	3	T7-LSS-C-6A	LSS	0.592	IITRI				1.4993	0.2230	0.2500	11.23	33.58	40.30	40.30	hole	
Avg. 1.5006 0.2177 0.2500 Sid. Dev. 0.23 1.51 1.80 1.97 4.30 4.28 % COV 1.5 9.4 11.3 19.5 28.6 27.7																	
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	40.43	hole	
	2	T7-LSS-C-6A	LSS	0.592	IITRI				1.5000	0.2170	0.1880	11.80	36.26	41.45	41.45	hole	
	3	T7-LSS-C-6A	LSS	0.592	IITRI				1.4998	0.2177	0.1880	11.96	36.63	41.88	41.88	hole	
Avg. 1.4998 0.2171 0.1880 Sid. Dev. 0.24 0.65 0.75 2.03 1.81 1.81 % COV 1.6 5.1 5.1 13.4 11.1 11.1																	
BH2-01-6S-x	4	T7-SLL-B-8A	2-D	0.601	Zabara Fixture	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	SLL	0.601	Fixture				1.4973	0.1057	0.3755	8.5	9.29	58.75	78.42	hole	
Avg. 1.4975 0.1068 0.3752 Sid. Dev. 0.57 4.16 5.57 6.61 7.66 7.69 % COV 7.1 38.4 48.8 50.6 50.6 50.6																	
BH2-01-6T-x	1	T7-SLL-B-8A	2-D	0.601	Zabara Fixture	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				1.4990	0.1073	0.2515	9.6	9.91	61.66	74.10	hole	
	3	T7-SLL-B-8A	SLL	0.601	Fixture				1.4960	0.1075	0.2515	7.6	10.99	68.34	82.15	hole	
Avg. 1.4975 0.1069 0.2517 Sid. Dev. 0.79 5.49 7.78 7.23 7.23 7.23 % COV 11.4 50.6 50.6 50.6 50.6 50.6																	
BH2-01-6U-x	1	T7-SLL-B-8A	2-D	0.601	Zabara Fixture	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	SLL	0.601	Fixture				1.4977	0.1064	0.1890	9.1	9.83	61.70	70.61	hole	
Avg. 1.4975 0.1076 0.1890 Sid. Dev. 0.55 3.41 3.90 5.35 5.29 5.30 % COV 3.7 23.4 23.4 23.4 23.4 23.4																	

Project #: BH0002

intec Engineer: Maryann Emanson
Boeing Engineer: Mark Fedro

Material: AS4 Sheel 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 Thick (in.)	Nominal Width (in.)	Nominal Diam. (in.)	Avg. Thick (in.)	Avg. Width (in.)	Hole Diameter (in.)	Load at Audible (lbf)	Ultimate Load (lbf)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments	
BH2-02-6S-x	4	T7-LLS-B-11B	2-D	0.601	Zabara	0.125	1.5	3/8	1.4973	1.4973	0.3750	5.2	7.04	42.12	56.19	hole		
	5	T7-LLS-B-11B	LLS	0.601	Fixture				1.4982	1.4982	0.3750	6.3	6.77	40.11	53.50	hole		
	6	T7-LLS B 11B		0.601					1.4970	1.4970	0.3755	5.7	7.00	41.48	55.37	hole		
Avg. 1.4975 0.1123 0.3752												6.93	6.93	41.23	55.02			
Std Dev 0.15 1.38												2.12	2.12	2.49	2.51			
% COV																		
BH2-02-6T-x	1	T7-LLS-B-11B	2-D	0.601	Zabara	0.125	1.5	1/4	1.4975	1.4975	0.2520	6.0	6.93	41.82	50.28	hole		
	2	T7-LLS B-11B	LLS	0.601	Fixture				1.4978	1.4978	0.2520	4.6	7.68	47.79	57.46	hole		
	3	T7-LLS-B-11B		0.601					1.4975	1.4975	0.2515	5.9	8.44	52.77	63.42	hole		
Avg. 1.4976 0.1083 0.2518												7.68	7.68	47.46	57.05			
Std Dev. 0.75 6.58												0.75	0.75	4.38	6.58			
% COV												9.82	9.82	11.55	11.53			
BH2-02-6U-x	1	T7-LLS-B-11B	2-D	0.601	Zabara	0.125	1.5	3/16	1.4975	1.4975	0.1890	7.7	8.90	54.31	62.16	hole		
	2	T7-LLS-B-11B	LLS	0.601	Fixture				1.4975	1.4975	0.1890	6.3	8.57	51.69	59.15	hole		
	3	T7-LLS-B-11B		0.601					1.4973	1.4973	0.1890	5.7	9.48	56.96	65.19	hole		
Avg. 1.4974 0.1104 0.1890												8.98	8.98	54.32	62.17			
Std Dev. 0.46 3.02												0.46	0.46	2.64	3.02			
% COV												5.14	5.14	4.86	4.86			
BH2-03-6S-x	4	T7-LLS-B-4B	2-D	0.622	Zabara	0.125	1.5	3/8	1.4982	1.4982	0.3755	6.1	8.56	50.70	67.66	hole		
	5	T7-LLS-B-4B	LLL	0.622	Fixture				1.4972	1.4972	0.3755	5.6	9.08	53.19	70.99	hole		
	6	T7-LLS-B-4B		0.622					1.4977	1.4977	0.3760	7.4	8.56	49.41	65.97	hole		
Avg. 1.4977 0.1141 0.3757												8.73	8.73	51.10	68.21			
Std Dev. 1.92 2.56												0.30	0.30	3.44	3.75			
% COV												3.75	3.75	3.75	3.75			
BH2-03-6T-x	1	T7-LLS-B-4B	2-D	0.622	Zabara	0.125	1.5	1/4	1.4975	1.4975	0.2515	6.8	7.42	42.47	51.04	hole		
	2	T7-LLS-B-4B	LLL	0.622	Fixture				1.4977	1.4977	0.2520	7.5	8.33	47.52	57.13	hole		
	3	T7-LLS-B-4B		0.622					1.4968	1.4968	0.2510	6.7	8.80	51.19	61.51	hole		
Avg. 1.4973 0.1162 0.2515												8.19	8.19	47.06	56.56			
Std Dev. 0.70 4.38												0.70	0.70	4.38	5.26			
% COV												8.57	8.57	9.31	9.29			
BH2-03-6U-x	1	T7-LLS-B-4B	2-D	0.622	Zabara	0.125	1.5	3/16	1.4977	1.4977	0.1875	7.5	9.80	59.47	68.01	hole		
	2	T7-LLS-B-4B	LLL	0.622	Fixture				1.4970	1.4970	0.1875	9.4	10.95	65.28	74.63	hole		
	3	T7-LLS-B-4B		0.622					1.4972	1.4972	0.1880	7.6	8.35	49.07	56.12	hole		
Avg. 1.4973 0.1119 0.1878												9.70	9.70	57.94	66.25			
Std Dev 1.30 8.21												1.30	1.30	8.21	9.38			
% COV												14.12	14.12	14.16	14.16			
BH2-04-6S-x	4	T7-LSS-B-6B	2-D	0.602	Zabara	0.125	1.5	3/8	1.4982	1.4982	0.3760	4.3	4.81	30.61	40.86	hole		
	5	T7-LSS-B-6B	LLL	0.602	Fixture				1.4978	1.4978	0.3760	4.3	4.79	30.47	40.89	hole		
	6	T7-LSS-B-6B		0.602					1.4972	1.4972	0.3760	3.8	4.69	30.02	40.06	hole		
Avg. 1.4977 0.1047 0.3760												4.76	4.76	30.37	40.54			
Std Dev 0.06 0.31												0.06	0.06	0.31	0.41			
% COV												1.35	1.35	1.02	1.00			

Material: AS4/Shell 1895

Project #: BH0002

intec Engineer: Maryann Einanson
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		Avg. Thickness (in)	Avg. Width (in)	Avg. Hole Diameter (in)	Load # Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
						Thick. (in)	Width (in)									
BH2-04-6T-x	1	T7-LSS-B-6B	2-D	0.602	Zabara	0.125	1.5	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						8.07	3.18	3.82		
						% COV						8.07	8.29	8.28		
BH2-04-6U-x	1	T7-LSS-B-6B	2-D	0.602	Zabara	0.125	1.5	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	0.1038	0.1880	5.7	6.26	40.22	45.99		
						Std Dev						0.45	2.69	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: ASA/Sheal 1895

Boeing Engineer: Maryann Emanson
Mark Fedro
No instrumentation

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions (Thick, Width, Diam, W/D)	Avg. Thick (in)	Avg. Width (in)	Hole Diameter (in)	Load at Audible (MPS)	Ultimate Load (KSI)	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	65.96	hole	
	2	T7-TS1-A-2A	TS-1	0.628	OH Comp		1.5007	0.2321	0.2495	18.78	53.96	64.72	64.72	hole	
	3	T7-TS1-A-2A		0.628			1.4992	0.2340	0.2495	19.62	55.93	67.10	67.10	hole	
Avg. Std. Dev. % COV															
1.5002 0.2334 0.2497															
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	73.71	hole	
	2	T7-TS2-A-2B	TS-2	0.632	OH Comp		1.5000	0.2066	0.2520	17.89	57.17	68.71	68.71	hole	
	3	T7-TS2-A-2B		0.632			1.5002	0.2067	0.2510	17.82	57.47	69.02	69.02	hole	
Avg. Std. Dev. % COV															
1.4998 0.2103 0.2513															
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	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	82.02	hole	
	3	T7-OS1-A-3B		0.643			1.5013	0.2253	0.2520	21.94	64.85	77.84	77.84	hole	
Avg. Std. Dev. % COV															
1.5011 0.2244 0.2515															
BH2-08-6B-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	64.19	hole	
	2	T7-LS1-A-7A	LS-1	0.656	OH Comp		1.4982	0.2510	0.2510	19.15	50.89	61.13	61.13	hole	
	3	T7-LS1-A-7A		0.656			1.4980	0.2525	0.2510	22.99	60.78	73.01	73.01	hole	
Avg. Std. Dev. % COV															
1.4986 0.2515 0.2510															
BH2-10-6B-x	1	T7-LS2-A-2A	3-D	0.653	Boeing	0.250 1.5 1/4 6	1.4985	0.2124	0.2520	18.64	58.54	70.37	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	73.67	hole	
	3	T7-LS2-A-2A		0.653			1.5017	0.2084	0.2520	20.57	65.72	78.98	78.98	hole	
Avg. Std. Dev. % COV															
1.5007 0.2097 0.2520															
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. Std. Dev. % COV															
1.5008 0.2248 0.3742															
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	hole	#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. Std. Dev. % COV															
1.5003 0.2359 0.2493															
12.9 0.71 1.98 2.39 3.64 3.61															

Project #: BH0002

Textile Test Method Development

Material: AS-4/Shell 1995

Task 6 & 8

Open Hole Compression Test Program
3-D Woven Architectures

inisc Engineer: Maryann Emanson
Boeing Engineer: Mark Fedro
No instrumentation

inisc Group ID	Rep. #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Thick (in)	Width (in)	W/D	Avg. Thick (in)	Avg. Width (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	1.5018	0.2274	0.1860	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		
<p>Avg. 1.5009 0.2281 0.1882 15.9 22.13 64.64 73.91 0.85 2.95 2.95 4.01 4.00</p> <p>Sid. Dev. % COV</p>																	
BH2-06-6P-x	1	T7-TS2-A-2B	3-D	0.632	Modified	0.250	1.5	3/8	1.4990	0.2081	0.3750	10.5	14.75	47.30	53.08	hole	
	2	T7-TS2-A-2B	TS-2	0.632	IITRI		1.4988		0.2081	0.3750	13.4	15.72	50.41	57.23	hole		
	3	T7-TS2-A-2B		0.632			1.4985		0.2118	0.3750	14.0	16.41	51.71	58.97	hole		
<p>Avg. 1.4988 0.2093 0.3750 12.5 15.63 49.81 56.43 0.83 2.27 3.03 4.54 4.56</p> <p>Sid. Dev. % COV</p>																	
BH2-06-6Q-x	1	T7-TS2-A-2B	3-D	0.632	Modified	0.250	1.5	1/4	1.4985	0.2132	0.2505	14.7	18.23	57.01	68.45	hole	
	2	T7-TS2-A-2B	TS-2	0.632	IITRI		1.4982		0.2176	0.2500	16.0	20.24	62.04	74.45	hole		
	3	T7-TS2-A-2B		0.632			1.4978		0.2229	0.2505	18.1	20.45	61.25	73.55	hole		
<p>Avg. 1.4988 0.2179 0.2503 16.3 19.84 60.10 72.15 1.23 2.70 3.24 4.54 4.49</p> <p>Sid. Dev. % COV</p>																	
BH2-06-6R-x	1	T7-TS2-A-2B	3-D	0.632	Modified	0.250	1.5	3/16	1.5010	0.2078	0.1870	17.8	20.29	63.05	74.50	hole	
	2	T7-TS2-A-2B	TS-2	0.632	IITRI		1.4978		0.2096	0.1875	16.6	20.37	63.21	74.54	hole		
	3	T7-TS2-A-2B		0.632			1.4980		0.2106	0.1880	14.5	19.20	60.80	69.52	hole		
<p>Avg. 1.4989 0.2091 0.1875 16.3 19.95 63.68 72.79 0.65 2.50 2.83 3.89 3.89</p> <p>Sid. Dev. % COV</p>																	
BH2-07-6P-x	1	T7-OS1-A-3B	3-D	0.643	Modified	0.250	1.5	3/8	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	59.88	78.56	hole		
	3	T7-OS1-A-3B		0.643			1.4985		0.2313	0.3750	15.4	20.25	58.38	77.85	hole		
<p>Avg. 1.4993 0.2303 0.3752 13.7 20.02 57.99 77.34 0.45 1.14 1.35 2.01 2.01</p> <p>Sid. Dev. % COV</p>																	
BH2-07-6Q-x	1	T7-OS1-A-3B	3-D	0.643	Modified	0.250	1.5	1/4	1.4985	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		22.85	66.57	80.23	hole		
<p>Avg. 1.4985 0.2306 0.2537 23.30 67.44 81.19 1.42 4.29 5.22 6.08 6.36 6.43</p> <p>Sid. Dev. % COV</p>																	
BH2-07-6R-x	1	T7-OS1-A-3B	3-D	0.643	Modified	0.250	1.5	3/16	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		
<p>Avg. 1.4978 0.2255 0.1900 24.16 71.52 81.91 1.03 2.82 3.36 4.28 4.09 4.10</p> <p>Sid. Dev. % COV</p>																	

Project #: BH10002

Textile Test Method Development
Task 6 & 8
Open Hole Compression Test Program
3-D Woven Architectures

Material: AS4/Shell 1895

inlec Engineer: Maryann Emairson
Boeing Engineer: Mark Fedio
No instrumentation

inlec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Thick (in)	Nominal Width (in)	W/D	Avg. Thick (in)	Avg. Width (in)	Hole Diameter (in)	Load at Audible (kpsi)	Ultimate Load (kpsi)	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	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		
									Sid. Dev.					0.74	2.10	2.79		
									% COV					4.42	4.41			
BH2-08-6R-x	1	T7-OS2-A-3A	3-D	0.564	Modified	0.250	1.5	1/4	1.4992	0.2400	0.2485		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	0.2368	0.2498		15.35	42.87	51.44		
									Sid. Dev.					1.26	3.31	3.96		
									% COV					8.23	7.73	7.70		
BH2-08-6Q-x	1	T7-OS2-A-3A	3-D	0.564	Modified	0.250	1.5	3/16	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					1.4950	0.2458	0.1900		24.59	66.74	76.43	hole		
									Avg.	1.5007	0.2475	0.1900		23.72	63.89	73.15		
									Sid. 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	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		14.98	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		
									Sid. 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	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	74.08		
									Sid. 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	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		
									Sid. Dev.					1.62	5.39	6.17		
									% COV					7.72	8.18	8.18		
BH2-10-6P-x	1	T7-LS2-A-2A	3-D	0.653	Modified	0.250	1.5	3/8	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		
									Sid. Dev.					9.30	9.17	9.19		
									% COV									

Project #: sht0002
 inec Engineer: Maryann Emanson
 Boeing Engineer: Mark Fedro
 No instrumentation

Task 6 & 8

Textile Test Method Development
 Open Hole Compression Test Program
 3-D Woven Architectures

Material: AS4/Shell 1885

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

Project #: BH0002

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

Textile Test Method Development

Task 8
 Open Hole Compression Test Program
 Stitched Unweave Architectures

Material: AS4/Shell 1895

Inlec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions		W/D	Hole Diameter (in)	Avg Thick (in)	Avg Width (in)	Load at Audible (kips)	Ultimate Load (kips)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
						Thick (in)	Width (in)										
BH2-11-6B-x	1	T7-SUW-G3K8B1	SU-1	0.668	Boeing	0.250	1.5	1/4	6	1.5000	0.2231	13.5	16.30	48.72	58.51	hole	
	2	T7-SUW-G3K8B1	SU-1	0.668	OH Comp	0.2515	1.4	0	17.71	1.4995	0.2235	14.0	17.71	52.85	63.50	hole	
	3	T7-SUW-G3K8B1	SU-1	0.668	OH Comp	0.2495	1.6	0	16.97	1.5000	0.2238	12.8	16.97	50.55	60.64	hole	
Avg. Sid Dev. % COV																	
13.4 0.71 2.07 2.51 4.15 4.08 4.12																	
BH2-12-6B-x	1	T7-SUW-G6K8B1	SU-2	0.644	Boeing	0.250	1.5	1/4	6	1.5010	0.2467	9.7	16.31	44.05	52.85	hole	
	2	T7-SUW-G6K8B1	SU-2	0.644	OH Comp	0.2510	1.6	0	16.47	1.5000	0.2466	11.6	16.47	44.53	53.48	hole	
	3	T7-SUW-G6K8B1	SU-2	0.644	OH Comp	0.2510	1.6	0	15.80	1.5010	0.2469	10.9	15.80	42.90	51.51	hole	
Avg. Sid Dev. % COV																	
10.7 16.23 43.83 52.61 0.29 0.84 1.01 1.81 1.91																	
BH2-13-6B-x	1	T7-SUW-K6K8B1	SU-3	0.635	Boeing	0.250	1.5	1/4	6	1.5067	0.2381	13.0	14.58	40.64	48.72	hole	
	2	T7-SUW-K6K8B1	SU-3	0.635	OH Comp	0.2510	1.6	0	15.37	1.4958	0.2403	12.1	15.37	42.75	51.33	hole	
	3	T7-SUW-K6K8B1	SU-3	0.635	OH Comp	0.2495	1.6	0	15.71	1.4985	0.2418	10.9	15.71	43.35	52.01	hole	
Avg. Sid Dev. % COV																	
12.0 15.22 42.25 50.69 0.58 1.43 1.74 3.81 3.38 3.43																	
BH2-14-6B-x	1	T7-SUW-K6K4B1	SU-4	0.648	Boeing	0.250	1.5	1/4	6	1.4965	0.2298	12.2	13.87	40.54	48.71	hole	
	2	T7-SUW-K6K4B1	SU-4	0.648	OH Comp	0.2500	1.6	0	14.49	1.5010	0.2313	9.9	14.49	41.73	50.07	hole	
	3	T7-SUW-K6K4B1	SU-4	0.648	OH Comp	0.2500	1.6	0	14.27	1.5037	0.2328	9.6	14.27	40.74	48.87	hole	
Avg. Sid Dev. % COV																	
10.6 14.24 41.00 49.21 0.26 0.64 0.74 1.83 1.55 1.51																	
BH2-15-6B-x	1	T7-SUW-K12K8B1	SU-5	0.654	Boeing	0.250	1.5	1/4	6	1.5017	0.2616	10.2	18.36	46.74	56.05	hole	
	2	T7-SUW-K12K8B1	SU-5	0.654	OH Comp	0.2500	1.6	0	18.10	1.5067	0.2626	13.1	18.10	45.74	54.84	hole	
	3	T7-SUW-K12K8B1	SU-5	0.654	OH Comp	0.2495	1.6	0	18.38	1.4950	0.2634	9.8	18.38	46.68	56.03	hole	
Avg. Sid Dev. % COV																	
11.0 18.28 46.39 55.64 0.16 0.56 0.69 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	14.39	14.39	43.25	57.63	hole	
	2	T7-SUW-G3K8B1	SU-1	0.668	IITRI	0.2510	1.6	0	15.33	1.5000	0.2219	13.1	15.33	46.06	61.35	hole	
	3	T7-SUW-G3K8B1	SU-1	0.668	IITRI	0.2510	1.6	0	14.57	1.4988	0.2224	10.6	14.57	43.71	58.24	hole	
Avg. Sid Dev. % COV																	
14.76 44.34 59.08 0.50 1.50 2.00 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	15.81	15.81	47.63	57.20	hole	
	2	T7-SUW-G3K8B1	SU-1	0.668	IITRI	0.2505	1.6	0	16.62	1.4990	0.2207	16.62	16.62	50.24	60.33	hole	
	3	T7-SUW-G3K8B1	SU-1	0.668	IITRI	0.2510	1.6	0	15.61	1.5010	0.2207	10.6	15.61	47.11	56.58	hole	
Avg. Sid Dev. % COV																	
16.01 48.33 58.03 0.53 1.68 2.01 3.34 3.47 3.46																	

Material AS4/Shell 1895

Textile Test Method Development

Project #: BH0002

Task 8

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

**Open Hole Compression Test Program
Stitched Unilaminate Architectures**

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Nominal Dimensions			W/D	Avg Thick (in)	Avg Width (in)	Avg Thick (in)	Hole Diameter (in)	Load at Audible (kpsi)	Ultimate Load (kpsi)	Gross Ultimate Stress (ksi)	Net Ultimate Stress (ksi)	Failure Location	Comments
						Thick (in)	Width (in)	Diam (in)											
BH2-11-6R-x	1	T7-SUW-G6K8B1	SU-1	0.668	Modified	0.250	1.5	3/16	8	1.5000	0.2241	0.1875	17.04	50.70	57.94		hole		
	2	T7-SUW-G6K8B1	SU-1	0.668	IIITRI	0.250	1.5	3/16	8	1.4990	0.2241	0.1875	17.78	52.93	60.50		hole		
	3	T7-SUW-G6K8B1	SU-1	0.668	Modified	0.250	1.5	3/16	8	1.5000	0.2240	0.1875	17.57	52.30	59.77		hole		
Avg Sid Dev % COV																			
17.46 0.38 1.15 1.32 2.18 2.22 2.22																			
BH2-12-6P-x	1	T7-SUW-G6K8B1	SU-2	0.644	Modified	0.250	1.5	3/8	4	1.5000	0.2469	0.3740	13.30	35.91	47.84		hole		
	2	T7-SUW-G6K8B1	SU-2	0.644	IIITRI	0.250	1.5	3/8	4	1.5000	0.2467	0.3740	14.25	38.51	51.30		hole		
	3	T7-SUW-G6K8B1	SU-2	0.644	Modified	0.250	1.5	3/8	4	1.4978	0.2461	0.3745	13.83	37.51	50.02		hole		
Avg Sid Dev % COV																			
13.79 0.48 1.31 1.75 3.45 3.51 3.51																			
BH2-12-6Q-x	1	T7-SUW-G6K8B1	SU-2	0.644	Modified	0.250	1.5	1/4	6	1.4890	0.2454	0.2505	15.77	42.86	51.46		hole		
	2	T7-SUW-G6K8B1	SU-2	0.644	IIITRI	0.250	1.5	1/4	6	1.5018	0.2404	0.2530	13.98	38.73	46.57		hole		
	3	T7-SUW-G6K8B1	SU-2	0.644	Modified	0.250	1.5	1/4	6	1.5003	0.2453	0.2505	15.97	43.39	52.08		hole		
Avg Sid Dev % COV																			
15.24 1.10 2.55 3.02 7.19 6.13 6.03																			
BH2-12-6R-x	1	T7-SUW-G6K8B1	SU-2	0.644	Modified	0.250	1.5	3/16	8	1.5005	0.2473	0.1860	16.31	43.95	50.25		hole		
	2	T7-SUW-G6K8B1	SU-2	0.644	IIITRI	0.250	1.5	3/16	8	1.4995	0.2469	0.1875	16.48	44.52	50.88		hole		
	3	T7-SUW-G6K8B1	SU-2	0.644	Modified	0.250	1.5	3/16	8	1.4990	0.2470	0.1875	16.97	45.83	52.39		hole		
Avg Sid Dev % COV																			
16.59 0.34 0.97 1.10 2.07 2.16 2.15																			
BH2-13-6P-x	1	T7-SUW-K6K8B1	SU-3	0.635	Modified	0.250	1.5	3/8	4	1.4967	0.2399	0.3740	13.86	38.61	51.47		hole		
	2	T7-SUW-K6K8B1	SU-3	0.635	IIITRI	0.250	1.5	3/8	4	1.5078	0.2396	0.3740	13.66	37.81	50.28		hole		
	3	T7-SUW-K6K8B1	SU-3	0.635	Modified	0.250	1.5	3/8	4	1.5010	0.2400	0.3750	13.77	38.22	50.95		hole		
Avg Sid Dev % COV																			
13.76 0.10 0.40 0.60 0.73 1.05 1.17																			
BH2-13-6Q-x	1	T7-SUW-K6K8B1	SU-3	0.635	Modified	0.250	1.5	1/4	6	1.4977	0.2357	0.2510	14.74	41.76	50.16		hole		
	2	T7-SUW-K6K8B1	SU-3	0.635	IIITRI	0.250	1.5	1/4	6	1.5098	0.2362	0.2505	15.50	43.47	52.11		hole		
	3	T7-SUW-K6K8B1	SU-3	0.635	Modified	0.250	1.5	1/4	6	1.4993	0.2377	0.2510	16.21	45.49	54.63		hole		
Avg Sid Dev % COV																			
15.48 0.74 1.87 2.24 4.75 4.29 4.28																			
BH2-13-6R-x	1	T7-SUW-K6K8B1	SU-3	0.635	Modified	0.250	1.5	3/16	8	1.4940	0.2444	0.1875	17.17	47.02	53.77		hole		
	2	T7-SUW-K6K8B1	SU-3	0.635	IIITRI	0.250	1.5	3/16	8	1.4913	0.2444	0.1875	17.11	46.95	53.71		hole		
	3	T7-SUW-K6K8B1	SU-3	0.635	Modified	0.250	1.5	3/16	8	1.5027	0.2433	0.1875	17.57	48.05	54.90		hole		
Avg Sid Dev % COV																			
17.28 0.25 0.62 0.67 1.45 1.30 1.24																			

Project #: BH0002

Inlec Engineer: Maryann Einerson
 Boeing Engineer: Mark Fedro
 No instrumentation

Textile Test Method Development

Task 8

**Open Hole Compression Test Program
 Stitched Unlweave Architectures**

Material: AS4/Shell 1895

Inlec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Configuration Type	Normal Dimensions			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	
						Thick (in)	Width (in)	Diam (in)											
BH2-14-6P-x	1	T7-SUW-K6K4B1	SU-4	0.648	Modified	0.250	1.5	3/8	4	1.4983	0.2312	0.3735	12.98	37.47	49.91	hole			
	2	T7-SUW-K6K4B1	SU-4	0.648	IITRI	0.250	1.5	3/8	4	1.5007	0.2312	0.3740	13.22	38.10	50.75	hole			
	3	T7-SUW-K6K4B1	SU-4	0.648	IITRI	0.250	1.5	3/8	4	1.4990	0.2317	0.3740	13.05	37.58	50.07	hole			
Avg. Sid. Dev. % COV																			
BH2-14-6O-x	1	T7-SUW-K6K4B1	SU-4	0.648	Modified	0.250	1.5	1/4	6	1.4975	0.2360	0.2515	15.32	43.36	52.11	hole			
	2	T7-SUW-K6K4B1	SU-4	0.648	IITRI	0.250	1.5	1/4	6	1.4995	0.2293	0.2505	15.15	44.07	52.91	hole			
	3	T7-SUW-K6K4B1	SU-4	0.648	IITRI	0.250	1.5	1/4	6	1.4970	0.2302	0.2505	14.69	42.62	51.18	hole			
Avg. Sid. Dev. % COV																			
BH2-14-6R-x	1	T7-SUW-K6K4B1	SU-4	0.648	Modified	0.250	1.5	3/16	8	1.4990	0.2288	0.1875	15.84	46.17	52.77	hole			
	2	T7-SUW-K6K4B1	SU-4	0.648	IITRI	0.250	1.5	3/16	8	1.4983	0.2354	0.1880	16.61	47.10	53.85	hole			
	3	T7-SUW-K6K4B1	SU-4	0.648	IITRI	0.250	1.5	3/16	8	1.4960	0.2365	0.1875	16.88	47.70	54.54	hole			
Avg. Sid. Dev. % COV																			
BH2-15-6P-x	1	T7-SUW-K12K8B1	SU-5	0.654	Modified	0.250	1.5	3/8	4	1.4990	0.2591	0.3740	15.09	38.86	51.78	hole			
	2	T7-SUW-K12K8B1	SU-5	0.654	IITRI	0.250	1.5	3/8	4	1.4975	0.2585	0.3735	14.78	38.18	50.86	hole			
	3	T7-SUW-K12K8B1	SU-5	0.654	IITRI	0.250	1.5	3/8	4	1.4948	0.2577	0.3740	14.70	38.17	50.90	hole			
Avg. Sid. Dev. % COV																			
BH2-15-6O-x	1	T7-SUW-K12K8B1	SU-5	0.654	Modified	0.250	1.5	1/4	6	1.4975	0.2596	0.2505	15.8	45.55	54.70	hole			
	2	T7-SUW-K12K8B1	SU-5	0.654	IITRI	0.250	1.5	1/4	6	1.4952	0.2586	0.2510	13.4	44.09	52.99	hole			
	3	T7-SUW-K12K8B1	SU-5	0.654	IITRI	0.250	1.5	1/4	6	1.5107	0.2584	0.2510	14.5	42.74	51.25	hole			
Avg. Sid. Dev. % COV																			
BH2-15-6R-x	1	T7-SUW-K12K8B1	SU-5	0.654	Modified	0.250	1.5	3/16	8	1.4977	0.2642	0.1880	14.6	47.44	54.25	hole			
	2	T7-SUW-K12K8B1	SU-5	0.654	IITRI	0.250	1.5	3/16	8	1.5100	0.2645	0.1880	15.2	48.08	54.92	hole			
	3	T7-SUW-K12K8B1	SU-5	0.654	IITRI	0.250	1.5	3/16	8	1.4930	0.2640	0.1880	14.2	47.57	54.42	hole			
Avg. Sid. Dev. % COV																			
													14.7	18.91	47.70	54.53			
													1.34	0.25	0.34	0.34			
													1.34	0.71	0.71	0.63			

In-Plane Shear Test Program

Task 7
Textile Test Method Development
 In-Plane Shear/ Test Program
 2-D Braided Architectures

Intec Engineer: Maryann Ematson
 Boeing Engineer: Mark Fedro

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction	Tabbed	Notch Length (in)	Avg Thick (in)	Load at Audible (lbf)	Ultimate Load (kpsi)	Ultimate Shear Stress (ksi)	Ultimate +45 Strain (%)	Ultimate -45 Strain (%)	Ultimate 0° Strain (%)	Ultimate 90° Strain (%)	Shear Modulus		Failure Mode	Comments	
															Axial 1 (msi)	Axial 2 (msi)			
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	-4.45	-4.423	1.62	1.42	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	-1.71	-9.37	1.67	1.52	shear	Failed just off center, along braid	
	5	T7-SLL-B-8B	SLL	0.615	Y	3.0075	0.1044	6.0	6.44	20.49	6.847	-6.370	-2.63	-2.094	1.67	1.67	shear	Failed along braid in gage section	
	6	T7-SLL-B-8B	SLL	0.615	Y	3.0140	0.1091	4.5	5.38	16.37	7.109	-5.205	4.2	2.821	1.46	1.48	shear	Failed at notch, along braid	
	Average								4.8	6.16	19.14	6.681	-6.174	-1.31	-7.0	1.58	1.53		
	Std. Dev.								0.57	2.17	9.29	11.31				0.11	0.13		
% COV								9.29	35.5	47.8	169.3				6.94	8.60			
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	-4.06	1.078	2.22	2.53	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	-2.12	2.62	2.45	shear	Failed just off center, along braid	
	5	T7-LLS-B-11A	LLS	0.538	Y	2.8895	0.1058	4.1	5.21	16.46	3.088	-3.429	-7.1	11	2.62	2.45	shear	Failed at notch	
	6	T7-LLS-B-11A	LLS	0.538	Y	3.0050	0.1137	3.8	6.88	20.15	6.883	-3.658	8.58	2.970	2.22	2.68	shear	Failed at notch	
	Average								4.2	6.11	18.30	4.800	-3.923	-1.10	9.23	2.36	2.55		
	Std. Dev.								0.95	2.53	15.51	13.83				0.23	0.12		
% COV								15.51	41.3	84.8	287.3				9.83	4.51			
BH2-03-7A-x	1	T7-LLS-B-3B	2-D	0.661	N	3.0090	0.1118	4.7	6.19	18.41	na	-6.107	-6.88	1.443	2.02	1.95	shear	Failed at notch.	
	2	T7-LLS-B-3B	LLS	0.661	N	3.0080	0.1159	4.5	5.73	16.43	5.846	-5.342	108	-2	1.44	1.68	shear	Failed just off center, along braid	
	3	T7-LLS-B-3B	LLS	0.661	N	3.0085	0.1097	3.7	5.85	17.74	4.242	-6.284	761	-1.918	2.08	1.88	shear	Failed at notch	
	Average								4.3	5.92	17.53	5.044	-5.911	60	2.99	2.08			
	Std. Dev.								0.24	1.01	4.07	5.74			0.35	0.16			
	% COV								4.07	16.9	22.3	112.3			11.87	7.60			
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	Failed at notch	
	4	T7-LSS-B-6A	LSS	0.623	Y	3.0085	0.1088	10.1	11.62	35.51	5.112	-4.923	-6.50	1.444	3.44	3.87	shear	Failed at notch	
	5	T7-LSS-B-6A	LSS	0.623	Y	3.0090	0.1013	5.4	12.42	40.74	4.925	-4.776	-7.50	1.913	4.33	4.61	shear	Partial failure along 0 deg braid	
	6	T7-LSS-B-6A	LSS	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	shear	and partial failure along 45 deg	
	Average								5.7	10.73	34.41	5.141	-4.661	-9.97	2.574	3.94	4.51		
	Std. Dev.								0.41	2.83	3.63	8.22			11.59	13.36			
% COV								3.63	26.3	73.3	157.8			44.7	31.6				

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

Textile Test Method Development
Task 7 & 8
In-Plane ShearTest Program
3-D Woven Architecture

Project #: BH0002
Inlec Engineer: Maryann Emanson
Boeing Engineer: Mark Fedro

Inlec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Tabbed 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		Failure Mode	Comments		
												Axial 1 (ksi)	Axial 2 (ksi)				
BH2-05-7A-x	1	T7-TS1-A-3A	3-D	0.615	Y	3.0080	5.7	8.96	13.16			0.602	0.676	0.639	Failed at notch bearing failure Failed at notch Extreme Extension - w/o Abrupt Load Drop		
	2	T7-TS1-A-3A	TS1	0.615	Y	3.0070	7.4	9.08	13.17			0.696	0.696	0.696			
	3	T7-TS1-A-3A		0.615	Y	3.0050	5.3	9.05	13.28			0.620	0.596	0.608			
Average													0.639	0.656	0.648		
Std. Dev.													0.050	0.053	0.045		
% COV													7.84	8.07	6.93		
BH2-06-7A-x	1	T7-TS2-A-2A	3-D	0.634	Y	3.0065		6.78	9.72	14		0.681	0.688	0.688	Extreme Extension - w/o Abrupt Load Drop Failure at notch		
	2	T7-TS2-A-2A	TS2	0.634	Y	3.0030		6.68	9.66			0.658	0.716	0.687			
	3	T7-TS2-A-2A		0.634	Y	3.0045		9.69	14.20			0.718	0.747	0.732			
Average													0.688	0.719	0.702		
Std. Dev.													0.030	0.028	0.026		
% COV													4.39	3.63	3.69		
BH2-07-7A-x	1	T7-OS1-A-3A	3-D	0.610	Y	3.0020		5.50	7.81	-12.420		0.561	0.604	0.583	Damage along centerline Failed at notch Failed at notch		
	2	T7-OS1-A-3A	OS1	0.610	Y	2.9900		11.92	17.16			0.590	0.576	0.583			
	3	T7-OS1-A-3A		0.610	Y	3.0020		11.66	16.78			0.568	0.547	0.558			
Average													0.573	0.576	0.574		
Std. Dev.													0.015	0.029	0.015		
% COV													2.61	5.02	2.55		
BH2-08-7A-x	1	T7-OS2-A-3A	3-D	0.564	Y	2.9965		13.61	18.77			0.490	0.517	0.503	Extreme Extension - w/o Abrupt Load Drop		
	2	T7-OS2-A-3A	OS2	0.564	Y	2.9965		13.17	18.42			0.475	0.531	0.503			
	3	T7-OS2-A-3A		0.564	Y	2.9980		14.65	20.52			0.518	0.525	0.522			
Average													0.494	0.525	0.510		
Std. Dev.													0.022	0.007	0.011		
% COV													4.41	1.37	2.08		
BH2-09-7A-x	1	T7-LS1-A-5B	3-D	0.646	Y	3.0050		5.4	8.74	7.581		0.710	0.765	0.738	Failed at notch Failed at notch Failed at notch		
	2	T7-LS1-A-5A	LS1	0.646	Y	2.9935		5.14	7.97			0.675	0.838	0.756			
	3	T7-LS1-A-5A		0.646	Y	3.0000		5.52	8.71			0.724	0.881	0.817			
Average													0.720	0.821	0.770		
Std. Dev.													0.050	0.050	0.042		
% COV													6.97	6.05	5.40		
BH2-10-7A-x	1	T5-LS2-A-1B	3-D	0.629	Y	3.0065		6.27	9.40	9.183		0.668	0.720	0.694	Failed at notch Failed at notch Failed at notch		
	2	T5-LS2-A-1B	LS2	0.629	Y	2.9970		6.18	9.34			0.733	0.763	0.748			
	3	T5-LS2-A-1B		0.629	Y	2.9940		6.43	9.73			0.821	0.779	0.749			
Average													0.708	0.754	0.730		
Std. Dev.													0.034	0.030	0.031		
% COV													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 Emanson
 Boeing Engineer: Mark Fedro
 Task 8
 Textile Test Method Development
 In-Plane Shear Test Program
 SUW Architectures

Intec Group ID	Rep #	Boeing Plate #	Material Form	Fiber Volume Fraction (%)	Tabbed	Notch Length (in)	Avg Thick (in)	Load at Audible (lps)	Ultimate Load (kps)	Ultimate Shear Stress (ksi)	Ultimate +45 Strain (µε)	Ultimate -45 Strain (µε)	Ultimate Strain (µε)	Ultimate Strain (µε)	Shear Modulus		Failure Mode	Comments	
															Axial 1 (ksi)	Axial 2 (ksi)			
BH2-11-7A-x	1	T7-SUW-G3K8B-2	SU-1	0.668	Y	3.0060	0.2236	13.40	19.93	3.790	32	214	2.53	2.77	2.65	Bearing bolt sheared off Top left hole Top left hole Top left hole			
	2	T7-SUW-G3K8B-2	SU-1	0.668	Y	3.0025	0.2233	16.3	17.33	5.031	-124	538	2.58	2.60	2.69				
	3	T7-SUW-G3K8B-2	SU-1	0.668	Y	2.9760	0.2233	17.0	17.19	5.262	-283	75	2.53	2.81	2.67				
Average														2.55	2.79	2.67			
Std. Dev.														0.03	0.02	0.02			
% COV														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	31	421	2.25	2.44	2.35	Top left hole Top left hole Top left hole			
	2	T7-SUW-G6K8B-2	SU-2	0.644	Y	2.9945	0.2441	16.9	17.19	5.224	-4,776	34	2.30	2.57	2.43				
	3	T7-SUW-G6K8B-2	SU-2	0.644	Y	2.9860	0.2462	16.74	22.77	4.622	-3,799	134	2.47	2.92	2.70				
Average														2.34	2.64	2.49			
Std. Dev.														0.12	0.25	0.18			
% COV														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	Top left hole Top left hole Top left hole			
	2	T7-SUW-K6K8B-2	SU-3	0.635	Y	3.0055	0.2407	16.0	17.06	23.58	-370	598	2.65	2.62	2.64				
	3	T7-SUW-K6K8B-2	SU-3	0.635	Y	2.9945	0.2400	16.0	16.50	22.95	-4,494	-315	169	2.33	2.63		2.48		
Average														2.47	2.58	2.52			
Std. Dev.														0.17	0.08	0.10			
% COV														6.70	3.25	3.90			
BH2-14-7A-x	1	T7-SUW-K8K4B-2	SU-4	0.648	Y	3.0060	0.2316	13.8	14.89	21.09	33	367	2.71	2.64	2.68	Top left hole Bottom right hole Bottom right hole			
	2	T7-SUW-K8K4B-2	SU-4	0.648	Y	2.9970	0.2312	16.7	16.95	24.45	-4,415	283	116	2.77	2.69		2.73		
	3	T7-SUW-K8K4B-2	SU-4	0.648	Y	3.0090	0.2310	15.5	17.47	25.14	-4,585	303	83	2.69	2.85		2.77		
Average														2.72	2.73	2.73			
Std. Dev.														0.04	0.11	0.05			
% COV														1.55	3.96	1.75			
BH2-15-7A-x	1	T7-SUW-K12K8B-2	SU-5	0.654	Y	3.0090	0.2540	17.5	17.77	23.07	-4,664	-373	639	2.48	2.63	2.66	Bolt failure Top left hole Top left hole		
	2	T7-SUW-K12K8B-2	SU-5	0.654	Y	2.9975	0.2547	15.5	16.99	22.26	-4,568	-4,471	447	2.41	2.59	2.50			
	3	T7-SUW-K12K8B-2	SU-5	0.654	Y	2.9960	0.2550	15.7	16.92	20.84	-4,259	-289	52	2.59	2.47	2.53			
Average														2.46	2.56	2.53			
Std. Dev.														0.09	0.08	0.03			
% COV														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														
Specimen ID	Test Cell ID	Test Type	Mat. Class	Mat. Desc.	Nom. W/D	Average Dimensions			Test Date	Ult. Load (lbs)	Ult. Net Stress (ksi)	Ult. Gross Stress (ksi)	Failure Mode	
						Length (in)	Thickness (in)	Hole Dia (in)						
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	14300	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%		
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	86.74	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%		3.89%	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
Gross stress calculated from: Load/actual thickness/actual width

Bolt Bearing Test Program

Stabilized Single Shear Bearing

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

Specimen ID	Test Cell ID	Test Type	Mtl. Class	Mtl. Desc.	Nominal Drms W/D	e/D	Width (in)	Length (in)	Average Dimensions				Failure Load		Bearing Stress		Failure Mode		
									Thick ness (in)	Hole Dia 1 (in)	Hole Dia 2 (in)	Edge Dist 1 (in)	Edge Dist 2 (in)	Limit (lbs)	Ult (lbs)	Limit (ksi)		Ultimate (ksi)	
BH4-16	141a	SSSB	1	SLL	4	3	1.000	3.49	0.1087	0.2515	0.2515	0.628	0.628	4943	5138	90.12	93.87	Bearing at holes 1 and 4	
BH4-17	141a	SSSB	1	SLL	4	3	0.999	3.49	0.1087	0.2515	0.2515	0.627	0.627	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	0.2515	0.2515	0.628	0.628	5168	5425	96.42	101.21	Bearing at holes 1 and 4	
BH4-19	141a	SSSB	1	SLL	4	3	0.999	3.50	0.1068	0.2515	0.2515	0.627	0.628	5168	5425	97.87	102.52	Bearing at holes 1 and 4	
BH4-20	141a	SSSB	1	SLL	4	3	0.999	3.49	0.1046	0.2510	0.2510	0.626	0.630	5331	5591	101.70	106.66	Bearing at holes 1 and 4	
BH4-21	141a	SSSB	1	SLL	4	3	1.000	3.49	0.1040	0.2520	0.2520	0.626	0.624	5331	5591	102.52	107.52	Bearing at holes 1 and 4	
BH4-22	141b	SSSB	1	SLL	4	2	0.999	3.50	0.1103	0.2520	0.2520	0.377	0.377	4779	4783	85.69	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	4779	4783	87.82	88.00	End margin shear out at holes 1 and 4	
BH4-24	141b	SSSB	1	SLL	4	2	0.998	3.49	0.1079	0.2520	0.2520	0.375	0.370	4620	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	0.377	4620	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	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	0.2525	0.379	0.379	4711	4778	88.42	89.03	End margin shear out at holes 1 and 4	
BH4-28	141c	SSSB	1	SLL	4	4	0.999	3.49	0.1040	0.2520	0.2523	0.376	0.376	4763	4787	87.13	88.87	Bearing at holes 1 and 4	
BH4-29	141c	SSSB	1	SLL	4	4	1.000	3.63	0.1094	0.2510	0.2510	0.375	0.377	5206	5649	96.20	103.32	Bearing at holes 1 and 4	
BH4-30	141c	SSSB	1	SLL	4	4	1.000	3.63	0.1071	0.2510	0.2510	0.375	0.378	5206	5649	97.23	105.52	Bearing at holes 1 and 4	
BH4-31	141c	SSSB	1	SLL	4	4	0.998	3.63	0.1069	0.2510	0.2515	0.375	0.378	5387	5534	100.79	103.54	Bearing at holes 1 and 4	
BH4-32	141c	SSSB	1	SLL	4	4	0.999	3.63	0.1049	0.2510	0.2510	0.380	0.380	5387	5534	102.69	105.49	Bearing at holes 1 and 4	
BH4-33	141c	SSSB	1	SLL	4	4	0.999	3.63	0.1044	0.2510	0.2515	0.378	0.381	5299	5654	101.50	108.30	Bearing at holes 1 and 4	
BH4-34	141d	SSSB	1	SLL	6	2	1.500	3.63	0.1071	0.2519	0.2513	0.376	0.376	5297	5612	98.96	104.82	Bearing at holes 1 and 4	
BH4-35	141d	SSSB	1	SLL	6	2	1.500	3.50	0.1087	0.2520	0.2515	0.375	0.375	5474	N/A	N/A	N/A	End margin shear out at holes 1 and 4	
BH4-36	141d	SSSB	1	SLL	6	2	1.501	3.50	0.1053	0.2520	0.2530	0.377	0.383	N/A	N/A	N/A	N/A	End margin shear out at holes 1 and 4	
BH4-37	141d	SSSB	1	SLL	6	2	1.501	3.49	0.1049	0.2530	0.2520	0.380	0.379	5041	5141	96.14	98.06	End margin shear out at holes 1 and 4	
BH4-38	141d	SSSB	1	SLL	6	2	1.501	3.50	0.1083	0.2515	0.2520	0.375	0.374	5041	5141	94.82	96.70	End margin shear out at holes 1 and 4	
BH4-39	141d	SSSB	1	SLL	6	2	1.501	3.50	0.1082	0.2515	0.2530	0.375	0.382	N/A	5087	N/A	93.20	93.20	End margin shear out at holes 1 and 3
BH4-40	141e	SSSB	1	SLL	6	2	1.500	3.50	0.1177	0.2522	0.2522	0.376	0.378	N/A	5087	N/A	91.12	92.38	End margin shear out at holes 1 and 3
BH4-41	141e	SSSB	1	SLL	6	3	1.500	3.49	0.1067	0.2523	0.2522	0.376	0.378	5041	4947	85.48	85.48	Bearing at holes 1 and 4	
BH4-42	141e	SSSB	1	SLL	6	3	1.499	3.50	0.1074	0.2530	0.2520	0.376	0.378	5440	5581	101.39	103.96	Bearing at holes 1 and 4	
BH4-43	141e	SSSB	1	SLL	6	3	1.500	3.49	0.1069	0.2520	0.2520	0.375	0.378	5440	5581	102.74	105.40	Bearing at holes 1 and 4	
BH4-44	141e	SSSB	1	SLL	6	3	1.501	3.49	0.1062	0.2520	0.2520	0.375	0.379	N/A	5659	N/A	107.56	107.56	Bearing at holes 1 and 4
BH4-45	141e	SSSB	1	SLL	6	3	1.500	3.48	0.1075	0.2525	0.2530	0.375	0.375	N/A	5659	N/A	106.12	106.12	Bearing at holes 1 and 4
BH4-46	141f	SSSB	1	SLL	6	3	1.500	3.48	0.1067	0.2523	0.2522	0.375	0.375	5287	5712	98.06	106.34	Bearing at holes 1 and 4	
BH4-47	141f	SSSB	1	SLL	6	4	1.500	3.48	0.1067	0.2523	0.2522	0.375	0.375	5354	5651	100.82	108.93	Bearing at holes 1 and 4	
BH4-48	141f	SSSB	1	SLL	6	4	1.499	3.63	0.1084	0.2520	0.2525	0.375	0.375	5310	5624	97.21	102.78	Bearing at holes 1 and 4	
BH4-49	141f	SSSB	1	SLL	6	4	1.499	3.63	0.1076	0.2530	0.2535	0.375	0.371	5310	5624	98.90	104.57	Bearing at holes 1 and 4	
BH4-50	141f	SSSB	1	SLL	6	4	1.502	3.63	0.1062	0.2520	0.2520	0.375	0.371	5223	5502	98.51	101.67	Bearing at holes 1 and 4	
BH4-51	141f	SSSB	1	SLL	6	4	1.500	3.63	0.1079	0.2530	0.2520	0.374	0.373	5223	5502	96.57	101.73	Bearing at holes 1 and 4	
BH4-51	141f	SSSB	1	SLL	6	4	1.501	3.63	0.1084	0.2520	0.2520	0.374	0.373	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	0.374	0.373	5575	5881	102.84	108.49	Bearing at holes 1 and 4	
BH4-51	141f	SSSB	1	SLL	6	4	1.500	3.63	0.1083	0.2523	0.2523	0.375	0.374	5372	5668	99.23	104.71	Bearing at holes 1 and 4	
BH4-51	141f	SSSB	1	SLL	6	4	1.500	3.63	0.1083	0.2523	0.2523	0.375	0.374	5372	5668	99.23	104.71	Bearing at holes 1 and 4	
BH4-51	141f	SSSB	1	SLL	6	4	0.07%	0.02%	0.59%	0.24%	0.24%	0.06%	0.06%	3.03%	3.05%	3.14%	3.16%	Bearing at holes 1 and 4	

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, Hitch side. Hole 3: Second specimen, Hitch side. Hole 4: Second specimen, fastener head side. (See diagram in report)

Specimen ID		Test Cell ID	Test Type	Mat. Class	Mat. Desc.	Normal Dirns W/D e/D	Width (in)	Length (in)	Thickness (in)	Average Dimensions				Edge Dist 1 (in)	Edge Dist 2 (in)	Test Date	Failure Load Limit (lbs)	Failure Load UL (lbs)	Bearing Stress Limit (ksi)	Failure Mode	
										Hole Dia 1 (in)	Hole Dia 2 (in)	Hole Dia 1 (in)	Hole Dia 2 (in)								
BH4-52	1419	SSSB	1	SLL	8	2	2.001	3.50	0.1133	0.2520	0.2520	0.2520	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	1419	SSSB	1	SLL	8	2	2.000	3.50	0.1114	0.2510	0.2505	0.2510	0.2505	0.374	0.378	10/6/93	N/A	4381	N/A	78.56	End margin shear out at holes 1 and 4
BH4-54	1419	SSSB	1	SLL	8	2	2.004	3.49	0.1112	0.2535	0.2515	0.2535	0.2515	0.370	0.375	10/6/93	N/A	4872	N/A	84.05	End margin shear out at holes 1 and 4
BH4-55	1419	SSSB	1	SLL	8	2	2.001	3.50	0.1108	0.2515	0.2525	0.2515	0.2525	0.371	0.369	10/6/93	N/A	4630	N/A	83.85	End margin shear out at holes 1 and 4
BH4-56	1419	SSSB	1	SLL	8	2	2.000	3.50	0.1081	0.2515	0.2525	0.2515	0.2525	0.372	0.375	10/6/93	N/A	4127	N/A	76.36	End margin shear out at holes 1 and 4
BH4-57	1419	SSSB	1	SLL	8	2	2.001	3.50	0.1076	0.2525	0.2520	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
BH4-58	141h	SSSB	1	SLL	8	3	2.001	3.50	0.1088	0.2525	0.2520	0.2525	0.2520	0.372	0.373	10/6/93	4636	4893	83.34	79.82	End margin shear out at holes 1 and 4
BH4-59	141h	SSSB	1	SLL	8	3	2.001	3.50	0.1068	0.2525	0.2520	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
BH4-60	141h	SSSB	1	SLL	8	3	2.002	3.50	0.1064	0.2520	0.2520	0.2520	0.622	0.631	10/6/93	5180	5294	97.35	96.50	End margin shear out at holes 1 and 3	
BH4-61	141h	SSSB	1	SLL	8	3	2.001	3.50	0.1095	0.2515	0.2525	0.2515	0.628	0.628	10/6/93	4817	5484	92.21	102.84	Bearing at holes 1 and 4	
BH4-62	141h	SSSB	1	SLL	8	3	2.002	3.50	0.1067	0.2520	0.2520	0.2520	0.629	0.632	10/6/93	4917	5484	88.82	100.18	Bearing at holes 1 and 4	
BH4-63	141h	SSSB	1	SLL	8	3	2.002	3.50	0.1071	0.2525	0.2520	0.2525	0.624	0.629	10/6/93	5335	5240	97.52	100.02	Bearing at holes 1 and 4	
BH4-64	141h	SSSB	1	SLL	8	3	2.001	3.50	0.1075	0.2522	0.2521	0.2522	0.628	0.629	10/6/93	6112	6371	96.18	96.90	Bearing at holes 1 and 4	
BH4-65	141h	SSSB	1	SLL	8	4	2.000	3.63	0.1126	0.2520	0.2520	0.2520	0.879	0.875	10/6/93	5223	5513	92.85	98.01	Bearing at holes 1 and 4	
BH4-66	141h	SSSB	1	SLL	8	4	2.001	3.63	0.1085	0.2520	0.2515	0.2520	0.878	0.877	10/6/93	5223	5513	96.28	101.62	Bearing at holes 1 and 4	
BH4-67	141h	SSSB	1	SLL	8	4	2.002	3.63	0.1066	0.2530	0.2520	0.2530	0.875	0.880	10/6/93	5228	5817	98.13	106.43	Bearing at holes 1 and 4	
BH4-68	141h	SSSB	1	SLL	8	4	2.001	3.63	0.1147	0.2530	0.2520	0.2530	0.874	0.879	10/6/93	5228	5617	91.13	97.91	Bearing at holes 1 and 4	
BH4-69	141h	SSSB	1	SLL	8	4	2.000	3.63	0.1089	0.2520	0.2520	0.2520	0.880	0.875	10/6/93	5119	5346	93.17	97.30	Bearing at holes 1 and 4	
BH4-136	242h	SSSB	2	LLS	4	2	1.999	3.53	0.1082	0.2520	0.2520	0.2520	0.875	0.875	10/6/93	5180	5482	94.22	96.70	Bearing at holes 1 and 4	
BH4-137	242h	SSSB	2	LLS	4	2	1.000	3.50	0.1083	0.2515	0.2515	0.2515	0.373	0.373	10/6/93	N/A	3881	N/A	71.30	73.08	Shear out at holes 1 and 4
BH4-138	242h	SSSB	2	LLS	4	2	1.000	3.50	0.1057	0.2520	0.2520	0.2520	0.372	0.381	10/6/93	N/A	3615	N/A	63.34	63.34	Shear out at holes 1 and 3
BH4-139	242h	SSSB	2	LLS	4	2	0.998	3.50	0.1078	0.2525	0.2520	0.2520	0.374	0.384	10/6/93	N/A	3415	N/A	63.35	63.35	Shear out at holes 1 and 3
BH4-140	242h	SSSB	2	LLS	4	2	1.000	3.50	0.1080	0.2520	0.2520	0.2520	0.373	0.365	10/6/93	2230	3060	41.28	56.46	End margin splitting at hole 1. Shear out hole 4.	
BH4-141	242h	SSSB	2	LLS	4	2	0.998	3.49	0.1054	0.2510	0.2515	0.2510	0.372	0.382	10/6/93	2230	3060	42.32	57.88	End margin splitting at hole 1. Shear out hole 4.	
BH4-142	242b	SSSB	2	LLS	4	3	1.000	3.50	0.1078	0.2518	0.2518	0.2518	0.373	0.374	10/6/93	2230	3442	41.88	64.34	End margin splitting at hole 1. Shear out hole 4.	
BH4-143	242b	SSSB	2	LLS	4	3	1.000	3.50	0.1078	0.2510	0.2525	0.2510	0.628	0.628	10/6/93	4314	4807	80.23	80.39	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	0.2515	0.622	0.622	10/6/93	4314	4807	80.33	80.52	Bearing hole 1. Interlaminar shear out of 0 plies at hole 3	
BH4-145	242b	SSSB	2	LLS	4	3	0.999	3.51	0.1078	0.2525	0.2520	0.2525	0.624	0.622	10/6/93	4845	5184	90.31	96.07	Bearing at hole 1 and 4	
BH4-146	242b	SSSB	2	LLS	4	3	0.999	3.51	0.1076	0.2525	0.2525	0.2525	0.627	0.627	10/6/93	4845	5184	90.10	96.84	Bearing at hole 1 and 4	
BH4-147	242b	SSSB	2	LLS	4	3	0.992	3.49	0.1081	0.2515	0.2520	0.2515	0.622	0.631	10/6/93	4781	4904	88.67	90.98	Interlaminar shear out of 0 plies at holes 1 and 4	
BH4-148	242c	SSSB	2	LLS	4	4	1.000	3.65	0.1073	0.2516	0.2521	0.2516	0.623	0.628	10/6/93	4648	4985	88.82	92.37	Interlaminar shear out of 0 plies at holes 1 and 4	
BH4-149	242c	SSSB	2	LLS	4	4	1.000	3.65	0.1105	0.2525	0.2525	0.2525	0.879	0.880	10/6/93	5598	5725	82.32	82.32	Bearing at hole 1 and 4	
BH4-150	242c	SSSB	2	LLS	4	4	0.998	3.65	0.1069	0.2525	0.2520	0.2525	0.887	0.880	10/6/93	4577	5215	82.84	94.38	Bearing at hole 1 and 4	
BH4-151	242c	SSSB	2	LLS	4	4	0.998	3.65	0.1101	0.2510	0.2515	0.2510	0.883	0.878	10/6/93	5025	5406	91.28	98.20	Bearing at hole 1 and 4	
BH4-152	242c	SSSB	2	LLS	4	4	0.999	3.65	0.1089	0.2520	0.2520	0.2520	0.876	0.875	10/6/93	4866	5240	91.19	96.22	Bearing at hole 1 and 4	
BH4-153	242c	SSSB	2	LLS	4	4	0.997	3.65	0.1082	0.2518	0.2522	0.2518	0.880	0.878	10/6/93	4866	5240	93.07	96.20	Bearing at hole 1 and 4	

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/factual 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)

Stabilized Single Shear Bearing

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

Specimen ID	Test Cell ID	Test Type	Mat Class	Mat Desc.	Nominal Dims		Length (in)	Thickness (in)	Average Dimensions				Edge Dist 1 (in)	Edge Dist 2 (in)	Test Date	Failure Load		Bearing Stress Limit (ksi)	Ultimate (ksi)	Failure Mode
					W/D	e/D			Hole Dia 1 (in)	Hole Dia 2 (in)	Thick ness (in)	Limit (lbf)				Ult (lbf)				
BH4-154	242d	SSSB	2	LLS	6	2	1.500	3.50	0.1110	0.2510	0.2510	0.2510	0.360	0.377	10/6/93	4179	N/A	N/A	75.33	Interlamellar shear out of 0 piles at holes 1 and 4
BH4-155	242d	SSSB	2	LLS	6	2	1.500	3.50	0.1110	0.2510	0.2510	0.2510	0.378	0.376	10/6/93	4179	N/A	N/A	75.92	Interlamellar shear out of 0 piles at holes 1 and 4
BH4-156	242d	SSSB	2	LLS	6	2	1.488	3.48	0.1103	0.2510	0.2510	0.2510	0.377	0.378	10/6/93	2970	3662	53.86	70.04	Interlamellar shear out of 0 piles at holes 2 and 4
BH4-157	242d	SSSB	2	LLS	6	2	1.489	3.48	0.1067	0.2505	0.2510	0.2505	0.377	0.378	10/6/93	2970	3662	55.66	72.38	Interlamellar shear out of 0 piles at holes 2 and 4
BH4-158	242d	SSSB	2	LLS	6	2	1.489	3.49	0.1049	0.2510	0.2505	0.2505	0.377	0.373	10/6/93	2962	3697	55.12	70.46	Interlamellar shear out of 0 piles at holes 1 and 3
BH4-159	242d	SSSB	2	LLS	6	2	1.484	3.48	0.1079	0.2508	0.2508	0.2508	0.380	0.378	10/6/93	2931	3913	55.90	71.46	Interlamellar shear out of 0 piles at holes 1 and 3
BH4-160	242e	SSSB	2	LLS	6	3	1.500	3.50	0.1068	0.2505	0.2505	0.2505	0.628	1.077	10/6/93	3723	4216	68.70	76.93	Bearing at hole 1 and 4
BH4-161	242e	SSSB	2	LLS	6	3	1.502	3.50	0.1136	0.2505	0.2505	0.2505	0.632	0.626	10/6/93	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	0.2505	0.628	0.624	10/6/93	4901	5152	89.48	94.07	Interlamellar shear out of 0 piles at holes 1 and 4
BH4-163	242e	SSSB	2	LLS	6	3	1.490	3.50	0.1072	0.2506	0.2506	0.2506	0.628	0.628	10/6/93	4901	5152	91.41	96.09	Interlamellar shear out of 0 piles at holes 1 and 4
BH4-164	242e	SSSB	2	LLS	6	3	1.489	3.50	0.1058	0.2510	0.2500	0.2500	0.630	0.625	10/6/93	4890	5108	92.22	96.53	Interlamellar shear out of 0 piles at holes 1 and 4
BH4-165	242e	SSSB	2	LLS	6	3	1.489	3.50	0.1064	0.2505	0.2510	0.2510	0.627	0.624	10/6/93	4890	5108	91.78	96.05	Interlamellar shear out of 0 piles at holes 1 and 3
BH4-166	242f	SSSB	2	LLS	6	4	1.485	3.45	0.1082	0.2508	0.2508	0.2508	0.628	0.624	10/6/93	4691	4828	83.38	89.31	Interlamellar shear out of 0 piles at holes 1 and 3
BH4-167	242f	SSSB	2	LLS	6	4	1.500	3.65	0.1068	0.2510	0.2505	0.2505	0.675	0.668	10/6/93	4528	4820	85.53	91.03	Bearing at hole 1 and 4
BH4-168	242f	SSSB	2	LLS	6	4	1.499	3.65	0.1070	0.2505	0.2510	0.2510	0.678	0.675	10/6/93	4528	4820	85.00	90.46	Bearing at hole 1 and 4
BH4-169	242f	SSSB	2	LLS	6	4	1.499	3.65	0.1068	0.2500	0.2505	0.2505	0.677	0.677	10/6/93	4528	4820	85.00	90.46	Bearing at hole 1 and 4
BH4-170	242f	SSSB	2	LLS	6	4	1.490	3.66	0.1055	0.2505	0.2505	0.2505	0.677	0.677	10/6/93	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	0.2505	0.674	0.682	10/6/93	4700	4945	88.95	93.80	Bearing at hole 1 and 4
BH4-172	242g	SSSB	2	LLS	8	2	2.001	3.50	0.1081	0.2506	0.2507	0.2507	0.678	0.676	10/6/93	4768	4968	89.84	93.89	Bearing at hole 1 and 4
BH4-173	242g	SSSB	2	LLS	8	2	2.000	3.50	0.1108	0.2510	0.2510	0.2510	0.678	0.678	10/6/93	4768	4968	89.84	93.89	Bearing at hole 1 and 4
BH4-174	242g	SSSB	2	LLS	8	2	2.001	3.50	0.1120	0.2510	0.2510	0.2510	0.678	0.678	10/6/93	4768	4968	89.84	93.89	Bearing at hole 1 and 4
BH4-175	242g	SSSB	2	LLS	8	2	2.001	3.50	0.1083	0.2510	0.2510	0.2510	0.678	0.678	10/6/93	4768	4968	89.84	93.89	Bearing at hole 1 and 4
BH4-176	242g	SSSB	2	LLS	8	2	2.002	3.51	0.1091	0.2510	0.2510	0.2510	0.677	0.677	10/6/93	4768	4968	89.84	93.89	Bearing at hole 1 and 4
BH4-177	242g	SSSB	2	LLS	8	2	1.999	3.51	0.1085	0.2510	0.2505	0.2505	0.674	0.675	10/6/93	4768	4968	89.84	93.89	Bearing at hole 1 and 4
BH4-178	242h	SSSB	2	LLS	8	3	2.001	3.50	0.1088	0.2511	0.2510	0.2510	0.678	0.678	10/6/93	4768	4968	89.84	93.89	Bearing at hole 1 and 4
BH4-179	242h	SSSB	2	LLS	8	3	2.001	3.50	0.1087	0.2515	0.2515	0.2515	0.678	0.678	10/6/93	4768	4968	89.84	93.89	Bearing at hole 1 and 4
BH4-180	242h	SSSB	2	LLS	8	3	2.000	3.50	0.1088	0.2505	0.2505	0.2505	0.620	0.618	10/6/93	4771	4871	87.76	89.60	Bearing at hole 1 and 4
BH4-181	242h	SSSB	2	LLS	8	3	2.000	3.50	0.1089	0.2510	0.2510	0.2510	0.630	0.631	10/6/93	4771	4871	87.76	89.60	Bearing at hole 1 and 4
BH4-182	242h	SSSB	2	LLS	8	3	2.000	3.50	0.1117	0.2500	0.2510	0.2510	0.624	0.627	10/6/93	4559	4890	81.66	87.40	Bearing at hole 1 and 4
BH4-183	242h	SSSB	2	LLS	8	3	2.001	3.51	0.1096	0.2510	0.2510	0.2510	0.626	0.624	10/6/93	4903	4904	90.57	89.60	Interlamellar shear out of 0 piles at holes 1 and 4
BH4-184	242i	SSSB	2	LLS	8	3	2.000	3.50	0.1105	0.2505	0.2505	0.2505	0.625	0.624	10/6/93	4903	4903	88.76	88.79	Interlamellar shear out of 0 piles at holes 1 and 4
BH4-185	242i	SSSB	2	LLS	8	4	2.000	3.63	0.1098	0.2508	0.2511	0.2511	0.624	0.624	10/6/93	4744	4895	84.44	88.99	Interlamellar shear out of 0 piles at holes 1 and 4
BH4-186	242i	SSSB	2	LLS	8	4	2.002	3.63	0.1057	0.2505	0.2510	0.2510	0.578	0.705	10/6/93	5281	5427	94.79	97.76	Bearing at hole 1 and 4
BH4-187	242i	SSSB	2	LLS	8	4	2.001	3.63	0.1102	0.2510	0.2505	0.2505	0.675	0.675	10/6/93	5281	5427	94.79	97.76	Bearing at hole 1 and 4
BH4-188	242i	SSSB	2	LLS	8	4	2.000	3.63	0.1092	0.2505	0.2505	0.2505	0.672	0.674	10/6/93	5281	5427	94.79	97.76	Bearing at hole 1 and 4
BH4-189	242i	SSSB	2	LLS	8	4	2.000	3.63	0.1089	0.2510	0.2510	0.2510	0.674	0.677	10/6/93	5281	5427	94.79	97.76	Bearing at hole 1 and 4
BH4-189	242i	SSSB	2	LLS	8	4	2.000	3.63	0.1085	0.2505	0.2505	0.2505	0.675	0.676	10/6/93	5281	5427	94.79	97.76	Bearing at hole 1 and 4
BH4-189	242i	SSSB	2	LLS	8	4	2.001	3.63	0.1092	0.2507	0.2507	0.2507	0.674	0.675	10/6/93	5183	5223	93.75	95.88	Bearing at hole 1 and 4
BH4-189	242i	SSSB	2	LLS	8	4	2.001	3.63	0.1092	0.2507	0.2507	0.2507	0.674	0.675	10/6/93	5183	5223	93.75	95.88	Bearing at hole 1 and 4

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, H/ick side, Hole 3: Second specimen, H/ick 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			Average Dimensions			Edge		Failure Load		Bearing Stress		Failure Mode			
					W/D	e/D	e/D	Thick ness	Hole Dia 1	Hole Dia 2	Hole Dia 3	Dist 1	Dist 2	Dist 3	Limit	UK		Limit	Ultimate	
BH4-262	343a	SSSB	3	LLL	6	3	1.500	3.50	0.1091	0.2505	0.2505	0.2505	0.623	0.623	0.623	4804	5261	60.80	96.47	Interlaminar shear out at hole 1. Bearing at hole 4
BH4-263	343a	SSSB	3	LLL	6	3	1.500	3.50	0.1068	0.2505	0.2505	0.2505	0.623	0.624	0.624	4904	5261	91.86	96.55	Interlaminar shear out at hole 1. Bearing at hole 4
BH4-264	343a	SSSB	3	LLL	6	3	1.500	3.50	0.1080	0.2510	0.2510	0.2510	0.624	0.626	0.626	N/A	5028	N/A	93.11	Bearing at holes 1 and 4
BH4-265	343a	SSSB	3	LLL	6	3	1.501	3.50	0.1083	0.2506	0.2510	0.2510	0.625	0.626	0.626	N/A	5028	N/A	92.85	Bearing at holes 1 and 4
BH4-266	343a	SSSB	3	LLL	6	3	1.501	3.50	0.1078	0.2500	0.2505	0.2505	0.626	0.626	0.626	N/A	5279	N/A	97.91	Bearing at holes 1 and 4
BH4-267	343a	SSSB	3	LLL	6	3	1.501	3.50	0.1077	0.2500	0.2505	0.2505	0.625	0.627	0.627	4804	5189	90.94	96.08	Bearing at holes 1 and 4
							1.500	3.50	0.1079	0.2504	0.2507	0.2507	0.624	0.626	0.626	0.00%	5189	90.94	96.16	
							0.04%	0.03%	0.70%	0.15%	0.10%	0.19%	0.19%	0.19%	0.19%	0.00%	2.41%	1.51%	2.05%	

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, thick side. Hole 3: Second specimen, thick side. Hole 4: Second specimen, fastener head side. (See diagram in report)

intec																
Project #: BH10004 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		Average Dimensions			Test Date	Failure Load		Bearing Stress Ultimate (ksi)	Failure Mode		
					W/D	e/O	Length (in)	Width (in)	Thick ness (in)		Hole Dia (in)	Ult (lbs)			Limit (lbs)	
BH4-70	145a	USSB	1	SLL	6	2	1.500	7.25	0.1117	0.2510	10/13/93	2156	2251	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	2177	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
BH4-76	145b	USSB	1	SLL	6	3	1.481	7.25	0.1107	0.2508		2112	2176	76.30	78.58	
BH4-77	145b	USSB	1	SLL	6	3	2.78%	0.04%	1.20%	0.10%		1.71%	3.17%	1.51%	2.66%	
BH4-78	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
BH4-79	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
BH4-80	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
BH4-81	145b	USSB	1	SLL	6	3	1.501	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
BH4-82	145c	USSB	1	SLL	6	4	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
BH4-83	145c	USSB	1	SLL	6	4	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
BH4-84	145c	USSB	1	SLL	6	4	1.501	7.25	0.1045	0.2505		2382	2514	91.21	96.24	
BH4-85	145c	USSB	1	SLL	6	4	0.04%	0.03%	0.95%	0.23%		6.43%	5.62%	7.06%	6.11%	
BH4-86	145c	USSB	1	SLL	6	4	1.501	7.25	0.1067	0.2510	10/13/93	2557	2578	95.66	96.64	Bearing on bolt side. Aud at 1700 lbs
BH4-87	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
BH4-88	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
BH4-89	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
BH4-90	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
BH4-91	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
BH4-92	246a	USSB	2	LLS	6	2	1.501	7.25	0.1054	0.2510		2383	2482	90.45	94.20	
BH4-93	246a	USSB	2	LLS	6	2	0.04%	0.03%	0.96%	0.00%		5.84%	3.71%	5.25%	2.86%	
BH4-94	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
BH4-95	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
BH4-96	246a	USSB	2	LLS	6	2	1.499	7.24	0.1096	0.2520	10/13/93	1838	1870	66.37	67.51	Shear out at bolt side. Aud at 1100 lbs
BH4-97	246a	USSB	2	LLS	6	2	1.500	7.24	0.1131	0.2520	10/13/93	1838	1870	67.11	68.26	Shear out at bolt side. Aud at 1100 lbs
BH4-98	246a	USSB	2	LLS	6	2	1.499	7.24	0.1120	0.2520	10/13/93	1717	1742	60.72	61.60	Shear out at bolt side. Aud at 1150 lbs
BH4-99	246a	USSB	2	LLS	6	2	1.499	7.24	0.1106	0.2519		1778	1803	61.32	62.21	Shear out at bolt side. Aud at 1150 lbs
BH4-100	246b	USSB	2	LLS	6	3	0.03%	0.03%	1.62%	0.08%		3.94%	3.79%	5.20%	4.25%	
BH4-101	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
BH4-102	246b	USSB	2	LLS	6	3	1.500	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
BH4-103	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
BH4-104	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
BH4-105	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
BH4-106	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
BH4-107	246c	USSB	2	LLS	6	4	1.500	7.25	0.1037	0.2519		2110	2255	81.38	87.01	
BH4-108	246c	USSB	2	LLS	6	4	0.03%	0.02%	1.30%	0.15%		5.41%	3.12%	4.21%	2.30%	
BH4-109	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
BH4-110	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
BH4-111	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
BH4-112	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
BH4-113	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
BH4-114	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
BH4-115	246c	USSB	2	LLS	6	4	1.499	7.25	0.1052	0.2519		2274	2363	86.20	89.85	
BH4-116	246c	USSB	2	LLS	6	4	0.04%	0.08%	1.91%	0.09%		3.35%	5.93%	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.

<i>intec</i> 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		Average Dimensions			Test Date		Failure Load		Bearing Stress		Failure Mode	
					W/D	e/D	Length (m)	Thickness (m)	Hole Dia (m)	Limit (lbf)	Ult (lbf)	Limit (ksi)	Ultimate (ksi)				
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	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	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%	1.270%	0.64%	1.312%		

Notes: Limit load calculated from an offset of 2% hole diameter (0.005 m) 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																	
Specimen ID	Test Cell ID	Test Type	Mat. Class	Mat. Desc.	Nominal Dims		Average Dimensions				Test		Failure Load		Bearing Stress		Failure Mode
					W/D	e/D	Length (in)	Thickness (in)	Hole Dia (in)	Edge Dist (in)	Date	Limit (lbs)	Ult (lbs)	Limit (ksi)	Ultimate (ksi)		
BH4-088	149a	DSB	1	SLL	4	2	0.999	7.25	0.1034	0.2530	0.379	10/13/93	3233	3350	129.53	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
BH4-091							0.999	7.254	0.104	0.253	0.379		3103	3212	119.76	123.97	
BH4-091							0.03%	0.02%	0.17%	0.23%	0.40%		3.76%	4.25%	3.93%	4.39%	
BH4-092	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
BH4-093	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
BH4-094	149c	DSB	1	SLL	4	4	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
BH4-094	149c	DSB	1	SLL	4	4	0.999	7.243	0.108	0.253	0.628		3243	3741	120.17	138.56	
BH4-094	149c	DSB	1	SLL	4	4	0.04%	0.04%	0.45%	0.11%	0.41%		3.32%	5.59%	1.90%	3.47%	
BH4-095	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
BH4-096	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
BH4-097	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
BH4-100	149e	DSB	1	SLL	6	3	1.501	7.252	0.111	0.251	0.371		2924	3055	105.74	110.49	
BH4-101	149e	DSB	1	SLL	6	3	0.03%	0.04%	0.57%	0.00%	0.49%		3.47%	3.92%	2.93%	3.44%	
BH4-102	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
BH4-103	149f	DSB	1	SLL	6	4	1.500	7.25	0.1064	0.2515	0.621	10/14/93	3413	3755	128.37	141.23	Shear out. Aud at 3080 lbs
BH4-104	149f	DSB	1	SLL	6	4	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
BH4-105	149f	DSB	1	SLL	6	4	1.500	7.255	0.107	0.251	0.622		3364	3741	126.00	140.13	
BH4-106	149g	DSB	1	SLL	6	4	0.03%	0.03%	3.03%	0.11%	0.19%		2.83%	2.59%	1.69%	0.80%	
BH4-107	149g	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
BH4-108	149g	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
BH4-109	149g	DSB	1	SLL	6	4	1.499	7.250	0.1026	0.2515	0.873	10/14/93	3213	4154	125.30	162.00	Shear out. Aud at 3220 lbs
BH4-110	149h	DSB	1	SLL	8	2	1.999	7.25	0.1023	0.2520	0.372		3383	4073	131.69	158.55	
BH4-111	149h	DSB	1	SLL	8	2	0.04%	0.02%	0.35%	0.11%	0.43%		8.22%	4.05%	8.41%	4.40%	
BH4-110	149h	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
BH4-111	149h	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
BH4-111	149h	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
BH4-110	149h	DSB	1	SLL	8	2	2.000	7.251	0.104	0.252	0.375		2902	3020	111.38	115.94	
BH4-110	149h	DSB	1	SLL	8	2	0.02%	0.03%	2.46%	0.23%	0.98%		2.23%	1.18%	3.62%	3.39%	
BH4-110	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
BH4-111	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
BH4-111	149h	DSB	1	SLL	8	3	2.000	7.248	0.104	0.253	0.628		3241	3697	125.13	142.78	
BH4-111	149h	DSB	1	SLL	8	3	0.02%	0.05%	1.51%	0.20%	0.76%		1.82%	1.44%	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 Temperature: RT																	
Specimen ID	Test Cell ID	Test Type	Mat. Class	Mat. Desc.	Nominal Dims W/D	e/D	Average Dimensions			Edge Dist (in)	Test Date	Failure Load		Bearing Stress		Failure Mode	
							Length (in)	Thickness (in)	Hole Dia (in)			Limit (lbs)	Ult (lbs)	Limit (ksi)	Ultimate (ksi)		
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%	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	134.98	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%		8.83%	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%	0.15%	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%		5.76%	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

Flange Bend Results

Specimen D	Test Cell ID	Test Type	Mat. Class	Panel D	Nominal Dimensions		Average Dimensions			Test Date	Ultimate Load (lbs)	Out-of-Plane Tension Stress (ksi)	Failure Mode		
					Width (in)	Flange Length (in)	Thickness (in)	Width (in)	Length (in)					Thickness (in)	Edge Distance (in)
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 multi 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 multi 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 multi 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 multi 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 multi 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 multi 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 multi 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 multi 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 multi 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 multi 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 multi 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 multi ply interfaces in radius
								2.029	3.436	0.2525	0.418		80.4	3.55	
								0.55%	0.31%	0.19%	0.51%		5.9%	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	2.16	
								0.59%	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%	0.63%	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: $3 \cdot U \cdot \text{moment} / 2 \cdot \text{Mid-ply radius} \cdot \text{actual thickness} \cdot \text{actual width}$ (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 (lbs)	Out-of-Plane Tension Stress (ksi)	Failure Mode
					Width (in)	Flange Length (in)	Width (in)	Length (in)	Thickness (in)				
BH4-525	961	FB2-2	9	LS-1	2.00	3.5	2.031	3.045	0.2513	0.418	73.5	3.08	Inplane tension at inner radius.
BH4-526	961	FB2-2	9	LS-1	2.00	3.5	2.040	3.019	0.2505	0.423	66.7	2.78	Inplane tension at inner radius.
BH4-527	961	FB2-2	9	LS-1	2.00	3.5	2.027	3.028	0.2496	0.425	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	2.028	2.957	0.2484	0.426	50.7	2.13	Inplane tension at inner radius.
BH4-529	1062	FB2-2	10	LS-2	2.00	3.5	2.026	2.970	0.2483	0.427	50.5	2.13	Inplane tension at inner radius.
BH4-530	1062	FB2-2	10	LS-2	2.00	3.5	2.013	2.941	0.2481	0.427	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: $3 \cdot U_{T} \text{ moment} / 2 \text{Mid-ply radius} / \text{actual thickness} / \text{actual width}$ (see report for calculation of moment arm)

Intec 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			Thick-ness (in)	Moment Arm (in)	Test Date	Ultimate Load (lbs)	Ultimate Moment (in-lbs)	Out-of-Plane Tension Stress (ksi)	Failure Mode
						Width (in)	Depth (in)	Length (in)							
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	68.17	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	0.1283	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	0.1288	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: $3 \times \text{Ult moment} / (2 \times \text{Midply radius} \times \text{actual thickness} \times \text{actual width})$
 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 D	Nominal Midply Radius (in)	Average Dimensions			Thick-ness (in)	Moment Arm (in)	Test Date	Ultimate Load (lbs)	Ultimate Moment (in-lbs)	Out-of-Plane Tension Stress (ksi)	Failure Mode
						Width (in)	Depth (in)	Length (in)							
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
	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
	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%	0.70%	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
	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
	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
	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
	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
	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
	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%	0.21%			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
	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
	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%	0.78%			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
	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
	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%	0.70%	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
	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
	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
	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
	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%	0.21%			8.57%	8.57%	8.45%	

Notes: Out-of-plane Tension Stress calculated from 3/16th 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				Overlap (in)	Test Date	Failure Load Ultimate (lbs)	Shear Stress (ksi)	Failure Mode			
						Length (in)	Thickness (in)	Notch 1 Depth (in)	Notch 2 Depth (in)								
BH4-001	109	CILS	1	SLL	T7-SLL-C-4A	0.501	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	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	0.2272	0.1240	0.1245	0.501	10/20/93	1141	4.56	Interlaminar shear			
					Average:	0.500	0.2302	0.1253	0.1257	0.501		1301	5.20				
					COV	0.18%	1.88%	1.51%	1.61%	0.001		12.30%	12.18%				
BH4-121	210	CILS	2	LLS	T7-LLS-C-3B	0.502	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	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	0.2138	0.1175	0.1175	0.505	10/20/93	2002	7.93	Interlaminar shear			
					Average:	0.501	0.2138	0.1175	0.1175	0.504		1828	7.24				
					COV	0.16%	0.00%	0.43%	0.25%	0.002		10.14%	10.21%				
BH4-241	311	CILS	3	LLL	T7-LLL-C-4A	0.500	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	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	0.2302	0.1255	0.1260	0.501	10/20/93	1598	6.40	Interlaminar shear			
					Average:	0.500	0.2295	0.1252	0.1257	0.500		1505	6.03				
					COV	0.10%	0.38%	0.46%	0.46%	0.002		5.33%	5.29%				
BH4-307	412	CILS	4	LSS	T7-LSS-C-6A	0.501	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	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	0.2240	0.1225	0.1225	0.501	10/20/93	1559	6.22	Interlaminar shear			
					Average:	0.501	0.2271	0.1240	0.1242	0.501		1719	6.86				
					COV	0.30%	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	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	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	0.2215	0.1215	0.1210	0.501	10/20/93	1473	5.88	Interlaminar shear			
					Average:	0.501	0.2215	0.1212	0.1210	0.501		1334	5.32				
					COV	0.12%	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	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	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	0.2282	0.1245	0.1250	0.503	10/20/93	1488	5.91	Interlaminar shear			
					Average:	0.501	0.2302	0.1255	0.1260	0.503		1575	6.25				
					COV	0.09%	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	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	0.2310	0.1265	0.1265	0.503	10/20/93	1333	5.31	Interlaminar shear			
BH4-387	715	CILS	7	OS-1	T7-OS1-A-3A	0.499	0.2307	0.1260	0.1265	0.503	10/20/93	1102	4.39	Interlaminar shear			
					Average:	0.500	0.2309	0.1262	0.1265	0.501		1138	4.54				
					COV	0.20%	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 gauges 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				Notch 1 Depth (in)	Notch 2 Depth (in)	Overlap (in)	Test Date	Failure Load Ultimate (lbs)	Shear Stress (ksi)	Failure Mode
						Length (in)	Thickness (in)	Width (in)	Depth (in)							
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 inter-laminar 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	0.1369	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	6.89		
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.

Inftec															
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			Average Dimensions			Test Date	Ult. Load (lbs)	Shear Stress (ksi)	Failure Mode
						Width (in)	Thickness (in)	Length (in)	Width (in)	Thickness (in)	Length (in)				
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.

Inftec															
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			Average Dimensions			Test Date	Ult Load (lbs)	Shear Stress (ksi)	Failure Mode
						Width (in)	Thick (in)	Length (in)	Width (in)	Thick (in)	Length (in)				
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			COV			
				Width (in)	Thick (in)	Length (in)		1	2	3	1	2	3		Avg.		
BH4-409	DCB	A	572-011L	0.5008	0.2529	13.0	11/2/93	6.84	4.87	6.23	5.98	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	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	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	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	5.86	10.08	13.52	9.82	39.0%	
				Average:	0.4999	0.2542					7.03				7.89	40.5%	
				COV	0.25%	0.00%											33.2%
BH4-431	DCB	B	572-008U	0.5023	0.2525	13.0	11/2/93	See Note 2			4.44	6.24	4.53	4.31	5.02	21.0%	
BH4-432	DCB	B	572-008U	0.5002	0.2523	13.0	11/2/93	5.21	3.93	4.20	4.44	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	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	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	4.82	3.57	3.66	4.02	17.3%	
				Average:	0.5007	0.2530					4.72				4.72	20.8%	
				COV	0.19%	0.00%											38.1%
BH4-453	DCB	C	572-004L	0.5000	0.2503	13.0	11/3/93	4.56	5.57	4.17	4.77	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	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	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	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	4.68	4.28	4.49	4.49	4.5%	
				Average:	0.4988	0.2502					4.49				5.19	20.8%	
				COV	0.16%	1.17%											17.7%
BH4-475	DCB	D	572-008	0.4990	0.2557	13.0	11/4/93	5.57	6.55	5.47	5.86	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	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	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	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	6.70	7.51	8.61	7.61	12.6%	
				Average:	0.4989	0.2572					7.43				7.18	13.2%	
				COV	0.15%	0.00%											33.7%

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.

Intec												
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			Test Date	GIIC			COV	
				Width (in)	Thick (in)	Length (in)		1	2	3		Avg.
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 B-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.

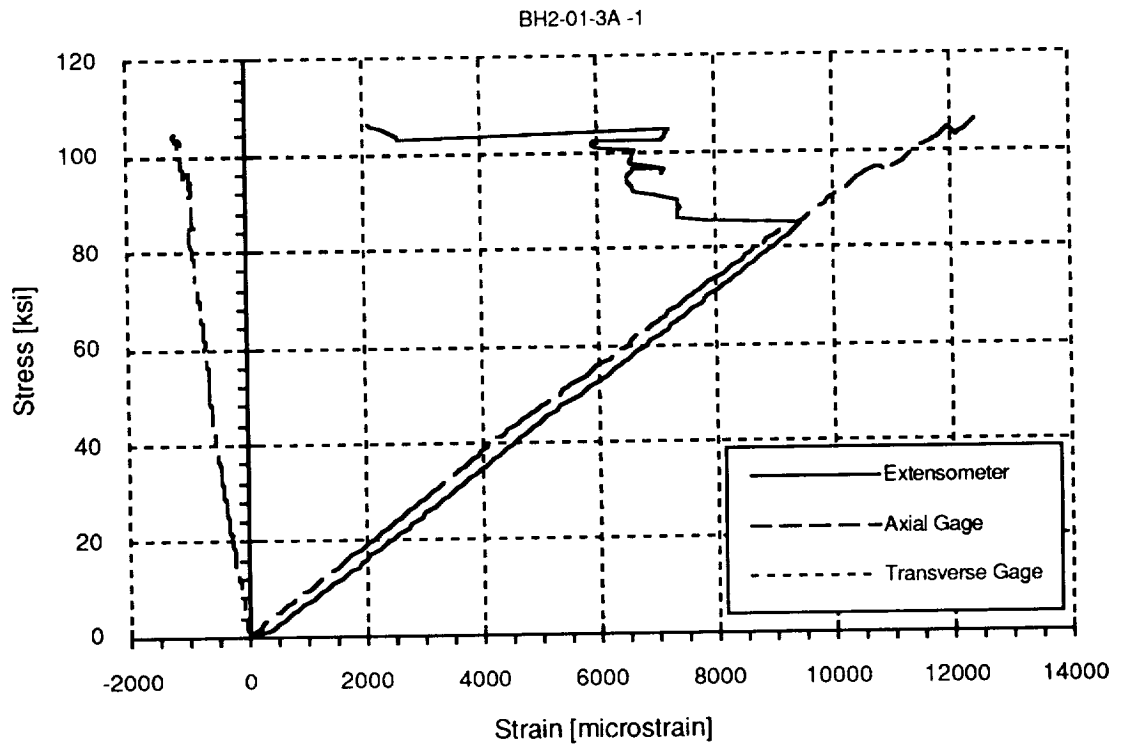


Figure B.1 Typical 0° Tension Test Strain Data for 2-D Braided Material SLL.

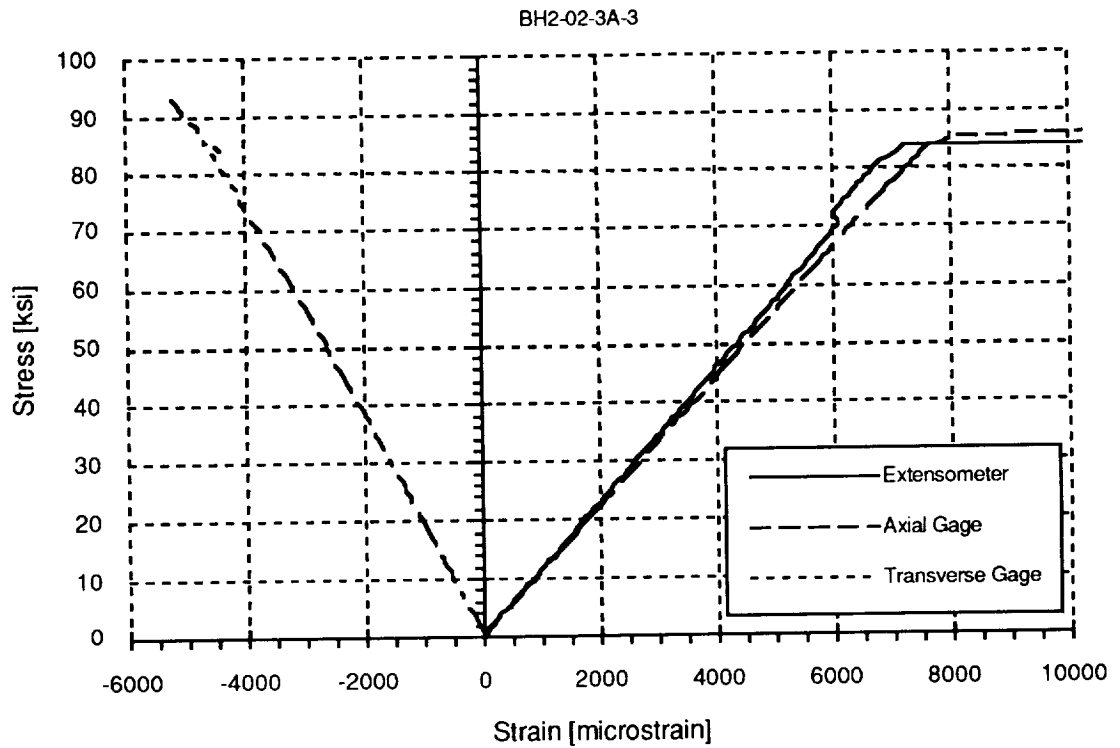


Figure B.2 Typical 0° Tension Test Strain Data for 2-D Braided Material LLL.

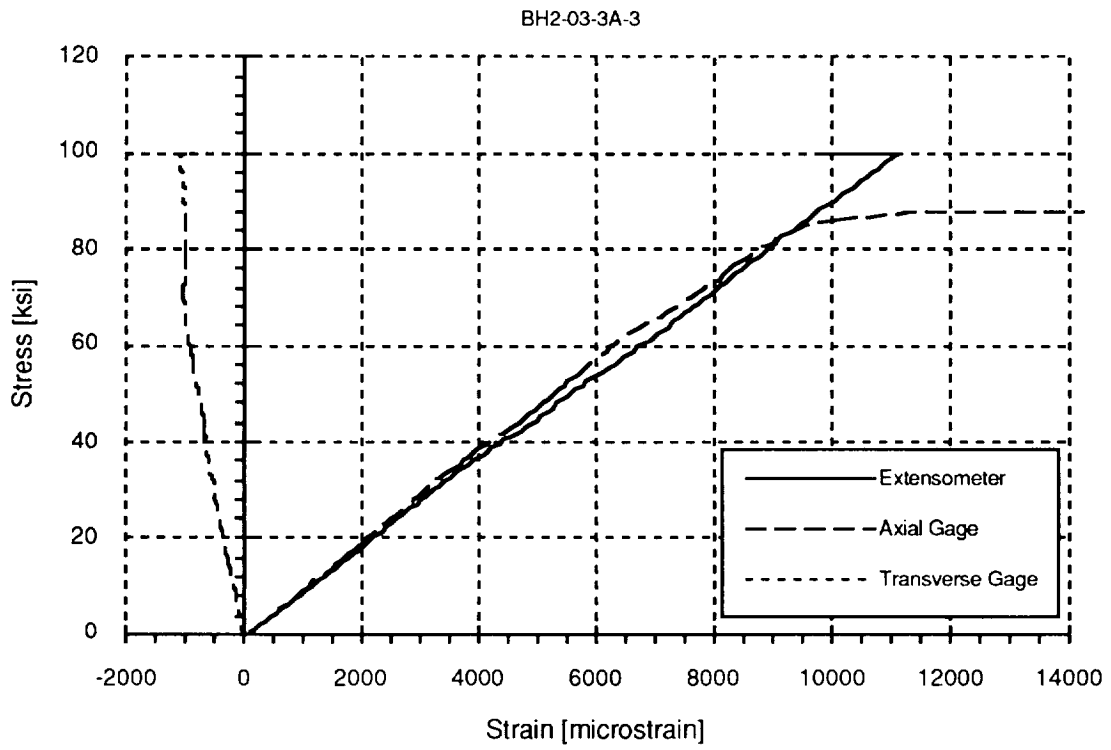


Figure B.3 Typical 0° Tension Test Strain Data for 2-D Braided Material LLS.

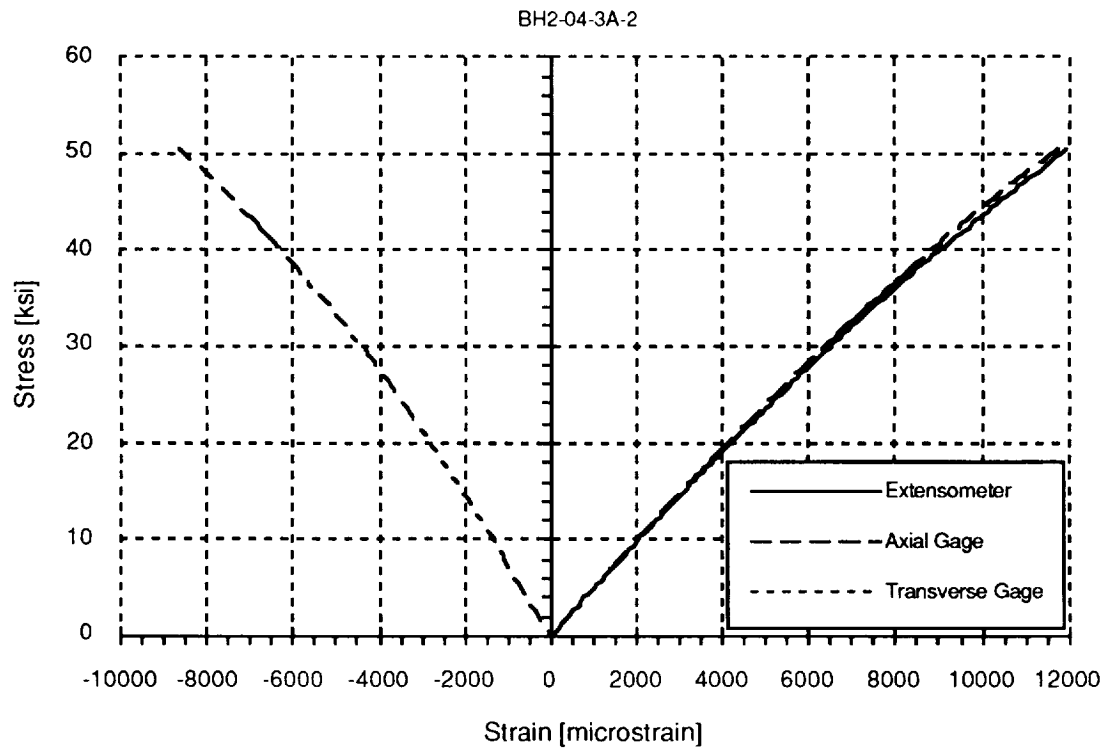


Figure B.4 Typical 0° Tension Test Strain Data for 2-D Braided Material LSS.

C-3.

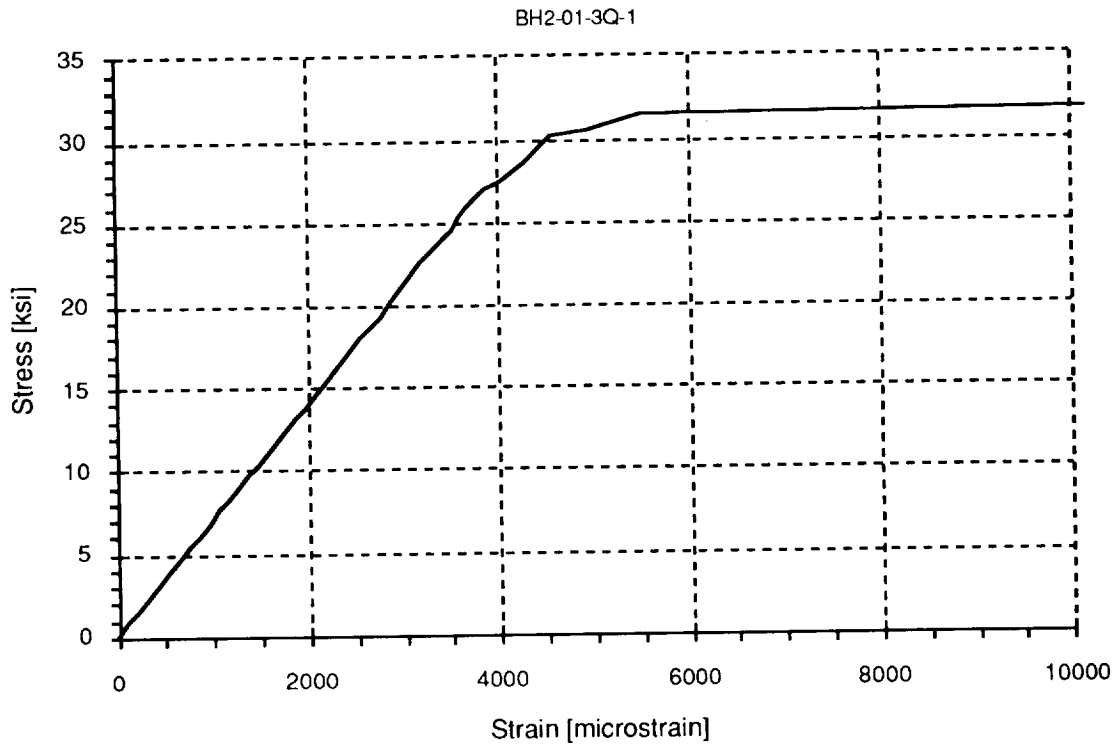


Figure B.5 Typical 90° Tension Test Strain Data for 2-D Braided Material SLL.

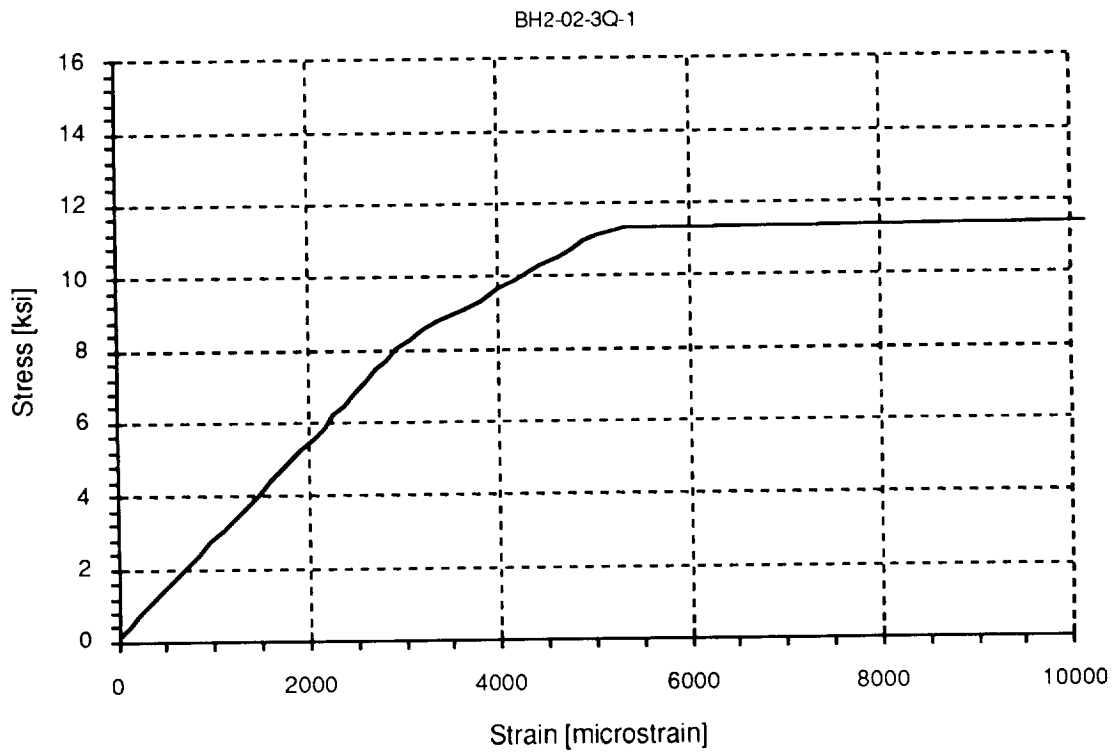


Figure B.6 Typical 90° Tension Test Strain Data for 2-D Braided Material LLL.

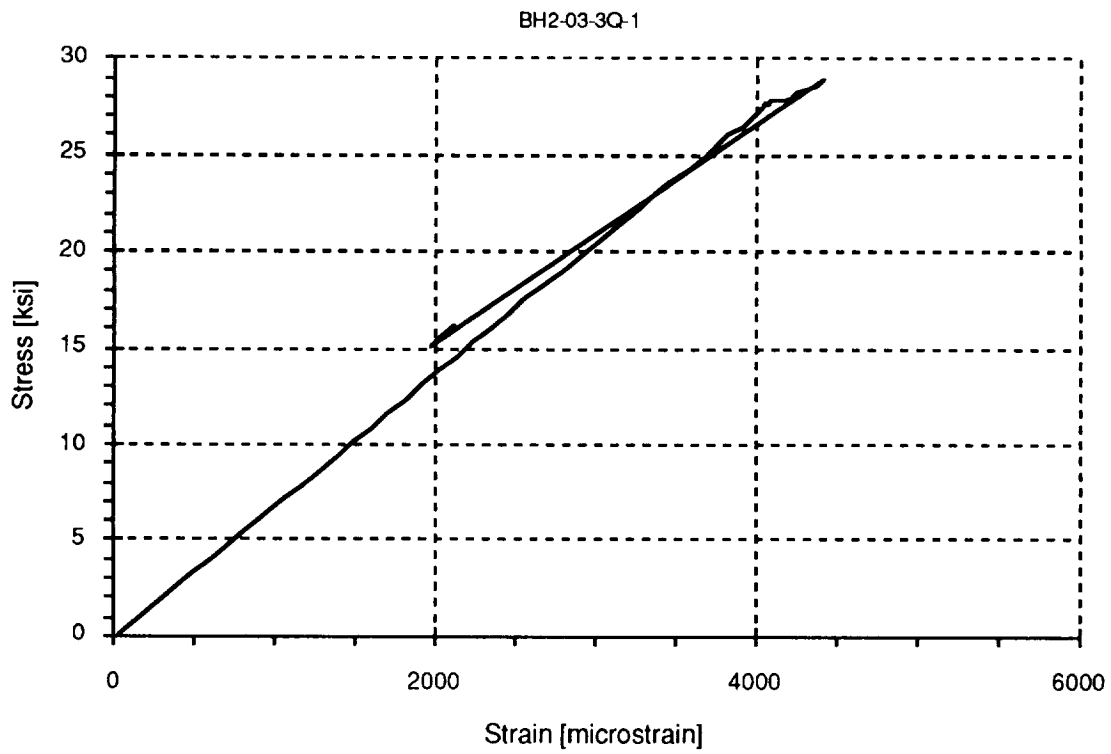


Figure B.7 Typical 90° Tension Test Strain Data for 2-D Braided Material LLS.

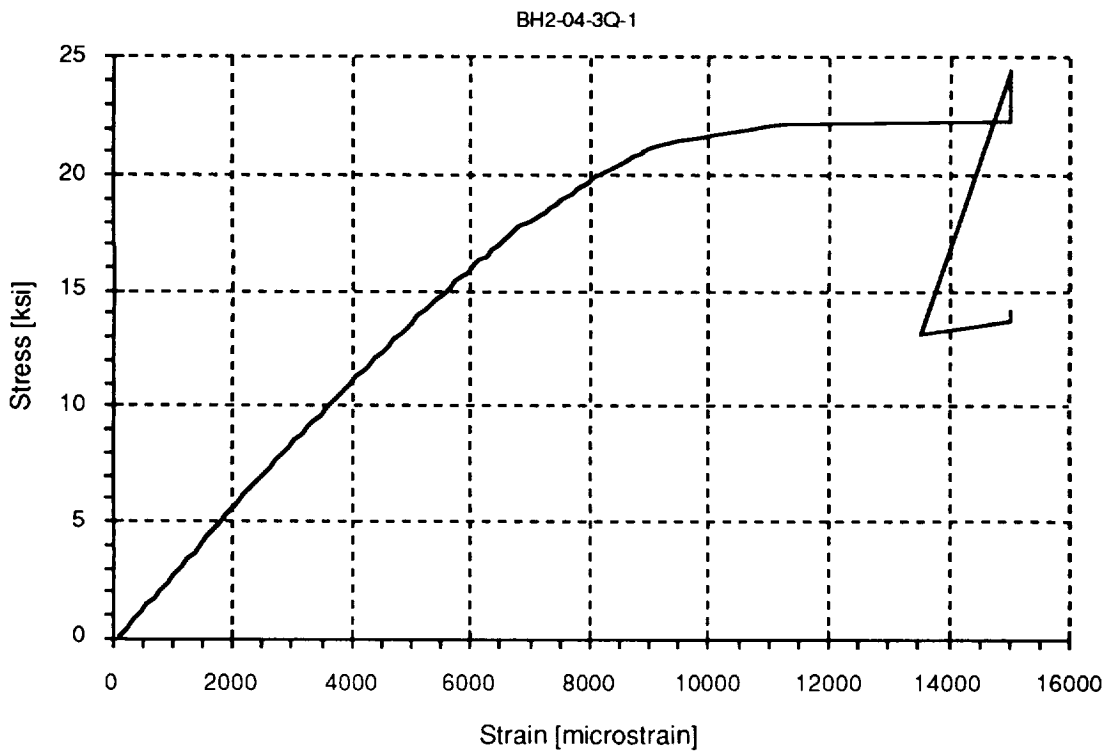


Figure B.8 Typical 90° Tension Test Strain Data for 2-D Braided Material LSS.

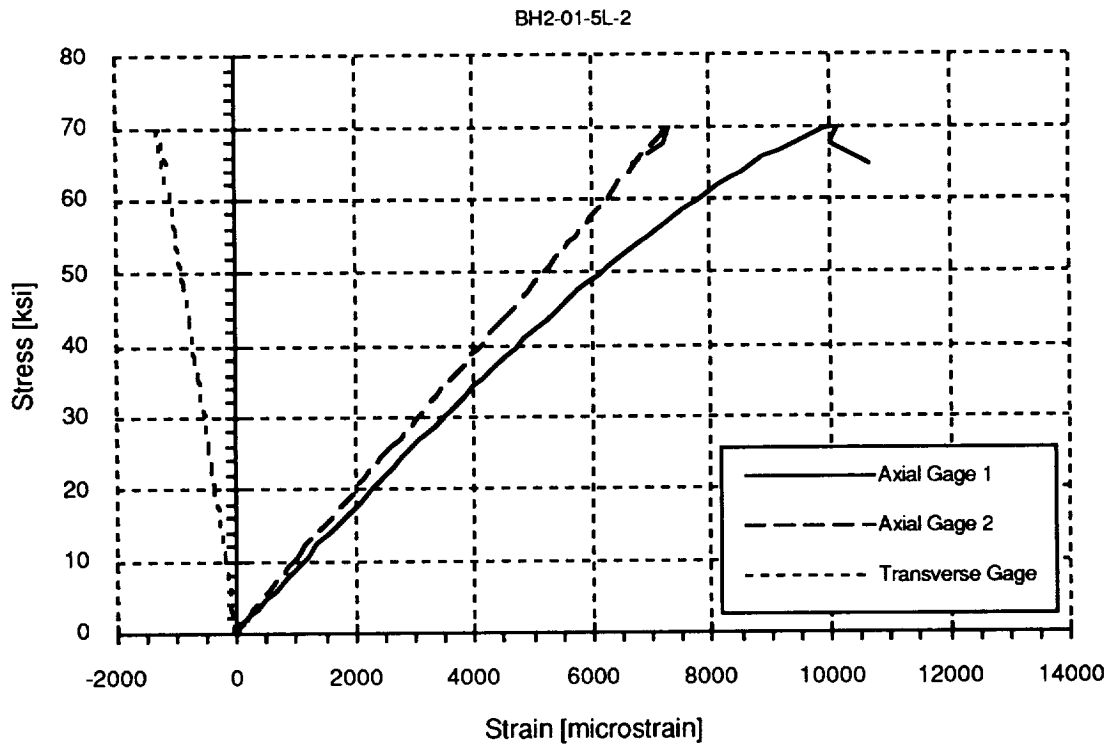


Figure B.9.a Typical IITRI Compression Test Strain Data for 2-D Braided Material SLL, (1/8" Thick, 1." Long).

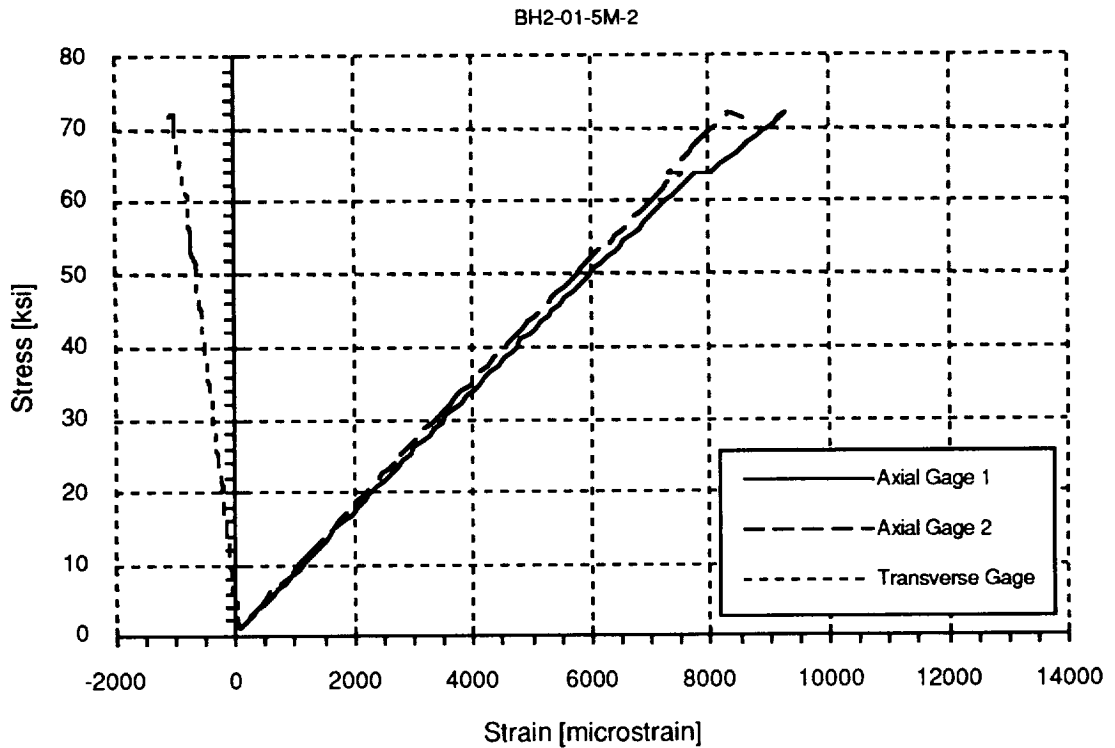


Figure B.9.b Typical IITRI Compression Test Strain Data for 2-D Braided Material SLL, (1/4" Thick, 1.5" Long).

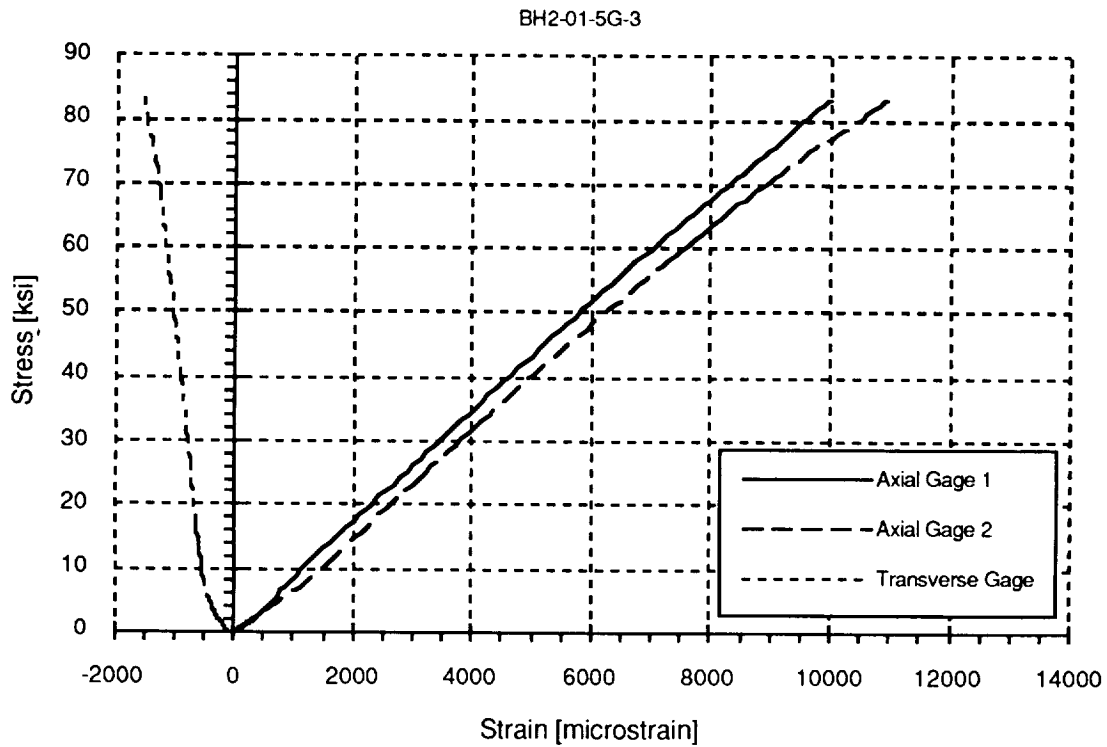


Figure B.9.c Typical Short Block Compression Test Strain Data for 2-D Braided Material SLL, (1/4" Thick, 1.5" Long).

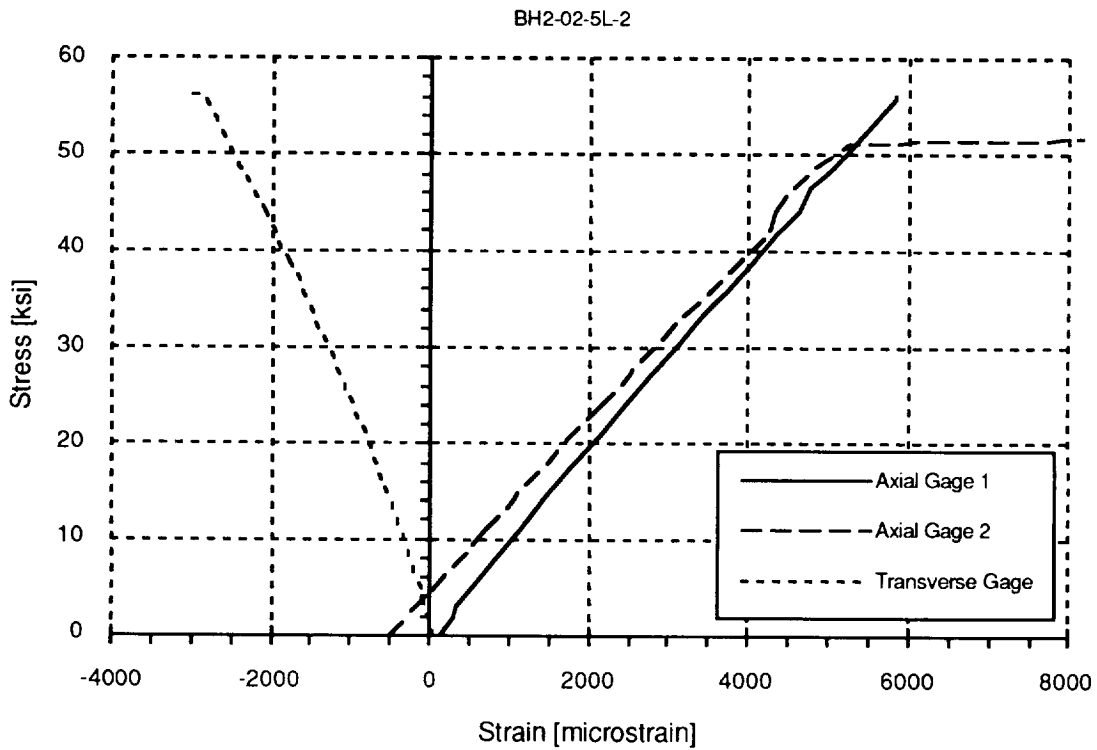


Figure B.10.a Typical IITRI Compression Test Strain Data for 2-D Braided Material LLS, (1/8" Thick, 1." Long).

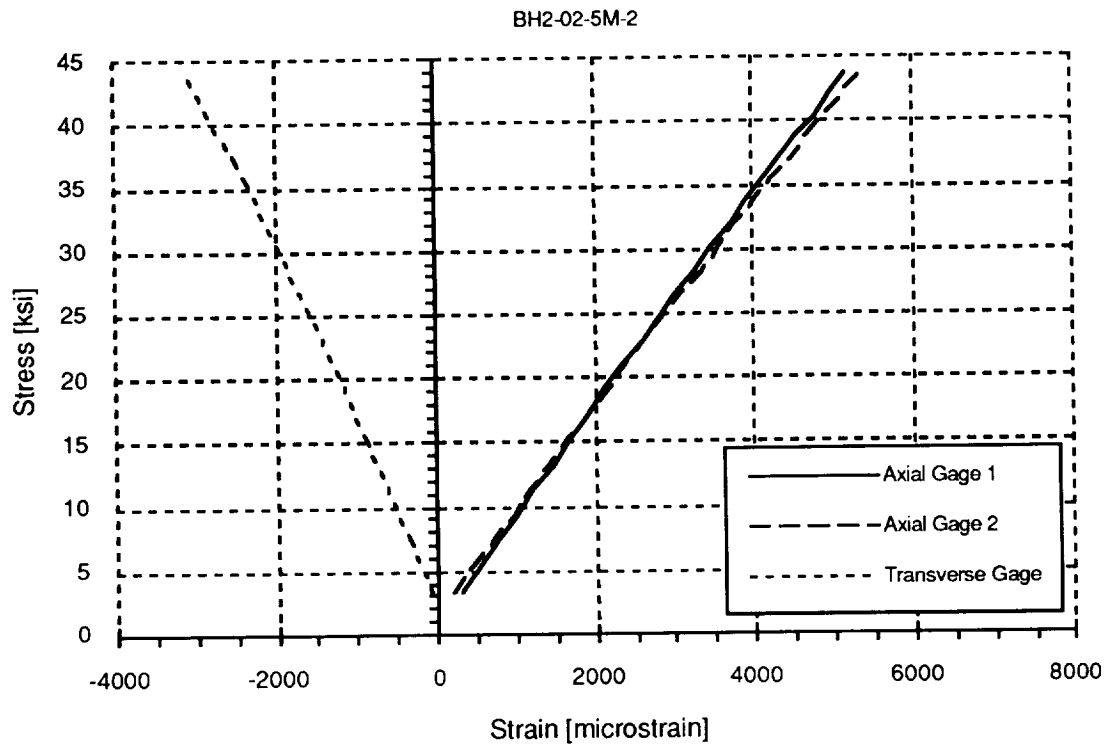


Figure B.10.b Typical IITRI Compression Test Strain Data for 2-D Braided Material LLS, (1/4" Thick, 1.5" Long).

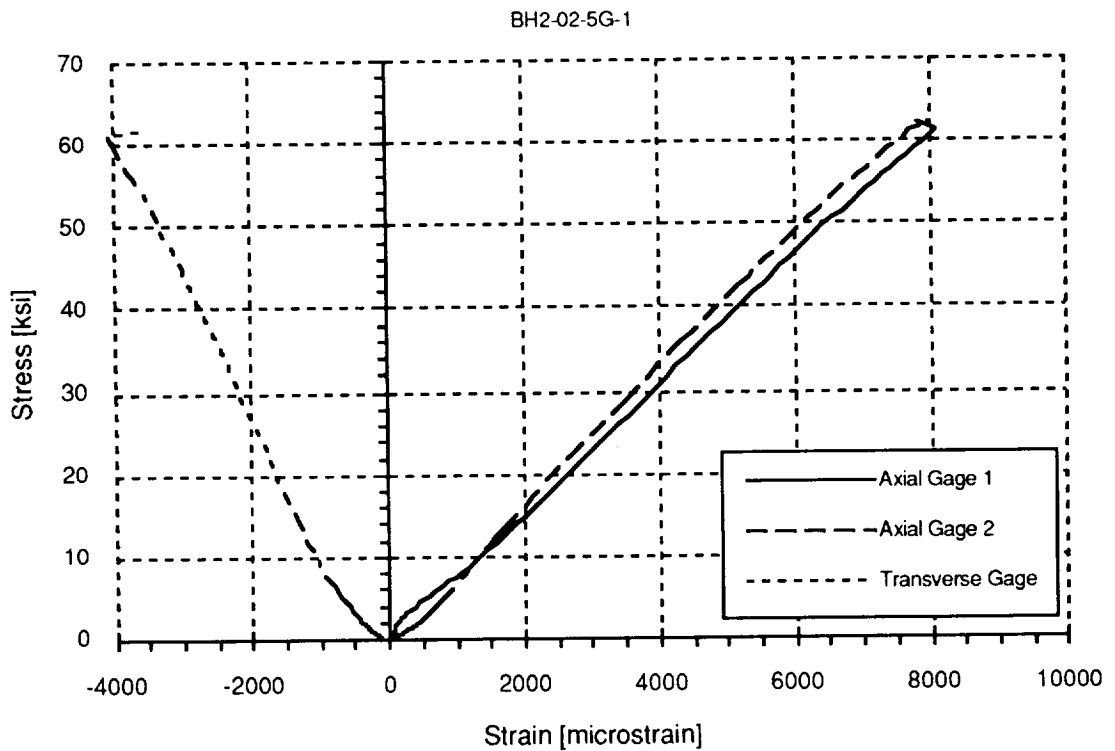


Figure B.10.c Typical Short Block Compression Test Strain Data for 2-D Braided Material LLS, (1/4" Thick, 1.5" Long).

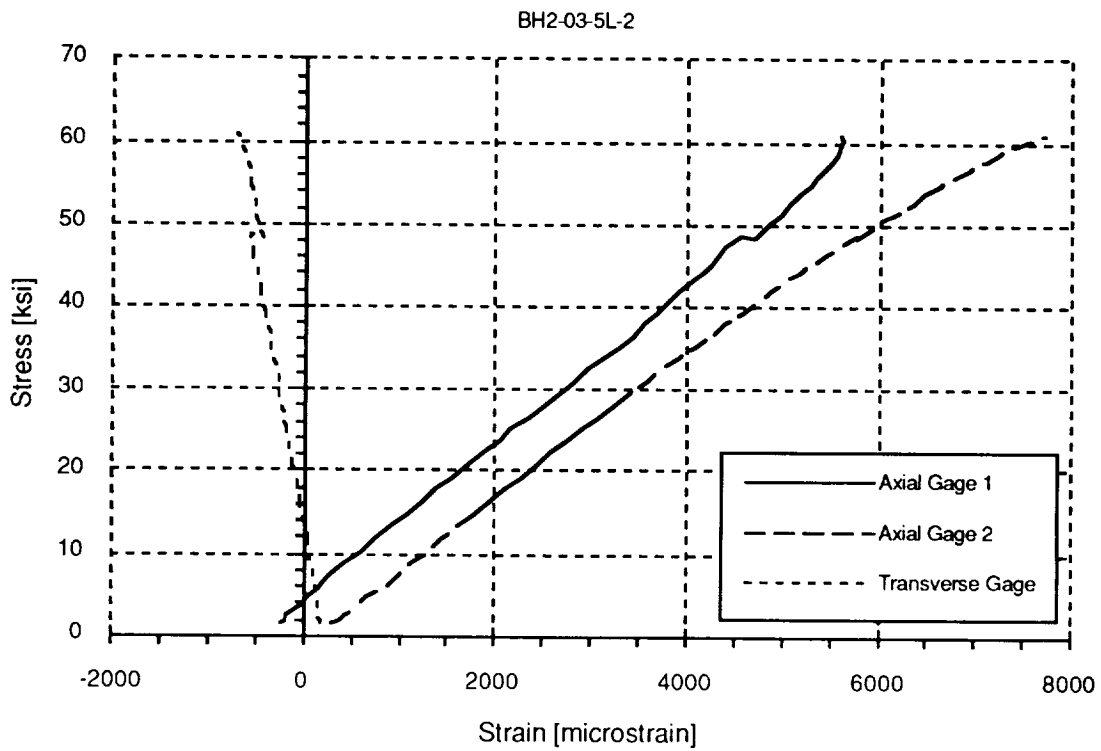


Figure B.11.a Typical IITRI Compression Test Strain Data for 2-D Braided Material LLL, (1/8" Thick, 1." Long).

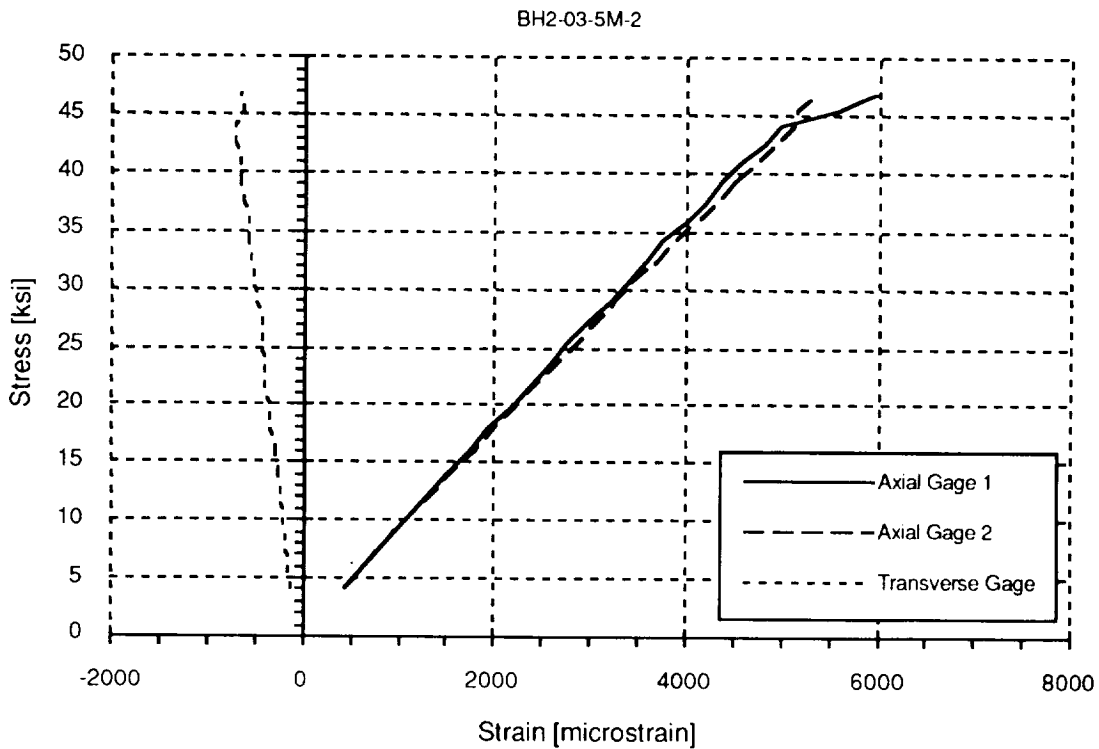


Figure B.11.b Typical IITRI Compression Test Strain Data for 2-D Braided Material LLL, (1/4" Thick, 1.5" Long).

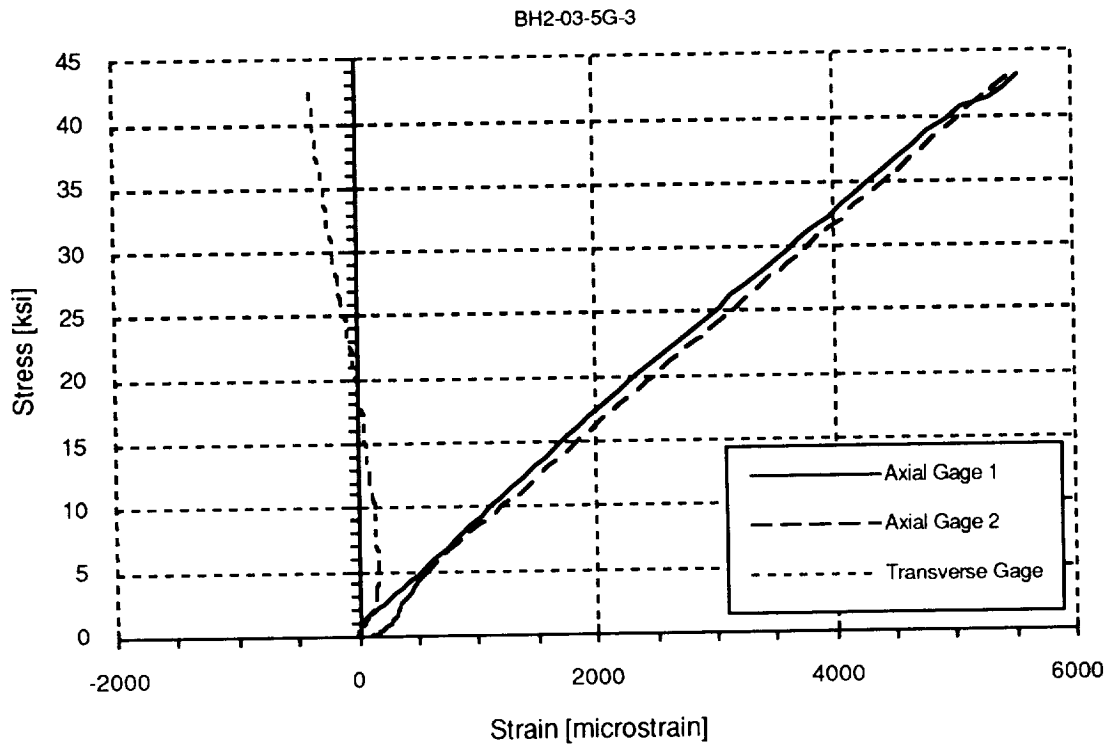


Figure B.11.c Typical Short Block Compression Test Strain Data for 2-D Braided Material LLL, (1/4" Thick, 1.5" Long).

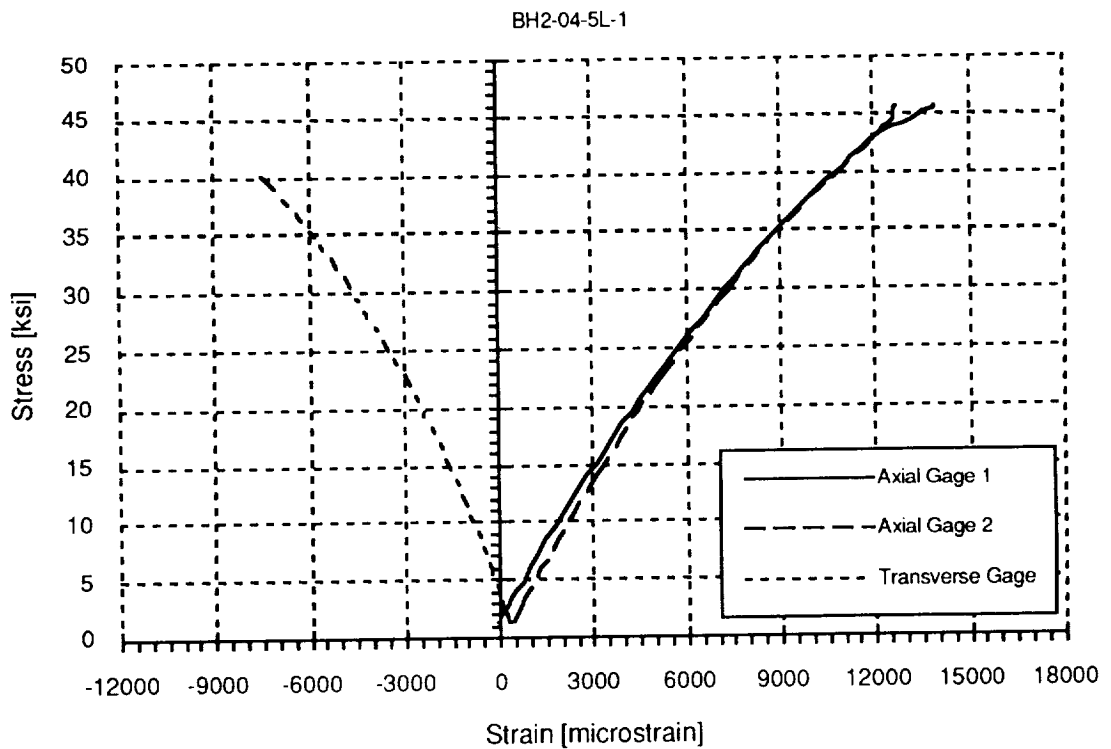


Figure B.12.a Typical IITRI Compression Test Strain Data for 2-D Braided Material LSS, (1/8" Thick, 1." Long).

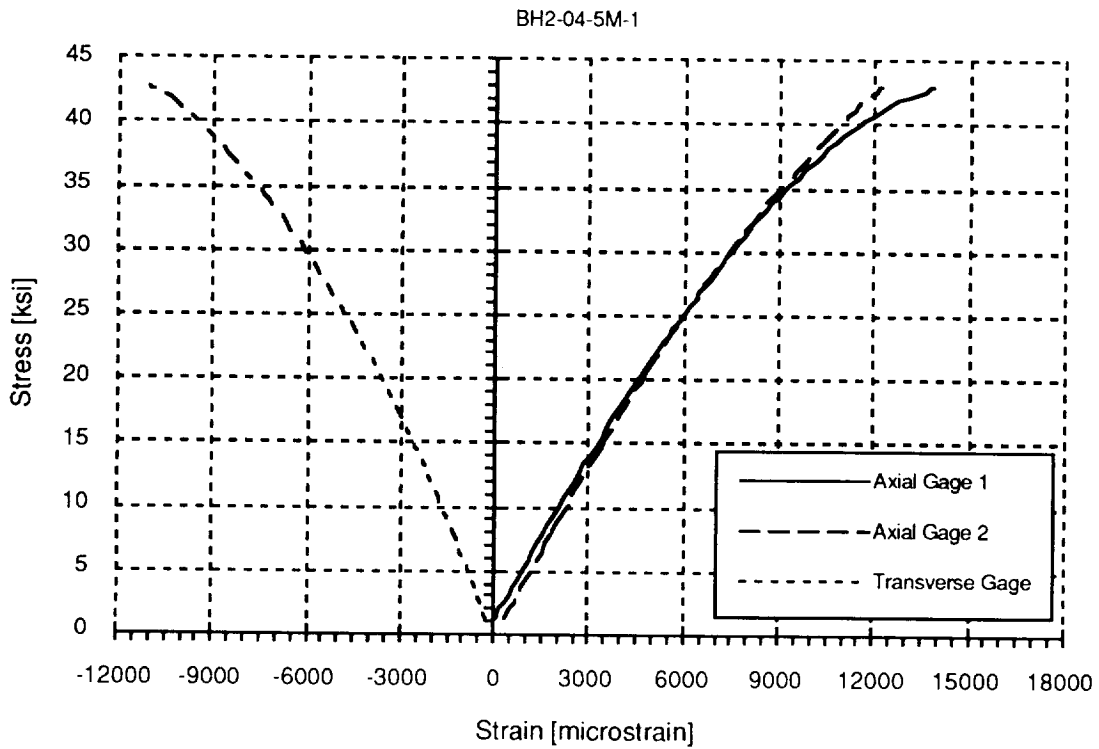


Figure B.12.b Typical IITRI Compression Test Strain Data for 2-D Braided Material LSS, (1/4" Thick, 1.5" Long).

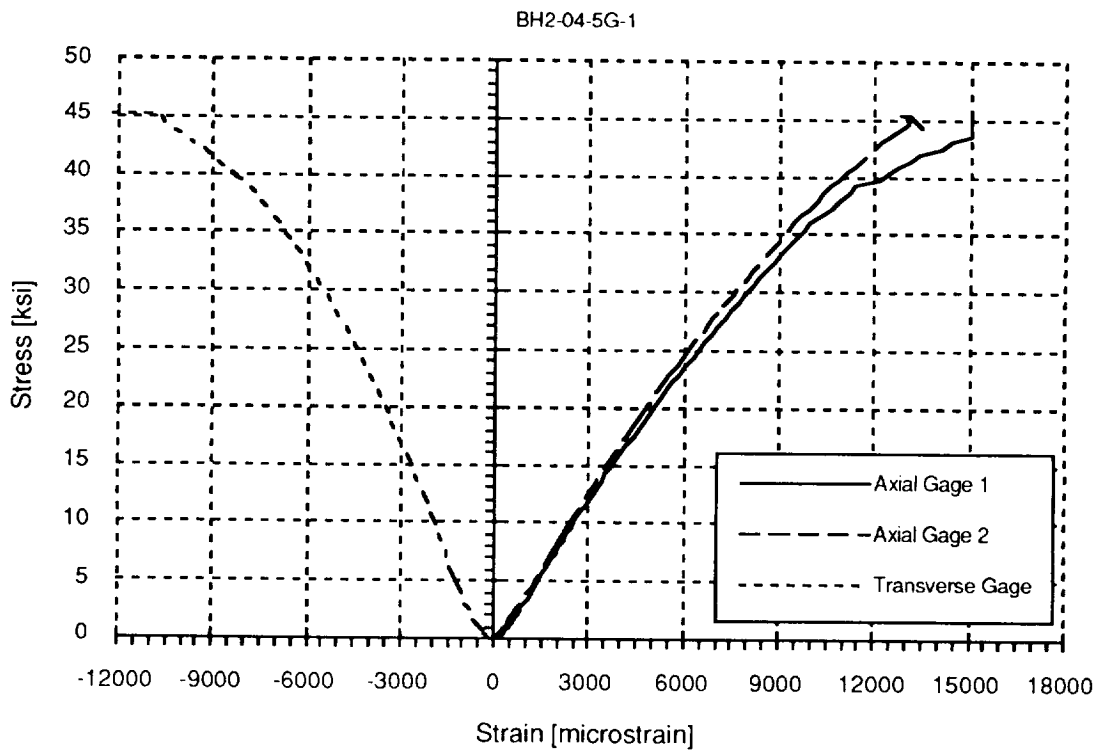


Figure B.12.c Typical Short Block Compression Test Strain Data for 2-D Braided Material LSS, (1/4" Thick, 1.5" Long).

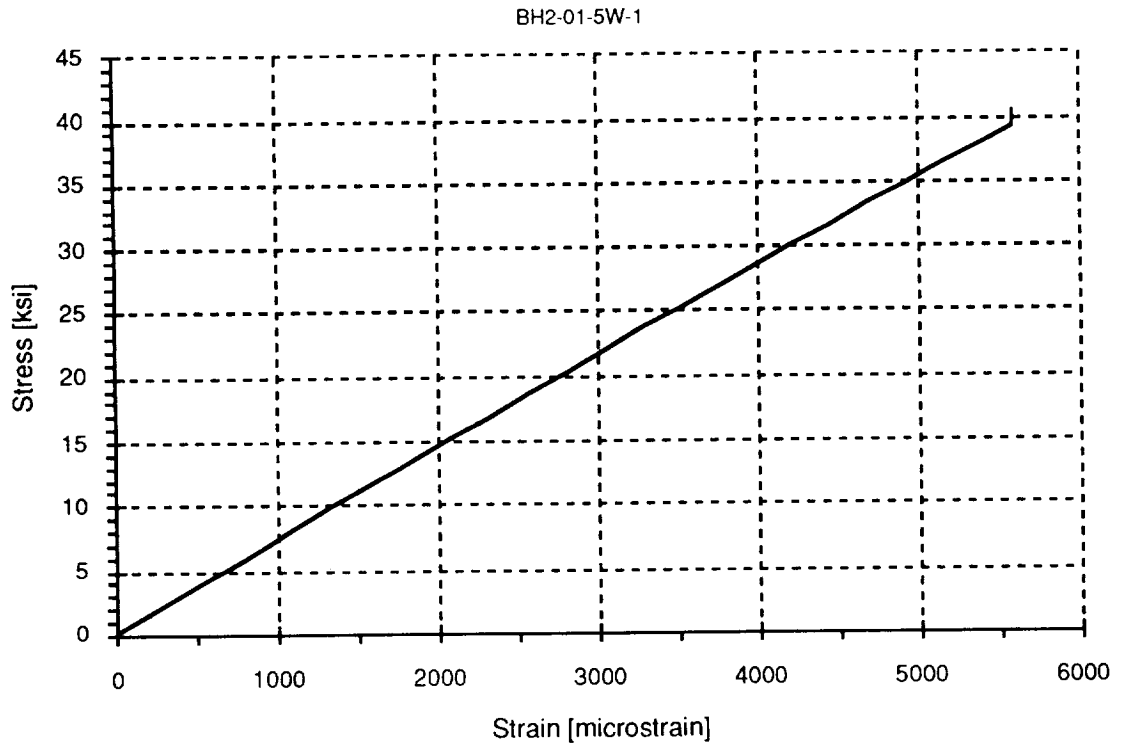


Figure B.13 Typical IITRI 90° Compression Strain Data for 2-D Braided Material SLL.

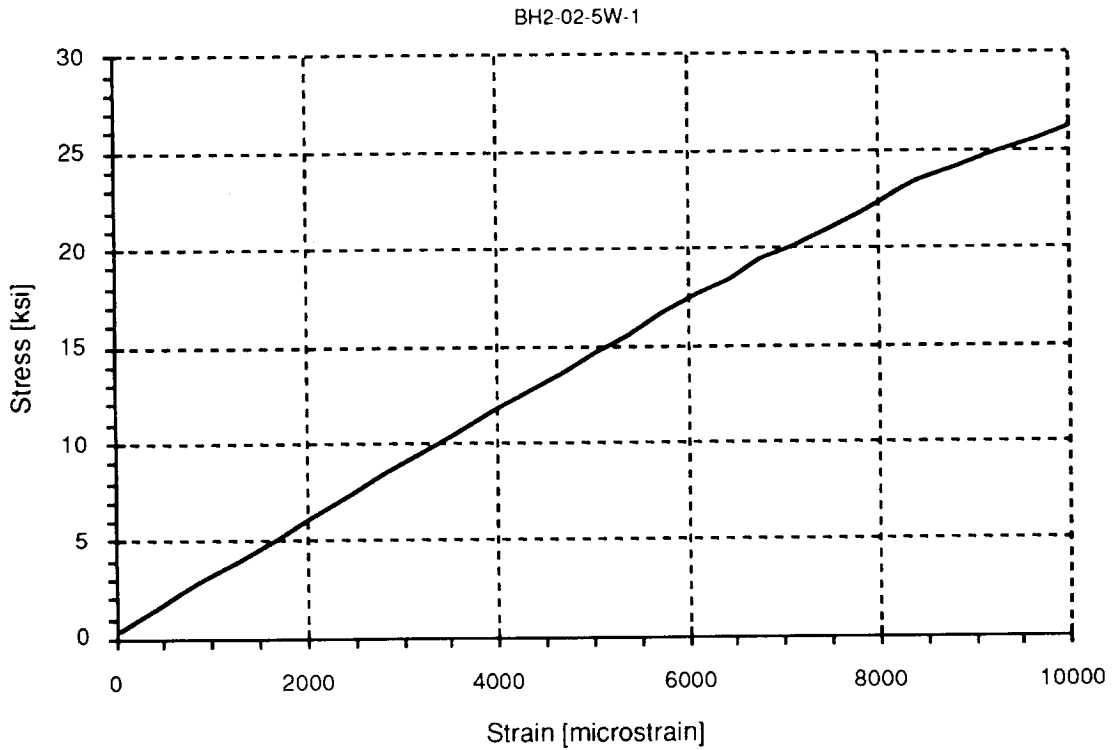


Figure B.14 Typical IITRI 90° Compression Strain Data for 2-D Braided Material LLL.

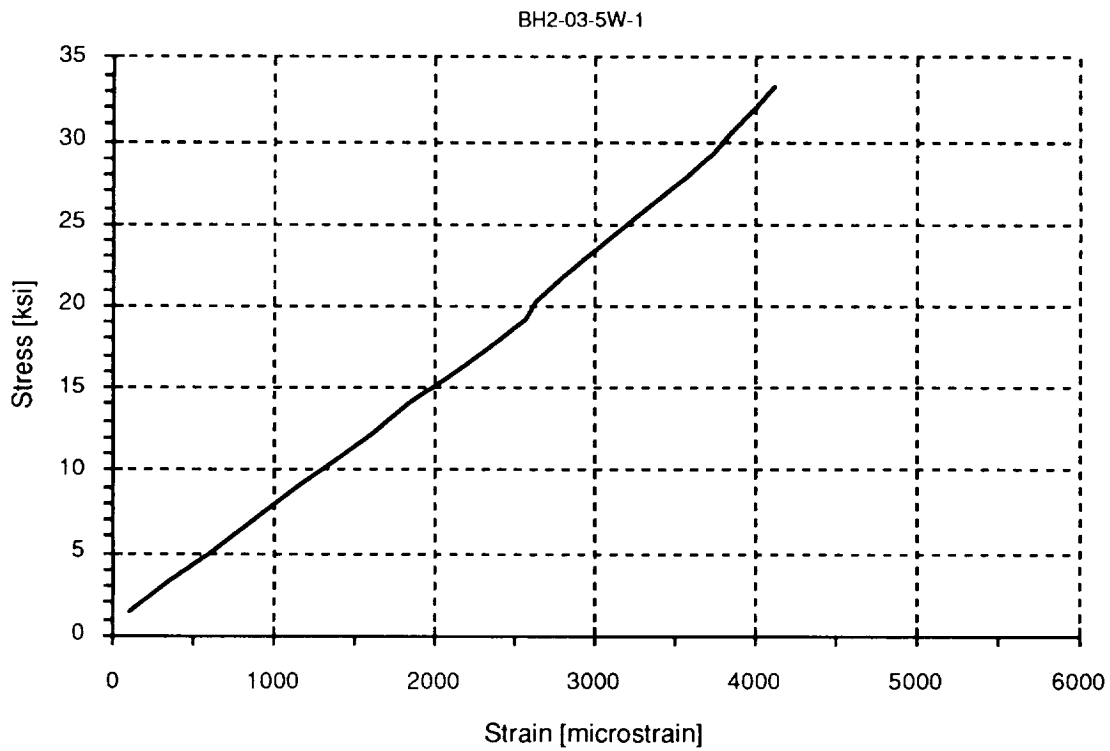


Figure B.15 Typical IITRI 90° Compression Strain Data for 2-D Braided Material LLS.

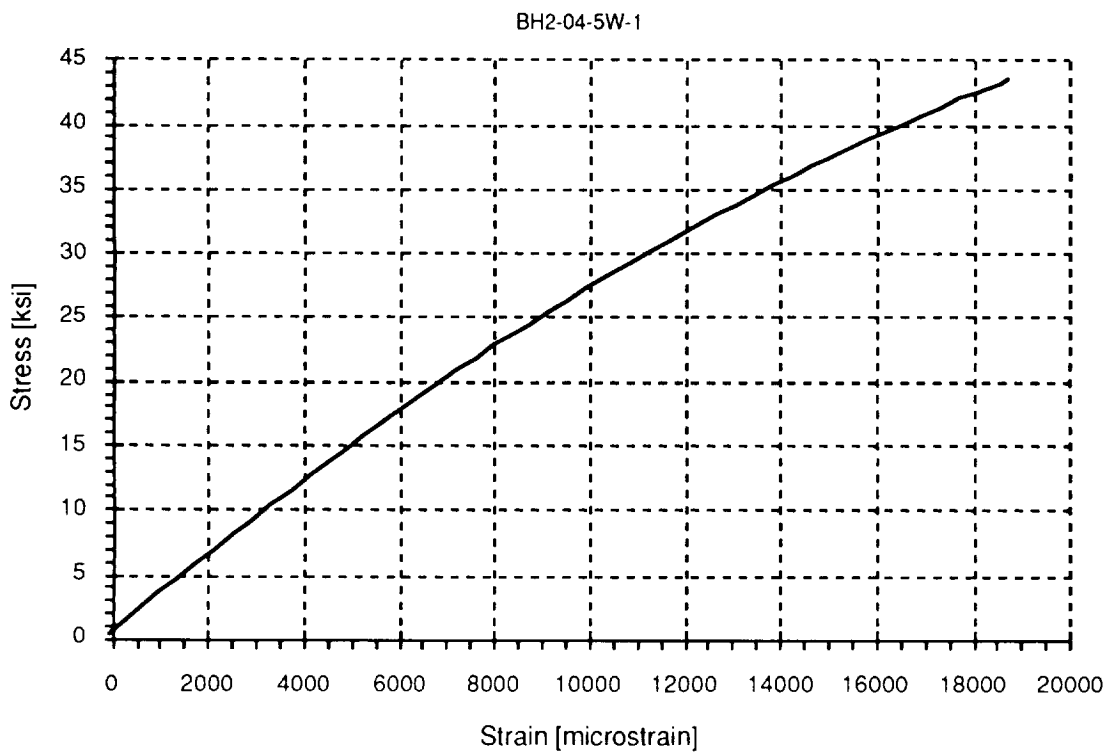


Figure B.16 Typical IITRI 90° Compression Strain Data for 2-D Braided Material LSS.

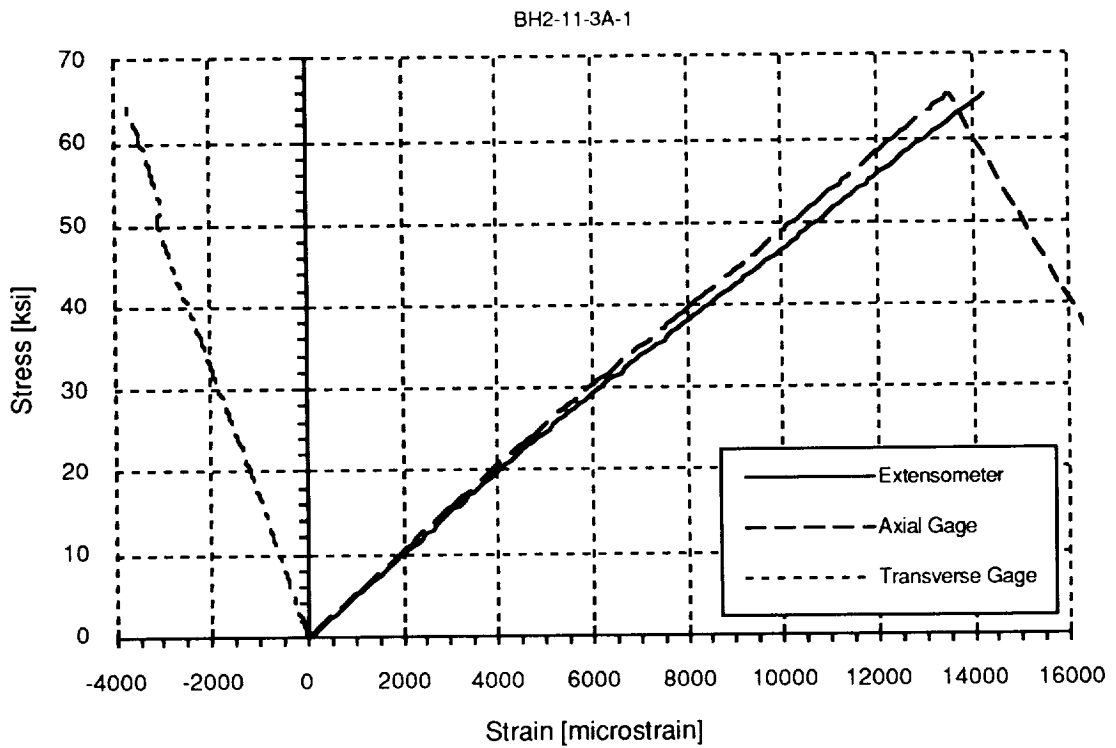


Figure B.17 Typical Tension Test Strain Data for Stitched Uniweave Material SU-1.

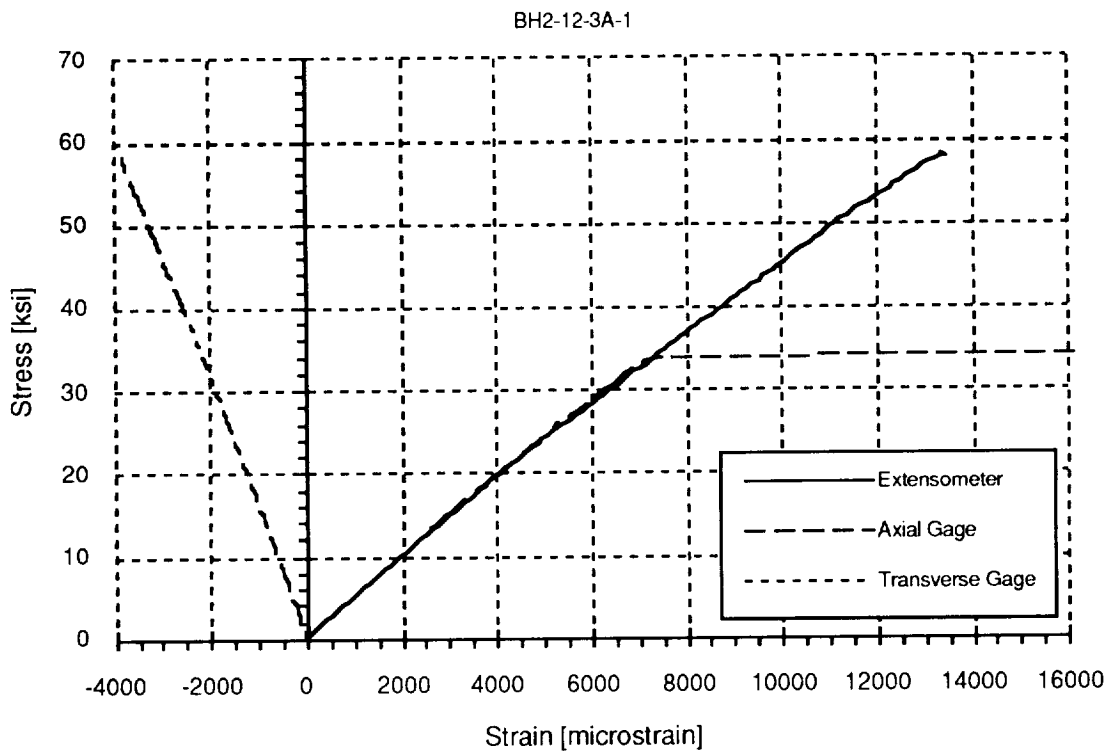


Figure B.18 Typical Tension Test Strain Data for Stitched Uniweave Material SU-2.

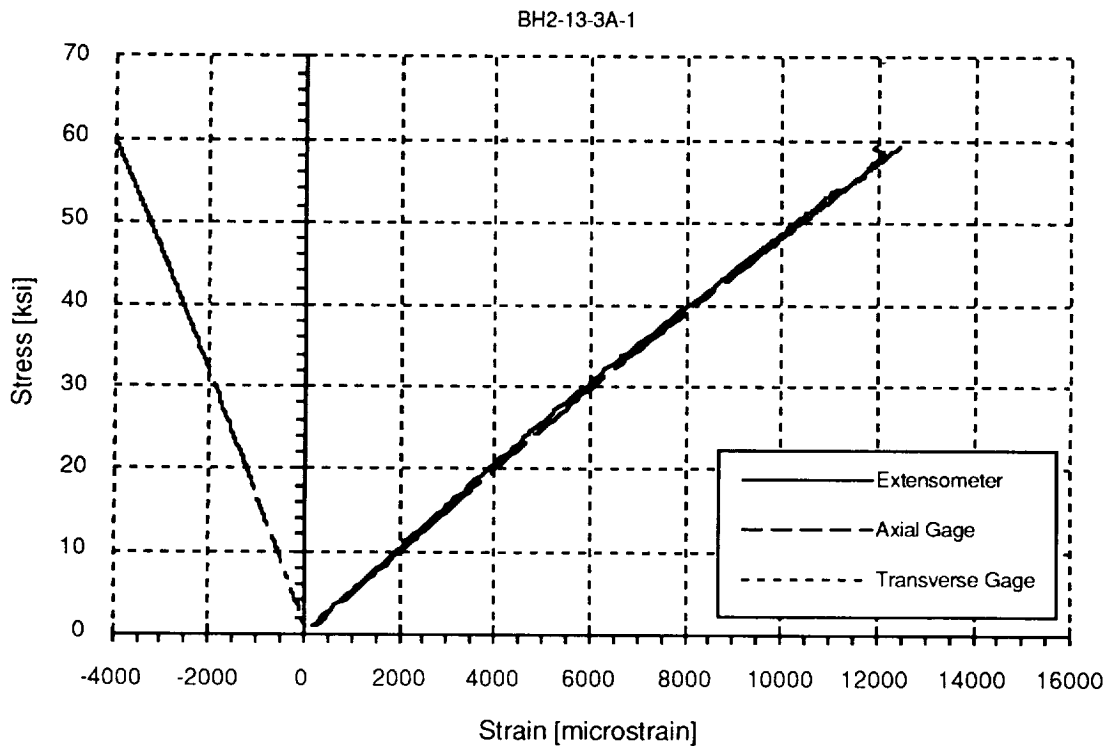


Figure B.19 Typical Tension Test Strain Data for Stitched Uniweave Material SU-3.

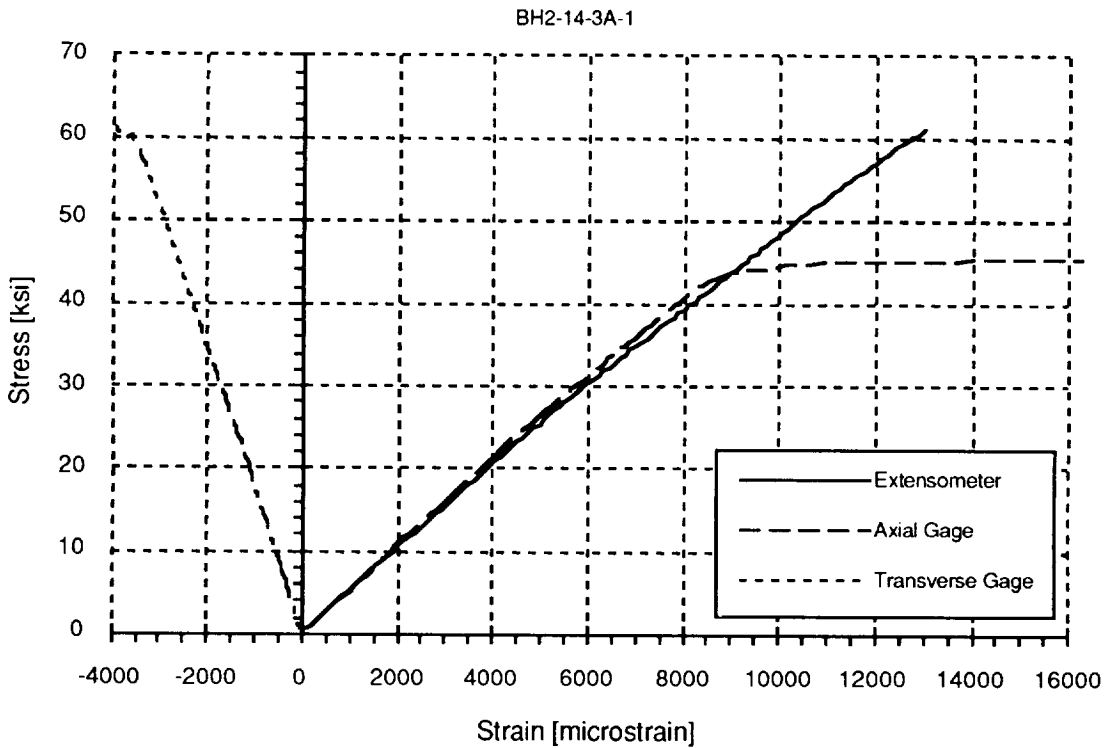


Figure B.20 Typical Tension Test Strain Data for Stitched Uniweave Material SU-4.

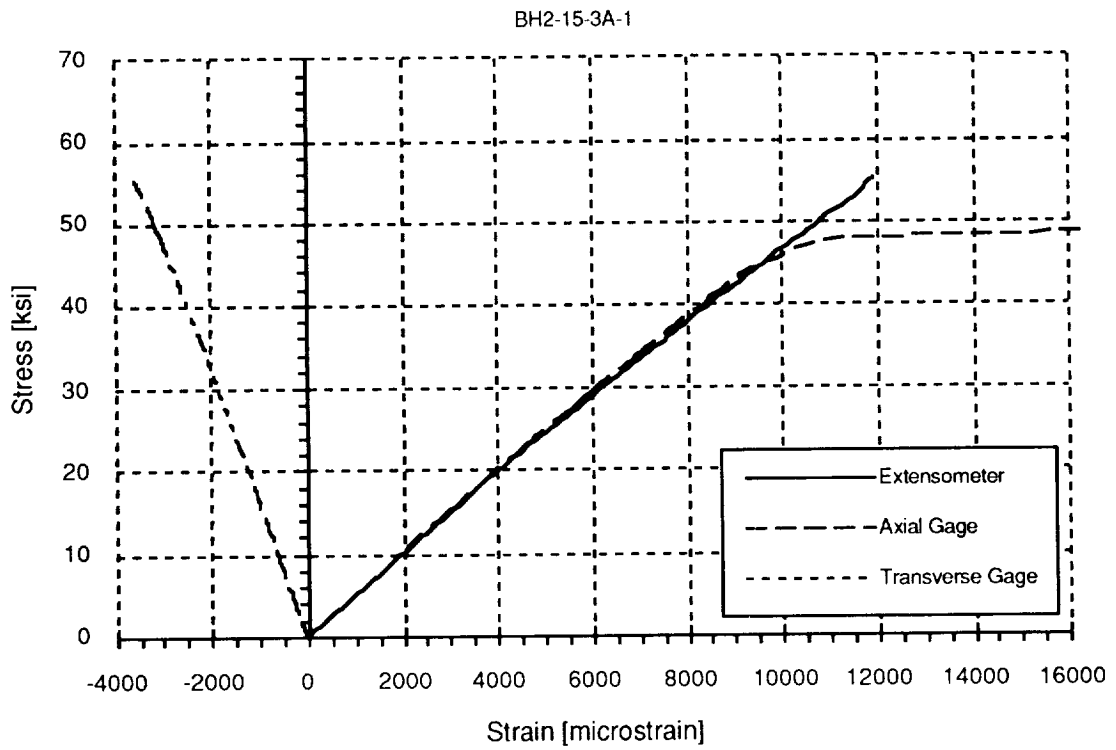


Figure B.21 Typical Tension Test Strain Data for Stitched Uniweave Material SU-5.

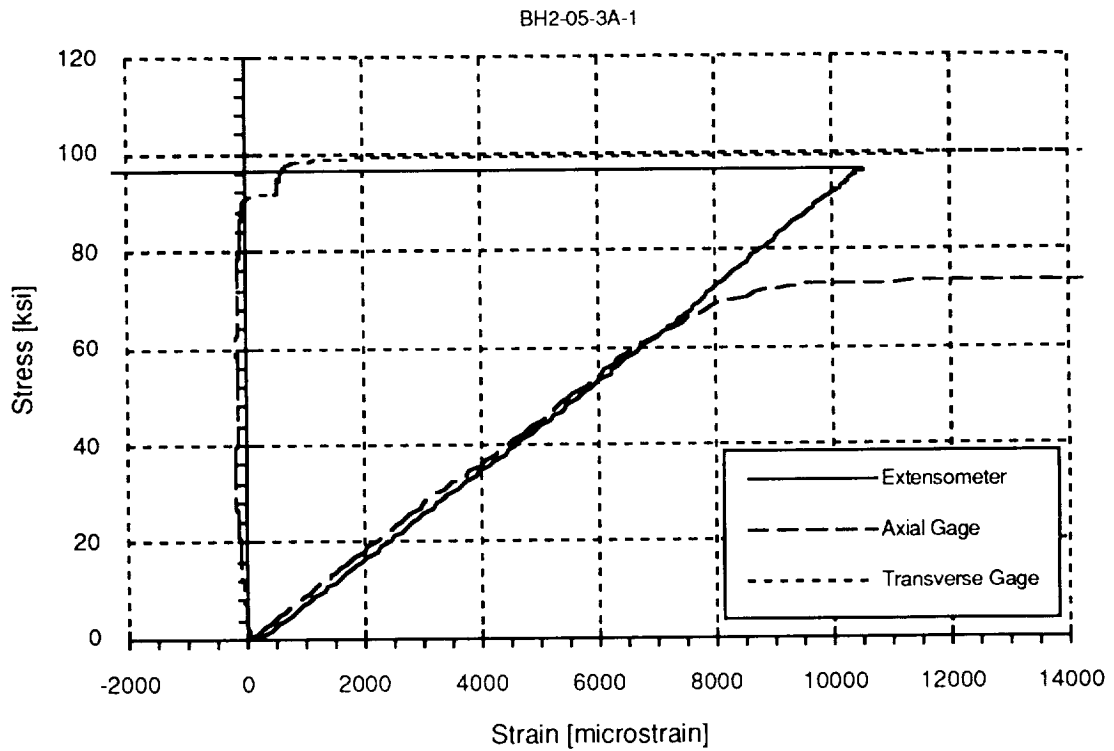


Figure B.22 Typical Tension Test Strain Data for 3-D Woven Material TS-1.

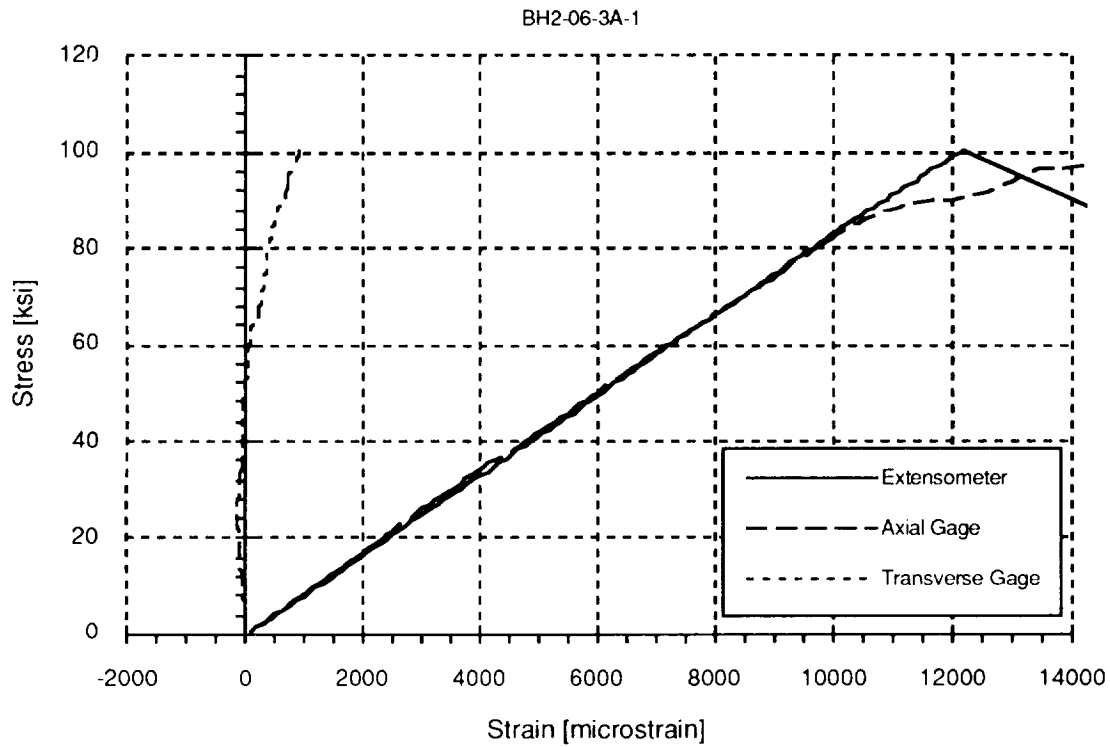


Figure B.23 Typical Tension Test Strain Data for 3-D Woven Material TS-2.

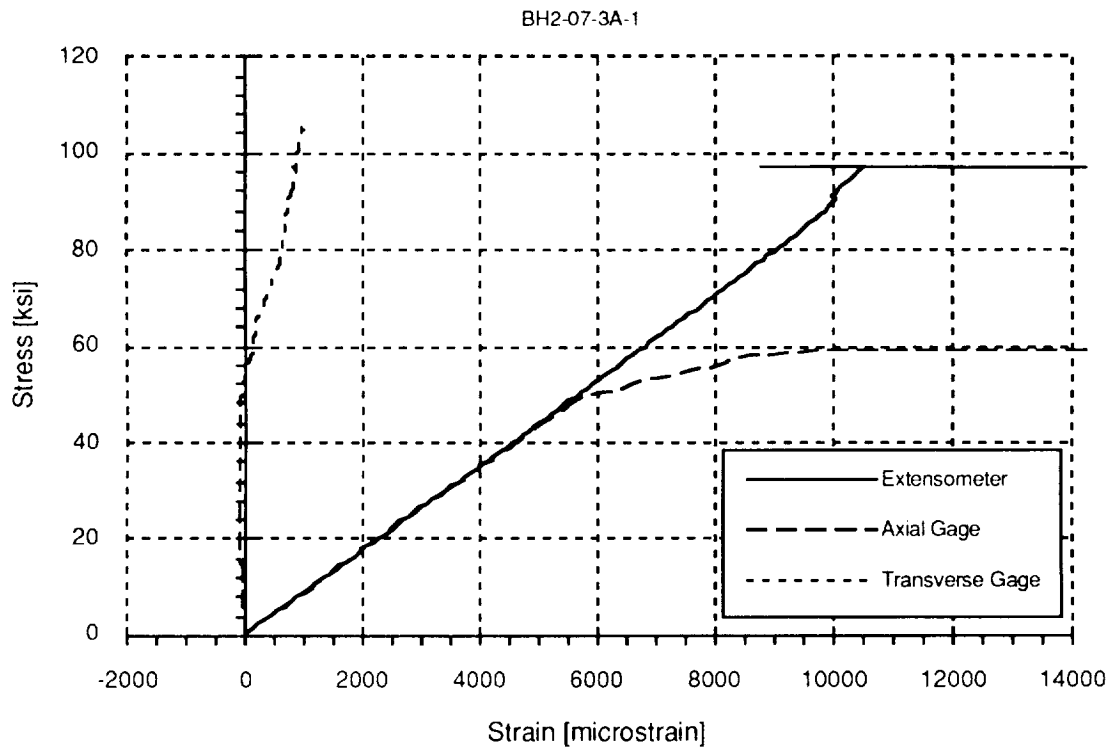


Figure B.24 Typical Tension Test Strain Data for 3-D Woven Material OS-1.

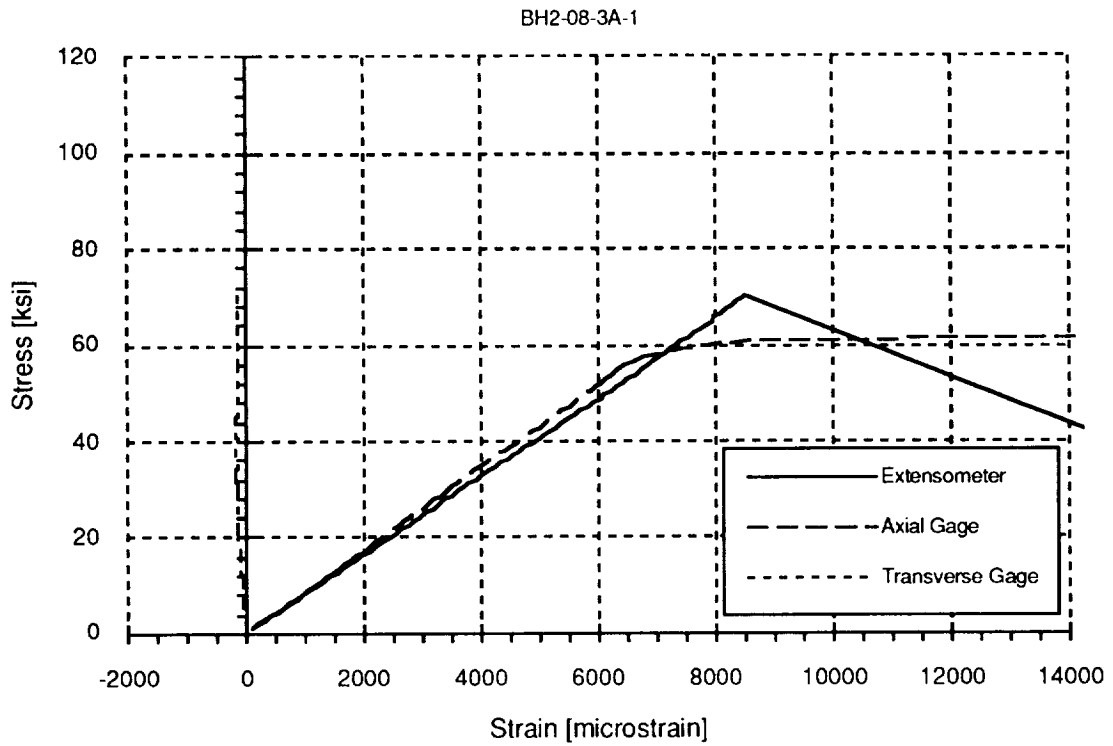


Figure B.25 Typical Tension Test Strain Data for 3-D Woven Material OS-2.

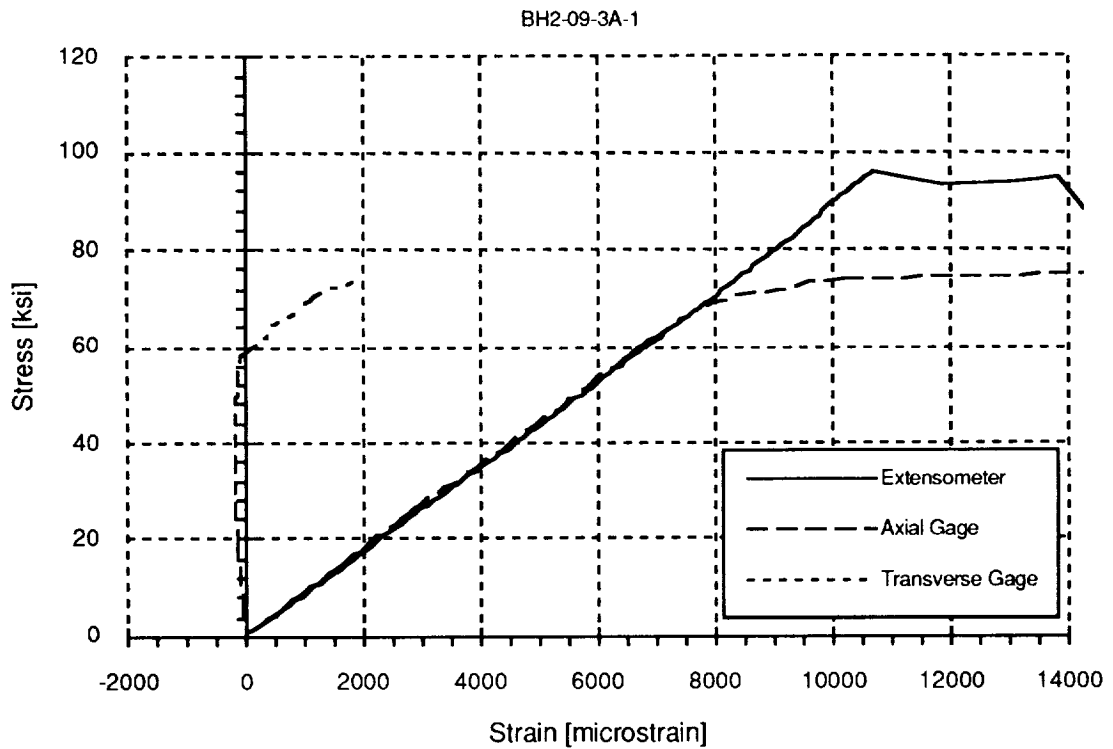


Figure B.26 Typical Tension Test Strain Data for 3-D Woven Material LS-1.

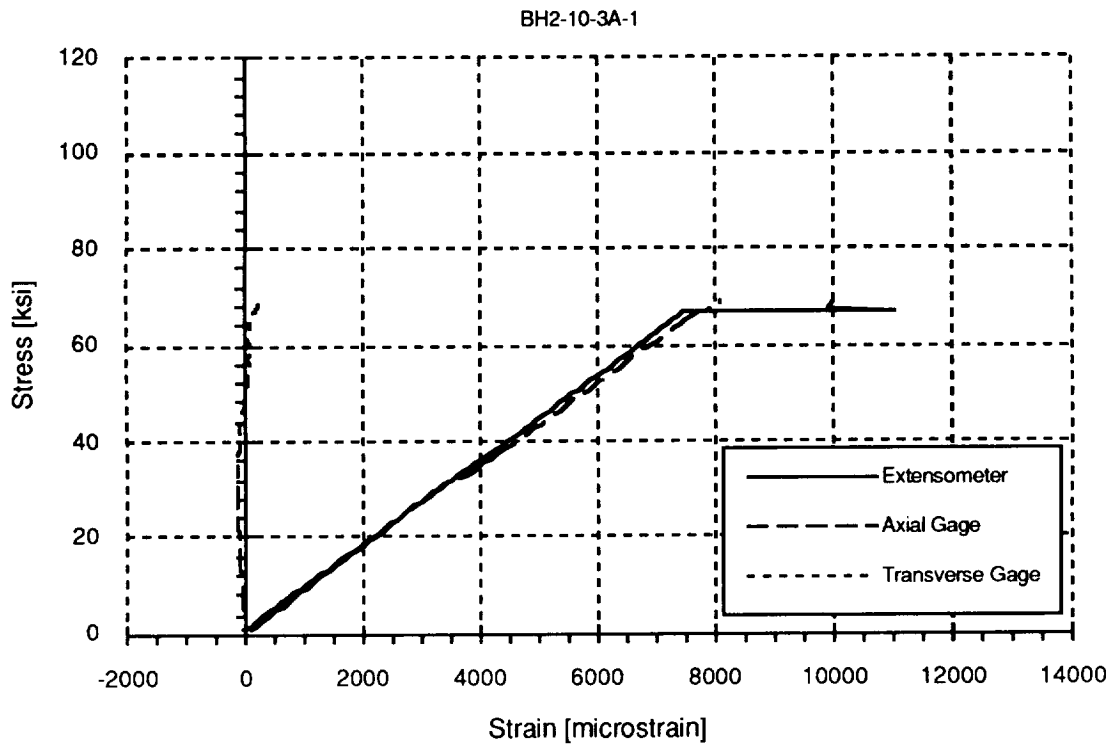


Figure B.27 Typical Tension Test Strain Data for 3-D Woven Material LS-2.

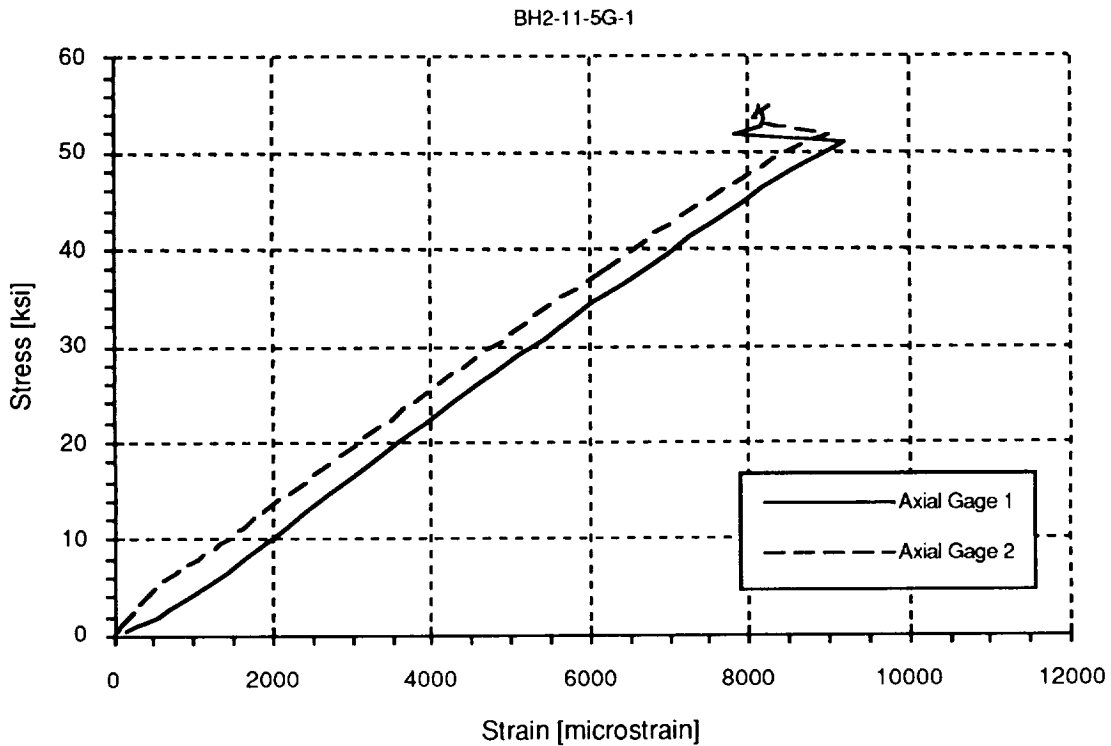


Figure B.28 Typical Short Block Compression Test Strain Data for Stitched Uniweave Material SU-1.

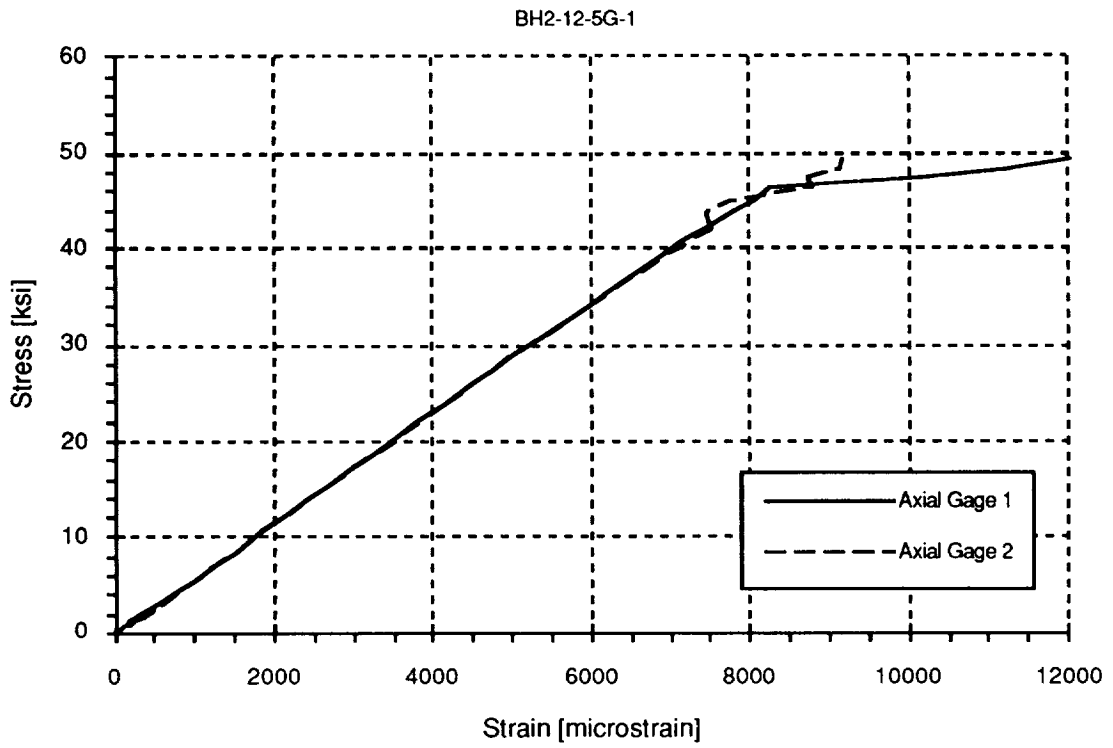


Figure B.29 Typical Short Block Compression Test Strain Data for Stitched Uniweave Material SU-2.

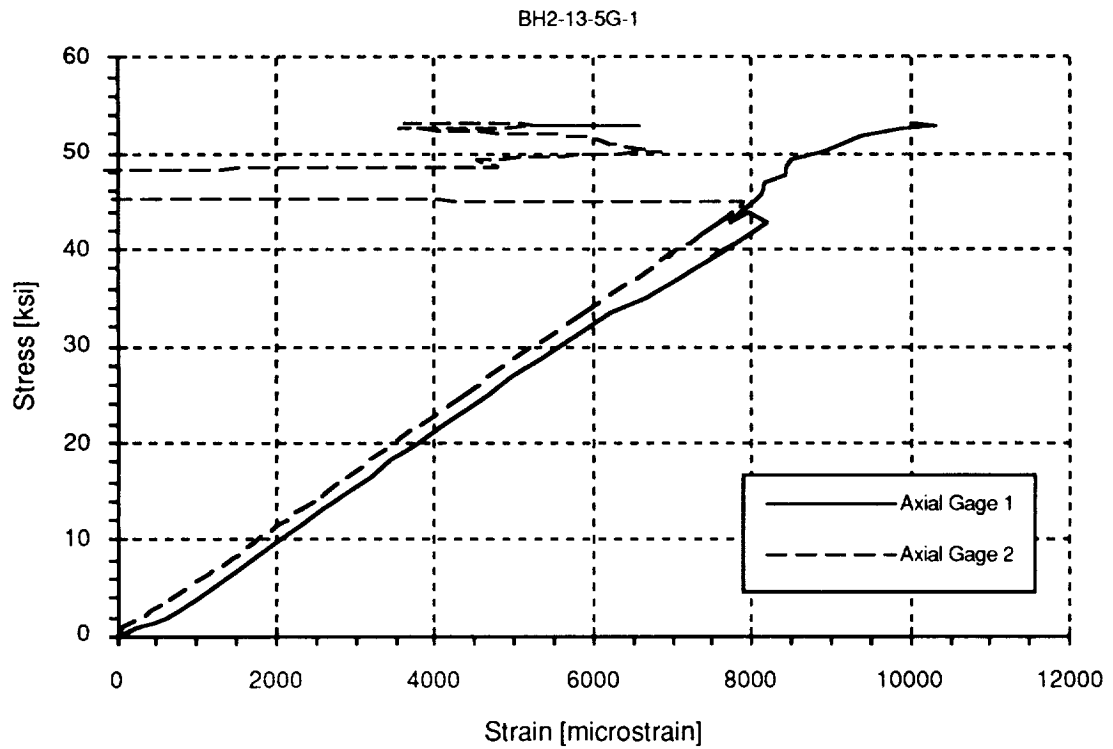


Figure B.30 Typical Short Block Compression Test Strain Data for Stitched Uniweave Material SU-3.

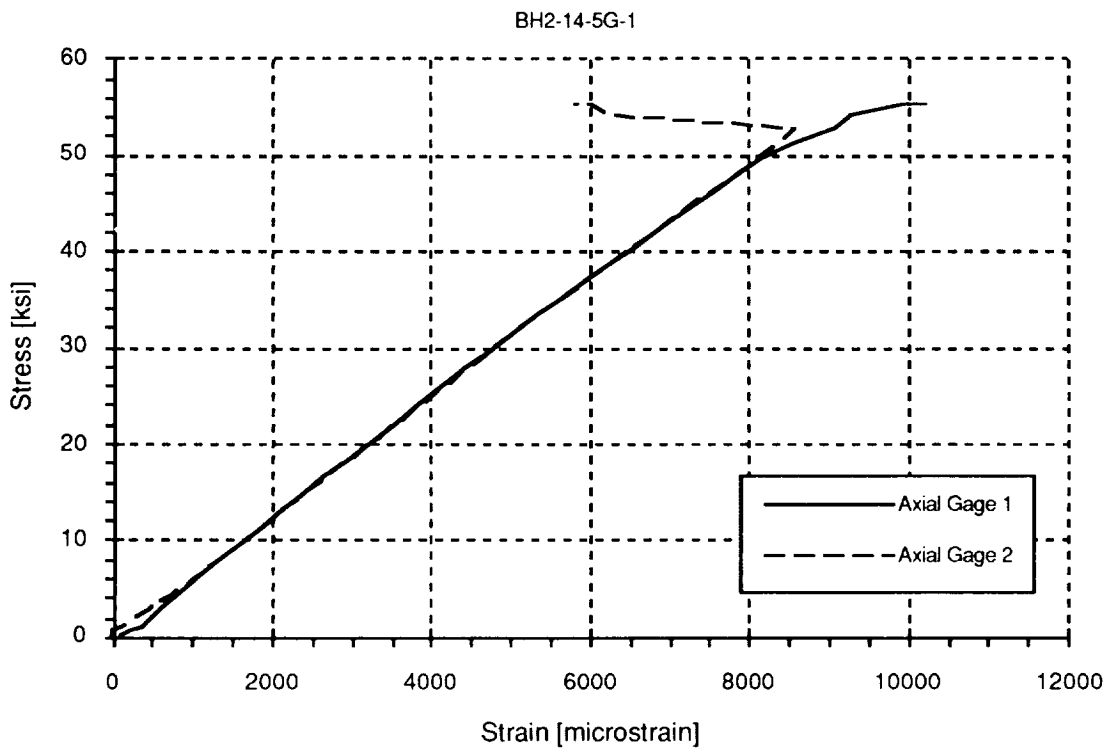


Figure B.31 Typical Short Block Compression Test Strain Data for Stitched Uniweave Material SU-4.

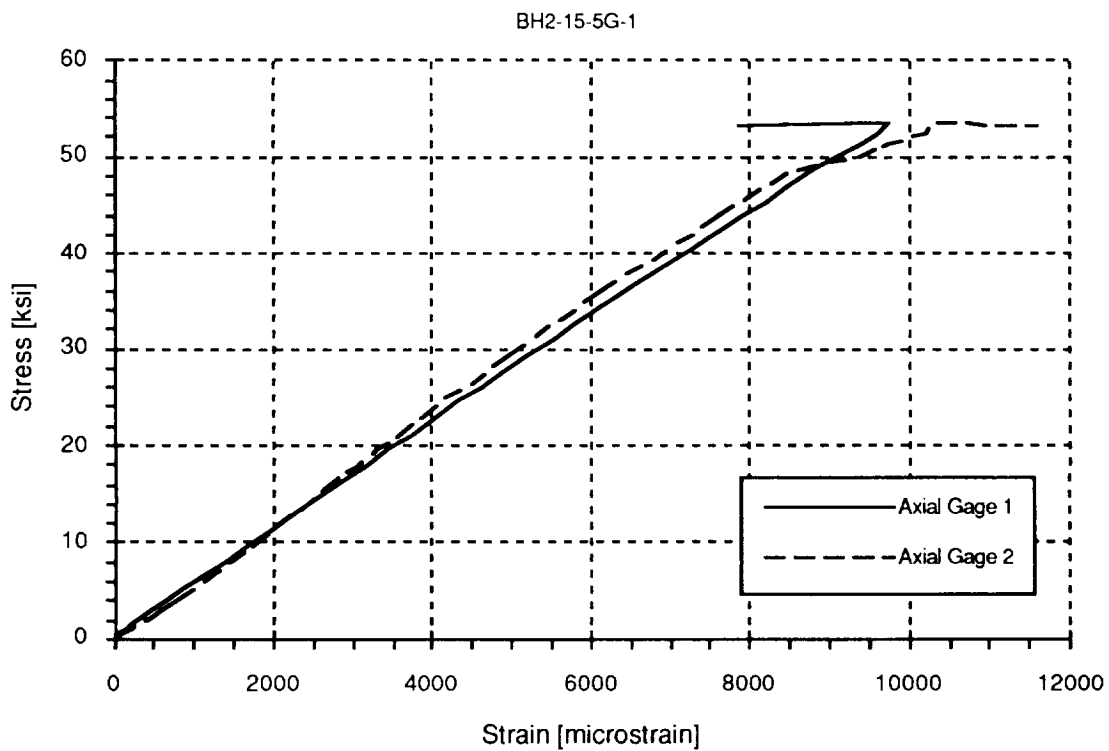


Figure B.32 Typical Short Block Compression Test Strain Data for Stitched Uniweave Material SU-5.

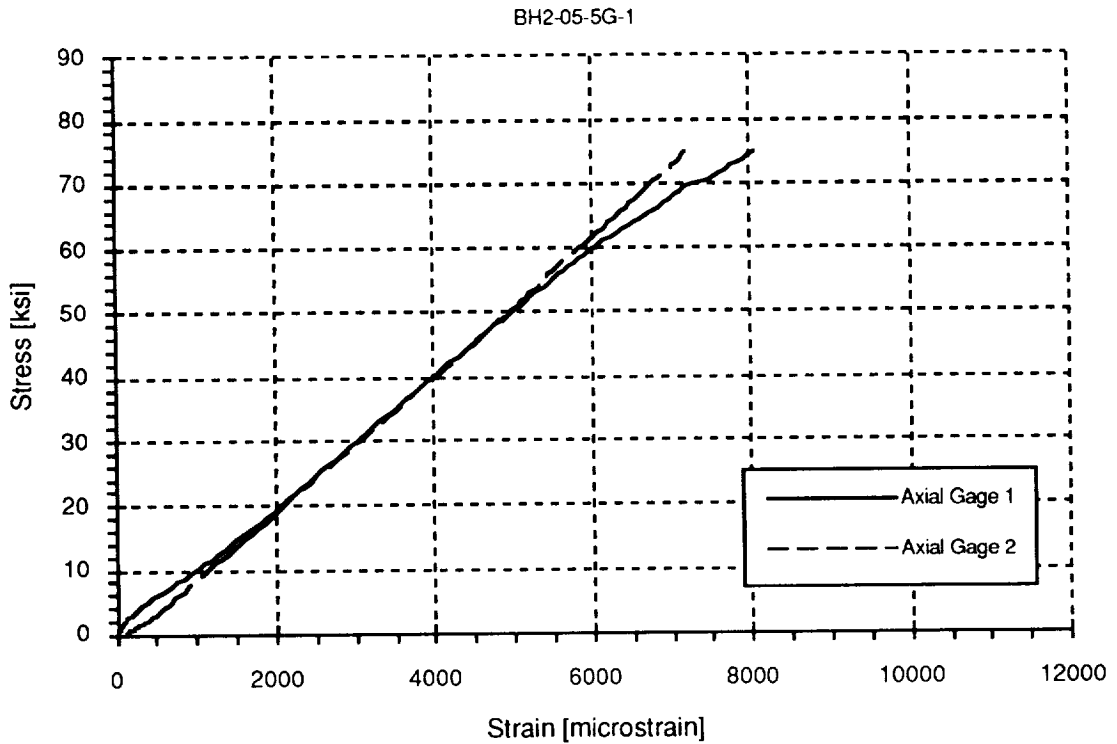


Figure B.33 Typical Short Block Compression Test Strain Data for 3-D Woven Material TS-1.

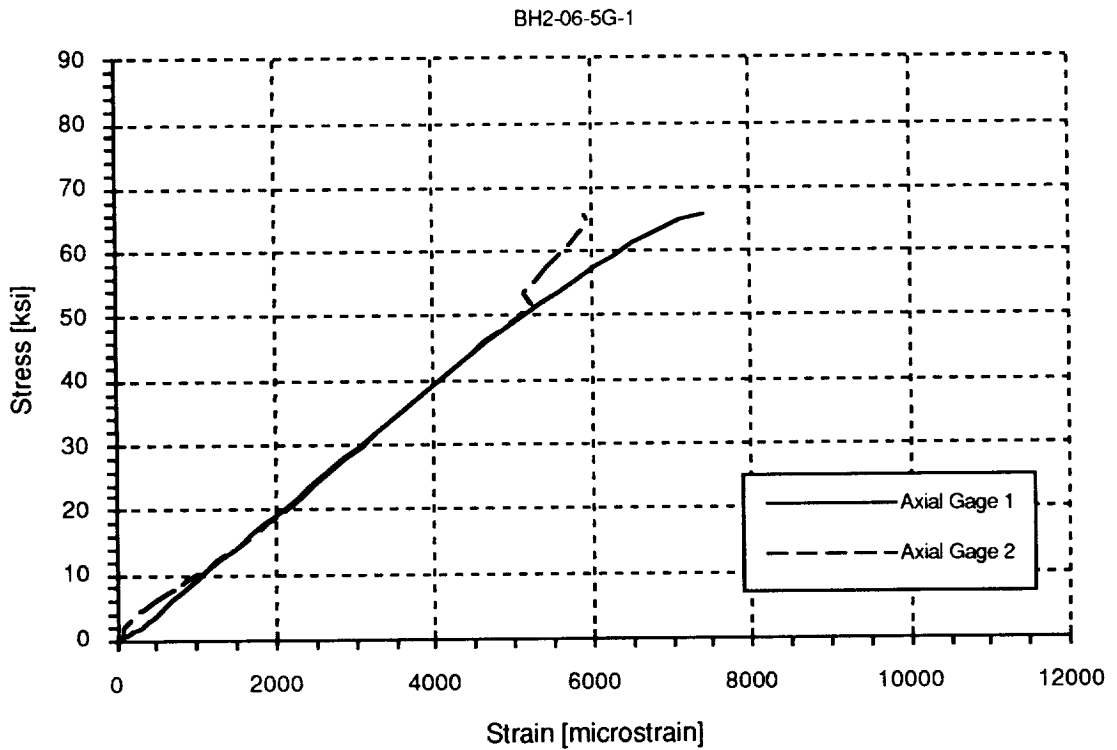


Figure B.34 Typical Short Block Compression Test Strain Data for 3-D Woven Material TS-2.

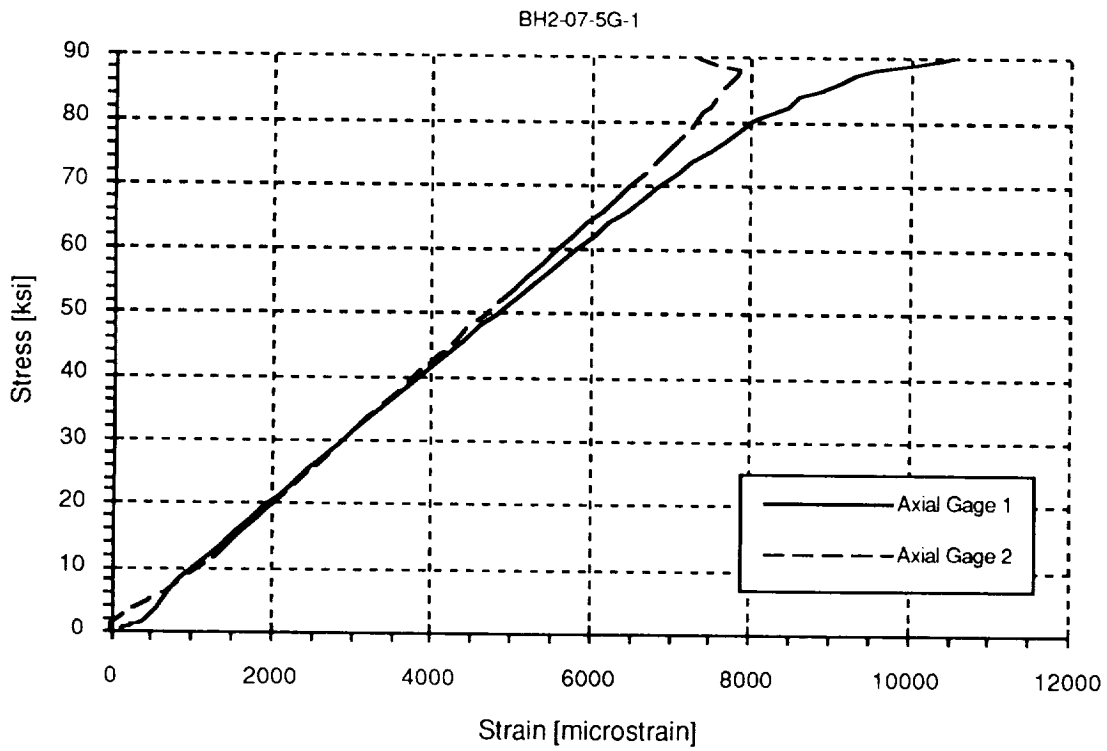


Figure B.35 Typical Short Block Compression Test Strain Data for 3-D Woven Material OS-1.

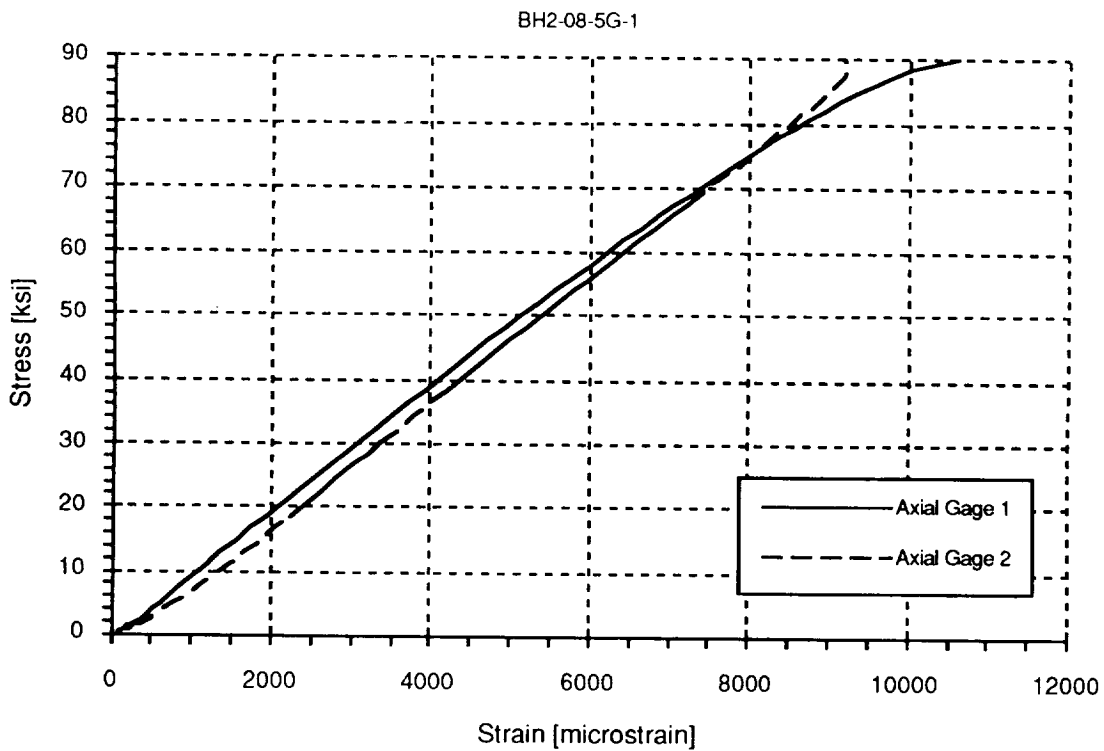


Figure B.36 Typical Short Block Compression Test Strain Data for 3-D Woven Material OS-2.

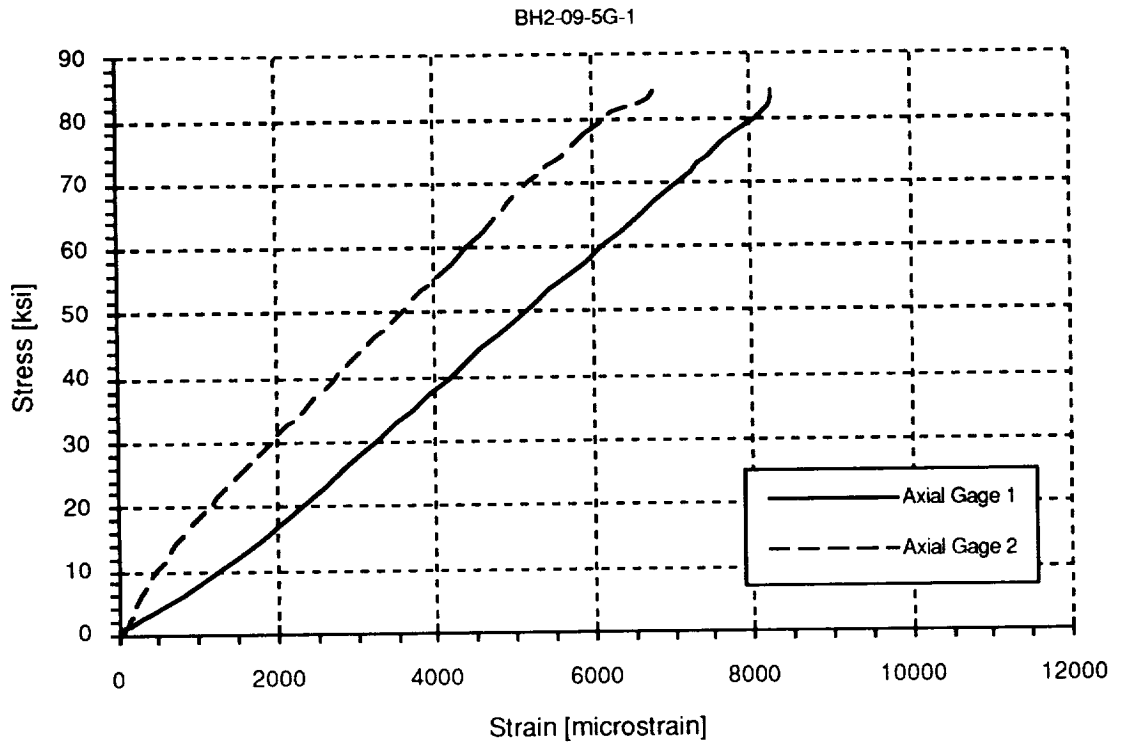


Figure B.37 Typical Short Block Compression Test Strain Data for 3-D Woven Material LS-1.

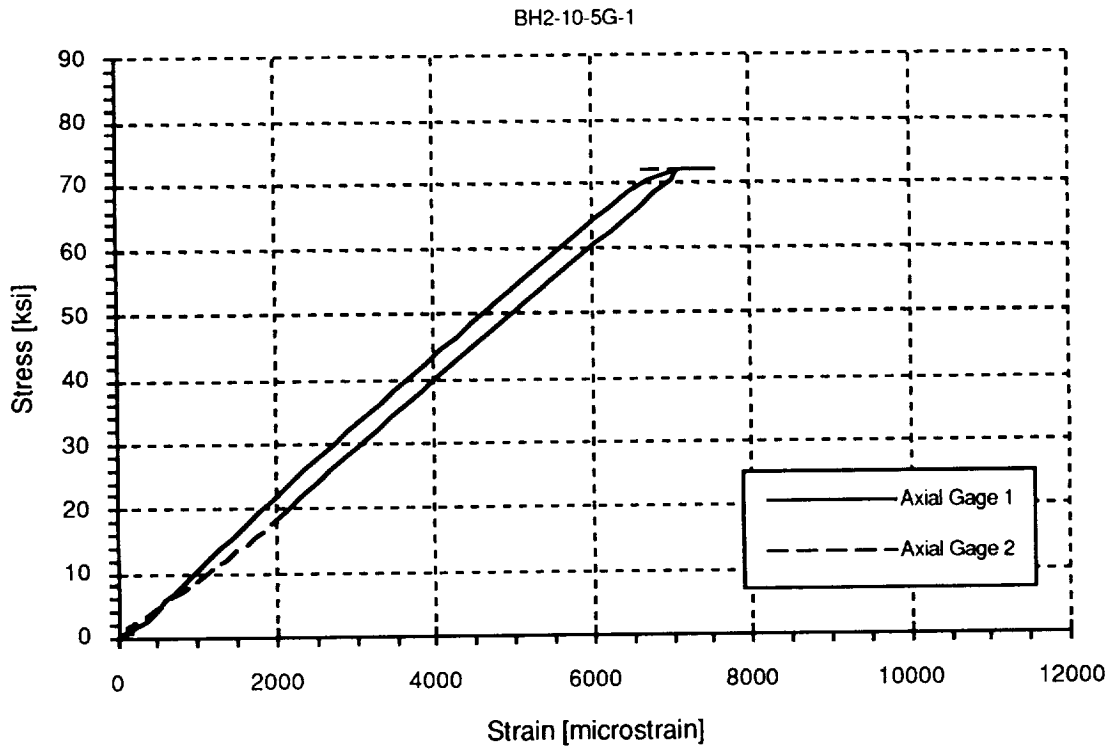
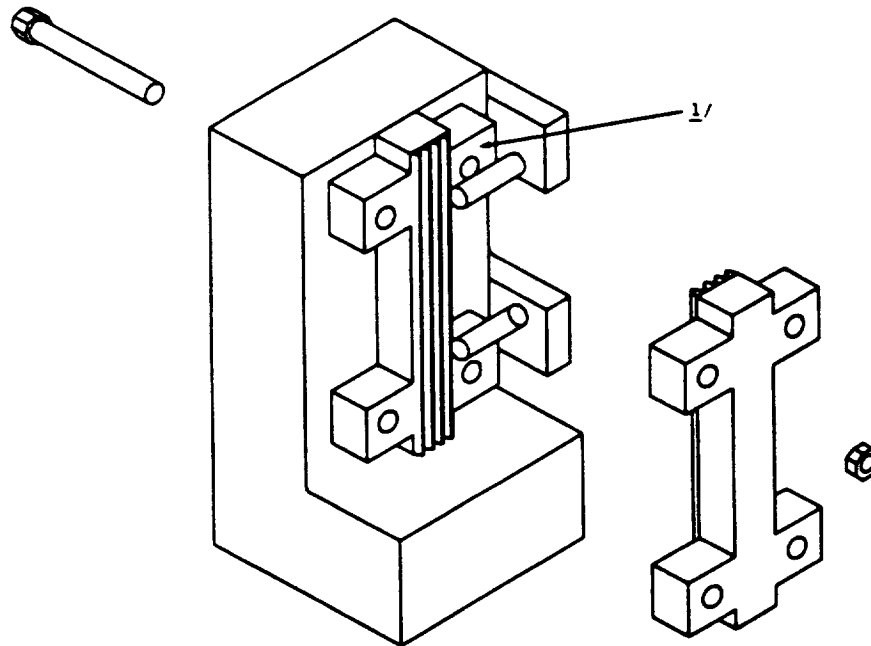


Figure B.38 Typical Short Block Compression Test Strain Data for 3-D Woven Material LS-2.

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

BSS

7260
Page 26

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.

ACTIVE PAGES: (1) Rev. B (2) Rev. B (3) Rev. B (4) Rev. B (5) Rev. B (6) Rev. B

ORIGINAL ISSUE: 5-12-83		REV.: "A" 9-8-83 "B" 10-21-88		BSS 7273 1 of 6
BY <i>[Signature]</i> B. Slavon	MFG <i>[Signature]</i> R. G. Christner	Mode I INTERLAMINAR FRACTURE TOUGHNESS FIBER-REINFORCED COMPOSITES BOEING SPECIFICATION SUPPORT STANDARD		
CK'D <i>[Signature]</i>	QC <i>[Signature]</i>			
ENG <i>[Signature]</i>	MAT'L <i>[Signature]</i> R. G. Christner			

FSCM NO. 81205
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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.

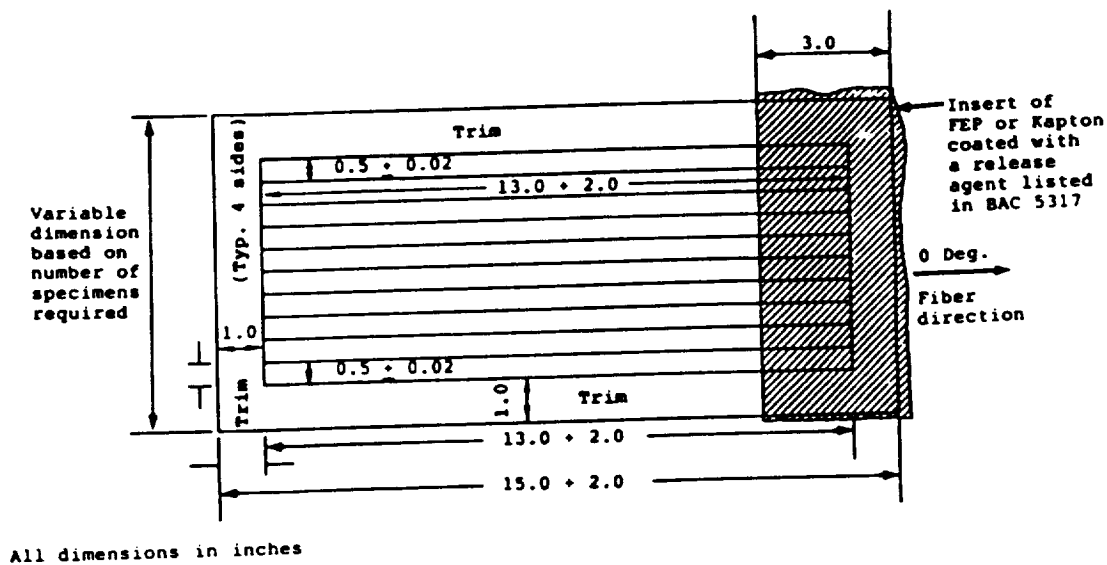
5

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.



DCB SPECIMEN AND PANEL GEOMETRY AND DIMENSIONS; PLAN VIEW

Figure 1

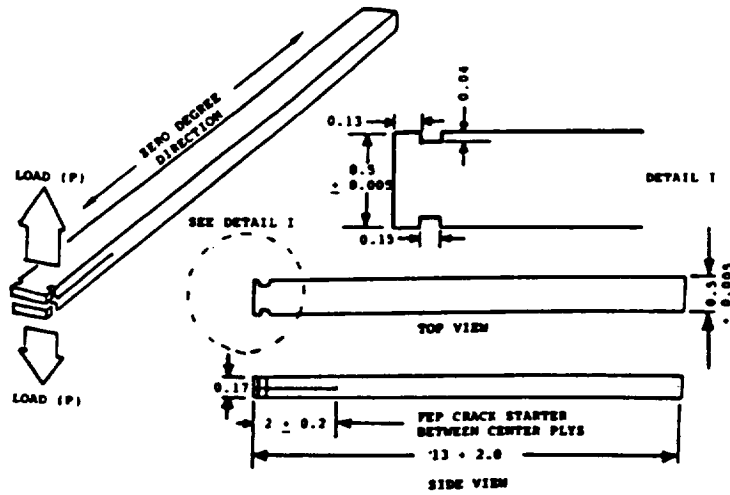
BSS

7273
Page 2

5.2

SPECIMEN PREPARATION

Machine specimens to the dimensions as shown in Figure 2.



- GENERAL NOTES: (1) Tolerances except as noted ± 0.02
 (2) Surfaces Finish: 125/
 (3) All Dimensions in inches

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.

- NOTE: All dimensions in inches
 All Tolerances $\pm 0.02 D$

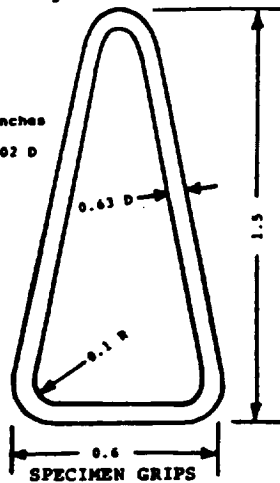


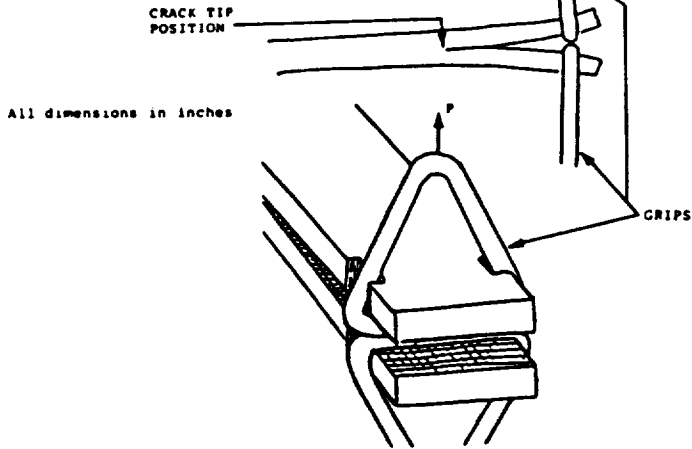
Figure 3

BSS

7273
 Page 3

6.2

SPECIMEN GRIPS (Continued)



POSITIONS OF THE TRIANGULAR SPECIMEN GRIP IN THE DCB SPECIMEN

Figure 4

7

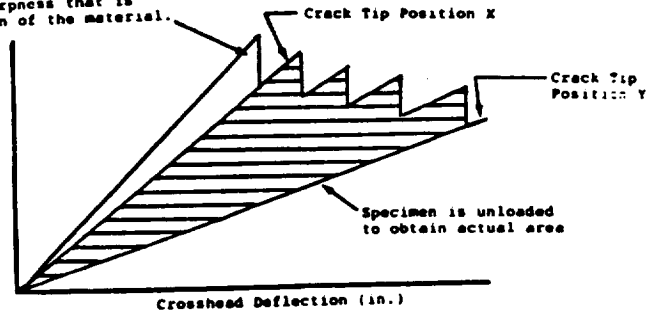
PROCEDURE

7.1

PARAMETERS/MEASUREMENTS

- a. A minimum of five specimens shall be tested for each desired temperature. Room temperature shall be $75 \pm 10F$.
- 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.

Ignore first Peak, 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.



AREA METHOD LOAD DEFLECTION CURVE AND DATA DETERMINATION

Figure 5

BSS

7273
Page 4

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/in²), 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:

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

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.

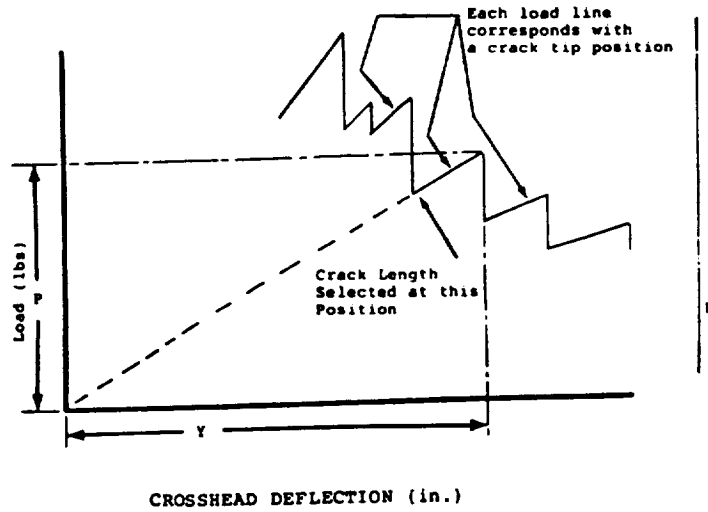
BSS

7273
Page 5

7.2.2

INITIATION METHOD (Continued)

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



INITIATION METHOD LOAD-DEFLECTION CURVE AND DATA POINT DETERMINATION

Figure 6

8

REPORTING

Report specimen identification, test temperature, and G_{IC} to the nearest in-lb/in².

BSS

7273
Page 6

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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.				
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