



CENTER FOR ADVANCED MINERAL AND MATERIAL PROCESSING

Montana Tech of The University of Montana

1300 West Park Street

Butte, MT 59701

406-496-4808

SKU 25511 Rev B

Tube – Rectangle – Fabric

2.0 x 2.5 – 4.0 x 4.6 x 105 inch

Testing Results

June 2016

PREPARED FOR:

**Rockwest Composites
3392 West 8600 South
West Jordan, UT 84088**

PREPARED BY:

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Lab Manager

The Center for Advanced Minerals, Materials and Metallurgical Processing (CAMP) was contracted by Rockwest Composites to characterize an innovative Carbon/Epoxy composite material formed into a 4" x 2" beam. All testing was performed within the CAMP Materials Testing Lab, located on the Montana Tech campus in Butte, Montana. The specimens were cut from two locations; the 4" side walls and the 2" caps. The specimen location for each test is noted in the results. The test matrix used for this program is shown in Table 1.

Table 1
Test Matrix

Test Type	ASTM	Specimen Location
Tensile	D3039	2" Cap
Compression	D6641	2" Cap
Bearing Stress	D5961	4" Side
Fastener Pull Thru	D7332, Proc A	4" Side
Coefficient of Thermal Expansion	D696	Both Locations
Density	D792	Both Locations

PROCEDURES

Tensile testing

The tensile tests were performed according to ASTM D3039. Specimens were cut to nominally 1.0 inch wide and 9.0 inches long from the 2" beam caps. The samples were tabbed with G-10 fiberglass material. The tab ends were tapered 25° and cut to a final length of 2". Micro-Measurements axial gages CEA-06-250UW-350 were applied to each specimen. The modulus was determined over the strain range of 1000-3000 $\mu\epsilon$. All testing was performed on an MTS universal hydraulic test frame with a maximum load capacity of 55,000 pounds. Tests were run at 0.1in/min and data was collected at 50Hz. Data tables can be observed in the Results section. Plots with individual curves can be viewed in Appendix A.

Compression Testing

The compression tests were performed according to ASTM D6641. Specimens were cut to nominally 0.500" wide from the 2" beam caps. All specimens were end ground to a final length of 5.5". Micro-Measurement axial gages EA-06-125EP-350. The modulus of each specimen was determined over the strain range of 3000-4000 $\mu\epsilon$. All testing was performed on an MTS universal hydraulic test frame with a maximum load capacity of 55,000 pounds. Tests were run at 0.05in/min and data was collected at 50Hz.

Bearing Stress

The Bearing Stress tests were performed according to ASTM D5961. Specimens were cut to nominally 1.500" wide and 5.5" long from the 4" beam walls. Per the ASTM the hardened pin was 0.250" 17-4 stainless steel and the hole was 0.250" diameter. Tests were run at 0.1in/min and data was collected at 10Hz.

Fastener Pull-Thru

The Fastener Pull-Thru tests were performed per ASTM D7332. Specimens were cut nominally 4.25" x 4.25" square from the 4" beam walls with a 0.250" diameter hole in the center of the specimens. The holes had a countersink at 82° that allowed the fasteners to sit flush. The fasteners were Stainless Steel hex-head socket cap screws, ¼"-20. The fasteners were tightened to 20 in-lb pre-test. Washers were used between the nut and plate and the nuts were ¼"-20. The specimens were placed on top of each other as to have the fastener on the outside surface of the beam and the nut and washer on the inside. All testing was performed on an MTS universal hydraulic test frame with a maximum load capacity of 55,000 pounds. Tests were run at 0.025in/min and data was collected at 5Hz. Data tables can be observed in the Results section.

Coefficient of Thermal Expansion

Coefficient of Thermal Expansion was determined per ASTM D696 on samples were randomly chosen from the beam from both the 2" caps and 4" walls. The tests were run on a Netzsch DIL over the temperature range of -18°C to 47°C.

Density

Density was performed per ASTM D792 by Archimedes principles. The data can be viewed in the Results section.

RESULTS-Tables**Tensile Test Results****D3039**

Specimens Taken from 2" Beam Caps

Specimen ID	Width (in)	Thickness (in)	Stress (ksi)	Modulus (Msi)
TB-1	0.785	0.302	142.5	12.2
TB-2	0.815	0.297	131.3	11.7
TB-3	0.800	0.307	141.4	11.6
TB-4	0.826	0.300	140.3	12.2
TB-5	0.808	0.308	140.8	11.9
Average	0.807	0.303	138.5	11.9
SD	0.02	0.005	4.5	0.3
CV(%)	2	2	3	2

Compression Test Results**D6641**

Specimens taken from 2" Beam Caps

Specimen ID	Width (in)	Thickness (in)	Stress (ksi)	Modulus (Msi)
C1	0.499	0.300	81.8	33.3
C2	0.507	0.290	85.5	36.8
C3	0.500	0.292	94.6	38.0
C4	0.503	0.299	97.6	38.1
C5	0.490	0.297	75.9	35.6
Average	0.500	0.296	87.1	36.3
SD	0.006	0.004	8.9	3.0
CV(%)	1	1	12	8

**Fastener Pull-Thru
ASTM D7332**

Specimens taken from 4" Beam Sides

Nominal Thickness = 0.250"

Nominal Countersink Depth = 0.139"

Specimen ID Panel No. (Top/Bottom)	Failure Load (lb)	Max Load (lb)	Ca/D*	D/h	dcsk/h
B-FTP-1	1733	1733	10.9	0.98	0.55
B-FTP-2	2344	2344	10.9	1.00	0.55
B-FTP-3	1604	1604	10.9	0.96	0.54
B-FTP-4	2126	2126	10.9	0.99	0.55
B-FTP-5	2160	2160	10.9	0.99	0.55
Average	1993	1993	10.9	0.99	0.55
SD	311	311	0.00	0.017	0.01
CV(%)	16	16	0	2	2

*Nominal hole diameter (D) of 0.250"

**Bearing Stress
ASTM D5961**

Specimens taken from 4" Beam Sides

Nominal Thickness = 0.250"

Sample	Side Thickness (in)	Initial Peak Bearing Stress (ksi)	Ultimate Bearing Stress (ksi)
BBR-1	0.247	69.1	69.1
BBR-2	0.247	71.3	71.3
BBR-3	0.246	75.4	75.4
BBR-4	0.255	73.9	73.9
BBR-5	0.253	70.7	70.7
Average	0.250	72.1	72.1
SD	0.004	2.5	2.5
CV(%)	2	4	4

**CTE by Dilatometer
ASTM D696**

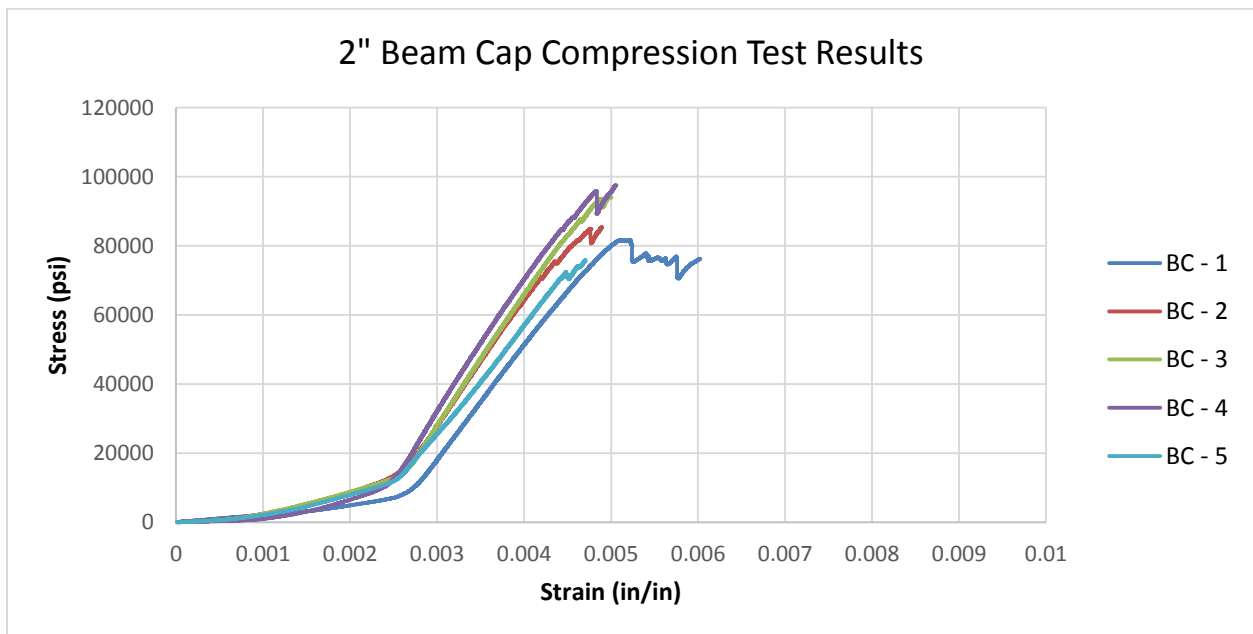
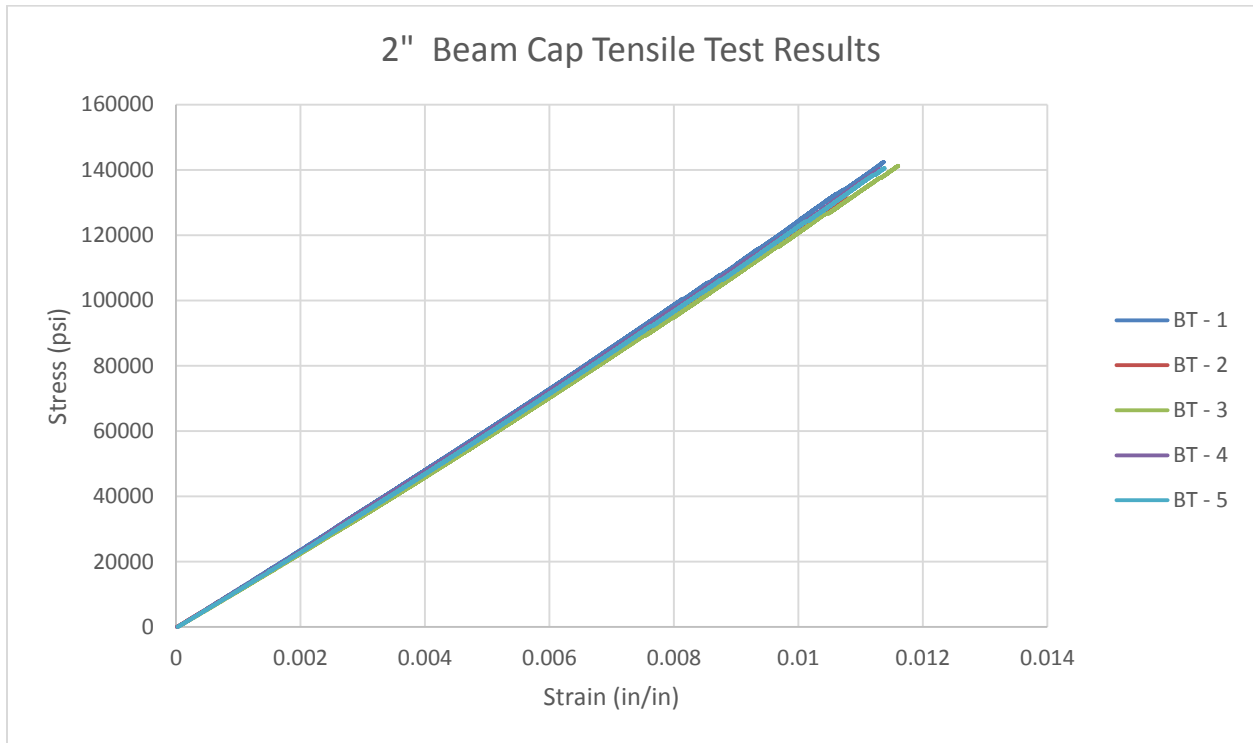
Sample ID	CTE (-18 to 47°C)
Cap	1.2570×10^{-6}
Side	2.0305×10^{-6}

**Density
D792**

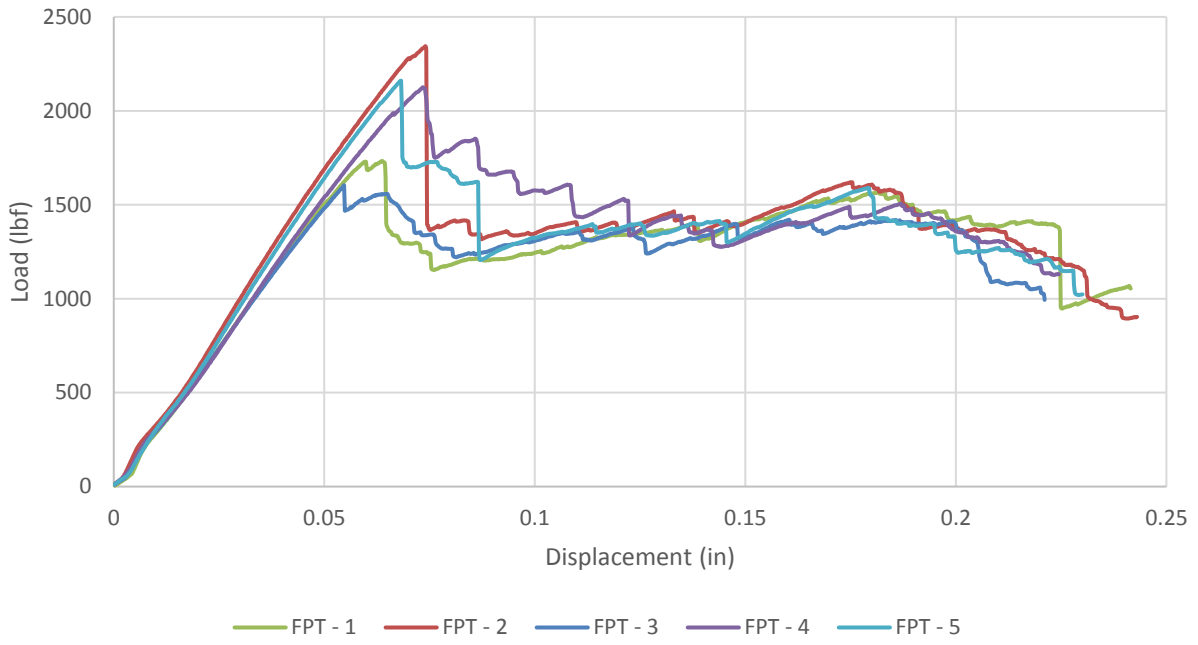
Specimens Taken Randomly from Beam

Sample ID	Density g/cm ³
1	1.5058
2	1.5328
3	1.5398
4	1.5153
5	1.5372
6	1.5216
7	1.5231
8	1.5229
9	1.5192
10	1.5204
Average	1.5238
SD	0.010
CV(%)	0.67

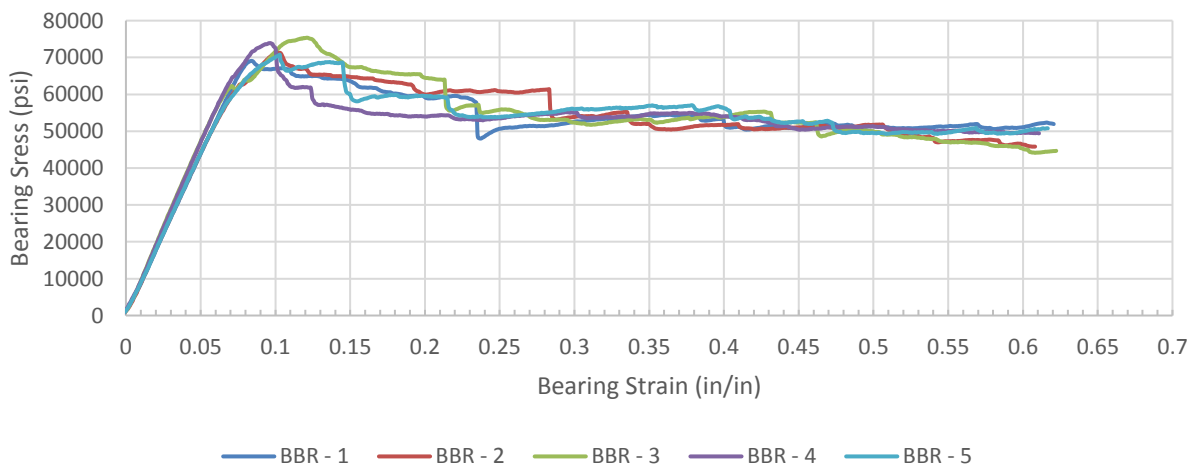
RESULTS-Plots

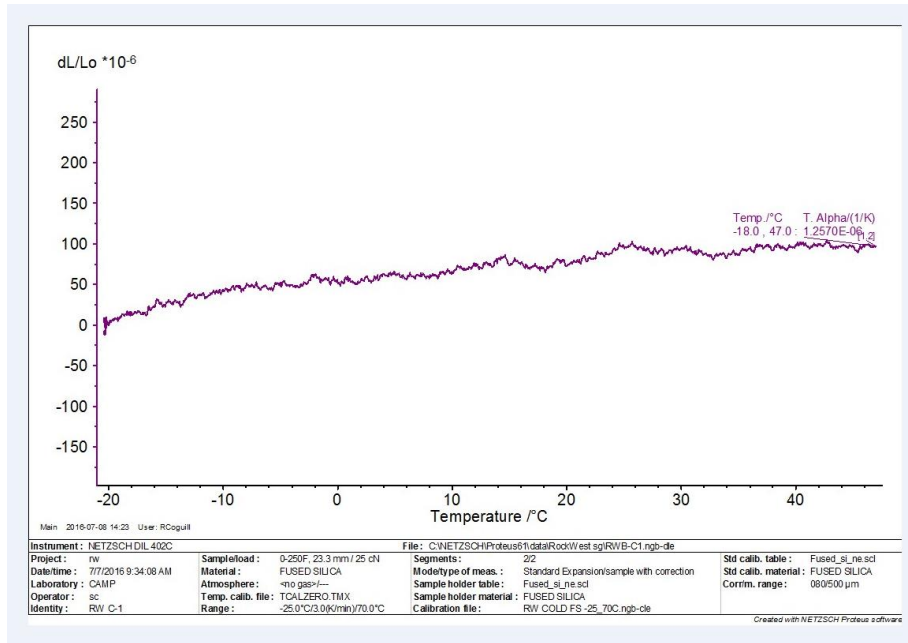


4" Beam Wall FPT Load Vs. Displacement

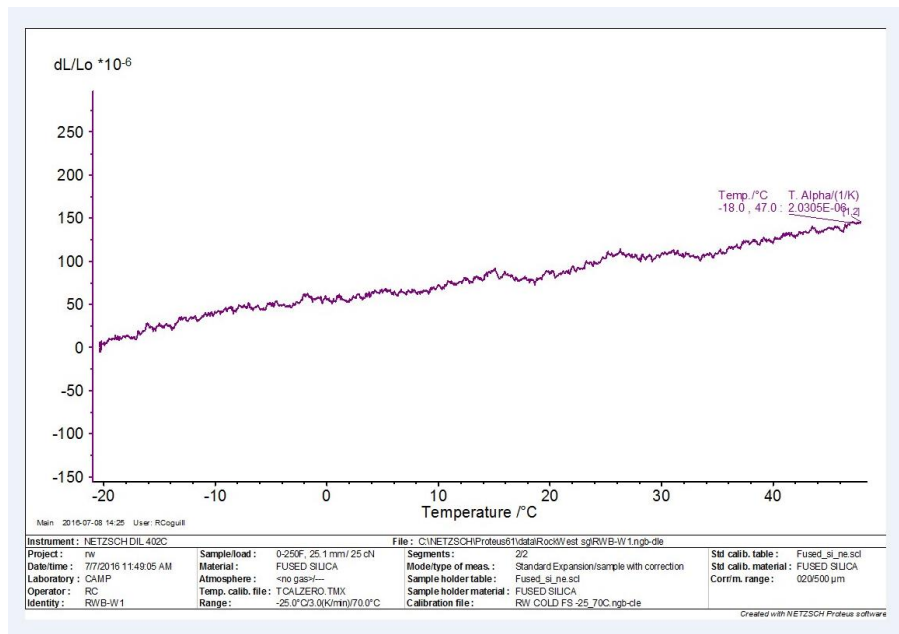


4" Beam Wall Bearing Stress vs. Bearing Strain





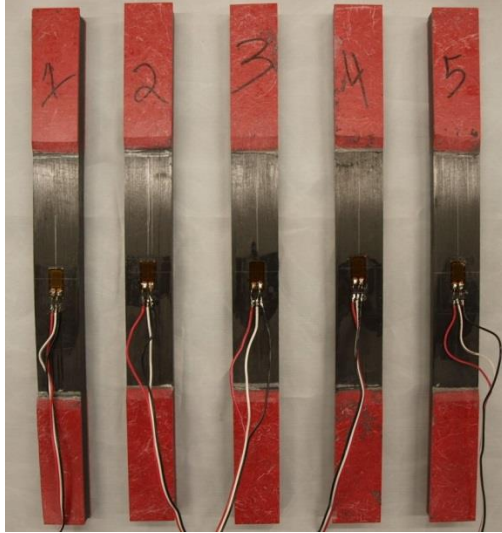
CTE Plot, Cap Sample



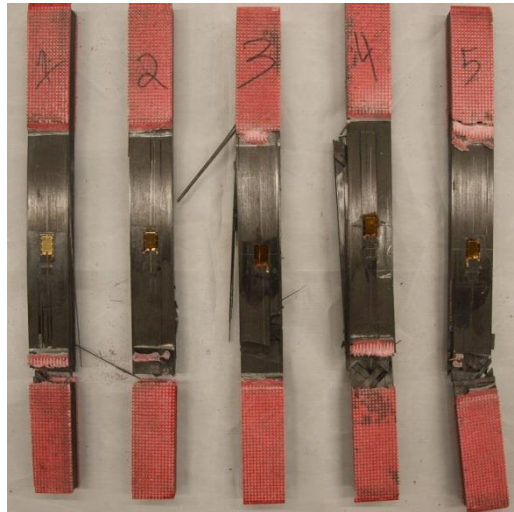
CTE Plot, Side Sample

TESTING PHOTOS

Tensile Specimens

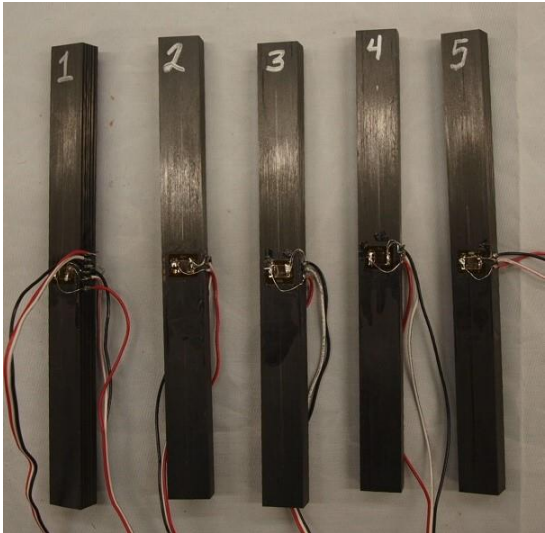


Tensile Specimens Pre-test



Tensile Specimens Post-test

Compression Specimens



Beam Compression Pre-Test



Beam Compression Post -Test

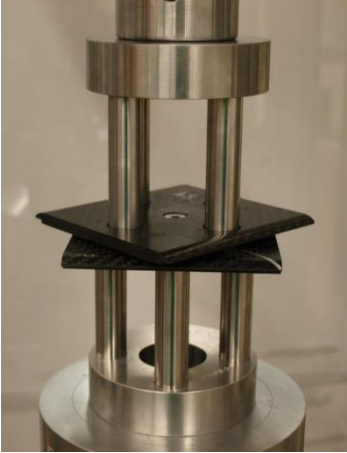
Fastener Pull-Thru Specimens



Fastener Pull-Thru Specimens pre test

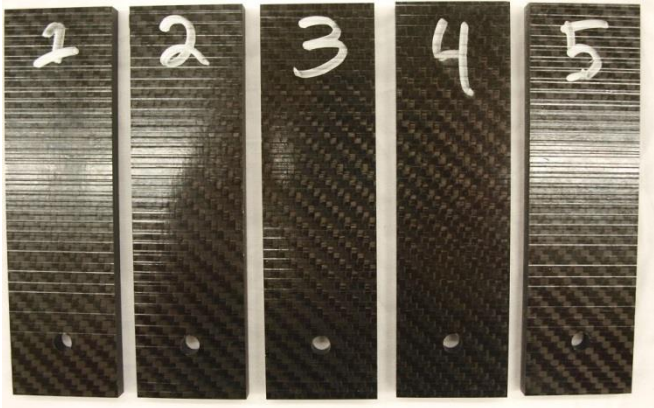


Fastener Pull-Thru Specimens post-test

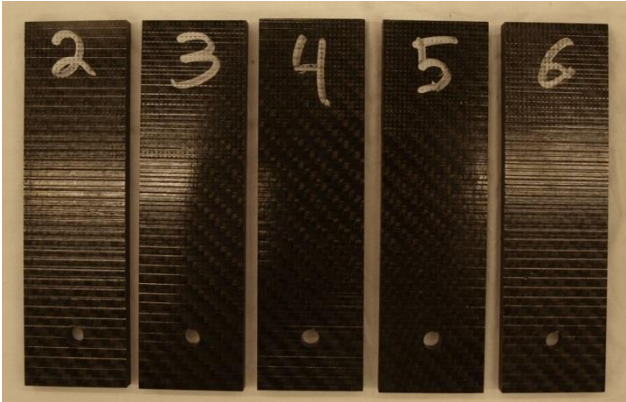


Fastener Pull-Thru Test Fixture

Bearing Stress Specimens



Beam Bearing Stress Specimens, Pre-Test



Beam Bearing Stress Specimens, Post-Test



Beam Bearing Stress specimen in Test Fixture

25511 Rev B Layup

PLY	MATERIAL	ANGLE	LENGTH
1	14060	0	
2	14060	0	
3	14060	0	
4	14060	90	
5	14060	90	
6	14060	0	Strip on narrow side
7	14060	0	Strip on narrow side
8	14060	0	Strip on narrow side
9	14060	0	Strip on narrow side
10	14060	0	Strip on narrow side
11	14060	0	Strip on narrow side
12	14060	45	
13	14060	-45	
14	14060	0	
15	14060	0	
16	14060	90	
17	14060	0	
18	14060	0	
19	14060	-45	
20	14060	45	
21	14060	0	Strip on narrow side
22	14060	0	Strip on narrow side
23	14060	0	Strip on narrow side
24	14060	0	Strip on narrow side
25	14060	0	Strip on narrow side
26	14060	0	Strip on narrow side
27	14060	90	
28	14060	90	
29	14060	0	
30	14060	0	
31	14060	0	
32	14033	0/90	

Material Codes

Raw Material Code	Weave	Aerial Weight	Fiber	Resin System
14060	Uni	300 gsm	<u>TR50S Fiber</u>	<u>Newport 301</u>
14033	2x2 Twill	300 gsm	<u>TR50S Fiber</u> or equivalent	<u>Newport 301</u>