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**MMC PROGRAM**

**MATERIALS:**  
 High Compressive Strength Composites (HCSC)  
 Carbon & Boron fiber reinforced epoxy (Hy-Bor)      Al<sub>2</sub>O<sub>3</sub> fiber reinforced Al (MMC)

**POTENTIAL APPLICATIONS**  
 Gun tubes  
 Projectiles

**PROGRAM GOALS**  
 Measure compressive properties at 0° & 90°  
 Evaluate and compare IITRI & CLC testing methods

**EXPERIMENTATION**

Specimen Requirements to Achieve Material Failure

Uniform stress region along gage length  

$$L_u \propto \left( \frac{R}{G_c} \right)^{1/2}$$

No buckling before failure  

$$\sigma_{cr} \propto \frac{K}{L^2} \left( \frac{R}{G_c} \right)$$

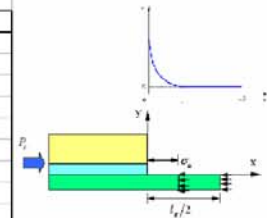
The two conflict  
 Thickness increases – buckling stress increases – uniform stress region decreases  
 Thickness decreases – buckling stress decreases – uniform stress region increases

**RESULTS OF MODELING TEST SPECIMENS**

- Must calculate ultimate strength for 90° and 0° with specimens that exhibit material failure (unif. stress region and no buckling)
  - At 90° above conditions can be met
  - At 0° uniform stress very difficult to obtain – need cross-ply laminates to backcalculate 0° ult. strength

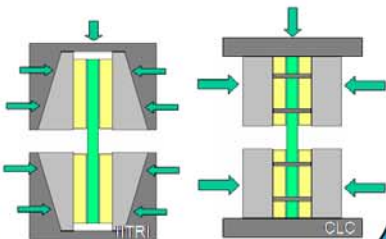
Uniform Stress Region for Hy-Bor

Lay-up	L <sub>u1</sub>	L <sub>uult</sub>
[90] <sub>18</sub>	0.1	0.3
[0/90 <sub>2</sub> ] <sub>25</sub>	0.14	0.22
[0/90 <sub>3</sub> ] <sub>25</sub>	0.13	0.24
[0/90 <sub>2</sub> ] <sub>25</sub>	0.17	0.16
[0/90] <sub>25</sub>	0.22	0.06
[0 <sub>2</sub> /90] <sub>25</sub>	0.29	-0.06
[0 <sub>3</sub> /90] <sub>25</sub>	0.3	-0.1
[0 <sub>4</sub> /90] <sub>25</sub>	0.37	-0.24
[0] <sub>14</sub>	0.59	-0.68



**TEST METHODS**

IITRI – shear loading  
 Machining precision requirements are lower  
 CLC – Combined loading = shear and end loading  
 End tab and adhesive failure less likely



**RESULTS**

Properties Table

	90		0/90 <sub>2</sub>		0/90	
	Strength (ksi)	Modulus (Msi)	Strength (ksi)	Modulus (Msi)	Strength (ksi)	Modulus (Msi)
Measured Properties	26.2	2.9	124	9.7	203	16.3
Volume Fraction	59		59		58	
Normalized Properties	32.6	3.47	153	12	254	20.4
Backcalculated 0 properties	-	-	417.4	30.4	380	29.8
Backcalculated & normalized 0 properties	-	-	516	37.6	470	36.9
Expected 0 strength = 469 ksi						
Expected 0 modulus = 41 Msi						

**ANALYSIS**

- A methodology was developed to design compressive specimens for HCSC without buckling and with a uniform stress region
- IITRI and CLC are equivalent; they provide similar mean and standard deviation values
- Back calculations of compressive properties at 0° agree with properties provided by the manufacturer

**FUTURE WORK**

- Further testing of Hy-Bor lay-ups
  - Vary gage size to check uniform stress region
- Compressive testing to be performed on MMC

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