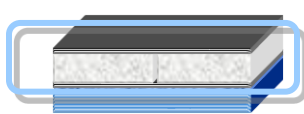


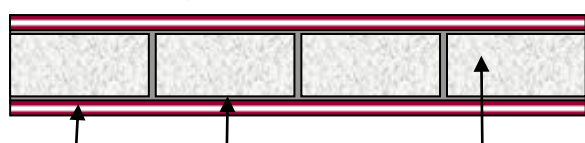
A. Gawandi, S. Alfredsson, L. Carlsson, T. Bogetti, and J. W. Gillespie, Jr.

University of Delaware . Center for Composite Materials

### FATIGUE AND DURABILITY OF DISCONTINUOUS CORE SANDWICH STRUCTURE



Ceramic Composite Hybrid Structure



Face sheet

Adhesive layer  
(may or may not be a discrete layer)

Discontinuous ceramic core

### FATIGUE AND DURABILITY OF DISCONTINUOUS CORE SANDWICH STRUCTURE

**Analytical Model**

$$\sigma_x^f = \sigma_x^{0f} + \frac{t_1}{t_3} \psi(x, T) - \frac{t_2}{t_3} \sigma_T^{ad}$$

$$\tau_{xz}^f = \frac{t_1}{t_3} \psi'(x, T) (h_2 - h_1 - \frac{t_3}{2})$$

$$\sigma_z^f = \frac{t_1}{2t_3} \psi''(x, T) (\frac{t_3}{2})^2$$

$$\sigma_x^{ad} = \sigma_x^{0ad} - \psi(x, T)$$

$$\tau_{xz}^{ad} = \psi'(x, T) t_1$$


$$\sigma_z^{ad} = \frac{\psi''(x, T)}{2} t_1 (t_2 + h_2)$$

$$\sigma_x^{ad} = \sigma_x^{0ad} + \sigma_T^{ad}$$

$$\tau_{xz}^{ad} = \psi'(x, T) t_1$$

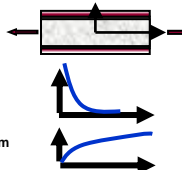
$$\sigma_z^{ad} = \psi''(x, T) t_1 (h_1 + \frac{t_3}{2} - (t_1 + \frac{t_2}{2}))$$

Global stress analysis



From [www.dewengineering.com/vehicle-crew-protection/vcp\\_products.htm](http://www.dewengineering.com/vehicle-crew-protection/vcp_products.htm)

**Unsmearing Critical Stress States Failure Analysis**

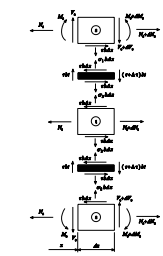


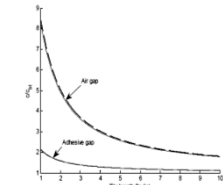
**Smearing**

Effective Modulus  
Effective Shear Modulus  
Effective CTE

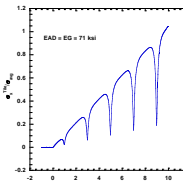
**Experiments to generate strength allowables**

### ANALYTICAL MODELS

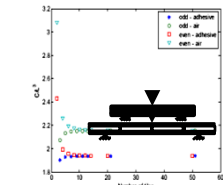




Compliance under in tension





Bending stress in tile in three-point flexure




Sandwich compliance in three-point flexure

### TENSION-TENSION FATIGUE AT 11% OF P<sub>ULT</sub>

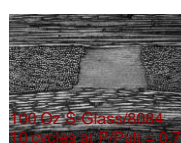
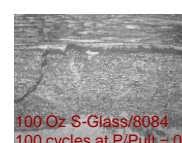
Tile crack near gap



Face sheet cracking

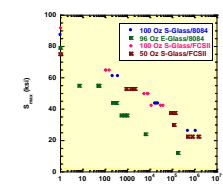
- ◆ 1st Crack developed in tile just above or below the gap on first cycle
- ◆ 2nd Crack at tile interface @ 1000 cycles; arrests in less than 0.2 inches)
- ◆ Outer crack in face sheet @ 4000 cycles
  - ◆ At 90/0 interface
  - ◆ Grows all the way to the grips

### FATIGUE TESTING OF FACE SHEET MATERIALS



100 Oz S-Glass/8184  
1 cycle at P/P<sub>ult</sub> = 0.7

100 Oz S-Glass/8084  
100 cycles at P/P<sub>ult</sub> = 0.5



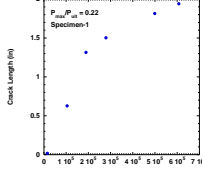
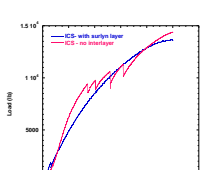
S/N curves

### EXPERIMENTS WITH COMPLIANT INTERLAYER

Specimen without interlayer

Specimen with interlayer

### ACKNOWLEDGEMENTS

This work is supported by the Army Research Laboratory through the Composites Applied Research and Technology Program.