DESIGN OF FIRE SAFE COMPOSITE STRUCTURES

J. Tierney, A. Paesano

J. W. Gillespie, Jr.

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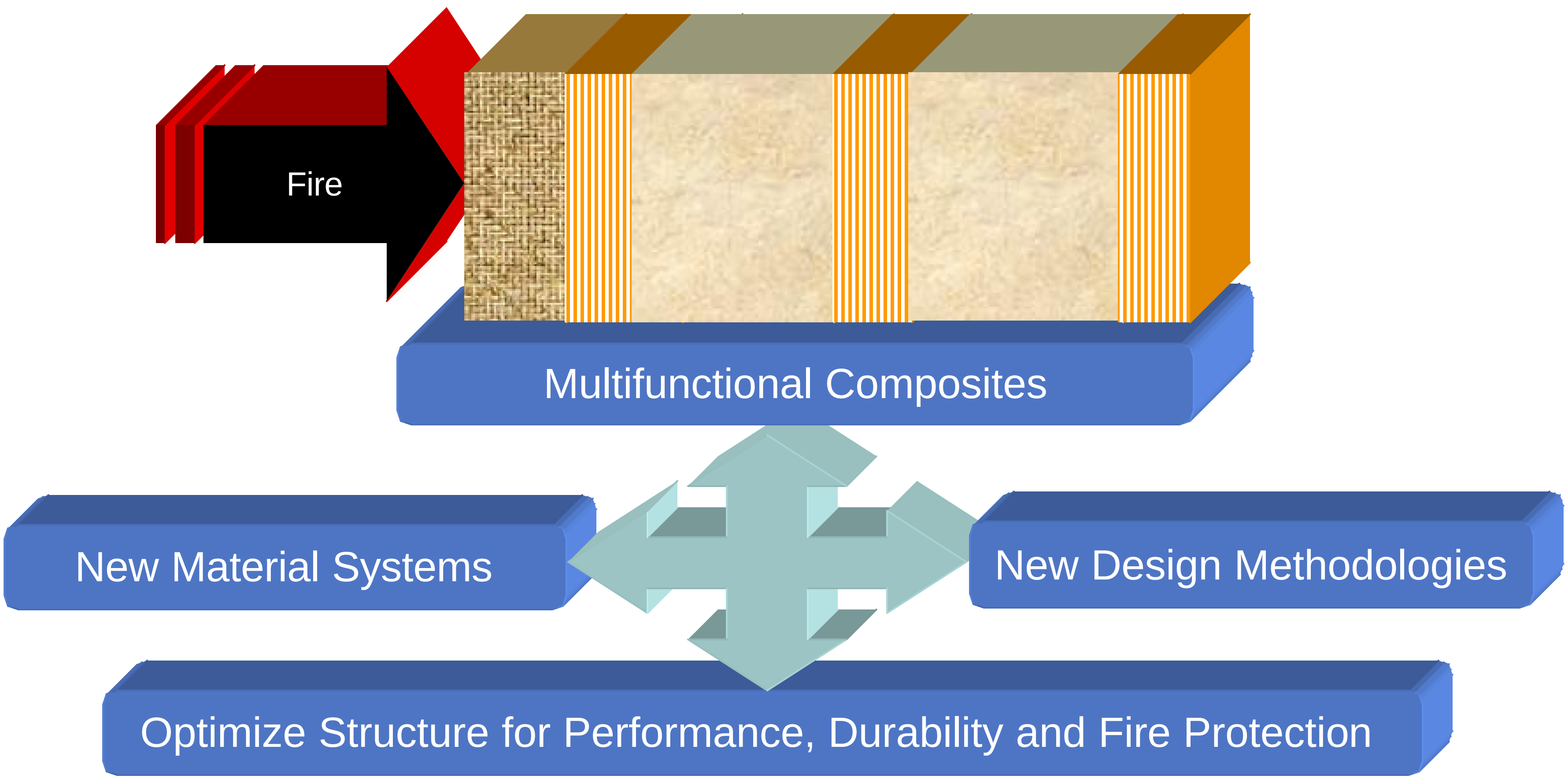
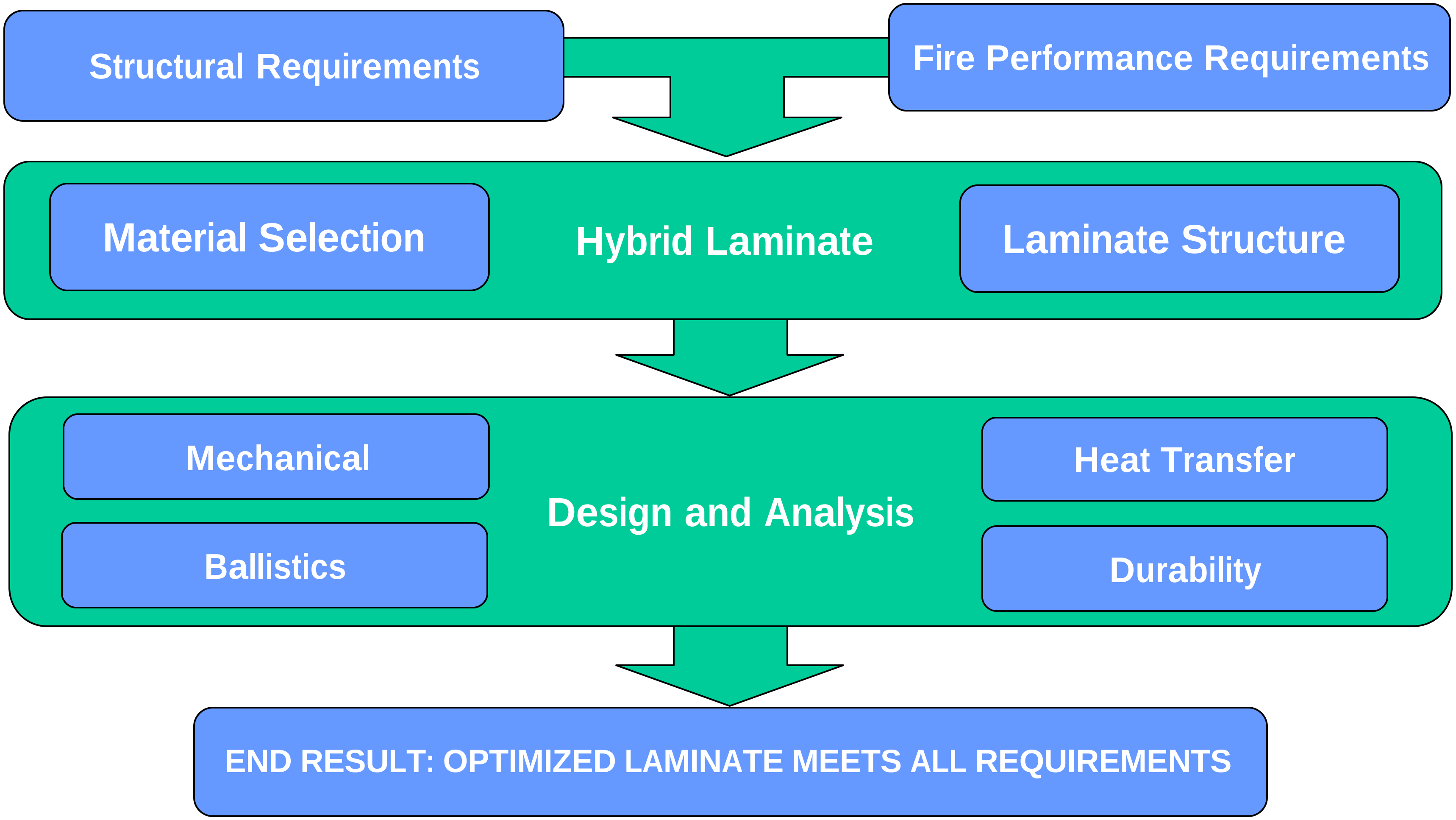
Model Based Approach

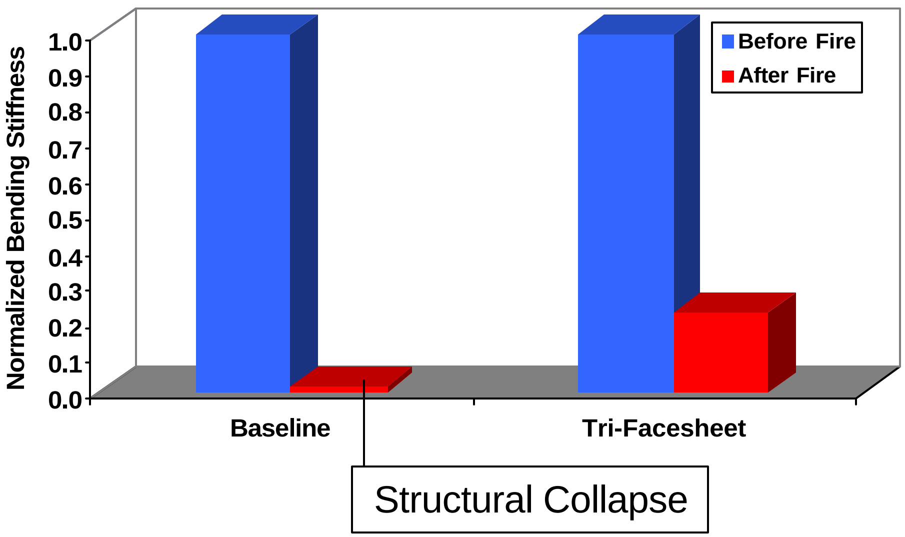


Model Based Approach

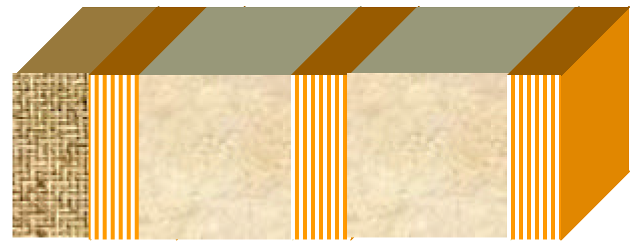


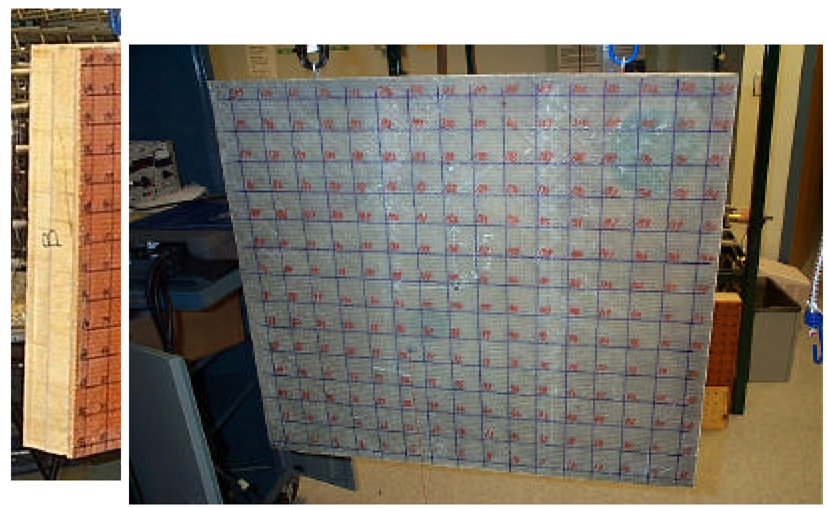
Structural Advantages of Hybrid Composites

Baseline Design



Tri-Facesheet Design

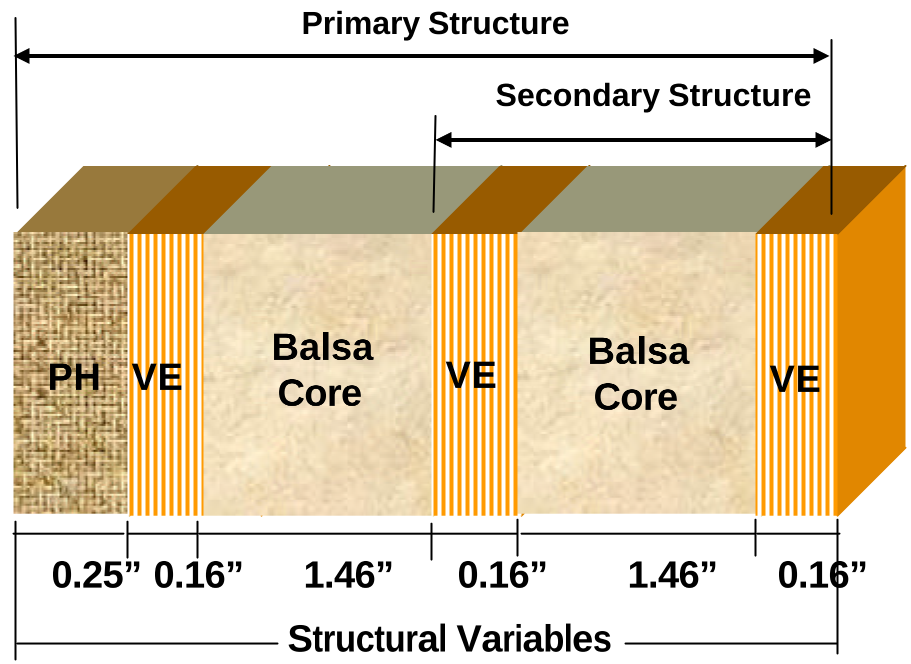


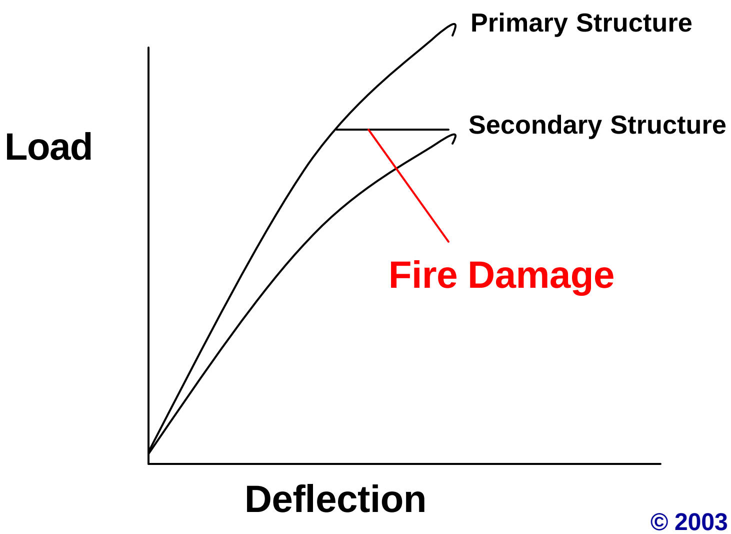


Director Room Structure

Phase II SBIR Program

- ✦Co-Injection Resin Transfer Molding (CIRTM) Process for Fire-Hard Composites.
- ✦SBIR with Anholt Technologies (Dan Coppens, Dave Harris)
- ✦Case study utilized a three layer vinyl-ester composite with balsa core material and a phenolic surface layer.

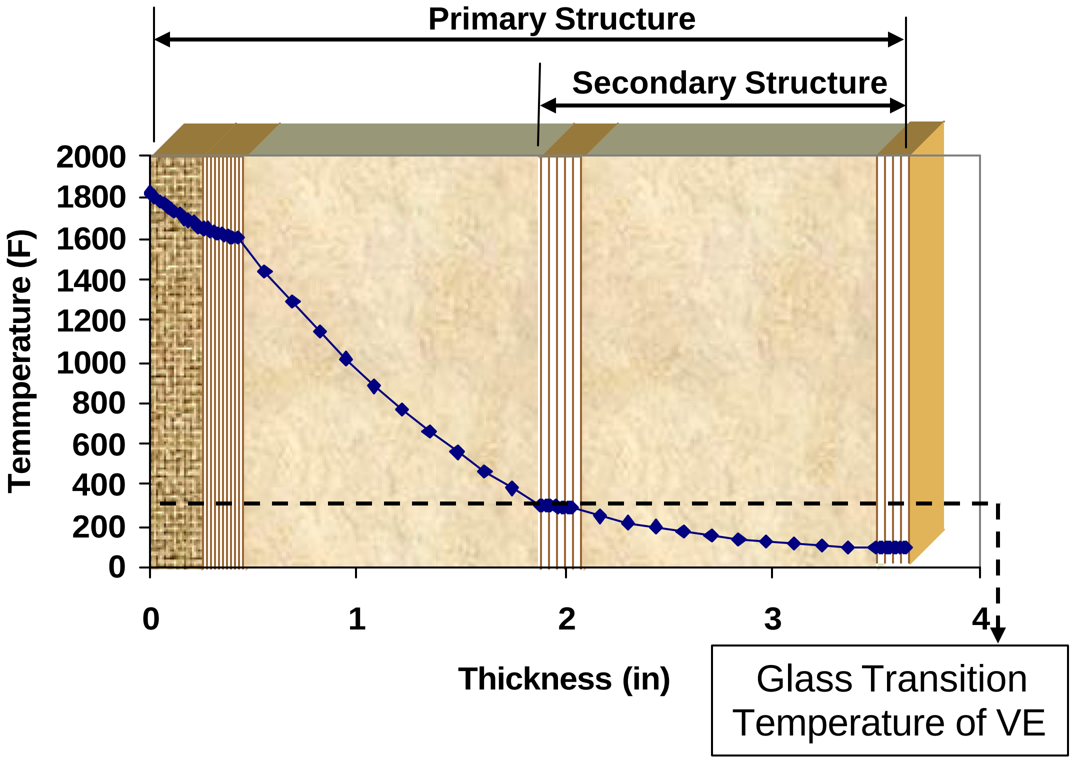




- ✦Structure exhibits change in stiffness due to fire damage.
- ✦Design variables shown can be used to optimize performance of structure under fire conditions

Transient Temperature Profile

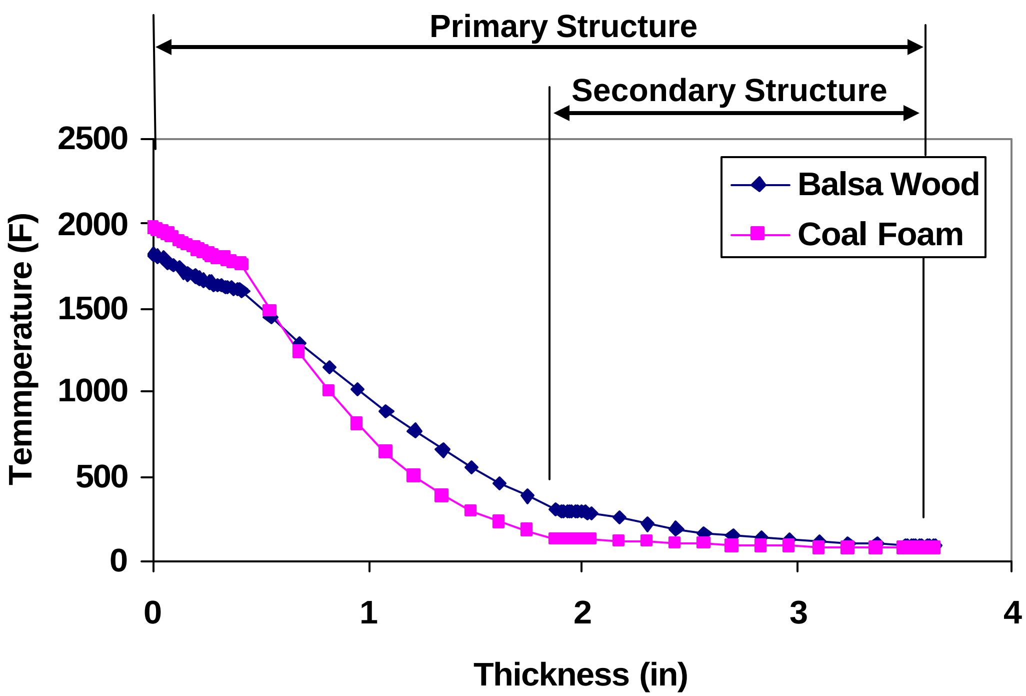
Steady State Temperature Profile with 2000°F Surface Heating (1/2 hour exposure)



- ✦ **Case study shows that the phenolic layer coupled with the balsa core successfully shields the secondary structure from exceeding the glass transition temperature of vinyl ester.**
- ✦ **Bending Stiffness is reduced by 6.75 when primary structure is reduced to secondary structure**

Alternative Hybrid Materials

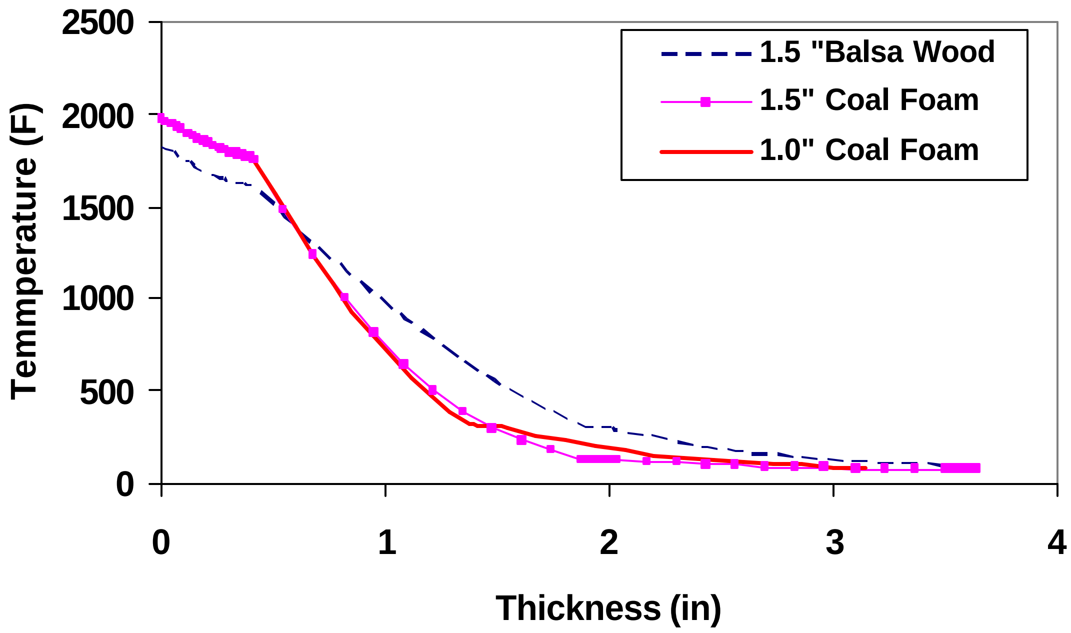
2000°F Surface Heating (1/2 hour exposure)



- ✦Replacing balsa core with coal foam insulation is found to significantly reduce secondary structure temperatures
- ✦Maximization of structural performance possible with optimization of core insulation material.

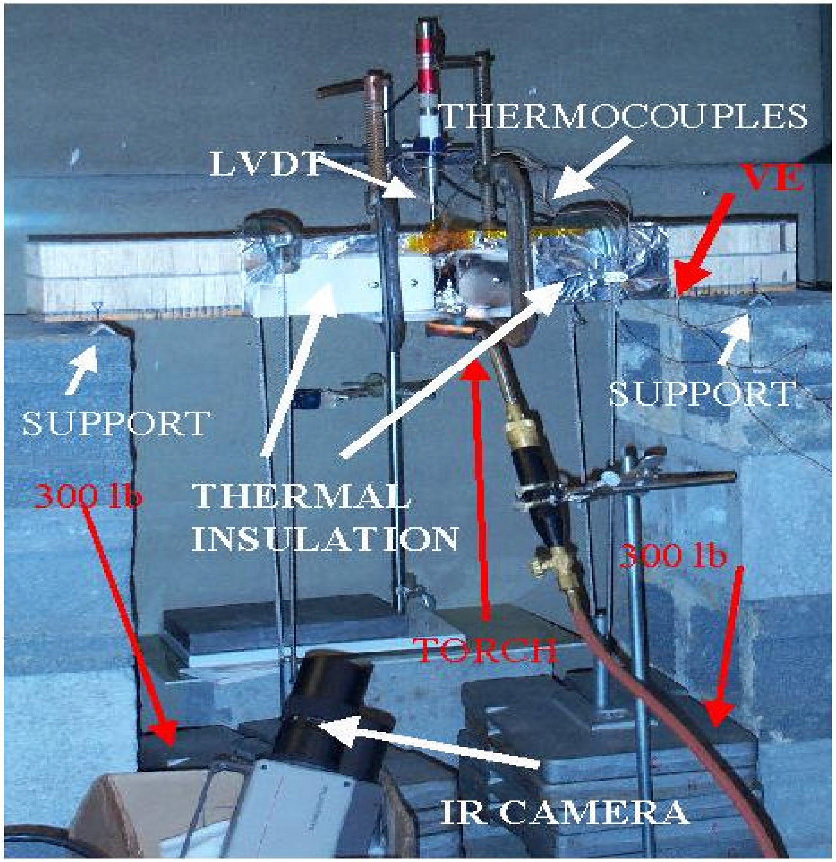
Alternative Hybrid Materials

2000°F Surface Heating (1/2 hour exposure)

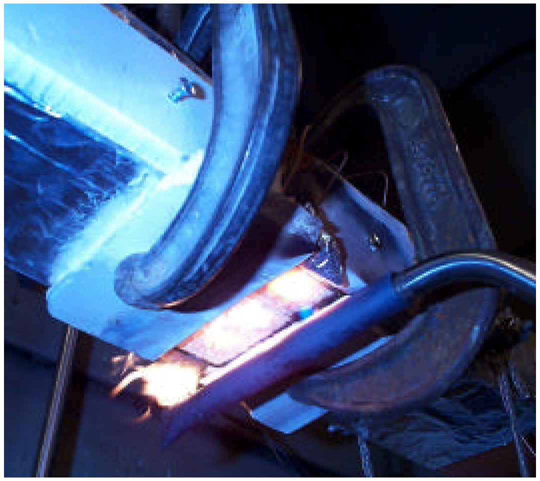


- ✦1" thick coal foam insulation still provides adequate protection to secondary structure after ½ hour exposure
- ✦Maximization of structural performance possible with optimization of core insulation properties and thickness.

Fire Testing

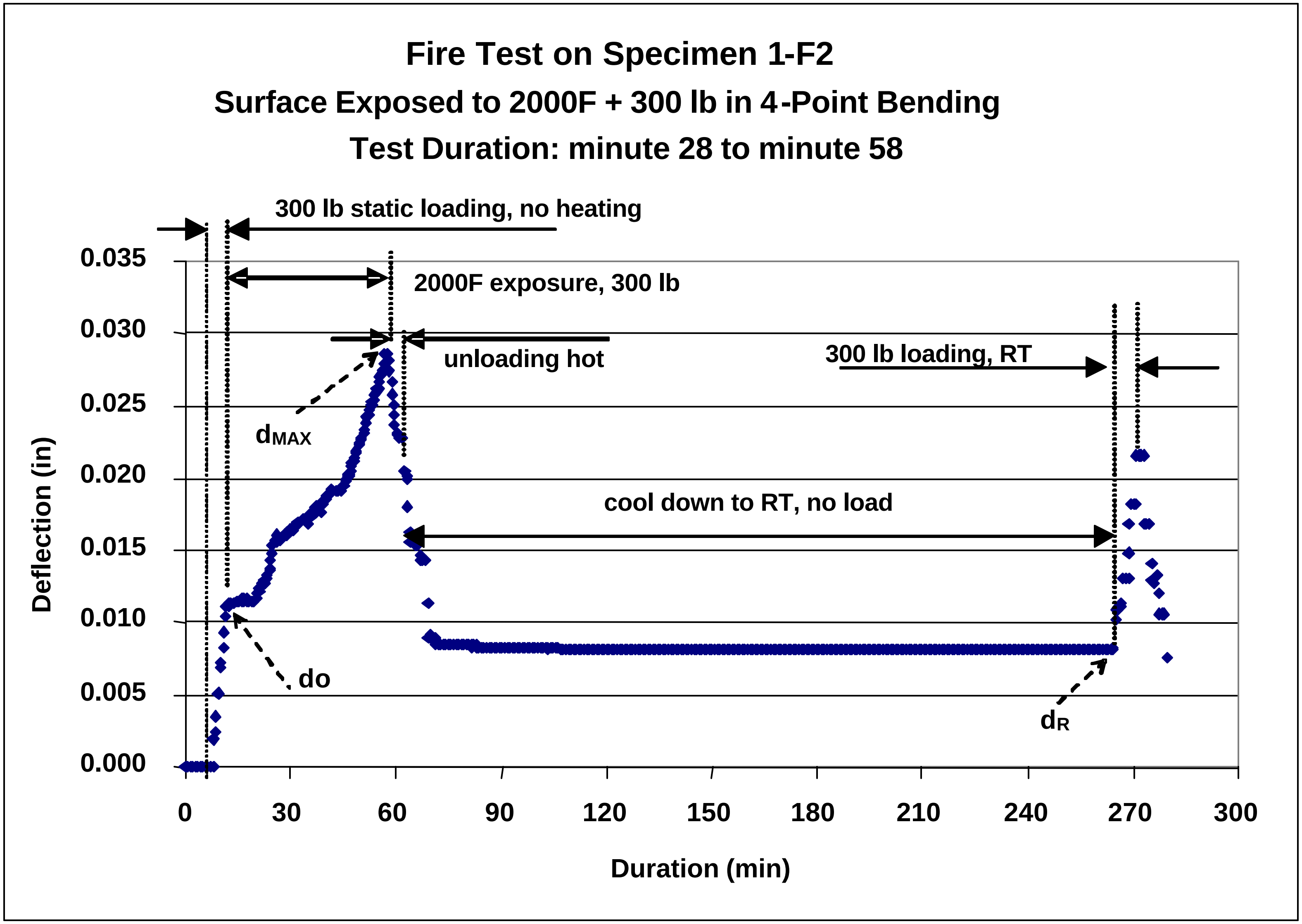


Successful Fire Testing of Hybrid Composite Beam under Bending Load using a Distributed Flame at 2000°F



- ✦ **Fire exposure was found to reduce the bending stiffness by 14% to 17%.**
- ✦ **The ultimate failure strength was reduced by 60%.**

Fire Testing Under Applied Load

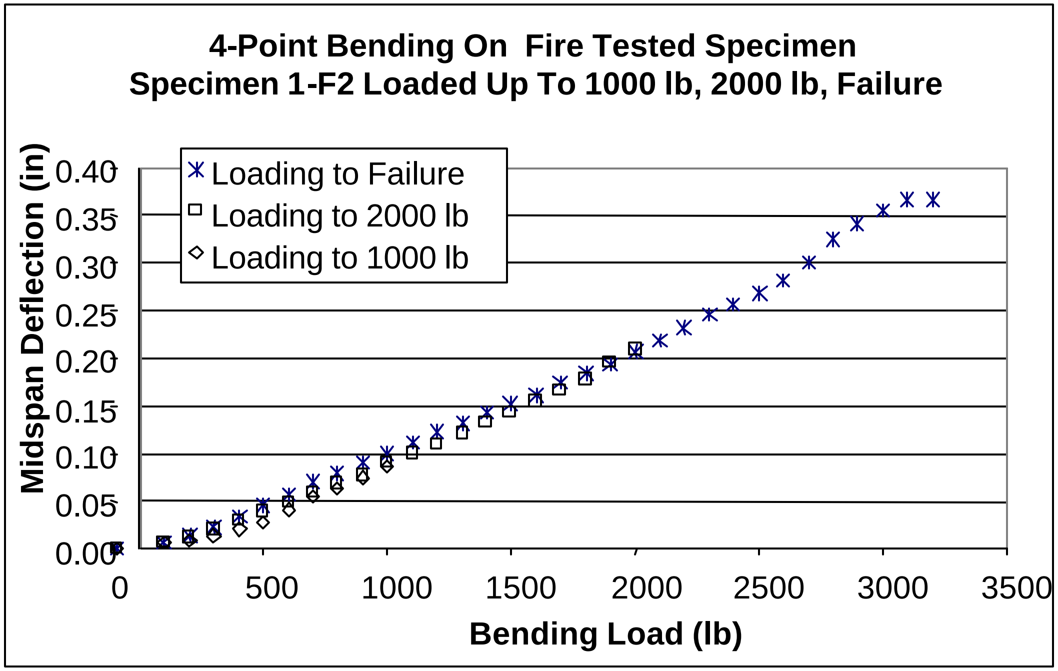


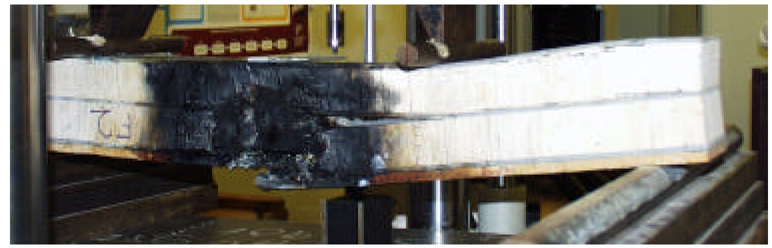
Fire Testing under Applied Load

	Midspan Deflection (in) Upon 300 lb Loading in 4-Point Bending					
Specimen	d_0	d_H	d_R	d_H/d_0		
1-F1	0.0112	0.0233	0.0053	2.08		
1-F2	0.0115	0.0286	0.0082	2.49		
	Panel Bending Stiffness (10^6 lb-in^2)					
Specimen	D_0	D_H	D_R	D_H/D_0	D_R/D_0	
1-F1	8.23	5.12	6.79	0.62	0.83	
1-F2	8.01	4.64	6.90	0.60	0.86	

The value of D_R show that the fire exposure reduces the bending stiffness by 14% to 17%.

Failure Testing



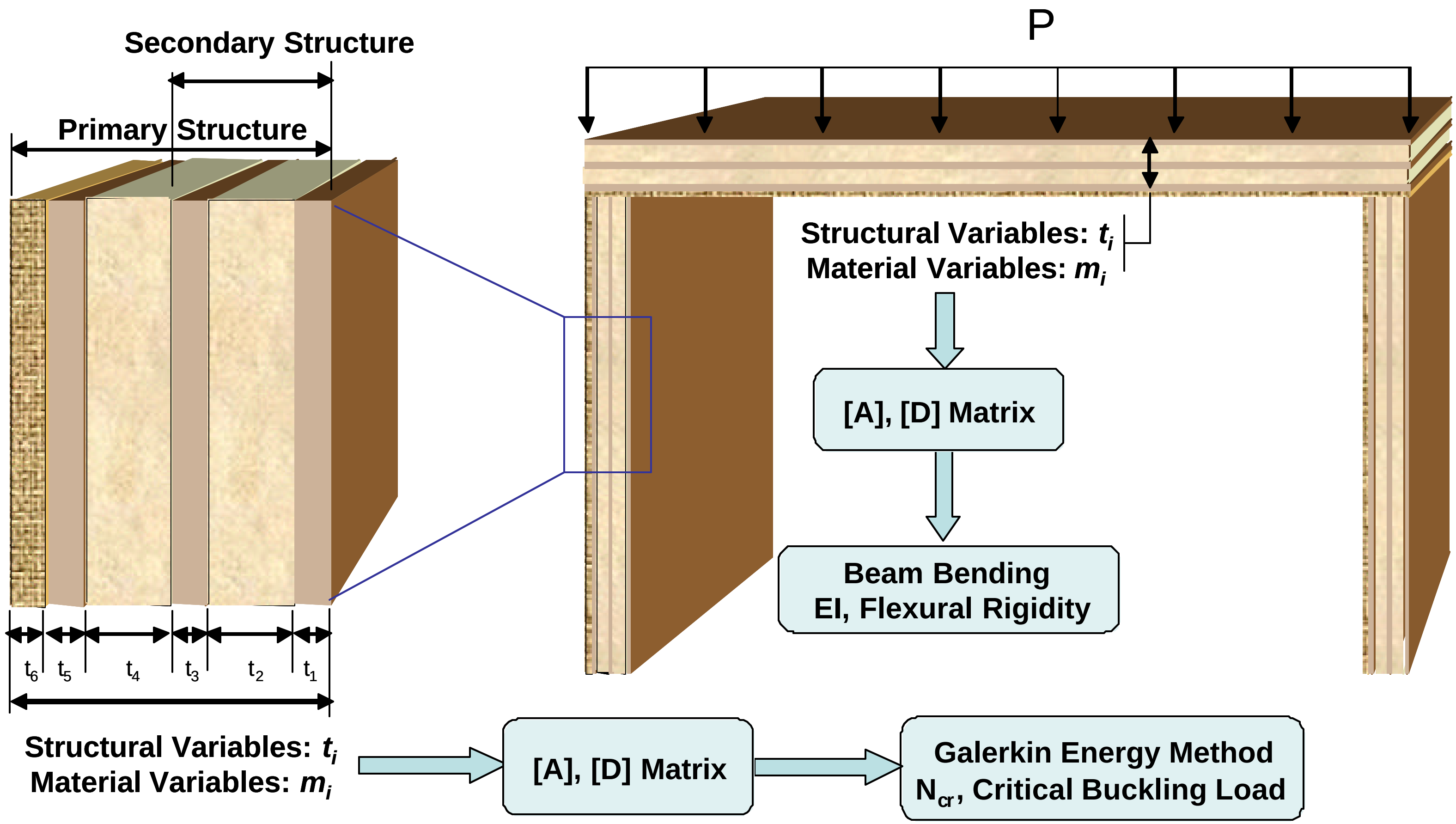


Panel after ultimate failure

	1st Test: Max. Load: 1000 lb	2nd Test: Max. Load: 2000 lb	3rd test: Max. Load (failure): 3380 lb	Virgin Specimen
Midspan Deflection (in) at 1000 lb	0.112	0.116	0.129	
D (10^6 lb-in^2)	6.54	4.55	3.94	16.8

Panels failed at 40% of the expected 5600lb load

Future Work: Generalized Optimization Techniques for Navy Structures



Summary and Future Work

- Hybrid composites show promise as an effective system for both structural performance and thermal protection.
- Fire testing at UD-CCM showed that CIRTM laminates retained significant strength and stiffness after prolonged exposure to a 2000°F open flame.
- Future work will involve development of a series of genetic algorithms to solve the problem of optimizing navy deck structures using a model based design approach rather than extensive testing.
- The optimization scheme will also take into account any weighted design variables such as the necessity to include additional fire protection materials, radar absorption material and a minimum damage resistance level.