DESIGN, FABRICATION AND TESTING OF COMPOSITE MATERIALS

Objective

The objective of this experiment is to demonstrate the principles of design, materials selection, fabrication and mechanical properties of composites, and to have fun doing it. We will design, fabricate and test a reinforced plaster-matrix composite. The goal of the material's design will be high strength, low weight and low cost. A test sample of this composite will be made and then 3-point bend tested. The best composite material will be the one that has the highest strength-to-weight-to-cost ratio.

Composite Materials

Composite materials are mixtures of distinctly different materials which, in combination, produce a material that has some of the best qualities of each. For example, combining an adhesive and small silver beads can produce a strong and electrically conductive glue. Or, by encasing strong and light, but brittle, carbon fibers in a tough and protective epoxy gives us high-performance carbon fiber composites used in aircraft, race cars and sports equipment. While these are examples of fairly exotic materials, the materials we use the most are also composites. Concrete and asphalt are aggregate composites and wood is a natural cellulose fiber/resin composite.

For structural composites, the role of the matrix material in a composite is to support and protect the reinforcing material. The reinforcing material, which is the stronger and stiffer component, is held together by the matrix. The matrix, or filler, material helps determine how loads are transferred to the reinforcing material, and protects it from the environment. Even with this simple picture of a structural composite material, there are three basic types:

Dispersion Strengthened Composites

These materials utilize low concentrations of very fine particles to improve strength by impeding the operation of the matrix material's normal deformation processes (how the atoms move past each other). Examples of dispersion strengthened composites include many metal-matrix composites (MMCs) such as thoria-dispersed nickel (TD-nickel, which retains its strength at high temperature because the microscopic ThO_2 particles do not soften or melt as easily as the nickel.), and aluminum oxide and silicon carbide reinforced aluminum used in high-performance bicycle frames. (Note, MMCs can also be fiber-reinforced composites.)

Figure 1 Final fracture during 3-point bend testing of a composite material

Particle-reinforced Composites

These materials utilize larger particles than in dispersion-strengthened composites, and in greater concentrations. The particles strengthen the composite by bearing a significant portion of the load and by restricting the flow of the softer matrix material. Examples of particle-reinforced composites include plastics which contain filler materials, and carbide cutting tools.

Fiber-reinforced Composites
These materials use stiff and strong fibers to reinforce a tough matrix material. These fibers may be short or long, and they may be aligned in the directions where loading will be greatest, or randomly oriented to give it equal strength in all directions. Examples of fiber-reinforced composite materials include fiberglass such as that used in boat hulls and automobile (Corvette) body panels and carbon-fiber composites used in high-performance air craft and sports equipment.

Mechanical Failure in Composites
Fractures in composites may originate in the reinforcing material, the matrix material, or in the interface between them. Failure may be due simply to an overload, but failure at loads below the design strength may be due to the presence of air bubbles or foreign materials, uneven distribution of the reinforcing material, poor bonding between the reinforcing and matrix materials, and external factors such as corrosion, heat, ultraviolet light, etc. Keep these factors in mind when designing and fabricating your composite test sample.

Raw Materials

Material	Cost Per Kilogram	Quantity Used (kg)	Cost
Fix-It-All	$0.75		
Water	$0.25		
Sand	$0.32		
Gravel	n/a		
Iron Wire	$1.93		
Wooden Dowel	$33.33		
Mono-Filament	$40.15		
Nylon Twine	$52.28		
Cotton Cord	$17.72		
Jute Rope	$7.53		
Aluminum Wire	$64.52		
Steel Cable	$10.89		
Aluminum Screen	$14.82		
Fiberglass Screen	$13.72		
	Totals:		

Making the Composite Test Sample

1. Assemble a mold, using masking tape to hold it together.
2. Write your name or sample number on the masking tape.
3. Collect up all of the materials you will need.
4. Thoroughly mix the water and plaster using 2 kg of plaster and 900 ml of water.

5. Combine the reinforcing and matrix materials.
6. When set, remove it from the mold, label it, and set it aside to fully harden and dry.
7. Weigh the sample and calculate the cost per weight ratio.

3-Point Bend Testing Procedure

Testing will be done using Instron 4204 universal testing systems. These are computer controlled systems which use electric motors to move a screw driven crosshead. Tensile and compressive forces up to 50 kN (11,000 pounds force) can be generated.

The testing procedure is:

1. Turn on the Instron system and perform the start-up calibrations.
2. Start the Series IX software and prepare testing method 02, 3-point bend.
3. Install the 3-point bend fixture (see figure 2).
4. Install the sample, taking care to align it correctly.
5. Lower the crosshead to where it almost touches the sample.
6. Start the automated test procedure.
7. Carefully watch the sample for the first cracks to form, and monitor the loads and the load-elongation graph.
8. Stop the test after the sample fails completely or before the fractured sample touches the base of the 3-point bend fixture.

Analysis of the Results

Print out the load-elongation plot and determine the load and elongation at which the sample failed. Use the attached form to compile the results from each test.

Determine which sample has the best strength-to-weight-to-cost ratio.

Examine the fractures to see if you can determine how your sample failed and how you might improve its performance.

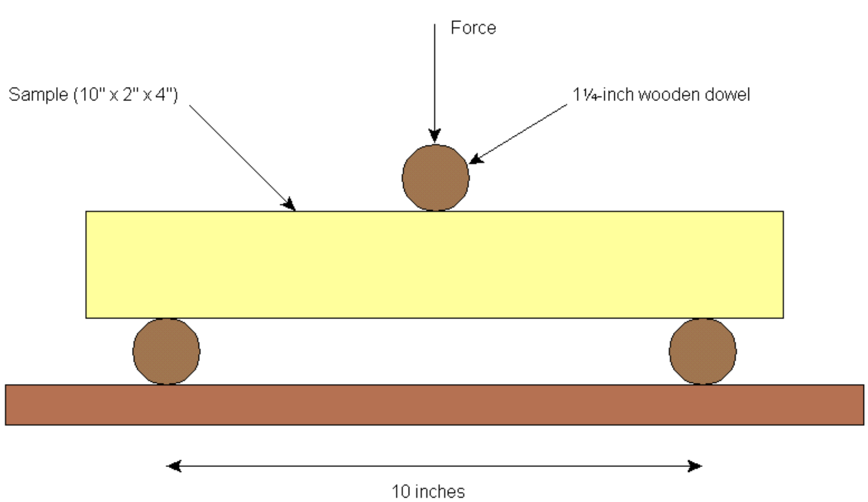

Figure 2 The 3-point bend fixture used in this experiment.

Results of Composites Testing

#	Designer	Description	Weight (kg)	Cost ($)	Max Load (kN)	Strength-Weight-Cost Ratio (kN/kg/$)
1	Instructor	Unreinforced plaster				
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						