Composites

Introduction

A composite material is a combination of two or more separate materials that has characteristics not shown by either of the materials separately. An automobile tire, for instance—an example of a composite material—is made of rubber reinforced by one or more types of fibers, such as nylon, rayon, steel, glass, or Kevlar. The rubber does a fine job of keeping the pressurized air inside, but would not survive the stresses imposed on it by the car as it is driven. The fibers are strong and tough, but it would be impossible for a structure made only from the fibers to hold air. Together, the materials form a composite structure that both holds air and resists stresses.

Looking more closely at the composition and structure of the tire tread, we can see that it too is a composite. The rubber provides a high friction force, very handy to have in the case of a car. A pure rubber tire wouldn't last very long, because the material is not very strong and becomes gummy when heated. Tiny balls of carbon known as carbon black reinforce the rubber and give it resistance to wear. Tire rubber compounds represent a trade-off between friction and durability, these factors being adjusted by the relative amounts of rubber and carbon black.

Composite materials have been around for a long time. Wood, a natural composite, is composed of cells made from cellulose fibers and bound together with a natural glue called lignin. If dried wood is examined under a microscope, the cellular arrangement becomes obvious. Although wood can be split parallel to these long cells, it is strong with the grain. The air spaces provided inside the cells of dried wood make it light in weight. This arrangement contributes to high strength at low weight and to toughness.

In the thirteenth century, the Mongols made composite bows from combinations of wood, animal tendons, silk, and adhesives. Even before that time, the Hebrew people added straw to their clay bricks to increase their durability.

Concrete is another example of a composite, and it has been made since Roman times. The rocks and sand are the reinforcement part of this composite, and the cement provides the cohesion that binds the structure/material together.

In addition to these "old" composites, the drive for stronger, stiffer, and lighter materials has produced many more modern composites of even higher performance such as tennis racquets, fishing poles, aircraft, space and automobile parts, and hulls of boats.

At the heart of any composite, a strong fibrous material bears the load. The fiber is constrained by the second material in the composite (the matrix) such that it takes the desired shape. Modern fishing rods are almost universally made from composites, whether the reinforcing fibers are glass, graphite, boron, or a mixture of these materials. The fibers, although strong, are not very stiff because they are very small in diameter, less than one-thousandth of an inch. By adding a matrix material, which is usually some type of epoxy in the case of the fishing rod, the fibers are tied together so that stress can be transferred from one fiber to another and so the fibers share the load. To further lighten the rod, it is made with a hollow core and is tapered so that the handle is thicker than the tip.

Most composites are used to make “things” that require high values of mechanical properties such as strength (resistance to breakage) or stiffness (resistance to bending) at a minimum weight. In these roles, composites can be made superior to structures made from any single material.

Modern composites use started with fiberglass in 1930, which is made from fine glass fibers bonded in most cases by polyester resin. The glass fibers are very strong in tension, and the resin helps to define the shape, bonds well to the fibers, and prevents the fibers from damaging each other by rubbing against their neighbors. Currently, many different types of fibers are available; the fibers are often quite expensive but are worth the price when the alternatives are considered. As more and more composite materials are used, the price will drop or become more compatible. Example: Some racquets, when they first came out, were $280 and now sell for $35.

A few years ago, composites were used only in parts of airplanes where their complete failure would have caused no serious problems. As confidence and reliability continues to increase, composites are being used in increasingly critical applications. Currently, several critical parts of passenger airliners are made from composites; some military airplanes are made largely from composites. Building the Voyager, the airplane that flew around the world without refueling in 1986, would have been impossible without modern composite materials.

Activity: Making Concrete

Student Learning Objectives

At the end of the activity students will be able to:

- describe a composite material
- explain why a composite might be chosen to replace more conventional materials
- participate in making concrete materials
- describe the process used in the experiment
- identify several composite materials used commonly in our lives.

Materials

- Portland cement
- Water
- Sand
- Gravel or small rock

Equipment

- 1- to 2-gallon plastic container
- Mold or dam (see #1 of procedure in Making Concrete or #1 under Testing Materials)
- Scale
- Stirring stick (strong wooden dowel would work)
- Clamp for securing concrete for testing
- Weights for testing strength of concrete

Procedure

1. Make a mold or dam into which the concrete can be poured. A dam could be as simple as placing 2- x 4-in. pieces of wood together to create a 4- x 4-in. square. A rectangle of larger dimensions also could be made. An appropriate mold could be a plastic glove or a silicone mold for shaping a part.
2. In a 1- to 2-gallon plastic container, thoroughly mix 258 g of sand, 404 g of rock, 93 g of water, and 118 g Portland cement.
3. Pour the mixture into the mold or dam.
4. Let the concrete cure over night before handling it.

Project: Varying Concrete Components and Testing New Materials

In this project you get to experiment with different com-positions of materials to make concrete and then test the concrete samples you create.

Procedure

Other concrete components—like sand or cement—can be varied, tested and the results compared. More sophisticated tests can be made by add-ing two component variables such as water and sand to the matrix.

1. Using the composition from step 2 in Making Concrete, change a single component in the composition, and test and evaluate how this variable will affect the material. An example would be to add 5% more water to a concrete batch. Try another sample with an additional 5% water, and analyze the material. A suggested test for your samples is found below (see Testing Materials).
2. Now reverse the process, and see how less water (5% and 10% less) affects the concrete. Test and record these results in your journal. Can the strength of these materials be evaluated from the results of these tests?
3. Another variation to the composition would be to replace rock with other materials, and investigate the results. Our garbage landfills are rapidly filling up. Are there some materials that could take the place of rock? Try ground-up milk jug parts or pieces of metal or ground automobile tires, and test the results of these concretes.

Testing Materials

1. To establish consistency in the data, you must establish a stan-dard method to test each concrete sample. An example would be to make a standard size mold (i.e., a wood mold 1 x 1 x 10 in.). Each concrete sample could then be poured into the mold and cured for the same length of time (i.e., 3 days or maybe 7 days—just be consistent). A simple procedure for testing the strength of concrete could be applied as follows. The set up is shown in Figure 8.1.
2. Secure each sample with a “C” clamp 2 in. in from the edge of a table. On the end of the sample suspended over the edge of the table, add a device (basket or hanger) from which weights can be added.
3. Obtain weights of approximately the same mass. Weights could be small blocks of concrete you can make and weigh or blocks of metal weighing approximately the same.

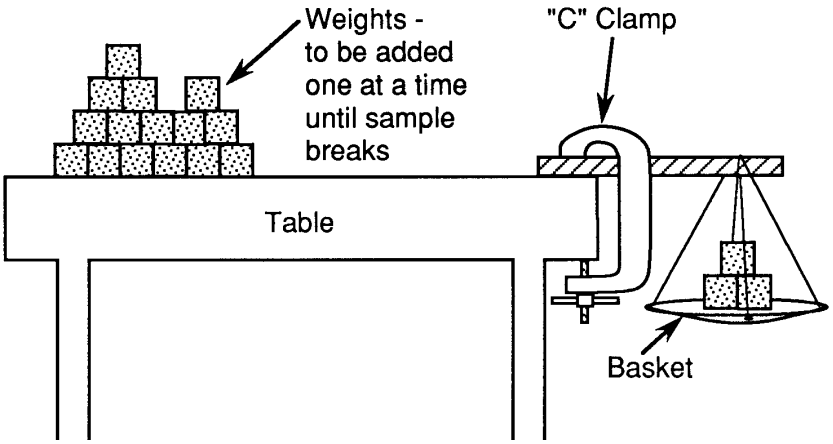

Figure 8.1. Testing Materials

4. Add weights one at a time to the basket until the sample breaks.
5. In your journal, record the weight necessary for failure to occur.

Composite Experiments
Instructor Notes

Reliability

All these experiments work well. Some experiments may require several trials if they have never been tried before.

Teacher Tips

1. These experiments help familiarize students with the processes and materials used to make common composites.
2. The experiments demonstrate the relationship among materials, weight, design of structure, and cost by taking students through building and testing different materials, doing a simple and crude strength-to-weight comparison, or a cost analysis of material types.
3. The experiments can also be highly detailed exercises in building and testing several identically sized test samples exposed to identical test conditions (See Young's Modulus Testing of Beams). Students can observe vastly differing results because of different material characteristics, even though objects are built to the same design. To accurately test materials this way, it is important that dimensions of each sample be identical.
4. Good examples exist of cross-linkage, types of fiber orientation, matrix formation, and stress/strain matrix curves in the Jacobs' textbook.
5. Epoxy curing time can be decreased by heating the epoxy in a furnace. Do not overheat the epoxy; it will burn. A suggested temperature of 50°C will dramatically decrease the curing time.
6. Fantastic household cleaner is an excellent substitute for cleaning sticky epoxy messes. We recommend this product (over acetone) because acetone has some health hazards associated with it.
7. Honeycomb is a difficult product to obtain. Boeing Surplus in Seattle, Washington, has been the main supply source. Contact a mentor teacher or PNL staff if additional material is needed.
8. Kevlar is made from fibers that are strong and thin. Special ceramic scissors from Jensen Tools, Inc. (See Vendor List in Appendix) are needed to effectively cut the fabric. These scissors are quite spendy. Use only as directed by manufacturer.
9. Tacky tape (zinc chromate) for the honeycomb composite project (#4) is supplied by Schnee-Morehead, Inc. (See Vendor List in Appendix). Some teachers have used molding clay with success.