Composite materials: Sticks and Glue

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Abstract
This module provides a specific example of the effect on strength and stiffness of a material when it is manufactured as a composite. In this case, one piece of wood (here a tongue depressor or a popsicle stick) is the control, and it can be bent as needed. By gluing two of these pieces of wood together (using just Elmer's glue), the strength and stiffness increases not by a factor of 2 (for 2 tongue depressors) but by a factor of almost 4. This can be a demonstrated but it is more convincing if the students can feel the difference in strength and stiffness for themselves. For a class activity, the instructor or an aide would need to glue together a set of pieces of wood sufficient for one per group of 2 or 3 students.

Objective: The student will be able to
Observe and explain the increase in stiffness and strength in a composite structure as compared to the initial components.

MatEd core competencies addressed (most important in bold)
0B Prepare tests and analyze data
4B Determine and develop effective project interactions
7C Relate the general nature of composite materials
8F Perform appropriate tests of composites
11A Illustrate the structure and advantages of composite materials

Key Words: Composite, sticks, glue, strength, stiffness

Type of Module: Demonstration or class laboratory

Time required
As a demonstration, 5 minutes
As a class lab, 15 to 20 minutes
Sample prep needs to be done the day before to allow for drying time

Grade Level
Grades 4 through college

Equipment and supplies needed
A supply of tongue depressors (or popsicle sticks if tongue depressors not available)
Woodworking glue (Elmer's works well)
Means of weighting down the samples while drying (books work fine)

If desired, additional means of testing (see below)

Instructor background and notes

The Boeing® Composites Glossary defines a composite material as one that:

a) Consists of two or more physically distinct and mechanically separable phases;
b) Can be made by mixing the separate materials in such a way that the dispersion of one material in the other can be done in a controlled way to achieve optimum properties; and
c) Has properties are superior, and possibly unique in some respects, to the properties of the individual components.

Composites are usually classified into 3 categories. Lamellar composites have layers such as in our experiment, usually glued together. The most obvious example is plywood. Particulate-reinforced composites have particles suspended in a matrix to add strength. Concrete is an example. Most commercial composites are fiber reinforced, such as the fiberglass used in boats and the high strength graphite fiber reinforced materials used in aircraft. In the latter case, the fibers provide strength while the matrix provides toughness.

In this simple experiment, just gluing the tongue depressors together to make a beam adds strength and stiffness. Simply speaking, the glue prevents the wood from sliding past one another, adding stiffness and preventing deformation. However, when tested in bending, it is also found that the beam is stronger not only than one tongue depressor but also stronger than 2 tongue depressors without the glue. As in most composites, the resultant glued beam is stronger than either of the components.

In this experiment, the increase in strength and stiffness is clear just by hand bending. This simple testing method is not unusual and is often used in technology. If desired, one can set up a more scientific bending experiment by supporting both ends of the beam and hanging weights from the middle, perhaps by adding weights to a bucket suspended from the center of the beam.

The time consuming part of this experiment is to make up the glued beams. The students can do this the day before, or an assistant can do this. The glue should be evenly spread and the tongue depressors held in contact by weights until dry. Doing this in a warm room speeds the drying.

Be sure to remind the students that wood itself is a composite material (before one of them does so). Wood is a hybrid that most closely could be classified as a fiber reinforced composite.

Experimental process

1. Discuss the concept of composites and discuss a few examples (or show some examples if you have any, such as plywood)
2. Pass out single tongue depressors to all students—ask them what properties they have. Also discuss wood as a composite
3. Demonstrate the properties of one tongue depressor then of one of the beams you have made by gluing two together. The latter will be stiffer and stronger.
4. If available, pass out similar glued beams, perhaps one per group of 2 or 3 students, and ask them to confirm your observation.
5. If desired, continue with tests by hanging weights on the beam. Compare to the simple tongue depressor.
6. Discuss the role of the matrix (the glue) and the wood in what is observed.

Further study

1. What would happen if 3 tongue depressors were glued together? Try it!
2. Investigate the structure of wood—why is it classified as a composite?
3. Investigate the structure of other common composites such as concrete and fiberglass. How are they used? What properties are enhanced? Why?
4. Research advanced composite use on an advanced aircraft such as the Boeing 787. What advantages come from using the composite instead of metals?

References

1. Structure of wood: http://waynesword.palomar.edu/trjuly99.htm
2. Basic composites: http://www.science.org.au/nova/059/059key.htm
3. Advanced composites search site: http://www.wwcomposites.com/

Evaluation:

Student evaluation questions (discussion or quiz):

1. What does "strength" mean?
2. What does "stiffness" mean?
3. What causes the glued beam to be stronger and stiffer than the single tongue depressor?
4. Suggest 3 places in your classroom where composites are used and explain why they are the best choice for that application.

Instructor evaluation questions:

1. At what grade level was this module used?
2. Was the level and rigor of the module what you expected? If not, how can it be improved?
3. Did the activity work as presented? Did they add to student learning? Please note any problems or suggestions.
4. Was the background material sufficient for your background? Sufficient for your discussion with the students? Comments?
5. Did the activity generate interest among the students? Explain.
6. Please provide your input on how this module can be improved, including comments or suggestions concerning the approach, focus and effectiveness of this activity in your context.

Evaluation:

Course evaluation questions (for the students)

1. Was the activity clear and understandable?
2. Was the instructor's explanation comprehensive and thorough?
3. Was the instructor interested in your questions?
4. Was the instructor able to answer your questions?
5. Was the importance of materials testing made clear?
6. What was the most interesting thing that you learned?