Composites

	Day 1	Day 2
Learning Objectives	Apply knowledge of composite materials from lecture to design a composite plaster brick to withstand the most weight before fracture subject to a cost constraint.	Evaluate the performance of their brick versus a plaster-only brick using knowledge of composite materials from lecture.
Time	45-60 minutes	45-60 minutes (can be shortened to 30 minutes if necessary)
Topics	1) Role of filler type and distribution in composite material performance. 2) Cost as a constraint in design.	1) Sample preparation in three-point bend tests. 2) How to conduct and analyze three-point bend test results.

Before the Lab:

Supplies to buy every time you run the activity:

1) Matrix material
   - Plaster of Paris (Michaels or Amazon)
   - ~ 8 lbs for four bricks (dim. 6" x 3" x ½")

Supplies to buy once:

1) Silicon mold-brick shaped (see example here)
2) Two 2" x 4" wooden boards long enough to span a 2 ft gap
3) 5 gallon bucket
4) Weights (we used bags of sand)
5) Tool to create the notch in the composite bricks (e.g., triangular file, nail file, razor blade)

Supplies to buy as needed: Should last 3-5 iterations of the activity:

1) Disposable 8-12 oz cups to measure out Plaster of Paris and water
2) Filler materials
   - Popsicle sticks
   - Rubber bands
   - Pipe cleaners
   - Pennies
   - Dry spaghetti
3) Tongue depressors to use to stir the Plaster of Paris

Prior Knowledge Recommended for Instructor:

1) Familiarity with basic mechanical properties
   - Stress and strain equations and curves
   - Three-point bend testing
2) Basic understanding of material fracture
   - Explain difference between ductile and brittle materials

Prior Knowledge Recommended for Students:

1) Types of bonding: metallic, covalent, non-covalent, ionic
2) Understand difference between material classes by look and feel: ceramic vs. metal vs. polymer

Composites: Day 1

Lab Set-up:

1) Before the students arrive, make sure each station has
   - A silicone mold that they will fill with the Plaster of Paris
   - Gloves
   - A pair of safety glasses
   - $6 worth of play money to use to buy their filler materials

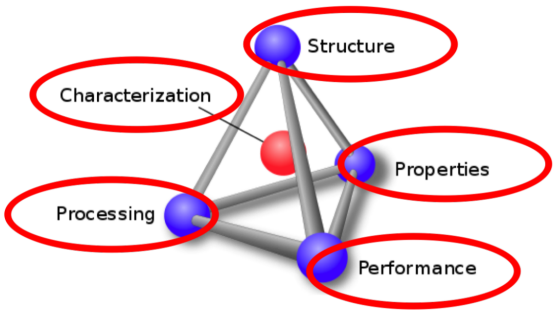
2) Place the filler materials in the middle of the students' table.

3) For each group, prepare one disposable cup that contains two cups of Plaster of Paris and one disposable cup that contains one cup of water to be given to the groups after they answer the design check question. This will make one 6" x 3" x ½" Plaster of Paris brick.

Pre-lab Questions:

The lecture before this lab should explain the basics of what components make up a composite and how the type and composition of the filler affects the fracture properties. After lecture, students will answer and then discuss the following questions with each other:

1) The composites activity fits into every category of the tetrahedron. Please explain why composites fits every category.



Answer: Composites fits with every category because you need to take into account the structure of the composite in order to describe its properties. We process the material by adding the filler material while the matrix is still wet. We then characterize the composite by testing its strength in the three-point bend test.

2) Why does adding filler materials to a material change how much force it takes to break the material?

Answer: The filler material interrupts the formation of dislocations along the direction of the applied force, which weaken the material enough to fracture.

Composites: Day 1

Running the lab Day 1:

1) Have the students sit at their stations and put on their safety glasses and gloves.

2) They should have already answered the pre-lab questions. Ask the students if they had any unresolved questions about the pre-lab questions.

3) Instruct the students to read all of the directions. At a certain point they will be asked to answer a concept check question. They will need to check their answer with a TA/instructor in order to get a certain piece of necessary equipment (in this case the Plaster of Paris and water.)

4) Do not give them the instructions verbally. The goal is to get the students to read everything and think about why they are doing what they are doing. At this point let them jump in but encourage them to raise their hands if they have questions.

Design check:

The design check for this lab tests students' ability to justify the type of filler as well as its distribution. Generally the more successful designs will include stiff filler that are arranged parallel to how the load is applied.

Have the students verify that their filler materials fall within the $6 budget.

When the students have explained their design, bring them two cups of Plaster of Paris and one cup of water. Use big enough cups for their Plaster of Paris so they can pour their water into the cup with the Plaster of Paris.

Material	Units	Cost	Modulus (GPa)
Plaster of Paris			10
Popsicle sticks	2	$3	5
Pipe Cleaners	2	$3	50
Rubber Bands	3	$1	0.05
Pennies	4	$3	100
Spaghetti	6	$2	1

Discussion points to cover after Day 1:

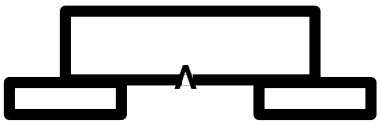
1) Why did your group choose the design it did?
2) Were there other designs you considered? Why did you not use them?
3) If cost was not a concern, how would you change your design?

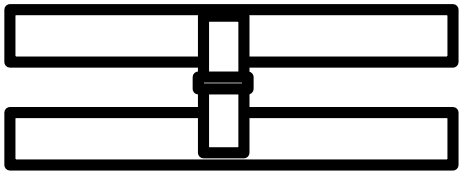
Composites: Day 2

Lab set up:

1) Notch each group's brick on the smoothest side of the brick. Notch should be a 2-4 mm deep, but needs to be consistent across each brick. Changes in the notch depth will affect how much force is required to break the brick and so the results will not be comparable.

1) Arrange two tables so there is a two-foot gap. Place the wooden boards across the gap. The brick will rest on the wooden boards and the bucket will rest on the brick. Make sure the teams place brick notch-side down.





Top view

Running the lab Day 2:

1) Have students sit by their group and wear safety glasses.
2) Conduct the three-point bend test on the non-composite control brick. Add weights one at a time. We suggest using 5 N and 10 N weights. We use 10 N and 5 N bags of sand. Add the 10 N bags first until the brick starts to bend and then switch to 5 N. Usually the brick will bend first and then snap.
3) Call groups up one at a time. Have the group place their brick on the boards. Ask the students which way the notch should face before they start.
4) Have students do the three-point bend test using the same procedure you showed them for the control brick.
5) Have the students report the amount of N their brick withstood to you or a TA.

Discussion points to cover after Day 2:

1) How much force (in N) did your composite withstand?
2) Describe what the fracture surface looks like.
3) What type of filler and distribution of filler did the strongest brick use?
4) How would you change your design to improve performance?