Engineering with Reinforced Concrete

Audience: Grades 6 - 8

Objectives: The students will:

- Design and build at least two reinforced concrete structural elements.
- Design and implement a test to evaluate the strength of their structural elements.
- Synthesize the results of numerous tests to arrive at an optimal design for a specific application.

Background Information

The Romans began using concrete around 300 BCE. It enabled them to build structures such as the world had never seen. The Pantheon, still standing in Rome, is capped by what remains the world's largest unreinforced dome. When Roman civilization collapsed, the secret of concrete was lost. It would take the world nearly 1,200 years to rediscover how to make it.

Today, concrete is the most commonly used building material (steel is #2). Concrete is composed of sand and gravel, glued together by Portland cement and water. Portland cement is made by grinding and baking a mixture of limestone and clay. The water in concrete serves two purposes. It is a component of the chemical reactions which allow the cement to harden and bond with the sand and gravel. The water also allows concrete to flow before it hardens. This property is extremely important as concrete is generally poured into molds called **forms** to achieve the desired shape.

The most common elements in concrete are silicon, oxygen, calcium, and aluminum. These are present in the cement as well as the sand and gravel.

Concrete is very strong at resisting compression forces. Unfortunately it is very weak in tension. Stretching or bending allows cracks to spread rapidly. To help it resist tension forces, concrete is usually reinforced by being poured around a mesh of steel bars, called **rebar** in the construction industry.

Materials for this Activity

Per group of 2:

- 1 cardstock sheet with forms and spreading tool
- 4 Styrofoam cups
- 1 Styrofoam plate
- 1 craft sticks
- 1 roll of tape
- 1 pair scissors
- 1 ruler

Per class of 30:

- 100 small, smooth paper clips
- 100 small, textured paper clips
- 3 kg of Portland cement
- 3 kg of sand
- 4 graduated cylinders (50+ ml)
- 15 meter sticks
- 2 liters of tap water
- 1 scale (accurate to 1 gram)
- 30 goggles
- 30 pair lab gloves
- Assortment of small, heavy objects for dropping on concrete
- String, buckets, and sand for doing load tests

NGSS Performance Expectations Addressed

- Physical Science: MS–PS1-3
- Engineering Design: MS–ETS1-1 through 4

An additional three NGSS performance expectations may be addressed using optional extensions described in the *Extensions* section on the last page of this document.

Logistics

Workspace: A classroom with level tables/desks and bare floors is required. Desks with sloping tops are not suitable. Concrete (wet or dry) spilled on a tile floor is an easy cleanup. Such spills could cause permanent damage to carpeting.

Time: Total time is approximately 140 minutes as detailed below:

1. Choosing a disaster and designing the test: 25 minutes
2. Designing the slab: 15 minutes
3. Making slab A: 25 minutes (must be completed in one session)
4. Making slab B: 25 minutes (must be completed in one session)
5. Testing the slabs: 35 minutes (after slabs have had 24+ hours to dry)
6. Synthesis and debrief: 15 minutes

Suggested Inquiry Approach

Advanced preparation:

Place a chair or other large object in the classroom sink. Put a sign on the object: "DO NOT PUT ANYTHING INTO THE SINK TODAY". Portland cement and wet concrete can easily clog drains. All waste should be put in plastic bags or lined trash cans during this activity.

Begin with a class discussion:

- What do you already know about concrete?
- Name some different uses for concrete.
- What makes concrete a good choice for those applications?
- Have you ever seen a toothbrush or a hat made from concrete?
- What makes it unsuitable for these applications?

Show students the slideshow about the history and chemistry of concrete.

Have a volunteer read the **Problem Statement**. Another volunteer can read **Choose Your Disaster**.

Give the students any restrictions or guidelines you prefer on choice of disasters. The disaster must involve a physical force that could severely damage a home or school building. Famine, disease, and radiation are all potential threats, but don't require protection from physical forces.

Have students form groups of two or three and begin working from the Student Pages. Be sure they get your approval on their ideas. Get them to commit to details in their testing plan. They may use a destructive test (which destroys their slab) but in any case the test must be able to **quantify the strength** of their slab. The test should, in some way, model forces being applied by their chosen disaster.

Allow them to collect the materials listed on their student pages. Show them the location of gloves and goggles which they will need before mixing concrete.

Steps 1 – 4 have students creating a card stock form for holding their concrete.

In step 5 they will need four paper clips for rebar. Show them that one box has smooth paper clips, while the other has textured clips. They should choose one or the other, but not mix.

Steps 6 – 11 have students choosing the amounts of sand, Portland cement, and water to use in their concrete.

SAFETY NOTE: Before proceeding, ensure all students are wearing goggles and gloves. Wet concrete has a high pH, meaning it is caustic. Prolonged exposure can burn the skin.

Steps 9 – 18 have students mixing their ingredients and pouring the wet concrete into their forms.

The reinforced concrete slabs will need to dry overnight.

The next day of the activity begins with students comparing their slabs with those made by other groups. Encourage them to look for relationships between the amounts of materials used and the appearance of the concrete.

Students will conduct their tests to assess the strengths of their slabs. Remind them that the goal is to quantify the strength of each slab.

After everyone has finished testing, have them circulate around the room examining the Design Sheets of other groups.

Lead a class discussion in which students attempt to identify which design features resulted in the strongest slabs. You may choose to discuss each variable in turn and ask students who evaluated that variable to state their findings.

Finally, based on all the testing performed by the class, students will describe what they feel would be the ideal design for their particular application. Remind them to justify their choices by citing test data.

Debrief

- What are the three ingredients of concrete?
- What purpose was served by the rebar?
- What additional tests would you want to do before deciding what type of reinforced concrete to use in your shelter?

Cleanup

Dry Portland cement and wet concrete can be easily cleaned up using a damp paper towel. Do not allow wet concrete to dry on tables or floors.

Extensions

- Research the frequencies of natural disasters in your area to determine the greatest threat. This extension allows NGSS Performance Expectation MS-ESS3-2 to be addressed as well.
- The production of Portland cement puts a great deal of carbon dioxide into the atmosphere. This contributes to global climate change. Research the use of "green" alternatives to Portland cement. This extension allows NGSS Performance Expectation MS-ESS3-3 to be addressed as well.
- After testing their slabs, ask students if the formation of concrete involves a chemical change or just a physical change. Using leftover materials, have them design an experiment to test their ideas. This allows NGSS Performance Expectation MS–PS1-2 to be addressed as well.
- Modern concrete tends to deteriorate within 100 years. The Romans, however, built concrete structures which are still in use after nearly 2,000 years. Do some research online to see what made "Roman concrete" different from modern concrete.
- Research the Pantheon, the Coliseum, and Roman aqueducts to learn how concrete was used in these structures.

Assessment

Use whatever rubric you prefer for grading laboratory experiments. This activity includes a set of Student Pages which require them to document every decision and observation. These pages may be collected and graded by assigning point values to each response.