Taking Concrete Sustainability into the Elementary Classroom

Hands-on experimentation introduces students to science, technology, and engineering

by Ara A. Jeknavorian

In the growing movement of advancing science, technology, engineering, arts, and math (STEAM) education in school curriculums, can introducing concrete sustainability to the elementary school classroom be a meaningful and enriching experience? An opportunity to address this question was made possible thanks to the annual Baker Elementary School (Moorestown, NJ) Science Day program.

The process began with the school's Science Day coordinators reaching out to science-oriented parent volunteers who would be willing to make a 10- to 15-minute presentation on a technology and then engage elementary school students with a related hands-on science activity lasting approximately 30 minutes.

Two of my granddaughters attend the school, so my daughter introduced me to the Science Day program to gauge my interest in possibly participating with a chemistry-related project. With a strong interest in introducing young students to scientific concepts, I took on the challenge with enthusiasm. Having spent 34 years conducting research and development on chemical admixtures for concrete, a concrete-related project was my natural first choice. After all, the students should be aware of the properties of concrete, the most manufactured material in the world. Their prior exposure to it made the project something students could readily grasp.

After reviewing possible topics related to concrete and chemical admixtures and considering the opportunity to introduce the very relevant issue of sustainability in concrete construction, I decided students could readily appreciate a project dealing with leftover concrete.

Topics presented by other participants included:
- Computer forensics;
- Dentistry;
- Elevator engineering;
- Orthodontics;
- Cognitive science;
- Instructional app design;
- Diabetes research;
- Astronomy;
- The human heart;
- Architecture; and
- Pharmacology.

Presentation

My picture-laden PowerPoint presentation introduced students to basic concrete technology. The specific discussion topics focused on:
- What a chemist does;
- The composition of concrete;
- The difference between cement and concrete;
- Concrete as a global building material;
- The basic function of chemical admixtures;
- The reasons a construction project can have leftover concrete and the value of recycling concrete;
- Details of the experiment; and
- Ensuring the safety of the students while conducting the various procedures.

The students learned that if the concrete could be kept in a workable condition for some period, under certain circumstances, it could eventually be blended with fresh concrete and used for certain allowed applications such as walls and blocks. This would avoid the cost and effort of disposing of the concrete or of mechanically separating the concrete and reclaiming the sand and stone for use as a partial replacement of fresh sand and stone.

With respect to enabling the use of leftover concrete, I developed the idea for an interesting project whereby students would learn how a common sweetener, sugar (sucrose), can keep mortar from hardening for an extended period. Having the Science Day on a Friday created a special challenge requiring that the mortar samples prepared with the sucrose solution be kept from hardening over the weekend.

In designing the hands-on experiment, a set of objectives was developed to:
- Help students understand the mixing process to make mortar;

- Introduce the concept of how certain chemicals can alter the hardening rate of cementitious mixtures;
- Explain how to set up a control experiment and follow a set procedure; and
- Demonstrate how the hardening of mortar can be significantly delayed.

While the presentation was in progress, sealed samples of cement clinker, cement, sand, and a small toy concrete mixer truck along with a small piece of polished concrete were passed around the classroom to help the students visualize the difference between cement and concrete—two terms very commonly confused by the general public.

Summary of Hands-on Science Experiment

Each student prepared a mortar mixture using a preweighed mixture of cement and sand contained in a plastic vial. Half of the students used water, while the other half used a sucrose solution as the mixing water. After the mortar samples were prepared, an "anchor" was immersed in the mortar and the vials were covered. After 72 hours, the students pulled on the anchors and recorded their observations.

Equipment and materials

Each student was given a test kit with the following items contained in a sealed ziplock plastic bag (Fig. 1):

Fig. 1: Each student was provided a science kit in a ziplock plastic bag

Fig. 2: A 25 mL vial with a cement and sand mixture. The vial cover was fitted with a paper clip affixed to a small clothespin

- A pair of small rubber gloves;
- Plastic safety glasses appropriate for young students;
- A 25 mL clear, numbered plastic vial with a snap cover containing a mixture of 2 g of portland cement and 3 g of concrete sand conforming to ASTM C33/C33M, "Standard Specification for Concrete Aggregates." A small hole was made in the vial cover through which a paper clip was inserted. A 10 mm long clothespin was attached to one end of the paper clip, while the other end of the paper clip was bent to form a loop (Fig. 2);
- A 12 mL plastic vial with a snap cover containing either 4 mL of water or a 10% sucrose solution (students were informed whether they received water or the sucrose solution). I had previously prepared the sucrose solution to provide 10% sucrose by weight of cement when 2 mL of the solution was mixed with the cement-sand mixture. The smaller vial had the same number as the 25 mL vial;
- A small flat wooden stirrer (110 x 10 mm craft sticks);
- A 2 mL plastic pipette with a mark corresponding to 1 mL; and
- Several paper towels.

Procedure

The students were cautioned to follow my instructions, step-by-step, to ensure their safety as well as to minimize the variability in how the mortar mixtures were prepared. After they opened their plastic bags, the students put on their safety glasses and gloves, and they placed their paper towels on their desks. Then they were directed to take the following steps:

- Open the vials with the cement-sand mixture and water (or sucrose solution);
- Using the pipette, add 2 mL of the mixing water (or 2 mL of the sucrose solution) to the vial containing the cement-sand mixture;
- Carefully mix the mortar with the wooden stirrer for 30 seconds by gently moving the stirrer deeper into the mortar;
- Examine the bottom of the vial to check for any dry material;
- After mixing, carefully insert the clothespin attached to the paper clip into the mortar using a twisting motion to fully submerge the clothespin in the mortar; and
- Firmly secure the snap cover on the vial.

Twelve mortar mixtures were prepared with water (control mixtures), and 12 mixtures were prepared with the sucrose solution (retarded mixtures). I kept a log of the students' first names and their respective sample numbers. We then placed the samples in a container, and we left the container in the classroom over the weekend. On Monday, the students examined their vials. First, they were directed to lift the cover and report what they saw. Then they were directed to pull on the paper clip embedded in the mortar and report what happened (Fig. 3).

Results

The students found that the control mortar mixtures (mixed using water) were solid and firmly held the clothespins. They also

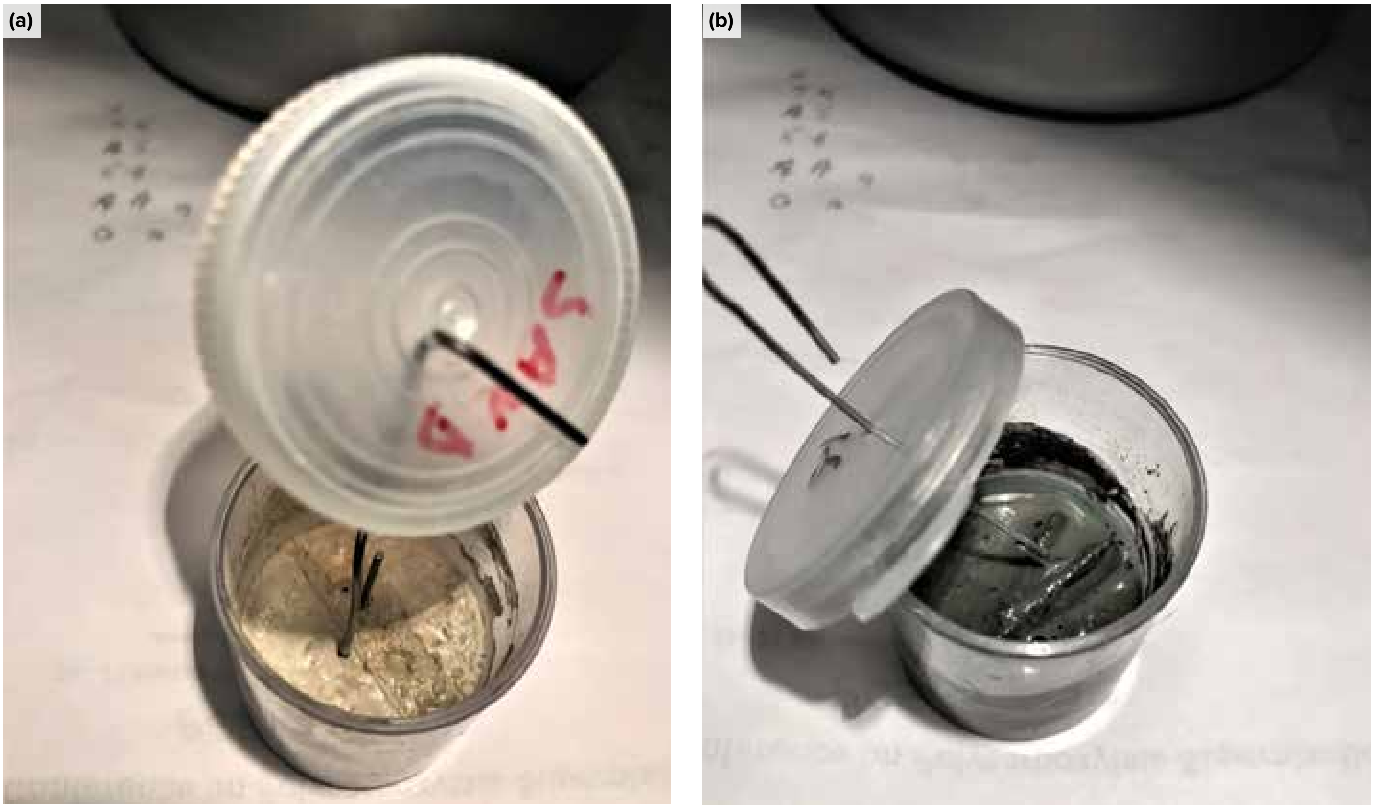

Fig. 3: Three-day-old mortar samples prepared with: (a) water; and (b) sucrose solution

found that all but one of the retarded mortars (mixed using a sucrose solution) were still soft. The students could easily pull the clothespins from the retarded mortars. We couldn't determine why one sample of sucrose-treated mortar was able to harden over the weekend. This possibly resulted from mislabeling the solution in the test kit.

In Conclusion

All the students were able to safely prepare their mortar samples. Pulling on the paper clip affixed to the clothespin proved to give the students an effective visual and physical interaction with the hardened and soft mortars. (Optionally, the clothespin could have been omitted, and the students could have probed their mortar with a toothpick.)

A sampling of the comments from thank you letters sent by the students helped underscore the value of the experiment:

- "It was fun to learn about concrete and how you can keep it soft for many days."
- "I loved wearing the safety goggles and gloves. Made me feel like a scientist."
- "It was interesting to see how the sucrose kept the concrete squishy."
- "I appreciate how you let us do the experiment, and not just showing us."
- "Now I know that concrete is made from cement, sand, rocks, water, and different chemicals."
- "I tried to pull the clothespin out of my mortar, but it would not come out!"

Note: Additional information on the ASTM standard discussed in this article can be found at **www.astm.org**.

Selected for reader interest by the editors.

Ara A. Jeknavorian, FACI, serves the concrete construction industry as an independent consultant on the development and application of chemical admixtures. Prior to starting Jeknavorian Consulting Services, he completed a 34-year career as a Research Fellow with the Construction Products Division of W.R. Grace, Cambridge, MA. He holds 19 patents for concrete and masonry admixtures and was responsible for polycarboxylate product development with W.R. Grace. Jeknavorian is a member of the American Chemical Society and a Fellow of ASTM International, where he chaired the subcommittee on chemical admixtures and served on ASTM Committee C09, Concrete and Concrete Aggregates. He has authored 51 publications related to chemical admixtures for concrete, and he has received several industry awards for his contribution to standards and technology development for concrete admixtures. Jeknavorian received his PhD in analytical chemistry from the University of Massachusetts.