<u>Taking Concrete to the Next Level: The Effect of Fun Additives</u>

Las Vegas Homeschool Team (Middle School) Team 106

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Introduction
Winter is a time when concrete is damaged. Water from melted snow and ice is absorbed into the concrete. When the temperature drops below freezing, the water turns into ice and expands with force. That force is powerful enough to exceed the "yield point" of the concrete and crack it. This problem is very well known in the industry.

Background
Billingsly Engineering in Las Vegas is spending a lot of time and money trying to figure out how to make New Mexico's bridges and highways safer. This is because moisture that soaks into concrete, and then expands as ice with the same force, can weaken a bridge and may cause it to crack under pressure, which would be very dangerous. The engineers try to prevent "spalling-" the breaking off of concrete that exposes rebar, and "delamination-" longitudinal cracks along the underside of a bridge; by testing concrete samples for durability. They do this by following different recipes for making concrete and then comparing how durable they are. These tests are very intense and interesting to watch, and that's where we got our idea from. We wanted to study whether we could improve concrete strength by adding new materials that would help form a stronger bond. We picked things that we throw away as trash and that we have a lot of in New Mexico; plastic bags, dryer lint, Chile pods, hair and pinion shells.

Specific Problem: Macroscopic Degradation
Ongoing freezing and thawing causes the cracks to grow and may eventually lead to "macroscopic degradation," the scientific name for "ice damage" (Schulson, Erland M).

Why are some concrete things more affected by macroscopic degradation than others? The basketball court across the street from my house, for example, has a snake-like crack about 15 feet long. We can still play but have to be careful. The concrete parking lot at my sister's school, however, has a round pothole about eight inches deep. Parents picking up their kids or dropping them off have to drive all the way around it; or smash up their car. Potholes and cracks are examples of "differential weathering" and it has to do with the difference in resistance of various rock types (p. 587).

In construction, workers add water, sand and gravel (usually different sizes & shapes of rock) to the cement. These ingredients bind together to form concrete. When chalk and clay has been heated and crushed, Portland cement is made. When water is added, it crystallizes into a mass that binds sand and gravel together (p.102). Sometimes special additives are added. As the concrete hardens, sand and gravel are joined together by the cement and form a rocklike mass with amazing "compressive strengths" (p.102).

Compressive Strength

Compressive strength refers how much weight or pressure it can support. The workers at Billingsly Engineering test compressive strength using a hydraulic ram. The hydraulic ram puts pressure on a concrete samples until they break. Compressive strength is measured in megapascals (MPa) or pounds per square inch (psi). This test takes place after the concrete has had a chance to harden. Normally, that's twenty-eight days. Twenty eight days is a long wait, especially if there's an urgent need. Sometimes three-day and seven-day strengths are used to predict 28-day compressive strengths.

Use of Additives

The workers at Billingsly Engineering test special ingredients in their lab hoping to decrease cold weather damage out in the field. When water freezes and turns into ice, its volume expands by about nine percent. If there is not enough room for this expansion, the ice will break the needles of the interlocking cement paste crystals. Additives are poured in the cement mixer that creates small air bubbles inside the concrete when it dries. These air bubbles provide a place for expanding ice crystals to relieve its pressure.

Solution Strategy

There are many things that we normally just throw away that might offer improved workability and resistance to spalling, delamination, and macroscopic degradation. The primary purpose of this study is to determine whether adding additional items improves the durability of hardened concrete. The additives that we picked were things normally thrown away as trash; plastic bags, dryer lint, Chile pods, hair and pinion shells.

Permission was received to remove enough cement from the mixer to fill 5 forms. The following ingredients will be added:

Form 1: Cement + shredded Wal-Mart bags
Form 2: Cement + dryer lint
Form 3: Cement + pinion shells
Form 4: Cement + shredded human hair
Form 5: Cement + green Chile pods, stems & seeds

Once hardened, these six blocks were tested for durability.

Data Analysis

How can computers help us understand? We used a program called "Mathematica" to calculate percents, pounds per square inch (psi), and to compare the durability data.

Hypotheses
We predicted that the pinion shells would be the most durable. We also predicted that the green chile pods & stems would hold the least amount of weight.

Findings
All of the concrete samples were able to hold over 25,000 pounds which means that any one of our samples, except chile, could be used in construction. Chile however could only support 4,082 pounds.

We had a problem. We needed to calculate pounds per square inch (psi) but the hydraulic ram only gave us "load" in pounds. We back calculated psi using the following formula:

$$A = \frac{\pi d^2}{4} = in^2$$

$$PSI = \frac{\text{load (lbs)}}{In^2}$$

In Mathematica the code looks like this:

```
3.14*4
 12.56
 4082/12.56
 325.
 3.14*4
 12.56
 36030/12.56
 2868.63
 3.14*4
 12.56
 50750/12.56
 4040.61
 3.14*4
 12.56
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```
23480/12.56
1869.43
3.14*4
12.56
35381520/12.56

3.14*4
12.56
25044.64/12.56
1994.
```

Mathematica indicated that our most durable sample was hair. Hair supported 36, 030 lbs or 2,867 psi.

The second most durable sample was pinion. Pinion supported 35,381.52 lbs and 2,817 psi.

Plastic was the next durable sample which supported 25,044.64 lbs and 1994 psi.

Lint came next. Lint supported 19, 706.64 and 1,569 psi.

Chili came in last place. 4,082 lbs and 325 psi was all it could support, plus it smelled nasty.

Discussion:

All of our samples, except for chile, were durable enough to be used in the field. We predicted pinion shells would be the most durable. Our hypothesis was not supported by the data. We predicted the green chile pods and stems would support the least and we were correct. Although they met the engineering standards for durability, none of them were stronger than concrete alone. The extra additives made it difficult to consolidate. The engineer suggested that next time we add our additives one at a time directly into the cement mixer rather than mixing it proportionally by hand.

Conclusion

We learned a lot about engineering while having fun at the same time. One thing we discovered was that there are only two female engineers in all New Mexico, and we were lucky enough to have one of them encouraging, helping and inspiring us. We were unable to do the freeze-thaw test because it takes about three and a half months but this is still one of our interests.

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