Internal degradation of concrete with the addition of various substances

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Introduction

Due to its incredible strength and durability, concrete is widely used in a variety of construction projects such as roads, buildings, and pavements. It is often considered the best material for construction due to these superior characteristics. Concrete, however, is not invincible and can be weakened by the addition of chemicals and other substances. According to a recent study, molasses was found to weaken the flexural strength of concrete at a concentration of 0.3% or greater (Aalm & Singh, 2016). Deicers have also been known to degrade concrete. Another study involving commonly used deicers found that "at low concentrations, magnesium chloride and calcium magnesium acetate can cause measurable damage to concrete," (Darwin, Browning, Gong, & Hughes, 2007). These studies have demonstrated that chemicals can degrade concrete externally, even at low concentrations. However, the effect of internal degradation has not been as extensively researched. This area of research would be particularly useful in developing military strategies, such as sabotaging enemy bases or determining the possibility of enemy sabotage towards the American government. Thus, the purpose of this study was to determine the effects of additives in concrete mix on its compressive strength. It was hypothesized that as the concentration of the added substance increases, the compressive strength of the mortar cubes decreases.

Materials and Methods

A series of compression tests were performed on 1-inch mortar cubes to determine the relationship between the concentration of a salt and the strength of concrete. Varying concentrations of salts or sugar were added into multiple commercial mortar powders. The amount of substance added depended on the weight of the concrete powder and the concentration of the substance. The mortar cubes were then cured in a temperature and moisture controlled environment for 28 days, as instructed in the ASTM C192M-16a (2016); examples are shown below in Figure 1. The cubes were massed and measured before being tested by the Applied Test Systems Series 910 Universal Test Machine® to quantify their compressive strength.

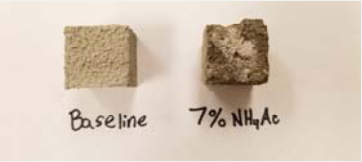
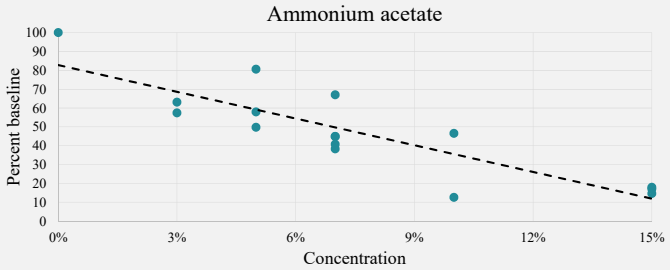


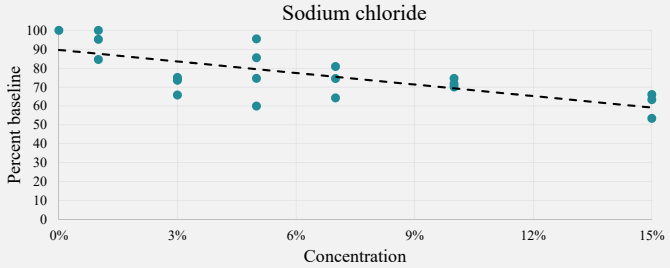
Figure 1 (left): A comparison of a 1-inch baseline and a 1-inch 7% ammonium acetate Sakrete Fiber Reinforced® cube. The visual effects of the salt are seen by the right cube's loss of matter around its corners and edges.

Results

After testing normality, calculations revealed strong, negative correlations between percent concentration and compressive strength for every substance tested. Graphs 1 and 2 present the effects of the most and least degrading salts: ammonium acetate (NH_4Ac) and sodium chloride (NaCl), respectively. The slopes of the trendlines, −427.67 for NH_4Ac and −203.92 for NaCl, suggest that NH_4Ac is more than two times as degrading to the concrete mix as NaCl.



Graph 1 (above): The effect of the concentration of NH_4Ac on the compressive strength of the Rapid Set concrete mixes ($N = 16$). A Pearson's correlation test found that there is a strong negative correlation between percent concentration and compressive strength, $r(14) = -0.863$, $p < 0.001$. Overall, an increase in concentration caused a large decrease in compressive strength.



Graph 2 (above): The effect of the concentration of NaCl on the compressive strength of Rapid Set concrete mixes ($N = 22$). A strong, negative correlation was found by a Pearson's correlation test between the percent concentration and compressive strength, $r(20) = -0.697$, $p < 0.001$. Overall, an increase in concentration led to a small decrease in compressive strength.

It was found that each of the substances tested resulted in similar degradation patterns for all mortar powders utilized. It was also observed that the ammonium nitrate (NH_4NO_3) and the NH_4Ac caused the most internal degradation in cured concrete. Sugar, which is well-known for retarding the setting time of concrete mix, was found to have virtually no effect on the concrete's compressive strength.

Results (cont.)

Among the other substances tested, anhydrous magnesium sulfate and magnesium sulfate heptahydrate (Epsom salt) made the concrete completely unworkable, as seen in Figure 2. A concentration of 3% was enough to harden the concrete before it could be molded.

Figure 2 (right): A 3-inch Cement All® concrete cube with a concentration of 3% anhydrous magnesium sulfate. Only a few seconds after hydrating the mixture, the concrete had already hardened, becoming completely unworkable.

Conclusion

The purpose of this study was to investigate the relationship between the compressive strength of concrete and added substance concentration. It was found that there was a decrease in the compressive strength of a mortar cube as the salt becomes significantly more concentrated. The negative relationship suggested by the data could assist in military strategies, such as determining the possible threat of sabotage of a military base. It was observed that substances such as ammonium nitrate and ammonium acetate were much more degrading to the concrete than others including sugar and sodium chloride. A total of 270 experiments were conducted, all of which validate the results displayed in Graphs 1 and 2 with Rapid Set concrete mix for other common commercial mixes. Magnesium sulfate was found to make the concrete immediately unworkable. This implies that the use of magnesium sulfate may be applicable in the elimination of enemy bases before the base can even be constructed. Future studies are necessary to examine the effects of other additives such as aggressive chemical agents into mortar mix.

References

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