Accelerated degradation of concrete through chemical exposure

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Introduction

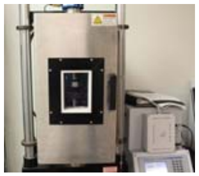
In the penetration of concrete, traditional mechanical methods are used almost exclusively. Currently, the military uses drills, guns, and even bombs to penetrate concrete, which can be a long and dangerous process. Adding a chemical component could make this process more time and energy efficient. Although the study aims to investigate concrete, mortar was used for testing, because it is better for small scale experimentation. Mortar is a mixture of water, sand, and cement used in construction, which stiffens when it dries, giving it high load bearing capacity. It has been shown that cementitious materials in a saline environment are susceptible to chemical damage from the dissolved salts (Bucea, Khatri, & Sirivivatnanon, 2005). The purpose of this study was to investigate chemical degradation of mortar due to exposure to aqueous salts, and to expand on the quantitative data available for concrete degradation.

Materials and Methods

A series of compression tests were performed to determine which aqueous salts have the greatest effect, and to determine the effects of weaker acids on concrete. Collins, Felts, & Roop (2016) found that hydrochloric acid greatly reduced the structural integrity of concrete, especially around 6 M, and this study aims to discover if salts and weak acids cause similar damage. Mortar was prepared in 1” cube molds and cured for 28 days in a temperature and moisture controlled environment as stated in ASTM C192 (2014). Saturated solutions of the aqueous salts were then prepared. The salts used were ammonium acetate, ammonium nitrate, ammonium chloride, ammonium formate, ammonium fluoride, sodium propionate, cupric acetate, zinc acetate, and sodium acetate. The weak acid used was acetic acid. The cured mortar cubes were exposed to the saturated solution or acid for designated times that ranged from 1 hour to 28 days. Exposure consists of a cube being submerged in a specific solution in a glass container, as shown in Figure 1, for the designated amount of time. After exposure, the cubes were tested for compressive strength using an Applied Test System Series 910 Universal Test Machine®, as shown in Figure 2, which is capable of supplying 10,000 lbs (~44,000 N) of compressive force per ASTM C109 (2013).

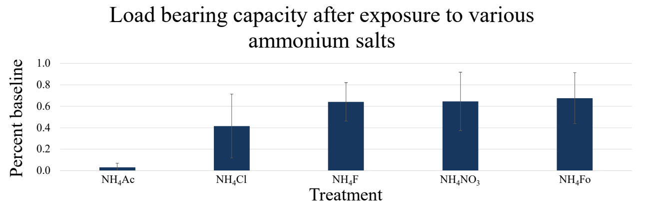
Figure 1 (left): A cube being exposed in a glass container.

Figure 2 (right): The Universal Testing machine used to test each cube after exposure.

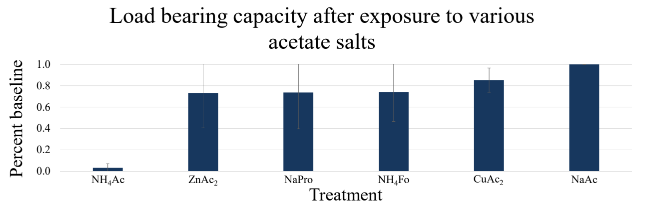


Results

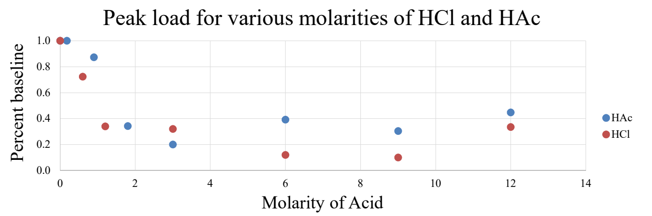
The salt that worked the best was ammonium acetate. Graph 1 and Graph 2 show the percent reduction in load bearing capacity of different mortars after a 21 day exposure to various salts. Salts which contain either the acetate or ammonium ion by themselves were not as effective as when the two were together, which means they enhance each other’s effect by some unknown mechanism. To further isolate the acetate ion, tests were conducted in acetic acid at various molarities, and it was determined that, similar to hydrochloric acid, increasing molarity has very little effect after a certain point, as shown in Graph 3. Even though acetic acid is approximately 100 times weaker than hydrochloric acid, it performs as well at similar concentrations.



Graph 1 (above): Shows the load bearing capacity and standard deviation of concrete samples ($N = 20$) after exposure to various ammonium salts. The loads are reported as a percent of baseline for that concrete, so all the tests can be represented on the same scale.



Graph 2 (above): Shows the load bearing capacity and standard deviation of concrete samples ($N = 24$) after exposure to various acetate salts. The loads are reported as a percent of baseline for that concrete, so all the tests can be represented on the same scale.



Graph 3 (above): Shows the load bearing capacity of concrete samples ($N = 35$) after exposure to various molarities of hydrochloric and acetic acid. Points are averages of multiple tests ($n = 2$ to 4), which is why there are less points than total samples.

Results (cont.)

Figure 3 (above): Pictures of the same type of concrete before exposure (a), and after exposure to NH_4NO_3 (b) and NH_4Ac (c). Each was taken with a ruler of scale 1 mm.

It was also seen that in comparison to other salts which reduced strength, ammonium acetate caused much more physical damage. Specifically, it caused a greater increase in the pore size of the concrete, as seen in Figure 3.

Conclusions

The purpose of this study was to determine the relative effectiveness of various aqueous salts on the degradation of concrete, and to further establish quantitative data for the degradation of mortar and concrete. Through a series of compression tests, it was determined that ammonium acetate is the most successful salt in the degradation of concrete, and that acetic acid performs similarly to hydrochloric acid at similar concentrations. Testing of other salts, however, showed that neither the ammonium ion or the acetate ion alone is responsible, but that either one or both somehow enhance the effectiveness of the other.

Although this study and others conducted by Collins, Felts, & Roop (2016) have identified effective saline and acidic solutions, no work has been done on an efficient method for applying the solutions. Further testing needs to be done to determine if the addition of a surfactant or thickening agent to a solution will alter its effectiveness in any way. Also, due to equipment upgrades, any future study could take advantage of the use of two inch cubes to increase the scale of the project.

References

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