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CORROSION RESISTANCE OF ARMAKAP CEMENT FOR NUCLEAR APPLICATIONS

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INTRODUCTION

Used nuclear fuel storage is one of the most pressing concerns of the nuclear industry. Historically, nuclear waste was intended to be stored in long-term storage facilities such as Yucca Mountain, but a permanent solution of this nature had eluded the nuclear industry thus far (Slovic et al. 1991). The nuclear waste accumulated over the last forty years is currently stored in temporary containments. Environmental degradation is a significant safety hazard present at these facilities (Cong at al.).

Armakap Technologies, LLC (Armakap) is developing ceramic concrete formulations that can withstand extreme chemical, thermal and radiation environments. The Armakap cement products have shown exceptional resilience to thermal shock, mechanical load and nuclear (gamma) radiation. In this work, we test the corrosion behavior of two specialized formulations of cement – Armakap 2020 and Armakap 3030, and compare their performance against that of ordinary Portland cement as well as the Armakap Base formulation.

METHODS

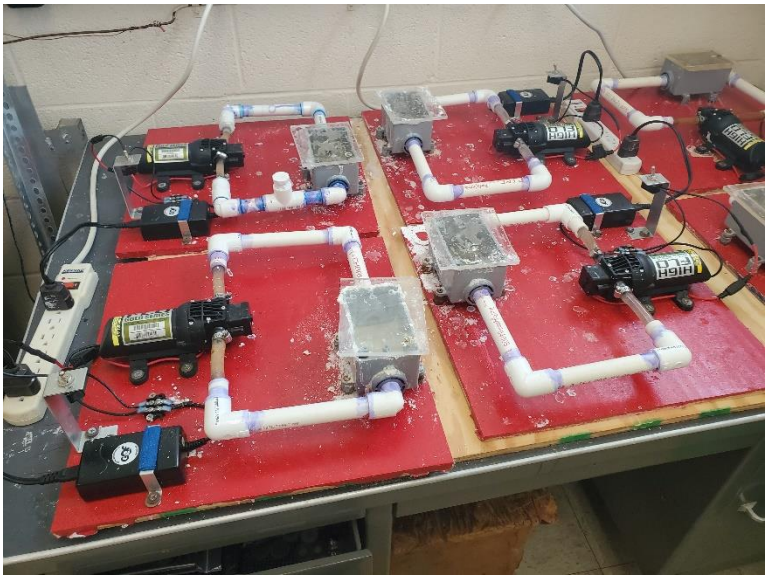

Figure 1. Water corrosion circulator.

Concrete samples of two inches per side and one inch in height are prepared in each of the four compositions; they are loaded into a water corrosion circulator as shown in Figure 1. The circulator is comprised of a closed piping system with a small pump. Two pH levels are tested separately; the pH is controlled by adding required amount of sulfuric acid to the fluid. The first pH setting corresponds to 6.3, which is slightly below neutral – this level is chosen to approximate the natural conditions of water, which is marginally acidic due to the presence of various naturally occurring mineral impurities (Bertolini et al. 2004). The second solution is prepared in the same manner as the first, but to an acidity of 0.7 pH. While this is stronger than anything commonly found in nature, it does allow the acceleration of corrosion processes. Thus relative differences in the corrosion rates can be assessed at accelerated conditions. While a pH of 0.7 is extremely unlikely to occur in nature, acid rain and similar phenomena have been measured to acidities of ~2 pH (NASA Observatory, acid rain). The samples are left in the circulator for 60 days and the sample masses are recorded periodically.

RESULTS

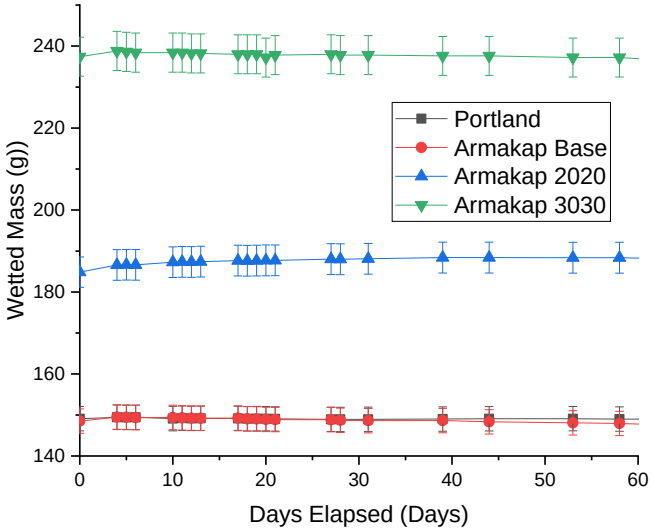

Figure 2. Sample mass over time with 6.3 pH corrosion circulation.

Figure 2 shows the change in mass using the 6.3 pH solution over a 60 day period. As can be seen from the figure, no samples have any significant change during the experiment, indicating minimal corrosion at this pH level. The error bars on this figure indicate 2% of the initial mass, and all the measured values fall within this range. Thus near neutral pH, none of the formulations exhibit short-term mass loss.

Figure 3 depicts the mass loss under an accelerated corrosion condition with 0.7 pH. Strikingly, Portland sample shows obvious and consistent mass loss over the course of the experiment, with an estimated corrosion rate of 0.31g/day. This is significantly more than any Armakap formulation; the corresponding corrosion rates with Base, 2020, and 3030 compositions are 0.01g/day, 0.1g/day, and 0.06g/day, respectively.

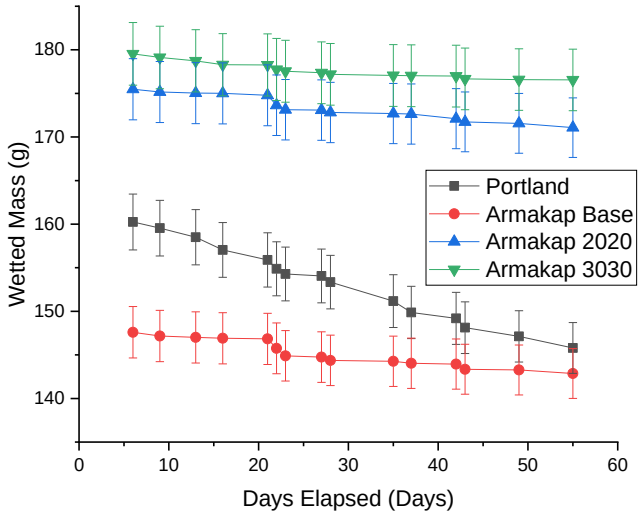

Figure 3. Sample mass over time with 0.7 pH corrosion circulation.

Another way to quantify the difference in corrosion behavior is by estimating mass retention. Figure 4 shows the mass retention of each of the four cement compositions, calculated as the percentage of the initial mass remaining after 60 days.

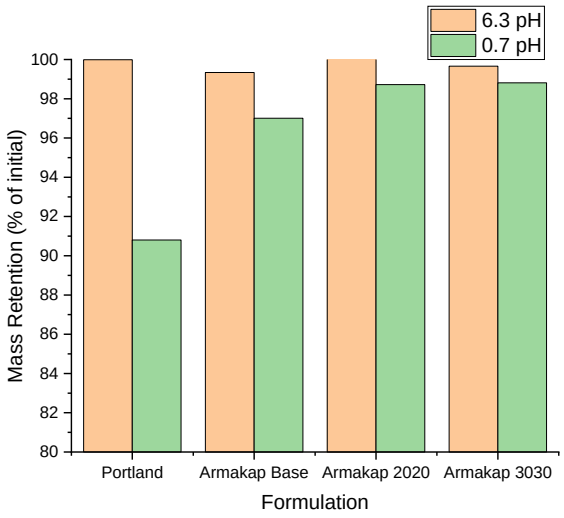

Figure 4. Mass retention of different formulations of concrete over 60 days.

From the above figure, it can be seen that under the highly acidic condition, the Portland sample has lost nearly 10% of the initial mass over the course of two months exposure. Over the same period, Armakap formulations have lost only 3% (or less) of their initial masses. As expected, mass retention for all the compositions with the 6.3 pH circulation runs is negligible.

CONCLUSION

In this work, we have tested the corrosion behavior of two specialized formulations of concrete – Armakap 2020 and Armakap 3030 at two pH levels (6.3 and 0.7). At the accelerated level of 0.7 pH, Armakap concrete formulations 2020 and 3030 are able to resist corrosion three times better than the Portland sample. The corrosion rates of 2020 and 3030 compositions are 0.1 and 0.06 g/day respectively, while the corresponding rate for the Portland sample is 0.31g/day. Over the 60 day duration, Portland sample retained only 91% of the initial mass with the 0.7 pH solution, while both Armakap 2020 and 3030 formulations retained 99% of their initial mass. We thus conclude that Armakap specialized formulations 2020 and 3030 have superior corrosion tolerance relative to Portland cement.

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