Florida Department of Transportation Research

Performance of High Performance Concrete (HPC) in Low pH and Sulfate Environments
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High-performance concrete (HPC) refers to any concrete formulation with enhanced characteristics, compared to normal concrete. One might think this refers to strength, but in Florida, the HPC standard emphasizes withstanding aggressive environments, defined by acidity and chloride and sulfate concentrations. Chloride penetration into concrete has been widely studied. In this study, Florida International University researchers focused attention on acidic, sulfate environments.

Sulfate attack on concrete is complex, involving physical and chemical processes that alter concrete properties such as porosity, permeability, and strength. Sulfate attack can be limited by controlling material composition and transport properties. This can be achieved by limiting the water-to-cementitious material ratio, limiting tricalcium aluminate in Portland cement, use of supplementary cementitious materials, proper compaction and curing, and use of air entrainment. However, the selected formulation must also withstand low pH.

Wet-dry cycling speeds the effect of sulfate and pH, as shown by the heavily etched region of this piling installed in 2009.

In the first set of tasks, the researchers sought to determine the risk of deterioration of HPC in sulfate-low pH environments and the concentration regimes in which deterioration occurs in order to compare them with Florida's current system for environment classification.

In the field, researchers examined eight HPC bridges set in sulfate-low pH environment. Environmental data collected at each bridge was compared to Florida's current data. Chemical composition of cores was identified with scanning electron microscopy and energy-dispersive X-ray spectroscopy (EDS). Results showed that HPC exposed to moderate sulfate levels (150–1500 ppm) and pH < 6.5 had a high risk of early deterioration. In fact, corroded steel reinforcing was found on two bridges with only 21 years of service. A 4-year-old bridge also had significant scaling. Therefore, environments in which HPC is exposed to moderate sulfate and low pH should be reclassified as extremely aggressive.

In a second series of tasks, the researchers tested concrete formulations and curing practices to find the best combination for use in sulfate-low pH environments. In the lab, researchers evaluated expansion and flexural and compressive strength of HPC mortar, as well as water absorption and scaling of concrete. Twelve HPC mixes included fly ash, slag, silica fume, and metakoalin additives. Slag cement and silica fume provided the best resistance to low pH-moderate sulfate environments.

Researchers also examined several computer models of service life. They found that the models treated chloride diffusion well, but poorly predicted sulfate-low pH attack because of the complex mechanisms involved, suggesting a direction for development of service life models.

A more solid basis for classifying sulfate-low pH environments and designing bridge components to withstand them promises to bring the service life of bridges in these environments closer to the desired 75 years. Considering the expense of repairing or replacing even a single bridge, research of this type can save Florida many millions of dollars.

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