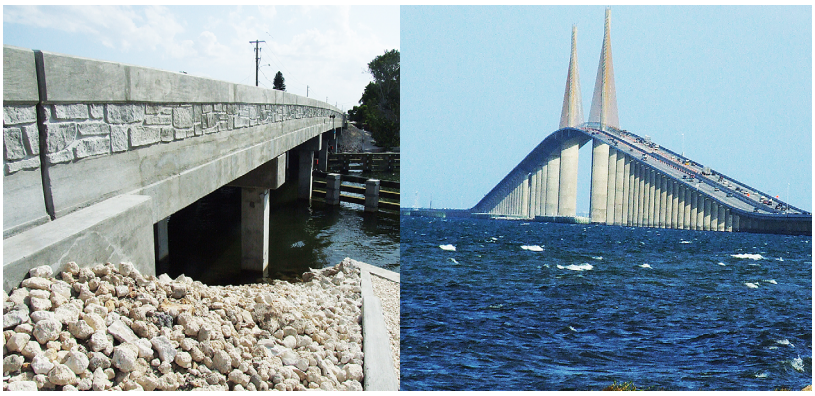
Florida Department of Transportation Research

Diffusion vs. Concentration of Chloride Ions in Concrete
BDK79-977-03

The Florida Department of Transportation (FDOT) maintains hundreds of bridges, and also builds new ones, in marine environments. These structures are built with reinforced steel, and over time, chloride ions from sea salt can migrate through concrete to attack reinforcing steel. FDOT has adopted concrete formulas and structure designs intended to delay this process and give marine bridges a 75-year service life.



From small to large, many bridges in Florida are continuously exposed to seawater and its potentially damaging effects.

In this project, Florida Atlantic University researchers examined reinforced concrete specimens exposed for up to two years to various seawater and salt conditions. They simulated exposure of bridge components to continual immersion as if underwater, cyclic immersion as in the tidal zone, and lesser exposure of the splash zone. They also investigated the effects of salt spray on reinforced concrete not directly exposed to seawater and thus not saturated; in that case, high humidity or rain may provide the moisture that gives the ions mobility. Samples exposed for over 18 years were also part of this investigation.

Three concrete mixes with different supplements were tested: 20% fly ash; 20% fly ash plus 8% silica fume; and 50% slag. For each mix, water-to-cement-mix ratios were varied: 0.35, 0.41, or 0.47. Samples were cast as blocks in two sizes and cylinders and cured under various temperature and humidity regimens. Reinforced concrete columns were made for tidal testing and for partial immersion testing. Some samples were partially coated with a water sealant. Samples were exposed both indoors and outdoors.

Basically, samples were exposed to conditions resembling the splash, tidal, and immersed portions of a marine structure, using brackish water, 10% seawater, or seawater. Bulk diffusion experiments were conducted in solutions containing 0.1, 0.6 or 2.8 M sodium chloride. The full range of treatments included many other exposure protocols.

To examine changes in concrete's resistivity to chloride ions over time, rapid migration tests and resistivity measurements were performed several times over two years, and the non-saturated migration coefficient was correlated with resistivity. Apparent diffusion from bulk diffusion tests was correlated to equivalent resistivity. Field work investigated the chloride concentration as a function of elevation. Other experiments were conducted in which the degree of saturation was controlled and exposed to finely ground salt. These apparent diffusion results were compared to the apparent diffusion results from specimens in which the chloride transport was due to natural marine atmosphere.

As commonplace as concrete and seawater are, they are very complex substances which can change with time, so the critical issues of chloride penetration of concrete and the corrosion of steel must be subjects of continuing scientific investigation. Projects like this one extend knowledge of the behavior of concrete in realistic settings, providing the basis for new standards and new construction methods that lead to more durable, lower maintenance structures.

Project Manager: Ron Simmons, FDOT Materials Office
Principal Investigator: Francisco Presuel-Moreno, Florida Atlantic University
For more information, visit http://www.dot.state.fl.us/research-center