

UTILITY OF HIGH ALKALINITY CEMENTS FOR CONTROL OF REINFORCING STEEL CORROSION IN CONCRETE

BACKGROUND

Corrosion-induced deterioration of reinforced concrete bridge substructures in Florida coastal waters has been recognized for decades as a pervasive problem. Such distress arises as a consequence of several processes:

- progressive chloride intrusion into the concrete
- breakdown of the otherwise protective passive film upon the embedded steel once chlorides achieve a critical concentration at the steel depth
- corrosion of the reinforcing steel at a rate controlled by oxygen and moisture availability
- cracking and spalling of the concrete cover from tensile hoop stresses generated in the concrete about the reinforcement by expansive corrosion products.

These processes can lead to structural failure if either the reinforcement or concrete cross-section (or a combination of the two) becomes sufficiently reduced. Previous research has determined that the use of high alkalinity cements can extend the time-to-corrosion of reinforcing steel in concrete. However, such cements can cause other deterioration processes, specifically alkali-silica reaction (ASR).

OBJECTIVES

The objective of this study was to investigate the extent to which high alkalinity cements promote ASR for materials relevant to concrete bridge construction in Florida.

FINDINGS AND CONCLUSIONS

Researchers tested a series of 55 concrete mixes that contained five different candidate coarse aggregates and cements of three different alkalinities. They measured concrete specimen length change (periodically for up to two years); alkalinity by both ex-situ leaching and pore water expression; compression and flexural strength; and electrical resistivity. In addition, the study included for comparison purposes two coarse aggregates with high susceptibility to ASR, as documented by previous research. Additional mix variables included fly ash and lithium nitrate admixture, the latter of which is a known ASR inhibitor. The researchers established criteria for qualifying a particular FDOT Class V concrete based upon 1.2 percent alkali content and no lithium admixture, as listed below:

- Concrete expansion after one and two years of ASTM C1293 exposure (38oC and 100 percent relative humidity) should be below 0.010 percent.
- There should be no significant concrete length change between the first and second years of ASTM C1293 exposure.
- There should be a complete absence of cracking after two years of ASTM C1293 exposure, as determined by microscopic examination of molded and cast prism surfaces.

- Petrographic examination (ASTM C295) should confirm that the fine and coarse aggregates contain no known silica phases that are potentially alkali-silica reactive (strained quartz, microcrystalline quartz, chalcedony, chert, tridymite, cristobalite, opal, and others).
- Petrographic examination (ASTM C856) should confirm the absence of any microstructural features indicative of ASR activity. (alkali-silica gel, diagnostic cracking within aggregate particles and within cement paste adjacent to cracked aggregate particles, reaction rims on aggregate particles, and gel-stained cement paste adjacent to cracked aggregate particles) after two years of ASTM C1293 exposure.
- There should be a normal, expected increase in concrete flexural and compressive strengths as measured at one year when compared to respective strengths measured at 28 days.

Based upon the above criteria, two of the five experimental concretes, both of which are Florida limestones, were qualified for further study. Features of the first choice (Rinker Materials Miami Oolitic Limerock, Pit 87-089) that support its being qualified include the following:

- Petrographic examination confirmed that (1) no potentially ASR reactive forms of silica are present and (2) no microstructural features indicative of ASR activity and no cracking of any type were observed in prisms after two years exposure.
- After experiencing a very slight average prism expansion of 0.0060 percent after two months of ASTM C1293 exposure, no significant length change occurred during two subsequent years of testing.
- Concrete with the highest alkali content had greater compressive strength after 365 days of ASTM C1293 exposure than at 28 days (51 MPa (7400 psi) compared to 43 MPa (6200 psi)). Flexural strength of the FPL-1 concrete containing 1.0 percent alkali and the lithium admixture was 7.2 MPa (1050 psi) following two years of exposure.

On the basis of this performance, the first ranked Florida limestone aggregate concrete should be considered for further trials.

BENEFITS

If additional trials of high-alkali concretes are successful, their use in reinforced concrete Florida bridge structures could significantly extend the service life of those bridge structures, at no additional cost or construction complexity. Moreover, use of such concrete should make it possible to relax other design parameters, such as concrete cover over reinforcement, which, would result in a cost reduction.

This research project was conducted by William H. Hartt, Ph.D., of the Florida Atlantic University. For more information, contact Michael Bergin, Project Manager, at (352) 955-6666, michael.bergin@dot.state.fl.us.