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CORROSION PERFORMANCE OF CONCRETE CYLINDER PILES

PROBLEM STATEMENT

FDOT bridge substructures constructed with concrete cylinder piles in aggressive marine service have shown promising corrosion resistance after several decades of service. Earlier field investigations of the dual Escambia Bay bridges have shown minimal corrosion damage after 30 years of service even though concrete clear cover was as low as 1.1 in (2.75 cm). Cylinder piles are finding renewed applications in FDOT projects. However, present FDOT guidelines for reinforcement corrosion protection in aggressive marine service specify at least 3 inch (7.6 cm) cover, which tends to constrain the manufacturing process and mechanical performance of cylinder piles. Only limited information regarding corrosion performance and durability issues of concrete cylinder piles in marine service has been available for FDOT bridges. More information is needed to verify observed corrosion resistance and to validate future cylinder pile construction.

OBJECTIVES

The objectives of this project are to (1) determine whether other FDOT bridges built with cylinder piles exhibit high corrosion resistance similar to that demonstrated by the Escambia Bay bridges, and (2) establish factors responsible for such performance, which can be used to consider whether to redefine concrete clear cover guidelines. Researchers will evaluate three FDOT bridges constructed with cylinder piles in marine service for approximately 40 years (i.e., Hathaway, Pensacola Bay, and Brooks bridges) and a recently constructed bridge built with cylinder piles per modern FDOT material and construction specifications (i.e., the St. George Island Bridge).

FINDINGS AND CONCLUSIONS

The results for the older FDOT bridges with cylinder pile construction indicated, in general, only minor, highly isolated or nonexistent corrosion distress of the spiral reinforcement in the piles (with the exception of damage near pile caps likely reflecting original mechanical distress, and earlier repair patches for topical deterioration) in spite of very thin concrete clear cover (~ 1.2 in (~30 mm) on average). Whenever exposed by coring, the deeper grouted strand was unaffected or showed only vestigial corrosion. Chloride penetration through the concrete cover was shown to be extremely slow. The apparent diffusion coefficient had a median value of only ~0.005 in^2/y (~1.10^{-13} m^2/s). Thin (< 0.013 in (<0.3 mm)) concrete cracks unrelated to corrosion were observed in some of the piles in the 40-year-old bridges. However, preferential chloride penetration along the cracks was less pronounced than in cases recently noted in other FDOT bridges with conventional concrete substructure.

The newer bridge (St. George Island) had been in service for only a short period at the time of the survey, so chloride penetration rate measurements are subject to significant uncertainty. Nevertheless, the results indicated that the concrete exhibited excellent resistance to chloride penetration, which is expected to improve as long-term aging takes place. Physicochemical tests of the concrete also indicated good performance. As in the older bridges, thin cracks (not caused by corrosion distress) were observed, but cores centered on those cracks showed clearer evidence of enhanced chloride penetration, at least at shallow depths. As expected from the early time in service, no corrosion distress from reinforcement corrosion was identified in this bridge.

An estimate of the prevalent range of effective critical chloride threshold values for corrosion initiation in the older bridges was consistent with the reported high cement content of the concrete and the observed pH. The concrete in the new bridge piles had a desirably high pore water pH despite its high pozzolanic content, suggesting that normal chloride threshold values are to be expected.

Simplified corrosion damage forecasts were made for the older and the new piles using the apparent chloride transport parameters observed, actual and alternative cover values, threshold bound values, and informed assumptions for the other model parameters. The projections suggest that moderate relaxation of cover requirements for new construction (for example from 3 in (7.5 cm) to 2 in (5 cm) could be made without severely compromising the requirements for minimum corrosion damage within a 75-year service life goal. Recommendations of alternative cover guidelines are presented for consideration of manufacturing and quality control factors.

BENEFITS

This investigation has verified that cylinder pile construction in FDOT bridges offers positive corrosion resistance in aggressive marine service, and that they may, therefore, be regarded as an option for enhanced durability. The findings of this study should thus be useful in future decision making regarding existing cylinder pile bridges.

This study has shown that modern piles have good durability and that, if concrete quality can be assured, a moderate relaxation of current FDOT concrete clear cover specifications may be proposed for lower cost and potentially improved reliability—easier and more reliable pile production may result from judiciously reduced clear cover. From an inspection standpoint, this investigation uncovered evidence of some enhanced chloride penetration at thin preexisting cracks, so future monitoring of these structures will benefit from assessing chloride penetration there.

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