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ADVANCED ANALYSIS OF CHLORIDE ION PENETRATION PROFILES IN MARINE SUBSTRUCTURE

PROBLEM STATEMENT

Corrosion of reinforcing steel in the substructures of Florida marine bridges is a major cause of deterioration requiring costly maintenance. The corrosion results from chloride ion penetration through the concrete (i.e., salt water, whose chemical composition is NaCl, or sodium chloride, diffuses into the concrete, wherein the chloride ions cause damage). The Florida Department of Transportation (FDOT) has implemented numerous design guidelines and repair strategies to minimize this problem. Assessment of existing structures is routinely conducted to evaluate the success of the corrosion control methods, to forecast future corrosion performance, and to improve on current practice. A common form of assessment consists of extracting and analyzing concrete cores for chloride content as a function of depth from the surface. A chloride concentration profile is thus obtained that can be analyzed to quantify the severity of chloride exposure and the permeability of the concrete.

The present method of analysis is highly simplified; it relies on assumption of simple (Fickian) diffusion for chloride transport and yields an apparent diffusion coefficient (D) and an estimate of surface (C_S) and bulk (C_0) chloride concentrations in the concrete. Those parameters can be used in conjunction with an assumed value of critical chloride concentration to estimate how long it will take for active steel corrosion to start, which is a key value in predicting durability. However, this simplified approach is subject to many known limitations, including inaccuracy from not accounting for complications in the transport processes (such as chloride binding), non-optimized sampling positions in the cores, and operator-dependent mathematical procedures for analysis of the data even under simplifying assumptions.

OBJECTIVES

The purpose of this investigation was to examine the suitability of (1) more advanced transport models for chloride analysis and (2) operator-independent procedures for improving the accuracy of the analysis of filed extracted cores and related durability projections.

FINDINGS AND CONCLUSIONS

The work conducted involved formulating the transport processes in concrete, examining alternative methods for sampling and analysis, and developing appropriate improved procedures. These activities produced several numerically sound approaches, requiring no operator intervention, for determining the parameters C_S, C_0, and D for sliced specimens. A user-friendly computer spreadsheet program was developed using these procedures.

Researchers examined the results from several computational models to determine the variation in the profile for different assumptions. Alternative approaches to fitting slice data were developed, capitalizing on the observation that many profiles still maintain a "square root of time" dependence, even if not Fickian. These techniques permit forward prediction of chloride intrusion and, with chloride binding information, may provide much improved durability estimates.

Researchers investigated the effect of surface layers (for example, from concrete carbonation) that produce "peaks" in the profile data. Relatively simple modeling was found to provide a satisfactory estimate of the chloride profile. Modeling indicates that the carbonation/release mechanism had little or no effect on the total chloride profile ahead of the carbonation front, so that a square root of time dependence of the profile shape is maintained, facilitating durability projection. The researchers also developed core slicing strategies to optimize the prediction of chloride intrusion and to minimize the costs associated with analysis were developed, and examined chloride profile fitting procedures, including time dependent diffusion and cylindrical geometries. They tentatively concluded that cores cut from typical cylindrical piles can be analyzed by assuming planar geometry.

A new fitting procedure, to include chloride binding, was developed. If the potential for physico-chemical binding exists, the choice of a model for chloride intrusion will be impacted. Researchers concluded that in the presence of binding the simplified (Fickian) analysis will produce conservative (but not accurate) predictions of time to corrosion initiation. An advanced binding model, which produces binding parameter information from a total chloride profile alone, was developed and tested.

BENEFITS

The results of this research will allow the Department to be more accurate in determining the remaining service life of existing structures in a marine environment. The research will also improve the prediction methods for determining the effects of corrosion preventive strategies in the design of new structures. Such information is valuable for the design and maintenance of structures in a marine environment, and insofar as this research contributes to the process of improving of corrosion prevention, so it contributes to the realization of cost savings.

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