Summary of Final Report, Contract BC353-33
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CORROSION OF POST-TENSIONING STRANDS

PROBLEM STATEMENT

Severe corrosion distress and instances of complete failure of external post-tensioning (PT) strands were observed in recent years in tendons of pillars or superstructures of three Florida pre-cast segmental bridges over saltwater. PT tendons are critical to the integrity of these structures, and the operating corrosion mechanism needs to be determined to support the rational development of corrosion control measures in new and existing FDOT structures. The available evidence suggests that the key deterioration factor was the formation of large grout voids at or near the anchorages. The region where the steel emerges from the grout-void interface may be particularly vulnerable because of a combination of detrimental factors including lowered pH of the grout pore water by carbonation from atmospheric carbon dioxide, evaporative local chloride ion enrichment, and adverse galvanic coupling with the rest of the metallic tendon assembly. More information is needed to verify observed corrosion resistance and to validate future cylinder pile construction.

OBJECTIVES

The objective of this investigation is to evaluate the validity of the corrosion mechanism suggested above, leading to a predictive model of the corrosion rate of PT steel based on properties of the system that may be quantified by measurement. Such prediction could then be applied to the selection of optimal grout properties and construction methods to minimize deterioration in future construction, and to appropriate preventive rehabilitation of existing structures. Emphasis was given to investigating long term conditions after the initial period when the voids are filled with free bleed water.

FINDINGS AND CONCLUSIONS

The results of this research showed that conditions leading to strand steel depassivation can develop in anchorages with grout voids if openings to the exterior allow for even modest carbonation of the grout and periodic water intrusion. Fresh water could initiate corrosion if the native chloride content of the grout exceeds a relatively small amount (e.g. 600 ppm). Currently allowable chloride limits for grout materials may need revision. Galvanic coupling between strand steel and anchorage iron was found to have the potential to significantly aggravate corrosion of the strands. Corrosion of strands in the air void space can be considerable, especially in grouts that support a high internal relative humidity. Projections of the combined effects of the deterioration mechanisms identified here are consistent with the observation of tendon failures after as little as a few years of service.

A simplified mathematical model of a corroding strand bundle was formulated, which incorporated both polarization and oxygen transport behavior. This initial computational study indicated that oxygen availability is a key factor in determining corrosion severity. Grout resistivity was a secondary but still important factor within the range of validity of the model assumptions. Predicted corrosion rates were in general agreement with field and laboratory observations. Issues for subsequent model development were identified.

BENEFITS

This investigation identified the main aspects of the process responsible for corrosion deterioration of critical structural components in major Florida bridges. The results provide evidence that supports the strategy adopted by FDOT to minimize the risk of corrosion in PT components, including the use of low-bleed grouts, improved grout insertion and control methods, and multiple barriers to prevent the ingress of water into tendon assemblies. The investigation revealed a potentially important need for lowering the present FDOT specification of maximum allowed chloride content in PT grouts, and it established practical methodologies for resistivity and internal relative humidity measurement that can be used to aid the selection of the most desirable among grout materials candidates and/or for quality control of a product after selection.

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