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THE ROLE OF POLYETHYLENE DUCT CRACKING IN FAILURE OF POST TENSIONING CABLES IN FLORIDA'S SEGMENTED BRIDGES

PROBLEM STATEMENT

During the past 20-plus years, designs based on the post-tension segmental box concept have evolved to become a predominant form of bridge construction. Critical to safety and longevity of such structures is the integrity of post-tensioning tendons; however, during the past five years, instances of tendon deterioration and failure have been disclosed on several Florida bridges. The underlying mechanism has been diagnosed as strand corrosion at grout voids in which bleed water accumulated. Cracking of high-density polyethylene (HDPE) ducts within which the grouted strands reside has also been disclosed; and while none of the failures to-date has been related to this cracking, left unaddressed, access of moisture, chlorides, and oxygen to the strands will invariably result in corrosion in the long term.

OBJECTIVES

For the purpose of (1) assessing the cause(s) and mechanism(s) of this HDPE duct cracking, (2) developing performance based assessment tests, and (3) proposing a standard for HDPE ducts employed in Florida bridges, researchers performed the following tasks:

1. Acquisition of New and In-Service Polyethylene (PE) Cable Duct Samples.
2. Evaluation of Material Properties of Retrieved and New Duct Samples.
3. Evaluation of Duct Cracking Mechanism.
4. Evaluation of Pipe SCR Using Performance Tests.
5. Assessment of Current Material Specifications for Smooth PE Duct.
6. Experimental and Analytical Modeling of Tendon Duct Cracking.

FINDINGS AND CONCLUSIONS

Testing of simulated tendon specimens and results of finite element modeling indicated that grout voids facilitate, but are not necessary requisites for, duct cracking. Duct material properties that were determined via standardized tests, both for samples acquired from seven Florida bridges and samples representing the present technology limit, included density (ASTM D 792), melt index (ASTM D 1238), carbon black (ASTM D 4218), flexural modulus (ASTM D 790), tensile yield strength (ASTM D 638), environmental stress cracking resistance (ESCR, ASTM D 1693), oxidative induction time (ASTM D 3895), single point notched constant tensile load (SP-NCTL, ASTM D 5397-Appendix) test, fatigue tests, three-point bend tests, and positron annihilation lifetime spectroscopy (PALS).

In some cases, methods were modified to be performance based. The results indicate that duct samples from the Mid Bay (MB) and Sunshine Skyway (SSK) Bridges, both of which have exhibited cracking in service, were of relatively poor quality such that cracking is projected to have commenced within several years of construction. Results for samples from the Long Key and Seven Mile Bridges indicated that these ducts are intermediate in quality and performance with times-to-cracking in excess of 50 years in service being projected. The PE-3408 material (the duct material employed in the SSK rehabilitation), on the other hand, performed best and should serve maintenance free in tendon duct applications for the design life of bridges.

Material properties of high density polyethylene (HDPE) duct samples from seven Florida post-tensioned bridges and new PE3408 duct were evaluated for the purpose of (1) defining material properties, (2) projecting performance in segmental bridge applications, (3) understanding cracking mechanisms in cases where cracking has occurred, and (4) developing a performance-based standard. Also, experiments and analyses were conducted that modeled duct stressing in service. The following conclusions were reached regarding quality and performance of high density polyethylene (HDPE) ducts in Florida post-tensioned bridges:

1. For the Mid Bay (MB) and Sunshine Skyway (SSK) Bridges, where extensive duct cracking has occurred, initiation generally occurred at defects (impurities and air voids) on the interior surface and from there propagated through thickness and longitudinally. This required that a tensile stress (either applied or residual or a combination of the two) be present at the internal duct surface. The predominant mechanism of crack propagation was slow crack growth and fatigue. Also, various material properties did not meet the specification requirements. In particular, stress crack resistance was poor and the remaining amount of antioxidant was low.

2. Duct samples acquired from the Garcon Point, Seven Mile, Long Key, Channel Five and Niles Channel Bridges generally conformed to the applicable specifications. This finding is consistent with the observation that little or no duct cracking has occurred on these bridges. However, there were relatively large differences in stress cracking resistance and antioxidant content between the different samples.

3. The best material properties were found in recent duct samples that are based on the PE3408 resin. Such ducts should provide satisfactory service for the design life of major bridge structures.

4. Based upon results from fatigue tests, experiments involving strain-gage instrumented simulated tendons, and finite element analysis, it is projected that thermal cycle induced fatigue is a probably source of stressing and that this caused the cracking in the lower duct quality cases (see Conclusion 1). Stresses arising from thermal cycling are likely to be higher at locations where a grout void is present. The analysis projected that cracking of the MB and SSK ducts probably commenced within the initial few years of construction, whereas ducts in the Garcon Point, Seven Mile, Long Key, Channel Five and Niles Channel Bridges should see 50-plus years of crack-free service provided material properties, antioxidant content in particular, do not degrade with time.

BENEFITS

This research has increased the understanding of the physical mechanisms that contribute to and the role that material defects play in duct cracking. By identifying duct material properties and tendon system parameters upon which satisfactory long-term integrity of segmental bridge tendons depend and by developing a materials based duct specification, greater confidence can be placed in integrity of new structural systems based on this technology. Also, by determining the duct material properties on existing bridges, this project has projected the expected service life prior to cracking. Consequently, a sound technical basis for both inspection and maintenance planning has been established (e.g., vital information necessary for the maintenance planning of the Sunshine Skyway Bridge was provided through this project). In addition, this research has increased the understanding of the role of cracked ducts with regard to corrosion.

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