Design and Construction of Precast Piles with Stainless Reinforcing Steel

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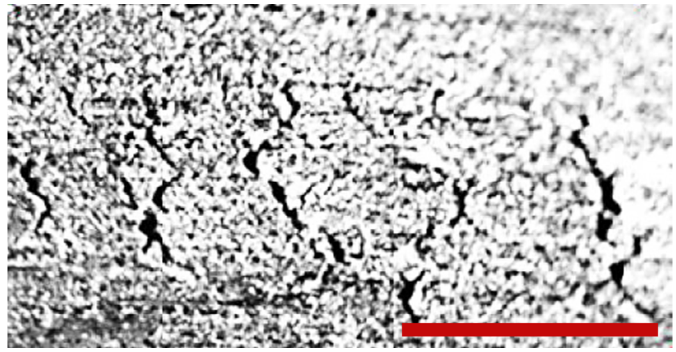
In Florida, about two thirds of the 5,500 bridges maintained by the Florida Department of Transportation (FDOT) are set in marine environments, making corrosion a major cause of reduced service life. Most susceptible to this damage are elements exposed to salt water, such as piles or drilled shafts, footings, and columns. Service life of these elements is partly dictated by how long it takes chloride ions to migrate through concrete to reach the steel surface and how long it takes to initiate corrosion.

Stainless steel (SS) is several times more tolerant of chloride ions than conventional steel and might seem like the obvious choice in marine settings. This is true for steel reinforcing bar, but for stressing strand, SS's lower strength relative to carbon steel affects the level of effective prestress or the number of required strands to provide an acceptable level of prestress. Many SS grades would not meet the strength requirements, and SS is often not available in strand form. Further, if the strength of SS is increased through cold working or a similar process, concerns would still exist about the increased potential for stress corrosion cracking (SCC), in which stress leads to cracks in the SS microstructure.

In this project, University of South Florida researchers studied the corrosion and structural performance of three SS types with the goal of identifying one for use in prestressed concrete piles suitable for Florida marine environments.

From the many types of SS, three were selected for evaluation: an austenitic Grade 316; a low-nickel/high-manganese XM-29; and a duplex 2205. For each SS, the researchers screened for SCC development in single wire specimens, documented tensile strength and relaxation properties of 7-wire strands, and determined transfer length from fabrication and testing of full-scale prestressed piles. Candidate materials were largely selected on the basis of their availability in strand form.



Stress applied to stainless steel can amplify the effects of corrosion, leading to the cracking shown above (bar = 1 mm).

Corrosion testing was conducted at various temperatures in magnesium chloride solutions and also in a simulated concrete pore water solution at 60°C, followed by anodic polarization as an alternative test acceleration method. Although none showed very poor performance, the results suggested that high-strength duplex 2205 performed better than the other two alloys.

Relaxation testing was conducted on the SS candidates and the commonly used low-lax Grade 270 carbon steel strand. The low magnetic permeability of SS meant that induction furnaces could not be used to relax the material, and therefore, each material was not relaxed in the as-received state. As a result, tests showed high relaxation values that exceeded normally accepted levels. A cyclic loading methodology was adopted to mechanically relax the stainless strands and bring the relaxation to a usable level.

Finally, full-scale piles were cast with each of the candidate strands. A control pile used low-lax Grade 270 carbon steel. Use of SS strand showed no adverse effects on transfer length, compared to traditional low-lax Grade 270 carbon steel.

The use of an appropriate SS prestressing strand could extend the service life of bridge components in Florida waters, resulting in lower maintenance and replacement costs over the bridge's life.

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For more information, visit http://www.dot.state.fl.us/research-center