Scott, P.

Aspects of CFRP prestressed concrete in the marine environment

Paul Scott

Abstract

Carbon fibre reinforced polymer (CFRP) prestressed concrete can offer increased design life and reduced maintenance requirements compared to steel structures used in the marine environment. The durability of CFRP tendons is not fully understood, yet is central to their use in such applications. This research investigates various aspects of CFRP tendon durability in a simulated marine environment.

Uptake of aqueous solutions (water, salt water and concrete pore solution (CPS)) into epoxy and epoxy matrix CFRP tendons is observed and modelled using non-Fickian diffusion equations. To predict long term diffusion in CFRP tendons using parameters calculated from short term matrix tests, modelling of knock-down diffusion coefficients is found unreliable. A better approach is shown to be short term diffusion tests on both materials.

The bounds of expected uptake behaviour in a cracked yet serviceable CFRP prestressed concrete structure; either proceeding only at sites of concrete cracking, or along the full tendon length, are considered. To evaluate the first bound, a novel finite difference model is proposed to predict simultaneous axial and radial diffusion in CFRP tendons. By modelling the predicted diffusion of solution through concrete and the concrete/tendon interface, it is concluded that in-situ uptake is likely to be closer to the second bound than to the first.

Using a novel technique, uptake-induced swelling transverse to the fibre direction in the tendons studied has been measured to be greater than the thermal expansion effects likely to occur in practice. Modelling undertaken shows the swelling observed is likely to cause cracking of concrete cover at the tendon surface even in high strength concrete when allowing for creep effects.

The effect of uptake on the dowel strength of CFRP tendons has been investigated. Tests show that exposure to aqueous solutions causes considerable degradation of matrix-dominated properties (shear stiffness and shear strength) and slight degradation of a key fibre-dominated property (axial strength). Dowel tests of prestressed and unprestressed specimens using a method proposed by the ACI 440 Committee show matrix dominated effects to be significant in early test stages, but fibre dominated mechanisms are responsible for sustaining ultimate loading. As a result the dowel strength of CFRP prestressed concrete may be less prone to uptake induced degradation than might be expected.

Aqueous solution exposure was found to reduce the force required to strip a commonly used silica coating from the surface of the tendons studied. CPS exposure is seen to be particularly aggressive, causing greater plasticisation of the matrix in which the silica is held. A chemical reaction between CPS and the silica coating was observed which is thought to further compromise the chemical bond between the silica grains and the matrix meniscuses in which they are held. Degradation in the tendon/concrete bond strength is expected as a result.

In summary, this investigation has advanced the understanding of how in-situ solution uptake may proceed in CFRP prestressing tendons. The significant consequences including uptake-induced swelling, the capacity of the tendons to sustain dowel loading, and the durability of a silica coating commonly used to improve the bond have been studied in depth for the first time.