ABSTRACT

Ultra-high-performance concrete (UHPC) is widely recognized for its dense matrix, low transport properties, and high resistance to chloride ingress and reinforcement corrosion. Cracking, however, can create preferential pathways for chloride ions, moisture, and oxygen, potentially reducing the protection provided by the UHPC cover in coastal and marine environments. The durability of cracked reinforced UHPC remains insufficiently understood, particularly for large crack widths, different cover thicknesses, multiple-crack patterns, realistic marine exposure, and electrochemical monitoring.

This dissertation investigates the effects of cracking on chloride transport and chloride-induced corrosion in reinforced UHPC through four related experimental studies. Reinforced UHPC specimens with different cover thicknesses and primary crack widths were subjected to long-term laboratory chloride wetting–drying exposure. Chloride transport was also evaluated in uncracked, single-cracked, and multi-cracked specimens using colorimetric measurements, acid-soluble chloride testing, and simplified two-dimensional diffusion simulations. Additional specimens were exposed to a marine tidal environment at Seahorse Key Island to compare field and laboratory corrosion behavior. The applicability of several electrochemical monitoring methods was further examined using reinforced specimens made with a nonproprietary UHPC mixture.

The results confirmed that uncracked UHPC provided strong protection for embedded reinforcement. Steel in uncracked specimens generally remained passive, and the apparent chloride diffusion coefficients of uncracked UHPC remained on the order of 10^{-14} m²/s after long-term exposure. Once cracking occurred, however, chloride transport and corrosion behavior were governed primarily by the effective crack pathway rather than by the intact UHPC matrix. Primary crack width was identified as the most practical indicator of chloride ingress and corrosion susceptibility. Greater primary crack widths generally resulted in larger chloride-penetration regions, higher apparent chloride diffusion coefficients, and less stable corrosion performance. Specimens with primary crack widths near 300 μm generally maintained low corrosion activity under the tested conditions, whereas wider cracks produced deeper and more continuous chloride penetration. In multi-cracked specimens, closely spaced secondary cracks created overlapping chloride-affected regions, indicating that crack spacing and connectivity also influence transport behavior. The apparent chloride diffusion coefficient within cracked regions increased by approximately three orders of magnitude relative to uncracked UHPC.

Field-exposed specimens generally exhibited lower corrosion current densities than laboratory specimens with comparable crack widths, likely because of differences in wetting and drying, crack closure, surface deposition, biofilm formation, and oxygen availability. Electrochemical testing further showed that corrosion potential should be used primarily as a screening indicator in cracked UHPC. Corrosion measurements must also be interpreted with consideration of moisture condition, oxygen transport, cover-region resistance, and steel-interface response.

Overall, this dissertation demonstrates that the chloride durability of cracked reinforced UHPC is governed largely by the width and connectivity of primary cracks, particularly their connection to the reinforcement. The findings provide experimental support for crack-width control,

appropriate cover selection, realistic field assessment, and improved interpretation of electrochemical measurements in reinforced UHPC structures exposed to coastal and marine environment。