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Experimental Investigation on Tensile Durability of Glass Fiber Reinforced Polymer (GFRP) Rebar Embedded in High Performance Concrete

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Abstract : The objective of this research is to comprehensively evaluate the impact of alkaline environments on the durability of Glass Fiber Reinforced Polymer (GFRP) reinforcements in concrete structures and further explore their potential value within the construction industry. Specifically, we investigate the effects of two widely used high-performance concrete (HPC) materials on the durability of GFRP bars when embedded within them under varying temperature conditions. A total of 279 GFRP bar specimens were manufactured for microcosmic and mechanical performance tests. Among them, 270 specimens were used to test the residual tensile strength after 120 days of immersion, while 9 specimens were utilized for microscopic testing to analyze degradation damage. SEM techniques were employed to examine the microstructure of GFRP and cover concrete. Unidirectional tensile strength experiments were conducted to determine the remaining tensile strength after corrosion. The experimental variables consisted of four types of concrete (engineering cementitious composite (ECC), ultra-high-performance concrete (UHPC), and two types of ordinary concrete with different compressive strengths) as well as three acceleration temperatures (20, 40, and 60℃). The experimental results demonstrate that high-performance concrete (HPC) offers superior protection for GFRP bars compared to ordinary concrete. Two types of HPC enhance durability through different mechanisms: one by reducing the pH of the concrete pore fluid and the other by decreasing permeability. For instance, ECC improves embedded GFRP's durability by lowering the pH of the pore fluid. After 120 days of immersion at 60°C under accelerated conditions, ECC (pH=11.5) retained 68.99% of its strength, while PC1 (pH=13.5) retained 54.88%. On the other hand, UHPC enhances FRP steel's durability by increasing porosity and compactness in its protective layer to reinforce FRP reinforcement's longevity. Due to fillers present in UHPC, it typically exhibits lower porosity, higher densities, and greater resistance to permeation compared to PC2 with similar pore fluid pH levels, resulting in varying degrees of durability for GFRP bars embedded in UHPC and PC2 after 120 days of immersion at a temperature of 60°C - with residual strengths being 66.32% and 60.89%, respectively. Furthermore, SEM analysis revealed no noticeable evidence indicating fiber deterioration in any examined specimens, thus suggesting that uneven stress distribution resulting from interface segregation and matrix damage emerges as a primary causative factor for tensile strength reduction in GFRP rather than fiber corrosion. Moreover, long-term prediction models were utilized to calculate residual strength values over time for reinforcement embedded in HPC under high temperature and high humidity conditions - demonstrating that approximately 75% of its initial strength was retained by reinforcement embedded in HPC after 100 years of service.

Keywords : GFRP bars, HPC, degeneration, durability, residual tensile strength.
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