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Research at a Glance

Technical Brief

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Advanced Reinforced Concrete Materials for Transportation Infrastructures

A range of new materials have been developed to improve the service life of reinforced concrete transportation infrastructure. For example, concrete materials with high ductility improve the mechanical performance and durability when compared with traditional concrete systems. Such systems can be used in new construction and rehabilitation projects to improve constructability, reduce material consumption, and enhance service life and resistance to deterioration.

Research Problem Statement

New Jersey's transportation infrastructure systems must resist conditioning from the natural environment and physical demands from service loading to meet the needs of users across the state. Reinforced concrete, which is widely used in bridge decks, pavements, super- and substructures, and other systems, deteriorates under environmental conditioning due to electro-chemical processes that cause expansive mechanics stresses at various length scales (e.g., reinforcement corrosion, freeze-thaw, etc.), leading to costly and timely durability and maintenance challenges. As deterioration accelerates, the serviceability and structural safety of infrastructure systems decrease, requiring intervention to repair, replace, or temporarily close a structure.

Research Objectives

The overall objective of this project was to understand how advanced materials can be used to improve the durability of reinforced concrete transportation infrastructure in the State of New Jersey. A primary focus of the research program was to investigate highly ductile concrete materials, often referred to as high-performance fiberreinforced cementitious composites (HPFRCCs). Specific objectives included: (i) identifying novel materials that can be deployed to enhance transportation infrastructure durability, (ii) experimentally investigating the durability of these systems across a range of deterioration metrics, (iii) evaluating the in-service performance through detailed numerical simulations, and (iv) predicting the life-cycle costs of transportation infrastructure when using advanced concrete materials.

Methodology

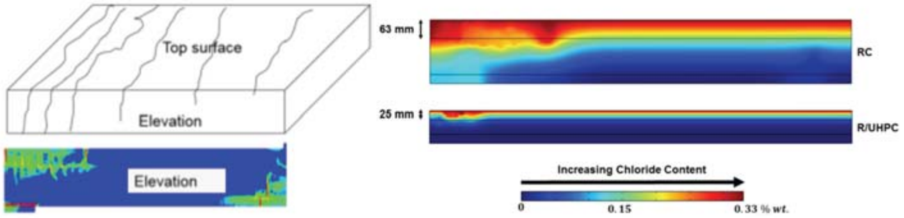
The experimental testing program involved mechanical testing, corrosion testing, testing in freezing environments, and shrinkage testing. Corrosion testing of ductile and normal concrete systems used a chloride ponding test method with exposure to an aggressive environment for over one year. Various steel reinforcing bars were studied, and systems were tested in uncracked and pre-cracked conditions. Freeze-thaw and salt-scaling experimental activities were conducted. Drying shrinkage behavior of the ductile and normal concrete systems was also investigated.

A numerical modeling approach for simulating the corrosion behavior of ductile concrete systems was developed. This was used to understand the long-term chloride ingress and corrosion performance of ductile and non-ductile concrete systems. A study on the in-service and life-cycle behavior of a reinforced concrete bridge deck using reinforced ultra-high performance concrete and traditional reinforced concrete materials was completed. Life-cycle cost modeling was completed to assess the lifecycle costs of a representative bridge-deck made with normal reinforced concrete and the ductile concrete system.

Results

The mechanical behavior of the highly ductile concrete materials restrained crack widths, which is believed to have blocked corrosion product formation or resulted in self-healing of cracks. Two of the highly ductile concrete materials had freeze-thaw and salt-scaling performance that exceeded the behavior of the standard concrete mixtures. The two best performing materials had a mortar matrix, without coarse aggregate. Test procedures showed that the inclusion of fibers in the highly ductile concrete materials required slight modifications to standard testing procedures, which need to be considered when evaluating durability performance.

The in-service performance of highly ductile concrete materials was evaluated through numerical modeling techniques and life-cycle costs were reported. Reinforced bridge deck specimens were designed and analyzed under the combined effects of mechanical loading and environmental conditioning. Bridge decks with the highly ductile concrete materials exhibited improved resistance to chloride penetration and corrosion propagation according to the numerical simulations. Structural deterioration occurred at a significantly slower rate in the highly ductile concrete bridge deck systems compared to that of reinforced normal strength concrete systems. Life-cycle cost analysis showed that bridge decks made with ductile concrete materials have high economic potential, although the life-cycle cost varies significantly depending on construction cost.



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