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RESEARCH PROJECT TITLE

Evaluation of Corrosion Resistance of Different Steel Reinforcement Types

SPONSORS

Iowa Department of Transportation (CTRE Project 02-103)

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The Bridge Engineering Center (BEC) is part of the Center for Transportation Research and Education (CTRE) at Iowa State University. The mission of the BEC is to conduct research on bridge technologies to help bridge designers/owners design, build, and maintain long-lasting bridges.

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Corrosion Resistance in Different Steel Reinforcement Types

tech transfer summary

Steel reinforcement that demonstrates effective corrosion resistance can improve the life expectancy and cost-effectiveness of bridges.

Objectives

- Measure the difference in corrosion resistance between MMFX microcomposite steel, epoxy-coated reinforcement, and uncoated reinforcement in bridge decks to determine whether MMFX steel provides corrosion resistance superior to epoxy-coated steel.
- Determine the initiation of corrosion and the rate of corrosion growth in these three reinforcement materials.

Problem Statement

The corrosion of steel reinforcement is the primary and most costly form of deterioration currently impacting the performance of reinforced concrete bridge structures. In the United States, maintenance and replacement costs for deficient bridges are measured in billions of dollars.

Eliminating or slowing the deterioration of reinforced concrete structures due to the corrosion of steel reinforcement requires innovative solutions. Over the last three decades, the principle techniques for corrosion prevention in bridge decks have included increased concrete cover depth and the application of epoxy coating over the steel reinforcement. However, increasing concrete cover depth increases both dead load and construction costs and is generally unnecessary for structural reasons. Additionally, while epoxy coatings limit the exposure of the steel to chlorides, oxygen, and moisture and add minimally to bridge construction costs, breaks in the epoxy coating at cracked locations, in combination with high chloride concentrations, may result in corrosion of the steel reinforcement, which affects the overall performance of the bridge. Moreover, epoxy coatings in aging bridge decks may become brittle and eventually delaminate from the steel reinforcement.

As alternative measures for mitigating corrosion in bridge deck reinforcements, dense concretes, corrosion inhibitors, and both nonmetallic and steel-alloy corrosion-resistant reinforcement are among the most common techniques being considered.

Technology/Technique Description

MMFX microcomposite steel reinforcement has been publicized as a proprietary chemical composition material with a unique microstructure, enhanced corrosion resistance characteristics, and higher yield and tensile strengths than conventional ASTM A 615 steel.

To test the corrosion resistance properties of MMFX microcomposite reinforcement, MMFX, epoxy-coated steel, and uncoated steel were

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evaluated in both field and laboratory studies. The field evaluation program consisted of construction documentation and post-construction monitoring of two side-by-side bridges constructed using MMFX and epoxy-coated reinforcement. Sensors were installed in the two newly constructed concrete bridge decks, and periodic measurements were made to assess corrosion performance. In the laboratory evaluations, Rapid Macrocell and ASTM G 109 (Determining the Effects of Chemical Admixtures on the Corrosion of Embedded Steel Reinforcement in Concrete Exposed to Chloride Environments) accelerated corrosion tests were conducted to evaluate the corrosion properties of MMFX, epoxy-coated reinforcement, and uncoated reinforcement.

Key Findings

- According to the laboratory evaluation data, MMFX reinforcement is more corrosion-resistant than uncoated mild steel reinforcement and exhibits similar corrosion resistance to epoxy-coated reinforcement that meets the requirements of ASTM A 775. MMFX reinforcement requires a higher chloride ion concentration than uncoated reinforcement for corrosion initiation.
- The field evaluation data indicate that corrosion-related measurements were lower for the MMFX bridge than for the epoxy bridge. However, no significant corrosion activity was observed in either bridge deck.
- After 40 weeks of laboratory testing, the ASTM G 109 accelerated corrosion test indicated that corrosion had not initiated for either MMFX or the as-delivered epoxy-coated reinforcement. The uncoated mild steel underwent corrosion within the fifth week, while the epoxy-coated reinforcement with induced coating breaks underwent corrosion between 15 and 30 weeks.
- Within the fifth week of testing, the Rapid Macrocell ACT produced corrosion risk potentials indicative of active corrosion for all three reinforcement types. The concrete surrounding the MMFX and uncoated reinforcement discolored due to deposition of corrosion products.

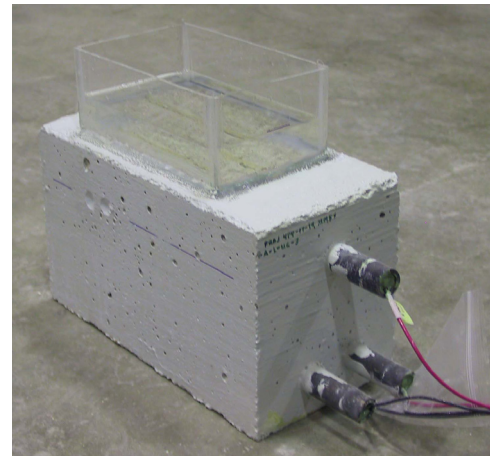
Implementation Benefits

Reinforcing concrete with materials that exhibit better corrosion resistance than commonly used uncoated steel reinforcements can improve both the life expectancy and cost-effectiveness of bridge structures.

Implementation Readiness

While the limited results from 40 weeks of laboratory testing do not constitute a prediction of life expectancy and life-cycle cost, a procedure has been developed for determining the life expectancy and life-cycle cost when definitive evidence is attained.

Through continued monitoring and evaluation, the ongoing field evaluation system is expected to provide evidence of the corrosion resistance of the MMFX reinforcements in the state of Iowa.



Typical as-constructed ASTM G 109 ACT



Typical as-constructed Rapid Macrocell ACT



Extending lead wires for data measurement