CENTER FOR TRANSPORTATION RESEARCH

# PROJECT SUMMARY

Texas Department of Transportation

# 0-6952: Synthesis of Alternate Reinforcements for Enhanced Corrosion Resistance in TxDOT Bridges

## Background

The corrosion of reinforcing steel in concrete is the leading cause of deterioration for reinforced concrete structures, especially bridges. Practitioners and researchers have evaluated and implemented various technologies to combat this problem, including the use of high-performance concrete, chemical corrosion inhibitors, sealers and barriers, and alternative reinforcement. This synthesis project addressed the latter, specifically the use of alternative reinforcement (e.g., fiber-reinforced polymer [FRP], epoxy-coated steel, stainless steel, and galvanized steel) to extend the service life of bridge structures subjected to external chlorides from marine environments or from de-icing salt applications.

## What the Researchers Did

The project's primary goals were to (a) review and synthesize published literature, (b) review and synthesize current DOT practice, (c) identify gaps in our current knowledge and state of practice, and (d) provide recommendations, based on current knowledge, for evaluating and selecting alternative reinforcement for bridges subjected to external chlorides.

## What They Found

Some of the main findings from this synthesis study include the following:

- Improving the corrosion resistance of reinforced concrete bridges (and other structures) that are subjected to external chlorides is increasingly needed, but complicated by the recent shortage of fly ash, a material long used to combat corrosion by reducing the chloride diffusion rate.
- Several commercially available alternative reinforcement products have been used in bridges nationwide, with epoxy-coated steel being by far the most commonly used to date, followed distantly by galvanized steel, stainless steel, low-carbon chromium steel, and FRP.
- Some of the alternative reinforcements, specifically stainless steel and epoxy-coated steel, are already integrated into service-life prediction software, such as ConcreteWorks V3.0, with appropriate modifications to the chloride threshold value included as defaults.
- By evaluating a specific bridge to be constructed in a given chloride-laden environment, it is possible to quantify the potential increase in service life imparted by a specific alternative reinforcement type, using either default chloride threshold values or values input by the user. One can use available cost data, coupled with the predicted service life (or time to corrosion initiation) from ConcreteWorks, to compare the various alternative reinforcements for a given exposure condition.
- Some alternative reinforcement types require modifications to standard construction and design methodologies. Increased development lengths are required for some alternative

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reinforcement types, such as epoxy-coated steel or FRP. Appropriate specifications and codes should be followed to ensure that the appropriate modifications are applied to account for reduced bonding with the concrete and for the potential, long-term degradation of FRP, particularly in a wet environment.

- Currently, there is no standardized test method to accurately measure the chloride threshold value for a given alternative reinforcement type.
- Very little information is available on the long-term corrosion resistance of alternative reinforcement types. Monitoring existing structures (or reinforced concrete samples at a marine exposure site) containing alternative reinforcement is essential, and new construction projects should integrate long-term monitoring into the project scope.
- The use of alternative reinforcement may affect the structural performance and design of reinforced concrete members if the mechanical properties or bond characteristics of the bars differ from those of conventional reinforcement. Implications include the cracking and deformability of structural members (to be considered for serviceability design), the ultimate load-carrying capacity and ductility of the members (to be considered in strength design), and the required development and lap-splice lengths of the reinforcing bars. Such differences are generally considered in current design practice and specifications. However, several issues concerning the structural design deserve more detailed studies:

  —Limited research conducted on stainless-clad reinforcement has shown that the core and the cladding of the bars may separate prior to the developing its full tensile capacity; the bond performance and composite action of the core and cladding need to be further investigated.

  —Current design specifications present a number of limitations regarding the use of alternative reinforcement with nominal yield strengths higher than 60 ksi. Current codes limit the application of high-strength bars to certain applications. Research is needed to support a more general use of steel bars with excess of Grade 60 to exploit the benefits of their higher tensile strength.

  —The use of alternative reinforcement with significantly higher corrosion resistance, such as stainless steel, could allow for more relaxed durability design requirements (e.g., concrete cover) to optimize structural design and compensate the higher cost of the reinforcement. The design possibilities offered by the use of corrosion-resistant bars should be further explored.

## What This Means

The need for alternative reinforcement will likely increase in the coming years, especially given the fly ash shortage. The information collected and synthesized in this project provides a better understanding of the state of the art and current practice related to the use of alternative reinforcement to reduce the potential corrosion of reinforced concrete bridges. This review identified several gaps in our current understanding, which should be addressed in future research and/or implementation projects.

## For More Information

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