

Research Spotlight

Project Information

REPORT NAME: Design and Construction Guidelines for Strengthening Bridges Using Fiber Reinforced Polymers (FRP)

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Guidelines for using fiber-reinforced polymer composite materials to extend bridge life

With a high strength-to-weight ratio, fiber-reinforced polymer (FRP) composite fabrics have become a promising technology for strengthening concrete bridge elements that are starting to deteriorate. To take full advantage of the benefits of these materials, MDOT needed design and construction guidelines specific to the environmental conditions that highway bridges in Michigan experience. The guidelines developed in this project will help MDOT expand its use of FRP composites. This will allow the department to extend the service lives of bridges, while minimizing rehabilitation costs and impacts on traffic.

Problem

As highway bridges age, transportation agencies must inspect, maintain and occasionally rehabilitate them. However, replacing the weakened parts of a bridge structure can be expensive and disruptive to traffic. As an alternative, transportation agencies sometimes opt to strengthen bridge elements by repairing damaged areas, adding stiffeners or applying protective coatings.

In recent years, methods have been developed to strengthen and repair bridge elements using fiber-reinforced polymer composite materials. Composed of epoxy resin and various fibers, such as glass or carbon, FRP fabrics and wraps can be externally bonded to bridge beams, columns and decks to improve their strength and performance. Because FRP



Researchers applied FRP composite fabrics to concrete specimens using epoxy adhesive. They then tested the specimens for various properties, including how well FRP materials adhered when subjected to cold weather conditions.

“This project gives MDOT a much more robust design procedure that is in alignment with bridge design code and geared specifically to Michigan environmental conditions.”

Steven Kahl, P.E.
Project Manager

materials have a high strength-to-weight ratio, they are easy to transport and install, and can be used without significantly increasing a structure’s dead load. Finally, their resistance to corrosion is especially important given Michigan’s winter climate, since moisture and chlorides from deicing materials can damage the reinforcing steel in concrete bridge elements.

Many foundational guidance documents on the use of FRP to strengthen structural components are geared toward the use of FRP in concrete structures, which can apply to bridge elements. These include the guidance developed by the American Concrete Institute that forms the basis of MDOT’s existing guidelines on strengthening bridges with FRP.

Research was needed to develop guidelines for the use of FRP composite materials to strengthen bridges in Michigan, taking into account the effects of the state’s unique environmental conditions on FRP systems’ durability. Michigan-specific guidelines would also help ensure reliability consistent with AASHTO LRFD bridge design specifications.

Research

The goal of this project was to develop design, construction, maintenance and inspection guidelines for using FRP composite materials to strengthen deteriorated bridge elements in Michigan. To develop the guidelines, researchers began

by conducting a comprehensive review of existing literature on FRP strengthening. They selected six representative sets of U.S. and international guidelines and compared their approaches regarding design, installation and usage.

Researchers then conducted laboratory testing to evaluate how the bond between FRP composites and bridge structural elements would degrade when exposed to Michigan’s climate. They prepared approximately 120 FRP-strengthened concrete specimens, subjecting some to accelerated weathering in the laboratory (including up to 240 freeze-thaw cycles) and others to natural outdoor weathering. After this weathering, they conducted laboratory tests to assess various properties, including the bond strength between FRP composites and concrete.

Results

Researchers found many similarities among the six U.S. and international FRP guides, although there were some differences in design guidance and in the details of implementation. Installation and usage procedures also varied across the guidelines.

Researchers used the results of the bond strength testing to compare bond degradation rates caused by natural outdoor weathering and laboratory-accelerated weathering. Using this data, they developed short-term and long-term acceleration factors that allow the use of accelerated weathering test results to predict bond losses due to Michigan conditions.

Based on these results, researchers developed recommendations for the use of FRP composite materials to strengthen bridges in Michigan. In general, researchers recommended using a modified version of design provisions developed by the American Association of State Highway and Transportation Officials (AASHTO), with the modifications including changes in bond strength reduction factors. Researchers also provided a second series of general recommendations for installation, inspec-

tion and quality control, and maintenance and repair. Researchers reviewed a pilot FRP pier strengthening design and observed a field installation.

Value

MDOT is reviewing these recommendations for incorporation into the department’s FRP design guidelines. Once they are approved, MDOT will begin using the new design procedures on additional pilot projects. With design procedures developed specifically for bridges and Michigan weather conditions, MDOT will ultimately be able to expand its use of FRP systems, which are currently employed on about 5 percent of bridge rehabilitation projects. This will allow the department to extend the service lives of bridges across the state, while minimizing rehabilitation costs and traffic impacts.

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**This final report is available
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