PUTTING RESEARCH TO WORK BRIEF

Preventing Bridge Deck Corrosion Through Fiber-Reinforced Polymers

Though designed to last 75 years or more, concrete bridges sometimes require extensive repair or replacement before that point. Almost all concrete bridge decks crack to some degree, but the fissures themselves do not shorten deck life. The incursion of water into cracks, particularly when it carries deicing salt used for wintertime safety, inevitably corrodes the steel reinforcement bars strengthening the decks. This corrosion shortens bridge deck life, forcing overlays or, in situations of extreme deterioration, full replacement to ensure the structure will last for its full design life.

What's the Problem?

Alternative reinforcement materials, including fiber-reinforced polymers, can be used to avoid corrosion damage. This emerging material does not react to water and salt, and so does not corrode as steel does. Though more expensive initially than steel rebar, FRP grillwork can be cost-effective if it limits bridge deck damage over a structure's life, incurring fewer maintenance and replacement costs than a steel-reinforced alternative.

Two Wisconsin bridges were built in 2003 and 2004 with FRP reinforcement under FHWA's Innovative Bridge Research and Construction, or IBRC, program. Each was matched with a traditional, steel-reinforced partner bridge of the same design. The Waupun bridges featured two-span continuous precast, prestressed concrete girders, and the IBRC bridge there employed FRP stay-in-place formwork at the bridge piers and FRP grillwork reinforcement within the concrete bridge deck. The Fond du Lac bridges were designed as simply supported concrete spans, with FRP gridwork reinforcing the IBRC bridge. Evaluation and monitoring were not fully funded by the FHWA program, and so their performance required research attention.

Research Objectives

Researchers sought to evaluate the condition and structural behavior of these FRP-reinforced bridges as compared to traditional, steel-reinforced bridges. This would involve annual inspections, load testing (once late during the five-year period), simulations of deck behavior and a projection of performance over the life of the bridge.

Methodology

In addition to site inspections and a literature survey, investigators defined the project as comprising four tasks for lab and fieldwork:

- Evaluating moisture presence after soaking and exposure of lab specimens to 100 freeze-thaw cycles.
- Testing various non-destructive evaluation methods through laboratory and field evaluations; methods reviewed included infrared thermography, chain dragging, tap testing with impact hammers and ultrasonic testing.
- Designing a distribution monitoring system and performing four types of on-site load testing: bridge deck deflection relative to girders, wheel load distribution within the deck, composite beam behavior in the superstructure and lane load distribution within the superstructure.
- Using finite element modeling to study the likelihood of cracking due to shrinkage and traffic stresses, cracking severity and long-term implications for each configuration of bridges with numerical modeling.

Results

Based on the relatively brief, five-year duration of the study, analysis confirmed that current WisDOT

Investigator

"Considering long-term performance, fiber-reinforced bridge decks represent a promising alternative to steel-reinforced."

–Christopher Foley
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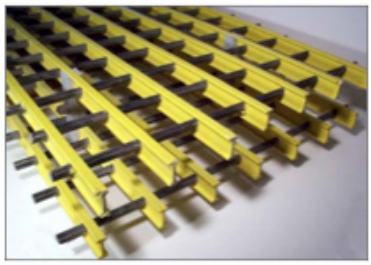

Gridwork of fiber-reinforced polymer (left) was used to reinforce the deck of this bridge south of Fond du Lac. Inspections, load testing and instrumentation showed the alternative grill material performs well and does not suffer the corrosion that typically shortens steel-reinforced deck life.

bridge designs using steel reinforcement work well, and that FRP reinforcement could viably be used as an alternative that may offer long-term cost benefits. Key specific findings include the following:

- Freeze-thaw and water could hamper interfacial shear strength at the convergence of concrete and the stay-in-place FRP formwork. Soaking and 100 freeze-thaw cycles diminished shear strength at this interface, but finite-element modeling shows that these reductions do not threaten acceptable long-term performance.
- Both bridges at Waupun showed significant transverse cracking after four years of traffic, allowing water incursion. Lab testing, however, indicates that the cracking presents little long-term threat to the IBRC bridge. Water was not pooling at the interface of formwork and concrete. The Fond du Lac IBRC bridge remains in excellent condition after four years of traffic, with no discernible cracking, and little on the steel-reinforced control structure.
- Tap testing was found to be the most useful method of monitoring these structures, and infrared thermography the least useful. Limitations in every non-destructive evaluation method employed for these bridge designs suggest that coring may also be necessary in future research.
- In situ load testing revealed little or no degradation in these bridges for any of the four studied load distribution mechanisms. All designs performed very well in distributing loads without degradation over time. Portable strain sensor systems developed for this study performed very well and were installed with little difficulty.
- Drying shrinkage seems to cause early cracking of bridge decks, and simulations showed that this cracking can occur within four to eight days of deck placement. Tensile strength modeling suggests traffic and shrinkage stresses cause the cracking seen in the Waupun design. FRP and steel-reinforced bridges do not seem to crack differently.

Further Research

Investigators suggest that further analysis with regard to relative humidity will help in long-term evaluation of bridge decks with FRP formwork. The two-span continuous superstructure design of the Waupun bridges requires further evaluation as well for its long-term efficacy.

Project Manager

"The goal of using fiber-reinforced polymers as reinforcement is to avoid doing a full replacement of the deck for the entire service life of the bridge. That's why we are interested in the technology."

–Travis McDaniel
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