

TECHNICAL SUMMARY

Questions?

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PROJECT COST:

\$100,104



A GFRP sample underwent a variety of lab tests to demonstrate its material characteristics.

Assessment of GFRP-Reinforced Bridge Deck Performance

What Was the Need?

Corrosion of steel reinforcement embedded in concrete is the primary cause of bridge deck degradation. Damage results when moisture and chlorides from road salts penetrate bridge superstructures and corrode the steel. Cycles of freezing and thawing during Minnesota's harsh winters can magnify the effects, leading to concrete cracking, which further exposes the embedded reinforcement.

Glass fiber-reinforced polymer (GFRP) rebar is a nonmetallic alternative to conventional steel rebar that does not oxidize or rust, making it highly resistant to corrosion. GFRP has been used as bridge deck reinforcement in parts of Canada, but has had only limited use in the U.S. [Previous research](#) on Minnesota's first and (then) only bridge using this alternative reinforcement found that GFRP resisted corrosion significantly better than traditional steel rebar, and there were no structural issues.

In 2018, MnDOT constructed a pair of side-by-side bridges—one using GFRP deck reinforcement and the other using conventional epoxy-coated steel reinforcement—on Trunk Highway 169. This construction project presented a unique opportunity to compare the performance of the two reinforcement types as the bridges were exposed to the same environmental stressors and experienced very similar traffic conditions.

What Was Our Goal?

The goal of this project was to compare the structural performance and durability of two in-service bridge decks and assess the potential of GFRP as an alternative to traditional steel reinforcement.

What Did We Do?

A multifaceted effort that began at the time of bridge construction allowed a thorough assessment of the performance of GFRP compared to steel rebar reinforcement in bridge decks. First, guided by the bridge design, researchers installed sensors inside the decks before the concrete was placed. This helped measure strain and temperature developments in the bridge decks over time.

Monitoring over nearly four years included collecting the temperature and strain data from the sensors, evaluating associated stresses and comparing performance to design guidelines. Measurements captured both general and extreme deck responses.

Additional instrumentation attached to the girders and the bridge decks measured stresses and strains during live-load testing immediately after construction, after one year and after two years. The live-load tests replicated traffic load effects and were used to understand how the live loads are distributed from the points of application to the bridge deck and individual girders.

Visual bridge deck inspections every six months throughout the project allowed investigators to evaluate the condition of both bridge superstructures, document any cracks and explain the potential causes based on the collected sensor data.

A nonmetallic alternative to the steel rebars that reinforce concrete bridge decks has the potential to be longer lasting and more cost-effective in keeping bridges maintained in Minnesota's harsh climate. Initial studies show that the performance of bridge decks built with glass fiber-reinforced polymer is comparable to—if not better than—conventionally built decks.

“This was an excellent opportunity to directly compare adjacent bridge decks reinforced with GFRP and epoxy-coated reinforcement. The stresses, strains and deflections of each bridge deck are very similar, and the early performance has been excellent.”

—Paul Rowekamp,
Bridge Standards and
Research Engineer,
MnDOT Bridge Office

“We found that using glass fiber-reinforced polymer instead of epoxy-coated steel rebar to reinforce bridge decks results in superior corrosion resistance, decreased maintenance needs and a longer service life for Minnesota bridges.”

—Behrouz Shafei,
Associate Professor,
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Girder distribution factors calculated from strain measurements taken during live-load testing were comparable to those calculated using AASHTO bridge design specifications.

In the laboratory, GFRP samples supplied by MnDOT underwent tension loading until failure, enabling researchers to develop stress-strain curves to confirm the material's mechanical properties. Lastly, life-cycle cost analyses of the two bridge decks, including construction, materials, labor, operation and long-term maintenance costs, evaluated the economic potential of GFRP rebar as compared to traditional steel.

What Did We Learn?

The short- and long-term performance comparisons between the bridge decks revealed no significant differences or any unusual behavior in either one.

The live-load testing showed the performance of the bridge decks was comparable and consistent with design specifications. Similarly, long-term monitoring data revealed that while the GFRP deck recorded slightly higher strain values overall, the two decks behaved similarly over the monitoring period.

The first round of inspections of the bridges found top surface and full-depth cracks in both bridge decks. Initially, the steel-reinforced bridge showed more cracking than the GFRP-reinforced bridge deck. Crack patterns became similar in both bridges over time, however, investigators noted that cracks in GFRP decks are potentially less concerning as they do not lead to corrosion of embedded reinforcement and further concrete cracking that can result from corrosion.

Lab tests indicated that the GFRP rebar has a high tensile strength, however, it is more brittle than steel, resulting in a more sudden failure unlike steel's more gradual yielding under stress. Because single GFRP rebars would not bear exceeded capacity, any GFRP failure will likely be more drawn out, providing warning of a potential failure.

Comparing the life-cycle costs of the two bridge decks, the GFRP deck with a 65-year service life is less costly than the steel-reinforced deck with the same service life. The differential increases as the target service life of the GFRP deck increases.

What's Next?

While GFRP rebars have performed well over approximately four years in two bridge decks, it is too early for MnDOT to definitively embrace the new material as bridges are typically designed with a 75-year life span. The coming years will provide more information on GFRP performance, and the agency will continue to investigate its use.