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TECHNICAL SUMMARY

Questions?
Contact research.dot@state.mn.us.

Technical Liaison:
Paul Rowekamp, MnDOT
Paul.Rowekamp@state.mn.us

Principal Investigator:
Behrouz Shafei, Iowa State University

LRRB PROJECT COST:
$22,000

Researchers used this loaded dump truck to conduct load testing on the Dry Creek bridge.

DEPARTMENT OF TRANSPORTATION
OFFICE OF RESEARCH & INNOVATION

GFRP Rebar Shows Promise for Use in Bridge Decks

Researchers studied a rural bridge built in 2016 near Elgin, Minnesota, that used GFRP rebar in the bridge deck. GFRP performed well, proving sufficiently strong for use as an alternative to corrosion-susceptible steel rebar.

What Was the Need?

Reinforced concrete bridges are built to handle heavy loads and routine traffic for 75 years or more. But bridges in climates like Minnesota's are exposed to moisture and chlorides from road salts that may penetrate these structures and corrode the steel. Corrosion of reinforcing steel is the primary cause of bridge deck degradation and cracking. Multiple cycles of freezing and thawing can also cause concrete to crack, further exposing reinforcement.

Damage to bridge decks increases over time, requiring costly maintenance and repair, and potentially shortening the bridge deck's service life. Crack sealing and drainage systems help manage moisture and chloride impact, but bridge owners often consider alternatives to enhance the longevity of the reinforcement. Epoxy coating of reinforcement, for example, is frequently used in Minnesota to help rebar resist corrosion.

Over the last decade, glass fiber–reinforced polymer (GFRP) reinforcement has gained interest among Minnesota bridge owners. GFRP, which does not corrode, has been used in Canada but not to the same level in the United States.

What Was Our Goal?

In 2016, MnDOT built a GFRP-reinforced concrete bridge deck on State Highway 42 over Dry Creek, north of Elgin. In the current study, researchers examined this pilot implementation, evaluating the performance of the bridge deck over its first three years of service.

What Did We Do?

After reviewing research on GFRP performance in the lab and field, investigators placed an array of strain and temperature gauges on the GFRP rebar at the Dry Creek bridge before the concrete deck was placed and connected the gauges to the monitoring equipment mounted beneath the deck. Temperature and stress response data were collected every hour for the three-year period of this study.

Before the deck was opened to regular traffic, the research team conducted live load tests in November 2016 with a three-axle dump truck loaded with sand and driven slowly over the structure. Load tests were conducted again in November 2017 and in late October 2018.

Bridge inspections documented the surface cracks and overall deck condition during the three-year course of the research project. Laboratory tests examined the loading capacity and failure characteristics of GFRP rebar used in the bridge. Researchers also conducted a life cycle cost analysis, comparing initial expenses and expected maintenance needs over the expected service life of GFRP compared with epoxy-coated rebar.

What Did We Learn?

GFRP reinforcement resisted corrosion very well and offered sufficient structural capacity and performance.

continued

"The findings met our expectations. We learned a lot about the design process, ironed out some ambiguities in the design code and are trying GFRP in another new bridge to compare its performance to epoxy-coated rebar."

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

"GFRP is a promising reinforcement alternative. The long-term saving advantages in repair, maintenance and labor compared with conventional steel can be significant."

—Behrouz Shafei,
Assistant Professor, Iowa State University Department of Civil, Construction and Environmental Engineering

Produced by CTC & Associates for:
Minnesota Department of Transportation
Office of Research & Innovation
MS 330, First Floor
395 John Ireland Blvd.
St. Paul, MN 55155-1899
651-366-3780
www.mndot.gov/research

Researchers attached strain and temperature gauges to the GFRP reinforcement bars before concrete was poured on the bridge deck.

Under live loading, the Dry Creek bridge deck and girders performed as expected, resisting loads consistently over the three-year period. In the first 150 days of service, standard concrete shrinkage had more impact on strain levels than did temperature variation. Strain and temperature relationships became and remained consistent over subsequent years.

Inspection identified no unusual cracking behaviors. Early investigations found cracking near abutments that was related to the concrete placement, not the deck reinforcement. While initial cracks grew in the first year of service, no significant cracks formed in the second and third years of monitoring.

Laboratory testing delivered results consistent with previous studies. GFRP failure occurred within the length of the rebar, not at anchors. Failure was sudden; bars did not show significant bending or yielding before failure but 30 to 40 seconds before breaking, the glass fibers snapped and frayed from the polymer material.

Though GFRP can cost more than epoxy-coated rebar initially, it appears to resist corrosion much better than epoxy-coated rebar and potentially offers lower life cycle costs.

What's Next?

GFRP performs well and may be suitable for bridges where road widening and invasive bridge maintenance activity are rarely required. A similar study will examine performance of a bridge on State Highway 169 in the northwest Metro District. In side-by-side spans at this site, one deck employs GFRP reinforcement and the other epoxy-coated rebar.

Long-term durability remains unknown. Gauges remain in the Dry Creek bridge, and strain and temperature relationships may still be monitored over time. The response of GFRP to fires under or on bridges also may require further investigation.

This Technical Summary pertains to Report 2020-05, "Field Investigation of Bridge Deck Reinforced With Glass Fiber Reinforced Polymer (GFRP) Rebar," published February 2020. The full report can be accessed at mndot.gov/research/reports/2020/202005.pdf.