



Project Summary

Texas Department of Transportation

0-6069: Long-Term Performance of Glass Fiber Reinforced Polymer (GFRP) Reinforcement

Background

Glass fiber reinforced polymer (GFRP) reinforcement is being used in concrete structures. This material has many advantages over conventional steel reinforcement:

- it is lightweight,
- it has a high strength-to-weight ratio, and
- the chemical or electrochemical reactions between the environment and GFRP do not increase volumes that result in concrete cracking and spalling.

A past research project performed by TTI personnel evaluated the potential use of GFRP reinforcement for bridge decks and reported significant strength loss after exposure to aggressive solutions (TxDOT research project 9-1520, FRP Reinforcing Bars in Bridge Decks). Most research projects are limited in duration, and accelerated exposure testing is common. However, exposing GFRP reinforcement to aggressive conditions may not represent the actual performance of GFRP reinforcement embedded in concrete. Limited data are available on the actual performance of embedded GFRP bars. Limited research has been performed on assessing the longer-term performance, specifically the residual tensile capacity, of GFRP reinforcement. Researchers found in the literature that the residual capacity of GFRP reinforcement has been assessed only for bars embedded in concrete for a maximum duration of 3 years. Because of the many potential advantages of using GFRP reinforcement, longer-term studies were needed.

What the Researchers Did

TTI researchers originally cast samples as part of project 9-1520. These samples were tested and stored at the Riverside Campus at Texas A&M University. GFRP reinforcements from three manufacturers were embedded in beams. Two sizes, #5 and #6, of GFRP reinforcement from the three manufacturers were embedded in concrete beams. After 7 years of storage at the College Station site [mean annual temperature of 69 F (21 C) and average annual precipitation of 39.7 inches (1008 mm)], the GFRP reinforcement in the samples was removed from the concrete and assessed for residual strength and modulus of elasticity.

Research Performed by:

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Based on exposure time and the limited data available in the literature on GFRP reinforcement embedded in concrete, the researchers developed a state-of-the-art time-variant deterioration model that can provide the required information to assess the safety and performance of GFRP reinforcing bars embedded in decks, pavements, and other infrastructure elements over time. The model is probabilistic and properly accounts for the relevant sources of uncertainties, including the statistical uncertainty in the estimation of the unknown model parameters and the model error associated with the inexact model form.

What They Found

The research team found that the modulus of elasticity of the GFRP reinforcement did not significantly change as a function of time embedded in concrete. Tensile capacity is a function of time of embedment, apparent diffusion coefficient of the GFRP polymer matrix, and initial GFRP bar diameter. A time-variant model, based on a general diffusion transport model, predicts the residual capacity of GFRP bars embedded in concrete. The model predicts that GFRP reinforcement bars with smaller diameters exhibit faster reductions in residual strength than larger-diameter GFRP reinforcing bars. The research indicates that the American Concrete Institute (ACI) design tensile strength, f_{ju} , for GFRP reinforcing bars is likely not a conservative value, as the times required for the tensile capacity of the GFRP bars to fall below this design limit before the service life of a structure. In particular, the model indicates that in 100 years:

- #3 bars reach a 0.44 probability of not meeting the ACI 440 requirement,
- #5 bars reach a 0.25 probability, and
- #6 bars reach a 0.2 probability.

What This Means

Although further research is needed to determine how these reduced tensile capacities can influence the performance of GFRP-reinforced structures, changes to the ACI design requirements for GFRP structures may be warranted, especially for smaller diameter GFRP reinforcing bars. The research indicates that the reduction in tensile capacity of GFRP reinforcing bars embedded in concrete is a function of bar diameter, diffusion characteristic of the GFRP polymer resin, and time. Using larger diameters of GFRP bars and lower design tensile strengths may extend the anticipated service life of GFRP-reinforced structures. However, further research on the performance of GFRP-reinforced concrete specimens that have been exposed to loads for longer durations is recommended.

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