Toward Non-Corrosion and Highly Sustainable Structural Members by Using Ultra-High-Performance Materials for Transportation Infrastructure

Developing next-generation highly corrosion-resistant and sustainable structural members by utilizing ultra-high-performance fiber-reinforced concrete (UHP-FRC)

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This project uses a new design concept referred to as ductile concrete strong Reinforcement (DCSR), which uses ultra-high-performance fiber-reinforced concrete (UHP-FRC) as the ductile element and fiber-reinforced polymer (FRP) bars as the brittle element; the opposite to conventional reinforced concrete, where the steel bars are the ductile element and the concrete is the brittle element. UHP-FRC's high compressive ductility allows a large reinforcement ratio of high-strength FRP bars to be used, thereby achieving high structural efficiency in members. High FRP reinforcement ratio allows the FRP bars to remain fully elastic which can reduce residual deformation (i.e., self-centering) once a member experiences large deformation under overloading. FRP bars are an excellent alternative to steel reinforcing bars when reinforced concrete is exposed to deicing salts, when standing in or close to seawater or subjected to other corrosive agents, when required to maintain low electric conductivity or be electromagnetic-transparent (therefore nonferrous), or required to meet weight limits (FRP is about 75% lighter than steel). In addition, UHP-FRC high shear strength allows partial or total elimination of shear reinforcement.

Background

Corrosion of steel reinforcing bars is the greatest threat to the durability of reinforced concrete structures. Using high-strength FRP bars can eliminate the corrosion concern prevalent in conventional RC structural members. However, FRP materials are brittle and cannot provide enough warning sign upon failure as required by current design codes. ACI 440 suggests a conservative design for concrete members reinforced with FRP bars because both conventional concrete and FRP bars are brittle materials. However, combining the ductile UHP-FRC with the brittle (but high-strength) FRP bars can provide the corrosion-free characteristics needed for future concrete infrastructure. In addition, the high shear strength of UHP-FRC allows total or substantial elimination of supplemental shear reinforcement.

Project Summary

This project will investage the: (1) type of FRP bars, (2) fiber types of UHP-FRC: high-strength micro steel fibers and ultra-high-molecular-weight polyethylene fibers), and (3) shear reinforcement (steel, FRP, or none). The primary objective is to develop a design procedure for the new durable structural members through large-scale beam testing. The economics of using the proposed UHP-FRC/FRP members can be justified as follows:

- The much greater stiffness and strength allow lighter, longer, and fewer members to be used. These in turn save construction time and labor cost;
- UHP-FRC has a high early strength of 10 to 12 ksi after 24 hours. This will allow rapid construction and an overall savings in time and costs;
- Eliminating most shear reinforcement leads to simple design and construction; and
- Lower life-cycle costs will be incurred due to the sustainability and corrosion-resistance capability of UHP-FRC. Thus, savings will accrue due to less initial maintenance and repair and fewer social, environmental, and demolition expenses.

Figure 1. Student posing with fiber and conventional reinforcement.

Status Update

The research team has completed design of pilot specimens and the fabrication of the specimens are underway. Experimental testing includes monotonic and cyclic loadings.

Figure 2. Student placing reinforement into formwork.

Impacts

The findings will have a major impact for regions suffer corrosion issues in reinforced concrete structures which use traditional steel bars. A non-corrosive reinforcement and durable concrete can significantly enhance the service life of the structures.

Tran-SET

Tran-SET is Region 6's University Transportation Center. It is a collaborative partnership between 11 institutions (see below) across 5 states (AR, LA, NM, OK, and TX). Tran-SET is led by Louisiana State University. It was established in late November 2016 "to address the accelerated deterioration of transportation infrastructure through the development, evaluation, and implementation of cutting-edge technologies, novel materials, and innovative construction management processes".

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