PROJECT SUMMARY REPORT

0-6982: Utilization of UHPC Bridge Superstructures in Texas

Background

The advanced material properties and superior durability of ultra-high-performance concrete (UHPC) provide an opportunity for significant design and construction benefits for Texas bridges. However, several challenges have slowed the application of UHPC in the precast industry, such as the high cost of proprietary UHPC mixtures, slower production due to longer curing times, and limited structural design guidance.

What the Researchers Did

To address these concerns, cost-effective nonproprietary UHPC mixtures were developed for precast, pretensioned bridge girders to meet target strengths at release and service while retaining current production practices such as curing time without heat treatment and using materials available to the precast industry in Texas. Full-scale UHPC bridge girders were fabricated at a Texas precast plant and tested in the laboratory to study structural behavior.

Analytical Feasibility Study

Preliminary UHPC girder designs were developed to identify strength requirements for UHPC and potential benefits of using UHPC in lieu of conventional concrete. A set of target properties were identified to be achieved by the nonproprietary UHPC mixture designs.

Nonproprietary UHPC Mixture Development and Material-Level Tests

UHPC mixtures were developed using materials sourced in Texas to achieve target properties including compression strength at release and service, along with sufficient flow spread, set time, and tension properties. Uniaxial direct tension testing was conducted to select a fiber volume of 1.5 percent for a cost-effective mixture. Fresh and hardened properties and durability measures were evaluated.

Fabrication of Precast UHPC Girders

After conducting a trial batch at a Texas precast plant, two Tx34 girder specimens (50 ft long) and one Tx54 girder specimen (70 ft long) were fabricated at the same plant.

Full-Scale Testing of UHPC Girders

Full-scale girder testing (Figure 1) was conducted to study the structural behavior under shear and flexure. Transfer length and camber were monitored. Nondestructive testing was used to study fiber distribution and detect possible defects.

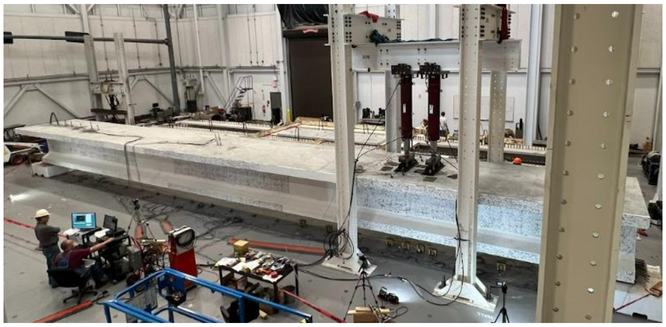

Figure 1. Testing of Full-Scale Girder with Conventional Concrete Deck.

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What They Found

Researchers found the following:

- Nonproprietary UHPC: UHPC mixtures can be developed to meet design requirements for precast bridge girders using locally sourced and commonly used Texas precast plant materials (Type III cement, silica fume, Class F fly ash, superplasticizer, and natural sand). Short straight steel fibers were also used.
- Plant-made UHPC material properties: The following average properties were measured:
  - Compressive strength: > 12 ksi (20 hours), 14–16 ksi (24 hours), and 17–19 ksi (28 days).
  - Modulus of elasticity: 6300–7400 ksi.
  - Uniaxial tensile strength: 0.30–1.3 ksi .
  - Flexural tension strength: 2.0–2.4 ksi.
  - Creep coefficient: 0.5–0.7.
  - Shrinkage: 700 με.
- Durability: The developed UHPC mixture showed superior durability performance as follows:
  - A very low range of resistivity and high range of formation factor values, indicative of very dense microstructure.
  - Negligible chloride ion penetrability.
  - 150+ years of service life prediction using formation factor-based transport properties.
  - Superior performance in terms of freeze-thaw, scaling, abrasion, and alkali–silica reaction resistance.
- Precast plant production: UHPC can be produced and placed using existing precast plant facilities. The performance of plant-made UHPC was comparable to lab-made UHPC mixtures.
- Fiber distribution and orientation: Overall, well-distributed steel fibers with random orientation are achievable provided the recommended optimum flow range (10–10.5 in.) is maintained. Limited fiber segregation was found for higher flow spread (> 11 in.).
- General structural behavior: Fiber distribution and tensile strength impacted flexure and shear behavior. The selected prediction models and recommended design approach provided results consistent with the measured behavior.
- Flexure: No cracking was observed up to factored moment demands. The moment applied to each girder was 30–50 percent higher than the corresponding design factored moment.
- Shear: Use of harped strands and minimum transverse reinforcement enhanced the shear performance. The Tx34 girder with straight strands had a lower tensile strength, and the applied shear was slightly below the design factored shear at the unreinforced end. For all other girder ends, the experimental shear capacity was at least twice the design factored shear demand.
- Composite action: Interface shear reinforcement effectively transferred shear up to the design factored loads with negligible slip.

What This Means

UHPC bridge girders provide increased design efficiency compared to conventional concrete girders, including reduced cross sections, longer spans, and larger girder spacings. Structural models and design guidelines are supported by the full-scale testing. With appropriate quality control, Texas precast facilities can produce UHPC bridge girders using available materials and production practices, providing an opportunity for enhanced durability and service life of Texas bridges.

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