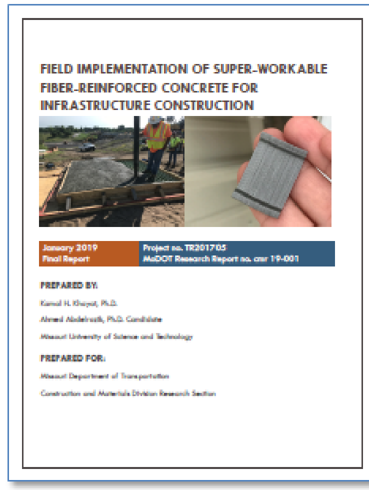
Research Summary

Field Implementation of Super-Workable Fiber-Reinforced Concrete for Infrastructure Construction



FIELD IMPLEMENTATION OF SUPER-WORKABLE FIBER-REINFORCED CONCRETE FOR INFRASTRUCTURE CONSTRUCTION

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A fiber-reinforced super-workable concrete (FR-SWC) made with 0.5% micro-macro steel fibers and 5% CaO-based expansive agent was selected for the new deck slab reconstruction of Bridge A8509. The selected FR-SWC had a targeted slump flow of 20 in. at the casting location. Multiple trial batches were performed, in collaboration with the concrete supplier, to adjust the mixture composition to meet the targeted performance criteria. This was followed up by casting the fibrous concrete in a mock-up slab measuring 10 × 10 ft that was prepared to simulate the tight rebar and the roadway crown slope in the transverse direction.

The results indicated the necessity to lower the concrete slump from the intended value for FR-SWC to hold the 2% crown slope of the bridge deck in the transverse direction. The final mixture that was selected following the trial batches and mock-up placement had a slump consistency of 8 ± 2 in. (FRC). Six sensor towers were installed in the slab within 18 ft to the East and West sides of the intermediate bent to monitor in-situ properties of the concrete. Each tower had three humidity sensors, three thermocouples, and 12 concrete strain gauges.

The slump values varied between 6 and 10 in. The fresh air volume ranged from 4.4% to 5.8%, and the concrete temperature ranged from 85 to 97 °F. At 56 days, the compressive strength ranged from 7,020 to 8,360 psi and had a mean value of 7,770 psi. Data up to 260 days are reported at the time of the preparation of this report. The in-situ concrete temperature was shown to increase around 45 °F during the first day, reaching a maximal temperature of 140 °F. The temperature then dropped to ambient temperature of approximately 95 °F during the second day. It then varied on a daily basis with the ambient temperature. The relative humidity of concrete ranged between 90% and 100% initially, then decreased with time until reaching approximate values of 80% to 85%. The loss of humidity was higher in magnitude and rate near the top surface of the bridge deck compared to the middle and bottom of the slab.

A 3D finite element model (FEM) was developed to predict the top and bottom structural strain values in the concrete deck that can be developed due to the weight of the bridge. The estimated strain values were compared to those recorded by the in-situ sensors in the longitudinal and transverse directions. In the longitudinal direction, the stresses were shown to reach the maximum positive values at the points of contact of the girder with the concrete diaphragm. The values decreased gradually along the length of the bridge to reach the maximum negative values approximately at the mid-span of the bridge deck. The area under consideration, where the towers are located, was in complete tension in the longitudinal and transverse directions. The highest tensile strain values reached 2100 micro-strain at the intersection of the intermediate bent with one of the pre-cast concrete girders. A strain model was proposed to evaluate the strain data collected from the embedded sensors.

The model represents the total strain as a summation of strains due to thermal deformation, drying and autogenous shrinkage, and structural deformation. The model was used to evaluate strains and estimate values of the concrete shrinkage during the first 30-36 hours, which corresponded to the time of demolding of the shrinkage samples as well as the load distribution factor between the concrete slab and the steel corrugated sheet that varied with concrete age. Findings indicated that the load distribution factor increased with concrete age reaching a value of 0.98 at 260 days. The concrete shrinkage during the first 36 hours was then estimated to be 75 micro-strain.

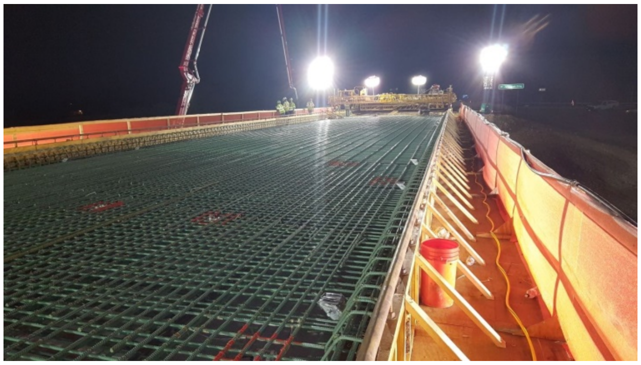
A life cycle cost analysis (LCCA) was performed to estimate the life cycle cost (LCC) savings of using the FRC in bridge deck compared to regular bridge deck cast using conventional vibrated concrete (CVC). In addition to the Taos Bridge (Bridge 1), two reference bridges were considered in this analysis. The first reference bridge (Bridge 2) is located on Route 13 over the Log Creek near Kingston, MO. The bridge desk was cast using CVC. The bridge has two spans measuring 120 and 124 ft and has a width of 30 ft, which is geometrically similar to Bridge 1.

Both bridges have one travel lane in each direction and are located in relatively low traffic areas. The analysis included traffic scenarios involving 668 and 3,387 ADT with truck traffics of 5% and 22%, respectively. The second reference bridge (Bridge 3) was considered at an area of much higher traffic volume (114,739 ADT and 1.55% truck traffic) in a different climate condition. The bridge is located on I-80 in New Jersey 0.7 miles east of the Passaic River and is used as benchmark for LCCA studies in high traffic areas. The bridge deck was constructed using CVC.

The LCCA indicated that the use of FRC can provide cost savings for both user and social costs for the low and high traffic volume scenarios. It should be noted that although the percentage of cost savings is high in the case of the low volume scenario, the absolute values of the costs are actually small because of the low traffic volume (e.g., 668 ADT). When calculating the total LCC by summing up the agency, user, and social costs, the use of FRC was shown to provide a cost saving of up to 55% for the high traffic volume scenario.

*"The use of FRC can provide **cost savings** for both user and social costs for the low and high traffic volume scenarios."*

Completed concrete pavement



Concrete forms prior to pour

Project Information
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