TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): ____Kansas DOT__________________________

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project #	**Transportation Pooled Fund Program - Report Period:**
TPF-5(392)	☐Quarter 1 (January 1 – March 31) 2021 ☐Quarter 2 (April 1 – June 30) ☒Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 1 – December 31)

Project Title:
Construction of Low-Cracking High-Performance Bridge Decks Incorporating New Technology

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Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:** **January 1, 2019**
Original Project End Date: **December 31, 2021**	**Current Project End Date:** **December 31, 2021**	**Number of Extensions:** 0

Project schedule status:

☒On schedule ☐ On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Total Percentage of Work Completed
$390,000	$339,588.58	80%

Quarterly Project Statistics:

Total Project Expenses This Quarter	Total Amount of Funds Expended This Quarter	Percentage of Work Completed This Quarter
$103,732.72	$103,732.72	10%

Project Description:

Bridge decks constructed using low-cracking high-performance concrete (LC-HPC) have performed exceedingly well when compared with bridge decks constructed using conventional procedures. LC-HPC decks constructed prior to 2016 have included only portland cement as a cementitious material. Four LC-HPC decks were constructed between 2016 and 2018 and include a partial replacement of portland cement with slag cement along with internal curing through a pre-wetted fine lightweight aggregate. All LC-HPC projects used concrete with low cement paste contents and lower concrete slumps, along with controlled concrete temperature, minimum finishing, and the early initiation of extended curing. Methods to further minimize cracking–such as shrinkage-reducing admixtures, shrinkage-compensating admixtures, and fibers–have yet to be applied in conjunction with the LC-HPC approach to bridge-deck construction. Laboratory research and limited field applications have demonstrated that the use of two new technologies, (1) internal curing provided through the use of pre-wetted fine lightweight aggregate in combination with slag cement, with or without small quantities of silica fume, and (2) shrinkage compensating admixtures, can reduce cracking below values obtained using current LC-HPC specifications. The goal of this project is to apply these technologies to new bridge deck construction in Kansas and Minnesota and establish their effectiveness in practice.

The purpose of this study is to implement new technologies in conjunction with LC-HPC specifications to improve bridge deck life through reduction of cracking. The work involves cooperation between state departments of transportation (DOTs), material suppliers, contractors, and designers. The following tasks will be performed to achieve this objective.

In 2020, the current study was expanded to perform crack surveys on an additional 20 bridge decks per year for two years in Minnesota to correlate the cracking on those decks with environmental and site conditions, construction techniques, design specifications, and material properties, and compare them with results obtained from previously studied conventional and LC-HPC bridge decks, as is currently being done for the newly constructed decks. The results of this expanded effort will be documented in project reports. MnDOT will select the bridges and provide plans and specifications, dates of construction, concrete mixture proportions, material test reports, and observations recorded during construction, if any, as well as traffic control during bridge deck crack surveys.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

TASK 1: Work with state DOTs on specifications for LC-HPC bridge decks to be constructed over the three-year period of performance of this project.

The 199th St. over I-35 bridge deck was placed on 09/16/2021. The mixture included a 30% cement replacement with slag cement and a 3% replacement with silica fume by weight of binder. The design paste content and the water-to-cementitious material (*w/cm*) ratio were 24.4% (by concrete volume) and 0.45, respectively. The design quantity of internal curing water was 7% by the weight of binder. The absorption of the lightweight fine aggregate measured by KU and KDOT personnel was 43.0% (on average), higher than the design value (33.0%, OD basis). No adjustments were made to the mixture proportions based on the differences in lightweight aggregate properties from those used in the original design. The concrete properties were tested after pumping at the job site with an average for air content and slump of 7% and 5¾ in., respectively. KU researchers and KDOT personnel believe that the concrete supplier did not account for the addition of ice as part of the mixing water, which resulted in higher *w/cm* ratios than intended. KU researchers are working with KDOT and the concrete supplier to obtain additional information. During construction, the contractor used a finishing-aid for about 50 ft from the east end of the deck. The contractor was directed to not use the finishing aid on the rest of the deck. The contractor was also asked to turn off the fogging equipment due to excessive water on the deck surface. Some delays (up to 35 min) in delivery of concrete occurred near the end of the placement.

One more internally-cured bridge deck is planned for Kansas. Construction is anticipated in Spring 2022. This bridge is located on K-33 over BNSF Rail Road.

90% COMPLETE

TASK 2: Provide laboratory support prior to construction and on-site guidance during construction of the LC-HPC bridge decks.

A series of concrete mixtures were cast to assess if the freeze-thaw durability of IC concrete is a function of the percentage of IC water or the total amount of absorbed water in the lightweight aggregate (LWA). These mixtures have paste contents of 23.7, 26.7 and 33.7%, contain 100% portland cement as the binder, and include nominal internal curing (IC) water contents of either 9 or 13% by the weight of binder. The mixtures have a water-to-cement (*w/c*) ratio of either 0.41 or 0.45.

The mixtures are being evaluated for freeze-thaw durability following the regime specified in Kansas Department of Transportation (KDOT) Test Method KTMR-22, *Resistance of Concrete to Rapid Freezing and Thawing*, exposed to rapid freeze-thaw cycles as specified in ASTM C666 (Procedure B). This work duplicates earlier work that followed MnDOT specifications, which requires the use of ASTM C666 (Procedure A).

90% COMPLETE

TASK 3: Perform detailed crack surveys on the bridge decks. If desired, DOT personal will be trained in the survey techniques and may assist in the surveys, as appropriate.

This quarter, as part of the construction of LC-HPC bridge decks incorporating internal curing technology (IC-LC-HPC), crack surveys were performed on two internally-cured bridge decks, one located on Sunflower Rd. over I-35 in Edgerton, which was constructed in 2019, and the other on Montana Rd. over I-35 near Ottawa, which was constructed in 2020. This was the first survey for both decks. The Sunflower Rd. bridge deck was not surveyed in 2020 due to restrictions imposed by weather and temperature.

The Sunflower Rd .bridge deck exhibited a low crack density (0.045 m/m^2) 19.8 months after construction, with cracks observed only near the center pier and the abutments of the bridge. Crack widths ranged from 0.003 to 0.025 in., with an average of 0.015 in. Some scaling was observed, mainly near the shoulders. Scaling may have occurred because the concrete had air contents as low as 5.5%. Overall, air contents ranged from 5.5 to 7.6%, with an average of 6.3%, which compared with the LC-HPC specifications that require air contents between 6.5 and 9.5%. Previous studies have recommended providing air contents above 7% to improve freeze-thaw durability and scaling resistance of concrete mixtures incorporating IC water. The Sunflower Rd. bridge deck was constructed in late November (cured in cold ambient temperature), where on the day of placement, the air temperature ranged from 38 to 49 °F with an average of 43 °F, which may have also increased the potential of concrete durability damage.

The Montana Rd. bridge deck exhibited a low crack density (0.002 m/m^2) through the first-year, with cracks observed only near the first and third piers from the north end and near the south abutment of the bridge. Crack widths ranged from 0.002 to 0.007 in., with an average of 0.004 in. Similar to the Sunflower Rd. bridge deck, scaling damage was observed in multiple spots on the surface of the deck. The surface damage on this IC deck could be the result of multiple issues. During construction, workers made repeated bullfloat passes while bleeding water was visible on the surface. Much of that excess water was worked back into the surface. Overfinishing the deck in the presence of bleed water, leads to a thin paste layer with a high *w/cm* at the concrete surface, which can result in scaling damage. Moreover, according to LC-HPC specifications, no finishing aids are permitted. In spite of this, the contractor applied a finishing aid on the concrete for the entire deck. The use of the finishing aid increases the *w/cm* ratio at the surface, which may also contribute to increased scaling damage. This shortcoming was pointed out to the contracted (non-KDOT) inspector who said that this was “not a big deal at this point.” Additionally, it was observed that the fogging system deposited excessive water on the bridge deck. During the construction, it was also observed that the burlap had not been soaked in water. Some ponding was observed along the deck, mainly due to sprayed water on the surface to wet the burlap by the contractor.

During this quarter, surveys were also performed on 14 bridge decks constructed in Minnesota with either low slump or silica fume overlays, with or without nonmetallic fibers. Crack surveys also were conducted on 5 monolithic decks with or without nonmetallic fibers. The results will be summarized in the next quarter.

90% COMPLETE

TASK 4: Correlate the cracking measured under Objective 3 with environmental and site conditions, construction techniques, design specifications, and material properties, and compare with results obtained on earlier conventional and LC-HPC bridge decks.

KU researchers are working on drafting a report on the cracking performance of twenty monolithic bridge decks with or without incorporating nonmetallic fibers surveyed in Minnesota in summer 2020.

50% COMPLETE

TASK 5: Document the results of the study. Provide recommendations for changes in specifications.

50% COMPLETE

Anticipated work next quarter:

Future meetings and conference calls will be held. Pre-construction meetings will be held with representatives from KU, KDOT, and the contractors to discuss the details of mixture proportions and construction procedures.

Laboratory testing of concrete IC mixtures with internal curing will continue to be evaluated for the mixtures with a *w/c* ratio of either 0.41 and nominal IC water contents of either 9 or 13% by the weight of binder.

Significant Results this quarter:

The freeze-thaw results in accordance with ASTM C666 Procedure A for the IC mixtures with paste contents of 23.7 and 33.7%, nominal IC water contents of 9 and 13% by the weight of binder, and a *w/c* ratio of 0.41 were presented in the June 2021 quarterly report. This quarter, freeze-thaw resistance of IC mixtures with paste contents of either 23.7, 26.7, or 33.7%, with nominal IC water contents of 9 and 13% by the weight of binder, and a *w/c* ratio of 0.45 was evaluated. The mixtures were tested following the regime specified in Kansas Department of Transportation (KDOT) Test Method KTMR-22, *Resistance of Concrete to Rapid Freezing and Thawing* and exposed to rapid freeze-thaw cycles as specified in ASTM C666-Procedure B with a failure limit of 95% of the initial dynamic modulus of elasticity.

The results indicate that increasing the quantity of IC water decreases the freeze-thaw durability of concrete mixtures. As expected, the testing procedure has a considerable effect on the freeze-thaw performance of IC mixtures. In contrast with the paired mixtures tested in accordance with ASTM C666-Procedure A, except for one mixture (the mixture with a 9% IC water content and a paste content of 33.7%), the dynamic modulus of elasticity of the mixtures with a 9% IC water content (by the weight of binder) remained above 95% of the initial value through 660 freeze-thaw cycles, and passed the test. The dynamic modulus of elasticity of the mixtures with a 9% IC water content (by the weight of binder) and paste contents of 23.7 and 26.7%, dropped below 95% of the initial value after 688 and 781 cycles, respectively. The dynamic modulus of elasticity of the mixture with a 9% IC water content (by the weight of binder) and a paste content of 33.7%, dropped below 95% of the initial value after 426 cycles, and failed the test. This mixture, however, had an air content of just 6.25%, lower than the lower LC-HPC specification limit of 6.5%.

The dynamic modulus of elasticity of the mixtures with 13% IC water content by the weight of binder and paste contents of either 23.7%, 26.7, or 33.7%, dropped below 95% of the initial value after 619, 560, and 338 cycles, respectively, and failed the test.

As an overall observation, compared to the paired IC mixtures with 9% IC water content tested in accordance with ASTM C666-Procedure A, where all specimens failed the test (the dynamic modulus of elasticity of the mixtures dropped below 90% of the initial value in less than 300 cycles), IC mixtures with 9% IC water content, except for the mixture with 33.7% paste content, showed adequate freeze-thaw resistance (passed the test) when tested following the regime specified by the Kansas Department of Transportation, exposed to rapid freeze-thaw cycles as specified in ASTM C666-Procedure B. Longer curing periods and less intense the testing environment appear to improve freeze-thaw resistance of IC mixtures.

Freeze-thaw results for the mixtures with a *w/c* ratio of 0.41 followed the regime specified in KTMR-22, will be presented next quarter.

Circumstances affecting project or budget. (Please describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

None.