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		
Project Manager: Dan Wadley	**Phone:** 785-291-2718	**E-mail:** Dan.Wadley@ks.gov
Project Investigator: David Darwin	**Phone:** 785-864-3827	**E-mail:** daved@ku.edu
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	$228,495.36	70%

Quarterly Project Statistics:

Total Project Expenses This Quarter	Total Amount of Funds Expended This Quarter	Percentage of Work Completed This Quarter
$25,995.37	$25,995.37	5%

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.

A trial batch for a Kansas internally-cured bridge deck (located on 199th St. over I-35) was completed on 5/5/2021, with KU and KDOT personnel in attendance. The mixture proportions contained a ternary composition (a 30% replacement by weight of binder with slag cement and a 3% replacement by weight of binder with silica fume). The design paste content and the water-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 lightweight aggregate was pre-wetted for at least 72 hours prior to batching, and the absorption measured by KU and KDOT personnel was 40.0% (on average), higher than the design value (30.0%, OD basis). The concrete properties were tested before and after pumping at the job site. The air content and slump were 7.0% and 6½ in., respectively, before pumping. After the addition of 4 oz/yd^3 of air-entraining admixture, the air content was 7.9% (measured after pumping). Construction of the 199th St. bridge deck is anticipated to be placed in late July 2021.

The second internally-cured LC-HPC bridge deck is located on K-33 over BNSF Rail Road, Kansas. Construction of this deck is anticipated to be placed in fall 2021.

75% 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 freeze-thaw durability of concrete is a function of the total weight of the binder or the 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 contain 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), scaling resistance in accordance with ASTM C672 and Canadian test BNQ NQ 2621-900, and compressive strength per ASTM C39. This work duplicates earlier work that followed MnDOT specifications, which requires the use of ASTM C666 (Procedure A).

75% 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.

Crack surveys of bridge decks are conducted during the summer, scheduled one and three years after construction. This quarter, crack surveys were performed on seven internally-cured LC-HPC and one control deck placed in Minnesota. This was the third survey for the deck placed in 2018 (38th St. over I-35W in Minneapolis), the second survey for the decks placed in 2019 (Pokegama Lake Rd over I-35 in Pine City and 40th St. over I-35W in Minneapolis), and the first survey for decks placed in Winona in 2020 (CSAH 12 over TH 90 and TH 90 EB over Rd. 231). A one-year crack survey also was performed for Dale St. deck placed in St.Paul in 2020. Only one roadway and two sidewalks of Dale St. deck were surveyed due to restrictions imposed by traffic control.

Additionally, the fifth crack survey was conducted for one internally-cured bridge deck (Mackubin St. over I-94) along with a control deck (Grotto St. over I-94) constructed in 2016, St Paul, Minnesota.

The 2018 LC-HPC deck (38th St. over I-35W in Minneapolis) exhibited a low crack density (0.045 m/m^2) through the third-year cracking survey, with narrow cracks observed with widths that ranged from 0.002 to 0.003 in. The Pine City LC-HPC deck exhibited a crack density as low as 0.003 m/m^2. The pedestrian bridge deck constructed in 2019 (40th St. over I-35W in Minneapolis) had a crack density of 0.091 m/m^2, an increase from the 0.009 m/m^2 density observed during the 2020 survey. Some long transverse cracks were observed over the entire deck, mainly with lengths of 3 to 6 ft. The cracking performance of the deck may have been affected due to inadequate consolidation, as observed during the construction. Construction personnel were observed walking through areas that had been previously vibrated, resulting in deconsolidation of the concrete. While KU personnel informed the MnDOT representative and construction personnel about this occurrence, the construction personnel opposed changing their procedures. They believed that by using the vibrating screed, this problem would be solved.AS demonstrated in multiple decks in Kansas, inadequate consolidation can result in a higher crack density. The internally-cured LC-HPC bridge decks constructed in Winona (CSAH 12 over TH 90 and TH 90 EB over Rd. 231 in Winona) exhibited low crack densities (0.013 m/m^2 and 0.004 m/m^2, respectively) during the first-year crack surveys. For the IC deck located in CSAH 12 over TH 90, cracks only were observed near the center pier and abutments of the bridge. The Dale St. bridge deck exhibited a low crack density (below 0.050 m/m^2) through the first-year cracking survey, with cracks observed mainly on the sidewalks near the center pier.

Additionally, the internally-cured and control decks constructed in 2016 exhibited low crack densities (0.024 and 0.003 m/m^2, respectively) in crack surveys conducted this year, with cracks only being observed near the center pier of the bridges.

70% 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.

0% COMPLETE

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

0% COMPLETE

Anticipated work next quarter:

Laboratory testing of concrete mixtures with different quantities of internal curing, paste contents, and water-to-cement ratios will continue to be evaluated.

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.

The bridge decks constructed in Kansas with internal curing water, including Sunflower Rd. over I-35 and Montana Rd. bridge decks will be surveyed during next quarter.

Additional surveys will be performed on twenty-one bridge decks constructed in Minnesota with either low slump or silica fume overlays.

Significant Results this quarter:

The freeze-thaw results for the IC mixtures with paste contents of 23.7 and 33.7%, with nominal IC water contents of 9 and 13% by the weight of binder, and a *w/c* ratio of 0.45 were presented in March 2021 quarterly report. This quarter, freeze-thaw resistance testing was completed on the IC mixtures with paste contents of 23.7 and 33.7%, with nominal IC water contents of 9 and 13% by the weight of binder, and a *w/c* ratio of 0.41. The mixtures were tested in accordance with ASTM C666 (Procedure A) with a failure limit of 90% of the initial dynamic modulus of elasticity.

Similar to the IC mixtures with a *w/c* ratio of 0.45, the results indicate that increasing the quantity of IC water (from 9 to 13%) decreases the freeze-thaw durability of concrete mixtures, regardless of the paste content or quantity of LWA. 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 33.7%, dropped below 90% of the initial value after 292 and 259 cycles, respectively, and failed the test. 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% and 33.7%, dropped below 90% of the initial value in fewer cycles, 188 and 174, respectively. As an overall observation, compared to the IC mixtures with a *w/c* ratio of 0.45, reducing the *w/c* ratio from 0.45 to 0.41 improved the freeze-thaw durability of concrete.

Freeze-thaw results for the mixtures followed the regime specified in KTMR-22, exposed to rapid freeze-thaw cycles as specified in ASTM C666 (Procedure B) will be presented next quarter.

This quarter, scaling resistance testing was completed on 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 *w/c* ratios of 0.41 and 0.45, in accordance with ASTM C672 and Canadian test BNQ NQ 2621-900.

The scaling results in accordance with ASTM C672 of the concrete mixtures with a 23.7% paste content, a *w/c* ratio of 0.45, with nominal IC water contents of 9 or 13% by weight of binder showed a visual rating of (2) by the end of 50 freeze-thaw cycles. The paired mixtures exhibited mass losses of 0.09 (slightly lower than the failure limit of 0.1 lb/ft^2 when tested in accordance with Canadian test BNQ NQ 2621-900) and 0.14 lb/ft^2 (which failed the test), respectively, by the end of 56 freeze-thaw cycles.

The scaling results in accordance with ASTM C672 of the concrete mixtures with a 23.7% paste content, a *w/c* ratio of 0.41, with nominal IC water contents of 9 or 13% by weight of binder showed visual ratings of (1) and (2), respectively, by the end of 50 freeze-thaw cycles. The paired mixtures exhibited mass losses of 0.07 and 0.08 lb/ft^2, respectively, by the end of 56 freeze-thaw cycles, lower than the failure limit of 0.1 lb/ft^2 when tested in accordance with Canadian test BNQ NQ 2621-900.

The scaling results in accordance with ASTM C672 of the concrete mixtures with a 33.7% paste content, a *w/c* ratio of 0.45, with nominal IC water contents of 9 or 13% by weight of binder showed a visual rating of (3) by the end of 50 freeze-thaw cycles. The paired mixtures exhibited mass losses of 0.15 and 0.19 lb/ft^2, respectively, by the end of 56 freeze-thaw cycles when tested in accordance with Canadian test BNQ NQ 2621-900 and failed the test.

The scaling results in accordance with ASTM C672 of the concrete mixtures with a 33.7% paste content, a *w/c* ratio of 0.41, with nominal IC water contents of 9 or 13% by weight of binder showed a visual rating of (2) by the end of 50 freeze-thaw cycles. The paired mixtures exhibited mass losses of 0.09 and 0.11 lb/ft^2, respectively, by the end of 56 freeze-thaw cycles when tested in accordance with Canadian test BNQ NQ 2621-900.

As a general observation, the mixtures tested in accordance with Canadian test BNQ NQ 2621-900 had lower mass losses than the paired mixtures tested in accordance with ASTM C672. The test results also indicate that as the paste content increased from 23.7 to 33.7%, the scaling resistance of the specimens considerably decreased. To clarify, for a given *w/c* ratio (either 0.41 or 0.45) and quantity of IC water by weight of cement (9 or 13%), the mixtures with a higher paste content had more mass loss than the mixtures with the lower paste content. None of the IC mixtures with a nominal IC water content of 13% by weight of binder passed the scaling test in accordance with Canadian test BNQ NQ 2621-900.

As with results obtained from the freeze-thaw test, reducing the *w/c* ratio from 0.45 to 0.41 improved the scaling resistance of the concrete mixtures.

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).

COVID-19 has resulted in a reduction of work in the laboratory, but the project is now back on track.