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) 2022 ☐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, 2023**	**Number of Extensions:** 1

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**
$390,000.00	$385,979.27	89%

Quarterly Project Statistics:

Total Project Expenses This Quarter	**Total Amount of Funds Expended This Quarter**	**Percentage of Work Completed This Quarter**
$6,984.45	$6,984.45	1%

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.

One more internally-cured bridge deck is planned for Kansas. Construction is anticipated in October 2022. This bridge is located on K-33 over a BNSF Railroad line.

95% 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 evaluate the effects of total internal water (TIW) provided by all aggregates (not just LWA), ranging from 7 to 17% by the weight of binder (corresponding to IC contents ranging from 0 to 14%) on the durability of concrete. The mixtures have different binder compositions (either 100% portland cement or 30% replacement of portland cement with slag cement, SCM) and contain either limestone or granite as coarse aggregate. The mixtures have a paste content of 24.2% and a water-to-cementitious material (*w/cm*) ratio of 0.43.

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 in accordance with a modified version of BNQ NQ 2621-900 (with minor changes to temperature), and compressive strength in accordance with ASTM C39.
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92% 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 will be performed for four internally-cured low-cracking high-performance (IC-LC-HPC) bridge decks constructed in Kansas (Sunflower Rd., Montana Rd., 199th St. over I-35), including the upcoming bridge deck located on K-33, in summer 2023.

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 have submitted the first draft report (SL Report 22-1, on July 25, 2022) on cracking performance of 19 monolithic bridge decks with or without incorporating nonmetallic fibers surveyed in Minnesota during summer 2020. It is now under the first revision after receiving MnDOT feedback on September 1, 2022. Additionally, a report on crack surveys of 19 bridge decks with either low slump or silica fume overlays, with or without nonmetallic fibers and monolithic decks with or without nonmetallic fibers surveyed in Minnesota during summer 2021 is being drafted, and it is expected to be submitted by December 2022 at the latest.

50% COMPLETE

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

55% 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 mixtures with different quantities of internal curing water and total internal water will continue to be evaluated for scaling and freeze-thaw durability.

Significant Results this quarter:

Scaling resistance is being evaluated in accordance with a modified version of BNQ NQ 2621-900 with a failure limit of 0.1 lb/ft^2 of mass loss by the end of 56 freeze-thaw cycles. For mixtures with limestone as the coarse aggregate, mixtures with total internal water (TIW) contents of either 7 or 12% by the weight of binder with portland cement as the only binder, exhibited lower mass losses (0.012 or 0.014 lb/ft^2, respectively) compared to paired mixtures with 30% mass replacement of portland cement with slag cement (0.160 or 0.063 lb/ft^2, respectively) by the end of 56 freeze-thaw cycles. A single mixture with 16% TIW and portland cement as the only binder, however, exhibited a higher mass loss (0.066 vs. 0.054 lb/ft^2) than a similar mixture with 30% mass replacement of slag cement by the end of 56 freeze-thaw cycles. A mixture with 30% mass replacement of portland cement with slag cement and no IC water (or 7% TIW) failed the test after 56 freeze-thaw cycles with a mass loss of 0.160 lb/ft^2. The results also indicate that for a given binder composition, increasing the quantity of TIW has different effects on scaling resistance. For mixtures with portland cement as the only binder, increasing the quantity of TIW above 12% by the weight of binder (corresponding to 7% IC water by the weight of binder) resulted in higher mass losses. On the contrary, for mixtures with 30% mass replacement of portland cement with slag cement, increasing the quantity of TIW from 7 to 16% (0 to 10% IC water by the weight of binder) resulted in lower mass losses. Results also show that mixtures with granite as the coarse aggregate exhibited lower mass losses (ranging from 0.006 to 0.050 lb/ft^2) than paired mixtures with limestone (ranging from 0.006 to 0.112 lb/ft^2) by the end of 35 freeze-thaw cycles. The only exception was in the case of 16% TIW with 30% mass replacement of slag cement, where the granite mixes have higher mass loss at the end of 35 freeze-thaw cycles (0.021 lb/ft^2 for limestone vs the 0.050 lb/ft^2 for granite). One possible reason for the higher scaling resistance of granite mixtures could be the lower absorption of granite (0.6% OD) mixtures compared to that of the limestone mixtures (1.8% OD), when compared with the same TIW content.

Freeze-thaw tests for the mixtures followed the regime specified in KTMR-22 and exposed to rapid freeze-thaw cycles, as specified in ASTM C666 (Procedure B). Regardless of the binder compositions, all of the mixtures with limestone as the coarse aggregate failed the test (with the average relative E_{Dyn} dropped below 95% of the initial value much below 660 freeze-thaw cycles). This observation is in line with what KDOT observed in similar specimens when tested for freeze-thaw resistance.The likely reason of the poor performance of the limestone aggregate mixtures is the high absorption of the limestone aggregate (1.8% OD). Additionally, for the limestone aggregate mixtures, the number of cycles for the average relative E_{Dyn} to drop below 95% of the initial values increased by increasing the quantity of IC in the mixtures with portland cement as the only binder (the number of cycles for the average relative E_{Dyn} to drop below 95% of the initial values were

153, 260 and 278 for mixtures with 0, 7, and 10% IC, respectively). For the paired mixtures with 30% mass replacement of portland cement with slag cement (the number of cycles for the average relative E_{Dyn} to drop below 95% of the initial values were 150, 137 and 208 for mixtures with 0, 7, and 10% IC, respectively). This indicates that increasing the quantity of IC improves the freeze-thaw resistance of the limestone mixtures, but it is not adequate enough to improve the performance so that failure is observed before 660 cycles.

Mixtures with granite exhibited higher freeze-thaw resistance compared to similar mixtures with limestone as coarse aggregate. The relative dynamic moduli of elasticity of the granite mixtures with either portland cement as the only binder or 30% slag cement were above 99% of the initial value after 300 and 30 freeze-thaw cycles, respectively.

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.