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	$382,890.29	91%

Quarterly Project Statistics:

Total Project Expenses This Quarter	Total Amount of Funds Expended This Quarter	Percentage of Work Completed This Quarter
$3,895.47	$3,895.47	3%

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 either late summer or early fall 2022. This bridge is located on K-33 over BNSF Rail Road.

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 16% by the weight of binder (corresponding to IC contents ranging from 0 to 10%) 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.

One control deck (Grotto St. over I-94 in St. Paul) and seven internally-cured bridge decks in Minnesota (Mackubin St. over I-94 in St. Paul, 38th and 40th St. over I-35W in Minneapolis, Pokegama Lake Rd over I-35 near Pine City; two bridge decks in Winona and Dale St. over I-94) were surveyed in May 2022. This was the sixth year survey for the decks placed in 2016 (Mackubin St. and Grotto St. decks over I-94 in St. Paul), the third survey for the deck placed in 2018 (38th St. over I-35W in Minneapolis), the third year survey for the decks placed in 2019 (40th St. over I-35W in Minneapolis and Pokegama Lake Rd over I-35 near Pine City), the second survey for decks placed in 2020 (C.H.A.H. 12 over T.H. 90, T.H.90 over TWP Rd 231 in Winona, and Dale St. over T.H. 94 in St. Paul). Due to high crack density, only one lane and a shoulder of the Winona decks were surveyed. Additionally, due to limitations in traffic control, only one lane and a shoulder of the two placements on the Dale St. deck in St. Paul were surveyed.

The 2016 deck (Mackubin St. over I-94 in St. Paul) exhibited no observable cracks, and had only minor durability issues. The 2016 control deck (Grotto St. over I-94 in St. Paul) exhibited a low crack density of 0.021 m/m^2, with cracks only near the piers, with crack widths ranging from 0.013 to 0.020 in, similar to previous years. The 2018 deck (38th St. over I-35W in Minneapolis) had short cracks scattered throughout the deck with a crack density of 0.046 m/m^2 with crack widths ranging from 0.002 to 0.007 in. The 2019 deck (40th St over I-35W in Minneapolis) had transverse cracks that extended almost one-third of the deck width, and had a crack density of 0.153 m/m^2. The 2019 deck (Pokegama Lake Rd over I-35 near Pine City) exhibited a low crack density as low as 0.011 m/m^2. Similar to previous years, the cracks were short and scattered at discrete locations on the deck. The 2020 decks in Winona (C.H.A.H. 12 over T.H.90, and T.H.90 over TWP Rd 231 in Winona) were heavily cracked, with narrow map cracking throughout the deck. The crack density of C.H.A.H. 12 over T.H. 90, and T.H.90 over TWP Rd 231 were 0.671 m/m^2 and 0.788 m/m^2, respectively, significantly higher than last year. One possible cause of the poor cracking performance of these decks could be the non-uniform distribution of curing compound applied during construction, which can result in plastic shrinkage. Another reason may be having a lower actual *w/cm* ratio (0.40 on average) than the design value (0.43), which may reduce bleed water on the surface, leading to an increase in plastic shrinkage cracking, although the evaporation rates for those bridges averaged 0.06 $lb/ft^2/hr$, slightly below 0.1 $lb/ft^2/hr$ (the recommended limit for concretes containing SCMs). The 2020 deck (Dale St. over T.H. 94 in St. Paul) was constructed in two placements that had crack densities of 0.037 m/m^2 and 0.024 m/m^2. Surveys were performed on one lane and a shoulder of each placement. Cracks were observed to be short and narrow, with the exception of some longer cracks near the north end of the deck.

Three internally-cured low-cracking high-performance (IC-LC-HPC) bridge decks constructed in Kansas (Sunflower Rd. over I-35; Montana Rd. over I-35; 199th St. over I-35) were surveyed in June 2022. This is the third year survey for the deck placed in 2019 (Sunflower Rd. over I-35), the second year survey for the deck placed in 2020 (Montana Rd. over I-35), the first year survey for the deck placed in 2021 (199th St. over I-35).

The 2019 deck (Sunflower Rd. over I-35) exhibited a low crack density of 0.019 m/m^2, with crack concentrations mostly near the piers and the abutments, similar to last year. Crack widths ranged from 0.013 to 0.020 in.with an average of 0.016 in.

The 2020 deck (Montana Rd. over I-35) had a crack density of 0.003 m/m^2. Crack widths ranged from 0.002 to 0.005 in. In this second year crack survey, few cracks were observed, mostly near the abutments and the shoulders. Similar to last year, scaling damage was observed in multiple locations on the surface of the deck.

The first year survey of the deck placed in 2021 in Kansas (199th St. over I-35) showed a crack density of 0.061 m/m^2. The cracks were present mostly around 60 ft and 200 ft from the east end of the deck. The cracks observed in those portions of the deck could be the result of multiple factors that occurred during the construction. Malfunctioning fogging equipment was observed spraying excess water directly onto the deck surface. The excess water later was worked back into the surface by the contractors when bullfloating the deck, which brought a thin paste layer with a high *w/cm* at the concrete surface, causing high cracks in those areas. Although it is not permitted by the IC-LC-HPC specifications, a finishing aid was also used on the first half of the deck. The use of a finishing aid increases the *w/cm* ratio at the surface, which may also contribute to increased scaling damage. Additionally, a bullfloat was repeatedly used in the longitudinal direction while the excess water was visible on the surface. The use of finishing aid was discontinued after pointing out to KDOT and contractor personnel.

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, as well as nineteen 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 summers 2020 and 2021.

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 containing portland cement as the only binder with TIW contents of either 7 or 12% by the weight of binder, exhibited lower mass losses (higher scaling resistance) by the end of 21 freeze-thaw cycles, than similar mixtures containing a 30% replacement of portland cement with slag cement (by weight). The results indicate that increasing the quantity of TIW has different effects on scaling resistance for different binder compositions. For the mixture with portland cement as the only binder, increasing the quantity of total internal water from 7 to 16% by the weight of binder (0 to 10% IC) resulted in higher mass losses (lower scaling resistance). On the contrary, for mixtures with 30% replacement of portland cement with slag cement (by weight), increasing the quantity of total internal water from 7 to 16% (0 to 10% IC) resulted in lower mass losses (higher scaling resistance).

For mixtures with granite as the coarse aggregate, the mixtures are yet to be evaluated for scaling resistance. Comparisons of the performance between different aggregates will be presented next quarter.

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.

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.