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) 2019 ☒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	$135,171.11	46%

Quarterly Project Statistics:

Total Project Expenses This Quarter	**Total Amount of Funds Expended This Quarter**	**Percentage of Work Completed This Quarter**
$23,854.59	$23,854.59	6%

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 Montana Rd. over I-35 near Ottawa) was completed on 6/4/2020 with KU and KDOT personnel in attendance. The mixture proportions contained a binary binder composition (a 30% replacement by weight of portland cement with slag cement). The design paste content and the water-cementitious material (*w/cm*) ratio were 24.2% (by concrete volume) and 0.43, respectively. The design quantity of internal curing water was 7% by the weight of binder. The lightweight aggregate was pre-wetted 72 hours prior to batching, and the absorption measured by KU personnel was 16.8%, slightly higher than the design value (14.1%, OD basis). The concrete properties at the ready-mix plant after about 15 minutes haul time were within KDOT specifications for air content (with an average of 8.0%), and slump (with an average of 4¾ in., slightly lower than the upper KDOT specification limit of 5 in.). Construction of the bridge deck is planned for either mid-August or early-September.

Two more internally-cured LC-HPC bridge decks are planned for Kansas. The first bridge deck is located on 199th St over I-35 and is anticipated to be placed in fall 2020. The second bridge deck is located on K-33 over BNSF Rail Road and will be let in either August or September 2020.

For the upcoming placement of internally-cured low-cracking high-performance concrete (IC-LC-HPC) bridge decks in Minnesota (Br. 85862, and 85963), KU researchers and MnDOT representatives held an online meeting with the concrete supplier and the contractor to discuss the mixture proportions, concrete batching, and placement procedures. At the meeting, the importance of determining the lightweight aggregate properties at the ready-mix plant before construction, providing adequate air content, and minimizing finishing of the concrete during the construction were emphasized.

The Minnesota Department of Transportation also identified an internally-cured (IC) bridge deck (Br.62735) located in Minneapolis, in addition to two IC-LC-HPC bridge decks (located in New Hartford Township) scheduled for construction in the summer 2020. The concrete supplier for this bridge deck (Br.62735) proposed the same mixture proportions as the one used in the construction of the bridge deck in Pine City (Br.58826) last year. KU researchers traveled to St. Paul and worked with the concrete supplier to correctly determine the lightweight aggregate (LWA) properties and provide adjustments in the mixture proportions to maintain the desired amount of internal curing water before batching the concrete. The bridge deck

(Br. 62735) is located on Dale Street in St. Paul and was planned to be placed in two placements. The first placement of the Dale St. bridge was placed on 6/24/2020. The average values for the absorption and the specific gravity of the lightweight aggregate were 34.0% and 1.20, respectively, which differed slightly from the values obtained last year for this material (32.9% and 1.21, respectively). No significant issues arose during concrete pumping, placement, or finishing. Based on the trip tickets, the average amount of internal curing water provided by the lightweight aggregate was approximately 7% by the weight of binder. The average water-to-cementitious material ratio (*w/cm*) was 0.41 and paste contents ranged from 24.8% to 25.7%, with an average of 25.3%. The second placement of the Dale St. bridge is scheduled to be placed in October.

60% COMPLETE

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

Due to COVID-19 health and safety regulations, no new mixtures were cast in this quarter. A series of concrete mixtures cast before and included in the March quarterly report are being evaluated at KU lab for shrinkage, freeze-thaw durability, scaling, compressive strength, and permeability. These mixtures have different binder compositions (either 100% portland cement or a ternary binder composition including slag cement and silica fume), and various types of coarse aggregates (either granite or limestone) to evaluate the effects of total internal water (TW) provided by all aggregates (ranging from 3.0% to 12.5% by the weight of binder) on the durability of concrete. The mixtures were designed to provide various nominal quantities of internal curing (IC) water provided by pre-wetted lightweight aggregate (LWA) equal to 0, 6, and 9% by the weight of binder.

The mixtures are being evaluated for free shrinkage in accordance with a modified version of ASTM C157 (readings begin just after final set), scaling resistance in accordance with ASTM C672, freeze-thaw durability in accordance with ASTM C666 (Procedure A), rapid chloride permeability in accordance with ASTM C1202, surface resistivity results obtained per AASHTO TP-95 and Louisiana Department of Transportation and Development (LA DOTD TR 233-11), and compressive strength in accordance with ASTM C39.

50% 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.

The identified monolithic bridge decks constructed in Minnesota with or without incorporating nonmetallic fibers are scheduled for crack surveys in this quarter. MnDOT and Kansas personnel held an online meeting and had a discussion on performing crack surveys in the period July to August 2020.

Additional surveys as part of the construction of LC-HPC bridge decks incorporating internal curing technology are scheduled for this quarter in Minnesota and Kansas. The bridge decks in Minnesota include one internally-cured bridge deck (TH 52 SB over Cannon River) along with a control deck (TH 52 NB over Cannon River) located in Cannon Falls; one internally-cured bridge deck (TH 58 over TH 52) near Zumbrota; one internally-cured bridge decks (38th St. St. over I-35W) in Minneapolis, and one internally-cured bridge deck (Pokegama Lake Rd. over I-35) near Pine City. The single bridge deck constructed in Kansas with internal curing (Sunflower Rd. over I-35) in Edgerton will also be surveyed.

This quarter, crack surveys were performed on three bridge decks, including one internally-cured bridge deck (Mackubin St. over I-94) along with a control deck (Grotto St. over I-94) located in St. Paul and one internally-cured bridge deck located in Minneapolis (40th St. over I-35W) in Minnesota. This was the fourth survey for bridge decks placed in St. Paul in 2016 and the first survey for the deck placed in Minneapolis in 2019. The two IC-LC-HPC decks and the control deck exhibited low crack densities (below 0.05 m/m^2) in crack surveys conducted this year with cracks only being observed near the center pier of the bridges. However, in multiple spots, mainly near each side of the bridge barrier, scaling and freeze-thaw durability damage was observed on both IC decks. The surface damage of the IC deck placed in 2019 was possibly the result of the contractor overfinishing the deck in an attempt to remove excess bleed water, leading to a thin paste layer with a high *w/cm* at the concrete surface. Additionally, two initial tests for air content of this bridge deck were below 6.5% the lower limit of the MnDOT specifications. Although the IC deck placed in 2016 had an average air content of 7.5%, it was constructed in late September (cured in cold ambient temperature), which increased the potential of concrete durability damage.

50% 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.

0% COMPLETE

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

0% COMPLETE

Anticipated work next quarter:

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

Four internally-cured LC-HPC bridge decks will be constructed; two in Kansas and two in Minnesota. The tentative construction dates of these bridge decks are scheduled for the late-summer of 2020. KU researchers will travel to the concrete ready-mix plants prior to construction to test the lightweight aggregate and provide modifications for the mixture proportions as required.

Crack surveys will be conducted during this quarter.

Additional IC mixtures will be cast, including a series using the same materials to be used for the upcoming internally-cured LC-HPC bridge deck in Minnesota and Kansas.

Significant Results this quarter:

One IC-LC-HPC bridge deck was successfully constructed in Minnesota this quarter. KU researchers found a free-surface moisture of 9.2% prior to casting, but a value of 11.5% was determined and used by ready-mix plant personnel. The deviation of moisture content resulted in a 3.7 lb/yd^3 decrease in mixture water content or an 0.006 decrease of *w/cm* ratio. Based on the average of trip ticket values, the average paste content for the IC-LC-HPC deck was 25.3%, and the average *w/cm* ratio was 0.41, compared with the design value of 0.43.

Free shrinkage results in accordance with modified ASTM C157 procedures indicate that for a given binder composition, as the total internal water (TW) increases, shrinkage of concrete decreases. Ternary mixtures exhibited lower shrinkage than mixtures containing 100% portland cement as the binder for similar quantities of IC water. For example, the ternary mixture with 6% IC water (12.0% TW) exhibited the lowest shrinkage, with 310 microstrain through 90 days of drying, while the mixture with 100% portland cement as the binder and 6% IC water (8.7% TW) had 490 microstrain of shrinkage during the same period. The mixture with 100% portland cement as the binder and no IC water (3.0% of TW) exhibited the greatest shrinkage through 90 days of drying with 530 microstrain.

Freeze-thaw resistance is being evaluated in accordance with ASTM C666 (Procedure A) with a failure limit of 90% of the initial dynamic modulus of elasticity. The results indicate that the total internal water (TW) provided by all aggregates is a paramount factor in the freeze-thaw durability of concrete compared to the quantity of IC water provided by LWA. Regardless of the binder composition, in the mixtures with IC water nominally equal to either 0 or 6% (by the weight of binder), the dynamic modulus of elasticity of the mixtures with higher quantities of total internal water dropped below 90% of the initial value in fewer cycles. The dynamic modulus of elasticity of the mixtures with more than 12% of TW (by the weight of binder), dropped below 90% of their initial values in less than 225 cycles and failed the test. For mixtures with the same quantities of TW (either 3.4% or 8.7%), mixtures with 100% portland cement as the binder had considerably higher freeze-thaw resistance compared to the paired ternary mixtures.

Scaling tests have been completed on this series of mixtures, including the mixtures with different binder compositions, coarse aggregates, and various IC water nominally equal to 0 to 9% by weight of binder (3.0% to 12.5% TW). In contrast to the freeze-thaw test, total internal water (TW) did not negatively affect the scaling resistance. At the same time, the binder compositions did impact on the scaling resistance of the mixtures. The mixtures with 100% portland cement, with either 0 or 6% of IC water (3.4% or 8.7% of TW), had higher mass losses than the ternary mixtures with the same quantities of IC water. The mass loss of mixtures with no IC water in 100% portland cement and ternary mixtures were 0.35 and 0.23 lb/ft^2, respectively, after 50 freeze-thaw cycles. The mass loss of mixtures with 6% IC water in 100% portland cement and ternary mixtures were 0.20 and 0.08 lb/ft^2, respectively, after 50 freeze-thaw cycles. The ternary mixtures with either 6% or 9% of IC water (above 8.7% of TW) exhibited mass losses ranging from 0.08 to 0.12 lb/ft^2, with a visual rating of either 0 or 1. One likely cause of the better performance of the ternary mixtures is the effect of supplementary cementitious materials in reducing calcium hydroxide that leads to the formation of calcium oxychloride, which forms when hydrated cement comes in contact with calcium chloride at low temperatures. Calcium oxychloride does not form when scaling tests are performed using sodium chloride. Thus, scaling tests that use calcium chloride are really testing both scaling and calcium oxychloride resistance.

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. Existing specimens continue to be evaluated, but work on new mixtures was halted temporarily. Laboratory work, however, is again underway.