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 # *TPF-5(336)*	**Transportation Pooled Fund Program - Report Period:** ☒Quarter 1 (January 1 – March 31) 2018 ☐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, 2016**
Original Project End Date: **December 31, 2018**	**Current Project End Date:** **December 31, 2018**	**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
$270,000	$161,912.69	65%

Quarterly Project Statistics:

Total Project Expenses This Quarter	Total Amount of Funds Expended This Quarter	Percentage of Work Completed This Quarter
$9,217.87	$9,217.87	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. The LC-HPC decks have been constructed using 100% portland cement concretes with low cement paste contents, lower concrete slumps, controlled concrete temperature, minimum finishing, and the early initiation of extended curing. Methods to further minimize cracking, such as internal curing in conjunction with selected supplementary cementitious materials, 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.

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

TASK 1: Work with state DOTs on specifications for the construction of six LC-HPC bridge decks per state to be constructed over a three-year period.

MnDOT has identified two internally cured LC-HPC bridge deck projects for construction in 2018. This includes a bridge on I-35 near Pine City, MN, which has been let. The other project is an interchange located near Chaska, MN, which will be let in June. KU researchers will work with the contractor and material supplier in developing mixture proportions and share experience from the previous two years of working with internally cured concrete.

100% COMPLETE

TASK 2: Provide on-site guidance during construction of the LC-HPC bridge decks.

On-site guidance will continue in 2018 when new projects are underway. KU researchers will continue to provide material suppliers and contractors suggestions for handling, storage, and batching with pre-wetted fine lightweight aggregate for use in internally cured concrete.

60% COMPLETE

TASK 3: Perform detailed crack surveys on the bridge decks, 1 year, 2-3 years, and (if approved) 4-5 years after construction. Prior research has demonstrated that it takes at least three years to consistently establish the long-term cracking performance of a bridge deck. The surveys will be performed using techniques developed at the University of Kansas to identify and measure all cracks visible on the upper surface of the bridge deck. If desired, DOT personal will be trained in the survey techniques and may assist in the surveys, as appropriate.

Crack surveys of the internal curing and control decks will be conducted during the summer, one and three years after construction.

35% COMPLETE

TASK 4: Correlate the cracking measured in Task 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. Interim and final reports will be prepared covering the findings in Tasks 1-4.

20% COMPLETE

Anticipated work next quarter:

Laboratory testing of concrete mixtures with internal curing will continue to be evaluated by KU researchers, including series of mixtures replicating 2017 MnDOT internally cured concrete mix proportions.

Significant Results this quarter:

The concrete mixture proportions for internally cured LC-HPC bridges submitted to MnDOT for 2017 include a 27.3% replacement (by weight) of cementitious material with slag cement and a 26.0% paste content. Variations of this mixture in laboratory batches include varying the *w/cm* ratio (0.45, 0.43, and 0.41) and amount of internal curing water (0, 7, and 9 lb/cwt). Replications of mixtures at each *w/cm* ratio with 9 lb/cwt of internal curing water will include the same dosage of set retarder as the Cannon Falls bridge and part of the Zumbrota bridge (3 oz/cwt). An additional ternary series with and without internal curing includes a 3% cement replacement with silica fume in addition to the 27.3% replacement of cement with slag at a *w/cm* ratio of 0.43. One mixture, also with a 27.3% replacement of cement with slag and 0.43 *w/cm* ratio included 14 lb/cwt of internal curing water to evaluate the effects of having an excessive amount of internal curing water. The mix design for the control deck, which includes a 35% replacement (by weight) of cement with Class F fly ash (and no internal curing) was also replicated, along with a mixture including 35% fly ash and 9 lb/cwt of internal curing water at a *w/cm* ratio of 0.42. Two mixtures replicating average trip ticket proportions for bridges placed in 2017, one with 3 oz/cwt of set retarder and one without, are also included. A control series, also with 26% paste and a *w/cm* of 0.43, includes only portland cement as the binder and internal curing water of 0 and 9 lb/cwt.

For freeze-thaw testing, MnDOT specifications state that specimens shall be evaluated under ASTM C666 Procedure A and must maintain at least 90% of the initial dynamic modulus at the end of 300 cycles. To date, all batches that have been tested through 300 freeze-thaw cycles were within this limit. The only batch that completed 300 cycles and resulted in a remaining dynamic modulus less than 100% was the mixture that included 14 lb/cwt of internal curing water (with a dynamic modulus at the end of testing of approximately 92%). This set was allowed to continue testing beyond 300 cycles to observe when it would drop below the limit. After approximately 330 cycles, the dynamic modulus dropped below 90% of its original value. After 460 cycles, this value dropped below 60%. Other sets that are being tested beyond 300 cycles include two batches at a 0.45 *w/cm* ratio with 27.3% slag (one with 8.4 lb/cwt of internal curing water and one with zero) and one at a 0.43 *w/cm* ratio with 100% portland cement and 8.8 lb/cwt of internal curing water. After 570 cycles, the dynamic modulus for these three batches was at least 102%. These results demonstrate that including excessive internal curing water can have detrimental effects on durability of concrete, a conclusion also made by other researchers on this topic. Although some mixtures are still undergoing tests, including both batches with 35% fly ash and some at each *w/cm* ratio used in this study, it is expected that all batches will be within MnDOT specification limits through 300 cycles. The ternary and 100% portland cement series have completed 300 freeze-thaw cycles with all batches having a dynamic modulus above 100% of the initial value.

An additional series of scaling tests have been completed for specimens containing a 27.3% slag replacement at a *w/cm* ratio of 0.45 with approximately 8.4 lb/cwt of internal curing water to evaluate the impact of extended curing and removing the effect of bleed water, factors intended to improve scaling performance. One set of scaling specimens that followed ASTM C672 procedures was cured for 14 days after casting, similar to all other tests in this series. Another set was cured for 28 days. A third set was cured for 14 days, but the bottom surface of the concrete was used for the scaling test to determine the effect of bleed water and finishing on scaling. For this series, the lowest mass loss was associated with the set that tested the bottom surface, which was less than 0.01 lb/ft^2 by the end of testing, and received a visual rating of 0. The 14-day and 28-day-cure sets had mass losses of 0.06 and 0.04 lb/ft^2, respectively, and both received a visual rating of 1 at the end of testing. Previously tested batches that also received a visual rating of 1 include one of the batches replicating the average trip ticket proportions and several others, with *w/cm* ratios of 0.45, 0.43, and 0.41. These batches include the ternary mixture without internal curing and both of the mixtures that used 100% portland cement as binder.

Many mixtures that have been evaluated exceeded a visual rating of 1 (the limit set by MnDOT specifications) by the end of testing. For batches at *w/cm* ratios of 0.43 and 0.41, higher mass loss and visual ratings have been associated with higher dosages of water reducing admixture, which may prolong bleeding, regardless of the amount of internal curing water provided. The only batch that received a visual rating of 3 at the end of testing was a mixture containing 35% fly ash with no internal curing water. Despite having a majority of batches receive a visual rating higher than 1, resultant mass losses for batches that have completed testing have been relatively low (below 0.15 lb/ft^2). Those that exceeded 0.15 lb/ft^2 include the batch at a *w/cm* ratio of 0.43 with 14 lb/cwt of internal curing water, the batch with the highest dosage of water reducing admixture at a *w/cm* ratio of 0.41, and the 35% fly ash mixture without internal curing water (0.42 *w/cm* ratio).

Additional batches were cast to evaluate shrinkage behavior according to both ASTM C157 and a modified version of the test. The modified procedure involves demolding specimens at the final set time of the concrete (approximately 5 ½ hours after casting for a *w/cm* of 0.45), rather than at 24 hours, and measuring length change of specimens daily throughout the curing period. Mix proportions for these batches replicate previous ones from 2017, including two with cement replacements of 27.3% slag, one with a cement replacement of 35% Class F fly ash, and two with 100% portland cement as binder at a *w/cm* ratio of 0.43, one with 9 lb/cwt of internal curing water and one without internal curing. Of the mixtures containing slag, one has a *w/cm* of 0.45 and 8.4 lb/cwt of internal curing water and the other has a *w/cm* ratio of 0.41 and 9 lb/cwt of internal curing water. The mixture containing fly ash has a *w/cm* ratio of 0.42 and 9 lb/cwt of internal curing water. In all cases, accounting for early-age expansion on these series reveals a greater amount of swelling (and smaller corresponding net shrinkage) for the specimens demolded around the time of final set compared to the sets demolded at 24-hours per ASTM C157. For the mixture containing 27.3% slag at a 0.45 *w/cm*, the difference in swelling at the end of the curing period was 33 microstrain. For the mixture containing 27.3% slag at a 0.41 *w/cm* ratio, this difference was 106 microstrain. For the mixture containing fly ash, the final set time was closer to 8 hours after casting, and the measured difference in swelling between early-age and 24-hour demold times was only 10 microstrain. For the 100% portland cement mixture with no internal curing water, the measured difference between early-age and 24-hour demold times resulted in a difference of 47 microstrain. For the 100% portland cement mixture with 9 lb/cwt of internal curing water, this difference was 150 microstrain. These results demonstrate that ASTM C157 procedures do not completely account for the effects of internal curing on concrete shrinkage.

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).

The second internally cured bridge for Minnesota in 2016 was not successfully completed, and as previously indicated by MnDOT, a replacement bridge is not planned. KU, however, is prepared to work with MnDOT if the decision is made to include a replacement bridge in the study.