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(174)*		**Transportation Pooled Fund Program - Report Period:** ☐Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) XQuarter 4 (October 1 – December 31)
Project Title: Construction of Crack-Free Concrete Bridge Decks, Phase II		
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Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:** **July 1, 2008**
Original Project End Date: **June 30, 2013**	**Current Project End Date:** **August 31, 2016**	**Number of Extensions:** 0

Project schedule status:

☐ On schedule X 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**
$995,000*	$539,158.02**	67%

Quarterly Project Statistics:

Total Project Expenses This Quarter	**Total Amount of Funds Expended This Quarter**	**Percentage of Work Completed This Quarter**
$4,085.16	$4,085.16	3%

*$1,545,000 including KUTRI, BASF, and SFA funds, **$1,025,686.70 including KUTRI, BASF, and SFA funds

Project Description:
Cracks in concrete bridge decks provide easy access for water and deicing chemicals that shorten the life of the deck. Both materials increase the effects of freeze-thaw damage, while the deicing chemicals lead to higher concentrations of chlorides, and subsequently, corrosion of reinforcing steel. Measurements taken on bridges in Kansas show that dense, high quality concrete can significantly slow the penetration of chlorides to the level of the reinforcing steel. However, measurements taken at cracks show that the chloride content of the concrete can exceed the corrosion threshold at the level of the reinforcing steel by the end of the first winter. The formation of cracks, thus, significantly lowers the effectiveness of other techniques that are used to increase the life of a deck.

Research, some of which dates back nearly 40 years, has addressed the causes of cracking in bridge decks in North America. The research includes three detailed bridge deck surveys carried out by the University of Kansas since 1993. The results of the studies provide specific guidance on modifications in materials and construction techniques that will reduce the amount of cracking in bridge decks. In spite of this accumulation of knowledge, only a small number of these findings have been used to implement changes in bridge deck design and construction procedures. In specific cases, on-site observations indicate that it is possible to develop nearly crack-free bridge decks, if "best practices" are followed. Even with these few successes, most bridge decks exhibit significant cracking, exposing the reinforcing steel to deicing chemicals and subsequent corrosion and increasing the degree of saturation, which increases the impact of freeze-thaw cycles. The current level of understanding, however, offers strong direction for constructing bridge decks with minimum cracking.

This improved understanding was put to use during the first phase of this study, in which 20 low-cracking, high-performance concrete (LC-HPC) bridge decks, with an equal number of control decks, were planned for construction. The decks involved the use of low cement and water contents, increased air contents, optimized aggregate gradations that produce pumpable, workable, placeable, finishable concrete with cement contents as low as 535 lb per cubic yard, temperature control during placement, limited finishing, and early curing. The study was successful in identifying low-cracking portland cement concrete mixtures. Several additional approaches, however, have been identified that have the potential to increase the benefits of the project, including using mineral admixtures, new sources of aggregate, and new approaches to finishing. These approaches could not be fully exploited in Phase I. Data indicates that, when coupled with internal curing (provided by fully or partially saturated KsDOT approved limestone with 2½ - 3% absorption), using blast furnace slag as a replacement for portland cement can reduce drying shrinkage by an additional 40%. Two other mineral admixtures, fly ash and silica fume (microsilica), are also under investigation, although with less advantageous results. They will continue to be evaluated, however, because of their widespread use and the desire to construct decks with minimum permeability (achieved using silica fume) and environmentally beneficial waste materials (fly ash). The new mixtures must be investigated for their shrinkage and freeze-thaw properties, as well as construction qualities, especially the ability to use pumps to place the new mixtures. Optimum procedures for concrete placement and fogging will continue to be areas of special emphasis. Finishing techniques have been restricted in the current study. Additional work is necessary to determine if some of the restrictions (principally on the placement and finishing equipment) may be lifted.

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

TASK 1: Update plans to construct bridge decks with minimum cracking by incorporating "best practices" dealing with materials, construction procedures, and structural design. This step involves improving techniques in use in Phase I and meeting with department of transportation personnel from multiple states, as well as other experts, to select the procedures to be used and the bridge types to which they will be applied.

This task was largely completed during the Annual Meeting of Pooled Fund Sponsors held in Kansas City, MO at the Kansas City Airport Hilton on July 24, 2008, as well as in meetings with KDOT officials as reported in the report for the 1st quarter of 2009. This task will remain open until the end of the project to allow for slight modifications to LC-HPC bridge deck specifications and additional LC-HPC bridge deck construction as warranted.

90% COMPLETE

TASK 2: Perform laboratory work to evaluate the effects of slag cement, fly ash, silica fume, shrinkage reducing admixtures, and internal curing on the performance of concrete mixtures for use on LC-HPC decks.

A number of mixtures are currently being tested for shrinkage, scaling resistance, freeze-thaw durability, strength, and air void properties in hardened concrete, including mixtures containing different replacement levels of total aggregate with pre-wetted lightweight aggregate (LWA), mixtures containing different dosages of Control 40, a shrinkage reducing admixture (SRA) produced by Sika, and mixtures containing different dosages of Acti-Gel (0.05, 0.075, and 0.15% by weight of total dry material), a rheology modifying admixture, both with and without Type C fly ash (20 and 40% replacements by volume of cement). Settlement cracking tests are being performed for a number of different concrete clear covers and slumps to produce a repeatable procedure that consistently produces settlement cracks. Mixtures containing Acti-Gel, with and without fly ash, and synthetic and steel fibers are currently being evaluated for settlement cracking.

67% COMPLETE

TASK 3: Work with state DOTs, designers, contractors, inspectors, and material suppliers to modify designs, specifications, contracting procedures, construction techniques, and materials to obtain decks exhibiting minimal cracking.

This task was largely completed during the Annual Meeting of Pooled Fund Sponsors held in Kansas City, MO at the Kansas City Airport Hilton on July 23, 2009, as well as in meetings with KDOT officials as reported in the report for the 1st quarter of 2009. This task will remain open until the end of the project to allow for slight modification to LC-HPC bridge deck specifications, construction methods and materials as warranted.

90% COMPLETE

TASK 4: Select and schedule bridges to be constructed using "best practices," and pre-qualify designers and contractors in application of the techniques. To date, 14 bridges in Kansas, two in South Dakota, one in Minnesota, and one in Missouri have been identified for construction. Twenty additional bridges are proposed for Phase II. Researchers from the University of Kansas and state DOT personnel will work closely with designers and contractors to achieve the desired results. Pre-qualification of designers and contractors includes the presentation of workshops sponsored by the University of Kansas to help educate and train engineers in implementing the "best-practices" identified in Tasks 1 and 3.

To date for Phase II, 4 LC-HPC bridge decks have been constructed in Minnesota, 3 LC-HPC bridge decks have been constructed in Kansas, with the 3rd Kansas LC-HPC bridge deck completed on September 28, 2011. Details on the construction of the first two bridge decks can be found in the 4th Quarter report for 2010. Details on the 3rd deck can be found in the 3rd Quarter report for 2011.

Seven bridge decks that are to contain fibers are planned for construction in Kansas. To date, two of the seven decks have been constructed. The two decks were deck replacements located in Wyandotte County and were completed in two placements each. Both decks contained polypropylene macro fibers and one contained glass fiber reinforced polymer reinforcement. The first two placements were constructed in the previous quarter, while the third and fourth placements were constructed,on November 6 and 14, respectively, with KU personnel in attendance monitoring construction. The five remaining decks include new bridge construction, with three in Douglas County and two in Shawnee County. Three of the remaining decks have yet to be let.
This task remains open until the end of the project to allow for additional LC-HPC bridge construction as requested.

67% COMPLETE

TASK 5: Perform detailed crack surveys on the bridge decks one year, two years, and three years after construction. The surveys are performed using techniques developed at the University of Kansas that involve identifying and measuring all cracks visible on the upper surface of the bridge deck. The majority of the early surveys will be done by the University of Kansas. As the project progresses, teams outside of the State of Kansas will be trained in the survey techniques. Three teams in South Dakota have been trained to date.

Annual crack surveys of LC-HPC and associated control decks were completed in the previous quarter. In general, the decks experienced increased cracking compared to the previous year's surveys. Crack densities for the LC-HPC decks were found to be lower than those observed for the control decks. Detailed results from the crack surveys will be presented in subsequent reports. Six bridge decks were surveyed in Minnesota in the previous quarter, including two constructed in accordance with Minnesota low-cracking specifications and four constructed in accordance with Minnesota standard specifications. The decks in Minnesota constructed in accordance with the low-cracking specifications have lower cracking than those constructed in accordance with the standard specifications. The decks constructed in Minnesota in accordance with either the low-cracking or standard specifications have greater cracking than the LC-HPC decks constructed in Kansas. The Minnesota decks also have greater cracking at similar ages than a majority of the decks constructed in Kansas in accordance with the standard KDOT specifications. As is the case on most bridge decks. cracks on the Minnesota decks have commonly developed in the transverse direction, parallel to the top reinforcement, and longitudinal cracks have propagated from the abutments. Cracking was generally evenly distributed throughout the decks, although increased cracking was noted occasionally directly above the piers. Reports on the results from Minnesota dec surveys and a summary report on the past three years of deck surveys in Kansas were issued during the quarter.

67% COMPLETE

TASK 6: Correlate the cracking measured in Task 5 with environmental and site conditions, construction techniques, design specifications, and material properties and compare with earlier data. Similar data from participating states, where it exists, will be incorporated in the analysis. Actual costs and future cost estimates will be compared with potential benefits.

The correlation of cracking with the factors listed above is completed at the end of each annual crack survey. Results of the cracking analysis have been presented at the Annual Meeting of Pooled Fund participants. There was not an Annual Meeting held in 2013. The latest results will be documented in a report to be completed in the next quarter.

67% COMPLETE

TASK 7: Document the results of the study. A final report will be prepared and disseminated to participating states regarding the findings of Tasks 1-6.
The results of the study prior to 2012 are documented in the following report:

Yuan, J., Darwin, D., and Browning, J. (2011). "Development and Construction of Low-Cracking High-Performance Concrete Bridge Decks: Free Shrinkage Tests, Restrained Shrinkage Tests, Construction Experience, and Crack Survey Results," *SM Report* No. 103, University of Kansas Center for Research, Lawrence, KS, 505 pp.

In the report, the development, construction, and evaluation of LC-HPC bridge decks are described based on laboratory test results and experiences gained during the construction of 13 LC-HPC decks. Free shrinkage properties of LC-HPC candidate mixtures are evaluated. Relationships between the evaporable water content in cement paste and the free shrinkage of concrete are investigated. The restrained shrinkage performance of LC-HPC is evaluated using restrained ring tests. A description of the construction and preliminary evaluation of LC-HPC and control bridge decks constructed in Kansas is presented in the report.

Results acquired after completion of Yuan et al. (2011) will be documented in subsequent reports.

This task is scheduled to begin in Summer 2016.

67% COMPLETE

TASK 8: Update the training program developed (and currently being presented) in Phase I to assist the participating states in implementing the findings of the study. The program consists of workshops to be held at the representative state DOT offices. These workshops are individually coordinated with each participating DOT. A technical committee, structured with one representative from each state providing funds, will oversee the project. A meeting of the committee will be held each year, as has been done for Phase I. The first meeting is scheduled for July 24, 2008.

Information was disseminated at the annual meeting on July 19th, 2012 at the Kansas City Airport Hilton. Meeting CDs were sent to all representatives.
100% COMPLETE

Anticipated work next quarter:

Tests evaluating settlement cracking will continue next quarter. Mixtures containing synthetic and steel fibers will be analyzed.

Testing will continue evaluating free shrinkage, scaling resistance, freeze-thaw durability, strength, and air-void properties of the following: mixtures containing different dosages of Eclipse 4500, an SRA produced by W.R. Grace, (0.5, 1, and 2% by weight of cement) and different volume replacement levels of lightweight aggregate (0 and 10% of total aggregate), mixtures containing one of two shrinkage reducing admixtures produced by Euclid, Conex and Eucon SRA-XT, mixtures containing different additions of the shrinkage reducing admixture PREVent-C (2.5, 5, and

7.5% by weight of cement) with 20 and 40% replacements by volume of cement with Type C and Type F fly ash, mixtures containing varying replacement levels of total aggregate with pre-wetted fine lightweight aggregate, mixtures containing different dosages of the Sika SRA (Control 40), and mixtures containing different amounts of Acti-Gel. Rheology tests will begin on mixtures containing Acti-Gel.

Significant Results this quarter:

LABORATORY RESULTS:

Concrete mixtures with different dosages of the Sika SRA (0, 0.5, 1, and 2% by weight of cement) and mixtures containing the Sika SRA with pre-wetted LWA (10% replacement by total volume of aggregate) are currently undergoing free shrinkage testing. When comparing post-curing shrinkage, mixtures containing 0.5, 1 and 2% of the Sika SRA by weight of cement have approximately 165, 160 and 200 microstrain less shrinkage after approximately 135 days of drying than a comparable control mixture without the SRA. After approximately 135 days of drying, mixtures containing 1 and 2% of the Sika SRA by weight of cement and a 10% volume replacement of total aggregate with pre-wetted lightweight aggregate have approximately 65 and 110 microstrain less shrinkage after curing than a comparable mixture with 10% LWA but no SRA. The mixture with a 0.5% dosage of the Sika SRA and 10% LWA experienced approximately the same shrinkage after curing as the mixture with 10% LWA and no SRA after 135 days.

Mixtures with different amounts of Acti-Gel (0, 0.05, 0.075, and 0.15% by total dry weight of materials) and mixtures containing Acti-Gel with different replacement levels of cement with fly ash (0, 20, and 40% by volume) are currently undergoing free shrinkage testing. A clear relationship between quantity of Acti-Gel and shrinkage has not been established, although specimens with greater amounts of Acti-Gel tend to have more shrinkage. After 75 days of drying, mixtures with additions of Acti-Gel of 0.05, 0.075, and 0.15% have average free shrinkage of 475, 590, and 580 microstrain, respectively.

Mixtures containing different amounts of Acti-Gel (0, 0.05, 0.075 and 0.15% by total dry weight of materials) with different replacement levels of cement with Type C fly ash (0, 20 and 40% by volume) are currently undergoing scaling tests (BNQ NQ 2621-900). After 35 freeze-thaw cycles, low mass loss has been observed for the mixtures containing different amounts of Acti-Gel without fly ash. Mixtures containing different dosages of Acti-Gel with 20% Type C fly ash have also exhibited low mass loss, but have exhibited higher mass loss than the mixtures with Acti-gel and no fly ash and a control mixture with no Acti-Gel or fly ash. Mixtures with 40% Type C fly ash with or without Acti-Gel have exhibited mass loss near or above the limit of 0.31 lb/ft^2 specified by BNQ NQ 2621-900 after 56 cycles.

Nine mixtures containing different dosages of the Sika SRA (0.5%, 1%, and 2% by weight of cement) along with different replacement levels of total aggregate with LWA (0 and 10% by volume) have completed testing for freeze-thaw durability. All nine mixtures retained at least 95% of their initial dynamic modulus through 300 cycles. In addition, two mixtures containing 40% fly ash and one mixture containing 20% fly ash have maintained at least 95% of their initial dynamic modulus through 300 cycles.

Mixtures containing Acti-Gel have been tested for settlement cracking. The testing has included two series with different target slumps, 5 and 8 in., respectively. For both series, the mixtures containing Acti-Gel exhibited less overall cracking.

A series of mixtures containing FORTA synthetic fibers has been analyzed for settlement cracking at a target slump of 5 in. The mixtures contained 7.5 lb/yd^3 of 2.25-in. fibers. Mixtures containing the FORTA fibers have exhibited considerably less cracking than mixtures with no fibers.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might the completion of the project within the time, scope and fiscal constraints set forth in the agreement, alon recommended solutions to those problems).

Nothing to report.