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(174)	X Quarter 1 (January 1 – March 31) ☐ Quarter 2 (April 1 – June 30) ☐ Quarter 3 (July 1 – September 30) ☐ Quarter 4 (October 1 – December 31)

Project Title:
Construction of Crack-Free Concrete Bridge Decks, Phase II

Project Manager:	**Phone:**	**E-mail:**
Rodney Montney	785-291-3844	Rodney@ksdot.org

Project Investigator:	**Phone:**	**E-mail:**
David Darwin	785-864-3827	daved@ku.edu

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:** 1

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*	$504,176.24**	58%

Quarterly Project Statistics:

Total Project Expenses This Quarter	**Total Amount of Funds Expended This Quarter**	**Percentage of Work Completed This Quarter**
$26,369.19		3%

*$1,545,000 including KUTRI, BASF, and SFA funds, **$990,704.92 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.

Mixtures with varying amounts of a shrinkage reducing admixture (SRA) known as PREVent-C are being analyzed for shrinkage, scaling, freeze-thaw performance, strength, and air void properties in hardened concrete. Mixtures containing PREVent-C and air contents below the LC-HPC specification requirement (< 6.5%) with Micro Air are being tested for scaling and freeze-thaw performance. Mixtures containing 20 and 40% replacements of cement by volume with Type C and F fly ash along with a 10% replacement of total aggregate by volume with lightweight aggregate are currently being tested for shrinkage, scaling, freeze-thaw performance, strength, and air void properties in hardened concrete to examine the effects of internal curing in mixtures containing fly ash. Settlement cracking tests are in the preliminary stages in an effort to better understand the mechanisms of settlement cracking.

77% 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.

This task remains open until the end of the project to allow for additional LC-HPC bridge construction as requested.

75% 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.

All annual crack surveys for Low Cracking-High Performance Concrete (LC-HPC) bridges and corresponding control bridges in Kansas were completed and discussed in the 3rd quarter report for 2012. Surveys for 2013 will begin when environmental conditions become favorable.

75% 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 are presented at each Annual Meeting of Pooled Fund participants. The latest results were presented at the annual meeting that was held on July 19th, 2012 at the Kansas City Airport Hilton, which was described in the 3rd quarter report for 2012.

75% 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.

This task is scheduled to begin in Fall 2012.

0% 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.
75% COMPLETE

Anticipated work next quarter:

Mixtures containing 20 and 40% replacements of cement by volume with Type C and F fly ash, a 10% replacement of total aggregate by volume with lightweight aggregate, and varying dosages of shrinkage reducing admixture (SRA) will be tested for shrinkage, scaling, freeze-thaw performance, strength, and air void properties in the hardened concrete. Both intermediate and fine-sized lightweight aggregates will be tested. Mixtures containing 10 and 15% replacements of total aggregate by volume with lightweight aggregate and varying dosages of SRA (0.5, 1.0, and 2.0% by weight of cement) will be tested for shrinkage, scaling, freeze-thaw performance, strength, and air void properties in the hardened concrete. Mixtures containing varying amounts of the shrinkage reducing admixture powder, PREVent-C, and fly ash will be tested for shrinkage, scaling, freeze-thaw performance, strength, and void properties. Settlement cracking test procedures will be developed to examine the mechanisms that lead to settlement cracking. Settlement cracking tests will be performed on concrete mixtures with slumps between 5 and 6 in. containing varying dosages of synthetic fibers. It is also anticipated that settlement cracking tests will be performed with mixtures containing steel fibers.

Significant Results this quarter:

<u>LABORATORY RESULTS:</u>

Concrete mixtures containing varying dosages of PREVent-C (0, 2.5, 5, and 7.5% by weight of cement) are undergoing free shrinkage testing. All concrete mixtures containing PREVent-C are performing better than the comparable control mixtures. Mixtures containing higher dosages of PREVent-C exhibit lower shrinkage. After approximately 180 drying days, mixtures containing 2.5, 5 and 7.5% of PREVent-C by weight of cement shrinkage was reduced, respectively, by approximately 40, 66 and 55 microstrain compared to the control mixture. For a second set of concrete mixtures containing 2.5, 5 and 7.5% dosages of PREVent-C by weight of cement, shrinkage was reduced, respectively, by approximately 105, 135 and 145 microstrain compared to the control mixture at 120 drying days. A concrete mixture containing 30% and 6% replacements of cement with slag and silica fume, respectively, with a 10% replacement of total aggregate by volume with lightweight aggregate has 40 microstrain less shrinkage after 50 drying days than a mixture containing 30% and 3% volume replacements of cement with slag and silica fume, respectively, with 10% lightweight aggregate by volume of total aggregate. A mixture containing a 20% volume replacement of cement with fly ash and a 10% replacement of total aggregate with lightweight aggregate has 10 microstrain less shrinkage than a mixture with 40% fly ash and 10% lightweight aggregate.

Mixtures containing varying dosages of PREVent-C (0, 2.5, 5, and 7.5% by weight of cement) have been tested for scaling and freeze-thaw performance. Most of the mixtures maintained a scaling mass loss below the failure limit of the scaling test. Mixtures containing 2.5% PREVent-C and 7, 8.5 and 8.75% air contents have maintained low scaling mass loss through 56 freeze-thaw cycles. Mixtures containing 5% PREVent-C and 4.75, 6.80 and 8% air contents have also maintained low scaling mass loss through 56 freeze-thaw cycles. A mixture containing 7.5% PREVent-C and an 8.9% air content maintained low mass loss through 56 freeze-thaw cycles, but a mixture containing 7.5% PREVent-C and a 4% air content exceeded the mass loss limit after 35 days of freeze- thaw cycles. A mixture containing by volume of cementitious materials 30% slag, 3% silica fume, 10% lightweight aggregate by volume of total aggregate and an air content of 9% has low mass loss after 7 days of freeze-thaw cycles. Another mixture containing 30% slag, 6% silica fume and 10% lightweight aggregate and an air content of 8% has low mass loss after 7 days of freeze- thaw cycles. A mixture containing 20% fly ash and 10% lightweight aggregate and an air content of 9% has maintained low mass loss after 21 days of freeze- thaw cycles.

Thirteen mixtures containing PREVent-C have undergone freeze-thaw durability tests. A mixture containing 5% PREVent-C and a 4.25% air content dropped below 95% of its initial dynamic modulus after 263 cycles. Another mixture containing 7.5% PREVent-C and a 5% air content dropped below 95% of its initial dynamic modulus after 40 cycles. Two mixtures containing 2.5% PREVent-C with 7 and 8.5% air contents dropped below 95% of its initial dynamic modulus after 181 and 197 cycles, respectively. All other mixtures containing PREVent-C maintained at least 95% of their initial dynamic modulus through 300 cycles. A duplicate mixture containing 2.5% PREVent-C and 7% air maintained 95% of its dynamic modulus through completion of the test.

Settlement cracking tests have been performed on three concrete mixtures with slumps ranging from 7.25 to 8.25 in., including one control mixture, one mixture with 3 lb/yd^3 of STRUX 90/40 synthetic fibers, and one mixture with 5 lb/yd^3 of STRUX 90/40 synthetic fibers. All tests were conducted using a 1/2 in. concrete cover over a No. 5 reinforcing bar. All three mixtures exhibited measurable cracking within 4 hours after casting. No correlation was determined between the crack widths of the three different mixtures.

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, along with recommended solutions to those problems).

Nothing to report.