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) XQuarter 3 (July 1 – September 30) ☐Quarter 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*	$535,072.86	64%

Quarterly Project Statistics:

Total Project Expenses This Quarter	Total Amount of Funds Expended This Quarter	Percentage of Work Completed This Quarter
$7,604.73	$7,604.73	3%

*$1,545,000 including KUTRI, BASF, and SFA funds, **$1,021,601.54 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 analyzed for shrinkage, scaling resistance, freeze-thaw performance, strength, and air void properties in hardened concrete, including mixtures containing different replacement levels of total aggregate with pre-wetted lightweight aggregate, mixtures containing different dosages of Control 40, a shrinkage reducing admixture (SRA) produced by Sika, mixtures containing 20 and 40% volume replacements of cement with Type F fly ash, 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, with and without Type C fly ash (20 and 40% replacements by volume of cement). The addition of Acti-Gel presumably improves the pumpability and cohesiveness of concrete while maintaining low potential for settlement cracking. Mixtures containing different dosages of an SRA powder, PREVent-C, are undergoing shrinkage tests. 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, have been evaluated for settlement cracking.

64% 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. Five of the decks are included in new bridge construction and two decks consist of deck replacements on existing structures. The deck replacements are to be completed in phased construction. The new bridge construction is located in Douglas (three bridges) and Shawnee (two bridges) Counties. The three decks in Douglas County are to contain synthetic macro fibers, while the two decks in Shawnee County are to contain polypropylene micro fibers. The two deck replacements are located in Wyandotte County and are to contain polypropylene macro fibers. One of the deck replacements will also contain glass fiber reinforced polymer reinforcement. Four of the decks were let earlier this year and three decks are scheduled to let in September. The first phase of the deck replacement without glass fiber reinforced polymer reinforcement was completed in August without KU personnel in attendance (error by contractor). The first phase of the deck replacement containing glass fiber reinforced polymer reinforcement was completed on September 25 with KU personnel in attendance monitoring the construction.
This task remains open until the end of the project to allow for additional LC-HPC bridge construction as requested.

64% 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 this quarter. 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 this quarter, including two decks constructed in accordance with Minnesota low-cracking specifications and four decks constructed in accordance with Minnesota standard specifications. The crack densities for the two decks constructed in accordance with the low-cracking specifications were lower than the crack densities for the four decks constructed in accordance with standard specifications. Detailed results on the crack surveys will be presented in the next quarterly report.

64% 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.

64% 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.

64% 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 the admixture Acti-Gel will be tested both with and without the addition of synthetic and steel fibers. The influence of temperature and relative humidity on settlement cracking will be evaluated.

Freeze-thaw testing will begin on a series of mixtures containing different dosages of the SRA, Sika Control 40. Freeze-thaw testing will also begin on mixtures containing different dosages of Acti-Gel with 20 and 40% volume replacements of cement with Type C fly ash.

Testing will continue to evaluate free shrinkage, scaling resistance, freeze-thaw durability, strength, and air-void properties of the following: mixtures containing a 0.15% addition of Acti-Gel by total dry weight of material with 20 and 40% replacements of cement with Type C fly ash, mixtures containing varying replacement levels of total aggregate with fine lightweight aggregate, and 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. The fine lightweight aggregate will be evaluated in both vacuum-wetted and atmospherically-wetted conditions. Mixtures containing SRAs produced by W.R. Grace (Eclipse 4500) and Euclid are also scheduled for testing.

Rheology tests will begin on mixtures containing Acti-Gel.

The KU research team will observe the construction of bridge decks in Kansas in the next quarter that contain fibers. Crack surveys will be completed on the decks in the future. Data collected during the construction and information regarding the concrete mixture designs will be used in conjunction with crack survey data to analyze the cracking performance of the decks and determine the factors that affect cracking..

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 lightweight aggregate (LWA) (10% replacement by total volume of aggregate) are currently undergoing free shrinkage testing. When comparing post-curing shrinkage, all mixtures containing the Sika SRA are performing better than comparable control mixtures without the SRA. Mixtures containing higher dosages of the Sika SRA have exhibited lower shrinkage. Mixtures with the SRA and LWA are performing better than mixtures with only the SRA within the first two weeks of drying; however, no significant difference in shrinkage has been observed after the first two to three weeks of drying. Concrete mixtures with Type F fly ash (20% and 40% replacement by volume of cement) are also undergoing free shrinkage testing. At 90 drying days, mixtures with 20 and 40% replacements by volume of cement with Type F fly ash are exhibiting less shrinkage than a comparable control mixture with no fly ash. Two mixtures with 20% fly ash have exhibited approximately 115 microstrain less shrinkage than a comparable control mixture with no fly ash. In addition, two mixtures with 40% fly ash have exhibited approximately 80 microstrain less shrinkage than the control mixture. These mixtures have been subjected to 14 days of wet curing. Concrete mixtures with Acti-Gel (0.05, 0.075, and 0.15% by total dry weight of material), with and without fly ash (20 and 40% replacement by volume of cement), are undergoing free shrinkage testing. No correlation has been observed between Acti-Gel dosage rate and free shrinkage.

When comparing post-curing shrinkage,, mixtures containing 0.5, 1 and 2% of the Sika SRA by weight of cement have approximately 155, 160 and 210 microstrain less shrinkage after approximately 90 drying days than a comparable control mixture without the SRA. After approximately 90 drying days, mixtures containing 1 and 2% of the Sika SRA by weight of cement and a 10% replacement by volume of total aggregate with pre-wetted lightweight aggregate have approximately 80 and 145 microstrain less shrinkage after curing than a comparable mixture with LWA but no SRA. The mixture with a 0.5% dosage of the Sika SRA and 10% LWA experienced approximately 25 microstrain greater shrinkage after curing than the mixture with 10% LWA at 90 drying days.

Scaling tests are currently being completed for concrete mixtures with different dosages of the Sika SRA, Control 40, (0.5, 1 and 2% by weight of cement) and mixtures containing the Sika SRA with 10% replacement of pre-wetted lightweight aggregate (LWA) by total volume of aggregate. Low mass loss has been observed after 56 freeze-thaw cycles for mixtures containing the SRA and LWA; however, the mixtures with the SRA and LWA have experienced greater mass loss than comparative control mixtures with no SRA or LWA. A single mixture containing the SRA (0.5% dosage) has experienced lower mass loss than the control mixture. No direct correlation has been established between scaling resistance and dosage of SRA. An additional series of mixtures containing different dosages of the Sika SRA (0.5, 1 and 2% by weight of cement) is currently undergoing curing.

Mixtures containing 20 and 40% Type F fly ash are currently being evaluated for scaling resistance. Mixtures with fly ash have experienced increased mass loss compared to a mixture with no fly ash. In addition, a mixture with 40% fly ash has experienced increased mass loss compared to a mixture with 20% fly ash. These mixtures containing fly ash, however, have experienced mass losses below the failure limit of 0.31 lb/ft^2 specified in the scaling test (BNQ NQ 2621-900). Concrete mixtures with Type C fly ash (20 and 40% replacements by volume of cement) are in the initial stages of freeze-thaw cycles, and scaling results are not yet available.

Freeze-thaw testing has begun for two mixtures containing a 40% replacement by volume of cement with Type F fly ash and a mixture containing a 2% dosage of Control 40. The specimens have maintained at least 95% of their initial dynamic modulus through 120 cycles. A series of mixtures containing a 10% replacement by volume of total aggregate with pre-wetted lightweight aggregate with different dosages of the Sika SRA, Control 40, are currently being tested for freeze-thaw durability. All of these specimens have maintained 95% of their initial dynamic modulus through 85 cycles. Mixtures containing Acti-Gel with a target slump of 5 in. have been evaluated for settlement cracking. Two mixtures containing a 0.05% addition of Acti-Gel (by dry weight of material) have exhibited shorter and narrower cracks than two mixtures with no Acti-Gel. Settlement cracking tests have begun on a series of mixtures containing Acti-Gel with an 8 in. target slump. Initial results from these tests indicate that mixtures containing Acti-Gel have lower slumps than similar mixtures without Acti-Gel. The addition of Acti-Gel appears to reduce the length and width of cracks that develop directly above reinforcement.

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.