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:** 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		
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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:** **June 30, 2013**	**Number of Extensions:** 0

Project schedule status:

X 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
$995,000*	$396,218.62**	75%

Quarterly Project Statistics:

Total Project Expenses This Quarter	Total Amount of Funds Expended This Quarter	Percentage of Work Completed This Quarter
$21,599.41		5%

*$1,545,000 including KUTRI, BASF, and SFA funds, **$946,574.62 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 different dosages of SRA and air contents lower than the LC-HPC specification requires (< 7%) are undergoing durability tests to determine if SRA mixtures can maintain durability at lower air contents. Concrete mixtures with different dosages of shrinkage reducing admixture (SRA), Tetraguard AS20, (0, 0.5, 1.0, and 2.0% by weight of cement) and MasterLIFE CRA 007 which is described as a crack reducing admixture (CRA) (0, 0.5, 1.0, and 2.0% by weight of cement) and two different air-entraining admixtures, Mixtures containing Micro Air and Tough Air, are being analyzed for shrinkage, scaling, freeze-thaw performance, strength, and air void properties in hardened concrete. Mixtures with different quantities of pea gravel size lightweight aggregate (LWA) (0, 8, and 10% replacement by volume of total aggregate) for internal curing, silica fume (0, 3 and 6% replacements by volume of cement), and slag (0 or 30% replacements by volume of cement) are being retested for shrinkage, scaling, freeze-thaw performance, strength, and air void properties in hardened concrete to confirm repeatability with prior results.

75% 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 2011. Surveys for 2012 will begin when environmental conditions become favorable.

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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, 2011 at the Kansas City Airport Hilton, which was described in the 3rd quarter report for 2011. The next annual meeting will be held on July 19th, 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, 2011 at the Kansas City Airport Hilton. Meeting CDs were sent to all representatives. The next meeting is scheduled for July 19th, 2012.

75% COMPLETE

Anticipated work next quarter:

Mixtures with different dosages of SRA and low air contents (> 7%) will continue to be tested to determine durability performance at lower air contents. Mixtures with different combinations of lightweight aggregate, slag, and silica fume with low air contents also will be tested next quarter to determine durability performance.

Annual bridge deck crack surveys will begin in May and continue through the next quarter.

Significant Results this quarter:

LABORATORY RESULTS:

Concrete mixtures with lightweight aggregate and mixtures containing shrinkage reducing admixtures (SRA or CRA) with Micro Air are undergoing free shrinkage testing. Concrete mixtures with the different replacement levels of lightweight aggregate are performing significantly better than comparable control mixtures after approximately 70 drying days. These results are similar to those in past research. Mixtures with a combination of lightweight aggregate and slag and mixtures with lightweight aggregate, slag, and silica fume are performing even better than mixtures with only the addition of lightweight aggregate after approximately 70 drying days. The mixtures with lightweight aggregate and slag (no silica fume) perform better than the mixtures with lightweight aggregate, slag, and silica fume until approximately 20 drying days. From 20 to 70 drying days, the mixtures with lightweight aggregate, slag, and silica fume have a lower shrinkage.

Mixtures with dosages by weight of cement of 0.5, 1.0, and 2.0% SRA with Tough Air have experienced approximately 20, 30, and 110 microstrain less shrinkage, respectively, than a comparable control mixture after approximately 150 days of drying. Mixtures with dosages of both 1.0 and 2.0% SRA with Micro Air have experienced approximately 40 and 100 microstrain less shrinkage, respectively, than a comparable control mixture after approximately 90 days of drying. A mixture with a dosage of 0.5% SRA with Micro Air has experienced approximately 35 microstrain less shrinkage than a comparable control mix after 28 drying days.

Concrete mixtures containing different combinations of lightweight aggregate (LWA), slag, and silica fume have been retested for scaling performance. Mixtures with 8 and 10% LWA replacement by volume of total aggregate performed equal to or better than a comparable control mixture after 56 freeze-thaw cycles. A mixture with 10% LWA replacement and 30% slag replacement by volume of cement experienced higher mass losses than the mixtures without slag. Mixtures with 10% LWA replacement, 30% slag replacement, and both 3 and 6% silica fume replacement by volume of cement experienced the highest amount of mass loss after 56 freeze-thaw cycles. All mixtures, however, remained below the mass loss fail limit at test completion.

Concrete mixtures containing different combinations of LWA, slag, and silica fume have also been tested for freeze-thaw performance in accordance with Procedure B of ASTM C666. Mixtures containing 8% and 10% LWA replacements by volume of total aggregate have been retested to confirm repeatability and have passed test requirements by maintaining close to 100% of their initial dynamic modulus of elasticity after 300 cycles. A mix with 10% LWA replacement and 30% slag replacement by volume of cement has also passed test requirements by maintaining approximately 100% of the initial dynamic modulus of elasticity through 300 cycles. Mixtures with 10% LWA replacement, 30% slag replacement, and both 3% and 6% silica fume replacement by volume of cement passed test requirements by maintaining over 99% of the initial dynamic modulus of elasticity after 300 cycles.

Mixtures containing different dosages of SRA (0, 0.5, 1.0, and 2.0% by weight of cement) with Tough Air have been tested for scaling and freeze-thaw performance. Mixtures with 0 and 1.0% SRA experienced very low mass loss at scaling test completion. Mixtures with 0.5 and 2.0% SRA, however, experienced mass losses equal to nearly twice the fail limit after only 35 freeze-thaw cycles. A mixture with 1.0% SRA and Tough Air has maintained just 78% of the initial dynamic modulus of elasticity during freeze-thaw testing after 226 cycles. Mixtures containing 0.5% and 2.0% SRA with Tough Air have failed freeze-thaw testing requirements by dropping below 60% of their initial dynamic modulus of elasticity after less than 70 cycles.

Mixtures containing different dosages of SRA (0, 0.5, 1.0, and 2.0% by weight of cement) and air contents below the LC-HPC specification requirement (< 7%) with Micro Air have been tested for scaling and freeze-thaw performance. A mixture with 1.0% SRA and 6.5% air content maintained low mass loss through 56 freeze-thaw cycles. A mixture with 2.0% SRA and 3.5% air content experienced over two times the mass loss scaling fail limit after only 21 freeze-thaw cycles. A mixture with 1.0% SRA and 5.25% air content and a control mixture with 3.5% air content are experiencing low mass loss through 21 freeze-thaw cycles. A mixture with 1.0% SRA and 6.5% air content with Micro Air has maintained 94% of the initial dynamic modulus of elasticity during freeze-thaw testing after 111 cycles. A mix with 2.0% SRA and 3.5% air content with Micro Air dropped to 40% of the initial dynamic modulus of elasticity after only 74 freeze-thaw testing cycles.

Air void spacing factor data has been obtained and compared with scaling performance for many of the concrete mixtures completed within the past year. An exponential increase in mass loss from scaling has been found to occur in these mixes with an increase in air void spacing factor. More data points will be added to this analysis as more air void analysis data becomes available.

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.