# 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 #**<br><br>*TPF-5(174)* | | **Transportation Pooled Fund Program - Report Period:**<br>☐Quarter 1 (January 1 – March 31)<br>☐Quarter 2 (April 1 – June 30)<br>☐Quarter 3 (July 1 – September 30)<br>XQuarter 4 (October 1 – December 31) |
|---|---|---|
| **Project Title:**<br>Construction of Crack-Free Concrete Bridge Decks, Phase II | | |
| **Project Manager:**<br>Rodney Montney | **Phone:**<br>785-291-3844 | **E-mail:**<br>Rodney@ksdot.org |
| **Project Investigator:**<br>David Darwin | **Phone:**<br>785-864-3827 | **E-mail:**<br>daved@ku.edu |
| **Lead Agency Project ID:** | **Other Project ID (i.e., contract #):** | **Project Start Date:**<br>**July 1, 2008** |
| **Original Project End Date:**<br>**June 30, 2013** | **Current Project End Date:**<br>**June 30, 2013** | **Number of Extensions:**<br>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* | $374,619.21** | 70% |

***Quarterly*** Project Statistics:

| Total Project Expenses This Quarter | Total Amount of Funds Expended This Quarter | Percentage of Work Completed This Quarter |
|---|---|---|
| $20,744.01 | | 5% |

*$1,545,000 including KUTRI, BASF, and SFA funds, **$924,975.21 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 mixes. 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 mixes 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 mixes. 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.**

Concrete mixes with different dosages of shrinkage reducing admixture (SRA), Tetraguard AS20 by BASF, (0, 0.5, 1.0, and 2.0% by weight of cement) and a new SRA, SRA 575 also by BASF, which is termed a crack reducing admixture

(CRA) (0, 0.5, 1.0, and 2.0% by weight of cement), are being tested for shrinkage, scaling, freeze-thaw performance, strength, and air void properties in hardened concrete. Mixes with different quantities of 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 also being tested for shrinkage, scaling, freeze-thaw performance, strength, and air void properties in hardened concrete. Both Micro Air, a tall oil-based admixture, and Tough Air, a polymer-based foam, are being evaluated as air-entraining agents in these mixes.

70% 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.

A post-construction meeting was held at the KDOT office in Bonner Springs, Kansas on November 28, 2011. Construction procedures and concrete properties for the 3rd LC-HPC Kansas bridge deck were discussed. Representatives of KDOT, KU, contractor, and material supplier were present and provided comments. Issues with construction included high slumps in portions of the concrete, locations of overfinishing by bullfloating, the use of curing compound as a finishing aid, significant lags in burlap placement, and placing unsoaked burlap on the deck.

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

70% 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.

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70% 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.

70% 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.

70% COMPLETE

**Anticipated work next quarter**:

A procedure is under development to evaluate the effects of slump, bar size, clear cover, and fibers on settlement cracking. The goal is to develop a procedure in which plastic concrete is placed in molds with reinforcing steel to represent concrete in bridge decks. The plastic concrete will then be vibrated in the molds to simulate construction vibrations. The plastic concrete will remain in the molds for approximately 3-5 hours and a visual inspection will then determine if a settlement crack has developed.

Mixes with different dosages of SRA and low air contents (< 7%) will continue to be tested to determine SRA durability performance at lower air contents.

**Significant Results this quarter:**

**<u>LABORATORY RESULTS:</u>**

Concrete mixes with different dosages of shrinkage reducing admixture (SRA), Tetraguard AS20, (0, 0.5, 1.0, and 2.0% by weight of cement) and SRA 575 [a crack reducing admixture (CRA) at 0, 0.5, 1.0, and 2.0% by weight 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. Mixes with different dosages of SRA and air contents lower than the LC-HPC specification requirements (< 7%) are undergoing durability tests to determine if SRA mixes can maintain durability at lower air contents. Mixes with different quantities of lightweight aggregate (LWA) (0, 8, and 10% replacement of pea gravel 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 also being retested for shrinkage, scaling, freeze-thaw performance, strength, and air void properties in hardened concrete to confirm repeatability with prior results. Both Micro Air, a tall oil-based admixture, and Tough Air, a polymer-based foam, are being evaluated as air-entraining agents in these mixes. Settlement cracking test procedures are currently being developed.

Concrete mixes with lightweight aggregate and mixes containing shrinkage reducing admixtures (SRA or CRA) with Tough Air are undergoing free shrinkage testing. The results for concrete mixes with the different replacement levels of lightweight aggregate are not significantly better than comparable control mixes. These results are different than those in past research. Mixes with a combination of lightweight aggregate, slag and silica fume, however, are performing significantly better in terms of free shrinkage after approximately 120 drying days. Mixes with dosages of both 0.5 and 1% SRA with Tough Air have experienced approximately 25 less microstrain of shrinkage than a comparable control mix after 80 drying days. Mixes with dosages of both 1 and 2% CRA with Tough Air have experienced approximately 10 and 30 less microstrain of shrinkage, respectively, than a comparable control mix after approximately 100 drying days. No shrinkage decrease was found for the 0.5% CRA with Tough Air mix. This data follows the same trend as the previous tests.

Concrete mixes with the two shrinkage reducing admixtures (SRA and CRA) have been tested for scaling with ToughAir as the air entraining agent. The scaling losses for the control mix and 0.5% SRA mix is well below the failure limit, but the 1% and 2% SRA mixes have exceeded the limit. For the CRA series, the control, 0.5% CRA and 2% CRA mixes are below the failure limit, while the 1% CRA mix has exceeded the limit.

All of the lightweight aggregate (LWA) with slag and silica fume mixes have passed the scaling test.

Concrete mixes containing lightweight aggregate (LWA), slag, silica fume, and SRA have been tested for freeze-thaw performance in accordance with Procedure B of ASTM C666. Mixes 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 a 10% LWA replacement and 30% slag replacement by volume of cement has maintained approximately 100% of the initial dynamic modulus of elasticity through 250 cycles. Mixes with 10% LWA replacement, 30% slag replacement, and both 3% and 6% silica fume replacement by volume of cement have maintained over 99% of the initial dynamic modulus of elasticity after 250 and 190 cycles, respectively. Mixes with 0.5%, 1.0%, and 2.0% SRA with Tough Air are currently being retested after experiencing poor freeze-thaw durability performance in previous tests.

**FIELD WORK:**

Data from the 3rd Kansas LC-HPC bridge deck were obtained from KDOT and the materials supplier.

**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.