

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: <input type="checkbox"/> Quarter 1 (January 1 – March 31) <input checked="" type="checkbox"/> Quarter 2 (April 1 – June 30) <input type="checkbox"/> Quarter 3 (July 1 – September 30) <input type="checkbox"/> 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
 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*	\$621,281.68	73%

Quarterly Project Statistics:

Total Project Expenses This Quarter	Total Amount of Funds Expended This Quarter	Percentage of Work Completed This Quarter
\$43,775.63	\$43,775.63	3%

*\$1,545,000 including KUTRI, BASF, and SFA funds, **\$1,107,880.65 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.

Mixtures containing Conex, a shrinkage reducing admixture (SRA) produced by Euclid Chemical, are currently undergoing free-shrinkage and scaling tests; freeze-thaw testing will be performed.

Mixtures containing Eclipse 4500, an SRA produced by W. R. Grace, with and without 10% volume replacement of total aggregate by pre-wetted lightweight aggregate (LWA) are undergoing free-shrinkage and scaling tests. Freeze-thaw tests will be performed in the next quarter.

One mixture containing 10% volume replacement of total aggregate with pre-wetted LWA, one containing 10% LWA with 30% weight replacement of cement with slag, and two containing 10% LWA, 30% slag and 3% replacement by weight of cement with silica fume are currently undergoing free-shrinkage and scaling resistance tests; freeze-thaw tests will be performed in the next quarter.

Mixtures containing varying dosages (0.05, 0.075, and 0.15% by weight of total dry material) of Acti-Gel, a rheology modifying admixture, with and without Type C fly ash (20 and 40% replacements by volume of cement), are currently undergoing freeze-thaw tests.

A consistent settlement cracking test procedure has been developed. Specimens are 12" x 12" and 8" deep with a #6 bar located with ¾" clear cover. They are cast in two lifts and consolidated with vibration. The specimens are then air cured in a room with constant temperature (73° ± 3°) and humidity (50% ± 5%). After 24 hours they are checked for cracking. The tester uses their naked eye to find cracks in the area above the bar. When the widest crack is found, a crack comparator is used to determine the width of the crack in mils. Finally the total length of cracks is measured and recorded.

73% 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.

73% 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 began this quarter. Crack surveys of the LC-HPC decks have been completed for westbound 103rd St. over US-69, southbound US-69 flyover bridge to westbound I-435, southbound US-69 to I-435 ramp over 103rd St., northbound and southbound K-7 over Johnson Drive, Clear Creek Parkway over K-7, and County Road 150 over US-75, eastbound Parallel Parkway over I-635, and 34th St. over I-635. The control decks that have been surveyed include K-99 over I-335, US-50 over BNSF RR, eastbound 103rd St. over US-69, southbound US-69 flyover to eastbound I-435, northbound Antioch over I-435, and westbound Parallel Parkway over I-635. Crack densities for the LC-HPC decks were found to be lower than those observed for the control decks. Additionally, crack surveys on US-59 for both the northbound and southbound lanes have been completed over I-35, the BNSF RR, and Sand Creek Rd.

73% 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.

73% 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 through 2012 are documented in:

Pendergrass, B. and Darwin, D., "Low-Cracking High-Performance Concrete (LC-HPC) Bridge Decks: Shrinkage-Reducing Admixtures, Internal Curing, and Cracking Performance," *SM Report* No. 107, University of Kansas Center for Research, Inc., Lawrence, Kansas, January 2014, 625 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 16 LC-HPC decks. Free shrinkage and durability of LC-HPC candidate mixtures are evaluated, with emphasis on internal curing and shrinkage reducing admixtures. A description of the construction and evaluation of LC-HPC and control bridge decks constructed in Kansas is presented in the report.

Crack survey data through 2011, 2012, and 2013 is presented in:

Bohaty, B., Riedel, E., and Darwin, D., "Crack Surveys of Low-Cracking High-Performance Concrete Bridge Decks in Kansas 2011-2013," *SL Report* 13-6, University of Kansas Center for Research, Inc., Lawrence, Kansas, December 2013, 153 pp.

Results acquired after completion of Pendergrass and Darwin (2014) and Bohaty et al. (2013) will be documented in subsequent reports

73% 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 or steel fibers will be tested. The influence of concrete temperature and slump on settlement cracking will be evaluated.

Freeze-thaw testing will begin on a series of mixtures containing varying dosages of Eclipse 4500 with and without pre-wetted LWA. Testing will also begin on a series of mixtures containing 10% volume replacement of total aggregate with pre-wetted LWA, with and without 30% and 3% weight replacement of cement with slag and silica fume respectively.

Mixtures containing SRA-XT, an SRA produced by Euclid Chemical, are also scheduled for testing.

Rheology tests will begin on mixtures containing Acti-Gel.

Testing to evaluate air-void properties of hardened concrete will begin. Mixtures to be evaluated include mixtures containing varying dosages of 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 dosages of Acti-Gel (0.05, 0.075, and 0.15% by weight of total dry material), with and without Type C fly ash (20 and 40% replacements by volume of cement), mixtures made with Tstrata, a pre-packaged material produced by Structural Technologies, mixtures containing different dosages of Eclipse 4500 with and without pre-wetted LWA, and mixtures containing different dosages of Conex.

Crack surveys will continue of the LC-HPC and control decks in Kansas.

The KU research team is also traveling to Virginia in July to perform crack surveys on nine bridge decks constructed over the past two years with either an SRA or pre-wetted lightweight aggregate. Travel funds are being supplied under a separate grant to the University of Kansas and will not be charged to this project, but the results will be applicable to the current study.

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 125, 155 and 165 microstrain less shrinkage after approximately 250 days of drying than a comparable control mixture without the SRA. After approximately 250 days of drying, mixtures containing 0.5% and 1% of the Sika SRA by weight of cement and a 10% volume replacement of total aggregate with pre-wetted lightweight aggregate have approximately 115 and 15 microstrain greater shrinkage after curing than a comparable mixture with 10% LWA but no SRA. The mixture with a 2% dosage of the Sika SRA and 10% LWA has approximately 35 microstrain less shrinkage after curing than the mixture with 10% LWA and no SRA after 250 days.

Mixtures with different dosages of Acti-Gel (0, 0.05, 0.075, and 0.15% by total dry weight of materials) and mixtures containing Acti-Gel with varying replacement levels of cement with fly ash (0, 20, and 40% by volume) are currently undergoing free shrinkage testing. After 200 days of drying, mixtures with additions of Acti-Gel of 0.05, 0.075, and 0.15% have average free shrinkage of 500, 610, and 625 microstrain, respectively.

Mixtures with different dosages of Eclipse 4500, the Euclid SRA (0.75%, 1.5%, 2.25% by weight of cement) have recently begun shrinkage tests. Test results are inconclusive at this time; however, the mixtures with higher dosages of SRA tend to have less total shrinkage.

Mixtures containing Euclid 1.5 in. steel crimped fibers with varying dosages have exhibited significantly less settlement cracking than control mixes without fibers. Mixtures containing Grace Strux 90-40 fibers have not been as consistent, and in some cases, cracks appear in line with the fibers.

Concrete mixtures with different dosages of Eclipse 4500 (0.75%, 1.5%, 2.25% by weight of cement) with and without 10% replacement of pre-wetted lightweight aggregate (LWA) by total volume of aggregate are currently undergoing scaling testing. Mixtures containing both SRA and LWA exhibited low mass loss up to date. Mixtures containing 1.5% and 2.25% of SRA without the addition of LWA exceeded the failure limit of 0.31 lb/ft² specified in the scaling test (BNQ NQ 2621-900) by the end of 56 freeze-thaw cycles. Comparative control mixtures with no LWA or SRA exhibited lower mass loss than both mixtures containing SRA only and mixtures containing both SRA and LWA. Mixtures containing higher dosage of SRA have higher mass loss. Concrete mixtures containing Conex are in the curing stages, and scaling results are not yet available.

Freeze-thaw testing has begun for mixtures containing Acti-Gel. The specimens have maintained at least 95% of their initial dynamic modulus through 160 cycles.

Circumstances affecting project or budget. (Please describe any challenges encountered or anticipated that affect 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.