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(189)*	**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 4 – December 31)

Project Title:
"***Enhancement of Welded Steel Bridge Girders Susceptible to Distortion-Induced Fatigue***"

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Lead Agency Project ID:	**Other Project ID (i.e., contract #):** **KAN00063732**	**Project Start Date:** 08/31/2008
Original Project End Date: **08/31/2011**	**Current Project End Date:** **08/31/2013**	**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 + additional new commitments	$812,060.61	68%

Quarterly Project Statistics:

Total Project Expenses This Quarter	Total Amount of Funds Expended This Quarter	Percentage of Work Completed This Quarter
$72,652.00	$72,652.00	8%

Project Description:

A large number of steel bridges within the national inventory are affected by distortion-induced fatigue cracks. Repairs for this type of failure can be very costly, both in terms of direct construction costs and indirect costs due to disruption of traffic. Furthermore, physical constraints inherent to connection repairs conducted in the field sometimes limit the type of technique that may be employed. The goal of the proposed research is to investigate the relative merit of novel repair techniques for distortion-induced fatigue cracks.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

Project Meetings

On July 7, 2011, the Kansas DOT (KDOT) coordinated a visit with Drs. Matamoros and Bennett to a bridge in Topeka, KS that had been repaired extensively for distortion-induced fatigue. This field visit served as an opportunity to obtain detailed specifics for current retrofits being applied on steel bridges for distortion-induced fatigue, and to observe distortion-induced fatigue crack locations and geometry in a large highway bridge structure.

Six representatives from the KDOT Bridge Design Office and Bridge Operations Office) met with the investigators at the University of Kansas (KU) on July 18, 2011 to observe the multiple test set-ups in the KU structures lab, receive a progress presentation, and provide feedback. Feedback from this meeting has informed finite element modeling and experimental efforts this quarter.

Weekly research meetings have continued to be held with all investigators attending regularly. The research meetings serve to define and assign tasks for TPF-5(189). The weekly meetings also serve to analyze new results and discuss recent findings. The weekly research meetings are in addition to nearly daily meetings with graduate students working on TPF-5(189) and laboratory technicians.

A date for the TPF-5(189) participant's meeting has been set for **Friday, March, 16, 2012.** Funds are budgeted in the project to support travel costs (airfare and one night hotel stay) for one representative from each participating state DOT. The meeting will be held in Lawrence, KS, at the University of Kansas so that laboratory tests may be viewed. More details on the participant's meeting will be forthcoming. The intent of this notification is to inform state DOT representatives of the meeting date well in advance.

Contract Status

The contract for TPF-5(189) has been extended to August 31, 2013. To-date, Kansas, Tennessee, Illinois, New York, Pennsylvania, and Louisiana have each committed to contributing additional funds through the project extension. The KU Transportation Research Institute (KU TRI) will provide a 50% match to these contributions. As described in the June 21, 2011 letter sent to participating State DOTs and in the June 30, 2011 progress report, the request for one additional $35K commitment was made: to close the original funding shortfall, to fund student personnel while testing is completed, and to allow for an expansion in project scope.

Technical Updates

1. 30 ft. Three-Girder Specimens

The 30-ft bridge was made composite with the concrete deck slabs this quarter (Figs. 1 and 2). This was accomplished by bolting through the deck into the top flanges of each of the steel girders, and then surrounding the tightened bolts with grout to ensure transfer of horizontal shear forces between the deck and girders. Grouting the bolts proved to be a time-consuming process, as the voided area at each bolt location required "damming" before the grout could be poured. Once a reliable technique was developed for achieving this, the process accelerated significantly. This task was a good example of a procedure that can be expected to take significantly less time in future test set-ups, as the procedure was developed and refined in the first test set-up.

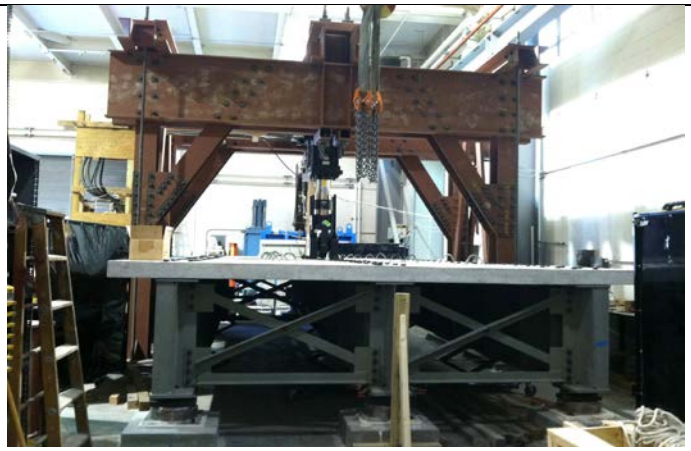

Fig. 1 View of three-girder test set-up with composite concrete deck

Fig. 2 A325 bolts connecting the deck to the girder top flanges to develop composite action

Also completed this quarter: Cabling is being run from individual gages to the National Instruments Data Acquisition (DA) system, and a VI routine is being programmed in LabVIEW for strain data collection. The instrumentation within the test set-up is being calibrated.

2. 9 ft. Girder Specimens

Two 9 ft. girder specimens have been tested, and a third test is in-progress (Specimen 3). Fatigue cracking has initiated at the stiffener-to-web weld and at the flange-to-web weld in Specimen 3. Cracks will be allowed to grow until the horizontal flange-to-web weld crack is approximately 1.0 in. long before the angle retrofit (described in the June 30 2011 progress report) is applied. The purpose of testing Specimen 3 is to capture crack behavior after the angle retrofit is applied when starting with a small crack, as opposed to the 8 in. long crack studied in Specimen 2. A suite of finite element models have been created and studied to aid in assessing the effect of crack length on the angle retrofit's effectiveness. Additionally, new retrofit techniques are being explored using the finite element models developed.

A second test frame has been erected to expedite testing of the 9 ft. test specimens (Fig. 3). The column on the new test frame has been post-tensioned (Fig. 4), and the test floor tie-down system is currently being post-tensioned. The addition of the second test set-up for the 9 ft. girders will greatly accelerate testing, which is beneficial in informing the retrofits to be applied in the 30 ft. test set-up. An additional investment in accelerating the test schedule was made through purchase of a new servo valve for the actuator to be installed in the second test frame. The new servo valve will allow for testing at frequencies at or above 2 Hz in both frames, which will result in a more efficient test schedule.

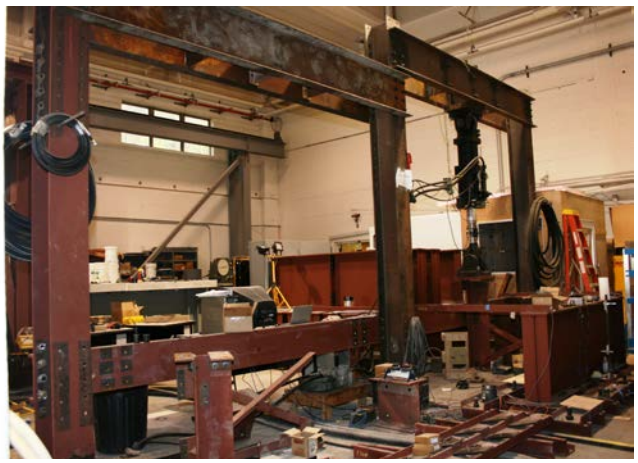

Fig. 3 View of the two 9-ft test specimen set-ups

Fig. 4 Post-tensioning the column for the second 9-ft. test set-up

A series of finite element models have been created to examine the contribution of bending stresses on the expected crack propagation path. Since the flange representing the top flange is rigidly fixed to the laboratory strong floor in the 9 ft. test set-up, longitudinal bending stresses do not develop in the 9 ft. test girders. Bending stresses will clearly be present in the 30 ft. test setup, but this series of models is intended to help clarify to what extent longitudinal bending stresses contribute to the formation of a "horseshoe" shaped distortion-induced fatigue crack, as opposed to a vertical crack running along the weld between the connection stiffener and web. These findings will help to guide development of further retrofit techniques.

3. Component Level Testing

3.1. *PICK-Tool Development and Testing Program*

Research on the PICK tool this reporting quarter has focused on identifying requirements for scaling the tool up to treat larger diameter holes and thicker plate. Strain response of the tool is being measured at ultrasonic frequencies to capture the current force input into treated specimens. Power requirements needed to treat a larger volume of steel at the crack-stop hole are being determined.

Three additional specimens have been sent to a metallurgical testing company in St. Louis, MO for microscopic examination and hardness testing to examine relative properties between PICK-treated, pressure-only treated, and non-treated specimens.

3.2. *CFRP-Treated Specimens*

Additional sheet-type tensile fatigue specimens have been ordered from a local fabricator shop. These new specimens are thicker than the specimens in the current test program (1/2" and 3/8" compared to 1/8" and 1/4") so that tests can be performed on steel with thicknesses closer to that of typical girder webs. CFRP overlays are continuing to be manufactured in-house so that testing can begin as soon as specimens are received.

Anticipated work next quarter:

- Fatigue testing the first 30 ft. bridge test set-up.
- Fatigue testing Specimen 3 in the 9 ft. girder test set-up.
- Completion of the test frame and installation of the actuator for the second 9 ft. girder test set-up.
- Fatigue testing of Specimen 4 in the second 9 ft. girder test set-up.
- Recommendations for scaling up the PICK tool will continue to be developed, and should be completed.
- Fatigue testing of CFRP-treated tensile specimens will occur for 1/2" and 3/8" steel thicknesses

Significant Results:

The angle retrofit described in the June 30, 2011 report performed excellently under fatigue testing. This retrofit technique has a great deal of promise for practical field application, as it avoids complications that arise with connecting to a top flange. Modifications to this retrofit are being studied analytically to provide further benefit to the horizontal weld between the flange and web, and will be applied on subsequent laboratory test specimens.

A list of in-print publications produced by the project team in direct relation to TPF-5(189) is presented here, for the reader interested in further analysis of results to-date.

Alemdar, F., Matamoros, A., Bennett, C., Barrett-Gonzalez, R., and Rolfe, S. (2011). "Use of CFRP Overlays to Strengthen Welded Connections under Fatigue Loading," Accepted for publication in the *Journal of Bridge Engineering*, ASCE.

Alemdar, F., Matamoros, A., Bennett, C., Barrett-Gonzalez, R., and Rolfe, S. (2011). "Improved Method for Bonding CFRP Overlays to Steel for Fatigue Repair," Proceedings of the ASCE/SEI Structures Congress, Las Vegas, NV, April 14-16, 2011.

Hartman, A., Hassel, H., Adams, C., Bennett, C., Matamoros, A., and Rolfe, S. "Effects of lateral bracing placement and skew on distortion-induced fatigue in steel bridges," *Transportation Research Record: The Journal of the Transportation Research Board,* No. 2200, 62-68.

Crain, J., Simmons, G., Bennett, C., Barrett-Gonzalez, R., Matamoros, A., and Rolfe, S. (2010). "Development of a technique to improve fatigue lives of crack-stop holes in steel bridges," *Transportation Research Record: The*

Journal of the Transportation Research Board, No. 2200, 69-77.
Hassel, H., Hartman, A., Bennett, C., Matamoros, A., and Rolfe, S. "Distortion-induced fatigue in steel bridges: causes, parameters, and fixes," Proceedings of the ASCE/SEI Structures Congress, Orlando, FL, May 12-15, 2010.
Alemdar, F., Kaan., B., Bennett, C., Matamoros, A., Barrett-Gonzalez, R., and Rolfe, S. "Parameters Affecting Behavior of CFRP Overlay Elements as Retrofit Measures for Fatigue Vulnerable Steel Bridge Girders," Proceedings of the Fatigue and Fracture in the Infrastructure Conference, Philadelphia, PA, July 26-29, 2009.
Kaan, B., Barrett, R., Bennett, C., Matamoros, A., and Rolfe, S. "Fatigue enhancement of welded coverplates using carbon-fiber composites," Proceedings of the ASCE / SEI Structures Congress, Vancouver, BC, April 24-26, 2008.

Circumstance affecting project or budget. (Please describe any challenges encountered or anticipated that might 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).