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) XQuarter 2 (April 1 – June 30) ☐Quarter 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 (contract modification currently being completed)**	**Number of Extensions:** **First extension requested.**

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
$892,496.00 + new commitments	$783,376.00	60%

Quarterly Project Statistics:

Total Project Expenses This Quarter	Total Amount of Funds Expended This Quarter	Percentage of Work Completed This Quarter
$136,022.00	$136,022.00	15%

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.):

1. 30 ft. Three-Girder Specimens

The first steel test set-up is complete, and is shown in Figs. 1 and 2. Calibrated load cells were leveled on top of the concrete support blocks. The first outside girder and interior girder were spliced on the ground and then lifted on cribbing to complete the bottom flange splice. Once an individual girder was placed on cribbing, rollers were placed beneath the ends of the girder to maneuver it into the appropriate placement on the load cell. The first exterior girder and interior girder were lifted into place and attached through cross-frames before the second exterior girder was constructed. Once the final girder was lifted into place and firmly attached to adjacent girders, strain gaging began. Currently 26 bondable strain gages are in place to monitor critical areas within the test section of the bridge (Fig. 3). In addition to these gages, bending within each girder will be monitored through reusable Bridge Diagnostics Incorporated (BDI) strain transducers.

Fig 1. View of three-girder test set-up

Fig 2. Alternate view of three-girder test set-up and end cross-frame

Fig 3. View of web gap region in test section with applied strain gage

When placing gages in the critical web gaps of the test section, two different critical hot spots needed to be instrumented: regions surrounding the connection stiffener weld and flange-web weld. Since crack patterns noted in the 9 ft. specimen test set-up has correlated well with maximum principle stresses determined through FEM, maximum principal stresses were used when determining gage locations in the 30 ft. girder set-up. Because critical detail locations contain high stresses with significant gradients, it was important to establish a location of slightly lower stresses and smaller gradients. Therefore, gages were placed in the locations shown in Fig. 4.

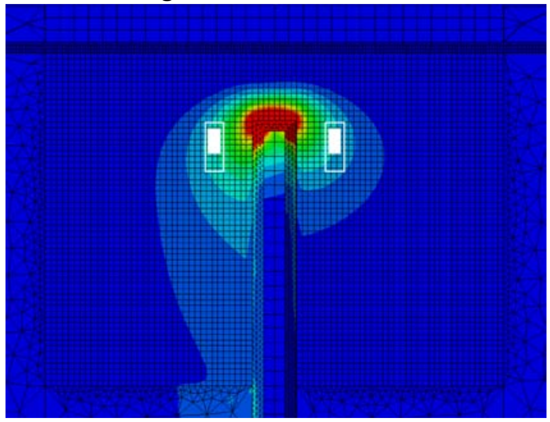

Fig 4. Strain gage locations as determined by FEA of the 30 ft. bridge girder specimens

2. 9 ft. Girder Specimens

As discussed in the Dec. 30, 2010 and March 31, 2011 progress reports, the Kansas Department of Transportation (KDOT) is supporting two projects that directly complement work being performed inTPF5-(189), and progress on work done is included here as it is closely related to TPF5-(189). The projects are entitled "*Extending Useable Lives of Steel Bridges by Halting Distortion-Induced Fatigue Crack Propagation Using Fully-Tightened Bolts and Plate Washers"* and "*Repairing Existing Fatigue Cracks in Steel Bridges Using CFRP Materials*". Additionally, work on these projects is reported herein as it is proposed that <u>additional</u> 9 ft girder work be performed as part of an expanded scope of TPF-5(189) (see letter attached at the end of this progress report). Significant progress was made this quarter on these "sister" projects, that directly relates to and informs work on TPF-5(189).

Two retrofits were applied to Specimen 2 this quarter: (1) crack-stop holes and (2) bolted steel angles, connecting the connection stiffener and girder web. The test procedure for Specimen 2 was conducted as follows. First, Specimen 2 was allowed to develop cracking under cyclic loads (load range of 4.5 kips, corresponding to an approximate stress range of 28.5 ksi in the web gap, as determined by strain gages). Cracking developed rapidly in the bottom web gap, circled in Fig. 5. *(The reader should be aware that in this test set-up, the web gaps are referenced herein according to the orientation of the test girder; in other words, "bottom web gap" in this report refers to the web gap in the bottom of the 9 ft test girder, which is representative of a top web gap in a bridge system.)*

Fig 5. View of 9-ft girder test set-up; bottom web gap (representative of real top web gap) is circled.

Two distinct crack patterns formed in the bottom web gap: a horizontal crack between the bottom flange and the web, and one running vertically along the welds connecting the connection stiffener to the girder web. These cracks were allowed to propagate until they reached lengths of 8 in. and 5 in., respectively. At this point, the bottom web gap was repaired with a double-angle retrofit. The double-angle retrofit designed consisted of two L6x6x3/4, each with one leg bolted to the connection stiffener and one leg bolted to the girder web in the bottom web gap region. Since the girder being studied is representative of an exterior girder, a stiff steel plate with dimensions PL 18"x18"x3/4" was bolted on the fascia side of the girder web to aid in load transfer. If this had been an interior girder, double angles could have also been applied on the opposite side of the web. Details of the completed angle retrofit are shown in Figs. 6, 7, and 8.

Fig 6. View of angle retrofit in bottom web gap; connection is made between the web and connection stiffener

Fig 7. Alternate view of angle retrofit in bottom web gap; connection is made between the web and connection stiffener

Fig 8. Fascia view of angle retrofit in bottom web gap; steel back plate is applied on fascia side of girder to aid in load transfer around the web gap region.

The girder was cycled with the bottom web gap retrofit for an additional 1.2 million cycles, which was considered run-out at the stress range being utilized. During this time, the top web gap developed a 2.5" crack while it was cycling in an unreinforced condition. Therefore, the top web gap was retrofitted with an identical double-angle repair as had been used in the bottom web gap (Figs. 9 and 10). The specimen was then subjected to another 1.2 million cycles, during which the bottom web gap cracks experienced no growth and the top web gap crack grew approximately 1 in. Reasons for crack growth in the top web gap are currently being investigated.

Fig 9. Fascia view of girder after angle retrofit has been applied in both the top and bottom web gaps.

Fig 10. Interior view of girder after angle retrofit has been applied to both the top and bottom web gap

Results from detailed, 3D finite element analyses corroborated the experimental results. The base finite element model has been described in previous progress reports, and a cross-section view of the FEM is shown here in Fig. 11. The model was further refined to reflect the crack geometries seen in the physical test, using ABAQUS Extended Finite Element Modeling (XFEM) capabilities. A view of the model in the bottom web gap region both before and after the retrofit is applied can be seen in Figs. 12 and 13. It is clear that the hot spot stresses have been drastically reduced in the web gap region after the retrofit was introduced. Similar behavior was predicted by the FEA for the top web gap region, as shown in Figs. 14 and 15. The retrofit has been removed from the model views in Figs. 13 and 15 so that stresses in the girder are apparent.

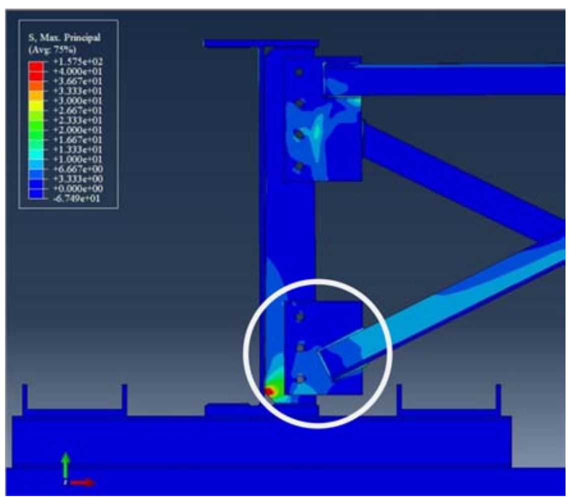

Fig 11. Cross-section view of FEM shown; bottom web gap is shown (representative of "real" top web gap)

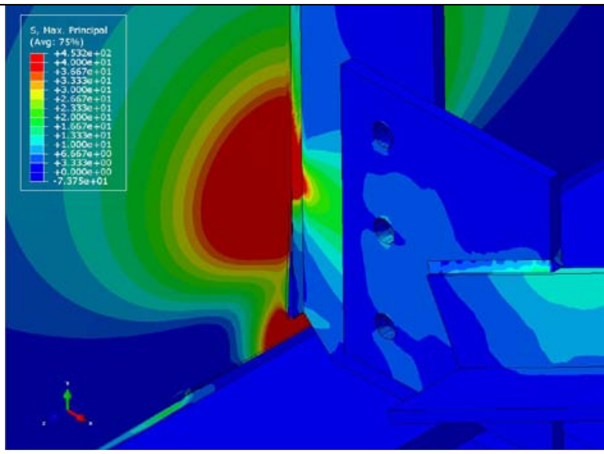

Fig 12. FEA results (with cracks modeled) before any applied retrofits

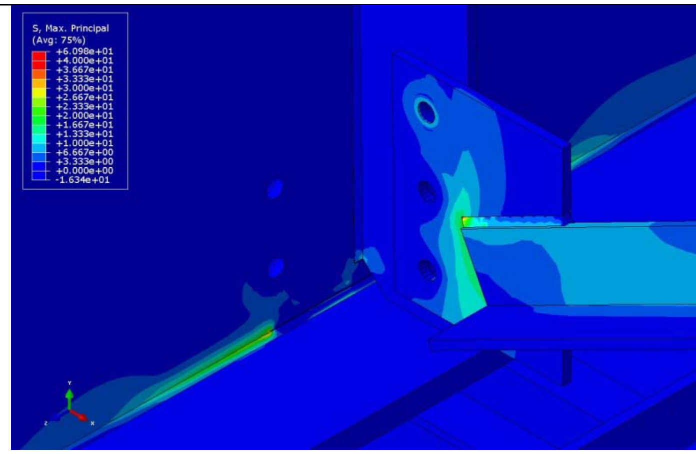

Fig 13. FEA results after steel angles (connecting connection stiffener and web) are included

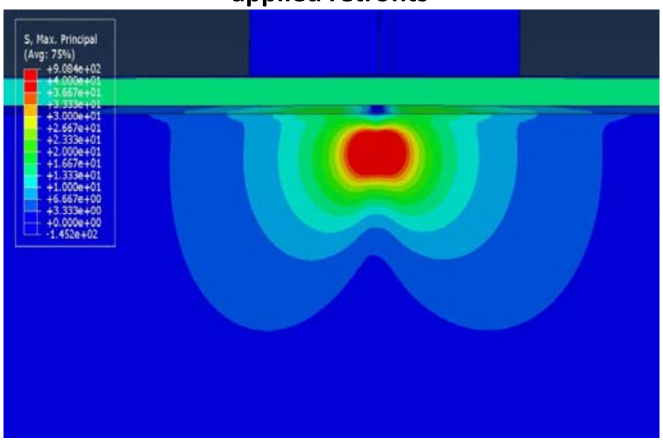

Fig 14. FEA results in top web gap (representative of real bottom web gap) before retrofit

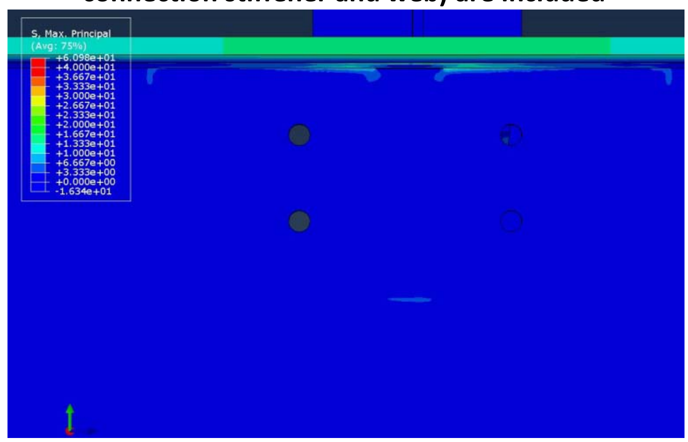

Fig 15. FEA results in top web gap (representative of real bottom web gap) after angle retrofit was installed

The potential benefits of using this novel angle retrofit are clear. Angle retrofits are commonly used to mitigate distortion-induced fatigue cracking in web gaps, however, they are generally oriented such that the legs connect the top flange to the connection stiffener. This latter orientation has proven to be effective in the field, however, making the connection to the top flange often proves to be difficult and expensive. Often it is required to remove portions of the concrete deck to make this repair, which is expensive and results in partial or full closure of the bridge. Orientation of the angles as shown in Figs. 6, 7, 8, 9, and 10 does not require any connection to the flange, therefore, installation of this retrofit can be performed from beneath the bridge structure with no interference to the concrete deck. Additional benefits to this retrofit technique are that: (1) it is performed with commonly-available materials and (2) does not require any specialized skill to make the installation. Therefore, based on the experimental performance and finite element results that will be discussed further, the authors believe this retrofit to hold significant promise for bridge field applications.

It should be noted that after the retrofitted specimen was subjected to a total of 2.4 million cycles in the reinforced configurations, the retrofits were removed and ¾" diameter crack stop holes were drilled at the tips of the various cracks in the top and bottom web gaps. This can be seen in Figs. 16 and 17. This diameter of crack-stop hole was chosen because of the tight geometry in this region, which would not accommodate significantly larger crack-stop holes. This is often a realistic field consideration when drilling crack stop holes in bridge web gaps, and often the holes cannot be drilled to proper diameter. Specimen 2 was then subjected to additional cycles to evaluate the effectiveness of undersized crack-stop holes. Within an additional 40,000 fatigue cycles at the same stress range as used throughout the testing, the bottom horizontal crack had "jumped" the crack-stop holes and grown an additional 0.5 in. on one side of the crack. Additionally, the vertical cracks in the bottom web gap also "jumped" the crack stop holes and grew an additional 2.5 in. A comparison in performance between the angle-retrofitted case and the crack-stop hole case shows the ineffectiveness of the crack-stop holes in this particular test, and the high degree of effectiveness of the angle retrofit.

Fig 16. Specimen 2 with drilled crack-stop holes (four) in top web gap region

Fig 17. Specimen 2 with drilled crack-stop holes (six) in bottom web gap region

3. Component Level Testing

3.1. *PICK-Tool Development and Testing Program*

An unstressed steel sample was sent to Oak Ridge National Laboratory (ORNL) and it was determined that the diffraction characteristics of the steel would provide excellent results when bombarded with neutrons. Once this was determined, a PhD candidate travelled to ORNL with two PICK-treated steel samples to work under the direction of ORNL personnel to determine the effectiveness of the PICK tool in introducing compressive residual tangential stress around the circumference of the hole.

3.1.1. *Neutron Diffraction:*

Neutron diffraction is a 3-D process capable of measuring elastic strain at various depths in the plate. The volume of the sample for measuring strain varied from 0.5 x 0.5 x 1.0 mm to 0.5 x 1.0x 1.0 mm; the strain was averaged over these volumes. The sample volumes were configured such that the minimum dimensions were in the direction of the component of strain being measured. For example, when measuring the radial strain, the 0.5 mm dimension was oriented along the radial direction.

Fig. 18 shows an ORNL technician arranging the specimen in preparation for residual strain measurement. The neutron beam exits the incident beam guide and the diffracted beam guide collects and guides the diffracted neutron beam onto sensors that register their number and intensity. By comparing with an unstressed reference sample, the existing strain can be determined.

There was some obvious error in the measured strain when the sample volume was partially in the hole and partially in the plate. The error was obvious when the sample volume was totally in the hole and when it was totally in the plate; in between, however, it is a matter of judgment as to whether the residual strain measurements were valid. Below are the results of the residual stress measurement plotted as measured strain versus the distance from the center of the hole. The plot shows residual tangential, radial, and through-thickness normal strain as a result of treatment by the PICK tool. The shape of the lines near hole may be the result of the sample volume being partially in the hole and partially in the steel. The results agree with those published from cold-worked holes in aluminum.

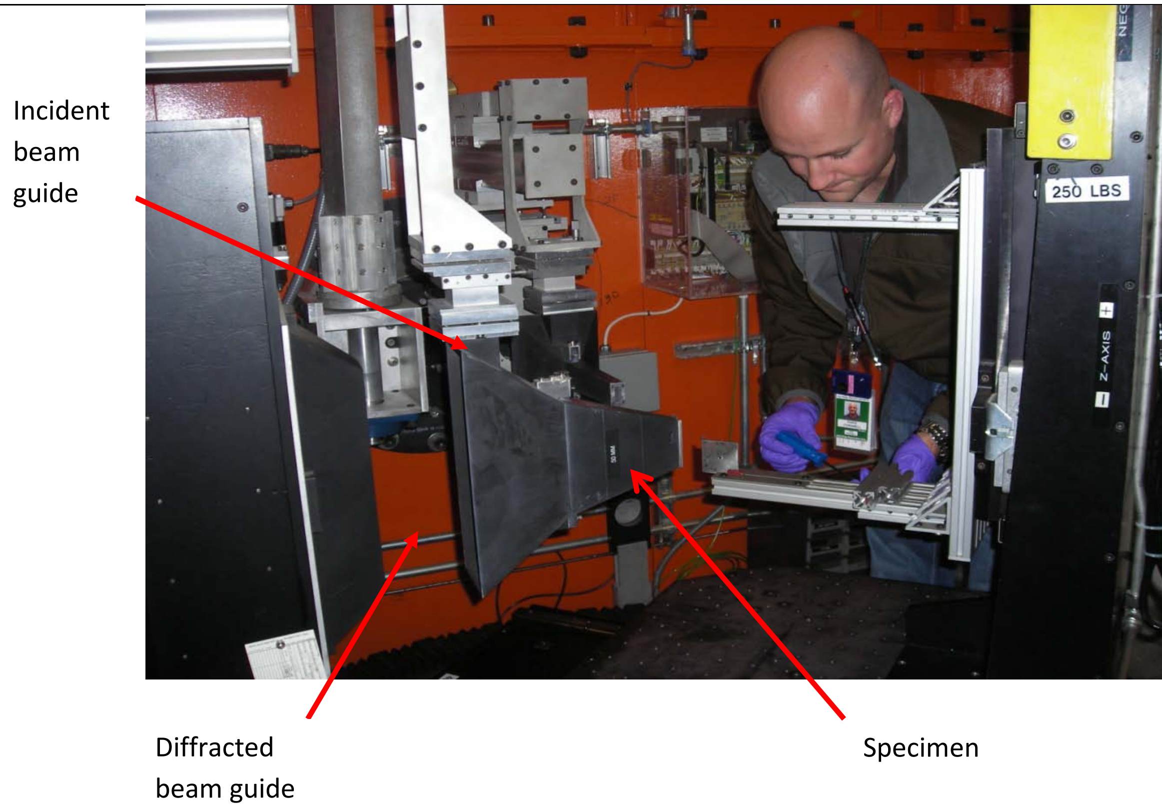

Fig 18. Residual strain measurement using Neutron Diffraction at Oakridge National Laboratories (ORNL)

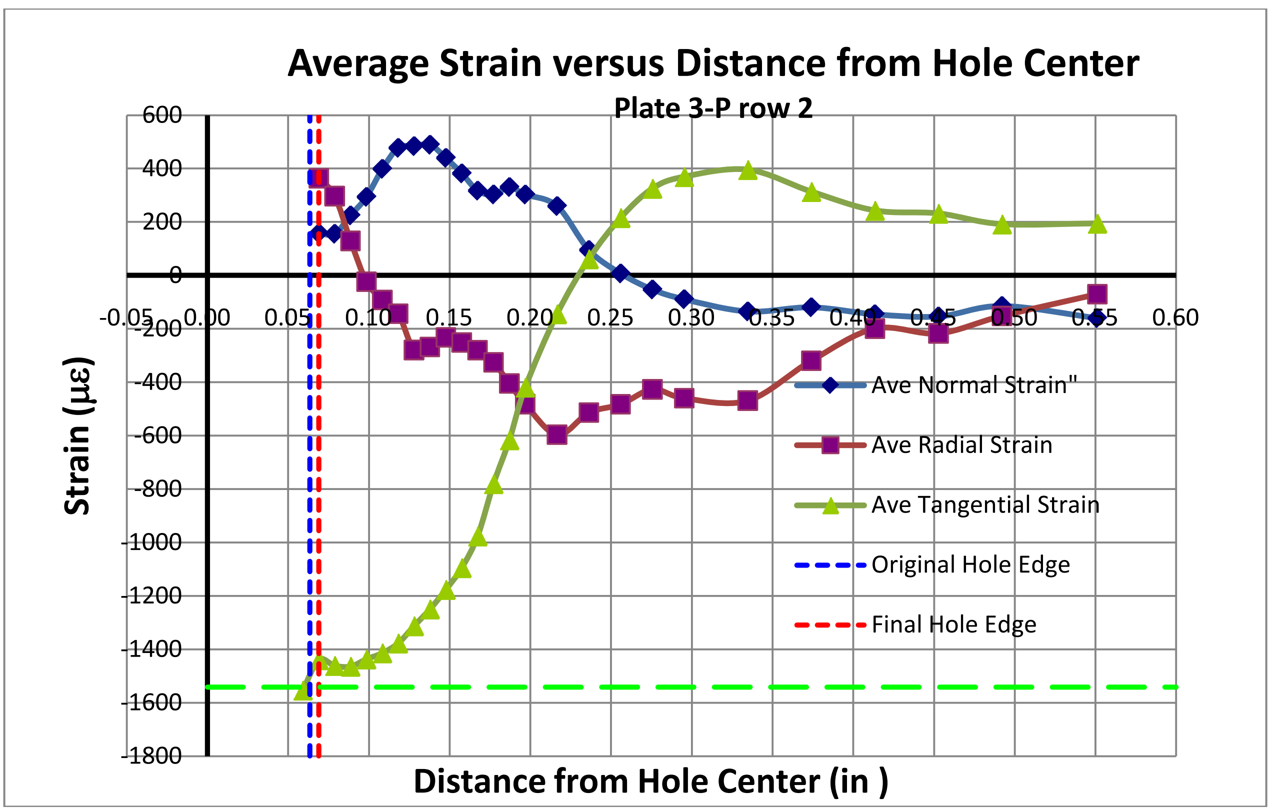

Fig 19. Residual strain measurements in PICK-treated specimen, obtained used neutron diffraction technique

3.1.2. X-ray diffraction:

The second sample brought to ORNL was used for residual strain measurement by X-ray diffraction. X-ray diffraction is a surface technique that measures strain in the crystal lattice in two orthogonal directions within a few microns of the plate surface. To use X-ray diffraction, the surface must been clean and free of residual stresses from rolling, heat treatment, or any other cause. The surface of the specimen was covered with mill scale that had to be removed. To remove the mill scale and the surface residual stress from rolling, the surface was polished with successively finer grit sandpaper and with a final polish with an electrolytical polisher. The electrolytical polisher used a supersaturated salt – water solution to conduct an electric current to the surface and the combination produces a polished surface without any induced strain from the polishing process (Fig. 20). Once this was done, a series of residual stress measurement were taken and the electro-polish and measurement procedure repeated until successive residual stress measurements were consistent with each other.

Once polishing was complete, the X-ray diffraction device was calibrated and residual stress measured in the tangential and radial directions. The X-ray diffraction device was much smaller and more user-friendly than the neutron diffraction equipment; it does not require a nuclear reactor to provide x-rays. See picture below showing an ORNL scientist and their new X-Ray Diffraction equipment (Fig. 21). The residual strain results from the X-ray diffraction qualitatively matched those from the neutron diffraction but seem to be somewhat smaller in value. These are still being studied to determine the cause of the differences.

Fig 20. Electropolishing set-up; specimen preparation for X-ray diffraction

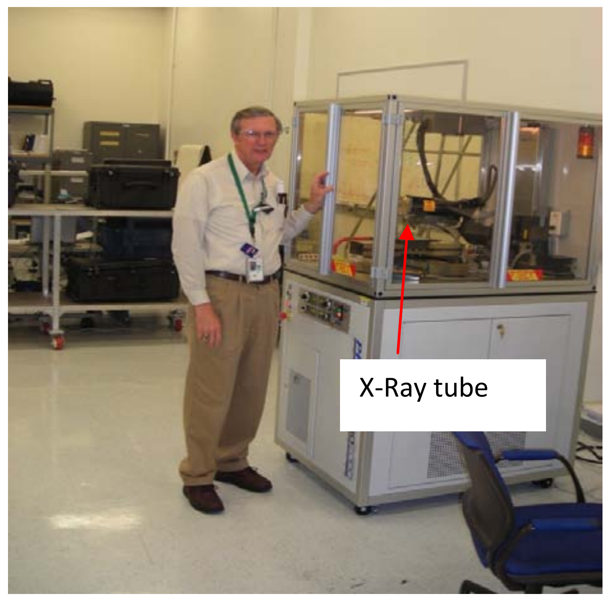

Fig 21. X-ray diffraction set-up at Oakridge National Laboratories (ORNL)

3.2. *CFRP-Treated Specimens*

Over the past three months, component testing of tensile fatigue specimens treated with CFRP overlays has continued and is nearly complete.

In total, 10 component tests have been performed using 1/8 in. thick steel specimens, and four tests were performed using 1/4 in. thick steel specimens. The tests were performed with varying thicknesses of CFRP overlays and at various stress ranges. A test matrix for component testing is shown in Table 1.

Table 1: Test matrix for tensile fatigue specimens treated with CFRP

Specimen Designation	Specimen Thickness mm (in)	CFRP Overlay Thickness mm (in)	Stress Range MPa (ksi)	Number of cycles
F15	3.2 (0.125)	1.6 (0.063)	263 (38.0)	18,900
F3	3.2 (0.125)	1.6 (0.063)	221 (32.0)	60,000
F6	3.2 (0.125)	1.6 (0.063)	166 (24.0)	340,700
Pick 12	3.2 (0.125)	2.4 (.094)	221 (32.0)	271,100
Pick 11	3.2 (0.125)	3.2 (0.125)	263 (38.0)	95,100
F14	3.2 (0.125)	3.2 (0.125)	221 (32.0)	313,050
F2	3.2 (0.125)	3.2 (0.125)	166 (24.0)	1,450,095
Pick 10	3.2 (0.125)	6.4 (0.25)	263 (38.0)	1,450,095
Pick 13	3.2 (0.125)	6.4 (0.25)	221 (32.0)	Run-out
Pick 7	3.2 (0.125)	6.4 (0.25)	166 (24.0)	Run-out
F4-25	6.4 (0.25)	1.6 (0.063)	221 (32.0)	15,600
F4-21	6.4 (0.25)	3.2 (0.125)	221 (32.0)	160,150
F4-23	6.4 (0.25)	6.4 (0.250)	221 (32.0)	571,650
F4-20	6.4 (0.25)	12.8 (0.500)	221 (32.0)	Run-out

The data shows that the number of cycles until the specimen fails (fatigue crack propagates the entire width of the specimen) increases as the thickness of the CFRP overlay increases and as the stress range decreases.

Also of note is that bond failure has been engineered such that it did not control failure in any of the tests. This is a significant advance in this area, as much of the literature on this topic has struggled with maintaining adequate bond between CFRP overlays and steel substrate. Instead, all failures were either run-out or represent the number of cycles to complete propagation failure of the steel substrate. The length of fatigue life was found to be directly correlated to the stiffness ratio of the composite overlay to the steel section.

Anticipated work next quarter:

Work expected to occur over the next quarter includes:

- Fatigue testing of the 30 ft. bridge system,
- Fatigue testing of Specimen 3 in the 9 ft. specimen test suite,
- Additional finite element modeling of retrofits in both the 30 ft. and 9 ft. test setups,
- Additional component-level tests performed on PICK-treated fatigue specimens, and
- Additional component-level tests performed on CFRP-treated tensile fatigue specimens.

Significant Results:

1. An angle retrofit connecting the connection stiffener and the web performed excellently under fatigue testing when applied on the 9 ft. specimens. Finite element analyses corroborated the experimental results, by showing a drastic reduction in stress within the web gap region after the retrofit was applied. 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 (i.e., removal of the concrete deck to accommodate bolting, or welding to the top flange), utilizes inexpensive, common materials, and requires no special skill to implement. Because of the excellent results in the 9 ft. test set-up, this will likely be the first retrofit scheme tested in the 30 ft. bridge system.

2. Neutron diffraction of a PICK-treated tensile fatigue specimen, performed at Oakridge National Laboratories in Oakridge, TN, showed the level of residual strain locked-in the treated steel specimens was comparable to that

achieved in aluminum within the aerospace industry, and are considered to be significant enough to aid in retarding fatigue crack initiation. These results support the PICK fatigue test results, which have been reported in past progress reports.

3. Tensile fatigue testing of steel specimens treated with CFRP overlays has shown that fatigue life of the steel is directly correlated with the stiffness ratio of the composite overlay with respect to the underlying steel. Also worthy of note is that in all 14 tests performed to-date, no failures have occurred within the bond layer – all failures have occurred in the steel specimens. This is a significant achievement in the field of composites applied to steel substrates and loaded in fatigue.

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).

A letter was sent to representatives of all participating DOTs and FHWA on June 21, 2011. The letter describes the need for a 24-month time extension, which is supported by the lead state for TPF-5(189), Kansas DOT. Additionally, a request is made for one additional $35,000 commitment from each state, to help close the original funding shortfall, to fund student personnel while testing is completed, and to allow for an expansion in project scope. The body of the letter is replicated at the end of this progress report.

In addition to information presented in the attached letter, since mailing, **The University of Kansas Transportation Research Institute (KU TRI) has agreed to match new State contributions to TPF-5(189) on a 50% basis. This will leverage State contributions significantly.**

THE UNIVERSITY OF KANSAS
School of Engineering

Civil, Environmental & Architectural Engineering

Caroline R. Bennett, Ph.D.
Assistant Professor

June 21, 2011

Dear ,

The purpose of this letter is two-fold. First, to ensure that you are updated with the technical progress consistently being made with Transportation Pooled Fund study TPF-5(189), *"Enhancement of Welded Steel Bridge Girders Susceptible to Distortion-Induced Fatigue,"* please find enclosed a copy of the most recent progress report, dated March 31, 2011. The second purpose of this letter is to communicate the overall status and vision for TFP-5(189).

The close of the budgeted three-year term for TPF-5(189) is August 31, 2011. To be able to complete the project as currently envisioned with the rigor and diligence exercised throughout to date, we are requesting additional funding and a 24 month extension to TPF-5(189). This decision is fully-supported by the lead state on the project, Kansas DOT. Extension of TPF-5(189) is being requested for two reasons.

1) The project has experienced a number of delays outside of control of the researchers, and
2) Support is requested for a proposed expansion of the scope of work.

TPF-5(189) has experienced a series of obstacles that have resulted in delays to the original project schedule. These have included: failure of a hydraulic pump used to run testing equipment and subsequent replacement; problems with the cooling water system needed for the hydraulic pumps to operate correctly; delays to test frame construction and 330-kip actuator delivery; and fabrication delays with the 30 ft. girder specimens. These obstacles have been since overcome. The cumulative effect of these unforeseen experimental research hurdles have unfortunately slowed the pace of progress, however, we cannot stress enough that progress on repairing distortion-induced fatigue damage has been consistently made throughout this project. Specifically, the retrofits to be implemented have been verified experimentally through component-level laboratory testing and analytically in numerous FEA. Progress may also be evidenced in part by the list of seven publications provided at the end of the March, 2011 progress report, all directly stemming from research performed under TPF-5(189). These are in addition to the periodic Progress Reports that you receive. The primary deliverable of this project will hinge on successful testing of the 30 ft. bridge system in distortion-induced fatigue. The test set-up is complete, and the girders have been received at the KU Structures Lab. Physical testing commences this reporting quarter.

With the need to extend the project's time frame also comes a need to staff the project for additional time. A portion ($107,496) of these funds are also needed close the shortfall in commitments received to date and the original budget. We are requesting one additional $35,000 commitment during FFY 2011 or 2012 from each of our 12 state partners and the FHWA to fund the project through the extended 24 mo. project duration. Additional partners are also being solicited. If new partners join the project and all current partners participate, the above amount will be adjusted accordingly.

The large majority of the funds will be for student support and tuition while fatigue testing is completed. Additionally, the project has created an enormous (and growing) amount of valuable data, and students are needed to analyze the data produced. It should be noted that the Kansas DOT has already committed to supporting the project extension with an additional $25,000 commitment.

Learned Hall | 1530 West 15th Street | Lawrence, KS 66045-7609 | (785) 864-3766 | Fax (785) 864-5631

As described in the past few progress reports, we have also been performing tests and repairs on 9' long girders loaded in distortion-induced fatigue. Fourteen such tests are being supported by the Kansas DOT, but as the studies are so closely aligned with work being done under TPF-5(189), progress has been reported regularly with that of the pooled-fund study. We have the capability, materials, and momentum to obtain an additional 14 tests from the existing 9' girder specimens, however, support is necessary to fund personnel to perform these 14 tests. These additional 14 tests would be outside the scope of the KDOT projects, and would be included in the cost extension to TPF-5(189). Additionally, we are proposing to perform advanced FE modeling to correlate results of the 9' specimens to results from the 30' girders. In the case that partial commitments are received from supporting States, the proposed expansion of scope will be revised.

The investment that you have made in TPF-5(189) is now paying off. Practical, innovative, implementable repairs are being developed for distortion-induced fatigue through a rigorous research program. We ask that you further support the project with a $35,000 commitment, to extend the project time frame, allow for additional data analysis, and expand the project scope.

Sincerely,

Caroline R. Bennett

Caroline R. Bennett, Ph.D.,
Stan Rolfe, PE, PhD,
Adolfo Matamoros, PhD
Ron Barrett-Gonzalez

cc: Loren Risch, KDOT
John Jones, KDOT
Susan Barker, KDOT
Dick McReynolds, McReynolds Research, LLC
Cathy Johnson, KU TRI
Bob Honea, KU TRI
Marcella Bentley-Salmon, KUCR