TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): Oregon Department of Transportation

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 #	**Transportation Pooled Fund Program - Report Period:**
TPF 5(259)	☐Quarter 1 (January 1 – March 31) XQuarter 2 (April 1 – June 30) ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 1 – December 31)

Project Title:
Imaging Tools for Evaluation of Gusset Plate Connections in Steel Truss Bridges

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Lead Agency Project ID: **TPF5259**	**Other Project ID (i.e., contract #):** **Agreement 17384** **Work Order 12-05**	**Project Start Date:** April 2012
Original Project End Date: **9/30/2014**	**Current Project End Date:** **9/30/2014**	**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**	**Percentage of Work Completed to Date**
$440,000	$87,577.47	30%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	$4,213.19	50%

Project Description:

The collapse of the I-35W Bridge in Minnesota has resulted in considerable interest in steel truss and gusset plate connection performance. The load paths in many truss bridges are non-redundant and thus failure of a truss member or connection may cause collapse of the structure. Periodic inspections and structural evaluations are crucial for these types of bridges.

The most common method of evaluation that has been used to assess the safety of highway bridges is load rating, an approach used to estimate the available strength and allowable load on a bridge. Although sophisticated bridge load rating computer programs are available, these programs do not explicitly consider the gusset plates connecting the truss members. Hence, after the initial design calculations are completed and checked, it is unlikely that recalculations for load rating purposes have been made for gusset plates. As an outcome of the investigation into the collapse of the I-35W Bridge, steel truss bridge connections are required to undergo review. This additional scrutiny requires development of new tools to efficiently and effectively evaluate the large numbers of steel truss bridge connections in the inventory.

Digital imaging techniques have been developed to enable rapid collection of field geometric data from in-service gusset plates. These tools are implemented in software that allows extraction of gusset plate dimensional information to facilitate ratings. The present tools provide a basic set of functionality such as image rectification and scaling and allow geometric data extraction such as length, perimeter, and angles. However, these basic functions need enhancement to take full advantage of the advancements available to bridge inspection and management with digital imaging. Enhancements such as automation of rectification tasks and identification of features within the images are proposed that will enable transportation agencies to efficiently and effectively collect geometric and condition data and use this data to evaluate and rate gusset plate connections.

There are four main objectives of this research:

1. Develop methods to collect dimensional gusset plate connection information including surface geometry and out-of-plane deformations on in-service gusset plates. The information to be collected includes the geometry of the connectors, members, and overall plate dimensions. It also includes out-of-plane distortions of the gusset plate.
2. Develop methods to automate identification and optimization of reference target points, and to automate identification and extraction of the gusset plate edges, fastener locations and their corresponding member affiliations, as well as member orientations. These dimensional data feed directly into the connection rating tasks.
3. Develop finite element modeling and analysis techniques to directly rate gusset plates using extracted digital image data as the input source.
4. Develop software tools to manage and organize images and image data to enhance bridge management and allow identification of condition changes over time.

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

Task 1: Literature Review
Schedule status: *On schedule*
Percent complete: 75%

Task status: *Literature being collected and synthesized as research progresses.*

Task 2: Software Development and Data Collection
Schedule status: *On schedule*
Percent complete: 55%

Task status: *Computer Science graduate students continuing to develop software. Currently runs as a java application. Process chart illustrated in Fig. 1, below. Boundary edge detection automated for 5 member connection (typical case). User acceptance or corrections are enabled after software makes first automated attempt. Other connections with different number of members presently need user guided initial boundary location until general methods can be developed. Fastener location methods are robust and enable user addition/subtraction after initial software search. Fasteners are assigned members based on analysis of fastener geometry. Here again the user can override or accept software soultions.*

New targets being developed to better establish scale across entire image (magnetic rectangles scattered across gusset).

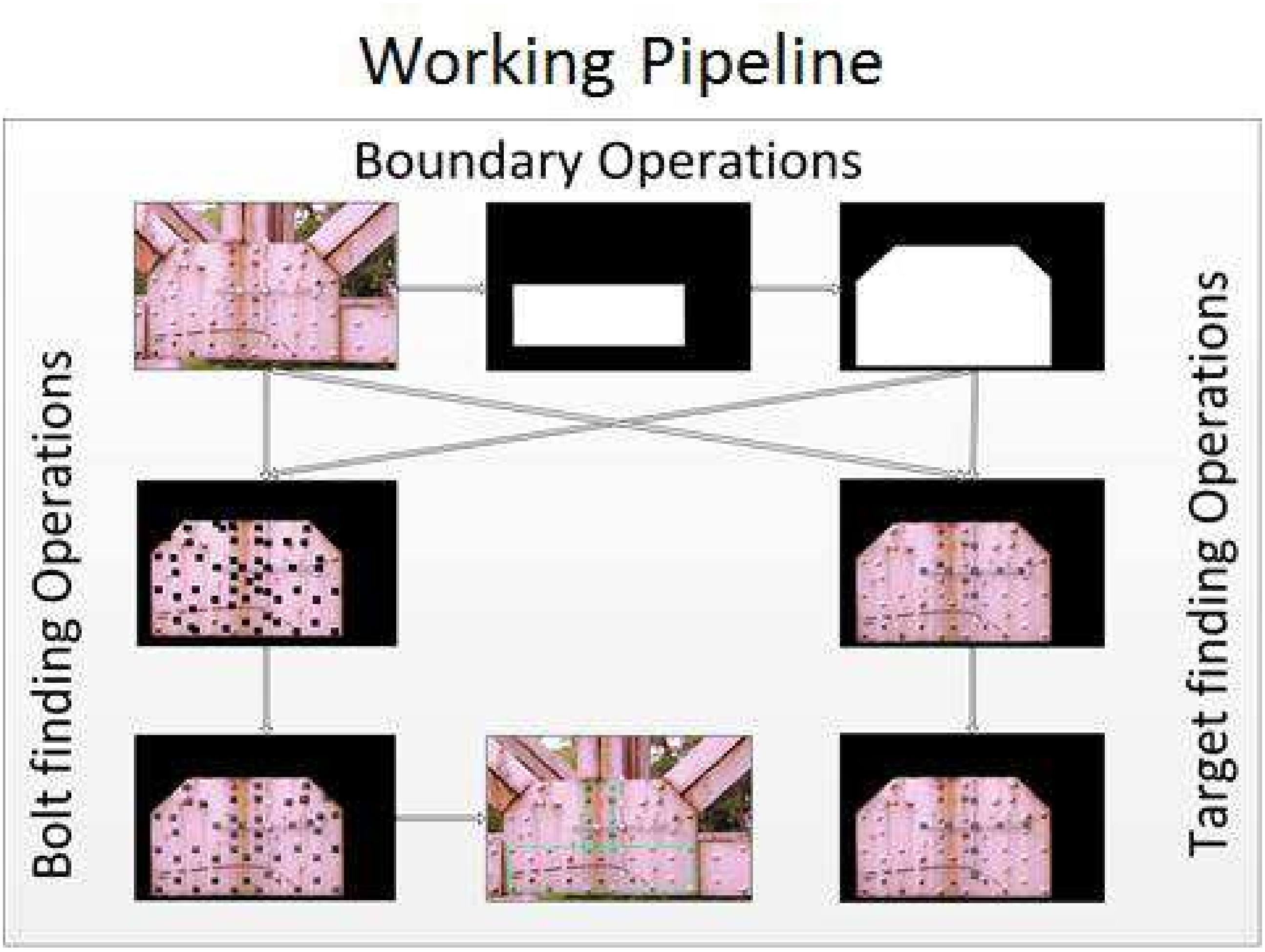

Figure 1. Process for image processing of gusset plate.

Task 3: Gusset Plate Analysis
Schedule status: *On schedule*
Percent complete: 0%

Task status: *Gusset plate analysis will use latest AASHTO LRFR provisions.*

Task 4: Implementation Example
Schedule status: *On schedule*
Percent complete: 0%

Task status: *Not yet underway*

Task 5: Imaging Data Informatics for Bridge Management
Schedule status: *On schedule*
Percent complete: 0%

Task status: *Not yet underway*

Task 6: Analysis Software
Schedule status: *On schedule*
Percent complete: 70%

Task status: *Comparisons of gusset plate finite element analyses using OpenSees and Abaqus were performed. After confirming the two softwares give the same load-displacement response for the basic test case of a bar in pure tension, analyses of gusset plates revealed different results. Although both programs gave the same initial stiffness and yield point in their load-displacement curves, the post-yield response from OpenSees was stiffer than that reported by Abaqus. With differences in constitutive modeling resolved between the two programs, our focus turned to the element formulations. The Abaqus analysis used three node shell elements (S3R) with finite membrane strain while the OpenSees analysis used degenerate four node shell elements (ShellMITC4) with small membrane strain. The small strain assumption explains the stiffer post-yield results from OpenSees. Additional work required to verify findings.*

Anticipated work next quarter:

Task 1: Literature Review- *Continue review and synthesis*

Task 2: Software Development and Data Collection – *Develop generalized edge detection for other gusset plate configurations (other than 5 member connection). Optimize new image targets. Work though software to make efficient and user-friendly.*

Task 3: Gusset Plate Analysis – *Begin using image data sets to develop specification-based analysis.*

Task 4: Implementation Example - *None*

Task 5: Imaging Data Informatics for Bridge Management – *Investigate GIS software options to enable management of images and metadata.*

Task 6: Analysis Software – *Abaqus analyses using the S3RS element will be conducted. There is no finite membrane strain shell element in OpenSees; however, it can be implemented if necessary for the project. Other anticipated work for the upcoming quarter is improvement of the OpenSees graphics and post-processing for gusset plate evaluation. Further validation of the OpenSees formulations across different idealized and progressively more complex plates.*

Significant Results:

While results are preliminary, the following results are significant:

A working software application was developed for automated image processing of gusset plates and is being used by the research team.

Finite element analysis results correlates well to commercial software for tension and compression bending of bars modeled with shell elements.

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).

No significant issues.

Potential Implementation:

To be determined.