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 # TPF 5(259)	**Transportation Pooled Fund Program - Report Period:** ☐Quarter 1 (January 1 – March 31) ☐Quarter 2 (April 1 – June 30) **X**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	142854.18	35

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	Total Amount of Funds Expended This Quarter	Total Percentage of Time Used to Date
	55276.71	60

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: 65%

Task status: *Computer Science graduate students continuing to develop software. A generalized boundary edge detection approach has been implemented to quantify any number of members connected to the plate. Additional user acceptance or corrections are enabled. Scaling and panning are now implemented in the process windows to allow users to zoom into the images to identify characteristics at the pixel level (if need be).*

A new set of targets is under development to better establish scale across entire image. The targets are magnetic angles with no standoff scattered across gusset as illustrated in Fig. 1. These allow independent image rectification and then error minimization across the entire image. The different colors allow the software to uniquely identify them. These are low cost and easy to implement while retaining fidelity.

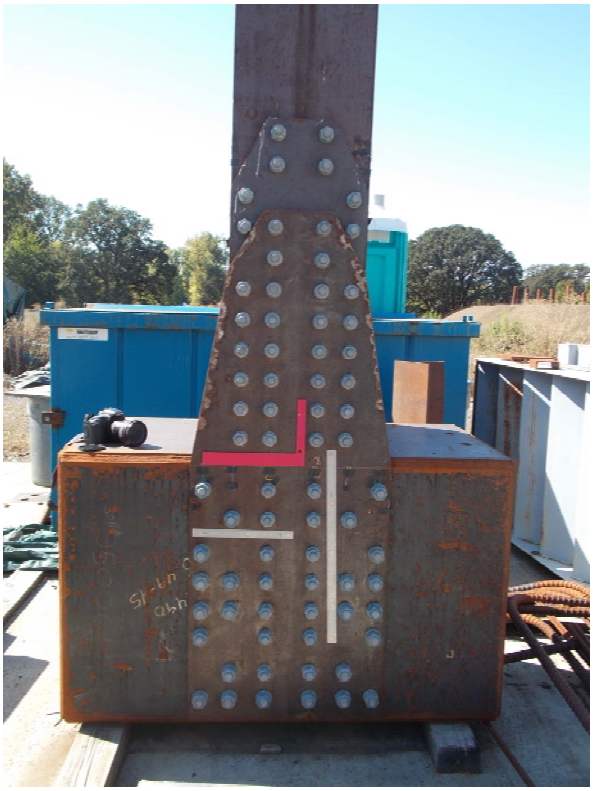

Figure 1. New image target applied to laboratory gusset plate. Straight rules are to verify scale in post-processed images.

Task 3: Gusset Plate Analysis
Schedule status: *On schedule*
Percent complete: 5%

Task status: *Manual calculations of gusset plate components according to the latest AASHTO MBE provisions are underway. Data extraction features are being incorporated in the above software features. Geometry will be taken*

from the image and used in the computations. Solution will be interactive with user.

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: 3%

Task status: *ArcGIS identified as commercial package that is capable of implementing this feature. Will be used to enable this task.*

Task 6: Analysis Software
Schedule status: *On schedule*
Percent complete: 80%

Task status: The OpenSees gusset plate analysis module has been linked with the output format of plate dimensions and bolt locations generated by the digital image graphical user interface. Comparisons of OpenSees and ABAQUS are nearing completion and improvements in the presentation of OpenSees analysis results, namely stress contours, are underway.

Anticipated work next quarter:

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

Task 2: Software Development and Data Collection – *Continue to optimize new image targets. Continue working though software to make more efficient and user-friendly. Incorporate features to interactively measure dimensions for use in the manual calculations.*

Task 3: Gusset Plate Analysis – *Continue to develop software to use image data to develop specification-based analysis.*

Task 4: Implementation Example - *None*

Task 5: Imaging Data Informatics for Bridge Management – *Start developing ArcGIS software for management of images and metadata (such as drawing, calculations, finite element analysis results).A trial bridge will be selected that has a large number of collected images (candidates are Ross Island or Bridge of the Gods).*

Task 6: Analysis Software – *Finalize comparative analysis results with Abaqus and compare with past experimental results. Implement analysis with attached compression truss member stiffness properties. Continue refinement of analysis output (stress outputs).*

Significant Results:

While results are preliminary, the following results are significant:

A revised set of image targets shows good rectification with significantly reduced cost and eliminates the need for standoff correction in the scaling.

The software application can now automate image processing of a general gusset plate. It requires refinement and further development by the research team.

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 problems.

Potential Implementation:

We anticipate a working version of the software will be available for review by the project participants by the end of the quarter.