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)	X Quarter 1 (January 1 – March 31) ☐ Quarter 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	$83,364.28	23%

Quarterly Project Statistics:

Total Project Expenses and Percentage This Quarter	**Total Amount of Funds Expended This Quarter**	**Total Percentage of Time Used to Date**
	NA	40%

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: 45%

Task status: *Computer Science Graduate student continuing to develop software. Algorithm for automated target recognition complete and is robust. Fastener detection algorithms were improved with better results for detecting bolts. The improved approach consists of two computational steps. The first step detects likely locations of bolts, called candidates. This typically includes a number of false positives among the candidates. The second step reduces the false positive rate by considering other geometric constraints, such as symmetry and parallelness of the fastener patterns on the gusset plate. The techniques have been applied successfully to field images of gusset plates as seen in Fig. 1.*

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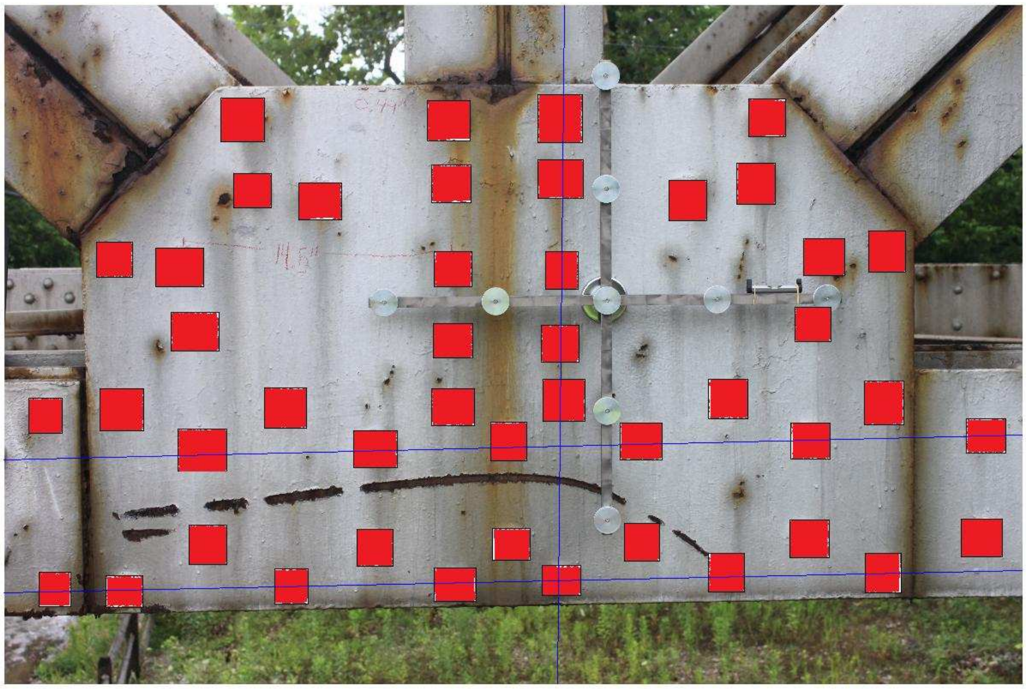

Figure 1. Example of fasteners detected in actual gusset plate by the developed scanning methods.

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

Task status: *Reviewed present AASHTO ballot to consider possible impacts on project. Waiting to see final disposition prior to embarking on task.*

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: 60%

Task status: *Triangular meshing algorithm was implemented in OpenSees and gusset plate geometries were meshed accurately. Shell element formulation in use for elastic and inelastic behaviors. Eigenvalues and eigenvectors of gusset plate model are computed and mesh is distorted out of plane according to the eigenvector corresponding to the fundamental mode of plate deformation. All possible loading combinations of bolt groups are included in the analysis sequence and the von Mises yield criterion is used as the terminating condition for each analysis. The above algorithms were used to develop an OpenSees model of an in situ gusset plate as shown below in Fig. 2. The analysis results will be compared with the ABAQUS solution. Refinements were made in the analysis software to improve loading sequences and a streamlined J2 plasticity model was developed. The software now tracks the load-deformation response of each of the loaded members and based on the failure criterion can determine the controlling capacity for different members in the connection. The user input requires the gusset plate yield stress, thickness, and ratio of member loads for cases where multiple members are loaded. Coordinating image input requirements with Task 2.*

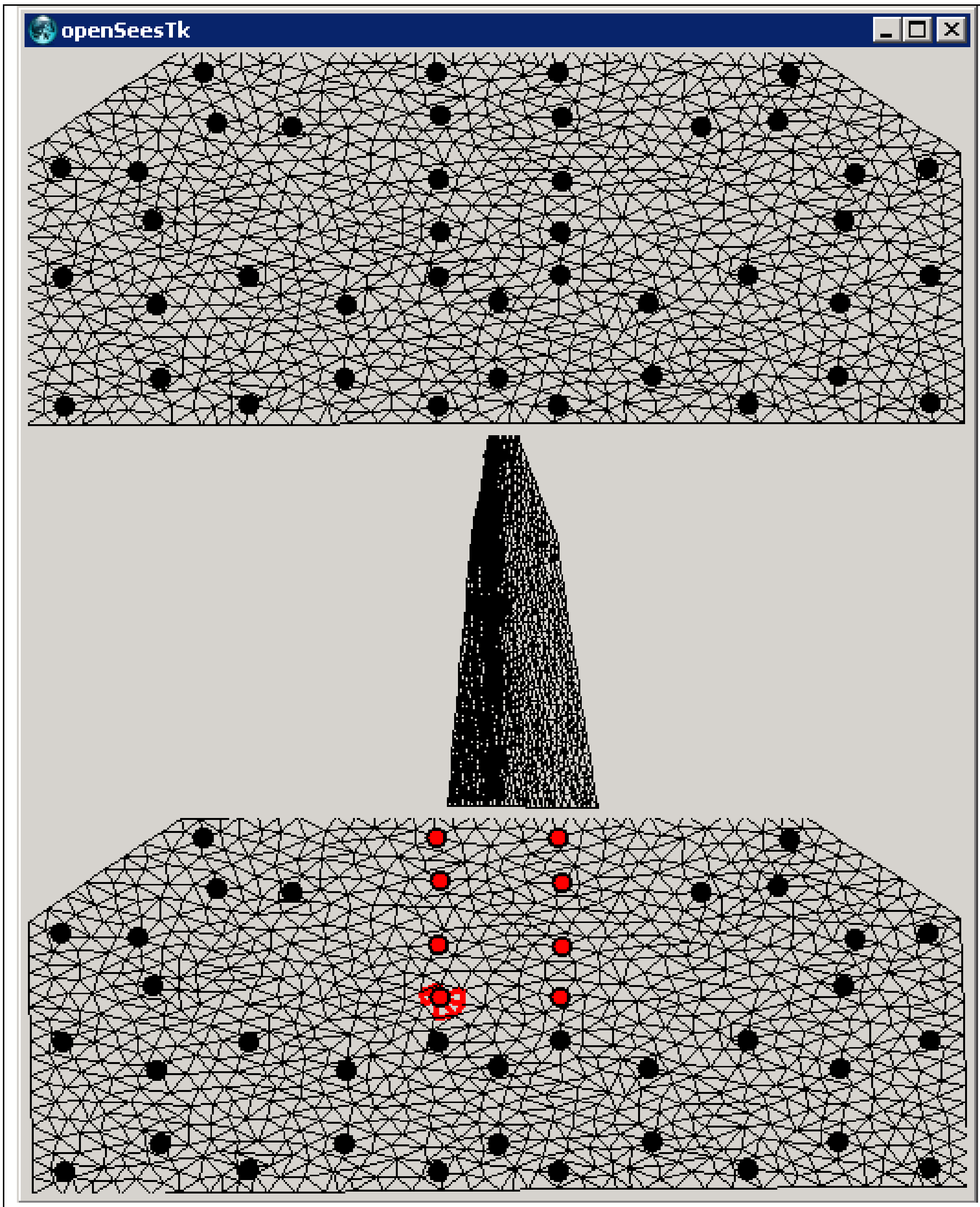

Figure 2. Example of screen shot of analysis (same gusset as that used in image processing).

Anticipated work next quarter:

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

Task 2: Software Development and Data Collection – *Develop edge detection algorithm and member assignments of fasteners to enable export algorithms to transfer information to analysis software inputs.*

Task 3: Gusset Plate Analysis – *Follow AASHTO ballot and develop strategies based on results.*

Task 4: Implementation Example - *None*

Task 5: Imaging Data Informatics for Bridge Management - *None*

Task 6: Analysis Software – *Compare OpenSees results for inelastic member responses (yielding and buckling) against commercial finite element software. Integrate with image inputs.*

Significant Results:

While most results are preliminary, the following results are significant:

Algorithm developed to identify image target and fasteners in actual gusset plate images.

Finite element analysis software can mesh, load, and analyze gusset plates to collect load-deformation responses of the different members and establish controlling capacity.

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).

None significant

Potential Implementation: