# TRANSPORTATION POOLED FUND PROGRAM
# QUARTERLY PROGRESS REPORT

## Lead Agency: Utah 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.*

<table>
<tr><td colspan="2">Transportation Pooled Fund Program Project #<br><br>TPF-5(264)</td><td>Transportation Pooled Fund Program - Report Period:<br>_ Quarter 1 (January 1 – March 31, 2015)<br>_ Quarter 2 (April 1 – June 30, 2015)<br>_ Quarter 3 (July 1 – September 30, 2015)<br>X Quarter 4 (October 1 – December 31, 2015)</td></tr>
<tr><td colspan="3">Project Title:<br>Passive Force-Displacement Relationships for Skewed Abutments</td></tr>
<tr><td>Name of Project Manager(s):<br>David Stevens</td><td>Phone Number:<br>801-589-8340</td><td>E-Mail<br>davidstevens@utah.gov</td></tr>
<tr><td>Lead Agency Project ID:<br>FINET 42051, ePM PIN 10903<br>UDOT PIC No. UT11.406</td><td>Other Project ID (i.e., contract #):<br>UDOT Contract No. 138123</td><td>Project Start Date:<br>August 13, 2012</td></tr>
<tr><td>Original Project End Date:<br>September 30, 2014</td><td>Current Project End Date:<br>December 15, 2016</td><td>Number of Extensions:<br>3</td></tr>
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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 | Percentage of Work Completed to Date |
|---|---|---|
| $270,000.00 (current contract)<br>$400,000.00 (total committed) | $160,800.00 | 75% |

***Quarterly*** Project Statistics:

| Total Project Expenses and Percentage This Quarter | Total Amount of Funds Expended This Quarter | Total Percentage of Time Used to Date |
|---|---|---|
| 0% | $0 | 75% |

**Project Description**:

At present, about 40% of the 600,000 bridges in the FHWA database are constructed at a skew angle (Silas Nichols, Personal Communication). There is considerable uncertainty about the passive force on skewed abutments where the passive force develops at an angle relative to the longitudinal axis of the bridge structure. Although current design codes (AASHTO 2011) consider that the ultimate passive force will be the same for a skewed abutment as for a non-skewed abutment, numerical analyses performed by Shamsabadi et al. (2006) indicate that the passive force will decrease substantially as the skew angle increases. Reduced passive force on skewed abutments would be particularly important for bridges subject to seismic forces or integral abutments subject to thermal expansion. Unfortunately, there have not been any physical test results for skewed abutments reported in the literature which could guide engineers in making appropriate adjustments for skewed conditions. Nevertheless, some field evidence has clearly shown poorer performance of skewed abutments during seismic events and distress to skewed abutments due to thermal expansion (Shamsabadi et al. 2006, Steinberg and Sargand 2010).

This study builds on previous pooled fund testing conducted by Rollins and his students at BYU to evaluate passive force-deflection relationships for non-skewed abutments (TPF-5(122), Dynamic Passive Pressure on Abutments and Pile Caps, Rollins et al, 2010). The test facilities can readily be modified to allow for the test program with relatively small additional costs because of the test fixtures (reaction shafts, reaction walls, and pile supported cap) which are already constructed at the site. Results from this study can be compared with previous testing to assess overall performance.

Four objectives are outlined for this new study:

1. Determine static passive force-displacement curves for skewed abutments with and without wingwalls from large scale tests.
2. Provide comparisons of behavior of skewed abutments with that of normal abutments.
3. Evaluate the effect of wingwalls on skewed abutment response.
4. Develop design procedures for calculating passive force-displacement curves for skewed abutments.

The scope of work consists of twelve specific tasks, including new tasks 7 through 12:

1. Literature Review and Collection of Existing Test Data
2. Perform Laboratory Passive Force-Deflection Tests on 2 ft High Wall with Skew Angles of 0º, 15º, 30º, and 45º
3. Perform Field Passive Force-Deflection Tests on 5.5 ft High Wall with Skew Angles of 0º, 15º, and 30º and Transverse Wingwalls
4. Perform Field Passive Force-Deflection Tests on 5.5 ft High Abutment with Skew angles of 0º, 15º, 30º and MSE Wingwalls
5. Calibrate Computer Model and Conduct Parametric Studies
6. Preparation of Final Report
7. Perform Additional Field Passive Force-Deflection Tests on 5.5 ft High Abutment with a Skew Angle of 45º with and without MSE Wingwalls
8. Perform Field Passive Force-Deflection Tests on 3.0 ft High Unconfined Backfill with Skew Angles of 0º and 30º
9. Perform Field Passive Force-Deflection Tests on 5.5 ft High Pile Cap with Concrete Wingwalls and Skew Angles of 0º and 45º
10. Perform Field Passive Force-Deflection Tests on 3.5 ft High Unconfined Gravel Backfill with Skew Angles of 0º and 30º
11. Perform Field Passive Force-Deflection Tests on 3.5 ft High GRS Gravel Backfill with Skew Angles of 0º and 30º
12. Present the Results of the Study at TRB and AASHTO Meetings

Dr. Kyle Rollins of BYU is the Principal Investigator for this research project. Individual task reports will be prepared for Tasks 1 through 5 and 7 through 11 when these are completed. Up to two in-person meetings with the multi-state technical advisory committee (TAC) are planned to be held in Salt Lake City, Utah during the project. Other TAC meetings will be tele-conference or web meetings.

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

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Task 1 – 100% complete.

Task 2 – 100% complete.
Task 3 – 100% complete.
Task 4 – 100% complete.
Task 5 – 80% complete. BYU continued data analysis and worked on task report.
Task 6 – 30% complete. Progress was made on multiple draft final reports to be published.
Task 7 – 80% complete. BYU continued data analysis and worked on task report.
Task 8 – 80% complete. BYU continued data analysis and worked on task report.
Task 9 – 80% complete. BYU continued data analysis and worked on task report. Reviewed/updated draft final report.
Task 10 – 80% complete. BYU continued data analysis and worked on task report.
Task 11 – 80% complete. BYU continued data analysis and worked on task report.
Task 12 – 60% complete.
TAC Meetings – No meetings this quarter.
Contract – UDOT reviewed a draft work plan developed by Dr. Rollins and Caltrans for a new field testing task involving passive force/skewed abutments using controlled low-strength material (CLSM) as backfill. Caltrans posted a new funding commitment online for the additional work. Contract end date was extended to Dec. 2016 to allow additional time for completion of the current scope and deliverables, as well as planning of the additional work.

**Anticipated work next quarter**:

Task 1 – None.
Task 2 – None.
Task 3 – None.
Task 4 – None.
Task 5 – Report nearing completion on report no wingwall case. Work continuing on RC Wingwall case..
Task 6 – Finalize the planned list of final task reports (and project summary report) to be published. Combine portions of other task reports for the Final Summary Report.
Task 7 – Complete the full task report within the revised Tasks 3.report
Task 8 – Complete the full task report within the revised Task 4 report
Task 9 – Revise the draft final report for this task based on TAC feedback.
Task 10 – Full task report nearing completion
Task 11 – Full task report nearing completion
Task 12 – None.
TAC Meetings – We will hold a TAC web conference to discuss additional results, completed reports, and next steps. We'll also make initial plans for an in-person TAC meeting in Utah to be held in 2016.
Contract – Add some baseline push-and-rotate tests on the test abutment/pile cap into the CLSM proposed additional work plan. Share the proposed new work plan with the TAC for their review. Identify additional funding needs and sources. The contract will be amended for the new tasks, schedule, and budget.

**Significant Results:**

During the past quarter work has been completed on numerical analyses of the abutment with wingwalls transverse to the direction of loading. Plaxis 3D was used to compute the response and comparisons were made with measured behavior in terms of passive force vs. deflection, heave contours, ground surface displacement and failure plane location. Analyses were performed for skew angles of 0, 15, 30 and 45 degrees. Subsequently parametric analyses were conducted to determine the factors which would affect passive force. A report on this work is in final review and will be submitted to the TAC in the next quarter. Additional numerical analyses are currently being carried out on the abutment with RC wingwalls parallel to the direction of loading.

Fig. 1 provides a comparison of measured and computed heave contours for the $0^{o}$ skew test while Fig. 2 provides the same comparison for the 30 case. In general, the computer model provides a reasonable approximation of the general shape of the measured heave contours. For example heave is symmetric about the centerline for the $0^{o}$ skew case, but is skewed towards the acute corner for the $30^{o}$ case. In addition, for the $30^{o}$ skew, heave contours are normal to the obtuse corner of the abutment and parallel to the acute corner of the abutment. However, the heave tends to be overestimated to some degree and the length of the zone of heave is somewhat underestimated.

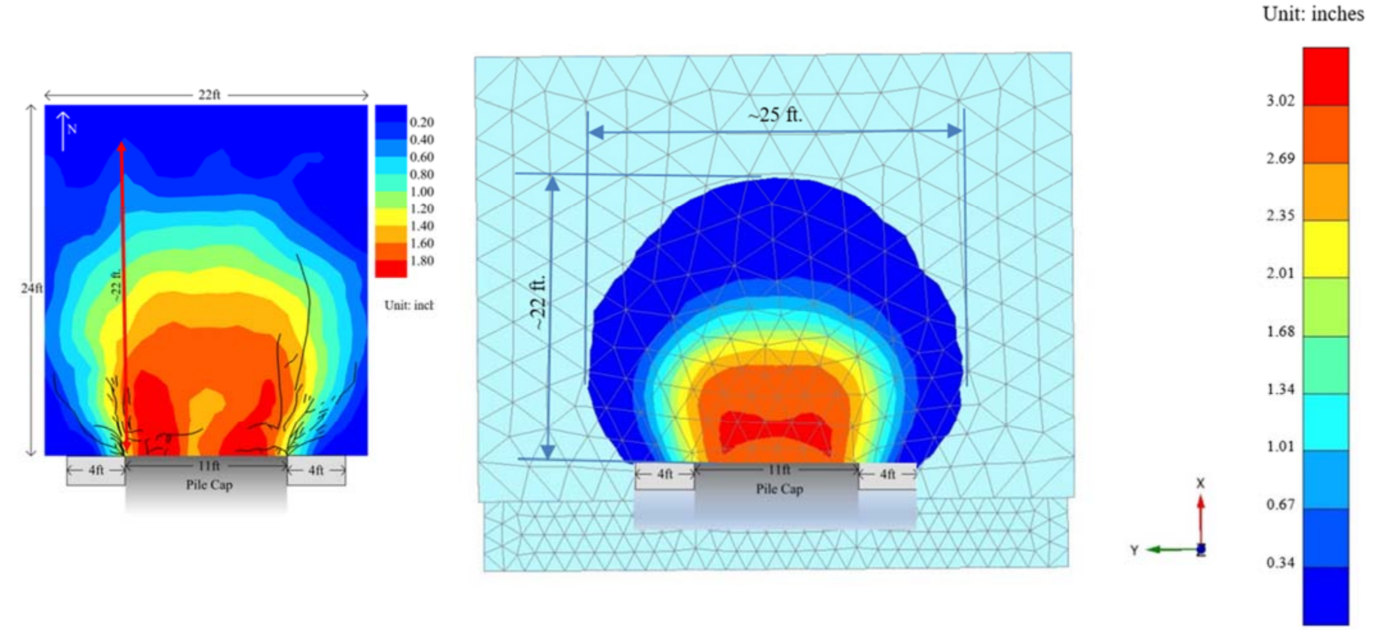


**Fig. 1 Contours of measured and computed ground surface heave for the 0 degree skew tests.**

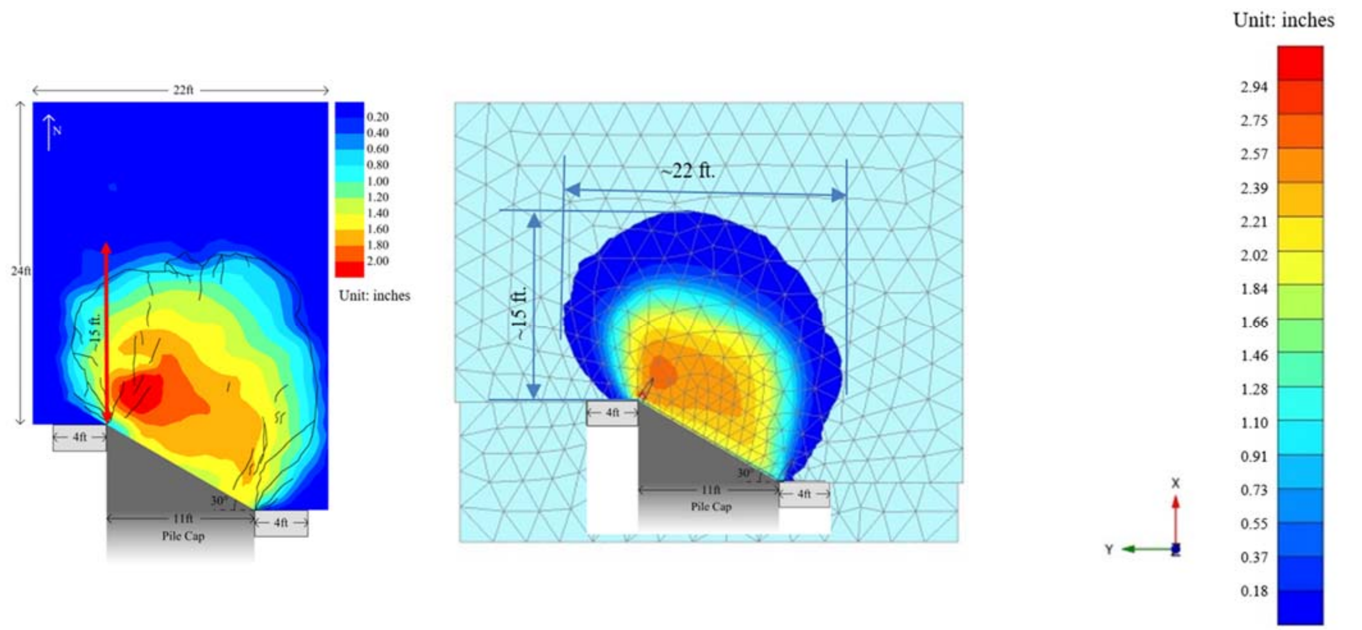


**Fig. 2 Contours of measured and computed ground surface heave for the 30 degree skew tests.**

Fig. 3 provides a plot of the skew reduction factors computed with the computer model in comparison to the curve proposed by Rollins and Jessee (2013) and the results of the field tests for the transverse wingwall tests. The result for the 15º skew is somewhat higher than that measured in the field test but the value for the 30º skew is in good agreement with field results. The computer models indicates that excessive transverse sliding would occur for the 45º skew case and no result was obtained. This result is in good agreement with expectations based on simple mechanics and indicates that the piles in the field case were preventing the abutment from sliding excessively for the 45º skew case. Modeling the abutment piles required excessive computer times and the transverse resistance of the piles was not well constrained.

Fig. 4 provides a plot of shear strain contours on a longitudinal cross-section through the 0º skew abutment and backfill. A plot of the measured shear plane location during the field testing is overlaid on the cross section and the upper and lower shear zones seem to fall in the zone of high computed shear strain. The computer model does not compute high shear strains beyond 10 ft and this is also the zone where no physical evidence of shearing was obtained in the field.

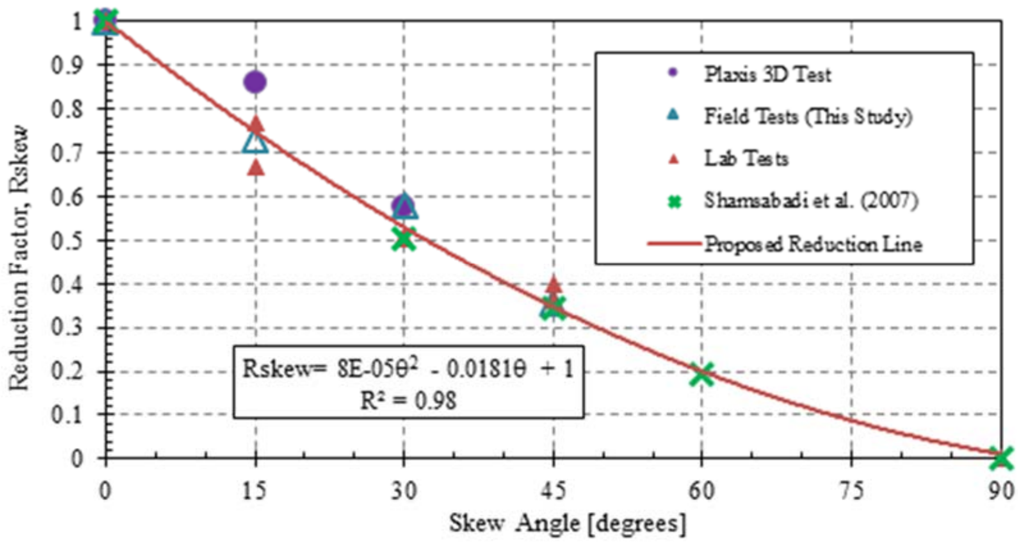


**Fig. 3 Plot of passive force reduction factor computer using Plaxis 3D in comparison to cure proposed by Rollins and Jessee (2013) along with values obtained from field testing and computer modeling by Shamsabadi et al (2007).**

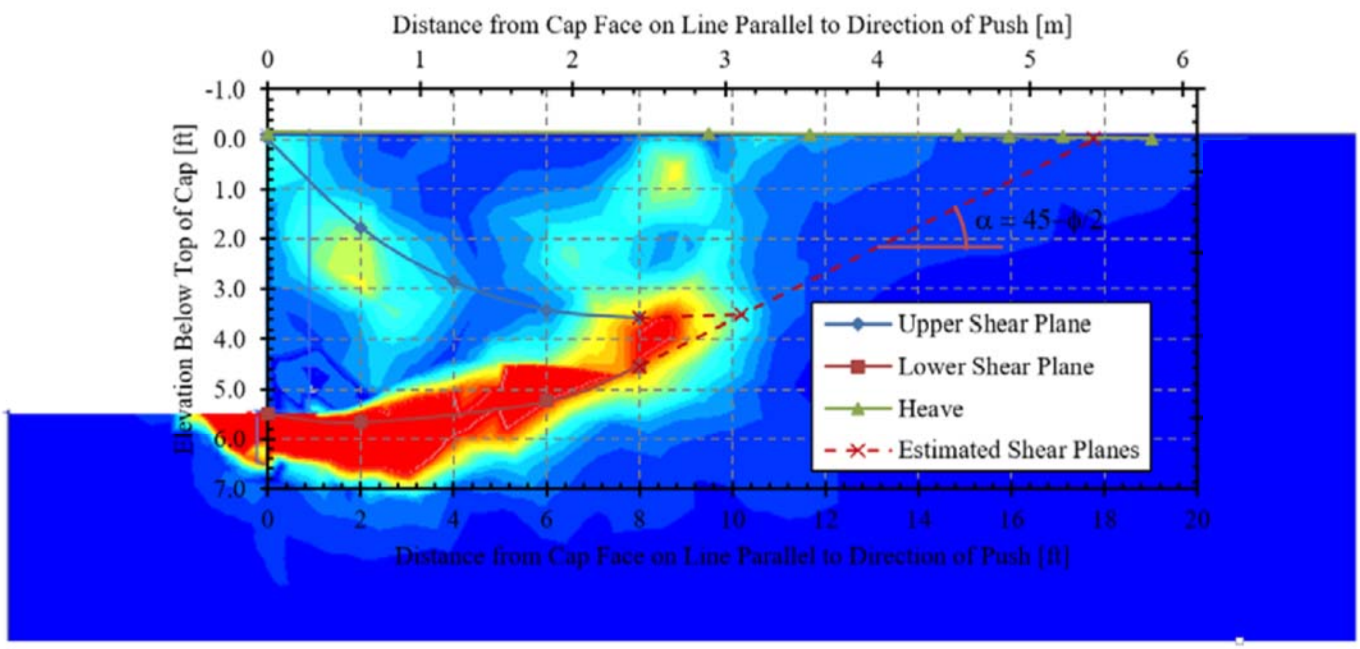


**Fig 4. Contours of computed shear strain on a longitudinal cross section through the 0 skew backfill with measured shear failure planes from the field investigation.**

Fig.5 provides a comparison of computed longitudinal displacement contours on two longitudinal cross-sections drawn through the sections located two feet in from the acute and obtuse corners of the abutments for the 0º, 15º and 30º skew cases. The longitudinal shear planes can be considered a proxy for the failure plane. For the 0º and 15º skew cases, the displacement contours are relatively similar on the acute and obtuse sides. However, for the 30 skew case, the contours extend much further back on the acute side than on the obtuse side. This response may partially explain the reason for the lower passive resistance that develops as the skew angle increases.

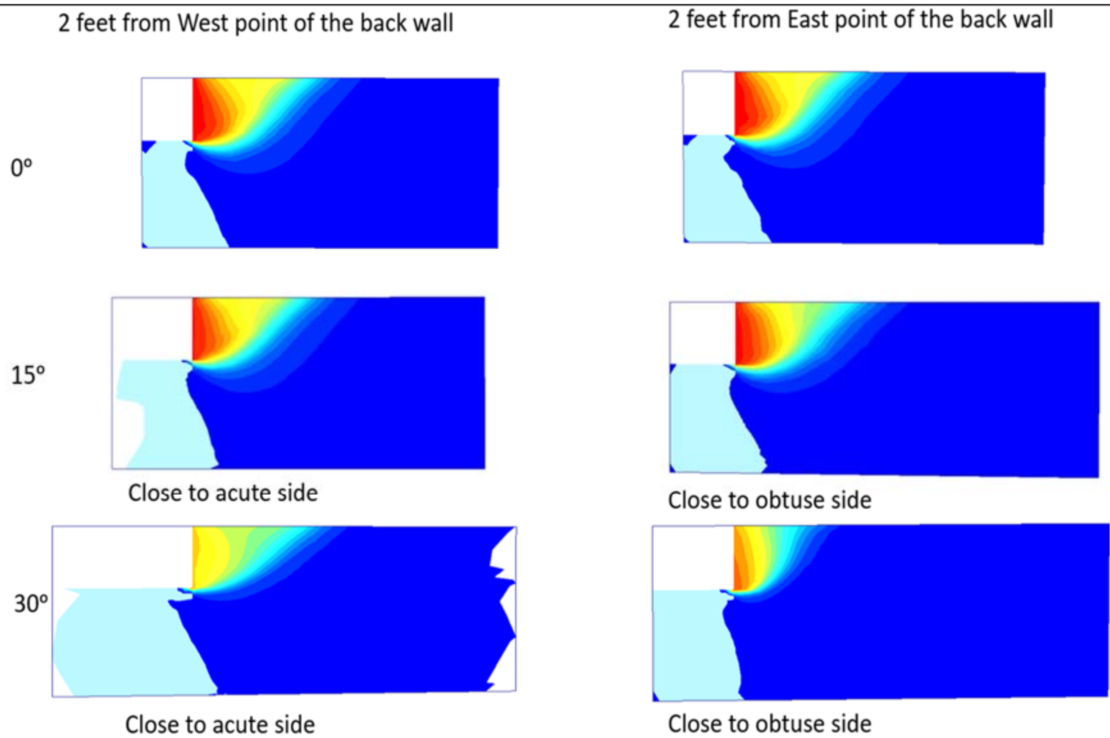


**Fig.5 Contours of computed longitudinal displacement on longitudinal cross-sections drawn two ft in from the acute and obtuse corners of the abutments for the 0°, 15° and 30° skew cases.**

**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).**

Reports are being completed relative to first 12 work tasks. Additional work tasks related to CLSM backfill tests are being added at the request of Caltrans and Utah DOT. Once the work plan for additional field testing with CLSM backfill and push-and-rotate tests is prepared, this will be incorporated into a new contract amendment which will also extend the contract end date through at least 2016.

**Potential Implementation:**

UDOT is considering early adoption of the skew reduction factor for passive force based on the laboratory and field test results. In June 2013 and June 2014, Dr. Rollins presented the results of the research to date to technical committees at the AASHTO Subcommittee on Bridges and Structures Annual Meetings in Oregon and Ohio on behalf of the project TAC. This interaction is intended by the TAC and Dr. Rollins to prepare the way for design code revisions once the research is completed. Caltrans is also promoting use of the research results in their design methods. Dr. Rollins is proposing changes to the AASHTO code that will be presented at the AASHTO meeting in Minnesota this June.