**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.*

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| **Transportation Pooled Fund Program Project #****TPF-5(272)** | **Transportation Pooled Fund Program - Report Period:**\_ Quarter 1 (January 1 – March 31, 2016) X **Quarter 2 (April 1 – June 30, 2016)**\_ Quarter 3 (July 1 – September 30, 2016)\_ Quarter 4 (October 1 – December 31, 2016) |
| **Project Title:**Evaluation of Lateral Pile Resistance Near MSE Walls at a Dedicated Wall Site |
| **Name of Project Manager(s):**Jason Richins | **Phone Number:** 801-360-4985 | **E-Mail** jtrichins@utah.gov |
| **Lead Agency Project ID:**Finet 42053, ePM PIN 11075UDOT PIC No. UT11.404 | **Other Project ID (i.e., contract #):** UDOT Contract No. 148434  | **Project Start Date:** December 2, 2013 |
| **Original Project End Date:**September 30, 2016 | **Current Project End Date:** September 30, 2016 | **Number of Extensions:** |

Project schedule status:

 **X** On schedule \_ On revised schedule \_ Ahead of schedule \_ Behind schedule

Overall Project Statistics:

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|  **Total Project Budget** |  **Total Cost to Date for Project** |  **Percentage of Work**  **Completed to Date** |
| $322,000.00 (current contract)$332,000.00 (total committed online)$352,000.00 (total actual committed) | $229,500.00 | 71% |

***Quarterly*** Project Statistics:

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|  **Total Project Expenses**  **and Percentage This Quarter** |  **Total Amount of Funds**  **Expended This Quarter** |  **Total Percentage of**  **Time Used to Date** |
| $0, 0% | $0 | 93% |

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| **Project Description**:Pile foundations for bridges with integral abutments must resist lateral loads produced by earthquakes and thermal expansion or contraction. Increasingly, right-of-way constraints are also leading to vertical mechanically stabilized earth (MSE) walls at abutment faces. Currently, there is relatively little guidance for engineers in assessing the lateral resistance of piles located close to these MSE walls. As a result, some designers assume that the soil provides no resistance whatsoever which leads to larger pile diameters and increased foundation cost. Other designers locate the abutment piles six to eight pile diameters behind a wall face to minimize the interaction and use conventional design approaches. However, this approach increases the bridge span and the cost of the bridge structure. Still other designers position the pile close to the wall face and reduce the lateral pile resistance using engineering judgment. However, the appropriate reduction factor to use as a function of pile spacing is not well defined. Recent testing conducted by Rollins et al (2013) and Pierson et al (2008) indicate that lateral resistance decreases substantially as pile spacing from the wall decreases; however, reinforcing can reduce this effect. Rollins et al also found that p-multipliers defined as a function normalized spacing and reinforcement length seemed to provide reasonable agreement with measured pile response. Furthermore, Rollins et al found that the tensile force in the reinforcements owing to the lateral load on the pile could be estimated for design purposes using a correlation with pile load, spacing behind the wall, and distance transverse from the pile load.  Although the tests to date provide a framework for understanding the mechanisms involved and likely design approaches, the available data is too limited to make firm design recommendations. To improve our understanding of pile-MSE wall interaction, this project will involve construction of a test embankment approximately 80 ft long and 20 ft tall where it will be possible to conduct a number of lateral pile load tests on different pile types behind an MSE wall with both strip and grid type steel reinforcements. Additional contributions to the project will consist of in-kind donations from various contractors and material suppliers.Objectives for this study include: 1. Measure reduced lateral pile resistance vs. displacement curves for circular, square, and H piles behind an MSE wall with steel strips and grid reinforcement. 2. Measure the increase and distribution of tensile force in the MSE reinforcement induced by lateral pile loading.3. Measure effect of special pile head geometry (e.g. corrugated pipe sleeves, double plastic sheeting) on lateral pile resistance. 4. Develop design rules (e.g. p-multipliers) to account for reduced pile resistance as a function of spacing and reinforcement.5. Develop equation to predict reinforcement force induced by pile loading.6. Develop design equations to account for pile shape and pile head geometry. Tasks for this study include: 1. Instrument test piles and reinforcements.2. Drive test piles and construct MSE wall to height of 15 ft.3. Perform lateral load tests on piles with 15 ft high MSE wall.4. Reduce data and develop report on the testing for the 15 ft high wall.5. Determine p-multipliers and reinforcement force equations for 15 ft high wall test results.6. Perform lateral load tests on piles with 20 ft high MSE wall.7. Reduce data and develop report on the testing for the 20 ft high wall.8. Determine p-multipliers and reinforcement force equations for 20 ft high wall test results. 9. Develop design recommendations to account for pile sleeves and plastic sheeting effects. 10. Prepare final report with recommendations based on all tests. 11. Hold Technical Advisory Committee (TAC) meetings.12. Present results of the study at AASHTO, TRB, and ASCE meetings. Dr. Kyle Rollins of BYU is the Principal Investigator for this research project. The technical advisory committee (TAC) includes representatives from UT, FL, IA, KS, MA, MN, MT, NY, OR, TX, and WI DOTs. |

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| **Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):**Task 1 – 100% complete.Task 2 – 100% complete.Task 3 – 100% CompleteTask 4 – 100% CompleteTask 5 – 100% CompleteTask 6 – 100% Complete.Task 7 – 100% Complete.Task 8 – 100% Complete.Task 9 – 100% Complete.Task 10 – 80% CompleteTask 11 – 100% CompleteContract – A contract modification was completed to provide funding for all the work tasks.  |
| **Anticipated work next quarter**:Task 1 – Completed.Task 2 – Completed.Task 3 – Completed.Task 4 – CompletedTask 5 – Completed.Task 6 – Completed.Task 7 – CompletedTask 8 – CompletedTask 9 – CompletedTask 10 – Report is in preparationTask 11 – TAC meeting CompletedTask 12 – Presentation at AASHTO meeting completedContract – A contract modification may be prepared for additional work tasks based on available funding. |

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| **Significant Results:**During the past quarter, we have been working to compile an abbreviated document which provides basic information regarding the testing program, the reduction in lateral pile resistance near the wall, and the induced force on the reinforcements owing to lateral load. The report will also indicate the maximum deflections on the wall panel for deflection levels of 1.0 and 3.0 inch. The report is about 80% complete at the present time.Based on response from the TAC members, we have worked to develop somewhat simpler equations for predicting the induced force on the reinforcing elements during pile loading. The reinforcement length to height (L/H) ratio has been eliminated along with cross terms. These changes reduce the R2 value from about 0.77 to about 0.72 but eliminate several terms. For the welded wire reinforcement, the maximum induced force, ΔF, in a reinforcement is given by the equationWhere P= applied lateral force on the pile in kips σ = vertical effective stress in lbs/ft2 T = transverse distance from the center of the pile in inches, and D = pile diameter in inchesThis equation is based on a regression analysis with 1058 data points from the tests performed during the study and the R2 is 0.72. A plot of measured maximum force versus computed maximum force for the entire data set is provided in Figure 1. The scatter generally appears to be quite uniform and residual analysis of the variables does not indicate any consistent trends which would need to be corrected. **Figure 1. A plot of measured maximum tensile force versus computed maximum tensile force for welded wire reinforcement**For the ribbed-strip reinforcement, the maximum induced force, ΔF, in a reinforcement is given by the equationWhere P= applied lateral force on the pile in kips σ = vertical effective stress in lbs/ft2 T = transverse distance from the center of the pile in inches D = pile diameter in inches, S = distance from the back face of the MSE wall panel to the center of the pile in inches.This equation is based on a regression analysis with 942 data points from the tests performed during the study and the R2 is 0.71. A plot of measured maximum force versus computed maximum force for the entire data set is provided in Figure 2. **Figure 2. A plot of measured maximum tensile force versus computed maximum tensile force for ribbed-strip reinforcements.**Prof. Rollins attended the AASHTO SCOBS T-15 Substructures and Retaining Wall committee meeting in Minneapolis, Minnesota this past June and made a 30-minute presentation on the results of the pooled fund study. In addition, he suggested potential code changes where the results of the study could be incorporated into the AASHTO code. The presentation was very well received and we have laid the groundwork for implementing the results of the study into engineering practice. Some committee members felt it would be helpful to publish a peer-reviewed paper on the study as a reference that could be noted in the code. We are planning to submit the condensed summary of the research to the ASCE Journal of Geotechnical and Geoenvironmental Engineering for review in the next quarter.Prof. Rollins also made a 30-minute presentation on the results of the study at the International Bridge Conference (IBC) which has traditionally been held in Pittsburgh, but was held for the first time in Washington, DC this past June. Approximately 130 people were in attendance and the response was positive. A paper describing a subset of the research study has already been submitted and will be published later this year in the IBC proceedings.  |
| **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).**The project work tasks have nearly been completed within the original time and budget anticipated. Additional work tasks suggested during the recent TAC meeting will require an extension and solicitation of additional funds from TAC members. |

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| **Potential Implementation:**We are working with the AASHTO SCOBS T-15 committee to have the results of the study incorporated into new AASHTO codes. Papers are being prepared. |