**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, 2014) \_Quarter 2 (April 1 – June 30, 2014)\_Quarter 3 (July 1 – September 30, 2014)X **Quarter 4 (October 1 – December 31, 2014)** |
| **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:**5H07203H, 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** |
| $204,500.00 (current contract)$292,000.00 (total committed) | $48,800.00 | 24% |

***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 | 40% |

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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. (Not funded in original contract.)8. Determine p-multipliers and reinforcement force equations for 20 ft high wall test results. (Not funded in original contract.)9. Develop design recommendations to account for pile sleeves and plastic sheeting effects. (Not funded in original contract.)10. Prepare final report with recommendations based on all tests. (Not funded in original contract.)11. Hold Technical Advisory Committee (TAC) meetings.12. Present results of the study at AASHTO, TRB, and ASCE meetings. (Not funded in original contract.)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, and TX 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 – Completed testing for the piles at the 15-ft wall height.Task 4 – Work has started.Task 5 – Work has started.Task 6 – Completed testing for the piles at the 20-ft wall height.Task 7 – Funding is available. Working on Amendment to the contract.Task 8 – Funding is available. Working on Amendment to the contract.Task 9 – Funding is available. Working on Amendment to the contract.Task 10 – Funding is available. Working on Amendment to the contract.Task 11 – 10% complete. Follow-up teleconferences were held with suppliers of the MSE wall panels and reinforcements, UDOT staff, and Dr. Rollins to discuss options for including surcharge at the top of the wall, behind the piles.Task 12 – Funding is available. Working on Amendment to the contract.Contract – Additional funding transfers from state partners were received, including our new partner Massachusetts DOT. Working on amendment to the contract. |
| **Anticipated work next quarter**:Task 1 – Completed.Task 2 – Completed.Task 3 – Completed.Task 4 – Data reduction will continue for the 15-ft pile testing.Task 5 – p-multipliers will be back-calculated based on the results of the test.Task 6 – Completed.Task 7 – Data reduction will continue for the 20-ft pile testing.Task 8 – p-multipliers will be back-calculated based on the results of the test.Task 9 – Work will begin.Task 10 – Work will begin.Task 11 – Plan a date for a TAC meeting to review test results.Task 12 – None planned.Contract – The contract will be amended to include funding recently transferred from partner states, for Tasks 7 through 10 and 12, and to address MSE wall design and construction changes. |

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| **Significant Results:**During the past quarter the research team has been focused on reducing data from the field load testing completed in the previous quarter. Some selected highlights are provided in this section. Fig.1 provides a plot of pile head load vs. deflection curves for square, pipe and H reaction piles located 23 ft behind the wall. The piles were loaded transverse to the wall face. Although the pipe and square piles have about the same moment of inertia, the square piles have higher resistance for a given displacement than the pipe pile. This suggests that the square shape of the pile is producing higher lateral resistance presumably due to increased side friction, although increased normal resistance could also be occurring. The lateral resistance of the H pile is significantly lower than the pipe pile because the pile is loaded about the weak axis. Fig. 2 provides a plot of the measured pile head load-deflection curve for the round pile in comparison with the back-calculated load-deflection curve using the computer model LPILE. The agreement is very good although the parameters for the φ and k are higher than what might be used in routine design practice. Subsequently, analyses were performed with LPILE using the same soil parameters back-calculated for the round pile. These results are presented in Fig. 3. In both cases the computed lateral resistance is considerably less than the measured resistance for a given deflection. This result suggests that there is actually is a geometrical effect, as suspected, that increases the lateral pile resistance relative to the round pile. Several proposed approaches were used in an attempt to obtain agreement with the measured curve including increasing the effective pile width as proposed by Reese and Van Impe (2001) and increasing the shear component of resistance as suggested by Briaud et al (1987); however, neither approach provided satisfactory agreement. As an alternative p-multipliers were used to increase the lateral soil resistance to account for the geometrical effects. Excellent agreement was obtained with the measured load-deflection cures for the square and H piles using p-multipliers of 1.20 and 1.35, respectively as shown in Fig. 3. **Fig. 1 Measured pile head load versus deflection curves for two square piles, a pipe pile and an H pile loaded on its weak axis.** **Fig. 2 Comparison of back-calculated pile head load-deflection curve for round pile computed using LPILE and measured load-deflection curve.****Fig. 3 Comparison of pile head load-deflection curve for the square and H piles computed using LPILE with soil parameters back-calculated from test of round pile with measured load-deflection curves.****Fig. 4 Comparison of measured pile head load-deflection curve for the square and H piles with curves computed with LPILE using p-multipliers of 1.2 and 1.35 for the square and H piles, respectively.**Fig. 5 shows preliminary back-calculated p-multipliers as a function of pile spacing obtained using the computer program LPILE for eight round piles tested with strip reinforcements and eight piles with welded wire reinforcement. Eight of the tests involve reinforcement length to height (L/H) ratios of 0.9 and eight involve L/H ratios of 0.72. Soil parameters for the backfill were first selected to fit the measured load-deflection curve for the pile farthest back from the wall. Afterwards, these same soil properties were used to analyze the piles at other spacing, and a constant p-multiplier was back-calculated for each test to provide the best agreement with the measured response. The p-multipliers obtained from this study are in very good agreement with the p-multipliers obtained from the previous tests conducted at bridge sites in Utah where the reinforcement length to height ratios were between 0.9 and 1.2. P-multipliers were found to be 1.0 (no wall interaction effects) when the pile was located more than about 3.75 pile diameters behind the wall. P-multipliers decreased approximately linearly as pile spacing behind the wall increased and became about 0.2 at a normalized spacing of 1.5 pile diameters. Although there is some scatter about the best-fit curve. The results are generally quite consistent considering the variation in reinforcement L/H and reinforcement type. Additional, analysis is currently underway to determine if the results from the H and Square pile tests are consistent with those from the round piles.**Fig. 8 Back-calculated p-multipliers as a function of pile spacing behind the MSE wall for 16 lateral pile load tests conducted during this study with reinforcement L/H ratios of 0.9 and 0.72 along with eight lateral load tests conducted previously at three bridge sites in Utah. SSL reinforcements are welded wire, while RECo reinforcements are ribbed strips.** Data reduction was also focused on the tensile force developed in the reinforcement as a result of pile loading. Although the results are somewhat fuzzy, the following trends are generally observed. * Tensile force increases as the pile head load and deflection increase.
* Tensile force generally increases as the pile is placed closer to the wall
* Tensile force tends to increase with depth but often peaks in the second or third layer of reinforcement
* Tensile force decreases with transverse distance from the loaded pile.

We are presently consulting with a statistics professor to develop a multi-variable linear regression model that can identify independent variables that are statistically significant in influence the measured maximum tensile force. We hope that some preliminary data will be available in the next quarter. |
| **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 to report. |

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| **Potential Implementation:**  |