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.

Transportation Pooled Fund Program Project #	**Transportation Pooled Fund Program - Report Period:**
TPF-5(381)	**X Quarter 1 (January 1 – March 31, 2020)** _ Quarter 2 (April 1 – June 30, 2020) _ Quarter 3 (July 1 – September 30, 2020) _ Quarter 4 (October 1 – December 31, 2020)

Project Title:
Evaluation of Lateral Pile Resistance Near MSE Walls at a Dedicated Wall Site – Phase 2

Name of Project Manager(s): David Stevens	**Phone Number:** 801-589-8340	**E-Mail** davidstevens@utah.gov
Lead Agency Project ID: FINET 42085, ePM PIN 16761 UDOT PIC No. UT17.404	**Other Project ID (i.e., contract #):** UDOT Contract No. 19-8182	**Project Start Date:** August 20, 2018
Original Project End Date: September 30, 2020	**Current Project End Date:** September 30, 2020	**Number of Extensions:** 1

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
$220,000.00 (current contract) $240,000.00 (total commitments) $240,000.00 (obligated on PIN)	$120,000.00	60%

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	77%

Project Description:

Bridge abutment piles are frequently surrounded by mechanically stabilized earth (MSE) walls rather than a soil slope. Piles near MSE walls must be designed for lateral loads from earthquakes and thermal expansion/contraction. In the TPF-5(272) Phase 1 study involving several state DOTs, a series of 31 tests on free-head piles provided p-multipliers as a function of pile spacing which can be used to account for reduced lateral soil resistance due to the presence of an MSE wall. Equations were also developed to compute the induced force developed in the reinforcements by the lateral pile loading. However, a number of questions came up when the results of the Phase 1 study were presented to engineers and those responsible for code changes. These issues involve (a) the effect of cyclic loading when previous testing was monotonic, (b) the effect of pile head fixity because previous tests were on free-head piles while most abutment piles are "fixed-head", (c) the effect of pile group loading when previous tests were for single piles, and (d) the effect of pile diameter on the p-multiplier and induced force equations because previous tests were all for piles about 12 inches in diameter.

Objective: To provide closure relative to the outstanding issues described above, a series of additional tests will be conducted as a Phase 2 follow-up to the original test series.

The Phase 1 study included construction of a dedicated MSE wall site in Utah with instrumented piles behind the 20-ft high wall.

Tasks for this Phase 2 study include:

1. Excavate the top 6 ft of the soil backfill behind the existing MSE wall.
2. Instrument MSE reinforcements and piles with strain gauges.
3. Re-compact the top 6 ft of the soil backfill behind the existing MSE wall.
4. Conduct cyclic lateral pile load testing.
5. Conduct fixed-head lateral pile load testing.
6. Conduct lateral pile load testing of larger-diameter piles (24-inch diameter), to be newly placed between cut-off existing piles.
7. Conduct lateral pile load testing of a pile group.
8. Develop p-multipliers for Phase 2 lateral pile load testing results, compare these with the Phase 1 results, and update the overall p-multiplier equation as necessary.
9. Develop tensile force equations for Phase 2 lateral pile load testing results, compare these with the Phase 1 results, and update the overall tensile force equations as necessary.
10. Submit a final report that documents the Phase 2 research effort.
11. Report results to TAC committee members in video conferences.
12. Make presentations at AASHTO bridge engineers' committee meetings and TRB events to aid in national efforts to implement the study results.

Dr. Kyle Rollins of BYU is the Principal Investigator for this research project. The technical advisory committee (TAC) for the study currently includes representatives from UT, CA, FL, KS, MN, NY, and WI state DOTs.

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

Task 1 – Completed.
Task 2 – Completed.
Task 3 – Completed.
Task 4 – Completed.
Task 5 – Completed.
Task 6 – Completed.
Task 7 – Worked on memo reporting on this completed testing.
Task 8 – Continued this task.
Task 9 – Started this work
Task 10 – Not started.
Task 11 – Not started.
Task 12 – Some presentations given already.

Contract – No changes this quarter.

Anticipated work next quarter:

Task 1 – Completed.
Task 2 – Completed.
Task 3 – Completed.
Task 4 – Completed.
Task 5 – Completed.
Task 6 – Completed.
Task 7 – Submit the task completion memo with test layout, procedure, basic results, and load-deflection curves.
Task 8 – Develop p-multipliers for Phase 2 lateral pile load testing results, and submit the task completion memo.
Task 9 – Start developing reinforcement tensile force equations.
Task 10 – None planned.
Task 11 – Hold a TAC web conference to provide updates and discuss progress.
Task 12 – None planned.

Contract – Add the remaining pooled fund commitment amount to the contract for face-to-face TAC meetings and/or additional numerical analysis and pressure cell analysis.

Significant Results:

This quarter the research team has been analyzing the lateral group load test that was performed at the dedicated MSE wall test site. Piles behind an MSE are typically connected to the abutment which allows the piles to act together as a group during lateral loading from an earthquake or thermal expansion and contraction. However, previous testing has almost exclusively been conducted on individual piles rather than pile groups. In this study, full scale lateral deflection testing was performed on a group of three 12.75" x 0.375" pipe piles spaced at 1.8, 2.8, and 3.0 pile-diameters from a 20-ft tall MSE wall reinforced with galvanized ribbed steel strips. An additional test was performed on an adjacent individual pile with the same dimensions but spaced at 4.0 pile-diameters to act as a control and to calibrate the backfill parameters used in analysis with the computer program LPILE.

Fig. 1 shows the locations of the three piles in the group and a near-by single pile along with their identifying names as well as the load frame used to transfer load to the pile group. The frame was designed to produce the same deflection at each pile. Each pile was attached to the frame by a tie-rod load cell so that the load carried by each pile could be independently measured. In addition, deflection of each pile head was measured by a string pot attached to an independent reference frame. Stacks of pre-cast concrete blocks, measuring 2'x2'x6', were placed to simulate the surcharge induced by the abutment and approach fill typical for a bridge. Fig. 2 shows a photo of the loading system used during testing of the grouped piles. Load was applied to the frame using two 120 kip MTS hydraulic actuators which reacted against a steel beam supported by a number of reaction piles located behind the reinforced soil zone. During testing the piles were pushed in increments, holding steady at each increment for about 5 minutes between each push. Measurements of pile head load and deflection were taken for each displacement increment and reported at 1 minute after the beginning of each hold period when measurements had largely stabilized.

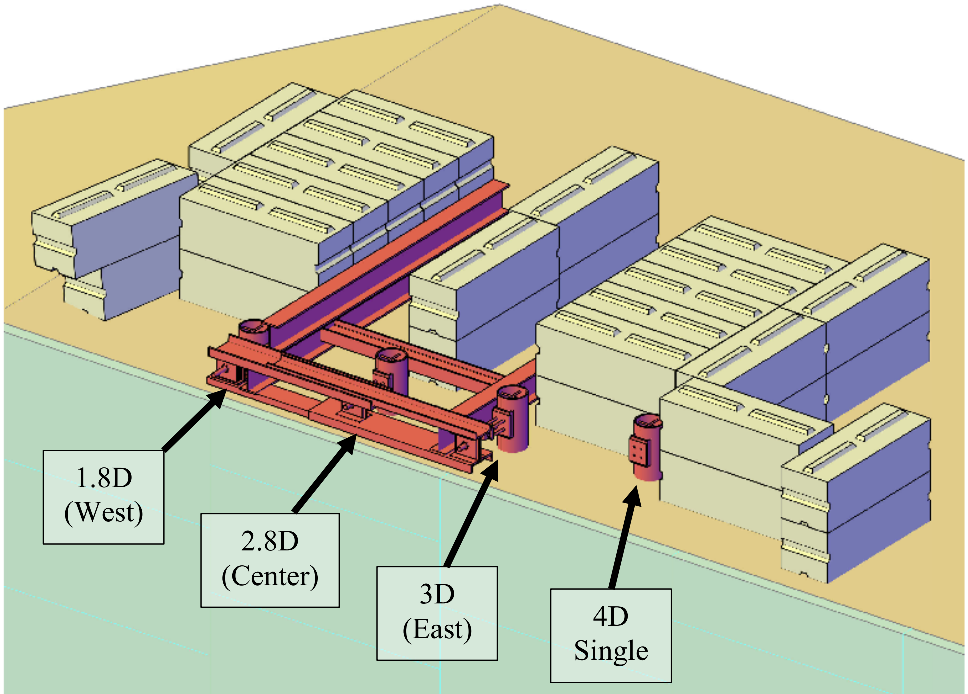

Fig. 1: Three-dimensional rendering of piles and load frame for pile group test.

Fig. 2: Grouped test loading system.

Fig. 3 shows the pile head load versus pile head displacements observed during the grouped and single pile tests. As expected, the pile furthest from the wall—the 4D single pile—exhibited the stiffest response. However, the grouped piles responses were somewhat unexpected. The pile closest to the wall—the 1.8D (West) pile—was observed to deflect under load similarly to the grouped pile furthest from the wall—the 3D (East) pile—until deflections greater than about 1.75-inches. It is unclear whether the similar responses of the two piles were due to pile group effects or to differences in compaction of the backfill.

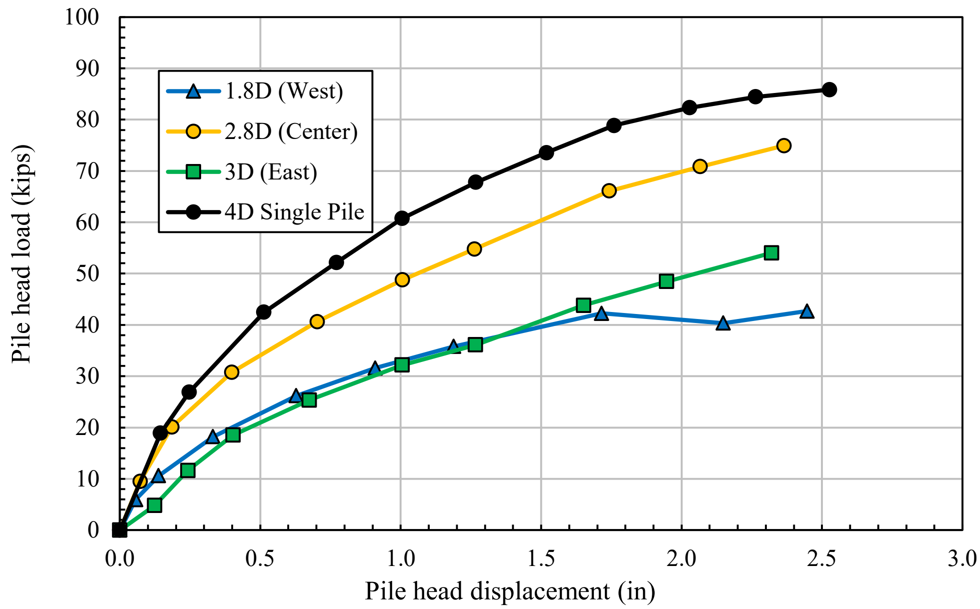

Fig 3: Observed pile head load versus pile head displacement.

The pile placed in the center of the group—the 2.8D (Center) pile—exhibited a significantly stiffer response than either pile on an outside edge. This is in contrast to full-scale testing of grouped pile arrays placed in normal soil without soil reinforcement or a nearby retaining wall, where the piles placed on the edges of the row typically carried loads equal to or sometimes greater than those carried by the piles in the middle of the rows. However, this finding is in general keeping with the only other full-scale test performed on grouped piles near an MSE wall shown in Figure 4 (Pierson et al., 2009). All shafts in this figure were placed at 2 shaft-diameters from the wall face. Shaft B was tested individually and the other three were tested as a group. Shaft BG1 and BG3 were placed on the edges of the group and BG2 was placed in the center. Although the differences in lateral stiffness were not very pronounced between the grouped shafts, the shaft placed in the center, BG2, did exhibit somewhat greater stiffness than the two outside shafts for much of the test.

We modeled the test results from the single and grouped test piles in this study with the finite-difference program LPILE for analysis and selection of appropriate p-multipliers. Soil properties were initially calibrated using the pile head load versus displacement curve of the pile furthest from the wall, the 4D single pile. Reduction in lateral resistance of the soil for the grouped piles was modeled using p-multipliers, back calculated for each pile that best fit the measured pile head load versus pile head deflection data. Fig. 5 shows the LPILE generated load-deflection curves with the appropriate p-multipliers compared with the observed test data.

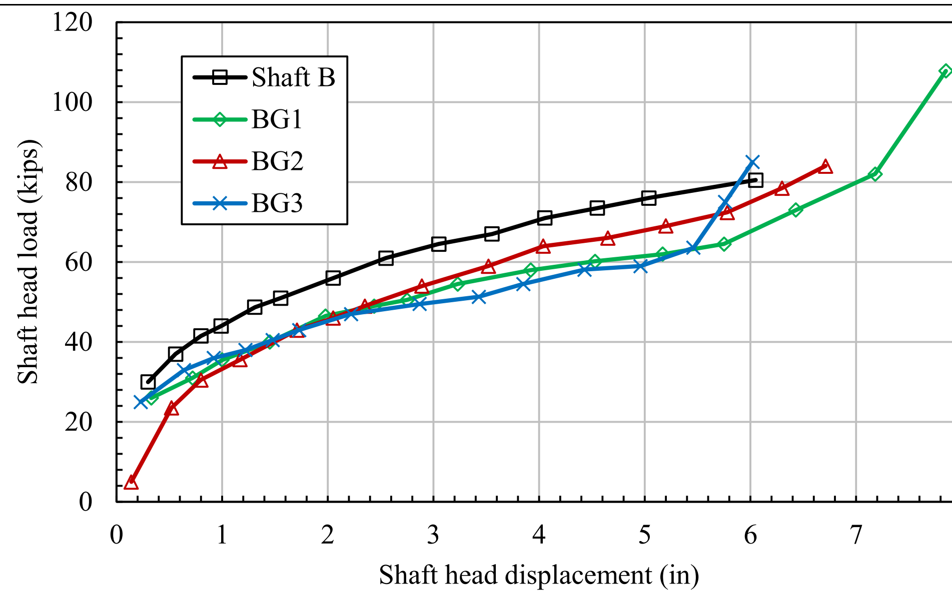

Figure 4: Individual and grouped shaft lateral responses from Pierson et al. (2009).

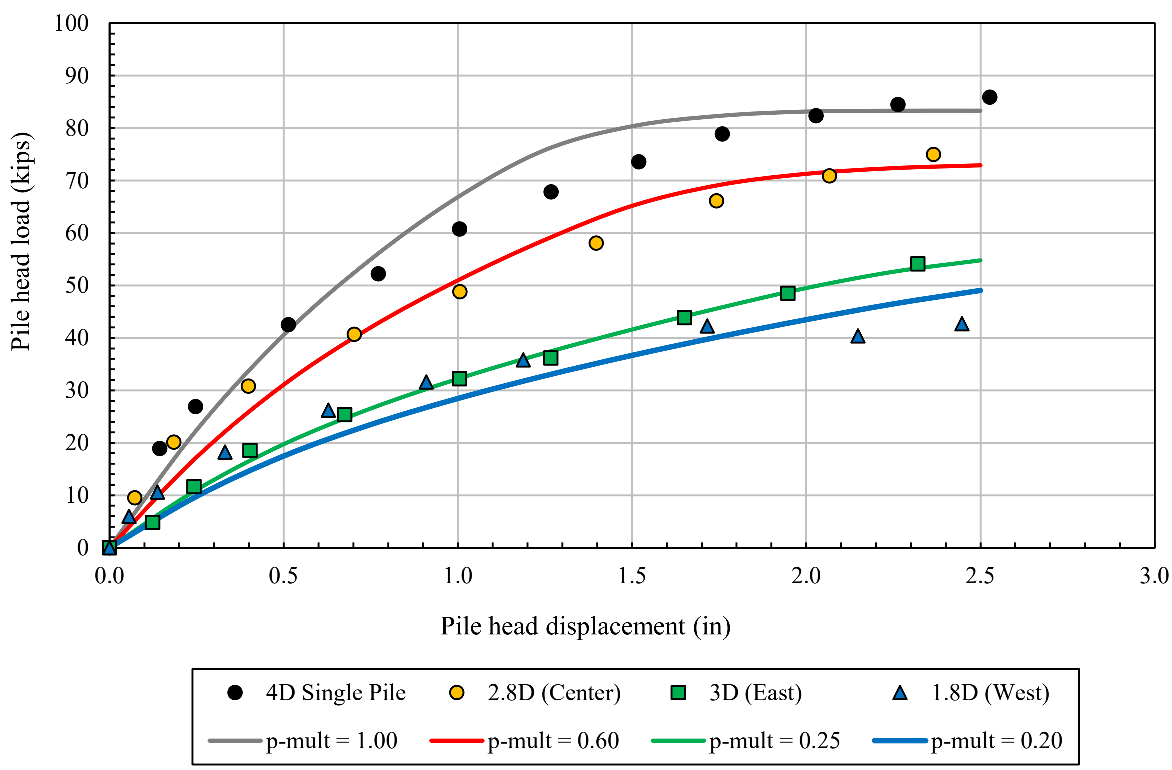

Fig. 5: Comparison of the pile head load versus pile head displacement for all test piles and LPILE analyses.

The p-multipliers for each grouped pile and the group average is compared with the single pile tests from previous studies in Fig. 6. The most recent regression equation for p-multipliers based on relative distance from the wall is also plotted in Fig. 6. Expected p-multipliers from this regression equation is 0.72, 0.66, and 0.34 for the 3D (East), 2.8D (Center), and 1.8D (West) piles, respectively. Actual, back-calculated p-multipliers for these piles were 0.32, 0.60, and

0.20. The actual p-multipliers for each grouped pile was below the regression line, though only the 3D (East) pile p-multiplier falls significantly lower than was typically observed in previous tests.

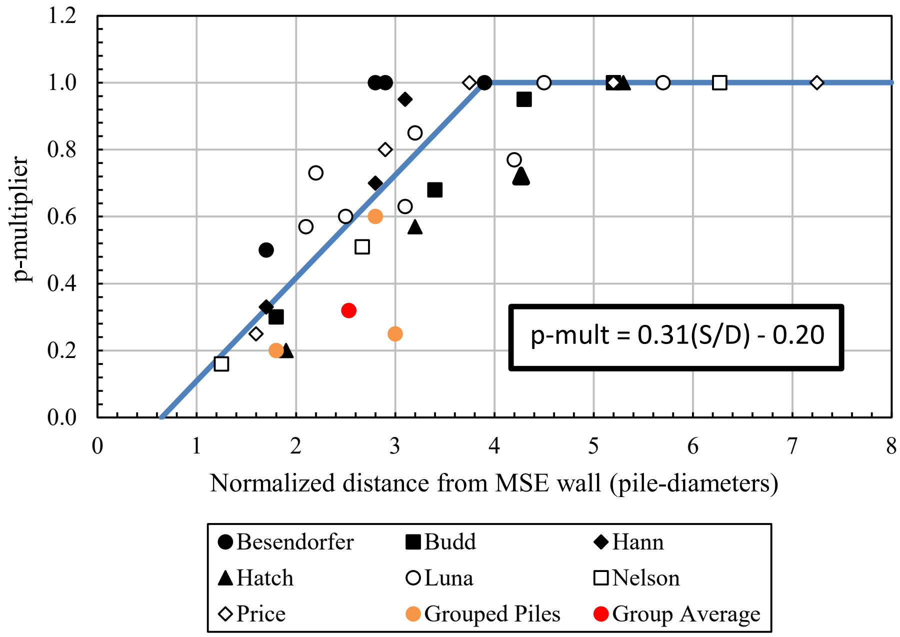

Fig. 6: P-multiplier versus normalized distance from MSE wall.

It is proposed that in addition to the loss of lateral resistance due to the proximity of the wall, the piles in this test experienced an additional loss of lateral, resistance due to group effects. Therefore, the total p-multiplier for piles in the group near the wall, $(P_m)_{group}$, would be given by Eq. 1,

$$(P_m)_{total} = (P_m)_{group} * (P_m)_{wall} \quad \textbf{(1)}$$

where $(P_m)_{group}$ = the group effect p-multiplier, and $(P_m)_{wall}$ = the pile-to-wall spacing p-multiplier.

No side to side group interaction would be expected due to typical group interaction effects in this case because the piles are spaced about 4.7 pile diameters apart transverse to the loading. Nevertheless, the group of three piles are applying load, in many cases, to the same set of reinforcement strips that would normally carry load for only a single pile in previous single pile tests. If the p-multiplier associated with the pile position relative to the wall for each pile is assumed to be that calculated by the regression equation shown in Fig. 6, then the group effect p-multipliers are 0.35, 0.91, and 0.59 for the 3D, 2.8D, and 1.8D piles, respectively, to satisfy equation 1. This amounts to an average group p-multiplier of 0.62 for the three piles in the group.

Because this average p-multiplier for pile groups behind an MSE wall is the only value available, it is not possible at this point to determine how reasonable this value might be. If, for example, the pile at 3D on the west side of the pile group carried a load equal to the pile in the center of the group, then the group p-multiplier would be equal to 0.80. Because of the lack of pile group load tests behind an MSE wall, we are also planning to use LPILE to back-calculate the pile group p-multiplier for the drilled shaft group test in Kansas. Preliminary analyses to this point indicate a group p-multiplier of about 0.78, which is on the high end of the possible range of group p-multipliers from the test in this study.

References

Pierson, M., Parsons, R.L., Han, J., Brown, D.A. and Thompson, W.R. (2009). “Capacity of Laterally Loaded Shafts Constructed Behind the Face of a Mechanically Stabilized Earth Block Wall” Kansas Department of Transportation, K-TRAN: KU-07-6.

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.

Potential Implementation: