Memo

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From: Kyle Rollins, Prof. Civil & Environ. Engrg. Dept., 430 EB, email: rollinsk@byu.edu
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Re: Task 7 Memo reporting completion of lateral pile group load test.

We have completed the lateral group load test at the dedicated MSE wall test site and much of the analysis associated with the test results. 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. Ideally, all the piles would be located at the same distance behind the wall, but it was not possible to extract the test pile at 1.8 pile-diameters and insert another test pile without severely compromising the test results. Therefore, this geometry was the best that could be done given the situation. 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. 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.

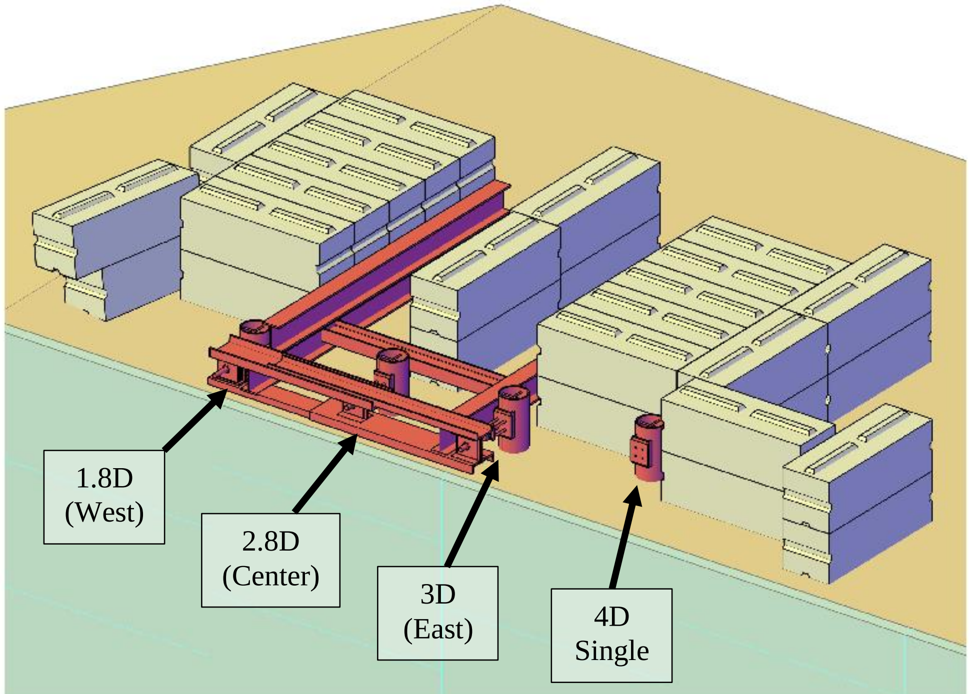

Fig. 1: Three-dimensional rendering of piles and load frame for pile group test.

Fig. 2: Grouped test loading system.

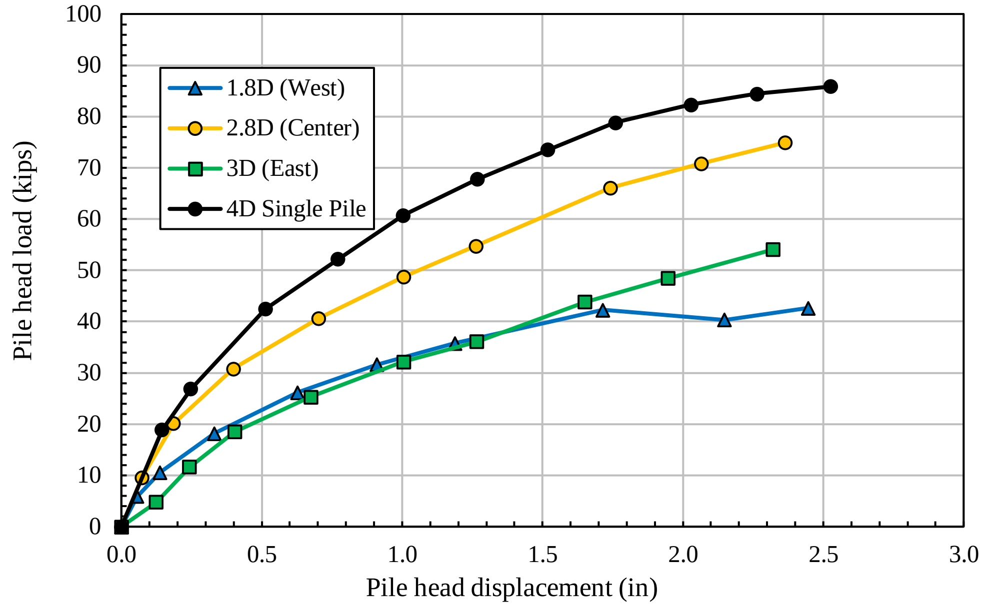

Fig 3: Observed pile head load versus pile head displacement.

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.

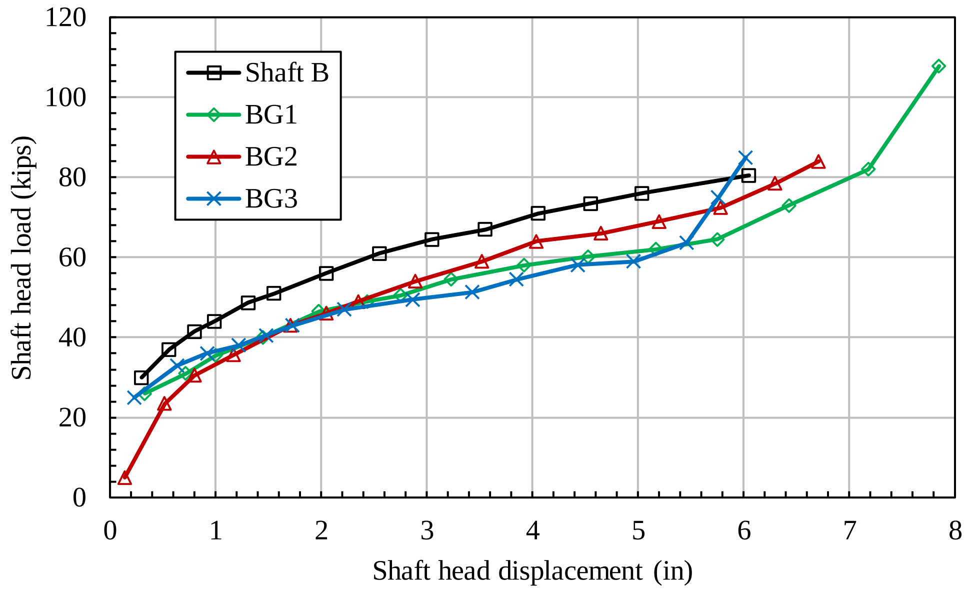

Figure 4: Individual and grouped shaft lateral responses from Pierson et al. (2009).

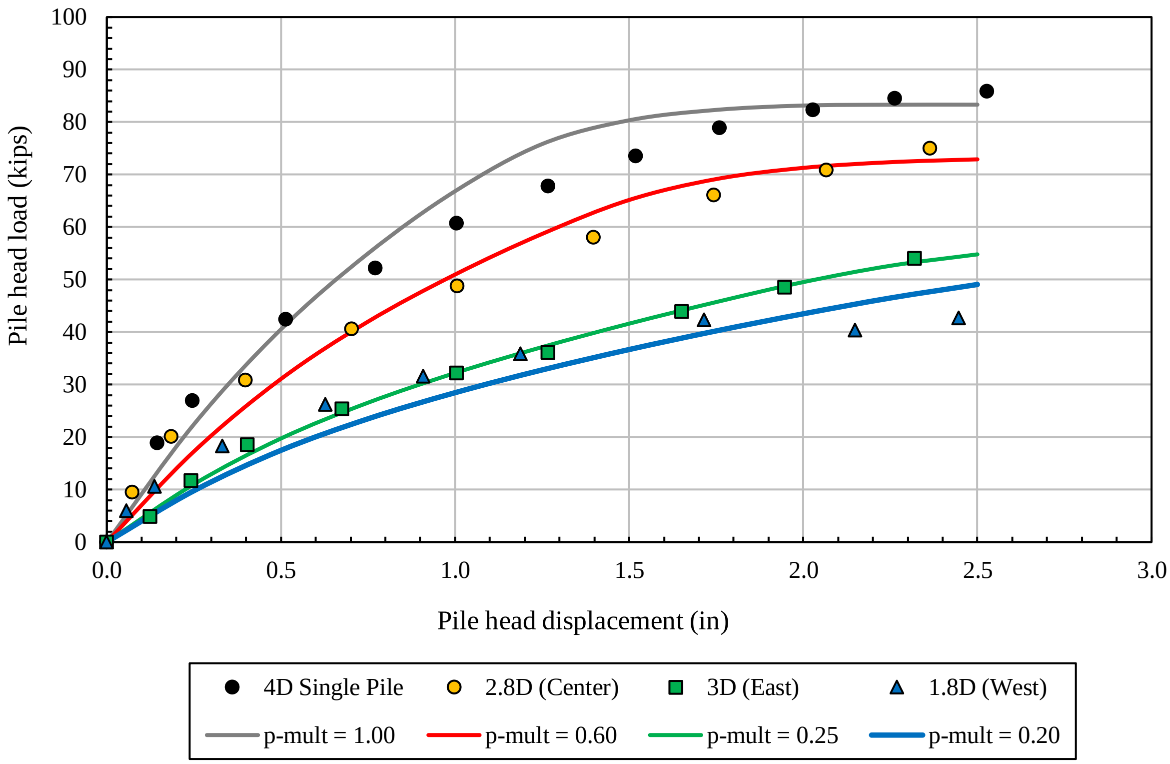

Fig. 5: Comparison of the pile head load versus pile head displacement for all test piles and LPILE analyses.

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 0.25, 0.60, and 0.25. 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.

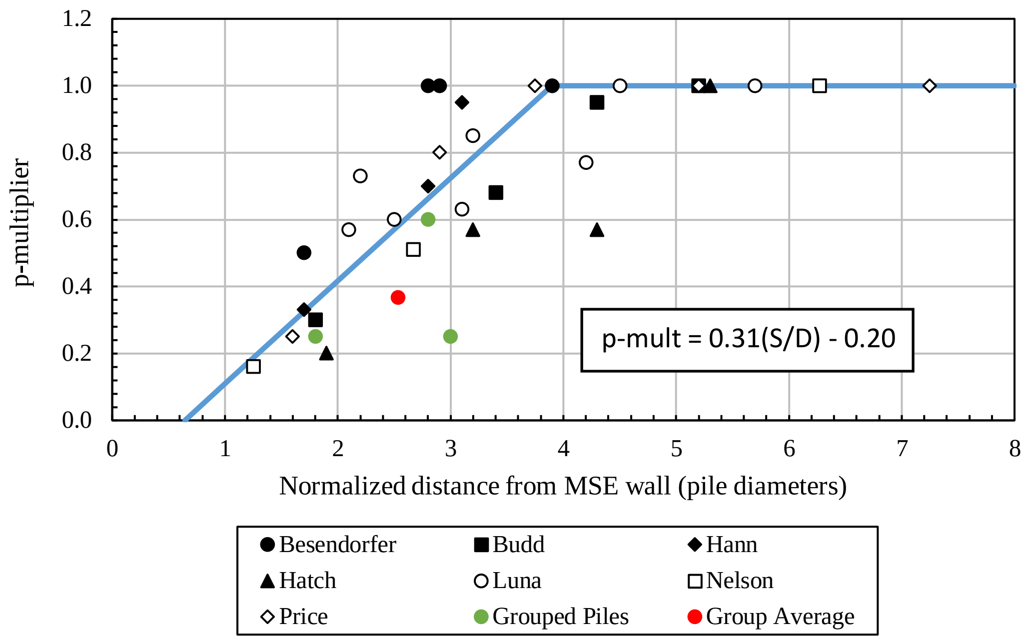

Fig. 6: P-multiplier versus normalized distance from MSE wall.

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 0.74 for the 3D, 2.8D, and 1.8D piles, respectively, to satisfy equation 1. This amounts to an average group p-multiplier of 0.66 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.