

# Comparing the Response of Static Loading Tests on Two Model Pile Groups in Soft Clay

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**Abstract** Static load test program was performed on a single pile and two 16-pile groups with equal and different pile lengths. The soil profile consists of sand fill to 0.5 m depth placed on a thick deposit of soft, normally consolidated and compressible clay. The closed end steel pipe piles in 60 mm diameter were installed from 1.5 m through 2.1 m depth within soft clay deposit. The center-to-center distance of piles in group is about 3 times of pile diameter. The strain gages were installed at one level above and two through four levels below ground surface. Tests were carried out about 7 days after driving by method of a

series of load increments placed every 5-min until plunging failure occurred. The load at plunging failure for the single pile, the equal-length pile group and the different-length pile group were about 3, 40 and 48 kN, respectively. The movements at start of failure were about 12, 18, and 17 mm, respectively. The analysis of strain gage measurements indicates that the load distribution on piles in the different-length pile group has become significantly uniform.

**Keywords** Different-length pile group · Equal-length pile group · Static load test · Load-movement curves

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## 1 Introduction

Research during past four to five decades has proved piled raft foundation to be one of the cost-effective solutions to the problem of controlling total and differential settlement of the low-rise buildings and light structures constructed in the soft soil regions (Burland et al. 1977; Poulos and Davis 1980; Padfield and Sharrock 1983; Hansbo and Jendebly 1983; Hansbo 1984; Cooke 1986; Randolph 1994; Horikoshi and Randolph 1996; Fellenius 2016). Conventionally, piles of the piled raft foundation are often designed with uniform lengths. However, recent studies have shown that using non-uniform piles are more suitable for controlling settlement of foundations (Poulos

2001; Liew et al. 2002; Tan et al. 2004b, 2005; Chow and Small 2005; Katzenbach et al. 2016).

To improve the working of pile group, many theoretical studies were made on the pile group and piled rafts with the different lengths and locations using the optimization technique (Chow and Thevendran 1987; Leung et al. 2010). Their analysis demonstrated that it is possible to optimize pile groups with rigid caps to reduce (to almost zero) the variation of load being shared between piles, while controlling the overall settlements of the groups. The pile groups were also optimized with regards to the differential settlements, which theoretically could be zero, when the pile caps are flexible. Moreover, an optimal pile arrangement scheme was able to minimize the differential settlements and bending moments of piled raft foundations (Kim et al. 2001). However, these authors have dealt only with some theoretical aspects of pile group optimization and the practical aspects of construction have not been considered.

This paper presents the results of static loading tests performed on a single pile and on two groups, each made up of 16 piles, one with equal and other with differing pile lengths. The soil profile consisted of sand fill to 0.5 m depth placed on a thick deposit of soft, normally consolidated, compressible clay. The single pile and the piles of the equal-length group were driven to 1.8 m depth. For different-length pile group, four corner piles had been driven to 1.5 m, eight edge piles to 1.8 m and four center piles to 2.1 m depth. The entire model piles were 60-mm diameter steel pipe piles and the center-to-center distance of piles in both group were 3 times the pile diameter. The single pile and the three piles of each group were equipped with strain gages. All instrumented piles had one gage level placed above the ground surface and two gage levels at depths of 0.7 and 1.5 m. The 1.8 m long piles had one additional gage level at 1.8 and the 2.1 m long piles had two additional gage levels at 1.8 and 2.1 m. The strain-gage evaluations, distributions of load and shaft resistance, and correlations derived from the results of the tests with respect to the site conditions are presented.

## 2 Soil Conditions

The soil profile consists of sand fill to 0.5 m depth underlain by organic soft clay with 80% water content

that was about 15% larger than the liquid limit. The plastic limit was 40%. The clay and silt size fractions were 50% and 45%, respectively. The pore pressure distribution is hydrostatic and corresponds to a groundwater table at 1.0 m depth below the ground surface. The average saturated density of the soft clay was 1490 kg/m<sup>3</sup>. Table 1 shows the properties of soil at depths of 1.6, 3.6 and 5.6 m below the elevation of ground surface. Figure 1 shows the measured distribution of cone stress ( $q_t$ ), sleeve friction ( $f_s$ ), pore pressure ( $U_2$ ), and soil classification from CPTU sounding pushed close to the test pile locations.

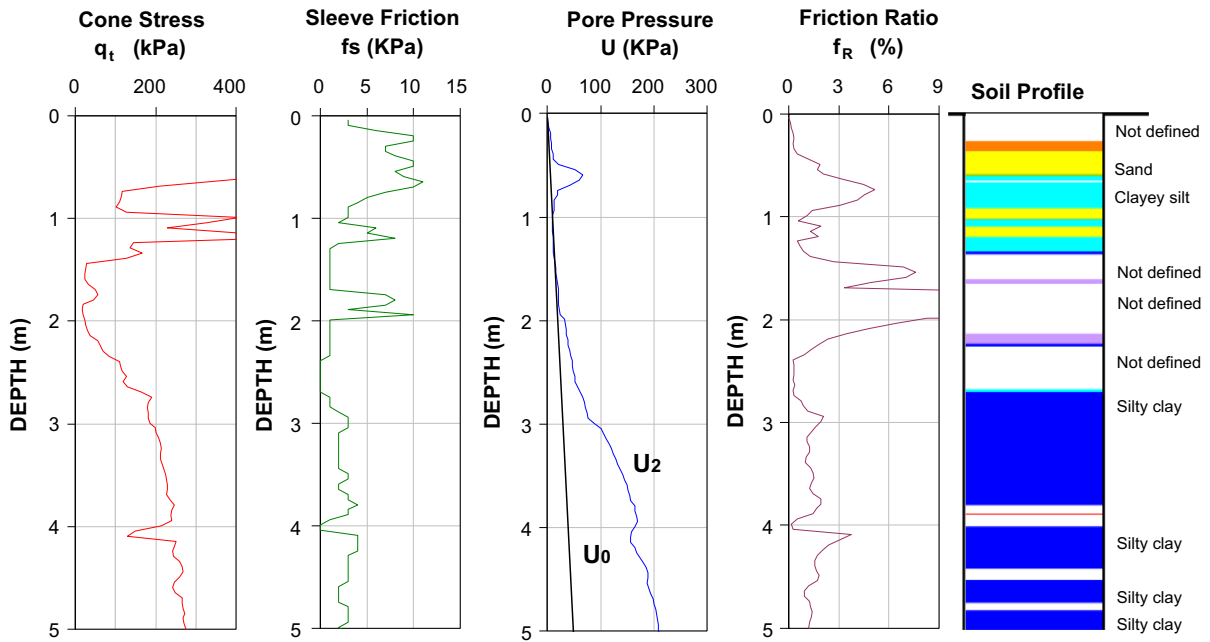
## 3 Pile Installation

A single pile and two groups each consisting of 16 piles was installed into 1.5 m through 2.1 m depth below ground surface to serve the static load as shown in Fig. 2. All of the closed-toe steel pipe piles have the same diameter and thickness of 60 and 5 mm, respectively. Distance between two pile groups is about 13 m and distance from the single pile to the pile groups is about 8 m. The single pile had strain gages attached at four levels and was driven to 1.8 m depth on October 03, 2015 as shown in Fig. 3 (1.8 m pile). At the same time, the equal-length pile group was installed to 1.8 m depth. The centre-to-centre spacing of the piles is three times of pile diameter. Three of sixteen piles were attached by strain gages at the four levels as indicated in the right diagram of Fig. 2 and Fig. 3 (1.8 m Pile). The different-length pile group was pushed to depth of 1.5 m through 2.1 m on October 18, 2015. At this pile group, the strain gages were attached at three, four and five levels for the piles in lengths of 1.5, 1.8 and 2.1 m, respectively, as found in the right diagram of Figs. 2 and 3. It should be noted that all of the instrumented piles have had a strain gage level above ground surface to measure the load distribution from rigid caps during loading.

Figure 4 shows the installation of 16-pile groups and the set-up of kentledge system. To ensure the centre-to-centre spacing of the piles, a steel plate 25 mm in thickness was manufactured with 16 attached steel tubes having diameter of 67 mm and length of 200 mm, to guide the piles during driving. Before installing piles, the fill sand layers of 0.5 m thickness were removed. Moreover, the rigid caps were also built by three square steel plates having

**Table 1** Soil Parameters

| Items                              |                   | Depth below original ground surface |       |       |
|------------------------------------|-------------------|-------------------------------------|-------|-------|
|                                    |                   | 1.6 m                               | 3.6 m | 5.6 m |
| Water content ( $W_n$ )            | %                 | 81                                  | 89    | 86    |
| Saturated density ( $\rho_{sat}$ ) | kN/m <sup>3</sup> | 14.8                                | 14.6  | 14.5  |
| Void ratio ( $e_0$ )               | –                 | 2.18                                | 2.37  | 2.32  |
| Liquid limit (LL)                  | %                 | 75.8                                | 76.3  | 70.8  |
| Plastic limit (PL)                 | %                 | 42.4                                | 45.2  | 39.6  |
| Clay fraction                      | %                 | 49.3                                | 56.7  | 48.8  |
| Silt fraction                      | %                 | 44.3                                | 36.3  | 50.3  |
| Sand fraction                      | %                 | 6.4                                 | 7.0   | 0.9   |
| Friction angle ( $\phi$ )          | (°)               | 2°39'                               | 1°43' | 2°17' |
| Cohesion (c)                       | kPa               | 6.9                                 | 5.9   | 7.8   |
| SPT index range                    | bl/0.3 m          | 0                                   | 0     | 0     |



**Fig. 1** CPTU diagrams near the test pile locations

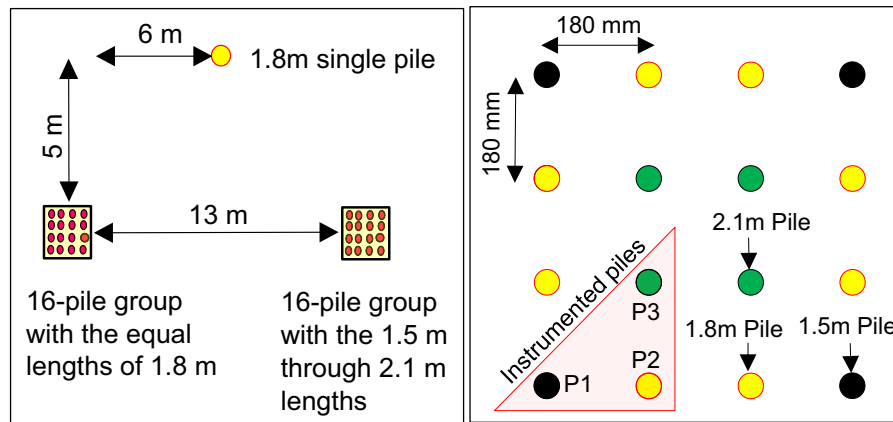
0.5 m thru 0.8 m diameter and 12 mm of thickness for each to serve for the static load test of the pile groups.

**4 Static Loading Test Programme**

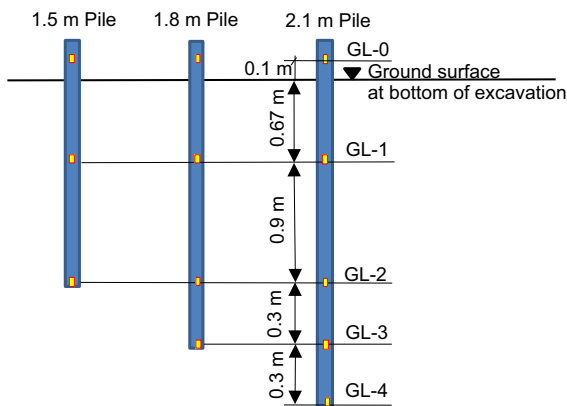
A static loading test programme was carried out on October 11 through 25, 2015. Eight days after completing the pile installation, testing of the equal-length pile group was performed in two cycles. The

loading of cycle 1 and 2 was executed in 11 through 10 increment levels to reach the maximum load of about 24 through 40 kN and the unloading was done in 6 through 10 steps, respectively. Each of loading increment was about 2 and 4 kN for cycle 1 and 2 respectively, which was held constant for 5 min.

The single pile and different-length pile group were tested in one cycle on October 11 and 25, 2015, respectively. Loading and unloading of both the single pile and the different-length pile group were carried



**Fig. 2** Layout of the pile groups and single pile



**Fig. 3** Details of the instrumented piles

out in 12 and 8 steps until obtaining the maximum load of 3.2 and 48.3 kN, respectively. Moreover, each of load increment was about 0.4 and 4.0 kN, respectively, and was also held constant for 5 min; similar to the equal-length pile group.

## 5 Static Loading Test Programme

### 5.1 Load Versus Movement

Figure 5 shows the measured load-movement curves of single pile and two pile groups. All tests were done until reaching the plunging failures. The maximum load and movement of single pile measured were about 3.2 kN and 14.3 mm as displayed in the right diagram, respectively. At the plunging failures, the maximum loads and movements of the equal-length

and different-length pile groups were about 40.2 through 48.3 kN and 22.5 through 22.3 mm, respectively, as indicated in the left diagrams.

The measurements showed that the capacity of the different-length pile group was greater than the equal-length pile group by approximately 20% at movement of approximately 18 mm. Moreover, the load-movement curve of the different-length pile group became stiffer than that of the equal-length pile group and was clearly manifested from the initial left portion of the diagrams. It should be noticed that the slope of the load-movement curve of the different-length pile group became softer after load increment of about 32 kN; whereas, the curve of the equal-length group had a relatively dramatic change of slope after load increment of about 20 kN.

Another important point is that the slope of both curves has become similar beyond load increment of 20 and 32 kN for the equal and different length group, respectively. It appears that the following load increments of 20 and 32 kN have been transferred into the pile toe because the shaft resistances are often mobilized fully at the small movements, about 4 mm (Fellenius and Nguyen 2013; Nguyen and Fellenius 2014). Therefore, the most significant difference of both groups is the mobilized shaft resistances and this implies that the soil resistance at location of the different-length group is possibly better or the fill sand at this location has not been removed completely.

In addition, the cycled loading test on the equal-length pile group has probably influenced the pile capacity; however, it appears that this influence is not significant because beyond the maximum load level of



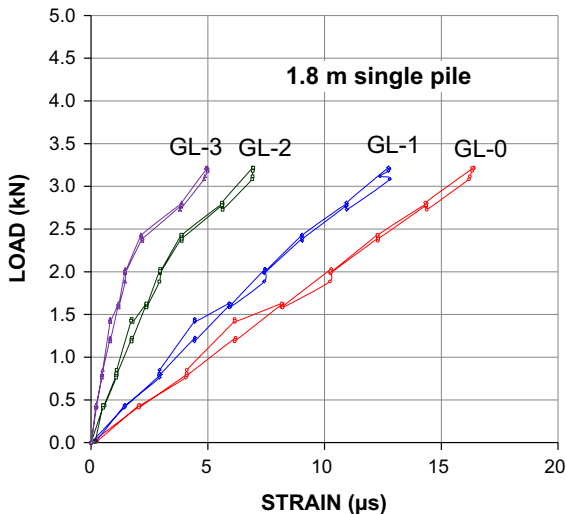
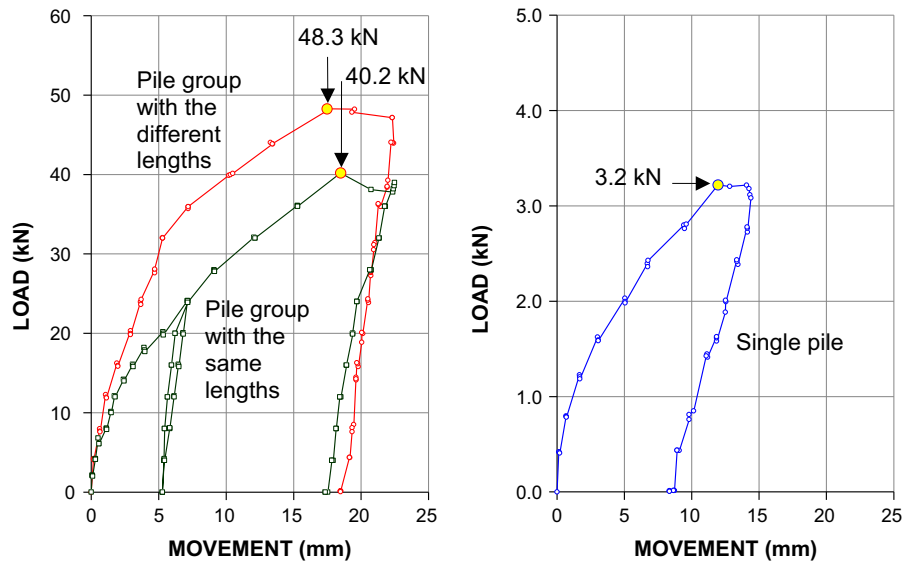
**Fig. 4** Installation and test of the pile groups: **a** installation of 16-pile group, **b** Construction of rigid cap and **c** Set-up of kentledge system (Authors' photo)

cycle 1, the load-movement curve of cycle 2 has become similar to the load-movement curve of cycle 1. If correlated to the capacity of the single pile, the group efficiency factors are about 0.78 and 0.94 for the equal-length and different-length pile groups, respectively. Additionally, the movements to mobilize fully the capacity of pile groups are greater than of single pile by approximately 50%.

## 5.2 Load Versus Strain

The strain gage records of the static loading tests on single pile and the pile groups are presented in Fig. 6 thru 8. It is surprising to see that there was no residual strain remaining along the pile shafts after unloading. This is rarely found in the test results of full-scale instrumented piles. It seems that no presence of the

**Fig. 5** Load-movement curves of single pile and pile groups



**Fig. 6** Load-strain curves of single pile

residual strains along pile shafts after unload is because the elasticity of pile material is greater than the resistances of soil surrounding piles. Therefore, the influences from the cycled loading test on the equal-length pile group were not significant for the recorded strain gage data and it can be ignored in the analysis (Fig. 7).

In addition, although all the three tests reached plunging failures, the maximum strains recorded were relatively small, about 16  $\mu$ s. All of the load-strain curves are relatively linear, except at gage levels GL-2 and GL-3 of single pile.

It is noted that the load-strain curves of single pile measured at the strain gage levels GL-2 and GL-3 show a slope change after the loading increment of 2.4 kN as can be seen in Fig. 8. It is likely that the shaft resistances were mobilized fully after loading increment of 2.5 kN. Note that Piles P1, P2 and P3 are corner pile, edge pile and center pile in each pile group, respectively.

## 6 Analysis

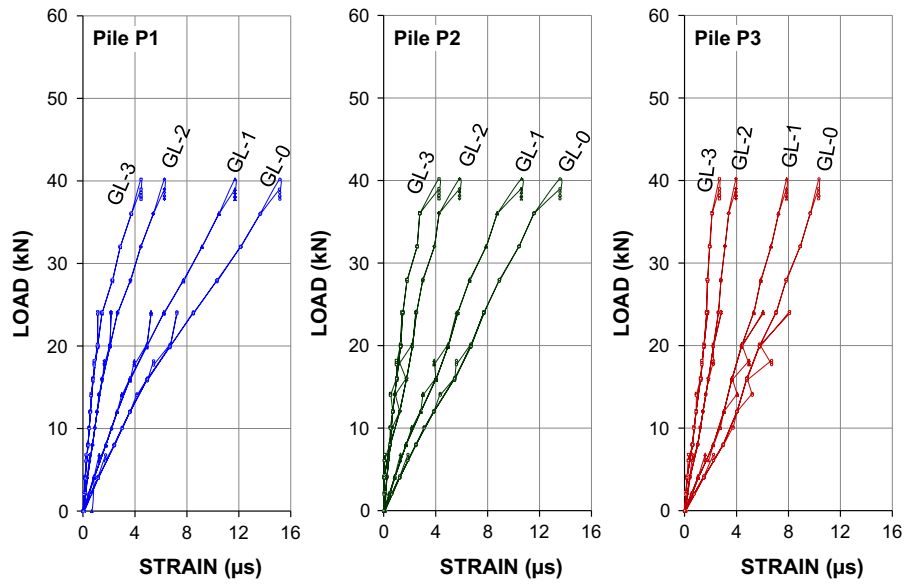
To convert strains measured by strain gages into the values of load, it is necessary to know modulus of the pile material. Tensile tests conducted on three samples of pile material showed an average elastic modulus value of about 225 GPa.

### 6.1 Single Pile

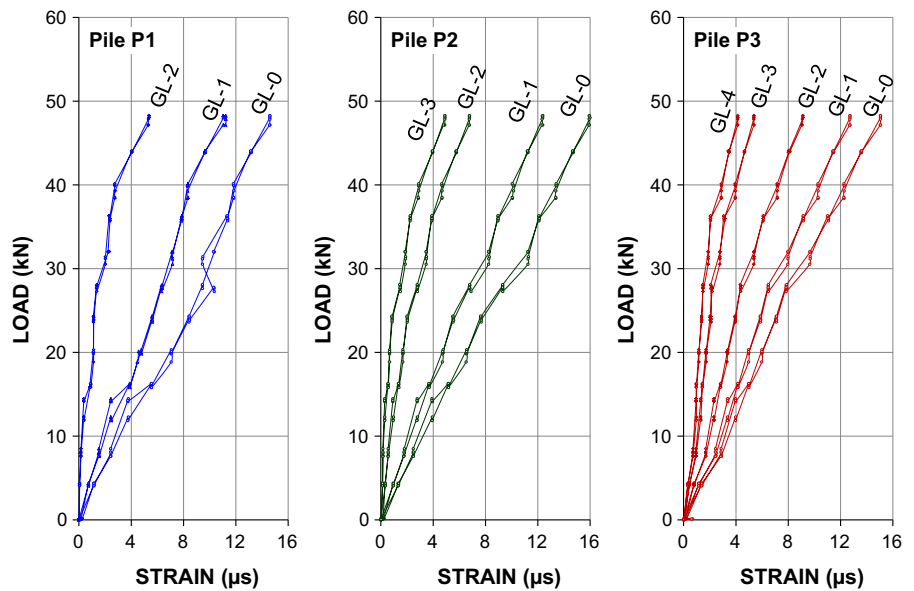
Figure 9 represents the unit shaft resistances versus movements and load distribution versus depths of single pile. The left diagram shows that the maximum unit shaft resistances were about 5.6 kN for the gage level GL0-GL1 and 6.7 kN for both levels GL1-GL2 and GL2-GL3, all at movements of about 12 mm.

The right diagrams display the load distribution versus depths. The maximum load at the pile head was about 3.2 kN and then decreased linearly into 1.0 kN at 1.8 m depth below the ground surface. The shaft and

**Fig. 7** Load-strain curves of equal-length pile group



**Fig. 8** Load-strain curves of different-length pile group



toe resistances of the tested pile were about 2.2 and 1.0 kN, respectively.

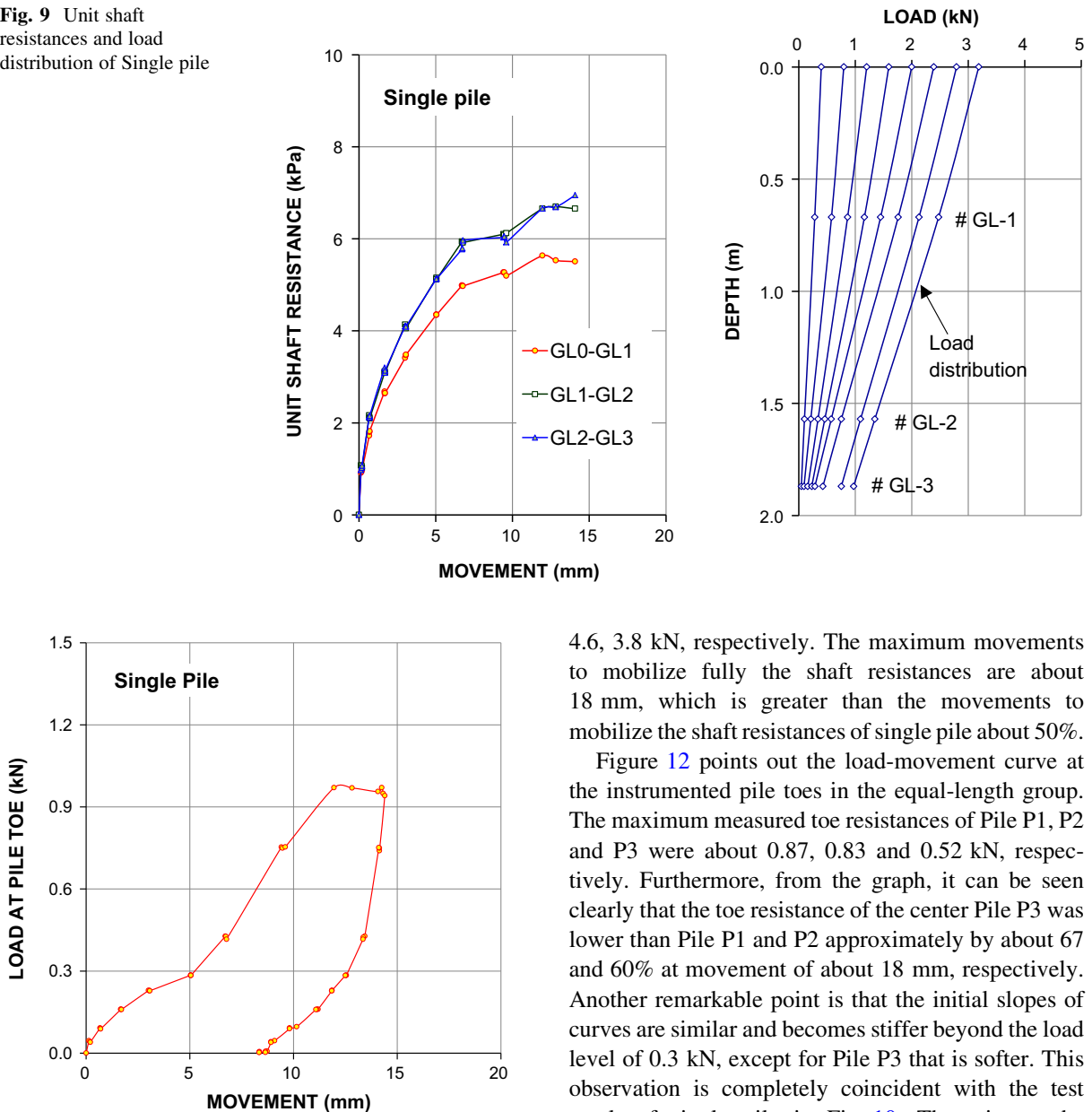
Figure 10 shows the load-movement curve at pile toe of single pile. It can be seen clearly from the diagram that when the load started transferring into pile toe on reaching the load level of 0.3 kN, the slope of the curve reduced gradually and became significantly steeper. After loading of 0.3 kN, the slope of curve had remained steady until reaching a maximum value of about 1.0 kN at movement of 12 mm. It is

likely that the initially low toe resistances were because the soil below the pile toes was disturbed by the pile installation. It is noted that the elastic shortening of the pile material has been ignored in this case due to insignificant length of pile.

## 6.2 Equal-Length Pile Group

Figure 11 provides the unit shaft resistances versus movements of three instrumented piles in the equal-

**Fig. 9** Unit shaft resistances and load distribution of Single pile



**Fig. 10** Load at pile toe-movement curve of single pile

length pile group. The striking observation emerged from the diagrams is that the unit shaft resistances at the gage levels GL1 thru GL2 is similar to the GL2 thru GL3 for all piles. The maximum unit shaft resistances at these gage levels were approximately 6.2, 5.4, and 4.5 kN for Pile P1, P2 and P3, respectively.

At the gage levels from GL0 to GL1 of these piles, the maximum unit shaft resistances were about 5.3,

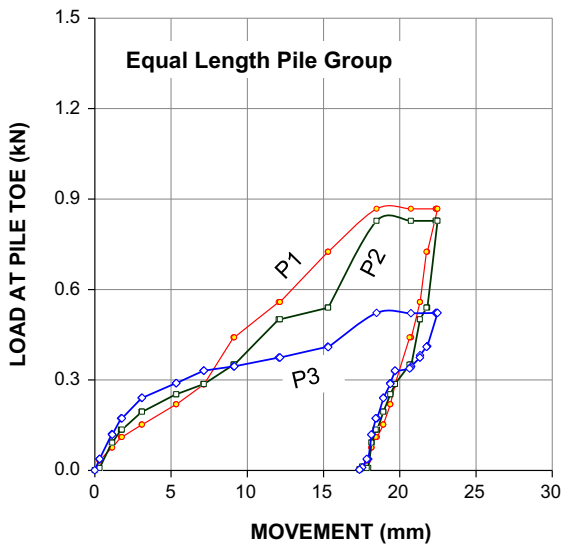
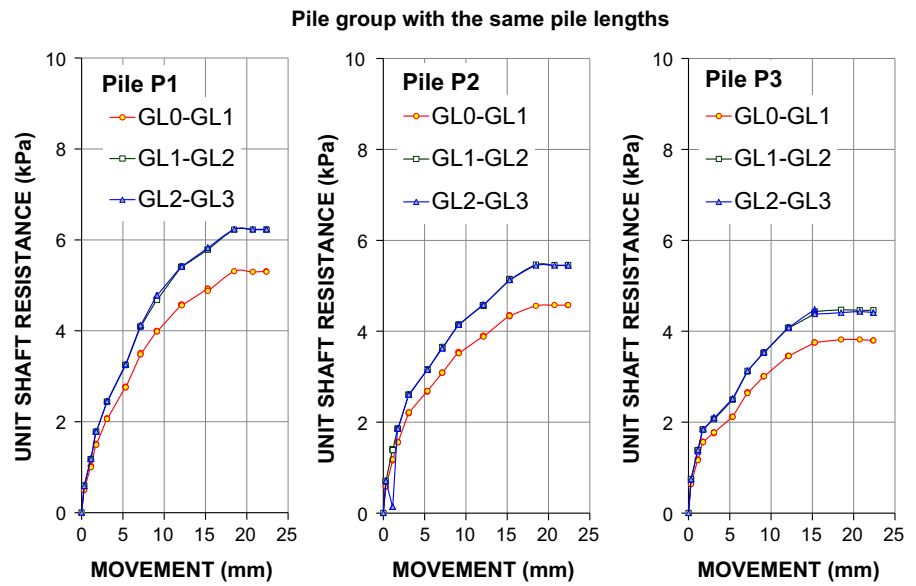
4.6, 3.8 kN, respectively. The maximum movements to mobilize fully the shaft resistances are about 18 mm, which is greater than the movements to mobilize the shaft resistances of single pile about 50%.

Figure 12 points out the load-movement curve at the instrumented pile toes in the equal-length group. The maximum measured toe resistances of Pile P1, P2 and P3 were about 0.87, 0.83 and 0.52 kN, respectively. Furthermore, from the graph, it can be seen clearly that the toe resistance of the center Pile P3 was lower than Pile P1 and P2 approximately by about 67 and 60% at movement of about 18 mm, respectively. Another remarkable point is that the initial slopes of curves are similar and becomes stiffer beyond the load level of 0.3 kN, except for Pile P3 that is softer. This observation is completely coincident with the test result of single pile in Fig. 10. Thus, it can be concluded that the toe resistances of this group were influenced by disturbance of soil during pile installation.

Figure 13 displays the load distribution curves versus depth of single pile and three instrumented piles in the equal-length pile group. It is interesting to find that the load distribution on Pile head P1 (Corner pile) is greater than Pile head P2 (Edge pile) and Pile head P3 (Center pile) by about 10 and 31%, respectively. Moreover, the load transfers of tested pile versus depth are relatively linear. These test results are in



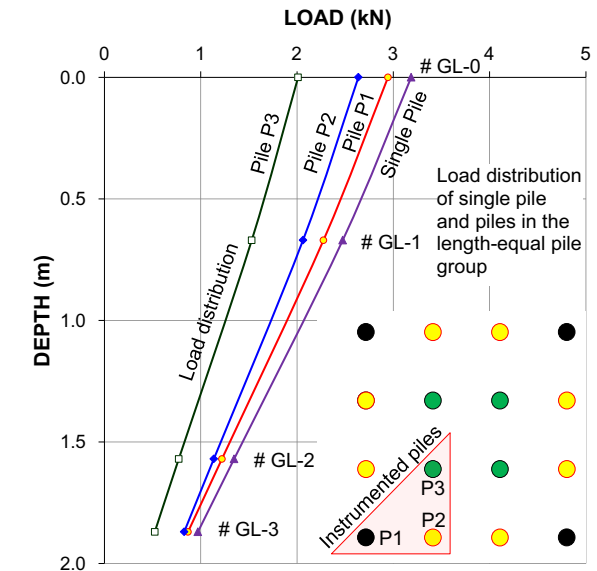
**Fig. 11** Unit shaft resistances of the equal-length pile group



**Fig. 12** Load-movement curves at pile toe of the equal-length pile group

agreement with the test results reported by O’Neill et al. (1981).

The load distribution curve of single pile was also added into the load distribution curves of the instrumented piles in pile group to show the capacity efficiency of piles acting in pile group in comparison with the measured capacity of single pile, which is often used for designing the piled foundations. These



**Fig. 13** Load distribution curves of single pile and three instrumented piles in the equal-length pile group

capacity efficiencies versus depths are presented in Table 2. The efficiencies of the total pile resistance were about 0.924, 0.828 and 0.631 for Pile P1, P2 and P3, respectively. The efficiencies of the shaft resistance were about 0.909, 0.727 and 0.682 for Pile P1, P2 and P3, respectively. The efficiencies of the toe resistance were about 0.894, 0.853 and 0.538 for Pile P1, P2 and P3, respectively.

**Table 2** Difference of load distribution between single pile and piles in the equal-length pile group

| Gage level | Load distribution (kN) |                     |     |     | Efficiency |       |       |
|------------|------------------------|---------------------|-----|-----|------------|-------|-------|
|            | Single pile            | Piles in pile group |     |     | P1         | P2    | P3    |
|            |                        | P1                  | P2  | P3  |            |       |       |
| GL0        | 3.2                    | 2.9                 | 2.6 | 2.0 | 0.924      | 0.828 | 0.631 |
| GL1        | 2.5                    | 2.3                 | 2.1 | 1.5 | 0.919      | 0.833 | 0.618 |
| GL2        | 1.3                    | 1.2                 | 1.1 | 0.8 | 0.906      | 0.843 | 0.573 |
| GL3        | 1.0                    | 0.9                 | 0.8 | 0.5 | 0.894      | 0.853 | 0.538 |
| Shaft      | 2.2                    | 2.0                 | 1.6 | 1.5 | 0.909      | 0.727 | 0.682 |

Efficiency at GL0 is the efficiency of the total pile resistance  
 Efficiency at GL3 is the efficiency of only pile toe resistance

### 6.3 Different-Length Pile Group

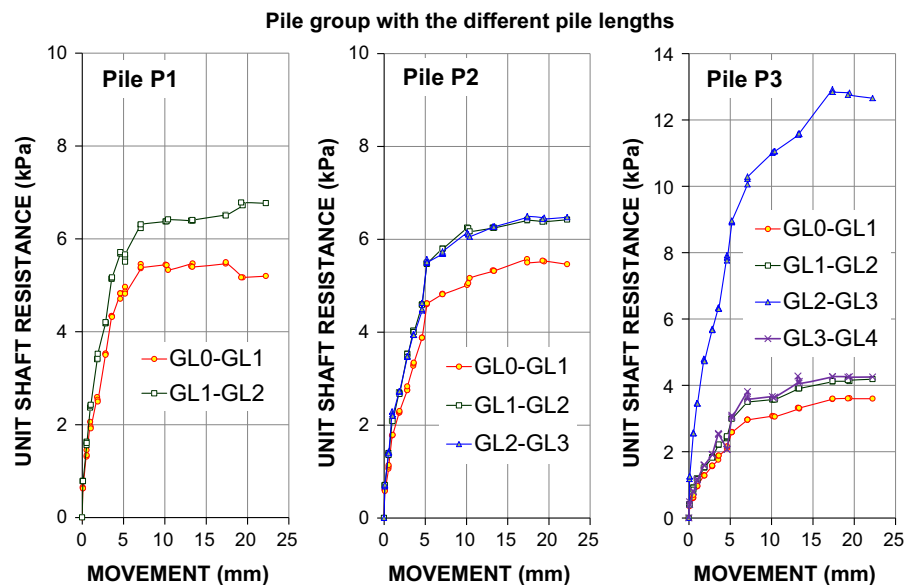
Figure 14 reports the unit shaft resistances versus movements of three instrumented piles in the different-length pile group. It is surprising to note that there were no significant differences of the unit shaft resistances between the Pile P1 and P2 as can be seen clearly in the left and middle diagrams. The maximum unit shaft resistances of both these piles are about 5.5 and 6.5 kN for gage levels from GL0 through GL1 and GL1 through GL2, respectively. It is noted that the unit shaft resistance of Pile P2 from the gage level GL1 through GL2 and GL2 through GL3 is similar.

For Pile P3, the unit shaft resistances are less than about 30 and 25% at the same gage levels of Pile P1,

respectively. Although, the soil profile is similar throughout the length of piles, the maximum unit shaft resistance of gage level GL2-GL3 is about 12.9 kN, which is greater than the different gage levels by about 3 times. However, the unit shaft resistances of Pile P3 at gage levels GL1-GL2 and GL3-GL4 is completely similar. It is apparent that the measurements of the shaft resistance at level GL2-GL3 have not reflected the actual condition of soil at the site.

The maximum movements to mobilize fully the shaft resistances of this pile group was about 10 mm, which is considerably less than the observed movements to mobilize fully the shaft resistances of the equal-length pile group, but equal to observed movements to mobilize the shaft resistances of single pile.

**Fig. 14** Unit shaft resistances of different-length pile group



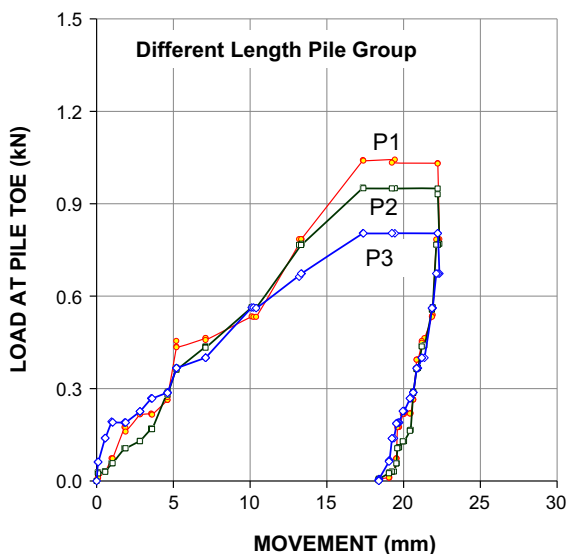
This implies that at the similar movements the capacity of the different-length pile group was greater than the equal-length pile group.

Figure 15 displays the load-movement curves at the instrumented pile toes in the different-length pile group. The maximum toe resistances of Piles P1, P2 and P3 are about 1.04, 0.95, and 0.80 kN, respectively. All the load-movement curves measured are relatively linear.

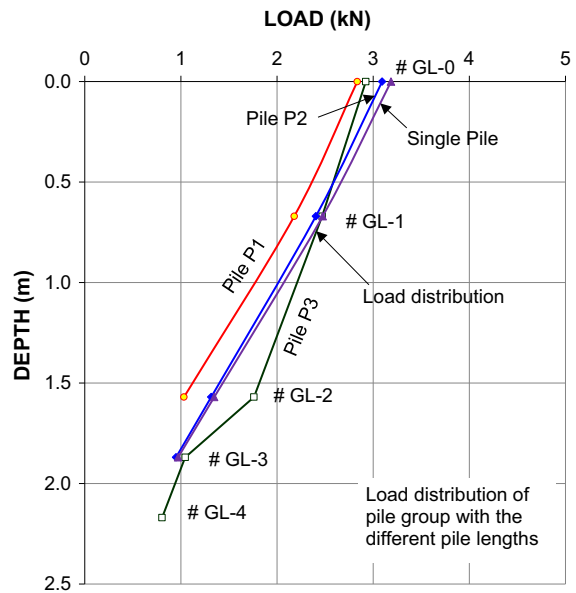
However, it is illogical that the maximum toe resistance of pile P1 was greater than P2 and P3 about 9% and 23% at movement of 17 mm, respectively, since length of this pile was shortest. Similar to Pile P1, Pile P2 was shorter than Pile P3, but its toe resistance was higher than Pile P3 about 16%. It is clear that system of piled raft is complicated and much additional work is required before a complete understanding can be reached for the different-length pile group.

Figure 16 plots the load distribution curves versus depth of single pile and three instrumented piles in the different-length pile group. Strong evidence of changing the pile lengths in a pile group was found when the load distribution from rigid cap into pile heads is nearly equal.

Also, it is important to note that the capacity and load distribution of the edge pile P2 is equal to the single pile through depth of the installed piles, which



**Fig. 15** Load at pile toe-movement curves of the different-length pile group



**Fig. 16** Load distribution curves of single pile and three instrumented piles in the different-length pile group

is greater than the capacity of the same pile in the equal-length group by about 17%. It is clear that the length change of the corner and center piles has improved the capacity of the edge piles in group and this has provided evident to demonstrate the capacity of the different-length pile group to be greater than of the equal-length pile group.

Nevertheless, the load distribution of the center pile P3 is significantly different with the other piles in group as shown in the graph (Fig. 16). The slope of load distribution curve is substantially steeper from gage level GL0 through GL2 and then has become softer below this depth to gage level GL3. Slope from gage level GL3 to GL4 is nearly similar to the remaining piles. Furthermore, even though the length of the center piles was extended up to 2.1 m, the capacity of these piles is still less than of the 1.8 m long edge piles.

The load distribution curve of single pile was also added into the load distribution curves of the instrumented piles in the different-length pile group to show the efficiencies of the unit shaft and toe resistances. The capacity efficiencies versus depths were presented in Table 3. The average unit shaft resistance efficiency of Pile P1 was about 0.95, while that of Pile P2 was equal to unit. The most significant difference was the unit shaft resistance of Pile P3. The average unit shaft

**Table 3** Difference of unit shaft and toe resistance between single pile and piles in the different-length pile group

| Gage level         | Unit shaft and toe resistance (kPa) |                                      |     |      | Efficiency |       |       |
|--------------------|-------------------------------------|--------------------------------------|-----|------|------------|-------|-------|
|                    | Single pile                         | Piles in different-length pile group |     |      | P1         | P2    | P3    |
|                    |                                     | P1                                   | P2  | P3   |            |       |       |
| Ground surface-GL1 | 5.5                                 | 5.2                                  | 5.5 | 3.6  | 0.945      | 1.000 | 0.655 |
| GL1-GL2            | 7.1                                 | 6.8                                  | 6.4 | 4.2  | 0.958      | 0.901 | 0.592 |
| GL2-GL3            | 5.3                                 | –                                    | 6.5 | 12.7 | –          | 1.226 | 2.400 |
| Toe                | 1.0                                 | 1.0                                  | 1.0 | 0.8  | 1.000      | 1.000 | 0.800 |

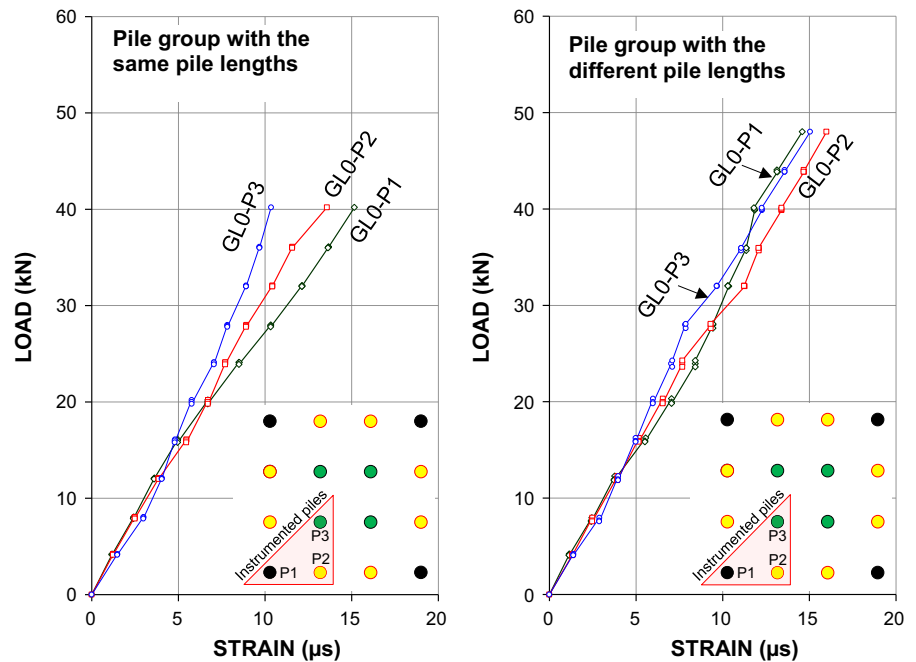
resistance efficiency of Pile P3 was about 0.59 for the pile segment from ground surface to to Gage level GL2. Below this depth to the pile toe level, the unit shaft resistance efficiency of Pile P3 was about 2.40. For the toe resistances, the efficiency was about 0.8 for Pile P3 and about 1.0 for both remaining piles, which reflected the soil conditions at the site as presented in Table 1.

### 6.4 Load Sharing Comparison of Piles in Pile Groups

Figure 17 shows a comparison of load sharing between piles in two pile groups during the loading increments applied via rigid caps. It can be seen from the left side diagram that the load distribution on pile heads of the equal-length group is relatively similar up

to 20 kN (about 50% capacity). Nevertheless, above this loading increment, the load distribution on piles has increased gradually and varies dramatically at the loading increment of the plunging failure. For the load distribution on the piles of the different-length pile group (right side diagram) there has not been an enormous difference between these piles below the loading level of 12 kN (about 25% capacity). Beyond this loading level up to the loading level of 28 kN, the load distribution has had a slight change. The corner pile P1 is sharing greater load than the other piles. However, from the loading level of 28–36 kN, the load sharing of this pile is reduced gradually and thereafter becomes least. It seems that the capacity of this pile has been mobilized fully at the loading level of 28 kN. For the edge pile P2 and the center pile P3, the load sharing is relatively similar after the loading

**Fig. 17** Load sharing of the piles in the pile groups



level of 28 kN. It is apparent that the change of the pile lengths in pile group has not only increased the capacity of pile group but also significantly improved the load distribution on the piles in group.

## 7 Conclusion

Static load tests and the measurements on instrumented single pile and the pile groups have been reported. Analysis of the test results was also performed. The following main conclusions can be drawn from the present study.

- The capacity of the different-length pile group is about 48 kN, which is greater than of the equal-length pile group about 20%. The maximum movements of both pile groups are similar, at about 22.5 mm.
- The length change of the corner and center piles in the different-length pile group has improved significantly the capacity of the edge piles, which is likely to contribute mostly to the capacity improvement of the group.
- The load distribution on the piles in the different-length pile group has become dramatically more uniform than on the piles in the equal-length pile group under a rigid cap.
- The pile toe bearing capacity of the piles in the different-length pile group is considerably greater than of the piles in the equal-length pile group.
- Residual strains were not found along the pile shafts after unloading, which reflect that the records of the strain gage was not been affected significantly by the cycled loading test.
- The load and movement of single pile at the plunging failure is about 3.2 kN and 12.0 mm, respectively. Correlating with the capacities of the equal-length and different-length pile group indicates the efficiency factors of about 0.78 and 0.94, respectively. The necessary movements to mobilize fully the resistances of pile groups are greater than of single pile by about 50%.
- The average unit shaft resistance of single pile is about 6.0 kN and the movements to mobilize fully the shaft resistances are about 12 mm.
- The effective stress analysis with a  $\beta$ -coefficient of 0.15 and an effective cohesion coefficient of 5 kPa has shown a good agreement with the measured shaft resistances of single pile.

Promising test results obtained from this research indicate great potential benefits in designing piles of unequal length when used in group to improve its load carrying capacity and the differential settlement of raft. However, this evidence is obtained from small scale testing. It is suggested that similar but full-scale testing be performed that could bolster this new light of evidence from present research.

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