Construction of bored piles in Hawthornden Formation using different stabilizing fluids

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ABSTRACT

Bored piles had been adopted as the foundation for an infrastructure project located on Hawthornden Formation of Middle Ordovician to Middle Silurian which generally overlain by the Kuala Lumpur Limestone Formation. This Hawthornden Formation is a mixture of quartz-mica amphibolites and carbonaceous schists, phyllites and quartzites. At most of the areas, the formation is usually highly to completely weathered and become residual soil. The design of bored pile is based on empirical method commonly adopted in local practice. Two numbers of Preliminary Test Piles (PTP), one constructed using Bentonite stabilizing fluid and the other one using Polymer stabilizing fluid had been carried out. Static maintained load tests conducted on these two PTP showed significant different in the pile capacity especially the mobilized unit shaft friction. This paper briefly describes the empirical method adopted for bored pile design and presents the soil investigation results carried out at these two PTP locations. The test results will also be presented and discussed. Recommendation is also presented based on this study.

Keywords: Hawthornden Formation; bored pile; stabilizing fluid; bentonite; polymer

1 INTRODUCTION

Large diameter bored piles, due to their high capacities and advantages of low noise and vibration during construction, had become popular as deep foundation to support heavy structural load especially for infrastructure works in down town and congested area. As the bored pile length can be adjusted easily, they are very suitable to be used in residual soil. For local practice, the design of bored pile is usually based on empirical method. In addition to the design, the bored pile capacity may also be affected by the workmanship and its construction method. This paper presents the pile load test results of two bored piles constructed in the Hawthornden Formation but using different types of stabilizing fluid. The results indicate that the capacity and the mobilized unit shaft friction for bored pile constructed using Polymer as stabilizing fluid is higher and the performance of pile is also much better.

2 HAWTHORNDEN FORMATION

The Hawthornden Formation can be found at localized areas in Kuala Lumpur. This formation of Silurian to Middle Ordovician is generally overlain by the Kuala Lumpur Limestone Formation and is a mixture of quartz-mica amphibolites and carbonaceous schists, phyllites and quartzites. The top of this formation is usually highly to completely weathered and had become residual soil. This soil especially when it composed of schist is usually stable when buried underground but once exposed to air, the soil structure could be disintegrated easily and soil strength could be lost significantly.

3 BORED PILE DESIGN

The design of bored pile in residual soil is based on empirical method for local practice. This is mainly due to the difficulties in obtaining undisturbed soil samples for laboratory strength tests. This empirical method uses the results of the Standard Penetration Test (SPT-N) for assessment of the unit shaft friction of subsoil. Many static pile load tests on fully instrumented test piles had been carried out locally and there were many attempts done to correlate the pile load test results to the SPT-N. The empirical correlation between the unit shaft friction (fs, kPa) and unit base resistance (fb, kPa) with the SPT-N values had been established, regardless of stabilizing fluids used, are as follow:

$$fs = Ks\ N \quad \text{(kPa)} \qquad (1)$$
$$fb = Kb\ N \quad \text{(kPa)} \qquad (2)$$

where Ks and Kb are the empirical factors for shaft friction and base resistance respectively. The Ks values generally vary from 2 to 3. Toh et al. (1989), after studied 9 numbers of fully instrumented test piles, found that the Ks values for residual soil in Kenny Hill Formation is about 2.5 to 2.7 for SPT-N values of less than 120. Further study by Phienwej et al. (1994) reported that Ks is about 2.3 for SPT-N values of less than 120. Tan et al. (1998) had also carried out a study on test results of 13 numbers of bored piles in residual soil and had suggested Ks of 2 for design purpose. For Singapore residual soil, similar study had been carried out by Chang and Broms (1991) and their recommended Ks value is 2 for SPT-N values of less than 150.

As for the Kb value, it varies significantly which may range from 7 to 60. Toh et al. reported Kb values of 27 to 60 while Chang and Broms suggested Kb of 30 to 45 for bored pile design. Tan et al. found lower Kb values of about 7 to 10 from their study. It is quite often that unless there is considerable confidence in overcoming the base cleaning of bored pile during construction, the bored pile design should consider the shaft friction only and ignore base resistance.

4 DETAILS OF THE PRELIMINARY TEST PILES

To assess the bored pile performance and to verify the empirical design method, it is common that preliminary test pile to be carried out prior to the construction of the working piles. The pile performance is considered acceptable for this project are: (i) pile head settlement is 12.5mm or less at working load, (ii) the residual settlement is less than 6.5mm upon removal of working load and (iii) the pile head settlement is less than 10% of pile diameter at 2 times working load. A fully instrumented test pile had been constructed using bentonite stabilizing fluid. However, the pile capacity was significantly low. It was decided to carry out another test pile but constructed using polymer as stabilizing fluid. The test result show much higher pile capacity. Details of these two test piles are shown in the following sections.

4.1 Preliminary test pile constructed using bentonite stabilizing fluid

The first preliminary test pile (PTP-1) is designed based on the empirical method as mentioned above. The pile diameter is 1200mm. A borehole was carried out to obtain the subsoil profile at this test pile location. The design was based on information from this borehole. Total seven levels of Vibration Wire Strain Gauges (VWSG) and 3 levels of telltale (TT) had been installed in this PTP-1. At each level, there are 4 numbers of VWSG. As for the TT, there are 2 numbers of TT at each level. Figure 1 below shows the subsoil profile and the details of PTP-1.

4.2 Preliminary test pile constructed using polymer stabilizing fluid

The second preliminary test pile (PTP-1A) is located 5m away from the PTP-1. A borehole had also been carried out and the similar design method was adopted. Similarly, there are seven levels of VWSG with 4 VWSG at each levels. Three levels of TT with 2 TT at each level. The pile diameter is also 1200mm. Figure 2 below shows the details of the boreholes and PTP-1A.

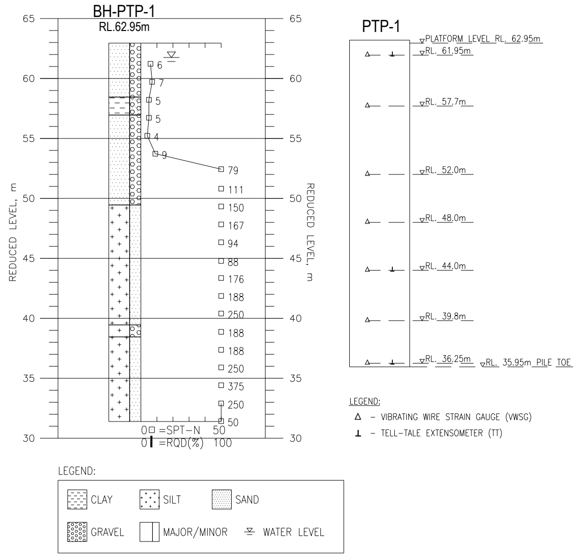

Fig. 1. Details of PTP-1.

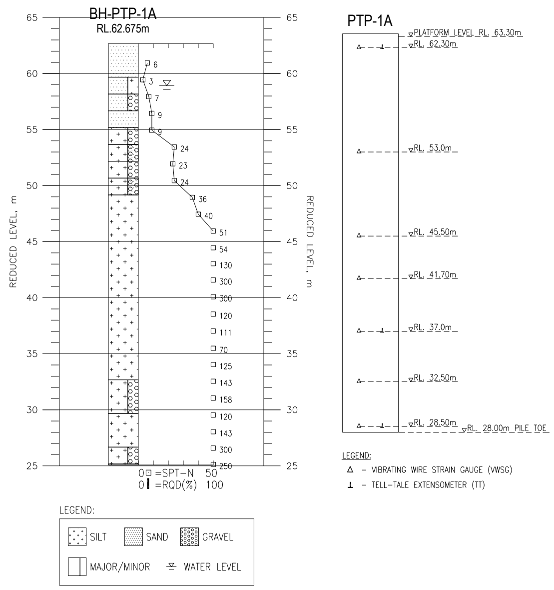

Fig. 2. Details of PTP-1A.

5 RESULTS OF PILE LOAD TEST

The design working load of the 1200mm diameter bored pile is 9800kN. For PTP-1, the pile head settled more than 78mm when the applied load was only 8800kN. The maximum applied load on PTP-1 was 10500kN and the pile head settled some 150mm. For PTP-1A, the performance of the pile is much better. Upon loaded to 9800kN, the pile head settled 12.5mm only. At maximum applied load of 20000kN, the pile head settled more than 130mm. Figure 3 below presents the load-settlement behaviors of these two test piles. The performance of PTP-1A is generally much better and the obtained capacity is about twice the capacity of PTP-1.

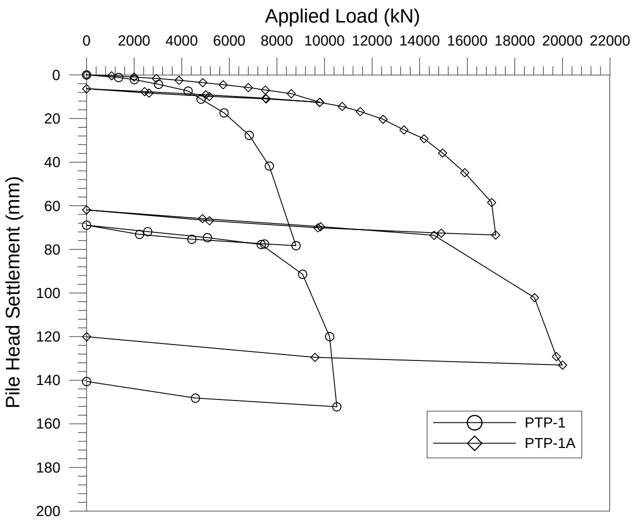

Fig. 3. The pile load test results.

5.1 Mobilized unit shaft frictions

The mobilized unit shaft frictions at each soil layer are interpreted from the results recorded by the VWSG. Figure 4 presents the mobilized unit shaft frictions for subsoil with SPT-N values of less than 50 obtained from these two test piles. Figure 5 presents the obtained mobilized unit shaft frictions for subsoil with SPT-N values of more than 50. The results show that higher mobilized unit shaft friction can be obtained from the bored pile (PTP-1A) constructed using Polymer as stabilizing fluid at this site.

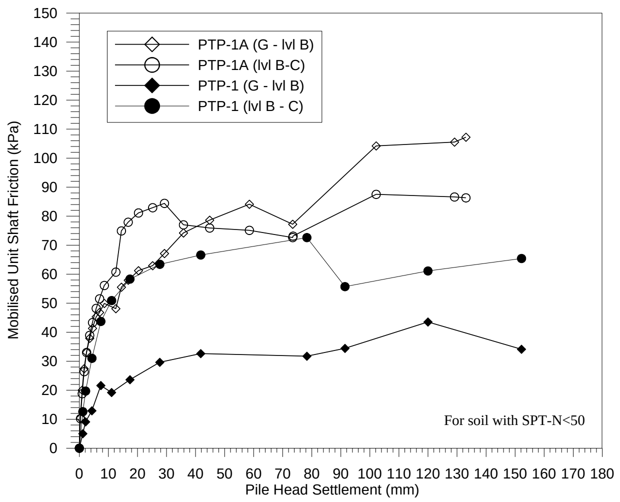

Fig. 4. The mobilized unit shaft frictions of soil with SPT-N <50

5.2 Mobilized base resistance

As the test piles had settled quite significant, it is also able to obtained the mobilized base resistance from these two test piles. Figure 6 compares the results and it was found that there could be some soft deposits below PTP-1A. The base resistance only started to mobilize after some 10mm settlement took place. In general, the mobilized base resistance from PTP-1A is higher as compared with the mobilized base resistance from PTP-1.

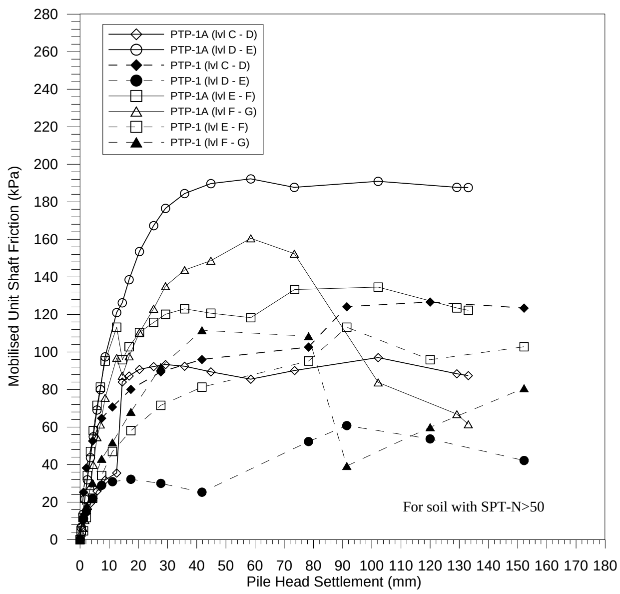

Fig. 5. The mobilized unit shaft frictions of soil with SPT-N >50

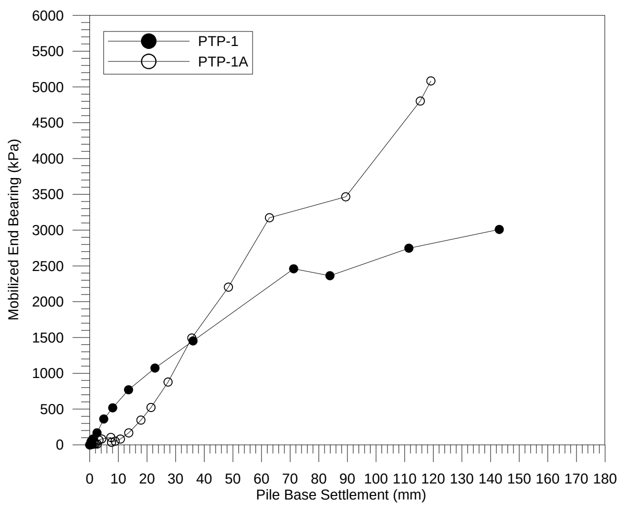

Fig.6. The mobilized base resistances

6 DISCUSSION

For subsoil with SPT-N values of less than 50, the maximum obtained unit shaft frictions from PTP-1 and PTP-1A are about 40 to 70 kPa and 85 to 110 kPa respectively. For the very hard soil layer with SPT-N values of more than 50, the obtained maximum unit shaft frictions from PTP-1 are about 60 to 120 kPa and about 90 to 190 kPa from PTP-1A. The empirical factor Ks for the subsoil with SPT-N less than 50 is generally higher than the recommended value of 2 to 3. However, for the hard soil layer, the back calculated Ks values are much lower especially for the bored pile constructed using bentonite as stabilizing fluid. Figure 7 shows the back calculated Ks from the test piles and compares with recommended design Ks values from various researchers. In summary, the recommended design Ks values are on the conservative side and applicable for subsoil with SPT-N of less than 50. However, these Ks values could over-estimate the mobilized unit shaft friction of very hard soil with SPT-N of more than 50.

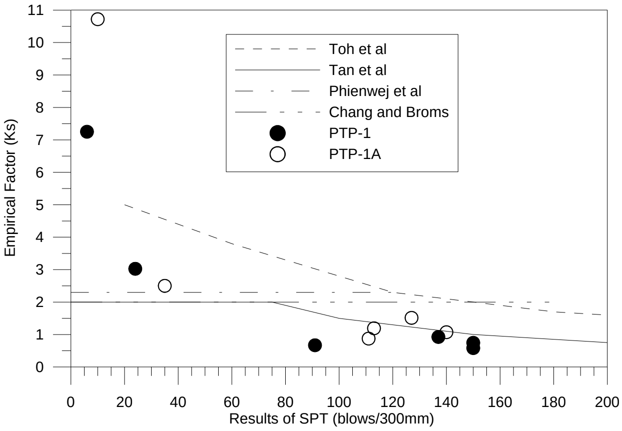

Fig. 7. The back calculated empirical factor Ks.

The ultimate base resistance of the test pile PTP-1 is about 3000 kPa, and about 5000 kPa for PTP-1A. If the soft deposit at the toe of PTP-1A had been cleaned properly, the mobilized base resistance from PTP-1A is generally higher. The average SPT-N value below the pile base and within twice the pile diameter for PTP-1 is about 292. The back calculated Kb is 10 only. As for PTP-1A, the average SPT-N value below pile toe is about 231, the back calculated Kb is slightly higher which is about 22. As compared with findings from others as shown in Fig.8, the obtained Kb values are within the range but at low side. The better performance of pile constructed using polymer stabilizing fluid could be due to the ability of the polymer molecules to coat the soil surface which could prevent the swelling of soil and disintegrating of soil structure.

7 CONCLUSION

Comparison of the mobilized shaft friction and base resistance for bored piles constructed in Hawthornden Formation using bentonite and polymer stabilizing fluids had been carried out. Static load tests were conducted on two fully instrumented test piles. Based on the test results, it was found that the mobilized shaft friction and the ultimate base resistance for pile constructed using polymer as stabilizing fluid are generally higher. It is therefore recommended that polymer should be used as stabilizing fluid for piles to be constructed in Hawthornden Formation. Based on limited information obtained from this study, it is also recommended that the empirical method can still be used for bored pile design using polymer stabilizing fluid with the followings limits:

$$fs = 2\ N \leq 150\ kPa \quad (1)$$
$$fb = 20\ N \leq 5000\ kPa \quad (2)$$

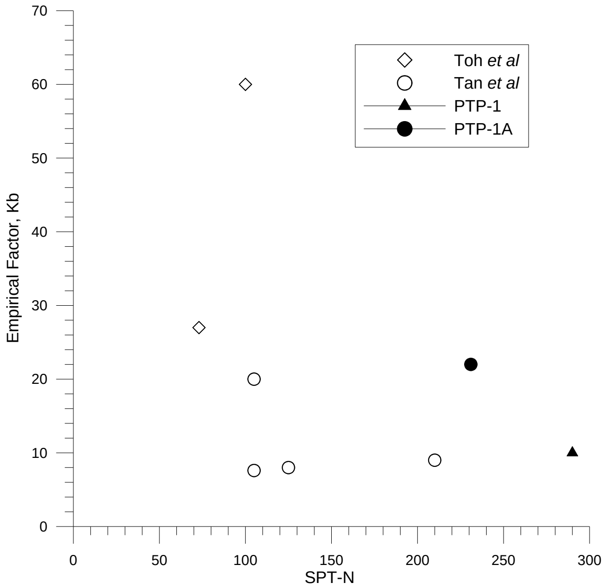

Fig 8. Comparison of Kb with published data

The based resistance is very much depending on the workmanship and effectiveness of base cleaning. Preliminary pile load test should always be carried out to verify it prior to the construction of working piles. It is also suggested that more test piles to be carried out to further verify the above recommended empirical values.

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