Design and construction of an unbalanced excavation near historical structures with bored piles as retaining structure in Hong Kong

Conception et construction d'un excavation inequilibre pres des edifices historique

Lucy Wu
formerly Ove Arup HK Ltd., Hong Kong, lucywu@alum.mit.edu

Gordon Fung Wing Fai & Alvin Lam King Ming
Ove Arup HK Ltd., Hong Kong, gordon.fung@arup.com

ABSTRACT: This paper presents an excavation in a highly congested district of Hong Kong in which the proposed basement was immediately next to historically valuable structures built in the 19th century. An innovative application of using an 810mm diameter bored pile wall served as the temporary retaining system for an unbalanced excavation as well as designed to be the permanent basement wall to resist the unbalanced earth load. The excavation took place on a terrace with 13m high ground to the south and 5m to the north. The site was underlain by completely decomposed granite without encountering bedrock at 90m below ground. The site was surrounded by historical buildings on shallow footings and stone masonry retaining walls on all four sides. Due to heavy rainfall during the wet seasons, major changes in the groundwater table were expected. Plaxis 2D was chosen as the analytical tool to analyse the seepage forces, groundwater damming effects and the permanent soil structure interaction. GSA was used in combination with Plaxis 2D to reflect the building load combinations on the composite basement structure. The excavation took place successfully with minimal disturbance to the surrounding structures. The predicted forces and displacements are compared with field results.

1 INTRODUCTION

The site is located in the Central District of Hong Kong. The excavation was designed to facilitate the construction of a 13m deep basement for a new building within a historical conservation site. The basement structure is approximately 15m by 40m.

2 PROJECT DESCRIPTION

The project is located within a historical conservation site. The excavation was constrained on all four sides by historical structures built in the 1800s and early 1900s. To the south, a building on shallow foundations built in the 1920s is located 1m away and required underpinning by friction minipiles prior to the excavation. The northern and western edges of the excavation comprised retaining walls that were kept as façade. To the east, one of the oldest buildings in the complex, built in the 1850s, is located 3m away and also founded on shallow footings. Figure 1 shows the north-south section, illustrating the level differences.

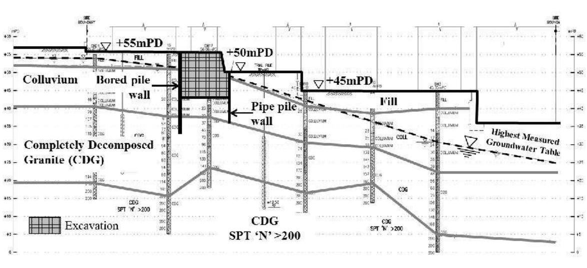

Figure 1. North-south section

The new building is composed of a two-level basement that allows passage of people and utilities in a north-south direction. The superstructure is a 5 storey structure that cantilevers out towards the northern side.

3 GROUND CONDITIONS

The site is underlain successively by about 2-7m thick fill, about 6-9m thick boulder colluvium, about 3-6m thick colluvium, and more than 30m thick decomposed granite. Soil stratum of SPT N value greater than 200 is encountered about 30-40m below ground No bedrock is encountered at depth of 90m or greater

High groundwater conditions and seepage flows govern the design of the excavation and permanent structure. The site itself is a miniature representation of the overall topography. The terrain continues to rise to the south and the ground dips steeply into Victoria Harbour to the north. This region of Hong Kong is characterised by the high groundwater flows within the bouldery colluvium layer. One of the main concerns during the design stage was the effect of the proposed deep basement, which goes beneath this highly permeable layer, on the groundwater flow in the immediate area. It was determined that due to the continuity of the structure over a length of 40m, it might create a damming effect on the groundwater flow and raise the level of the groundwater on the retaining side of the basement above the measured phreatic surface.

4 EXCAVATION AND LATERAL SUPPORT SYSTEM

Due to the sensitivity of the nearby buildings to settlement and the ground conditions, small diameter (810mm) bored piles excavated using concentric air flush drilling was selected as the main retaining element for the northern side. The piles would be excavated with steel casing support and the reinforced piles would be cast in place. In addition to control of settlement during piling, the bored piles were designed as both a temporary and permanent retaining wall, maximising the use of space. A 200mm thick permanent basement wall was designed to be constructed against the bored pile wall after excavation has taken place and coupled together to provide the necessary permanent stiffness.

The remaining three sides were supported using steel pipe piles of 355mm diameter, also constructed using concentric air flush method. The piles were left in place after excavation but were designed as temporary supports only. Initial preliminary design investigated the use of tie-backs as an efficient method to retain the ground to the northern side of the site. However, tie-back installation would require drilling underneath the historical building, which could disturb the newly constructed friction minipiles as well as the remaining portion of the building on footings. Therefore, internal shoring was used throughout the excavation to retain the ground. Four levels of raking shoring were designed with the bottom three layers preloaded to a design load in order to control the deflection of the bored pile wall to the northern side. In order to provide watertight excavation conditions and to prevent drawdown of the water table around the site, a grout curtain was installed surrounding the excavation. Bentonite-cement grout was used as a first phase grouting, followed by silicon cement grout.

The building vertical loads were designed to be taken by the foundation piles. The foundation piles consist of shaft grouted pre-bored friction steel H-piles excavated using concentric air flushed methods.

5 METHOD OF ANALYSIS

Plaxis 2D with Mohr-Coulomb drained soil model was used. The design soil elastic modulus was adopted based on the SPT N values obtained on site. The empirical correlation between the soil stiffness and SPT N values was determined to be 1.5N (MPa) for all the soil stratums in order to achieve a reasonable and conservative estimate of the excavation lateral movement caused by deep excavation.

The excavation and temporary structures was designed assuming a design water level of 1m above the highest measured groundwater level. Using a seepage model, the water level rose to 1m below ground level. The water forces from this seepage model were used to design the temporary excavation works.

The temporary excavation case was assumed to have induced active soil pressures (Ka) on the retaining side of the bored piles and mobilised passive soil pressures (Kp) via the pipe piles to the north. The permanent structure, modeled using Oasys GSA takes the remaining soil load which is assumed to be the difference of soil pressures at rest (Ko) and mobilised Ka. The resisting capacity of the soil is assumed to be the remaining Kp that was not utilised during the temporary excavation. Soil passive resistance was modeled using horizontal springs in GSA.

The overturning moment induced by the unbalanced soil forces is assumed to be resisted by the foundation piles. The foundation piles were modeled in GSA only as they are connected to the excavation only after the base slab is concreted. The delineation between lateral loads to be taken by the bored piles and the axial loads to be taken by the foundation piles allows for a simplified and conservative way to design the entire structural system.

6 RESULTS AND MONITORING

1 .1 *Groundwater monitoring*

Groundwater monitoring data was collected throughout construction and the results were analysed for damming effects and changes to the groundwater flow before and after the bored pile wall construction for a period of two wet seasons. Daily groundwater monitoring results were examined and filtered for abnormal readings due to construction activities. The records were examined in conjunction with daily rainfall data from the Hong Kong Observatory, which operates rain gauges and collects rainfall data throughout Hong Kong. The damming effect of the bored pile wall was not found from analysis of the monitoring data.

1 .1 *Ground movements during excavation*

A total of six inclinometers were installed in the vertical supports to measure lateral displacement during excavation. Strain gauges were placed on main shoring to measure the preload and subsequent forces on the struts. Ground settlement and building settlement points were placed in various places around the excavation to measure ground settlement.

Figure 3 presents the measured inclinometer displacements against the Plaxis 2D results for one of the bored piles. The measured displacements were less than the predicted movements.

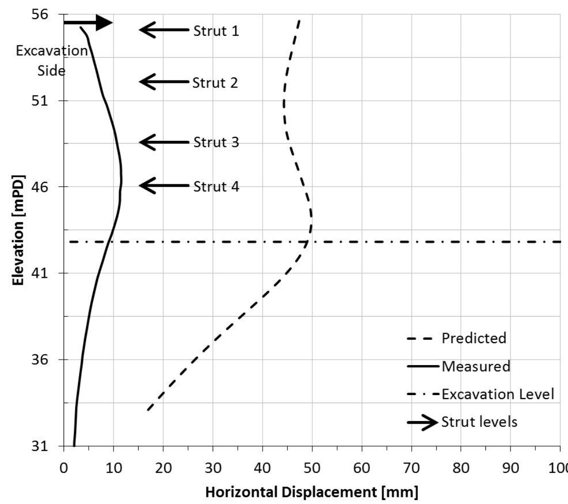

Figure 3. Comparison of predicted and measured values of bored pile movements at final excavation stage.

Ground improvement works comprising of the injection of microfine cement into the retaining side of the bored piles were carried out prior to the excavation in order to provide additional protection to the historical building. This stiffening of the soil was not captured in the modeling. In addition, the actual soil stiffness is likely to be higher than the empirical correlation of 1.5N under a small strain condition. These contributed to the differences between the measured the predicted results.

7 CONCLUSION

The use of small dimater reinforced concrete secant bored pile walls are uncommon in Hong Kong. This composite bored pile wall and basement wall allowed for space savings as well as satisfactorily performing in its capacity to support the excavation and protect the surrounding historical structures.

8 ACKNOWLEDGEMENTS

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9 REFERENCES

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