

Study on the Influence of Different Section Construction of Subway Station on Maintenance Piles

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Abstract: Taking the Pile-Beam-Arch (PBA) construction of subway station as the research object, the influence of different section construction on the maintenance pile and the law of the variation of the lateral displacement with the excavation depth are discussed. By comparing and analyzing the influence of bracing and non-bracing on the internal force and displacement of the retaining pile in the process of excavation of soil under the plate of different sections, the two-dimensional analysis of soil under the plate of PBA (Pile-Beam-Arch) method in Xinbai subway station is carried out by using GTS Software and the distance and position of steel braces are determined.

Key words: Pile-beam-arch, subway station, section construction, GTS, braces, retaining

INTRODUCTION

In the excavation process of underground excavation station foundation pit, the stability is restricted by a variety of factors and each factor affects each other (Minguillon *et al.*, 2018). Under the premise that the second lining of the arch ring has reached the design strength and the middle partition has been formed and can play a supporting role in the excavation of the station, the bending moment of the retaining pile will change continuously with the increase of the excavation depth during the step excavation of the lower soil. The horizontal displacement of pile body will also change. These are the factors that can easily lead to the failure of support structure or the instability of the whole structure (Van Drooge *et al.*, 2018; Munoz *et al.*, 2018; Koc *et al.*, 2018; Yu *et al.*, 2018; Mouzakis *et al.*, 2019). At present, there are few studies in this area (Loy-Benitez *et al.*, 2018). Based on the example of Shijiazhuang subway project, this study uses GTS software to obtain the bending moment and displacement of the retaining pile through numerical simulation, so as to systematically analyze the construction of the guiding tunnel. The influence mode and influence level of the pile determine the spacing and position of the steel support which provides a scientific basis for the subsequent construction of the subway station.

MATERIALS AND METHODS

Mechanical model and parameters: Under the condition that the secondary lining of arch ring has been completed and the strength of the plate has reached the design requirements and has already played a supporting role, the model simulates the construction process of the soil in the lower part of the arch ring. The comparison of internal forces and deformation of retaining piles in the process of soil excavation without and with steel bracing is studied. Two of the sections are selected. The first section is Tongrentang Pharmacy-women's world section with a span of 23.5 m and a depth of 10.15 m. The section is excavated in four construction sections. The excavation depths are: 2.5, 2.7, 2.2, 2.75 m. The second section is the section of the Commercial City-0101 popular Pavilion. The span is 19.7 m and the excavation depth is 8.56 m. The excavation is divided into three sections. The excavation depths are: 3.0, 2.45, 3.11 m. The calculation model Fig. 1 and the main parameters are shown in Table 1.

RESULTS AND DISCUSSION

First section analysis: After the excavation of the first section, it is known from the simulation data that the maximum bending moment value of the retaining pile

Table 1: Physical parameters of the mode

Material name	Thickness h (m)	Elastic modulus E _e (Pa)	Poisson ratio (u)	Unit weight (kN/m ³)	(kpa) cohesive strength (kPa)	Angle of friction φ (°)
Miscellaneous fill	6.2	7.94×10 ⁶	0.450	20.1	26	13
Medium-coarse sand	3.4	1.98×10 ⁷	0.280	17.36	8.8	30.7
Gravelly sand	2.4	2.74×10 ⁷	0.260	18.15	21.5	34.7
Medium plate	0.45	3.0×10 ¹⁰	0.167	25	-	-
Retaining pile	0.8 (diameter)	3.0×10 ¹⁰	0.167	25	-	-
Arch ring	0.75	3.0×10 ¹⁰	0.167	25	-	-

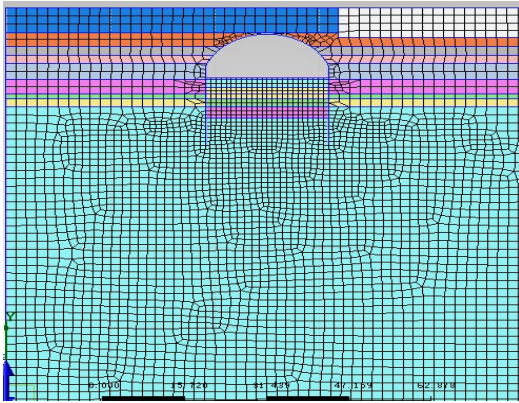


Fig. 1: Calculation model diagram

occurs at 1459.99 kN.m on the left side of the pile which is greater than the design bending moment and steel support should be erected during the excavation process. The distance between the steel supports is 1.5, 2 and 2.5 m. The axial forces of the steel supports under different spacings were simulated. The simulated axial forces were -913.07, -1536.8 and -2279 kN, respectively. The appropriate steel support spacing was selected by comparison.

From the axial force diagram analysis of the steel support, it can be concluded that: when the steel support spacing is 2.5 m, the axial force of the steel support is 2279.04 kN after the excavation of the soil which is greater than the design capacity of 1395 kN. The steel support will be unstable during the excavation process which will eventually lead to the fracture of the main structure when the steel support spacing is 2 m, the axial force of the steel support after the excavation is 1536.83 kN which is slightly larger than the designed axial force. Therefore, the theoretical distance between the steel supports should be 1.5 m. Considering the matching problem between the stiffness of the vertical and horizontal components and the loading of the upper building with a safe load, the simulation results will be larger than the actual value. Considering the ease of construction, the spacing of the steel supports can be appropriately enlarged to 2 m in actual engineering.

Bending moment: The spacing of the steel support is set to 2 m and the construction process is simulated. The bending moment of the retaining pile after the excavation is completed is compared with the bending moment of the retaining pile without the steel support. The curves of bending moment of the left and right pile are obtained when the spacing of steel support is 2 m and that of the pile body without steel support. As shown in Fig. 2 and 3 is a comparison diagram of the bending moment of the left pile and Fig.3b is a comparison diagram of the bending moment of the right pile.

The symbol of the bending moment represents its direction, the positive value represents the excavation side and the negative value is the outside of the station. The maximum positive bending moment occurs at the arch foot (top of the pile) and the right pile is reversed. The maximum bending moment occurs in the fifth construction stage, the size is 1459.99 kN.m which is greater than the bending capacity of the retaining pile M value. After the steel support is erected, the bending moment of the maximum bending moment of the left retaining pile is received. It is 1053.67 kN.m. Reduced by 27.8% compared to when the steel support was not erected. The maximum bending moment of the right side retaining pile is 863.014 kN.m. It is reduced by nearly 31.7% when the steel support is not erected.

Displacement: The spacing of the steel support is set to 2 m and the displacement of the retaining pile after the excavation is completed is simulated and compared with the displacement of the retaining pile without the steel support. The comparison of the displacement curves of the left and right side piles after the excavation is completed is obtained when the distance between the steel supports is 2 m and the steel support is not added. As shown in Fig. 4a is a comparison of the displacement of the left pile and Fig. 4b is a comparison of the displacement of the right pile.

As can be seen from Fig. 3, when the foundation pit has no steel support during the excavation process, the lateral displacement of the first section is 16.339 mm, which occurs on the left side of the pile which is 0.08% of the excavation depth of the foundation pit. The maximum lateral displacement of the second section occurs on the

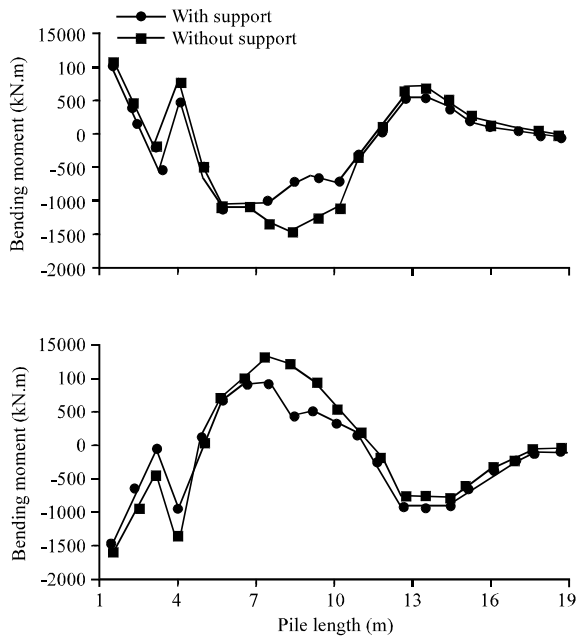


Fig. 2: Comparing diagram of bending moment between with and without support

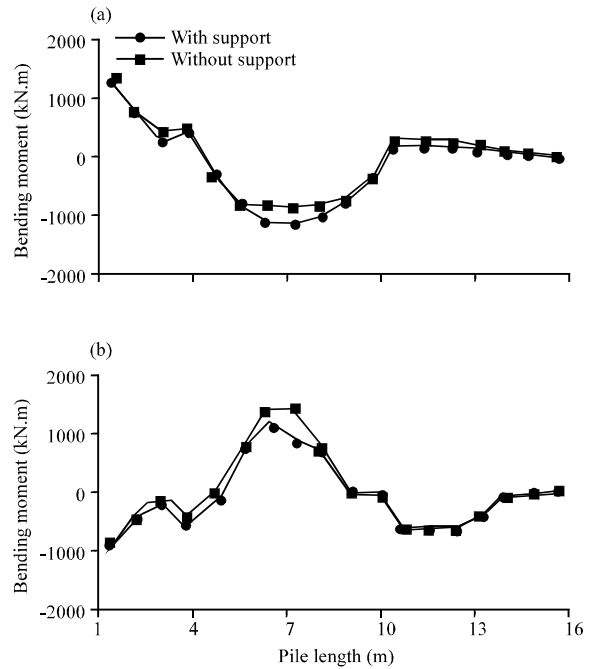


Fig. 4: Comparing diagram of bending moment between with and without support

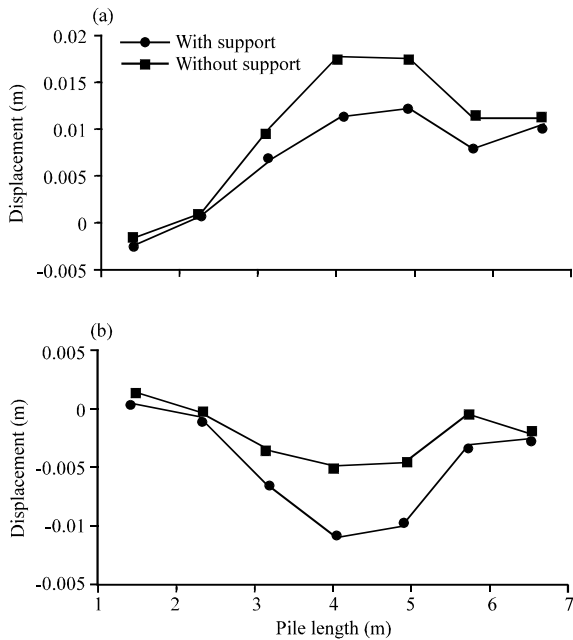


Fig. 3: Displacement comparing diagram between with and without support

right side of the pile body and the size is 22.29 mm which is 0.13% of the excavation depth of the foundation pit. The recommended maximum value (0.3-0.5%) in accordance with the specification, after the steel support

is erected, the maximum offset of the left pile is reduced by 5.19 mm compared with the maximum offset of the unsupported steel support. The maximum offset of the right pile is 6.18 mm less than the maximum offset of the unsupported steel support.

Second section analysis: It can be seen from the engineering overview that the maximum bending moment of the right retaining pile after the excavation is completed is 1446.21 kN which is larger than the design bending moment and steel support must be erected during the excavation process. According to the experience value, the pre-axial force of the steel support is 30-50% of the design axial force and the pre-added axial force in this project is 500 kN. In the simulation, the spacing between the steel supports is 3 and 4 m. The axial forces received after the completion of the excavation of the lower soil are -710.78 and -115.113 kN, respectively. When the steel support spacing is 4 m, after the excavation is completed, the axial force of the steel support is 2503.59 kN which is greater than the design bearing capacity of 1710 kN that is the steel support will be unstable during the excavation process. When the steel support spacing is 3 m, after the excavation is completed, the internal force of the steel support is 1547.19 kN which is less than the ultimate bearing capacity of the steel support. Therefore, the spacing of the steel supports should be controlled to 3 m in this section.

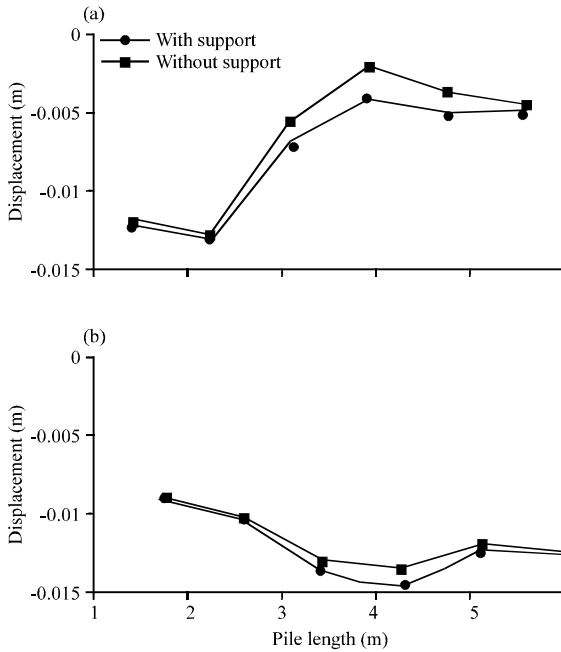


Fig. 5: Displacement comparing diagram between with and without support

Bending moment: The spacing of the steel support is set to 3 m and the bending moment of the retaining pile after the excavation is simulated is compared with the bending moment of the retaining pile without the steel support. The bending moment curves of the left and right piles are obtained when the steel supports. As shown in Fig. 6a is a comparison diagram of the bending moment of the left pile and Fig. 6b is a comparison diagram of the bending moment of the right pile.

It can be seen from Fig. 4 that after the steel support is erected, the maximum bending moment of the left retaining pile is 885.759 kN.m which is 21.2% less than when the steel support is not installed. The maximum bending moment of the right retaining pile is 1093.7 kN.m which is 10.2% less than when the steel support is not installed. It can be seen that the bending moment is suddenly changed at the position of the middle partition. As the depth of the excavation increases, the maximum bending moment value increases continuously and this value occurs after the excavation is completed.

Displacement comparison analysis: The spacing of the steel support is set to 3 m and the displacement of the retaining pile after the excavation is simulated is compared with the displacement of the retaining pile without the steel support. The comparison of the curves of the left and right side piles after the excavation is completed is obtained when the distance between the steel supports is

3 m and the steel support is not added. As shown in Fig. 5a is a comparison diagram of the displacement of the left pile, and Fig. 5b is a comparison diagram of the displacement of the right pile.

It can be seen from Fig. 5 that after the steel support is erected, the maximum offset of the left pile does not change much (with a small increase) compared with the maximum offset when the steel support is not installed. The maximum offset of the right pile is reduced by 2.25 mm compared to the maximum offset of the unsupported steel support.

CONCLUSION

During the excavation process, the bending moment and lateral displacement of the retaining pile increase with the increase of the excavation depth. After the excavation is completed, the bending moment of the retaining pile reaches the maximum value and the value is greater than the bending bearing capacity of the retaining pile itself, so, the steel support must be erected in time during the excavation process.

For the first section, the steel support should be erected at a distance of 2 m. After the support, the maximum bending moment of the left retaining pile is reduced by 27.8% and the lateral offset is reduced by 31.7%; the maximum bending moment of the right side retaining pile is reduced by 23.7% and the lateral offset is reduced by 51.5%.

For the second section, the steel support should be erected at a distance of 3 m, which is 21.2% less than that without the steel support but the lateral displacement does not change much; the lateral displacement of the right retaining pile is reduced by 10.2% compared with the case without the support and the maximum pile bending moment is reduced by 24.3%. The effect of steel support is more obvious.

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