Optimization of Construction Sequence of Buckle Arch in PBA Subway Station

Xiaowei Cheng*, Xin Fu, Fusheng Wang

CCCC No.3 Engineering Co., Ltd, Beijing 101102, Ltd, P.R. China

* Corresponding author's e-mail address: 463970903@qq.com

Abstract. In the construction of the pile-beam-arch station, the construction procedure and force transformation of buckle arch are complex, which has a great influence on the stability and safety of the whole structure construction. In view of this, based on the subway station project, this paper uses the method of numerical simulation to study. The results show that it is a more reasonable construction sequence to span the initial buckle arch in the construction first, and then to stagger the safety step after the construction side span. It can effectively control the surface deformation and the horizontal displacement of the top longitudinal beam, and ensure the stability and safety of the existing structure.

Keywords: Loess stratum; Pile-Beam-Arch method; Construction sequence of buckle arch

1 INTRODUCTION

Compared with the traditional underground tunnel construction method, the tunnel pile method has shorter construction period, better stability, less temporary support and lower project cost[1-6]. It is suitable for areas with dense ground buildings, tunnels under other stations, or areas with dense underground pipelines. During the construction of the pile-beam-arch station, when the soil under the buckle arch is excavated, the adjacent buckle arch construction often interferes with each other, resulting in a large surface settlement caused by the buckle arch construction. At the same time, in the process of the formation of the initial arch support and the removal of the small guide tunnel, the structural force transformation is more complex, and the construction risk is higher. Therefore, it is necessary to optimize the construction scheme of the buckle arch to prevent excessive soil deformation and structural instability failure[7].

The original construction scheme of the buckle arch is the simultaneous excavation of both sides of the span first, the excavation of the middle span after, and the new construction scheme of the buckle arch is the excavation of the middle span first. Hereinafter referred to as Option 1 and Option 2, the construction steps and specific construction contents are shown in Table 1 and 2.

B. Yuan et al. (eds.), *Proceedings of the 2024 8th International Conference on Civil Architecture and Structural Engineering (ICCASE 2024)*, Atlantis Highlights in Engineering 33,
https://doi.org/10.2991/978-94-6463-449-5_76

In this paper, the finite element software PLAXIS 3D is used to study the stratum deformation and structural stress law under different construction sequence of buckle arch, and obtain the most favorable construction plan.

2 SIMULATION RESULT ANALYSIS

2.1 Model Overview

Simplify the station model when establishing the model. The thickness of the overlying soil from the top of the station arch to the ground is set to 21m, the lower boundary of the model is taken as 20m below the station floor, and the Z-axis direction of the model is taken as 60m. The X-axis direction is 60m positive and 60m negative, with a total length of 120m. Take 18m in the positive direction of the Y-axis. The calculation model of the tunnel pile method station is shown in Figure 1.The soils in each layer of the model are: plain filled soil, 3-1-1 new loess, 3-2 ancient soil, 4-1-1 old loess, 4-2-1 ancient. The three dimensional solid unit is used to simulate the middle plate, bottom plate, crown beam, top longitudinal beam, backfilled concrete and secondary lining. The initial support of the pilot tunnel and buckle arch, and the middle door of the lower pilot tunnel are simulated by the plate element.

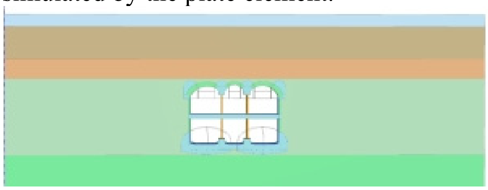
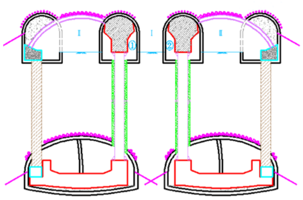


Fig. 1. Calculation model of subway stations

2.2 Formation Deformation

The calculation results of the two options are extracted and compared from angles of formation deformation and horizontal displacement of the top longitudinal beam.

Table 1. Construction Option 1 of primary supporting buckle arch

Step	Schematic diagram	Construction content
The first step		The upper side guide tunnel is strengthened to the inner side of the longitudinal beam, and the advanced support of the top arch II and III is constructed. Excavate the soil of buckle arch II and III, and construct the initial support of buckle arch in time.

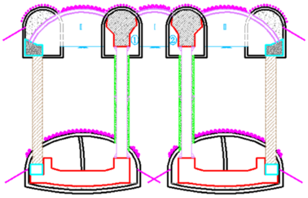
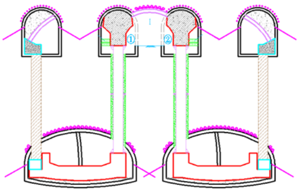
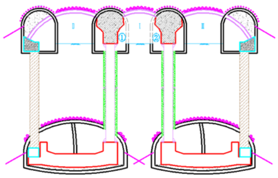
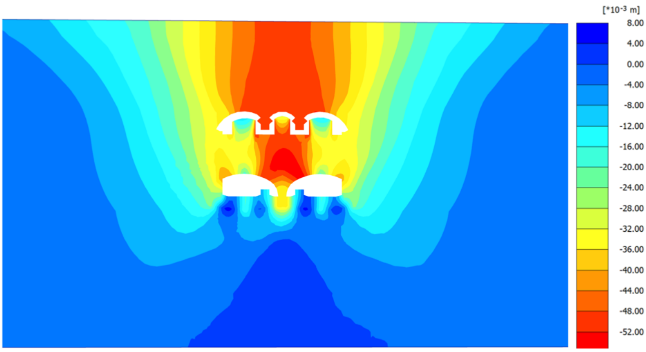
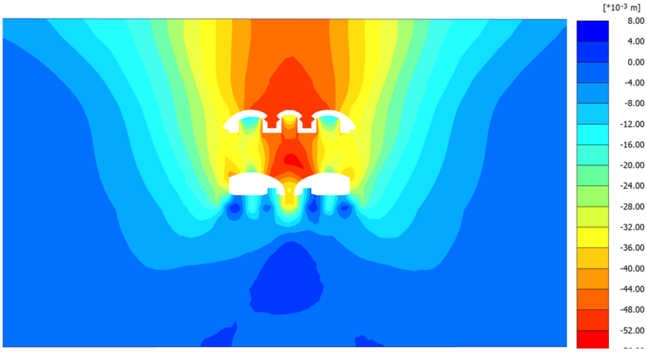
The second step		Construction of the top arch I advance support, and grouting to strengthen the stratum. Excavate the soil in the first part of the buckle arch, and construct the initial support of the buckle arch.

Table 2. Construction Option 2 of primary supporting buckle arch

Step	Schematic diagram	Construction content
The first step		Reinforce the top longitudinal beam of the upper middle guide tunnel, construct the top arch I advance support. Excavate the soil of buckle arch I and construct the initial support of buckle arch in time.
The second step		Construction of roof arch II and III advance support, and grouting to strengthen the stratum. Excavate the soil of buckle arch II and III, and construct the initial support of buckle arch.



(a)Option 1



(b)Option2

Fig. 2. Cloud map of deformation in the construction of the initial support of buckle arch

It can be seen from Figure 2 that the vertical displacement cloud map of the formation is approximately symmetrical. The buckle arch at the top of the station structure settles down, and the bottom plate of the station structure rises up. In both construction options, the maximum vertical settlement is on the upper side of the arch of the two lower guide holes, but the settlement value of Option 1 is larger.

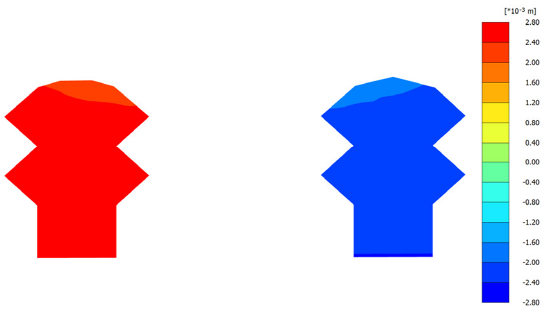
As can be seen from Table 3, the maximum ground settlement value caused by the construction of Option 1 is -14.60mm, and that caused by the construction of Option is -13.21mm, with a difference of 9.52%. Obviously, the Option2 is more favorable to the control of surface deformation.

Table 3. Maximum surface subsidence table

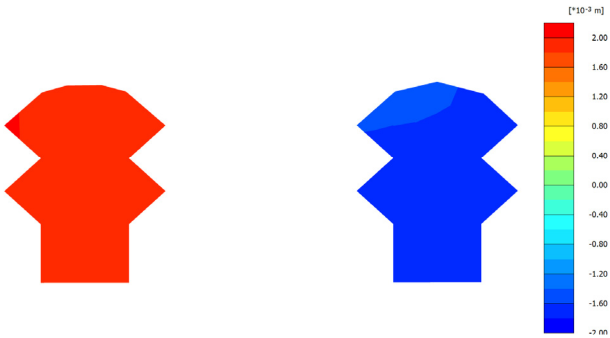
Initial support construction sequence	Option 1	Option2
Maximum surface subsidence/mm	-14.60	-13.21

2.3 Horizontal Displacement of the Top Longitudinal Beam

In order to verify whether the two sides of the middle column tend to fall to one side under different initial construction options, the upper top longitudinal beam of the middle column is studied, as shown in Figure 3.



(a)Option 1



(b) Option 1

Fig. 3. Cloud map of horizontal displacement of top longitudinal beam

The horizontal displacement at the bottom of the top stringer caused by Option 1 and Option2 both appeared in the initial button-arch construction stage of the side span. Table 4 shows that the horizontal displacement of the top longitudinal beam caused by Option2 decreases by 25.1%.

Table 4. Summary of horizontal displacement values at the bottom of the top longitudinal beam

Horizontal displacement in each stage (mm)		Left beam	Right beam
Option 1	Side span initial branch stage	3.206	-3.087
	Mid-span initial branch stage	-0.448	0.441
Option2	Mid-span initial branch stage	-0.706	0.696
	Side span initial branch stage	2.772	-2.591

The results show that when the soil under the side-span buckle arch is excavated first, the supporting effect of the side-span soil at the arch foot of the middle span is lost when the initial support is applied, and becomes an unconstrained structure with horizontal degrees of freedom. When the upper load is transferred to the buckle arch, it is decomposed into vertical force and a part of horizontal force, and excessive horizontal thrust will lead to horizontal displacement of the top longitudinal beam, which is not conducive to structural stability. The option 2 is that the soil under the arch is excavated in advance, and the side-span soil bears most of the horizontal thrust of the arch, which will help to reduce the horizontal thrust applied on the top longitudinal beam, so the horizontal displacement at the bottom of the top longitudinal beam of the option 2 is small.

3 CONCLUSION

Through the comparison of the construction sequence of the initial support of two kinds of buckle arch, this chapter analyzes the stratum deformation and the horizontal displacement of the top longitudinal beam respectively, draws the following conclusions:

- When the initial buckle arch is applied, the surface settlement of option 1 and option 2 reaches 14.6mm and 13.21mm respectively, while the surface subsidence caused by option 2 is relatively small.
- In option 2, the soil under the middle span buckle arch is excavated first, the middle span is small, and the horizontal thrust is small, which will help to reduce the horizontal displacement of the top longitudinal beam.

REFERENCES

1. Sun Yuhui, Zhang Zizhen, Chen Changyan, et al. Study on the Stress and Deformation Characteristics of Single Layer Pile-Beam-Arch Method for Underground Excavation of Station Side Pile Structure [J]. Urban Rail Transit Research, 2021, 24 (09): 30-34+38.
2. Guo Xinping, Jiang Annan, Wang Shanyong. Study on the Applicability of an Improved Pile-Beam-Arch Method of Metro Station Construction in the Upper-Soft and Lower-Hard Stratum[J]. Advances in Civil Engineering, 2021.
3. Lv Jianbing, Li Xulong, Li Zhanrong, et al. Numerical Simulations of Construction of Shield Tunnel with Small Clearance to Adjacent Tunnel without and with Isolation Pile Reinforcement [J]. KSCE Journal of Civil Engineering, 2020, 24 (3): 295-309.
4. Wu Jingyi, Ye Xinfeng, Yu Peng, et al. Study on the Settlement Law of PBA Station in Beijing Subway Fine Sand Layer [J]. Tunnel Construction (Chinese), 2020, 40 (10): 1408-1416.
5. ET Ağbay, Topal T. Evaluation of twin tunnel-induced surface ground deformation by empirical and numerical analyses (NATM part of Eurasia tunnel, Turkey)[J]. Computers and Geotechnics, 2020, 119.
6. Bobet, Antonio. Analytical Solutions for Shallow Tunnels in Saturated Ground[J]. Journal of Engineering Mechanics, 2001, 127(12):1258-1266.
7. Sagaseta, Cesar. Analysis of undraind soil deformation due to ground loss[J]. Geotechnique, 1987, 37(3):301-320.