Analysis on the influence of shield construction to pile group of hefei high-speed rail south station

Donglin Wang, Yusheng Jia

School of Civil Engineering, Anhui Jianzhu University, Hefei, Anhui, 230601, China

Corresponding author's e-mail: donglinwang2014@163.com

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Abstract

Since the tunnel shield construction produces the disturbance to the surrounding soil, causes the force impact of the near pile foundation, and leads to the additional stress and strain of the pile foundation. This paper uses the station pile group of Hefei No.1 Subway Line adjacent to the Hefei High-speed Rail South Station as the engineering example, utilizes the large finite element calculation software MIDAS GTS\NX to establish the three-dimensional calculation model, so as to make dynamic simulation of shield tunnel construction and conduct the analysis on the influence of displacement and stress of pile foundation during the shield construction process. Then make comparative analysis on the data of measured ground subsidence deformation on the site, the results show that this simulation analysis objectively reflects the influence law of pile foundation and ground subsidence deformation, which can provide the theoretical basis for the safe and quick construction of the similar engineering.

Keyword: Shield construction, Pile foundation, Numerical simulation, Land subsidence

1 Introduction

With the great development of Chinese city construction, the city concentration degree becomes higher and higher, and the pressure of ground traffic becomes bigger and bigger. In order to comply with the need of city construction and development, alleviate the ground city traffic pressure, subway transit construction has obtained great development [1-3]. Since most of the subway construction lag behind other constructions, it is also affected by the surrounding buildings, underground pipelines and many other aspects, subway tunnel is inevitably close to the high-rise buildings, the viaducts and other buildings. In general, high-speed rail, elevated bridge and high-rise buildings use pile foundation, during the construction process of shield tunnel method, the unloading effect of excavation will cause the changes of internal force and displacement of pile foundation and pile cushion cap, and then make effects on the safe operation of buildings [4-6].At the same time, since the loading effect of buildings, it will also make greater influence on the tunnel excavation face. Scholars at domestic and foreign countries have made the related researches on this topic, Sun Jizhu[7] puts forward the simple calculation method of the settlement and stability of pile, according to the different spatial position of pile and tunnel; Zhang Heng, Chen Shougen[8] and other scholars utilize the whole process of the finite difference software simulating the shield tunnel excavation to make the prediction and analysis on the ground surface subsidence and the lateral deformation of the bridge pile foundation generated by construction; scholars both home and from abroad simulate the influence of shield excavation on the adjacent buildings[9-13].

This paper utilizes the large-scale finite element software MIDAS GTS to conduct the simulation calculation on the station pile group of Hefei High-speed Rail South Station during the shield construction process, conduct the impact analysis of shield construction on pile foundation, and then make comparative analysis on the on-site measured data. Since there is a few of this kind of engineering examples, the calculation and analysis results of this paper can be used to provide reference for the design and construction of similar underground engineering.

2 Project overview

Hefei No.1 Subway Line starts from Fanhua Avenue, passes through G312 Country Road and Hefei High-speed Rail South Station, then the shield machine turns around at the position marked in the figure, and then conducts the construction of No. 5 tunnel line, as shown in Figure 1. Hefei South Station uses frame structure as the main structure, uses the pile group foundation of diameter of 1.2m as the foundation, the length of pile is 45~55 m, the pile foundation is located at both sides of the tunnel and parallel to the direction along the tunnel line, in the position of course.

TABLE 1 Physical and mechanical property of soil

Layer	**Unit weight** (KN/m^3)	**The layer thickness** (m)	**Compression modulus** (MPa)	**Poisson's ratio**	**Friction angle** (°)	**Cohesion force** (kPa)
Miscellaneous fill	18.5	2	3	0.3	8	16
Clay 1	20	4.1	10	0.31	12	40
Clay 2	19.6	32.3	12	0.31	13	50
Clay 3	20	2.4	12	0.31	13	52
Completely weathered siltstone	21.5	2	18	0.35	16	20
Strong weathered sandstone	21.5	/	18	0.35	20	18

K15+120.270~K15+343.572 (the overall length is about 223 meters), and the shield machine will construct adjacent to the high-speed rail pile group. The least distance between pile group foundation and tunnel structure is 0.98m.

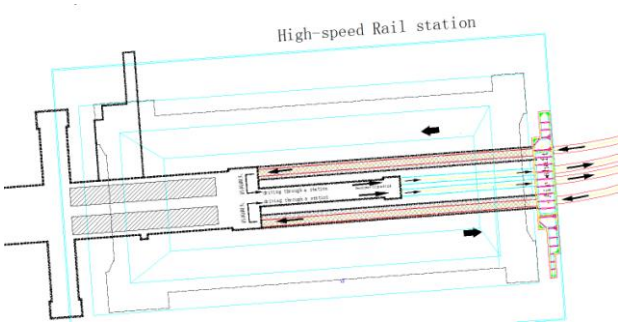

FIGURE 1 Tunnel and Pile Group Foundation Location

The tunnel lining is reinforced concrete segment, the segment uses 3+2+1 mode to combine, and the lining ring uses the staggered assembling. The width of segment is 1500mm, the thickness is 300mm, the outer diameter of lining is 6000mm, and the inner diameter is 5400mm. The strength grade of lining concrete is C50.

The geological exploration data shows that, the strata deposition has a certain regularity, which is composed by the following four parts: overlying quaternary Holocene alluvial clay within the site; upper Pleistocene alluvium clay; middle Pleistocene alluvium clay, and the underlying bedrock is third series siltstone. The main physical and mechanical indexes of the rock and soil in each layer are shown in table 1.

3 Three-dimensional numerical model

3.1 ESTABLISH THE MODEL

This paper uses the three dimension numerical simulation calculation, the outer diameter of shield construction is 6m, in order to precisely conduct the analysis of shield construction on the influence of pile and pile cushion cap, the shield tunneling influence scope take 3 times of the diameter on the horizontal direction and the depth direction[14-15]. The three dimensional calculation model size is 60m×80m×60m, as shown in figure 2. The position relationship of pile and tunnel is shown in figure 3. Set the equal property of them as the material properties, select Mohr-

Coulomb as the soil constitutive relationship, the concrete soil and mortar are defined as linear elastic body.

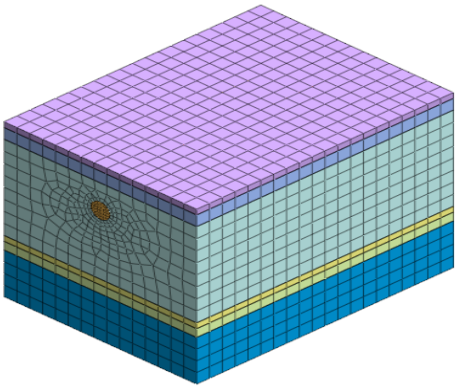

FIGURE 2 Three Dimensional Entity Calculation Model

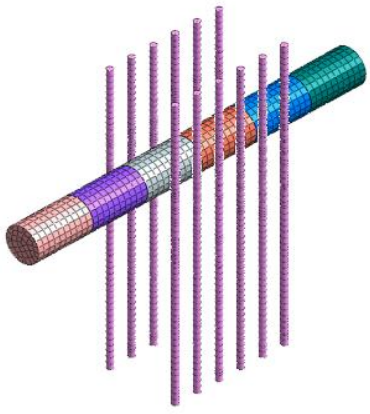

FIGURE 3 Tunnel and pile group foundation position relationship

3.2 SIMULATION PROCESS ANALYSIS

(1) Establish the model, apply the initial conditions according to the actual situation of the engineering and let the model reach to the steady state under the initial conditions;

(2) When the model reaches to the steady state, return the displacement to zero, activate the cushion cap and pile, and add the upper loading of cushion cap, when the

model is steady again, return the displacement of soil body and pile foundation to zero;

(3) Begin to make dynamic simulation of the excavation process of shield tunnel, and then combines the shield construction process, segment installation and other impacts to determine the excavation step length.

(4) After all the steps are completed, start to cycle from the fourth step, until the tunnel construction is over.

4 Result analysis of simulation calculation

4.1 ANALYSIS ON THE EFFECT OF GROUND SUBSIDENCE

With the continually advancing of shield machine, the continually expanding of soil displacement field scope, the soil underneath of shield tunnel swells because of excavation unloading effect, while the soil at the top of shield construction generates subsidence due to the lack of strata, the maximum subsidence value of surface displacement is 6.3mm, as shown in figure 4 and figure 5.

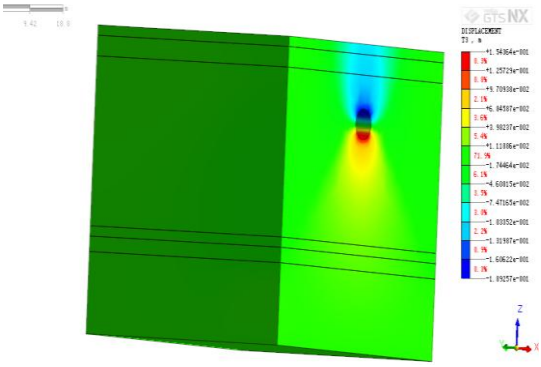

FIGURE 4 Subsidence deformation of soil when excavating for 40m of shield construction

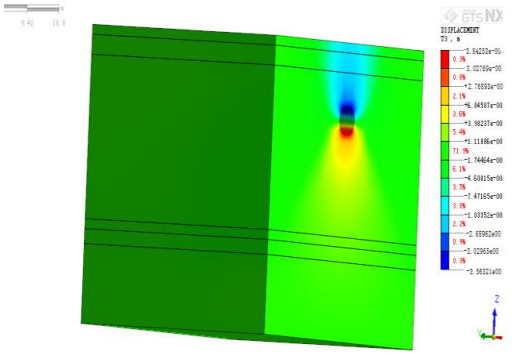

FIGURE 5 Subsidence deformation of soil when excavatin for 80m of shield construction

During the process of tunnel excavation, the soil displacement around the tunnel has the characteristic of dynamic change; the change law is that the maximum vertical deformation subsidence is increasing with the shield tunneling. Its subsidence deformation rate emerges the trend of increasing first and then decreasing during the process of shield pushing, and the ground subsidence deformation rate reaches to the maximum when the shield construction passes through that area.

4.2 ANALYSIS ON THE INFLUENCE OF SHIELD CONSTRUCTION ON PILE FOUNDATION DISPLACEMENT

4.2.1 Subsidence deformation of pile foundation

The additional stress of the around soil of the pile foundation caused by shield construction will cause the deformation of pile foundation, the subsidence of soil around pile foundation will generate drag effect on the pile foundation, so as to cause the subsidence deformation of pile foundation and reduce its bearing capacity. According to the simulation calculation result, the maximum subsidence amount of pile foundation is located at the top of pile; it is about 0.8mm, as shown in figure 6.

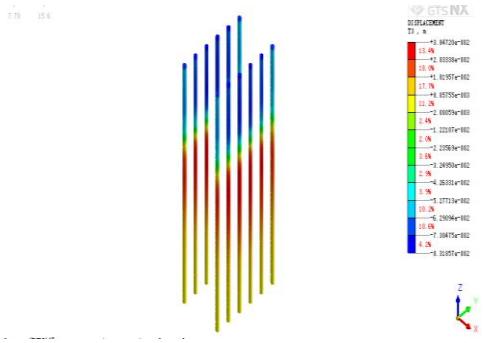

FIGURE 6 Subsidence amount of pile after the completion of shield construction

4.2.2 Lateral displacement along the tunnel of pile foundation

The buried depth of shield tunnel is shallower; the initial stress field of soil is the self-weight stress field. During the shield construction process, the soil initial stress field generates changes under the effect of the shield tail grouting pressure, thrust force of shield machine and other external loads. The upper and the lower side of tunnel will generate inward deformation (the top of tunnel generate subsidence downward, and the tunnel bottom generate uplift deformation), the left and right side of tunnel generate the outer deformation. Soil in both sides of tunnel will move to the direction away from the tunnel, so as the pile foundation generate the lateral deformation on the direction away from the tunnel, the maximum lateral displacement of pile is 3.4mm, as shown in figure 7 and figure 8.

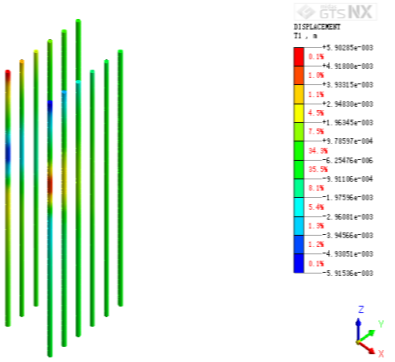

FIGURE 7 The pile lateral displaces along the tunnel when excavating for 40m of shield construction

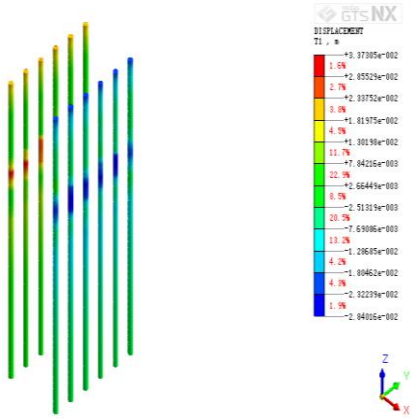

FIGURE 8 The pile lateral displaces along the tunnel when the shield construction is completed

4.2.3 Displacement of pile foundation along the excavation direction of tunne

It can be known from the three dimensional numerical simulation, the horizontal displacement of pile along the excavation direction of tunnel is shown in figure 9. The maximum horizontal deformation value of pile is 3.9mm, the minimum horizontal deformation value is 0.2mm, the direction is the same with the minimum horizontal deformation, and the horizontal deformation value of pile is gradually decreasing with the increase of depth.

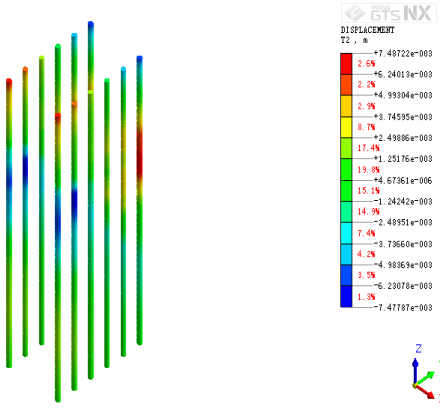

FIGURE 9 The pile displaces along the excavation direction of tunnel when the shield construction is completed

4.2.4 Comparative analysis on the ground surface subsidence calculation value and monitoring data

During the process of three dimensional numerical simulation calculation, uses K15+150 section as the specified monitoring section, and then make the comparative analysis on the ground subsidence deformation monitoring data during engineering construction process, as shown in figure 10. After the numerical simulation calculation, the maximum ground surface subsidence is 6.3mm, which occurs at the upper of middle line of shield shaft. The field monitored maximum subsidence value is 6.95mm. It can be known from the figure 11 that, the results of simulation analysis on the maximum ground subsidence deformation amount and the field monitoring is more closed, and the occurrence locations are basically the same.

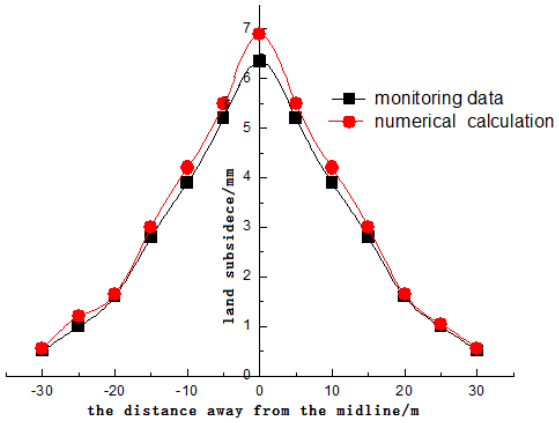

FIGURE 10 Transverse subsidence of ground surface deformation

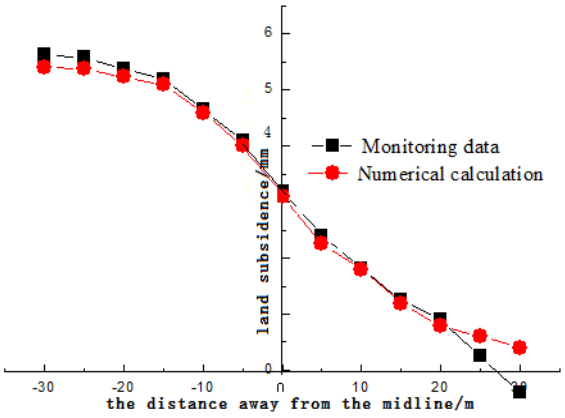

FIGURE 11 surface longitudinal settlement

5 Conclusion

This paper uses the station pile group engineering examples adjacent to the High-speed Rail South Station of Hefei No.1 Subway Line as the support, uses the three dimensional numerical simulation and field monitoring, conduct deeper study on the ground surface subsidence and pile foundation deformation law caused by shield method construction, and then obtain the following conclusions:

(1) It can be known from the three dimensional numerical simulation results that, during the construction process that is adjacent to pile group foundation of shield construction, the maximum ground surface subsidence is 6.3mm, the maximum subsidence amount of pile foundation is 0.8mm, the displacement along the excavation direction of tunnel is 3.9mm, the maximum horizontal lateral deformation is 3.4mm, which are in the tolerable scope of the pile foundation deformation.

(2) During the excavation process of tunnel, the displacement variation rule of the soil around is that, with the pushing of shield construction, the maximum ground subsidence value continually increase, and the subsidence rate presents the trend of increasing first and then decreasing during the pushing of shield construction, the subsidence rate reaches to the maximum when the shield construction passes through that area.

(3) Use finite element software MIDAS GTS can really simulate physical mechanics state of each construction stage in the process of shield excavation, the ground surface subsidence deformation amount obtained by the three dimensional simulation calculation and the actual on-site monitoring value are more closed, which can provide theoretical support for the similar underground engineering in the future.

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Authors

Donglin Wang , born on October 26, 1979, Xuan Cheng City, Anhui Province, P.R.China

Current position, grades: associate professor in School of Civil Engineering, Anhui Jianzhu University, Hefei, Anhui, China
University studies: Dalian University of Technology, China
Scientific interest: Geotechnical Engineer

Yusheng Jia, born on September 21, 1991, Su Cheng City, Anhui Province, P.R.China

Current position, grades: Post-graduate student of Anhui Jianzhu University
University studies: B.S. degree from West Anhui University of Civil engineering, AnHui, China, in 2008
Scientific interest: Geotechnical numerical calculation and its application.