Study on the law of ground subsidence caused by shield construction in composite stratum

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Abstract: In this paper, based on the actual working conditions of the shield tunnel of Jinan R3 line through the composite stratum, the engineering monitoring work was carried out. Combined with the GTS/NX finite element calculation software, the numerical simulation of shield construction in the composite stratum was carried out, and the law of ground subsidence caused by shield construction in the composite stratum was obtained, which can provide experience for similar projects, to prevent the damage caused by excessive surface subsidence above the composite strata.

1. Introduction

With the increasing demand of China's economic development for urban rail transit, shield tunneling method has been widely used by virtue of its advantages such as fast tunneling speed, high degree of mechanical automation and no influence on ground traffic. However, when the tunnel through the composite stratum, it will greatly disturb the stratum and threaten the buildings on the surface. Therefore, it is necessary to study the law of ground subsidence caused by shield construction in the composite stratum.

Scholars at china and abroad have done a series of research and analysis on the surface subsidence caused by shield tunneling in composite strata. Wang Jun [1] studied the disturbance characteristics of earth pressure shield tunneling on composite strata, and unearthed the settlement law of surface surface surface of pressure shield tunneling machine in different hard and soft strata. Zhao Xianpeng [2] studied and analyzed the ground subsidence caused by the construction, the key technology of shield construction and the mechanical properties of segments, etc., and proposed the reinforcement method of soil layer when shield tunnel passes through composite strata. Xiao Guowei [3] studied the law of ground subsidence caused by shield tunneling in composite soil layers with different ratios of soft and hard rocks, and carried out finite element simulation. The simulation results were in good agreement with the measured data. Yin Yebing et al. [4] combined the upper soft and lower hard geological structures and the law of surface subsidence, analyzed and summarized the measures to control the surface subsidence. Zhu Hongwei et al. [5] used GTX NX software to simulate the construction of a composite stratum shield, and analyzed the impact of shield construction on the surface settlement in the upper soft and lower hard stratum.

At present, there are many researches on the optimization of construction parameters, cutter head and segment in composite stratum, but there are few researches on the variation law of ground subsidence and settlement control caused by shield construction in uneven soft and hard stratum. Therefore, this paper, based on Jinan R3 line shield tunnel crossing composite stratum engineering
project, through the measured data and GTS/NX finite element analysis software simulation analysis, obtained the rules of ground subsidence caused by shield construction in composite stratum, which can provide experience for similar projects.

2. Project summary
Mengjiazhuang Station ~ Longao Station is located in Lixia District, Jinan City. It goes north along Longding Avenue to the west near the Armed Police Fire Brigade, crosses Daxin River and mountains, and then arrives at Longao Station, Aoti West Road, on the west side of the Municipal Procuratorate.

Menglong section is a single round shield tunnel, which is mainly composed of plain fill soil, silty clay, gravel soil, moderately weathered limestone and fully weathered marl from top to bottom. According to the crossing strata, it can be roughly divided into three sections. From north to south, the first section crosses 1,328m long moderately weathered limestone and moderately weathered marl. The second section crosses 118m long gravel and moderately weathered limestone mixed stratum (soft on top and hard on bottom). The third section passes through a 370m long mixture of gravel and silty clay. The uniaxial unsaturated compressive strength of moderately weathered limestone is 40 ~ 60MPa. In the depth range of investigation, there are dissolution pores, caves and other dissolution phenomena, relatively developed, the geological situation is complex.

3. Law of ground subsidence

3.1 Actual Settlement
During tunnel construction, the surrounding rock and soil collapse and excessive deformation or damage of buildings (structures), underground pipelines and other safety risk events often occur. Therefore, carrying out engineering monitoring work is of great significance to the prevention and control of safety risk events.

According to the "Underground Railway Construction and Acceptance Code", construction drawing design and site actual conditions layout point, according to the site measured value to draw the settlement map. Shield crossing composite stratum is mainly concentrated in XK1+1909.9~XK2+202.5, and they are all composite forms of silty clay in the upper part and gravel soil in the lower part, but the thickness of the two is different in different sections.
3.2 Numerical Simulation
In this paper, GTS NX finite element software is used for numerical simulation to verify the ground subsidence law during shield tunnel excavation in composite stratum. In order to make the establishment and calculation of the model as simple as possible, the size of the model in this paper is 53m×34m×43m, and the number of cells is 23,996. According to the actual situation, the mileage of the tunnel between XK1+909.9~XK1+953.1 Stratum, and the proportion of soft and hard rock in the direction of the tunnel is different.
Fig. 5 Surface settlement cloud map of shield tunnel in composite stratum

Extract the data from the model and draw the time history change diagram.

Fig. 6 Time history variation diagram of measuring point 4

Fig. 7 Time history variation diagram of measuring point 28

Compared with the actual testing schedule as variation can be found that are almost uniformly at
the top of the surface subsidence about line, the rest of the settlement measurement points are started in the current position before the excavation 3-4 ring, sedimentation rate increases progressively with the excavation, the peak when under excavation to the measuring point position, after the settlement gradually converges to the excavation to the measuring point position 5-8 ring; In combination with geological data, the section of the composite upper formation is silty clay, the lower is gravel soil, belong to the soft hard formation, at the beginning of the simulation of construction in tunnel into volume is higher than silty clay and gravel, simulate the end silty clay is higher than the gravel soil accounted for, combined with the schedule variation can be concluded that in shield through composite formation, When the volume of hard rock in the tunnel is larger than that of soft rock, the surface settlement is higher than that of soft rock in the tunnel.

4. Conclusion
Based on the shield tunnel project of Jinan Metro Line R3, the settlement law is summarized through the monitoring data of surface subsidence. For further verification, numerical simulation and theoretical calculation are carried out, and the following conclusions are drawn:

1. It can be seen from the monitoring data that the maximum settlement occurs in the construction stage, and the settlement gradually increases before construction, and reaches the peak when it reaches directly below the monitoring point. After construction, the settlement gradually tends to be stable.

2. Combined with the geological conditions and monitoring data, it can be seen that the biggest factor affecting the surface subsidence is the ratio of soft and hard rock in the composite stratum of the tunnel section. When the ratio of hard rock in the tunnel section is higher than that of soft rock, the subsidence is smaller; if the ratio of soft rock is higher than that of hard rock, the subsidence is larger.

3. Using GTS NX for numerical simulation calculation, the results obtained under the condition of considering grouting pressure have been proved by comparison that grouting is helpful to reduce surface subsidence.

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