Study on the technique of single-layer initial arch cover method in Hongyan Village Station

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Abstract: Aiming at the geological characteristics of the upper soft and hard stratum in Chongqing area, taking the Hongyan Village Station of Metro Line 9 as an example, the excavation method of super-large section single-layer initial arch cover method is proposed. The finite element numerical simulation is used to analyze the horizontal and vertical displacement of the surrounding rock, the axial force and bending moment of the single-layer initial arch cover, and the axial force distribution of the anchor. It is concluded that the single-layer initial arch cover method can meet the control requirements of deformation and surface settlement of super-large section surrounding rock. The initial arch cover of H220 grill steel frame + φ25, L=4.5m hollow grouting anchor + 300mm thick C25 wet-sprayed concrete can meet the bearing capacity requirements and ensure the overall stability of the structure. The connection mode of the large arch and the side wall arch is optimized to ensure that the initial branch is completely closed and looped. Combined with on-site monitoring and measurement data, it is feasible to use a single-layer initial arch cover method at Hongyan Village Station.

1. Introduction

The subway has developed rapidly due to its advantages of saving land, saving energy, less noise pollution, less traffic interference and guaranteed commuting time. The subway lines are generally arranged under the main trunk line of the city. The construction of the open-cut method is bound to cause traffic congestion. Therefore, most cities choose to use the underground excavation method. Chongqing is an important city in southwest China. In recent years, the subway has developed rapidly. Chongqing is a typical mountainous city. From the perspective of geological conditions, mountainous cities generally have a shallow distribution of bedrock. Most of the subway stations are in rock formations, and more conditions are used for underground excavation.

Most of the construction excavations of the underground subway station use the double-side guide pit method. In the later period, the safety risk during the construction of the central core rock pillar was relieved. However, under the condition of poor surrounding rock of Grade V and Grade IV, considering the technical maturity, high construction safety factor and good control effect on surface settlement, the double-side guide pit method is more suitable. For mountainous cities, the surrounding rock conditions are generally better. Under the circumstances, the arched cover method with higher construction efficiency is more advantageous[1-10].

The arch cover method is based on the open cut method, the cover cut method and the PBA method, and is an undercut construction method suitable for special strata. The arch cover method can generally be divided into a two-line arch cover method and an initial arch cover method. The initial arch cover method can be divided into a double-layer initial arch cover method and a single-layer initial support arch cover method.
According to the application of the arch cover method in Qingdao, Dalian, etc., as shown in Table 1, the second lining arch cover method and the double-layer initial arch cover method have been successfully applied and promoted, but the single layer initial arch cover method is rarely used[^11-15]. This paper studies the deformation of surrounding rock and the stress of supporting structure by single-layer initial arch method.

| No. | Site | Section size / m | Buried depth / m | Construction method | Initial support | Second lining |
|-----|------|------------------|-----------------|---------------------|-----------------|--------------|
| 1   | Qingdao Metro Line 2 Kaohsiung Road Station | 19.3*15.65 | 11.34~14.79 | Two-line arch cover method | C25,350 | 700 |
| 2   | Qingdao Metro Line 2 Xujia Maidaop Station | 20.82*19.6 | 13.64~16.7 | Double-layer initial arch method | C25,350+ | 800 |
| 3   | Qingdao Metro Line 2 Haichuan Road Station | 20.3*19.6 | 12.72~14.27 | Double-layer initial arch method | C25,350+ | 700 |
| 4   | Qingdao Metro Line 4 Neimenggu Road Station | 20*17 | 10~11.73 | Double-layer initial arch method | C25,350+ | 700 |
| 5   | Qingdao Metro Line 11 Liaoayang Road Station | 22.86*17.36 | 14.5~18 | Two-line arch cover method | C25,350 | 700 |
| 6   | Dalian Metro Line 2 Zhongshan Station | 19.5*17.4 | 5.2~6.7 | Two-line arch cover method | C25,350 | 800 |
| 7   | Dalian Metro Line 1 Xinggong Street Station | 24.3*18.1 | 12.8~15.82 | Double-layer initial arch method | C25,350+ | 700 |
| 8   | Chongqing Metro Line 5 Fengxi Road Station | 22.6*19.79 | 16.5~18.4 | Double-layer initial arch method | C25,350+ | 700 |
| 9   | Chongqing Metro Loop Line Min'an Station | 30*28.9 | 58 | Two-line arch cover method | C25,350 | 900 |
| 10  | Guiyang Metro Line 3 Intermediate Station | 20.9*17.6 | 8.4~11.0 | Double-layer initial arch method | C25,350+ | 800 |

2. Project Overview
Hongyan Village Station of Chongqing Metro Line 9 is located in Yuzhong District, Chongqing, the sixth station of the line. The station is a two-story underground excavation station. The basement level is the station floor and the second basement is the platform floor. The total length of the station is 262.3m. The excavation has a net width of 24.24m and an excavation height of 21.23m. The surrounding rock level is III~IV, and the geological conditions are good.

3. Analysis of surrounding rock deformation and support structure stress

3.1 Modeling
Using MIDAS-GTS NX general finite element analysis software modeling analysis. The constitutive model of the surrounding rock of the tunnel adopts the Drucker-Prager (D-P) model to consider the nonlinear deformation of the surrounding rock. The lining structure is simulated by elastoplastic isotropic material. The bolt is simulated by full-length bonded rod material, which is an implanted truss unit. The initial lining of shotcrete is simulated by full-length bonded straight beam material. The calculation steps are performed in accordance with the tunnel construction sequence.

3.2 Analysis of surrounding rock deformation
The vertical displacement analysis from the surrounding rock is shown in Figure 1. The maximum settlement of the arch of the tunnel occurred after the core soil was taken, which was -12.34mm. The maximum bulge at the bottom of the intrusion occurred at the end of the last central lower guide pit, which was 17.57mm. The vertical displacement of the surrounding rock around the tunnel was small.

From the lateral horizontal displacement analysis of the surrounding rock as shown in Figure 1. The maximum convergence displacement of the side wall of the tunnel occurred 6.39 mm after the core soil was taken, and the horizontal displacement of the surrounding rock around the tunnel was...
small.

Generally speaking, the displacement deformation of the surrounding rock of the tunnel is small, the surrounding rock of the tunnel is basically stable, and the risk is controllable.

3.3 Stress analysis of supporting structure

From the force diagram of the supporting structure (Figs. 2, 3, 4). The bending moment at the arch is about 48.97kN·m, the axial force is 1429.27kN; the bending moment at the side wall is about 68.23kN·m, the axial force is 1787.76kN; The bending moment at the arch is the largest, about 88.03kN·m, and the axial force is 1080.17kN. According to the calculation of the reinforced concrete beam, the maximum reinforcement area is 700mm². The actual H220 steel grille arch frame is used. The reinforcement area is: 2*380/0.75=1013mm²>700mm², can meet the requirements. The maximum axial force of the bolt is 127.01kN, which is less than the yield strength of 335MPa. The bolt is in good condition and meets the requirements.

In summary, according to the calculation results and engineering experience analogy analysis, the tunnel section support structure can meet the surrounding rock stability and support structure stress.
requirements.

4. Large arch construction points

The large arch is the key node in the construction process of the initial arch cover method, which plays a key role in the stability of the tunnel arch. The following points should be noted for the construction of the large arch.

1. The construction of the large arch foot needs to be carried out by means of blasting excavation and mechanical construction. The arched foot surface should be trimmed to the excavation completion surface by manual chiseling to maximize the protection of the rock mass.

2. The arched feet shall not have any scum; the rock face of the arched foot of the large arched steel frame shall be smeared with M30 cement mortar to smooth the rock face, and ensure that the base of the large arched steel frame is closely attached to the rock face.

3. When constructing the side wall steel arch frame, firstly remove the concrete outside the large arch, and then connect the side wall arch frame with the large arch frame.

5. Field application and monitoring measurement

The main structure of Hongyan Village Station was constructed by single-layer initial arching method. Construction began in June 2018. At the end of May 2019, the main structure excavation and initial branch were completed. The average work efficiency is 1m/day. The construction progress is good, the construction quality meets the requirements, and the construction site is safe and controllable.

During the construction process, the whole process monitoring of the ground settlement, dome settlement and clearance of the tunnel is carried out.

The monitoring measurement results are shown in Figures 5, and 6. The cumulative maximum settlement of the dome is monitored by 6.91mm<20mm (design value), the maximum convergence value around is 4.33mm<10mm (design value). The Hongyan Village Station uses a single-layer initial arch cover method to control the surrounding rock deformation and surface settlement well, meeting the requirements of urban subway construction.

6. Conclusion

1. The single-layer initial arch cover method can meet the control requirements of deformation and surface settlement of super-large section surrounding rock.

2. The use of H220 grill steel frame + φ25, L = 4.5m hollow grouting anchor + 300mm thick C25 wet-sprayed concrete initial arch cover can meet the bearing capacity requirements.

3. The large arch foot is the key node in the construction process of the initial arch cover method.

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