Research on Water Inrush Disaster Control Technology in Double Shield TBM Excavation Process

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Abstract: Taking the TBM water inrush accident in An-Xue section of Qingdao Metro Line 1 as the engineering background, the research is carried out from two aspects of TBM water inrush emergency measures and grouting reinforcement treatment technology, which can ensure the strength of stratum reinforcement and water shutoff, and at the same time prevent the slurry from damaging the cutter head. For different areas, the grouting construction technology is proposed. After the reinforcement, the water stopping effect is obvious, the water inrush point has no water flow out, the hole drilling effect is good, the core removal rate is 75%~85%, and the strength meets TBM excavation requirements.

1. Introduction

Whole section Rock tunneler have fast, efficient, high quality, safety and environmental protection and other technical characteristics, the driving speed is 3~10 times of drilling and blasting method, there is no back break phenomenon, small disturbance of surrounding Rock, and blasting vibration, has been more and more used in large water conservancy and hydropower engineering and urban subway Tunnel engineering [1-5].

James Robbins in the United States successfully applied TBM in field engineering by improving the hob technology based on Charles Wilson at 1956 [6,7]. Since then, TBM has been gradually promoted and applied. The research on TBM in China started relatively late and began to be developed in the 1950s, but the development was relatively slow due to technical, economic and other reasons [8]. However, a large number of TBM technology for underground space construction has become an inevitable trend of urban construction. According to statistics, China will soon become the first application country of TBM [9-11].

However, the adaptability of TBM formation is poor, and water inrush and other disasters occur in the construction project, which can easily lead to serious accidents such as machinery scrapping. Taking the TBM water inrush accident in anxue section of Qingdao metro line 1 as the engineering background, this paper studies the emergency measures of TBM water inrush and grouting reinforcement treatment technology. The treatment effect is obvious, so as to provide some reference and guidance for similar projects.

2. Engineering background

2.1. Project overview
The starting point of Anzi east station and Xuejiadao station in no.2 engineering survey section of Qingdao metro line 1 is located in the east section of Xingang mountain road, Huangdao development zone, with a length of about 1826.5m. The specific traffic location is shown in figure 1.

2.2. Water inrush
On November 22, 2018, 6 o’clock in the morning 10 points, xue interval line right TBM to YK19 + 436.557, the knife dish above sudden flood water (see figure 2), the ground appeared according to (as shown in figure 3), the early stage of the location of about 2400 m³/h (how about 40 min), the late water decreases to 500 m³/h, the scene immediately began to smoke at the water drainage, at 2 PM to the water began to decline, the average water level drop speed of 10 cm/h.

3. Cause analysis of water inrush
According to the geological prospecting data, the fractures and joints of the strong weathering strata traversed by TBM are developed. TBM further disturbs the bottom layer in the course of tunneling, further destroys the weak layer and leads to the connection of water capsule, mud capsule and seawater supply pathway, and finally forms water inrush on the face of the palm.

4. TBM water inrush disaster treatment methods and measures

4.1. Emergency treatment measures
After the TBM water inrush, the site immediately arranged emergency pumping, while the ground subsidence area was back filled with concrete, two rows of grouting holes were set outside the TBM contour, oil polyurethane was injected for emergency water plugging.

4.2. Grouting reinforcement and treatment technology
In order to prevent the recurrence of water inrush disaster and ensure the smooth tunneling of TBM, the construction technology of separate hole sequential and segmented mould bag grouting is adopted. The construction process is shown in figure 4.
4.3. Grouting reinforcement scope and drilling design

Take into account the grouting reinforcement process, the protection of the TBM cutter head is crucial, so for the inlet line around the double shield TBM is to cutter location 5 meters in front of the key research area, the knife dish in front of the 4 meters 1.5 meters to the knife dish rear area using mould bags pile construction, 4 meters area just behind the inlet side to TBM cutter disc and cutter in front of the 1.5 m to 5 m in control and grouting, the rest of the region by jet grouting pile.

Selection of grouting materials and grouting equipment: P.O 42.5 ordinary Portland cement slurry was selected as the material of filter grouting compaction pile and controlled cement grouting material. The water-cement ratio of slurry is about 1:1~0.5:1. The mixing time and quantity of control fluid (patented material) are determined according to the boost pressure in the hole and the change of slurry amount, which is generally 6 ~ 10% of the weight of cement.

Determination of grouting parameters: According to the experience of similar projects and considering the bearing capacity of strata, the final grouting pressure is determined to be 0.5~3Mpa and the grouting rate is determined to be 10~40L/min.

Drilling construction: It is proposed to adopt type-90 crawler drilling machine for drilling. The diameter of the drilling hole is 146~168mm, and the depth of the hole is 21.0m. The deviation slope of drilling hole should be controlled within 1% and should not exceed the hole spacing.

Grouting construction technology: Both the mold bag compaction pile and the controlled cement grouting are constructed in sequence. The grouting sequence is in accordance with the hole formation sequence, hole formation one by one construction. When the bag reaches a certain degree of saturation, the block is lifted to the top section to continue grouting.

5. Grouting effect inspection

After grouting treatment, the water-resistance effect is obvious and no water flows out of the water inrush point. Meanwhile, inspection hole is applied to check the grouting reinforcement effect of the stratum, as shown in figure 8. The core extraction rate reaches 75%~85%, and its strength meets the requirements of TBM tunneling.
6. Conclusions and recommendations

(1) For water inrush accident during TBM tunneling, when taking immediate drainage and drainage measures, chemical slurry can be used for emergency water shut off.

(2) The grouting operation in the TBM cutter head area should ensure the strength of the formation reinforcement on the one hand, and prevent the damage of the slurry to the cutter head on the other hand. In view of this, we can consider to adopt the grouting construction technology of divided and segmented mold bag with separated holes in the actual project.

(3) After grouting reinforcement, the water stopping effect is obvious, no water flow is flowing out of the water inrush point, the drilling effect is good, the coring rate is up to 75%~85%, and its strength meets the requirements of TBM tunneling.

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