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Research on TBM type selection risk for long draw water tunnel

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Abstract.The draw water tunnel of west line project is composed by tunnels group, the longest tunnel section is 73km, belonging to the super long tunnel. The tunnel construction method is TBM. The engineering geology and hydrological geology is complex along the tunnel, facing a lot of engineering geological problems in the excavation process, such as water inrush and rock burst. Through the TBM type selection factors analysis in West super long tunnel, drilling and blasting method and TBM methods are compared, the advantages and disadvantages between shield TBM and open type TBM are also be compared, the double shield TBM is selected as the construction machinery. At the end of the analysis, the adaptability to the formation of TBM is analyzed, and the improvement measures of TBM is put forward.

1. Introduction

The west route project is located in southeastern Tibetan Plateau, at an altitude of about 4000 meters. The area where the project is located has complex landforms, and its geological conditions are extremely complicated[1-3].

The rock stratum in project area is mainly belongs to Trias, the lithology is mainly thin to thick layer sandstone and slate, sandstone and slate is medium to hard rock, part of the carbonaceous slate strength is very low.

The deeply buried long tunnel is main part of the West Route Project, which is divided into five tunnels. Daqu to Niqu(13.6km), Niqu to Duke River(73km),Duke River to Ma Ke River(36.2km), Ma Ke River to A Ke River(15.5 km) , A Ke River to the Yellow River(50.4km). The longest tunnel is 73km, tunnel diameter is 12m, the maximum depth is 1150m, TBM is used in tunnel excavation process.

The project area is located in alpine and gorge region and geologic conditions are extremely complex, the construction may encounter many problems, such as high stress and rock burst, water gushing, harmful gas, landslides [4,5].

At present, there is no experience of similar projects for reference, so how to choose the suitable TBM type according to the characteristics of the project itself is the key to successful completion of the project.

2. Development and application of TBM in China

The full face rock TBM manufacturing began in the 1960s, with a diameter of 2.5 to 5.8m, but compared to foreign imported TBM, the domestic TBM is fall behind in mechanical properties, equipment, design and manufacture. Driving speed is slow, the highest monthly footage does not exceed 300m. The TBM manufacturing technology has been listed in the national high technology research and development program.

The introduction of full face rock tunnel boring machine construction has made considerable progress, widely applied in railway, water conservancy and hydropower engineering, such as Guizhou Tianshengqiao secondary hydropower station diversion tunnel, Xikang Qinling railway tunnel, Liaoning Dahuofang reservoir water diversion project, Guangzhou metro, Beijing and Chengdu subway project. Among them, the diameter of Tianshengqiao secondary hydropower station diversion tunnel is 10.8 m, and achieved some experience.

Compared with traditional DB method, TBM has the advantages of efficient, fast, high quality and safety. The construction is convenient and beneficial for environment protection and saving labor force, reduces the labor intensity of the workers, easy to construction management.

The shortcomings of TBM construction is poor adaptability to geological conditions than conventional drilling blasting method, especially in the face of karst caves and underground water, the one-time investment cost is large and the proportion of equipment investment is very much.

3. Analysis of TBM type-selection

3.1. Factors affecting the choice of TBM

TBM is largely dependent on the geological conditions, once the model is determined, it is very difficult to carry on modification. Therefore, the choice of TBM should combine with geological conditions and the technical and economic feasibility.

3.1.1. Geological factors. Geological factors should be considered in the selection of TBM including: the topography, fault zone location and groundwater distribution, rock physical and mechanical properties and various parameters. Because of complex geology and geomorphology, rock strength and crack distribution will affect the TBM driving speed. Stress and water inrush also has great effect on the support form.

3.1.2. Eequipment and scientific management factors. As a complex mechanical system, each TBM should be manufactured according to different geological, support and diameter, the follow-up protection, maintenance and parts supply are related to the construction success or failure. As the project location is very remote, the staff always face different construction environment, construction risk is rather high, construction manager and organizer should have ability to respond to various circumstances.

3.2. Analysis of TBM selection

According to the tunnel construction experience at home and abroad, the success rate of TBM construction depends on whether the correct the selection of TBM. Because TBM is a very strong professional machinery, the models is wide range. TBM selection mainly consider three aspects:

(1)Technology and economic comparison between drilling and blasting method and TBM method;

(2)Comparison between shield TBM and open and TBM (single and double);

(3)Comparison between mechanical structure and construction parameters of the same type of TBM.

3.2.1. Comparison between drilling and blasting method and TBM method. For the tunnel of length more than 3km, the construction of boring machine is preferred. From the cost of excavation, the tunnel cost is the sum of excavation and lining. In China, TBM pure excavation cost is 10% - 25% higher than drilling and blasting method, due to the TBM overbreak volume is less 3% - 10% than drilling and blasting method, it can save nearly 50% of the concrete lining costs, so the assembly tunnel cost is not higher than drilling and blasting method. TBM method obviously better than drilling and blasting method from the economic cost, construction speed, environmental protection, safe and reliable, tunnel in western line project is deep buried long tunnel, has complex geological conditions, TBM construction should be selected.

3.2.2. The choice between open TBM and shield TBM. The full face TBM machine can be divided into open type and shield type from the head type. The open tunnel boring machine is generally applicable to the tunnel with good surrounding rock conditions and can be self stable after excavation, and the strength of the rock should provide enough support, and it also needs to withstand the pressure of the grounding of the machine head without sinking. Open TBM can timely identify the geological conditions before heading and deal with unfavorable geological conditions in time. But when the fault is encountered, the open type TBM support is unable to work and is forced to shut down. Large area of surrounding rock support is needed, especially when large water is poured into the tunnel. Under the condition of very weak surrounding rock, it is difficult to control the heading direction of roadheader.

The most used shield TBM is the double shield TBM. Because of the shield structure, this type of shield can be applied to complex strata, especially the complex and changeable strata. When the fault and the broken zone are more, the personnel can be protected under shield protection, and the safety is better. But the double shield TBM has a high cost, about 30% higher than the open type. The comparison of different types of TBM construction is compared in table 1.

Table 1. Comparison between open and shield TBM construction

Contrastive items	Open type TBM	Double shield TBM	Single shield TBM
Driving performance	Parameters can be adjusted according to different geology	Parameters can be adjusted according to different geology	Parameters can be adjusted according to different geology
Support speed	Support work is heavy and slow	The support speed is fast	The support speed is fast
Geological adaptability	The adaptability of hard rock is good, and soft surrounding rock needs advanced reinforcement.	The adaptability of hard rock driving is better than that of open type	Mainly aimed at weak surrounding rock
Safety	Safety is bad	Safety is good	High security
Driving speed	Greatly influenced by geological conditions	Less affected by geological conditions than open	Less affected by geological conditions than open

According to the complicated geological conditions of the west line tunnel, there are many hard rocks and many fault belts, so the double shield TBM can be preferred.

3.2.3. Analysis of the adaptability of TBM to formation. The geological conditions of the west line engineering area are complex. TBM selection should be combined with the formation conditions, TBM construction experience and the construction environment

(1) Geology that is not suitable for using TBM construction

According to engineering experience, TBM is not suitable for all projects, and the following conditions are not suitable for TBM construction. First is a large deformation zone of weak surrounding rock; second is the expansive surrounding rock with more sand grains; third is a fault and its broken zone; fourth is a zone with more karst distribution; fifth is a serious area of water inrush and water inrush; and sixth is a hard rock and rock material.

According to the experience of the built tunnel, the TBM is most suitable for the hard rock with uniaxial compression strength 30-150MPa, the uniaxial compressive strength of the surrounding rock is between 40 and 90MPa in the first phase project, which is medium and hard rock, so it is more suitable for the use of TBM. Along the tunnel, the main types of surrounding rock are class II and III, and the stability is relatively good. At the same time, the dip angle of the rock strata is steep, which is beneficial to the stability of the surrounding rock. The open type or double shield type TBM construction can be used.

(2)TBM selection requirements for West Line Project

①Crossing fault and broken zone

The tunnels in west line passes through a number of active faults. The width of the local fault zone is often hundreds of meters wide, its integrity is poor, the fault joints and cracks are developed, the self stability is poor, and the collapse is easily produced, which brings the risk to the construction of TBM. Moreover, the area is often a water rich zone, prone to water bursting and mud bursting accidents, which requires TBM to have good sealing performance and powerful drainage equipment. In order to make accurate prediction of fault attribute and influence area, it is necessary for TBM to reserve advanced prediction system in design and manufacture, and grouting equipment is also essential.

②Can effectively deal with a large amount of water inrush

The water inflow of deep buried long tunnel is mainly bedrock fissure water and structural fissure water, with large amount of water inflow, high head pressure and abundant supply. At present, there are some researches on prediction of water inrush from fractured rock mass at home and abroad, but the accuracy needs to be further improved. Therefore, TBM should be equipped with larger power drainage equipment, and has a device to prevent the risk of water spray and surge.

③Traversing the sandy slate zone

This is the main rock stratum in the west line tunnel, which is interbedded. The strength of sandstone is high, the slate is low, the strength and stability of the rock are changed greatly. The composite type of TBM is needed. Due to the high strength of sandstone, TBM type cutter with high rigidity should be selected, and different types of hob should be prepared according to the situation.

④Adaptability to high temperature construction environment

The surrounding rock temperature of the tunnel geothermal anomaly area of the west line project can reach 53 to 68 degrees Celsius. High temperature will affect the working life of TBM, especially the construction of 73km tunnel with single head ventilation. Special design should be adopted to ensure adequate cooling.

⑤Can adapt to the climate conditions of high cold and anoxic

In the engineering area, the altitude is high, the oxygen content in the air is very low and the temperature difference is great. The mechanical efficiency, heat dissipation and power performance of the TBM construction will be greatly reduced. A special high-power engine should be designed to adapt to the extreme situation of the dynamic failure of plateau.

4. TBM improvement measures

During the use of double shield TBM in west line project, there is a great risk in construction. If it is not suitable for the project, it will cause immeasurable loss. Therefore, the double shield TBM needs to be improved to suit the special conditions of the tunnel. According to domestic research, it is believed that TBM can be improved from the following aspects.

(1)Shorten the body of TBM as much as possible to reduce the chance of being stuck.

(2)Design the conical body to reduce the friction of shield.

(3)The cutter head is equipped with reaming equipment to reduce the friction of shield.

(4)The front face of the cutter head is designed as a plane, reducing the friction between the cutter head and the surrounding rock, supporting the surrounding rock surface at the same time.

(5)Increase the cutter torque design.

(6)Add the control system of the slag quantity to reduce the probability of stopping the slag.

(7)Add the grouting and advance forecast system.

(8)Iimprove the bearing capacity of cutting tools to prevent tool wear too fast.

(9)Equipped with a strong cooling equipment.

(10)The power of the ventilation equipment is large enough to ensure adequate oxygen.

5. Conclusion

The diversion tunnel of the west line project is in the high mountain and canyon zone with complex geological conditions. It is necessary to select TBM with advanced technology and reliable quality. In this project, we should integrate the domestic and foreign manufacturers, consult and prefix the mechanical parameters and types as early as possible, and provide corresponding auxiliary equipment, such as ahead of forecast, grouting and reservation of different hobs, which will provide technical support for the smooth development of future projects.

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