Comparison of Route Selection Schemes of Dong Tianshan Tunnel based on Geological Analysis

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Abstract. Based on the understanding of the engineering geological conditions in the tunnel site area of the Dong Tianshan Tunnel and the summary of engineering practice, an engineering geological route selection method for the Dong Tianshan Tunnel is proposed. Focused on the research and analysis of the engineering geological conditions and surrounding rock geological conditions and classifications related to the various line schemes of the tunnel section. And on this basis, analyze the situation of the two lines from the tunnel length, surrounding rock conditions, water gushing, unfavorable geological conditions and so on. Considering the stability of the opening and the construction safety of the cave body, the recommended scheme K is less risky than scheme B, and is safer and more reasonable.

Keywords: Dong Tianshan Tunnel; Engineering Geological Conditions; Surrounding Rock; Adverse Geological.

1. Preface

With the sustained and rapid development of China's economy, the development of transportation in the western region has attracted more attention from the state. More and more major lifeline projects such as water conservancy, transportation, and mines have been carried out one after another, and tunnels are particularly important as the key control projects of these lifeline projects. Due to the complex and changeable geological conditions of the tunnel, unfavorable geological problems such as subsidence, mud outburst, water gushing, rockburst, and harmful gas are often encountered during construction. Geological disasters such as landslides, collapses, mudslides, and avalanches are also common along the line. These problems not only increase the difficulty of construction, endanger the lives and health of people, but also cause great losses to the economy[1-6].

Furthermore, the tunnel project is a typical geotechnical project, and the concealed project is mostly affected by geological factors, the construction risk is relatively high, and the construction is very difficult. If we do a good job in the design of the tunnel line selection, it will be a good start for the smooth construction of the tunnel. Creating a good construction and operation safety environment will undoubtedly play an extremely important role in reducing project cost, ensuring construction period, ensuring transportation safety, and building railways well and quickly[7-9]. Many domestic scholars have conducted research on this. For example, Cao Huaping emphasized the investigation and analysis of karst development law and karst water system supplementary discharge conditions, and put forward the views and suggestions for railway line selection in karst areas[10]. Ma Tao discussed the topographic route selection, geological route selection and the determination of the main control point scheme of mountainous roads from the aspects of mountainous road topography, geology, and main control points [11]. Yin Hang took the Maluqing Tunnel as an example to carry out the research on the route scheme of the tunnel crossing the karst geological development area, and put forward the selection criteria for the tunnel crossing the karst area[12].

This article will summarize the understanding and engineering practice of the engineering geological conditions in the tunnel site area of the Tianshan Tunnel in the east. Based on the analysis of tunnel length, surrounding rock conditions, water gushing, and unfavorable geological conditions, an engineering geological route selection method for Dong Tianshan Tunnel is proposed.

2. Project Overview

The entrance of the Dong Tianshan Special Long Tunnel is arranged on the downstream side of Pine Pond Ski Resort north of Tianshan, and the exit is arranged on the right bank of Hulugou, which is about 2.6km away from the exit of Hulugou and the tunnel length is 11865m. The tunnel site has a temperate continental arid climate, and the higher the altitude, the richer the precipitation, up to 500mm. The tunnel site area belongs to the landform type of high mountains and deep valleys. The tunnel crosses the Tianshan Mountains and is a typical "V"-shaped canyon area. The exposed strata are mainly Devonian, Quaternary and Variscan intrusive rocks. The peak acceleration of the earthquake is 0.20g, and the corresponding basic earthquake intensity is VIII degree.

3. Geological Overview of the Region

3.1 Topography

The tunnel site belongs to the landform type of high mountains and deep valleys. The tunnel crosses the Tianshan Mountains. The line enters the tunnel from the vicinity of Songshutang. The entrance slope is relatively gentle and the vegetation is relatively dense, mainly pine trees and other trees. Gullies are developed on the north and south sides of the Tianshan Mountains, and the tunnel lines are mainly on both sides of the Hulugou on the south side of the Tianshan Mountains.

Among them, the section K from the entrance to K20+670m is on the left bank of Hulugou, which belongs to the high mountain area. The section from K20+670 to K20+800m is the Hulugou section, which is a typical "V"-shaped canyon area, and the water flows in the ditch all the year round; The section from K20+800m to the exit is arranged on the right bank of Hulugou. The watershed between the valleys is relatively thin, and the bottom of the valley is generally covered by flood deposits.

The whole line of Scheme B is arranged on the left bank of Hulugou. The landform is a landform between rivers with gullies and beams. The cutting depth of gullies is relatively large, the slope is steep, and the height difference between the bottom of the gully and the ridge is greater than about 1000m. , is a typical landform of high mountains and deep valleys.

3.2 Geological Conditions

3.2.1 Formation Lithology

According to the survey, the section through which the tunnel passes is dominated by weathered (strong to slightly) tuffaceous siltstone interbedded with sandstone. The entrance and exit sections of the tunnel are covering layers, and the surrounding rock formations are middle Devonian Dananhu Formation tuffaceous siltstone and tuffaceous sandstone layers, interbedded with slightly weathered granite and diorite. The inlet section is the diluvial silty clay containing gravel and the fault fracture zone of the F1 fault fracture zone. The body of the cave mainly exposes two regional faults, F2 and F3, with a width of 240m-350m, mainly composed of mylonite and extruded cataclysmic rock. The exit section is a crushed rock soil layer formed by the collapse.

3.2.2 Geological Structure

Three regional faults such as F1, F2, and F3 are developed. The rocks in the F1 and F2 fault zones are broken, and the rocks in some sections are severely mylonitized. When the caverns are excavated, under the action of gravity, plastic deformation is easy to occur, causing collapse, roof fall, etc. Accidents happen. The rock mass of the tuffaceous siltstone interbedded with sandstone strips is relatively hard, and the joints are relatively developed. The joints cut each other, easily forming unstable blocks, and prone to block loss during the excavation process. The rock mass south of the F3 fault is mainly composed of micro-weathered tuffaceous sandstone, diorite, and granite. The rock mass is dense and hard. During the excavation process, some blocks were lost due to joint cutting, and the stability of the surrounding rock of the cavern is relatively good. F1 is the Holocene active fault, F2 and F3 fault zones are pre-late Pleistocene faults, and F1, F2 and F3 have an impact on the stability of the tunnel surrounding rock.

3.2.3 Hydrogeological Conditions

The main exposed lithology in the tunnel site area is tuffaceous sandstone, siltstone, diorite, granite and Quaternary Holocene strata, and the groundwater types are mainly bedrock fissure pore water and loose layer pore water. Groundwater is mainly recharged by atmospheric precipitation. The hillside in the area is steep, and the precipitation can quickly concentrate in the gullies as slope runoff, which directly affects the infiltration recharge of the precipitation to the water-bearing rock formation. The runoff of groundwater is mainly controlled by the rock properties and geological structure of the aquifer, and the discharge methods are mainly atmospheric evaporation and lateral seepage into the Hulugou. Root. According to the hydraulic test results, the water quality in the tunnel site area is judged according to the " Code for Highway Engineering Geological Investigation " [13] (JTG C20-2011), and the water quality in the tunnel site area is slightly corrosive to concrete.

3.2.4 Adverse Geological Conditions

The main adverse geological phenomena developed in the tunnel site area include collapse, loosening and deformation, as well as dangerous rocks and debris flows.

(1) Collapse and dangerous rocks: mainly distributed on both sides of valleys in high and medium mountain areas. Due to the steep mountain slopes of 60-80 °, there are many dangerous rock masses on both sides of Hulugou, which are prone to collapse and collapse. According to the on-site geological survey data, the collapse bodies are mainly developed on both sides of the valley, and the loose bodies that have a significant impact on the tunnel exit are B1 and B2 collapse bodies.

The B1 collapse body is distributed at the exit of Line B, mainly consisting of a layer of crushed stones. The volume of the collapse body is about 78000 m3, and the original rock is granite, tuffaceous sandstone, etc., in an angular shape. The surface is relatively loose, the lower part is dense, and the mud content is high. It is recommended to clean and take necessary support measures at the entrance of Line B.

The B2 collapse body is distributed in the B line BK19+970~BK20+320, mainly consisting of gravel soil layer, with loose block and gravel, with a total volume of about 568000 m3. The original rock is mainly granite, tuffaceous sandstone, etc. The large volume of the collapsed body causes the right side of the B-line tunnel to easily collapse. It is recommended to strengthen support at this location.

The remaining collapse bodies are mainly distributed on both sides of Hulugou and its tributaries. The volume of the collapse body is not large and mainly consists of a layer of crushed stones. The lower part has a high mud content and is relatively dense, which has no impact on the tunnel engineering.

(2) Debris flow: The gullies in the Hulugou watershed are relatively developed, and two gullies such as N15 and N14 have been mainly investigated for their impact on the route. The following are the details:

The N15 debris flow gully is located about 80m downstream of the tunnel exit in Scheme A. The gully is mainly composed of colluvial blocks and crushed stones. The length of the debris flow gully is 1.96km, with a drainage area of 1.7km2, and a single solid material discharge of about 14000m3. The debris flow is a small debris flow, which has little impact on Scheme K. It is recommended to guide and discharge the N15 debris flow gully, reduce the elevation of the gully mouth, and protect key lateral slopes, avoid threats to the safety of debris flow gully routes.

The N14 debris flow gully is located approximately 480m downstream of the exit of the K-line tunnel in the comparative plan, in the deep section of the B-line tunnel. The burial depth of the B-line section passing through the N14 debris flow gully is nearly 90m, with a thickness of 37.1m and a distance of about 450m from the exit of the K-line. It is located on the opposite bank upstream of the exit of the K-line. The ditch is mainly composed of colluvial block gravel and alluvial gravel soil, and the N14 debris flow ditch is a large valley type debris flow. Taking into account the peak flood duration of the generalized flood process curve and the duration of other valley debris flows in the area, based on the characteristics of debris flow development in the northwest region, it is calculated that the total amount of solid matter washed out by a debris flow is 104200 m3. The N14 debris flow has a significant impact on the exit bridge of the K line. As the B line passes through the bottom of the N14 debris flow gully, the debris flow has no impact on the line.

In summary, the N14 debris flow is directly facing the Hulugou Bridge on the K line, which has a significant impact. The B line passes through the debris flow gully, and through drilling and geophysical exploration, it has been revealed that the minimum thickness of the tunnel roof at this location is about 30m, which may cause disasters such as roof fall and large water inflow in the B line tunnel.

4. Research on Route Selection of Dong Tianshan Tunnel

4.1 Line Selection Principles

When selecting the tunnel location based on geological conditions, the following points should be noted:

(1) The location of the tunnel should be chosen as much as possible in a geological structure that is simple, with underdeveloped joints and fissures, good lithology, and stable strata.Weak structural planes, fractures, folds, and twisted zones in rock formations are often prone to collapse, rock block sliding, and significant uneven surrounding rock pressure due to the development of joint fissures, severe fragmentation, convenient groundwater movement, and low rock strength, which are unfavorable for tunnel construction and operation. Attention should be paid to avoiding them. When it is necessary to pass through, the length of the tunnel should be minimized.

(2) When a tunnel passes through the contact zone of two rock layers with vastly different lithology, it should avoid being parallel or nearly parallel, and try to cross the contact zone in a vertical or nearly vertical direction as much as possible.

(3) The location of the tunnel entrance should be based on the terrain, engineering geology, and hydrogeological conditions, with a focus on considering the stability of the tunnel front slope and slope to ensure the safety of construction and operation. Combined with the relevant engineering and construction conditions of the entrance, a comprehensive study and comparison should be conducted to determine. Generally, tunnels should enter early and exit late.

(4) The entrance should not be located in low-lying valleys with poor geological conditions and difficult drainage, or under unstable hanging rock steep walls, and should try to avoid areas such as landslides, collapses, rock piles, and mudslides. Attention should be paid to the stability of mountain slopes. Rock openings should pay attention to the occurrence of rock layers, weak structural planes, joint fissures, and degree of weathering and fragmentation. For openings located under steep cliffs, attention should be paid to the stability of mountain slope rocks.

4.2 Comparison of Route K and B Schemes

According to the on-site survey data, the basic situation of route selection K and B is shown in Table 1:

Table 1. Basic Information of Route K and B Selection

line	length	surrounding rock classification	Water inflow situation	Adverse geological conditions
K line	11840m	Class III rock mass is 3745m, accounting for approximately 31.6%, Class IV rock mass is 6647m, accounting for approximately 56.2%, and Class V rock mass is 1448m, accounting for approximately 12.2%.	Predicted maximum water inflow 35123.82 m^3/d	It is necessary to pass through three regional fractures: F1, F2, F3, etc; There is a possibility of debris flow disasters occurring at the exit.
B line	11710m	Among them, Grade III rock mass is 3649m, accounting for about 31.2%, Grade IV rock mass is 6294m, accounting for about 53.7%, and Grade V rock mass is 1767m, accounting for about 15.1%.	Predicted maximum water inflow 35337.37 m^3/d	It is necessary to pass through three regional fractures: F1, F2, F3, etc; There is a risk of collapse at the exit, and there may be roof fall and collapse in the BK20+000~K20+300m section.

(1) The geological conditions of the two tunnel schemes are similar, and they all need to pass through three regional faults, including F1, F2 and F3. The F1 fault section is broken in a cataclastic structure and is an active fault in Holocene; The integrity of the rock mass in the F2 fault zone is poor, presenting a fragmented structure, and the fault zone is water bearing; The F3 fault is relatively tightly compressed, mainly composed of schistose and cataclastic rocks, with relatively fractured rock masses.

(2) The tunnel entrances of the two schemes are located at the same location, with similar geological conditions, both located in the alluvial gravel soil layer. The surrounding rock conditions are poor, and it is a loose structure. The entrance and entrance slopes may collapse or partially slide during excavation. It is recommended to strengthen slope support during construction.

(3) The lithology and proportion of the two schemes for the tunnel body section are not significantly different, and the surrounding rock conditions are similar. However, the BK20+000~K20+300m section of the scheme may experience roof fall and collapse.

(4) The exit of Scheme B tunnel is a gentle slope colluvial platform, with exposed bedrock and poor integrity on the tunnel slope, mixed with tuffaceous sandstone strips. The surface is affected by crack cutting, weathering, and unloading, and there are dangerous rocks and unstable blocks. It is recommended to clean up the unstable blocks and rocks during construction.

Compared with the two schemes, the tunnel section K line is slightly better than the B line, but the super large bridge connected to the exit of the K line tunnel is located at the mouth of the N15 debris flow gully. The elevation of the debris flow gully is about 8 meters higher than the elevation of the K line super large bridge. Floods and debris flows have a certain impact on the super large bridge. It is recommended to take effective measures such as dredging the N15 debris flow gully and reducing the elevation of the gully.

5. Conclusion

Based on the understanding of the engineering geological conditions in the tunnel site area and the summary of engineering practice, a geological route selection method for the Dong Tianshan Tunnel is proposed. The key research and analysis were focused on the engineering geological conditions, surrounding rock geological conditions, and grading related to the various line locations of the tunnel section. Based on this, the two line selection situations were analyzed from the aspects of tunnel length, surrounding rock conditions, water inrush, and unfavorable geological conditions. The main conclusions obtained are as follows:

(1) As a control engineering of mountainous highways, tunnels constrain the formulation of overall route plans. The size of the tunnel, surrounding rock conditions, unfavorable geological conditions at the entrance, and geological structure directly affect the selection of tunnel location.

(2) In this project, there is little difference in tunnel length, water inflow, and surrounding rock conditions. Due to the possibility of adverse geological disasters such as collapse at the entrance of the B-line plan, as well as possible roof fall and collapse phenomena in the BK20+000~K20+300m section, more uncertain risks are brought to tunnel construction. Therefore, the K line of this project is the best route selection plan for the tunnel.

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