

# Analysis and Evaluation of Engineering Geological Conditions of Dong Tianshan Tunnel

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**Abstract.** Through the investigation of the topography, stratum lithology, geological structure, and rock and soil engineering geological characteristics of the tunnel site area of the Dong Tianshan Extra-long Tunnel, combined with the survey results of geophysical prospecting, drilling, hydrogeological tests, and rock mass physical and mechanical tests, the engineering project was carried out. geological analysis. The geological conditions in the tunnel site area are complex and risky, and there is a risk of collapse on the slope of the tunnel entrance. The fault fracture zone is prone to instability of surrounding rock and water inrush. Rock bursts may occur in locally deeply buried hard surrounding rock sections. During construction, advance geological forecasts should be followed, tunnel advanced support should be done, and drainage prevention should be strengthened.

**Keywords:** Engineering geological features; Complexity; Engineering geological evaluation; Measures and suggestions.

## 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]. In addition, whether it is design, construction, construction period calculation, budget cost and many other links will be restricted by the geological conditions of the area where the project is located. A comprehensive understanding of the geological conditions of the engineering area can make the tunnel engineering construction achieve twice the result with half the effort. Therefore, it is of great significance to actively investigate the geological conditions in the area where the tunnel project is located[7-9]. At present, the engineering geology of the Dong Tianshan Tunnel is analyzed from many aspects such as surrounding rock classification, cave mouth stability, and water inflow.

## 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. Engineering geological features

#### 3.1 Classification and distribution of tunnel surrounding rock

The inlet and outlet sections of the tunnel are overburdened, and the surrounding rock body strata are tuff siltstone, tuff sandstone layer, etc., sandwiched with slightly weathered granite and diorite. The inlet section is a flood silty clay containing crushed stone and a fault fracture zone of the F1 fault fracture zone, The cave body section mainly exposes two regional faults F2 and F3, with a width of 240m~350m, mainly mylonite and extruded fractured rock, and the outlet section is a lump gravel soil layer formed by collapse. The classification standard for tunnel surrounding rock shall be implemented in accordance with the "Design Specification for Highway Tunnels" for tunnel surrounding rock classification [10] (See Table 1 below).

**Table 1** Tunnel surrounding rock classification

Surrounding rock level	III	IV	V
Mileage number	ZK16+209~ZK16+846ZK16+953~ZK19+176ZK19+296~ZK20+181	ZK9+247~ZK11+356 ZK11+783~ZK13+801 ZK14+172~ZK16+209 ZK16+846~ZK16+953 ZK19+176~ZK19+296 ZK20+181~ZK20+481	ZK8+830~ZK9+247 ZK11+356~ZK11+783 ZK13+801~ZK14+172 ZK20+481~ZK20+670
length (m)	3745	6647	1448
Main engineering geological features	Microweathered - fresh granite, diorite, tuff sandstone, relatively intact rock mass - complete, hard rock	Microweathered - fresh tuff siltstone, thin layered structure, relatively complete rock mass - complete, hard rock	In the tunnel section through which the regional fault passes, the rock mass is relatively broken and the integrity is poor; the covering layer section has a loose structure
Rc(MPa)	72.8~110	12~63.6	
joint	4	5	>5
Rock Integrity Factor	0.59~0.79	0.22~0.54	<0.15
[BQ]	364~465	191~276	<250
Structural characteristics and integrity	The rock mass is a block or thick layered structure, the average spacing of the structural surface is greater than 1m, and the rock mass is relatively complete	The rock mass is thin-bedded or medium-thin interbedded, the structural surface is more developed, and the rock mass is more broken	The rock mass has a fragmented structure, and the rock mass is broken
Stable state after surrounding rock excavation	Stable or basically stable, local block phenomenon occurs	Poor stability, local collapse or collapse	The surrounding rock is prone to plastic deformation and collapse, and large collapse will occur if it is not handled properly.

#### 3.2 Uneven settlement deformation of foundation and slope stability

The tunnel inlet is in the overburden, mainly composed of a silty clay layer containing crushed stone, the crushed stone is generally about 15cm, partially uneven, and local hard plastic

characteristics. According to the results of on-site dynamic penetration testing, the allowable value of its bearing capacity is 140KPa, and its deformation modulus is 12.7MPa. Due to the uneven distribution of crushed stones, there is a possibility of uneven settlement and deformation of the foundation. It is recommended to deal with the foundation during the excavation process. The tunnel slope is mainly silty clay, with an internal friction angle of 28.2° and an internal cohesion of 26KPa. Under conditions such as rainfall infiltration, the slope may undergo plastic deformation and local collapse. It is recommended to take drainage measures and carry out slope support in time.

The exit of the tunnel is colluvial body mainly composed of crushed rocks, with a height difference of about 130m, large volume and relatively loose. When the slope is excavated, there will be local collapse, local section instability, etc., it is recommended to effectively support the lateral slope and do a good job in drainage measures; When excavating the cave, effective measures such as advanced support and timely support are taken to deal with it.

### 3.3 Prediction of tunnel water inflow

According to the analysis of the source of water inflow replenishment in the cave, the characteristics of engineering geology and hydrogeological conditions of the tunnel site area, climate and atmospheric rainfall of the tunnel site area were combined. Through atmospheric precipitation method, underground seepage method, Darcy's law and other methods estimating tunnel water inflow. The general water inflow of the tunnel is about 71058.02m<sup>3</sup>/d, and the maximum average water inflow of a single tunnel is taken as 35934.2m<sup>3</sup>/d. The maximum water inflow of the tunnel passing through the Hulugou section is 1716.6m<sup>3</sup>/d, while the maximum water inflow of the F2 and F3 tunnels is 5597.98m<sup>3</sup>/d. Based on the evaluation of hydrogeological conditions in various layers of the area, it is recommended to avoid large water inflow during tunnel excavation and take reasonable drainage measures.

### 3.4 High ground temperature prediction

According to on-site investigation, the geothermal resources in the tunnel site area are not abundant. According to the actual measurement of ZK04, ZK05, ZK07 and other boreholes, in tunnel sections with a burial depth of less than 250m, the ground temperature is generally below 10 °C. The temperature change at 150 meters of ZK04 borehole is 2 °C, at 100 meters of ZK05 borehole is 2.8 °C, at 430 meters of ZK07 borehole is 7.9 °C, and at the bottom of the borehole is 13.8 °C. The temperature change per 100 meters is 1.8 °C, as shown in Figure 1. It can be inferred that when the maximum burial depth is 1200 meters, the geothermal temperature of the tunnel is around 29.8 °C, which is a medium to low geothermal temperature and does not pose any high or low temperature hazards.

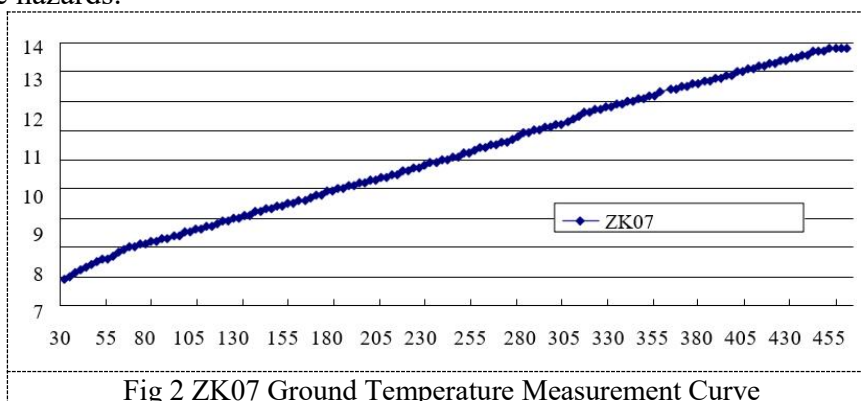


Fig 2 ZK07 Ground Temperature Measurement Curve

### 3.5 Prediction of crustal stress and rockburst

Rock burst prediction and analysis based on stress testing results and geological survey data. The maximum horizontal principal stress within the depth measurement range is 5.9-17.4MPa, the

minimum horizontal principal stress is 5.2-12.1MPa, and the vertical stress is 4.9 ~ 11.4MPa, and the range of side pressure coefficient is 1.2 ~ 1.6, with an average of 1.3. The regional crustal stress field is dominated by horizontal stress, and the direction of the maximum horizontal principal stress is basically parallel to the direction of the tunnel axis, which is conducive to the stability of the tunnel surrounding rock.

For Class III complete hard and brittle surrounding rock along the tunnel[11], when the burial depth of the tunnel is less than 200m, no rock burst will occur during the construction period. The burial depth is within the range of 200~335m, and slight rock burst may occur. The burial depth is within the range of 335~545m, and medium rock burst may occur. When the burial depth is greater than 545m, strong rock burst may occur. The main rock burst generating sections are concentrated in tuffaceous sandstone, diorite and other rock masses.

**3.6 Collapse and deformation of tunnel surrounding rock**

When the tunnel passes through F2 and F3 fault zones, the rock mass is broken and the fault zone composition mylonitization is serious. In particular, F2 fault is mainly mylonite, with general cementation, poor stability, easy to produce plastic deformation, and the sidewall is easy to lose stability. Under the action of gravity, plastic deformation is prone to occur, leading to accidents such as collapse, which may occur in sections such as ZK11+356~ZK11+783, ZK13+801~ZK14+172, ZK11+305~ZK11+746, and ZK13+776~ZK14+151.

**4. Classification and evaluation of geological complexity**

**4.1 Classification of geological complexity in tunnels**

Based on a comprehensive analysis of tunnel engineering geology and hydrogeological conditions, it is predicted that adverse geological disasters such as rock burst, large deformation, sudden water inrush, and instability of surrounding rock may occur during tunnel construction[12]. The main risk factors and specific geological complexity classification of surrounding rocks along the tunnel are shown in the table below:

Tunnel name	main risk factors	The impact of geological factors on tunnel construction	The degree of environmental issues induced	Complexity rating
Dong Tianshan Tunnel	The fold and fault structures are extremely developed, and they pass through faults, influence zones and joint dense zones, which are prone to instability of surrounding rock. Water inrush (mud) may occur due to large water gushing in the tunnel; For burial depths greater than 335m, rock burst and soft rock deformation may occur. The distribution of tunnel inlet and outlet overburden is prone to collapse and debris flow.	Endanger construction safety and may cause major safety accidents	May cause major environmental disaster	complex

**4.2 Evaluation and suggestion of tunnel engineering geological conditions**

(1) Three regional faults, F1, F2, and F3, are mainly developed in the tunnel site area. This area is prone to deformation, and rocks cause collapse, deformation and other accidents. Attention should be paid to the construction and support of this section. It is recommended that during the

excavation process, small dosage, short intake, and timely support should be carried out to prevent the cave from collapsing or deformation. The tunnel entrance and exit have loose overburden, and when the cavern is excavated, there is a possibility of collapse, roof and lateral slope instability, and it is recommended to take reasonable measures to carry out the excavation of the cavern in the loose body.

(2) The peak acceleration of ground motion in the tunnel site area is 0.20g, and the basic seismic intensity value is VIII degree. It is recommended to fortify according to IX degree.

(3) The maximum horizontal principal stress direction NE41° in the tunnel site area is parallel to the axis of the tunnel, which is conducive to the stability of the surrounding rock of the tunnel. When the buried depth is greater than 335, grade III. hard surrounding rock may have different degrees of rock burst. It is recommended to strengthen construction safety protection in the rock burst section, use fiber reinforced concrete and flexible steel mesh to reinforce the surrounding rock, and if necessary, drill additional stress relief holes to reduce risks.

(4) Groundwater has slight corrosiveness to reinforced concrete structures, and the maximum water inflow of the proposed tunnel is about 71058.02 m<sup>3</sup>/d. Passing through fault sections and Hulugou sections, water inflow may occur. It is recommended to control the construction time and avoid rainy season construction as much as possible, while strengthening drainage. In addition, drainage ditches and intercepting ditches shall be set on the front and side slopes of the tunnel portal, and drainage shall be carried out in combination with the cutting drainage system. Attention shall be paid to the infiltration of surface domestic wastewater and construction water, especially in the rainy season or rainstorm construction, corresponding drainage and waterproof measures shall be taken.

## 5. Conclusion

The geological conditions of the Dong Tianshan Tunnel are complex and it is a high-risk tunnel. Advance geological exploration and drilling work should be strengthened during construction, and dynamic design should be carried out based on geological logging and TSP. When abnormal sections are found, geological radar and infrared water exploration should be added for confirmation. Further investigate the geological conditions in front of the working face, analyze potential geological problems during construction, and propose engineering measures to reduce the probability and degree of geological disasters.

For fault fracture zones prone to collapse, deformation, and water inrush, lining support and drainage measures should be strengthened to reduce the impact on the surrounding rock and ensure its stability. For the problem of poor stability of the tunnel entrance slope, it is necessary to strengthen slope protection and drainage, and plan advance support measures for the excavation of the entrance chamber in advance.

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