Characteristics of Tunnel Water Inrush and Progress in Grouting Materials in Mira Mountain Tunnel

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Abstract. Mira mountain tunnel is located in high altitude and cold area. Due to the influence of fragile ecological environment such as thin air and complex geological conditions, the tunnel would be liable to cause geological hazards. This paper will analyze the characteristics and causes of geological disasters in Mira mountain tunnel, combined with the research progress of grouting water stop material for tuff tunnel in high altitude and high cold area, so as to further guide the actual grouting construction and reduce the risk of geological disasters.

1. Introduction
Along with the rapid development of tunnel, mine, water conservancy construction, the engineering geological problems are facing increasingly severe challenges, and the tunnel water inrush disaster also occurs at times. The Mira Mountain, with an elevation of 5013.25m, is located at the junction of Jiangda, Gongbu and Gongka, Mozhu in Tibet. As shown in Figure 1, the mountain is the watershed of the Niyang River system in the southeast and the Lhasa River system in the Northwest, and also one of the necessary passes of the southern Sichuan-Tibet Highway [1~3].

Due to the influence of special natural environmental factors such as thin air, low pressure, harsh regional climate, complex geological conditions and fragile ecological environment, a series of complex geological problems, such as deformation instability of surrounding rocks, freezing damage and water inrush disaster are very easy to occur when construct the tunnels in high altitude and cold regions. To fast and effectively plug the water burst channel, reduce the seepage flow of groundwater, grouting materials may put forward higher requirements for the water-stop performance and stability in this high altitude and cold area, so as to shorten the construction period and protect the ecological environment [2, 4].
2. Project Overview of Mira mountain tunnel

The Mira mountain tunnel is designed as a separate double-tunnel with a distance of 30-39 m and a maximum depth of 374 m. The total length of left tunnel is 5,727 m, the design elevation of the tunnel pavement is 4752.534 m (entrance) ~4774.592 m (exit), the total length of the right tunnel is 5,672 m, and the pavement elevation is 4753.035 m (entrance) ~4774.921 m (exit). As shown in Figure 2, end-wall portals are used for both import and export. The strata of the tunnel site are mainly Neogene Xindala granite, Lower Tertiary-Upper Cretaceous Linzizong tuff, glacial-hydrous gravel soil and slope-collapse gravel soils [2].

The surrounding rock of Mira mountain is mainly full weathered, strong weathered and weathered tuff, with low strength, small softening coefficient, easy to absorb water (as shown in Table 1). The complex geological structure and climate conditions will also cause large deformation of surrounding rock and water gushing disasters during the construction of the tunnel, which will have great adverse impact on the progress, quality and safety of the tunnel construction [3, 4].

![Figure 1. Watershed of the Mira Mountain passes](image)

![Figure 2. Entrance of Mira mountain tunnel](image)

| Description | Soil natural density (g/cm³) | Grain density (g/cm³) | Natural moisture content (%) | Saturated water ratio (%) | Porosity (%) |
|-------------|------------------------------|-----------------------|------------------------------|--------------------------|--------------|
| Tuff        | 2.42–2.46                    | 2.56–2.59             | 1.90–2.16                    | 2.50–3.42                | 6.02–8.13    |
(1) Climate factors
Due to the influence of warm and humid air flow in the Indian Ocean, the entrance of the tunnel is liable to form a semi-humid monsoon climate in the temperate zone of the plateau, which is warm and humid with abundant rainfall, with an average annual precipitation of 808.3 mm. The tunnel outlet belongs to the semi-arid monsoon climate of plateau temperate zone, with annual precipitation of 515.7 mm and concentrated rainfall, which is the main source of groundwater recharge. As for the changes of climate and temperature, the tuff of Mira mountain tunnel is continuously eroded by alternating wet-dry cycle and cold-heat cycle, which can reduce the strength of rock, make the stability of surrounding rock worse, and will be more prone to deformation and destruction.

(2) Geotectonic factors
Two main faults may pass through the area of Mira mountain tunnel. One of the overthrust fault of Mira Mountain Pass extends from east to west, develops a 20 m wide fracture zone, mainly consist of breccia and fault gouge in the zone. Another Xiamari fault zone passes along the NW-W direction near the exit of the tunnel, which develops a fractured zone of about 100-200 m. The occurrence is disordered and small faults are common in this fracture zone, where granite veins may often intrude.

As the Mira mountain tunnel is located in the fault fractured zone, the development of faults may lead to rock fragmentation and loosening, poor surrounding rock properties, resulting in high tunnel pressure and easy to occur severe deformation.

(3) Water factors
The Mira mountain tunnel is rich in groundwater, which mainly supplied by ice, snow melting and the atmospheric precipitation. The total water inflow of the main tunnel is 61800-71300 m$^3$/d in dry season, and 92700-106900 m$^3$/d in the wet season. Large amounts of ice and snow will melt directly from the fractured rock mass, and then penetrate into the underground. After the excavation of the tunnel, a relatively smooth passageway for groundwater drainage will gradually be formed. This may penetrate into the underground through fissures, which would be liable to cause geological hazards such as water inrush [4].

3. Grouting Material in Mira Mountain Tunnel

3.1. Application Characteristics of Grouting Material
Grouting is one of the main methods to control groundwater hazards. When grouting is pumped to a setting location, the rock and soil that does not meet the engineering requirements will be improved, or the in-situ soil will be improved through cementation, filling and compaction.

The common grouting materials can be divided into silicate cement, sulphoaluminate cement, cement water glass and polymer chemical materials, as well as all kinds of modified grouting materials on this basis. In practical grouting engineering, especially using cement-clay grouting material, the viscosity of grouting fluid is not invariable, and could be changed with time during grouting and transportation. Therefore, the ideal grouting material should require good stability, low viscosity and fine fluidity, also can be grouted in fine cracks or silty sand layers. To meet the different geological conditions and construction requirements, the grouting material could also possess the ability to adjust setting time, so as to minimize construction risks and damage to the environment [5, 6].

3.2. Characteristics of Grouting Material in Mira Mountain Tunnel
The tuff rock mass of Mira mountain tunnel will not be deformed and destroyed in dry environment. Once encountering water, the tuff would be easy to weathering or collapse, which may further aggravate the deformation of surrounding rock and support of the tunnel. As for the large amount of water gushing in the tunnel, the grouting may arise the problems such as slurry dilution and non-coagulation. Therefore, the key for the grouting materials of Mira mountain tunnel lies in how to effectively and rapidly plug the cracks, reduce water inflow, and prevent tuff softening, so as to ensure the safety of tunnel construction and the local ecological environment would not be destroyed, achieving the purpose of water stop [7, 8].
Considering the geological characteristics of Mira mountain tunnel, the grouting and water stop materials in the tunnel usually possess strong sealing ability, also can adjust the pumping period effectively, so as to meet the requirements of high altitude and other different geological conditions; after the pumpable period of the slurry, the slurry can condense quickly, with good characteristics such as strong grouting ability, controllable initial setting and final setting time. So that can not only meet the grouting water stop requirements of Mira mountain tunnel, but also greatly improve the tunneling construction progress and effectively reduce the project cost [8].

4. Conclusion
As one of the countries with the most serious water inrush and gushing mud disaster, the casualties and economic losses are in the forefront of all kinds of tunnel geological disasters. Therefore, the performance of grouting water-proof materials for tuff tunnels has become a hot topic in the high altitude and cold areas.

With the innovation of grouting materials, the further development of grouting materials is mainly concerned with good fluidity, combining with different geological conditions and construction requirements, so as to adjust the pumping period reasonably and effectively. Through further study on the diffusion mechanism of time-varying viscous controllable grout in fractured rock mass, the design of grouting reinforcement project and the prediction of grouting effect could also be obtained, which may possess great significance in guiding the actual construction of grouting, reducing the risk of geological hazards.

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