Characteristics of water environment along Baojiashan super long tunnel

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Abstract. Based on the synchronous monitoring data of surface runoff, groundwater level and water inflow of Baojiashan super long tunnel, the characteristics of water environment along the tunnel are studied. The results show that: (1) Both surface runoff and groundwater level are significantly affected by rainfall, and the lag is not obvious. (2) The tunnel water inflow is significantly affected by rainfall, and the water is mainly discharged from the North portal. (3) Through the monitoring of the water pressure after the tunnel lining, it shows that the sand settling basin in the later stage of tunnel supplementary construction has played a great role in drainage and decompression, and has played a powerful role in ensuring the safe operation of the tunnel. (4) The change of tunnel drainage flow is closely related to precipitation, and tunnel drainage will not have a great impact on the surrounding environment.

1. Introduction

In recent years, the construction and operation of highway and railway tunnels in China have made great progress. Since the successful construction of Zhongnanshan Super Long Highway Tunnel in Qinling Mountains, the construction and operation of extra long highway tunnel is no longer a difficult problem in technology. However, due to the difference of geological and hydrological conditions of tunnel construction location, the geological and hydrological survey is not detailed in design, and many tunnel construction problems such as water gushing, mud gushing and sand gushing appear. In the construction process of Baojiashan extra long tunnel of Xiaohe Ankang expressway, there were 7 times of water gushing, mud gushing and sand gushing. According to the field observation, the water inflow is obviously affected by rainfall, which seriously affects the operation safety of the tunnel.

Many researchers have done a lot of research on the law of water inrush disaster in long and high-risk tunnels. Foreign scholars Salis MD et al. [1-2] (1983) made a key study on the mechanism of water inrush in tunnels, especially put forward the mechanism of water inrush in karst areas; E. Both T. Shuster and W. B. white [3] have conducted in-depth study on the multiplicity of water bearing medium in tunnel, and drew a conclusion that different karst types have different risk of outburst in tunnel; Domestic scholar sun Hongyue [4] monitored and studied the groundwater level, surface runoff, rainfall and drainage tunnel drainage before and after the construction of underground drainage channel, analyzed the hydraulic connection characteristics between groundwater and surface water, and studied whether the tunnel drainage system met the drainage requirements under specific rainfall conditions; Wu Xiyong et al. [5] studied the movement process, reflection process and influencing factors of groundwater in the rock stratum, mastered the geological conditions and groundwater movement law around the engineering buildings, and analyzed the concrete corrosion characteristics of a tunnel and the corrosion mechanism of groundwater to concrete. These research results can be used to solve the
water inrush phenomenon in the process of tunnel construction.

The construction and operation of mountain tunnel is closely related to the local water environment. Most of the surface water and groundwater flow into the tunnel through the karst caves, and the external water environment also affects the water inflow in the tunnel. If the investigation of the water environment in the tunnel area is not detailed, it is easy to produce many problems in the construction and operation stage of the tunnel, such as wall cracking, which will cause serious engineering accidents and economic losses. Aiming at the current situation that the monitoring results of tunnel water environment are less, relying on the Baojiashan extra long highway tunnel project, this paper establishes a hydrological monitoring system to observe and analyze the surface runoff, groundwater level and tunnel water inflow in the tunnel area, and to study the water environment change law and its impact on the tunnel operation.

2. Project overview

2.1. Basic information

Baojiashan super long tunnel is located at the throat of Xiaohe Ankang section of Baomao Expressway. It starts from Tongmu township of Xunyang County in the north and reaches Ankang Valley in the south. It passes through Qingshan and yuhuangshan peaks in Qinling Mountains, with a total length of 11.2 km. The tunnel site has rugged and dangerous terrain, high mountains and deep gullies, dense vegetation, complex geological structure and changeable formation lithology. The maximum buried depth is about 677.4m, and the relative maximum elevation difference is about 700.5m, as shown in figure 1. The tunnel was fully opened in December 2008 and put into operation on May 28, 2009.

2.2. General situation of geological structure

The structural unit of the tunnel area belongs to Liuba Baihe fold belt in South Qinling, with nanyangshan fault as the boundary in the north and Shiquan Ankang fault (Yuehe fault) in the south, forming a large-scale syncline structure. The main structural line is mainly NW-SE trending, with dip of 41-50° and dip angle of 54-70°. The geological structure of the tunnel area is complex, and the lithology of the stratum is changeable. In the north section of the tunnel, sericite phyllite is the main part; In the tunnel area, joints and fissures are well developed in limestone, while sericite phyllite, carbonaceous slate and silty phyllite are not well developed. The tunnel passes through 37 faults, 3 large fold belts and 25 water gushing sections.

2.3. Hydrogeological conditions

(1) Overview of surface water runoff

There are seven surface currents in the tunnel site, namely Tongmu River, xiaoyanwugou River, Maping River in Heba street, Songjiagou River in foyeyan, lujia gou River and kojiagou stream and tizigou stream, tributaries of Maping river. Xiaoyanwugou is a tributary of Tongmu river. It passes through the top of the tunnel. It flows all the year round in the ditch. Some faults are intercalated with crystalline limestone to cross the river and tunnel, which is conducive to the development of
crystalline limestone karst; The Maping River and the Tizigou stream in Heba Street pass through the upper part of the tunnel, and most of them supply groundwater by leakage. There are 14 springs along the whole line, and 5 springs are found in the north section of the tunnel, which are mainly distributed at the foot of the slope on the east side of the tunnel, with small water volume; Eight springs were found in the middle section of the tunnel, which were mainly distributed on both sides of kejiagou, and one spring was found in the south section of the tunnel with large flow.

(2) Occurrence characteristics of groundwater
The tunnel site passes through bedrock structural fissure water. According to the occurrence conditions of groundwater and lithologic characteristics of water quality, the groundwater in tunnel area can be divided into two types: metamorphic rock fissure water and medium thick limestone fissure water (karst water). However, the medium thick limestone fissure water (karst water) can be divided into sericite phyllite intercalated with carbonaceous slate structural fissure water bearing rock group, silty phyllite intercalated with medium thick crystalline limestone structural fracture and karst water bearing rock group, Karst water bearing rock group of medium thick limestone, silty phyllite with thin layer of calcareous slate, joint fissure water bearing rock group of silty phyllite with thin layer of limestone, calcareous silty slate, calcareous sericite schist and structural fracture water bearing rock group.

(3) Characteristics of groundwater circulation
The tunnel area is located in a watershed area with steep peaks and deep valleys. It is difficult to form a horizontal hydraulic connection with the surrounding areas. Most of the atmospheric precipitation recharges groundwater in the form of vertical infiltration, and only a small part is in the form of surface runoff, which is collected and discharged from the watershed to the gullies on both sides through Maping River, kejiagou River and tizigou river. After infiltration, the meteoric water is stored or transported in the structural fissures and discharged to the nearby gullies on both sides of the watershed. In the gullies, the rainfall flows out of the surface in the form of springs in the favorable sections of faults or joint fissures. Some groundwater runoff infiltrates into the deep circulation to replenish the deep karst water or confined water.

3. Dynamic monitoring of groundwater environment in Baojiashan tunnel

3.1. layout of monitoring points
The monitoring network layout of the groundwater dynamic observation system in Baojiashan tunnel is shown in figure2.

i Three groundwater level monitoring holes, ZK1, ZK2 and ZK3, are arranged along the vertical direction of the tunnel in Maping river. The hole depth reaches the corresponding elevation of the tunnel floor.

ii Six monitoring points for surface river water flow are set up, which are upstream and downstream of Maping River in Sipu village, upstream and downstream of tizigou, and upstream and downstream of kejiagou.

iii Two water inflow monitoring points are set at the north and south of the tunnel.

iv Three water pressure monitoring points are set up in the 8# and 9# construction channels in the tunnel.

3.2. Monitoring equipment configuration
The configuration of monitoring equipment is shown in table 1

| Item | Category            | Quanti |
|------|---------------------|--------|
| Equipment | Hydrological tools | Manufacture of weir plate | 4 |
|        |                     | Electronic current meter | 1 |
### Monitoring indicators

Monitoring the water outlet point of the tunnel site: the flow (L/S) and water level (cm) of the surface water monitoring point of the river, the water level of the groundwater monitoring point (m), the water volume (m³) of the tunnel water inflow monitoring point, and the water pressure (MPa) of the tunnel lining monitoring point.

### Sampling frequency

Under normal conditions, the surface water level, water depth, velocity and groundwater level of the river are monitored every 5 days, intensive observation should be carried out during the wet season. In dry season, the observation times should be reduced according to the situation; The water pressure monitoring after tunnel lining is monitored according to the change of underground water level, which is generally once a month. In case of heavy rainfall or great change of underground water level, intensive monitoring is carried out.

### Research and analysis of water environment characteristics

#### Hydraulic connection between groundwater and surface water

According to the analysis of monitoring data in the five hydrological years from 2010 to 2015, as shown in figure 3, the surface runoff and groundwater level are significantly affected by rainfall, and the lag is not obvious. Groundwater is mainly supplied by the vertical infiltration of atmospheric precipitation, and only a small part is discharged in the form of surface runoff. According to the monitoring data of Maping River in wet, flat and dry seasons, the falling funnel discharging into the tunnel is formed on both sides of the tunnel. The groundwater flows to the tunnel within 450m on both sides of the tunnel. The tunnel has become a new discharge channel of groundwater and has formed a new flow field.
4.2. Relationship between surface water and tunnel water inflow
According to the monitoring data of the Maping River in the wet season, as shown in figure 4, more than 46% of the water in the upper and lower reaches of the Maping river has penetrated into the ground, which may be related to the existence of a large number of relatively developed faults and fracture zones in the area. In case of continuous rainfall, the surface water rises sharply, more surface water supplies to groundwater, and the tunnel water inflow will increase correspondingly.

4.3. Relationship between water inflow in tunnel and external water environment
According to the monitoring data of water inflow at the north and south of the tunnel, there is basically no flow at the South portal, and the water inflow at the North portal of the tunnel is very large, which is obviously controlled by rainfall and rainfall intensity. The relationship between water inflow and rainfall is analyzed, and the correlation diagram of rainfall and water inflow is drawn. As shown in figure 5, the correlation coefficient is 0.68601, which belongs to moderate correlation. According to the linear correlation analysis, the correlation equation between rainfall and tunnel water inflow is $y = 232.53x + 27133$, where $y$ is water inflow, $X$ is rainfall. The design limit value of tunnel drainage is 100000 m$^3$ per day. According to this equation, it can be inferred that in general, when the continuous rainfall reaches 313.37 mm, the tunnel drainage will reach the limit value.
4.4. Analysis of water pressure monitoring data in tunnel

The water pressure test in the tunnel is zero, indicating that the drainage in the tunnel is smooth and normal.

5. Conclusion

(1) Surface runoff and groundwater level are easily affected by rainfall, and lag is not obvious. Most of the surface flow is supplied to the tunnel through karst cave and fissure infiltration. In case of heavy rainfall, the surface water rises sharply and more surface water supplies to groundwater; The tunnel drainage does not make the groundwater level drained, so it will not have a great impact on the surrounding environment.

(2) The groundwater level has formed a depression funnel for a long time. The funnel is centered on the middle line of the tunnel, and the groundwater on both sides of the funnel moves to the tunnel, which has no obvious adverse effect on the natural environment of the tunnel passing through. It is inevitable that the groundwater level in a certain range at the top of the tunnel will drop, but the upper organisms can still receive rainfall supplement, and the rainfall is abundant in the year.

(3) The water inflow in the tunnel is mainly affected by rainfall, and the water is mainly discharged from the North portal. In case of rainstorm, the water volume in the tunnel will increase sharply.

(4) Generally, when the rainfall reaches 313.37 mm for five consecutive days, the tunnel drainage will exceed the limit value, but there are also special cases.

(5) The water pressure test in the tunnel is zero, which indicates that the sand basin of the supplementary construction in the later stage of the tunnel has played a great role in drainage and decompression, and has played a powerful role in ensuring the safe operation of the tunnel.

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