Research on Evaluation and Control of Karst Water Resources in a Certain Tunnel of Dalian Subway

Guang Qiang WANG
College of Geoscience and Surveying Engineering, China University of Mining & Technology, Beijing, Beijing 100083, China
Email: wgqiang0905@126.com

Abstract. Taking a certain tunnel in Dalian Metro as the research object, to evaluate the situation of karst development through geophysical prospecting and drilling data in study area. Karst water resources can be evaluated by quality and quantity in the study area, the correlation of the ion content can be analyzed according to the analysis results of chemical composition of groundwater and the maximum water inflow in karst water section tunnel can be calculated by using the Oshima Yoshi formula. Put forward measures and methods of groundwater control and tube well dewatering based on these evaluation, it has certain guiding significance for tunnel construction in karst area.

1 Introduction
Dalian area is located in the south of the block uplift in Liaodong Peninsula, and its west area is adjacent to the block depression of Liaodong Bay in Liaohe, and it meets the block depression at the Yellow Sea in the south[1].The geological structural conditions in the area are relatively complex. There are three groups of faults in the region: EW trending, NW trending, NE-NNE trending, and there has the distribution of ring fault structure. The geological conditions in Dalian area are complex and the lithology is diverse. The groundwater level in the whole area is shallow and the water quantity is large. There are many karst caves in the limestone area. The weathered rock zone of the slate, marl and limestone is very broken. The buried depth of the urban subway tunnel is generally deep[2].

This paper takes the sections from Nan Guan Ling Railway Station to Dalian North Railway Station as the research object which is belong to the northern section of Dalian Metro Line 2, and evaluates the karst development in the study area by geophysical prospecting and drilling data. The maximum water inflow of karst water in tunnel will be calculated on this basis, and put forward control measures of karst water in tunnel construction and the method of tube construction in karst region.

2 Karst Development Survey
The study area is located in the drainage area of karst water. Groundwater mainly occurs in karst development areas and karst caves, and the recharge sources are mainly upper atmospheric precipitation and lateral recharge of the upper and lower aquifers.

2.1. Geophysical Survey
The characteristics of rock structure and water abundance make electrical difference. The apparent resistivity is the observation parameter of the high-density resistivity profile method. Measuring instrument for high density measurement system, inquiring for drilling data, establish the stratigraphic
model of this area, then analysis on comparison between the known resistivity and the measured apparent resistivity, setting up the calibration value of the resistivity of stratigraphic structure such as karst structure and so on[3,4].

The resistivity of bedrock in this area is usually relatively high, generally between 0-5000Ω•m, the difference is very obvious, and it has a good foundation to detect karst fracture by resistivity method. Main factors affecting the resistivity are development degree of rock joint fracture, degree of crushing and development degree of karst etc, the greater the fracture development, the greater the degree of fragmentation and the higher the degree of karst development make the lower the resistivity.

According to the electrical variation of the detecting section in Figure 1, it can be seen that the value of surface resistivity in the upper Quaternary is between 15-200Ω•m while lower bedrock resistivity is between 40-200000Ω•m. The contrast between the measured section and the exploration section shows that the resistivity of the fracture and karst cave in the bedrock with high water content is characterized by low resistivity valued about 0-25Ω•m. Combined with the geological section, according to the low resistivity characteristics of the resistivity in the bedrock formation, bedrock fissure in high water bearing area and karst cave section can be divided.

![Figure 1 High Density Resistivity Method Cross Section(Right line and Left line)](image)

2.2. Drilling Survey

Based on the drilling data, exposing the height of karst cave is 0.20 to 5.50m while roof buried depth is 2.50-11.00m, the elevation of roof is -0.25-18.99m and the elevation of floor is -1.15-17.29m. The rate of drilling karst cave formation is about 14%, and the development degree of karst is weak.

Combined with geophysical prospecting and drilling data, the division of aqueous fracture and karst Cave (rich water zone diagram) in the study area is shown in Figure 2.
3 Evaluation of Karst Water Resources

3.1. Evaluation of Water Quality
The types of regional groundwater chemistry can be broadly divided into four categories. The specific division is as follows:

1) heavy calcium carbonate chloride water. This kind of water is widely distributed in the area, and its mineralization of water is less than 0.5g/l. Mainly distributed in mountain area such as Huang Long Wei, Wai Shi Li Zi, An Zi Shan, Cheng Shan and so on;

2) chloride calcium bicarbonate sodium type water. Its mineralization range of water is 0.5-1.0g/l. It is mainly distributed in the Dalian Wan, Xin Zhai Zi, Zhou Shui Zi and Ge Zhen Bao area;

3) Calcium bicarbonate water. Its mineralization of water is less than 1.0g/l. The main distribution area is Nan Guan Ling and Camel Mountain etc;

4) sodium chloride and calcium water. Its mineralization range of water is 1.0-3.0g/l. Its main distribution ranges are Jin Zhou Bay, Cheng Zi Wan and Mu Cheng Wan area.

In addition, sodium chloride type water appeared in other areas, mainly distributed in the spring exposed area of the Nanguan mountain, and the mineralization is more than 3.0g/l. The main reason for the occurrence of this type of water was sea water intrusion.

According to the results of chemical analysis of groundwater, the correlation coefficient of Pearson is used to analyze the ion content[5,6].

\[
R = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2} \sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}
\]

In general, the degree of correlation between variables is defined according to the range of values:
1) 0<R<0.2, not related; 2)0.2<R<0.4, weakly related; 3)0.4<R<0.6, moderately related; 4)0.6<R<0.8, strongly related; 5)0.8<R<1, extremely strongly related.

The calculated correlation coefficients of water chemical composition and index are shown in Table 1. As can be seen from Table 1, the total hardness is best correlated with TDS (total dissolved solids), with a correlation coefficient of 0.91, the correlations with sulfate and chloride were close to 0.73 and 0.71 respectively; the correlation between TDS and chloride was the highest, the correlation coefficient was 0.88 while the lowest correlation with fluoride was 0.09.

| R   | PH  | chloride | fluoride | sulfate | TDS    | Total hardness |
|-----|-----|----------|----------|---------|--------|----------------|
| PH  | 1   | -0.07    | 0.34     | -0.43   | -0.21  | -0.22         |
| chloride | 1    | 0.10     | 0.45     | 0.88    | 0.79   |
| fluoride | 0.01 | 0.09     | 0.73     |
| sulfate | 0.68 | 0.91     |
| TDS    | 1    |          |
| Total hardness | 1    |

3.2. Calculation of Maximum Water Inflow
Oshima Yoshi formula was used to calculate the maximum initial water inflow[7], as shown in Figure...
3. 

\[ q_0 = \frac{2\pi mKH}{\ln\frac{4H}{d}} \]  

\( q_0 \): the maximum initial water inflow, m\(^2\)/d;  
\( K \): Approximate osmotic coefficients or weighted values of aquifer, m/d  
\( H \): The vertical distance from the Static water level (water head) to the equivalent cross section center of tunnel, m;  
\( d \): tunnel diameter, m;  
\( m \): conversion factor, usually take 0.86.

According to the prediction of karst and buried depth of groundwater, the water bearing section of left line interval is divided into 5 sections, the range of the right line of water bearing section is divided into 4 sections, it is calculated that the maximum water inflow at the initial stage is 10312 m\(^3\)/d, the calculation parameters are shown in Table 2.

**Tab.2 Maximum water inflow tunnel**

| Section | Length (m) | K (m/d) | H (m) | d (m) | \( q_0 \) (m\(^2\)/d) | Water inflow (m\(^3\)/d) |
|---------|------------|---------|-------|-------|-------------------------|--------------------------|
| R1, L1, L2 | 248 | 0.5 | 18.6 | 6 | 19.9 | 4947.5 |
| R2, L3, L4 | 139 | 0.5 | 24 | 6 | 23.4 | 3249.1 |
| R3, L5 | 83 | 0.5 | 21 | 6 | 21.5 | 1783.5 |
| R4 | 17 | 0.5 | 18 | 6 | 19.6 | 332.5 |

**4 Control Measures of Karst Water**

This section is built by mining method, It is technically infeasible for underground continuous wall and rotary jet grouting pile to deal with the problem of displacement of road and pipeline. The water stopping schemes adopted are grouting method and freezing method, and the full face grouting scheme needs to be filled with double liquid grout in the 3.0m area of the tunnel circle. The grouting capacity is huge and the cost and time limit can not be accepted. The freezing scheme has strict demands on the velocity of groundwater seepage, and the cost is much higher than expected.

Therefore, tube well dewatering will be used as dewatering scheme which is relatively mature and stable. The specific process of karst area construction is shown in figure 4.
5 Conclusion
1) The effect using geophysical prospecting and drilling data to evaluate the developmental condition of karst is better;
2) The chemical types of groundwater in the study area can be mainly divided into heavy calcium carbonate chloride water, chloride calcium bicarbonate sodium type water, Calcium bicarbonate water and sodium chloride and calcium water. In the correlation coefficient of water chemical composition
and index, the total hardness is the best correlation with TDS.

3) The maximum water inflow at the initial stage of tunnel is 10312 m3/d, karst water needs to be controlled, tube well dewatering is a suitable scheme. This method in this area has some guiding significance to the control of karst water in other regions.

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