Analysis of the confined water of dam foundation in one water resource project

Qiguo Wang1*, Kunsheng Hu1, Jianjun Fu2, Fangquan Cheng1, Lianjun Chen2
1 Hubei, Wuhan, Changjiang Geotechnical Engineering Corporation, 430010, China
2 Hubei, Yunxi, Hanjiang River Hydropower Development of Gushan Co., Ltd, 442600, China
*E-mail: cjwwqg001@163.com

Abstract. Bedrock-confined water is distributing at the riverbed and the right bank of the one dam foundation. According to the preliminary analysis, it has been found that there are some confined water aquifers which appear along the rock’s fractures and the foliation planes in the dam site. The confined water has some negative influences on the dam and tunnel project because of the water head. Much attention should be paid to this and an engineering treatment needs to be taken.

1. Introduction
One project is located at the midstream of Xiabu river which is under the influence of Yaluzangbu in Tibet, and it’s about 100 km from Rikaze City. This project is the main one in Xiabu river, and it consists of an irrigation system, a power generation system and a flood control system. The normal pool level is 4300 m, the reservoir capacity is 336 000 000 m³, the maximum dam height is 65.5 m, and the installed capacity is 32 MW for 6 units. It is a large-scale hydro-project. According to the exploration test, there is some bedrock-confined water distributing at the dam foundation. The influence of this confined water on the hydro-project will be analyzed in this study [1-3].

2. Geology of dam site condition
The One hydro-project is located at the joint area of the Himalayan plate and Yaluzangbu; it belongs to the warped surface of the Himalayan boundary according to neotectonic movements, which is at the relatively steady plot rounding by 4 moving accidents [4].

The dam site is at the entrance of a gorge which is located in the downstream of one about 6 km. The width of the gorge is reduced gradually from upstream to downstream. The elevation of the slope is 4500-5000 m, the elevation of the river bed is 4240-4260 m, the width of the gorge bed is 240-280 m in Lieqiong, and 20-40 m in Karudang. The slope of the gorge is steep, but the left bank is gentle.

Quaternary sediments in the dam site consist of alluvium (Qa), proluvium (Qp), colluvium (Qc), and diluvium (Qd) etc. The bedrock is metamorphic rock of the Triassic age (T3n), which consists of argillaceous slate with sandy slate. The strike is north-east, and the dip is 30-75 degree.

Some geological phenomena, such as landslide, debris flow, collapse and weathering occurred in the dam site, but on a small scale.

The surface water in the dam site flows to the Xiabu river and three gullies. Xiabu river has water all the year, while the gullies have seasonal water. The unconfined water in the dam site distributes at the Quaternary period. The confined water distributes at the cracks of bed rock layers. There are three
springs in the dam site’s slope of the bed rock layer. Their discharge is 2-10 L/min and the amount of water is poor.

3. The analyses of the confined water characteristic

3.1. The distribution of the confined water

The confined water has been found in the bedrock (slate) of the river bed, flood bed and right bank (figure 1, figure 2, and table 1). The embedded depth of the confined water is 20.3-32.5 m at the river bed and the flood bed, and 33.1-49.1 m at the right bank. The level of the confined water is higher than the river about 0.5-8.8 m at the river bed and the flood bed, and about 38.5-81.4 m at the right bank. The water head is 26.6-34.52 m at the river bed and the flood bed, and 33.2-52.5 m at the right bank. The discharge is 2-10.7 L/min at the river bed and the flood bed, and 2-35 L/min at the right bank.

3.2. Variety of confined water discharge and characters of aquifer distribution

During the exploration period, the observation of borehole No. ZK28, showed that the roof of the confined water is 20 m under the ground (19 m under the bed), the initial discharge is 2 L/min, and the water level is 5265.5 m (8.7 m higher than the river). When the depth reaches 31 m, the discharge become higher (from 8 L/min to 10 L/min), and the water level, which is 2.2-3.34 m higher than the river, could be stabilized gradually (4259- 4260.14 m). The reason for this phenomenon is that when the confined water is exposed, the level will be reduced as the water is flowing out, and when the discharge and the supply is equal, the level will be stabilized gradually. This phenomenon indicates that the supply source is reliable, so the discharge becomes important while the borehole is deeper. Another reason for this may be that the permeability of fissures will increase while fine particles are flashed out by the mechanical erosion. The discharge of confined water has a linear relationship with the head changes.

Three boreholes have exposed the confined water. From the upstream to the downstream on the right bank of the dam site, these are ZK36, ZK35, and ZK37. The initial discharges are important with a high water head, 33 m, 49 m, and 53 m, or 36.34 m, 60 m, and 80 m higher than the river level respectively. According to the video of the borehole No. ZK35, the outlets distribute at 40.14- 40.44 m and 44.5- 44.59 m deep. In these areas, the video detector was shaken heavily, the core was perfect and a foliation was opened with a ferruginous plane. It is a significant possibility that the bedrock-confined water on the right bank appears along the fractures and the foliation planes.
Figure.1 The distribution of the confined water in the dam site

Figure.2 The distribution of the confined water in the dam site section
Table 1 The confined water in the dam site

| Borehole No | Position | Borehole elevation (m) | Unconfined water level (m) | Borehole depth where confined water is exposed first time (m) | Confined water level (m) | Maximum discharge L/min | Temperature of confined water |
|-------------|----------|------------------------|---------------------------|----------------------------------------------------------|--------------------------|------------------------|-----------------------------|
| ZK17        | River bed| 4258.23                | 4256.9                    | 28.0                                                     | 4263.3                   | 6.0                    | -                          |
| ZK28        | River bed| 4258.54                | 4256.9                    | 20.3-21.6                                                | 4265.5                   | 10.7                   | 8 (3-8)                    |
| ZK29        | River bed| 4258.48                | 4256.7                    | 32.5                                                     | 4260.5                   | 10.6                   | -                          |
| ZK32        | River bed| 4258.42                | 4257.9                    | 26.1-27.5                                                | 4258.9                   | 10.0                   | -                          |
| ZK35        | Right bank| 4312.93                | -                         | 43.7-45.0                                                | 4318.0                   | 35.0                   | 10 (15-9)                  |
| ZK36        | Right bank| 4294.13                | -                         | 33.1                                                     | 4294.23                  | About 2.0              | -                          |
| ZK37        | Right bank| 4334.34                | -                         | 49.1-50.6                                                | 4337.74                  | 14.4                   | 11 (10.3 (-))              |

3.3. The permeability of rock mass in the confined water distribution area

The results of the rock permeability test are shown in Table 2. Generally, the permeability of the rocks is decreased when the depth is increased, but the permeability is increased when the confined water is present (borehole No.ZK17). The hydraulic permeability is 10.3 Lu when the depth is 24.7~30 m. For borehole No. ZK18, it is 8.33 Lu when the depth is 13.45-19.2 m, 13.2~16.0 Lu when the depth is from 8.65-31.9 m. These rocks have medium permeability [5-6].

Table 2 Permeability of the rock mass in dam site

| Rock mass | Weathering | Test segment | High micro-permeability | Micro-permeability | Weak permeability | Medium permeability |
|-----------|------------|--------------|-------------------------|-------------------|-------------------|---------------------|
| Slate     | Intense weathering | 3 | - | - | - | 3 | 100 |
|           | Moderate weathering | 45 | - | - | 8 | 17.78 | 23 | 51.11 | 14 | 31.11 |
|           | Weak weathering    | 90 | 3 | 3.3 | 29 | 32.2 | 51 | 56.7 | 7 | 7.8 |

3.4. Hydraulic relation between the confined waters

In order to evaluate the hydraulic relation between the adjacent confined water veins, the pressure tests have been conducted in borehole No. ZK29 when the confined water is present. The borehole depth where the confined water is exposed for the first time is 31.9-33.8 m, the discharge is 10 L/min, and the level is 4260.50 m which is 3.2 m higher than the river. When the confined water is exposed in borehole No. ZK29, by observing the adjacent borehole No. ZK28 which has been completed for 45 days, the water discharge dropped from 8-10 L/min to 6.1-7.0 L/min. The level reduced considerably. When the pressure test has been carried out in the borehole ZK29, the water discharge of borehole ZK28 increased (figure.3), but the time is lagging. When the pressure test in the ZK29 was completed, the level of ZK28 reduced quickly. It is shown that those two boreholes have a hydraulic relationship. The boreholes ZK28, ZK17, and ZK29, which are in the dam axes line, have been analyzed in the same time. The borehole depth, where the confined water is exposed for the first time, was reduced from left to right, and the hydraulic slope is consistent with the apparent dip of the slate. According to
the analysis of the pressure test of those three boreholes, the hydraulic permeability of the rock mass is relatively large, the depth is about 10m, and those three boreholes have a hydraulic relationship.

![Figure 3: Water discharge of borehole ZK28 and pressure water head of borehole ZK29](image)

Figure 3: The water discharge of borehole ZK28 and the pressure water head of borehole ZK29

### 3.5. Temperature of the confined water
The change in the temperature of the confined water is small; it is 8 degrees Celsius at the top of the borehole. Transformation range of the confined water temperature is not large compared to the air temperature and the river temperature. It’s shown that the confined water aquifers don’t have a close relation with the river [7].

### 3.6. Chemical analyses of the confined water
The pH of the confined water is 7.3-8.4, just a little alkaline. Corrosion of CO2 is 0-10.8 mg/l, the amount of HCO3- is 121-220 mg/l, the total hardness is 125-208 mg/l, and the total alkalinity is 104~180 mg/l. There is no corrosion to the concrete.

In short, the confined water in the dam site has the following characteristics: (1) The distribution is random; there are multi-aquifers according to the differences of the borehole’s confined water. (2) According to the pressure test, the layers, where confined water distributes, have relatively strong permeability. The hydraulic relation along the trend of the rock mass is relatively good and bad along the dip direction. It is a significant possibility that the bedrock-confined water appears along the fractures and the foliation planes. According to the video of the borehole, the confined water is crack water, the supply origination is in the bilateral cryoconite mountains, and the cyclical depth is not deep.

### 4. Conclusion and suggestions
The probability for the confined water to break the cover board is small, but the confined water can flow along the cracks at the dam foundation. Due to the water head, the confined water would have some negative influences on the stability of the dam, so grouting is suggested to the aquifers; it can cut off the supply origin in the dam site. When the tunnel crosses the confined water aquifers, there are some influences on the stability of the tunnel, so the confined water should be considered also. In short, the bedrock-confined water is the main engineering geological problem [8-10]. Much attention to the design and the construction should be paid.
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