The Quality Inspection of Plastic Concrete Anti-Seepage Wall For Rushan River Groundwater Reservoir

Chen Li, Wanglin Li*, Ruchun Wei, Hairui Yu, Yun Hu

School of Water Conservancy and Environment, University of Jinan, Jinan, Shandong, 250000, China

*Corresponding author e-mail: cswlwe@163.com, 1853595613@qq.com, 2359766134@qq.com, 1353106670@qq.com, 1940960104@qq.com

Abstract. The construction of anti-seepage wall is an important part of the Rushan River underground reservoir project. The quality inspection of the anti-seepage wall is an important measure to ensure the anti-seepage reliability, and has important practical significance. The quality of anti-seepage wall is inspected by ultra-high density electrical method, on the basis of investigating the stratum lithology of Rushan River and the construction method of anti-seepage wall. The following conclusions are drawn. (1) Ultra-high density electrical method greatly improves the quantity of data acquisition by using the mode of multi-channel, multiple electrode, data automatic acquisition. (2) The arrangement of disposable survey line is adopted in the inspection, which can easy to operate and save inspection time. (3) With increasing of the inspection data, the error of inversion system is reduced, and the contour map of apparent resistivity is more reliable. (4) The contour map of apparent resistivity shows that the anti-seepage wall has good continuity, and obvious discontinuous anti-seepage wall is not found; the connection between the anti-seepage wall and the bedrock is well, indicating that the quality of anti-seepage wall meets the anticipated effect, the next construction can be implemented.

1. Introduction

1.1. Purpose and significance of topic selection
Rushan River groundwater reservoir is the first case in Weihai City, Shandong Province. It will play a positive role in the urban water supply, marginal revenues of water after the completion of project. The main purpose of constructing the anti-seepage wall is to cut off the subsurface flow, forming the groundwater storage space, preventing the subsurface flow from flowing into the sea, which could ensure the local residents' demand for water for production and living; at the same time, the large area of seawater intrusion along the gravel aquifer can be prevented when the groundwater table is lowered. Therefore, the quality inspection of anti-seepage wall have great practical significance.

1.2. Research status of ultra-high density electrical method
The ultra-high density electrical method began to be used in Britain in the late 1970s. Japan completed data automatic acquisition of ultra-high density electrical method by using electrode transformation in
the mid-1980s. The emergence of electronic computers in the 1990s lead to ultra-high density electrical method rapid development [1]. The essence of ultra-high density electrical method is also a method for calculating resistivity, widely used in abroad, such as inspection of incipient fault for reservoir dam foundation, inspection of the groundwater and soft soil layer exploration [2-4].

The application of ultra-high density electrical method in China is late. Bin Liu found that ultra-high density electrical method has many advantages by comparing with the exploration method of ground penetrating radar and ultrasonic, such as low requirement for field conditions, low cost, rapid data acquisition, intuitive and understandable of inspection results [5]. The uniformity of the anti-seepage wall of the Flower Pavilion reservoir is inspected by the ultra-high density electrical method, and the inspection effect is remarkable [6]. Two-dimensional inspection in one exploration could be completed and DC inversion system is developed, which is a new technology of resistivity method in the concealed engineering inspection [7].

2. Overview of engineering

2.1. Engineering location and hydrometeor
Rushan is located at the southeastern of the Shandong peninsula, which borders Wendeng area in the east, neighboring Haiyang city in the west, Muping District in Yantai City in the north, and the Yellow Sea in the south, across the sea from Korea and Japan. The groundwater reservoir (upstream reservoir and downstream reservoir) engineering task is to form groundwater storage space, causing the water transformation can be carried out quickly and effectively, which could solve the unreasonable situation of water utilization, adjusting the contradiction between economic development and water use, and shouldering the task of cutting off seawater intrusion. The Rushan River basin is located in a warm temperate maritime monsoon climate zone with small temperature differences, obvious four seasons and sufficient precipitation. The average annual precipitation of Rushan River basin is 753.2mm according to the statistical analysis of monthly precipitation data from 1956 to 2017. The annual change of precipitation is larger, and the dry-wet ratio is 3.73:1. The precipitation in a year is mainly concentrated in June-September, which can account for 74.5%. Therefore, it can be considered that the rainfall in the Rushan River Basin is unevenly distributed during the year.

2.2. Engineering design
The anti-seepage condition bottom of the groundwater reservoir and the two banks of the reservoir meet the requirements. The elevation of groundwater divide is higher than the design storage level of groundwater reservoir. Leakage in the reservoir area occurs in the middle-fine sand layer and gravel coarse sand. Therefore, this engineering is planned to construct anti-seepage wall at downstream channel, which can prevent surface water and groundwater discharge to the downstream.

The length of anti-seepage wall at the downstream reservoir is 5.996Km, the bottom elevation of anti-seepage wall is -1.5m and the top elevation is 2.0m. The plasticity concrete poured is marine concrete, and the aggregate also considers the seawater environment. The average depth of the wall is 13.82 m, the thickness of the wall is 400 mm, the permeability coefficient is less than $2 \times 10^6$ cm/s, the permissible permeability ratio is not less than 200, the elastic modulus is not more than 1200 MPa, and the compressive strength is not less than 3.0 MPa.

The length of anti-seepage wall of upstream reservoir is 1.2Km, The penetration depth of the anti-seepage wall is 1.5m. The top elevation of wall is 6.0m. The concrete poured is Portland cement. The average depth of the wall is 13.42 m, the thickness of the wall is 300 mm, the permeability coefficient is less than $2 \times 10^6$ cm/s, the permissible permeability ratio is not less than 200, the elastic modulus is not more than 1200 MPa, and the compressive strength is not less than 3.0 MPa.

3. Inspection of ultra-high density electrical method
Ultra-high density electrical method improves the conventional resistivity method, but the principle that different geological conditions will produce different potential difference is unchanged. Ultra-high
density electrical method develop novel data acquisition mode, adopting disposable survey line arrangement, multi-channel, automated acquisition way. Data acquisition in vertical and transverse are completed in a single exploration.

### 3.1. Test apparatus

The quality of plastic concrete anti-seepage wall of Rushan River underground reservoir is inspected by using Flash RES64 multi-channel ultra-high density exploration system developed by ZZ Resistivity Imaging Company of Australia. The electrode arrangement of this exploration system is very different from the conventional method, and also the data collection method is free combination of the multiple electrodes, causing the data information rapid collection. Ultra-high density electrical method uses the DC inversion system to obtain the apparent resistivity map, improving the accuracy and reliability of detection. The test apparatus is as shown in Figure.1.

#### Figure.1 test apparatus

### 3.2. Basic principles of ultra-high density electrical method

The complexity and the difference of resistivity for geologic composition provide theoretical support for resistivity method and ultra-high density electrical method. Therefore, the geological problems are detected and analyzed by the artificial DC electric field. The electrode can be combined freely if the resistivity of tested area is uniform. That is, the power is supplied to any two points (A, B) of the surface, and then detecting the potential of any two points (M, N), so that the potential difference between the two points (M, N) can be deduced.

\[
U_M = \frac{i\rho}{2\pi} \left( \frac{1}{AM} - \frac{1}{BM} \right) \tag{1}
\]

\[
U_N = \frac{i\rho}{2\pi} \left( \frac{1}{AN} - \frac{1}{BN} \right) \tag{2}
\]

By derivation, the potential difference between AB in MN is obtained.

\[
\Delta U_{MN} = \frac{i\rho}{2\pi} \left( \frac{1}{AM} - \frac{1}{BM} - \frac{1}{AN} + \frac{1}{BN} \right) \tag{3}
\]

The formula for calculating the apparent resistivity can be deduced.

\[
\rho = \frac{2\pi}{\frac{1}{AM} + \frac{1}{AN} + \frac{1}{BM} + \frac{1}{BN}} \left( \frac{\Delta U_{MN}}{I} \right) \tag{4}
\]

Where \(U_M\) and \(U_N\) are the potential difference of point M and N respectively, \(V\); \(\Delta U_{MN}\) is the potential difference between AB in MN, \(V\); \(\rho\) is resistivity, \(\Omega \cdot m\); AM and AN are the distance from point A to point M and N, respectively; BM and BN are the distance from point B to point M and N, respectively; I is the current intensity generated during the inspection, A.
4. Quality inspection of plastic concrete cut-off wall of Rushan River groundwater reservoir

4.1. Survey line arrangement and test apparatus assembly

Mud on the anti-seepage wall is removed before inspection to ensure that the top of the anti-seepage wall is leveled, and the medial axis and the measuring position are marked on the top of the wall. The stainless steel electrode rod is installed at the medial axis line every 2 m, and the penetration is 0.15-0.2 m. The special cable is clamped on the top of electrode by spring clip. The cables should be distributed symmetrically, and the main case is placed at the middle. Survey line arrangement is shown in Figure 2. Then, the special cable is connected to the Cable interface of the main apparatus, and main case is connected to the portable computer. Then the data acquisition can be started. How to connect the test apparatus is shown as Figure 3.

![Figure 2: Survey line arrangement](image)

![Figure 3: Field data acquisition instrument connection diagram](image)

4.2. Data acquisition and check

The main apparatus is connected with the portable computer after starting the FlashRES64 data acquisition system, then setting the measurement information, measurement parameters (output voltage, acquisition period), measurement layout (measurement mode, number of electrodes and electrode spacing) (as shown in Figure 4 (a)). Checking the electrode connection is shown in Figure 4(b). The data acquisition can be started after above operations are completed. The Flashdatacheck.exe software is started, and then inputting the V and I of the survey area, adjusting the value of the W area and E area are shown in Figure 4(c). The W area is to detect the connection of electrodes, setting value is generally 0.01A. The E area is to detect the accuracy of the data acquisition, setting value ranges from 5 to 10. E will appear in the yellow line position in the D area in Figure 4(d), ensuring the H is not less than 75%.
4.3. Data inversion
ZZ64in.exe inversion software is started, inputting *-iv_inv.inp file generated by the data check. The real-time correction in the inversion is needed to ensure the accuracy of inspection. Three files will be generated after the inversion, and the *-iv_inv.grd file containing the latest inversion iteration results will be input into SURFER11 software to derive the resistivity contour map. The quality of anti-seepage wall can be analyzed by resistivity contour map.

4.4. Data analysis and quality inspection
The material pouring the anti-seepage wall is uniform, that is, the resistivity of the wall is uniform. However, due to the complexity and uncertainty of the construction process, the ultimately completed wall will inevitably form holes of different sizes and fracture caused by insufficient pouring. In this way, the resistivity of construction defect is inconsistent with that of the whole wall, which will be intuitive and obvious displayed on the resistivity contour map. Figure 5 shows the quality inspection results of the anti-seepage wall.

![Figure 4](image1.png)
![Figure 4](image2.png)

**Figure.4** Parameter setting of FlashRES64

![Figure 5](image3.png)
![Figure 5](image4.png)

**Figure.5** The quality inspection results of the anti-seepage wall

The following results are made from Figure 5. Rushan River underground reservoir has a good continuity of the whole anti-seepage wall, the bottom of the wall and the bedrock maintain good
connection. The quality of the anti-seepage wall meets the expected effect, so the next step of construction can be implemented.

The partial inspection result of downstream reservoir is shown in Figure 5 (a) and (b), and that for upstream reservoir is shown in (c) and (d). The anti-seepage wall in Figure 5 (a) and (d) area is below the flatland, and the top of the wall is relatively flat, causing the resistivity contour map is relatively gentle. The top of the wall in Figure 5 (b) has a higher mound, the inspection area in Figure 5 (c) has a ditch with a certain depth, which is also reflected by the fluctuation in the resistivity contour map. The above results reflect the influence of terrain on the quality inspection of the anti-seepage wall.

5. Conclusions and suggestions

5.1. Conclusions

The quality of anti-seepage wall is inspected by the ultra-high density electrical method for engineering example for Rushan River groundwater reservoir, the following conclusions can be drawn. Ultra-high density electrical method breaks through the limitations of the previous data acquisition methods, using arrangement of disposable survey line, which can save time in the construction link, and improve work efficiency; The quantity of inspection data increased by the method of multi-channel, multiple electrode and automatic acquisition, improving the accuracy of the inversion results. The quality of anti-seepage wall in Rushan River underground reservoir is effectively tested by ultra-high density electrical method. It is found that there is no obvious wall discontinuity after comprehensive analysis of resistivity contour map combined with terrain. The bottom of anti-seepage wall and the bedrock maintain good connection.

5.2. Suggestions

The resistivity of anti-seepage wall will increase with the solidification of the wall, therefore, it is necessary to consider the timeliness of inspection and choose the appropriate time for quality inspection. The terrain of the cover-layer and the soil condition should be considered during inspecting if the anti-seepage wall has a certain cover-layer.

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