Study on anti-seepage treatment and seepage control effect of core dam foundation curtain of the fault fracture zone in Xinjiang province

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Abstract. The treatment effect of dam foundation fracture zone is related to dam safety, A case is provided base on the fault-fracture zone with large permeability in a core dam foundation in Xinjiang province, The dam foundation seepage model is established with the seepage finite element method base on The test results of post-grouting in the fault-fracture zone, simulation working conditions of different curtain depth and permeability indicate that significant impervious effects of compound grouting and depth-curtain at fault zone, leakage is less in the dam foundation and seepage stability meet the requirement on the riverbed overburden in the downstream, The results are high reference value for similar projects.

1. Introduction

The impervious curtain is usually used as seepage control measures in asphalt concrete core dam foundation, and the effect is one of the key factors that influence engineering safety, Especially there is fault zone or unfavorable geological body in the dam foundation. Once the treatment is ineffective, the engineering loss is huge, and the post-processing is difficult and expensive. Therefore, it is necessary to pay full attention during the design and construction phase (Bao&GU,2008; Liu & Zhou,2015). The excavation and concrete replacement are traditional treatment methods of dam foundation defects, but these methods have the disadvantages of high cost, difficulty, and long construction period. It is significant effect that the chemical grouting and composite cement grouting to deal with dam foundation fault zone usually, .The reasonable design and grouting technology can achieve good grouting effect (Wei & Shao,2014; Wei & Zhang,2015) .The dam foundation has larger scale faults in an Asphalt concrete core dam in Xinjiang province in China. in this paper, the treatment measures of fault zone is introduced briefly, the three-dimensional seepage field in typical dam section 0+216m is modelled with refined finite element method, and the effect is analysed for impervious curtain to control the seepage field. The main objective of this study is to analyse seepage control effect within different curtain depths and the rationality and reliability of seepage control measures is evaluated, A reference is provided for composite grouting treatment and curtain design of similar dam foundations.

2. Geological conditions and treatment measures of the dam foundation

2.1 Geological conditions

This dam locates in Xinjiang province in China. The maximum height of the asphalt concrete core dam is 116 m, The length of dam axis is 313 m, The total storage capacity is 0.99×10^7 m^3.

The river bed and the right dam foundation section are mainly introduced（Figure 1）. The dam foundation of the river bed is about 50m wide, The riverbed overburden are a mixed soil and erratic boulder, this layer thickness is 14.9m and the permeability coefficient is $5.8\times10^{-2}\sim6.2\times10^{-2}$cm/s, It is a strongly permeable layer(Figure 2, Figure 3). The underlying bedrock is diorite biotite feldspar granite with massive structures, the thickness of the strongly weathered layer of the rock mass is 2.0-4.0m, and the thickness of the weak-weathered layer is 12.0-14.0m. A fault f_{11} is developed in the bedrock of the river bed and the fault zone bandwidth is about 2 to 4m, the permeability of the rock mass is obviously larger than that of other sections. There are six faults in the right dam foundation, the f10 is one of the most influential faults and it is compressional fracture with bandwidth of 7.0～15.0m. Fractured rocks are dominant with a small amount of fault mud. The rock mass is generally broken in the influence zone on both sides of the fault within 10 m and the permeability of this zone is obviously larger than that of other sections too.

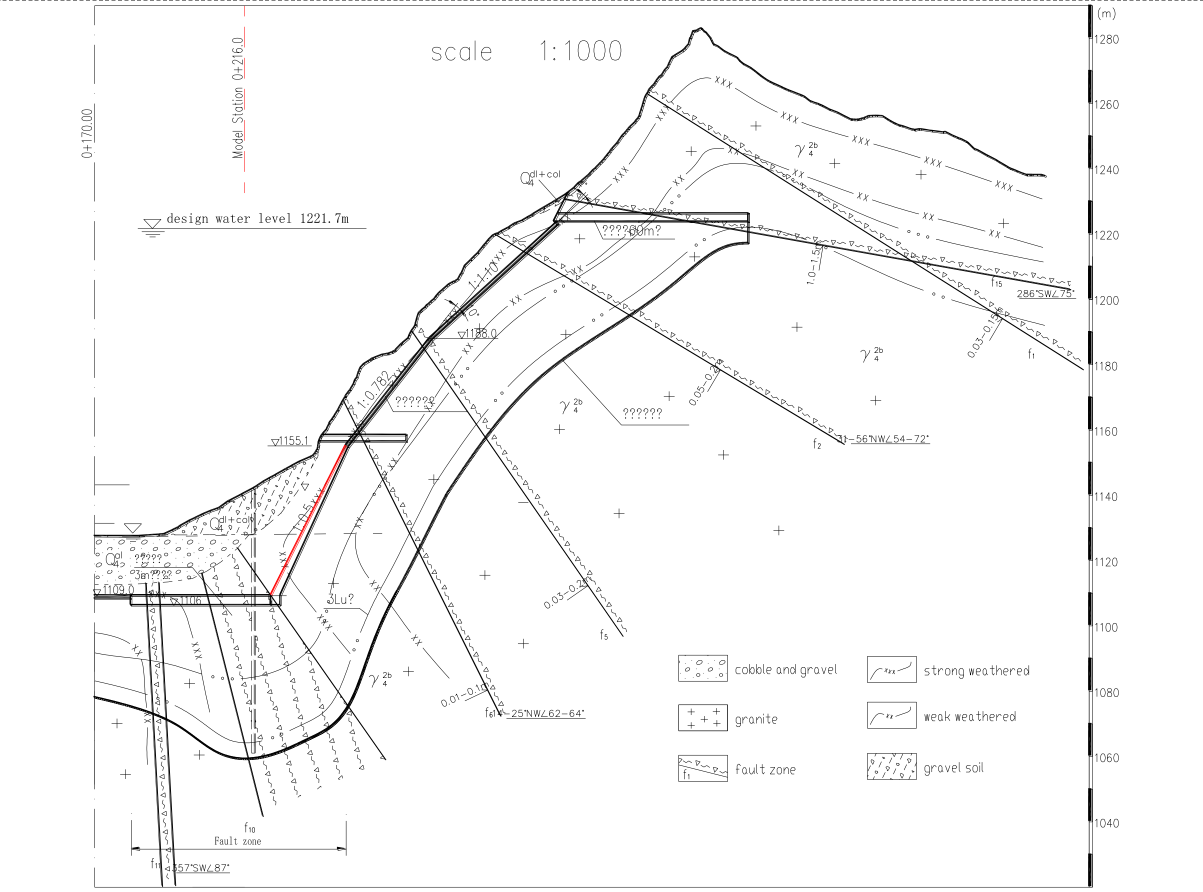

Figure 1. Right dam foundation longitudinal profile.

Figure2. Disturbance samples and test devices.

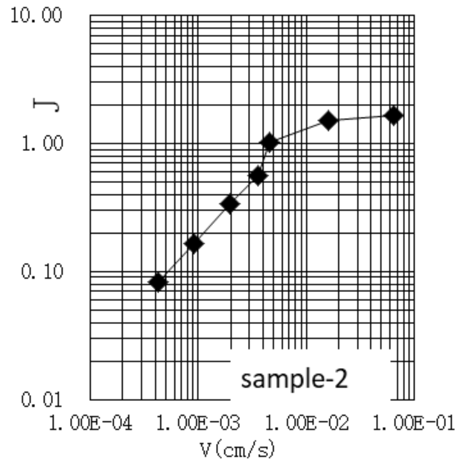

Figure 3. Permeability results of sample

2.2 treatment measures

The layer with mixed soil and erratic boulder is excavated within 3m of the river bed. In order to meet the anti-seepage requirements, according to the regulations, the impervious curtain is designed, especially, the dam foundation is grouted in different depth. the main treatment measures are concrete rock plug and double-row curtain chemical grouting in the fault zone which width is 5m. The cement-chemical compound grouting is the treatment of weak faults in different riverbed depth, the chemical grouting with low pressure is adopted to prevent lifting within the shallow dam foundation, the wet grinding cement is used within a certain depth of the dam foundation, the deeper of dam foundation is treated with conventional cement grouting. The display of the some core samples of dam foundation is obvious different before and after grouting, the Lugeon′ value is almost less 1.0Lu base on the water pressure test after grouting. According to the results of test, it is the satisfying effect by using these curtain grouting measures.

Figure4. The core samples of dam foundation.

Figure 5. The core samples of post-grouting.

3 Numerical simulation of the typical dam section

3.1 Parameters

The permeability coefficient of the fracture zone is different in this dam section. In this model, the value of the permeability coefficient of the fracture zone is acquired by pressure water tests and similar engineering experience. The permeability of fault zone (f_{10} and f_{11} fault zone of influence) as shown in Figure 1, the comprehensive value of permeability coefficient is 1×10^{-3} cm/s in fracture zone above the elevation of 1109m, the permeability coefficient is 5×10^{-4} cm/s with of elevation of 1109m~1084m and the coefficient is 5×10^{-5} cm/s with of elevation of 1084m~1064m in this dam section. The permeability coefficient of impervious curtain is 3×10^{-5} cm/s (compare case 1×10^{-5} cm/s). the concrete asphalt wall is 1×10^{-9} cm/s. The width of the consolidation grouting zone (depth is 7m) is 5.5m along the river. The upstream water level is 1221.7m and the downstream water level is 1114.9m in different cases.

3.2 Finite element model and case

The dam foundation seepage model is established with the seepage finite element method base on the test results of post-grouting in the fault-fracture zone, conditions of different curtain depth and permeability are simulated. The model is located in fracture zone（f_{10}）in the stake number 0+216m. The X original point of calculation model is the junction point of core wall base, the X axis is alone the downstream, The Y axis is practical elevation. According to the above coordinate system the depth of the elevation is 715 m in level model and depth is about 3.5 times the height of the dam, the upper and lower boundary range of the model is also 3.5 times the height of the dam. The model element is 6 sided 8-node element, the node number is 52108 and the element number is 43702. The grid of dam foundation and the anti-seepage treatment and stratigraphic division in dam foundation are shown in Figure 6 and Figure 7.

For the analysis of different conditions of dam foundation seepage control measures effect, four cases are assumed. The cases (case1 to case 3) ware assumed different curtain depth, the impervious curtain permeability of case 4 was different to case 1. Steady seepage flow was simulated with water head at boundary nodes immerged by reservoir water and tail water known as the respective water level. The downstream slope was assumed as possible exit surface. The bottom and the both side boundaries of the model were assumed as impermeable.

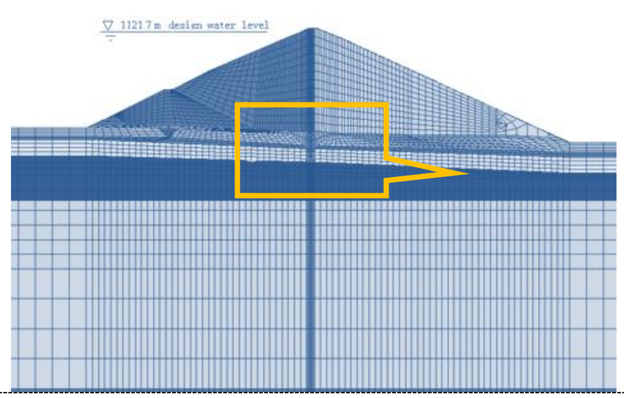

Figure 6. The FEM meshes.

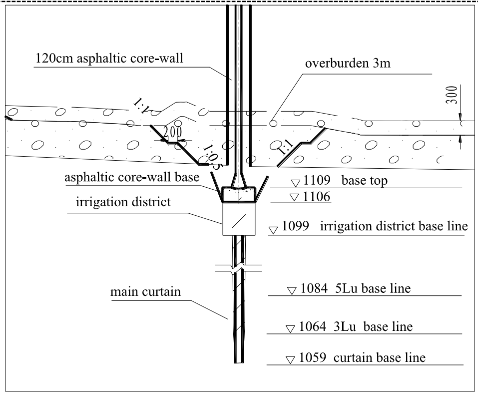

Figure 7. The anti-seepage treatment and stratigraphic division in dam foundation.

3.3. Numerical method for seepage field

The simulation of phreatic surface is usually involved in hydraulic engineering, underground engineering and dam, the fine efficient solution of complex seepage field analysis is the key. The seepage calculation of dam foundation involves precise simulation methods of solving seepage free surface, summarized as follows. In unconfined seepage problem, the free surface of seepage is nonlinear boundary. The location of the free surface, the line of exit points and the real domain of seepage are unknown first, which need iteration to obtain the solution to the unconfined seepage problem. The procedure of nodal virtual flux that is progressively developed and perfected by some scholars (Zhu,1997；Cui & Zhu, 2009). The autonomous software SFA1.0 was used in this paper.

3.4 Simulation results

Case 1 is the preliminary design case, the depth of curtain is 57m and the permeability coefficient of impervious curtain is 3×10^{-5} cm/s in case 1. The anti-seepage system is composed by the closed impervious curtain of the dam foundation and the asphalt concrete core wall of the dam, the simulation results indicated the most pressure head in the impervious core wall of the dam body and curtain in foundation(Figure 8), according to the water head contour of the dam foundation, which indicates the distribution of seepage field reasonably, the contour shape, direction and intensity are correctly reflect the seepage control measures characteristic, the gradient of permeation is almost negligible on the riverbed overburden in the downstream, the safety requirements is satisfied completely. The leakage is 9.44 m^3/d.m in case 1.

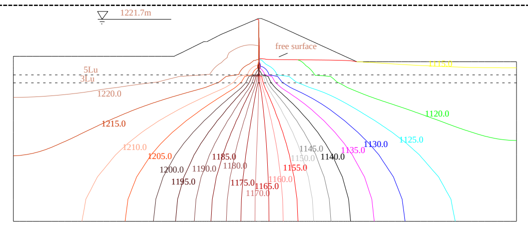

Figure 8. Water head contours in case1

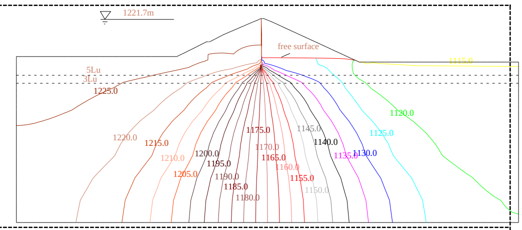

Figure 9. Water head contours in case 2

Case 2 is comparison scheme, the depth of curtain is 25m.We can see the water head contour distribution intensive near asphaltic core-wall and curtain in the dam foundation in Figure 9, which shows the water head pressure was cut by the anti-seepage system, but the leakage is 13.1 m3/d.m, which is almost 40% more than case1.The water head contour distribution is so similar between the case 1 and case 3. In case4, the depth of curtain is 57m, the permeability coefficient of impervious curtain is 1×10^{-5}, the result shows that the water head contour distribution is more concentrated in curtain and the leakage is less than case1.

According above the analysis, the distribution of program seepage field basically reflects the impact of complex geological conditions and seepage control measures and overall. The gradient of permeation of the key zone satisfy code requirements, which indicates design of seepage control measures is reasonable and effective in the case. Simulation working conditions of different curtain depth and permeability indicate that significant impervious effects of compound grouting and depth-curtain at fault zone.

Table 1. The discharge of dam foundation in different cases (m^3/d.m)

Site	Case 1	Case 2	Case 3	Case 4
typical section dam foundation 0+216	9.44	13.1	9.66	8.51

4. Discussion

The seepage field as a complete anti-seepage system provided with a complete anti-seepage system formed by grout curtain and asphaltic core-wall as Case 1, the seepage field is controlled by the measures of dam foundation significantly, but this does not mean that the dam seepage prevention can be careless, otherwise, strict requirements for grouting quality are more needed in whole construction period.

5. Conclusions

(1) The leakage is less in the dam foundation and seepage stability meet the requirement on the riverbed overburden in the downstream, which indicates that significant impervious effects of compound grouting and depth-curtain at fault zone, the results are high reference value for similar projects.

(2) According to dam seepage field analysis, the effect of seepage control measures is significantly, the preliminary design case is reasonable. There are fault zone in dam foundation，so the curtain depth of this project is not recommended to be optimized.

Acknowledgments

This work was financially supported by the National Key R&D Program of China (2017YFC0405001;2017YFC1502600).The Special Fund of Chinese Central Government for Basic Scientific Research Operations in Commonweal Research Institutes (CKSF2019477/YT; 41902260).

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