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Research Article

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Characteristic study on seepage field of dam under cutoff wall construction defects and freeze in winter

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ABSTRACT

The quality of construction of cutoff wall plays a vital role to its upper structure and normal operation of dam. In order to study the construction defects of concrete cutoff wall to the effects of dam seepage flow field and investigate the effects of seepage face freezing in winter on the dam. Combining a water conservancy project in north, the control section and super finite element mesh automatic generation method was used to set up the 3D finite element model and conduct the steady seepage analysis. Analysis results show that the groundwater level has landed in the cutoff wall simultaneously reduced the exit gradient downstream slope seepage and improved the stability of the slope. The effect on construction defects of cutoff wall in seepage field is more obvious in the local range. Winter freezing on dam seepage face has little effect.

Keywords: Cutoff wall, construction defects, winter freezing, seepage field.

INTRODUCTION

In the new earth and rockfill dam project, reinforcement project of dangerous reservoirs and embankment project, one important engineering measure is anti-seepage reinforcement. The cutoff wall is an underground continuous wall built in the water retaining structure and permeable layer to meet in seepage control, bearing or soil retaining function. It has the advantages of reliable structure, good seepage-control effectiveness and good adaptability for different stratum conditions, et al. Since the construction technology of the cutoff wall was introduced in 1950s and 1960s in China, it has got fast development. The construction quality of the cutoff wall plays a vital role to its upper structure and normal operation of the dam [1]. The construction quality of concrete cutoff wall is connected with the construction mud, raw material and concrete mixture, concrete and density of mud pore-forming process and its spacing and depth elevation difference of conduit, casting speed of concrete and siltation thickness at the bottom of the bore, et al [2]. If every factor do not meet the requirement or test inaccurately, that will affect the construction quality of the cutoff wall and it is easy to have a slot and any other construction defects. That water conservancy projects of north China, the freeze and expansion in the reservoir surface can strongly push the slope and destroy it. In the freezing condition, dam surface is no longer the seepage boundary and the seepage field and seepage surface will change in dam body and foundation. Therefore, it is necessary to study the concrete cutoff wall construction defects and the seepage characteristic under freezing condition in dam body and foundation, which can provide technical base for the design and construction of the cutoff wall and earth and rockfill dam.

CALCULATION MODEL AND PARAMETERS

Considering the effect of construction defects of the cutoff wall, a 13m clay homogeneous dam in northern region in China was studied and analyzed the influence of the winter freeze on dam seepage.

The normal level of the dam is 145.00m, 146.00m of crest elevation, 13.00 of dam height, 1:3.0 of upstream or downstream slope, and 1926.40m of length.

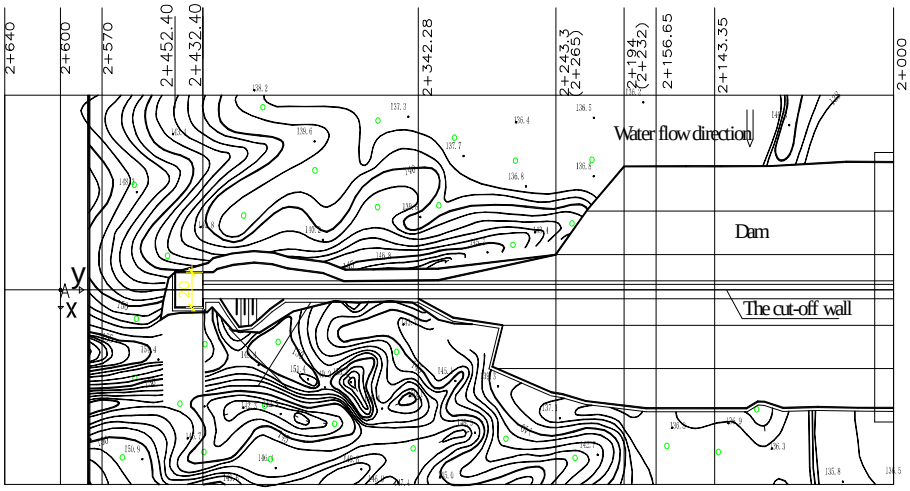

Fig. 1 Sketch of typical cross sections

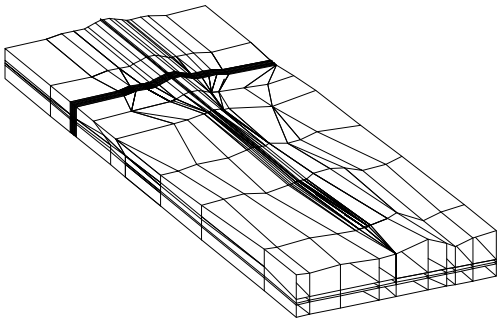

Fig. 2 3D total grid model

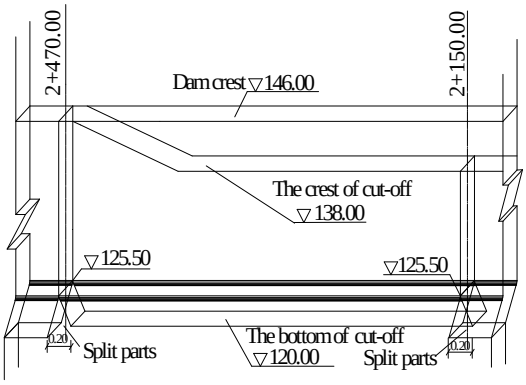

Fig. 3 Split parts of the bottom of the cutoff (unit: m)

Boundary type of stable seepage analysis mainly includes known water head boundary, seepage boundary and impermeable boundary: (1) known water head boundary includes the dam body below the water level of upstream and downstream, the surface boundary of banks and river bed; (2) seepage boundary includes the dam above the water level of upstream and downstream and the banks surface; (3) impermeable boundary includes the boundry around the modle.

Calculation model locate at the K2+000~K2+640. The sketch of typical cross sections can be shown as Fig. 1. Above the project, the finite element mesh automatic subdivision method with control cross-section super element was adopt [4-6], establishing a three-dimensional seepage finite element model as shown in Fig. 2. In the normal storage water level conditions, the influences of construction defects of the cutoff wall and freezing on seepage properties were analyzed. Limited to calculation scale, some part of calculation model less effect by seepage calculation was simplified, including 30cm stone cage of the upstream revetment and 30cm gravel cushion layer and the drain. Through geological survey, the hydraulic conductivity of the dam body and each foundation layer are shown in table 1.

Table 1 Model parameters

Material	Hydraulic conductivity (cm/s)	Allowable gradient [J]
Clay	2.92×10^{-5}	3～5
Coarse sand and fine gravel	8×10^{-2}	0.12
Medium sand	4×10^{-2}	0.10
Loam	1.15×10^{-5}	1.00
Plastic concrete	1×10^{-8}	
Weak weathered rock	1.3×10^{-4}	
Strong weathered rock	2.0×10^{-4}	

Here, the main problem of the cutoff wall construction defects is the split appearing under the adjacent cutoff wall, there are hypothetically two splits in the left of dam body located at K2+150.00 and right of dam abutment located at

K2+470.00, and the elevation is 125.50m and 125.00m respectively, where the largest crack width is 20cm both. The split part of the bottom of the cutoff was as shown in Fig. 3. The surface of dam and the right abutment is not a permeable boundary any more under the freezing condition. Considering this effect, the seepage field and the change of seepage surface in dam of freezing were calculated.

RESULTS AND DISCUSSION

The influence of construction defects on seepage field

By figure 4~6, the influence of construction defects on seepage field was more obvious in local scope. By the calculation and analysis of seepage flow, the seepage flow through the dam foundation, the right dam abutment and around the right bank increased 8.0%, 1.4% and 26% than normal storage level. In condition of construction defects, the maximum seepage slope decreased 0.0059 in dam body and increased 0.0002 on right dam abutment than normal storage level.

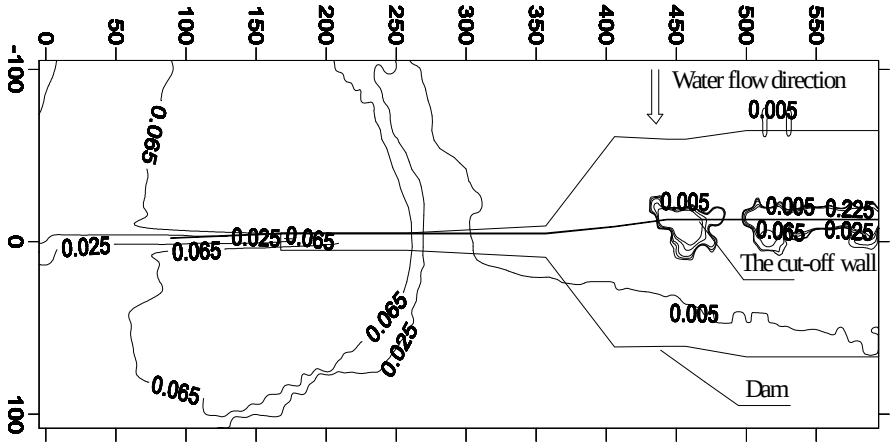

Fig. 4 Water surface slope contour (unit: m)

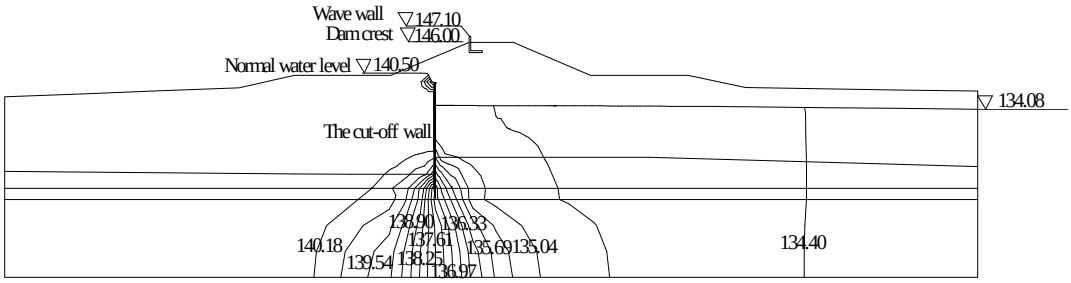

Fig. 5 The potential distribution of section K2+150.00 (unit: m)

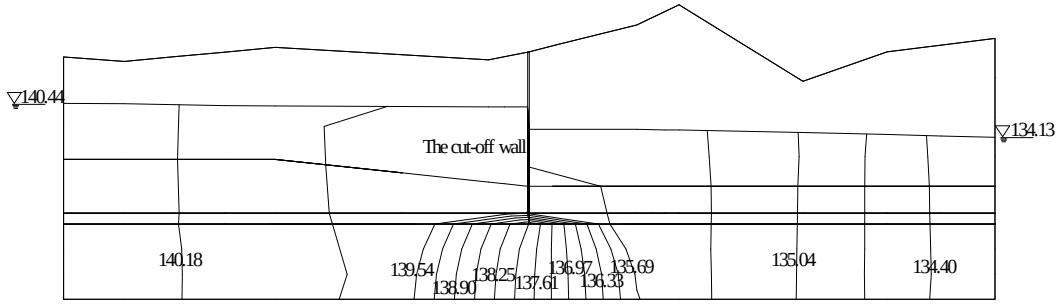

Fig. 6 The potential distribution of section K2+470.00 (unit: m)

The freezing influence on saturated surface in winter

By figure 7~9, freezing in winter has less effect on the seepage surface of the dam body. 30cm stone cage above the downstream water level of dam surface and the right dam abutment ground had been freezing in winter. The potential distribution (Fig. 8 and Fig. 9) show that infiltrates surface are located within the dam body, exceeding the maximum freezing depth, therefore, there is not affected by freezing. Contrasting Fig. 8 with Fig. 9, the seepage surface of the dam

body has no significant changes on profile K2+470.00. Freezing has little impact on dam seepage surface. The maximum dam seepage slope decreased 0.0026 and the right dam abutment seepage slope increased 0.0029 both than the normal storage level in freezing winter.

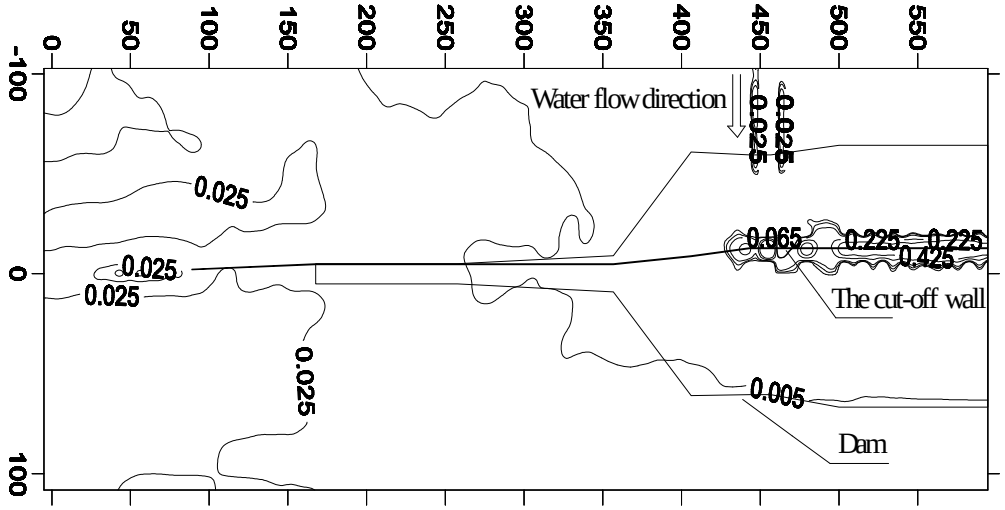

Fig. 7 Water surface slope contour (unit: m)

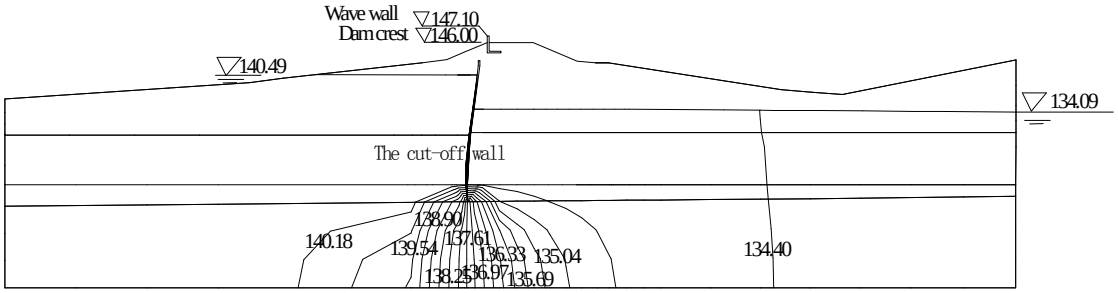

Fig. 8 The potential distribution of section K2+218.65 (unit: m)

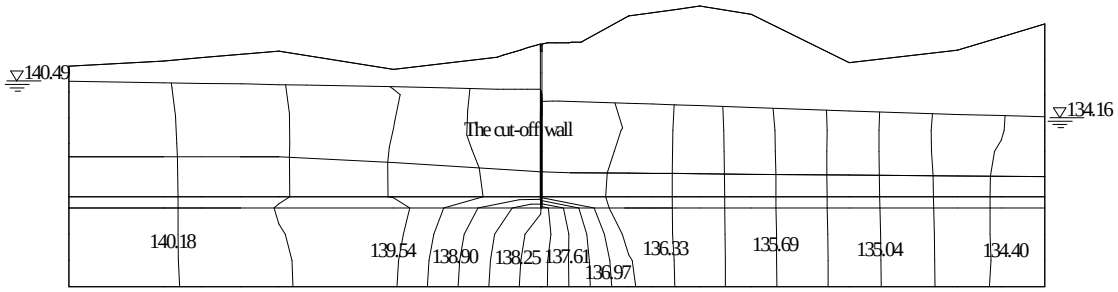

Fig. 9 The potential distribution of section K2+470.00 (unit: m)

CONCLUSION

(1) Cutoff wall has great influence on the characteristics of seepage field, also has obvious effect for blocking groundwater seepage. Underground water level behind the wall significantly decreased, the length and the depth is to change seepage field form and reduce the seepage flow by blocking seepage and forning a complete waterproof barrier. Groundwater level behind the cutoff wall has decreased obviously, which makes the groundwater seepage slope inside the cover before and behind the cutoff wall decrease too. It is good for preventing much seepage deformation and forming strong permeable channels by stong driving force of seepage slpoe inside the cover, at the same time, cutoff wall reduced the overswin slope of downstream side slope seepage and improved the stability of the slope.

(2) The construction defect has obvious influence on seepage field in the local scope and less influence on dam saturated surface in cold winter. Therefore, enhance the construction quality control was suggested. The concentration and large area of low strength concrete shall be stripped and concrete it again; the cracking parts of the cutoff wall shall be grouted, in order to increase the thickness of impervious layer.

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