

Numerical Analysis on Seepage in the deep overburden CFRD

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Abstract. There are many problems in the construction of hydraulic structures on deep overburden because of its complex foundation structure and poor geological condition. Seepage failure is one of the main problems. The Combination of the seepage control system of the face rockfill dam and the deep overburden can effectively control the seepage of construction of the concrete face rockfill dam on the deep overburden. Widely used anti-seepage measures are horizontal blanket, waterproof wall, curtain grouting and so on, but the method, technique and its effect of seepage control still have many problems thus need further study. Due to the above considerations, Three-dimensional seepage field numerical analysis based on practical engineering case is conducted to study the seepage prevention effect under different seepage prevention methods, which is of great significance to the development of dam technology and the development of hydropower resources in China.

1. Introduction

With the continuous development of China's water conservancy and hydropower construction, the western region has become the key area of water resources development. But in the west, especially in the southwest region, where rich hydropower resources are found, there are a large number of deep overburden. Deep overburden is generally the result of loose deposits formed in the fourth century of the Cenozoic, which has a thickness greater than 30m. It is characterized by loose structure, discontinuous lithology and complex genetic types. There are greater changes in the horizontal and vertical direction, resulting in a larger non-uniform nature in physical and mechanical properties. Construction of hydraulic structures in this kind of foundation exist seepage control, seepage stability, uneven settlement and other important issues. The seepage failure is one of the main reasons.

China has achieved some achievements in the construction of dam on the overburden, For example, the constructions over deep overburden of soil core rockfill dam, concrete face rockfill dam, asphalt concrete core dam and other types of dams. But this technology still largely depends on the existing engineering cases of seepage problems, a deeper look into the solutions can promote the development of dam technology.

2. Case study and calculation model

2.1 Engineering case

A hydropower station contains a concrete face rockfill dam, with a crest length of 328.0m and width of 10.0m. The maximum dam height is 111.0m and dam crest elevation is 805.0m. The upstream slope ratio is 1: 1.4, whereas that of downstream is 1: 1.55. The normal water level of the hydropower station is 800m and the dead water level is 795m. The thickness of river bed overburden is 44m ~ 48m. Among this, the thickness of the surface sedimentation layer is about 2m ~ 4m, the upper part of the



gravel layer with sand stone thickness are between 6m ~ 20m, while that of the middle part gravel layer are 12m ~ 15m, which is the main layer of bed cover., and the bottom part of the gravel layer with sand stone thickness of 5m ~ 10m. The seepage control system of river bed is concrete cutoff wall. Wall thickness is of 1.2m and the maximum depth is of 48m. The drilling of curtain grouting through the cut-off wall for bedrock grouting. On both sides of the depth, the weakly weathered rock mass are around 30 m, strongly weathered rock is less.

2.2 calculation model

The dam cross-section of the engineering case is shown in Figure 1. A coordinate system is created: the axis upstream-downstream direction is the X axis according to the vertical direction of the dam; left-right bank is the Y axis. Z axis refers to the vertical direction from the bottom to the top is. In Z axis direction: The overburden is divided into three layers, the upper part of the gravel layer with sand stone is overburden 1 (Thickness 20m), the middle part gravel layer is overburden 2 (Thickness 15m), and the bottom part of the gravel layer with sand is overburden 3 (Thickness 10m). The total thickness is 45m, where bedrock takes 165m. In X axis direction: along the dam toe and dam heel direction to the upstream and downstream were extended 2 times the maximum dam height of 222m. Y axis direction: left and right sides were extended 1.5 times the maximum dam height of 166.6m. The dam is simplified as a faceplate (Thickness 0.68m), an transition zone (Thickness 3m), and a rockfill area. The overall X, Y, Z dimensions of the model are 799m x 681.2m x 500m. The model mesh is shown in Figure 2. Using 4-node free mesh, a total of 15936 nodes and 87261 nodes were generated.

Water head is applied upstream at a normal water level of 800 mand 710 m at downstream. The coordinate origin is taken as the reference point, with the total head applied upstream was 300 m and downstream 210m. The bottom of the foundation, the left and right bank sides and the upstream and downstream side are considered as the impermeable boundary.

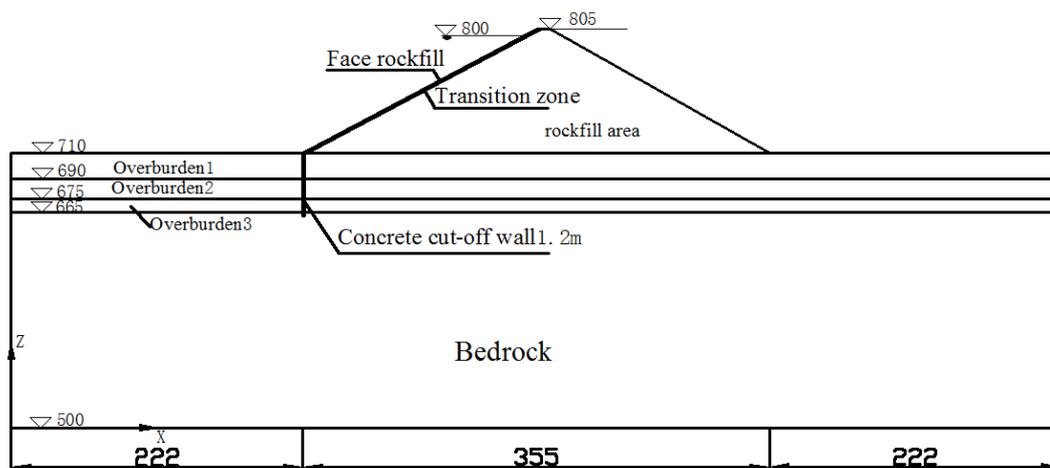


Figure 1. Section of the dam axis

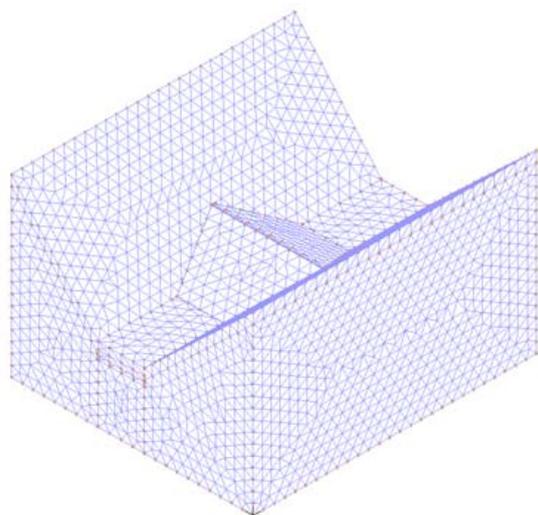


Figure 2. Model meshing

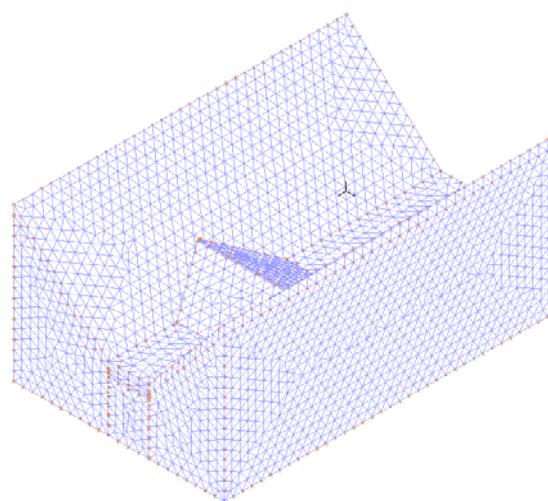


Figure 3. Model meshing

In order to study the effect of the blanket length on seepage field of dam foundation more effectively. The model is extended to the upstream of 278m to extend the total length of the model up to 1077m. The overall X, Y, Z dimensions of the model are 1077m x 681.2m x 500m. The model mesh is shown in Figure 3. Using 4-node free mesh, a total of 21522 nodes and 110606 nodes were generated. The permeability coefficient of each region is shown in Table 1

Table 1 Permeability Coefficients of each region

Serial number	region	permeability coefficient(m/s)
1	Bedrock	1×10^{-6}
2	Rock on both sides of the river	1×10^{-6}
3	Weakly weathered layer	1×10^{-5}
4	Overburden 1	5.2×10^{-4}
5	Overburden 2	5.8×10^{-4}
6	Overburden 3	5.2×10^{-4}
7	Face rockfill	1×10^{-12}
8	transition zone	1×10^{-5}
9	rockfill area	3.2×10^{-3}
10	concrete cut-off wall	1×10^{-9}

2.3 Calculation scheme

Twelve calculation programs were developed as shown in Table 2. Scheme 1-6 is to study the effect of concrete cut-off wall depth on dam foundation seepage field. Schemes 7-12 is to study the effect of the blanket length on dam foundation seepage field.

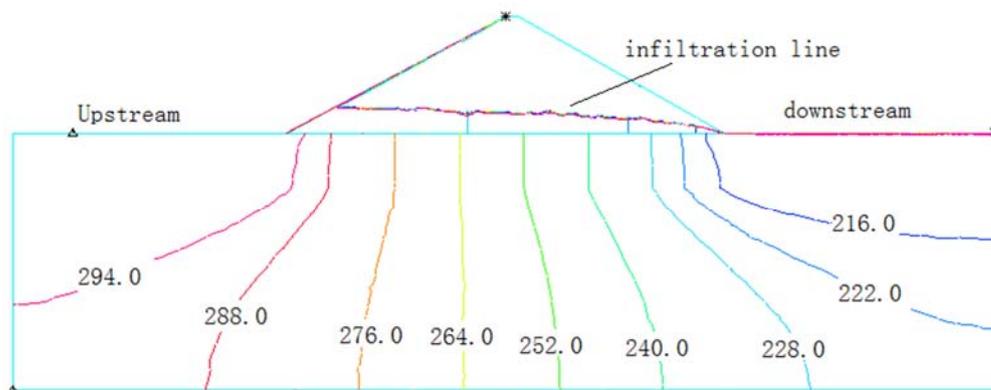
Table 2 Calculation scheme

Serial number	scheme content	Serial number	scheme content
1	concrete cut-off wall (0) m	7	blanket (0) m
2	concrete cut-off wall (10) m	8	blanket (100) m
3	concrete cut-off wall (20) m	9	blanket (200) m
4	concrete cut-off wall (30) m	10	blanket (300) m
5	concrete cut-off wall (40) m	11	blanket (400) m
6	concrete cut-off wall (48) m	12	blanket (500) m

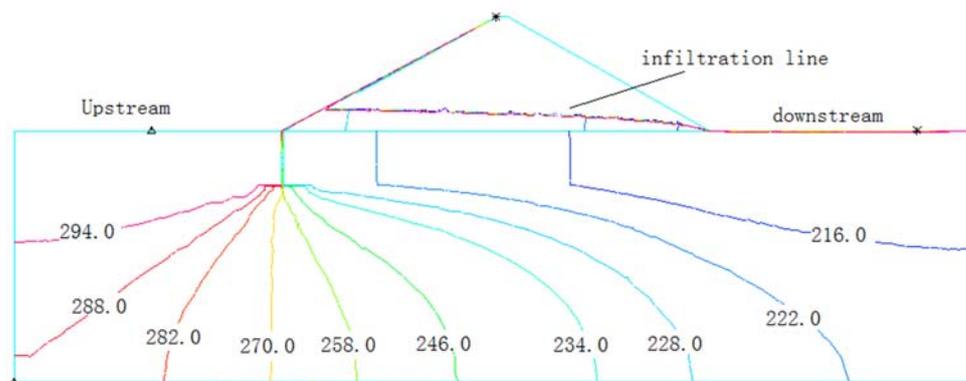
3.Calculation results and analysis

3.1 Influence of concrete cut-off wall depth on seepage field without blanket

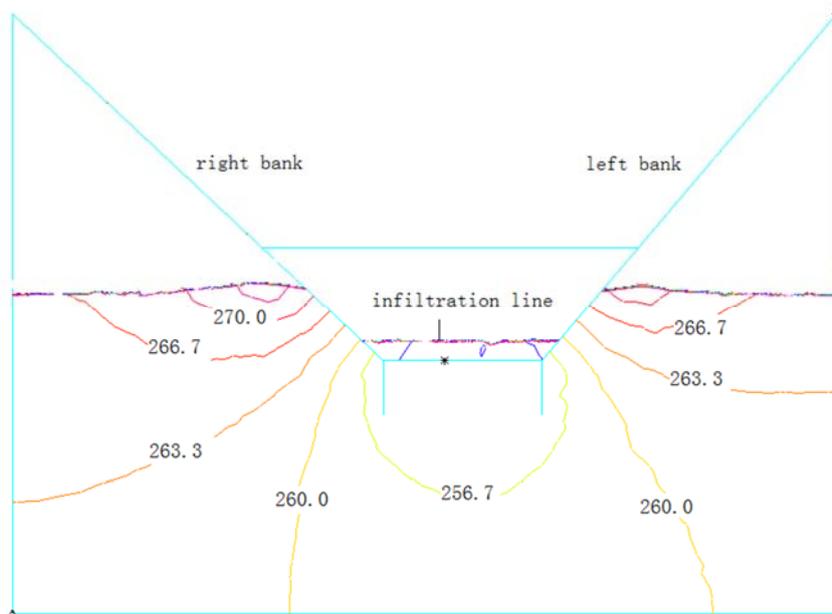
The depth of concrete cut-off wall gradually increased from 0m to 48m without blanket, corresponding to schemes 1 to 6). Figure 4 shows a comparison of the total head distribution, pressure head distribution, isopotential line and Infiltration line, Y=340m cross section view, X=405.2m section of the dam axis when the cut-off wall depth is 0m and 48m. It can be seen from the figure after the use of cut-off wall, the seepage line of the dam decreases. It shows that the cut-off wall has a certain effect on reducing the seepage line of the dam, which is beneficial to the dam slope stability. The cut-off wall has a significant effect on reducing the water head. In the vicinity of the cut-off wall, the water head line is of most dense, but then gradually becomes sparse. It shows that the water head difference near the cut-off wall is the biggest and the bottom hydraulic gradient is larger. The safety reserve is low in this area, so it is prone to seepage damage, so protective measures should be taken.



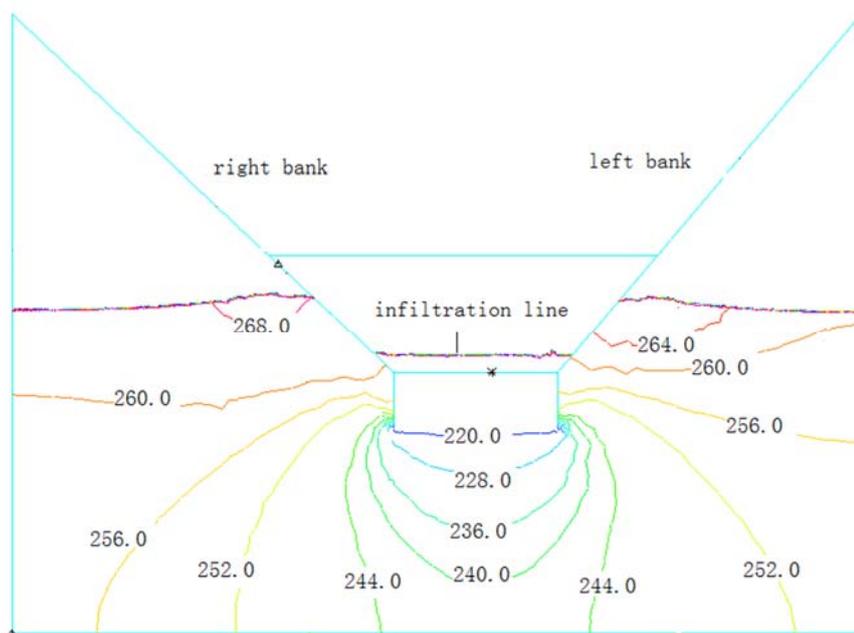
(a-1) cut-off wall depth 0m Y=340m cross section view



(a-2) cut-off wall depth 48m Y=340m cross section view



(b-1) cut-off wall depth 0m X=405.2m section of the dam axis



(b-2) cut-off wall depth 48m X=405.2m section of the dam axis

Figure 4. cut-off wall depth of 0m and 48m contrast

Figure 5 demonstrates the relationship between the seepage through the dam foundation and the depth of the cut-off wall. As it can be seen from the figure, the seepage flow of the dam foundation decreases with the increase of the depth of the cut-off wall before the cut-off wall has not reach the relative impermeable layer. But the decrease is not significant. When the cut-off wall reaches the relative impermeable layer, the seepage flow decreases greatly. When the depth reaches 48m, the seepage flow is reduced to $0.123\text{m}^3/\text{s}$. The results show that when the depth of the cut-off wall is

greater than 0.7 times the thickness of the overburden, the seepage flow decreases obviously. When the cut-off wall completely cut off the overburden, the anti-seepage effect is obvious.

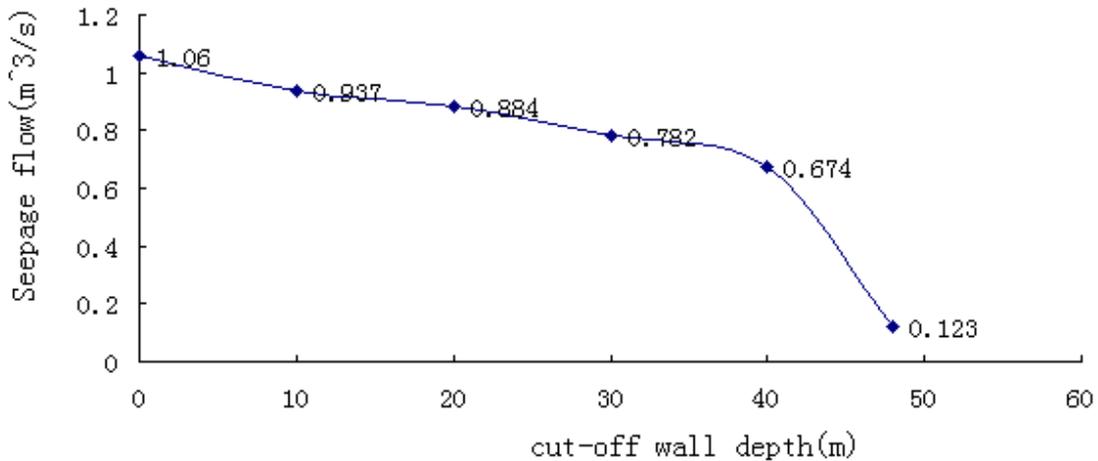
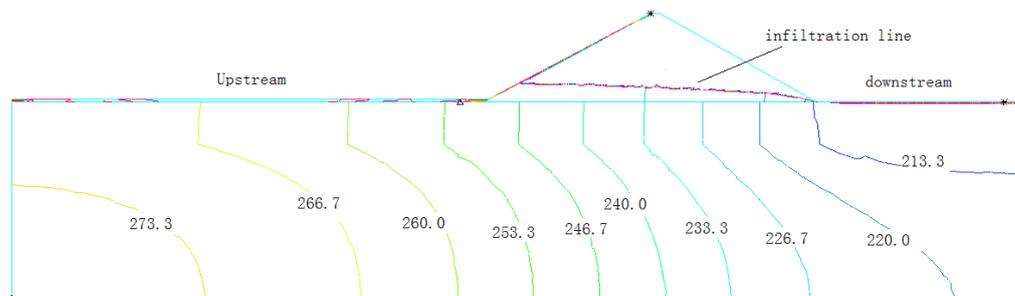


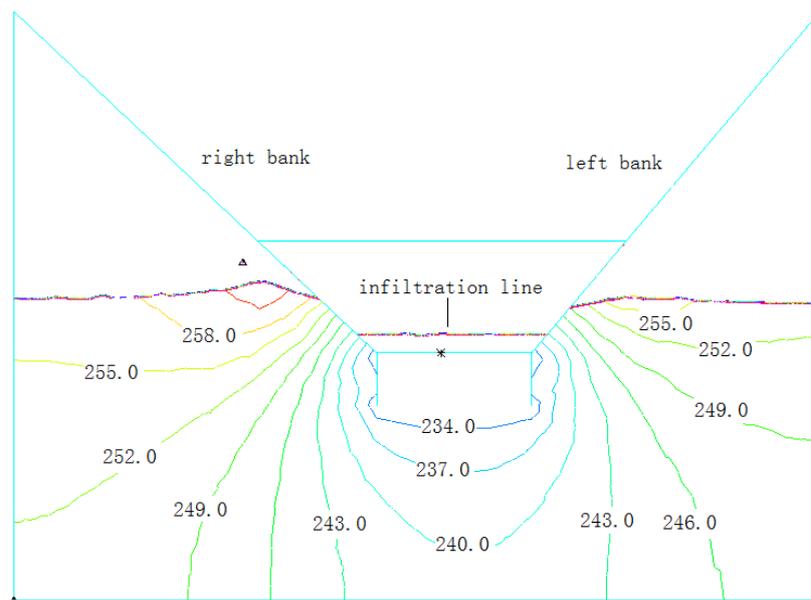
Figure 5. Curve of seepage flow with depth of cut-off wall

3.2 Influence of blanket Length on Seepage Field without cut-off Wall

The blanket length is gradually increased from 0 m to 500 m (corresponding to schemes 7 to 12). Figure 6 shows the total water head distribution, pressure head distribution, isopotential line and Infiltration line, Y=340m cross section view, X=683.2m section of the dam axis when the seepage wall is 500m. It can be seen from the figure, with the use of blanket, isopotential line in the vicinity of blanket becomes sparse, and the infiltration line of the dam are observable reduced. Which indicates that the blanket has a certain effect on reducing the dam infiltration line.



(a) blanket Length 500m Y=340m cross section view



(e) blanket Length 500m X=683.2m section of the dam axis

Figure 6. blanket length 500m

Figure 7 is the relationship between the seepage through the dam foundation and the length of the blanket. It can be seen from the figure, with the increase in the length of blanket, the seepage through the dam foundation is reduced. This shows that extension of the blanket length has certain function of seepage control. But when the length of blanket to reach 4 times the upstream head to continue to extend the blanket, no significant changes are shown in flow. This illustrates that for deep overburden, solely extending the length of blanket cannot effectively control the seepage. Thus combination of horizontal and vertical anti-seepage measures are needed.

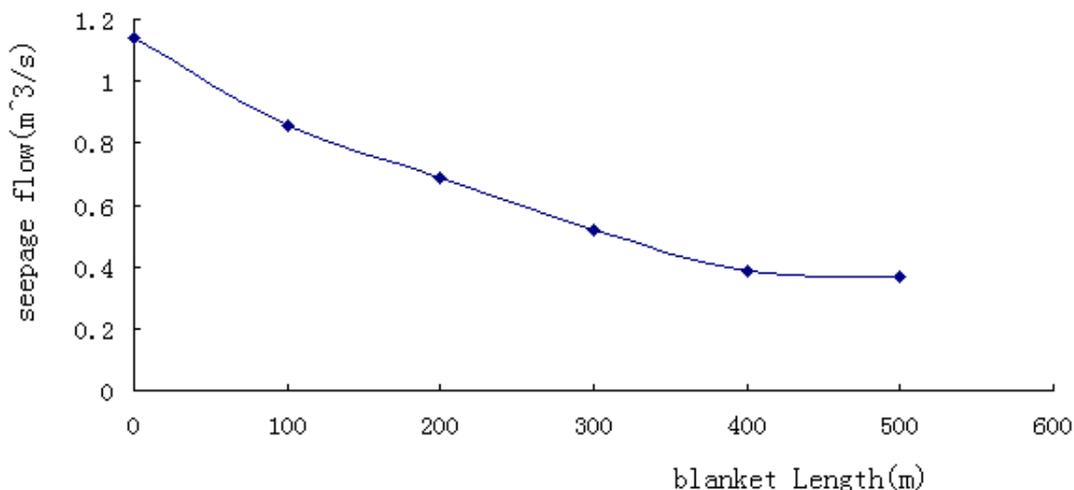


Figure 7. Curve of seepage flow with length of blanket

4. Conclusion

In this paper, the finite element method is used to analyze the seepage field of deep overburden foundation. Through the case study, the following conclusions can be drawn:

- (1) The cut-off wall has a certain effect on reducing the infiltration line of the dam, and has the obvious effect of reducing the water head. The bottom of cut-off wall hydraulic gradient is large, which easily produce seepage damage. Therefore, protective measures are needed.
- (2) The seepage flow of the dam foundation decreases with the increase of the depth of the cut-off wall before the cut-off wall is does not reach the relative impermeable layer, but the decrease is limited. when the depth of the cut-off wall is greater than 0.7 times the thickness of the overburden, the seepage flow decreases obviously. When the cut-off wall completely cut off the overburden, the anti-seepage effect is obvious.
- (3) The blanket has a certain effect on reducing the dam infiltration line. Extension of the blanket length has certain function of seepage control. But when the length of blanket to reach 4 times the upstream head to continue to extend the blanket, no significant changes are observed in flow. Horizontal and vertical anti-seepage measures need to be combined to achieve the purpose of seepage control.

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