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Experimental study on static stability of tailings dam with geotextile tubes

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ABSTRACT: Geotextile tubes are one of the emerging and promising technologies that help build fine-grain tailings dam. In this study, static stability tests are conducted to evaluate the effect of the geotextile tubes on the tailings dam. The test results indicate that the geotextile has a very significant effect on the stability of the dam body. The failure mode of the tailings dam with geotextile tubes is the interlayer sliding failure between the geotextile tubes. The fracture surface is deepened to a certain extent compared with the tailings dam without geotextile tubes. The failure pressure is larger and the displacement is smaller than that of the tailing dam without geotextile tubes. The displacement and deformation values of the tailings dam with large geotextile tubes are smaller than that of the tailings dam with small geotextile tubes under the same conditions. The stability of the tailings dam with geotextile tubes is better than that of a tailings dam without geotextile tubes.

1 INTRODUCTION

The safety and stability of tailings dam plays a very important role in ensuring safe production of mines and maintaining good social and economic benefits (Wei et al. 2002). With improvement in the current level of beneficiation technology and recovery rate, the particle size of the tailings entering the tailings pond is getting finer. The characteristics of fine-grained tailings are poor water permeability, long consolidation time, low mechanical strength, and difficulty in dissipating excess pore water pressure after storage. Therefore, using the traditional tailings storage method, tailings accumulation dams often encounter problems such as difficulty in dam construction, poor seepage and drainage through the dam body, the slow slope of the sedimentary beach, and poor stability. In domestic and foreign mines, examples of serious harms are frequent due to the failure of the tailings dam (Xu 2001).

Because of the practical problems existing in the fine-grained tailings dam, some scholars (Xue 2021; Ye 2020) studied the application of geotextile tubes in tailings dam and suggested that geotextile tubes used in tailings dam construction are an effective remedy for all these problems.

The zoomed-in partial view of a prototype tailings dam, which is constructed with geotextile tubes in Yunnan Province, China, is shown in Figure 1, while the schematic of cross-section of such a tailings dam is shown in Figure 2.

The successful application of geotextile tubes in tailings dam solves the problem of fine tailings dam difficulty, which is a major progress in the design and construction of tailings dams. However, this new construction technology still lacks basic theoretical research (Li 2016; Yang 2019). Therefore, it is necessary to carry out systematic research on it, which will be helpful for further popularization and application of the method of tailings accumulation technology.

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(a) Interior


(b) Exterior

Figure 1. Zoomed-in partial view of tailings dam: **a)** interior; **(b)** exterior.

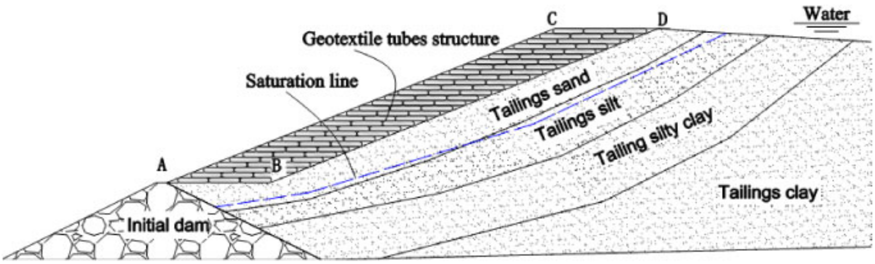


Figure 2. Schematic of cross-section of tailings dam.

In this paper, a physical model similar to the prototype tailings dam is used to conduct an indoor model test on the static stability of the tailings dam with and without geotextile tubes, and it is concluded that the tailings dam with geotextile tubes can improve the stability of fine tailings dam.

2 TAILINGS DAM MODEL TEST

2.1 *Test setting and model design*

The internal size of the model box is 200 cm×60 cm×100 cm (length × width × height) and the front of the model box is made of 20 mm thick transparent plexiglass to observe. To ensure that the model box does not deform during the test, three 5 cm wide ribs are reinforced on the front. The loading system adopts the American MTS hydraulic servo control system, and the size of the loading plate is 30 cm×59 cm. The entire model test device is shown in Figure 3.

Three model tests were carried out in this experiment, and the slope ratios of the three models are all 1:0.5. Scheme 1 is a tailings dam model without geotextile tubes; Scheme 2 is a tailings dam model with the size of 20 cm×20 cm×5 cm of the geotextile tubes; Scheme 3 is a tailings dam model with size 25 cm×25 cm×7.5 cm of the geotextile tubes.

Figure 3. The settings of model test.

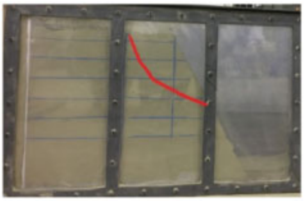
2.2 *Test material*

Similar test materials are adopted as those at the construction site of a prototype tailings dam in Yunnan Province (Li 2016).

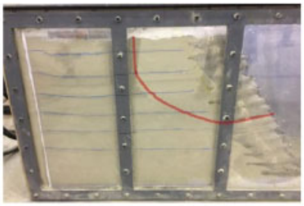
3 TEST RESULTS AND ANALYSIS

3.1 *Failure mode of tailings dam*

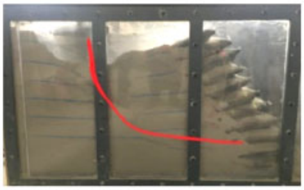
Figure 4 shows failure modes of the tailings dam under the three schemes.



(a) Scheme 1 (1:0.5, without geotextile tubes)



(b) Scheme 2 (1:0.5, small size geotextile tubes)



(c) Scheme 3 (1:0.5, large size geotextile bags)

Figure 4. The failure mode of the three-model dam.

According to the failure mode, the following conclusions can be drawn:

(1) The tailings dam with and without geotextile tubes have different failure modes. Figure 3(a) shows the failure of the tailings dam without geotextile tubes. The fracture surface is arc-shaped, which belongs to the arc-type sliding mode. Figures 3(b) and (c) show the damage to the tailings dam with geotextile tubes. Due to the supporting effect of the geotextile tubes on the dam body, the vertical displacement occurs first, and the failure surface is a vertical line. When the load acts to a certain stage, the dam body produces vertical and horizontal displacement, and the failure surface is arc-shaped at this time. As the load continues to increase, when the horizontal action of the upper sliding body on the geotextile tubes is greater than the friction force between the geotextile tubes' interfaces, the entire sliding body slides out along the geotextile tubes layers, and the geotextile tubes are not damaged. The entire failure surface

is divided into three parts—vertical-arc-horizontal, which belongs to the linear-arc-straight sliding mode.

(2) Comparing the three models, the fracture surface gradually deepens, indicating that the stability gradually increases.

3.2 *Stability of tailings dam*

(1) Dam crest pressure and vertical displacement
Figure 5 shows the relationship curve between the vertical displacement of the dam crest and the dam crest pressure under each scheme. It can be seen that with increase in dam crest pressure, the vertical displacement increases. The failure pressure of the tailings dam is 23.65 kN, 29.37 kN, and 34.89kN, respectively. Due to the effect of the geotextile tubes, the failure pressure of the tailings dam increases significantly. Under the same dam crest pressure, the vertical displacement of the geotextile tubes crest decreases; the larger the size of the geotextile tubes, the greater the failure pressure of the dam body.

(2) Dam crest pressure and horizontal displacement of mark point
Figure 6 shows the relationship between the horizontal displacement at the mark point on the geotextile tubes and the pressure on the top of the dam. It shows that under the action of the geotextile tubes when none of the three schemes is damaged, the displacement of the tailings dam without geotextile tubes is larger than others. When the dam failure pressure is reached, the displacement of tailings dams with large-sized geotextile tubes and small-sized geotextile tubes is reduced by 57.9% and 31.5%, respectively.

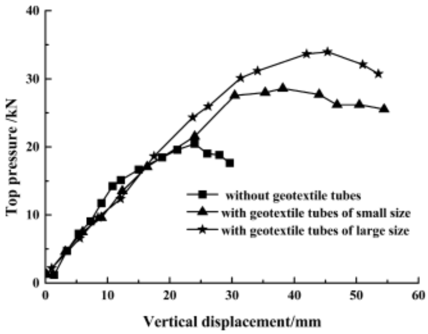


Figure 5. Top pressure against vertical displacement.

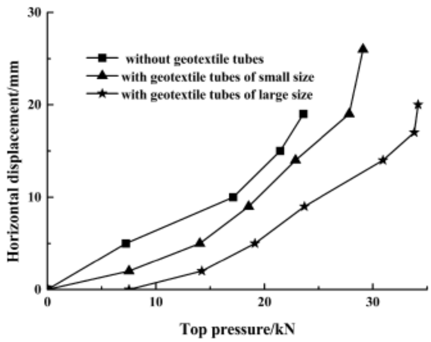


Figure 6. Top pressure against horizontal displacement at monitoring point B3.

(3) Dam crest pressure and vertical displacement of mark point
Figure 7 shows the relationship between the vertical displacement of the mark point on the geotextile and the pressure on the top of the dam.

Under the action of vertical pressure, the dam body not only produces horizontal displacement but also a certain vertical displacement, but the vertical displacement is much smaller than the horizontal displacement. In the initial stage, the tailings sand inside the dam body is squeezed and compacted, and vertical displacement occurs, causing the phenomenon of upturning of the geotextile tubes locally. The geotextile tubes move down, causing vertical displacement. It can be seen from the figure that the displacement of the tailings dam of the large-sized geotextile tubes is 33.3% lower than that of the small-sized geotextile tubes.

(4) Vertical displacement inside the dam body
Figure 8 shows the pressure on the top of the dam and the displacement of the mark point increase due to the tailings sand being compacted under load. The displacement of the tailings dam with the large-sized geotextile tubes is 31.8% lower than that of the small-sized geotextile tubes. The vertical displacement of the tailings dam with the large geotextile tubes is always smaller than others.

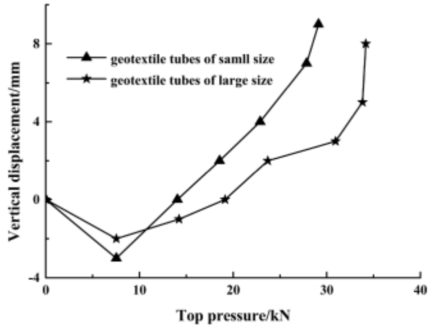


Figure 7. Top pressure against the vertical displacement at monitoring point B3.

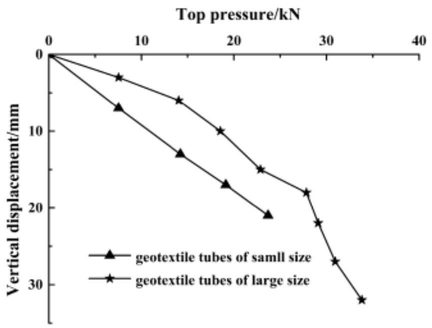


Figure 8. Top pressure against vertical displacement at monitoring point A5.

4 CONCLUSION

Based on the test results, the conclusions are as follows:

(1) The failure mode of the tailings dam with geotextile tubes is different from that of the tailings dam without geotextile tubes. The failure shape of the former is the interlayer sliding failure between the geotextile tubes but a straight line in the upper part and a circular arc in the lower part of the tailings dam without geotextile tubes.
(2) The fracture surface of the tailings dam with geotextile tubes is deepened to a certain extent compared with the tailings dam without geotextile tubes.
(3) The failure pressure of the tailings dam with geotextile tubes is larger and the displacement is smaller than that of the tailing dam without geotextile tubes. The displacement and deformation values of the tailings dam with large geotextile tubes are smaller than the tailings dam with small geotextile tubes under the same conditions.
(4) The stability of the tailings dam with geotextile tubes is better than that of a tailings dam without geotextile tubes. The tailings dam with large-sized geotextile tubes is more stable.

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