Study on Seepage Failure Index Factors of Tailings Dam

Tian Qi[1,a,*] and Changhong Li[1]

[1]*School of Civil and Resource Engineering, University of Science and Technology Beijing, Beijing, China*

a. qitian3683@163.com

**Tian Qi*

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Abstract: Based on measuring the physical and mechanical properties of tailings, a sand box model test was designed for the two index factors of the tailings dam drainage device and weak interlayer to conduct a comparative study, and the sand box model test device and filling method were introduced. The test results shows that: when the sand box model is installed with the drainage device, it will reduce the infiltration line and reduce the hidden danger of seepage damage to the tailings dam. When the sand box model is embedded in the weak interlayer, it will raise the infiltration line and increase the tailings dam hidden danger of infiltration.

1. Introduction

With the progress of the mining technology, the particle size gradation in the tailings pond is getting lower and lower, and the risk of infiltration and destruction of the tailings pond is getting higher and higher [1]. It is more important to study the index factors that may cause the seepage damage of tailings dams. In order to solve the problem of complicated identification of the hidden danger of seepage damage to tailings dams, and the influence degree of different influence factors on seepage damage has not been determined, this paper conducts research through sand box model tests. By comparing the test results of each group, and analyzing the influence of the two index factors of seepage drainage device and weak interlayer on seepage damage from the perspective of the infiltration line height [2, 3, 4], it provides an effective method for studying seepage damage of tailings dams.

2. Physical and Mechanical Properties of Tailings

The tailings for the test were sampled on-site for an iron tailings pond. According to the results of mass density experiment, permeability experiment, direct shear experiment, particle analysis experiment, specific gravity experiment, and moisture content experiment, it can be known that the dry density of tailings is $2.27g/cm^3$, the saturation density is $2.61g/cm^3$, and the permeability coefficient is $4.03\times10^{-5}cm/s$, cohesion c is 27kPa, internal friction angle φ is 25.53 °, tailings sample with particle size less than 0.074 mm accounts for 51.2%, specific gravity is 3.32, and water content is 15.15%.

3. Sand Box Model Test

3.1.Test Device

The sand box model test device consists of a sand box model box, a water supply control part and a pore water pressure measurement part. The physical assembly photos of each part are shown in Figure 1.

Among them, the sand box model box is composed of a box made of plexiglas and a bracket welded by galvanized iron. The box is composed of a water supply box upstream and a model test box downstream. The water supply control part is composed of a tripod, a chain hoist, a pump, a bucket, and so on. The pore water pressure measuring device is mainly composed of a pore water pressure sensor and a strain gauge.

Figure 1: Sand box model test device.

3.2.Tailings Sample Filling Method

(1) Check if the model box is leaking.

(2) Preparing the tailings sample: first mix the appropriate amount of water into the dry tailings to fully wet the tailings and then fully disperse them. The dam foundation and abutment materials should also be prepared in a similar way.

(3) Filling: firstly fill the dam foundation at the bottom of the sand box model, followed by the initial dam at the tail, followed by the abutments on both sides, and finally surrounded by the model box boundary, the dam foundation, the abutment, and the initial dam Model tailings pond. The dam foundation, abutment, and model tailings reservoir are all separated by geotextiles. The filling process is shown in Figure 2.


(a) Filling dam foundation (b) Filling tailings, initial dam, abutment (c) Dam slope ratio 1: 5

Figure 2: Sand box model filling process.

(4) Sensor arrangement

The sensors are arranged in three layers in the sand box model, 7 pieces are arranged at a height of 16cm from the bottom plate of the model (No. 502, 503, 302, 504-2, 510, 505-2, 506), and 6 pieces are arranged at a height of 27cm (No. 511, 513, 515, 516, 517, 521), 4 pieces with a height of 38cm (No. 523, 525, 526, 528). As shown in Figure 3, the sensors are arranged synchronously during the sand box model filling process.


Figure 3: Sensor arrangement.

3.3.Test Plan

Aiming at the two index factors of the drainage device and the weak interlayer, the experimental group and the control group were designed for comparative research respectively. Specific schemes are shown in Table 1 and Table 2.

Table 1: Sand box model test group scheme.

Impact factor	Parameter value	Remark
Upstream water pressure	Ladder loading, water pressure is gradually increased to three different water heights of 550mm, 600mm and 650mm.	Observe the changes in the water pressure distribution in the sand box model at three different water heights in the test group.
Drainage device	An infiltration device with a length of 1 meter is buried at a height of 20cm in the sand box model.	The drainage device is simulated by a flower tube inserted into the outer surface of the dam body inside the sand box model and covered with geotextile.
Weak interlayer	A weak interlayer with a thickness of about 1cm is tiled at a height of 20cm in the sand box model.	The fine grain content of soft interlayer below 0.075mm should exceed 80%.

Table 2: Sand box model control group test protocol.

Impact factor	Parameter value	Remark
Upstream water pressure	Ladder loading, water pressure is gradually increased to three different water heights of 550mm, 600mm and 650mm.	Observe the changes in the water pressure distribution in the sand box model at three different water heights in the test group.
No drainage device No weak interlayer	Corresponding to the test group, no drainage device and weak interlayer were set during the dam-filling process of the sand box model.	Both the test group and the control group piled the dam at a slope ratio of 1:5.

3.4.Test Results

3.4.1. Drainage Device Test Group

Figure 4 shows the loading curve of the total water height of the sand box model test with the drainage device installed. In the first 50 minutes of the test, the water height in the water box increased uniformly to 550mm, and then the water height remained basically stable for 160 minutes. After another 20 minutes, the water height is slowly raised from 50mm to 600mm, and then the water height is kept stable for 160 minutes. Finally, the water height was raised to 650mm in 20 minutes, and the stable water height was maintained until the end of the test in 600 minutes. The water level of the test group of the drainage device adopts the method of gradual loading. The total water height during the entire test is increased from 0mm to 650mm, and adjusted a total of 59 times, with an average time interval of about 10 minutes.

Figure 5 shows the pore water pressure change curve of each sensor in the test group of the drainage device. Because each sensor has completed zero water pressure calibration before the test, the pore water pressure value output by the sensor is relative to the water pressure value on the inner bottom plate of the sand box model.

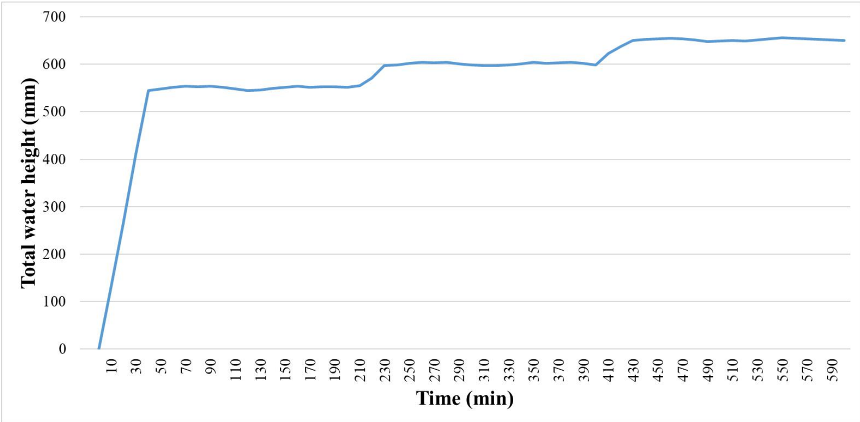

Figure 4: Total water height-time curve.

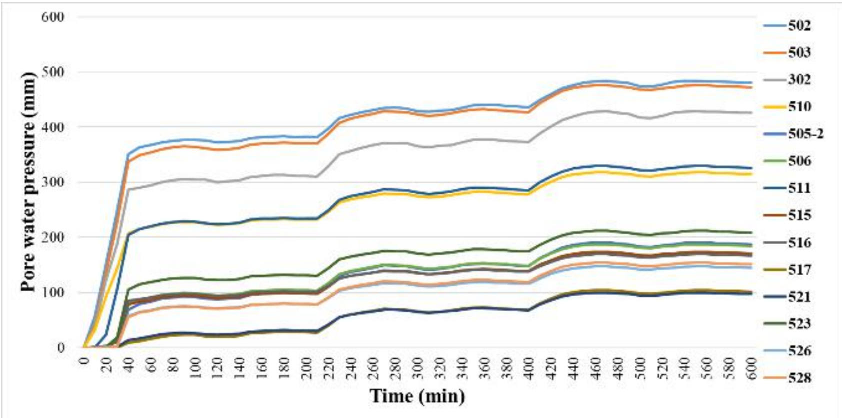

Figure 5: Pore water pressure-time curve.

3.4.2. Weak Interlayer Test Group

Figure 6 shows the water height loading curve of the embedded weak interlayer in the sand box model test. Similar to the loading process of the infiltration device test group, the water height of the weak interlayer test group is gradually loaded. The total water height of the whole test process is gradually increased from 0mm to 650mm, and adjusted a total of 59 times, with an average time interval of 10 minutes. The pore water pressure variation curve of each sensor in the weak interlayer group is shown in Figure 7.

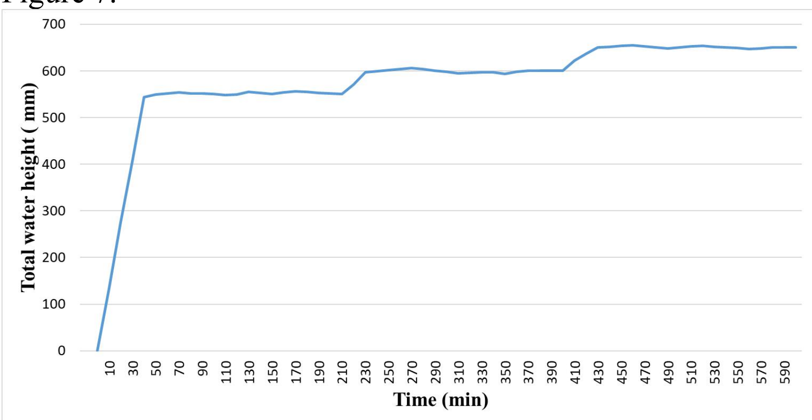

Figure 6: Total water height-time curve.

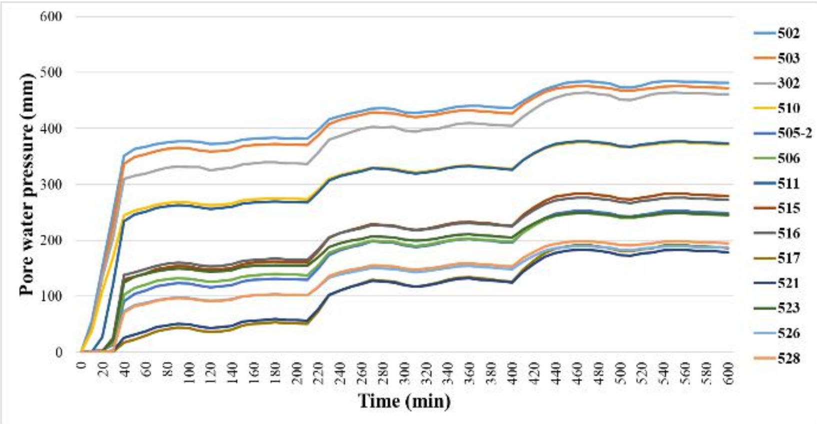

Figure 7: Pore water pressure-time curve.

3.4.3. Control Group

Figure 8 shows the water height loading curve of the sand box model test control group. Similar to the loading process of the infiltration device test group, the water height of the control group is gradually loaded, and the water height gradually increases from 0mm to 650mm throughout the test. The pore water pressure curve of each sensor in the control group is shown in Figure 9.

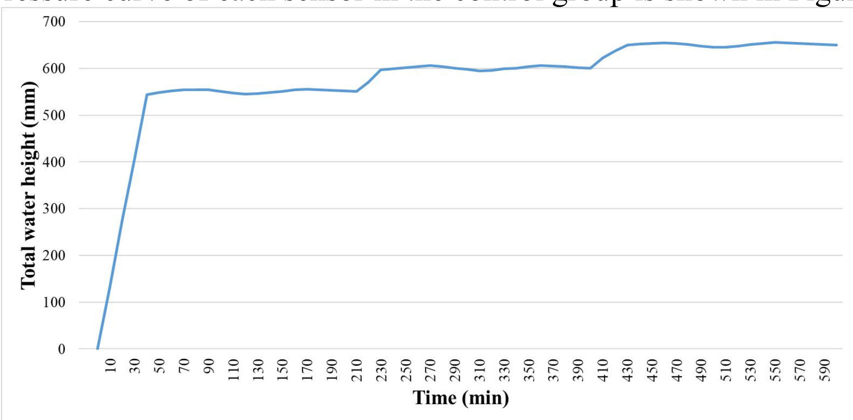

Figure 8: Total water height-time curve.

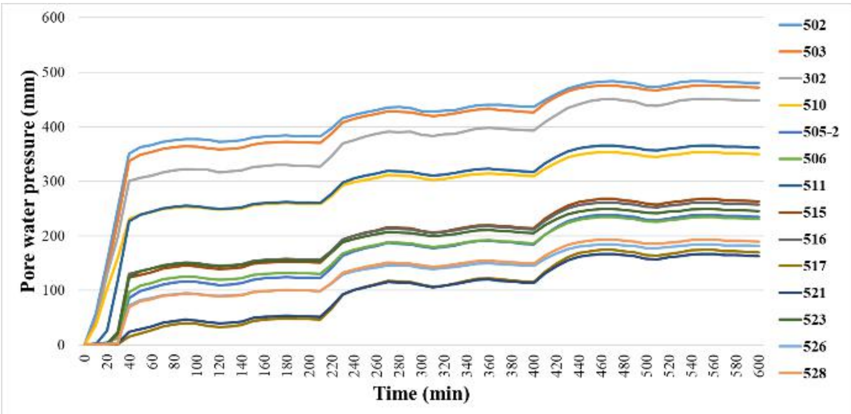

Figure 9: Pore water pressure-time curve.

4. Comparative Analysis of Sand Box Model Test Results

Based on the pore water pressure sensor output data of the test group and the control group, the height of the seepage line inside the sand box model can be plotted at any time. Because the total water loading of the test is roughly divided into three stable time periods, the intermediate time of the three periods is taken as a representative, draw the contrast curve of the infiltration line height at the 130min, 320min and 510min, the influence of the index factors of each test group and control group on the seepage damage of the tailings dam can be intuitively judged.

Figure 10 shows the comparison of the 130min seepage line height between the control group and the test group.

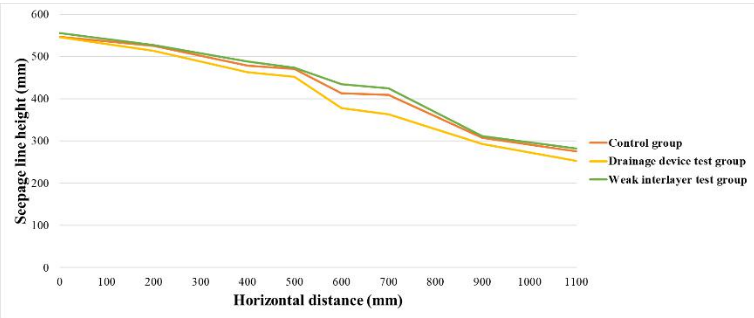

Figure 10: Comparison of 130min seepage line height between control group and test group.

Figure 11 shows the comparison of the 320min seepage line height between the control group and the test group.

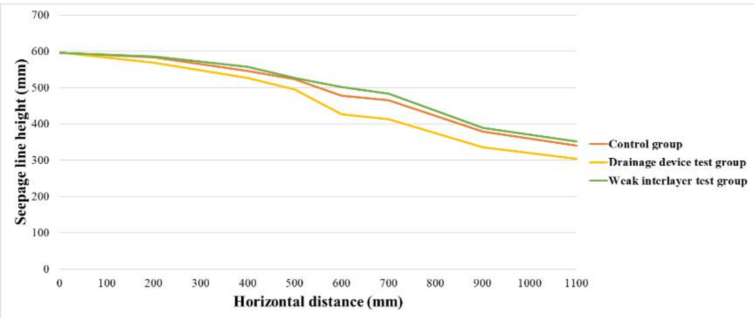

Figure 11: Comparison of 320min seepage line height between control group and test group.

Figure 12 shows the comparison of 510min seepage line height between the control group and the test group.

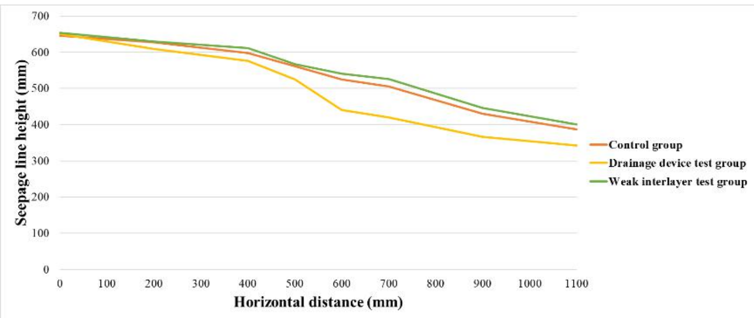

Figure 12: Comparison of 510min seepage line height between control group and test group.

By comparing the seepage line heights of the control group and the test group at different times, it is obvious that the drainage device can significantly reduce the seepage line height of the tailings dam model compared to the control group without the drainage device and the weak interlayer. The existence of weak interlayers can raise the height of the seepage line to a certain extent.

5. Conclusions

The overall pore water pressure measured by the drainage device test group is significantly lower than that of the control group without drainage and no weak interlayers. Among them, the six sensors at the second layer height (27mm) have the highest reduction in pore water pressure. The pore water pressure of the seven sensors at the height of the first layer (16mm) was the second, and the least significant change was the four sensors at the height of the third layer (38mm).

The addition of drainage device can significantly change the water pressure distribution of the seepage field near the drainage device of the tailings dam. The seepage line in the distribution area of the tailings dam drainage device will be significantly reduced, so the existence of the drainage device is beneficial to the safety and stability of the tailings dam.

The overall pore water pressure measured by the weak interlayer test group was higher than that of the non-exhaust device and the weak interlayer control group. Considering that the laying height of the weak interlayer is close to the position 5cm below the sensor of the second layer, focusing on the output values of the six sensors of the second layer height (27mm), it can be found that the pore water pressure values of the six sensors of the second layer height have increased significantly. The pore water pressure values of the first and third layer sensors also increased to some extent.

The weak interlayer can change the head pressure distribution in the seepage field of the tailings dam to some extent. The seepage line in the area with weak interlayers is higher than that in the control group, which increases the hidden danger of seepage failure of the tailings dam slope. Therefore, the existence of weak interlayers is not conducive to the safety and stability of the tailings dam.

Acknowledgments

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