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Research Article

Experimental Study on Capillary Water Migration Characteristics of Tailings with Different Particle Sizes

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Capillarity influences the long-term stability of the dam greatly and affects the sustainable development of tailings dam. The online monitoring capillary water rise test system was independently developed by SM3001B temperature and humidity sensor, SU9101B RS485 converter, SV3010 data acquisition system, and other equipment to carry out the whole process test of water absorption and water release of tailings with different particle sizes. The results show that the capillary rising trend of tailings with different particle sizes is basically consistent, the relationship between the rising height and the diameter are negatively correlated, and the logarithm function can better fit the height of capillary rising over time well enough. The water content of tailing capillary zone decreases with the height, and the smaller the size of tailings, the greater the change of water content. The water release process of tailings is an unsaturated permeability process, which largely depends on the saturation before water release. The larger the particle size of tailings is, the smaller the water content after water release. Based on the above results, the relationship between capillary diameter and tailings particle size was discussed, and the relationship formula between water content change and particle size was deduced. The research results systematically show the water migration law under the tailing capillaries. It is suggested that the unsaturated tailings water content index should be added in the monitoring of the saturated surface of tailings dam.

1. Introduction

The discharge of tailings in our country is very large. The accumulated tailings not only occupy land resources but also cause environmental pollution. The resource utilization of tailings has become a major concern. Tailing pond is a special hydraulic structure produced by the combination of two technologies of "tailing utilization" and "tailing storage" [1]. Its hydraulic phenomena are complex and changeable (see Figure 1), and it has the characteristics of service and construction at the same time. A large number of studies have shown that the most important factor affecting the stability of a dam is water [2–4]. Rain-

fall, tailing discharging, surface runoff, seepage [5], evaporation, etc. will all affect the water content of the dam. Generally, the water content of the dam body is in a dynamic equilibrium state. Once the equilibrium is broken, there will be safety hazards.

The relationship between gravity water and the stability of tailings dams is the research object of most existing tailings dam stability research methods and models, such as the mechanical properties of tailings [6, 7], liquefaction of the dam body [8], and seepage safety hazards [9–11], the mechanism and mode of dam failure caused by floodplain [12], and the mechanism of dam instability caused by rainfall [13], while the influence of stagnant water in the unsat-
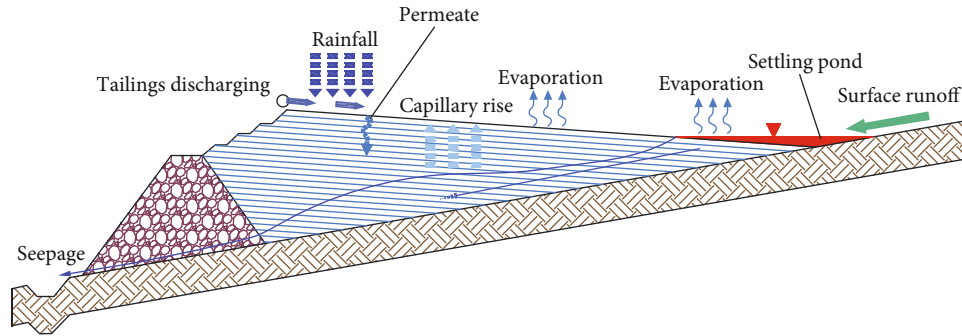
FIGURE 1: Complex hydraulic phenomena in tailing dam.

urated zone in the tailings dam on its stability is often ignored [14], until María et al. [15] first proposed in 2009 that the capillary action of water may greatly reduce the safety reserve of tailings dams. Prior to this, the research on capillary action at home and abroad was mainly carried out around the prevention of roadbed diseases. The research objects included the comprehensive test method of capillary water rise [16] and the rising law of capillary water in other media, such as sandy soil [17], clay [18, 19], and loess [20]. And the study of the effect of capillary water on the stability of tailings dams is rarely reported.

With the capillary water rising to the slope of the dam, after the water evaporates, the salt in it remains and crystallizes, which is the result of capillary action. Capillary ascent is a slow and continuous process that is often overlooked, which results in a large amount of capillary water in the pores between the tailing particles. Yin et al. [21] studied the characteristics of pore water migration and its mechanism of action on the mesostructure of tailings. They proposed that the calculated height of the infiltration line can be determined by the height of the capillary water above it and analyzed the dam stability accordingly. Liu et al. [22] studied the maximum rising height of tailings capillary water. Zhang et al. [23] systematically studied the impact of the difference in particle gradation on the rising process of capillary water and the physical and mechanical properties of the dam material in the capillary water belt. The results showed that the moisture content of the tailings in the capillary water belt and the physical and mechanical indexes such as severity, cohesion, and internal friction angle change with the change of capillary water height. Zhang et al. [24] studied the rise of capillary water in a tailing dam by temperature and air pressure through indoor experiments. However, none of the above studies dealt with the change of water content of the dam body caused by capillary absorption and release of water.

Tailings are a mixture of sand-powder-clay particles [25]. After the deposition and consolidation of tailings particles with different gradations, microscopically similar capillary channels are formed. In addition, due to the existence of matrix suction, external conditions for the formation of capillary action in the tailings dam are provided. The effect of capillary action on the dam is essentially the weakening of the strength of the dam after the water migration caused by the nonequilibrium matrix potential

and the capillary effect [26], which essentially affects the water content of the dam. In particular, the rise of the water level of the infiltration surface shortens the path of capillary action and speeds up the replenishment of the upper water by capillary action. The increase in water content will reduce the strength of the tailings and bring harm to its stability. Therefore, full attention should be paid to the design, monitoring, and subsequent maintenance of tailing dams.

At present, research on the change of water content of tailing dams under the influence of capillary action has just started. Based on the basic theories of capillary absorption and water release, using the self-developed capillary water absorption and release experiment device, the capillary water absorption and release experiments of tailings with different particle sizes were carried out to explore the migration characteristics of capillary water in tailings.

2. Materials and Methods

2.1. Tailings Samples. Tailings used in the test was taken from a copper mine tailing pond in Shaanxi province. The particle size ranged from 0.5 to 250 μm, mainly concentrated in 100 to 200 μm. To avoid the influence of impurity content, first wash the sample thoroughly, then air, grind, and dry it. Finally, the dried tailings are screened and graded to obtain tail fine sand, tail silty sand, and tail silty soil for test; the specification followed for determination of the grain size distribution of tailing soil is "Safety technical regulations for the tailing pond (AQ 2006-2005)." The cumulative particle distribution curve of tailings of tail fine sand, tail silty sand, and tail silty soil is shown in Figure 2. The particle grading index and main physical properties index are shown in Table 1.

2.2. Experimental Device. The test device is a self-developed on-line capillary-rising monitoring testing system (OM-CRT). Figure 3 shows the five main parts of the device, including capillary water absorption test device, online water content monitoring system, data acquisition system, water supply, and drainage system.

The main body of the testing system is composed of 3 transparent polymethyl methacrylate columns including specimen loading structure and the supporting structure. The size of specimen loading structure is designed to avoid
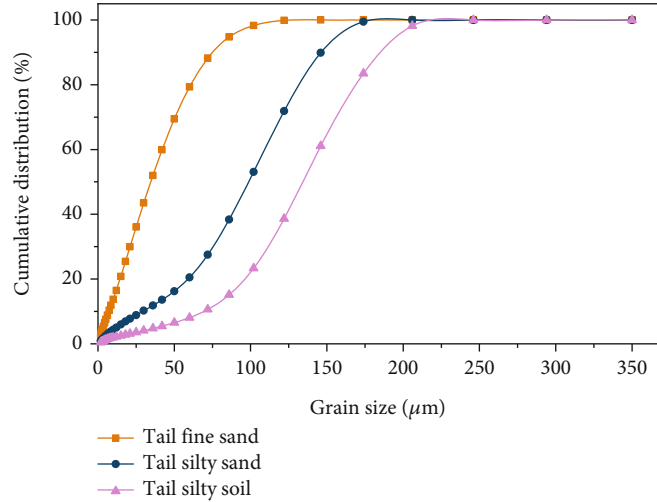
Figure 2: The cumulative particle distribution curve of tailings.

Table 1: Particle composition parameters tailings and main physical property indexes of tailings.

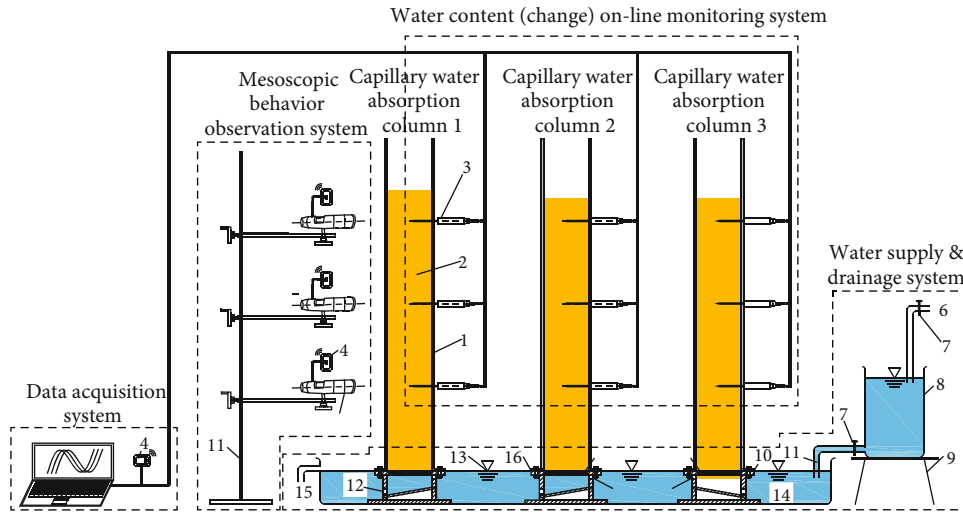| Particle group	Particle size range (μm)	Effective grain size d_{10} (μm)	Median grain size d_{50} (μm)	Constrained grain size d_{60} (μm)	Uniformity coefficient C_u	Initial moisture content w (%)
Tail fine sand	125~180	69.12	134.19	155.12	2.24	2.51
Tail silty sand	75~125	29.20	98.63	114.26	3.91	2.92
Tail silty soil	5 ~ 75	7.13	34.6	42.56	5.96	3.31

Figure 3: The schematic diagram of OM-CRT system. 1—tube wall; 2—tailings; 3—water sensor; 4—cloud module; 5—distortionless microscope; 6—water source; 7—valve; 8—water storage tank; 9—trestle; 10—porous disk; 11—constant speed water supply pipe; 12—scupper and outlet pipe; 13—constant water lever; 14—water-in; 15—water-out; 16—geotextile.

the influence of the polymethyl methacrylate columns radian on the observation effect and meet the requirements of specimen size [18] that the inner diameter is 110 mm, the height is1200 mm, and the wall thickness is 5 mm. The supporting structure is 100 mm high, and its inner diameter and thickness of the wall are consistent with the specimen loading structure. A water inlet is provided at a height of 50 mm on the side. The two are separated by a porous disk with a rubber gasket at the middle interval for sealing. The disk is 10 mm thick and filled with small holes with a diameter of 3 mm to ensure that the water can contact the tailings. Geotextile with a diameter of 110 mm covers the disk to prevent the leakage of tailings particles. The polymethyl methacrylate columns are engraved with scales, of which the zero point is cap height of the porous disc and minimum is 1 mm, with one on

TABLE 2: Main technical indexes of SM3001B.

Sensor type	Probe length (mm)	Probe diameter (mm)	Moisture measuring range (%)	Temperature range (°C)	Response time (s)	Moisture accuracy (%)	Temperature measurement accuracy (°C)	Voltage (V)
SM 3001B	75	3	0~100	-30~60	<1	3%	0.5	0~10

(a) Washing   (b) Sun-cure   (c) Drying

(f) Reserving sample   (e) Storing sample   (d) Screening

Tail fine sand

Tail silty sand

Tail silty soil

(g) Loading sample

FIGURE 4: Preparation process of tailing sample.

each side of symmetry to provide reference for recording the wetting front and the saturation front.

The online moisture content monitoring system is mainly consist of 9 SM3001B temperature and humidity sensors, a SU9101B RS485 converter, a SV3010 data acquisition system, and a computer. The key technical indexes of SM3001B temperature and humidity sensor can be seen in Table 2.

The data and image acquisition system mainly consists of computer and SV3010 data acquisition system. SV3010 data acquisition software has a main interface include measurement points list, running screen, real-time curve, historical curve, and data report. The main interface can be switched to the list of measurement points and the data report which could show the historical data in interface.

The water source is the water pipe in the laboratory, from which it is then distributed to the water tank through the siphon principle. The water tank is equipped with a drainage pipe to ensure the liquid level in the tank is constant.

2.3. Experimental Program. According to the composition of tailings' particle size, this test is divided into three groups including tail fine sand, tail silty sand, and tail silty soil. The specific steps are shown in Figure 4.

(1) Prepare and load specimens: the plexiglass columns are numbered 1#, 2#, and 3#. In order to prevent the formation of water migration channels between the loaded tailings and the inner wall of the column, a thin layer of petroleum jelly should be evenly coated on the inner wall. According to the test plan, put the prepared tailing sand, tailing silt, and tailing silt into columns 1#, 2#, and 3#, respectively (the

sensors placed on column 1# are M4, M5, M6, and the installation heights are 200 mm, 400 mm, 600 mm; the sensors placed on the 2# column are M1, M2, and M3, and the installation heights are 200 mm, 400 mm, and 600 mm; the sensors placed on the 3# column are M7, M8, and M9, and the installation heights are 200 mm, 400 mm, and 600 mm). Perform stratified sample loading and seismic compaction every 5 cm to ensure uniform sample loading, and maintain a certain dry density by the scale and filling mass calculations. Keep the loaded tailings specimen standing for 48 h for the test.

(2) Adjust and install equipment: install the online moisture-content sensor in the prepared hole reserved for the plexiglass column, seal it with glass glue, and check to make sure the sensor circuit is in good working condition. Adjust the online water-content monitoring equipment (M1–M9) to ensure effective data output and storage.

(3) Capillary-water absorption test: turn on the water-supply device to supply water to the tank according to the siphon principle. At the same time, turn on the drainage device to ensure that the water tank level (i.e., the height of the infiltration line) always remains at the bottom of the specimen.

(4) Record data: capillary water began to rise in the three columns which was consistent for observing and recording. The elevation of the wet front was regularly recorded, and digital imaging was carried out until the water column stopped rising and the ambient temperature was kept constant during the test. The water content distribution of the cylinder in the process of capillary water absorption is monitored by the water sensor, and the corresponding data are collected. When the data of each monitoring equipment is stable, the test is completed.

(5) Capillary-water release test (as shown in Figure 5): after the capillarity water absorption test is completed, drain the water from the tank and start the water release test in the natural state. The water collection system keeps recording the monitoring data of M1~M9 sensor during the whole test.

3. Results and Discussion

The movement characteristics of capillary water mainly include the height and water content distribution of capillary. The analysis and research on the capillary rise characteristics of different particle size tailings are as follows.

3.1. The Influence of Particle Size on the Capillary Height of Tailings. The force generated by water from wet tailings makes the water have an energy, which is converted into an equal amount of gravitational potential energy by work and exhibits a certain volume of capillary height [27]. By regularly measuring the rising height of the capillary wetting
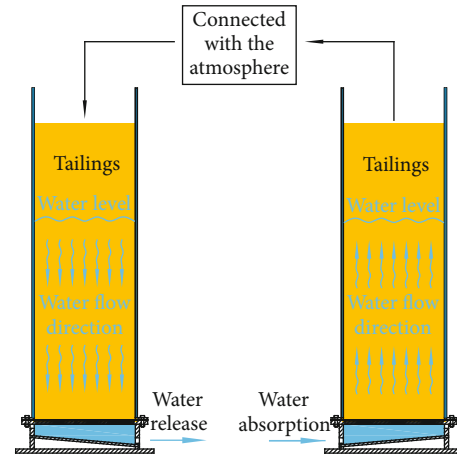

Figure 5: The schematic diagram of water absorption and release of tailings.

front in 1#, 2#, and 3# columns, the variation law of the capillary height with time could be obtained.

Figures 6(a)–6(c) show that the capillary height in the column of tail fine sand, tail silty sand, and tail silty soil is basically consistent over time, which can be divided into three stages: the early stage of rapid rise, the middle stage of slow rise, and the late stage of stability. The capillary height increases with time and stops until the rising height of capillary water reaches a stable value. Figure 6 also shows the capillary height is obviously affected by the particle size of tailings. The smaller the particle size is, the higher the capillary height is. Data of the first 11000 minutes of the capillary water with different particle size tailings are fitted, and the results are shown in Table 3.

The relationship between the rise height of capillary water with different particle sizes and time both satisfies the logarithmic function: $y = a$-$b * \ln (x + c)$ and the regression is significant. The fitting equation is

$$H = a\text{-b} * \ln (t + c), \tag{1}$$

where H is the height of capillary water rising, t is the corresponding time, and a, b, and c are the constant.

According to Table 3, the variation rules of constants a, b, and c in the fitting equation of capillary water rise with the particle size of tailings were obtained as shown in Figure 7. As can be seen in Figure 7, the value of constants a, b, and c gradually increased with the increase of the average particle size of the tailings. With the increase of the particle size of tailings, the value of the constant c generally decreases. According to the change rule of the rise height of capillary water over time as shown in Figures 6 and 7, the tailings corresponding to the fitting equation with a large coefficient c value can reach a large rise height of capillary water within a short time after the beginning of the test.

Figure 8 shows the time taken for the capillary water to rise to the height of 10 cm, 20 cm, 30 cm, and 40 cm in the column of tail fine sand is less than the tail silty sand and tail silty soil. However, when it rises to 50 cm, the rising rate of

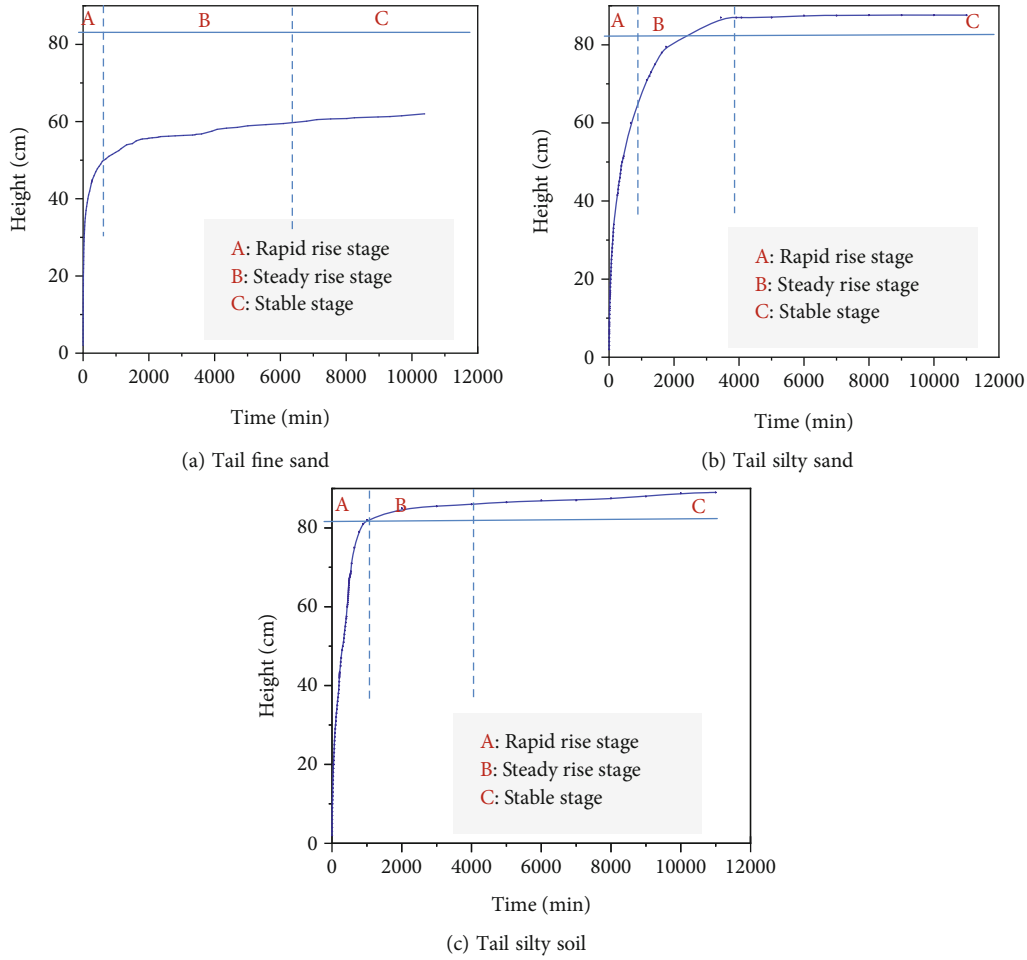(a) Tail fine sand

(b) Tail silty sand

(c) Tail silty soil

FIGURE 6: The relationship between capillary height and absorption time.

TABLE 3: Capillary water height fitting equations for tailings with different particle size.

Grain group	The average particle size (μm)	Coefficient			Fitting equation	Regression coefficient
		a	b	c		
Tail fine sand	152.5	6.59	-6.35	0.18	$y = 6.59 + 6.35 * \ln(x + 0.18)$	0.9924
Tail silty sand	100	-21.05	-12.1	0.5	$y = -21.05 + 12.10 * \ln(x + 0.5)$	0.9352
Tail silty soil	40	-138.98	-31.85	96.93	$y = -138.98 + 31.85 * \ln(x + 96.93)$	0.9924

capillary water decreased obviously. Meanwhile, the rising rate of capillary water in the column of tail silty sand and tail silty soil exceeded that of tail fine sand. The time it takes to reach 60 cm high in tail fine sand column is 2734 minutes less than that in the tail silty sand, but 233 minutes more than it takes in the tail silty soil. It has taken only 2.3 minutes for the capillary water in the tail fine sand column to rise to 10 cm high, followed by 11.5 min in the tail silty sand, and 10 min in the tail silty soil. It can be seen in the early stage of rainstorm, the capillary action of tailings shows up within a short time, and the infiltration surface of tailings dam will rise rapidly to a certain height, which should be considered in the engineering practice.

3.2. The Influence of Particle Size on Moisture Content of Capillary Zone

3.2.1. Capillary Water Absorption Test Results. The relationship between moisture content in different sections of tail fine sand, tail silty sand, and tailing silty soil columns and time are shown in Figures 9(a)–9(c), respectively.

As can be seen from Figure 9(c), the moisture content of the capillary water in the tail silty soil changed most significantly. The reason is that the particle size is small and the matrix potential is large. According to Kelvin's equation of equation (8) [28], when capillary water is absorbed at the beginning, capillary water migrates from bottom to top due
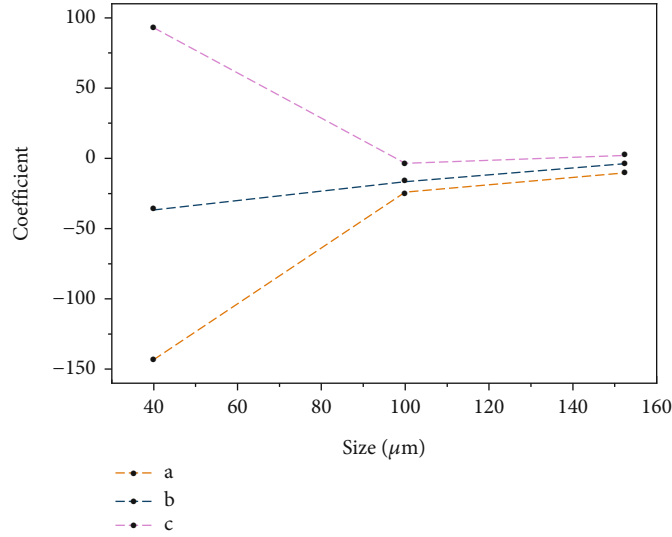
FIGURE 7: Relations between coefficients a, b, c and particle size.
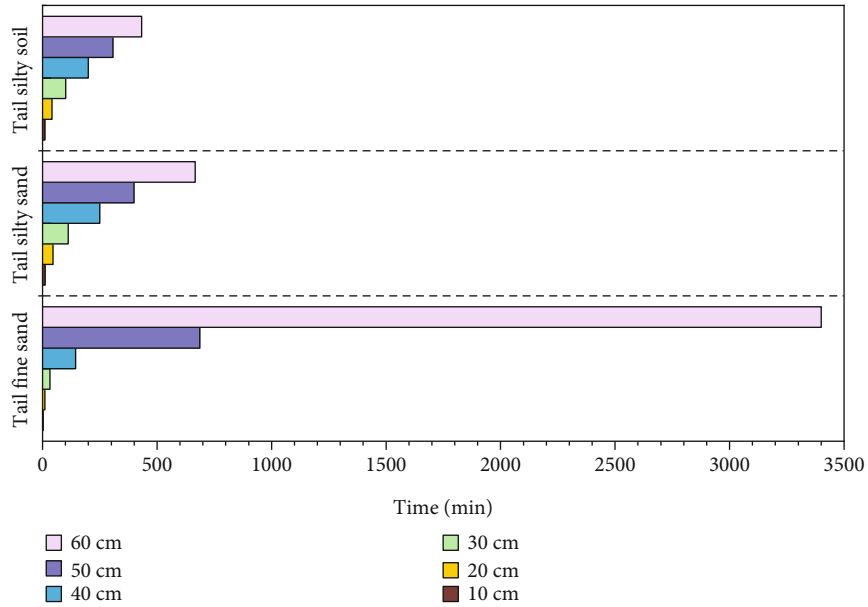

FIGURE 8: Comparison of capillary water height.

to the action of the matrix potential. When pore gas pressure equals pore water pressure, capillary water in tailings samples will no longer migrate.

$$(u_a - u_w) = \frac{2T_s}{R_s}, \qquad (2)$$

where u_a, u_w is the pore gas pressure and pore water pressure of tailings, T_s is the surface tension on both sides of the surface, and R_s is the radius of curvature.

The relationship between the instantaneous water content and time in different sections of the three columns is similar to that of the water-soil characteristic curve, which presents "S." The moisture content of tail fine sand ranged from 2.51% to 20.6%, with an average value of 11.55% and

a variation value of 18.09%. The moisture content of tail silty sand is 2.92%~21.05%, with an average value of 11.985% and a variation value of 18.13%. The moisture content of tail silty soil is 3.31%~23.77%, with an average value of 13.54% and a variation value of 20.46%. The sensors of M1, M4, and M7 are closest to the bottom of the cylinder, and the water content changes most significantly. The moisture content at the bottom of the tail silty soil is 23.77% at most and saturated.

Figure 10 shows the moisture content of the tailings capillary zone in the three columns decreased with the height of capillary water. The relationship between the height of capillary water and the moisture content is inverse "S." The smaller the particle size is, the smaller the difference of moisture content in each section after the rise of capillary water would be, indicating that the smaller the particle size of

(a) Tail fine sand

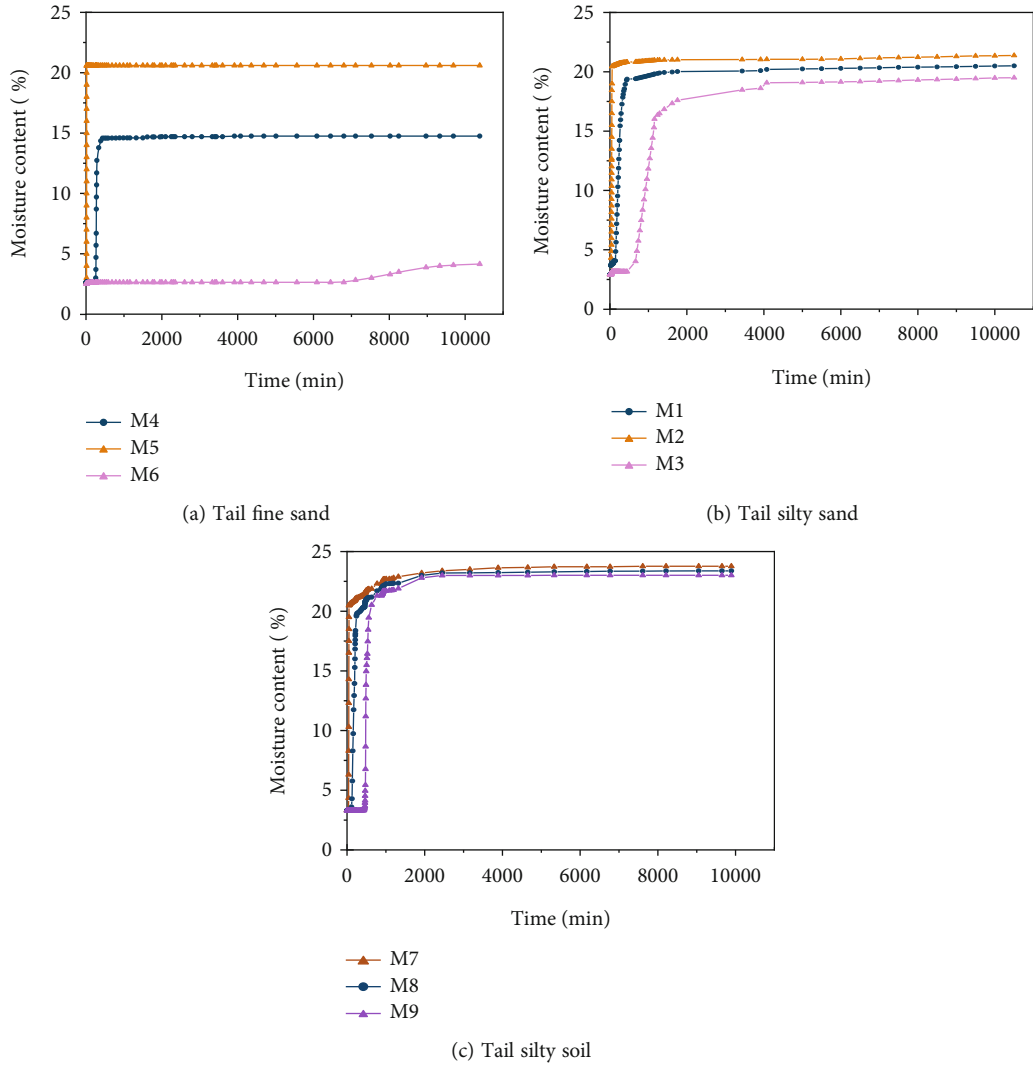(b) Tail silty sand

(c) Tail silty soil

FIGURE 9: The relationship between moisture content and time at different sections.
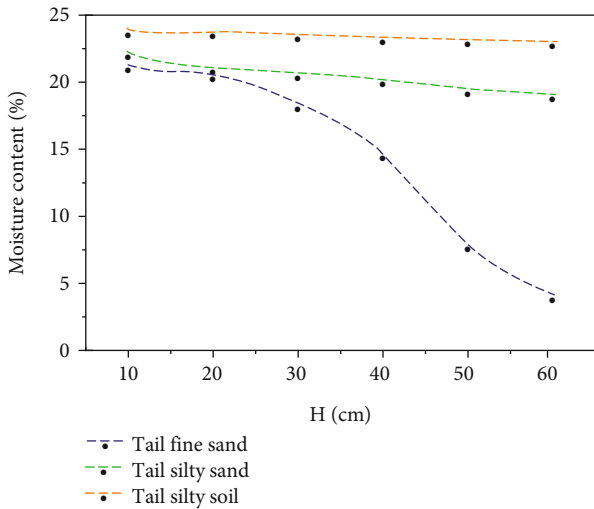

FIGURE 10: Relationship between moisture content and capillary height.

tailings is, the stronger the capillary water absorption capacity would be.

3.2.2. Capillary Water Release Test Results. Water release is the release by gravity of the water from the tailings that are saturated due to capillitia from the upper part of the dam as the position of the infiltration line drops. Figure 11 shows the changes of the water content in each section during the water release.

Capillary water release is an equal inverse process of capillary water absorption. However, due to hysteresis effect caused by the complex pore structure of tailings, the relationship between water content and matric suction in water absorption and water release process is not equivalent, which is also the fundamental reason why the water absorption and water release processes of tailings must be studied separately.

In the process of releasing water from tailings, the rate of releasing water affects the degree of saturation of tailings, and the degree of saturation also restricts the rate of releasing water. At the beginning of water release, tailings have a

(a) Tail fine sand

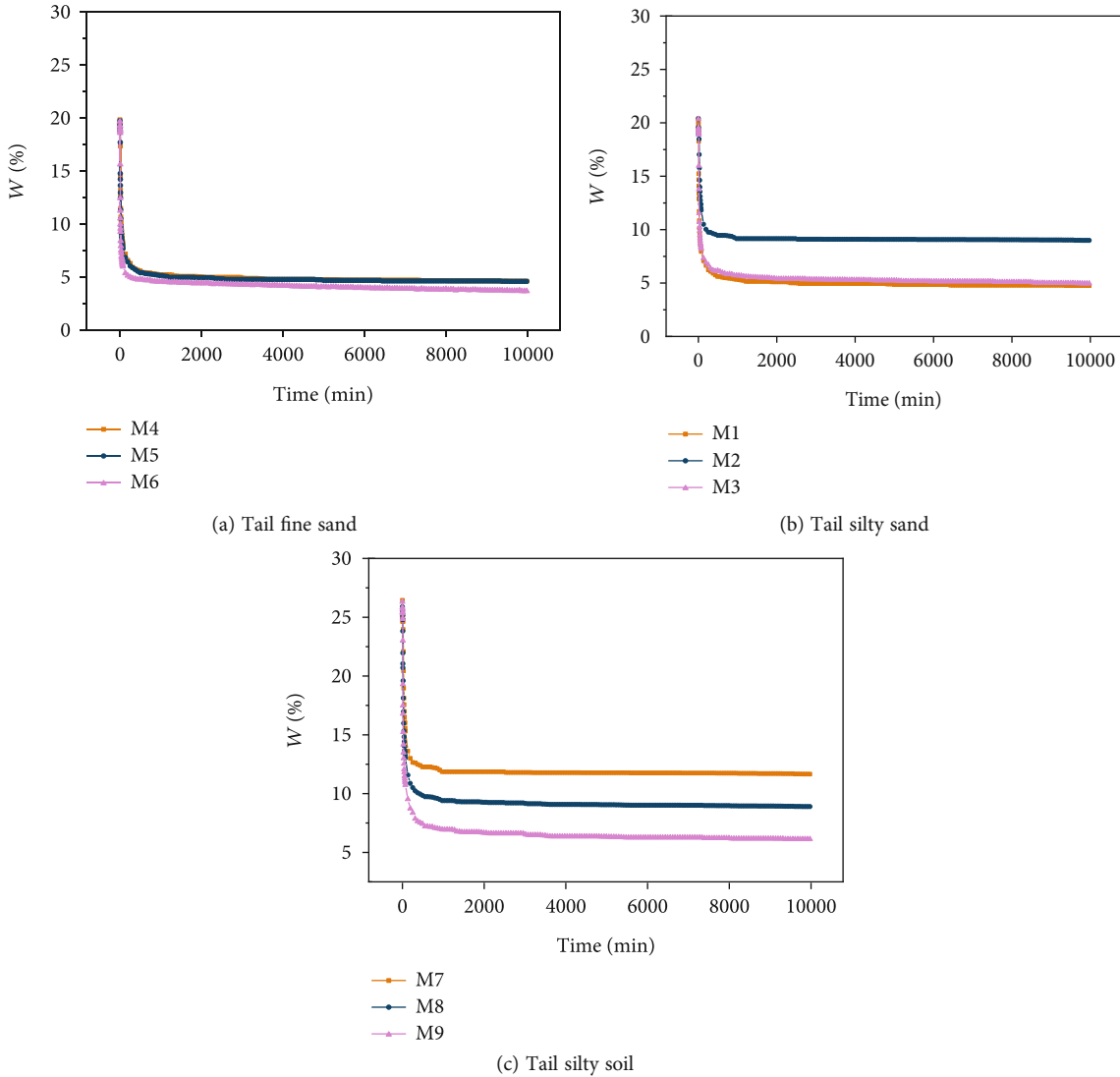(b) Tail silty sand

(c) Tail silty soil

FIGURE 11: The moisture content change diagram of different sections in the water release process.

high degree of saturation, and free water flows down under its own gravity. Take the water release process of tailings as an example. After 400 min of continuous water release, a large amount of capillarity water and gravity water in macropores begin to release, breaking the original capillarity equilibrium state. Matric suction continues to increase. When the tailings saturation reaches the capillary critical saturation, the capillary water flowing in the pores begins to release. The release water volume increases with the time, and the tailings saturation gradually decreases.

After 1800 min of continuous water release, most of the capillary water has been released, and the rate of water release becomes slower. The reason is that the amount of water between the particles is very small, and a completely connected bending liquid level cannot be formed. When the pressure of the air on the tailings is less than the suction of the tailings on the thin film water, the saturation of the tailings has become very low, and the release of water has become very small. The permeability coefficient is mainly dependent on the state of water in the macropores.

If the intake flow of macropores is interrupted, the permeability coefficient will be reduced. Meanwhile, the water in the small pores may be isolated, so the seepage cannot be carried out. Water in large pores, due to low suction, tends to be released when saturation is low, while water in small pores is the opposite. When the suction value of the tailings particles on the thin film water is less than the air pressure value, the thin film water on the surface of the tailings gradually breaks away from the suction force and is connected with each other to form a flow channel, which is released until the final water release is no longer changed. At this time, the saturation of the tailings has reached the critical saturation of the thin film and will no longer continue to reduce to a stable state.

In conclusion, the water release process is actually an unsaturated seepage process, which mainly depends on the saturation. When the water level drops, the pore channels are of different sizes, the smaller the channels, the greater the flow resistance, the smaller the hydraulic gradient, and the lower the flow rate, which also indicates that the smaller the
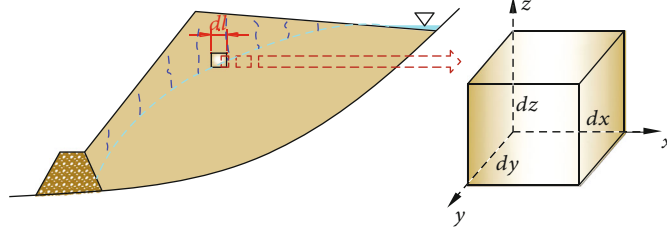
FIGURE 12: Tailing element model.

particle size is, the stronger the water-holding performance is. In other words, the moisture content after water release of powder tailings (as shown in Figure 11(c)) is greater than that of sand tailings (as shown in Figures 11(a) and 11(b)).

3.3. The Influence Mechanism of Particle Size on the Rise of Capillary Water in Tailings

3.3.1. Derivation of the Formula for Moisture Content Change under Capillary Action. The formula of water content per unit volume of tailings under capillary water absorption is preliminarily derived by using a microelement model (Figure 12) without considering other seepage effects. The initial volumetric water content is w_i, the water content after time t is w_t, and the change of water content in tailings after capillary action time t is

$$dQ_w = (w_t - w_i)dxdydz. \tag{3}$$

Q is moisture content. Considering the influence of capillary water pressure, the vertical capillary water velocity can be calculated as

$$q(z) = -\frac{k}{\mu}\left(\frac{ds}{dz} + \rho_w g \sin\phi\right), \tag{4}$$

where k is the permeability coefficient of unsaturated tailings, μ is the viscosity coefficient of the solution, ρ_w is the solution density, g is gravity acceleration, ϕ is the angle between capillary and horizontal direction, and s is the suction.

The buried depth of the infiltration line is h (the distance between the infiltration line and the dam slope), the maximum height of the capillary water rising is h_c, and then the integral of formula (4) is

$$\mu\int_h^{h_c}\frac{q}{k}dz = -[s + \rho_w g(h_c - h)\sin\phi]. \tag{5}$$

According to the law of conservation of mass, the velocity of capillary water can also be expressed as

$$q_t = \frac{dz}{dt}\frac{dA(h_c)}{dA(z)} = \frac{dz}{dt}. \tag{6}$$

Substituting formula (6) into formula (5),

$$\frac{\mu}{k(z)}(h_c - h)\frac{dz}{dt} = -[s + \rho_w g(h_c - h)\sin\phi]. \tag{7}$$

Assume $k(z)$ is constant, $\phi = 90°$; after interval integration formula (7) in $[h_c, z]$, the relationship between the time t and the corresponding capillary rise height $z(h < z < h_c)$ can be written as

$$t = \frac{\mu(h_c - h)(h_c - z)}{[P + \rho_w g(h_c - h)]k}, \tag{8}$$

where t is the time required for capillary water to reach height z.

$$Q_{w1} = \iiint(w_t - w_i)dxdydz = w_t - w_i = \Delta\omega, \tag{9}$$

where w_t is the moisture content in tailings after time t and w_i is the initial moisture content.

According to equations (4) and (8), the capillarity moisture content per unit volume after time t is

$$Q_{w2} = qt \times 1 = -\frac{(h_c - h)(h_c - z)}{s + \rho_w g(h_c - h)}\left[\frac{ds}{dz} + \rho_w g\right]. \tag{10}$$

From $Q_{w1} = Q_{w2}$, the change in moisture content $\Delta\omega$ can be calculated as

$$\Delta w = -\frac{(h_c - h)(h_c - z)}{s + \rho_w g(h_c - h)}\left[\frac{ds}{dz} + \rho_w g\right], \tag{11}$$

$$\text{or} \quad w_t = -\frac{(h_c - h)(h_c - z)}{H + h_c - h}\left[\frac{dH}{dz} + 1\right] + w_i, \tag{12}$$

where q is the vertical capillary velocity, H is the suction head elevation, h is the distance between subgrade surface and groundwater level, h_c is the maximum rising height of capillary, P is the suction in unsaturated soil, ρ_w is the capillary water density, g is the acceleration of gravity, and s is the suction force.

The change of tailing moisture content caused by capillarity is related to the maximum rise height h_c of capillary water and the elevation of capillary suction head. Both h_c and H are directly related to the particle size of tailings (capillary diameter d in tailings) and the properties
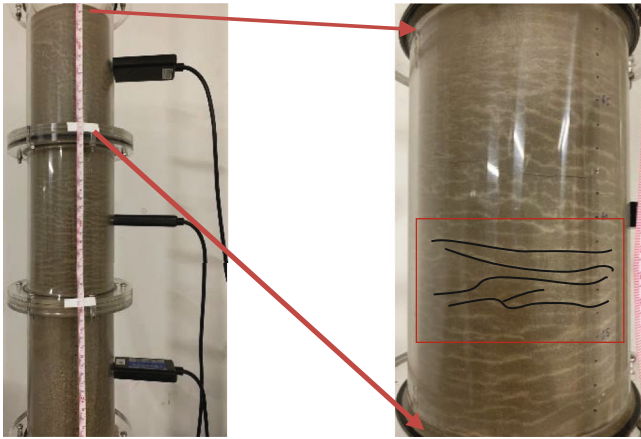
FIGURE 13: Discontinuous capillary band.

of tailings. Therefore, moisture content is a function of particle size of tailings.

3.3.2. Formation of Discontinuous Capillary Bands. The capillary water in the tailings is in a dynamic flow equilibrium state, and the capillary water is affected by the comprehensive action of capillary force, inertia force, viscous resistance, and its own gravity. In the early stage of capillary water rising, the surface tension is much greater than the gravity of the rising water column, so the rising speed is faster. However, as the capillary water column increases, its gravity gradually increases and approaches the surface tension, resulting in a gradual slowing of the rising velocity. Through the analysis of the ascent, in the initial stage of capillary water rising, the capillary water is less watery; the parameters related to the amount of liquid, such as viscous resistance and gravity of capillary water, are also relatively small; at this time, the capillary pressure and inertia force play a dominant role, which is enough to balance the gravity of the capillary water. Therefore, the early uplift force is very large. In addition, discontinuous capillary bands appeared on the upper part of the soil column, presenting a corrugated bedding structure (as see in Figure 13). This is due to the insufficient water supply caused by the rapid rise of capillary water in the initial stage of the rising. At this time, the tailings near the saturation line are close to the saturation state, and the larger water content produces a larger capillary uplift resistance, which reduces the capillary uplift force significantly, so the rise velocity decreases significantly. As the rising height of capillary water increases, the viscous resistance and gravity have balanced a large part of the capillary lifting force, and the content of capillary water in the tailing sand becomes very small, and the subtracting effect also becomes weak. Therefore, the late rising speed is slow and persistent. Synthetically analyzing the whole process of capillary rise, the dynamic of capillary rise showed an obvious decreasing trend.

4. Conclusions

The whole process of capillary water rising test was carried out for tailings with three particle sizes by using OM-CRT system. The conclusions are as follows:

(1) The rising trend of capillary water in tailings with different particle sizes is basically consistent. The process of the capillary water rising is obvious in three stages, which shows the characteristics of rising rapidly first, then slowly and stably lately. The height and rate of capillary rise are negatively correlated with the particle size of tailings. Logarithm function can fit the relationship between time and the height of capillary water rising in tailings and time very well: $H = a\text{-b} * \ln{(t + c)}$

(2) The inner moisture content of the tailings dam is always changing. The change of moisture content is a function of the particle size of tailings. The moisture content of the capillary zone of tailings with different particle size decreases with the increase of height and presents an "S" shape. The instantaneous moisture content of different sections showed an inverse "S" shape with the change of time. The smaller the particle size is, the smaller the moisture content difference of each section after the rise of capillary water is

(3) The process of releasing water with decreasing saturation of tailings is an unsaturated seepage process in the form of natural drainage. When the particle size of tailings is larger, the flow resistance of slurry water is smaller, and the moisture content after water release is smaller. In other words, the water content of sand tailings is greater than that of powder tailings

(4) A physical model for determining the capillary diameter from the inter-particle pore approximation is constructed by this paper. From the limit point of close packing and loose packing, the relationship between capillary diameter and particle size is derived, the relationship between tailing particle size and capillary water rise height is determined as well. The maximum rise height of capillary water and the change value of water content can be determined according to the particle size, which overcomes the difficulty in measuring them

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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