Research Article

Experimental Characterization of the Influence of Ore Drawing Parameters on Tailing Deposition

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The sedimentary structure is important for the engineering design, operation, and safety evaluation of tailing dams. For upstream-method tailing dams, tailing slurry flows and deposits in the pond and forms a complex dam structure. Ore drawing parameters (e.g., slurry concentration and flow rate) have significant influence on the sedimentary structure of tailing dams. However, there is a lack of unified and quantitative understanding of the complicated effects of ore drawing parameters on the deposition behaviour of tailings. In the present study, flume tests were applied to investigate the characteristics of the sedimentary structure of tailing dams. Seven ore drawing experiments were conducted to simulate different slurry concentrations and flow rates. The distribution of characteristic particle sizes $d_{50}$ and $d_{10}$ of sediment was obtained. Furthermore, considering two dominant features of particle size distribution, a mathematical model for the equation between characteristic particle size and deposition distance was established. The exponential part of this equation describes the decreasing trend of the characteristic particle size, and a smooth step function is introduced to characterize the abrupt decrease in particle size. The experimental data of $d_{50}$ and $d_{10}$ in all these test cases can be approximated by the equation with correlation coefficients $R^2$ greater than 0.861. As the slurry concentration of ore drawing increases, the hydraulic sorting gradually weakens. The characteristic particle size distribution curves corresponding to a larger flow rate are generally located above those corresponding to a small flow rate, indicating that the larger the flow rate is, the coarser the sediment. This study provided useful information for the determination of ore drawing parameters in actual tailing dams. The mathematical model of tailings’ particle size distribution can be further used for refined modelling of tailing dams, so as to analyse the safety and stability of the dams.

1. Introduction

Tailing dams are important geotechnical facilities for the disposal of tailings [1, 2]. A tailing dam consists of two parts: the artificially constructed dam and the pond which is formed by hydraulic deposition of tailing pulp. For upstream-method dams, the starter dams and subdams of multiple raisings are usually composed of coarse sand that has been compacted to ensure adequate strength [3–5]. However, the pond part of tailing dams has complicated sedimentary structure, and the sediment material is very soft which takes time to consolidate. Due to the poor geotechnical properties of sediment in tailing ponds, failure accidents of tailing dams occur frequently [3, 6–8]. Thus, it is of great significance to investigate the deposition process of tailings for the operation and management of tailing dams [9, 10]. In addition, the study of the characteristics of sedimentary structure, especially the distribution of tailing particles, also plays a fundamental role in the study of distribution and migration of heavy metal elements and other pollutants in tailing dams [11–15].

Tailing slurry is transported behind the starter dams or subdams, flows, and deposits in the pond. The geotechnical investigation results of several actual tailing dams show that
the particle size of tailings deposited in dams is highly discrete in both longitudinal and transverse directions, and its characteristic particle sizes fluctuate greatly with the change of the distance from the spigots [16, 17]. The variability in tailings sedimentary structure is more pronounced in different tailing dams due to the different composition of tailings produced by the processing plants and the ore drawing parameters such as slurry concentration and flow rate [18–20]. In order to study the influence of these factors on tailing deposition, researchers have conducted deposition model tests with different ore drawing conditions. Küpper [21] conducted a series of flume tests that covered a wide range of slurry concentration and flow rate values. In his study, the median particle size gradually decreased as the distance from the drawing point increased. In contrast, the highly plastic oil sand tailings used by Miller et al. [22] and the thickened tailings used by Pirouz et al. [23] showed that tailing slurry with high concentration did not exhibit particle separation. Several model tests conducted by Yin et al. [24, 25] showed that in the downstream direction, the coarse particle component decreased, and the tailing impoundment could be roughly divided into two subregions. Shao et al. [19] carried out four large-scale simulation tests of tailing hydraulic sorting in four Chinese tailing dams and summarized the hydraulic sedimentation and grain composition of iron tailings. Generally, the behaviour of tailing deposition shown by different studies are not consistent. This inconsistency is mainly due to the limited size of the flumes in these model tests and the strong boundary effects. The ore drawing parameters were also totally different in these flume tests [19, 21, 22]. Thus, there is no comprehensive and unified understanding of the effects of the ore drawing parameters on tailing deposition. Furthermore, the previous studies only qualitatively described the particle distribution characteristics, and there is a lack of quantitative research on the relationship between the particle distribution and the ore drawing parameters [26], which makes it difficult to apply to further refinement of numerical modelling of tailing dams.

To study the influence of ore drawing parameters on the deposition behaviour of tailings, tailing slurry with various discharge parameters was pumped into a large-scale flume, whose drainage conditions could also be controlled. In the flume, discharge tests under eight sets of working conditions including different slurry concentrations and flow rates were carried out. Furthermore, the influence of the slurry concentration, flow rate, and drainage conditions on the sedimentary structures was analysed.

2. Test Equipment and Material

2.1. Flume Experimental System. Figure 1 gives the layout of the flume experimental system. Before each discharge, a certain proportion of tailing material and water was injected into the mixing tank. The mixing tank could produce slurry with the corresponding concentration. The slurry was then transported to the storage tank before being pumped into a flume. The flume was designed with dimensions of 20 m in length, 2 m in width, and 1 m in height. Figure 2(a) is the photo of the flume. The length of the flume meets the requirements of hydraulic sorting and the formation of beaches, and the width provides enough space for the lateral movement of the slurry. To facilitate observation of depositional structures, transparent plexiglass was installed on one side of the flume (see Figure 2(b)). On the end wall of the flume near the inlet, a filter plate with holes was installed, and at the bottom of the end wall of the flume, two drainage valves were set up (see Figure 2(b)). The filter plate combined with the drainage valves were used to simulate the drainage conditions of starter dams and subdams that are artificially constructed in tailing dams.
2.2. Experimental Material. Although the characteristics of tailing particles have an impact on the deposition behaviors of tailings, the factors of concern in this paper are the ore drawing parameters: slurry concentration and flow rate. Thus, a typical tailing material was prepared for this study. The tailing material was collected from the Shouyun tailing dam, Miyun District, Beijing, China. In the Shouyun mine, the main iron ore body consists of a large deposit of magnetite quartzite, grading 28% Fe. The median grain size \( d_{50} \) and effective grain size \( d_{10} \) of Shouyun tailings are 0.068 mm and 0.0047 mm, respectively. Grading analysis of the total tailings was conducted following ASTM standard D422-63 [27], and the results are shown in Figure 3. The characteristic parameters are listed in Table 1. The particle size of the tailings used in this study has a wide range with both coarse and fine particles.

2.3. Experimental Scheme. Table 2 gives the seven deposition experiments (cases) conducted in this study. The cases are coded following these rules: the capital letter (1) \( C \) represents the slurry concentration (mass concentration), and (2) \( Q \) represents the discharge flow rate. The minimum slurry concentration \( C_w \) is 20%, and the maximum slurry concentration is 50%. The discharge per unit width is adopted in accordance with the discharge level of a single spigot in the Shouyun tailing dam, which ranges from 0.75 L/s·m to 6 L/s·m in the tests.

During deposition tests, the slurry was generated by mixing dry tailings with water until the slurry concentration met the required state in each case. Then, the slurry was discharged by a feed pump. The feed pump kept the slurry flow at a constant speed. The two valves controlled the flow rate coming out of the two spigots to keep the discharge from each spigot equal. The discharge process was repeated 3-5 times in each test. The interval between two releases was kept at a certain level to facilitate the consolidation process of tailing sediments. Table 2 gives the number of releases and the duration between the releases of different cases. At the end of the last discharge, samples were collected from different positions in the flume for further grain grading analysis.

3. Experimental Results and Discussion

3.1. Distribution Characteristics of Particle Size. Figures 4 and 5 show the distribution of particle sizes \( d_{50} \) and \( d_{10} \) of the tailings along the flume in the seven cases. The variation ranges of median particle size \( d_{50} \) and effective particle size \( d_{10} \) along path in every case are listed in Table 3. The ratio
of maximum values and minimum values of characteristic particle sizes under various experimental cases can be used to measure the sorting degree of coarse and fine particles deposited by tailings [19]. According to Table 3, in all these cases, the hydraulic sorting of the tailing particles is obvious. The degree of separation decreases with the increase of slurry concentrations and discharge flow rates.

From Figures 4 and 5, the trend of the characteristic particle sizes can be divided into three sections. In the vicinity of the spigots, the particle size decreases slightly with distance. In this area (called the fan-shaped zone), the sediment forms a fan-shaped fill centred on a scouring pit. \(d_{50}\) and \(d_{10}\) in the middle section of the flume do not decrease much in most areas. However, there exists an abrupt decrease of the characteristic particle sizes between the channel zone and the laminar flow zone in all these cases. At the end of the flume, \(d_{50}\) and \(d_{10}\) tend to be stable. In general, the variation degree of \(d_{10}\) is more dramatic than that of \(d_{50}\). In the case of C50 Q1.5, although the overall variation in \(d_{50}\) in the flume is small, the variation in \(d_{10}\) is still considerably significant.

The hydraulic sorting effect can be further shown by comparing the characteristic particle size of the sediment with that of the total tailing slurry from the spigot. The median particle size \(d_{50}\) of sediment within 6 m from the spigot is larger than that of the total tailing slurry from the spigot. This means that the tailing particles have been sorted, and the coarser particles near the spigot can lead to better permeability and shear strength [8, 28, 29]. There is a more significant difference in the effective particle size \(d_{10}\) between the total tailing slurry and the sediment. In the case of C20 Q1.5, the sediment 1.5 m away from the spigot has a \(d_{10}\) of 0.051 mm, which is approximately 10 times that of the total tailings. In all these cases, the effective particle size \(d_{10}\) of the sediment within 10 m from the inlet is generally larger than that of the total tailings. In the case of C30Q6.0, due to the high flow rate, fine particles in the slurry did not easily deposit, and the sediments other than those at the end of the flume all had larger \(d_{10}\) values than the total tailings.

### 3.2 Effects of Ore Drawing Parameters on the Distribution of Particles

Slurry concentration and discharge flow rate are the major discharge parameters of ore drawing. In this section, the effect of the two parameters on the horizontal distribution of tailing sediment was further analysed. To illuminate the influence of tailing particle size on deposition, the characteristic particle sizes of sediment are divided by that of the total tailings from spigots to obtain the relative characteristic particle sizes \(d_{50}\) and \(d_{10}\).

#### 3.2.1 Effect of Slurry Concentration on the Distribution of Particles

Figure 6 shows the experimental data of the relative characteristic particle sizes \(d_{50}\) and \(d_{10}\) at different slurry concentrations. The figure shows that the characteristic particle size has different patterns at different positions of the flume. At the upper side of the flume, the lower the concentration, the larger the characteristic particle size; while at the lower side of the flume, the characteristic particle size decreases with the reduction of slurry concentration. In general, as slurry concentration increases, the difference in the characteristic particle size of the sediment located at the flume inlet and outlet gradually narrows, which indicates that the hydraulic sorting effect weakens. When the slurry concentration is lower than 40%, the tailings are well separated. However, when the concentration is as high as 50%, the effect of hydraulic separation is absent from the flume inlet to outlet. In this case, the tailings’ median particle size at the end of the flume is 0.05 mm, which is much larger than that in other cases.

To further quantitatively study the influence of slurry concentration on the distribution of particle size, the relationship between particle size and distance is established and described by Equation (1). The equation considers two dominant features of particle distribution. The exponential part of Equation (1) describes the decreasing trend of the

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**Table 1:** Physical properties of the sample material.

<table>
<thead>
<tr>
<th>Physical property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific gravity (G_s)</td>
<td>2.74</td>
</tr>
<tr>
<td>Median grain size (d_{50}) (mm)</td>
<td>0.086</td>
</tr>
<tr>
<td>Dominant grain size (d_{50}) (mm)</td>
<td>0.13</td>
</tr>
<tr>
<td>Effective grain size (d_{10}) (mm)</td>
<td>0.0047</td>
</tr>
<tr>
<td>Coefficient of uniformity (C_u)</td>
<td>27.7</td>
</tr>
<tr>
<td>Coefficient of curvature (C_c)</td>
<td>1.67</td>
</tr>
</tbody>
</table>

**Table 2:** Experimental cases of depositional tests.

<table>
<thead>
<tr>
<th>Case number</th>
<th>Case code</th>
<th>Mass concentration ((C_m, %))</th>
<th>Flow rate per unit width ((L/s\cdot m))</th>
<th>Number of releases</th>
<th>Duration between releases ((h))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C20Q1.5</td>
<td>20</td>
<td>1.5</td>
<td>7</td>
<td>16.5</td>
</tr>
<tr>
<td>2</td>
<td>C30Q1.5</td>
<td>30</td>
<td>1.5</td>
<td>5</td>
<td>14.0</td>
</tr>
<tr>
<td>3</td>
<td>C40Q1.5</td>
<td>40</td>
<td>1.5</td>
<td>4</td>
<td>13.0</td>
</tr>
<tr>
<td>4</td>
<td>C50Q1.5</td>
<td>50</td>
<td>1.5</td>
<td>3</td>
<td>12.5</td>
</tr>
<tr>
<td>5</td>
<td>C30Q0.75</td>
<td>30</td>
<td>0.75</td>
<td>5</td>
<td>14.0</td>
</tr>
<tr>
<td>6</td>
<td>C30Q3.0</td>
<td>30</td>
<td>3.0</td>
<td>5</td>
<td>14.0</td>
</tr>
<tr>
<td>7</td>
<td>C30Q6.0</td>
<td>30</td>
<td>6.0</td>
<td>5</td>
<td>14.0</td>
</tr>
</tbody>
</table>
characteristic particle size, and a smooth step function is introduced to characterize the abrupt decrease in particle size in the transition region between the channel and laminar flow zones.

\[
D_c = \text{smooth\_step}(L) \exp \left[ a + b \cdot (L) + c \cdot (L)^2 \right],
\]

where \( D_c \) is the relative particle size that is equal to the characteristic particle sizes (i.e., \( d_{50} \) and \( d_{10} \)) of the sediment divided by that of the total tailings (0.086 and 0.0047 mm, respectively). \( L \) is the relative distance that is equal to the distance from the spigot divided by the whole length of the flume (20 m). The smooth step function \( \text{smooth\_step}(L) \) is defined as

\[
\text{smooth\_step}(L) = \begin{cases} 
1, & L \leq L_1, \\
1 - k_1 \left[ 3 \left( \frac{L - L_1}{L_2 - L_1} \right)^2 - 2 \left( \frac{L - L_1}{L_2 - L_1} \right) \right], & L_1 < L < L_2, \\
1 - k_1, & L_2 \leq L,
\end{cases}
\]

where \( L_1 \) and \( L_2 \) are the range of the transition region between the channel and laminar zone. The coefficient \( k_1 \) depends on the degree of the sudden change in the characteristic particle size, which is also related to the gradation of the total tailing slurry and the ore drawing parameters.

The fitting curve of the relative particle sizes of tailing sediment at different concentrations is also shown in Figure 6. It can be seen that Equation (1) fits well with the experimental data. The coefficients in Equations (1) and (2) are listed in Tables 4 and 5, and the relationship between these coefficients and the slurry concentration is plotted in Figure 7. According to Equation (1), the coefficient \( a \) determines the characteristic particle size at 0 m. Figure 7(a) shows that the coefficient \( a \) decreases with increasing slurry concentration. This decrease may be attributed to the fact that as the concentration increases, the fine particles in the slurry easily form a flocculation structure [30, 31], and the fine particles adhere to the surface of coarse particles and settle together. The increase in fine particle content in sediment will result in a decrease in the relative particle sizes \( d_{50} \) and \( d_{10} \). The coefficients \( b \) and \( c \) of the exponential terms have opposite trends with the change in slurry concentration, but they both change monotonically with the change in concentration. The coefficient \( k_1 \) in Equation (2) can measure the magnitude of particle size mutation and further reflect the degree of hydraulic sorting. For example, when

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**Figure 4:** Distribution of characteristic particle size along the path in the cases of different slurry concentrations: (a) C20Q1.5, (b) C30Q1.5, (c) C40Q1.5, (d) C50Q1.5.
the slurry concentration is 20%, \( k_1 \) is 0.50 and 0.78 for \( d_{50} \) and \( d_{10} \), respectively; that is, the particle size in the transition zone between the channel and laminar flow zone is reduced by 50% and 22%, respectively. However, when the slurry concentration reaches 50%, \( k_1 \) is 0.33 and 0.7 for \( d_{50} \) and \( d_{10} \), respectively, and the particle size in the transition zone between the channel and laminar flow zone is reduced by 67% and 30%, respectively. In terms of the general trends, the value of coefficient \( k_1 \) approximately decreases with increasing concentration, indicating that the degree of hydraulic sorting is reduced.

The influence of slurry concentration on tailing deposition can be interpreted by the viscosity of the slurry. Three effects increase the viscosity coefficient of the slurry: (1) the deformation of fluid near the solid particle, (2) the rotation of asymmetric particles in the velocity gradient field,
and (3) the increased resistance caused by the tailings' flocculation structure. The effects get more obvious under greater slurry concentration. For non-Newtonian fluids such as Bingham suspensions, the shear force $\tau_B$ is proportional to the higher power of the volume sand concentration $S_v$, i.e., \[ \tau_B \propto S_v^n. \]

Rheological tests on twenty-two different mineral tailings demonstrate the relationship proposed by Chien and Wan [33], and the strong dependence of viscosity on concentration is illustrated in Figure 8. The figure shows that the flow regime of the tailing slurry varies significantly with the solid concentration, particle size, and size distribution.

For the iron tailings used in this study, when the slurry concentration is equal to or greater than 50%, due to the

- Figure 6: Characteristic particle size of the experimental data and fitting equation at different slurry concentrations: (a) relative median particle size $d_{50}$; (b) relative effective particle size $d_{10}$.

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>$a$</th>
<th>$b$</th>
<th>$c$</th>
<th>$L_1$</th>
<th>$L_2$</th>
<th>$k_1$</th>
<th>$R^2$</th>
</tr>
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<tbody>
<tr>
<td>C20Q1.5</td>
<td>0.72</td>
<td>-2.85</td>
<td>1.10</td>
<td>0.50</td>
<td>0.60</td>
<td>0.50</td>
<td>0.983</td>
</tr>
<tr>
<td>C30Q1.5</td>
<td>0.60</td>
<td>-2.78</td>
<td>0.84</td>
<td>0.50</td>
<td>0.70</td>
<td>0.17</td>
<td>0.993</td>
</tr>
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<td>0.48</td>
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<td>0.50</td>
<td>0.70</td>
<td>0.36</td>
<td>0.995</td>
</tr>
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<td>0.50</td>
<td>0.70</td>
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<tr>
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<td>-1.91</td>
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<td>0.55</td>
<td>0.71</td>
<td>0.996</td>
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<tr>
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<td>0.75</td>
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<table>
<thead>
<tr>
<th>Coefficient</th>
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<th>$c$</th>
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<th>$L_2$</th>
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<td>0.70</td>
<td>0.70</td>
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<td>0.70</td>
<td>0.65</td>
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<td>C50Q1.5</td>
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<td>-0.89</td>
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<td>0.70</td>
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<td>0.62</td>
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<td>C30Q6.0</td>
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<td>-1.97</td>
<td>0.32</td>
<td>0.60</td>
<td>0.75</td>
<td>0.60</td>
<td>0.989</td>
</tr>
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</table>

Table 4: Coefficients for Equations (1) and (2) of relative median particle size $d_{50}$

Table 5: Coefficients for Equations (1) and (2) of relative effective particle size $d_{10}$
large shear force, the slurry moves in the form of plug flow. Compared with particle gravity, the large shear stress of the slurry plays a major role in the suspension system, resulting in the absence of hydraulic separation. Meanwhile, the magnitude of the sudden drop in particle size in the transition zone between the channel and laminar flow zone would diminish, indicating a smaller absolute value of \( k_1 \).

3.2.2. Effect of Flow Rate on Distribution of Particle. The distribution of relative characteristic particle sizes \( d_{50} \) and \( d_{10} \) at different flow rates is plotted in Figure 9. Within the section 10 m away from the spigot in the flume, the relative characteristic particle size distribution curves corresponding to a larger flow rate are generally located above those corresponding to a small flow rate. This result indicates that the larger the flow rate is, the coarser the sediment is. This is because the sand carrying capacity is larger when the flow rate is higher, and fine particles can be carried farther. In addition, the location of the transition zone, where a sudden drop in particle size takes place, also moves further toward the end of the flume under higher flow rate. The transition zone is located 10 m away from the inlet under the flow rate of 0.75 L/s, and when the flow rate reaches 6.0 L/s, the transition zone moves to 14 m away from the inlet, which moves by approximately 4 m.

As can be observed from Figure 9, all these distribution curves at different flow rates exhibit a similar shape and therefore can be approximated by Equation (1) with correlation coefficients \( R^2 \) greater than 0.958. The coefficients in Equation (1) are listed in Tables 4 and 5, and the relationship between these coefficients and the flow rate is plotted in Figure 10. As shown in this figure, the coefficients \( a, b, c \), and \( k_1 \) vary with the change in the flow rate, indicating that the flow rate has a certain influence on these coefficients. However, it is difficult to summarize the definite relationship between the flow rate and these coefficients from Figure 10. This is because the flow rate affects tailing deposition by changing hydraulic parameters such as the flow velocity and water depth [21, 26]. However, other factors, such as the changing topography of the bed during tailing deposition, will also result in differences in particle distribution by changing these hydraulic parameters. Therefore, the
Figure 8: Yield stress for different slurry concentrations of various tailings, data from Boger et al. [32] and Pullum et al. [18].

Figure 9: Characteristic particle size of the experimental data and fitting equation at different flow rates: (a) relative median particle size $d_{50}$; (b) relative effective particle size $d_{10}$. 
relationship between the flow rate and the coefficients in Equation (1) cannot be established directly.

By synthesizing the distribution of tailing particles under two factors, i.e., slurry concentration and discharge flow rate, this paper revealed the different effect of the two factors have on tailing deposition. The concentration determines the viscosity of the slurry. Suspensions at different concentrations manifest in different forms, from Newtonian fluids to Bingham fluids, with dramatic changes in the shear force. The discharge flow rate determines the flow field distribution in the flume and consequently affects the depositional process of tailing particles.

4. Conclusions

Flume tests were conducted for a comprehensive and systematic investigation of the sedimentary structures of tailing dams. A large-scale model flume was established, and seven deposition cases of different slurry concentrations and flow rates were carried out. The distribution characteristics of tailing sediment under the influence of ore drawing parameters were obtained. The observations and conclusions are summarized as follows.

(i) The distribution of $d_{50}$ and $d_{10}$ generally trends from coarse to fine along the slurry flow. The median particle size $d_{50}$ is in the range of 0.0192–0.144 mm, and $d_{10}$ varies from 0.0023 to 0.051 mm. Combined with the flow of the tailing slurry, the trend of the characteristic particle sizes is divided into three sections: the fan-shaped zone, channel zone, and laminar flow zone. In the transitional region between the channel zone and laminar flow zone, there exists an abrupt decrease in the characteristic particle sizes in all these test cases.

(ii) In general, the variation degree of $d_{10}$ is more dramatic than that of $d_{50}$. The region where the median particle size $d_{50}$ of sediment is larger than that of the total tailing slurry is within 6 m from the inlet, while the region for the effective particle size $d_{10}$ is within 10 m. That is, there is a more significant difference in the effective particle size $d_{10}$ between the total tailing slurry and the sediment.

(iii) A mathematical model for the relationship between the deposition distance and the relative characteristic particle sizes was established. The equation considers
two dominant features of particle distribution. The exponential part describes the decreasing trend of the characteristic particle size, and a smooth step function is introduced to characterize the abrupt decrease in particle size in the transition region between the channel and laminar flow zones.

As the slurry concentration of ore drawing increases, the hydraulic sorting gradually weakens, so the values of coefficients \( a \), \( c \), and \( k_1 \) approximately decrease, while \( b \) increases. The relative characteristic particle size distribution curves corresponding to a larger flow rate are generally located above those corresponding to a small flow rate, indicating that the larger the flow rate is, the coarser the sediment. However, it is difficult to summarize the definite relationship between the flow rate and these coefficients.

Based on the characteristic particle size distribution curves of tailing sediment obtained by a large number of model tests, the empirical formula of particle size distribution is proposed in this study. Combined with other studies [29, 34–36] on the relationship between characteristic particle size of tailings and physical and mechanical properties (e.g., permeability coefficient and shear strength parameters), these results can be further used for refined modeling of tailings, so as to analyze the safety and stability of the dams. In addition, there are some limitations in this paper. Only one kind of tailing material was used, and considering that the properties of tailing particle can also have important impact on its deposition characteristics, more studies should be carried out with different particle size and mineral components.

Data Availability

All data, models, and code generated or used during the study appear in the submitted article.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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