www.cafetinnova.org

Indexed in
Scopus Compendex and Geobase Elsevier,
Geo-Ref Information Services-USA, List B of Scientific Journals, Poland, Directory of Research Journals

ISSN 0974-5904, Volume 09, No. 02

International Journal of Earth Sciences and Engineering

April 2016, P.P.774-779

Study on the Tailings Depositional Law and Mechanical Properties in the Dry Beach

WANG GUANG-JIN[1,2], KONG XIANG-YUN[*1] AND YANG SHUO[1]
[1]*Kunming University of Science and Technology, Kunming, 650093, China*
[2]*State Key Laboratory of Geomechanics and Geotechnical Engineering, Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, Wuhan, 430071, China*
Email: *wangguangjin2005@163.com*

Abstract: In order to describe the depositional law and the mechanical properties of dry beach tailings, the paper used an indoor that the tailings in the dam exist overt classification of particle size, and the end of storehouse agglomerate fine tailings, coarse tailings exists in front of dam instead. Model of deposition distance reveals that the distribution of tailings on dry beach is affected by grain size, the initial flow velocity of pulp, gradient and so on. Mechanical test indicates that the shear strength of medium grain tailings is larger than that of fine particle, which draws a conclusion, that the larger the grain is, the better its mechanics is. And other measures such as reducing velocity of pulp, pulp density, increasing particle size taken can shorten the deposition distance of coarse tailings, improve coarsening phenomenon of dry beach. Research finding the characteristics of the tailings deposition dry beach, which provides reference for multi-scale research and distribution law of sedimentary tailings.

Keywords: *Tailing particle, indoor simulating test, deposition rule, mechanics experiment*

1. Introduction

The surface sedimentary tailings refer to accumulation body formed by flowing, settling and depositing after drawing in the tailing surface. Tailing sedimentary was affected by grain size, pulp density, flow velocity, drawing-ore forms, water level of tailings pond, Precipitation and so on. Tailings in different deposition location have different microscopic geometric structure.

YIN Guang-zhi, etc. through field testing and laboratory test analyze flow characteristics of the coarse and fine tailings in the storage, and point out the law that the large particle tailings will sediment at the head of dam and the small is the opposite. The dry beach formed by coarse tailings is steep due to the poor fluidity, while formed by fine tailings is subdued. LI Quan analysis the influences of the permeability coefficient, the filling speed, the drainage facilities and the tailings dam height of the beach width. The results show that the beach width should be expanded when the issue of tailings water cannot be effectively solved. ZHANG Qiangui, etc. obtained the dry beach's geometric features and particles' distribution rule of the tailings dam based on a model test of building tailings dam.

Particle size distribution has a major impact on the soil structure and macroscopic properties. M. Jopony put forward distribution function of particle size of copper tailings in Malaysia Lohan. V. Giuliano, etc. used a variety of techniques to measure the particle size of pyrite tailings, and propose with Rosin-Rammler function to describe the particle size distribution of tailings sediment. The particle shape is other important microscopic parameters, no uniform quantitative method for particle shape characterization. E. T. Bowman, etc. propose using Fourier series method for mathematical description of particle shape. The research of J. C. Santamarina and G. C. Cho show that the shape of clay is plates commonly can be presented from the three aspects--the grain contour, the angularity and the surface roughness. Tu Xinbin and Wang Sijing introduced the parameters used in the particle shape description of digital image processing, and point out that, the shape factor based on particle area and perimeter of S11 is one of the best shape descriptor. Tailings particle is influenced by pulverization and transportation; there still exist a large gap when comparing with the shape of natural soil. A further investigation is still needed in order to interpret the relation of the shape of tailing particle with different deposition distance and the particle size, as well as deposition distance.

The damming characteristic of the method of using tailing hydraulic fill is damming while producing, that is utilizing hydraulic fill of tailings deposition to form the dam body. Upstream dam construction method adopts dispersive pulp-discharge in front of dam. In the process of flowing to the storage from the draw point brow, complicated composition is due to the difference in sediment-carrying capacity of pulp, as the degree of drained mineral, initial flow velocity of pulp, grain size etc. However, the strength of tailing dam is determined by physical and mechanical characteristics such as composition and consolidation of particle. Therefore, Tailings deposition Law of

different particles it is necessary to analysis tailings deposition law of different particles before the study of physical and mechanical properties of tailings dam.

2. Indoor ore drawing test and Result Analysis:

Due to the limits of various reasons in test site, restrictions of drainage conditions particularly. Therefore, the test of rock dam formulate mine tailings concentration is 73%, This concentration can make the mine tailings flow into storehouse rely on gravity, also cannot erode mine tailings that has been deposited. The process of rising tailings dam adopt distributed ore drawing before dam, by using 50mm diameter's PVC pipe to draw ore. Figure 1 is the tailing mixing and transportas it is shown in. Four pipe were placed before dam house dispersedly.

Fig 1: *Tailing mixing and transport*

The test used handheld blender to mix mine tailings with water and pour into the material cup, then it will flow into the dam room with ore drawing pipes. Then regulated the place of drawing ore pipes to make the tailings be deposited regularly. The figure 2 was the dispersion pulling ore in front of dam.

A:

B:

Fig 2: *Dispersion pulling ore in front of dam*

Owing to the high concentration of tailings, the phenomenon that deposited tailings were obviously scoured is not happen. During the process of ore drawing, Particle size grading is apparent. The original mine tailings sample belongs to the large size, bad gradation and it contain little silt. Generally, with the distance of different ions dam increasing, article size grading is different, the farther to the ions dam, the size is smaller. The figure 3 was the Classification size analysis of tailings.

A:

B:

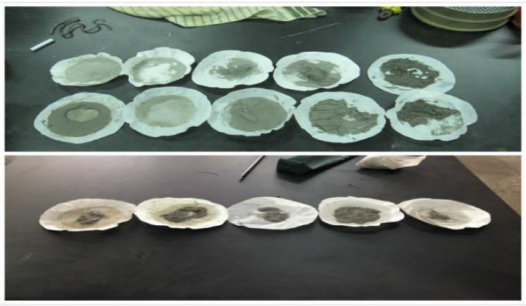

Fig 3: *Classification size analysis of tailings*

For this experiment, the particle-size separation of the surface and medium of dry beach was not obviously. The main reason is the difference between experiment and reality industry in ore drawing crafts. When the tailings slurry flowed into the dam room with PVC pipes, their status were "laminar flow", then we cannot get the apparent phenomenon. The tailings' shorter transport distance and disappearing in the tailings water is another major reason. However, for the area below the tailings water line, we can see mine tailings' granule became finer ,tailings and mud were gathered in the end of tailings.

The mine tailings' shorter transport distance and disappearing in the tailings water is another major reason. But, for the area below the tailings water line, we can see mine tailings' granule became smaller and mine tailings and mud are gathered in tail. In order to reflect the distribution of tailings particles in storage.

According to figure 4, we can find out the size distribution in the medium and end of the tailings have a greater difference. Among them, the head tailings particle size is d50=0.11mm, the medium is d50=0.051mm, the end is d50=0.035mm. The proportion of the size distribution that below 0.074mm in the end of tailings is larger than 50%. They are appeared with tailings sand and tailings mud. Regarding on the actual situation, upstream method was mostly used. The region exhibit a slim shape, tailing particle will be smaller with the advance towards tailings and the properties of soil mechanics

will be worse. So, for the tailing dam accumulation, we should try to use the coarse particles or rock to improve the stability of storage.

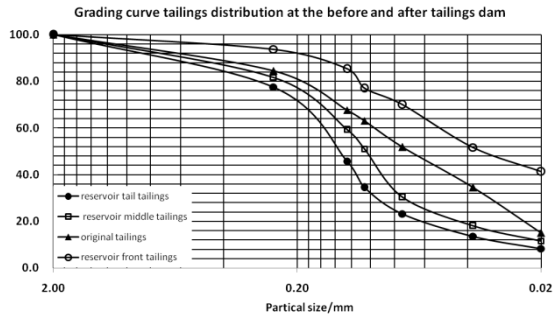

Fig 4: *Tailings particle size gradation contrast curve*

The length and the changes in slope of dry beach are related to many factors, such as the flow of tailings, the concentration, the velocity, and water level, etc. Theoretically, the higher of tailings concentration is, the lower flow is, the steeper slope of dry beach is. On the contrary, it will be slower. Tailing with high concentration has a faster velocity from dry beach to storehouse. Then they flow in to tailings with a lower velocity .After that, it will be disappeared. Finally, we will see the classification phenomenon, and mud-sand be gathered. For the realistic tailings engineering, the concentration of ore drawing pipes is 15%-25% in general .Tailings with a high moisture content lead to a high water level, so the transport distance of tailings will be farther .At the same time the slope will be gentle. Because of the tailings with a high concentration and coarse particles. Therefore, the result this experiment tested is the length and slope of dry beach after 4-class tailings dam had been built. The length is 1.63m and slope is 26.8%. The results show the slope is increasing with dam height with other conditions unchanged. The length of dry beach will increase with the change of time because of permeable dam at the beginning and each class dam will be shorter. Ore drawing and dam accumulation are a long process. Each of them will make a difference to the length of dry beach. Hence, we should anticipating the changes of dry beach, and adjust the flow and velocity to achieve the best drawing and make the tailings safety.

3. The deductive proof of the deposition distance formula of tailings:

The analysis suggests that the longer between beach ridge, the finer the particles are. Deposition distance of different particle size determines the coarse degree of tailings in the dry beach, dry beach tailings classifying effect has great influence on the stability of tailings. Therefore, the study of the deposited distance of tailings and its influencing factors of different size is of guiding significance in engineering practice.

The flow velocity of pulp decreased continuously because of mechanical energy loss. When the flow velocity is lower than the starting speed of a certain particle size, this size of particles separate from water, sedimentation occurs and the distribution of the pulb in the beach is from course to fine.

We could get theoretical formula of deposition distance derived from the limit equilibrium equation of the particle and the energy conservation equation of slurry flow.

Assuming pulp flow in the dry beach match all items below:

(1)The fluxion of pulp in the dry beach flow under permanent current and incompressible, total flow rate keeps invariant;

(2)Only gravity act on pulp;

(3)Dry beach face is a triangle, any section been through is gradient flow

(4)Particles move with the same velocity of water before reaching separation velocity, the effect on the composition of pulp can be neglect able after separation.

(5) The total head loss and the length of the process, the initial velocity requires the following conditions to be satisfied:

$$h_w = k_0 L v_L^{\,2} \tag{1}$$

h_w Total pumping head loss, k_0 value parameter, L circuit, v_L mash velocity.

Make stress analysis for the critical separated tailings particles within force restriction (water drag force, uplift force, gravity)to establish movement equilibrium equation in the pulp of the solid and liquid status.

$$F_D L_D + F_L L_L = W L_w \tag{2}$$

F_D drag force, L_D drag force arm, F_L uplift force, L_L uplift force arm, W gravity, L_w gravity arm.

$$F_D = C_D \alpha d_i^2 \frac{\rho v_c^2}{2} \tag{3}$$

$$F_L = C_L \alpha d_i^2 \frac{\rho v_c^2}{2} \tag{4}$$

$$W = \alpha(\gamma_s - \gamma) d_i^3 \tag{5}$$

C_D , C_L drag force coefficient ,uplift force coefficient; α Area coefficient; d_i Particles I area such as equivalent diameter circle; ρ Water density;

γ_s Solid particle density; γ Pulp density; v_c The critical separation velocity。

Let be

$$L_D = L_L = L_w \tag{6}$$

Connect (8)～(13),separation velocity:

$$v_c = \sqrt{\frac{2(\gamma_s - \gamma) d_i}{\rho(C_D + C_L)}} \tag{7}$$

For the pulb at the length of L, According to the Constant total flow Bernoulli equation

$$L\,i+\frac{\alpha_1 v_0^{\,2}}{2g}=\frac{\alpha_2 v_L^{\,2}}{2g}+k_0 L v_L^{\,2} \tag{8}$$

i dry beach slope ; α_1, α_2 kinetic energy Correction coefficient ; v_0 original velocity.

To calculate,

$$v_L=\sqrt{\frac{2gLi+\alpha_1 v_0^{\,2}}{\alpha_2+2gk_0 L}} \tag{9}$$

Combine (14)with(16),when $v_L=v_c$, d_i Particle size of d_i particle settlement will happen, it is:

$$L_c=\frac{\alpha_1\rho(C_D+C_L)v_0^{\,2}-2\alpha_2(\gamma_s-\gamma)d_i}{4(\gamma_s-\gamma)gk_0 d_i-2g\rho(C_D+C_L)i} \tag{10}$$

L_c -The farthest distance sedimentation of this size particle.

We can think in engineering applications:

$$L_c=M\frac{v_0^2}{(\gamma_s-\gamma)d_i}-N \tag{11}$$

M , N both are Setting parameters.

In summary, describing the farthest deposition distance of particle that diameter is 'd' at different initial conditions can be achieved. It also can be seen from the aircraft, increase particle size can shorten the deposition distance of coarse tailings, improving coarsening phenomenon of dry beach.

These should be brief and placed at the end of the text before the references.

4. Mechanical Properties of sedimentary tailings:

The figure5 were the triaxial strength test instrument with strain control.

Fig 5: *TSZ30-2.0 triaxial strength test instrument with strain control*

In this paper, direct shear and triaxial shear testing in tailings sample, has been made which shows that there are large differences in cohesion (c) and friction angle (φ) under various conditions. Cohesion(c) and friction angle (φ) always change with test method, which showing a tendency that CD>CU>UU. Mainly due to the effected by consolidation and water, but also shows water do obviously affect the strength of tailings. Direct shear full cut water consolidation and full water quick shear have two states of c and φ. it can be seen that quick shear c value is smaller than consolidation shear φ. The cohesion(c) with quick shear is smaller than that with direct shear, that is to say make tailings consolidated could improve its cohesion. The figure6, figure 7 and figure 8 were the triaxial strength test instrument with strain control.

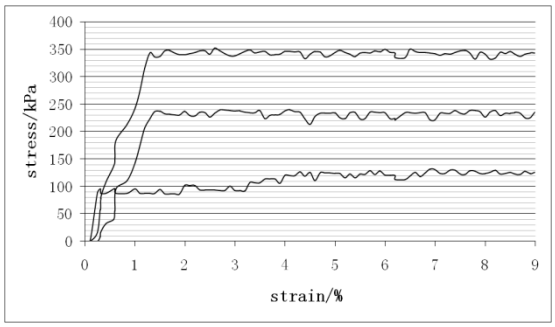

Fig 6: *The Relationship between principal stress difference and axial strain of coarse tailings (UU-test)*

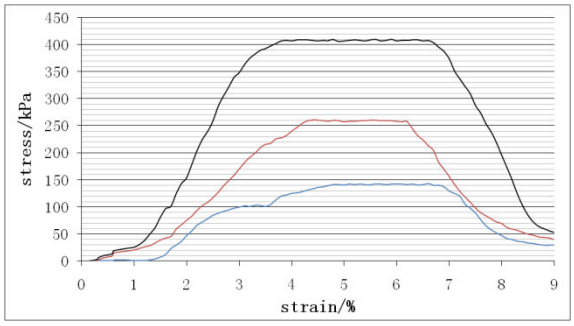

Fig 7: *The Relationship between principal stress difference and axial strain of coarse tailings (CU-test)*

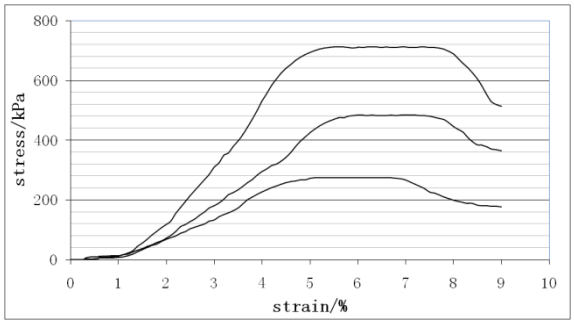

Fig 8: *The Relationship between principal stress difference and axial strain of coarse tailings (CD-test)*

The friction angle (φ) with quick shear is larger than that with direct shear. The studies on two testing methods get some results that the cohesion(c) of triaxial shear testing is larger than that of direct shear testing. The figure 9, figure 10 and figure 11 were the Mohr circle curve of coarse tailings under the triaxial strength.

Compare the shear strength of medium size particles to that of fine size particles shows that the cohesion(c) and the friction angle(φ) of medium size particles is larger in either case. The following conclusions can be drawn: the Mechanical properties of coarse tailings are superior to that of fine tailings. The Table 1 was the results of tailings triaxial compress test

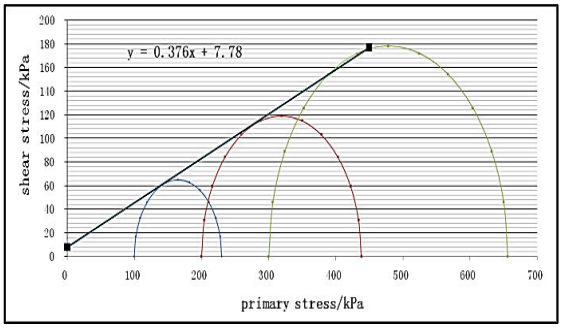

Fig 9: *Mohr circle curve of coarse tailings under the triaxial strength UU test*

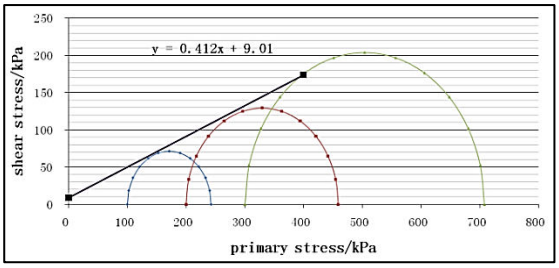

Fig 10: *Mohr circle curve of coarse tailings under the triaxial strength test (CU)*

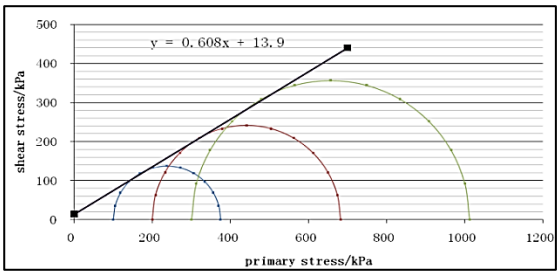

Fig 11: *Mohr circle curve of coarse tailings under the triaxial strength test (CD)*

Table 1: *The results of tailings triaxial compress test*

category	unconsolidated-undrained (UU)		Consolidated-undrained (CU)		Consolidated –drained (CD)	
	C_{UU} kPa	Φ_{UU} (°)	C_{CU} (kpa)	Φ_{CU} (°)	C_{CD} (kpa)	Φ_{CD} (°)
Coarse tailings	7.78	20.6	9.01	22.4	13.9	31.3
fine tailings	0.429	5.07	0.64	19.5	4.35	26.5

5. Conclusion:

(1)The tailings in the dam exist overt particle size grading, and the tail of reservoir agglomerate fine tailings, coarse particle exists in the front of dam instead.

(2) Cohesion(c) and friction angle (φ) always change with shearing methods, which showing a tendency that CD>CU>UU.

(3)Taking measures to reduce velocity of pulp, pulp density, and increase particle size can shorten the deposition distance of coarse tailings, improving coarsening phenomenon of dry beach.

Acknowledgments:

This research is supported by the State Key Laboratory of Geomechanics and Geotechnical Engineering Institute of Rock and Soil Mechanics, Chinese Academy of Sciences (No. Z014012), Key project of national natural science funds (No. 51234004), School-enterprise funds (No. KKZ4201221008), Yunnan Provincial Fund project (No. KKSY201221070), Yunnan Province Project Education Fund (No. KKJD201521003), Yunnan Copper Group School-enterprise funds (No. KKZ4201521005), the technology projects of key technologies with the major accident of safety production in 2016(No. yunnan-001-2016AQ).

References

[1] Ll Xibing, JIANG weidong, HE Huaijian. Study on distributing state of lenticle in tailings fill dam [J]. Rock and Soil Mechanics, 2004, 25(6): 947–949.

[2] Yin Guangzhi, Jing Xiaofei, Wei Zuoan, Li Xiaoshuang. Research on the mine debris flow surging from tailings dam-break based on simulation experiment [J]. Chinese Journal of Rock Mechanics and Engineering, 2010 29(12): 3710-3718.

[3] Yin Guangzhi, Wei Zuoan, Wan Ling. Numerical simulation analysis about seepage field of Longdu tail bay [J]. Rock and Soil Mechanics, 2003, 24(10): 25-28.

[4] Yin Guangzhi, Wei Zuoan, Wan Ling, Zhang Dongming. Test study on stability of fine grained tailings dam in geo-grid reinforcement situation [J]. Chinese Journal of Rock Mechanics and Engineering, 2005 24(3): 1030-1034.

[5] Li Quan, Dang Faning, Guo Zhenshi, Ren Jie. Determination method for beach width of tailings dams and its influence factors [J]. Journal of Water Resources and Architectural Engineering, 2014, 12(4): 14-17.

[6] Zhang Qiangui, Wang Yameng, Li Guangzhi, YinGuangzhi, Wang Wensong; Zhong Ye, Yang Huohai. Simulation of the mesomechanics mechanism of the tailings dam's deformation

with particle flow code [J]. Journal of Chongqing University, 2015, 38(3): 71-79.

[7] JOPONY M, USUP G, MOHAMED M. Particle size Distribution of copper mine tailings from Lohan Ranau Sabah and its relationship with heavy metal content [J]. Pertanika, 1987, 10(1): 37–40.

[8] GIULIANO V, PAGNANELLI F, BORNORONI L, et al. Toxic elements at a disused mine district: particle size distribution and total concentration in stream sediments and mine tailings [J]. Journal of Hazardous Materials, 2007, 148(1): 409–418.

[9] BOWMAN E T, SOGA K, DRUMMOND W. Particle shape characterization using Fourier descriptor analysis [J]. Geotechnique, 2001, 51(6): 545–554.

[10] SANTAMARINA J C, CHO G C. Soil behavior: The role of particle shape[C]// Advances in Geotechnical Engineering: The Skempton Conference. Thomas Telford: [s. n.], 2004: 604–617.

[11] TU Xinbin, WANG Sijing. Particle shape descriptor in digital image analysis [J]. Chinese Journal of Geotechnical Engineering, 2004, 26(5): 659–662.