EXPERIMENTAL STUDY ON OVERTOPPING FAILURE MODE OF REINFORCED TAILINGS DAM

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Keywords: tailings dam; reinforcement; overtopping; model experiment

Abstract. Recently, the tailings dam accidents have frequently occurred caused by flood overtopping, which have great harmful to the downstream people`s lives, property safety and the surrounding environment. Based on similarity theory and take the tailings in Sichuan as test materials to doing the physical model test which was the reinforced tailings dam under flood situation during tailings dam failure process. The results indicate that: (1) The erosion gully of reinforced tailings dam has been significantly step appearance failure; the whole overtopping processes of the reinforced tailings dam can be concluded to five stages: the erosion gully formation stage →the improvement of erosion gully, which got deepen stage →erosion gully internal extended stage →step appearance erosion gully formed stage →step shape erosion gully in stable stage, the whole overtopping is significantly in step failure model; (2) the existence of the reinforced belts has obvious blocking effect on the developing speed of tailings dam destruction and the of depth、width of erosion gully, the vertical and horizontal displacement, also as the change of internal stress of reinforced tailings dam are significantly less than the unreinforced. The results have been deeply analyzed the evolution law and failure mode of tailings stacking dam, and reveal the blocking effect of reinforced belts during overtopping destruction, having some new exploration on prevention and control of flood disaster.

Introduction

Recently, he tailings dam accidents have frequently occurred caused by flood overtopping, which have great harmful to the downstream people`s lives, property safety and the surrounding environment [1-3]. In recent years, domestic and international studies on the reinforced earth-rock dam are concentrated on the stability [4-9]; however, the research on the failure mode of the reinforced earth-rock dam is very rare, only some scholars have carried out some exploratory researches on the earth-rock dam under the condition of non reinforced. Based on non-constant unsaturated flow and sediment erosion mechanism of non-equilibrium theory, and according to the model similarity theory and dam breach erosion model, the tailings dam overtopping breach evolution pattern was investigated on a self-developed tailings dam breaking simulation platform (Zhang et al., 2011). Two basic theories to study the dam-surface erosion after overtopping and mechanism of dam break due to overtopping were used. Based on the research and analysis of the destruction process of earth-rock dam break due to overtopping and combined with tailing dam its own characteristics and related theories, the destruction process of tailing dam break due to overtopping was proposed (Wei et al.,2012). Mechanism and instability model of tailing dam are reviewed, and it is shown that the available results mainly focus on the dam instability model caused by the static stability against sliding and the seismic liquefaction of the tailing pond, but less on the asymptotic failure model caused by the seepage deformation and the dam overtopping (Zhang et al., 2013).

This paper is on account of the previous comprehensive study. Based on similarity theory and take the tailings in Sichuan as test materials. We used the physical model test method to establish an

evolution model of reinforced tailings dam under flood situation, analyzed thoroughly the floating evolution of reinforced tailings dam during the dam failure process. The research results can provide guidance and suggestion for the safety and stability of the tailings dam, and it has certain guiding significance for better understanding the block characteristics of geosynthetic materials to the tailings dam during overtopping.

Similar Model Tests

Through the indoor physical model test to study the whole failure process of reinforced tailings dam under the flood condition; seeking the law of tailings dam failure evolution during the flood overtopping and block characteristics of reinforcement during dam overtopping. Further analysis the bar strips of influence mechanism and method to the stability of tailings dam.

The main research contents: (1) explore the overtopping and failure mode of the reinforcement tailings dam; (2) expose bar strips have the retardative characteristic during the destruction process of the tailings dam. Considering this model test is used to analysis the influence of bar strips on tailings dam overtopping, so we taking the routine window screen as the test reinforcement instead of geogrid which used in field. The size of tailings dam model is 1.4m×0.3m× 0.4m (length × width × height), including proportion of external slope is 1:2. The test devices are composed of 5 parts, such as: testing tank, groundwater level testing system, flood control system, vertical/horizontal displacement monitoring markers and dynamic strain gauge. The subject part of test device is a test tank of 2.0m×0.6m× 0.5m (length × width × height). To reduce the influence of friction force, we coated Vaseline over the inner wall of teat tank; also, we arranged the groundwater level testing system in it. Because of this test is to study the effect of reinforcement on overtopping of tailings dam; therefore, in the layout of the test devices we should according to the tailings dam own property put some simulation materials like the earth dam similar reinforcement materials to reach a similar situation with practical field. In order to observe the whole process of the dam breaking, the test tank is made of transparent toughened glass which thickness is 10mm. Displacement monitoring markers are the marks which set up in the dam body by test groove wall in the process of tailings accumulation, also setting marks in the corresponding position of the test groove lateral to research the effect of reinforcement on the tailings dam displacement. The whole model test system is shown in Fig.1. Studying team has carried on two different overtopping model tests of tailings dam, one is unreinforced tailings dam (the bars number: N=0), the other on is reinforced tailings dam (the bars number: N=2), the schematic diagram of laying bar is shown in Fig.2. For the physical model which scale is l , the relationship between the prototype and the model is shown in Table 1[13].

Fig.1. Test model system of tailings dam

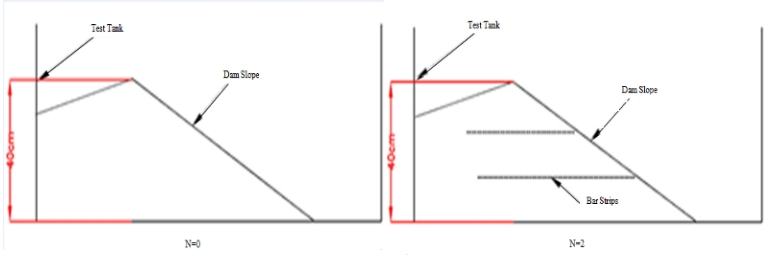


Fig.2. The schematic diagram of laying bar

Table 1 Similarity relationship between model and prototype

Similitude ratio relationship	Length	Displacement	Volume	Area	Permeability coefficient	Acceleration of gravity	Severe	Porosity	Flow	Time/Seepage
Prototype	λ	λ	λ^3	λ^2	1	1	1	1	$\lambda^{5/2}$	λ^2
Model	1	1	1	1	1	1	1	1	1	1

The sand material in this model tests is from a tailings dam in Sichuan, the ingredients of tailing is shown in Fig.3. The tests must be prepared the reinforced materials, according to reinforcement design data and literature information in home and abroad, reference to reinforced model test data of the similar roadbed and the retaining soil wall and the, etc[14]; we added the window screen into tailings accumulation instead of geogrid, the layout instruments of test is shown in Fig. 4.

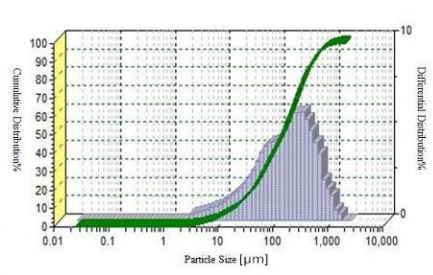


Fig.3. The ingredients of tailing

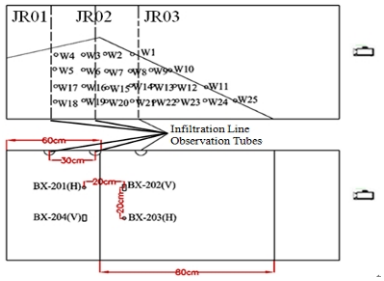
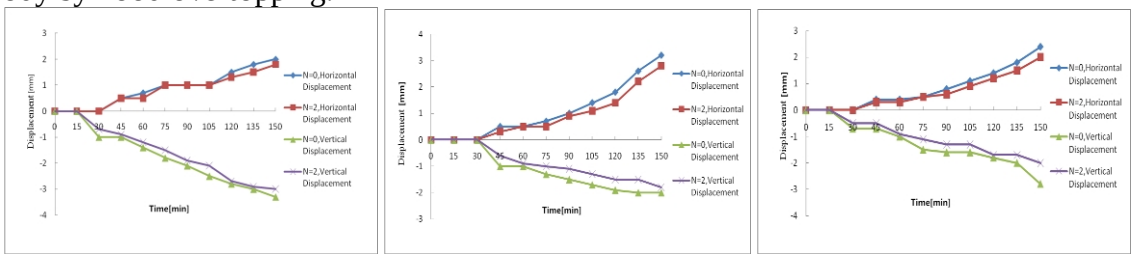


Fig.4. Layout instruments of test

Experiment results and analysis

The reinforced tailings dam model test: the physical model of tailings dam is constructed by ensure every layer soil in the same compactness and start the monitoring instruments, controlling enter water flow of reservoir by flood control system until the level reaches the highest level of design. Maintain the height of the water level till the water level in the observation tube has kept constant. Continue injection into the reservoir area until the dam has collapsed by flood overtopping.

Displacement Law. Inject water into the reservoir area by flood control system. According to the displacement monitoring data, we obtained the displacement variation of key points including unreinforced and reinforced tailings dam model tests, such as a point at dam top (W1), one in the middle of dam body (W8)and another point on the middle of dam slope (W10), which is shown in Fig. 5. From Fig.5 we can aware that the whole deformation law of tailings dam is developing toward under and external slope. The horizontal and vertical displacement of two points (W8, W10) which in the condition of reinforced tailings dam are less than unreinforced. The main reason is the retardative characteristic of reinforced zone after overtopping, which manifested as tuck net effect on tailings in the vertical direction and in the horizontal direction shown as pull effect; that effectively decreased the carrying amount of tailings by flood, leading to the vertical and horizontal displacement of reinforced tailings dam are significantly less than the unreinforced. Lying of bar strips reduces the damage effect to dam body by flood overtopping.



(a) The displacement variation of W1 (b) The displacement variation of W8 (c) The displacement variation of W10

Fig.5.The displacement variation of key points in tailings dam

Law of overtopping failure. The unreinforced tailings dam after overtopping formed the erosion gully at dam top (which is shown in Fig.6 (a)); with the continuous development of erosion gully and flood discharge increased gradually, the carrying amount of tailings also increased gradually and the transformed into silt flow (which is shown in Fig.6 (b)); as the development of erosion gully, its depth has gotten deeper; under the erosion effect, the two wings of gully collapsed toward internal on the pull effect of water flow, Leading the gully lateral expansion formed into significantly ”Y” font gully (which is shown in Fig.6 (c)); Gully developing continuously, the sloughing tailings which carried by the flood turned into debris flow and large scale destruction of tailings dam appeared (which is shown in Fig.6 (d)), until reservoir inflow with discharge of water balanced. After the end of floating, the gully width reaches 43cm and the maximum depth is 22cm after the unreinforced tailings dam failure, which is shown in Fig.7

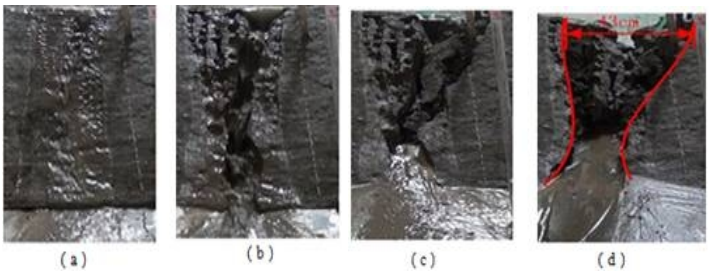


Fig.6. The flood overtopping evolution graph

Fig.7. The failure consequence graph of unreinforced tailings dam overtopping

Through the test of the reinforced tailings dam we can find that, the flood scouring dam body after overtopping occurred; on the pull effect of flood, there parts of erosion tailings washed to the dam tail which formed into minimal gully (which is shown in Fig.8 (a)), in this condition, the water discharged of gully is less than reservoir flood inflow; In the further development of gully, only small collapse happened at two wings; and the width of the formed gully from dam top to toe of slope are almost equal, but the depth of longitudinal fracture has obviously deepened (which is shown in Fig.8 (b)); Gully developing continuously until reservoir inflow with discharge of water balanced, the longitudinal fracture has not developed and significant scarp occurred on the position where lying the bar strips of the slope (which is shown in Fig.8 (c)); with further erosion by flood, the gully gradually expanded; tailings in the front part of every layer reinforcement zone has taken by flood which caused it hanging discharged directly from this layer (which is shown in Fig.8 (d)); at last, forming into a width and depth respectively are 8cm and 14cm dam burst, which is shown in Fig.9.

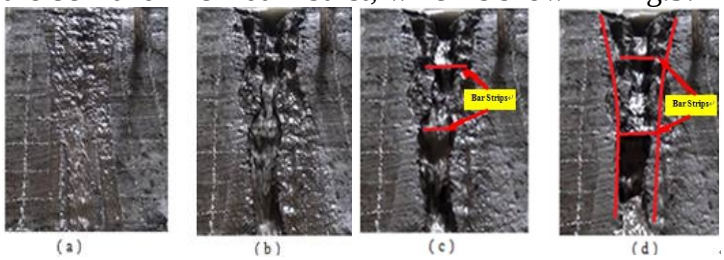


Fig.8. The flood overtopping evolution graph

Fig.9. The failure consequence graph of reinforced tailings dam overtopping

Through the digital camera, recording the change of dam breach width, depth including two tests and the relationships between the width/time and depth/time were gained finally. Respectively, are shown in Fig. 10 and Fig.11.

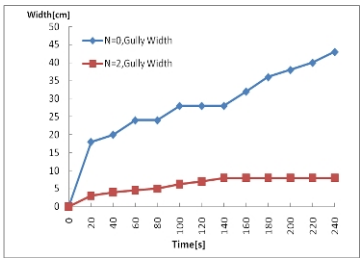


Fig.10. The width changes graph of gully

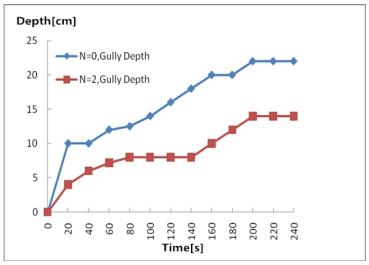


Fig.11.The depth changes graph of gully

From Fig.11 and Fig.11 we can know that: the existence of the reinforced belts has obvious blocking effect on the developing speed of tailings dam destruction and the of depth, width of erosion gully, the vertical and horizontal displacement, also as the change of internal stress of reinforced tailings dam are significantly less than the unreinforced;

(1) After occurred dam floating under the same condition, the developing speed of destruction and the depth, width of erosion gully of reinforced tailings dam are both less than unreinforced. In the case of reinforcement the bar strips have separation effect on discharged flow, which cloud be blocked the development of gully and ensured the stability of dam body to some extent; at the same time, it also blocks the excessive scouring at the dam bottom by flood, as to reduce the depth and width of gully. It is showed that the presence of the reinforcement has a better blocking effect on the failure of the tailings dam.

(2) The reinforced tailings dam carrying less tailing during the process failure of flood. This is due to the unreinforced tailings dam after gully formed; the two wings easily appeared the phenomenon of movement and instability collapse by flood. Therefore, after the collapsing, many tailings flooded away and turned into debris flow; however after the reinforcement, the tailings are separated by bar strips; the dam produced less slip surface with the lock force in the reinforced zone, and the tailings which in both sides of gully have become one body and formed into block, thus there will not being slide or collapse in a large area. The loss rate and amounts of the tailings were both decreased that effectively prevented further collapse of dam.

As the tailings dam occurred floating under the condition of reinforced, the stability of the dam has been greatly improved; at the same time, in case of lying bands which improved the retardative characteristic, ensured the stability of both wings and reduced risk of the dam outburst.

Conclusions

Through the model test analysis the failure mode of the reinforced tailings dam overtopping, the conclusions follow as:

(1) the whole overtopping processes of the reinforced tailings dam can be concluded to five stages: the erosion gully formation stage →the improvement of erosion gully, which got deepen stage →erosion gully internal extended stage →step appearance erosion gully formed stage →step shape erosion gully in stable stage, the whole overtopping is significantly in step failure model;

(2) the existence of the reinforced belts has obvious blocking effect on the developing speed of tailings dam destruction and the of depth, width of erosion gully, the vertical and horizontal displacement, also as the change of internal stress of reinforced tailings dam are significantly less than the unreinforced.

Acknowledgements

The research reported in this paper has been funded by the National Natural Science Foundation of China (No.51404049); Scientific and Technological Research Program of Chongqing Municipal Education Commission (Grant No. KJ1501328); the Interior Research Foundation of Chongqing University of Science & Technology (CK2014Z12); the Graduate Student Research Innovation Project of Chongqing (CYS15228), Innovative Team of Safety Risk Control Engineering Foundation of Chongqing University of Science & Technology, The authors thank very mush the reviewers for their constructive comments.

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