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Experimental Study of the Stability of Spur Dyke for Different Types

[1]Yu Tao, [2]Wang Ping-Yi and [1]Chen Li
[1]Key Laboratory of Hydraulic and Waterway Engineering of the Ministry of Education,
Chongqing Jiaotong University, 400074, Chongqing, China
[2]National Engineering Research Center for Inland Waterway Regulation,
Chongqing Jiaotong University, 400074, Chongqing, China

Abstract: The stability of spur dyke directly affect the regulation effect of waterway and therefore how to choose more suitable structures and materials of the spur dyke become the concerns of many scholars. Though flume tests, firstly the stability problem of enrockment dams which are used frequently now by comparing the cross-section of the dam body type was researched, pointing out that the arc-shaped cross-section of the the dam body structure is more stable than the trapezoidal structure under the same flow conditions and obtaining the boundary conditions lead to water damage of enrockment spur dyke. Secondly, comparison and analysis research of the stability of the two new types of spur dyke (dam body is riprapping and dyke furface is concrete hinge; dyke body is riprapping and dyke furface is concrete and dry-laid pitched stones revetment) under different water level drops before and after groins in the flow conditions obtained above are given in this study and proposed that the size of drop water height is one of the restriction factor of dyke's damage. It points out that these two new structure types of spur dyke has better stability than enrockment dams and problems should be noticeed in the engineering design which can be promoted and applied in practical engineering.

Key words: Spur dyke, structural type, stability, flume experiment

INTRODUCTION

Spur dyke as a channel regulation structures are widely used in channel regulation project (Przedwojski, 1995). At present most of the upper Yangtze river dyke is scattered riprap structure (Wang *et al*., 2001). In the actual project, due to the current top impact effect, its water damage is more serious (Fang, 2006; Wang *et al*., 2004). Such as head's flood damage, root's flood damage, body and back water slope's flood damage, they seriously affected the effect of spur dyke regulation (Li *et al*., 2005; Yu *et al*., 2010; Fazli *et al*., 2007). In order to find better stability of the dam structure, this study analyzes the different dam body section form and structure of the material and compared their corresponding spur dyke's stability through the tank model research, thus puts forward a better stability spur dyke pattern.

EXPERIMENT

Test layout and equipment: The experiment was carried out in Chongqing Jiaotong University, National Inland Waterway Regulation Engineering Technology Research Center. A rectangular glass flume having dimensions of 30 m long, 2 m wide and 1 m high and flume Central laying a 8.0 m-long movable bed segment,surrounding the spur dyke sanded height 0.22 m, the other area sanded height 0.12 m, The model layout shown in Fig. 1. The inlet flow controlled by the DCMS flow control system jointly developed by Tsinghua University and Beijing still water information technology company (Fig. 1), the controlled water level front of the dam was controlled through the water level of the stylus, Read water level measured by the level of the stylus, the scoured terrain was measured through the ultrasonic 3D terrain measurement system (TTMS).

Test scheme: In preliminary research, found that a certain section of the dam body (xiaomitan) was severely damaged on the spur dam, even a whole section of the dam body washed away or collapsed occurred (Fig. 2).

Analyze the reason, it is not difficult to find the cause of this phenomenon is determined by the specific flow conditions. This section of channel is bended, Yang Gong Bei, Mao Shi Pan, Wang Tan Shi which extend into the middle of the river on the left bank are opposite Mao Ze Qi on the right bank in the upper section (Fig. 3), dam body is riprap structure, sediment front of the dam was

Corresponding Author: Yu Tao, Key Laboratory of Hydraulic and Waterway Engineering of the Ministry of Education, Chongqing Jiaotong University, 400074, Chongqing, China Tel: +86-23-62652649

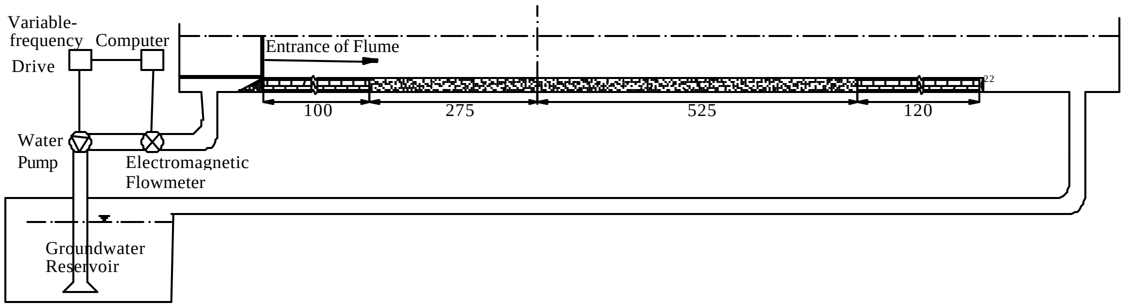

Fig. 1: Trial model layout

Fig. 2: Spur dyke water damage photos on xiaomitan

scoured by currents constantly during withdrawal of water period, scour hole occured at dam heel, leading to local dam foot rubble in suspending state, thus dam body loosening occurred, plus the following year flood, at this time spur dyke was scoured by flood in the mainstream scouring position, so repeatedly caused local dam body and dam surface rubble to be washed away.

This trial is carried out in a straight flat-bottomed flume, without shaping riverbed topography, also won't appear the flow conditions which the mainstream scours the dam heel or dam body , so it is difficult to simulate the phenomenon of erosion of the dam body and behind dam. Therefore, in the experiment was the amplification way of local dam body taken (dam body takes 2 meters long, truncating the flume), causing the flow conditions which the mainstream scours dam body to occur, to research water damage mechanism of dam surface and downstream slope of spur dyke.

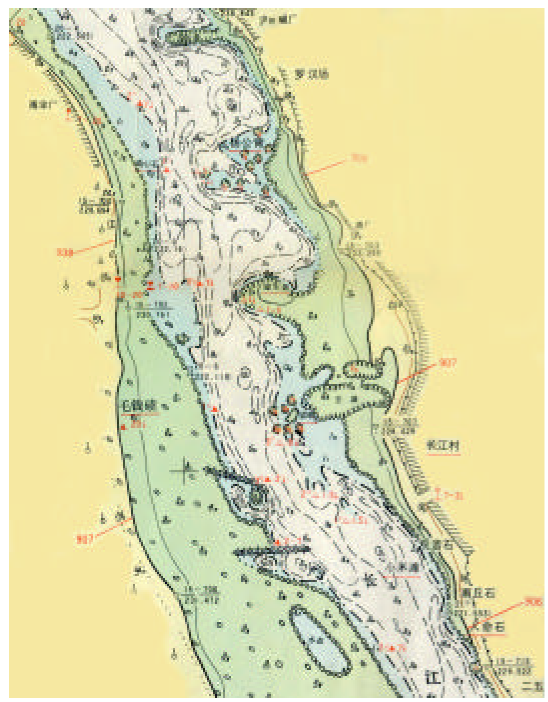

Fig. 3: Xiaomitan river regime

In accordance with the actual observations of the prototype, when the water flow just overtop the dam to approximately 2 m depth, the damaging effects on dam body is the most obvious, average velocity of overtopping water flow is about 3 m sec^{-1} , the calculated flow control is 0.038 m^3 sec^{-1}, taking this boundary condition as the initial boundary, observing the process of water damage destruction of the dam body by adjusting the downstream water level and record its corresponding flow conditions.

Dam body is 6-12 mm mixed gravel, dam crest width is 7.5 cm , upstream slope is 1:1.5, downstream slope is 1:2, aquifuge is setted in the cross-section through the top of upstream slope, control permeation rate of dam body is approximately 3%. The experiment model selected γ = 2.65 t m^{-3} natural quartz sand as model sand, d_{50} is 1 mm.

DAM STABILITY ANALYSIS

Stability of scattered riprap dam body: Select condition M4 (dam length is 50 cm, dam body section is trapezoidal, Q = 95 l sec^{-1}, H = 14 cm) and condition M5 (dam length is 50 cm, dam body section is circular-arc, Q = 95 l sec^{-1}, H = 14 cm) to comparing and analyzing the stability of the enrockment dam with different body section type. The line of X = 0 coincides with the axis of the spur dyke in Fig. 4.

It can be seen from Fig. 4, in the same flow conditions, different dam body cross-section will cause different scour range and depth of the bed and the influence of the arc one is less than the trapezoidal one; As is shown in Fig. 5, in the same flow conditions, the spur dyke whose body cross-section is circular arc was damaged by flood to a lesser degree (the trapezoid cross-section one is more 20% serious than the circular arc one). Therefore, the arc body cross-section structure of enrockment spur dyke is much steadier. This is because first the circular arc dam interferes to flow to a lesser degree, thus the whirlpool near and downstream the jetty head with less energy which in turn makes a smaller damage to the bed surface; Second the water-blocking level of the circular arc dam approximate the trapezoidal one (the area of the circular arc equals the trapezoid's), indicating that the arc dam will not produce more influence on the management effect. Therefore, the circular cross section of the dam body structure has better stability.

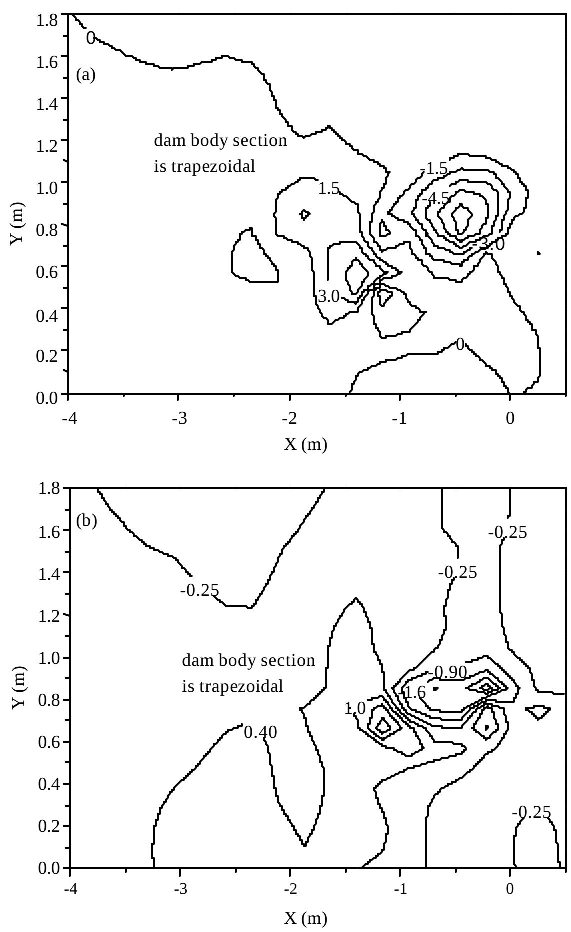

Fig. 4(a-b): Bed surface erosion contrast in different type of enrockment dam (the unit for values of contour lines: cm)

Stability of the ballast dam body with concrete and grouted band: In the regulation of Chuan River, about 1 m of the groyne's coat and head were grouted by cement and the other place built by thrown rubble. The model bulk of the enrockment dam is 10 cm high in the whole, 7.5 cm wide in crest, 1:1.5 in upstream Slope and 1:2 in downstream. In order to compare the two structures' stability, partial enlarge the ballast of concrete and grouted band under the condition of the overall model data constant, changing cement mortar paste build of the upper groyne from 1 cm to 2.5 cm and the lower dam with scattered riprap to 7.5 cm high (Fig. 6). Size distribution of the bed material median size is 1 mm.

As shown in Fig. 7a, basically the dam surface has not been destroyed, therein just the back water slope and its toe has a certain degree of erosion and the spur dyke is still available, indicating that the groyne's stability have been markedly improved after ballasted with concrete and grouted band.

With the continuous decline in the downstream water level, drop height increase gradually, the severe eddy

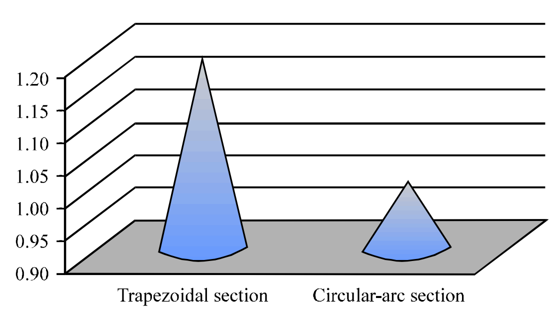

Fig. 5: Flood damage degree contrast in different type of enrockment dam

current after the dam scour pit constantly undercuts the gravel and sand foundation of the back water slope (Scattered riprap structure) under the ballast of grouted band, as time went on, the whole dam crest in the second half of the part is in an impending state (Fig. 7b-d); When a drop height of 7.1 cm, turn dam water flow's velocity is huge and ground bottom trend is very apparent, making the back water slope and slope foot's washing more and more serious, so that as the scour development to a certain degree the base ballasted with grouted band is mainly empty; With the development of flushing process,

Fig. 6: Photos of the ballast of concrete and grouted rag model

the larger the permeable rate of local area is, the bigger the flow velocity of its pore water is, plus the vertical velocity of turn dam body (or root) water flow to the dam crest and its back slope is more and more big (water flow to the dam crest have a downward force), leading the larger permeable rate place of dam to be first destroyed (Fig. 8a) and eventually the whole dam (or a section) collapse occurred (Fig. 8b), causing the spur dyke regulation function failure.

Stability of the dam body with concrete block hinge rank protective faceing: The model structure of concrete block hinge rank protective faceing spur dyke is like this, the dam body still consists of cast loose gravel (6-12 mm) and the size of the dam is similar with 3.2, the surface of the dam is covered and ballasted with the row body model that is advance production (Fig. 9) and embedded 7-8 cm row body extend to the bed surface in the toe of face water slope as well as the back, they are shown in Fig. 10.

From the above photos we can know that, the effect is obvious that concrete block hinge line body protects dam from impingement. Along with the reduction of tail gate, the drop height before and after the dam is bigger and bigger so that the velocity of the flow over crest also gradually increase, but the erosion to macadam of the dam

Fig. 7(a-b): Photos of the ballast dam body with concrete and grouted rag water damage process (a) Water head before and behind the spur dyke is 4.5 cm (b) Water head before and behind the spur dyke is 5.5 cm (c) Water head before and behind the spur dyke is 6.1 cm and (d) Water head before and behind the spur dyke is 7.1cm

Fig. 8: Photos of the ballast dam body with concrete and grouted rag collapse (a) Water damage firstly occurred where permeability rate is larger (b) Whole dam body damaged

Fig. 9: Model of concrete block hinge rank

Fig. 11: Sediment deposition and row body bulge in the back water slope

Fig. 10: Model of dam body with concrete block hinge rank protective faceing

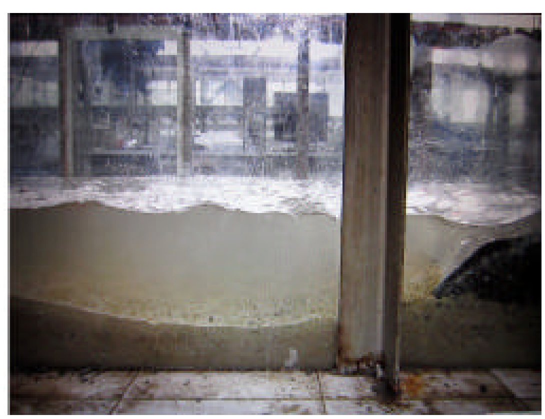

Fig. 12: Scouring pit in dam downstream

Fig. 13: Photos after scouring under the condition of 5 cm drop height before and after the dam

body which was covered by hinge line body isn't. That's because there is a part of space between the hinge line and the dam body, where water flow into, affected by various factors, its energy loss will be huge, when the water exposed to the dam's gravel, it has been unable to cause significant damage to the dam body. The bulge phenomenon (Fig. 11) of spur dyke's back water slope hinge line body appeared in the process is due to the flow uplift pressure caused by the pressure difference outside and inside the hinge line body. With the addition of drop height, the sediment deposition in the dam body back foot gradually increases, but also it play a positive role to the stability of spur dyke body. When drop height reach 5.0 cm (Fig. 12 and 13), under the same conditions the scattered riprap dam has been destroyed, the spur dyke with concrete block hinge rank protective faceing, instead, was mainly intact, what sound that the structure has better stability and can be promoted and applied in the actual project.

CONCLUSION

In the same flow conditions, the spur dyke structure whose body using circular cross section is much steadier than the trapezoidal cross sectional structure. The problem that the construction of circular arc form dam body transect is relatively difficult can be resolved by this solution, under the regulation stage adopt general construction method of riprap spur dyke and above the regulation stage apply modern advanced construction technology to the arc section part.

This study puts forward that the size of drop water height is one of the important restriction factor to destroy the dam, at the same time points out the two kind of new structure that the dam body with concrete and grouted band ballast and the one with concrete block hinge rank protective faceing has better stability than scattered riprap dam, so that can be promoted and applied in the actual project.

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