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Research Article

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Water damage mechanism of surface and downstream side of spur dike

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ABSTRACT

At present the research on water damage mechanism of spur dike are more confined to dike head, but that a large number of water damage phenomenon happened in the dike surface and downstream slope is found through analysing the field investigation and experimental phenomenon. This article first simulates the boundary condition on water damage of dike surface and downstream slope, and then observe the process of washout, so that reveals its mechanism. When the dike body is riprapping, destructive flow condition of recession period and the next flood season, leading to the unstable of dike body and the large pressure difference between its front and back, will cause dike surface and downstream slope be destroyed. When the dike body is riprapping and dike furface is concrete hinge, stream of overflowing dam with an apparently downward acting force causes the serious erosion on the downstream side. With the development of the scour process, local large permeable rate basis area will be scoured much more seriously. When the dam surface is unable to bear the force down to the dam crest from the downward water flow, it will be collapsed.

Key words: Spur dike; Water Damage Mechanism; dam surface; flume experiment

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INTRODUCTION

When a spur dike is located in the outer bank of a bend, the scour process is a complex phenomenon. Despite their abundant use, the spur dikes located at the bends of rivers have witnessed few comprehensive studies [1]. Domestic and foreign scholars have done a lot of research on water damage mechanism of spur dike. For ex-ample Przedwojski, Mesbahi, and Fazli et al. experimentally studied the influence of some of the important parameters on the maximum scour depth [2-4]. According to the sediment balance theory, the spur dike head of local scour depth calculation formula was derived, and which was verified by the Yellow River downstream of the prototype observation data and laboratory test data (Ma Jiye et al. 1998) [5]. Based on the data of the hydraulic model test, the calculation formula of the maximum depth of partial scouring of the groyne is put forward and the calculation formulas of the maximum depth of partial scouring of the groyne are given when the platform or the platform together with the toothed pit is applied as the protection measure of the groyne by FANG Daxian [6]. Obviously, much more research about water damage mechanism have been done on the head than the surface and downstream side of spur dike[7-8]. In this issue, it is simulated and studied through model experiments, and points out the reasons of breaking.

EXPERIMENTAL SECTION

IMMOVABLE BED EXPERIMENT

A serial of experiments used to study the water force on spur dike dam are carried out in a rectangle glass flume with the length=30m and the width=2m in Key Laboratory on Hydro and Water Transport Engineering of Chongqing City located in the Chongqing Jiaotong University.

Two different lengths of dike body, 30cm and 50cm, are adopted in experimental model. According to re-quirement about the body structure of spur dike in the Ministry of Communications Technical Code of Regu-laion Works for Navigation Channel, the dimensions of spur dike are as follows: trapezoidal cross section, up-stream slope=1:1.5, downstream slope=1:2, slope towards the river=1:2.5, width at the top of dike=12 cm, dike height=10 cm. The organic material is used for the construction of dike body. In order to study the hy-draulic pressures (including hydrostatic pressure, hydrodynamic pressure and fluctuation pressure) in different positions in the 7 pressure transducers are installed in the slope upstream and slope towards the river. The pressures have been recorded automatically by using Japanese production 3066 high accuracy pen type, whose error could be guaranteed within 5%.The distribution of the measurement points are shown in Figure 1.

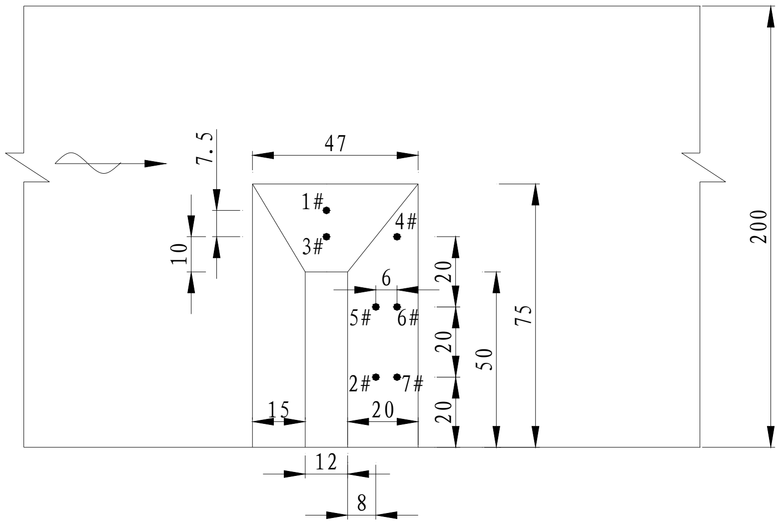

Figure 1(a) Horizontal view of measurement positions(uint: cm)

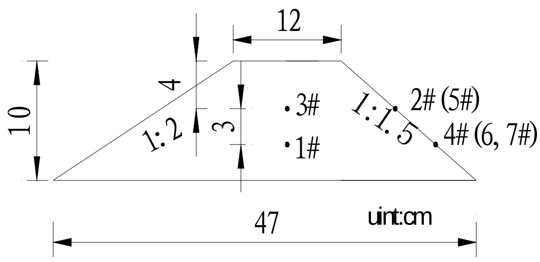

Figure 1(b) Vertical view of measurement positions

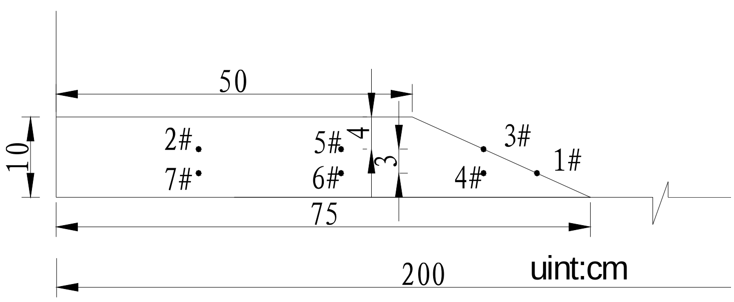

Figure 1(c) Lateral view of measurement positions

MOVABLE EXPERIMENT

The experiment was carried out in Chongqing Jiaotong University, National Inland Waterway Regulation Engineering Technology Research Center, 30 meters long, 2 meters wide and 1 m high rectangular glass flume. flume Central laying a 8.0m-long movable bed segment, surrounding the spur dike sanded height 0.22m, the other area sanded height 0.12m,the model layout shown in Figure 2. The inlet flow controlled by the DCMS flow control system jointly developed by Tsinghua University and Beijing still water information technology company(Shown in Figure 2), 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).

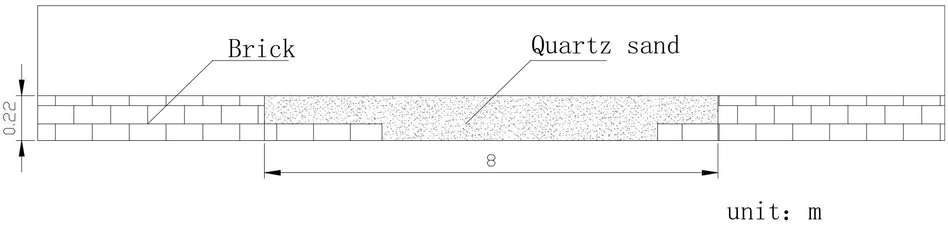

Figure 2. Trial model layout

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 dike.

In accordance with the actual observations of the prototype, when the water flow just overtop the dam to approximately 2m depth, the damaging effects on dam body is the most obvious, average velocity of overtopping water flow is about 3m/ s ,the calculated flow control is 0.038m^3/s, 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 6-12mm mixed gravel, dam crest width is 7.5cm , 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=2.65t/m^3 natural quartz sand as model sand, d_{50} is 1mm.

RESULTS AND ANALYSIS

EFFECT OF DISCHARGE ON THE PRESSURE ON DIKE BODY

Taking the easily-ruined spur dike head 1# the as the example, the pressure distribution at 1# measurement point under each experimental circumstance are given in Tables 1 and 2. Figures 2 and 3 respectively show re-lationship between the total pressure and the fluctuation pressure at the measurement point with different ex-perimental.

It can be seen from Figs. 3 and 4 that the total pressure and the fluctuation pressure acting on the dike body increases with the increasing discharge under different experimental circumstances.

Table 1 Capacity (Pa) table of different flow total pressure at 1#

Discharge(l/s)	51	68	80
L=50cm,h=10cm,i=2‰	707	710	714
L=30cm,h=10cm,i=2‰	610.0	650.6	669.3
L=50cm,h=12cm,i=2‰	1001	1118	1152
L=30cm,h=12cm,i=2‰	818.4	935.3	960.7
L=50cm,h=10cm,i=0	684.6	721.8	782.8
L=30cm,h=10cm,i=0	657.4	717.4	767.9
L=50cm,h=12cm,i=0	569.3	636.9	725.1
L=30cm,h=12cm,i=0	516.6	581.0	655.6

Table 2 Capacity (Pa) table of different fluctuation pressure at 1#

Discharge(l/s)	51	68	80
L=50cm,h=10cm,i=2‰	91	117	137
L=30cm,h=10cm,i=2‰	66.1	71.2	81.3
L=50cm,h=12cm,i=2‰	41	46	56
L=30cm,h=12cm,i=2‰	40.7	50.8	55.9
L=50cm,h=10cm,i=0	81.3	91.5	91.5
L=30cm,h=10cm,i=0	61.0	61.0	55.9
L=50cm,h=12cm,i=0	30.5	35.6	30.5
L=30cm,h=12cm,i=0	30.5	40.7	45.7

3.2 EFFECT OF DIKE LENGTH ON THE PRESSURE ON DIKE BODY

By using the data listed in Tables 1 and 2, the relationship of total pressure and the fluctuation pressure and length of dike at 1# point are shown in Figures 3 and 4.

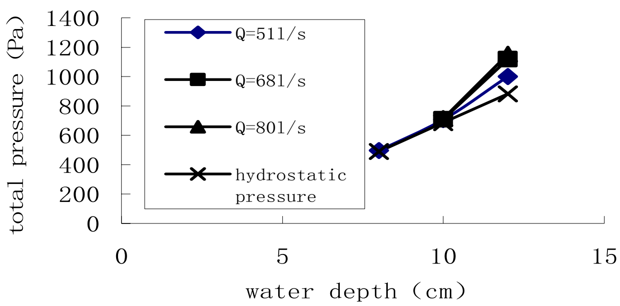

Figure 5. Effect of water depth on total pressure

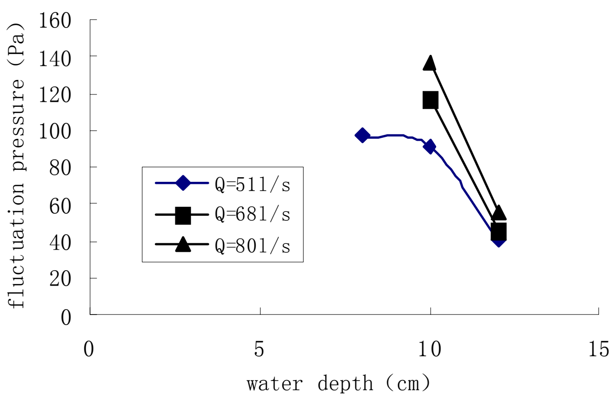

Figure 6. Effect of water depth on fluctuation pressure

As shown in Figure 5, the total pressure and the fluctuation pressure on the dike body increases with the in-creasing water depth. Moreover, the increasing speed the total pressure with an increase of water depth is big-ger than that of hydrostatic pressure, which explains that the destruction of dike is mainly caused by the hy-drodynamic pressure and the fluctuation pressure. In other words, the influence of hydrostatic pressure is smaller. It can be seem from Figure 6 that the fluctuation pressure on the dike body doesn't vary in the vertical direction when the water surface is under the top of dike. However, when the spur dike is submerged the fluc-tuation pressure will reduce with an increase of water depth. This indicates that for the case of water surface over the top of dike the turbulence around dike head will have certain extent reduction with an increasing wa-ter depth, and the pulsation velocity and the fluctuation pressure will have a certain extent of reduction as well.

STABILITY AND WATER DAMAGE MECHANISM OF DAM BODY

According to the initial boundary conditions mentioned above, flow is discharged and level is debugged. After water level is stable, the first measurement runs. Analysis results are shown in table 3 and Figure 7.

Table 3. Relationship between damage degree of dam body and drop

Time	Dam front water level	Hydraulic drop	Degree of water damage
	cm	cm	
Beginning	14.40	3.1	A little
Discharged 10 mins	14.30	3.8	Ordinary
Discharged 40 mins	14.25	4.5	Great
Discharged 60 mins	13.75	5.0	Complete

Under the steady discharge, range of stage, with the fall of downstream water level and invariableness of upstream water level, increase gradually. Flow velocity of stream of overflowing dam, especially down-stream side of dam crest, is very fast. And it caused the scour in dam face and downstream bed. When range of stage is to a certain degree, dam face and downstream bed cannot stand the force from the flow. Dam face and back of dam will be damaged by water.

As seen in table 3, at the beginning, when the drop is only 3.1cm, flow velocity of dam face can only in-duces a little gravel to start and rolling and causes slight damage. With the fall of level and the gradual in-crease of drop in front and behind dam, the level of damage becomes larger. After each debug of water level, when flow velocity begins to change, dam face is damaged apparently. When new slope is formed due to the rolling or sliding, dam body restores stability until the whole dam crest is damaged completely finally. Figure 7 shows the difference of prior to erosion and after erosion in dam body local enlarged pattern. It illustrates that damage of dam body takes place on dam crest firstly and concentrated in the dam crest and back slope of dike. And collapse and rolling of gravel are main failure modes. Some deposit occurs in back slope of dike due to the low permeable rate. This phenomenon also occurs in filed investigation.

(a)Not scoured

(b)Scoured

Figure 7. Comparison chart of prior to erosion and after erosion of enrockment dam body which is local enlarged

CONCLUSION

The sediment in front of dam is constantly scoured and undercut by flow in recession period. Scour hole oc-curs in the toe of dam which leads to the gravel in the local toe of dam to be in suspending state. So dam body becomes loose. In the following flood season, the mainstream return smooth. In this period, the dam is in the scouring position and is damaged by flood. Flow velocity of the stream of overflowing dam, especially downstream side of dam crest, is very fast. And it caused the scour in dam face and downstream bed. When hydraulic drop is to a certain degree, dam face and downstream bed cannot stand the force from the flow. Dam face and back of dam will be damaged by water.

When hydraulic drop is large enough, Flow velocity of stream of overflowing dam will be very fast and dip trend of flow will be obvious. And erosion is serious in the back slope of dike and its toe. With the continuous development of the erosion process, flow velocity is fast in the place where the permeable rate is large. With the development of erosion, the foundation under the ballast squared stone is almost emptied. And vertical Flow velocity of the stream of overflowing dam, toward the dam crest and back slope of dike, becomes faster (A downward force of the water on dam crest). So dam body (or dike root) is damaged firstly in the area where the permeable rate is bigger and the whole dam body (or a section of dam) is collapsed finally.

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REFERENCES

[1] James Fox. An Environmentally Friendly Barb Design For Washington State[J*].Research &Extension Regional Water Quality Conference*.**2002**.
[2] Mesbahi, J. On combined scour near groynes in river bends. M.Sc. thesis, Hydraulics Rep. HH 132, Delft Univ. of Technology,Delft, Netherlands, **1992**.
[3] Przedwojski, B. *J. Hydraul. Res*., 33(2), 257–273,**1995**.
[4] Fazli, M., Ghodsian, M., and Salehi, S. A. A. Experimental investigationon scour around spur dikes located at different positions in a 90° bend. 32nd Congress of IAHR, Venice, Italy, **2007**.
[5] Ma Jiye, Wei Zhilin, and Zhang Baishan. *Yellow River*, 20(3), 13-15,**1998**.
[6] FANG Daxian. *Journal Of Hefei University Of Technology,* 29(11), 1436-1439,**2006**.
[7] WANG Ping-yi, CHENG Chang-hua, RONG Xue-wen, HE Xiao-chun. Channel regulation buildings water destroy of theory and simulation technique. Beijing: People Communications Press, **2004**.
[8] Yu Tao, Wang Ping-yi, Gao Gui-jing. Turbulence Kinetic and Local Scour Around Spur Dike, Proceedings of the Ninth International Symposium on River Sedimentation, **2010**,09.