EXPERIMENTAL STUDY ON THE ENERGY DISSIPATION OF JETS COLLISION AND RAINFALL INTENSITY ALONG THE SIDE SLOPES

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ABSTRACT

For energy dissipation by collision of multilevel jet flows, the enlarge of collision area can not only enhance the dissipation rate but also generate high intensity splash at the slope of the stilling basin. The energy dissipation got enhanced is good for the safety of bottom of sting basin, but it may be harmful for the stability of the basin side slope. The energy dissipation and splash intensity are contradictions for the design of many large dams. In this paper, based on physical models, the dissipation efficiency and splash intensity of a collision energy dissipater with multi-surface outlets and mid-level outlets are investigated. A new collision dissipater, which enlarges the inner collision area and reduces the outer collision area by adjusting the thickness of collision flow, is proposed. The dissipater both enhances the dissipation efficiency and weakens the splash intensity, and is worthwhile to popularize.

Key words *: Energy dissipation by collision, dissipation efficiency, splash intensity*

1. INTRODUCTION

In many high arch dams, surface outlets, mid-level outlets and stilling basins are usually combined to dissipate huge energy. The combined dissipater has been successfully utilized in many high dam projects. The jet flow from surface outlets acts huge force on the bottom of stilling basin and may generate deep scouring pit there. The pit may deteriorate the safety of dam and stilling basin. So in design of surface-midlevel-stilling basin dissipaters, much efforts should be payed to increase the collision area of jets, for the purpose of better dissipation efficiency, and decrease forces on the bottom of stilling basin for fear of the bottom scouring.

Many researchers have conducted their work on the combined dissipaters, such as Diao[1-2] proposed a type of asymmetric collision of jets, and came up with a method for calculating the dissipation efficiency of jets collision. Sun[3] and Li[4] presented the surface outlets with broad tail pier plus mid-level outlets with narrow gap dissipaters, which utilized the un-collision jets for energy dissipation. Sun[5-6] studied the co-relationship between discharge magnitude and impact force on bottom of stilling basin.

Although the collision enhanced the dissipation efficiency, it also leads to the flood discharge atomization. Lian[7-9] studied the splash and proposed a model of predicting the atomization. Han[10] and Chen[11] presented their works on the manners of precipitation protection. Wang[12] make a dent in the precipitation intensity and range of atomization. These works gave much helps on understanding either the energy dissipation or flood discharge atomization, however, little research is on the balancing of energy dissipation and flood discharge atomization. Furthermore, the collision of jets will generate water splash on the slope near the stilling basin, which many the destroy the stability of slope. The two parameters for surface-midlevel-stilling basin dissipaters, impact forces on bottom of stilling basin and precipitation intensity, hold contradict relationship.

A high arch dam adopts five surface outlets and six mid-level outlets for discharging. The outlets are symmetrical arranged, and the axis is coincident with the axis of stilling basin. In order to optimate the energy dissipation and splash on side slopes of the dam, a physical model was produced to investigate the jets collision. The model lies in the hydraulic testing hall of CRSRI, and the model designed according to the gravity similarity criterion. Small gravels with the diameter of 14.2mm are put on the bottom of the stilling basin to simulate the scouring of bottom. The locations of the side surface outlets and side mid-level outlets are shown in Figure 1. Through series of tests, the study balanced the energy dissipation and splash on slopes, and it is a valuable reference for designing other dams.

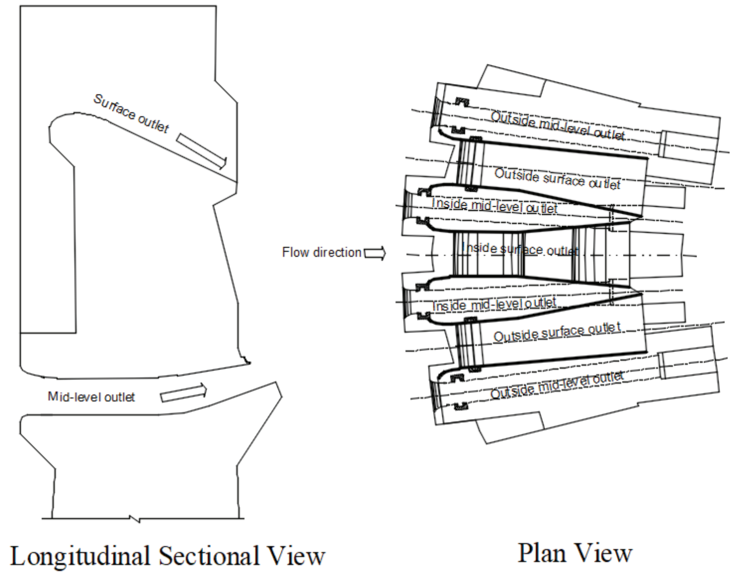

Figure 1 : Outlets layouts of the dam

2. EXPERIMENT TESTS

The major purpose of the experiments is to hold both the scouring depth and precipitation Intensity in an acceptable range. The original scheme is shown in Figure 2. The outlet angle is 25 degree, and width of outlet is 15.65m. For optimization scheme I, a 10m×1m×15m broad tail pier is added to the outside wall of the outside surface outlet. For optimization scheme II, a 3.6m×4m toothed pit is added to the outside. For optimization scheme III, a 7.7m×6.0m×3.6m wedge is added to bottom of the outside surface outlet. The flow conditions are listed in table 1.

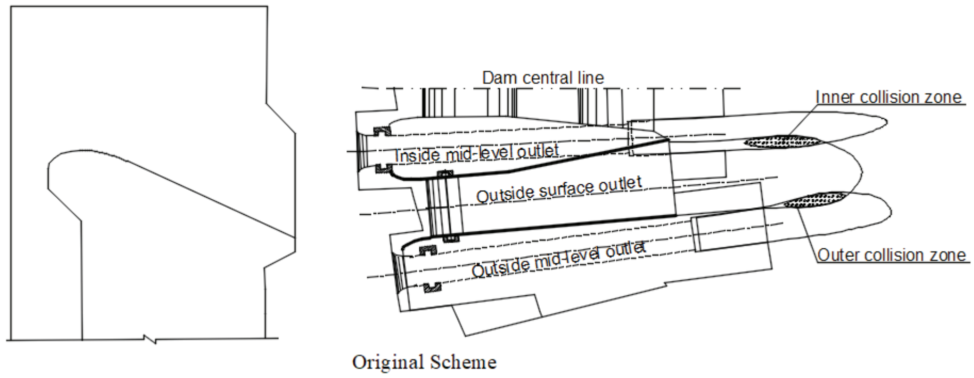

Figure 2 : Original scheme of outside surface outlets

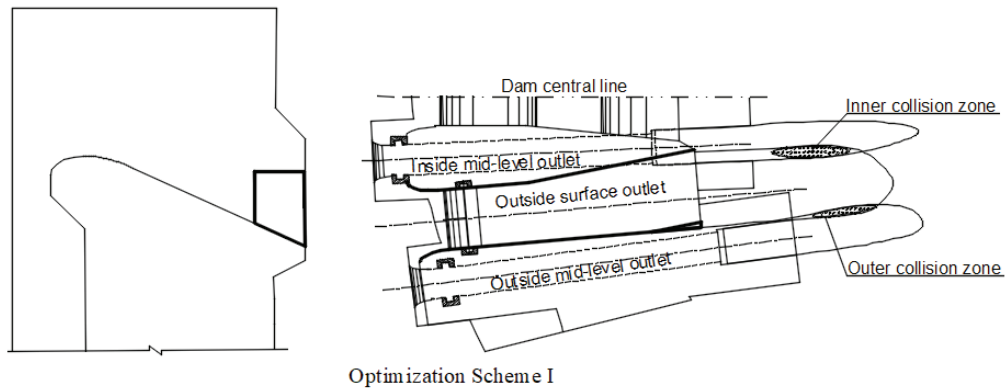

Figure 3 : Optimization scheme I of outside surface outlets

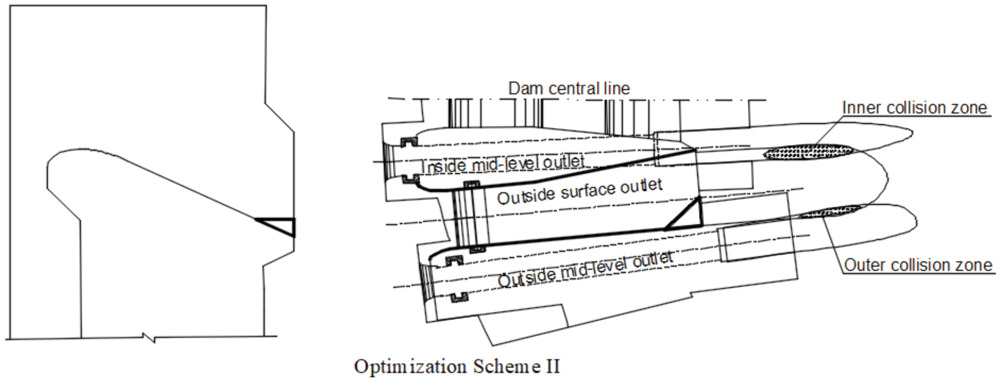

Figure 4 : Optimization scheme II of outside surface outlets

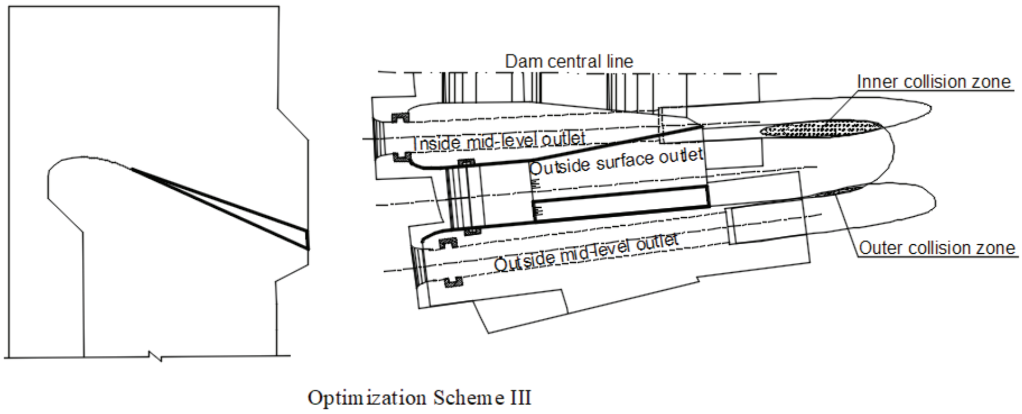

Figure 5 : Optimization scheme III of outside surface outlets

Table 1 : Parameters of the model test

Conditions	Upstream level (m)	Outlets used	Operation way of gates	Discharge (m^3/s)
1	249.38	Both Surface outlets and mid-level outlets are opened	Fully opened	201.9
2	245.0	Only surface outlets are opened	Fully opened	72.7

3. RESULTS

For the original scheme, the scouring depth is 5m and precipitation intensity is 633mm/h under flow condition 1, while the scouring depth is zero as the flow changed to condition 2. The collision zones of the jets for original scheme are shown in Figure 2. In order to reduce the side splash, the end width of outside surface outlet is cut by 0.5m in optimization scheme I. So more water will go through the left part of the outlet, and the inner collision zone get larger while the outer collision zone get smaller. Under condition 1, the precipitation intensity is reduced to 13mm/h, but the scouring depth got increased to 6m. Under condition 2, the scouring depth is 2.5m. In this scheme, the end with of surface outlet has just been cut by only 6%, but the scouring depth got deepen up to 20%, which means the scouring is very sensitive to the width of the jets, and it is not applicable to minimize the precipitation by cut the width of jets.

In optimization scheme II, the end width of surface outlet is reset to the same width as the original scheme, and a broad tail pier is added to the side wall. So the main flow can turn left a little without cutting the width of jets. The thickness of inner jet got larger while the outer jet got thinner. The experiment shows that the precipitation intensity is 165mm/h and scouring depth is 5.5m under condition 1. Furthermore, there is no scouring under condition 2. It means enlarging the thickness of inner jet while decreasing the thickness of outer jet can minimize precipitation intensity although the scouring depth got a bit larger. It is the right direction for further work.

In optimization scheme III, based on the result of scheme II, a wedge is added to the bottom of the surface outlet, which divides the surface outlet into two parts. The bottom of outer part is a bit higher than that of inner part. So the more flow are directed to the inner side and less flow are released through the outer side. The experiment result shows that the precipitation intensity is 36mm/h and scouring depth is 5.7m under condition 1. The precipitation got cut by 94%, and the scouring depth got deepen only 14%. There is also no scouring under condition 2, and both the precipitation and scouring depth fulfilled the requirement.

4. CONCLUSIONS

In design of surface-midlevel-stilling basin dissipaters, precipitation intensity of splash and scouring of stilling basin bottom are contradict demands to meet. However, a deep investigation on the dissipation principle of different dissipators may lead to an acceptable way of problem solving. In this study, we proposed a concept, increasing the inner side collision to enhance the dissipation efficiency and decreasing the outer side collision to minimize the splash precipitation intensity, to solve the rigor demand of high arch dam design. The optimized dissipator generate a extended jet, which is helpful for decreasing the scouring of stilling basin.

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REFERENCES

1. Diao Mingjun，Yang Yongquan, Study on unequal jet impact in air for energy dissipation, *Journal of Sichuan Union University (Engineering Science Edition)*, 1998, (11):96-101. (In Chinese).
2. Diao Mingjun，Yang Yongquan, *A new method to compute energy dissipation ratio of water jets impact in air, Journal of Sichuan University (Engineering Science Edition),*1999, (2):108-112 (In Chinese).
3. SUN Ning, ZHANG Fa-xing, LIU Shan-jun, SONG Wen-shuai, Experimental Study on Longitudinal Stretch of Jets of Surface Outlets in High Arch Dam without Impact of Jets in the Air, *Water Resources and Power, 2017, (5):*100-103. (In Chinese).
4. LI Naiwen, XU Weilin, ZHOU Maolin, TIAN Zhong, Experimental study on energy dissipation of flood discharge in high arch dams without impact of jets in air, Journal of Hydraulic Engineering, 2008, 39(8): 926-932. (In Chinese).
5. *SUN Shuangke, PENG Yu, XU Jianrong, Analysis of the maximum dam body flood discharge in large high arch dam: case study in Baihetan Hydropower Station, Journal of Hydraulic Engineering,* 2018, (9):1169-1177. (In Chinese).
6. *SUN Shuang-ke, Summary of research on flood discharge and energy dissipation of high dams in China, Journal of China Institute of Water Resources and Hydropower Research,*2009(2): 89-95. (In Chinese).
7. LIAN Jijian, LIU Dan, LIU Fang, *Numerical prediction of flood discharge atomization induced by complicated aerial collisions, Journal of Hydroelectric Engineering*, 2019, (5):46-56. (In Chinese).
8. LIAN Jijian, HE Junling, GOU Wenjuan, RAN Danjie, WANG Chang. Study on harnessing schemes of flood discharge atomization[J]. *Journal of Hydroelectric Engineering*, 2019, 38(11): 9-19. (In Chinese).
9. LIU Fang, LIAN Jijian, ZHANG Xiaojun, LI Chengye, *Experimental study of atomization and splashing caused by a ski-jump jet into scour pool, Journal of Hydroelectric Engineering,* 2010, (4):113-117. (In Chinese).
10. *HAN Xi-jun, QU Li-guang, CHENG Zi-bing, Research Progress of Engineering Protection Measures against Flood Discharge Atomization of High Dams, Journal of Yangtze River Scientific Research Institute, 2013, (8):63-69*. (In Chinese).
11. *CHEN Duan, JIN Feng, LI Jing,* Study on model law for intensity of rainfall from atomization of flood-discharging flow for high dam, Water Resources and Hydropower Engineering, 2005 36(10) :47-49. (In Chinese).
12. *Wang Huanling, Xu Weiya,* Advance on Research of Rainfall Intensity of Flood Discharge Atomization and Distribution Scope of Atomized Flow, *Journal of China Three Gorges University(Natural Sciences), 2010, (5):1-6*. (In Chinese).