HYDRAULIC CHARACTERISTICS OF DOUBLE-BEND SPILLWAY

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Double-bend spillway means that there are two curved conduits in the spillway. Xiaonanhai reservoir was formed in earthquake in 1856. To protect the relic of earthquake, the spillway is designed to be double-bend. In order to validate the feasibility of the design and optimize it, the approach of the combination of model investigation and numerical simulation is adopted. Double-bend spillway has a feature of curved conduit flow. However, the slope of the spillway is much larger than that of ordinary channels and natural rivers, so the problems of the curved conduit flow are more complex. In addition, the convex and concave banks in the first curved conduit of double-bend spillway are respectively connected with the concave and convex banks in the second curved conduit. In this way, the flow pattern varies greatly in a short distance, and the downstream energy dissipater is badly affected. Therefore, the study of double-bend spillway is important in hydraulic project. In the past, the study of the spillway was mainly based on physical models. Recently, some researchers have attempted to solve this problem with mathematical models and computational methods (Khan and Steffler 1996; Unami et al. 1999; Song and Zhou 1999; Causon et al. 1999), but the study of double-bend spillway has seldom reported.

In the experiment, the most important concern is the torrent in the curved conduits. By the action of the inertial centrifugal force, the water surface elevation of the concave bank is higher than that of the convex bank. When the discharge is $789m^3/s$, the overflow occurs at the concave bank. In addition, the transverse rotation in the stilling pool is caused because the flow is deviated from the axial direction, so the efficiency of energy dissipation is decreased. To weaken the bad effect of the spiral flow in the curved conduits, the approach of setting skew sills at the bottom of curved conduits is adopted. The specific layout of the skew sill must be determined by the experiment, and the angle between the skew sill and the axis is a main factor. The specific layouts of the skew sill in two curved conduits are shown in Figs. 1 and 2. The data of the discharge of $402m^3/s$ are shown in Table 1. After optimization, the difference of transverse water level decreases by around 35% in the first curved conduit, and around 45% in the second one.

Fluent software is used to simulate the three-dimensional turbulence flow of double-bend spillway. Through numerical simulation, free water surface and velocity are obtained and computed results are in agreement with measured data. Figs. 3 and 4 compare simulated results of water level with measured data in two curved conduits. Numerical simulation further verifies the feasibility of double-bend spillway at Xiaonanhai reservoir, and it plays an important role in engineering applications. The prediction of water depth along the spillway can offer reference data for the design of the side wall elevation, and the optimal scheme can be established conveniently for the change of the skew sill. Therefore, numerical simulation is an effective supplement for experimental investigation of double-bend spillway.

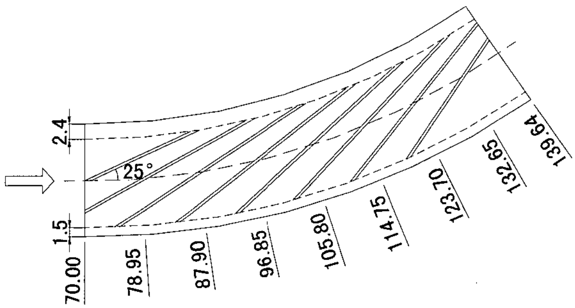

Fig. 1 Layout of skew sills in the first curved conduit (unit: m)

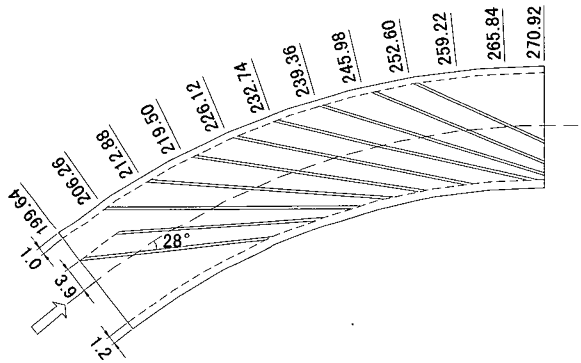

Fig. 2 Layout of skew sills in the second curved conduit (unit: m)

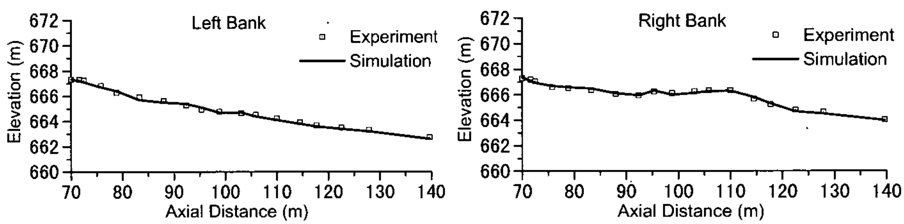

Fig. 3 Water level comparison between simulated results and measured data in the first curved conduits

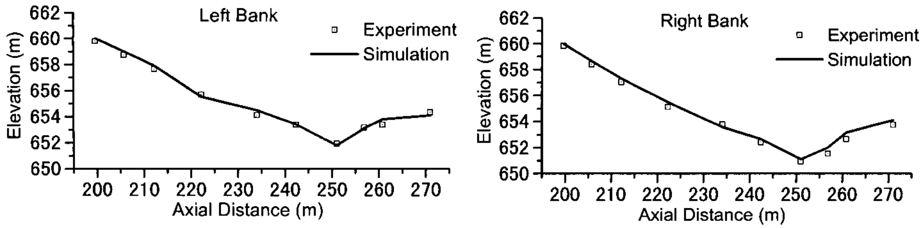

Fig. 4 Water surface comparison between simulated results and measured data in the second curved conduits

Table 1. The difference of transverse water level in two curved conduits

Axial distance (m)	Water level difference before optimization (m)	Water level difference after optimization (m)
87.90	0.71	0.44
105.80	2.74	1.80
123.70	1.96	1.32
139.64	1.93	1.32
206.26	0.72	0.34
219.50	1.04	0.53
232.74	1.41	0.75
245.98	1.72	0.98

REFERENCES

Causon, D. M., Mingham, C. G., and Ingram, D. M., 1999. Advances in calculation methods for supercritical flow in spillway channels. Journal of Hydraulic Engineering, 125(10), pp.1039-1050.

Khan, A. A., and Steffler, P. M., 1996. Vertically averaged and moment equations model for flow over curved beds. Journal of Hydraulic Engineering, 122(1), pp. 3-9.

Song, C. C. C., and Zhou, F. Y., 1999. Simulation of free surface flow over spillway. Journal of Hydraulic Engineering, 125(9), pp. 959-967.

Unami, K., Kawachi, T., Munir Babar, M., and Itagaki, H., 1999. Two-dimensional numerical model of spillway flow. Journal of Hydraulic Engineering, 125(4), pp. 369-375.