Desilting Laws of Precipitation Washout Test in Xiaolangdi Reservoir

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ABSTRACT: Precipitation washout is a common and effective measure to restore the storage capacity of reservoir. In order to study erosion effects under the condition of different boundary conditions, control water level and flood duration in later sediment retaining period of Xiaolangdi Reservoir flood duration, four groups of precipitation washout tests were conducted. The paper analyzes reservoir erosion effects of the different group. In this paper, the result show that, with more discharge and sediment, lower water level, longer duration and higher deposition surface, the more scour depth and better effect will be obtained. Based of experiment data, the relationship between output sediment discharge rate and input discharge, sediment concentration and water gradient is obtained and verified by measured data of Sanmenxia Reservoir, and the relationship between cumulative erosion and input water and sediment amount and water level before dam are obtained.

INTRODUCTION

Research of operational mode of Xiaolangdi Reservoir for flood control and sedimentation reduction during later sediment retaining period refer "multi-year sediment regulation and man-made precipitation washout at right occasion". Man-made precipitation washout at right occasion refers to under the favorable reservoir boundary condition, when suffer a large flood process, decrease reservoir water level, scour reservoir sediment, recover storage capacity, prolong the reservoir sediment storage life. At present, the operation of Xiaolangdi reservoir has entered the late sediment retaining period, recovery capacity is an important content. This paper studies the influence of boundary conditions, water and sand conditions, control water level and other factors on the scouring effect, and puts forward the relationship between sediment transport rate and the influence factors.

Introduction of test

Physical model

The prototype scope simulated by model is from Sanmenxia hydrologic station to Xiaolangdi dam. The length of prototype is 124.5km and the elevation range is from 155m to 290m. The model includes all tributaries and main buildings. The horizontal and vertical scales of the model are 1:300 and 1:60 respectively.

Boundary condition

The initial boundary condition of test is that the amount of sediment is 3.2 and 4.2 billion. The control level is 210m and 220m. The amount of water storaged is 0.3 billion.

water and sediment condition.

The incoming water-sediment condition is 12 and 16 day flood process. The process of water and sand is shown in Figure 1， figure2. Test scheme is shown in table1.

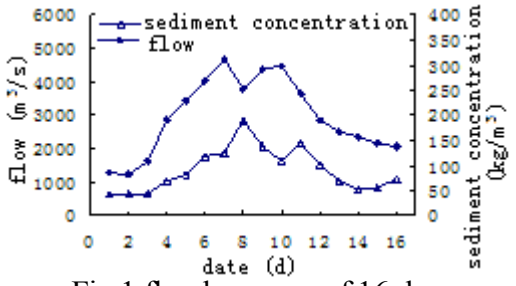


Fig.1 flood process of 16 day inflow water and sediment

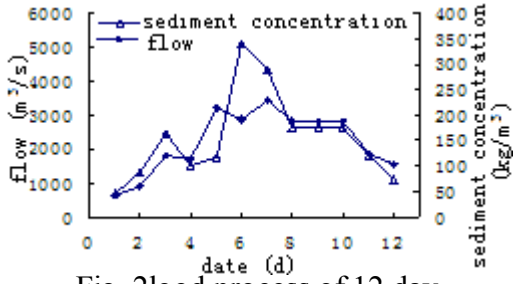


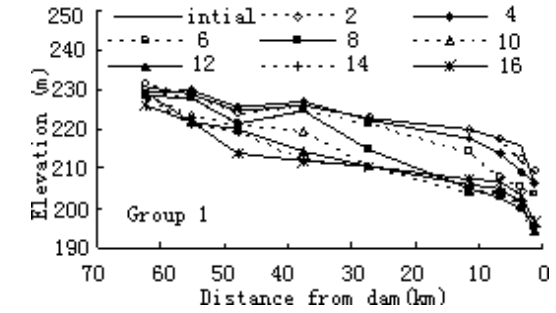
Fig. 2lood process of 12 day inflow water and sediment

Table 1 test scheme

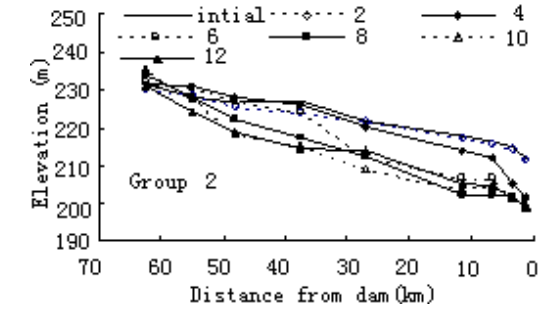
group	amount of sediment (billion m3)	water level (m)	duration (day)
1	3.2	210	16
2	3.2	210	12
3	4.2	210	12
4	4.2	220	12

Results of model test

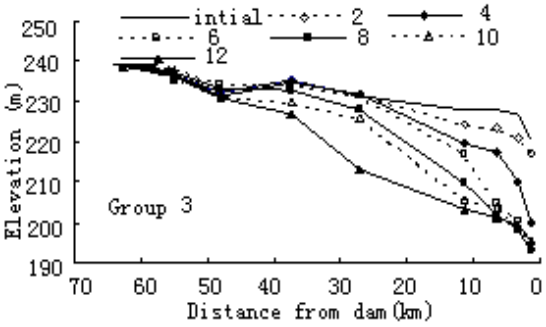
When the water area reduced to only in the dam before the small funnel zone, apparent headward erosion appear and extend upstream. The scour amplitude decreases from downstream to upstream, Figure 3. Under the same boundary condition and control the water level (group 1, 2), inflow and sediment amount is larger, the scour duration is longer, and the larger the scour depth and headward erosion distance. Under the same boundary conditions and the conditions of water and sediment (group 3, 4), control water level is low, the scour depth is greater, and scouring effect is better. Under the same condition of water and sediment and water level control (group 2, 3), the higher the pre deposition surface, the larger the scour depth, and the scouring effect is better. At the end of the experiment, maximum scour depth 4 of groups in order is 12.3m, 11.3m, 20.3m and 11.4m, and headward erosion distance reached 64.4, 57.0, 46.2 and 60.1km.



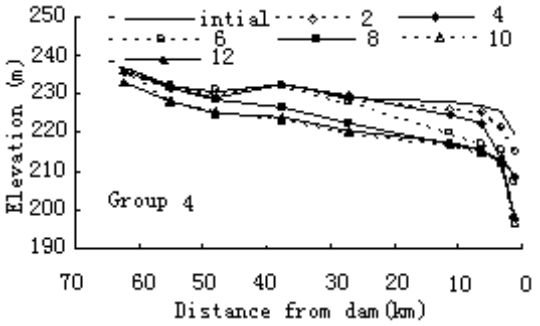
(a)group1



(b) group 2



(c) group 3

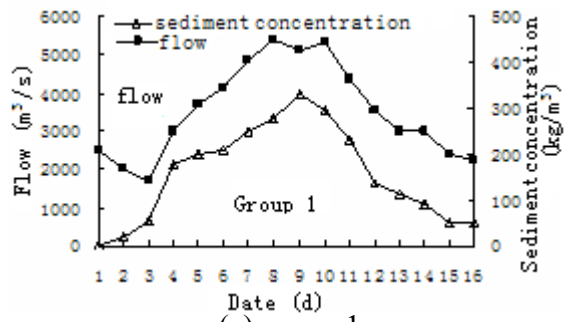


(d) group 4

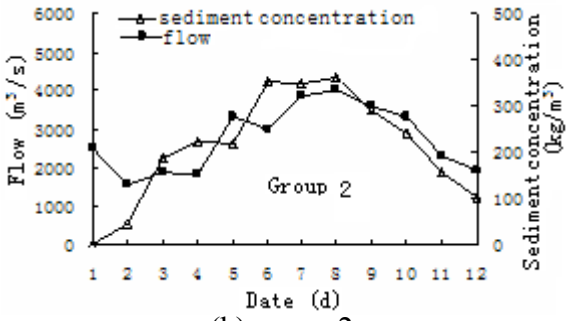
Fig. 3 Longitudinal profile of 4group

Outlet water and sediment

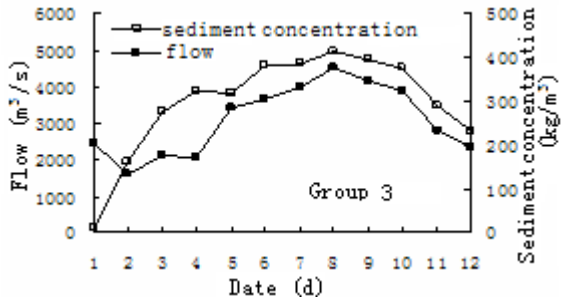
As the appear of headward erosion, the outflow and sediment concentration increase, figure 4. During the experiment, the maximum daily outlet sediment concentration 4 groups are 331.95, 363.78, 412.0 and 370.2kg/m^3 respectively, the largest increase respectively 194.95, 187.88 , 236.1 and 194.3 kg/m^3. The maximum daily outflow increase are 1430, 1716, 1224 and 1590m^3/s respectively, and correspondingly, the outflow are 5400, 4536, 4044 and 4250m^3/s.



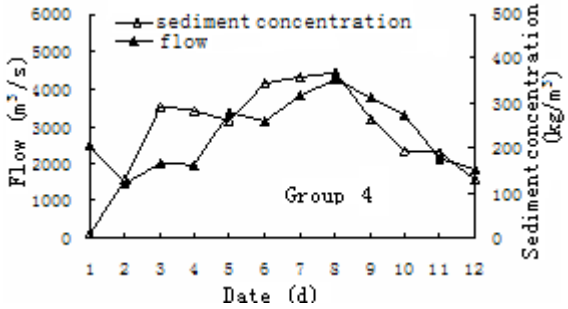
(a) group 1



(b) group 2



(c) group 3



(d) group 4

Fig. 4 Outlet flow and sediment concentration of 4 group test

Amount of scour

Influenced boundary, water and sediment and control level, the amount of scour of 4 group test is also different, table 2. Under the same conditions of terrain and control water level (group 1, 2), inflow and sediment amount is larger, scour duration is longer, the scour effect is better. Under the same terrain and incoming water and sediment condition (group 3 and 4), control level is lower, the scour effect is better. With the same water and sediment conditions and control water level (group 2, 3), the higher pre deposition surface, the better scour effect. There is a same result of 4 group test, namely, during the later sediment retaining period of Xiaolangdi Reservoir, lowing water level has a large role on capacity recovery.

Table 2 Amount of erosion of 4 group test

group	inflow amount of sediment (billion ton)	outflow amount of sediment (billion ton)	Amount of erosion and deposition (billion ton)
1	0.423	0.916	-0.493
2	0.412	0.674	-0.262
3	0.412	1.025	-0.613
4	0.412	0.743	-0.331

Reservoir sediment desilting

Text and indenting

Reservoir sediment desilting is closely related with inflow, sediment concentration, deposition morphology and water level before dam. During the scouring test of Xiaolangdi Reservoir, the water level is low and water storage is only in the funnel area, Therefore, the water level has little effect on sediment desilting. Based on experimental data analysis, the relationship formula (1) between sediment transport rate and inflow discharge, sediment concentration and water surface gradient of delta front slop section is put forward lose the relationship between sediment transport rate. The comparison of calculation value and measured value are shown in Figure 5.

$$Q_{So} = 0.04 Q_{i+t}^{1.15} S_i^{0.46} J^{0.23} \qquad (1)$$

Q_{So} stands for outflow sediment transportation rate, t/s. Q_{i+t} inflow and tributary discharge, m^3/s. S_i inflow sediment concentration, kg/m^3. J water surface gradient of delta front slop section.

In order to verify the reliability of formula (1), the scouring data from 1964 to 1995 of Sanmenxia reservoir 123.4km upstream Xiaolangdi Reservoir is used to verify the r formula (1). During the period of detention and sediment desilting from 1964 to 1973, strong scour occurred in Sanmenxia reservoir, and the amount of scour of six timesis 1.189 billion ton. During the period of storage clear and draining muddy from 1974 to 1995, strong headward erosion appeared. The verification result is shown in figure 6. Because Sanmenxia Reservoir is near Xiaolangdi Reservoir, water and sediment movement characteristics are very similar. Therefore, formula (1) can used to predict sediment sesilting of Xiaolangdi reservoir.

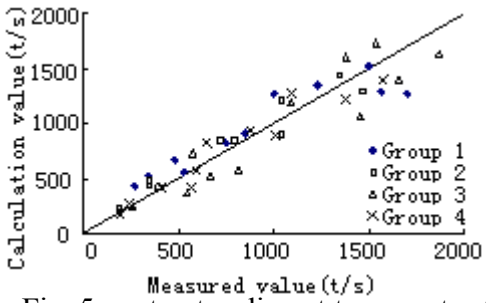


Fig. 5 contrast sediment transport rate

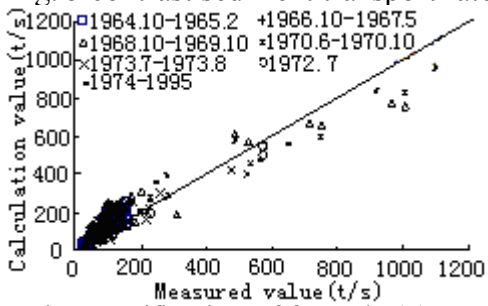


Fig.6 Verification of formula (1)

Conclusion

Experimental results show that, influenced boundary, water and sediment and control level, the erosion effect of 4 group test is different. But the same result of 4 group test is lowing water level has a larger role on capacity recovery. By now, operation of Xiaolangdi Reservoir has entered into later sediment retaining period. Considering the actual situation of reservoir operation, it is recommended, under the favorable reservoir boundary condition, when suffer a large flood process, decrease reservoir water level, scour reservoir sediment, recover storage capacity, prolong the reservoir sediment storage life.

Acknowledgements

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References

[1] Zhang J. H., Chen S. K., Ma H. B., Chen X. T., Li T., Wang T., Jiang S. Q., LI K. P., and Wang Y.: Report on model test of the operational mode of Xiaolangdi Reservoir for flood control and sedimentation reduction during later sediment retaining period (Yellow River Institute of Hydraulic Research, YRCC, China 2010, In Chinese).

[2] Wang T, Zhang JH, Ma HB and Gao GM. Study on deposition morphology of Xiaolangdi Reservoir. (Journal of hydraulic engineering, China 2013.6, in Chinese).

[3] Wang T, Li T,Fan WL. Study on influence factors of headward erosion effect.(Yellow River Institute of Hydraulic Research, YRCC, China 2013, In Chinese).

