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The hydraulic characteristics of end-dump closure with the assistance of back-water-sill in diversion channel*

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Abstract: The river closure is a key step in the water dam construction, and the end-dump closure is a general way to cut off the river flow. The hydraulic characteristics at the closure gap are the main factors which affect the extent of closure difficulty. A method is proposed to reduce the difficulty of diversion channel closure by pre-building a closure structure called the backwater-sill at the downstream toe of the closure gap to change the flow pattern at the closure gap. The results of the physical model test and the three-dimensional numerical simulation indicate that the backwater-sill has the effects of raising the water level at the downstream toe of the closure gap, decreasing the water surface gradient, and reducing the closure drop and the flow velocity at the closure gap. The schemes with different dike widths, different closure gap widths, and different backwater-sill widths and heights are simulated. The results show that the height of the backwater-sill is the key factor affecting the hydro-indicators at the closure gap, while the influence of the dike width, the closure gap width or the backwater-sill width can be ignored. The higher the backwater-sill is, the lower the hydro-indicators will be. Based on the numerical simulations and the physical model tests on the hydraulic characteristics at the closure gap of the backwater-sill assisted closure, the hydro-indicators and its calculation method are proposed to provide a theoretical support for the river closure.

Key words: diversion channel closure, closure structure, end-dump closure, backwater-sill, hydraulic characteristics

Introduction

In the construction of water dam projects, the flow in the riverbed should be cut off, and then the upstream and downstream cofferdams can be filled to temporarily protect the construction pit against the river water. In this way, the hydraulic structures (dam base) can be constructed in a dry riverbed. The process of cutting off the river and leading the flow into a discharge structure is called the river closure. The closure by dike or dikes is the most frequently-used method of river closure[1], which begins with casting the riprap and other materials into the water flow, forming a closure dike, and gradually narrowing the river flow, and ultimately ends with closing the river. The closure methods of the dike can be classified into the transverse-dump, the end-dump and the transverse-end-dump, as well as the single dike, the wide dike, the double dikes and the multiple dikes. The difficulty of a closure project can be evaluated in 3-D[2]. The first dimension is the scale of the closure project, which includes the dumping quantities, the diversion structure scale and the construction intensity, and can be represented by the closure flow discharge Q. The second dimension is the construction safety, which is related to the slump scale of the dike head during the process of the closure dike construction, and can be represented by the water depth at the closure gap. The last dimension is the diameter of the closure material, which is determined by the hydro-indicators at the closure gap, such as the closure drop and the average velocity. For a particular river closure project, the first two factors can be considered to be fixed, determined by the envi-

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ronment where the closure project is located. Thus, the effective way to reduce the closure difficulty is to reduce the hydro-indicators at the closure gap.

The flow pattern and the mechanical conditions of the riverbed at the closure gap determine the stability of the closure materials. The hydraulic characteristics of the closure gap is an important issue of the closure design. Meng et al.[3] and Hu et al.[4] studied the hydraulic characteristics of the closure gap in the end-dumping closure with a single dike. Wu and Molinas[5] and Chiang et al.[6] studied the discharge characteristics and the energy losses of local discontinuous contractions. Koken and Constantinescu[7] studied the hydraulic control conditions of the end-dump closure with double dikes. Lu and Du[8] studied the hydraulic characteristics of the gap closing with large framed cages. Wang et al.[9] developed and integrated 1-D and 2-D mathematical models to simulate the hydraulic conditions of the TGP's third-stage open channel closure. Chen and Shen[10] studied the hydraulics characteristics of the close gap in large-scale beach reclamation works. Choi et al.[11], Ha et al.[12] and Van Der Sande[13] described the construction of the tidal dikes and predicted the real-time flow fields during the gradual closure operation in the final stage. Another important issue is the stability of the closure materials. Hoan et al.[14] studied the stone stability in non-uniform flow. Escarameia and May[15] studied stability of riprap and concrete blocks in highly turbulent flows. Das[16] studied the stability of rockfill in end-dump river closures. Elkholy and Chaudhry[17] investiga- ted on the trajectory of large sandbags in open channel flow. For the closure in a deep water, Zhou et al.[18] built a theoretical model to calculate the slump of the dike head during the process of the cofferdam construction. For the closure on a deep-thickness covering riverbed, Li et al.[19] suggested some safety control countermeasures.

However, the above-mentioned studies mainly focused on the flow characteristics and the stability of the closure materials, without much discussions on reducing the difficulty of the closure. In a general closure design, the closure dike advancing is regarded as a main approach to break the flow, hence the selection of an appropriate closure method, with a suitable size of the riprap, a dumping intensity, and a discharge capacity of diversion structures, is the main concern, which often means high costs in general. Since all the construction conditions could be taken as the results of the construction scheme, the flow characteristics during the closure dike filling progress can be considered as a disturbance caused by the closure system. And all kinds of closure methods, such as the wide dike, the double dikes, the multiple dikes and the transverse-end-dump, are to create an intentional situation for specified flow characteristics. Therefore, it is feasible and necessary improving the hydraulic characteristics at the closure gap and decreasing the closure difficulty through a temporary closure structure.

Following the above idea and taking account of the diversion channel conditions: with a large closure discharge, a low discharge capacity of the diversion structure, high hydro-indicators in the closure gap, a smooth channel bed and the poor stability of closure materials, a method is proposed to reduce the difficulty of the channel closure by pre-building an auxiliary closure structure called the backwater-sill, as shown in Fig.1. Before the excavation construction of the diversion channel, the upstream and downstream cofferdams will be constructed previously to ensure that the diversion channel can be constructed on a dry ground, which provides a convenient condition for the installation of the backwater-sill. There are three ways to install the backwater-sill. If the bedrock is of good quaility, the backwater-sill can be installed by reserving and reinforcing the rock ridge. If the bedrock is of loose rubble, the backwater-sill can be installed by pouring concrete or installing a rock-filled steel cage. The backwater-sill is essentially a low submerged groin, with little impact on the discharge capacity of the diversion channel in a flood season. The intention of the backwater-sill is to raise the water level at the downstream toe of the closure gap, lower the flow velocity at the closure gap, save the closure materials and finally reduce the difficulty of the channel closure.

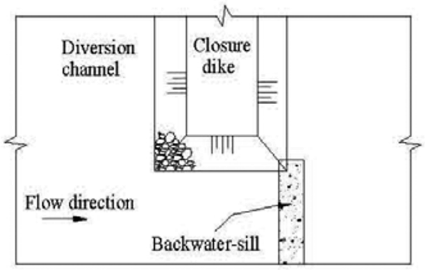

Fig.1 Schematic diagram of end-dump closure with the assistance of backwater-sill

In this paper, the 3-D Reynolds Averaged Navier-Stokes equations and the two-equation RNG k - ε turbulence model are employed to investigate the influence of the backwater-sill on the flow pattern at the closure gap of the end-dump closure, and the hydro-indicators of the end-dump closure with the assistance of the backwater-sill and its calculation method are proposed.

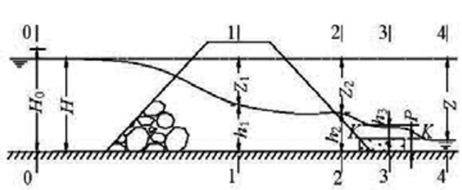

Fig.2 Water surface profile at the closure gap of the backwater-sill assisted closure