Numerical Study of Scouring Downstream of a Free Jet

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1- Introduction

The energy available in the terminal of dam structures causes erosion of the river bed. Different parameters such as discharge, difference between upstream and downstream, radius of jet, mean diameter of bed materials, velocity of the jet and the tail water are recognized on the score hole and its geometry. The cognizance of these parameters aids the designers to provide a suitable layout for the scoring pool. Abida, H. and Townsend, [2] showed that the length and depth of the score hole decrease by increasing the tail water. Westrich,[3] Kobus, H. investigated the height of overflow spillway on scoring. Wanyun [9]. modeled the score hole of a submerged jet using 2D models. In their study, the k-ε turbulence model is considered. The shear resistance between the grains, the seepage force, void ratio and the gravitational force are taken into account as the resistant forces and the local shear stress induced by flow as the tractive force.

As the majority of studies on scoring are based on experimental data, in this research, the experimental conditions for scoring are simulated numerically using SSIIM software. After the calibration tests in the numerical model, the effects of flow conditions and sediment characteristics on the depth of the score hole are evaluated as a function of the height of spillway, Froude number and the densimetric Froude number.

2- Governing equations and calibration of numerical model

The governing equations utilized to simulate the flow and sediment are: the continuum equation and momentum equations (Navier Stocks' equations) for flow, **k-ε** model for simulating the turbulence, advection-diffusion equation for suspended load and Englund Hansen equation for bed load.

Calibration tests are performed to provide the appropriate value for the roughness and mesh sizes, the turbulence model and bed load equation. In the calibration tests, the numerical results for the maximum depth of score holes are compared with their values obtained from the experimental tests. The mean sizes of sediment as the roughness height, the mesh cells in 35*5*301 numbers, k-ε for the turbulence model and Englund Hansen formula for bed load present more correlation factors between the numerical and experimental data.

3- Analysis of the numerical model

The effect of different parameters such as height of spillway, the densimetric Froude number and relative diameter of sediment are investigated on the maximum score hole depth. All data are presented in the dimensionless form.

Figure 1 presents the effect of the densimetric Froude number on the score hole for a constant Froude number. As shown in this Figure, the relative score hole is a linear function of the densimetric Froude number of bed materials with a positive slope. This linear attitude is the same for all spillway heights.

Figure 2 represents the effect of the relative height and relative diameter of sediment size on the relative score hole. As shown, the relative score hole increases with increasing the height of the spillway and decreasing the relative sediment sizes. Also, we could deduce that the score hole is more sensitive for small sized sediments.

In Figure 3 the relative score depth is shown versus the relative sediment size and Froude number. The relation between the different parameters has a logarithmic form. As shown in this Figure, for small sediment sizes the relative depth of the score hole is enormous, but for the bigger sediment sizes the relative depth of the score hole is small.

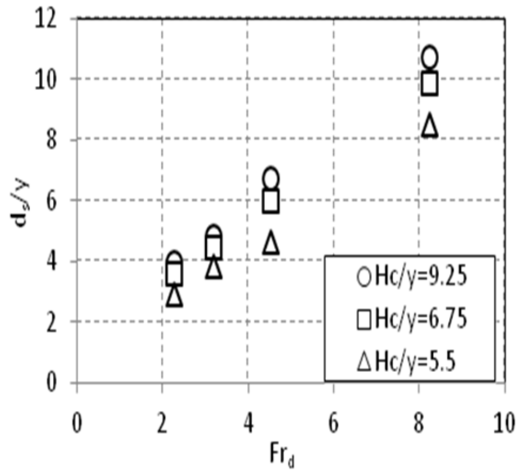

Fig. 1. The effect of densimetric Froude number and the relative spillway height on the relative depth of score hole for Fr= 0.918

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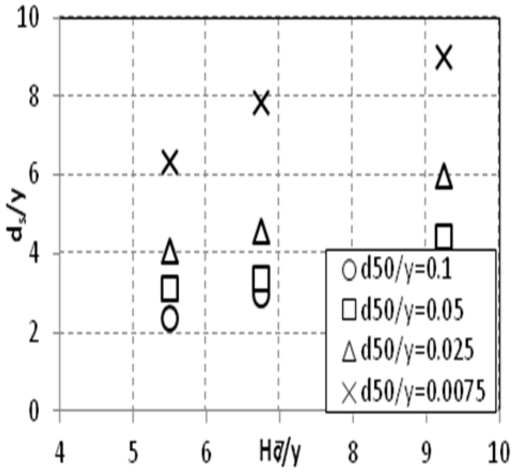

Fig. 2. The effect of the relative spillway height and the relative of sediment size on the relative depth of score hole for Fr= 0.758

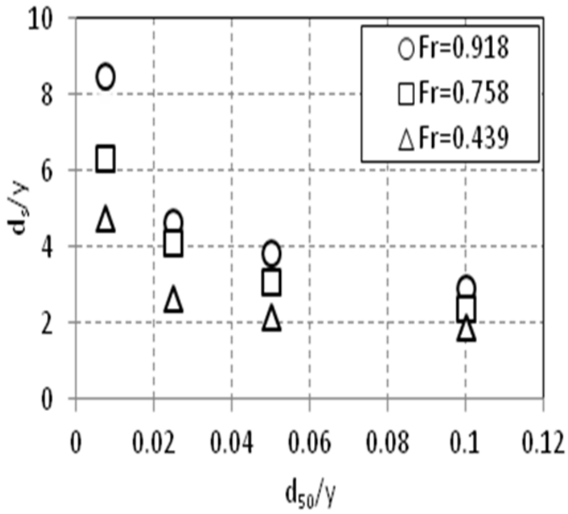

Fig. 3. The effect of the relative of sediment size and different Froude number on the relative depth of score hole for the constant relative spillway height Hc/y=5.5