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INVESTIGATION OF MESH INDEPENDENCE IN NUMERICAL MODELING OF SHARP-CRESTED WEIRS AT DIFFERENT HEIGHTS

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Introduction

Studies on the use of water started with the existence of humanity because water is an important natural resource for all creatures. Water is taken under control by hydraulic structures and used for various purposes. The hydraulic structures that are placed perpendicular to the axis of the open channel to measure the discharge, control the water flow, and raise the water level are called weir. There are different types and shapes of weirs according to their intended use.

Sharp-crested weir is a type of overflow weir. The first studies on sharp-crested weirs were made by Boileau (1854), Horton (1907), Escande and Sabathé (1937), Istomina (1937). Flow regime of the water is changed from subcritical to supercritical while water passing over the weir. In order to accurately design these structures that interact with the flow, profile, velocity and pressure of the flow must be accurately estimated.

In recent years, Computational Fluid Dynamics (CFD) based programs have been used frequently in the design of hydraulic structures. Numerical modeling techniques are economical compared to experiments, unlike the physical model, modifications can be made on the numerical models. Choosing the correct mesh size when creating a numerical model of a hydraulic structure is extremely important for the accuracy and duration of the analysis. Mesh independence is a term used in numerical analysis and simulation to refer to the situation where the numerical solution of a problem is insensitive to changes in the size or density of the computational mesh used to discretize the problem domain. In other words, a numerical solution is said to be mesh independent if it remains stable and accurate even when the mesh is refined or coarsened. This is important because the accuracy and stability of numerical simulations depend on the quality of the mesh used to discretize the problem domain. Achieving mesh independence often requires careful consideration of the choice of mesh, as well as the numerical method used to solve the problem. It is important to ensure that the mesh is fine enough to capture the important details of the problem, while avoiding excessive computational time.

Materials and methods

Equation (1) is used for calculation of discharge of flow passing over a sharp-crested weir. In this equation, it is assumed that H_T is the total head and $H_T=h+V^2/2*g$.

$$Q=\frac{2}{3}*C_d*L_{net}*\sqrt{2*g}*H_T^{1.5} \quad (1)$$

Q : Discharge

C_d : Discharge coefficient
L_{net} : Length of the weir
g : Gravity
H_T : Total head over the weir

The profile formed when the flow passes freely over a sharp-crested weir is called nappe flow (Figure 1). The flow formed over sharp-crested weirs forms a nappe flow depending on the aeration condition of the downstream surface of the weir. In the nape flow, after the water is poured over the weir, there is air between weir and water.

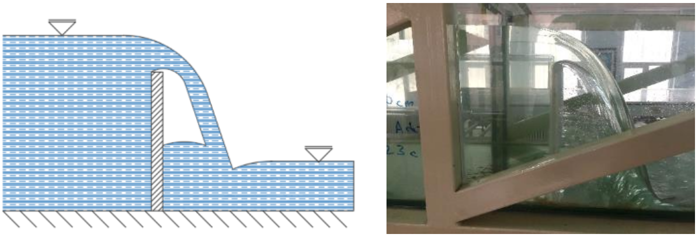

Fig. 1. Nappe flow over a sharp-crested weir

In this study, experiments were carried out on three different weir heights, P=20, 30 and 40 cm, on sharp-crested weirs and numerical models of these experimental setups were created. In this study, the aim was to find the mesh size that will provide the optimum consistency between the experimental results and the numerical model, while creating the numerical model of a sharp-crested weir, considering the analysis times. It is known that decreasing the mesh size will increase the accuracy of the numerical model and give results closer to the physical models. However, as the mesh size gets smaller, the analysis time increases significantly. For this reason, 4 different mesh sizes were used in numerical models and examined in terms of consistency-time.

Results and conclusions

3 different weir heights (P=20 cm, P=30 cm and P=40 cm) and 4 different discharge values (Q=5 lt/s, Q=10 lt/s, Q=15 lt/s and Q=20 lt/s) are used on sharp-crested weirs, at total of 12 different experiments were carried out. A total of 48 numerical models were created for each of these experimental sets in 4 different mesh sizes (s=10 mm, s=5 mm, s=2.5 mm and s=1.25 mm). According to the results, numerical models with 10 mm and 5 mm mesh sizes gave close analysis times and total heads at all weir heights and flow rates. Likewise, numerical models with 2.5 mm and 1.25 mm mesh sizes gave close analysis times and total heads at the same flow rates. However, the analysis times of the numerical models with 2.5 mm and 1.25 mm mesh sizes are 4 times the analysis times of the numerical models with 10 mm and 5 mm mesh sizes. While the numerical models with 10 mm and 5 mm mesh sizes gave 92% consistent results with the experiments, the numerical models with 2.5 mm and 1.25 mm mesh sizes gave 99% consistent results with the experiments.