HYDRODYNAMIC SIMULATION OF FLOW OVER SPILLWAY USING WEAKLY COMPRESSIBLE FLOW FORMULATION

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The major driving force for construction of dams throughout the world is the need for reliable water supply, flood control, navigation, hydroelectric power generation and recreation. Spillways and other flood outlets are designed to safely convey floods to the watercourse downstream from the dam and to prevent overtopping of the dam. Provision of a hydraulically efficient and structurally strong spillway is very important for the safety of the dam, the life and property along the river down below. Hydraulic models are being used extensively to visualize and to understand the complexity of hydraulic phenomena. Various hydraulic design aspects such as discharging capacity, pressures and water surface profiles and energy dissipation arrangement are considered, to evolve hydraulically efficient design of spillway.

Hydraulic modelling of spillways can be done through physical modelling or computer based numerical modelling. Physical model studies are indispensable to optimize various components of spillway structure. Physical modelling is expensive, cumbersome and time consuming. The advent of high-speed and large-memory computers has enabled to obtain numerical solutions to many complicated hydraulic problems. The main difficulties while solving the spillway problem numerically are: rapidly varied flow, existence of both sub-critical and supercritical flows, development of turbulent boundary layer, unknown free surface and air entrainment. To solve numerically the rapidly varying flow over a spillway crest, it is important that the free surface is accurately tracked. Usually, free surface is simulated using kinematic and dynamic conditions. For modelling a flow that varies rapidly in vertical direction and shows negligible flow variation in lateral direction such as the flow over the spillway, one can use 2-D (dimensional) vertical model. This model in its simplified form can be used as width-averaged model, which is analogous to physical 2-D sectional model.

Spillway, being one of the most studied hydraulic structures has recently attracted many researchers working in the area of CFD owing to enhanced computer resources. Most of them have used either potential flow theory or RANS equations and available commercial codes. Very few people have attempted space-averaged Navier-Stokes equations. The main objective of this paper is to describe the formulation of a numerical model based on weakly compressible flow equations and its application to a case study to investigate the hydraulic characteristics of flow over spillway crest profile simulating the velocity distribution, pressure distribution and discharge characteristics.

The model is based on the weakly compressible flow (also called compressible hydrodynamic) equations developed by Song and Yuan (1988) and are applicable to small Mach number and large Reynolds number flows. The method has been applied to a

number of steady as well as unsteady flows, and the numerical results have been validated with experimental data [Song et al. (1997)]. The proposed model is based on the inviscid weakly compressible flow equations. The body-fitted finite volume scheme has been adopted for discretization. The free surface is calculated based on the kinematic and dynamic conditions neglecting the wind stress, surface tension stress and aeration etc as they will have negligible influence on the flow near the crest. The upstream boundary has been setup on a reservoir section at which the reservoir water level and the incoming discharge can be known. This section should be far away from the spillway to avoid the reflection effect. For the study of the crest shape effect, the downstream condition will have no effect on the upstream flow since the flow over the downstream slope of the spillway is supercritical. The downstream section can be chosen on a sloping section where the flow was fully developed so that zero gradients of velocity and pressure can be assumed.

The equations written in conservative form are solved by Mac-Cormack's predictor-corrector method. The model has been applied to a real world case study of spillway. The calculated values of pressures, velocities and coefficient of discharge are compared with the results of physical model studies. The numerical experimentation was done using single zone body fitted mesh system. Simulated results showed reasonable agreement with the results obtained from physical model studies. The calculated value of coefficient of discharge was slightly higher than the observed value. The possible reason may be due to the omission of viscous terms and turbulence, which generally will induce damping effect in the flow.

REFERENCES

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