# CFD Modeling of Flow over Stepped Spillway - A Review

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*Abstract*- **Hydraulic model test was used to analyze the rapidly varied flow on the spillway. But it has some error to scale and expensive cost. KhadakWasla dam in Pune was selected as the study area. The terminal structure of a spillway plays a major role in dissipating specific energy of excess flood to safeguard the river channel and downstream structure. Relationship between critical depth flow and energy dissipation are presented and discussed in stepped spillway. The numerical result is compared with experimental result. Computational fluid dynamic (CFD) software with different numerical solver methods are suitable tools for solving various engineering problems. One such CFD software tool is ANSYS Fluent. In this report, the general guide and practical steps for developing a full 3D CFD spillway model using ANSYS Fluent have been presented. The energy dissipation over this model and pressure distribution on the horizontal and vertical step faces are studied for verification purpose of CFD.**

**Index Terms- stepped spillway, critical depth, energy dissipation, ansys fluent, computational fluid dynamics.**

## I. INTRODUCTION

Stepped channels and spillways have been used for more than 3500 year. The stepped spillways can be defined as that hydraulic structure in which a series of steps of different shapes, dimensions and arrangements are built into the spillways surface at some distance from the spillways crest and extended to toe. The stepped spillways dissipates much more energy than other type of spillways .Many researches studies energy loss due to steps depends primarily on the ratio of the critical depth of flow passing over spillways to steps height (Yc/h)and number of steps. To calculate energy dissipation of stepped spillways in the case of nappeflow (when Yc/h<0.8). Computational fluid dynamics (CFD) has the potential to provide an invaluable tool to model flow over stepped spillways. We compare the experimental data with the modeling result deriving from shallow water and detailed stock numerical model. Hydraulic characteristics of stepped spillways can be assessed in various ways by using empirical equations (during the primary design process), scale modeling and numerical modeling (in the final design process).These three approach are applied to the stepped spillways of 'Khadakwasla dam'. As experimental are both expensive and time consuming the use of high performance computer together with further developments in computational fluid dynamics(CFD)are important in order to investigate flow over spillways using reasonable resource, time, expense.

## II. LITRATURE REVIEW

BudoZindovic, LjubodragSavic (University Of Belgrade)
The comparison between the result of the scale model, empirical equations, and numerical model ANSYS FLUENT for the Bogovina dam are presented the following can be conclude : Location of the inception point is obtained with acceptable agreement for all three approaches. Uniform flow mixture depth by numerical model are predicted upstream from the position expected by empirical equations. Entrained air concentration for the uniform flow condition is significantly underestimated by the numerical model.

ChaiyuthChinnarasri (ICE)
The objectives of the present study was to simulate the flow behavior through smooth, 25 step and 50 steps spillways using a multiphase flow model with realizable k-( turbulent dissipation rate). The physical model, tested by Ward in (2002) was located in Colorado State University.For a smooth spillway, flow discharge of 0.57, 1.13, 1.70 were used. The

data on a five location were measured in the direction normal to spillway floor. Used to study the flow behavior through smooth and stepped spillway.

Hamid Reza Vosoughifar, AzadDolatshah, syedkazensadetshokouhi

This research deals with development of CFD code called V-flow using MATLAB for two dimensional modeled of unsteady flow over stepped spillways. The flow was considered to be a laminar fluid flow with no turbulent model. V flow model was validated against velocity vector, streamlines, static pressure ,dynamic pressure , and total pressure over the spillways obtained from the FLUENT model application .

M.R. Chamani& N. Raja Ratnam( Member of ASCE)

This technical note presents a method to estimate the energy loss on stepped spillways for the jet-flow regime, which occurs when the ratio of the critical depth (yc) to the height of the step hh is less than approximately 0.8. It introduces the concept of $\alpha\alpha$, the proportional energy loss per step, and using the extensive experimental results of Horner, $\alpha\alpha$; was evaluated. It was also found that the energy loss on a stepped spillway with a large number of steps can be very significant in the jet-flow regime. It also appears that for skimming flow, which occurs for yc/hyc/h larger than about 0.8, the average energy loss per step would be less than that for jet flow.

PredrajVojt&RadomirKapoor (IAHR Member)

Wall deflection in supercritical flow induces standing waves which significantly influence the flow field close to the wall. This paper analyses the flow in the converging stepped spillway, using two scale-models with different step heights and convergence angles. Results show that the height and the width of the standing wave increase with the increase of the convergence angle. Air concentration decreases while the air–water mixture velocity and residual energy head increase in the vicinity of the converging wall and gradually attain the values for the undisturbed flow outside the standing wave. Compared to the prismatic chutes of equal upstream width, converging spillways are less efficient energy dissipaters. Equations for predicting the maximum flow depth and the width-averaged residual energy are proposed.

WuthrichDavide& Chanson Hubert

The Hydraulic performances of gabion stepped weirs investigated experimentally in terms of flow pattern, air flow properties and energy dissipation. A laboratory study was conducted in a 26.6° slope (1V:2H) and 0.10m step height with smooth impervious gabion steps.

This experiment conducted in relatively large size stepped spillway model. The test section consist of broad crested weir followed by 10 steps with step height h=.0.1m and step length l=0.2m & stepped chute was 0.52m. The smooth impervious stepped configuration consists of flat horizontal steps made up of marine ply. The water flow was supplied by large upstream intake section followed by smooth sidewall with contraction ratio 4.23:1.The air- water flow measurement were conducted with dual-tip phase intrusive probeFor gabion chute, 10 identical gabion each gabion was 0.3m long, 0.1m high and 0.52m wide made up of galvanized metallic mesh with and filled with natural river pebbles.This experiments carried out for transition flow and skimming flow

Discharge $0.02 \leq Q \leq 0.11$ m³/s

$0.5 \leq dc/h \leq 1.7$

Reynolds no $1.4 \times 10^5$ and $8.8 \times 10^5$

Nappe flow = dc/h < 0.5 or 0.6

Transition flow = 0.6 < dc/h < 0.9

Skimming flow = dc/h > 0.9

S.L.Hunt, K.C.Kadavy

This paper currently working on a generalized model study to evaluate the effects that 4H:1V sloped stepped spillway chute has on the inception point the energy dissipation and velocities for given range of flows. The objectives of this work is to discuss velocity and energy dissipation findings upstream of the air entrainment inception point for 4H:1V stepped spillway with 38mm (1.5inch) stepsModel unit discharge ranging from 0.11m²/s to 0.82m²/s (discharge/length) Chanson may be used to determine the inception point for slope as flat as 4H:1V when fr ranges from 10 to 100Energy losses increase in linear fashion from near zero at the crest approximately 30% near the inception point for all flowsTo determine the energy loss in a spillway chute, the velocity must be known typical velocity profiles measured with the ADV and PT at different stations within the spillway chute upstream of the inception point for a unit discharge of 0.28m3 s-1 m-1The

average velocity obtained from the velocity profiles was used to determine the relative energy loss on the spillway chute upstream of the inception point. The total energy loss to a given step relative to the step of interest is: $\Delta H = H_o - H$.

**Sung DukKim, Ho –Jin Lee And Sang Do An(International Journal of the physical science )**

In this study , the 'karian dam 'in Indonesia was selected study area to examine the applicability of CFD model .the flow in spillway based on initial plan design was simulated by Flow 3D model. According to simulation result , the flow flowed over the wall of approach channel in PMF. The revise plan design suggested the height of approach channel to the guide wall is upwardly adjusted to the EL72.5m, sameas crest of dam. Hydraulic model test and the numerical simulation. it show that simulation of spillways flow using CFD model is possible.

**S. Felder and H. Chanson**

An experimental study was conducted on a large size stepped spillway model with a moderate slope (26.6°) for a range of discharges between 0.020 and 0.237 m3/s. In some experiments, the stepped chute was equipped with uniform steps of 5 and 10 cm heights respectively. In addition several non-uniform configurations with combinations of 5 and 10 cm high steps were investigated. For each configuration, the air-water flow properties were measured for several discharges.

The study yielded some challenging outcomes in terms of energy dissipation and aeration on stepped spillways with non-uniform cavity sizes. A comparative analysis with the stepped spillways with uniform step heights showed that the energy dissipation rate, the residual head, the flow resistance and the mean air concentration were close for all geometries.

This might be used for the design of prototype spillways with non-uniform step heights, but the flow pattern of the non-uniform step configurations showed some instabilities. A stepped spillway design with uniform step heights is the preferable design option.

**Zhang &JianHua( Science Direct- Journal of Hydronamics)**

The location of the inception point of the air entrainment directly affects the energy dissipation ratio, the cavitation damage control, and the training wall height designs for a stepped spillway and a stilling basin. In this paper, the boundary layer theory of plates is used to predict the location of the inception point of the air entrainment over the stepped spillways by assuming the steps on the spillways as a kind of roughness. An empirical formula is presented based on the physical model experiments, with the maximum error less than 1% except at one point where the error is 1.6%, as compared to the experimental data. Meanwhile, it is shown that the location of the inception point of the air entrainment for the stepped spillway is much nearer to the top of the spillway than that for a smooth spillways, which explains why the high ratio of the energy dissipation is provided for the stepped spillway.

## CONCLUSION

The present study research the performance of model for stepped spillways. Stepped spillway is designed based on non-dimensional parameters which shows that entire surface is effective for energy dissipation. ANSYS software can successfully model a spillway's water surface profile for variety of head water levels and different gate opening as compared to physical model testing. From this study we aim to obtain more energy dissipation with respect to least number of steps. We analyze and validate the existing result of Khadakwasla dam by numerical method and CFD software.

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