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Review Paper

Experimental and Numerical Modelling of Dam Spillways[#]

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Abstract: Each dam structure stands specific design according to the topography and climatic conditions of the intended purpose and the region to be constructed. Because of these specifications, each water structure is unique and needs to be projected differently. In the process of designing of hydraulic structures, there are many parameters should be included in order to describe the phenomena so it is not possible to define it exactly mathematically. In this point engineers try to avoid the mistakes and find the most appropriate solutions in these structures, which are very expensive to construct. The problems that can be seen after the dam structure is constructed and moreover opened to operation can cause the loss of life and property which cannot be compensated. It is not economical either. Physical and numerical model studies may prevent the dam structure from these damages. The experimental tests and mathematical model studies in hydraulic studies are the measures of the accuracy of the study. If there is no time, area and labour limitations experimental studies may be preferable. Otherwise, mathematical model studies, which use high performance computers, may be another choice to test the structure before constructed it. As a result, any modelling within the possibilities before the construction of the hydraulic structures is important in terms of preventing serious damages of life and property losses. In this study, experimental and numerical study of a dam spillway will be presented. Differences and similarities will be shown in hydraulic view.

***Keywords**: Dam spillway design, Experimental study, Numerical study, Spillway structure*

Introduction

One of the most focused subjects in hydraulic engineering has been the hydraulic design of spillways. In order to pass the flow over the spillway in the most efficient way is very important for both the social and economic view. So, it should be designed correctly and applied in the field. There are many parameters affecting the flow phenomena of the flow over the spillways (Bureau of Reclamation, 1977). During each step of the design procedure there are some assumptions because of the complexity of the problem (Şentürk, 1994). Experimental investigations give valuable ideas to improve the projects and to see the flow pattern directly (Kumcu, 2008; Kumcu 2010). It also enables to test all flow conditions and see the results (Teklemariam, 2008). While the hydraulic modelling is still widely accepted and utilized mechanism for the experimental investigation of flow over a spillway structure, numerical simulations for hydrodynamic processes became popular with increasing computer technology and without the necessity of time & budget consuming physical build-up progress. Although, the numerical solution is an alternative solution to the physical model solution, to describe the model may not be as easy as though (Willey *et al*., 2012). If it is described in the best way, to observe the results takes days, may be longer. Otherwise the solution is rough and may not be reliable. So, numerical solutions still need calibration and validation with hydraulic model results. The problems involving fluid flow are being solved by a branch of numerical modelling named as Computational Fluid Dynamics (CFD). FLOW-3D can provide 3-dimensional flow fields around curved objects as well as other flow detail not available in more simplified 1 or 2 dimensional models, conceding the disadvantage of noteworthy amount of computation time consuming (Kumcu, 2017). The study discusses the proficiency of CFD programming by means of result data and time consumption. In this study, rating curves observed from physical models and numerical models belonging to Yedigöze Dam and Kavsak Dam have been compared with each other.

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Material and Methods

Physical Model Studies

There are two main criteria in physical model scale selection. The first one, the physical model should reflect the all parameters which will be measured. The bigger the model scales the more similarity between the protype and the physical model. The second one is the enough model area and the construction. If the model scale increases, the area needed is getting larger and more over the construction material and workmanship increase. During the spillway modelling, viscous effects may be ignored with comparison to gravity and inertia forces so Froude similarity may be used in the model studies. Model scales are 1/70 and 1/60 belonging to Yedigoze Dam and Kavsak Dam, respectively. Main model parameters are given in Table 1 and Table 2 after application of the model scale.

Table 1. Scale rates of Kavsak Dam (1/50)

Length (m)	Velocity (m/s)	Discharge (m^3/s)
1/50	1/7,07107	1/17677,67

Table 2. Scale rates of Yedigöze Dam (1/70)

Length (m)	Velocity (m/s)	Discharge (m^3/s)
1/70	1/8,3666	1/40996,34

Model studies were constructed in the hydraulic laboratory of General Directorate of State Hydraulic Works in Ankara. Flow depths were measured by a sluice gate which is sensitive to 0,01 cm. Figure 1 and Figure 2 show the physical model set-up views of Kavsak Dam and Yedigöze Dam, respectively.

Figure 2. General view of Kavsak Dam

Figure 2. General view of Yedigöze Dam

Numerical Model Studies

The simulation of the flow was modelled in a commercially-available CFD package FLOW-3D Version 11.2. To solve the RANS equations, the program implements finite-volume method. Nichols and Hirt (1975), and more completely in Hirt and Nichols (1981) expressed that free surfaces are modelled with the Volume of Fluid (VOF) technique, trademarked as TruVOF. This technique facilitates three important functions for free surface flow: "location and orientation of free surfaces within computational cells, tracking of free surface motion through cells, and a boundary condition applied at the free surface interface". A cell porosity technique termed the fractional area/volume obstacle representation of FAVOR method (Hirt, 1992) is used by the program to identify the location of the flow obstacles. Staggered grid technique is being used at discrete times to compute the average values for the flow parameters (pressures and velocities) for each cell (Vesteeg & Malalasekera 1996). Figure 3 and Figure 4 show the numerical model set-up views of Kavsak Dam and Yedigöze Dam, respectively. After investigating the both numerical and physical model studies, water surface profiles were compared with each other. If the Figure 5 is analyzed, it can be concluded that, numerical results and the physical results are similar to each other, the trend lines overlaps.

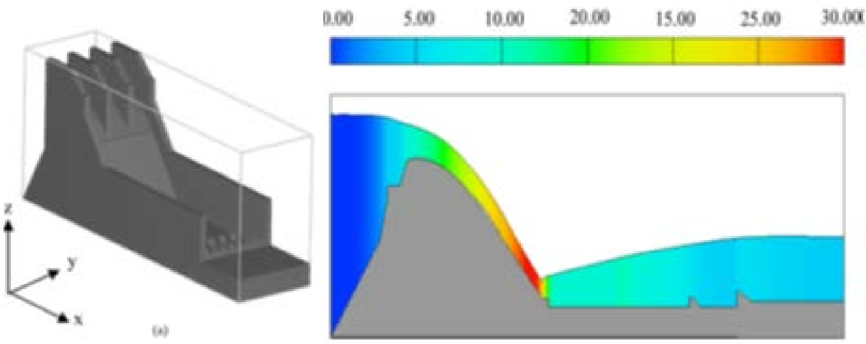


Figure 3. Numerical model set-up and the result of the Kavsak Dam

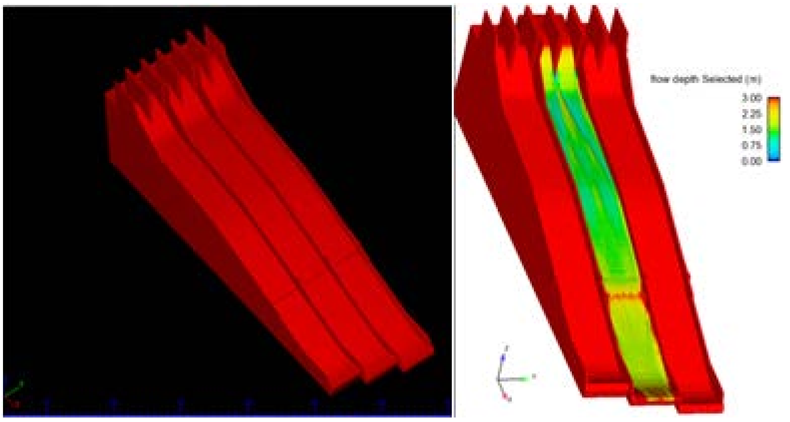
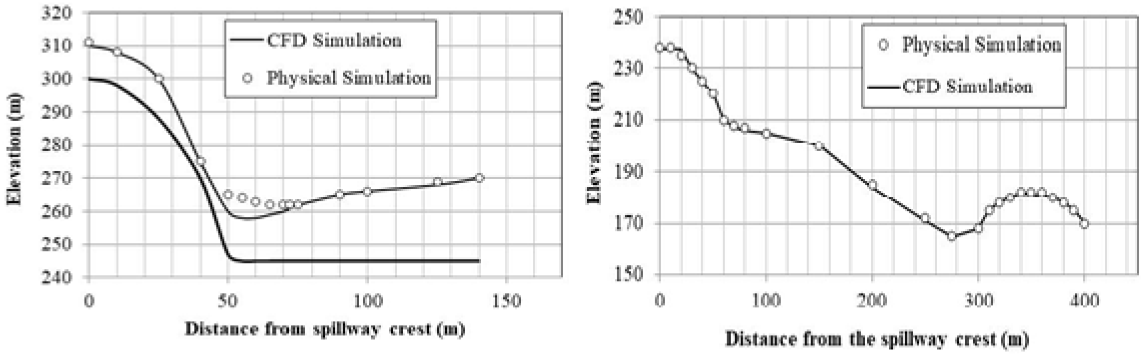


Figure 4. Numerical model set-up and the result of Yedigöze Dam



a) Kavsak Dam b) Yedigoze Dam

Figure 5. Comparison of the water surface profiles observed by numerical model and physical model

Conclusion

In this study, 1/50 and 1/70 - scaled physical models were conducted in order to investigate flow over the spillway for the operating conditions in the Kavsak Dam and the Yedigoze Dam, respectively. A series of experiments are tested in the State Hydraulic Works Hydraulic Laboratory. After observing final design for the approach flow conditions and spillway, CFD model was constructed to simulate flow over a spillway structure using commercially available CFD software. Water surface profiles were obtained for both by CFD and physical model studies. Obtained results from the full-scaled (prototyped) CFD models were compared to existing physical model data of the Kavsak Dam and Yedigoze Dam. The flow rate results show that the CFD model provided a reasonable solution.

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