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Investigation ofCavitation in Stepped Spillway of Siah-Bishe Dam by Using Flow-3d Model

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ABSTRACT: Cavitation is aphenomenon which damages and makes hole in hydraulic structure in high velocity and over-turbulent flows. In this research, stepped fast water formula of Siah-Bishe spillway is stimulated via Flow-3d software and compared with physical model. This software is an accurate tool in analyzing unsteady 3D flow problems with free surface and complex geometry. It solves problems by solving conservationof mass formulas, momentumand energy viafinite volume method. In this study, pressure parameter at the beginning, end and along the spillway is studied and negative pressure is observed in some parts. This pressure can make cavitation. The study shows the results of correspondence between physical model and finite volume method modeled by Flow-3d.

Key words:Cavitation, Stepped Spillway Of Siah-Bishe Dam, Flow-3DModel

INTRODUCTION

One of the complex issues drawing attention ofhydraulic experts and designers is designing stepped spillway. Many attempts have been done to find an appropriate design method for this type of spillway to find space and height of steps, dam body slope in downstream, step surface slope, roughnesscoefficient of steps, equivalent roughness coefficientfor theoreticalsolutionin different roughness, theaeration and its effect on energy dissipation, investigating flow profile, increasing roughness and cavitation, etc.

Numerical Modeling

Physical models and computer simulation are the common ways to analyze hydraulic problems, both of which can be complementary of the other. Todays, achieving powerful and fast computers and developing appropriate numerical methods, makes modeling complex geometry dimensions and real problems possible. Thus, using numerical methods spread fast due to its low expense of computer modeling.In general, it can be said that if all steps of computer modelingaccurately happen, we can expect reliable results.

Flow-3d software is used as an appropriate and accurate model to analyze complex fluid problems. This software is able to analyze unsteady 3-dimensional flow with free surface and complex geometry, and solves these problems based on discretizationof structured meshing. Flow-3d uses first and second order accuracy method to solve equations. One of the advantages of this software is that it needs no lateral software, such as Gambit, for meshing.

Review Of Literature

Olsenand Kjellesvig (1998), designed2-D and 3-Dflow model of ogee spillways for each geometric parameter by using numerical methods. They solved Navier - Stokesequations using k- ε turbulence model and find discharge coefficient of ogee spillway.

Chen et al. (2002)analyzed stepped spillways flow using finite volume method and also used k-ε model to determine flow turbulences.

Due to abundant errors, high expense and time consumption of physical models in dam spillways, David (2003) created a math model using Flow-3D. This was done on several spillways in Australia and showed good results.

Qu (2007) used finite volume method in studying sharp crested weirs in an open rectangularchannel. In this study,k- ε turbulence model was used to find flow parameters such as pressure head distribution, velocity distribution, and water level profile. The results of the study were acceptable.

Nadery Rad et al. (2007), compared energy dissipation of stepped spillways and ogee spillway by using volume of fluid method. They show that ratio of energy dissipation to initial energy in stepped spillway is increased 9.80% more than ogee spillway.

Bahrami (2008) investigates effective factors in aeration and the role of aerators in preventing cavitation in dam spillways. In this study, to simulate flow from shoot and determining air concentration parameter in bottom of chute, Flow-3D software was used. The main objective of this research is to find ways to prevent cavitation by aeration.

Esmaeily (2010) modeledexperimentally and numerically flow pattern of cylindrical spillway and simulates it by using Fluent Software. The results of his study show a good coordination betweenexprimental and Fluent results in flow pattern of spillway.

Dehdar (2011) studies cavitationof flip bucket in Bala-Rood dam spillway. In this research, the spillway of Bala-Rood was modeled by Flow-3D and hydraulic flow was simulated on it.

Research Objectives

Damages of cavitation on structures that designed for high velocity, high dams and big spillways is a constant problem. Studying mathematical model of this structure is very important in preventing and studying this phenomenon. Geometrical and hydrodynamic factors are the most important factors in cavitation. Therefore, the main aim of this research is mathematical modeling and studying possibility ofcavitation in stepped spillway of Siah Bishe dam by Flow-3D model. The following actions are done to achieve the objective:

Studying ability of Flow-3d model in cavitation simulation

Possibility of using aeration in preventing cavitation

In this research, input data was used to create math model and results of the study were analyzed after simulation by flow-3D software.

Geographical position of down Siah Bishe Dam Spillway

Siah Bishe Dam has constructed on Chalous River, Mazandaran, located in 125 Km of North of Tehran and 10 Km of North Kandovan tunnel. This project include two down and up soil dam with height difference of 500 m. Stepped chute is located after a low slope chute in downstream of ogee spillway. Height of first step is 0.34 m and its surface width is 3.20 m, other steps are in height of 0.7 m and width of 2.10 m. Probability maximum of flood (PMF) is 203 m^3/s and water height on spillway for PMF is 2.9 m. Steppedchute of down Siah Bishe dam has same width of spillway (30m) and starts from 1899.96m level and ends to 1802m levelled to stilling basin bed. Length of chute consists of two parts:

1) From 18999.98m to 1831.98m level with horizontal length of 84.73m and slope of 1:1.2.
2) From 1831.98m to 1802m levelwith horizontal length of 57.26m and slope of 1:2.

Physical model of Siah Bishe dam is in scale of 1/20 in Hydraulic Research Institute. The studies show that inlet water velocity of basin for maximum discharge 203m3/s is 14 m/s.Likewise outlet water velocity of basin is 6 m/s. Total height of spillway in real sample is 450/90cm but in model sample is 22.5/6cm.

Spillway section and physical model of Siah Bishe Dam, constructed by Hydraulic Research Institute in the scale of 20÷1 is asillustrated in below figure (number of steps in case study is 87):

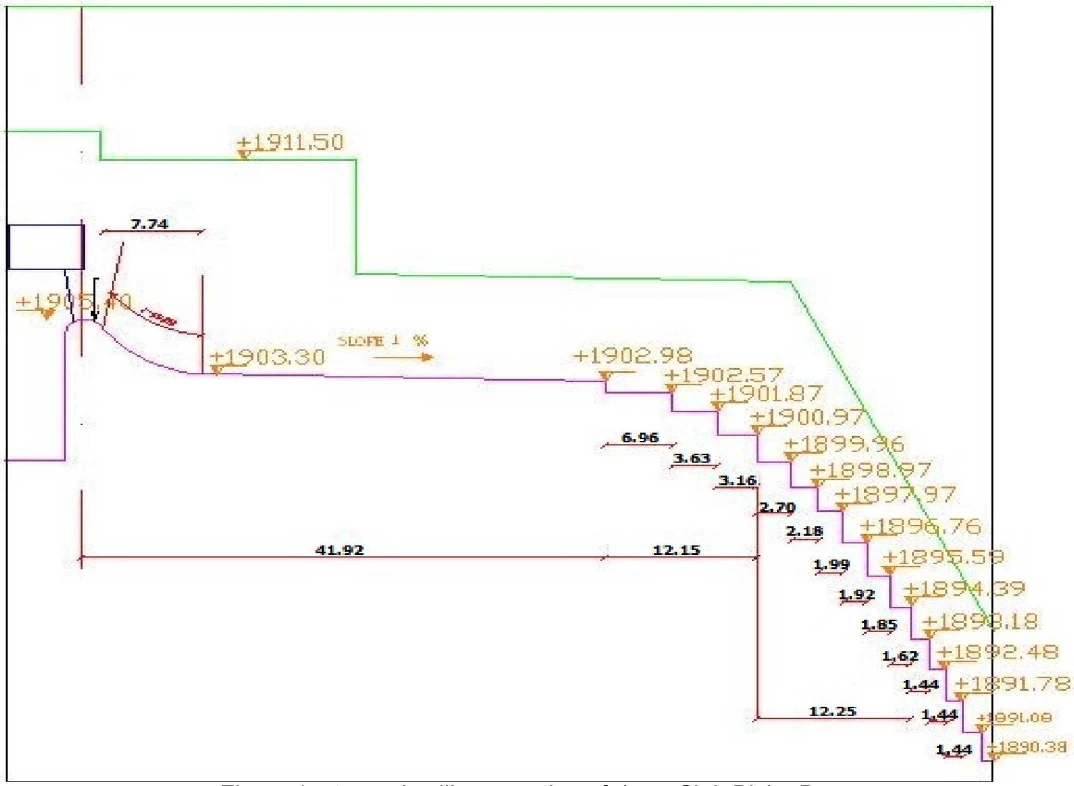

Figure 1. stepped spillway section of down Siah Bishe Dam


Figure 2. physical model section of stepped spillway

Analysis of numerical model

The aim of this research is simulation of flow and study cavitation of stepped spillway of Siah Bishe Dam. The main parameter in this research is pressure, therefore, amount and variation of pressure are studied at the initial, final and during profile of spillway.

Pressure variations in initial steps

Following figure shows the value of pressure in different places with constant width. Negative pressure is occurred in initial steps at height of 5.335m from the base, which can cause cavitation. It is obvious that by decreasing of depth and increasing velocity, the pressure decreases or in some parts is negative.

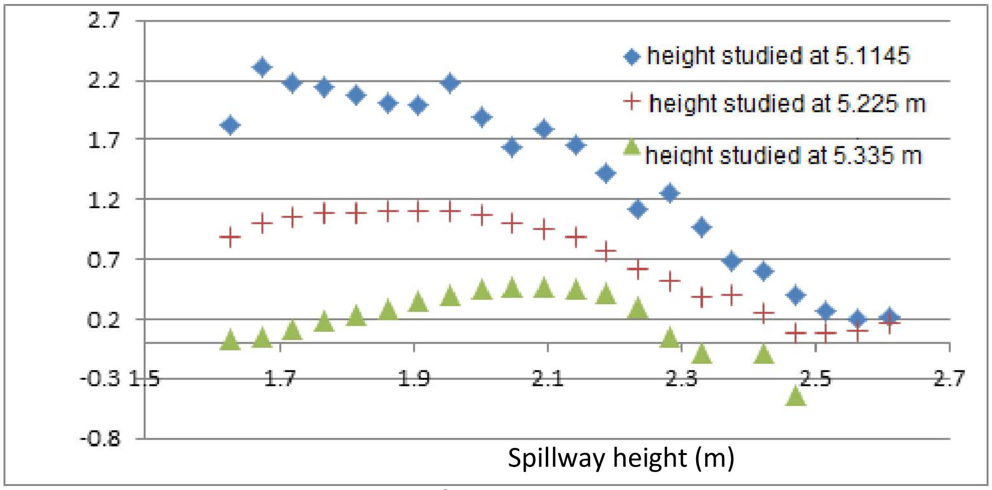

Figure 3. pressure (Pascal) of points in primary steps (width= 0.25m)

Pressure in final steps

Figure 4 illustrates pressure at the end of spillway in two different heights. By decreasingthe measured depth, decreasing of pressure and negative pressure are observable. Negative pressure shows possibility of cavitation at the end of spillway.

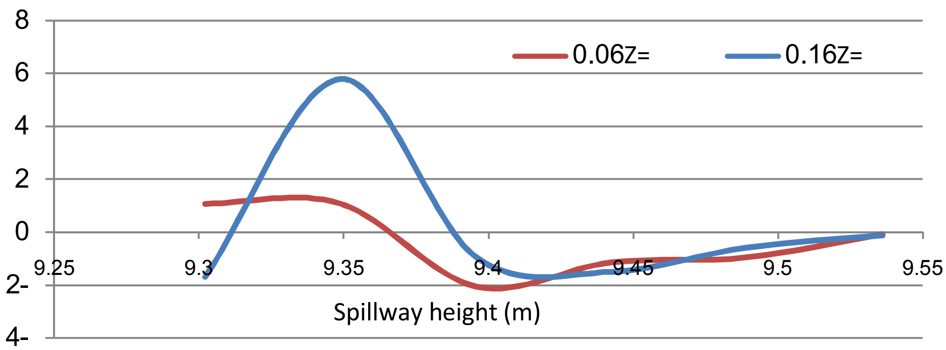

Figure 4. negative pressure at the end of spillway in steps 83, 84, 85, 86, 87

Figure 5 shows pressure distributionwithinthe step 4 with constant height and length. It’s shown than pressure is variable withinthe step.

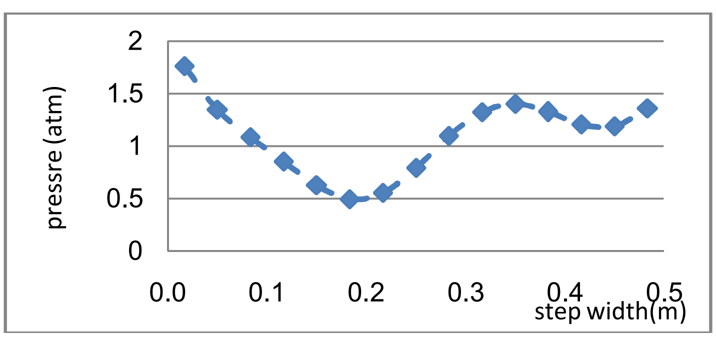

Figure 5. Distribution Of Pressure Within The Step 4 (X=2.2354 , Z=5.005)

Pressure distribution in length of spillway

To study pressure distribution, the values of pressure in simulated period and different times are shown in the following charts. To plot the charts, (x,y) is considered constant and pressure changes is drawn from beginning to the end of spillway. Constant pressure at the end of chart is due to inability of flow to reach the mentioned place during simulation. Maximum and minimum pressure in this chart is 3.2 and -1 atmosphere, respectively. Negative pressure predicts cavitation in t= 0.7s and distance 0.27 m from head of spillway.

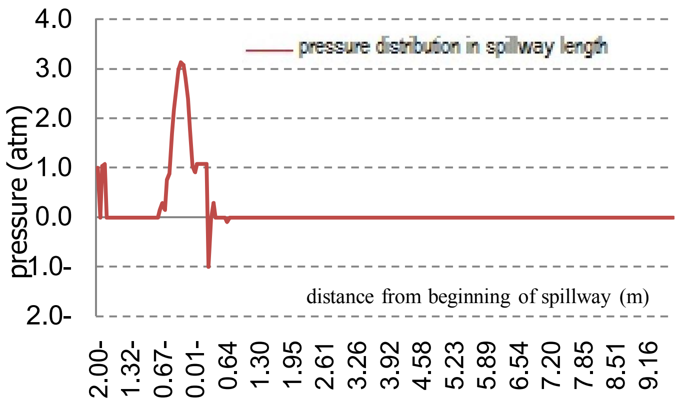

Figure 6. chart of pressure change in length of spillway in t=0.7 after stimulation

Figure 7 shows pressure variationsalong x axis after 6.4 s. As it's presented, in some parts pressure is negative which predicts cavitation. Maximum and minimum pressure is 1.9 and -1, respectively. Negative pressure in length of 2.52 m is due to change and increase of spillway slope.

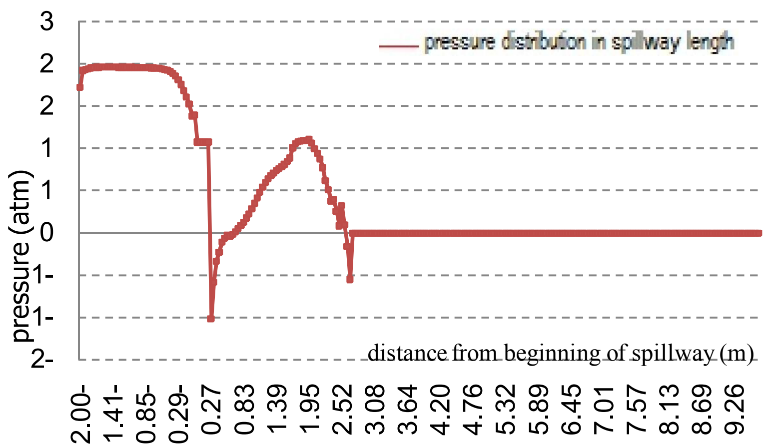

Figure 7. chart of pressure changes in length of spillway in t=6.4 s after stimulation

Following table presents maximum and minimum pressure in different times, in a specific interval of 2.8 m from beginning. This shows possibility of cavitation in length of spillway in different times.

Table 1. Maximum And Minimum Pressure In Different Times Of Stimulation

Time	0.7	1.6	2.4	3.22	4	4.8	5.6	6.4	7.2	8
Maximum pressure	3.2	2.2	1.9	2.2	1.8	1.7	1.7	1.9	2	2.1
Minimum pressure	-1	-2.3	-3.3	-3.3	-3.2	-5.5	-3	-1	-0.5	-0.5

In the following tables and figures, the result of experimental pressure and Flow-3d is compared in 0.0838 and 0.146 m^3/s discharges and error value is measured:

Table 2. Physical Model Pressure In 0.0838 And 0.146 M3/S Discharges

0.146 m^3/s discharge			0.0838 m^3/s discharge			SiahBishe Hydraulic Model - SC:1/20	
Error	Flow-3d model	Physical model	error	Flow-3d model	Physical model	Distance (m)	EL
0.01	2.43	2.46	0.06	2.2	2.07	2.164	1902.57
0.16	5.4	6.4	0.15	4.1	4.8	2.485	1901.87
0.15	3.9	4.6	0.17	3.55	4.21	2.643	1900.97
0.14	2.95	3.45	0.13	3.5	4.02	3.44	1891.98
0.13	1.96	2.26	0.14	3.15	3.68	5.22	1861.98
0.13	2.43	2.8	0.13	3.2	3.68	5.384	1859.58

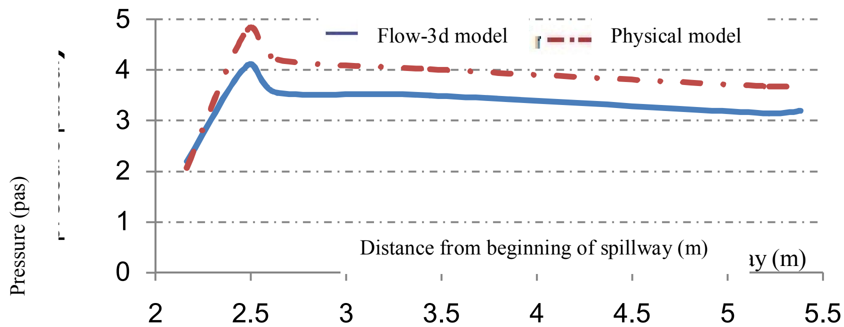

Figure 7. comparison of Flow-3d model and physical model in 0.0838 m^3/s discharge

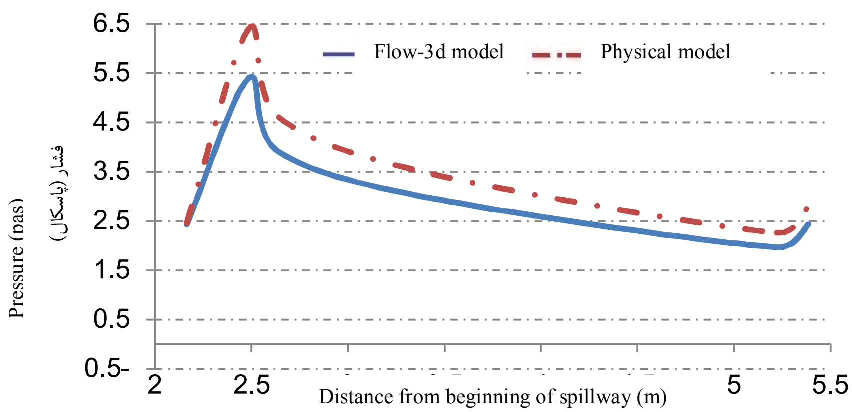

Figure 8. comparison of Flow-3D and physical model in 0.146 m^3/s discharge

Results show a relative coordination between pressure parameter in physical and calculated model. Therefore, Flow-3D model is able to simulate flow and study pressure on stepped spillway of down Siah Bishe dam. Furthermore, in this model, by increasing discharge pressure increases.

Discussion And Suggestions

In length of spillway, due to roughness of spillway bed, stream lines are separated from their bed. Due to this separation, local pressure decreases in separated place and may reach to the fluidvapor pressure. In this case, liquid of that part of fluid immediately boils and fluid changes to vapor and produces some bubbles. After passing a shortdistance,these bubbles reach a high pressure place, blow and make noise and blow waves. It blows boundary of fluid and structure and after a short time damages and makes corrosion in solid boundary. However, contact surface of the bubbles and spillway bed is very little, so they apply a high force to spillway beds and stilling basins due to these blows. In this research, possibility of cavitation phenomenon in Siah Bishe dam spillway is studied after simulation. To study possibility of cavitation, pressure is measured in initial and final steps of stepped spillway. In some parts pressure was negative, which shows possibility of cavitation.

Distribution of calculated pressure shows its variations in length of stepped spillway caused due to step dimensions and changes in energy equation terms (gravitationalpotential, velocity, pressure).

According to the results, at the beginning of spillway, velocity is low and pressure is high, while at the end of it, velocity is high and pressure is low due to slope changes. Therefore, at the end of spillway possibility of cavitation is high. Based on Flow-3D model, at the beginning of spillway in the steps of 7, 8 and 9, pressure is negative, likewise at the end of spillway, in the steps of 83, 84 , 85, 86 and 87 pressure is negative, yet. This phenomenon is due to type of steps design and their dimensions, since formation of flow profile can create negative pressure. Moreover, lumps on materials can be another factor of this phenomenon. It's suggested to change step dimensions and eliminate these lumps to prevent cavitation. Effect of other methods on preventing cavitation, such as hydraulic aeration along the flow in spillway, can be studied which need specific physical tools. Using aeration method in some places with cavitation hazard, is an appropriate way.

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