Advances in Bioresearch
Adv. Biores., Vol 6 (3) May 2015: 93-99
©2015 Society of Education, India
Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
ICV 7.20 [Poland]

Advances in Bioresearch

ORIGINAL ARTICLE

Examining Pressure Distribution on Crest Spillway Using ANSYS-Fluent Software

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ABSTRACT
The numerical model being investigated is the two-dimensional model of crest spillway without gates whose geometrical characteristics are presented by USACE. The results obtained through this study are different from the experimental results of non-hydrostatic pressure distribution on gated crest surface published by ASACE for various H/Hd. Studies indicate good conformity of numerical results with the published laboratory results. The studies show that as the slope is moderated the increase of pressure is directed towards the crest of spillway and as the hydraulic load (H/Hd) in the dam reservoir increases, the pressure and the area affected by it increase more.
Keywords: *Ansys Fluent, crest spillway, examining pressure distribution, Ali Eskandari Sabzi*

Received 07/02/2015 Accepted 24/04/2015 ©2015 Society of Education, India

How to cite this article:
Ali Eskanadari S, Ali A. Examining Pressure Distribution on Crest Spillway Using ANSYS-Fluent Software. Adv. Biores., Vol 6 [3] May 2015: 93-99. DOI: 10.15515/abr.0976-4585.6.3.9399

INTRODUCTION

The purpose of constructing spillways in dams is the pass of flood water that cannot be stored in the finite volume of dam. A lot of failure has been reported due to incorrect design of spillway in dam or not being equipped with a spillway with adequate capacity. Therefore, the analysis of water flow over the spillway is an important engineering issue. Since the determination of flow characteristics, such as profile position of water level, the rate of velocity at different points and the rate of pressure on the spillway crest, via physical model is very expensive and time-consuming, due to advances in computer science the use of numerical methods in the analysis of flow seems to be quite logical and economically affordable.

Crest spillways are the most useful spillways in diversion channels, short and long dams whose design is very important and has always been focused on by the hydraulic researchers due to special hydraulic characteristics and certain complexities of flow regime change. The manner of pressure on the spillway crest and the determination of flow discharge are the most important parameters considered in the studies. The formation of crest depends on determining the lower level of flow passing over the sharp-edge spillway and if the height of the flow passing over the spillway is equal to the designed height, atmospheric pressure is developed on the surface of crest spillway. If the rate of flow discharge through the spillway is more than the flow discharge of the desired design, negative pressure occurs on the surface and causes suction on the spillway. Therefore, if the spillway is designed in such a way that it imposes some negative pressure on the surface of spillway crest (to the extent that it doesn't destroy the structure), the spillway efficiency and productivity improves and the spillway permeability coefficient increases.

Many studies have been done on crest spillways hydraulic. However, the research has been mainly carried out on physical models. Numerical models in spillway overflows were used for the first time in 1965 by Cassidy as two-dimensional model to determine the pressure on the spillway crest according to the potential flow theory. The results of the research are well consistent with the laboratory model and indicate the slight effect of viscosity on determining free level.

Motalebizadeh et al. (2001) modeled the field of flow governing the free spillway according to the equations of momentum and depth buffer and quadratic variation assumption for the vertical distribution of velocity and pressure and linear variations for the horizontal velocity. They used finite element to solve the governing equations and used implicit algorithm for the time separation of equations. In comparison with the experimental results, the maximum error of 25% in water surface profile and the maximum error of 41% in distribution of pressure on the bottom of spillway are observed.

METHOD

The model studied in the research is the two-dimensional model of crest spillway without gates whose geometric features are presented by USACE in HDC 111-16 diagram. The presented reports indicate the pressure distribution on the surface of crest spillway. Therefore, after constructing two-dimensional geometry of spillway model, the model was meshed and the kinds of boundary conditions were determined. VOF method was used to determine the water level. Two-equation model k- ε (RNG) was used as the turbulence model and SIMPLE algorithm was used to couple velocity and pressure equations. By implementing the numerical model in Ansys-Fluent environment, the obtained results were compared with the results reported by USACE. The studies indicate that the numerical results are well consistent with experimental results.

For modeling, the standard gated crest spillway of USACE [1] has been used whose discharge coefficient, pressure distribution, and other hydraulic parameters are determined. The spillway upstream is made up of a flat vertical surface and is connected to the spillway crest with a curve which is made of the sectors of three circles with the radii of 0.5Hd, 0.2Hd, and 0.04Hd,. The spillway level after the crest involves crest part and stable slope and the crest section follows the equation (1-1).

Equation (1-1): $\boldsymbol{X^n = kH_d^{n-1}y}$

Where k=2, HD = 15.24 m (50 ft) and n = 1.85. The slop of the straight part is 45̊ (1/1:1).

RESULTS

The details of the level of gated crest spillway, under the study, are shown in Figure (1-1). Since the modeling is two-dimensional the unit thickness is intended for Z direction. In order to insure that the results of the experiment are published with the least amount of error during the experiments, some of the experiments have been repeated. The results of the experiments published by USACE for crest spillway, involve the pressure distribution on the surface of crest spillway and at different levels of water in the crest upstream.

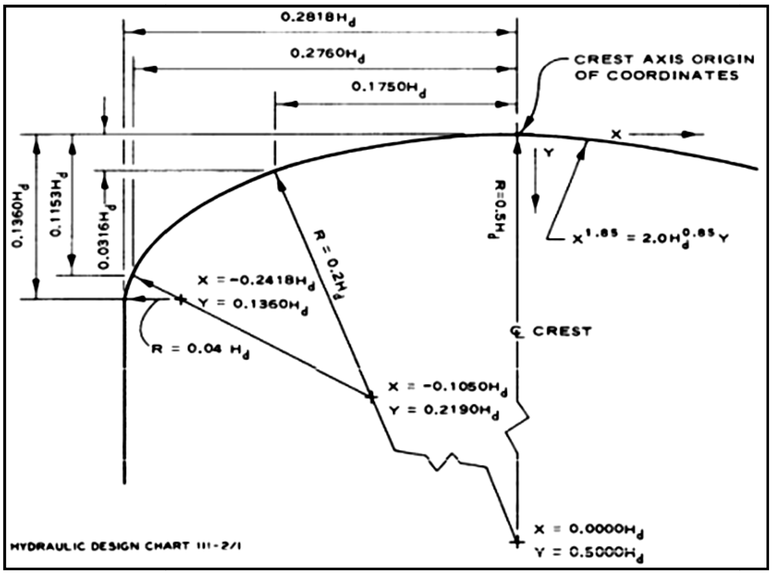

Figure (1-1): details of standard crest spillway level

The flow discharge over the crest spillway is calculated through Equation (1-2):

Equation (1-2): $Q = CLH_e^{(3/2)}$

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Where C is the discharge coefficient, L is the width of crest spillway which is considered as the unit in this research, H_e is the height of water from crest spillway level to the water surface according to Figure (1-2). I order to calculate discharge coefficient, HDC 111-3 presented by USACE has been used [1].

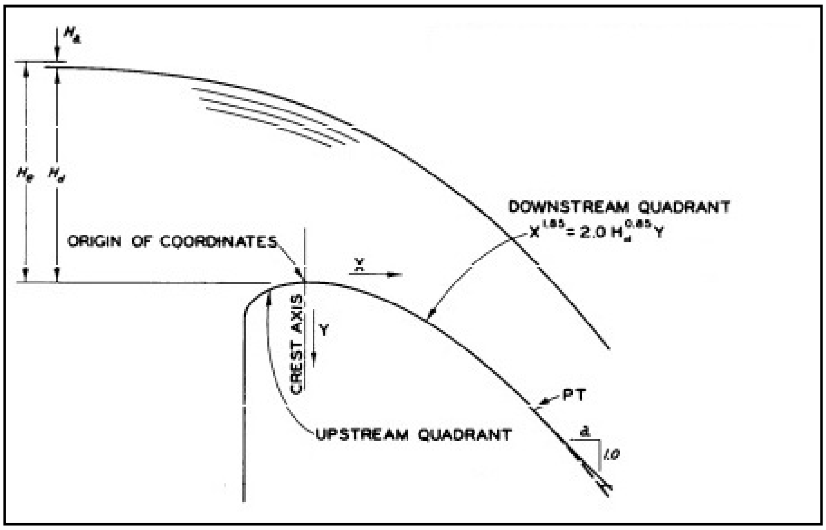


Figure (1-2): General Schema of crest spillway without gates [1]

The Dimensionless pressure distribution on the surface of crest spillway for the experimental model by USACE, which has considered different states of water level behind the gates, is displayed in figure (1-3).

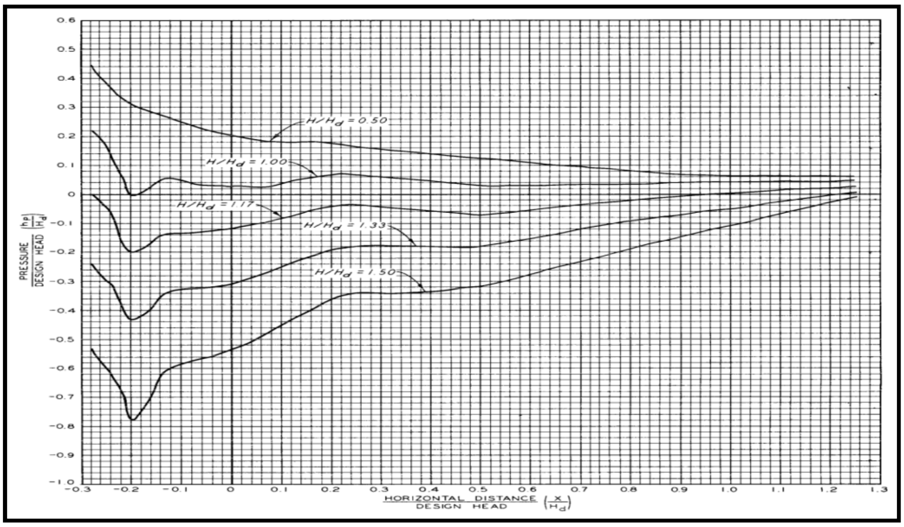


Figure 1 3: Experimental results of non-hydrostatic pressure distribution on the surface of gated spillway crest published by USACE for hydraulic load H/H_d=0.5, 1.00, 1.17, 1.33, 1.50]

Table (1-2): The features of the studied models

Model	Constant slope	C	H/Hd	Q (kg/s)
Model 1	30^0	3.612	0.50	41874.5
Model 2	37^0	3.612	0.50	41874.5
Model 3	45^0	3.612	0.50	41874.5
Model 4	60^0	3.612	0.50	41874.5
Model 5	30^0	3.922	1.00	127306
Model 6	37^0	3.922	1.00	127306
Model 7	45^0	3.922	1.00	127306
Model 8	60^0	3.922	1.00	127306
Model 9	30^0	4.077	1.33	205024
Model 10	37^0	4.077	1.33	205024
Model 11	45^0	4.077	1.33	205024
Model 12	60^0	4.077	1.33	205024

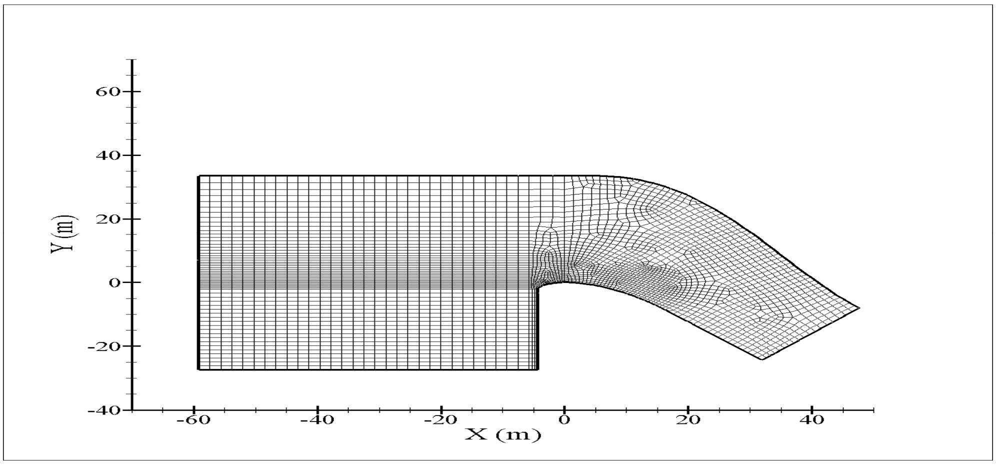
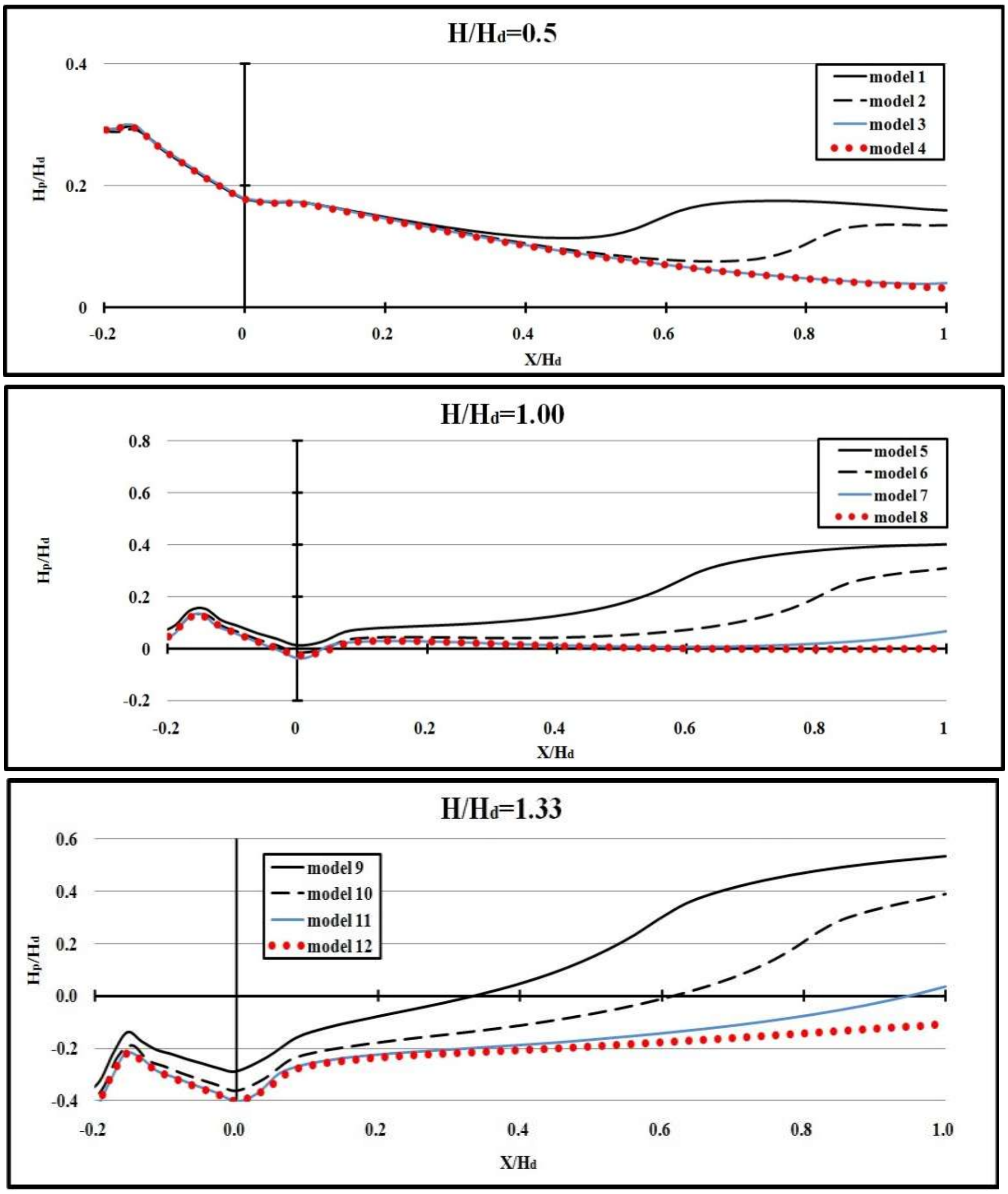


Figure (1-4): Networking numerical model

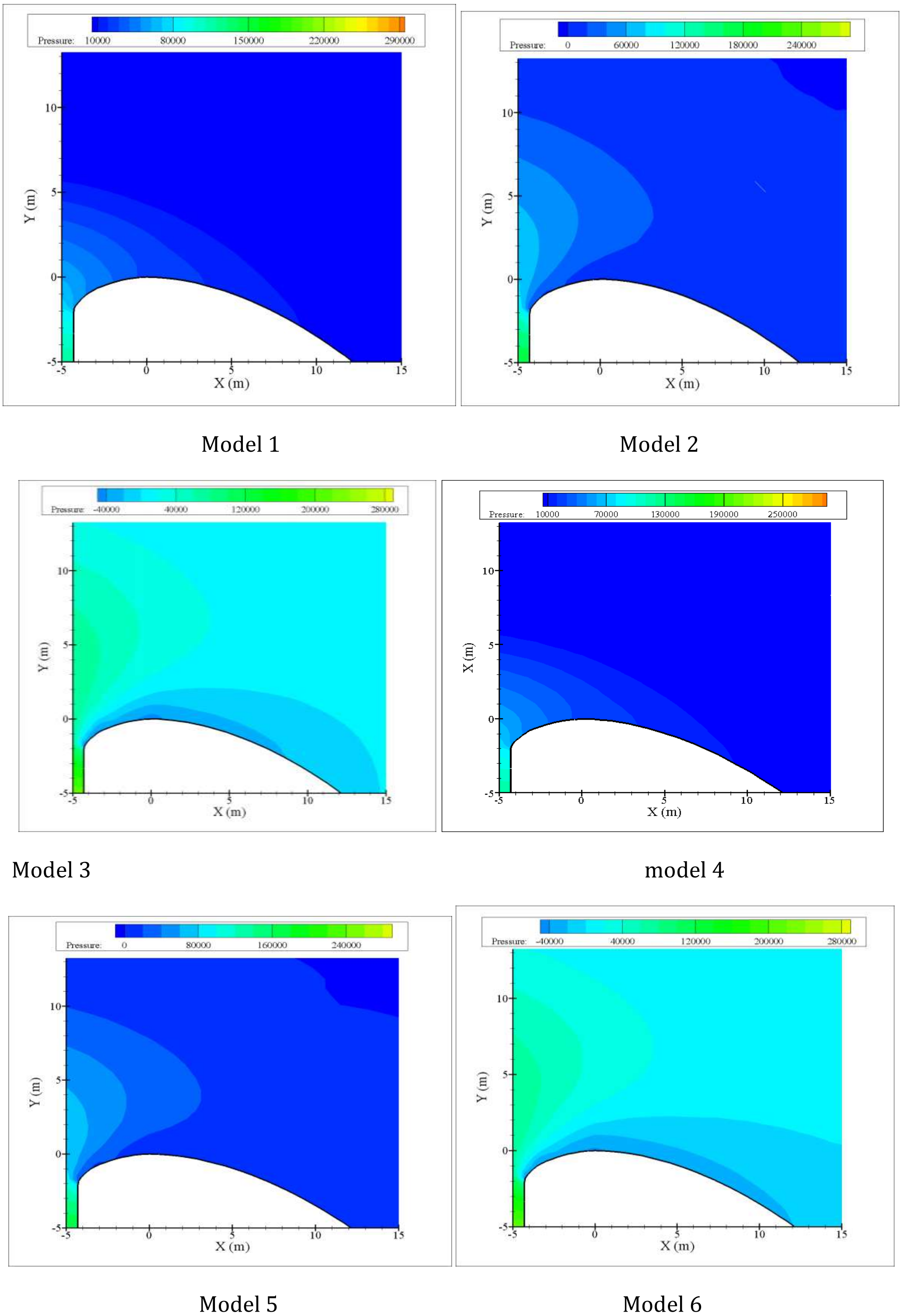


(A)

(B)

(C)

Figure (2-1): The results of pressure distribution on the surface of crest spillway for the mentioned models in the hydraulic loads (A) Hd0.5, (B) Hd 1.00, (C) Hd 1.33

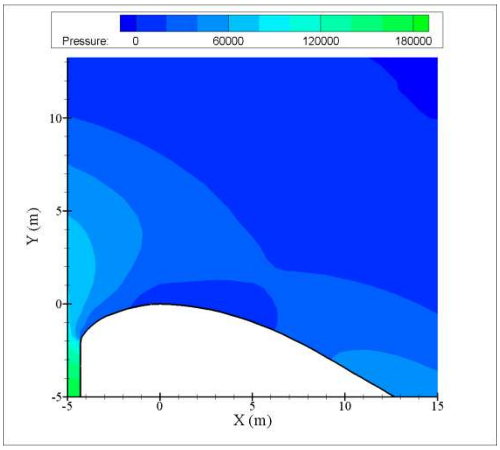


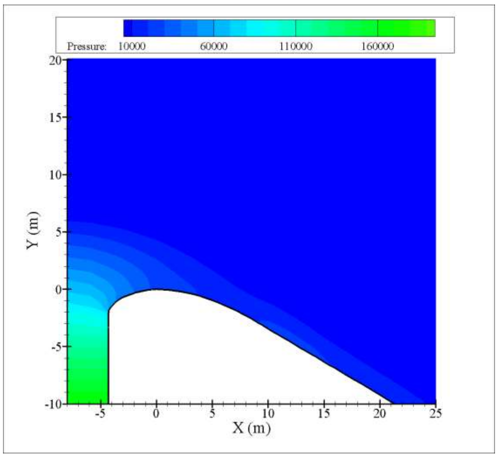
Model 1 Model 2

Model 3 model 4

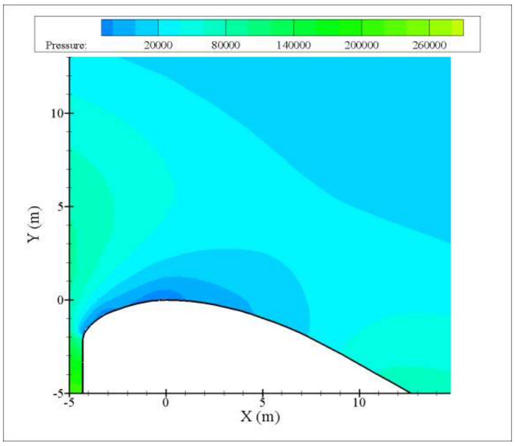
Model 5 Model 6

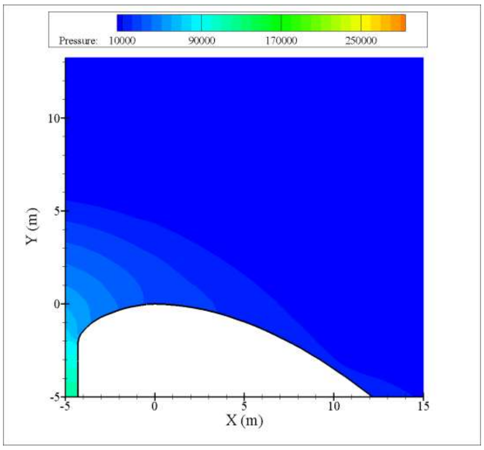
Figure (2-1): The results of pressure distribution on the surface of crest spillway for the mentioned models



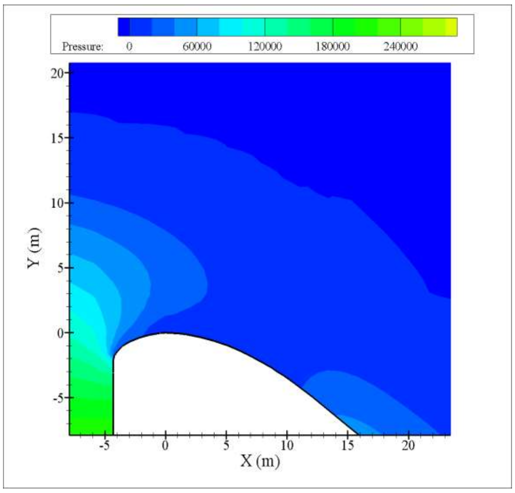


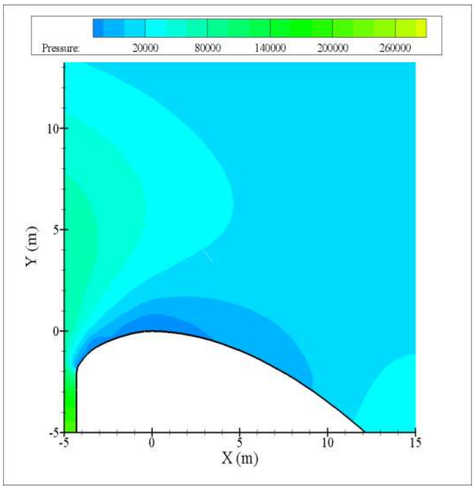
Model 7 model 8





Model 9 model 10





Model 11 Model 12

Figure (2-1): The results of pressure distribution on the surface of crest spillway for the mentioned models

DISCUSSION

The results of pressure distribution on the surface of crest spillway from the fluid in this condition are shown in Figure (1-2). By defining spillway with constant slope of 45̊ as the spillway with the basic

constant slope the problem has been analyzed. The reason for this choice is that the experimental results have been published by USACE. With regard to the obtained pressure distribution, in all states of hydraulic load, as the constant slop gets sharper (change of basic constant slope to the constant slope of 60̊) the reduction of pressure on the surface of spillway is observed. As the hydraulic load of reservoir increases, the pressure difference between the two spillways increases so that the decrease of pressure which in almost negligible in the constant hydraulic load of o.5, is more evident in the hydraulic load of 0.133. However, the pressure drop doesn't occur as the constant slope gets sharper before the 0.5 position in crest spillway downstream [3-5].
Considering the milder constant slope, there is some evidence indicating the increase of pressure on the surface of spillway and as the slope gets softer the increase of pressure is drawn towards the crest of spillway. When the softened constant slope is followed by the increase of hydraulic pressure in the dam reservoir the intensity of increase and the affected area by the increasing pressure will enhance too so that this point is quite evident in the hydraulic load of 1.33.
Another important point in the pressure distribution diagrams is that as the rate of constant slope changes, the magnitude of maximum negative pressure doesn't change or it decreases as the hydraulic load of reservoir decreases. This is an important point in the development of cavitation because it can be stated that, due to this problem, if the negative pressure developed in the spillway with the basic slope tested by USACE do not lead to the occurrence of cavitation, the other spillways examined in this research will not witness the development of cavitation, either. Otherwise, the cavitation development can be prevented only by softening the spillway constant slope [6-8].

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