

Minimizing scour of contraction stepped spillways

ABSTRACT

The scour below spillways can endanger the stability of the dams. Hence, determining the scour depth downstream of spillways is of vital importance. Scour holes formed around and near the foundations of spillways can endanger the stability and firmness of dams and may lead to their failure. . In this paper of The experimental flume 16.2 m length, 65cm depth and 66 cm width, the breaker used above the stepped spillway which of number 4 step, the improving the scour by using different shapes of openings as rectangle, triangle and trapezoidal and different numbers by 2,4,6 and 8 of beakers. the best number is 4 of rectangle shape by reduce the scour is 54.51 %.in finally to improve this scour by another cases, can be changes of the divergent angle by 45° , 30° , 15° and 10° , the best angle is 10° can be minimize the scour is 65.38 %.

KEYWORDS: Stepped spillways, scour, breakers, openings and divergent angle.

1. Introduction

Spillways are structures constructed in dams in order to drain water in excess of the reservoir capacity. Although flow through these structures is associated with a great deal of energy loss, a scour hole is created due to the impact of the high-velocity jet on the erodible downstream bed. Bormann and Julien (1991) reviewed experimental studies of scour downstream of hydraulic structures below free and submerged jets. Balachandar and Kells (1998) showed that the dynamics of local scour is dependent on the tailwater depth. Dargahi (2003) presented an experimental study to examine the similarity of scour profiles and the scour geometry. No experimental evidence was found in support of the similarity. Power-law type equations were introduced to predict the scour geometry, mainly in terms of the head above the spillway crest and the grain size of the sediment bed.. Marion et al. (2004) conducted a series of tests to determine the effect of bed sill spacing and sediment grading on the potential erosion by jets flowing over the sills. Adduce and Sciortino (2006) presented both numerical and experimental investigations on local scour downstream of a sill followed by a rigid apron. A one-dimensional numerical model simulating the evolution of the scour hole was developed and tested by laboratory measurements. Dey and Raikar (2007) studied the scour below a high vertical drop. They presented influences of various parameters and dimensionless parameters for their study. Hamidifar and Nasrabadi (2011) conducted experimental study to investigate the scour downstream of a roughened apron located downstream of a hydraulic jump. They carried out tests with five different roughness height sand one bed material size under different flow conditions. Giuseppe Oliveto (2013), deals with the temporal and spatial evolution of local scour downstream of low head spillways with a horizontal apron, It was found that the main dimensionless parameters governing the scouring process are the tail water densimetric Froude number, the relative time, and the relative distance of the toe of the hydraulic jump from the apron edge. E. Fadaei-Kerman and G.A. Barani (2014), study, numerical simulation of flow over a chute spillway is presented using the Computational Fluid Dynamics (CFD) method. The flow characteristics such as velocity, pressure and depth

through the spillway have been calculated for four different flow rates. Jiemin Zhan, Jianbo Zhang, Yejun Gong (2016), study, the volume of fluid (VOF), mixture, and Eulerian methods are utilized to simulate the air-entrainment by coupling with the Reynolds-averaged Navier–Stokes/large eddy simulation (RANS/LES) turbulence models. The free surface deformation, air volume fraction, pressure, and velocity are compared for the three different numerical methods.

2. Experimental work

Experimental work was carried out in the Hydraulic and water Engineering Laboratory, Faculty of Engineering, Zagazig University, Egypt. The experimental flume 16.2 m length, 65cm depth and 66 cm width as shown in Photo (1). The measuring discharge by weir was found in the lower flume, equation of the weir is: $Q = 1.088 * Y^{1.523}$, Where :Y is the height of water over the weir crest , Q :discharge. opening in breakers and downstream divergent angle in flume as shown in photo(2) , with median size (D50) is 3.1 mm as shown in fig.(1). The required time for each test, in which the relationship between ds/ds Equilibrium was plotted against the time as shown in fig.(2), It was found that 90% of maximum scour depth was achieved at 2 hours.



Photo (1) general view flume in lab.



Photo (2) .the opening in breakers and downstream divergent angle in flume.

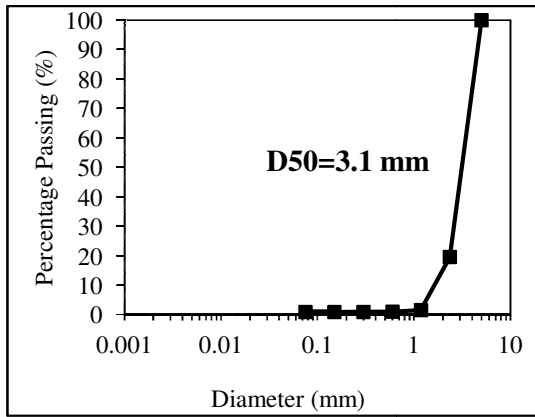


Fig.(1) Sieve analysis of the sample

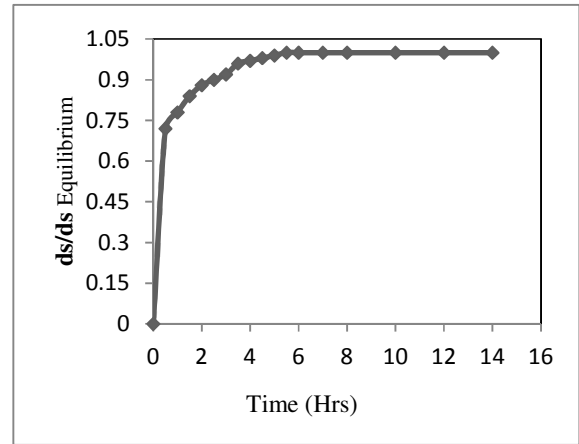


Fig.(2) Fig.(2) Ratio of maximum to equilibrium .scour depths (ds/ds Equilibrium) versus time

3. Dimensional analysis

The dimensional analysis of the experimental flume in fig. (3) Approach of π - Buckingham theory is obtained:

$$\frac{ds_{max}}{y_c} = f\left(\frac{B - 2C}{B}, \alpha, \frac{A_0}{Ab}, N, F_0\right)$$

Where: $d_{s_{max}}$: maximum depth of scour, y_c : critical water depth of spillway, B :flume width = spillway width, C : width of side wall in spillway, B : the channel width = the step Width, F_0 : Froude Number in upstream of spillway. α : downstream divergent angle, N : number of openings in breakers.

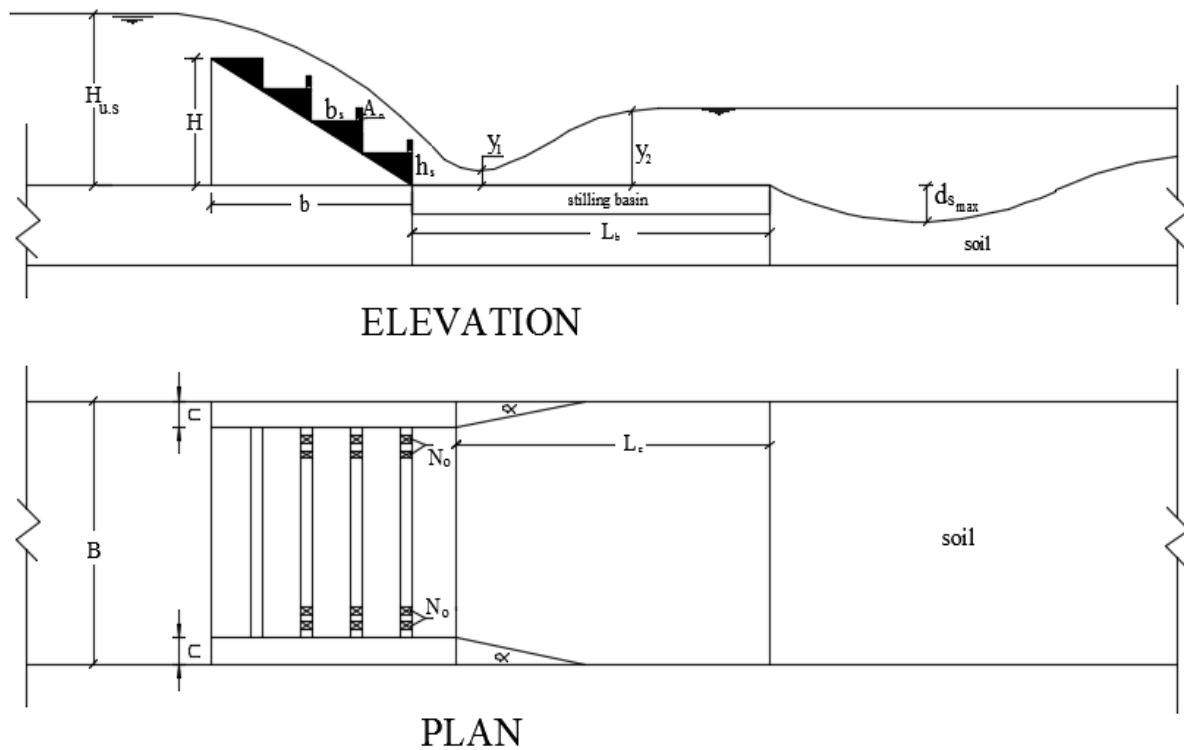


Fig.(3) Definition sketch for the experimental models.

4. Analysis and discussion

The used number of stepped spillways was 4 Sep, contraction ratio was 60% from flume width and the opening area in breaker 10% from the breaker area in all sides putting in down of breakers.

4-1 Effect of shape openings in breakers on the scour:

The effect of shape openings in breakers on local scour depth was investigated experimentally. The shape openings in breakers are Rectangle, Triangle and Trapezoidal with constant area opening ($A_0/A = 0.1$). The relationship between the maximum relative scour depth ($d_{s,max}/y_c$) and upstream Froude number (F_0) is shown in Fig. (4), for different shape openings in breakers. This figure shows that, the maximum relative scour depth increases as Froude number increases. In fig (5) shown scour hole in the contour maps for different shapes of openings. The reduction ratio of sour by using different shape openings in breakers rectangle, triangle and trapezoidal by 47.77 %, 24.05 % and 9.62 %, so the best shape of opening is rectangle.

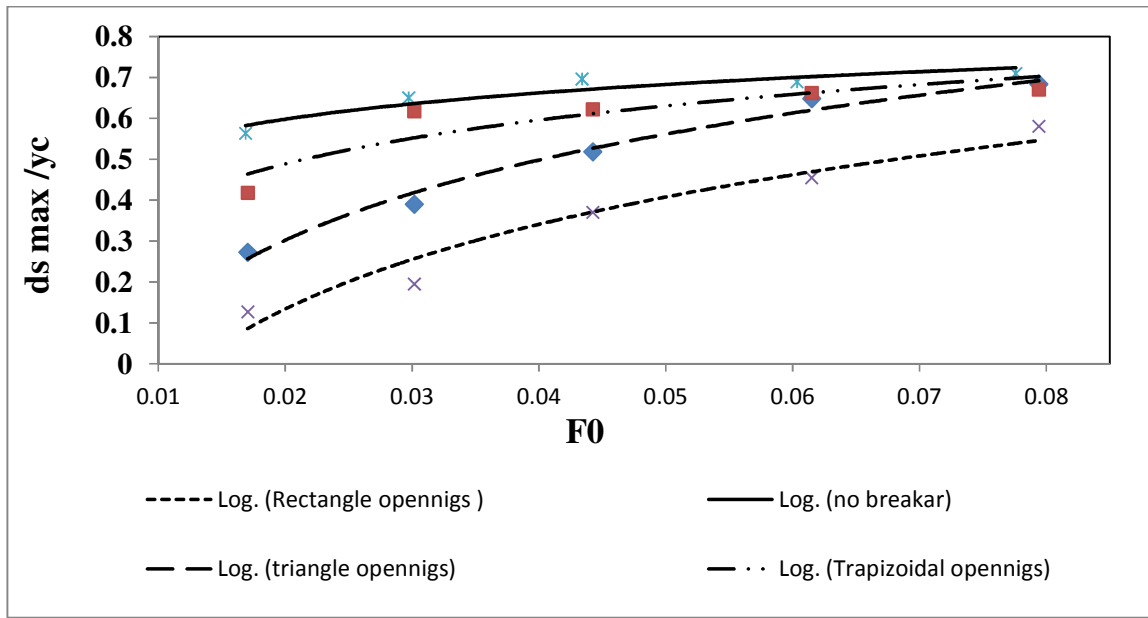
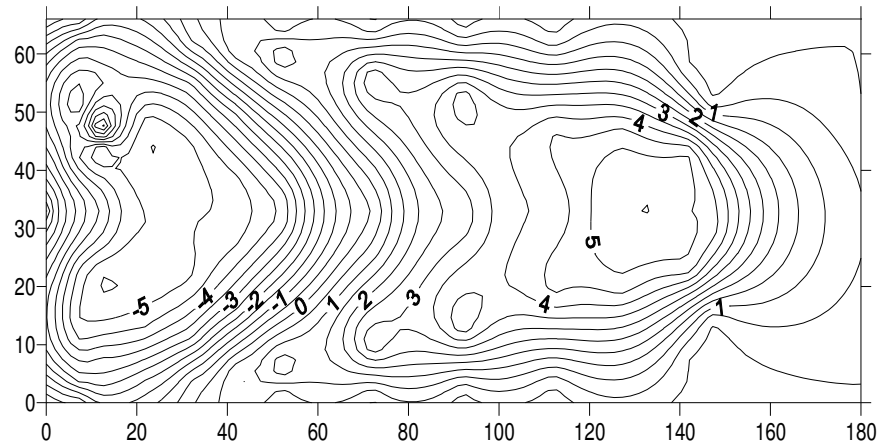
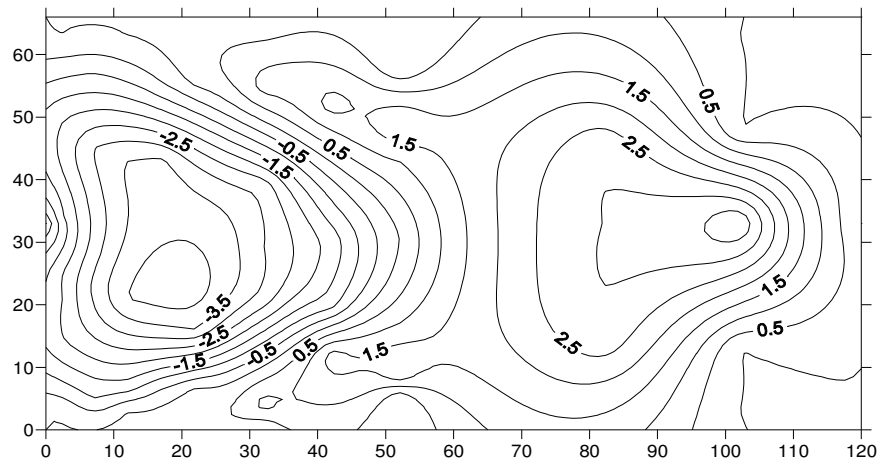


Fig.(4) The relationship between $d_{s \max}/y_c$ and F_0 at different shape openings in breakers.



(i)



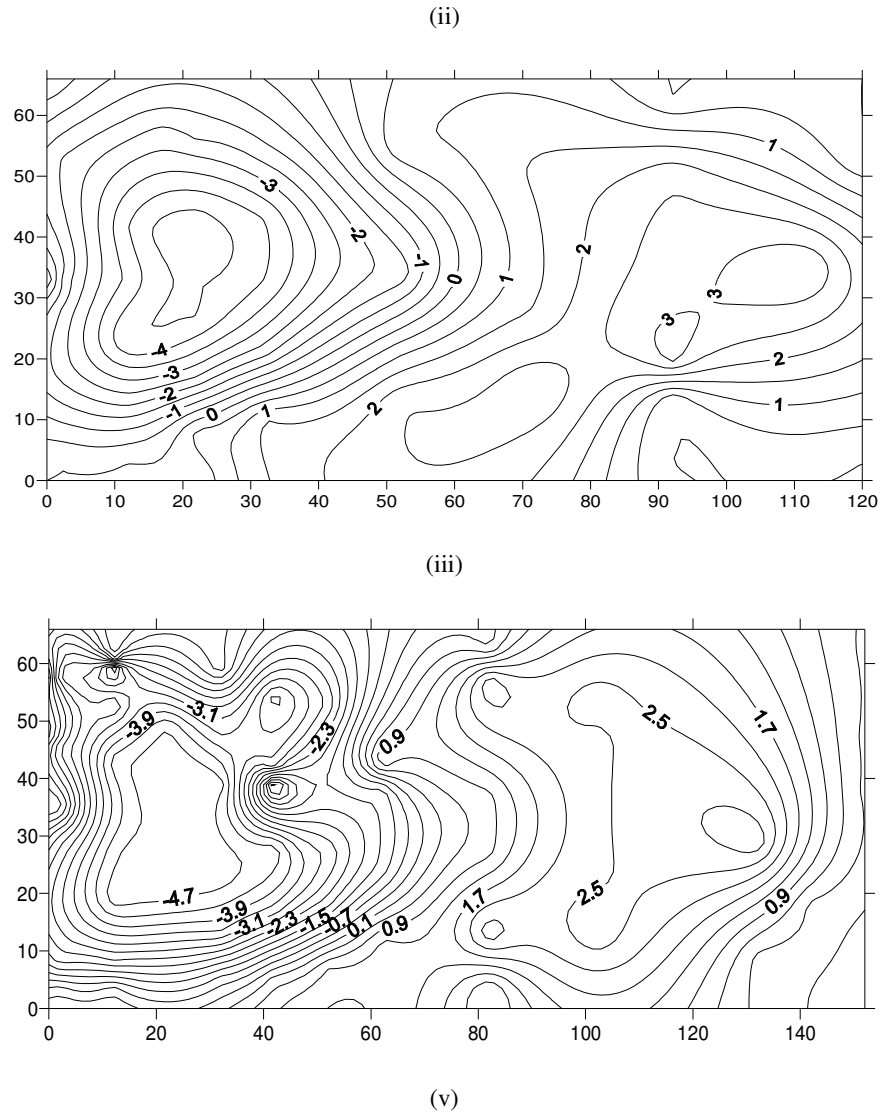


Fig.(5) Scour contour maps for different shape openings in breaker, (i) = no breaker , (ii) = rectangle,(iii) = triangle and (v) trapezoidal at $Q = 35L/s$

4-2 Effect of Number of openings in breakers on the scour:

The effect of Number of opening in breakers that rectangle shape on local scour depth was investigated experimentally. The Number of opening in breaker (N) = 2, 4, 6 and 8. The relationship between the maximum relative scour depth ($d_{s \max}/y_c$) and upstream Froude number (F_0) is shown in Fig. (6), for different Number of opening in breaker. This figure shows that, the maximum relative scour depth increases as Froude number increases. The best number of openings is 2 because the more of openings as orifice increase water depth above it so velocity increase ($v = \sqrt{2gH}$). The scour hole shown in fig.(7) and the reduction ration of sour by using different Number of opening in breaker 2,4,6 and 8 by 47.77 %,54.51 %, 34.76 % and 15.53 % , so the best number of openings in breakers 2 open n all sides.

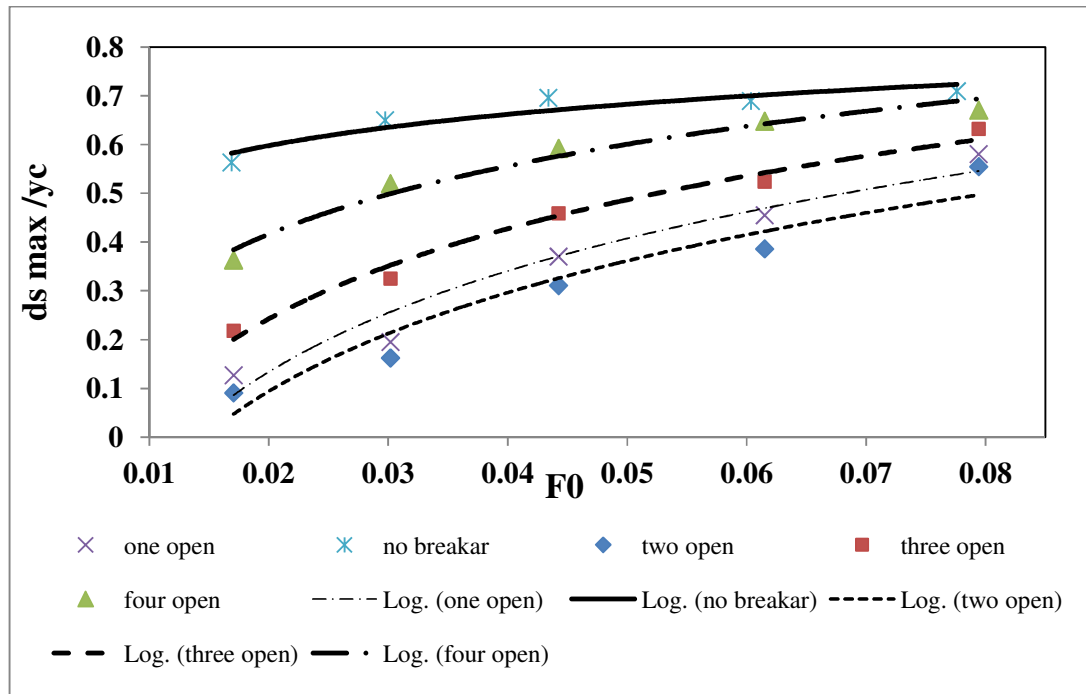
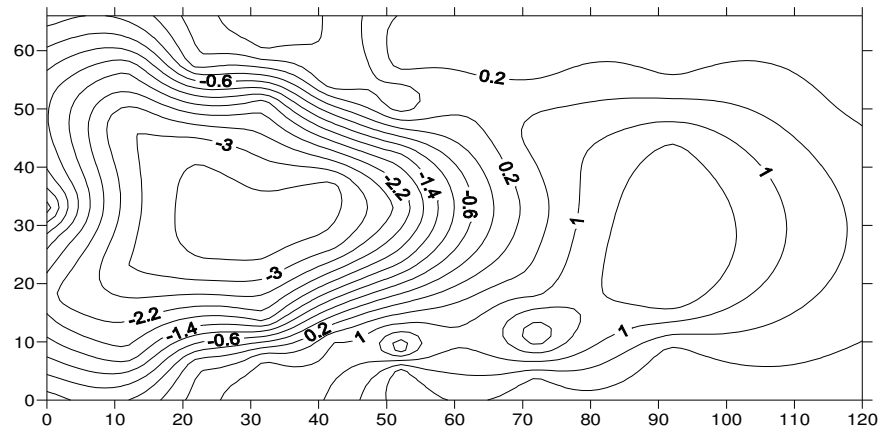


Fig.(6) The relationship between $d_{s \max}/y_c$ and F_0 at different Number of opening in breakers.



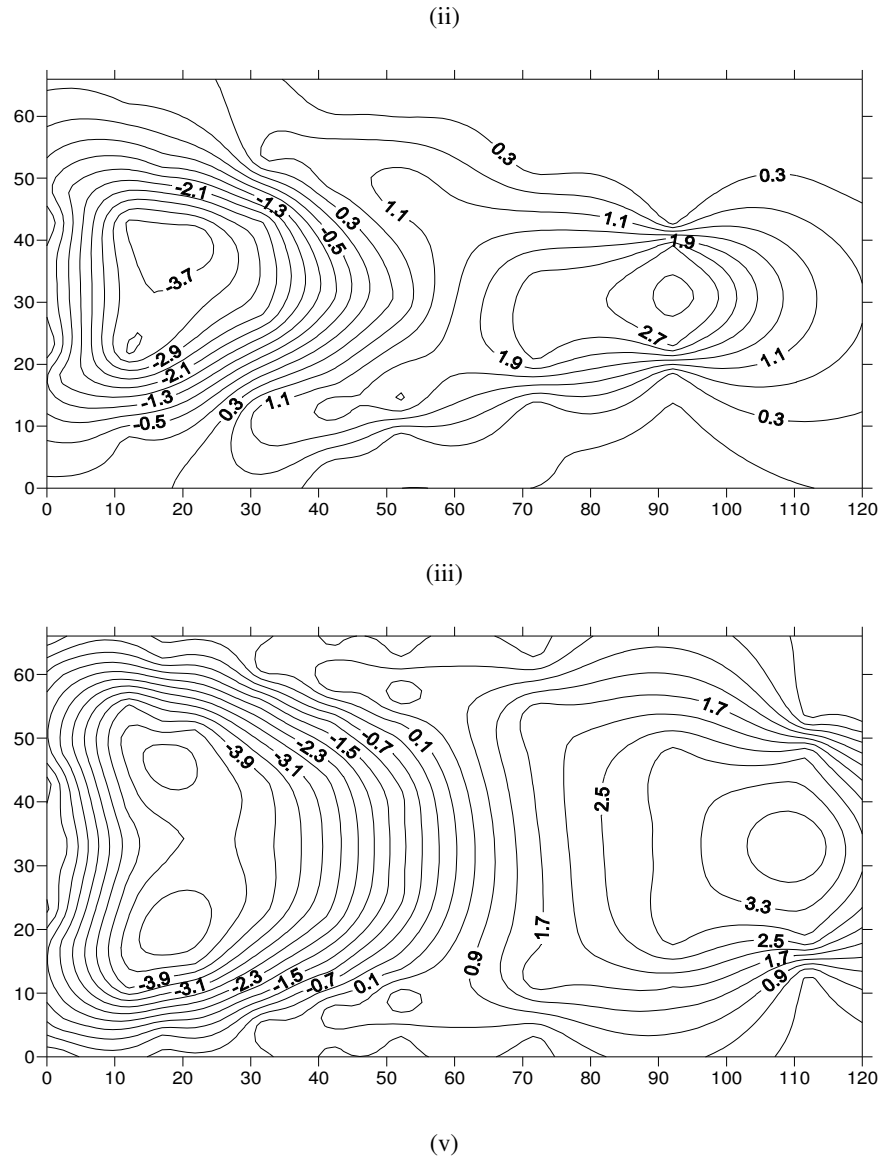


Fig. (7) Scour contour maps for different Number of opening in breakers,(i)=2,(ii)=4,(iii)=6 and (v)=8 at $Q = 30L/s$

4-3 Effect of downstream divergent angle on the scour:

The effect of downstream divergent angle on local scour depth was investigated experimentally. The downstream divergent angle (α) = 90, 45, 30, 15 and 10. The relationship between the maximum relative scour depth ($d_{s \max}/y_c$) and upstream Froude number (F_0) is shown in Fig. (8), for different downstream divergent angle. The decreasing downstream divergent angle decreasing scour because the width increase gradually. This figure shows that, the maximum relative scour depth increases as Froude number increases. The reduction ration of sour by using different downstream divergent angle (α) = 90°, 45°, 30°, 15° and 10° by 54.51 %, 57.07 %, 57.07 %, 57.07 %, 57.07 %.

60.27 %,62.91 % and 65.38 % The scour hole shown in fig.(9) by contour maps showed the best angle which was 10° .

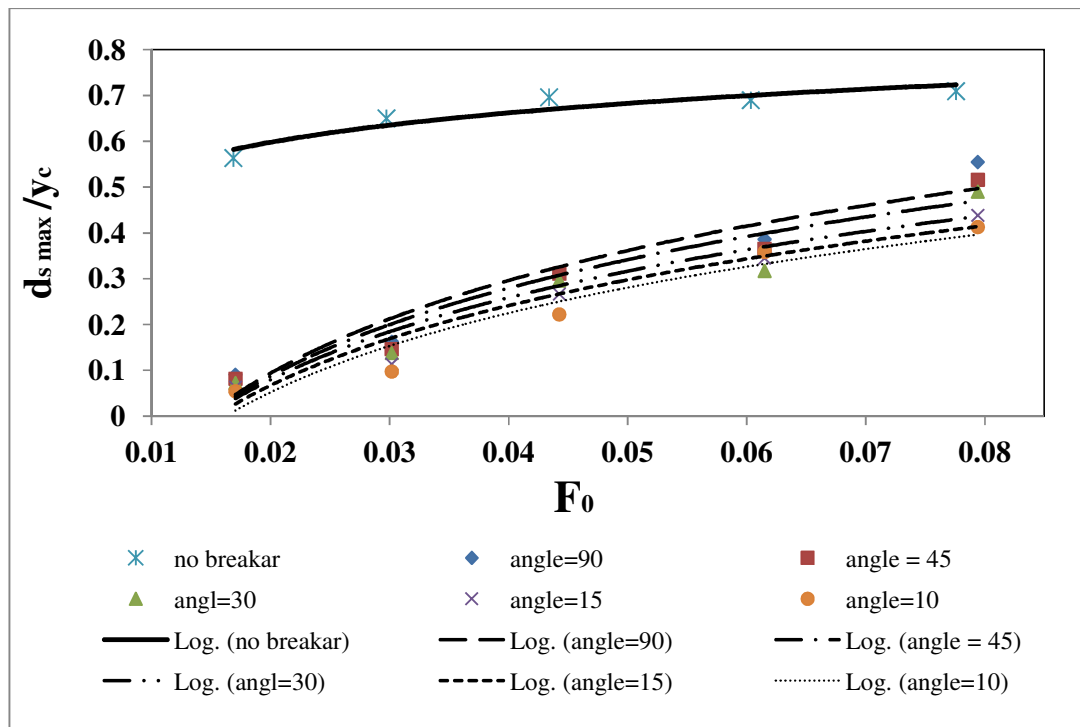
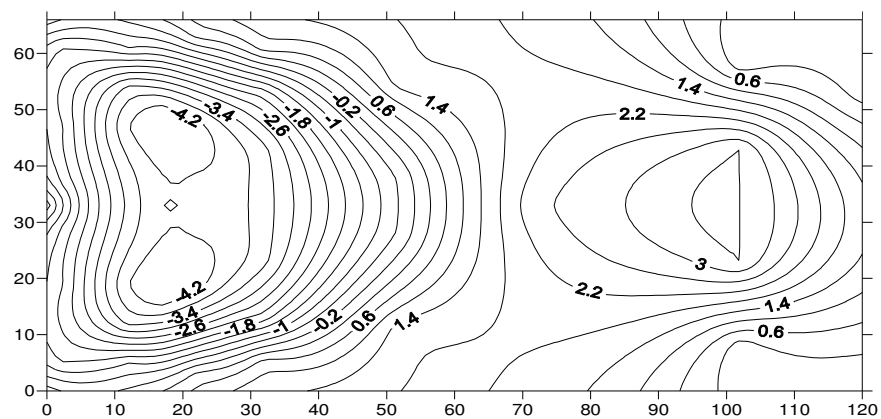
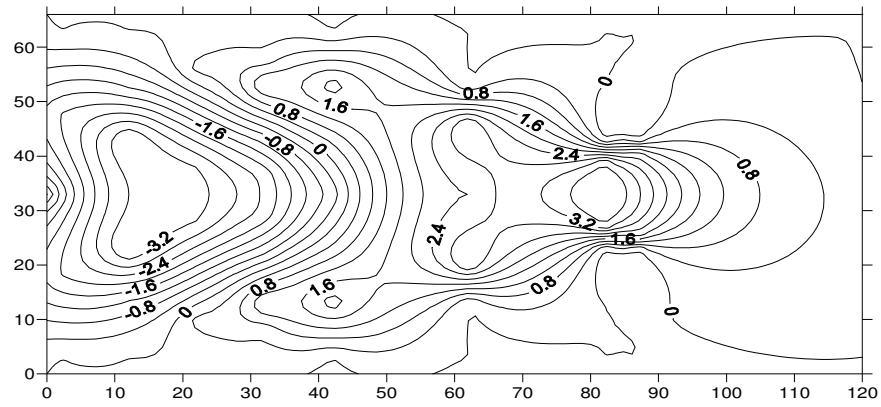


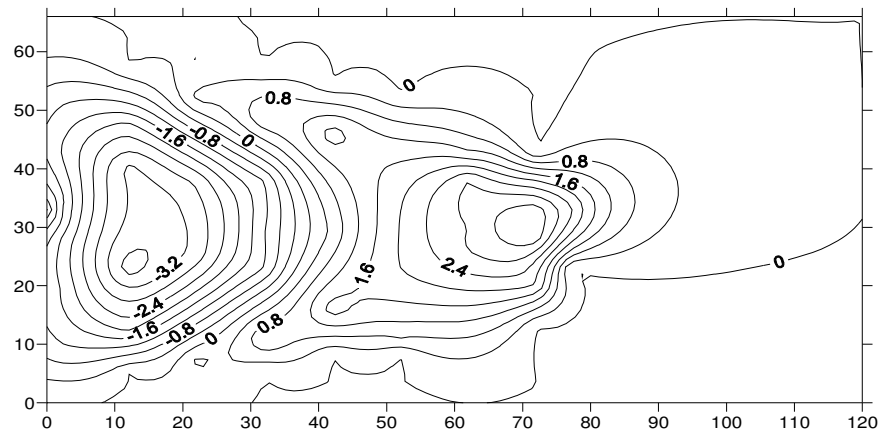
Fig.(8) The relationship between $d_{s \max}/y_c$ and F_0 at different downstream divergent angle



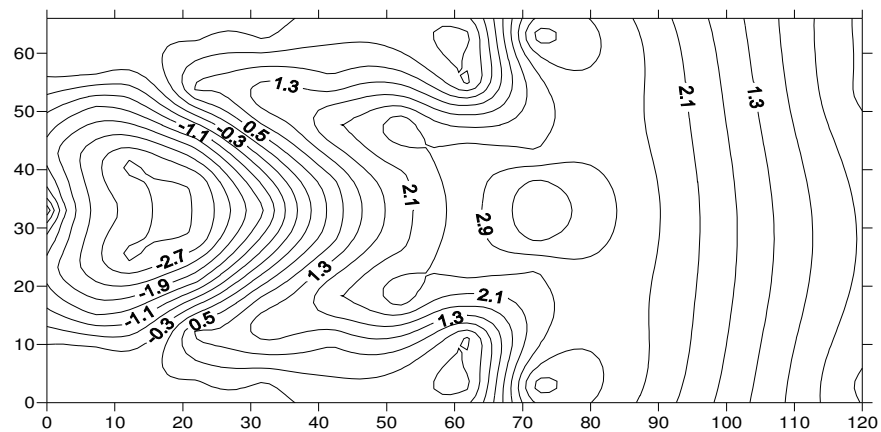
(i)



(ii)



(iii)



(v)

Fig. (9) Scour contour maps for different downstream divergent angle, (i)=90,(ii)=45,(iii)=30 and(v)=15 at $Q = 35L/s$

5- Conclusions

The experimental study of stepped spillway at contractions case led to the following conclusions:

- 1- The maximum relative scour depth increases with increasing the upstream Froude number.
- 2- Increasing contraction ration increase scour depth increases.
- 3- The scour reduced 47.77 %, 24.05 % and 9.62 %, for different shape of openings in breaker triangle and trapezoidal.
- 4- The scour reduced by 47.77 %, 54.51 %, 34.76 % and 15.53% by for different number of openings 2, 4,6 and 8.
- 5- The scour reduced by 54.51 %, 57.07 %, 60.27 %, 62.91 % and 65.38 % for different downstream divergent angle (α) = 90°,45°, 30° , 15° and 10° .

7-Reference

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