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Hydraulic Characteristics of Flow over Submerged Dams

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Abstract: This study investigates the hydraulic characteristics of two types of submerged dams, where a standard submerged dam and another one supported by an oblique plane with an angle of (16°) constructed with the channel surface. A total of 30 experiments were carried out and 5 discharges for each of the above models were tested. The changes in Froude number (Fr), the length of the hydraulic jump, the distance of the hydraulic jump away from the origin (Dj) in addition to the comparison of the percentage of flow dissipation of energy for the two cases have been studied. The results showed have been indicate a significant changes in the length values of the hydraulic jump (Lj), the distance of the hydraulic jump from the origin (Dj), in addition an increase in the percentage of flow dissipation (E%) when adding the oblique plane to the submerged dam. The two models have been verified based on the Computational Fluid Dynamics to evaluate values for the required variables(E%, Lj, Dj,…) then theoretical and practical results are compared to show the agreement between them . the obtained results exhibit a good compatibility for most cases, especially for the first model where the compatibility ratio of the discharge and the rate of flow dissipation is up to 95% for the standard submerged dam . A compatibility of 97% also has been obtained for the relation between Froude number (Fr) and percentage of flow dissipation E (%) between theoretical and practical laboratory calculations of the above model**.**

1. Introduction

Hydraulic installations spread all over the world for its importance in performing many necessary functions in the field of water resources. Submerged dams are the most hydraulic installations used to store and raise water levels, to measure channel discharges or to control steep slopes in rivers and canals. Wide submerged dams are of the most important types of submerged dams . It is also characterized practically in durability and being not affected by external influences. In addition ,it gives structural flexibility in the design of the additional accessories of the construction. One of the factors affecting the flow over the submerged dams are those deposits that occur over time at the top of the dam for the pressure drop of the normal atmospheric pressure under the waterfall (Nappe) in the back due to the air escape gradually under the waterfall, causing the push of water during the process .There are a lot of factors that are considered in the applications of submerged dams, one of which that may cause some types of rapid flow of water from erosion at the bottom of the canal and others [1] [2] . Tilted surface submerged dams are used to reduce the flow velocity and reduce the erosion problem at the bottom of the channel by dissipating the flow energy above the weir. Several studies and researches have been carried out to study the characteristics of flow above the standard submerged dams in rivers and canals. Many studies have been based on the results of laboratory experiments in which submerged dams were used in different forms to measure discharge above them as overflow installations to control the water level in channels [3][4] [5] [6]. In 2002, a series of experiments were conducted at the Water Research Center of the Ministry of Energy in Iran, where various submerged dams were studied by researchers (Kavianpour and Khosrojerdi) [7]

The researchers (Seyed Hooman Hoseini and Hossein Afshar, 2014) [8] carried out laboratory experiments on rectangular wide-edged submerged dams (Bourd crested weir)of different dimensions .

The discharge coefficient was closely correlated with water height above the weir, channel width and length of the submerged dam. Pagliara and chiavaccini 2006 [9] investigated the rate of change in flow energy dissipation by using a submerged dam supported by a inclined plane and by testing several slopes of this surface and comparing the two cases. They reached a relationship between the ratio of energy dissipation and the slope of the submerged dam with the rise of water above the weir.

2. Methodology of the suggested work:

In the experiment, an open laboratory channel with glass sides was used. The length of the channel is 12 meters long and the width is 50 meters and the depth is 45 meters. It is equipped with an antistatic pump. The channel is equipped with a coolant basin at the front of the channel for the purpose of calming the flow before entering the channel. The channel is equipped with a point gauge fixed on slide wheels to measure the depth of the flow in any section of the channel in figure 1.
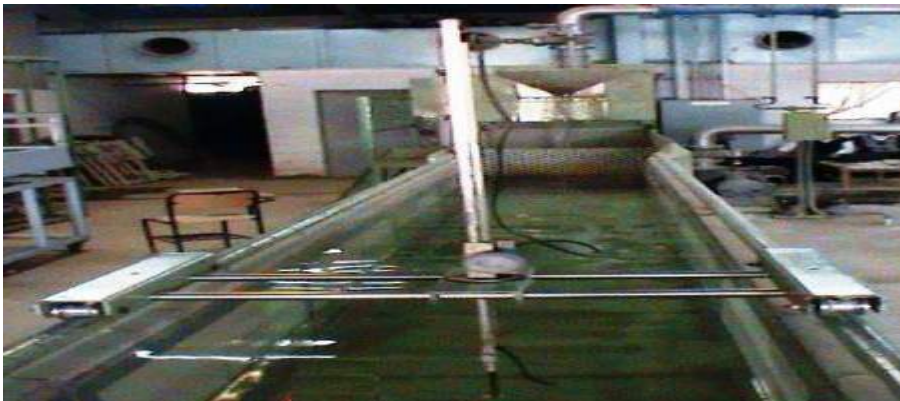

Figure 1. The laboratory channel

The flow of the channel is measured by a three-dimensional submerged dam. For the purpose of maintaining the constant pressure load and for a stable discharge with time, a constant relationship was made between the real discharge of the channel and the height of the water by the use of water tank of (0.246) moving on a rail at the end of the channel.

After a large number of attempts, the relationship between the real discharge of the channel (fixed size with variable time)with changed height of water . A submerged dam of 24 cm and width of (50) cm and side thickness of (8) cm made of thermo stone has been used .(30) experiments were conducted where (5) tests were carried out between the highest and lowest discharges and all the required measurements were taken. Then, a tilted surface of (56 * 50) cm and at a 16 ° angle was added to submerged dam with the channel surface, figure 2.

Figure 2. The Submerged dams supported by inclined plan

The following measurements have been implemented for the two models (standard submerged dam and a submerged dam supported by a sloping surface)

1. Measuring the water depth in the channel's lateral basin (h °) for the purpose of calculating discharge.
2. Measuring the water depth before the submerged dam (H) at a distance of (2) m.
3. Measuring the water depth above the submerged dam (Yw)
4. Measuring the Flow depth of hydraulic jump presenter (Y1)
5. Measuring Flow depth of hydraulic inertia (Y2)
6. Measuring hydraulic jump length (LJ)
7. Measuring the distance of the hydraulic jump from the submerged dam (DJ)
The equation used to calculate the velocity:

$$V = \frac{Q}{y.\,B}$$

To calculate the discharge

$$Q = \frac{K * h_0^{\ 5/2}}{60}$$

Where:
K = 81.44 + (0.24/h0) − (6.81* h0) + 47.34 * h02
Eq.used to calculate the velocity head

$$h = \frac{V^2}{2g}$$

Froude number is: $Fr = \frac{V}{\sqrt{gy}}$

Eq. to calculate total energy: $E = y + \frac{V^2}{2g}$

Eq. to calculate the percentage of the energy dissipation:

$$\frac{\Delta E}{E1} = \frac{E1 - E2}{E1}$$
$$E\% = \left(\frac{E1 - E2}{E1}\right) * 100\%$$

3. Analysis and Discussion of Results:

Based on the relation between the percentage of dissipation of the power of the flow and discharge (Q) shown in figure (3), each of the models under study (a standard submerged dam and submerged dam supported by a slope surface)., A reduction in the flow dissipation ratio is increased when the upper discharge transforms the flow (5%) to the highest discharges with highest percentage of energy dissipation (68%) using a submerged dam supported by a slope surface with an angle of (16 °) and a tendency of the channel (0.00) and a drainage discharge of (0.012) m3 / s.
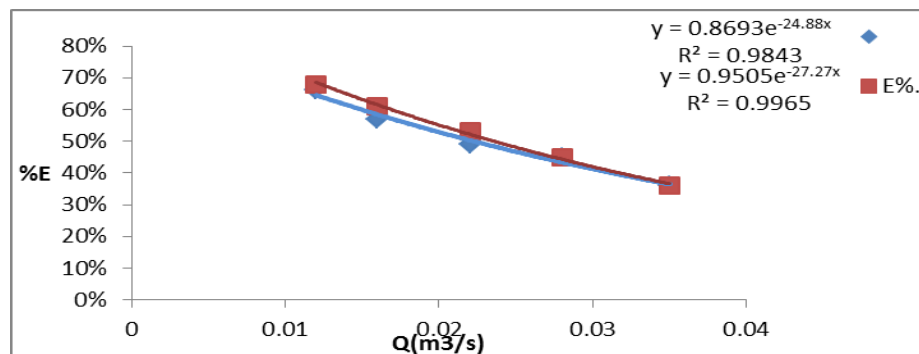

Figure 3. The correlation between the discharge and the percentage energy dissipation for the two models.

In figures 4 and 5, the relationship between the flow dissipation ratio (%) and discharge (Q) has been drawn using the practical results. Then they are compared them with theoretical results obtained from

the Computational Fluid Dynamics (CFD) for both models. It is noted that there is a good compatibility for the results of the first model. Figure 6 shows the mathematical relation between the length of the hydraulic jump (Lj) and the discharge (Q) for both models. An exponential relation of Q with Lj has been obtained, it explains an acceptable correlation coefficient about the effect of the slanted surface on increase the length of the hydraulic jump. Then the relation of the two models was plotted using the practical and theoretical results of each model with comparing the matching ratio between them, figures 7 and 8.
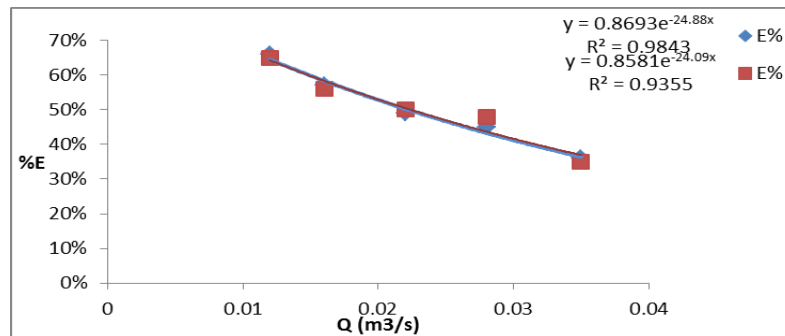
Figure 4. Correlation between the practical and the theoretical work for submerged weir
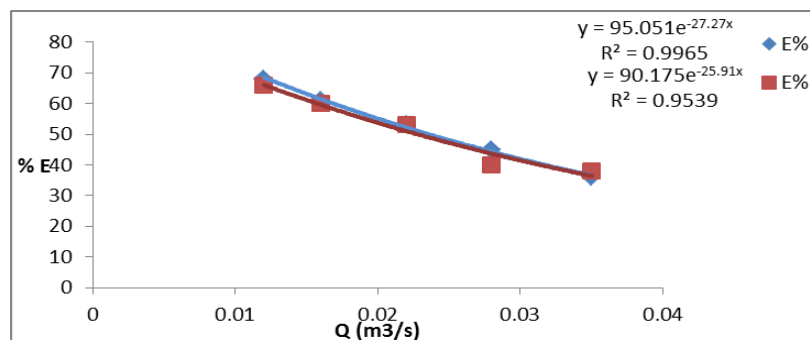
Figure 5. Correlation between practical and theoretical work for reinforced ramp weir .
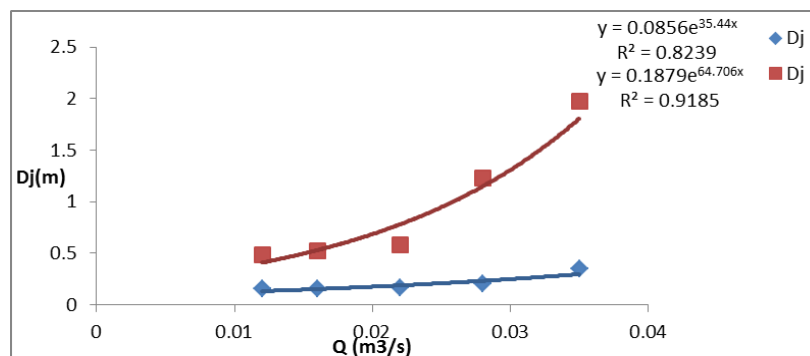
Figure 6. Correlation between discharge and the distance of the hydraulic jump from the weir for the two models
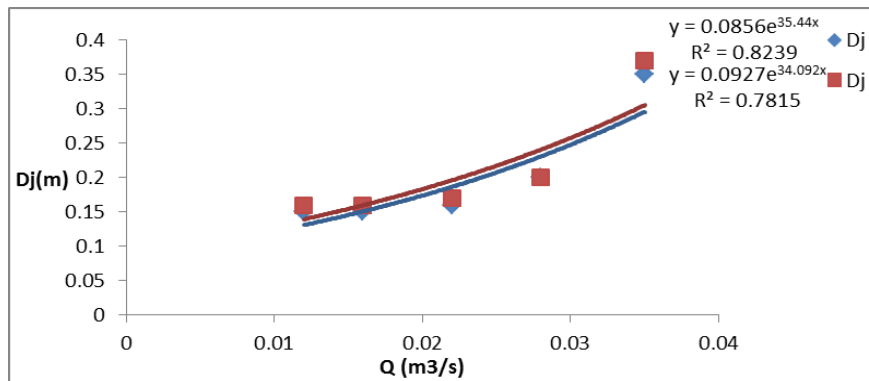
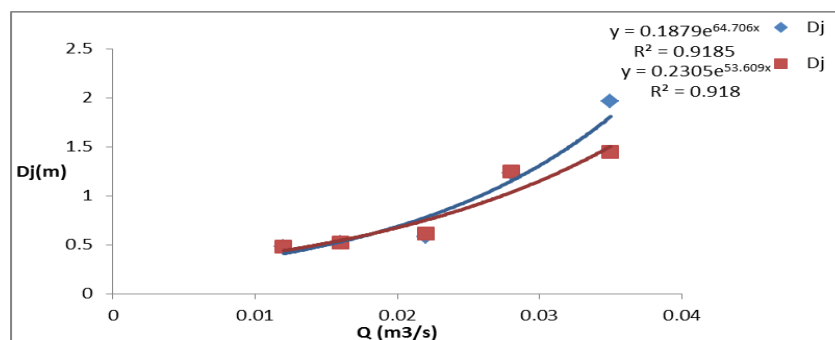**Figure 7.** Correlation between practical and thoiretical work for submerge weir .

Figure 8 : Correlation between practical and thoiretical work for reinforced ramp weir .

The relation between the discharge and the change in the position of the hydraulic jump (Dj) has been shown in figure 9 where the Dj distance reduces in the minimum discharges of the two models. The obvious effect of the sloping surface of the submerged dam also observed due to increasing the value of the post hydraulic jump (Dj) and the dimensions of the effect of the hydraulic jump (Dj) .
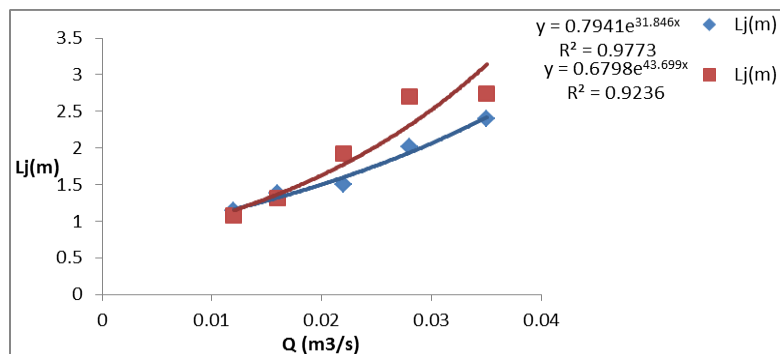
Figure 9. Correlation between discharge and the length of the hydraulic jump for the two models

The mathematical relation of the laboratory results was plotted and compared with the theoretical results. A relative correlation in the case of the submerged dam with a sloping surface is noted, figures 10 and 11.
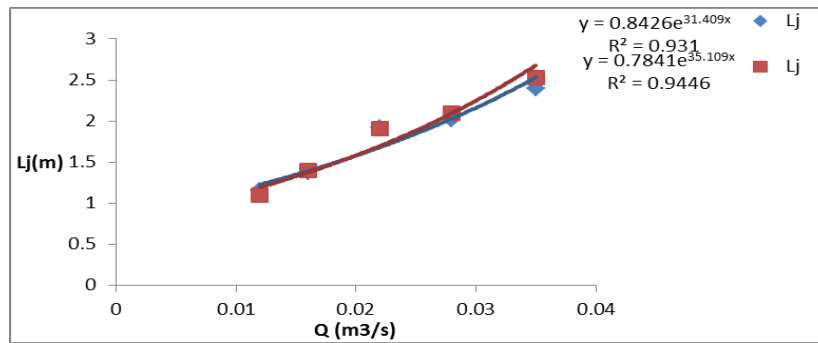
Figure 10. Correlation between practical and thoiretical work for the submerged weir
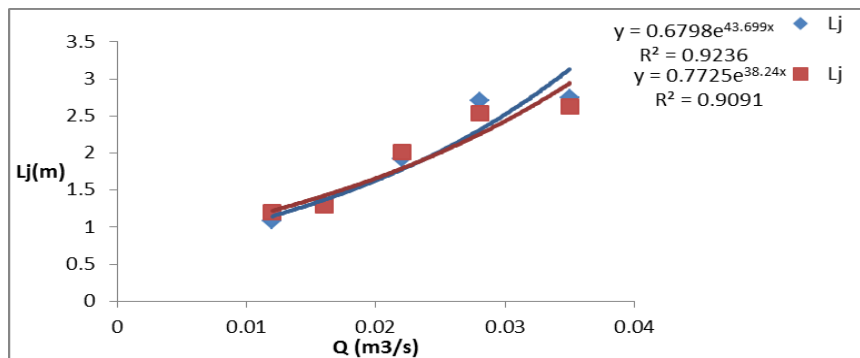

Figure 11. Correlation between the practical and thoiretical work for the reinforced ramp weir

Figure 12 shows an exponential relation has been obtained between Fr1 and L1 in addition to good correlation coefficient of the two models. The highest value of (7.879) with a drainage discharge of 0.012 m3 / s using a standard submerged dam .Whereas this value reached (8.491) for the same discharge when a submerged dam supported by a slope surface is used.
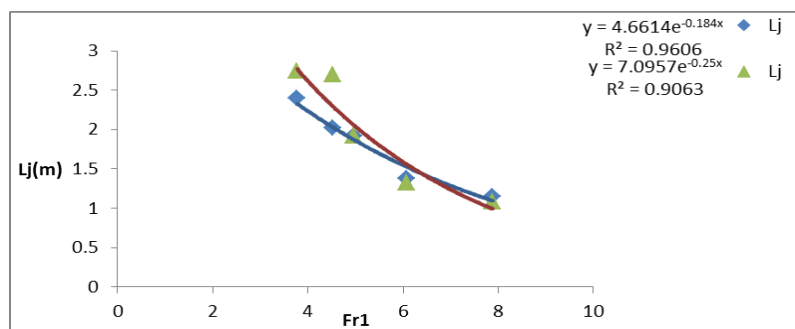
Figure 12. Correlation between Froude number and length of jump for the two models .

Value of length for the jump (Lj) is clearly reduced as the value of Fr1 increases, figures 13 and 14.
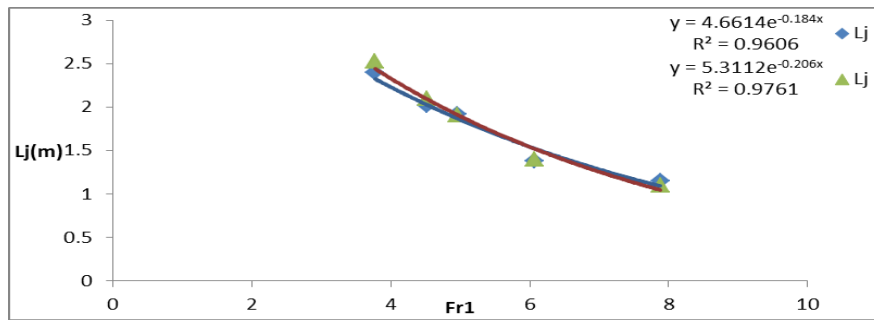
Figure 13. Correlation between pratical and theoretical work for the submerged weir .
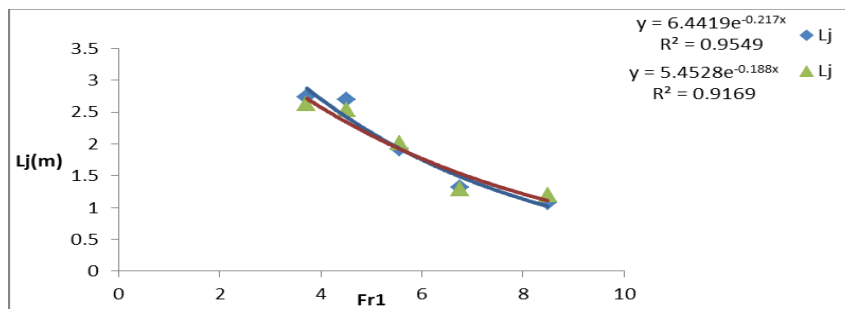

Figure 14. the correlation between the practical and theoretical work for the reinforced ramp weir

This means that the percentage of energy dissipation (E) is increased. The relation between flow dissipation ratio (% E) and the number of hydraulic jump presenter (Fr1) of the two models was plotted in Figures 15,16 and 17.
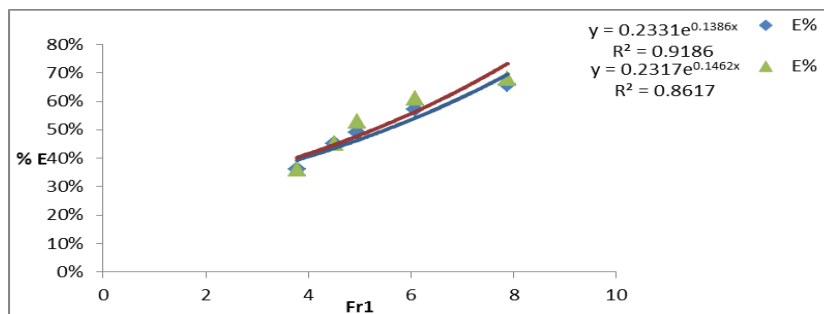

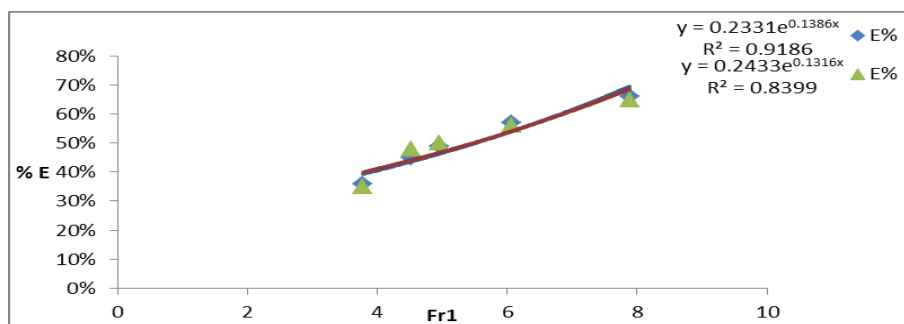**Figure 15.** Correlation between Froude No.1 and percentage energy dissipation for the two models

Figure 16. Correlation between Froude No.1 and percentage energy dissipation for the submerged weir
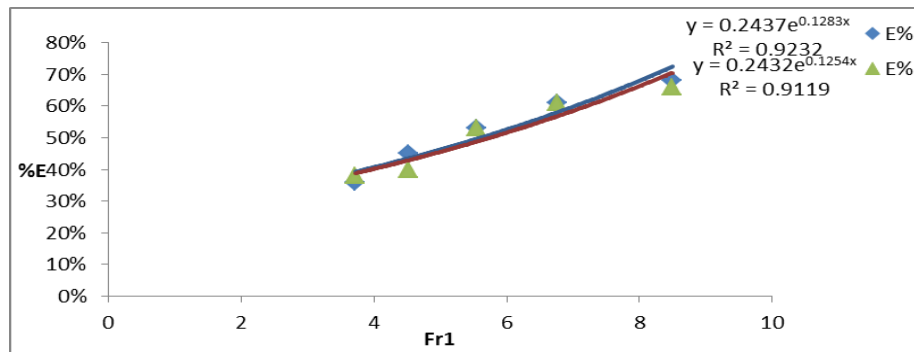
Figure 17. Correlation between Froude No.1 and the percentage energy dissipation for the reinforced ramp weir

It is clear from figure 17 that the power of the flow increases with the increase of (Fr1) and using the dam surface supported immersion slant, where this ratio is reached to 68%. The longitudinal sections of flow over the two models has been drawn with the computational fluid dynamics program in figures 18 to 22 for each discharge.
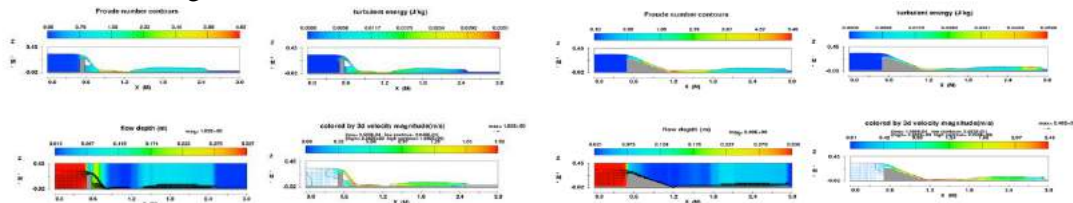

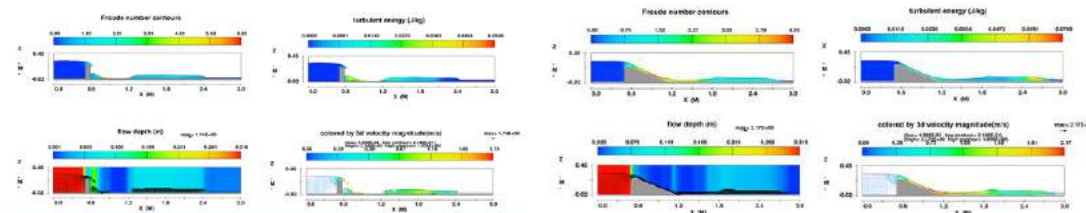**Figure 18.** Theoretical results obtaind from (CFD) for Q=0.03 m^3 /s

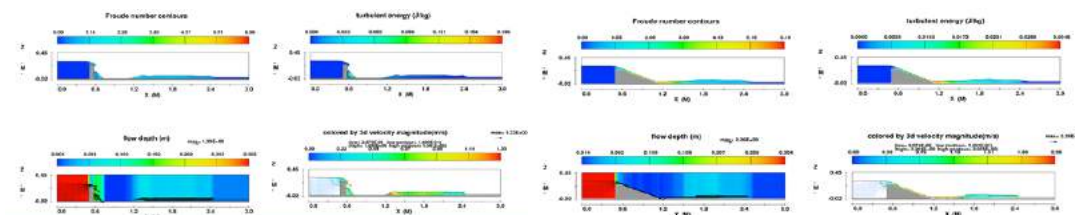**Figure19.** Theoretical results obtain from (CFD) for Q=0.028 m^3 /s

Figure 20. Theoretical results obtain from (CFD) for Q=0.022 m^3 /s

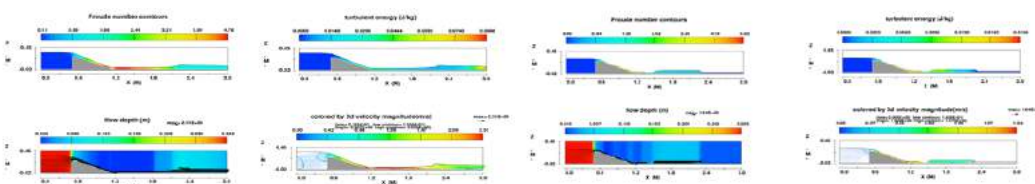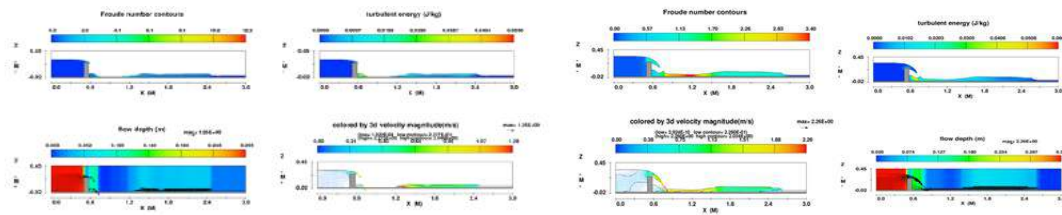**Figure 21.** Theoretical results obtaind from (CFD) for Q=0.016m^3 /s

Figure 22. Theoretical results obtain from (CFD) for Q=0.012m^3 /s

4. Conclusions

In this study, the properties of the runoff on two models of submerged dams and testing of the two laboratory models using the CFD software have been also studied .The theoretical and practical results of both models have been verified. The following results have been reached :

1. The reduction percentage in the distance of the hydraulic jump (Dj) from the hydraulic origin increases (the submerged dam supported by a sloping surface), which in turn determines the length of the channel basin taking into account the economic aspects of the design.

2. The rate of discharge of the flow energy is increased in the few and medium discharges where the hydraulic jump clearly appears.

3. The flow dissipation ratio is increased by increasing the number of the hydraulic jump presenter (Fr1) with the highest value in the minimum discharges

4. The highest dissipation ratio in flow power reached (68%) using a submerged dam supported by a sloping surface.

5. The results of laboratory work of the two models are very compatible with the theoretical results of the software used to test the two models of submerged dams.

6. Adding the sloping surface to the standard submerged dam improves both the hydraulic performance of the submerged dam and the flow characteristics .

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