Study of Side Weir in Acute Angle Diversion Channel

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Abstract

The problem of the weirs design is still receiving attention, especially, the design of the side weirs. The present paper deals with both a theoretical study and an experimental study of the side weir problem. The main objective of this study is to verify the theoretical relations used in computing the coefficient of discharge (Cd) of the side weir. The effect of the angle (θ) between the diversion channel and the main channel on the coefficient of discharge of the side weir is also studied, with regard that the side weir is located at the head of the diversion channel perpendicular on its centerline. The models results are presented for both the sharp crested side weir and the broad crested side weir. The results show that there is a good agreement between the laboratory results and the theoretical results. The following study also confirms that the De Marchi relations can be used in computing the coefficient of discharge of the side weir (Cd) for both the sharp crested weir and the broad crested weir with good accuracy. It is found that the angle θ between the diversion channel and the main channel affects clearly on the coefficient (Cd) up to $\theta = 45^0$, but when θ decreases than 45^0 the increase of Cd is so small that it is not practical to decrease the angle θ than 45^0.

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Introduction

Side weirs are used in many purposes such as, a regulating structures on the head of both distribution and branch canals, a escapes for the irrigation canals to keep on the water surface in allowable level, and as a water level adjustment in reservoir to keep on dams from collapse, like Toshki spillway upstream the high dam. It is also used to decanting excess flows in sewerage systems.

In 1941, De Marchi [2] studied the coefficient of discharge of the side weir analytically assuming that the energy remains constant along the side weir. In 1979 Kittur, et al [3] studied the side weir in a rectangular channel with the angle between the main channel and the branch channel equals 90^0 only. Kittur et al [3] confirmed the following De Marchi relation for computing the coefficient (Cd) for the sharp crested side weir:-

$$Cd = 0.81 - 0.6F_1 \quad \text{..........} \quad (1)$$

They also confirmed the following relation for computing (Cd) of the broad crested side weir;

$$Cd = (0.81 - 0.6F_1)K \quad \text{..........} \quad (2)$$

$$K = 0.8 + 0.1\frac{Y_1 - W}{L} \quad \text{..........} \quad (3)$$

In 1972, Subramanya and Awasthy [4] also proposed the following relation to compute the coefficient (Cd) for the sharp crested side weir:

$$Cd = 0.611\sqrt{1 - \frac{3F_1^2}{F_1^2 + 2}} \quad \text{..........} \quad (4)$$

where

Cd Coefficient of discharge of the side weir

F_1	Froude number at the outset point of the side weir with regard to the direction of flow in the main channel
W	Height of the side weir crest.
Y_1	Depth of flow in the main channel at the outset point of the side weir.
L	Broad crested weir thickness

Theoretical Study

As stated by De Marchi [2], for the side weir located in a rectangular channel the crest length can be calculated by the following equation:

$$B_2 = \frac{3}{2}\frac{B_1}{Cd}(\phi_2 - \phi_1) \qquad (5)$$

Then

$$Cd = \frac{3}{2}\frac{B_1}{B_e}(\phi_2 - \phi_1) \qquad (6)$$

$$\phi_1 = \frac{2E_1 - 3W}{E_1 - W}\sqrt{\frac{E_1 - Y_1}{Y_1 - W}} - 3Sin^{-1}\sqrt{\frac{E_1 - Y_1}{E_1 - W}} \qquad (7)$$

$$\phi_2 = \frac{2E_2 - 3W}{E_2 - W}\sqrt{\frac{E_2 - Y_2}{Y_2 - W}} - 3Sin^{-1}\sqrt{\frac{E_2 - Y_2}{E_2 - W}} \qquad (8)$$

$$E_1 = \frac{V_1^2}{2g} \qquad (9)$$

$$E_2 = \frac{V_2^2}{2g} \qquad (10)$$

Where

Subscript 1,2 refer to both the outset and the end points of the side weir, respectively, as shown in Fig. 1.

B_1	The width of the main channel.
B_2	The length of the side weir crest.
B_e	The effective crest length of the side weir $B_e = B_2 - 0.05$ in meter (Kitter et al [3])
E_1	Specific energy in the main channel at the outset point of the side weir.
E_2	Specific energy in the main channel at the end point of the side weir.
W	Height of side weir crest.
Y_1	Depth of flow in the main channel at the outset point of the side weir.
Y_2	Depth of flow in the main channel at the end point of the side weir.

Experimentation

The laboratory investigations were performed in a 17.40 m long brick flume having a rectangular cross section 0.6 m wide by 0.5 m deep. A wooden rectangular diversion channel of width changes from 0.275 to 0.20 m. and 0.5 m depth locates at the middle of the main channel. The side weir is located at the head of diversion channel perpendicular on its longitudinal centerline. The general setup arrangement of the experimentation is illustrated in Fig. 1. .The main channel was built up from brick, while the diversion one was constructed from wood sailed with non permeable material to prevent water leakage. The diversion channel is connected by the main channel by a flexible connection to facilitate changing the angle θ between the main channel and the diversion one. The flow of both the main channel and the diversion channel are recirculating in one line and driven by a centrifugal pump to the main channel.

At the downstream end of the main flume, a variable height weir is installed to control the flow depth in the main channel. Water levels are measured by vernier point gage and the flow rates are controlled with valves and measured with the digital current meter. The precautions are considered at the upstream tank to reduce water level disturbance. The beech side weir models with the required properties are fitted perpendicularly on the centerline of the diversion channel at its head. The water depths in the main channel adjacent to the side weir are measured at both the outset point and the end point of the side weir for each case of operation.. Also both the discharge and the mean velocity are measured at the same positions.

A- general study

A various cases of study for both sharp crested weir and broad crested weir with different models characteristics, different properties of both main and diversion channels, and different flow conditions are carried out in laboratory for a side weir locates on the head of a 90^0 diversion channel with the main channel. The various parameters, such as, $V_1, V_2, Y, Y_1, Y_2, W, B_1, B_2$, are measured for each case of study. The values of (Cd) resulted from laboratory experiments are used to verify the theoretical relations used in computing (Cd) for the corresponding cases. The cases of study of both the sharp crested weir and the broad crested weir are illustrated in Appendix, Table 1.

B- Effect of the angle θ on Cd of side weir

The cases of study illustrated in Table 1 for both the sharp crested weir and the broad crested weir, respectively, are carried out for different values of a confined angle θ between the main channel and the diversion channel,. The considered values of the angle θ are 90^0, 80^0, 60^0, 45^0, 30^0, and 20^0 respectively, for the sharp crested weir, while the values of θ for the broad crested weir are 90^0, 80^0, 60^0, 45^0, and 30^0. The coefficient (Cd) is determined for each case of operation for the different values of the angle θ.

Analysis And Interpretations

The experimental results are graphically and mathematically analyzed, in order to verify the theoretical equations used in calculating the coefficient of discharge, Cd of the side weir. The effect of the angle θ between the diversion channel and the main channel on the coefficient Cd is also studied.

A- Sharp Crested Weir

Experimental and numerical results shown in Fig. 2 illustrate the relationship between the coefficient of discharge (Cd) of the side weir and Froude number at the outset point of the side weir in main channel for both the study of the Author and the other studies. From Fig. 2, it can be observed that the experimental results of (Cd) resulted from the study of the Author for the sharp crested side weir locates at the head of the 90° branch channel show good agreement with both the results obtained from theoretical study and the results obtained from the De Marchi relation. Also, it can be observed that the coefficient (Cd) determined by Subramanya relation [4] differs from that obtained by, the theoretical results, the laboratory results, and the results obtained from the De Marchi relation. This difference can be explained as stated in Kitter et al study [3] due to the fact that Subramanya did not apply a correction for the crest length, which resulted from the flow separation at the left-hand upstream corner of the branch canal.

Fig. 3 shows the effect of the angle between the diversion channel and the main channel on the coefficient of discharge of the side weir (Cd). It is shown from Fig. 3 that the decrease of the angle θ between the diversion channel and the main channel, which means an increase of the angle θ_1 between the side weir and the center line of the main channel affects clearly on the coefficient of discharge (Cd), i.e., there is an inversely proportional between the angle θ and the coefficient (Cd). From experimental results, it is found that the decrease of the angle θ from 90° to 80° increases the values of Cd by an average ratio, 7.75%. It is also found that the decrease of the angle θ to 60^0 increases the values of Cd by an average ratio, 11.7%, and the decrease of the angle θ to 45^0 increase the values of Cd by an average ratio, 13.7%, while the decrease of angle θ to 30^0, and 20^0 increases the values of Cd by an average ratios, 14.3% and 14.7%, respectively. This trend can be interpreted due to the fact that, as the angle θ decreases the separation of the flow in the left-hand side corner of the side weir decreases and hence, the streamlines flow smoothly. The decrease of separation increases both the flow depth in the left-hand side of the side weir and the effective crest length, which increases the discharge over the side weir. It is clear that the increase of Cd due to the decrease of angle θ smaller than 45^0 is so small that it is not practical to decrease the angle θ than 45^0.

A- Broad Crested Weir

Fig. 4 shows the relation between the Froude number at the outset point of the side weir in main channel and the coefficient of discharge (Cd) of the broad crested side weir resulted from the Author experimental study, De Marchi relation, and theoretical study for the corresponding cases. It is clear that the experimental results show good agreement with the theoretical study results than that determined by De Marchi relation. Although this difference is very small, it can be explained due to the fact that the De Marchi relation was deduced for a 90^0 upstream edge weir, while the experimental work is carried out on a rounded upstream edge broad crested weir models. From this study, due to the small difference between both the theoretical results and the De Marchi results of the corresponding cases, it can be concluded that the De Marchi relation can be used in computing the coefficient Cd without an observed error compared with its simplicity in application, in which the Cd depends on the weir characteristics and the Froude number in the outset point of the side weir in the main channel.

Fig. 5 illustrates the effect of the angle θ on the coefficient (Cd) for the broad crest side weir. From Fig. 5, it can be observed that the effect of the angle θ follows the aforementioned trend illustrated in the sharp crested side weir, in which the decrease of the angle θ from 90^0 to 80^0 increases the coefficient Cd by an average ratio, 6.9%, the decrease of angle θ to 60^0 increases the coefficient Cd by an average ratio, 10.5%, the decrease of angle θ to 45^0 increases the coefficient Cd by an average ratio, 11.8%, while the decrease of angle θ to 30^0 increases the coefficient Cd by an average ratio, 12.2%. It is clear that as the angle θ decreases than 45, the values of Cd increase also, but by a decreasing rate.

It is clear that the increase ratios in the coefficient of discharge, (Cd) due to the decrease of the angle θ in the sharp crested weir are more than that in the broad crested one. This can be interpreted due to the fact that the big crest thickness of the broad crested weir causes the streamlines to be rearranged, which decreases the separation effect at the outset point of the broad crested weir than in the sharp crested weir in the initial position of the study, (the diversion channel is perpendicular on the main channel).

Conclusion

From the laboratory test results, the following conclusions can be drawn :-

1-The results of the tests carried out in the laboratory for the sharp crested side weir coefficient (Cd) show good agreement with both the results obtained from theoretical study and the results obtained from the De Marchi relation [2].

2-The De Marchi relations can be used in computing the coefficient (Cd) for both sharp crested side weir and broad crested side weir with good accuracy.

3-The coefficient Cd for the sharp crested side weir depends mainly on Froude number in the main channel at the outset point

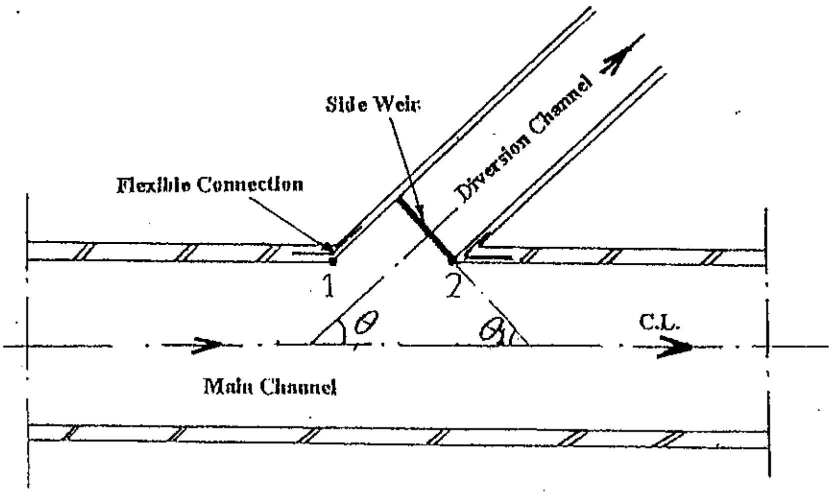


Fig. 1 General Arrangement Of The Experimentation

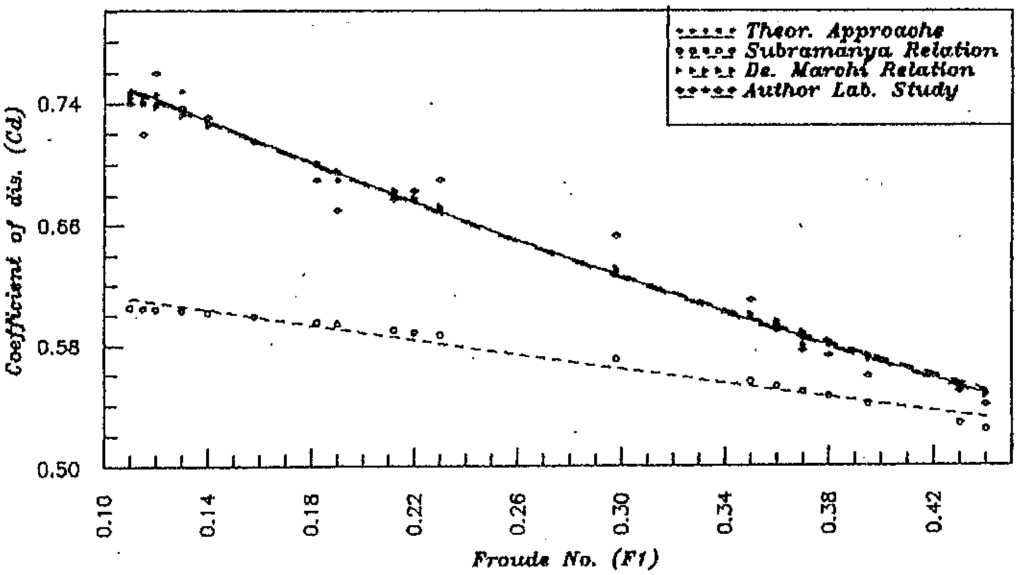


Fig. 2 The Coefficient of Discharge (Cd) versus Froude Number (F1) (Sharp Crested Weir)

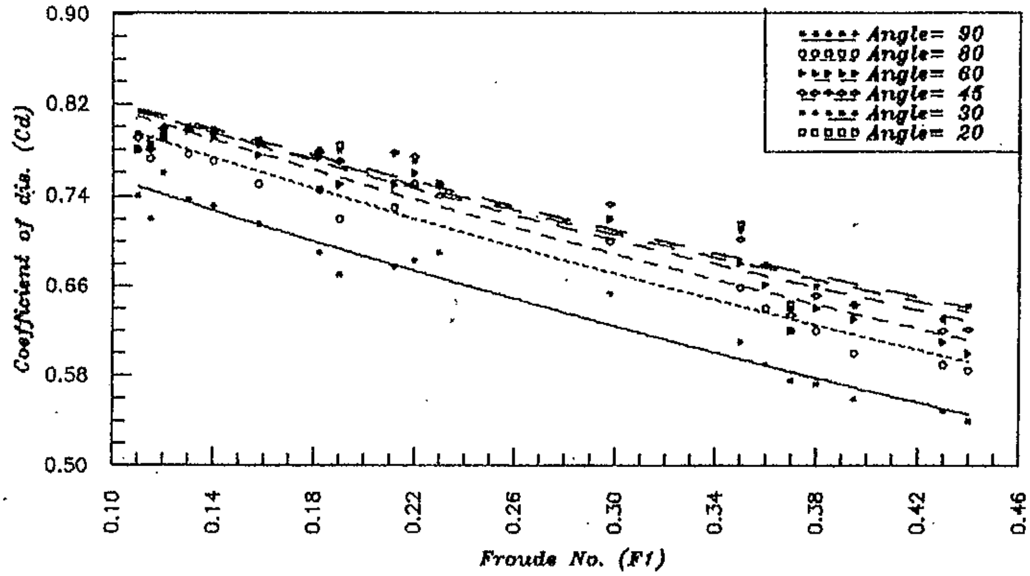


Fig. 3 The Coefficient (Cd) versus Froude No. for different values of the angle between both the Diversion and the main Channels (Sharp Crested Weir)

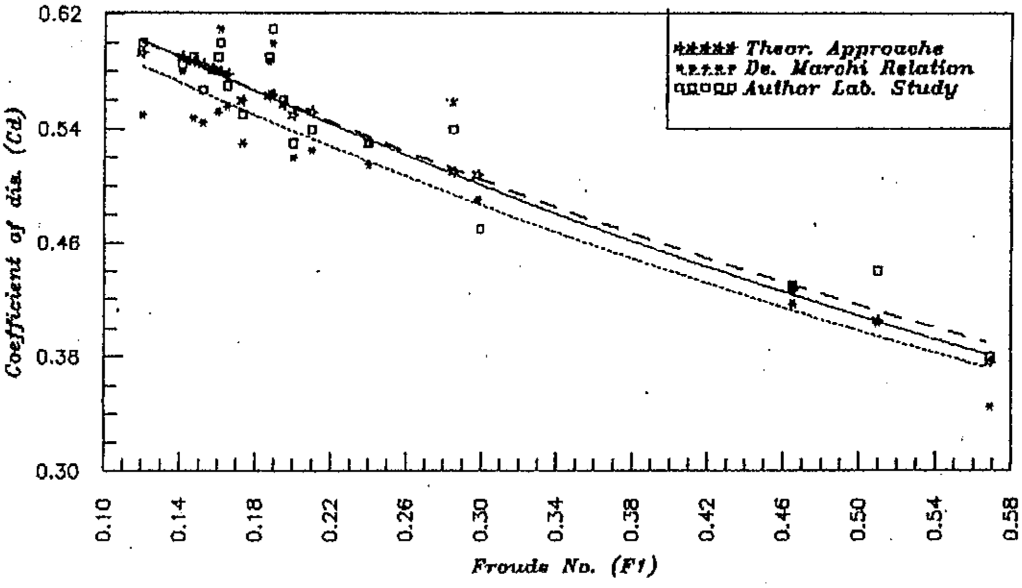


Fig. 4 The Coefficient of Discharge (Cd) versus Froude Number (F1) (Broad Crested Weir)

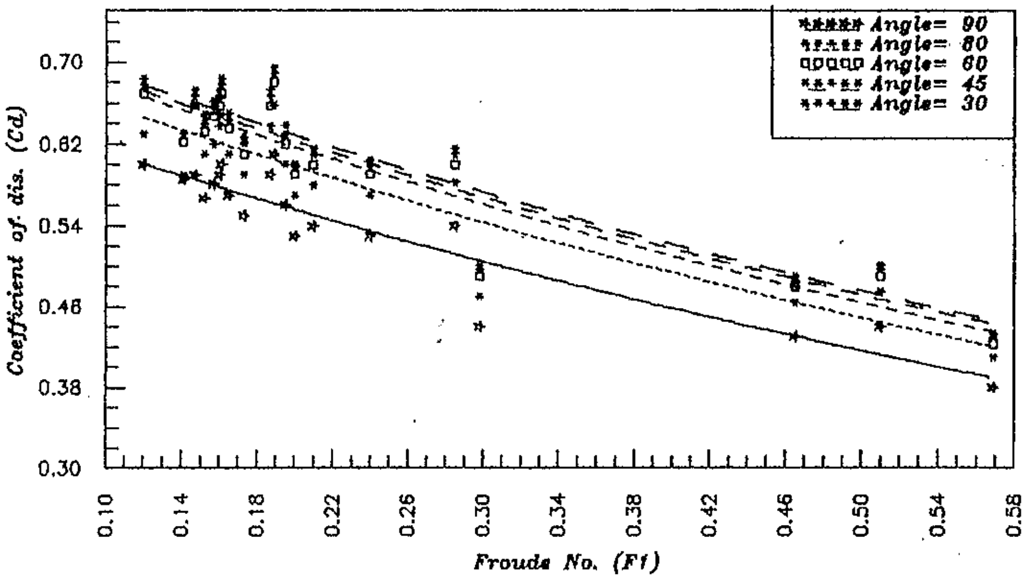


Fig. 5 The Coefficient (Cd) versus Froude No. for different values of the angle between both the Diversion and the main channels (Broad Crested Weir)

of the side weir, while for the broad crested weir beside Froude number it depends also on the crest height, head on the crest, and the weir length.

4-The acute angle θ between the diversion channel and the main channel affects on the coefficient (Cd) up to $\theta = 45^0$, but when θ decreases than 45^0 the coefficient Cd also increases but by a decreasing rate.

References

[1] Chow, V.T., "Open Channel Hydraulics", McGraw-Hill Book Co., Inc., New York.

[2] De Marchi G., "Channels with increasing Discharge" L' Energia Elettrica, Milano, Italy,Vol. 18, No. 6, pp. 351-360, July, 1941.

[3] Kitter G., Baidyanath P., and Sushil K., "Side Weir in Rectangular Channel", ASCE, Vol. 105, No. HY5, pp. 547- 554, May, 1979.

[4] Subramanya, K., and Awasthy, S. C., "Spatially Varied Flow Over Side Weir ", ASCE, Vol. 98, No. HY1, Proc. Paper 8627, pp. 1-10, Jan., 1972.

List of symbols

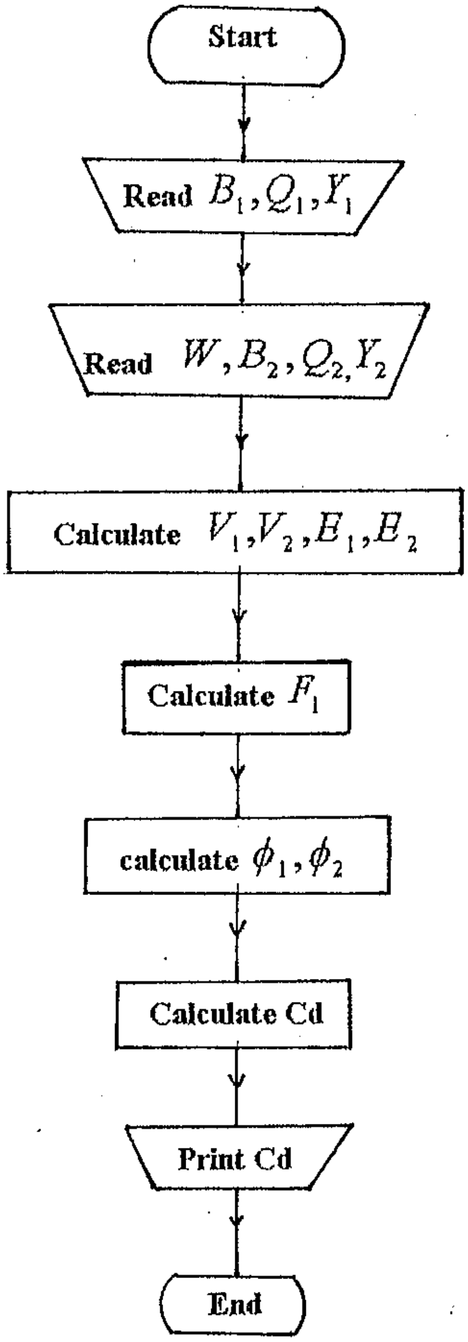
B_1	Width of the main channel.
B_2	Length of the side weir crest.
B_e	The effective crest length of the side weir.
Cd	Coefficient of discharge of the side weir.
g	Gravitation acceleration.
E_1	Specific energy in the main channel at the outset point of the side weir.
E_2	Specific energy in the main channel at the end point
of	the side weir.
F_1	Froude number at the outset side of the side weir in main channel.
K	Coefficient .
L	Crest width of the side weir.
Q_1	Discharge at the outset side of the side weir in main channel.
Q_2	Discharge at the end side of the side weir in main channel.
W	Height of side weir crest.
	Normal flow depth in main channel downstream the side weir position.
Y_1	Depth of flow in the main channel at the outset point of the side weir.
Y_2	Depth of flow in the main channel at the end point of the side weir.
ϕ_1	Coefficient
ϕ_2	Coefficient
θ	The angle between the diversion channel and the main channel.
θ_1	The angle between the side weir and the centerline of the main channel.

Appendix

Table (1) The Experimental Cases of Study

Case No.	Sharp crested Weir					Broad crested Weir					
	W	B1	B2	Q1	Y	L	W	B1	B2	Q1	Y
	m	m	m	L/s	Cm	m	m	m	m	L/s	m
1	17.5	40	27.5	45	23	35	22.5	60	20.0	45	25.4
2	15	40	27.5	41	18.2	35	20.0	60	20.0	40	23.5
3	15	40	25	41	20	35	17.5	60	20.0	35	20.8
4	15	40	22.5	41	20.6	35	15	60	20.0	28	21.2
5	15	40	20	41	21	45	22.5	60	20	45	29.2
6	15	40	20	45	20	45	20.0	60	20.0	41	27.5
7	17.5	40	20	45	22.3	45	20.0	60	20.0	41	27.5
8	19.0	40	20	35	25.5	45	17.5	60	20.0	35	25.5
9	20	40	20	45	25	45	15.0	60	20.0	28	26.5
10	22	40	20	35	29.3	55	22.5	60	20.0	45	33.5
11	25	40	20	45	30.0	55	22.5	60	20	41	35.5
12	10	60	20	18	19	55	20.0	60	20.0	41	33
13	12	60	20	28	22	55	10	60	20.0	45	13.7
14	17.5	60	20	35	28	55	15	60	20.0	45	18.8
15	20	60	20	35	27.5	60	10	60	20.0	41	13.5
16	25	60	20	35	30	60	15	60	20	41	18.2
17	25	60	22.5	35	34.5	60	17.5	60	20.0	41	22.3
18	25	60	25	35	35.5	70	10	60	20.0	45	12.4
19	25	60	27.5	35	33.5	70	15	60	20.0	35	18.5
						70	17.5	60	20.0	35	21
						70	20	60	20.0	45	27

A flowchart of computer program of the theoretical study



دراسة الهدار الجانبى لمجرى فرعى حاد الزاوية

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كلية الهندسة بشبين الكوم - قسم الهندسة المدنية

ملخص البحث

مازالت مشكلة تصميم الهدارات تستحوذ على جانب كبير من الأهمية و خاصة تصميم الهدارات الجانبية. و يتناول هذا البحث هذه المشكلة من الناحيتين النظرية و المعملية. و يعتبر تنقيح العلاقات النظرية المستخدمة فى حساب معامل التصريف للهدارات الجانبية باستخدام النتائج المعملية هو الهدف الرئيسى لهذا البحث. كما تم دراسة تأثير الزاوية الحادة (θ) بين كل من المجرى الفرعى حيث يقع الهدار الجانبى فى بدايته و عموديا على محوره الطولى و المجرى الرئيسى على قيمة معامل التصريف للهدار الجانبى. و قد شملت الدراسة كل من الهدار حاد العتبة و الهدار عريض العتب. و قد وجد أن النتائج المعملية قد أعطت توافقا بدرجة ملحوظة مع نتائج الدراسة النظرية. كما تؤكد هذه الدراسة على أنه يمكن استخدام علاقات De Maerchi فى حساب معامل التصريف لكل من الهدار حاد العتبة و الهدار عريض العتب. أما بالنسبة لتأثير الزاوية θ فقد وجد أن هناك تناسبا عكسيا بين قيمة الزاوية θ و قيمة معامل التصريف و ينطبق هذا حتى قيمة الزاوية 45^0 و لكن إذا نقصت قيمة الزاوية θ عن هذه القيمة فان معامل التصريف يزداد أيضا و لكن بمعدل متناقص.