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Hydraulic Characteristics of Flow Over Rectangular Weir With Three Rectangular Bottom Openings Using ANN

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Abstract

This research was based on laboratory experiments for hydraulic characteristics for a rectangular weir with three rectangular bottom openings (equal size of openings, different size of mid opening than an equal size sides opening. fifty-six physical models were made for this structure with different geometrical dimensions. Data set are analyzed in order to find the discharge coefficient for three flow cases when water level (under openings height or between openings height and under crest level and finally through openings and over the weir) and this analysis is done by using an equation prepared for each flow. Dimensional analysis was made to relate the discharge coefficient with different geometrical and flow variables for each flow cases . The highest value of the discharge coefficient, was obtained for flow case no.3, ($Cd_c = 0.462$), while the lowest value of discharge coefficient was occurred for flow case no.1,(Cd_p =0.0193). The correlation of (Cd_p , Cd_f , Cd_c)was higher negative with (b_o/H) with values of (-0.706,-0.937,-0.863) respectively.

For all the cases tested the coefficient of variation for the discharge coefficient were of range values (0.5632 - 0.211) which indicate the necessity of obtaining a model to describe this variation.

An ANN models was developed herein using (*SPSS software*) to express the discharge coefficient as a function of the different geometrical and flow variables, with range of correlation coefficient for all models (r=0.999 - 0.941) and applied the results in *VISUAL Studio Net,2010* in order to be used by Engineers to find the discharge coefficient and the actual discharge of each model.

Key words: Hydraulic, Rectangular weir, three Rectangular , bottom openings using ANN

الخلاصة

تم في هذا البحث اعتماد التجارب المختبرية لدراسة الخواص الهيدروليكية للهدار نوع مستطيل مع وجود ثلاث فتحات مستطيلة الشكل فى اسفله،(متساوية الابعاد مرة ومختلفة الابعاد للفتحة الوسطية مقارنة بأبعاد الفتحتين الجانبيتين مرة اخرى. تم عمل (٥٦) نموذج مختلف من هذا المنشأ بأختلاف الابعاد لكل من الهدار والفتحات لكل نموذج. حيث تم أجراء التجارب لكل النماذج مع قيم مختلفة للجريان بضوء ما تسمح به المنظومة المختبرية .لكل نموذج من النماذج أعلاه، تم تحلىل القراءات لغرض ايجاد معامل التصريف لثلاث حالات من الجريان لمستوى الماء (تحت منسوب الفتحات، بين منسوب أعلى الفتحات وأسفل حافة الهدار والحالة الاخيرة للجريان من الفتحات واعلى الهدار) باستخدام معادلة اشتقت لكل حالة من حالات الجريان. تم إجراء تحليل بعدى لأيجاد علاقة لا بعدية بين معامل التصريف و متغيرات تمثل إبعاد النموذج وأخرى تمثل الجريان لكل حالة من الحالات السابقة الذكر .

وان اعلى قيمة لمعامل التصريف كان للحالة الثالثة بقيمة (Cd_c = ٠,٤٦٢) واقل قيمة لمعامل التصريف كانت للحالة الاولى بقيمة(Cd_p= ٠,٠١٩٣).واعلى قيمة ارتباط لكل قيم معامل التصريف للحالات الثلاثة كانت مع (H/b_o) بقيم(-٠,٧٠٦،-٠,٩٣٧،-٠,٨٦٣) على التوالي وان معامل التغيير لكل حالات الجريان كانت تتراوح بين (٠,٥٦٣٢-٠,٢١١) مما يؤكد ضرورة عمل النماذج لوصف حالة التغيير.يقوم نموذج (*ANN*) بأيجاد معامل التصريف كدالة لمختلف المتغيرات المتعلقة بالابعاد الهندسية الخاصة بالنموذج والمتغيرات التي تمثل الجريان بقيم معامل ارتباط لكل الشبكات يتراوح بين (r=٠,٩٩٩-٠,٩٤١) والذى يصنف قوياً ضمن مقاييس الارتباط كما تم بناء نموذج (*Visual* Studio Net,2010) لغة بيسك المرئية سهلة التطبيق لغرض استخدامه من قبل مهندسىن لأيجاد معامل التصريف والتصريف الحقيقي لجميع النماذج.

الكلمات المفتاحية: الهيدروليكية، هدار مستطيل، ثلاثة مستطيلة، فتحات في القاع باستخدامANN

1.Iintroduction

Gates and weirs have been used extensively for flow control and discharge measurement in open channel flow. Works concerning the use of sluice gates as a discharge measurement structure may be found, Rajaratnam (1977), French (1986),Swamee (1992).developed a generalized discharge equation for sluice gates based on Henrys curves, Abdel-Azim *et al.*(2002),Bos (1989),and Munson *et al.*(1994).Weirs and gates may be combined together in one device yielding a simultaneous flow over the weir and below the gate.

The flow through combined devices may be free when both the flow over weir and below the gate are free it is termed submerged when the flow below the gate is submerged (and the flow over the weir may or may not be submerged). Problems concerning sedimentation and depositions are minimized by combined weirs and gates as outlined by Alhamid, Negm and Al-Brahim (1997), Fadil (1997) developed a meter for the combined flow through contracted sluice gate and weir, also combined-submerged flow through weirs and below gates were analyzed and discussed by Negm (2000).The characteristics of the combined flow over weirs and below gates of equal contraction are discussed by Abdel-Azim *et al.*(2002), different geometrical combination are used, the discharge characteristics of a combined weirs and gate structure are discussed, they found that the flow parameter (*H*/ *D*) (the ratio between the upstream water depth and the height of the opening) and the geometrical parameter (*y*/ *D*)(the ratio of the vertical distance between the lower edge of the weir and the upper edge of the gate opening and the height of the gate opening) have major effects on the discharge.

In the present work the characteristics of the combined flow over a rectangular weirs with three rectangular bottom openings are studied.

2. Theoretical Background

To compute the discharge through a combined weir (rectangular weir with three rectangular bottom openings).For each configuration mentioned in table(1) three different situations of flow can be classified as:

- **Flow case No. (1)**

Water level in the flume is less than the height of openings (partial area openings flow only) which can be denoted as, Q_p

To compute the discharge through three bottoms rectangular openings of this flow condition,

$$Qp.th. = \frac{2}{3} b_o \sqrt{2g.H^{\frac{3}{2}}} \;\ldots\ldots\ldots\ldots(1)$$

$$Qp.tot = 3(Qp.th.) \ldots\ldots\ldots\ldots(2)$$

Where:Qp.th. is the theoretical discharge partially through one (m^3/s);Qp.totis the total theoretical discharge partially through three opening(m^3/s); H is the total head (m), b_o is the opening width (*m*), g is the gravitational acceleration (*m*/s^2).

But the actual discharge for the opening is $Q_{p\,.act}$ which can be written as:

$$Q_{p\,act} = Cd_p \,.\, Q_{p\,theo} \qquad (3)$$

Where :Cd_p is the discharge coefficient for one opening.

For the flow condition of three openings, the actual flow is:

$$Q_{p\,act} = Cd_p\,(Q_{p\,tot}) \qquad (4)$$

Where: Cd_p is the discharge coefficient for three openings.

- **Flow case No. (2)**

Water level in the flume is more than the height of openings and less than weir crest (full area openings flow only) which can be denoted as, Q_f, the same equation of flow case no.2,but H: water level above opening and under crest weir:

$Q_{f\ act} = Cd_f)\ Q_{f.tot}$ (5)

Where: Cd_f is the discharge coefficient for three openings.

- **Flow case No. (3)**

Water level in the flume is more than the weir crest level (combined flow from openings and weir) which can be denoted as, Q_c.

To compute the discharge through a combined rectangular weir with sharp crested and three bottom rectangular openings ،the following equation can be obtained by adding the discharge over the weir and the discharge through three openings as follows:

$$Q_{c\ theo} = Q_{f\ tot} + Q_{w\ theo} \qquad (6)$$

$$Qf.th. = \frac{2}{3}.b_o\sqrt{2g}.[(P+h1)-(p+h1-h_o)]^{\frac{3}{2}} \ldots\ldots\ldots\ldots(7)$$

$$Qf.th. = b_o.h_o\sqrt{2gH} \ldots\ldots\ldots\ldots(8)$$

$$Qftot. = 3Q_{fthe.} \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

$$Qw.the. = \frac{2}{3}.B_w\sqrt{2gh_1^{\frac{3}{2}}} \ldots\ldots\ldots\ldots(10)$$

Where :$Q_{f\ tot}$ is the total discharge through the openings same as before but with $H=P+h_1$ (m^3/s); $Q_{w\ theo}$ is the theoretical discharge over rectangular weir (m^3/s); H is the total head (*m*); b_o is the opening width (m); h_o is the opening; height (m),g is the gravitational acceleration(m/s^2); P is the crest height (m), $P=d+h_o$; B_w is the width of the weir(*m*) and h_1 is the head over rectangular weir(m).

But the actual discharge are: $Q_{f\ act}$, $Q_{w\ act}$ for the openings and the weir respectively:

$$Q_{f\ act} = Cd_f.\ Qf_{tot} \qquad (11)$$

$$Q_{w\ act} = Cd_w.\ Qw_{theo} \qquad (12)$$

$$Q_{c.\ act} = Q_{f\ act} + Qw_{act.} \qquad (13)$$

Where: Cd_f and Cd_w are the discharge coefficients for the openings and the weir respectively.

The simplifying of equation (5.9, 5.10) into equation (13) yields:

$$Qc.act = C_{dc.}\sqrt{2g}\left[3(b_o.h_o\sqrt{H}) + (\frac{2}{3}B_w h_1^{\frac{3}{2}})\right] \ldots\ldots\ldots\ldots(14)$$

Where: is the combined discharge coefficient.

3. Experimental Set Up:

The experiments were carried out in a (17) m long horizontal tilting channel (Slope equal zero) of cross section (0.5) m width and (0. 5) m height. The channel consisted of toughened glass walls and a stainless steel floor. Two movable carriages with point gauges were mounted on brass rails at the top of channel sides see Fig.(1).Fifty -six combined weir model were manufactured from a 10mm thick glass, details of the models are shown in table (1) and figure(2). For discharge measurements, a full width thin-plate sharp-crested rectangular weir fixed at the tail end of the channel section manufactured according to British standard (1965).The head upstream of the standard weir and head over weir ,the combined weir were measured with a precision point gauges whose least count was (0.1) mm.

4.Dimensional Analysis for Discharge Coefficient

It is expected that the discharge coefficient of the three types of flow conditions which are mentioned above are dependent on the geometry of the models as well as the flow conditions, i.e.

$$Cd=f(h_L, b_L, h_M, b_M, h_R, b_R, d, H_w, B_w, h_1, H, v, g, \rho, \mu, So, \sigma, B) \quad (15)$$

Where:

h_L: height of left bottom opening

b_L: width of left bottom opening

h_M: height of middle bottom opening

b_M: width of middle bottom opening,

h_R: height of right bottom opening

b_R: width of right bottom opening,

d: vertical distance between the top of the opening and bottom of weir (weir crest)

H_w: vertical distance between weir crest and top of the weir.

B_w: width of the weir,

h_1: the head measured by point gage no.(1) in flow case no.(3) as mentioned above.

H: total head by point gage no.(2) in each flow case as mentioned above..

v: flow velocity.

g: gravitational acceleration.

ρ: water mass density.

μ: water viscosity.

S_o: flume slope.

σ: surface tension, and

B: flume width.

It should be noted that the flume bed slope and the flume width were kept constant at one value. As well as v can be considered in variable of H. Then, the discharge coefficient will be:

- ***Flow case No.(1)***

The functional relationship which describes the discharge coefficient may be written as:

$$Cd_p=F2(R, Fr, W, h_L/H, b_L/H, h_M/H, b_M/H, h_R/H, b_R/H) \quad (16)$$

- ***Flow case No.(2)***

  The functional relationship which describes the discharge coefficient may be written as:

$$Cd_f=F_3(R, Fr, W, h_L/H, b_L/H, h_M/H, b_M/H, h_R/H, b_R/H, d/H) \quad (17)$$

- ***Flow case No. (3)***

  The functional relationship, which describes the discharge coefficient, can be written as:

$$Cd_c=F_3(R, Fr, W, h_L/H, b_L/H, h_M/H, b_M/H, h_R/H, b_R/H, d/H, H_w/H, B_w/H) \quad (18)$$

5.Statistical analysis

Statistical results for all configurations for estimating Cd_p, Cd_f, Cd_c for Model of equal openings size are discussed here after:

This is for each model has constant height and constant width ($h_L = h_M = h_R = h_o$, $b_L = b_M = b_R = b_o$) .

- ***Flow case no. (1):***

$$Cd_p=F2(R, Fr, W, h_o/H, b_o/H) \quad (19)$$

- ***Flow case no.(2):***

$$Cd_f=F_3(R, Fr, W, h_o/H, b_o/H, d/H) \quad (20)$$

- ***Flow case no.(3):***

$$Cd_c=F_3\ (R, Fr, W, h_l/H, h_o/H, b_o/H, d/H, H_w/H, B_w/H) \quad (21)$$

Table (2,3 and 4) show the description of statistical and correlation analysis for each flow case for equal opening size models. For all tables, the highest correlations of *Cd* with b_o/H as negative value which indicates that *Cd* is inversely proportion with that variable and that corresponding with sensitive analysis that shows b_o/H is more effected variables on discharge coefficient for each flow case.

Table (5,6 and 7) shows the description of statistical and correlation analysis for each flow case for different opening size models. For all tables, the highest correlations of *Cd* with b_o/H as negative value which indicates that *Cd* is inversely proportion with that variable and that corresponding with sensitive analysis that shows b_o/H is more effected variables on discharge coefficient for each flow case.

6.Results and discussion:

The variation of (Cd_p, Cd_f, Cd_c) with each of the variables (h_o / H , b_o/H , h_M /H , d / H, h_l/H, h_w / H, b_w / H , b_M / H) are shown in Figure (3) to Figure(8) respectively . Even though single correlation between Cd and each variable is low, it is expected that multiple correlation for Cd with these variables will be significant.

Figure(3) shows the variation of discharge coefficients for the flow cases (Cd_p, Cd_f, Cd_c), with the value of (h_o/H) ratio. It is clear that the maximum discharge coefficient is less than 0.45 and this means that the correction the assumptions of the theoretical discharge accounts for 55%.Moreover it is found that the discharge coefficient decreases as (h_o/H) increases. Flow case no.(1) gives the lowest discharge coefficient followed by flow case no. (2) and finally flow case no.(3) due to increasing the losses.

Figure (4) shows the variation of discharge coefficients for the flow cases (Cd_p, Cd_f, Cd_c),with the values of (b_o/H) ratio. Similar observations are found as these observed in Figure (3), however, the relation exhibits less flocculated results.

Figure (5) shows that in general the discharge coefficients for the flow cases (Cd_f, Cd_c),decreases when(d/H) value increase. The presented values are not for fixed (d value) and variable (H) value but both are varied. For the combined discharge, the variations are much higher than for Cd_f (flow case no.2).For a given (d/H) value, different discharge coefficient can be obtained and that's indicates the effect of other values.

Similarity, the variations of discharge coefficient with (h_l/H), (h_w/H) and (b_w/H) are shown in Figures (6),(7) and (8) respectively. These Figures indicate proportional variation of the first variable and inverse variation for the other variables .However, for each unique value of the variables different discharge coefficient values can be obtained which indicate the effect with other variables.

7.Application of Artificial Neural Network Modeling for Discharge Coefficient

An artificial neural network (ANN), usually called neural network (NN), is a mathematical model or computational model that is inspired by the structure and/or functional aspects of biological neural networks.A neural network consists of an interconnected group of artificial neurons, and it processes information using a connectionist approach to computation. The three artificial neural network model for estimating the discharge coefficients (Cd_p , Cd_f, Cd_c) as a function of (h_o/H , b_o/H , h_l/H, d/H, b_L/ H, b_M / H, b_R /H, d/ H, h_w/H, B_w/H) were developed using the software "*SPSS*", this software allows the modeling with different network architecture, and use back propagation algorithm for adjusting the weights of the model.The software needs to identify the input variables which are those mentioned above as shown in Figures (9,10 and 11) respectively.

8.Conclusions

Under the limitations imposed in this study, the following conclusions are obtained:

1. All the flow conditions proposed exhibits sub critical flow at the upstream side of the structure, since Froude number range is less than (1).
2. For each model, with specific dimensions, as the head increased, the discharge coefficient for all three flow cases will increase too. The highest value of the discharge coefficient, was obtained for flow case no.3,(Cd_c=0.462), while the lowest value of discharge coefficient was occurred for flow case no.1,(Cd_p =0.0193).
3. For the case of equal size of three openings and for flow case no.(3) ,the discharge coefficient Cd_c has the highest value for a size of opening of (5*10)cm, while the lowest for the size (10*10),(10*8),(10*5).This indicates that the width of opening has the major effect on Cd_c than the opening height.
4. Correlation analysis for all types of discharge coefficients, indicates that (Cd_p), (Cd_f), (Cd_c) the correlation was higher negative of (b_o/H) with values of (-0.706,-0.937,-0.863) respectively. These above value indicate inverse proportionally.
5. For all the cases tested the coefficient of variation for the discharge coefficient were of range values (0.5632 -0.211) for all the flow cases, which indicate the necessity of obtaining a model to describe this variation.
6. The architecture of the ANN model suitable for relating the discharge coefficient with the geometry and the flow variables for equal opening size models for each flow case, the network correlation coefficients were range (0.999-0.883), which can be considered as very good correlation.

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Table (1) Details of weir models investigated

Models		Crest height ($P=h_o+d$) cm	Crest length (B_w) cm	Bottom Openings (bo x ho) cm		
				left	middle	right
1.a	a.1.1	٢٨	٢٠	١٠*٥	١٠*٥	١٠*٥
	1.a.2			١٠*١٠	١٠*١٠	١٠*١٠
	1.a.3			10*5	10*5	10*5
	1.a.4			10*8	10*8	10*8
	1.a.5			8*8	8*8	8*8
	1.a.6			8*10	10*10	8*10
	1.a.7			5*8	8*8	5*8
1.b	b.1.1	٢٨	٢٧	١٠*٥	١٠*٥	١٠*٥
	1.b.2			١٠*١٠	١٠*١٠	١٠*١٠
	1.b.3			10*5	10*5	10*5
	1.b.4			10*8	10*8	10*8
	1.b.5			8*8	8*8	8*8
	1.b.6			8*10	10*10	8*10
	1.b.7			5*8	8*8	5*8
2.a	2.a.1	٢٤	33	١٠*٥	١٠*٥	١٠*٥
	2.a.2			١٠*١٠	١٠*١٠	١٠*١٠
	2.a.3			10*5	10*5	10*5
	2.a.4			10*8	10*8	10*8
	2.a.5			8*8	8*8	8*8
	2.a.6			8*10	10*10	8*10
	2.a.7			5*8	8*8	5*8

To be continued

Models		Crest height ($P=h_o+d$) cm	Crest length (B_w) cm	Bottom Openings (bo x ho) cm		
				left	middle	right
b.٢	b.1.٢	٢٤	٢٥	١٠*٥	١٠*٥	١٠*٥
	2.b.2			١٠*١٠	١٠*١٠	١٠*١٠
	2.b.3			10*5	10*5	10*5
	2.b.4			10*8	10*8	10*8
	2.b.5			8*8	8*8	8*8
	2.b.6			8*10	10*10	8*10
	2.b.7			5*8	8*8	5*8
c.٢	c.1.٢	٢٤	١٧	١٠*٥	١٠*٥	١٠*٥
	2.c.2			١٠*١٠	١٠*١٠	١٠*١٠
	2.c.3			10*5	10*5	10*5
	2.c.4			10*8	10*8	10*8
	2.c.5			8*8	8*8	8*8
	2.c.6			8*10	10*10	8*10
	2.c.7			5*8	8*8	5*8
a.٣	a.1.٣	٢٠	٢٣	١٠*٥	١٠*٥	١٠*٥
	3.a.2			١٠*١٠	١٠*١٠	١٠*١٠
	3.a.3			10*5	10*5	10*5
	3.a.4			10*8	10*8	10*8
	3.a.5			8*8	8*8	8*8
	3.a.6			8*10	10*10	8*10
	3.a.7			5*8	8*8	5*8
b.٣	b.1.٣	٢٠	١٨	١٠*٥	١٠*٥	١٠*٥
	3.b.2			١٠*١٠	١٠*١٠	١٠*١٠
	3.b.3			10*5	10*5	10*5

To be continued

Models		Crest height ($P=h_o+d$) cm	Crest length (B_w) cm	Bottom Openings (bo x ho) cm		
				left	middle	right
3.c	b.4.٣	20	18	10*8	10*8	10*8
	3.b.5			8*8	8*8	8*8
	3.b.6			8*10	10*10	8*10
	3.b.7			5*8	8*8	5*8
	c.1.٣			١٠*٥	١٠*٥	١٠*٥
	3.c.2	٢٠	١٥	١٠*١٠	١٠*١٠	١٠*١٠
	3.c.3			10*5	10*5	10*5
	3.c.4			10*8	10*8	10*8
	3.c.5			8*8	8*8	8*8
	3.c.6			8*10	10*10	8*10
	3.c.7			5*8	8*8	5*8

Table (2)Description of statistical and correlation analysis (flow case.1)

	Correlation with Cd_p	Min.	Max.	Mean	Std. Deviation	Variance	Coefficient of variance C.V
Cd_p	1	.0193	.1651	.053863	.0303363	.001	0.5632
ho/H	-0.484	.3137	2.8571	1.473197	.4609197	.212	0.3128
bo/H	-0.871	.3922	3.3333	1.474331	.5708570	.326	0.3871

Table (3)Description of statistical and correlation analysis (flow case.2)

	Correlation with *Cdf*	Min.	Max.	Mean	Std. Deviation	Variance	Coefficient of variance C.V
Cdf	1	.0749	.3107	.141322	.0524722	.003	0.3712
ho/H	-0.151	.2083	.8621	.473677	.1503488	.023	0.3174
d/H	-0.5	.5051	1.6667	.931767	.3140890	.099	0.3370
bo/H	-0.937	.2083	.8621	.508815	.1485248	.022	0.2919

Table (4)Description of statistical and correlation analysis (flow case.3)

	Correlation with *Cdc*	Min.	Max.	Mean	Std. Deviation	Variance	Coefficient of variance C.V
Cdc	1	.0943	.4620	.240597	.0773471	.006	0.321
h1/H	0.106	.0050	1.0000	.190542	.1193733	.014	0.626
ho/H	0.026	.1220	.5128	.296288	.0805329	.006	0.2718
d/H	-0.361	.2825	.8042	.518042	.0998355	.010	0.1927
hw/H	-0.333	.2927	1.0256	.604175	.1852603	.034	0.3066
bw/H	-0.207	.4237	1.1744	.751341	.1802530	.032	0.2399
bo/H	-0.863	.1333	.4975	.277249	.0916826	.008	0.3306

Table (5) Description of statistical and correlation analysis (flowcase.1)

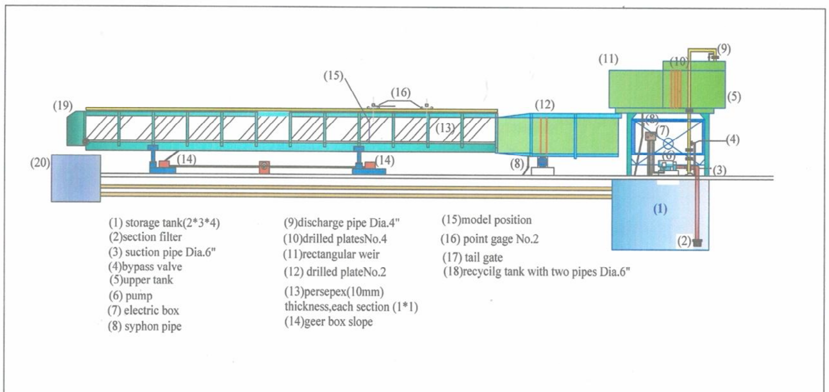
	Correlation with *Cdp*	Min.	Max.	Mean	Std. Deviation	Variance	Coefficient of variance C.V
Cd_p	1	.0343	.0871	.053457	.0148626	.000	0.278
ho/H	-0.829	.9877	2.6316	1.568840	.3618480	.131	0.230
bo/H	-0.953	.6173	1.6667	1.149196	.2829684	.080	0.2462
bm/H	-0.891	.9877	2.5000	1.546481	.3400340	.116	0.2199

Table (6) Description of statistical and correlation analysis (flowcase.2)

	Correlation with *Cdf*	Min.	Max.	Mean	Std. Deviation	Variance	Coefficient of variance C.V
Cdf	1	.1029	.2914	.172428	.0364571	.001	0.211
ho/H	-0.863	.2963	.7246	.486850	.0935586	.009	0.192
d/H	-0.267	.4184	1.4493	.785755	.2758444	.076	0.351
bo/H	-0.941	.1852	.5797	.347372	.0870414	.008	0.2505
bm/H	-0.913	.2963	.7246	.481407	.0879130	.008	0.182

Table (7) Description of statistical and correlation analysis (flowcase.3)

	Correlation with *Cdc*	Min.	Max.	Mean	Std. Deviation	Variance	Coefficient of variance C.V
Cdc	1	.1549	.4620	.272265	.0639901	.004	0.231
h_1/H	0.318	.0100	.4123	.179989	.0908628	.008	0.504
ho/H	-0.462	.2145	.4854	.317120	.0673664	.005	0.2122
d/H	-0.015	.3343	.6667	.492952	.0810564	.007	0.1643
hw/H	-0.242	.3217	.9950	.608215	.1913325	.037	0.3145
bw/H	-0.240	.4310	1.1744	.745965	.1709562	.029	0.229
bo/H	-0.503	.1340	.3883	.224240	.0721830	.005	0.3219
bm/H	-0.489	.2145	.4854	.314677	.0689368	.005	0.219



Fig(4.1) Expermental setup used for conducting experiments.

Figure(1) Channel cross section

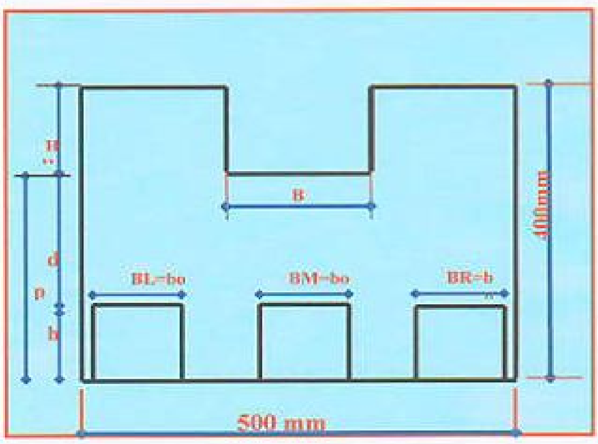


Figure (2) Physical Model of the Proposed Weir Section

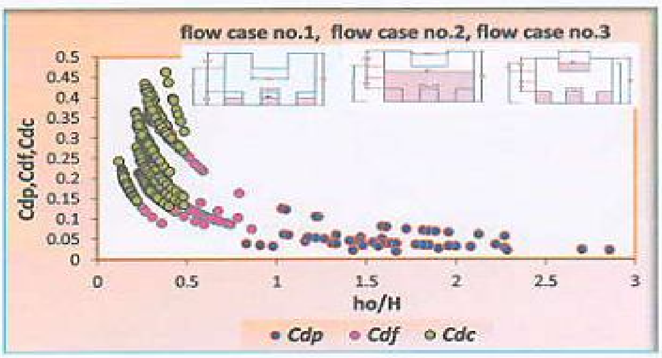


Figure (3) Variation of discharge coefficient with (ho/H)

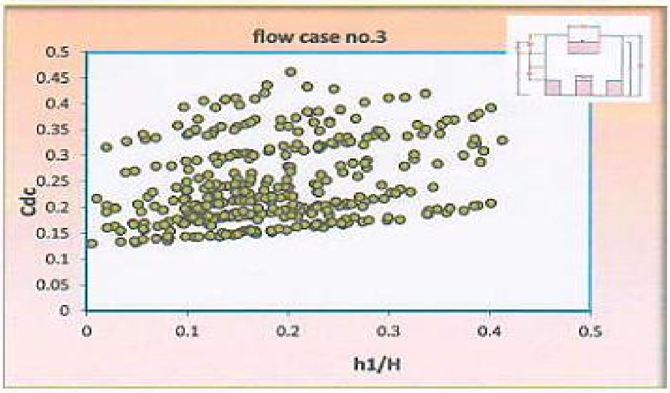


Figure (6) Variation of discharge coefficient with (h1/H)

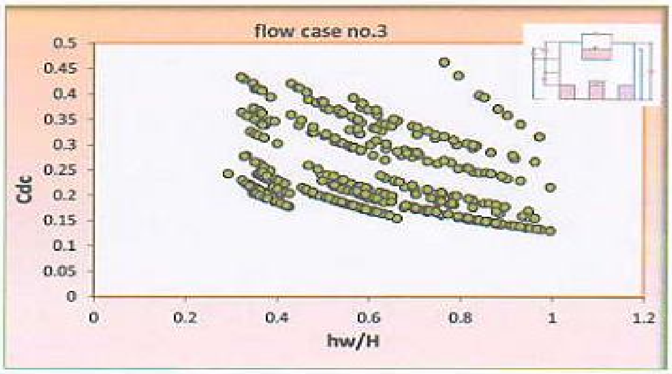


Figure (7)Variation of discharge coefficient with (hw/H)

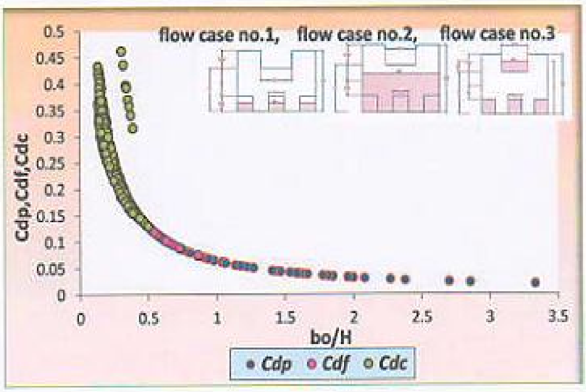


Figure (4) Variation of discharge coefficient with (bo/H).

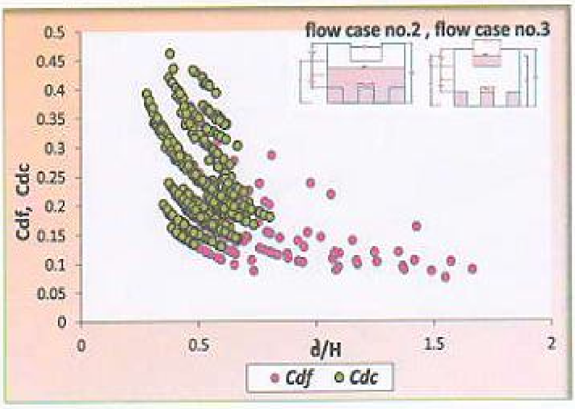


Figure (5) Variation of discharge coefficient with (d/H)

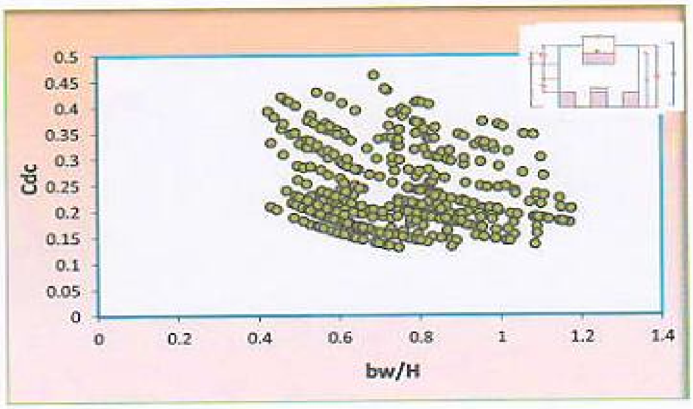


Figure (8) Variation of discharge coefficient with (bw/H)

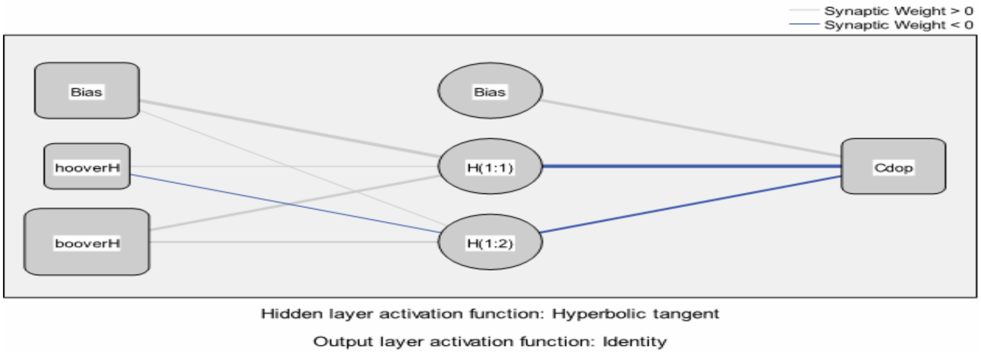


Figure (9) ANN for model with equal openings size and flow case no.(1) with (R=0.999)

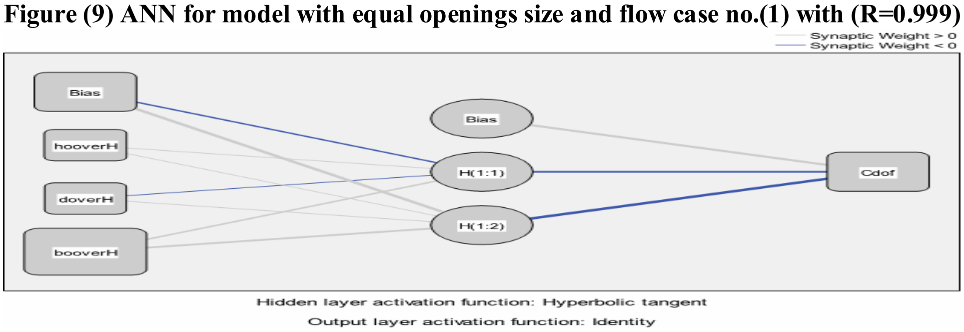


Figure (10) ANN for model with equal openings size and flow case no.(2) with (R=0.999)

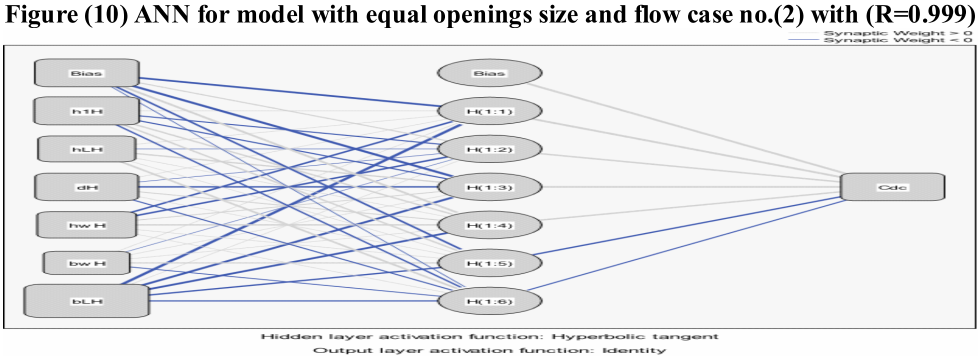


Figure (11) ANN for model with equal openings size and flow case no.(3) with (R=0.941)