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Prediction of the Discharge Coefficient for a Cipolletti Weir with Rectangular Bottom Opening

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Abstract
The hydraulic characteristics of a Cipolletti weir with rectangular bottom opening were investigated in this study. The work was carried out using an existing experimental setup of a flume with storage and re-circulating tanks, a pump, a flow meter and a piping system with valves. Thirty nine physical models were made for the Cipolletti weir with rectangular bottom opening with different geometrical dimensions called hereafter as configurations. Experimental measurements were taken for each configuration for different flow values to find the actual discharge, the head over the weir and the head of the approaching flow. For each configuration the data set were analyzed in order to find the discharge coefficient using equation, derived for the combined flow over the weir and from the bottom rectangular opening. All the flow cases tested were for free flow over the weir and sub-critical flows. Dimensional analysis was made to relate the discharge coefficient with different geometrical and flow variables using artificial neural networks modeling. The correlation coefficient found for the predicted values of the discharge coefficient is (r=0.88).

Key words: Cipolletti weir, Bottom opening, Discharge Coefficient, Artificial Neural Networks, Physical modeling.

I. Introduction

Weirs are built as a standing wall across the flow section with opening at the top. Sediments are often accumulated at the upstream side of the weir. These sediments will affect the weir function. This problem is exaggerated when the approaching channel has a high suspended load causing large changes in the upstream channel section. This results in many problems, such as high measuring errors and flow diversion problems. Many solutions were adopted before, such as the use of sediment excluder structure, sloping weirs, and continuous periodical removal of sediments. Sediments excluding structures are an alternative solution for sediment removal upstream hydraulic structures. Al-Suhaili and Auda(2001), had conducted a physical model study for Adhaim dam diversion weir located in Iraq. This weir was designed with sediment excluder that has two openings with gates. The main problem faced by hydraulic engineers is the difficulty in the design and operation of such structure, since it needs physical modeling to find the real ability of removal. Moreover many operation problems were also found.

Periodical removal of sediments is the other solution. However, this solution is rather expensive and difficult, especially for large weirs and for those rivers and channels that have high suspended loads, which usually settled and accumulated at the upstream side of the wier.

Other solutions have been adopted by Al-Hamid, *et. al.*, (1996) for triangular weirs and Negm,(1998) for rectangular weirs with unequal contractions. That is to provide an opening at the bottom of the weirs. It was found that sediments are partially removed through this opening.

In this research an attempt has been made to study the flow conditions and discharge coefficient for a Cipolletti weir with rectangle opening at the bottom for sediments removal. There is no equation available in the literature for calculating the discharge coefficient of such structure. The study is conducted using experimental physical modeling to calculate the discharge coefficient as a function of both geometrical and flow variables.

Al-Hamid, et.al., (1996-a) had investigated a discharge equation for simultaneous flow over rectangular contracted weir with bottom triangular opening. The .In this paper one generalized equation including all the important variables was obtained from an experimental investigation. The predictions of the equation agreed well with the experimental observations.

Al-Hamid, et.al. (1996-b) had investigated the hydraulics of a triangular weir with bottom rectangular opening. Different models with different geometric combinations were tested. These geometries include, gate opening, gate length and V-notch angle. Experiments were conducted for free gate flow (un-submerged) conditions on horizontal and sloping channels. Results showed that flow passes through the weir is affected by the weir and opening geometry and the flow parameters. Semi-empirical discharge equation was developed. This equation represents the collected experimental data well with an absolute error less than 4%.

Negm,(1998) had investigated the characteristics of combined flow over contracted weir and below submerged rectangular opening with unequal contractions. This paper presents the results of an experimental study on the characteristics of simultaneous flow over the contracted weir and below the contracted submerged opening with unequal contractions. A prediction equation relating the non-dimensional combined discharge to both flow and geometry parameters was developed. The predicted combined discharges agreed well with the experimentally measured ones.

Negm,et.al.,(2002) had investigated the combined –free flow over weirs and below rectangular opening of equal contraction. The experiments were carried out in a laboratory flume using various geometrical dimensions under different flow conditions. The experimental data were then used to develop a general non-dimensional equation for predicting the discharge through the combined system knowing its geometry and the head of water over the weir.

Negm, (2002) had investigated the modeling of submerged simultaneous flow through combined weirs and rectangular opening of unequal contractions. In this study, a generalized discharge model was proposed based on the known equations of weirs and openings. The proposed equation was calibrated using large series of experimental data for weirs having opening of unequal contractions under both free and submerged flow conditions. The predictions of the proposed model agree well with the observations with a deviation of less than ± 5 for about 90% of the data.

Hayawi*et.al*,(2008) had investigated free combined flow over a triangular weir and under rectangular opening. The main objective of this investigation is to find the characteristics of free flow through the combined triangular weir and a rectangular opening. Nine combined weirs were constructed and tested for three different triangular angles (30^o, 45^o*and* 60^o). The vertical distance between the weir crest and the top level of the opening was changed three times for each angle(5,10 and15) cm. A general expression was obtained for the discharge coefficient as a function of Froude number, angle of the weir, and different geometrical non dimensional terms. The estimated values of the discharge coefficient were compared well with the experimental results.

Saman and Mazaheri, (2009) had investigated combined flow over weir and under rectangular opening. Models of sharp-edged weirs and openings with no lateral contraction were combined. To calibrate and validate the proposed model, experiments have been carried out in a laboratory flume applying different submergence conditions. It was found that the model is able to predict the stage–discharge relationship with reasonable accuracy. The researchers had concluded that the results of the proposed model show good agreement between calculated and measured discharges implying reasonable precision.

II. Experimental work

For conducting the experiments on the proposed Cipolletti weir models with a rectangular opening at the bottom, a flume of conventional size was used. The conventional size is the size that can allow easy measurements of flow depth and permit good visualization of the flow pattern over the weir and at the downstream side from the bottom opening. This flume has other facilities, such as: storage tank, recirculation tank, pump, ultrasonic flow meter, point gauges and valves. The flume section is rectangular with 60cm width which is considered acceptable in accordance to (USBR, 2001) specifications. Along its length the flume has two different heights, 135cm height at the inlet (upstream) side with a length of 2.5m, and 70cm height at the downstream side with a length of 5.5m.

In order to investigate the hydraulics of Cipolletti weir with bottom rectangular opening, different configurations were used in this experimental work. Table (1) shows the details of these configurations. Figure (1) shows a general setup of the proposed weir model that covers all the configurations stated in table (1) with different dimensions.

Where:

h_w: Height of the Cipolletti weir.

B_w: Bed width of the Cipolletti weir.

h_o: Height of the rectangular bottom opening.

b_o: Width of the rectangular bottom opening.

P : Vertical distance between the bottom of the weir and its crest (h_o+d).

For each configuration from those mentioned in table (1), the number of flow values for which experimental measurements was conducted is different, according to what the experimental setup allows. For each configuration from those mentioned above and for each flow value, the following variables were measured:

1. Actual flow values (Q_{act}) using the flow meter.
2. The head over the crest (h_1') using point gage no.1

3. The total head (H) at a distance (3 h_1') upstream of the weir crest using point gage no.2

Using these data the discharge coefficient was calculated for each configuration and flow value.

To compute the discharge coefficient for the proposed hydraulic structure, the following equation may be obtained by adding the discharge over the weir and the discharge through the opening as follows:

$$Q_{theo} = Q_{g_{theo}} + Qw_{theo} \quad \ldots\ldots\ldots\ldots (1)$$

Where; $Q_{g_{theo}}$ = is the theoretical discharge through the opening which can be expressed as follows:

$$Q_{g_{theo}} = \sqrt{2gH} b_o h_o \quad \ldots\ldots\ldots (2)$$

Where; (H: Total head, b_o: opening width, h_o: opening height, g: gravitational acceleration.)

And $$Q_{w_{theo}} = \frac{2}{3}\sqrt{2g} B_w h_1^{1.5} \quad \ldots\ldots\ldots\ldots\ldots (3)$$

Where; (h_1=H-P, P: is the crest height, P=d+h_o).

The actual discharges are: $Q_{g_{act}}$, and $Q_{w_{act}}$ for the opening and the weir respectively:

$$Q_{g_{act}} = Cd_g \,.\, Q_{g_{theo}} \quad \ldots\ldots\ldots\ldots\ldots (4)$$

$$Q_{w_{act}} = Cd_w \,.\, Q_{w_{theo}} \quad \ldots\ldots\ldots (5)$$

Where;Cd_g and Cd_w are the discharge coefficients for the opening and the weir respectively.

For the flow condition of both from opening and over weir the theoretical flow is Q_{theo} ;

$$Q_{theo} = \sqrt{2gH} b_o h_o + \frac{2}{3}\sqrt{2g} B_w h_1^{1.5} \quad \ldots\ldots (6), \text{ and}$$

$$Q_{act} = Cd_g \,.\sqrt{2gH} b_o h_o + Cd_w \,.\, \frac{2}{3}\sqrt{2g} B_w h_1^{1.5} \quad \ldots\ldots (7)$$

Simplifying equations (7):

$$Q_{act} = Cd_c \,.\sqrt{2g}\left[\sqrt{H} b_o h_o + \frac{2}{3} B_w h_1^{1.5}\right] \quad \ldots. (8)$$

Where; Cd_c: is the combined discharge coefficient.

Hence this combined discharge coefficient will be estimated using equation (8). It is expected that the combined discharge coefficient is dependent on the geometry of the model as well as the flow conditions and properties , i.e. (h_o , b_o , d ,h_w , B_w , H, g, ρ , μ , □ ,S_o,σ)

g: gravitational acceleration.
ρ: water mass density.
μ: water viscosity.
□: weir angle.
S_o: slope of channel.
σ: surface tension.

For water at specific temperature (ρ,μ and σ) are constant, hence, can be excluded, Ackers,(1978) as mentioned in Al-Hamed *et. al.* (1996-a).This is evidence herein since the water temperature measured during the experimental work was ranged between (18, 25). Moreover, since the standard side slope is (1:4) for Cipolletti weir USBR, (2001), hence □ is constant. The available flume has no facility to change the bed slope of the channel, which is nearly horizontal, then (S_o) was also considered constant as well as (g). Then, the discharge coefficient can be expressed as:

$$Cd_c = \Phi(h_o / H , b_o /H , d/H , h_w /H , B_w/ H) \ldots\ldots..(10)$$

Or can be expressed using h_1= H – P, i.e.:

$$Cd_c = \Phi (h_o / h_1 , b_o /h_1, d/h_1 , h_w /h_1 , B_w/h_1)\ldots\ldots..(11)$$

Table (2) shows the calculations of the discharge coefficient for configuration (1.a.1), for a Cipolletti weir of a crest height “P=0.31m”and a crest length “B_w=0.22m” with a bottom opening of width “bo = 0.15m” and height “ho = 0.05m”. This table Shows that the discharge coefficient range is (0.6227-0.6458) with average value of (0.6346). The Froude number range is (0.0447-0.0526) which indicates a subcritical flow.

For the other configurations similar results were obtained as for configuration (1.a.1) above. Table (3) shows the summary of results for all of these other configurations.

The variation of Cd_c with each of the variables (h_o / h_1 , b_o /h_1, d/h_1 , h_w /h_1 , B_w/h_1) are shown in figures (2 to 6) respectively. Even though single correlation between Cd_c and each variable is low, it is expected that its multiple correlation with these variables will be significant, this will be shown later among the application of the ANN model.

III. Artificial Neural Network Model for the Discharge Coefficient

Artificial neural network models (ANN) had proved nowadays it's efficiency against nonlinear regression models. The calculations of the discharge coefficient presented above depend on equation (8).This equation requires the value of measured actual discharge. In practice, in order to use a Cipolletti weir with bottom rectangular opening, the actual discharge value should be calculated using equation (8) with the knowledge of discharge coefficient and by measuring the head value (h_1).Hence, a model is required to find the discharge coefficient as a function of (h_o / h_1 , b_o /h_1, d/h_1 , h_w /h_1 ,and B_w/h_1). This model could be a regression model or an (ANN)model. Since the experiments conducted covers different cases with different crest height, crest length and bottom opening dimensions the regression models are rather difficult , and may need classification ,i.e. different regression equations for different cases. In such situation the (ANN) models proved its superiority against regression models (Saoud, 2009). Moreover the use of one model in practice is much easier than using different equations. Therefore an (ANN) model was developed here including all the cases investigated to be used as a one applicable model for all cases rather than different models.

The artificial neural network model for estimating the discharge coefficient as a function of (h_o / h_1, b_o /h_1, d/h_1, h_w/h_1, B_w/ h_1) , was developed using a software called "**Neuframe**", 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 five variables and the number of output variables which was selected here as one, the discharge coefficient.

The next step is to find the number of nodes required in the hidden layer, which is a trial and error procedure. Before selecting the number of nodes in the hidden layer, the data division should be selected first, i.e. training set, testing set and verification (Querying) set. Different data set divisions are selected in table (4) which indicates that a data division of 65%, 25% and 10% is the best one.

The type of data division could be striped, blocked or random. Table (5) shows that the striped division method is the most suitable one. The numbers of nodes scanned are 1 to 11 as shown in table (6). It is shown that one node gives the minimum testing error and maximum correlation coefficient hence it is selected.

For the ANN model, a learning rate for a given momentum term should be selected. Table (7) shows the selection of learning rate for a momentum term of 0.80. The use of (0.8) momentum term is justified from table (8) .

Using these values selected above the resulted weights for the ANN model is shown in table (9) and the model is shown in equations (12) and (13). This model shows that the required activation function for the output layer is a tanh type.

$$y = \frac{1}{1+e^{(-3.921754+6.05452\tanh x)}} \quad \text{……. (12)}$$

Where;

X= {0.363191+ (*2.67587*V1) + (0.502867 V2) - (2.212595 V3) - (*0.873986 V4*) + (1.4752355V5)} ...……………………….(13)

IV. Conclusions

From the experimental study and the ANN modeling conducted for the discharge coefficient as a function of the geometry and flow properties of the proposed hydraulic structure (Cipolletti weir with rectangular bottom opening), the following conclusions could be deduced:

1. For all the cases tested the coefficient of variation for the estimated discharge coefficient is very low (0.001321), and ranged between (0.5385-0.6819) with an average value of (0.5887).
2. Correlation analysis of the discharge coefficient with the geometry and the flow variables indicate negative correlation of discharge coefficient with (h_o/h_1,b_o/h_1,h_w/h_1,B_w/h_1) with values (-0.7306,-0.1073,-0.2863, and -0.3513) respectively, while a positive correlation of (0.2931) was found between the discharge coefficient and (d/h_1). Even though these correlation coefficients are relatively low, the multiple correlations between the discharge coefficient and the other variables is significant as shown in the ANN modeling which has a correlation coefficient of (0.8815).
3. visual inspection of the flow condition downstream of the proposed hydraulic structure, shows that low turbulence is exist when the water level at the upstream side is below the height of the bottom opening. Turbulence at the downstream side increases as the water level at the upstream side increases and expected to create removal of the accumulated sediments .
4. The architecture of the ANN model suitable for relating the discharge coefficient with the geometry and the flow variables is of an input layer with five nodes, output layer with one node and one hidden layer with one node. The most suitable data division for training, testing, and validation is (65%, 25%, 10%) respectively. The most suitable type of data division is stripped division. The algorithm used is the back propagation algorithm with a learning rate of (0.2) and a momentum term of (0.80).the network correlation coefficient is (0.8815) which is classified as strong according to (Smith ,1986) criteria.

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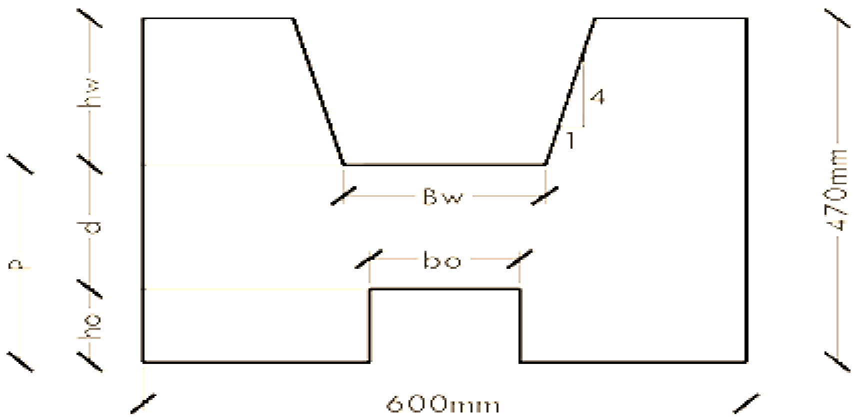


Fig.(1) General schematic diagram of the physical model of the weir.

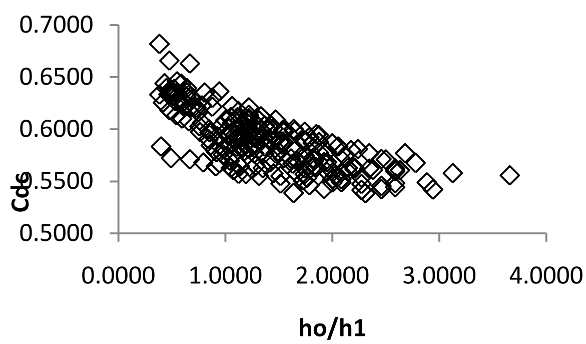
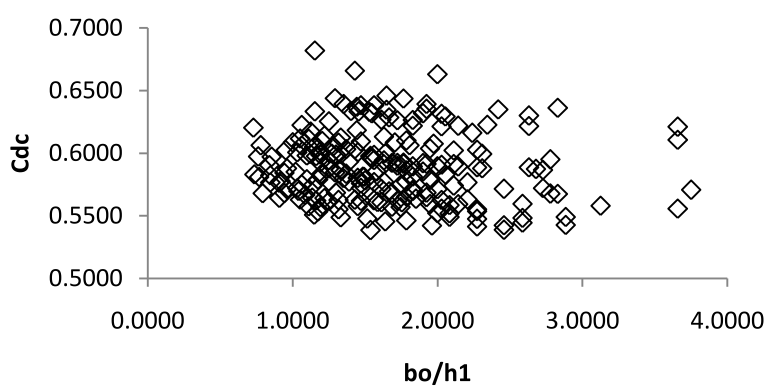


Fig.(2) Variation of discharge coefficient with ho/h_1.



Fig(3) Variation of discharge coefficient with bo/h1.

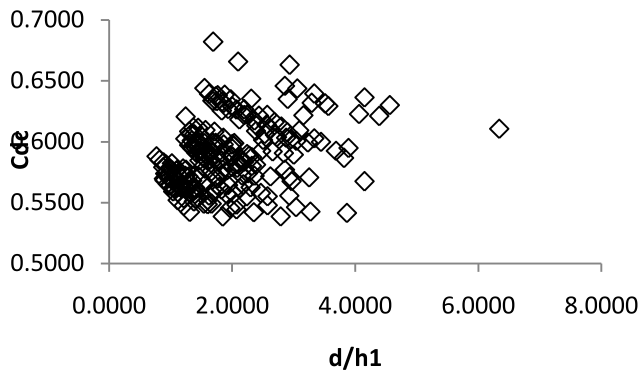


Fig.(4) Variation of discharge coefficient with d/h1.

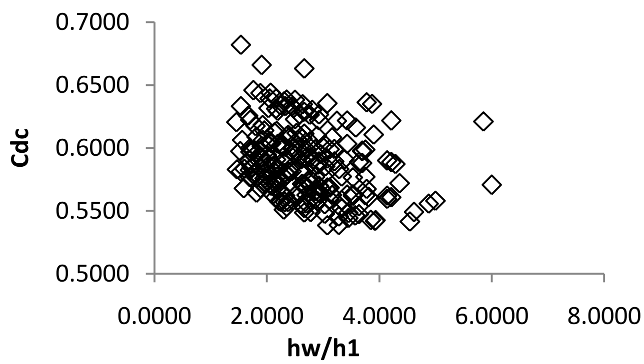


Fig.(5) Variation of discharge coefficient with hw/h1.

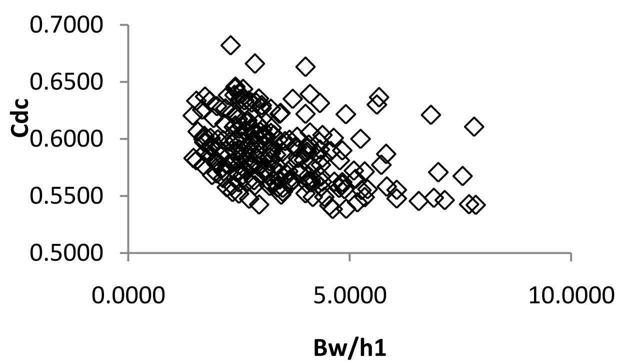


Fig.(6) Variation of discharge coefficient with B_w/h1.

Table (1) Different configurations used in the experimental work.

Configurations		**Crest height** *($P=h_o+d$) cm*	**Crest length** *(B_w) cm*	**Bottom Opening** *(b_o x h_o) cm*
1.a	*1.a.1*	*31*	*22*	15 x 5
	1.a.2			15 x 10
	1.a.3			15 x 15
	1.a.4			10 x 10
	1.a.5			10 x 15

1.b	*1.b.1*	*31*	*32*	15 x 5
	1.b.2			15 x 10
	1.b.3			10 x 10
	1.b.4			10 x 15
2.a	*2.a.1*	*27*	*40*	15 x 5
	2.a.2			15 x 10
	2.a.3			15 x 15
	2.a.4			10 x 10
	2.a.5			10 x 15
2.b	*2.b.1*	***27***	***30***	15 x 5
	2.b.2			15 x 10
	2.b.3			15 x 15
	2.b.4			10 x 10
	2.b.5			10 x 15
2.c	*2.c.1*	*27*	*20*	15 x 5
	2.c.2			15 x 10
	2.c.3			15 x 15
	2.c.4			10 x 10
	2.c.5			10 x 15
3.a	*3.a.1*	*23*	*28*	15 x 5
	3.a.2			15 x 10
	3.a.3			15 x 15
	3.a.4			10 x 10
	3.a.5			10 x 15
3.b	*3.b.1*	*23*	*23*	15 x 5
	3.b.2			15 x 10
	3.b.3			15 x 15
	3.b.4			10 x 10
	3.b.5			10 x 15
3.c	*3.c.1*	*23*	*23*	15 x 5
	3.c.2			15 x 10
	3.c.3			15 x 15
	3.c.4			10 x 10
	3.c.5			10 x 15

Table 2 Test results and calculations for Configuration1.a.1),(P=0.31m,B_W=0.22m,b_o = 0.15m,h_o = 0.05m).

Variables	***Test 1***	***Test 2***	***Test 3***	***Test 4***	***Test 5***
Q_{act} (m3/s)	0.0192	0.0210	0.0222	0.0238	0.0251
H(m)	0.3740	0.3830	0.3890	0.3950	0.4010
h_1(m)	0.0640	0.0730	0.0790	0.0850	0.0910
h_1'(m)	0.0530	0.0620	0.0680	0.0730	0.0800
V (m/S)	0.0856	0.0914	0.0951	0.1004	0.1043
Fr_1	0.0447	0.0471	0.0487	0.0510	0.0526
Cd_c	0.6227	0.6293	0.6317	0.6437	0.6458
h_o/h_1	0.7813	0.6849	0.6329	0.5882	0.5495
b_o/h_1	2.3438	2.0548	1.8987	1.7647	1.6484
d/h_1	4.0625	3.5616	3.2911	3.0588	2.8571
h_w/h_1	2.5000	2.1918	2.0253	1.8824	1.7582
B_w/h_1	3.4375	3.0137	2.7848	2.5882	2.4176

Note :(h_1 is the calculated water height above the crest which found by (h_1=H-P), but $h_1^{/}$ is the measured water height above the crest and V is the approach flow velocity upstream the weir which is found by continuity equation).

Table (3) Summary of analysis results for all of the configurations.

Config. No.	P (m)	Bw (m)	bo (m)	ho (m)	Cdc Range	Cdc Avg.	Cdc coeff. Of	Froud No. Range
1.a.1	0.31	0.22	0.15	0.05	0.6227-0.6458	0.6346	0.000152	0.0447-0.0526
1.a.2	0.31	0.22	0.15	0.1	0.5949-0.6087	0.6025	0.000040	0.0695-0.0759
1.a.3	0.31	0.22	0.15	0.15	0.5676-0.5784	0.5729	0.000036	0.0939-0.0970
1.a.4	0.31	0.22	0.1	0.1	0.6093-0.6222	0.6150	0.000040	0.0540-0.0604
1.a.5	0.31	0.22	0.1	0.15	0.5801-0.5982	0.5913	0.000104	0.0697-0.0751
1.b.1	0.31	0.32	0.15	0.05	0.6106-0.6393	0.6278	0.000237	0.0430-0.0581
1.b.2	0.31	0.32	0.15	0.1	0.5866-0.5925	0.5902	0.000009	0.0741-0.0828
1.b.3	0.31	0.32	0.1	0.1	0.5999-0.6055	0.6021	0.000008	0.0582-0.0657
1.b.4	0.31	0.32	0.1	0.15	0.5770-0.5924	0.5847	0.000050	0.0731-0.0825
2.a.1	0.27	0.4	0.15	0.05	0.5674-0.5835	0.5736	0.000084	0.0548-0.0914
2.a.2	0.27	0.4	0.15	0.1	0.5426-0.5812	0.5642	0.000444	0.0817-0.1073
2.a.3	0.27	0.4	0.15	0.15	0.5482-0.5557	0.5520	0.000051	0.1143-0.1205
2.a.4	0.27	0.4	0.1	0.1	0.5462-0.5680	0.5573	0.000124	0.0639-0.0979
2.a.5	0.27	0.4	0.1	0.15	0.5421-0.5712	0.5561	0.000267	0.0813-0.1066
2.b.1	0.27	0.3	0.15	0.05	0.6363-0.6819	0.6618	0.000541	0.0548-0.0897
2.b.2	0.27	0.3	0.15	0.1	0.5387-0.5845	0.5661	0.000525	0.0776-0.0989
2.b.3	0.27	0.3	0.15	0.15	0.5444-0.5569	0.5506	0.000050	0.1071-0.1141
2.b.4	0.27	0.3	0.1	0.1	0.5576-0.5972	0.5761	0.000408	0.0629-0.0876
2.b.5	0.27	0.3	0.1	0.15	0.5385-0.5822	0.5640	0.000607	0.0785-0.0991
2.c.1	0.27	0.2	0.15	0.05	0.6027-0.6333	0.6158	0.000185	0.0648-0.0482
2.c.2	0.27	0.2	0.15	0.1	0.5626-0.5996	0.5844	0.000340	0.0755-0.0862
2.c.3	0.27	0.2	0.15	0.15	0.5558-0.5780	0.5671	0.000152	0.1031-0.1084
2.c.4	0.27	0.2	0.1	0.1	0.5414-0.6204	0.5831	0.001079	0.0496-0.0740
2.c.5	0.27	0.2	0.1	0.15	0.5533-0.5830	0.5699	0.000271	0.0755-0.0863
3.a.1	0.23	0.28	0.15	0.05	0.6210-0.6438	0.6292	0.000096	0.0566-0.0879
3.a.2	0.23	0.28	0.15	0.1	0.5706-0.5955	0.5840	0.000148	0.0890-0.1067
3.a.3	0.23	0.28	0.15	0.15	0.5579-0.5746	0.5656	0.000073	0.124-0.1323
3.a.4	0.23	0.28	0.1	0.1	0.5899-0.6085	0.6009	0.000079	0.0717-0.0881
3.a.5	0.23	0.28	0.1	0.15	0.5618-0.5642	0.5625	0.000002	0.0913-0.0974
3.b.1	0.23	0.23	0.15	0.05	0.6350-0.6383	0.6363	0.000005	0.0609-0.0733
3.b.2	0.23	0.23	0.15	0.1	0.5886-0.5914	0.5903	0.000003	0.0913-0.0975
3.b.3	0.23	0.23	0.15	0.15	0.5490-0.5681	0.5586	0.000104	0.1189-0.1247
3.b.4	0.23	0.23	0.1	0.1	0.5979-0.6117	0.6070	0.000048	0.0701-0.0793
3.b.5	0.23	0.23	0.1	0.15	0.5607-0.5737	0.5653	0.000056	0.0870-0.0940
3.c.1	0.23	0.18	0.15	0.05	0.6161-0.6370	0.6271	0.000092	0.0553-0.0650
3.c.2	0.23	0.18	0.15	0.1	0.5872-0.5944	0.5901	0.000013	0.0870-0.0913
3.c.3	0.23	0.18	0.15	0.15	0.5424-0.5695	0.5559	0.000201	0.1136-0.1184
3.c.4	0.23	0.18	0.1	0.1	0.5986-0.6023	0.5998	0.000003	0.0652-0.0723
3.c.5	0.23	0.18	0.1	0.15	0.5770-0.5880	0.5807	0.000038	0.0860-0.0911

Table (4) Data sets selection for the ANN model.

Data Division			training error %	testing error %	coefficient correlation(r) %
% Training	% Testing	% Querying			
80	10	10	7.38%	8.55%	70.05%
75	15	10	9.30%	8.45%	73.73%
70	15	15	7.51%	7.82%	80.50%
70	10	20	8.96%	7.24%	84.35%
70	20	10	8.80%	7.08%	80.85%
65	20	10	6.60%	7.88%	81.08%
65	25	10	6.15%	7.02%	88.15%

max			88.15%
min	6.15%	7.02%	

Table (5) Data sets Division type selection for the ANN model.

Data Division			choices of division	training error	testing error	coefficient correlation
% Training	% Testing	% Querying				
65	25	10	Striped	6.15%	7.02%	88.15%
65	25	10	Blocked	7.90%	6.67%	82.60%
65	25	10	Random	7.34%	6.34%	81.38%
	max					88.15%
	min			6.15%	6.34%	

Table (6) Number of nodes in the hidden layer selection for a stripped data division of (65%, 25%, and 10%)

No. of Nodes	training error	testing error	coefficient correlation
1	6.15%	7.02%	88.15%
2	6.02%	7.93%	84.55%
3	6.13%	7.95%	83.49%
4	6.85%	7.77%	83.84%
5	6.68%	7.79%	83.09%
6	6.90%	7.00%	84.61%
7	6.80%	7.52%	84.97%
8	6.86%	7.71%	84.52%
9	6.70%	7.77%	84.25%
10	6.75%	8.60%	84.85%
11	7.10%	8.00%	85.29%

Table (7) learning rate selection for the ANN model.

momentum term	learning rate	training error	testing error	coefficient correlation®
0.8	0.2	6.15%	7.02%	88.15%
	0.1	6.65%	7.15%	86.78%
	0.2	6.15%	7.02%	88.15%
	0.3	6.65%	7.33%	84.95%
	0.4	6.84%	7.35%	84.92%
	0.5	6.65%	7.50%	84.77%
	0.6	6.23%	7.55%	75.20%
	0.7	6.33%	7.50%	77.58%
	0.8	6.45%	7.84%	76.89%

Table (8) Selection of the momentum term for the ANN model.

momentum term	training error	testing error	coefficient correlation®
0.8	6.15%	7.02%	88.15%
0.1	6.65%	7.64%	84.11%
0.2	6.92%	7.50%	84.75%
0.3	6.98%	7.50%	85.73%
0.4	6.92%	7.55%	84.00%
0.5	6.93%	7.87%	83.02%
0.6	6.92%	7.85%	83.33%
0.7	6.88%	8.58%	83.59%
0.8	6.15%	7.02%	88.15%
0.9	6.69%	7.08%	84.99%
0.95	6.69%	7.88%	84.89%

Table (9) Weights and Threshold Levels for the ANN Optimal Model .

<table>
<tr><th rowspan="2">Hidden layer nodes</th><th colspan="30">w_{ji}(weight from node i in the input layer to node j in the hidden layer)</th><th rowspan="2">Hidden layer threshold $\square_j$</th></tr>
<tr><th colspan="6">i=1</th><th colspan="6">i=2</th><th colspan="6">i=3</th><th colspan="6">i=4</th><th colspan="6">i=5</th></tr>
<tr><td>j=6</td><td colspan="6">2.675870</td><td colspan="6">0.502867</td><td colspan="6">-2.212595</td><td colspan="6">-0.873986</td><td colspan="6">1.4752355</td><td>0.363191</td></tr>
<tr><th rowspan="2">Output layer nodes</th><th colspan="30">w_{ji}(weight from node i in the hidden layer to node j in the output layer)</th><th rowspan="2">Output layer threshold $\square_j$</th></tr>
<tr><th colspan="5">i=6</th><th colspan="5">-</th><th colspan="5">-</th><th colspan="5">-</th><th colspan="5">-</th><th colspan="5">-</th></tr>
<tr><td>j=7</td><td colspan="5">-6.0545213</td><td colspan="5">-</td><td colspan="5">-</td><td colspan="5">-</td><td colspan="5">-</td><td colspan="5">-</td><td>3.921754</td></tr>
</table>