The Effect of Total Solids on the Discharge Coefficient of Spillway, Broad crested weir and Crump weir

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Abstract

In this experimental work the efforts was devote to study the effect of different amounts of total solids (TS) on the flow rate pattern and the coefficient of discharge in open channels and water treatment plant for ogee spillway, broad crested weir and crump weir. A total of ten experiments were done on each type of weir, the first experiment was of a tap water while the other nine had different values of TS varying from 620 to 1121 ppm. In each experiment eight values of discharges were taken. The results indicate that the discharge coefficient Cd varies with the value of the total solids TS. For viscous flow, at initial increasing of (TS), the value of Cd was greater than the corresponding value of the tap water. When the value of TS is greater than (600,750 &800) ppm, the values of Cd decrease with the continues increasing of TS for spillway, crump weir and broad crested weir respectively.

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تأثير المواد الصلبة على قيمة معامل التصريف للمسيل المائي والهدار العريض والمثلث

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الجامعة المستنصرية

بغداد/ العراق

الخلاصة

لقد تم في هذا البحث دراسة تأثير قيم مختلفة من المواد الصلبة على نمط الجريان وقيم معامل التصريف للمسيل المائي والهدار العريض والهدار المثلث الشكل. تم عمل عشرة تجارب على كل نوع من انواع الهدارات الثلاثة وكانت التجربة الاولى دائما لمياه الحنفية بيما التجارب التسع الباقية كانت لقيم مختلفة من المواد الصلبة تتراوح بين 620 الى 1121 ملغرام/لتر. في كل تجربة تم أخذ ثمانية قيم للتصاريف. لقد بينت النتائج ان قيم معامل التصريف تتأثر بشكل واضح مع قيم المواد الصلبة المتوفرة

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في الماء حيث كانت قيمة معامل التصريف في حالة السائل اللزج, عند الزيادة الأولية لقيم المواد الصلبة, أعلى من معدلها الطبيعي (لماء الحنفية). في حين اخذت قيم معامل التصريف بالتنازل في الحالات التي تواجدت فيها المواد الصلبة بتراكيز عالية (اكثر من 600 , 750 و 800) ملغرام/لتر لكل من المسيل المائي والهدار المثلث المجسم والهدار العريض على التوالي.

Keywords: Coefficient of discharge, Spillway, crump weir, broad crested weir

1- *Introduction*

   The discharge coefficient *C*d is not constant. It is influenced by a variety of factors including the depth of approach, relation of the actual crest shape to the ideal nappe shape, upstream face slope, downstream apron interference, and downstream submergence, *Chow(1994)&U.S. Bureau(1977).***Bruce***(2001)* and others compare flow parameters over a standard ogee-crested spillway using a physical model, numerical model, and existing literature. They found that a comparison of the discharge coefficients for a flow rate of (*He* /*Hd*= 0.87) resulted in the discharge coefficient being 0.743 for the physical model, 0.740 for the 3D computational model, and 0.745 for the 2D computational model.   Based on this comparison, it was determined that 2D analysis was sufficient and computationally faster. *Subramanya Awasthy (1972)* presents a study considering subcritical and supercritical flows. According to the authors, **F1** (upstream Froude number) is the parameter having greater influence on the variation of C. Also, they showed that the parameters representing the geometrical configuration, L/B, H1/L and p/h1, have low influence on the discharge coefficient. The discharge coefficient and spray angle measurement for small pressure-swirl nozzles was investigated by *Javier (1994) .* A report on determining discharge coefficient ratings for selected coastal structures in Broward and Palm Beach counties was developed by *Gina (1998)*. The discharge coefficient of side weirs was studied by *Antonio N. at (1999)*. The recent advances in the design of trench weir were carried out by *Ahmed Z. at (2011)*. *Also, many similar work were made by Raju et al. (1979), Hager (1987), Swamee (1988), Cheong (1991) and Singh et al. (1994).*

In this work the efforts was devoted to study the effect of the total solids **TS**, on the value of discharge coefficient *Cd* for spillway, broad crested weir and crump weir. The term "total solids" refers to matter suspended or dissolved in water or wastewater, and is related to both specific conductance and turbidity, *U.S. Bureau (2001).*Total Solids (**TS**) are solids in water that can be trapped by a filter as well as the dissolved materials that passes through the filter. TS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. This factor has a more interest for environmental engineers

who are dealing with wastewater plants. This is because the influence over the weirs of the plants is usually has high concentrations of solids which play a major role in estimating of flow rate.

2- *Experimental Work*

The experimental work is conducted in the Hydraulic Engineering Laboratory, Department of Environmental Engineering, Collage of Engineering, Al-Mustansiriya University in Baghdad. In order to simulate the water river at different seasons, ten experiments were done on each weir, in the first experiment tap water was used, and then nine different samples of water having different TS were used. This was done by mixing different weights of dried soil, ranging from (100) gm to (1000) gm, within the tap water to produce turbid water. The amount of (**TS**) were measured at the sanitary engineering laboratory by filtering the sample through a pre weighted filter, the residue retained on the filter is dried in an oven at 103 to 105 º C until the weight of the filter no longer changes. The increase in weight of the filter represents the total solids.

During the experimental work several devices were used as follows, see Figs.(1 to 4):

1- *52mm wide,1.5m long -open channel flume*
2- Armfield, F1-10Hydraulic Bench
3- Steel models of crump weir, broad crested weir and spillway.
4- Verniers and stop watch
5- Water bath
6- Sensitive balance

Fig.(1): 1.5m ,52mm-open channel flume &Armfield, F1-10Hydr. Bench.

Fig.(2):Crump weir, broad crested weir and spillway.

Fig.(3): Water bath.

Fig.(4): Sensitive balance.

3- Analysis and Calculations

The general equations for discharge of ogee spillway, broad crested weir and crump weir are given respectively, **Chin (2006) &Humberto (2007)**.

$$Q = \frac{2}{3}\sqrt{2g}\; b\; C_d [H_e]^{3/2} \qquad\qquad 1$$

$$Q = \sqrt{g}\; b\; C_d [\tfrac{2}{3}H_e]^{3/2} \qquad\qquad \textit{2}$$

$$Q = \sqrt{g}\; C_d [H_e]^{3/2} \qquad\qquad \textit{3}$$

Where:

Q = *Flow rate (m^3/s)*
Cd = *Discharge Coefficient, dimensionless*
g = *Gravity (m/s^2)*
b = *weir length or width of the channel (m).*
H_e = *Upstream total head including the velocity head (m). The datum is located on the top of the spillway or weirs.*

It is possible to simplify the equations (1 to 3), by using *K* as:

$$K = (2/3)(\sqrt{2g}).C_d\; b = 2.953\; b\; C_d \qquad \text{for spillway (4.a)}$$

$$K = \sqrt{g}\, C_d [\tfrac{2}{3}]^{3/2} b = 1.704\; b\; C_d \qquad \text{for broad weir (4.b)}$$

$$K = \sqrt{g}\, C_d\, b \qquad\qquad \text{for crump weir   (4.c)}$$

So the equations (1 to 3) can be re-written as:

$$Q = K \cdot H^{1.5} \qquad\qquad (5)$$

Where: K= general discharge coefficient

Equation 5 represents a nonlinear relationship between Q & H, but it takes a straight line form for Q and *(X=H^1.5)* has a slope equals to *K*. So:

$$Q = K\; X \qquad\qquad (6)$$

The value of *K* could be estimated using the liner regression analysis by plotting a

graph of *Q vs. (X=H$^{1.5}$)* with the experimental data and fit a linear equation with a form of Eq.6. Calculate *K* from the slope of the line and consequently the value of **Cd** could be estimated using equation 4 for each type of weirs and for each value of total solid TS .In this work, with each one of the ten experiments, eight values of discharges were taken starting from a low to high flow rate.

4- *Results and Discussions*

As illustrated in the experimental work several amounts of Total Solid (TS) were taken in this work, all of which were obtained by dissolving a certain amount of dry soil within a certain amount of tap water. **Table (1)** shows the results and **Figure (5)** shows the relation between (**TS**) and the weights. In this figure it is obvious that the relation has a positive relation having a power equation with R^2= 0.99.

Table (1) : Weight of dried soil and corresponding TS.

Ex. No.	Weight of dry soil (gm)	TS (ppm)
1	Tap Water	548
2	100	620
3	200	736
4	300	804
5	400	845
6	500	887
7	600	936
8	700	987
9	800	1016
10	1000	1121
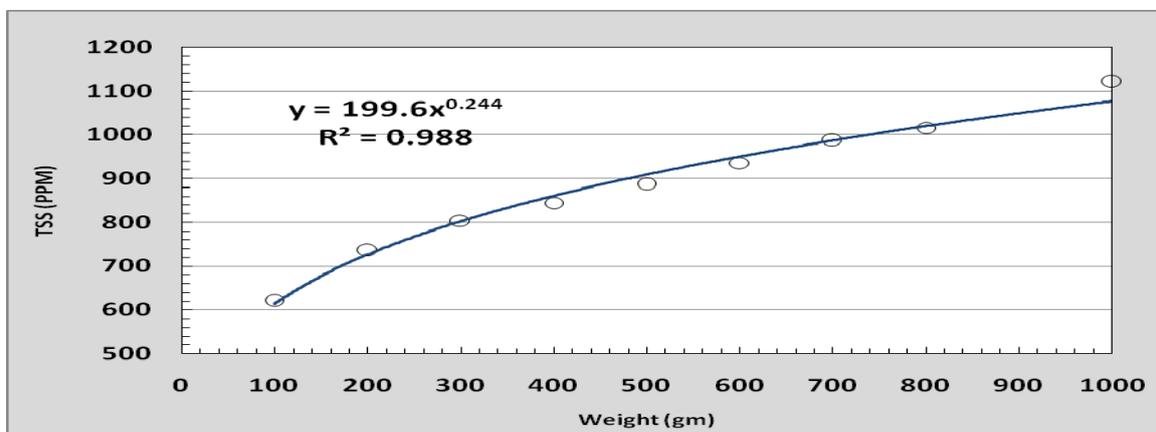
Figure(5): Weight of dried soil and TS Relationship.

Figures (6 a-c) shows the effect of the total solid TS, on the value of the discharge coefficient *Cd* for each of the broad crested weir, crump weir and spill way respectively. The figures explain that the value of *Cd*, begins to increase with the increasing of the total solid TS, and then returns to decreases again. This behavior of the *Cd* may be explained as follows:

At the beginning, and when the total solid starts to increase, some of the particles of the soil are dissolving in the water making the liquid to be more viscose. Consequently, the flow will not face a high friction through its flowing across the surface of the weirs which makes the value of Cd to increase. After that, and with the increasing of **TS**, the un dissolved solids available in the dry soil, begin to accumulate in the liquid and becomes to be permanents. Therefore the flow is expected to face much friction which consequently reduces the value of Cd.
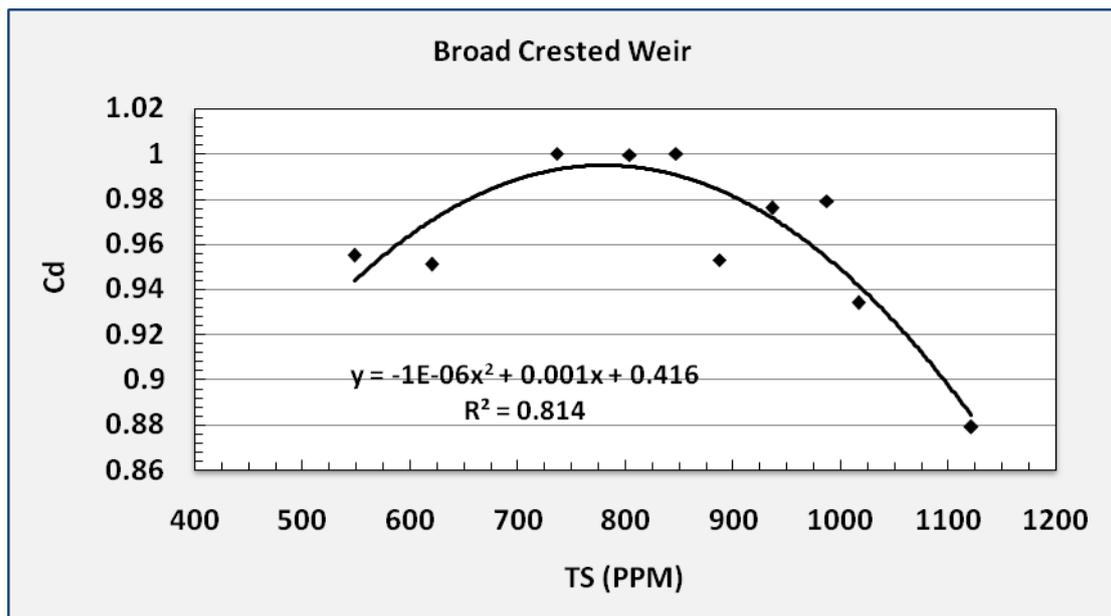

Broad Crested Weir

$y = -1E\text{-}06x^2 + 0.001x + 0.416$

$R^2 = 0.814$

Fig.(6-a): Effect of the total solid TS on the values of discharge coefficient Cd in the Broad crested weir.
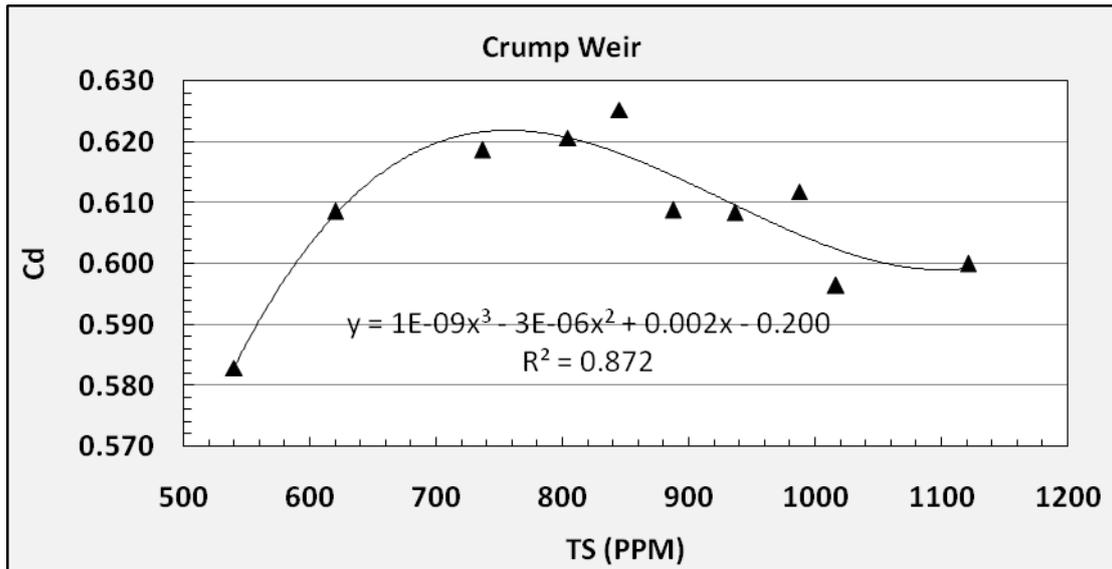
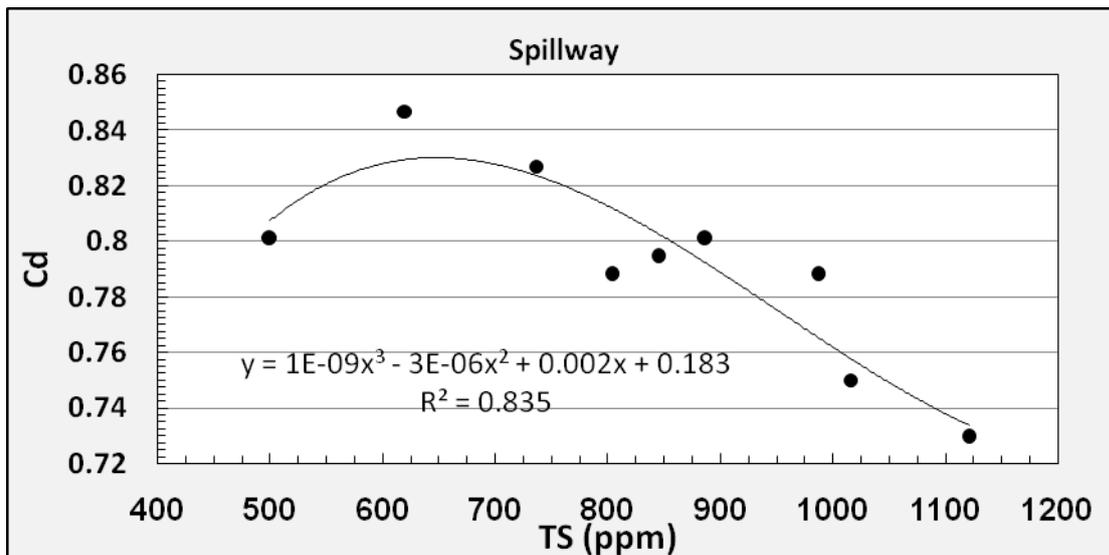**Fig.(6-b): Effect of the total solid TS on the values of discharge coefficient Cd in the Crump weir.**

Fig.(6-c): Effect of the total solid TS on the values of discharge coefficient Cd in the spillway.

5- *Conclusion*

According to the above results it can be concluded that the discharge coefficient *Cd*, varies with the value of the total solids **TS**. For the viscous flow, at initial increasing of **TS** until it reaches a value less than about 700 ppm, the value of *Cd* is greater than the corresponding value for the tap water duo to the increase of water viscosity. When the value of **TS** is greater than (600,750 &800) ppm, the values of *Cd* decrease with the continues increasing of **TS** for spillway, crump weir and broad crested weir respectively. This is attributed to the increase of particles that obstacle the flow and generate resistance. Another reason may be the decrease in the area of the channel duo to the settlement of particles at high rates of **TS**.

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