VARIATION OF WATER DEPTH ON NORMAL AND SKEWED BROAD CRESTED WEIRS

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ABSTRACT

This paper present the variation between brink and critical depths for free overfall, of water over two models of broad crested weirs with different edge, straight vertical and skewed with an angle $(30)^o$.

The discharge was measured for the two models and compared with calculated one observed from theoretical equation. The results showed that the calculated discharge is greater than the measured one by (3.5&14.5)% for straight vertical and skew models respectively, and the skew model discharge is greater than that for the straight vertical by (13%). Also, the results indicated that the coefficient of discharge for skew model is less than that for the straight vertical one by (8%). Meanwhile for the same discharges the brink depth for straight vertical model is greater than that for skew model by (11%).

The study also showed that the distance upstream the weir (x), at which the critical depth intersected with water surface

profile, for skew model is greater than the straight vertical model by (63%).

KEYWORDS

weir, freefall, broad crested weir, brink water depth, Froud number

LIST OF SYMBOLS

Symbol	Dimension	Meaning
h_e	L	Brink water depth
h_c	L	Critical water depth
S_c		Critical slope
S_o		Bed slope
H_w	L	Measurement (calibration) weir
Q	$L^3/T.L$	Discharge per unit width
Q_m	L^3/T	Measured discharge
Q_{cal}	L^3/T	Calculated discharge
F_o		Froud number
C_d		Discharge coefficient
h_o	L	Uniform water depth (upstream vertical and skewed broad crested weir)
$h_e$center	L	Brink water depth at center of skew broad crested weir
G	L/T^2	Acceleration due to gravity
X	L	Horizontal distance upstream crest of weir

INTRODUCTION

A free overfall refers to the downstream portion of the channel and not submerged by the tail water. The free overfall can be seen at the end of long crested weir, which is used in open channel of irrigation distribution systems. The concept of long crested weir simply provides more weir length than that which is possible typical weirs. Several studies have found a simple relationship between the depth of brink (h_e), which is easily measured, and critical depth(h_c).

Bauer &Graff (1971)[1] obtained a constant value for the ratio (h_e/h_c) equal to 0.78, although they reported that an insufficient length of their flume may have affected their results, using this value they were able to predict discharge with an error of no more than (5%).

Rajaratnam et. al. (1976) [2] and Davis et. al. (1998) [3] investigated the effect of slopes and roughness on the brink depth. They found that the influence of roughness is negilable but (h_e/h_c) was affected by the ratio of bed slope to critical slope (S_o/S_c).

This paper presents the results obtained from an experimental study conducted in the hydraulic laboratory at the college of engineering at Mosul University. In the study the free overfall of water over two broad crested weirs models were investigated. The relationship of brink and critical depth and the effects of skewed broad crested weir compared with straight vertical weir, were also studied.

EXPERIMENTAL WORK

The experiments were conducted in a rectangular flume with (10m) long, (0.3m) wide and (0.45m) depth with glass walls and aluminum bed. The discharge was measured by an installed sharp crested weir, (0.3m) wide and (0.15m) height, at the downstream end of the channel. The free overfall was studied at the end of two models of long (broad) crested weir with (2m) long and (0.3m) height, with straight vertical drop and $(30)^o$ skew edge, see figs. (1) and (2).

Eight different discharges have been used for each model through the experimental program. These, are vary from (2.68 – 17.86) l/s. All measured and calculated data for two models are shown in tables (1&2).

The variables which were measured for each experiment, are: the actual discharge of the flow, H_w, h_e, h_o and the water surface profile along the channel center. While, the other variables were computed as follows:

- Unit discharge $q=Q_m/B$, where B is the width of the channel, equal (0.3m) and Q_m is the measured discharge.
- Critical depth $h_c=\sqrt[3]{q^2/g}$, where g is the acceleration due to gravity

- Froud number $F_o=q/h_o\sqrt{gh_o}$, where h_o is the uniform water depth

- Calculated discharge $Q_{cal}=b\sqrt{gh_e^3}$, where h_e is the brink water depth

Brink and critical depths

The relationship between brink and critical depths (h_e and h_c), for both straight vertical and skewed broad crested weirs, are shown in Fig. (3). From this figure it can be seen that the relationship for the straight vertical broad crested weir is:

$h_c = 1.429\ h_e$ ---(1)

And the relationship for the skewed broad crested weir is:

$h_c = 1.572\ h_e$ ---(2)

Fig.(4) show the relation between (h_e/h_c) and Froud number (F_o). The equations represent these two parameters are given in:

$h_e/h_c = 0.6644\ e^{0.0688\ F_o}$ -------------------(3) for straight broad weir

And,

$h_e/h_c = 0.487e^{0.265Fo}$ -------------------(4) for skewed broad weir

The (R^2) values of for eqs. (3&4) are very small, ie.(0.14 & 0.11) respectively, this means that Froud number has no significant effect on flow characteristics and can be ignored in the computation of discharge.

The water surface profiles (W.S.P.) for straight vertical broad crested weir are shown in Figs.(5 & 6) for discharges (4.37 & 7.115)l/s, respectively, while Figs.(7 & 8) represents (W.S.P.) for skew model and discharges (4.55 & 7.589) l/s, respectively.

These figures show the actual values of brink & critical depths (experimental values) at a horizontal distance (x) (the point at which water surface profile (W.S.P.) & (h_c) are intersected), this value for skew models is greater than vertical by (63)%. The actual values of (h_e) compared with values measured from eq. (1&2).

In Fig.(9) the experimental data for skew & straight vertical broad crested weir are compared with Rouse (1936) [4] Bauer & Graff(1971) [1] and Davis et.al. (1998) [3], from this figure the data of the present work is in a good agreement with other works.

Predicting discharge

The discharge per unit width (q), for rectangular channel is a simple relationship with critical depth

$$q = \sqrt{h_C{}^3 g} \quad \text{----------------------(5)}$$

Fig. (10) represents the measured discharges (Q_{cal}) for vertical and skew models compared with the experimental values (Q_m), (see tables 1 and 2), the relationship between (Q_{cal}) and (Q_m) are shown in eq.(6&7)

$$Q_{cal.}=0.99Q_m^{1.019} \qquad \text{----------------------(6)}$$

$$Q_{cal.} = 0.934\, Q_m^{1.088} \qquad \text{------------------------ (7)}$$

From this figure and tables (1&2) it can be seen that the average increase of (Q_{cal}) with respect to (Q_m) for straight vertical model is about (3.5%) while in skew model this value increases about (14.5%). So, the average values of (Q_{cal}) for skew model is greater than straight vertical by (13%)

The relationship between values of variation (h_e/h_c) & coefficient of discharge (Q_{cal}/Q_m), for both straight vertical broad crested weir and skewed broad crested weir are shown in fig.(11) The relationship for straight vertical broad crested weir is:

$$h_e/h_c = 0.681\, (Q_m/Q_{cal})^{-0.666} \qquad \text{----------------(8)}$$

And relationship for skewed broad crested weir is:

$$h_e/h_c = 0.574\, (Q_m/Q_{cal})^{-0.666} \qquad \text{----------------(9)}$$

From this figure it can be seen that the coefficient of discharge for skewed broad crested weir is less than its values for straight vertical model by (8%), while the discharges predicted for skew model are greater than these for straight vertical by (13%), because the length of crest for skew model is greater than the crest of straight vertical model and the flow was more turbulent in skew model.

Fig. (12) Represents the relationship between calculated discharge and brink depth for straight vertical and skew free overfall. From this figure it can be seen that the discharge for skew model is greater than for straight vertical for the same values of brink depth. These means using skew shape models in irrigation channels are best than straight vertical model to increases the discharge in the channel.

CONCLUSIONS

From the present study it can be conclude the following:

1. The skew model increases the brink depth (h_e) about (11%) than the straight vertical model.
2. The average increasing of the measured discharge (Q_{cal}) with respect to (Q_m) for straight vertical model is about (3.5%) while this value is equal to (14.5%) in skew model.
3. the average values of (Q_{cal}) for skew model is greater than straight vertical by (13%)
4. the coefficient of discharge for skewed broad crested weir is less than its value for straight vertical model by (8%)

5. the discharge for skew model is greater than straight vertical for the same values of brink depth.
6. the horizontal distance up stream weir crest (x) for skew model is greater than vertical model by (63)%.

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Table (1): Experimental and computed data for straight vertical broad crested weir

H_W (cm)	Q_m (l/s)	q (m^3/s.m)	h_o (cm)	h_c (cm)	h_e (cm)	F_o	h_e/h_c	Q_{cal} (l/s)	$Cd=Q_m/Q_{cal}$
9.2	17.859	0.0595	8.2	7.122	5	0.809	0.702	18.682	0.95594
8.2	15.028	0.0500	8	6.347	4.5	0.706	0.708	15.951	0.94212
6.8	11.348	0.0378	6.8	5.264	3.7	0.681	0.702	11.892	0.95425
5	7.1554	0.0238	5.2	3.870	2.6	0.642	0.671	7.0054	1.02141
4.4	5.9068	0.0196	4.3	3.406	2.4	0.705	0.704	6.2128	0.95075
3.6	4.3715	0.0145	4	2.786	1.9	0.581	0.681	4.376	0.99891
3.2	3.6635	0.0122	3.8	2.477	1.7	0.526	0.686	3.7038	0.98913
2.6	2.6831	0.0089	3.5	2.012	1.4	0.436	0.695	2.7680	0.96933

Table (2): Experimental and computed data for skewed broad crested weir

H_W (cm)	Q_m (l/s)	q (m^3/s.m)	h_o (cm)	h_c (cm)	h_e(cm) center	F_o	h_e/h_c	Q_{cal} (l/s)	$cd=Q_m/Q_{cal}$
9.2	17.859	0.059	7.2	7.122	4.5	0.983	0.631	20.614	0.8664
8.2	15.028	0.050	7	6.347	4.2	0.863	0.661	18.587	0.8085
6.8	11.349	0.037	6.8	5.264	3.5	0.681	0.664	14.14	0.8026
5.2	7.589	0.025	4.6	4.025	2.45	0.818	0.608	8.281	0.9164
4.4	5.906	0.019	3.7	3.406	2	0.883	0.587	6.1077	0.9671
3.7	4.554	0.015	3.3	2.864	1.7	0.808	0.593	4.7864	0.9516
3.2	3.663	0.012	2.9	2.477	1.4	0.789	0.565	3.5771	1.0242
2.7	2.839	0.009	2.5	2.090	1.3	0.764	0.622	3.2007	0.8871

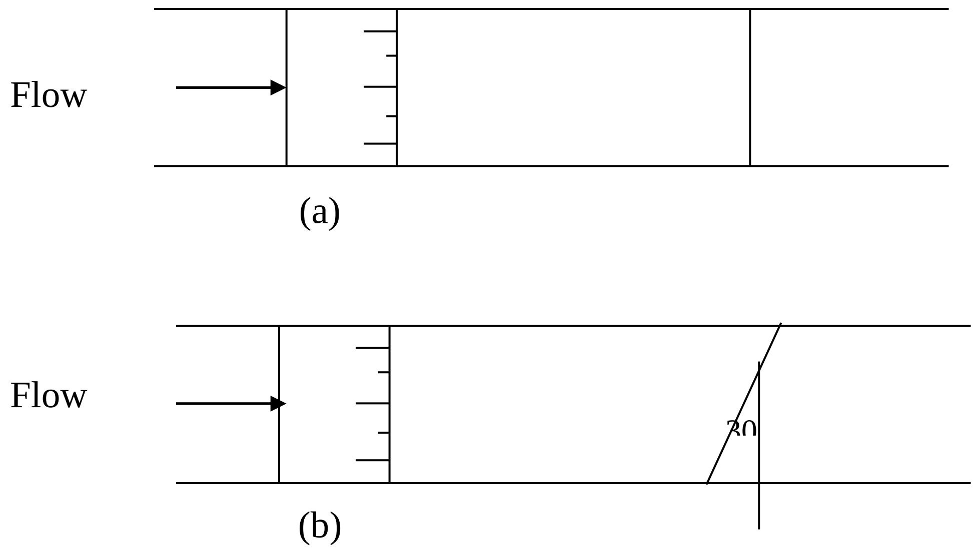

Fig.(1) plan view of broad crested weir,
(a) vertical model (b) skew model

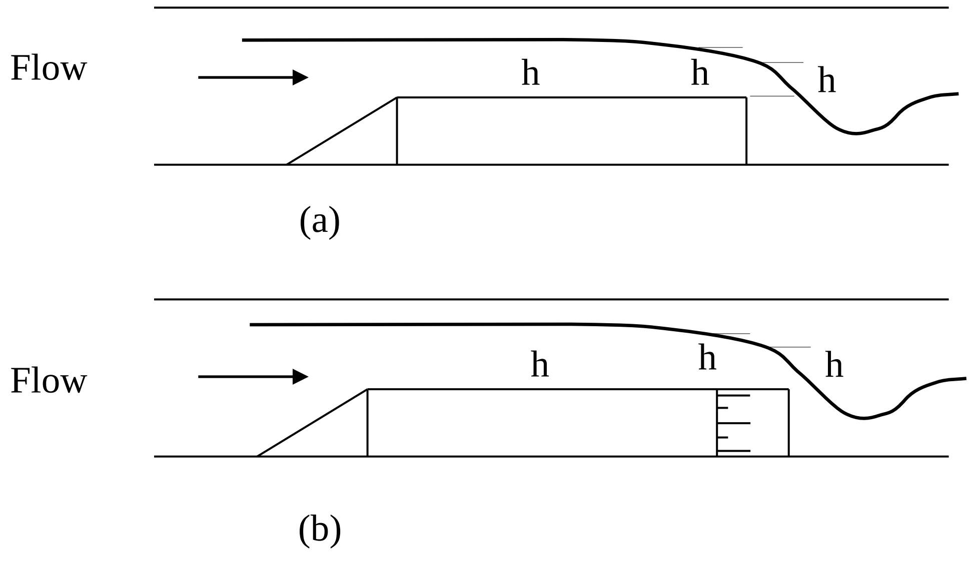

Fig.(2) side view of broad crested weir,
(a) vertical model (b) skew model

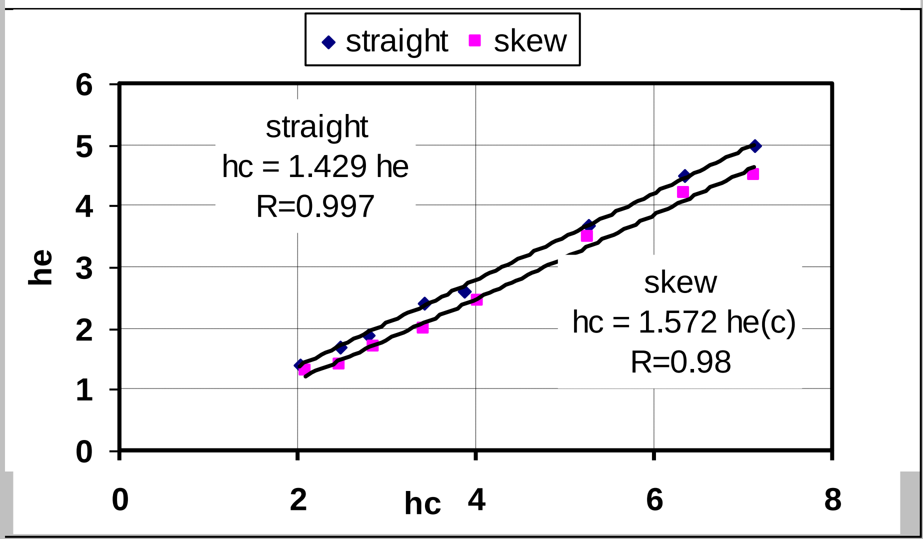

Fig. (3) Relationship between critical and brink depths for vertical and skew models

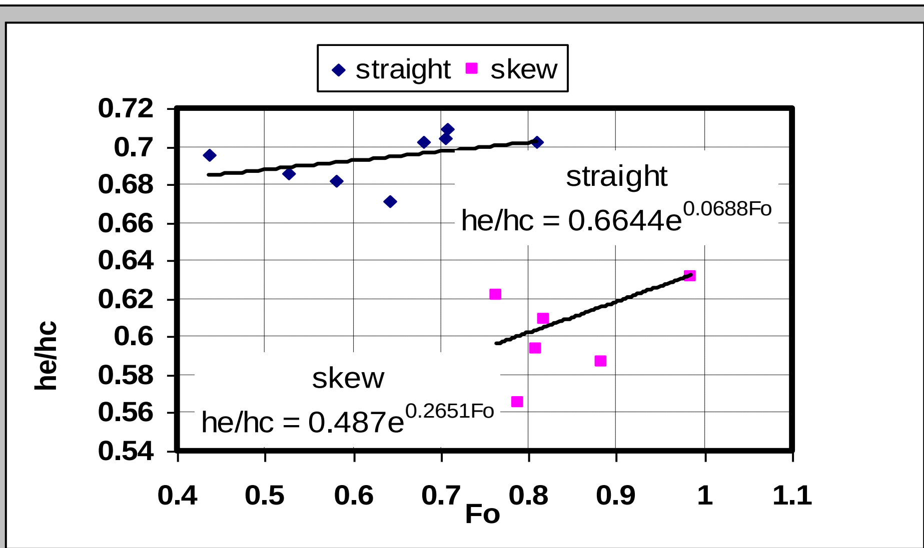

Fig. (4) Relationship between (h_e/h_c) ratio and Froud number for vertical and skew models

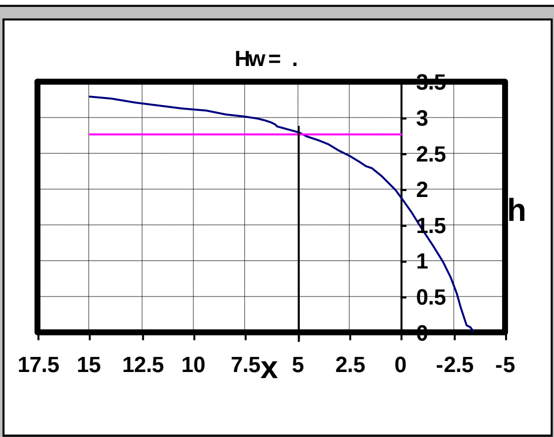

Fig.(5) water surface profile for vertical model(Q=4.37l/s)

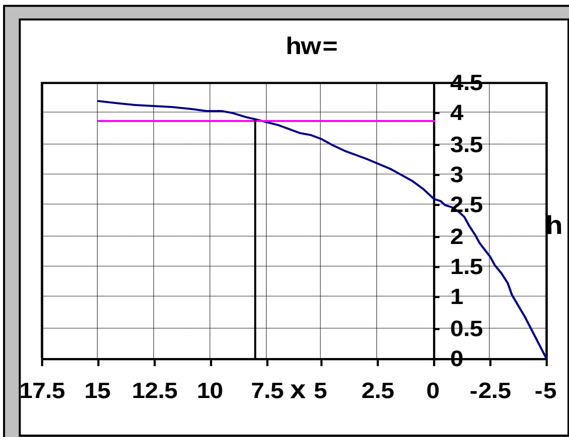

Fig. (6) Water surface profile for vertical model (Q=7.155l/s)

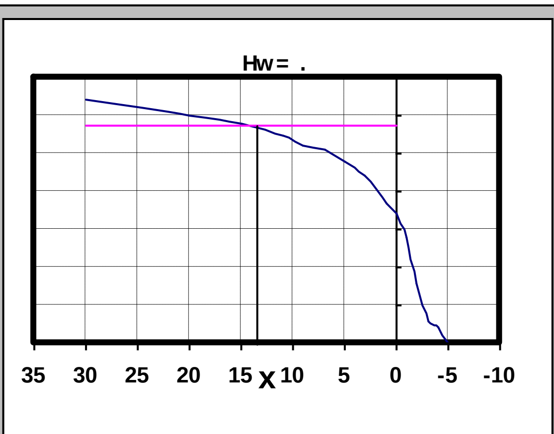

Fig. (7) Water surface profile for skew model (Q=4.554l/s)

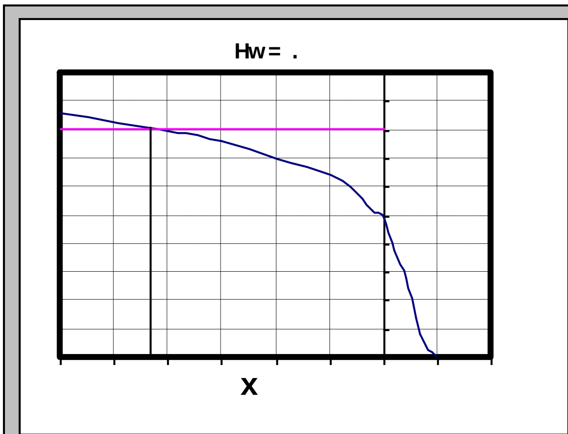

Fig. (8) Water surface profile for skew model (Q=7.589l/s)_

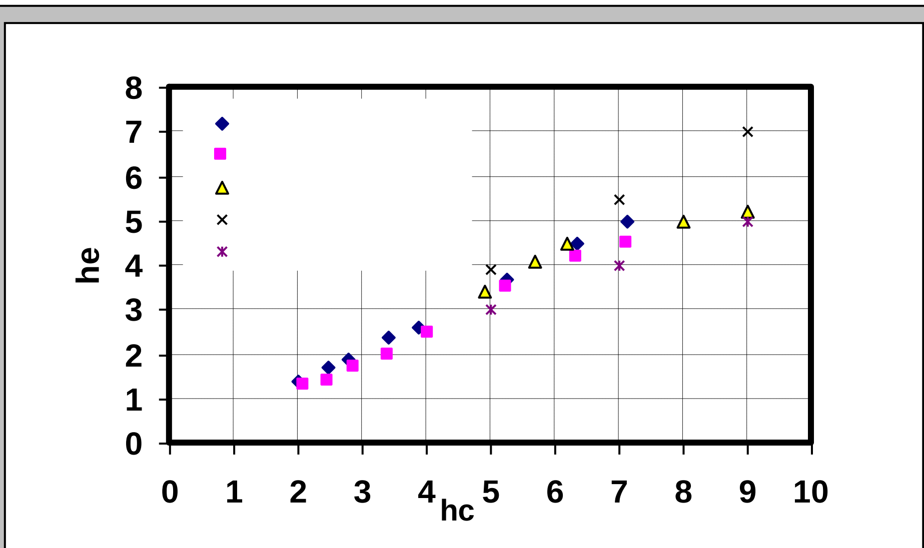

Fig. (9) The relation of critical and brink depths for the present study and the studies for others

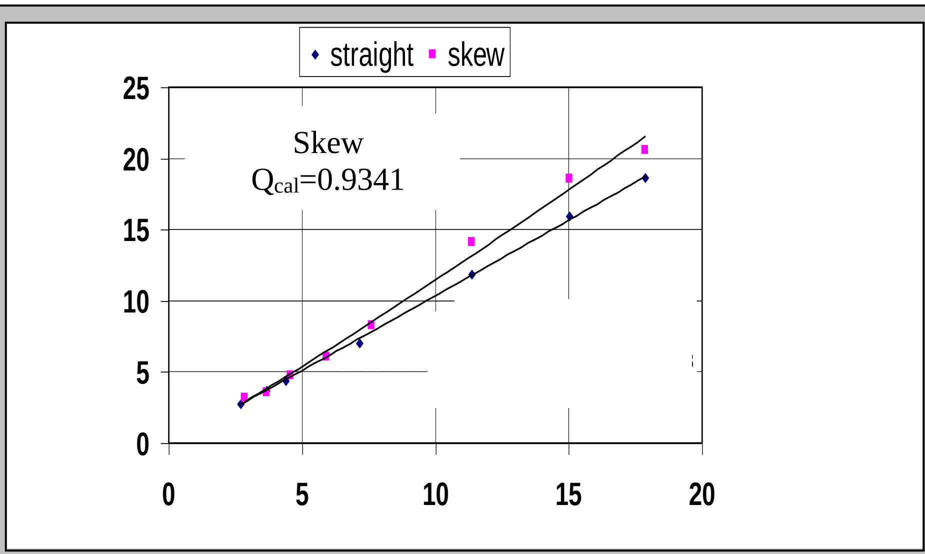

Fig. (10) Relationship between calculated and measured discharges for vertical and skew models

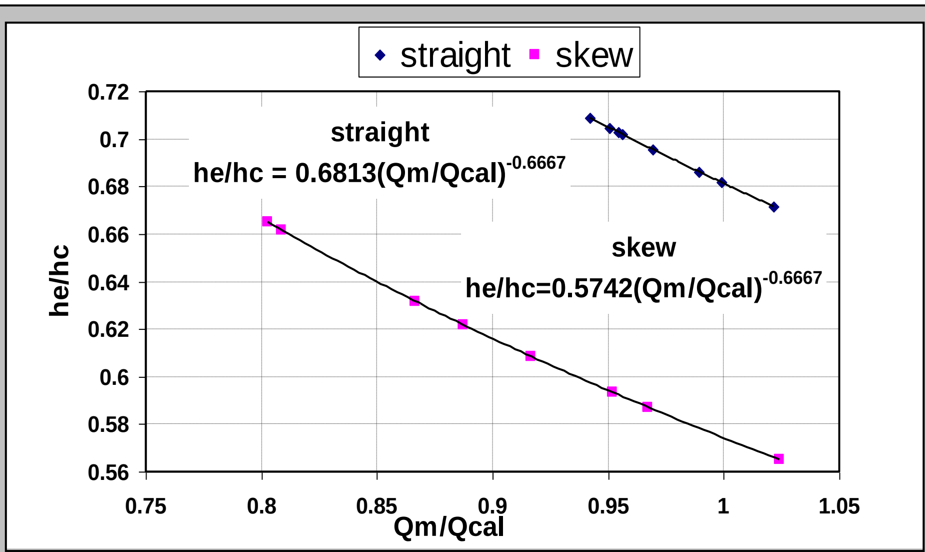

Fig. (11) Relationship between (h_e/h_c) and (Q_{cal}/Q_m) for vertical and skew models

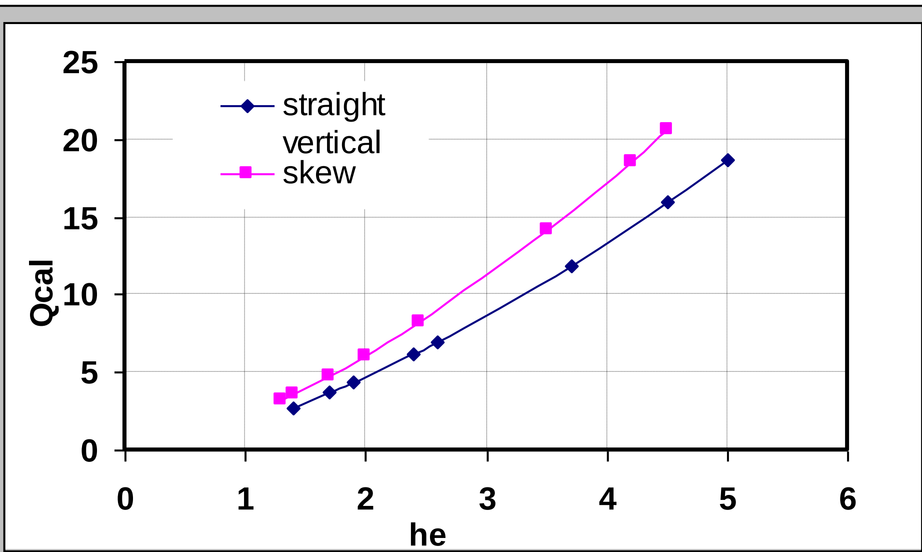

Fig. (12) Relationship between brink depth and calculating discharge for vertical and skew models

تغير أعماق الماء فوق الهدارات العريضة الاعتيادية والمنحرفة

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الخلاصة

يقدم هذا البحث فكرة اختلاف عمق الماء والعمق الحرج عند السقوط الحر للماء فوق نموذجين للهدارات العريضة العمودية الحافة والمنحرفة عن الجريان بزاوية (30).

تم قياس التصريف الحقيقي للنموذجين وقورن بالتصاريف المحسوبة من المعادلات النظرية. من النتائج تبين أن مقدار التصريف المحسوب اكبر من الحقيقي بمقدار (3.5و14.5)%, لنماذج الهدارات العمودية والمنحرفة على التوالي, وان التصريف للنموذج المنحرف اكبر منه للعمودي بمقدار (13%), ومعامل التصريف للنموذج المنحرف اقل بحدود (8%) للنموذج الاعتيادي العمودي, وعمق الماء فوق الحافة للنموذج العمودي كان اكبر من عمقه للمنحرف بحدود (11%) ولنفس التصريف.

وأخيرا أشارت نتائج البحث إلى أن المسافة الأفقية مقدم الهدار (التي عندها يتقاطع مخطط سطح الماء مع العمق الحرج) للنموذج المنحرف اكبر منه للنموذج الاعتيادي بحدود (63%).

الكلمات الدالة

قنطرة، السقوط الحر ، عدد فراود