EFFECT OF BED ROUGHNESS DISTRIBUTION AND CHANNEL SLOPE ON RECTANGULAR FREE OVERFALL

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ABSTRACT

In this paper, the free overfall in rectangular channel with a different slopes and bed rough distribution was studied. Bed roughness was made of wood allocated in three different cases: two, three and zigzag rows. The aim of this study is to obtain discharge equations for free overfall depending on brink depth and slope. Three empirical equations proposed for calculating discharge. These equations influenced by slope, channel bed roughness as well as method of roughness distribution. Three rows bed roughness having grater effect on these relationships at steeper slopes.

the average values of h_c/h_e at smooth bed is greater by (4%) with respect to that for bed rough at two rows, by (19%) with respect to that for bed rough at zigzag rows and by (24%) with respect to that for bed rough at three rows, so that values for three rows rough and horizontal channel is greater by (4%) with respect to that for channel slope at (1/200) and by (14%) with respect to that for channel slope at (1/100).

Keywords:
Overfall, brink depth, bed roughness, bed slope

تاثير توزيع خشونة القعر وميل القناة على المسقط المائي مستطيل المقطع

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الخلاصة:

تم في هذا البحث دراسة المسقط المائي مستطيل الحافة تحت ظروف تخشين مختلفة لمادة القعر وبميول مختلفة، حيث مثلت مادة تخشين القعر بالخشب ووضعت بثلاث طرق مختلفة: بصفين وثلاث صفوف وبثلاث صفوف متخالفة (زكزاك). هدف الدراسة هو لايجاد معادلات التصريف للمسقط المائي بالاعتماد على عمق الماء عند الحافة والميل. استنبطت ثلاث معادلات وضعية لايجاد التصريف وهذه المعادلات تعتمد على الميل وخشونة القعر بالاضافة الى طريقة توزيع التخشين. واوضحت البيانات بان التخشين بثلاث صفوف وميل حاد ذو تاثير اكبر على النتائج.

ان معدل القيم لعلاقة (h_c/h_e) عند القعر الاملس هي اكبر بحدود (4%) مقارنة بقيمها عند القعر المخشن بصفين من الخشب و اكبر بحدود (19%) مقارنة بقيمها عند القعر المخشن بثلاث سوف مخالف (زكزاك) بينما هي اكبر بحدود (24%) مقارنة بقيمها عند القعر المخشن بثلاث سوف، كما ان هذه القيم للمسقط المخشن بثلاث سوف وميل افقي هي اكبر بحدود (4%) مقارنة بميل القناة (1/200) واكبر بحدود (14%) مقارنة بميل القناة (1/100)

LIST OF NOTATION:

C_d	Coefficient of discharge
F_r	Froude number
g	Gravitational acceleration (LT^{-2})
h_c	Critical depth (L)
h_e	Brink depth (L)
h_o	Normal depth (L)
H_w	Head over sharp crested weir (L)
K	Roughness height (L)
n	Coefficient of Manning
Q	Discharge (L^3T^{-1})
Q_{act}	Actual discharge (L^3T^{-1})
S_o	Channel bed slope
ρ	Density of water (ML^{-3})

1. INTRODUCTION:

The study of free overfall is important because of possible usage of it as a discharge measuring devise (Tigrek et.al.,2008).Many investigators have studied the end depth discharge relationship in different channels cross section. Bauer S.and Graf W.(1971) submitted experimental study for free overfall with different channel slopes and obtained relationships between critical depth h_c and brink depth h_e ,this relationship using to find discharge equations and the results compared with data from previous investigators. Ferro V.(1992) presents experimental study of a free overfall in a rectangular channel, having different values of channel width ,the relationship between end depth h_e and critical depth h_c had to be established as h_e=0.76 h_c , this relationship was used to obtain discharge equation .Dey S.(1998) presents an analytical model for a free overfall from smooth circular channels applying a momentum approach based on the Boussinesq assumption. The end depths in subcritical and supercritical discharges were estimated. The relation of brink depth h_e to critical depth h_c is found to be around 0.75.Dey S.(2001) studied a simplified approach for the computation of end depth of a free overfall in horizontal or mildly slopping inverted semicircular channels. The free overfall is simulated by that over a sharp crested weir to calculate the end depth ratio. The mathematical model is calibrated by the experimental data.The end depth relationship related to the critical depth is around 0.705.Ramamurthy et.al.(2004) studied free overfall to determine vertical distribution of the velocity components and static presume heal at different points across the end section of a horizontal trapezoidal channel using momentum equation. Using this method improves the accuracy of predicting discharge Q from measurements of brink depth h_e. Pal M. and Goel A.(2006) presented an application of a support vector machine based modeling technique to determine the end depth ratio and discharge of free overfall occurring over an inverted smooth semi-circular channel and a circular channel with flat base , using data collected from other studied. The value of end depth raio is to be 0.704.

Ahmed Y.M. (2008) presented an experimental study and analysis for effect of channel slope on straight vertical and skew free overfall for a rectangular channel with different slopes, and find the discharge over skewed model is greater by (21%) from straight vertical.

Ahmed Y.M. (2009) studied the behavior of free surface flow on a rectangular free overfall which has a triangular shape, the results prevail that the ratio of brink depth to critical depth at center line for falls inclined with flow direction was greater by (3%) than that falls on the opposite direction, this value increased to (27%) when Froud number increased.

The purpose of this study is to experimentally investigate, the effect of bed roughness distribution and channel bed slope on the brink depth at horizontal bed slope, 1/100 and 1/200 slopes .The results obtained are presented to fined discharge equations for free overfall depending on brink depth as well as slope. This will be achieved practically using free overfall to calculate discharge in smooth and rough bed.

2. EXPERIMENTAL SETUP:

Experiments were setup in the hydraulic laboratory of the Water Resources Department, University of Mosul, Iraq. At a rectangular flume with glass sides was 0.3m wide 0.45m deep and 10m long shown in fig.(1). The flume was set to three slopes (0, 0.005 (1/200) and 0.01(1/100)), the discharge was conducted using a rectangular sharp crested weir installed upstream of the channel, with dimensions (30×30×1) cm. The upstream normal depths of approximately 4, 5.5, 6.5, 7.5 and 9.5 cm were produced in a flume. The free overfall was 0.3m wide 0.15m height and 1m long. Roughness was made using cylindrical wood 1cm diameter and 1cm height, allocated in three different cases: two rows; 20cm distance between them, three rows; 10cm distance between them and three rows zigzag; 10cm distance between them, shown in fig.(2). The water surface profile (W.S.P.) was measured using a point gage over and between roughness rows, head over brink h_e, normal depth over free overfall h_o and head over sharp crested weir upsteam H_w were measured ,so actual discharge Q_{act} can be calculated from the following equation:

$$Q_{act}=0.714\ H_w^{1.5} \qquad (1)$$

Where Q_{act} in (L/s) and H_w in (cm)

This equation was found from volumetric calibration by measuring H_w and volume of water with respect to time, the data shown in table 1.

3. EXPERIMENTAL PROGRAM:

In each experiment slope, normal depth, brink depth, water surface profile and discharge were measured. The total number of experiments conducted was 60. There were 15 experiments run for smooth bed and 45 experiments run for rough bed with three different slopes (0, 0.005 and 0.01) as well as three types of roughness distribution (two, three and zigzag rows).

4. RESULTS AND DISCUSSION:

4.1. Relation between h_e and h_c:

The relation between brink depth h_e and critical depth h_c for the three different slopes and the three types of roughness distribution were plotted and studied.

The magnitude of ratio h_e/h_c seems to be dependent of both slope and channel bottom roughness .At the same value of h_c ,the greatest value of h_e happened when bed is smooth and horizontal channel while the lowest values of h_e observed when bed is roughed at three rows and (1/100) channel slope.

Fig.(3) shows the effect of three types of roughness distribution in channel slope (1/100) .As depicted in this figure ,the magnitude of h_e increases when discharge value increasing and this value for smooth bed are grater by (4%) with respect to that two rows roughness, by (9%) with respect to that zigzag roughness and by (14%) with respect to that three rows roughness because of roughness distribution effects.

Fig.(4) shows the effect of the three channel slope at three rows roughness bed .As depicted in this figure the magnitude of h_e for horizontal channel is greater by (7%) with respect to that (1/200) channel slope and by (10%) with respect to that (1/100) channel slope for the same value of h_c (Tegrike et.al.,2008).

The brink depth h_e at sloping rough free overfall in a rectangular channel is depending on critical depth h_c ,channel slope S_o roughness hight K as folloing:

$$h_e=f(h_c , S_o ,K) \tag{2}$$

Dimensional analysis for the given parameters gives:

$$\frac{h_e}{h_c} = f(S_O, \frac{K}{h_e}) \tag{3}$$

it was found that a good relationship was obtained when h_e/h_c was a relation with S_o and $\frac{K}{h_e}$ .The following equations were obtained using the statistical package for the social sciences (SPSS, version 17).

The equation for two rows roughness distribution with R^2=0.985 is:

$$\frac{h_e}{h_c} = 0.628 - 0.18\sqrt{S_O / \frac{K}{h_e}} \tag{4}$$

The equation for zigzag roughness distribution R^2=0.975 is:

$$\frac{h_e}{h_c} = 0.58 - 0.168\sqrt{S_O / \frac{K}{h_e}} \qquad (5)$$

The equation for three rows roughness distribution R^2=0.988 is:

$$\frac{h_e}{h_c} = 0.56 - 0.16\sqrt{S_O / \frac{K}{h_e}} \qquad (6)$$

4.2. Predicting Discharge:

The critical depth h_c for a rectangular channel is a simple relationship between acceleration and uniform discharge per unit width q as following:

$$h_c = \sqrt[3]{\frac{q^2}{g}} \qquad (7)$$

Where g is acceleration due to gravity. Thus if h_c could be measured, then discharge in channel could be calculated.

The equations (4, 5 and 6) now be used to predicting discharge using equation (7).

So, discharge equation for two rows roughness distribution is:

$$Q = \frac{0.94 h_e^{\frac{3}{2}}}{(0.628 - 0.185\sqrt{S_o h_e})^{\frac{3}{2}}} \qquad (8)$$

And discharge equation for zigzag roughness distribution is:

$$Q = \frac{0.94 h_e^{\frac{3}{2}}}{(0.58 - 0.168\sqrt{S_o h_e})^{\frac{3}{2}}} \qquad (9)$$

Discharge equation for three rows roughness distribution is:

$$Q = \frac{0.94 h_e^{\frac{3}{2}}}{(0.56 - 0.16\sqrt{S_o h_e})^{\frac{3}{2}}} \qquad (10)$$

Fig. (5) shows the compared of discharge computed from eqs. (8-10) to experimental values as well as that values computed by Davis et. al. (1998), and Tigrek et. al. (2008). As depicted in this figure the overall correlation is 0.97 thus we can used eqs. (8-10) as discharge calculation when known the slope and the roughness distribution.

5. CONCLUSIONS:

In this study the effect of bed roughness distribution and channel bed slope were studied in a rectangular free overfall, the relation between critical and brink depth eqs. (4-6) as well as predicted discharge eqs. (8-10) were observed in all cases of bed rough and channel slopes.

the average values of h_c/h_e at smooth bed is greater by (4%) with respect to that for bed rough at two rows, by (19%) with respect to that for bed rough at zigzag rows and by (24%) with respect to that for bed rough at three rows, so that values for three rows rough and horizontal channel is greater by (4%) with respect to that for channel slope at (1/200) and by (14%) with respect to that for channel slope at (1/100), so the discharge predicted shown that the greatest values happened when bed rough at three rows.

These equation can used practically to calculate discharge in smooth and rough bed.

REFERENCES:

1. Ahmed Y.Mohammed (2008). "Effecting of Channel Slope on Flow Characteristics for Straight Vertical and Skew Free overfal", Alrafidain Eng. Journal, 17(1), 80-90.
2. Ahmed Y.Mohammed (2009). "Hydraulic Characteristics of Free Overfall with Triangular End Lip", 33rd IAHR Congress: Water Eng. For a Sust. Env., 1188-1199.
3. Bauer S.W.and Graf W.H.(1971). "Free Overfall as Flow Measuring Device", Journal of Irrigation and Drainage Engineering, ASCE, 97(1),73-83.
4. Davis A.C.,Brain G.S. and Jacob R.P.,(1998), " Flow Measurement in Sloping Channels with Rectangular Free Overfall ." Journal of Hydraulic Engineering, ASCE, 124(7), 760-763.
5. Dey S., (1998), " End Depth in Circular Channels", Journal of Hydraulic Engineering, ASCE, 124(8),856-863.
6. Dey S., (2001), "Flow Measurement by End-Depth Method in Inverted Semicircular Channels."Flow Measurement and Instrumentation, 12(4), 253-258.
7. Ferro V., (1992), " Flow Measurement with Rectangular Free overfall ", Journal of Irrigation and Drainage Engineering, ASCE, 118(6),650-657.
8. Pal M. and Goel A.,(2006)," Prediction of The End-Depth Ratio and Discharge in Semi-Circular and Circular Sloped Channels Using Supported Vector Machine. "Flow Measurement and Instrumentation, 17(3), 49-57.
9. Ramamurthy A.S., Zhai C. and Junying Q, (2004), " End Depth Discharges Relation at Free Overfall of Trapezoidal Channels", Journal of Irrigation and Drainage Engineering, ASCE, 130(5),432-436.
10. Tigrek S., Firat C.E. and Ger A.M, (2008) ," Use of Brink Depth in Discharge Measurement" Journal of Irrigation and Drainage Engineerge, ASCE, 134(1),89-95.

Table (1): discharge volumetric calculation

H(cm)	Volume(l)	Time(s)	Q(l/s)
2.5	20.2	7	2.886
3	20.2	5.5	3.673
4.5	20.2	3	6.733
5.5	20.2	2.2	9.182
6.5	20.2	1.7	11.882
7.5	20.2	1.4	14.429
8.5	20.2	1.2	16.833
9	20.2	1.1	18.364

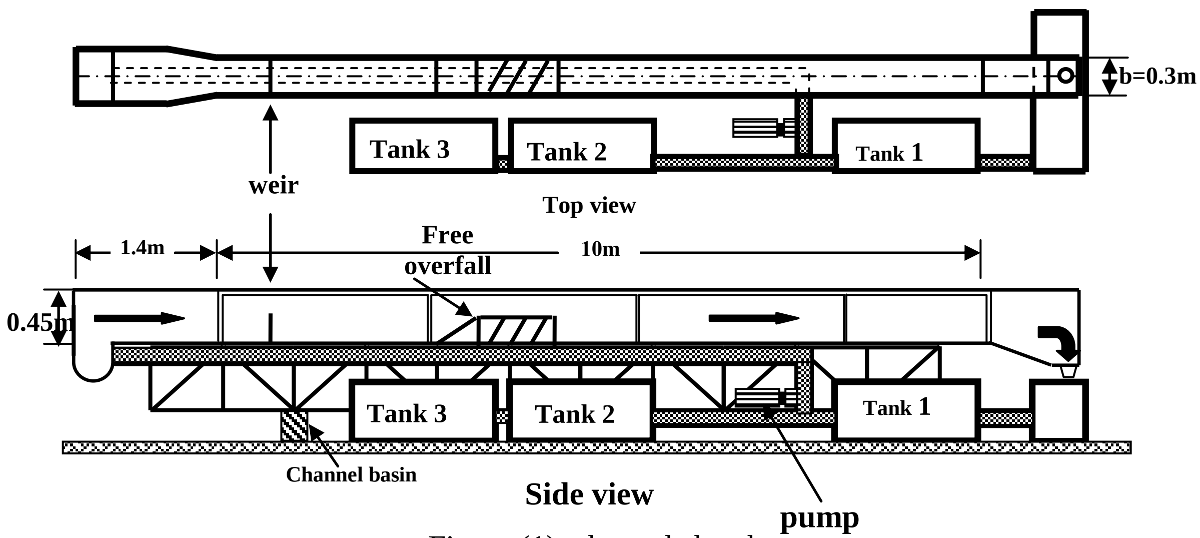

Figure (1): channel sketch

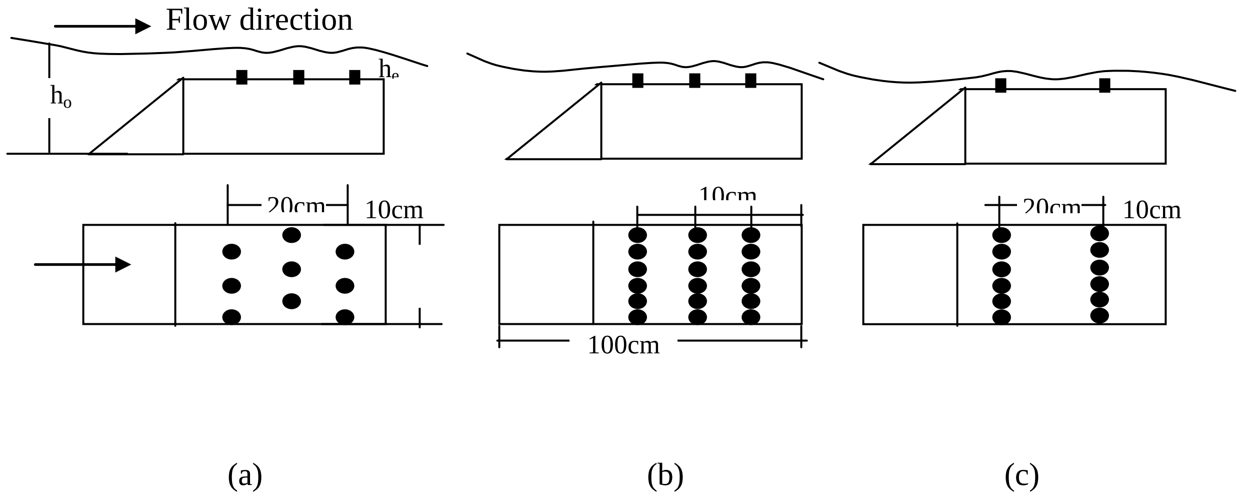

Fig. (2) Models of Roughness distribution; (a) zigzag, (b) three rows, (c) two rows

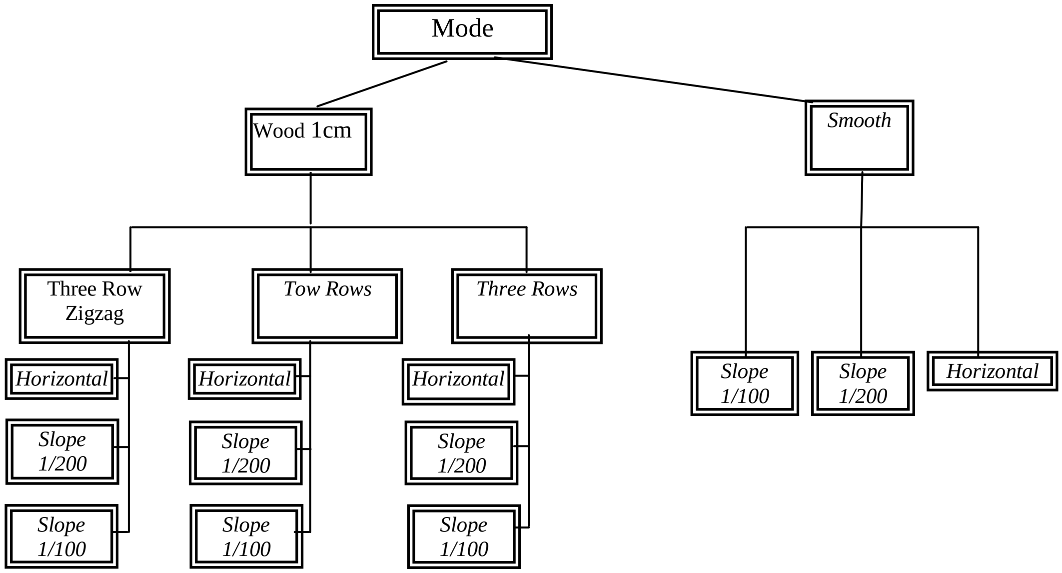

chart (1): Experimental Program

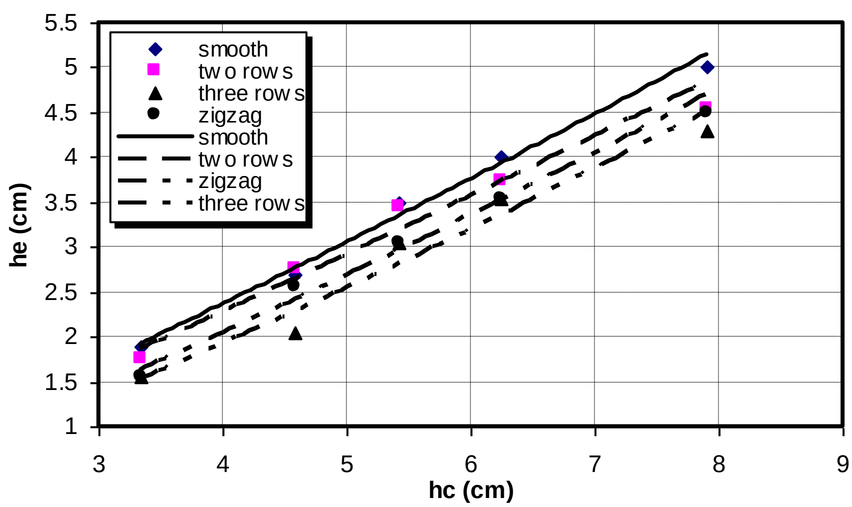

Figure (3) Effect three types of roughness distribution in channel bed slope (1/100)

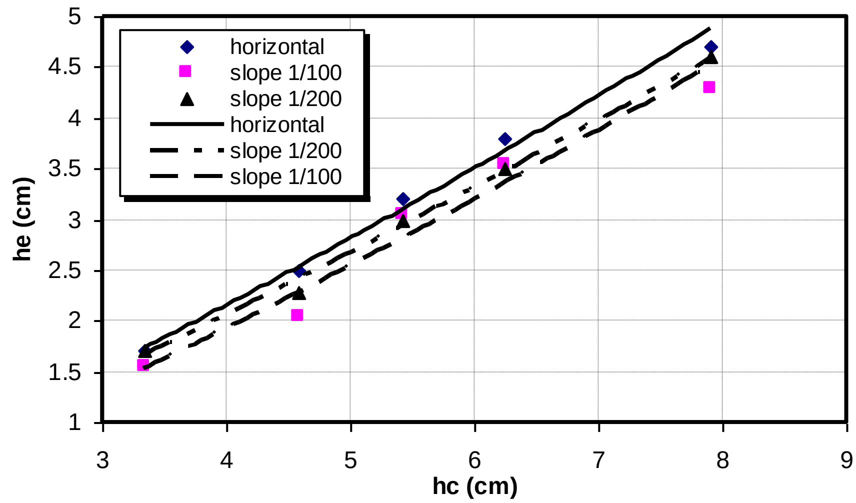

Figure (4) Effect of three channel slope at three rows roughness bed

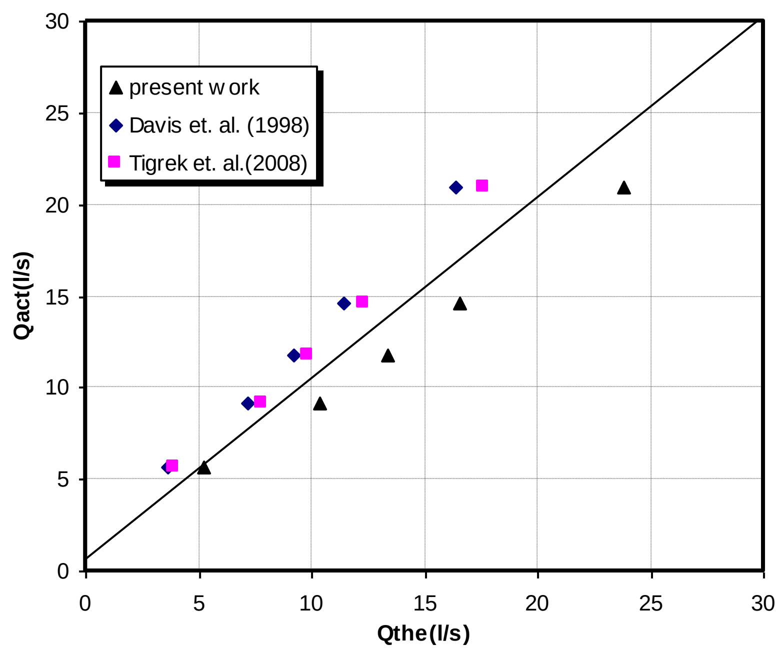

Figure (5) Comparison of actual and theoretical discharge