Hydraulic Engineering Software VIII, C.A. Brebbia & W.R. Blain (Editors)

Discharge measurements in sewers using combined weir-gate device

A.A. Alhamid
Civil Eng. Dept., College of Engineering, King Saud University, Riyadh, Saudi Arabia.

Abstract

In this paper a combined weir-gate device was tested experimentally in circular sewer for flow measurements. The device was tested in two different locations. One at the end of the system in which free fall is exist and the other is within the system. In both locations flow released from the gate is under free flow conditions. Different weir gate dimensions were tested. Results showed that location plays important role on discharge coefficient and that the discharge coefficient correlates well with the flow parameters, gate opening and weir height. Equation were developed for the device for both locations and agreements with experimental data was achieved.

Introduction

Accurate discharge records are essential in many ways. For example, flood events are needed for the design of culverts, storm sewer systems, bridges, ...etc in order to avoid extensive damages. Also, peak discharges are important for the design or extension of treatment plants and sewer sizing. Numerous techniques are available in literature for discharge measurements in open and closed conduits. These include weirs, gates, orifices, flumes and recently ultrasonic devices. Details of these techniques and related problems are available in literature, e.g. Ackers et al [1], Bos [2], French [3], Herschy [4], Rajaratnam and Subramanya [5], Swamee [6&7]. Although weirs and gates are simple and easy to use, some disadvantages are existing, such as deposition of sediment behind weirs and accumulation of floating materials upstream gates. Ultrasonic

Hydraulic Engineering Software VIII, C.A. Brebbia & W.R. Blain (Editors)
© 2000 WIT Press, www.witpress.com, ISBN 1-85312-814-7

equipment seems to be reliable and easy to use but in extreme weather conditions such as in arid regions reliability is questionable. A combined weir-gate device may overcome the problems of weirs and gates and provide a good solution for flow measurements in gravitational flow types where sedimentation might occur, Alhamid et al [8]. After the work of Ahmed [9], researchers investigate the combined devices in open channels and used different combinations of weir-gate devices, e.g. Negm et al [10], Alhamid et al [11], Alhamid et al [8]. Recently, Alhamid [12] developed a general semi empirical equation for the combined V-notch weir-gate device in rectangular channels. The equation is valid for free and submerged gate flow conditions and covers a wide range of weir-gate dimension combinations.

In dry seasons, deposits build up at the surface and in collection points of storm sewer systems. During rainy seasons, these settled materials washed out from the surface and collection points into the sewers. The combined device seems to be a good choice for flow measurements as it will allow both sediments and floating materials to pass through the system without affecting the accuracy of the device. This paper is a trial to utilize the combined weir-gate device in circular channels (sewers) under free gate flow conditions and to test the effect of different geometric weir-gate parameters and device location on discharge values.

Experimental set-up

Experiments were conducted in a glass flume of 9 m long, 30.5 cm wide and 30 cm deep. Working section was made of a steel circular pipe having 25 cm diameter. The working section consists of two pieces having 4m and 1m lengths and an opining was provided on the top for flow depth measurements. Two types of testes were performed. One with the device installed between the two pieces and the other at the end of the first piece representing free fall condition, Fig. 1. Ten devices were tested in this study, six of them installed within the working section and the rest installed at the end of the working section, details of the devices are given in Table 1. Water depths were measured by point gages having ±0.1 mm accuracy. Flow through the system was measured by a calibrated V-notch installed in the measuring tank below the outlet of the flume.

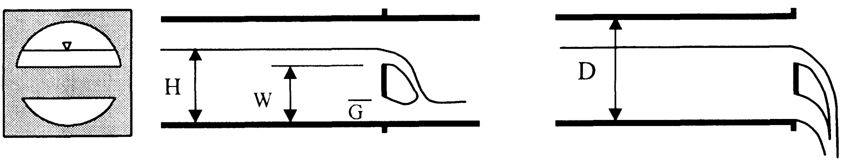

Figure 1: Definition sketch showing the combined weir-gate device and the location of testes.

Hydraulic Engineering Software VIII, C.A. Brebbia & W.R. Blain (Editors)
© 2000 WIT Press, www.witpress.com, ISBN 1-85312-814-7

Table 1. Location and geometric dimensions of the tested devices.

No.	G/D	W/D	G/W	location
1	0.48	0.64	0.75	Within the system
2	0.32	0.64	0.50	Within the system
3	0.24	0.64	0.375	Within & End of the system
4	0.16	0.64	0.25	Within & End of the system
5	0.24	0.56	0.429	Within & End of the system
6	0.24	0.48	0.50	Within & End of the system

Analysis of experimental data

From dimensional analysis principles, the discharge through the combined weir-gate device can be expressed in the following dimensionless from assuming that viscosity and surface tensions are of minor effect;

$$C_d = \frac{Q}{L^2\sqrt{2gL}} = \Phi\left(\frac{W}{L},\frac{G}{L},\frac{H}{L},\frac{D}{L},\frac{h}{L}\right) \tag{1}$$

where C_d is the discharge coefficient, Q is the discharge, D is the diameter of the pipe, W is the weir height, G is the gate opining, H is the flow depth behind the device measured 2D upstream, h is the head above the weir, L is a characteristic length such as H, W, G…etc, and g is the gravitational acceleration.

The above equation, i.e. eqn (1), will be used in analysis of the experimental data and development of the discharge equation for the device. The discharge coefficient is defined by the following equation;

$$C_d = \frac{Q}{A_G\sqrt{2gH}} \tag{2}$$

where A_G is the gate cross section area.

Geometric and flow parameters effect

Discharge coefficients computed by eqn (2) are drawn versus H/G in Fig. 2 for constant W/D ratio and different G/D ratios. In this figure data are grouped in a number of series each one represent a specific G/D ratio. In general, C_d is increasing with increased H/G ratio for the same device. But for the same W/D ratio, C_d is increasing with increased G/D ratio. Fig. 3 shows the Discharge coefficients versus H/G values for constant G/D ratio and different W/D ratios to demonstrate the effect of weir height effect on discharge coefficient. Similar results can be drawn from this figure but for the same H/G ratio the discharge coefficient is increasing with decreased W/D ratio. The above findings are completely logical and on selection of the device the dimensions of the device must be select properly with respect to the expected flow rate. Hence for high

Hydraulic Engineering Software VIII, C.A. Brebbia & W.R. Blain (Editors)

discharges, G/D should be maximum and W/D is minimum and vice versa for low discharge values.

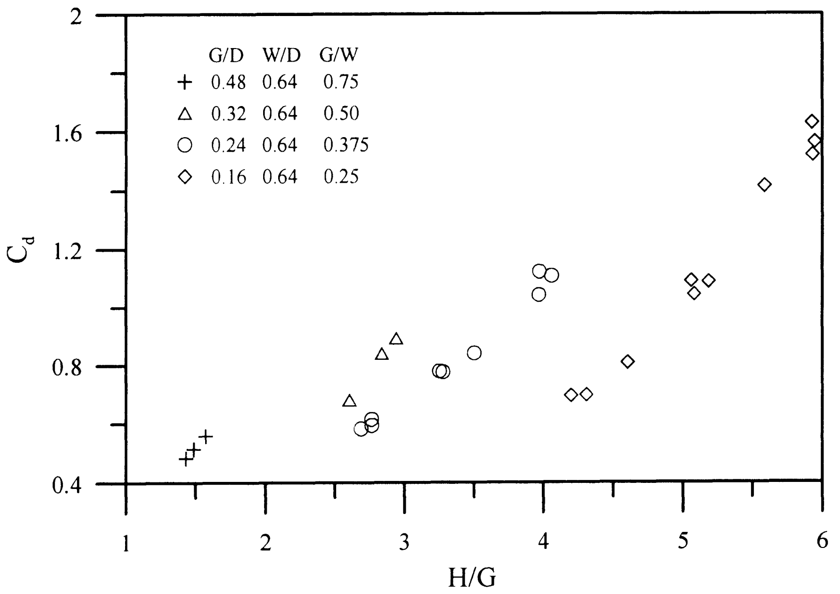

Figure 2: Variation of discharge coefficient for constant weir height and different gate openings.

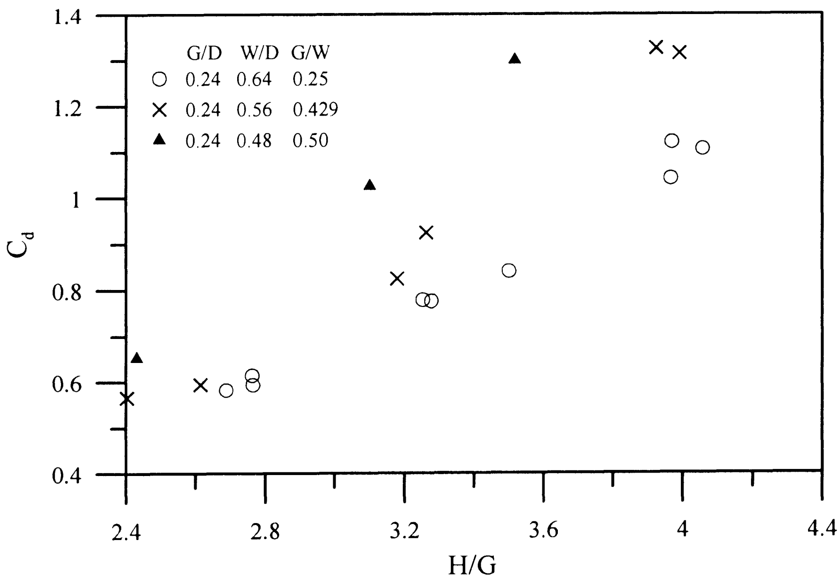

Figure 3: Variation of discharge coefficient for constant gate opening and different weir heights.

Hydraulic Engineering Software VIII, C.A. Brebbia & W.R. Blain (Editors)
© 2000 WIT Press, www.witpress.com, ISBN 1-85312-814-7

Discharge coefficients are drawn versus H/W and H/(W-G) in Figs 4 and 5 respectively for the device located within the sewer system. In both figures data are grouped for each G/W ratio with a general trend of increasing C_d with increased H/W or H/(W-G). In these figures it is clear that the device with the same G/W ratio, i.e. 0.5, are merged together on a single group representing the importance of this parameter on C_d values. But the range of C_d is quite wider for the device with G/D= 0.24 and W/D=0.48 which mean that this combination will allow more discharge to pass through compared to the other device with G/D=0.32 and W/D=0.64. Similar results are obtained for the device located at the end of the sewer system as shown in Fig. 6.

Device location effect

The effect of the location on discharge coefficient is demonstrated in Fig. 7. In this figure two sets of data are shown for two different devices installed in two different locations. The figure shows clearly that the device installed at the end of the sewer system has a higher discharge coefficient compared to that installed within the sewer system. Hence for high discharges it is recommended to fix the device at the end of the system rather than within the system.

Discharge equation

As seen from above the device is quite sensitive to the location and geometric dimensions in addition to the flow parameters. And in development of an equation these effect must be considered. Regression analysis was used to correlate the discharge coefficient to the different parameters described in eqn (1). Out of many trials using different combinations of flow and geometric parameters, equations for the different locations were developed. The developed equations have the following form;

$$C_d = 0.5\left(\frac{H}{W}\right)^{2.5}\left[\alpha + \beta\frac{h}{H} + \gamma\frac{G}{W} + \delta\frac{H}{G}\right] \qquad (3)$$

where α, β, γ and δ are constants depending on the location of the device on the sewer system. Values of these constants are given in Table 2. The developed equations estimate the C_d values accurately with a mean error of ±4.2 %, and comparison between the experimental and estimated values are shown in Fig. 8 for the two locations.

Table 2. Values of α, β, γ and δ in eqn (3).

Device location	α	β	γ	δ
Within the system	0.5385	-1.5097	0.2033	0.1771
End of the system	1.2104	-1.4683	-0.3766	0.1026

Hydraulic Engineering Software VIII, C.A. Brebbia & W.R. Blain (Editors)

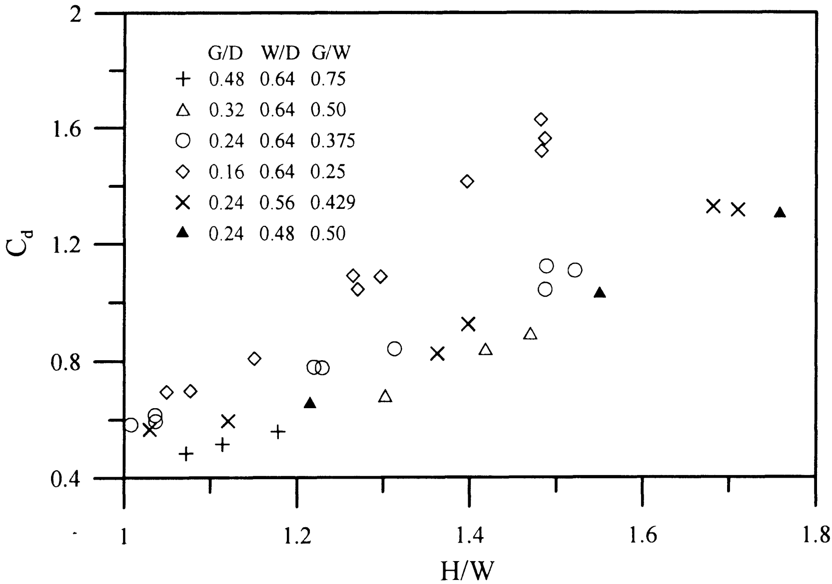

Figure 4: Variation of C_d with H/W for devices tested within the sewer system.

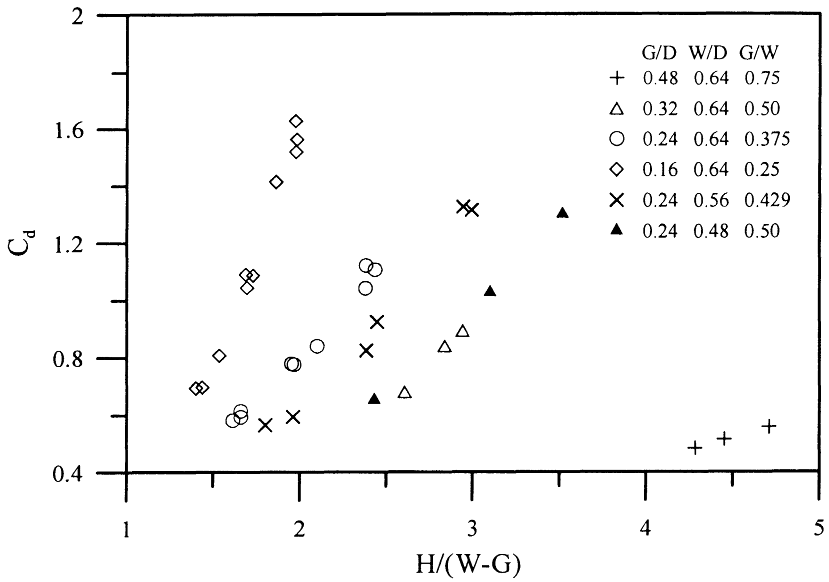

Figure 5: Variation of C_d with H/(W-G) for devices tested within the sewer system.

Hydraulic Engineering Software VIII, C.A. Brebbia & W.R. Blain (Editors)
© 2000 WIT Press, www.witpress.com, ISBN 1-85312-814-7

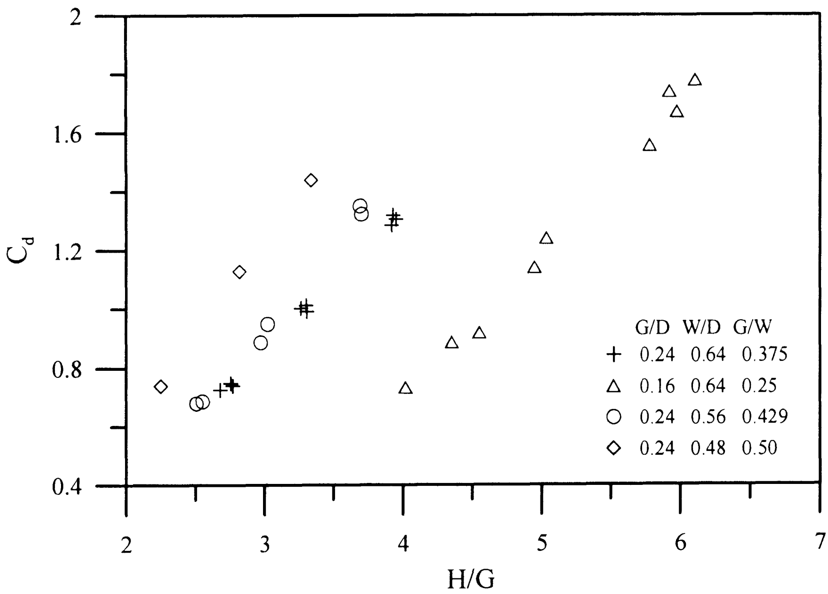

Figure 6: Discharge coefficient variation for devices located at the end of the sewer system.

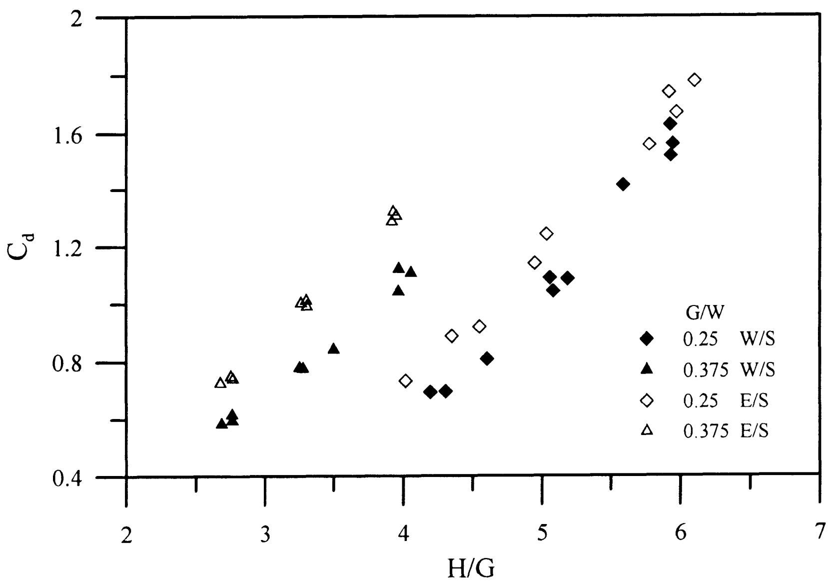

Figure 7: Effect of device location on discharge coefficient.

Hydraulic Engineering Software VIII, C.A. Brebbia & W.R. Blain (Editors)
© 2000 WIT Press, www.witpress.com, ISBN 1-85312-814-7

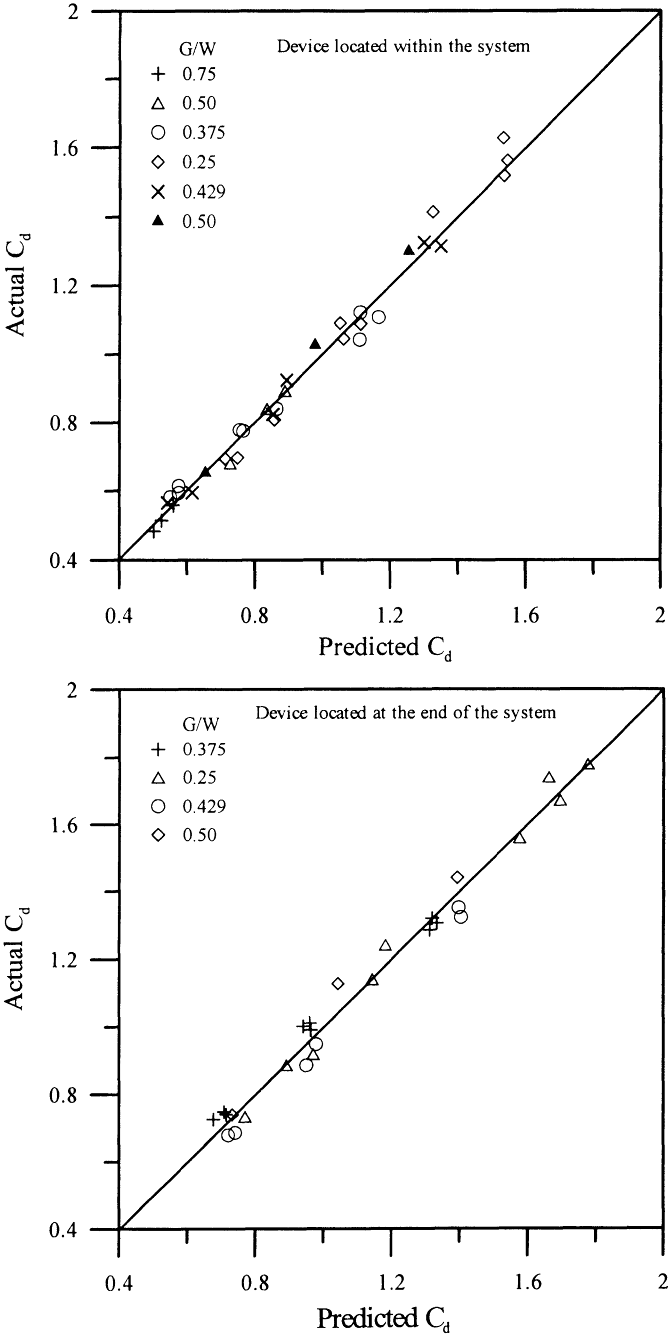

Figure 8: Predicted C_d values versus estimated ones.

Hydraulic Engineering Software VIII, C.A. Brebbia & W.R. Blain (Editors)

Conclusion

Combined weir-gate device was studied experimentally in circular sewer system. The study covered different combinations of weir-gate dimensions under free gate flow condition. The device was tested in two different locations along the system. Results showed that location, flow and geometric parameters play important role in the amount of discharge passing through the device. Also for flow measurements the dimensions of the device should be selected properly with respect to the expected rang of flow rate. Discharge equations were developed for the device for both locations. The developed equations predict discharge through the combined system accurately.

References

[1] Ackers, A., White, W. R., Perkins, J. A., and Harison, A. J. Weirs and Flumes for Flow Measurements, New York, John Wiley and Sons, 1978.
[2] Bos, M. G. Discharge Measurement Structures, New Delhi, Oxford and IBH Publishing Co., 1976.
[3] French, R. H., Open Channel Hydraulics, New York, McGraw Hill Book Company, 1986.
[4] Herschy, R. W.(Ed.)., Hydrometry; Principle and Practices, New York, John Wiley & sons, 1978.
[5] Rajaratnam, N. and Subramanya, K., Flow equation for the sluice gate, Journal of Irrigation and Drainage, ASCE, Vol. 93, No. 3, pp. 167-186, 1967.
[6] Swamee, P. K., Generalized rectangular weirs equations, Journal of Hydraulic Engineering, ASCE, Vol. 114, No. 8, pp. 945-949, 1988.
[7] Swamee, P. K., Sluice gate discharge equation, Journal of Irrigation and Drainage, ASCE, Vol. 118, No. 1, pp. 57-60, 1992.
[8] Alhamid, A. A., Negm, A. M. and AL-Brahim, A. M., Discharge equation for proposed self-cleaning device, Journal of King Saud University, Engineering Science, Riyadh, Saudi Arabia, Vol. 9, No. 1, pp13-24, 1997.
[9] Ahmed, F. H., Characteristics of discharge of combined flow through sluice gate and over weirs, Journal of Engineering and Technology, Iraq, Vol. 3, No. 2, pp. 49-63., 1985 (Arabic Article).
[10] Negm, A. M., EL-Saiad, A., Alhamid, A. A. and Husain, D., Characteristics of simultaneous flow over weir and below inverted v-notches, Civil Engineering Research Magazine, Faculty of Engineering, Al-Azher University, Cairo, Egypt, Vol. 16, No. 9, pp. 786-799, 1994.
[11] Alhamid, A. A., Husain, D. and Negm, A. M., Discharge equation for combined flow over rectangular weirs and below inverted triangular weirs, Arab Gulf Journal for Scientific Research, Riyadh, Saudi Arabia, Vol. 14, No. 3, pp. 595-607, 1996.

Hydraulic Engineering Software VIII, C.A. Brebbia & W.R. Blain (Editors)
© 2000 WIT Press, www.witpress.com, ISBN 1-85312-814-7

[12] Alhamid, A. A., Analysis and formulation of flow through combined v-notch-gate device, Journal of Hydraulic Research, IAHR, Vol. 37, No. 5, pp, 697-705, 1999.