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Investigation of the Discharge Coefficient and Energy loss in a semi Cylindrical weir and semi Cylindrical Weir-gate

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ABSTRACT: The present research investigate the discharge coefficient and energy loss flows of semi cylindrical wire- gate. The experiments were conducted in rectangular flume with the length of 8 m, width of 0.282 m and height of 0.3 m. In fact, the soil conservation and watershed management research that occurred in laboratory, used the physical models with diameters of 70, 120 and 160 mm in height of the opening between zero until radius and differently discharging. The ratio of cylindrical structure diameter to channel width (D/B) was included range of 0.25 to 0.57 and the Froude number was conducted range of 0.012 to 0.55. The research showed that all angles alignment structure discharge coefficient and dimensionless parameter H_f/H (the ratio of energy loss to the water depth upstream) cases curvature upstream and curvature of the downstream respectively with increasing dimensionless parameter H/P, increases and decreases. The constant a (H / P), discharge coefficient and dimensionless parameter H_f / H when the curvature is upstream semi cylindrical wire-gate due to the gradual shrinkage of flow lines and thus decrease the input is less than the curvature is downstream structure.

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1- Introduction

Flow measurement and controlling structures are among the most important components of the irrigation and drainage networks. Measurement of the water volume which is required for agricultural purposes and irrigation projects is absolutely vital. Therefore, there are many methods to measure the water discharge in open channels. Weirs and gates are among the flow control structures which are mainly utilized due to their simple and accurate equations for flow measurement and controlling the level of water. According to their applications, weirs and gates come in different types and shapes; they are used in locations such as crests of spillways and also for water withdrawal from a lake into a river or a canal. Each type of weirs/gates have their own advantages and disadvantages and the appropriate choice can be selected due to the situation and the required application. Metzler (1984) related the discharge coefficient of the circular weir to the ratio of the upstream water head, H and P/2, [1]. Chanson and Montes (1998) experimentally investigated and suggested that the discharge coefficient of circular-crested weirs is larger than that of the broad-crested and sharp-crested weirs [2]. Chanson (2009) discussed the effects of weir circulation on the pressure distributions and discharge coefficient. It was revealed that the circulation of the weir has remarkable effects on the flow pattern and discharge coefficient. Masoudian and Gharahgezlou (2012) investigated the effects of hydraulics and geometric parameters of cylindrical and semi-cylindrical weir-gate on discharge coefficient in a small laboratory canal. It was concluded that the discharge coefficient increases with increasing the parameters: H/a (the ratio of upstream head to the gate opening), H/D (the ratio of upstream head to the pipe diameter), Re (the Reynolds number), and We (the Weber number) [3].

In comparison to other flow controlling structures (weirs, gates and weir-gates), semi-cylindrical structures, as their curved side causes deflection in streamlines that followed by a loss in flow stagnation pressure and hence the increase in discharge coefficient, are more useful. In addition, continues varying rotation angle of the structure flat side, gives them the ability to smoothly convert from one model (weir/gate) to the other (gate/weir). In the current investigation, the semi-cylindrical structure rotate around its central (longitudinal) axis to develop weir and weir-gate modals, where in weir modal the fluid flows over it and in weir-gate modal some part of the fluid flows over and the other part flows under it.

2- Materials and Methods

Experiments were carried out in Soil Conservation and Watershed Management Research Institute for two upstream-directed-curvature (UDC) and downstream-directed-curvature (DDC) cases of the semi-cylindrical structure at angles in the ranges of $0° < \Theta < 180°$, that related to the horizontal axis. The experiments were conducted in following such manners: a) the flat-side angle of the structure resulted from rotation of the structure around the central axis in the ranges of $0° < \Theta < 60°$

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and 90°<ϴ<180° develops semi-cylindrical weir-gate model and semi-cylindrical weir model, respectively; b) a varying gate opening in the range of 0<a<R, where R is the radius of the structure; c) in an 8-m-long, 0.282-m-wide, and 3-m-high horizontal rectangular channel. The discharge rate was measured by a vertical V-notch (triangular) weir which has been previously calibrated. Figure 1 illustrated the schematic representation and image of the flume. In the current research three PVC pipes with three diameters of 70, 120 and 160 mm were utilized as prototype.

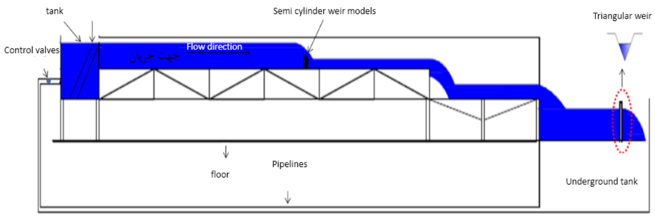

Figure 1: A plan of flume (SCWMRI)

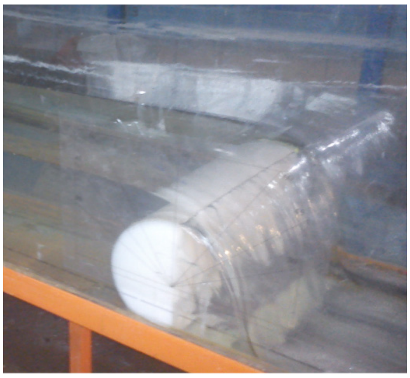

Figure 2: Section of the semi-cylindrical wire-gate in the upstream curve

2- 1- The Discharge Coefficient Estimation

Equation 1 indicates the general form of the estimated discharge through the weir (French 1987):

$$Q_g=C_{dg}\, ab\sqrt{2gH} \quad (1)$$

Where Q_g is the discharge under the gate, C_{dg} is the gate discharge coefficient, a is the gate opening, b is the channel width, H is the upstream water head, and g is the acceleration of gravity.

Bos (1976) proposed the following equation to obtain the discharge of cylindrical weirs [4]:

$$Q_w=C_{dw}\, b\, 2/3\, \sqrt{(2/3\, g)}\, H_w^{1.5} \quad (2)$$

Where Q_w is the discharge over the cylindrical weir, C_{dw} is the discharge coefficient of the weir, and H_w is upstream water head over the weir.

Combination of the Equation 1 and 2 yields the discharge coefficient of the combined structure as:

$$C_d=Q_s/(ab\sqrt{2gH}+b\, 2/3\, \sqrt{(2/3\, g)}\, H_w^{1.5}) \quad (3)$$

Where Q_s is the total discharge and passing through the combined structure, it measured by the triangular weir; and the denominator of the above-mentioned equation that is the discharge in the ideal case which is determined after measuring its associated parameters; and C_d is the combined discharge coefficient of the structure.

2- 2- Dimensional analysis

Based on geometrical properties, kinematics and dynamics of the flow, factors affecting the discharge coefficient can be written as follows; in addition, dimensionless products/groups can be simply obtained by using the dimensional analysis.

$$C_d=f_0\, (H,H_w,P,V,\delta,g,\sigma,\mu,\rho,S_0,B,a) \quad (4)$$

If parameters H,P and V are selected as repeating variables, a dimensional analysis by applying Buckingham pi theorem yields:

$$C_d=f_1\, (V^2/gH,\rho HV/\mu,(\rho HV^2)/\sigma,\delta/H,B/H,a/H,H/P,H_w/H,S_0) \quad (5)$$

3- Results and Discussion

After the verification and monitoring of the data, results of the experiments including discharge coefficient versus the dimensionless ratio of H/P , have been analyzed and shown in the proceeding sections. Figures 3 illustrated the discharge coefficient versus the dimensionless ratio of H/P in different angles for the three different values of the diameter in the both UDC and DDC cases. Results have shown that in the all cases with increasing the ratio of H/P, the discharge coefficient increases. It is also observed that discharge coefficient of the second group is larger than that of the first group. According to Figure 4, when the flat side of the structure makes an angle in the range of 0°<ϴ<60° (the weir-gate model) the curved side of the semi-cylinder, which causes a rather slight deflection of streamlines followed by an aerodynamic-status creation in the entrance as well as a reduction in flow resistance and hence a decline in stagnation pressure of the flow, that will significantly affect the discharge over the weir rather than the discharge under the gate. Since the curved side of the semi-cylinder causes a drop in the flow stagnation pressure thereby an increase in the discharge coefficient, the inflow stagnation pressure of the gate may be less than the weir. The other considerable note is the gaps in discharges coefficients of both groups in their diagrams that resulted from the change in curvature direction of the semi-cylinder converting from the weir-gate to the weir model. It is also observed that the highest discharge coefficient relates to the angle of ϴ=120° for UDC case, and at angles ϴ=150° and 135° for DDC case. On the other hand, the lowest discharge coefficient relates to the angles ϴ=0° and 30° in both cases of the curvature direction.

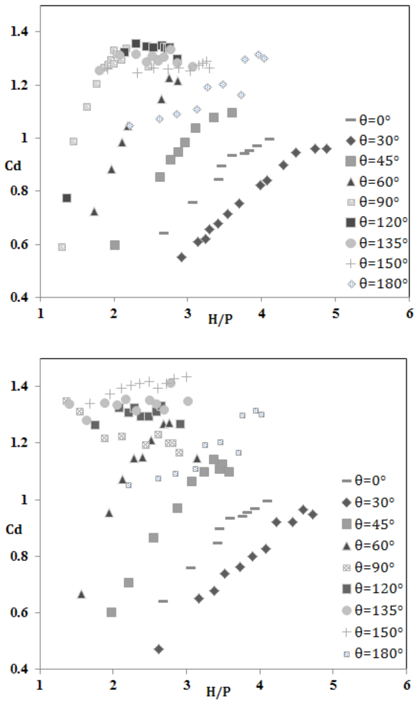

Figure 3: H/P dimensionless parameter against discharge coefficient, for different angles and diameters, a)Upstream curve and b) Downstream curve

Figure 4 shows variation of the discharge coefficient with dimensionless ratio of H/P for the 70-mm-diameter pipe and at the positioning angles ϴ=90°,135°, was selected as the sample. The results of the figures indicated that with increasing the discharge coefficient, the dimensionless ratio of H/P increases, i.e., for a constant H/P at ϴ=90° the discharge coefficient in UDC case is larger than the DDC case. Whereas at ϴ=135° the reverse can be observed. It can be concluded that at ϴ=135° , the flat side of the semi-cylinder causes the structure acts in a manner similar to the sharp-crested weir structures which leads to an increase in the discharge coefficient. This suggested that the amount of the energy loss isn't only affected by the curvature direction of the structure.

4- Conclusion

The results of the current research indicated that the discharge and the discharge coefficient is in a semi-cylindrical weir and weir-gate structures are in both UDC and DDC cases at all the positioning angles in the range of 0°<ϴ<180° that directly proportional to the upstream water head as well as the dimensionless ratio of H/P. It was also observed that for a constant H/P, the discharge coefficient in UDC case, due to rather slight deflection of streamlines (and hence, a drop in the flow stagnation pressure), is larger than that of DDC case. Therefore, it can be concluded that the positioning angle of the structure, related to the horizontal axis, considerably affects the amount of the discharge coefficient. Meanwhile, in both cases of the curvature (upstream-directed and downstream-directed) at the angles in the range 90°<ϴ<180° the discharge coefficient is larger than that of the range of 0°<ϴ<60°. The remarkable effects of the curvature direction of the structure, i.e. the flat-side angle of the structure, on the discharge coefficient might be noted as other results of the current research.

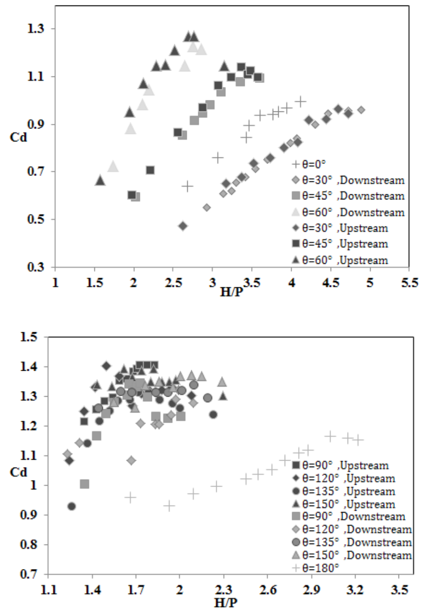

Figure 4: H/P dimensionless parameter against discharge coefficient, for different angles and diameter of 70 mm

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