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The Effect of the Asymmetrical W Shaped Weir as a Barrier on the Hydraulic Properties of Culverts

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ABSTRACT: In recent years, using of baffle sloped culverts is improved in order to energy dissipation and facility and improvement of fishes passage. In the present study, asymmetric shape w overflow is used as obstacles in Open Calvert. As spillway event angle two 40 degrees angle in 10 and 15 cm weir height to flume bottom were used.

Experiments of present research are done in a steep flume with bottom width of 25 cm length that w-shaped spillways attached at about 5 km from the flume, and the distance between barriers, variable slope from 3 to 7.6 percent in different discharge was scheduled. In this study, three physical model including models with 30 obstacles of kind of asymmetric w shape spillway, with relative distance of 6/0 (λ=0.6), and a model with 15 barriers with relative distance of 1.2, and a model with 10 models with relative distance of 1.8, was setup. The results obtained from these experiments showed that by increasing the relative distance, Manning coefficient and Darcy-Weisbach coefficient is decreased, and also by increasing the slope, Manning and Darcy-Weisbach coefficient decreases. Based on the obtained results in the slope of 3%, Manning roughness coefficient, reaches from 0.065 on the 0.6 relative distance reaches to 0.048 in the 1.8 relative distance. The square root of the Darcy-Weisbach coefficient, in slope of 3%, in relative distance of 1.8, reaches from 0.87 to 0.65.

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1- Introduction

Fish usually move unlike to water flow and migrate to areas where have been hatched out. Construction of diversion dams and impoundment structures in rivers path, will cause problem to moving fishes to upstream. In order to solve this problem in diversion dams, structures such as fish-path, and or baffled culvert are prepared [1]. Through these structures, fishes can migrate to upstream. Present culverts are approaching to the end of his life. Alternative proceedings to increase the longevity of culvert or aqueduct, are increasingly growing. Slip lining is one of these methods. Today, polyethylene pipes are placed into the worn-out culverts, that this act reduces the roughness coefficient of culverts. This method is called Slip lining. In this way, despite the reduction in the size of culvert, the flow discharge is passable, but the friction, erosion and depreciation are increased. In this case, using of barriers to flow through the culvert are necessary [2]. Rajaratnam and et al. studied an experimental research on evaluation on hydraulic conditions of fishways with a slotted-weir baffle system. A flow equation has been developed to predict the flow depth for any given discharge, diameter and slope [3].

Chanson reported the facilitate criteria design of passage in closed culvert. He has mentioned the en engineers and biologists need better, more reliable prediction 'tools' during the design stages to compare the bio-engineering performances of a range of design options. In all the cases, the turbulence of the flowing waters must be optimized efficiently to maximize fish migration. This project focused on the development of simple solutions to retrofit existing box culverts, with the aim to maximize slow flow regions suitable for small fish passage and to minimize the afflux increase. Herein, a physical study of a standard box culvert was performed under controlled flow conditions, and six baffle designs were tested. Two baffle configurations presented promising results: the corner baffles and the streamlined diagonal baffles [4]. Culvert internal barriers are necessary to both reducing energy and also increasing facility of fishes passing. In this study, considering to hydraulic performance of asymmetric w shape overflow, it was decided to investigate the hydraulic performance of culvert, this structure will use as a barrier in open culvert.

2- Materials and Methods

2- 1- Dimensional Analysis

Considering current studies goals, effect of parameters on the phenomenon, can be presented according to Equation 1:

$$f(B, g, l, \theta_1, \theta_2, p, \mu.Q, \rho, s_0, f, x) = 0 \tag{1}$$

In this relationship, B: the width of the channel, g: gravity acceleration, y: depth of flow, l: distance between the barriers, the angle of triangles apex in the asymmetrical W shaped

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Weir, p: barriers base height, μ: viscosity, Q: discharge, ρ: density, floor slope, f: coefficient of moody friction, X: the distance from the 0.5 m before barrier to the considered distance. Based on dimensional analysis, using the theory of π Buckingham, dimensionless parameter can be derived. Equation 2 shows these relationships.

$$F = \frac{gy}{v^2}, \frac{\mu}{\rho g y}, \frac{y}{B}, \frac{p}{B}, \theta_1, \theta_2, \frac{l}{B}, S_0, f, \frac{x}{B}, \frac{Q}{b^{2.5}\sqrt{g}} \tag{2}$$

In Equation 2, the first parameter is vice versa of Froude number, second parameter is vice versa of Reynolds number, third parameter is relative depth in the flume, fourth parameter is overflow height ratio, fifth and sixth parameter is the triangle apex angle in the asymmetrical W shaped weir, the seventh parameter is relative distance, eighth parameter is bottom slope, ninth parameter is Darcy-Weisbach coefficient, tenth parameter is relative length, and eleventh parameter is dimensionless discharge. The main goal in this study is calculating

Darcy-Weisbach friction factor (f), and consequently the Manning coefficient (n), since the angles of triangles tip in overflow is constant, the Equation 2 will be written as follow:

$$F = g\left(\frac{v}{\sqrt{gy}}, \frac{y}{B}, \frac{x}{B}, \frac{Q}{B^{2.5}\sqrt{g}}, \frac{\mu}{\rho v y}, \lambda^+, S_0\right) \tag{3}$$

In Equation 3, λ^+ was given as relative distance.

2- 2- Establish laboratory model

To access to the researches goals, we use a laboratory flume with a length of 10 m, width of 25 cm and height of 50 cm. This flumes slope can change from 0 to 7.6 percent. The considering slopes in this study, were considered variable from 3 to 7.6 percent. Discharges that have been used in this experiment, were between 16 and 45 liters per second. The used measurement equipment includes; a triangular overflow, point gage with 0.1 mm accuracy and accurate video camera. The asymmetrical w-shape over flow were placed as a barrier in the 0.6, 1.2, and 1.8 relative distance. The number of obstacles at the 30.6, 1.2, and 1.8 distances are, 15, and 10, respectively. Each model was tasted in three gradients of 3, 4.8, and 7.6 percent, and three discharges of 21.62, 32.68, and 46.64 liters per second. In this study, discharge and gradient, was primarily set for each test, and then it was taken video from the uniform flow in the channel.

Using engage digitizer software, the digitizer water surface profile was diagramed, then the presented dimensionless parameters were calculated. In this study, Darcy-Weisbach roughness coefficient (f), and consequently the Manning roughness coefficient (n), were calculated. For this purpose, the energy dissipation was calculated primarily in each experiment, and then the Manning roughness coefficient was calculated.

$$n = R^{\frac{1}{6}}\sqrt{\frac{f}{8g}} \tag{4}$$

In the above equation; n is Manning roughness coefficient, R is hydraulic radius, f is Moody friction factor, and g is acceleration due to gravity.

3- Results and Discussion

This section reviews the results of 27 examination within the Baffled culvert with free flow.

3- 1- Investigating the barrier roughness

To investigate the Manning roughness coefficient, and Moody friction coefficient in different models, Manning roughness coefficient and Moody friction coefficient was calculated.

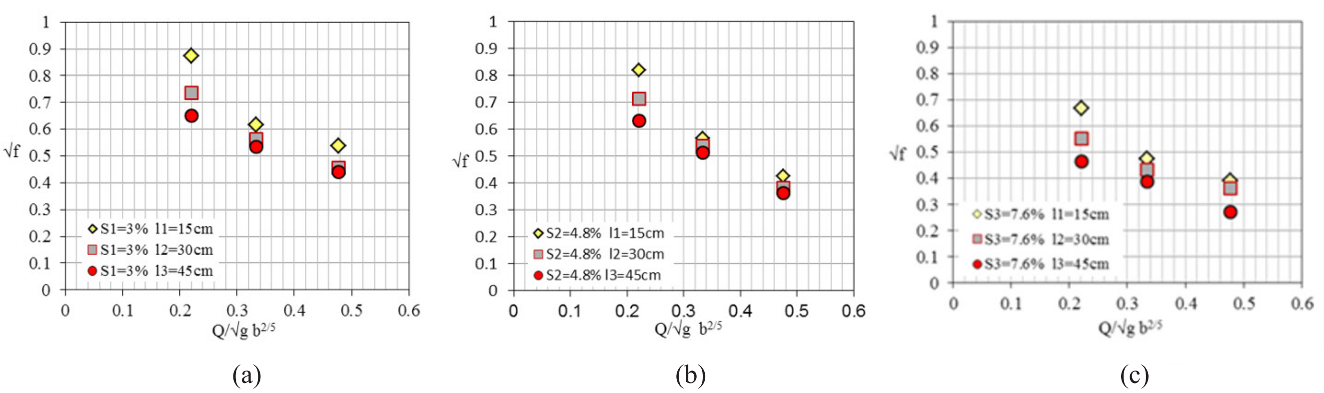
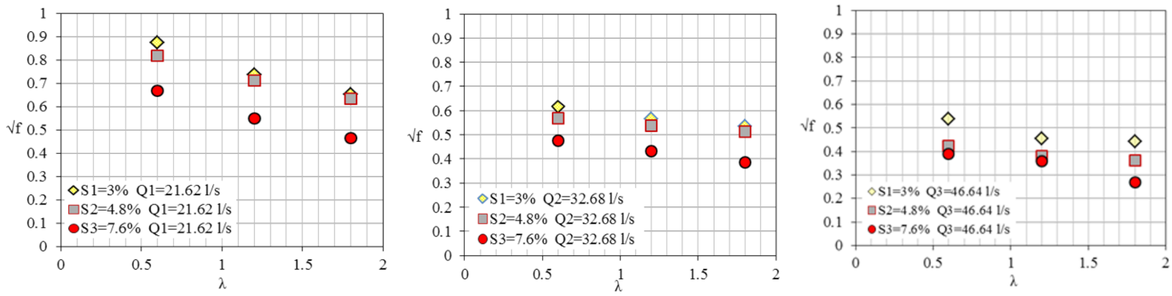


Figure 1: The graph changes square root of Moody friction coefficient rather than the dimensionless discharge of current in three different relative distance: a) slope of 0.03, b) slope of 0.048, c) slope of 0.076.



(a) (b) (c)

Figure 2: The graph of square root changes of coefficient of Moody friction, rather than a relative distance a) with 21.62 liters per second discharge, b) with 32.68 liters per second discharge, c) with 46.64 liters per second discharge

Considering the Figure 1, it is found that by increasing current dimensionless discharge, in a defined slope, the Moody friction coefficient square root (√f) will decrease. According to accomplished tests: by increasing the current discharge (Q), flow depth (y), and flow velocity (V) will increase. As a result, $u^*=\sqrt{gRS}$ also is increased, but because the flow velocity changes are greater than the shear flow speed, v/u^* will increased. According to Equation 5, mostly for rough bed, for a constant rough in a characterized slope, by increasing the hydraulic depth and radius; square root of the Moody friction coefficient will decrease, which it indicates the experimental results compliance and theoretical results obtained from Equation 5.

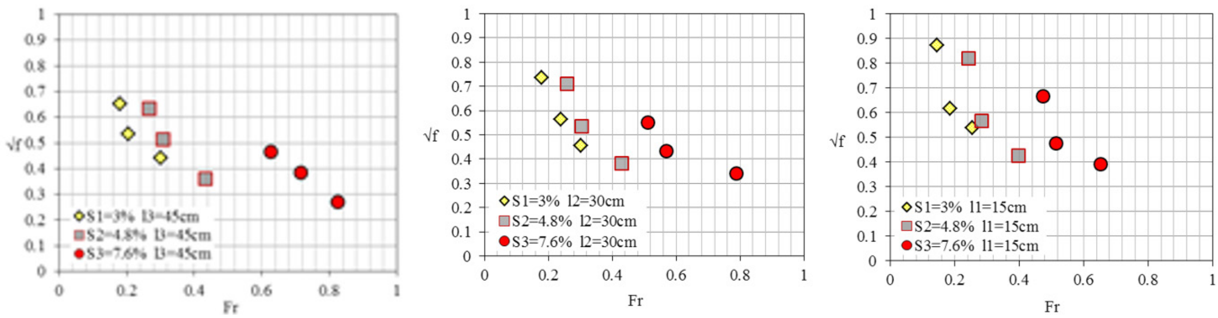
$$\sqrt{\frac{8}{f}} = \frac{v}{u_*} = 2.5\ln\frac{y}{k_s} + k_s \tag{5}$$

The rate of n and √f changes, versus the dimensionless flow discharge are the same. According to Equation 4, n and √f have direct relationship with each other, that it indicates that the laboratory results are consistent with the theory.

In Figure 2, it could be seen that by increasing the relative distance between the barriers, coefficient friction Moody square root will decrease. At the same height of structure, by reducing the relative distance, the number of obstacles and density will increase, and by decreasing the relative distance between the barriers with the type of w shape asymmetric overflow, the focus of vortex turbulent, between the obstacles will increase, and thus friction drag force that applied to the obstacles will increase. And as a result, the square root of coefficient of Moody friction (f) followed will increase, and according to the formula ($h_f = f\, L/D . V^2/2g$), the friction dissipation, and square root of the coefficient of friction losses have a direct relationship with each other. So by reducing the relative distance, and increasing the flow loss, the square root of the coefficient of Moody friction (f), will increases. So Manning roughness coefficient, which has a direct relationship with square root of the Darcy-Weisbach coefficient will decrease. "n" and √f have a direct relationship with each other. This represents the correctness of laboratory results with existing theories. Then the 0.6 relative distance, is the best relative distance to reduce culverts erosion.

To investigate the effect of Froude number on the Darcy-Weisbach Friction factor, the chart of coefficient of Moody friction, versus the flow Froude number, have been shown in Figure 3 for three different relative distance and three different slopes. According to Equation 6, Froude number (Fr) have direct relationship with flow velocity (V) and inverse relationship with the square root of the depth of flow. √f on the other hands, for a constant discharge, the flow velocity has an inverse relationship with the depth.

$$F = \frac{v}{\sqrt{gy}} \tag{6}$$



(a) (b) (c)

Figure 3: The diagram of square root changes of coefficient of Moody friction, rather than Froude number in, a) the relative distance of 0.6, b) the relative distance of 1.2 c) the relative distance of 1.8

According to equations, (Fr) has an inverse relationship with the Moody friction factor (f). According to the Figure 3, it is obvious that, with increasing Froude number, the coefficient of Moody friction will reduce, which indicates the compliance of laboratory results with theoretical results.

$$Fr = h(\frac{1}{f}, \frac{1}{y}) \quad (7)$$

4- Equation Presentation

By the use of SPSS software, and dimensional analyses, an equation for the square root of the coefficient of Moody friction, with a correlation coefficient 0.95, was presented.

$$\sqrt{f} = 0.75 q_*^{-0.354} + 0.354 \cos S_0 - 0.207 \lambda^+ - 0.524 Fr^{0.122} - 0.071 \mathrm{Re}^{0.071} \quad (8)$$

5- Conclusion

1) The placement of barriers together, with the relative distance of zero ($\lambda^+=0$), causes that only a limited part of the barrier be effective in creating effective loss. So to increase the rate of Friction loss, presence of the relative distance, between the barriers is essential, otherwise; barriers will greatly miss his performance.

2) By increasing the relative distance and decreasing the number of obstacles, the Manning roughness coefficient, and the square root of Moody friction factor will reduce.

3) By increasing the Froude number in the subcritical flow condition, the square root of the coefficient of Moody friction, and Manning roughness coefficient will reduce.

4) Up to 50,000 Reynolds number is effective on the f and n, and more than 50000, its effectiveness will reduce.

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