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Experimental Investigation of Efficiency of Increasing Dissolved Oxygen of Flow in Stepped-Labyrinth Weirs

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Extended Abstract

Introduction

One of the important parameters of water quality is the high level of dissolved oxygen (DO) content that is essential for the survival of all aquatic organisms and water quality improvement. Aeration refers to the physical process of oxygen absorption from the atmosphere and enhancement of the dissolved oxygen of water. Some hydraulic structures enhance the oxygen transfer by creating a great deal of turbulence and entering air bubbles. Stepped spillways are efficient in terms of air bubble entrainment. Advantages of stepped spillways include strong turbulent mixing, a large residence time and a substantial air bubble entrainment. Moreover, based on the laboratory data, some researchers have studied the aeration performance of labyrinth weirs in order to develop regression models for the prediction of aeration efficiency. The experimental results showed that the labyrinth weirs aerated significantly better than the normal weirs, especially at the lower drop heights. One of the methods to increase the content of dissolved oxygen is installation of structures that help increasing turbulence and entering small bubbles of air into water body. A falling jet of weirs is a specific case of creating turbulence in the water and increasing DO.

Methodology

Experimental measurements were conducted in the hydraulics modeling laboratory of University of Guilan, Iran in a flume with rectangular cross section having a 1.5 width, 1 m depth and 15 m length the experimental models consisted of five steps made of PVC panels. In this study three different slopes of spillway (1:1, 1:2 and 1:3 V: H) and one step height (h=0.10 m) were examined. In order to clarify the influence of labyrinth geometries on dissolved oxygen efficiency, intermediate blocks with different configurations were set in a zigzag pattern on every two steps. The height of labyrinths (H) was chosen 0.05 and 0.075 m, and the installed spacing between the labyrinths (L) along the width of channel were 0.1 and 0.2 m. In this study, the flow characteristics over the stepped weirs with intermediate labyrinths were compared with the pooled stepped ones which made by sill with height and thickness of 0.032 and 0.025 m, respectively. In order to investigate the aeration efficiency of stepped-labyrinth weirs, and in particular, to determine the effects of hydraulic and geometrical parameters, 572 tests were Experimental measurements were conducted in the hydraulics modeling laboratory of University of Guilan, Iran, in a flume with rectangular cross section having 1.5m width, 1m depth and 15m length the experimental models consisted of five steps made of PVC panels. In this study, three different slopes of spillway (1:1, 1:2 and 1:3 V:H) and one step height (h=0.10 m) were examined. In order to clarify the influences of labyrinth geometries on dissolved oxygen efficiency, intermediate blocks with different configurations were set in a zigzag pattern

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on every two steps. Two heights of labyrinths (H) were 0.05 and 0.075 m, and the installed spacing between the labyrinths (L) along the width of channel were 0.1 and 0.2 m. In this study, the flow characteristics over the stepped weirs with intermediate labyrinths were compared with that of pooled stepped ones which made by sill with height and thickness of 0.032 and 0.025 m, respectively. In order to investigate the aeration efficiency of stepped-labyrinth weirs, and in particular, to determine the effects of hydraulic and geometrical parameters, 572 tests were carried out. Moreover, the variation of DO concentration in water flowing over the weirs can be affected by a proportion of the upstream DO deficit. Therefore, in order to make the comparison as fair as possible, four different upstream DO concentrations (C_u) 2, 3, 4 and 5 (*mg/l*) were chosen to illustrate the effects of C_u value on the dissolved oxygen efficiency. The upstream DO concentrations were based on a range between minimum DO concentrations (2 *mg/l*) and dissolved oxygen saturation concentration (8-10 *mg/l*).

Results and Discussion

Comparison of results of DO concentrations (C_u) on aeration efficiency of the flat and stepped-labyrinth weirs with 1:1 slope under two tailwater conditions ($d_p=h$ and $d_p=2h$) indicated that the $S_1H_4L_4b_1$ configuration had the highest DO efficiency. Thus, for upstream oxygen transfer efficiency (E_u) of 1.28, the concentration of dissolved oxygen associated with the stepped-labyrinth weirs was almost 48% higher than that for flat stepped weirs.

For flat stepped weirs, since the upstream concentration of DO became larger (C_u = 2, 3 and 4 *mg/l*), there was a decreasing tendency of E_u to 0.56, 0.42 and 0.27, respectively. However, corresponding E_u values for stepped-labyrinth weirs were 0.65, 0.45 and 0.33. As a consequence, for a given geometry and hydraulic condition, decreasing the upstream dissolved oxygen concentration increased the average DO efficiency of stepped weirs. For C_u=2 (*mg/l*), the $S_1H_3L_3b_1$ was the most efficient configuration due to providing the strong turbulent mixing and substantial air bubble entrainment which the average value of E_u in flat stepped weirs with S_1 configuration, corresponding to the upstream dissolved oxygen concentration of 3, 4 and 5 (*mg/l*), was 0.55, 0.35 and 0.25, respectively (Fig. 12). However, intermediate labyrinths on the steps led to increase the air entrainment and the average value of E_u increased to 0.66, 0.42 and 0.33. for slope of 1:2, the $S_2H_3L_3b_2$ configuration had the best performance in this slope. Hence, for C_u=2 (*mg/l*), this configuration increased the E_{20} and E_u up to 47% and 71%, respectively, compared to the flat stepped weirs. By reduction of stepped weir slope to 1:3, C_d of tested labyrinth weirs with the average E_{20} =0.44 and E_u =1.25 increased by 50%. The DO efficiency in the $S_3H_3L_3b_2$, $S_3H_4L_4b_2$, $S_3H_6L_6b_1$ and $S_3H_7L_7b_1$ configurations, which labyrinths were installed at the same edge as the steps, had better performance, compared with that of other tested geometries.

Conclusion

The air bubbles transfer and dispersion into water are governed by overflowing the jet, hydraulic jump and interaction of flow jet with receiving pool. The stepped-labyrinth weirs were shown to have an overall aeration advantage over the flat stepped weirs, largely because of the high turbulence and the high air bubble entrainment.

The aeration advantages of the labyrinth-stepped weir become greater at smaller weir slopes. Conclusions revealed that for the slopes of 1:1, 1:2, 1:3 and tailwater of h, a labyrinth stepped weir with labyrinth height of 0.75h and labyrinth interspace of h, had 48%, 71% and 15% higher aeration efficiency than that of flat stepped weirs. However, with doubling of the tailwater depth, the dissolved oxygen efficiency increased by 77%, 51% and 15%, compared with the similar flat stepped weirs.

Keywords: Aeration, Dissolved Oxygen, Labyrinth Weir, Stepped Weir, Water Quality

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